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Canalscape : a conceptual study to modify the existing landform in relation to the environment for the sustainable development of rural Bangladesh

A. B. M. Mohiuddin

To the Graduate Council:

I am submitting herewith a thesis written by A. B. M. Mohiuddin entitled "Canalscape : a conceptual study to modify the existing landform in relation to the environment for the sustainable development of rural Bangladesh." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Landscape Architecture.

Samuel M. Rogers, Major Professor

We have read this thesis and recommend its acceptance:

Bruce A. Tschantz, Daniel C. Yoder, David A. Johnson, Don B. Williams

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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To the Graduate Council:

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David A. Johnson

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Date May 22, 1995

CANALSCAPE: A CONCEPTUAL STUDY TO MODIFY THE EXISTING LANDFORM IN RELATION TO THE ENVIRONMENT FOR THE SUSTAINABLE DEVELOPMENT OF RURAL BANGLADESH

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

A.B.M. Mohiuddin
August, 1995

DEDICATION

This thesis is dedicated to the rural people of Bangladesh, who form most of the population, who need the development most.

This thesis is also dedicated to my parents, Mr. and Mrs. Abdul Matin of Dhaka, Bangladesh, in appreciation of their love, guidance, and invaluable education that they have provided me in many facets of life.

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This thesis began as a simple proposal to fulfill the requirement of a research class. Sometime during this class, however, an excitement and challenge grew that made me believe I could actually succeed in writing a thesis. I would like to thank some significant people who have contributed in this endeavor.

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Finally, but above all, I wish to express my deepest gratitude to the Allmighty Allah who has made all possible, and I praise him for my many blessings.

ABSTRACT

This study reviews the existing physical, environmental, agricultural, and socioeconomical conditions of Bangladesh and problems associated with these. Poverty, exploding population, poor production in agricultural sectors with natural disturbance (such as excessive flooding and drought), and other environmental problems (such as deforestation and exitinction of biota) hinder the progress of the nation. This study also investigates the possibility to reshape the existing landscape to reduce the ongoing crises by carrying out a new idea "Canalscape."

In this investigation, an attempt has been made to test the idea into an actual vilage. An economic analysis of this project has also been done to test its effectiveness.

Findings

1. The rural poor makes up most of the population in Bangladesh, and their economy is predominantly dependent on agriculture. Thus, agriculture plays a major role in the nation's developmental planning.

2. Flooding is a major problem of Bangladesh. Primary and secondary floods cause damage to the standing crops and inhibit the cultivation of modern high yielding varieties (HYV). Although tertiary flooding causes severe destruction, this is not a regular event in the monsoon cycle. As for agriculture, primary and secondary floods seem more important because of their occurrence during the critical period of crop growth.

3. If primary and secondary floods can be controlled, the country can achieve a significant increase in crop production.

4. The flat topography of the existing landscape makes this delta prone to flooding. If the landform can be modified so that it can hold the excessive water during flooding seasons, more crop area can be opened for cultivation.

5. Embanking the major rivers without making any attempts to circulate the floodwater into the flood plain will cause long term economic and environmental harm.

6. A Canalscape is simply a network of canals along with levees/roads to reshape the existing flat topography. This will control the movement of floodwater during monsoons and provide irrigation for dry winter seasons by storing the excess water in its system. This transformation, moreover, will intensify the total use of the land. The Canalscape suggests coping with the flood events rather than stopping them.

7. The Canalscape provides a necessary physical infrastructure to apply a successful farming system. To increase the overall production the Canalscape generates other income sources such as fishery, forestry, livestock, and so forth.

8. The Canalscape induces a relatively safer environmental condition and designs an organized social structure into it to sustain the growth.

9. If the transformation can be done properly, the land will become more productive. The example analysis in this study indicates that an approximate 200 percent increase in overall production could be possible.

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CHAPTER I

INTRODUCTION

Allah meg de pane de	Oh Lord! Give us rain and water.
Chhaya de re Toi Allah meg de	Give us shade, save us from drought!
Asman hoilo tuta tuta,	The sky is hot!
Jomin hoilo fata	The Land is broken into pieces!
Megraja gumaya roichhya	The Rain God is sleeping,
Meg debo tur keda......	Who else shall give us rain......
-Abbasuddin Ahmed, 1953	
Allah meg de pane de	Oh God! We shall never pray
Koimunato ar	Pray for rain and water anymore!
Emon pani dila Tomi	Our homes, all our belongings are afloat
Bhaslo ghor-duar.....	We shall never pray for rain.....
-Fakir Alamgir, 1988	-Trans. by M. Q. Zaman (1993)

Bangladesh is well known as one of the most disaster-prone countries in the world. These songs by the two most famous folk singers of Bangladesh probably simplify the problem of the country. The most important of the country's many pressing environmental problems involve water, which is at various times too plentiful, too scarce, and too polluted. Besides being enmeshed in the familiar third world problems of endemic corruption, deepening poverty, and exploding population, the country grows poorer with each passing year even as billions of dollars pumped in as aid seemingly vanish into thin air. It never reaches the people who need it most, who form the vast majority of the country. These songs also reveal the simplicity and tolerance to any unfamiliar with the Bangladeshi's character. Coping with a problem rather than intermingling with both national and international politics to determine their fate is nothing new for a Bangladeshi. World famous economist Dr. Muhammad Yunus, founder of "Grameen Bank" of Bangladesh believes that social scientists and development experts overwhelm themselves with the seeming enormity of problems in the developing world. According to him, large problems are merely the composite of a great number of simple problems, and simple problems can be solved by simple people. "Removal of poverty must be a continuous process of creation of assets by the poor at a steady rate," said Yunus (Mahmud, 1992).

We cannot find a success story like Grameen Bank quite often. Loan recovery rates exceeded 80 percent and bad loans were less than 3 percent of all lending in 1992 (Sigaud, 1993). But the fact is, the system is more than impressive. The government initially owned 60 percent of Grameen Bank, but at the time of this research its 1.4 million borrowers, who have a mandatory share in the profit, owned 88 percent of this unique financial institution (Kamaluddin, 1993). The force behind such accomplishment is the rural poor who have no collateral to offer against their loans. On the other hand, Bangladesh is one of the poorest and most overpopulated nations in the world. Its development planning overwhelmingly depends on foreign aid (Zahid, 1993). Though the proportion of external aid was comparatively low in the Third Five Year Plan (1985-90) which suggests favorable economic growth (Table 1), there is still a long way for Bangladesh to go toward self-sufficiency. In spite of all its problems, Bangladesh has tremendous labor resources. Success in the garment industry is another example of proper utilization of excessive population. Thus, the Grameen Bank and the garment industry are the two different rural and urban success stories of Bangladesh. They are similar in that they target the most vital resource of the nation. The reason behind addressing these success stories are quite simple. The rural poor form the majority of the population in Bangladesh, and they need the development most. If this population can provide energy for one sector, it is very likely to think that this power can also be channeled into other sectors in generating resources.

Located in southeast Asia, Bangladesh is one of the most densely populated countries in the world. The estimated population of Bangladesh is 116.44 million (WRI, 1994). The country is largely bordered by India, with a 370-mile coastline along the Bay of Bengal. The land is a deltaic plain with a network of numerous rivers and canals (Fig. 1). Bangladesh has a tropical monsoon climate. The summer and the monsoon months are the time for tropical cyclones, storms, tidal bores, and floods. It has one of the highest annual rainfalls in the

TABLE 1: PLAN SIZE, ACTUAL OUTLAY AND AID INFLOW

(In crore Tk*.)

Plans	Plan-size	Actual Outlay	Gross Aid Inflow	Aid Inflow Percentage
First Five-Year Plan (1973-78)	4,474	2,074	1,491	79.9
Two-Year Plan (1978-80)	3,861	3,359	2,581	76.8
Second Five-Year Plan (1980-85)	17,200	15,297	9,708	63.8
Third Five-year Plan (1985-90)	38,600	27,011	7,772	28.8

Source: Zahid, 1993

* 1 US Dollar = Approx. 40 Taka
  1 Crore = 10,000,000

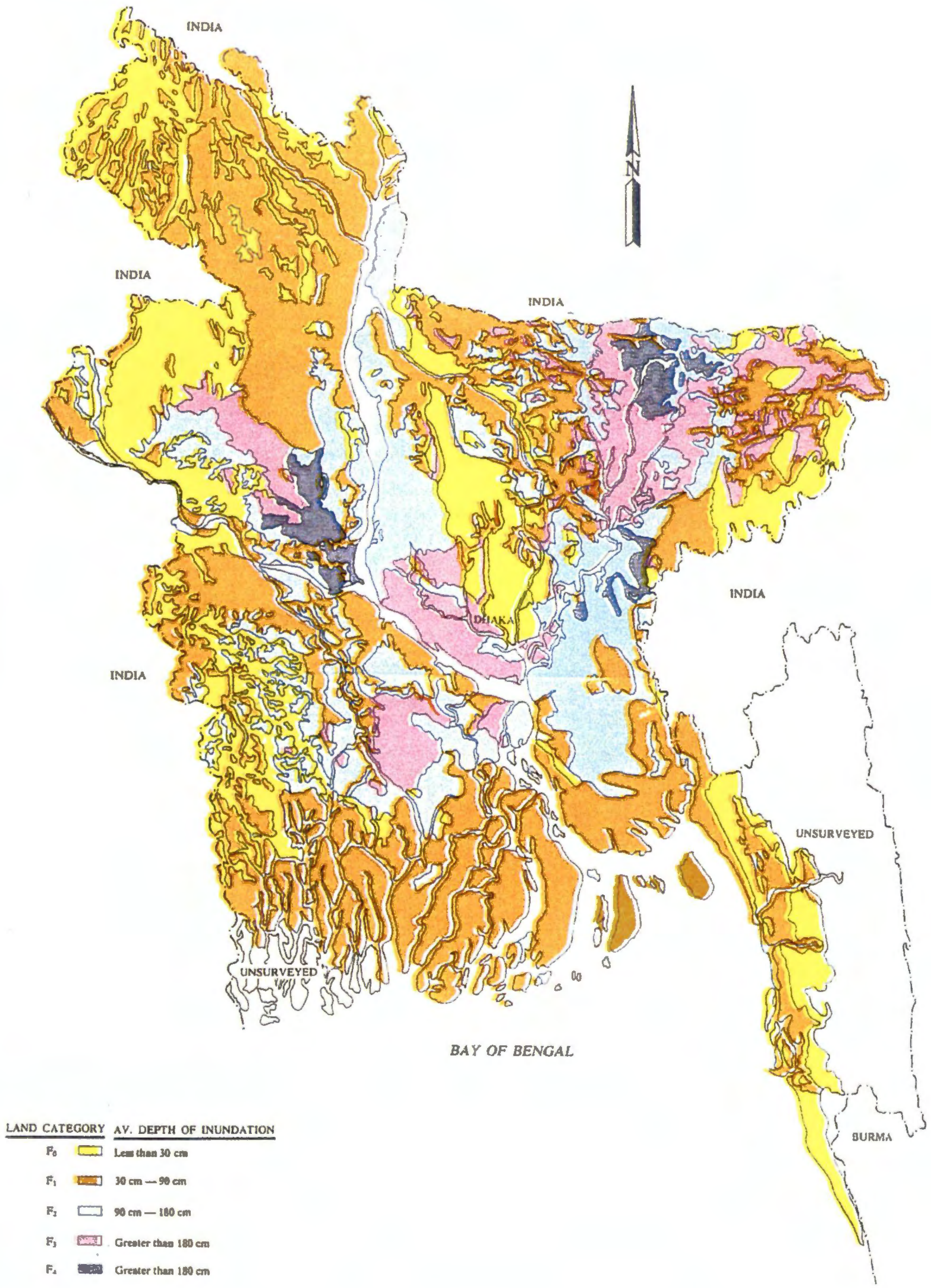


FIG 1: DISTRIBUTION OF FLOODED LAND IN BANGLADESH
(Average Annual Depth of Innundation)
Source: Ahmed, 1988

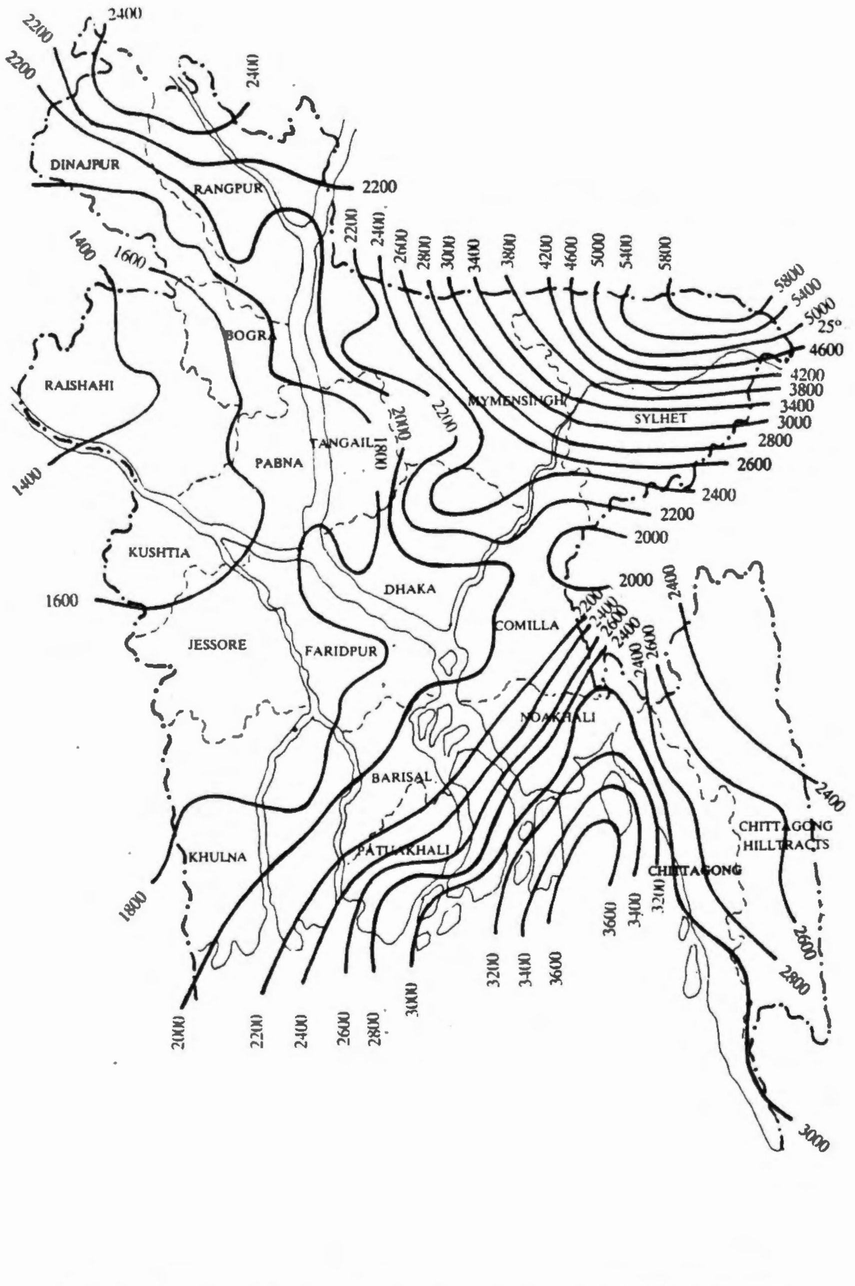


FIG 2: MEAN ANNUAL RAINFALL (mm) OF BANGLADESH
Source: Ahmed, 1988

world, averaging as much as 85 inches in its northeast (WRI, 1994). Figure 2 shows mean annual rain fall of Bangladesh.

The vast majority of Bangladeshi live in rural areas and are engaged in agriculture. About 90 percent of the people live in some 68,000 villages (DFP, 1989). Men work in the field from dawn to dusk tending crops and animals while women cook, wash, and take care of their children at home. Bangladesh's heavily sedimented soil is extremely fertile, but the people face a constant struggle to provide enough food for the country's rapidly increasing population. Moreover, the predominantly agricultural economy depends heavily on the erratic monsoon cycle, which causes periodic flooding and drought. Agriculture accounts for 50 percent of the country's Gross Domestic Product (GDP), and 85 percent of employment (DFP, 1989). Again, the resource-poor farmers constitute the bulk of the farming community in Bangladesh. According to Chowdhury et al. (1993) marginal (.2 to .5 ha of land) and small farmers (.51 to 1.0 ha) together with landless households constitute more than 70 percent of the farm families.

Flooding and availability of water for crops during dry season are the major limiting factors for agricultural production in Bangladesh. Large areas in Bangladesh are usually inundated, and floods are normally associated with the yearly monsoon rains. At least 18 percent of the land area gets flooded yearly, but the affected area may be as high as 36 percent of the country, which is 60 percent of the net cultivable area (Hossain, 1991). Figure 3 shows the land area that is flooded normally during monsoon. Scarcity of water is another limiting factor for increasing agricultural production. In Bangladesh the dry zones include almost one third of the country. The mean annual rainfall in this zone is 50 inches to 75 inches occuring mostly during the 4-5 months main rainy season. In the drier part of the of the country the agricultural production is hampered due to uncertainty of rainfall during pre and post monsoon periods and due to loss of soil moisture faster than other relatively wet zones. This area suffers from drought sooner than the other areas particularly during the main crops growing season. Figure 4 and 5 show drought indicated by rainfall during pre monsoon

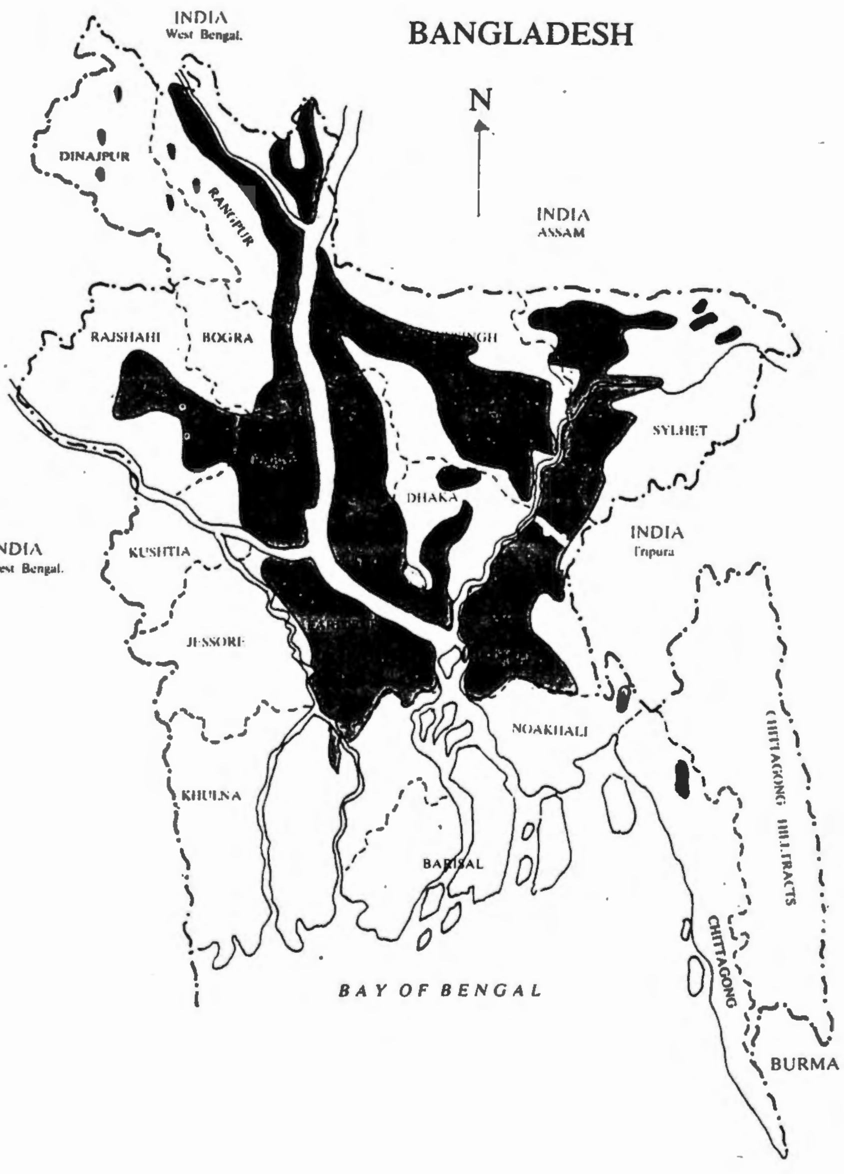


FIG 3: AREA NORMALLY FLOODED
Area Affected = 6.5 Million Acres (Approx)
Source: Ahmed, 1988

LEGEND

Between 36 and 70 mm

Between 71 and 120 mm

Between 121 and 170 mm

Between 171 and 220 mm

Between 221 and 420 mm

FIG 4: DROUGHT INDICATED BY RAINFALL FOR APRIL
Source: Ahmed, 1988

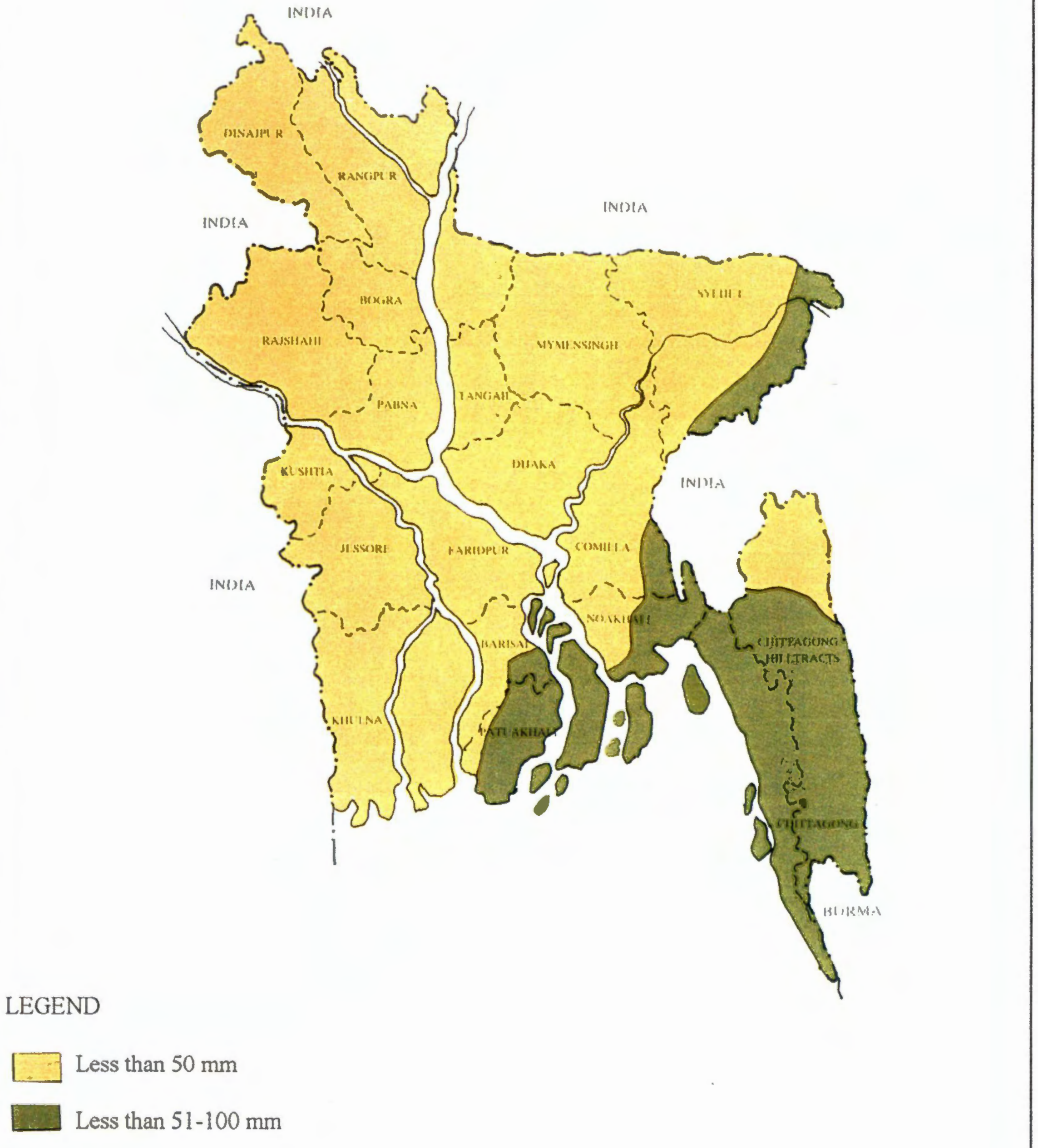


FIG 5: DROUGHT INDICATED BY RAINFALL FOR NOVEMBER
Source: Ahmed, 1988

(April), and post monsoon (November) seasons.

Rice is the main crop in the cropping pattern of Bangladesh. According to the growing seasons rice is named as aus, aman, and boro. Boro is the dry or winter (rabi) season (November to April) crop while aus and aman are summer or kharif season (May to October) crop. The monsoon is the main season for summer crops, when nearly 80 percent of the rice crops are grown (Hossain, 1991). Because of the risks of flood, farmers tend to choose local low yielding varieties of rice which can withstand floods. Limited use of modern varieties or high yielding varieties (HYVs) is another factor that influences agricultural production. In Bangladesh the spread of modern varieties (MVs) has mainly been limited to dry season crops; use of modern varieties is much more common in wheat and boro rice production than in other rice crops (aus and aman). According to Lein (1993) modern varieties were grown in 1985 on 78 percent of the boro area. Accordingly, the figures for aus and aman were 16 and 20 percent respectively. Among the most important long-term changes that have taken place in Bangladeshi agriculture during recent decades is the increased importance of boro rice in overall food grain production. This crop represented only 5 percent of total rice production in 1960-1965, while in 1990 the figure rose to more than 30 percent (Lein, 1993). The growth in production of wheat and boro has occurred at the expense of other crops, particularly aus and winter crops such as pulses and oilseed. The low coverage of MV-aus and aman indicates that there may be a considerable potential for expansion of MV coverage during aman and aus cropping seasons. The current annual population growth rate of Bangladesh is 2.17 percent (BBS, 1993). If one assumes an annual average population growth of 2.17 percent in the period 1985-2010, this will imply a growth in demand for food grain in the range 2.3-2.9 percent per annum (Hossain, 1989). So it is quite important to increase the production of aus and aman rice to meet the future demand. Unfortunately, only 20 percent of agricultural land is suitable for MV-aman under rain-fed conditions and 26 per cent under irrigated conditions (FAO, 1988). This is because most of the new varieties developed so far are relatively short-stemmed and thus less suited to heavily flooded monsoon areas.

TABLE 2: LAND OWNERSHIP AND FARM SIZE PATTERN, 1960 TO 1984

000

Household Type	1960	1977	1983/84
Rural Households	8239 (100.0)*	10871 (100.0)	13818 (100.0)
Farm Households	6139 (74.5)	6257 (57.6)	10048 (73.4)
Non farm Households	2100 (25.5)	4614 (42.4)	3770 (26.6)
Near Landless Households (owning less than 0.5 acres)	803 (9.7)	342 (3.1)	2417 (17.5)
Landless and Near Landless Households	2903 (35.2)	4956 (45.6)	6187 (44.8)

Farm Size (acres)	Percentage of Farms			Percentage of Land operated		
	1960	1977	1983/ 1984	1960	1977	1983/ 1984
Up to 1.0	24.3	15.9	40.5	3.2	2.7	7.8
1.1 to 2.5	27.3	33.8	29.9	12.9	16.3	21.2
2.51 to 7.5	37.7	40.9	24.7	45.7	49.4	45.1
7.51 and above	10.7	9.4	4.9	38.1	32.7	25.9

* Figures within parenthesis show percent of total household
Source: Ahmed, 1988

Many of the people of Bangladesh are landless. Most of the lands in the village are owned by rich and middle class farmers. Table 2 summarizes the trends in farm size, land ownership, and land distribution between 1969 and 1984 in Bangladesh. The table shows that the average size of land held by rich farmer families has doubled over a period of 34 years. On the other hand, almost 75 percent of near landless households have become landless during the same period. According to Ahmed (1988) in 1983/84, the agricultural census estimated the total number of rural households to be 13.82 million. Almost 73 percent or 10.05 million of the total rural households were agricultural or farm households. These households were mainly dependent on agriculture and owned agricultural land to work on. The census of 1983/84 also found the percentage of agricultural labor households to be 39.8 percent of all households and comprised of 5.49 million households. These households were dependent on wage income mainly from working on others' lands or in different rural activities. Increasing landlessness together with lack of off-farm employment opportunities in the rural areas and expectation of finding jobs in the urban centers has accelerated large scale rural-urban migration (Ahmed, 1988). In addition, millions of farmers are forced to migrate to cultivate unused and unsuitable coastal lands and inlands that are periodically flooded and devastated by cyclones.

Bangladesh has a highly complex farming system (Chowdhury et al., 1993). Farmers produce diversified products to meet their home consumption requirements and other household needs. Most farmers raise field crops, homestead vegetables and trees, cattle, poultry, and occasionally fish. Off-farm and non-farm activities are pursued to supplement cash requirements. People are struggling every day to improve their situation, but, resources are limited and are decreasing every day. However, more and more people are competing continually for the fixed resources. Natural calamities are a routine event. In addition, there is a gap between different development programs and the proper integration into resource generation required to sustain the progress of a nation with multifaceted problems. It is very important that any attempt at development for rural Bangladesh has to be not only problem solving, but also resource generating.

In this study, an attempt is made to find a grassroots-level developmental pattern that will not only stop the poor from becoming poorer, but will also utilize the nation's two vital resources, labor resources and agriculture, in a move towards development. As mentioned before, the latent resources of any developing countries are the key to the development. If development planning can be coordinated with the utilization of these resources, it is fair to say that a nation like Bangladesh can be transformed into a new era of progress. In the present investigation, the Canalscape project is one of the several ways through which the socioeconomic condition of Bangladesh can be reformed. The Canalscape suggests a change in existing physical, environmental, agricultural, and social conditions to sustain the growth of rural areas. Moreover, it recommends a cooperative community pattern to organize the people in utilizing the change toward sustainable development. Necessary information, proper communication and motivation of the rural people, perhaps the basic force, can make such an attempt successful. The modification of landform has been outlined to support the new community pattern by absorbing it into a safe environmental condition. Such a project alone might not be the only solution for a nation with numerous problems. However, related research would help in changing the nation's developmental strategy.

The General Objectives of this Investigation are

1. To identify the existing problems.
2. To develop a conceptual plan (Canalscape) to solve those problems.
3. To determine the feasibility of such solution.

The Purposes of the Canalscape are as follows:

- To create an economically stable population.
- To protect crops and people from floods (especially primary and secondary floods),

seasonal storms, drought, and to solve other environmental problems such as deforestation, extinction of biota, and so forth.

- Increased utilization of every portion of cultivable land and proper use of modern cultivation techniques to develop a highly productive farming system.
- To improve the local environment.
- To protect wildlife and native plants from extinction.
- To create job opportunities for rural poor and unemployed people.
- To indirectly provide proper education for both the adult and the younger population.
- To indirectly ensure proper nutrition and medical care.
- To encourage both agricultural and nonagricultural industrialization, including cottage industries.
- To stimulate individual villages to create their own economies to participate in national development.
- To improve the social and cultural life of rural people.
- Finally, to create a community pattern with maximum local participation for improvement of socioeconomic conditions.

CHAPTER II

PROBLEM IDENTIFICATION AND EXISTING CONDITIONS

The land in Bangladesh is predominantly flat and prone to flooding, which may range in depth from 0 cm to more than 180cm (Fig. 1, p. 4). According to flooding depths, land can classified as high lands (F_0), medium high lands (F_1), medium lowlands (F_2), low lands (F_3) and very low lands (F_4). Agricultural activities are intimately related to and dependent on the flooding condition of land. About 65 percent of the land area in Bangladesh is subject to flooding of different depth and duration (Ahmed, 1988). These floods are mostly due to spillover from the rivers and runoffs from heavy precipitation during monsoons. Crop sequences and types are affected by flood depth dynamics such as their periodicity, depth, and extent of inundation. These factors also determine the extent of crop damage due to floods. The elevated lands, where the annual flooding is intermittent and floodwater ranges between 30 cm and 180 cm, are suitable for growing various crops with primary irrigation. Lands where floodwater rises above 180 cm become unsuitable for agriculture. More than 12 percent of the net cultivable land belongs to this category (Hossain, 1991). As mentioned before, the economy of Bangladesh is predominantly dependent on agriculture. However, the rural economy is totally dependent on agriculture. Again, agricultural improvement is directly correlated with the surrounding physical, economical, and social environment of rural Bangladesh. In this chapter, different existing conditions and various problems of rural Bangladesh are described.

Crop Field Pattern

The existing land-man ratio in Bangladesh is very unfavorable, and almost all available land is under cultivation (Table 3). The land-man ratio will likely decline more rapidly through the years as the population increases. With only 15 percent of the total population currently in towns, urbanization will further reduce the availability of arable land (Hossain, 1991). Presently 63 percent of the total land area of Bangladesh is cropped.

TABLE 3: LAND UTILIZATION IN BANGLADESH (1984-85)

(In million hectare*)

Type of Land	Area	Percentage of total land
Land not available for cultivation	2.41	17
Forest	2.07	14
Cultivable waste	.23	2
Current fallow	.51	4
Net cropped area	9.05	63
Net cultivable area	9.56	67
Total land area	14.27	100

Source: Hossain, 1991

*1 hectare = 2.47 acre

Crop fields are highly irregular in shape and lands are subdivided into many small fragments (Fig. 6 and 7). In the same crop field, subplots are different in elevation. Each subplot is surrounded by thick (1 ft.-2 ft.) borders (Fig. 7), that not only reduce the cultivable land, but also serve as a barrier to use of modern cultivation techniques. Improper drainage conditions keep the water stagnant in the crop field. Since the topography is flat, even slight variations in elevation can cause disastrous problems in growing and standing crops during the sudden and prolonged seasonal floods (Hossain, 1991). Because people treat subplots differently, the fertility level is highly heterogenous in the same crop field. Excessive divisions of land make the crop fields inaccessible for modern farm machinery. This situation also reduces the benefits of proper irrigation and drainage. People excavate soil from their crop field to build new platforms and roads or to renovate the old one which reduces the cultivable area and destroys the physical shape of the crop field (Fig. 8).

Households

In Bangladesh, people usually live in households on " raised platforms" (Fig. 9). These platforms are raised earthen fill areas for protecting households from flood water. Sometimes these are not high enough, and floodwater easily enters the platform. In most cases, the shapes of these platforms are highly irregular, which causes various degrees of erosion and wastage of valuable land (Fig. 8). Newer platforms have been created by the expansion of older small platforms, so facilities are not always equal for every household in a platform. Since different shareholders live on the same platform, sometimes unorganized expansion blocks passage within the platform. If any household cannot expand their property line according to their needs, they move out to a new platform, which takes a considerable amount of cultivable land. Some platforms are too dense with plants and some are too open, so they might be destroyed easily by a gust of storm winds.

Since every family in a platform performs its agricultural or other practices individually, a large open space is usually needed in each platform all year round (Fig. 10 and

FIG 6: FRAGMENTATION OF LAND
Source: Saifuddin, 1994

FIG 7: THICK BORDER AROUND THE CROP FIELD
Source: Saifuddin, 1994

FIG 8: EXCAVATION OF SOIL FROM CROP FIELD
Source: Saifuddin, 1994

FIG 9: RAISED PLATFORM
Source: Saifuddin, 1994

FIG 10: ACTIVITIES IN THE PLATFORM (CROP HARVESTING)
Source: Saifuddin, 1994

FIG 11: ACTIVITIES IN THE PLATFORM (CARPENTRY)
Source: Saifuddin, 1994

11). Moreover, every household has a large stable for cattle, because people usually use cattle power to cultivate their land.

Existing Canals and Roads

Bangladesh is a river-and canal-oriented country. A major portion of transportation is done *via* waterway. According to Hossain (1991), in marketing their food grains 69 percent of transportation is done by people through waterways and "kutcha" roads (earthen roads) whereas "pucca" roads (brick soling, major roads and highways) are used to transport only 27 percent. A very limited portion, about 4 percent, moves *via* railways (Table 4). The navigability of rivers is highly reduced due to different levels of siltation. Some rivers are almost dead. These situations have affected the total canal system throughout the country.

In villages, the canals are not in an organized pattern. Villagers and, to some extent poor governmental policy, are responsible for creating unplanned canals. Even though in some situations they are beneficial, in most cases new canals are not deep enough to hold the water both for wet and dry season, and are not completely finished. As a result, these conditions block the flow of water. The same can be said about the older canals. Since they are old, the canal bottoms are filled with different levels of siltation (Fig. 12), which impedes the water flow without completing the water cycle (water flow from canal to canal, canal to river, and river to canal). In summer, these canals are almost dry. Figure 12 and 13 show the existing condition of a secondary canal during the month of January, which is still two months ahead of the driest period of rabi season.

Some villages are unnecessarily developed with a large number of roads and walkways, whereas others are poorly developed. In most cases, this unorganized road system blocks the canals and disturbs the flow of floodwater from the crop fields toward the canals and rivers (Pearce, 1991). This is one of the major reasons for the primary and secondary floods in Bangladesh. There is a lack of sufficient roads and walkways (mainly kutcha) in the

TABLE 4: VOLUME OF FOOD GRAIN HANDLED THROUGH DIFFERENT MEANS OF TRANSPORTATION

Type	All Markets	Primary	Secondary
Pucca Roads	27%	21%	39%
Kutcha Roads	42%	49%	27%
Railways	4%	4%	5%
Waterways	27%	26%	29%
Total	100%	100%	100%

Source: Hossain, 1991

FIG 12: RAISED UP CANAL BED
Source: Saifuddin, 1994

FIG 13: RAISING OF RICE SEEDLINGS AT CANALBASE
Source: Saifuddin, 1994

villages to connect every household to the major road system (Matin, 1995). Due to this, people reach their destination through crop fields or through the borders of different plots. People also do the same to move their livestock or their harvest. This situation not only damages the crops in the field but also takes a considerable amount of land from cultivation.

During the months of December/January the depth of water in the canals decreases considerably, and people use the canal bottoms to raise rice seedlings (Fig. 13, p. 23), or they block some portion of the canals and deposit mud/silt to do the same. Although fertile silt helps in the growth of rice seedlings, this practice also traps more silt and debris from the water and raises the canal bed. As a result water flow is seriously hampered. If it is possible to dig out the canal regularly, utilization of the canal bed might open more area for cultivation. This could be suited for short duration fodder crops such as Black gram (*Phaseolus mungo*).

Agriculture

Ironically, the availability of water for crops is one of the most limiting factors for increasing agricultural production. The major sources of water in Bangladesh, such as rainfall, stream flow, and ground water, are closely related. Traditionally, in Bangladesh water management has relied on rainwater and stream flow for agriculture, fisheries, domestic use, and cottage industries. Modern methods of low lift pumps, deep tube wells and irrigation canals have led to the utilization of surface and ground water for agriculture during the dry season. The main constraint for the growth of agricultural production through irrigation during the dry period is the scarcity of surface and ground water when it is needed most. The availability of surface water in the dry season from the main rivers and regional rivers is presented in Table 5. The main component of the available regional water is the inflow from the main rivers which come from India, and the stream flow generated within the catchment area. The flat topography and scarcity of land limit the potential of storing surface water (Hossain, 1991).

TABLE 5: VOLUME OF AVAILABLE REGIONAL AND MAIN RIVER SURFACE WATER

(Net of 1983 water use)

Resources	80% dependable streamflow volume available (Mm³)				Static water (Mm³)	Insteam Storage Potential (Mm³)
	Jan	Feb	March	April		
Regional Rivers*						
NW	1,290	875	875	1,110	167	103
NE	710	110	305	1,900	374	275
SE	1,870	690	730	690	0	57
SC	3,240	2,185	1,550	3,680	9	1
SW	655	385	255	355	62	64
Interregional flow between SC and SW	383	242	214	311	-	-

TABLE 5 CONTINUED

Resources	80% dependable streamflow volume available (Mm³)				Static water (Mm³)	Insteam Storage Potential (Mm³)
	Jan	Feb	March	April		
Total regional flow	6,382	4,003	4,501	7,424	612	503
Main Rivers						
Brahmaputra (Bahadurabad)	11,330	8,830	10,900	16,850	-	-
Ganges (Hardinge Bridge)	3,695	2,735	2,330	2,385	-	-
Padma (Baruria)	16,870	12,410	15,050	2 0,400	-	-

Source: Hossain, 1991

* NW: North West, NE: North East, SE: South East, SC: South Central, and SW: South West

Flooding is another limiting factor for agricultural production in Bangladesh. Floods are normally associated with the yearly monsoon rains. Large areas in Bangladesh are usually inundated. At least 18 percent of the land area gets flooded yearly, but the affected area may be as high as 36 percent of the country, which is 60 percent of the net cultivable area or 52,000 sq.km. (Hossain, 1991), where the total area of Bangladesh is 144,000 sq.km. Table 6 shows the distribution of the cultivable land according to the flood depth. The monsoon season is the main season for summer or kharip crops, when nearly 80 percent of the rice crops are grown. Because of the risks of floods, farmers tend to choose crops that can withstand floods, but since they are low yielding varieties, the yield remains poor.

According to Hossain (1991) in 1970, a group of scholars working at the Harvard University in the United States were of the opinion that with existing 1970 technology, Bangladesh was in a position to grow more than 50 million tons of food grains, while the actual output was only about 12 million tons. Though astonishing, this potential is nevertheless achievable. In the flood-free areas of Bangladesh, it is possible to grow three crops a year (Ahsan and Hussain, 1988). Of the eight million hectares of land under cultivation, two crops per year can be grown in nearly four million hectares despite some flooding. The total gross cropped area under rice cultivation works out to about 10 million hectares, but the total output of rice in the mid-eighties was a little more than 15 million tons (Hossain, 1991). Tables 7 and 8 represent the cropping patterns that are followed with only slight variations in the four main regions of Bangladesh. To achieve self sufficiency in food grains, Bangladesh does not have any other alternative but to control flooding so as to open more cultivable crop land at least for two crops in a year.

As previously described, Bangladesh suffers from a poor and highly disorganized drainage system. About two-thirds of the cultivable land is comprised of high and medium high land, flooded in an average year to a depth of one to 3 feet during monsoons (Hossain, 1991). This land is considered suitable for intensive cultivation without flood control and drainage works. Selective drainage would, however, increase the productivity of this land. Of

TABLE 6: DISTRIBUTION OF CULTIVABLE LAND ACCORDING TO FLOOD DEPTH

Land Type	Flood Depth	Nature of Flooding	Net Cultivatable Land (million hectares*)	
			Area	%
High Land	0-30 cm.	Intermittent	3.514	37
Medium High Land	30-90 cm.	Seasonal	3.288	34
Medium Low Land	90-160 cm.	Seasonal	1.558	16
Low Land	More than 180 cm.	Seasonal	1.124	12
Low to very Low Land	More than 180 cm.	Seasonal/ Perennial	0.078	1

Source: Hossain, 1991
* 1 hectare = 2.47 acres

TABLE 7: EXISTING CROPPING PATTERN IN BANGLADESH

Land Type		Characteristics	Land Distribution	Cropping Pattern
HIGH	Very High	Land is very high, water can never stand. Since, silt deposition does not occur by normal flood during monsoon, manuring and fertilization is very essential	Large part of Dhaka, Bogra, Mymensingh, Rangpur, Dinajpur, and Rajshahi.	Mainly Sugar cane.
	Medium High	These land are above flood level, where water movement can be controlled by ridges around the land. Manuring and fertilizing is essential. Sowing of seeds, and transplantation of seedlings may be delayed due to delayed rainfall.	North Bengal except Pabna, northern part of Barishal, and Dhaka, eastern part of Comilla, Noakhali, Chittagong, and parts of Mymensingh.	Aus or, Jute followed by Aman or, Pulse.
	High	This area is comparatively high where water seldom stands even in monsoon. Fertilizer and manure application is essential.	Large part of Dhaka, Mymensingh, Rangpur, Dinajpur, Kusstia, Rajshai, Jessore, and so forth.	Aus - Transplanted Aman- Rabi crops.
LOW	Medium Low	the soil is fertile and rich and is replenished by fresh deposits or silt carried by normal flood water. Fertilizing and manure application is not so essential.	Pabna, Faridpur, Southern part of Dhaka and Mymensingh, western part of commilla, Noakhali and Khulna, and some part of Sylhet.	Aus, Broadcast Aman followed by Pulse.
	Very Low	Low lying areas as haor, canal, beel, rivers, and so forth. Fertilizer and manure application is not at all necessary.	Faridpur, Noakhali, Dhaka, Pabna, Comilla, Mymensingh, and so forth.	Boro and Deep Water Aman- Pulse

Source: Kabir, 1986

TABLE 8: COMMON CROPPING PATTERN OF RICE IN BANGLADESH

Kharif (Summer and Monsoon)		Rabi (Winter)
Early	Late	
Aus	T. Aman	Rabi crops
Aus	T. Aman	Fallow
Aus/Jute	T. Aman	Rabi crops
Aus/Jute	T. Aman	Fallow
Mixed Aus and B. Aman		Rabi crops
Aus		Rabi crops
T. Aman	Fallow	
B. Aman	Fallow	
Boro	Fallow	

Source: Hossain, 1991

the rest, about half is medium low land (flooded from 3 to 6 ft.) That greatly benefits from effective drainage and flood control projects involving sizeable existing drainage and embankment works (Islam, 1978). The remainder of the cultivated area is the low-lying land, for which very expensive and major flood control and river training schemes do not exist, but would be necessary. However, such schemes are not considered feasible either financially or technologically, at least in the current century. In one of his recent studies, Saleh (1991) suggested small submersible embankments instead of expensive large embankments to protect the crop fields from flooding for a certain period of time during the monsoon season.

Low yielding indigenous cultivation methods are another barrier in agricultural production in Bangladesh. There is only a small portion of farmers who use modern technologies in rice or other crop cultivation. High Yielding Variety (HYV) rice cultivation is still limited to only a quarter of the total area of land under rice cultivation (Kashem and Jaim, 1991). Input shortages and lack of irrigation and credit facilities are still major constraints to higher productivity in rice. Small farmers borrow mainly from local money lenders at extremely high rates of interest, up to 600 percent a year in extreme cases (Kashem and Jain, 1991). Even though a survey of the existing empirical studies does not confirm the generally held view that, in Bangladesh, mechanized cultivation is superior to traditional methods, many farmers report that mechanization increases cropping intensity and makes possible the introduction of new crops (Hossain, 1991). Moreover, mechanized cultivation alleviates acute draft power shortage arising from loss of draft animals due to natural calamities. Many areas of Bangladesh still have an acute shortage of draft animals, and consequently, the agricultural economy is seriously constrained.

It is often observed that recorded yield achieved in controlled research at the research station cannot be obtained in the fields (Fig.14). Some of these differences are basically due to factors beyond the control of farmers, but the rest can be solved and accomplished through an organized cultivation system. Improper harvest and storage methods also cause a considerable amount of loss in harvested products. For example, post-harvest rice losses are

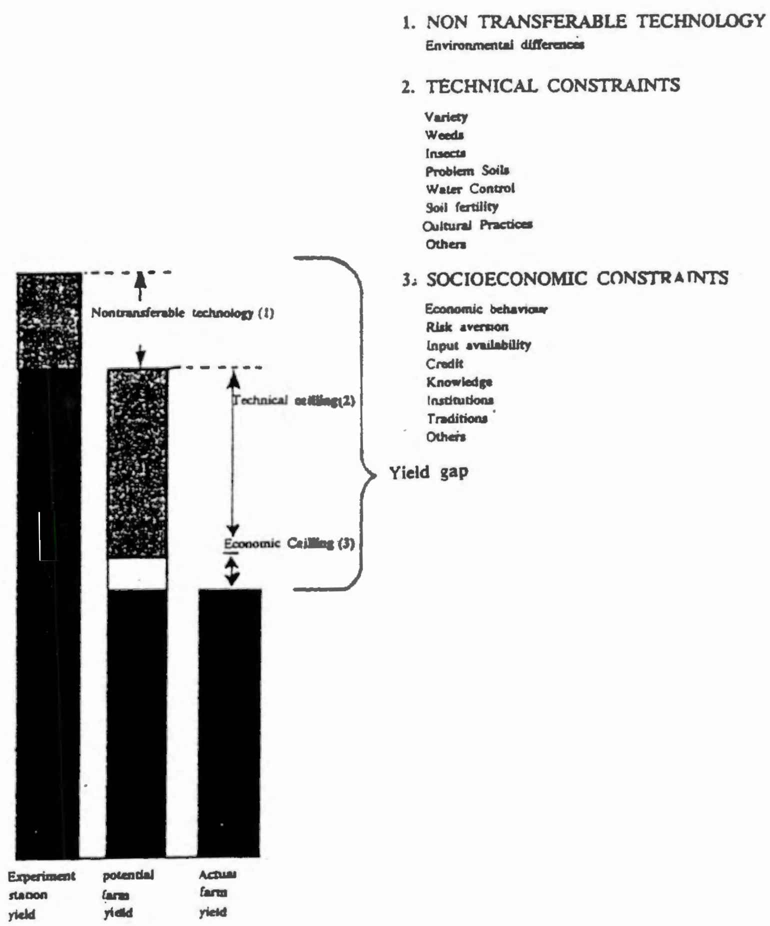


FIG 14: SCHEMATIC EXPLANATION FOR DIFFERENTIALS AMONG POTENTIAL AND ACTUAL FARM YIELDS AND RESEARCH STATION RESULTS

estimated to be around 10-12 percent of total output (Ahmed, 1988).

Livestock, forestry, and fisheries together contributed 13.2 percent of Gross Domestic Product(GDP) in 1984-85 (Hossain, 1991). Despite the importance of these sectors, their significance to agriculture and national economy does not appear to have received due consideration. The fact that the crops, livestock, and forests together form a system where the various components are interdependent seems to be inadequately realized by the policy makers, whether they are in the government or employed by the aid donors.

Fish is a very important food item in Bangladeshis' diets. Minkin (1989) said, "Perhaps more than people in any country, Bangladesh's citizens depend on natural wild fisheries resources for their livelihood." According to Minkin 60 percent of 251 identified fish species in Bangladesh are floodplain dependent. Approximately 80 percent of the animal protein in the Bangladeshi diet comes from fish. Data for 1983-84 indicate that inland fresh water fisheries accounted for 77 percent of the country's total fish harvest, and marine fisheries for the remaining 23 percent (Boyce, 1990). The flood plains, rivers, beels, haors, and lakes have traditionally been the major source of fisheries production (Fig. 15).

Environment

The major natural events of Bangladesh are storms and floods. Storms generally occur in Bangladesh in the months of April-May and early part of October-November (BBS, 1993). In April each year, seasonal storm 'Kal Baishakhi' or, "destructive baishakhi" (Baishakh is the bengali month when seasonal storms occur) starts and lasts for 15 to 30 days, sometimes more. Table 9 shows different types of storms and their characteristics according to the Meteorological Department of Bangladesh.

During the Baishakh storm season one of the main winter crops (boro rice) is ready to harvest while other crops are also in the field. Most of the croplands are open, so a storm

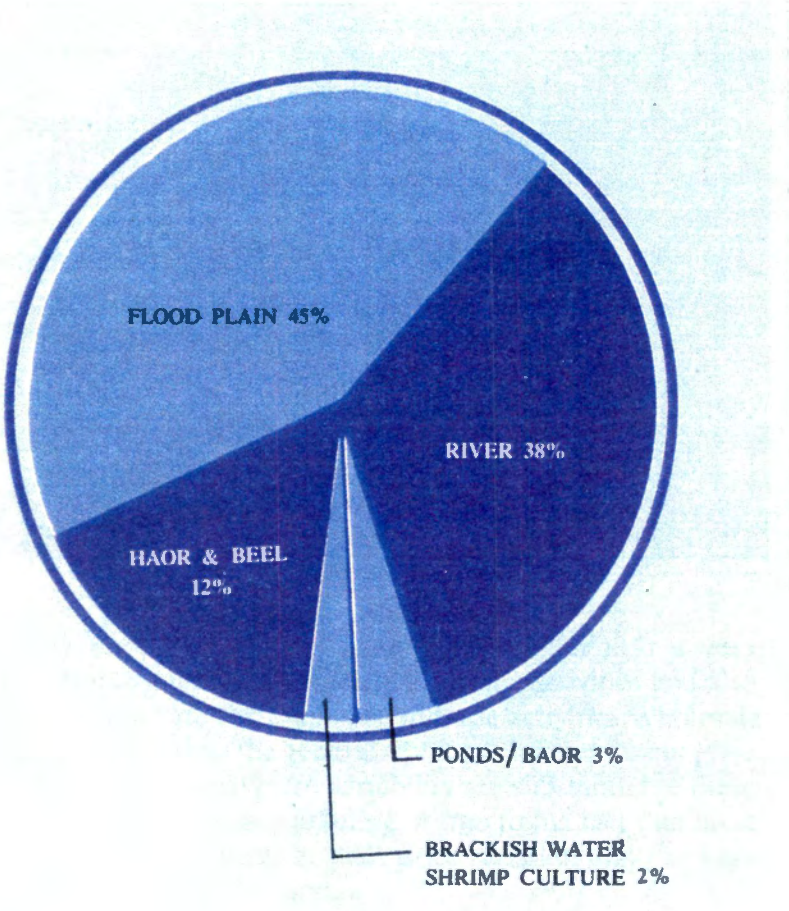


FIG 15: DISTRIBUTION OF INLAND FISH PRODUCTION ACCORDING TO WATER BODY AND FISHERY TYPE

Source: Ahmed, 1988

TABLE 9: DIFFERENT TYPES OF STORMS AND THEIR INDICATION

Name	Indication	Wind speed (At 33 feet) MPH
Strong Breeze	Large branches sway. Telephone wires whistle. Difficult to use umbrella.	25-31
Moderate Gale	Whole tree sway. Difficult to walk against wind.	32-38
Fresh Gale	Twigs broken off trees. Wind Impedes progress when walking.	39-46
Strong Gale	Branches broken off trees. Slight structural damage to Buildings (chimneys, roof slates).	47-54
Whole Gale	Trees uprooted. Considerable structural damage to buildings.	55-63
Storm	Widespread damage to trees and properties .	64-75

Source: BBS, 1993

can easily hit and destroy the crops. This time is also the beginning of monsoon rainfall. Excessive rainfall together with overflow from rivers frequently causes floods. A large amount of area in Bangladesh is subject to flooding of different depth and duration each year. These floods are mostly due to spillover from rivers and runoff from heavy precipitation during monsoons. For the purpose of this study an attempt has been made to categorize floods according to their nature and severity.

1. Primary floods

   Caused by:

   * Excessive rainfall during first few weeks of monsoon.
   * Runoff from mountainous region.
   * Improper local drainage.
   * Disturbed water flow by blockage of canals.

2. Secondary floods

   Caused by:

   * All of the above.
   * Continuous rainfall.
   * Sudden flow of excessive water from neighboring country from rivers

3. Tertiary floods

   Caused by:

   * All of the above.
   * Reduced river depth.
   * Cyclones and other natural hazards.

Control of tertiary floods will need a tremendous amount of effort, which is beyond the realistic capacity of the country at the present time. So, concentration has been focused primarily on primary and secondary floods in the proposed study.

Indeed, the causes of floods in Bangladesh are varied and complex. They are best understood by considering floods in four categories (UNDP/GOB, 1989). The approximate relationship of these categories with the previous categories is as follows:

1. Flash flooding (Primary floods)

This is caused by localized rainfall in the nearby river catchments. The floods often rise quickly and fall rapidly, with high water velocities which can cause damage to crops and properties. This type of flooding may occur in the pre monsoon months of April and May.

2. Monsoon rain flooding (Secondary floods)

In between June and September, this type of flooding is caused by localized high intensity or long duration rainfall. Flooding occurs when the runoff exceeds the local drainage capacity.

3. Over bank floods (Secondary and Tertiary floods)

This occurs from the major rivers. The Meghna and the Brahmaputra river levels peak in July and August, the Ganges in August and September. Generally the major rivers rise slowly over a period of several weeks.

4. Storm surges (Tertiary floods)

These are generated by tropical cyclones in the coastal areas of Bangladesh which causes severe damage to life and property. Cyclones are most common during the pre monsoon and post monsoon periods, April-May and October-November.

Excessive rainfall frequently causes primary floods. Primary floods rise quickly and fall rapidly. But if it stays in the field sometimes this kind of flood destroys the standing crop in the field, which is ready to harvest. Besides, standing water in the crop field delays the transplanting of the following crops such as aman rice. When secondary floods (sometimes tertiary) occur in July/August, there are always some crops in the field which are in the process of maturation. Since there is no barrier between the crop field and the river/canal (Fig. 16 and 17), early flooding fully or partially destroys the crop. It is a great economic loss for Bangladesh.

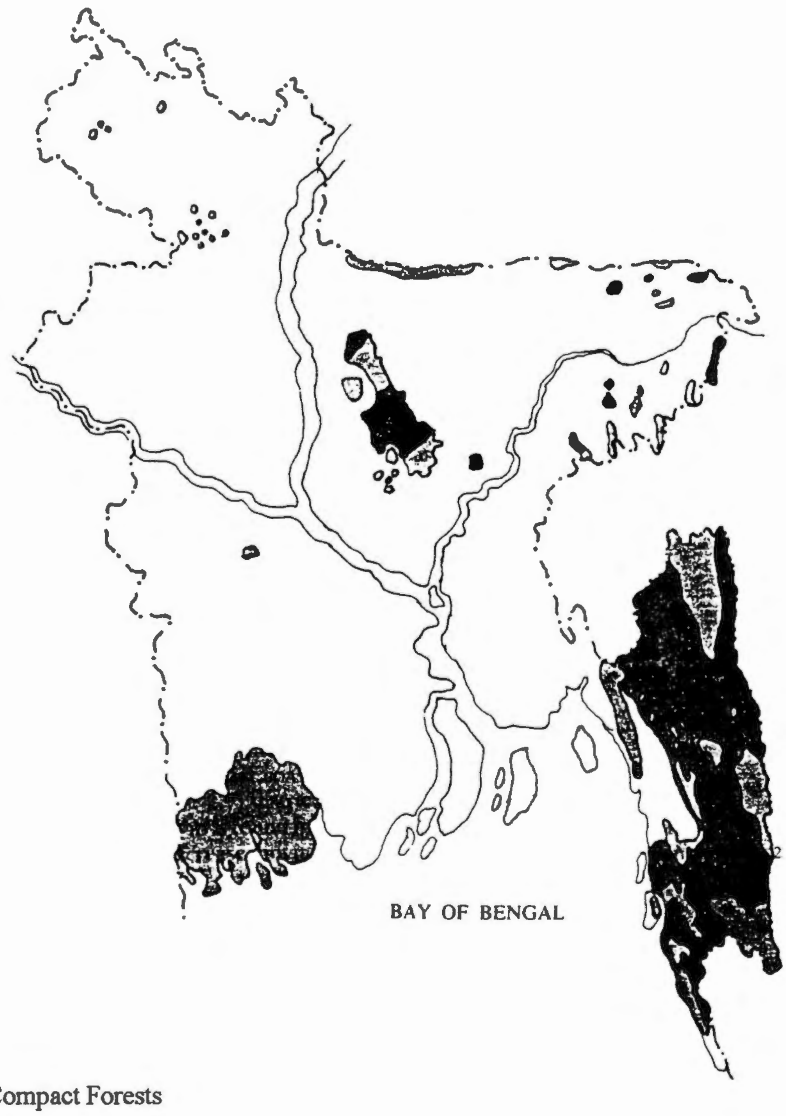
Flooding has deteriorating effects on the economic condition of the country. Crops get destroyed; cattle are killed or fall ill; disruptions occur in the transportation system; and houses, farmland and roads are destroyed. Though there is very little that can be done to

FIG 16: UNPROTECTED RIVER BANK AND VILLAGE
Source: Saifuddin, 1994

FIG 17: UNPROTECTED CANAL BANK AND CROP FIELD
Source: Saifuddin, 1994

control the amount of rain and river water that rushes into Bangladesh, proper policy making and implementation can possibly alleviate the primary and secondary floods from causing serious destruction. However, controlled floods would require international cooperation to solve problems during the wet season. Excess water during the wet season could potentially be stored by building enough reservoirs to provide irrigation during the dry season and fresh water for household uses and fish culture.

Bangladesh is a country with very little forest land (Fig. 18). This has a great impact on both the micro and macro climate of the country. In Bangladesh, only 14 percent of the total land is considered forest land. The forest area designated in the reserved, protected and acquired categories is 3.25 million acres, which is 9.2 percent of the total area (Hossain, 1991). The forest reserves, apart from their economic benefit, are useful from the point of agroecological development and natural growth, watershed protection, reduction of runoff potential, and so forth. Forests maintain ecological balance by their beneficial effects on water catchment areas, soil conservation, control of siltation of dams and canals, air pollution control, and wildlife habitat (Mahat, 1993). In Bangladesh, there is little possibility of extending the forest area controlled by the government. The scarcity of forest cover, acute land shortage, and lack of excess public land are the main factors motivating the concept of social forestry, a forestry approach that is dependent upon the participation of local people (Mahat and Amin, 1993). Social forestry includes community forestry, and farm forestry. This approach involves the growing of trees for fuel, timber, fodder, and other products by local people. Often this is done on available underutilized lands such as on homesteads, or in strip plantations along roadsides, railways, canals, embankments, or in public places like schools, mosques, and office compounds. According to Mahat (1993) social forestry or agroforestry has tremendous potential in resource generation. The main purposes of social forestry are (1) to readily create resources at the users' level, (2) to alleviate rural poverty through tree growing activity, and (3) to create a "buffer zone" resource to save the traditional forestry from the wrath of a hungry population.



LEGEND

Fairly Compact Forests

Scattered Patches of Forest and Shrubs

FIG 18: BANGLADESH FORESTED AREAS
Source: Ahmed, 1988

In Bangladesh, homestead forests play a vital role in providing fuel wood, fodder, fruits, and timber. It is estimated that about 65 percent to 85 percent of fuel wood and bamboos come from homestead forest lands (Hossain, 1991). Decrease of wildlife population is another major concern for Bangladesh. In most cases data on the status of the wildlife situation in Bangladesh is not precise enough. But the population of a number of species has shrunk considerably, of which 35 species have been listed as endangered (Kabir, 1993). Because of the scarcity of forest land, overpopulation, and ignorance in the rural area, native wildlife is on the verge of extinction. Numerous native medicinal and other economic plant species which are also important to balance the local environment have been destroyed during the course of time (Chowdhury, 1995).

Residual effects of different chemicals, especially pesticides that are used in crop fields, are another environmental hazard for Bangladesh. Pesticides applied to the field spread almost everywhere. The toxicants, after being washed by rain, find their way to ponds, streams, and rivers. The resulting effects of these are borne by the fish and other aquatic organisms. Inside the platform, improper sanitation methods not only spread diseases, but also create unhealthy situations. In most cases, toilets are open and the wastage enters directly into the crop fields (Fig. 9 p.19). This situation greatly increases the spreading of diseases epidemically during the monsoon or flood season, diarrhea being the most prominent one.

People and Rural Economy

In villages, people usually live on multiple raised platforms. A large portion of the population in villages does not have its own land, or has very little. Only 25 percent of the population owns the major share (Table 2, p. 11). Wealthy farmers have large amounts of land, but most of their family members do not live in the village permanently. People who have little or no land cultivate that owned by others (Ahsan and Hussain, 1988). A considerable number of working people move from households each year to go to college and universities, or to find a job. They rarely get involved in agriculture again. Wages are low in the village compared to the urban area, so a large numbers of rural people move toward the city. Sometimes it is difficult to find enough labor during the cropping season. Because of irregularities and occasional dishonesty in keeping records on property boundaries, it is very common for people to sue each other, and this sometimes continues generation after generation. Inevitably, the poor farmers sell their land and become landless, whereas middle class farmers become poor. Finally, if there is no other way, they move towards the city at the first chance they get and become a social burden. For most of the people in rural areas their economic condition is very poor. Some of them only work for food and some of them spend all of their savings to buy a small portion of land. They cannot produce a crop profitably because of higher production and maintenance costs (Ahsan and Hussain, 1988). Natural hazards also affect them seriously. Most of the people cannot provide collateral to receive enough credit to produce a crop successfully. If they receive credit, it is very common that they may not be able to pay it back due to lack of profit. So they remain in the same economical status where they started. However, in most of the cases, the situation becomes worse, hence the flow of rural poor toward the city continues. In rural areas, women usually spend most of their time in their houses to process crops, cook food, and take care of the children and the elderly. Can it be possible to turn this huge population into a resource to rebuild the economy of Bangladesh?

As poverty increases, women in poor families seek work to support their family. This trend has resulted in expansion of female opportunities. Different organizations like **GRAMEEN BANK**, **BRAC** (BANGLADESH RURAL ADVANCEMENT COMMITTEE), **BARD** (BANGLADESH ACADEMY FOR RURAL DEVELOPMENT) and others have already taken the rural women into account in cottage industries. In Bangladesh, modern large scale industries employ only 2 percent of the labor force whereas cottage and small industries account for 80 percent of overall employment (Ahmed, 1988). The agricultural census of 1983-84 observed that about 7 percent of the total households responded being dependent on a cottage industry of one type or another for their livelihood (Fig. 19). There is no doubt that this figure is getting bigger each year, which is indicative of

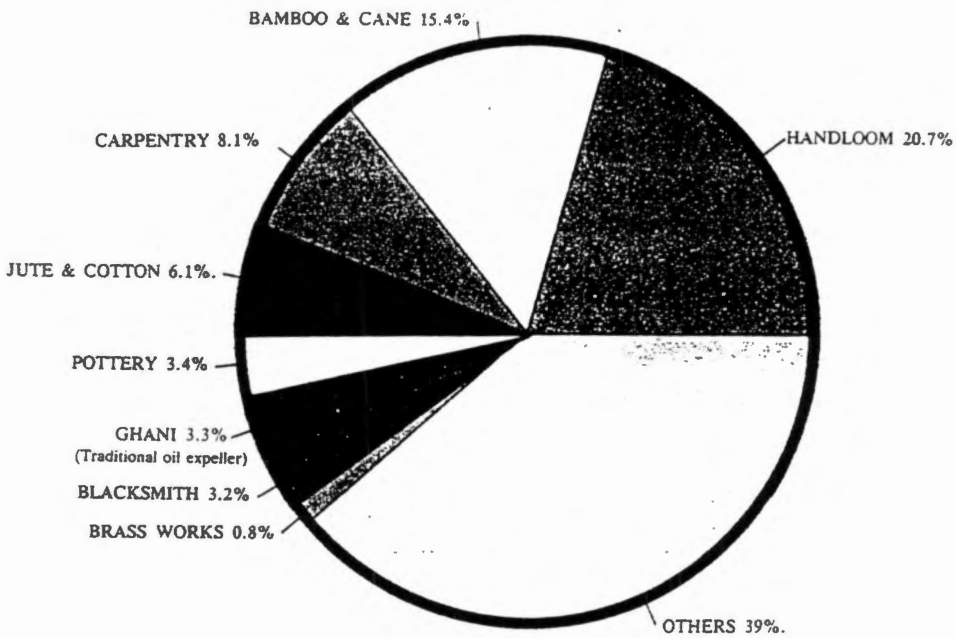


FIG 19: DISTRIBUTION OF COTTAGE INDUSTRIES
Source: Ahmed, 1988

the utilization of this huge amount of labor toward self-sufficiency for themselves and for the nation.

Education

The average literacy rate (seven years and above) in Bangladesh is 32.4 percent (BBS, 1993). Illiteracy in the villages is much higher than in the city. Every village does not have well-organized primary and secondary schools. A great number of children do not go to school because they help their parents in cultivation and household work. Poor farmers' families do not have the ability to pay the educational expenses of their children, and most of the parents have very limited capabilities to continue higher level education for their children. Even though the government has provided free education up to the 8th grade, it has not helped much in solving the major problem. In poor families, of necessity, parents are occupied in earning for their livelihood rather than promoting education. Moreover, a country like Bangladesh also has financial limitations in supporting this vital issue. Besides, inappropriate governmental policy in the educational sector is also responsible for poor development in this area. Unplanned free education up to a certain level might increase the literacy rate, but it has very little effect on improving the economic condition of the poor unless the government also provides vocational training/education and creates some opportunities to utilize such training. Until then the parents in poor families will have no other choice but to keep their children at home to help to earn money, thus neglecting education.

CHAPTER III

CANALSCAPE AND PROPOSED IMPROVEMENT

Bangladesh is a country with numerous problems, and the solutions are often prohibitively expensive. Any single solution might not solve all of the problems, but certainly could improve the situation. Coordination and integration with different developmental programs are of vital importance to Bangladesh. Since its birth, government, individuals, and other organizations have tried to improve the socioeconomic condition of Bangladesh. There are successes, failures, and hope. The proposed Canalscape project is one of the several ways through which a sustainable developmental pattern could be developed for the rural majority of Bangladesh who need it most.

Sustainability is nothing but a renewal process. It is a combination of production with conservation (Young, 1990). Sustainability works for the present and the future.

Sustainability = Production + Conservation (Renewal or regenaration)

The Canalscape suggests sustainable development. It depicts the idea of utilizing the existing resources rather than importing them. Since resources are limited, it shows the way to generate resources. It also reveals the idea that transformation of uses can generate resources. In this chapter, an attempt is made to simplify the concept of Canalscape and to suggest the possible implications for the existing rural landscape.

Canalscape

Conceptually, Canalscape refers to the shaping or forming of a network of canals that will make the water flow continuously and hold the excessive water during the monsoon season. Along with the network of canals, an elevated road system is proposed on both sides of each canal, acting as embankments to prevent floodwater from entering the crop fields. Both the canals and the newly built road system will aid transportation and communication inside and outside of the village. Planting of trees (fruit and other cash crops, and native plants) is also a part of this canalscape. Planting trees will help to protect field crops from storms and will improve and conserve the environment by protecting wildlife. Figures 20, 21, and 22 show land distribution utilizing the concept of Canalscape and its components.

<u>**Components of Canalscape**</u>

(Design Criteria for a Typical Village)

Canals and Roads

<u>Existing features (Roads and Highways)</u>

Highways (Zila/ Subdivision to Zila): >25 ft. wide

Ist Major Road (Upazila to Upazila): >15 ft.

2nd Major Road (Village to Village): >10 ft.

Within the village roads and walkways are irregular in shape and are disorganized. (Matin, 1995)

<u>Proposed</u>

Primary Road (village to village):

Or, Major road in the village: >15 ft. Wide

Secondary Road (other roads

Inside each village): >10 ft. Wide

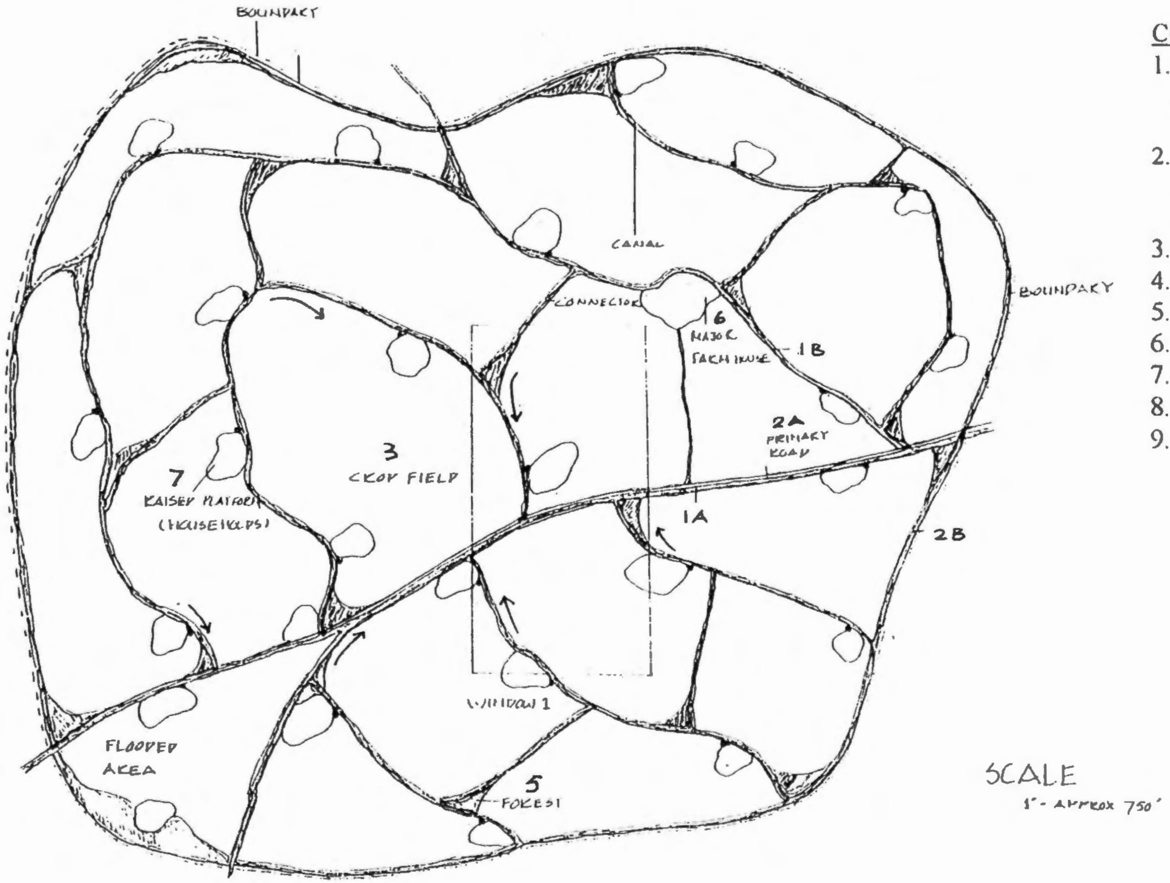
<u>Existing features (Canals)</u>

Primary (village to village): >20 ft. wide

Secondary (first branch form primary

Canal among villages): <20 ft.

Other canals within the village are highly disorganized. Canal width varies from village to village. Some villages have very few canals. However, in most villages canals are not continuous. Moreover, canals are not deep enough to hold the excess water during monsoon. Again, different levels of siltation raise the canal bed higher each year.



COMPONENTS OF CANALSCAPE

1. Canals
   A. Primary Canal
   B. Secondary Canal
2. Roads
   A. Primary Road
   B. Secondary Road
3. Crop Field
4. Filter
5. Forest
6. Major Farm House
7. Raised Platform
8. Reservoir/ Pond
9. Temporary Flooded Area

FIG 20: CANALSCAPE: MAJOR LAND DISTRIBUTION INTO AN IMAGINARY VILLAGE

Conceptual Application of the Entire Canalscape System, Showing How Components Might Fit Together

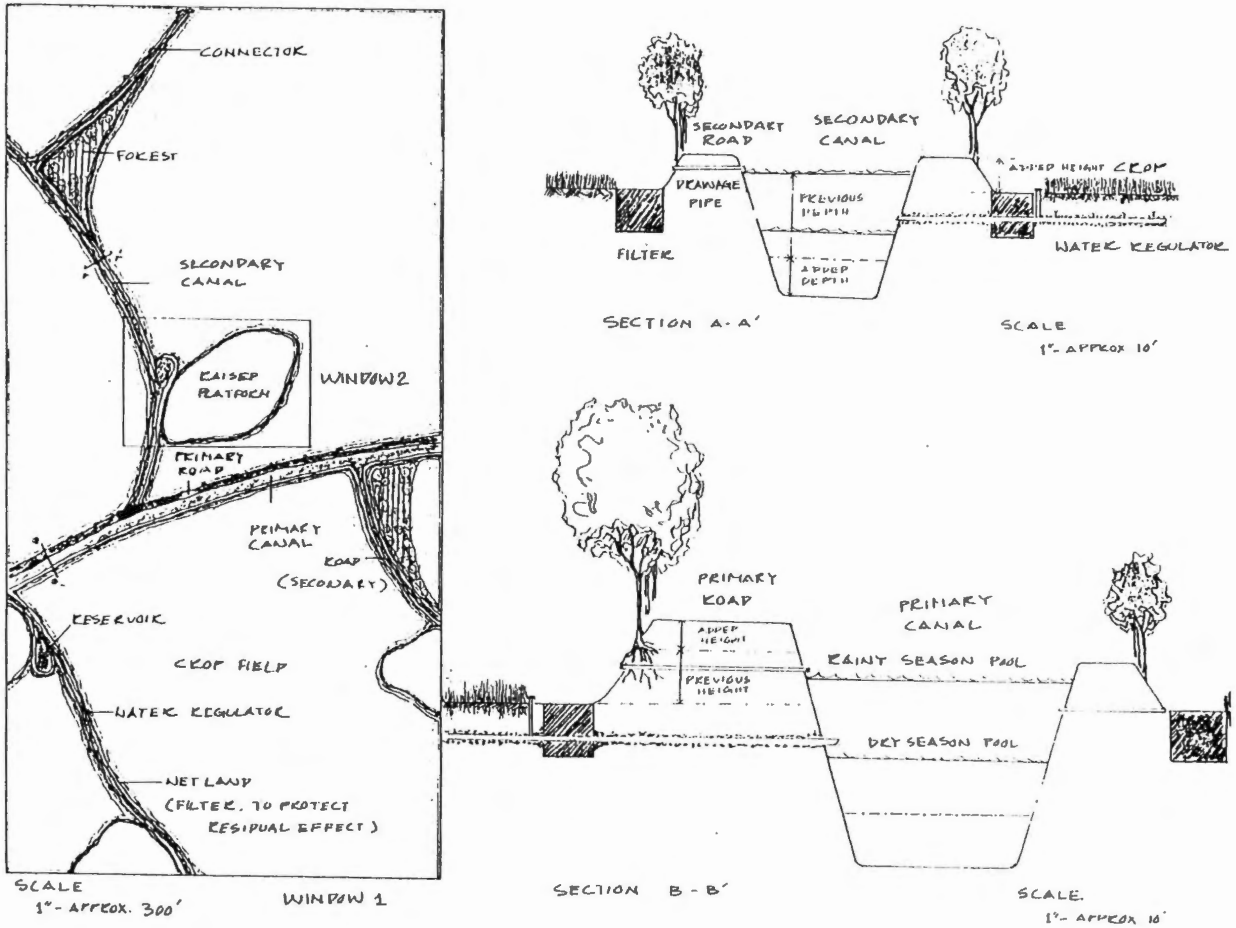


FIG 21: CANALSCAPE AND ITS COMPONENTS

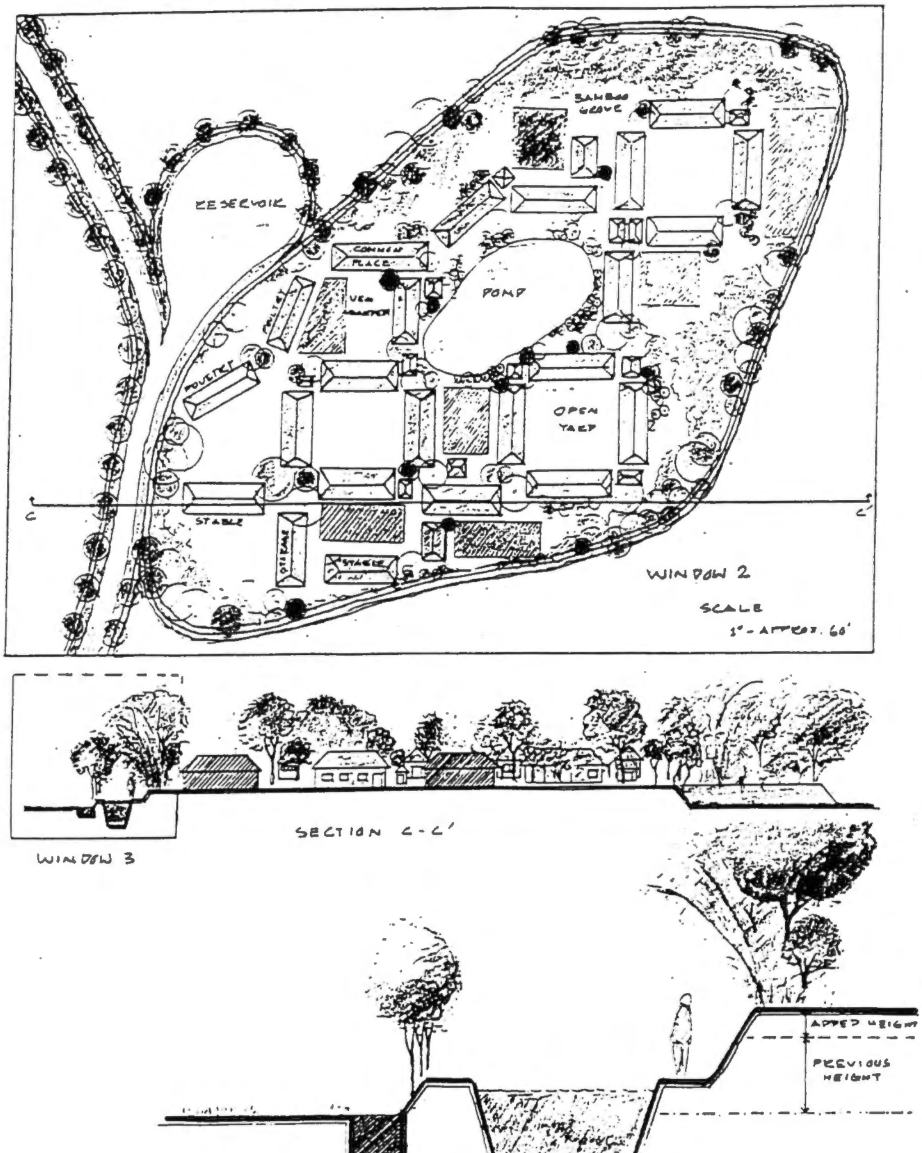


FIG 22: CANALSCAPE: RAISED PLATFORM AND HOUSEHOLDS

Proposed

The main purpose of the Canalscape is to modify the existing landform in such a way that the newly built canals can hold and drain the excess water during the monsoons, and store water for the dry season. The depth of the canal will depend on the depth of water table and depth of the flood water in a particular region.

Crop Fields

Crop fields are large patches of land that are formed by removing borders among different small plots, and that are surrounded by canals. The newly-built road system acts as embankments to keep flood water from leaving the canal and entering the crop field (Fig. 21, p. 46). Necessary regulators will be provided in the Canalscape through which water level can be controlled in these patches of land. Since siltation during flooding makes the crop field fertile, these crop fields can be flooded at the proper time through the regulator (Fig. 20, p. 45).

Filter

A filter is a strip of wetland (Fig. 21 and 22, p. 46 and 47) between a crop field and canal where different pollutant-absorbing plants will be grown. This filter has been designed along with the Canalscape to reduce the residual effect of pesticides. It will act as a bio-barrier or filter for the residual runoff of chemicals from crop field to the canal. Wolverton et al. (1989) have identified a list of plants which can reduce indoor pollution. These plants are capable of trapping and absorbing different toxic chemicals through their leaves and roots. It may be possible to find such plants in Bangladesh that can be planted or naturalized in the filter area to reduce the toxic pollutants from residual runoff of chemicals. Intensive research in this area might open a new door in safe agricultural management.

Temporary Flooded Areas

In the Canalscape, within a village a large area will be kept open to be flooded naturally to reduce water pressure due to over bank flooding during monsoons (Fig. 20, p.45). Deep water rice and fish cultivation could be done through proper management in this area. This area could be expanded and joined among villages.

Forests

Forests are another vital component of the Canalscape (Fig. 20 and 21, p. 45 and 46) where important native and economic plants can be planted. This will significantly increase the total amount of woded land in Bangladesh. In addition, organized planting (shelter belts) will be made on one side of the secondary road (between crop fields and roads), which will also protect the crop fields and households from seasonal storms. Since the primary road is wider than the secondary road, plantation of trees could be done on both sides of the road (Fig. 23 and 24).

Major Farm House

Since the community farming system will provide all necessary management of crops, the individual households will not need spaces for crop processing inside their platform. There will be a major area to do so located in a suitable site in this village pattern (Fig. 20, p. 45).

Raised Platform

In Bangladesh, people typically live in a cluster configuration, consisting of a raised earthen bed or platform (Fig. 8 and 9, p.19) to protect homeowners from floodwater (except in case of very high land and hilly regions).

Reservoir

In the proposed concept, large reservoirs, a major component of the Canalscape, have been designed next to each raised platform to hold and reserve the excess water during the monsoon season. This will provide irrigation in the dry season and fresh water for both the households and the fish cultivation (Fig. 20-22, p. 45-47). Number and size of these reservoirs will depend on the water demand of a particular village. In most cases, there will be at least one pond in the lower part of each compartment. These ponds would possibly help to reduce

FIG 23: EXISTING CONDITION OF PRIMARY CANAL AND ROAD
Source: Saifuddin, 1994

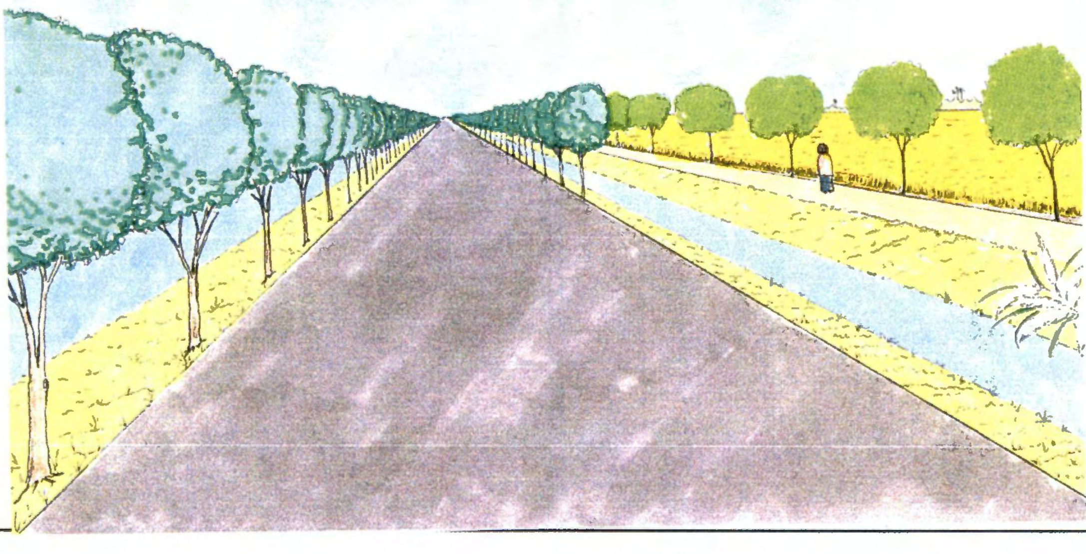


FIG 24: PROPOSED IMPROVEMENT (PRIMARY CANAL SYSTEM)

the flow of silt from the crop field to the canal (Yoder, 1995a).

Community Farming System

A community farming system is a typical cooperative farming system where every household in a village will participate in cultivation under a cooperative society. This is one of the most vital components in implementing the Canalscape into reality. A local governing body in the community will control the total mechanism (crop production, processing, and marketing). Not everyone in the village has to invest time in crop production. Villagers can work in the city, or study, and the elderly persons (who are the only members of their family staying in the village to take care of their property) are free to leave their household.

In every village there will be a record system maintained by the community to keep a record of the initial size of the land, its fertility level and other physical features of the land. For the first 2-3 years (after this period of time the crop field will be homogeneous in fertility) the fertility level of the land will be considered to ensure a fair crop distribution. Each community will recruit its employees from the same village (not less than 80 percent). Those who do not have any land will have the priority to do the labor. Those who do not want to do the labor in crop cultivation might take their crop/share home by the end of the season or year against their land. They can deposit their share in the community saving system. The community/cooperative society can do business with that money and can use the profit for the common development of the people in the village. In each season or year, the net profit/production (excluding production and maintenance cost, labor, and so forth) will be divided among the shareholders. The community will encourage the villagers to deposit their share into their own community banking system. A certain amount of their share will be saved mandatorily by the community which will be returned after a certain period of time to the shareholders or their nominees. This will provide security in any kind of emergency and for their future comfort. People of that village will form their committee. The chairman and the members of the committee will perform in a voluntary capacity.

Organizational Structure of the Cooperative Society

The present conceptual village pattern is a combination of landform modification (the Canalscape, which will modify the flat topography of the existing land form to provide the necessary physical feature to introduce a new social structure into a safe environment) and an organized cooperative community system. In this system, there are no significant risks, rather benefits for all. Since every piece of land will be recorded against its owner with every detail, farmers (both large and small) will be ensured a fair income distribution from their land by the proposed cooperative system. People can sell their property to anyone or to a cooperative group. The cooperative will encourage landless farmers to buy property using their savings or a loan from the cooperative society. Irrespective of whether farmers work in their social cooperative or not, they will always receive their share against their land. But the cooperative society will have the privilege to choose the landless farmers to do labor over others. This organized cooperative society will also ensure a proper distribution of the annual profit into different sectors of that village such as, school, college, health clinic, and so forth.

The social cooperative can give loans to the other villages or to units above them in the hierarchy of the administration (Fig. 25), which will contribute to the national development. The cooperative society of a village itself is a building block of the entire nation. There will be no conflict between the society and political system of the nation. They will work alongside, yet individually. One individual society can communicate to the highest level of administrative body of the nation directly; in case of emergency, bypassing its superior unit (such as Upazila/Thana, Zila, and so forth). Bank, school, clinic will be independent within its society and will be controlled by a higher unit in the hierarchy. The society will participate voluntarily to improve these institutions. Although the idealistic vision of the proposed cooperative society might seem very enthusiastic, indeed, an organized society can only deal with problems toward a common solution for all. This conceptual village pattern is one of the several ways through which the socioeconomic condition of Bangladesh can be reformed.

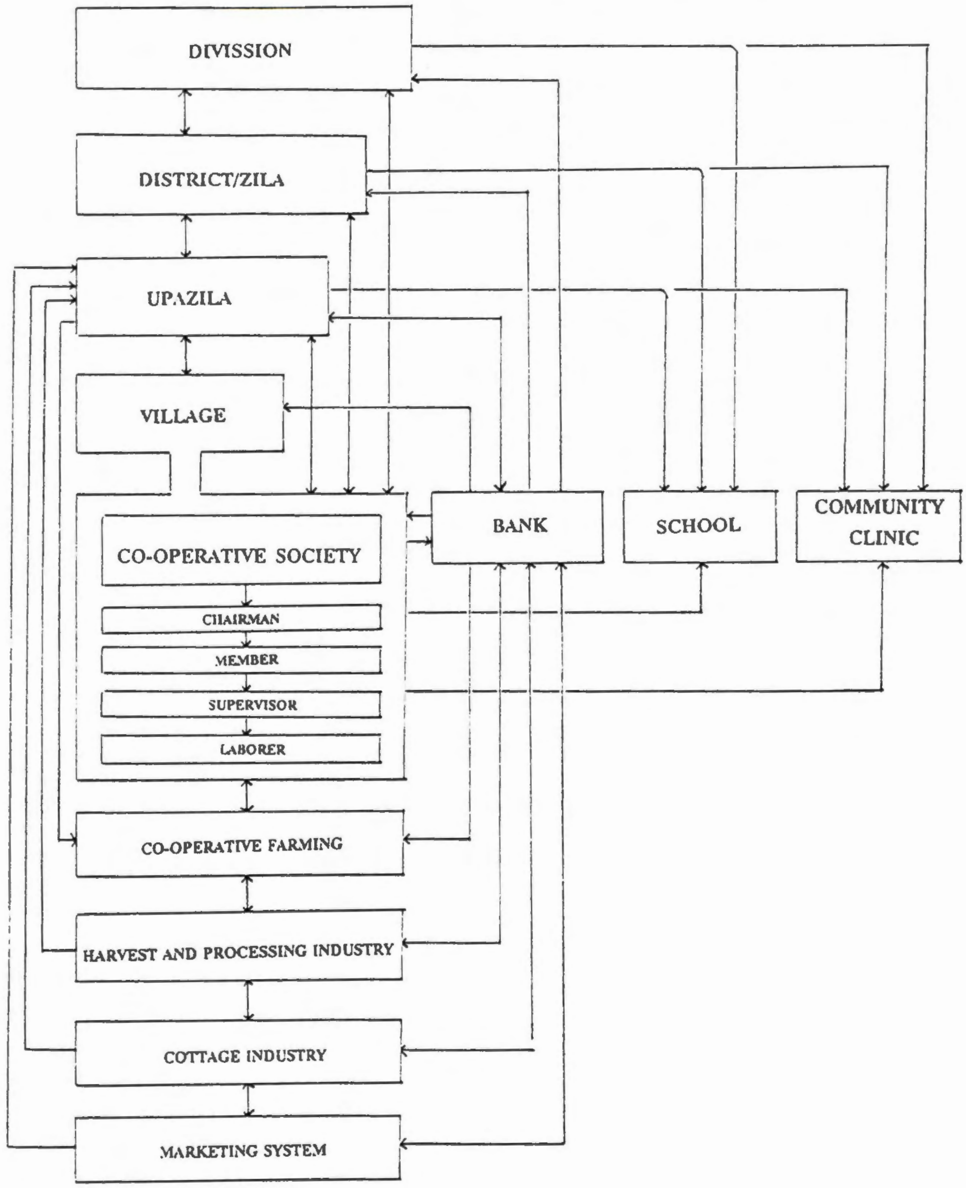


FIG 25 : ORGANOGRAM OF A COOPERATIVE SOCIETY

Proposed Improvement

Crop Field Pattern

The Canalscape will change the physical shape of the existing landform which will provide necessary support in proper land distribution under a newly designed community. Patches of large land will be created by developing the newly elevated (height will be determined based on the land type and depth of flooding) road system within the canalscape (Fig. 21, p. 46) When the borders among current crop fields are removed, a considerable amount of cultivable land will be opened. The land will be more gradual and plain, which will facilitate quicker and easier cultivation techniques. It will also be easier to keep the fertility level of a large land homogeneous. A suitable cropping pattern within different patches of land could be followed to balance the fertility level of the soil as well as to serve as a large barrier to prevent insects and diseases from moving from one crop field to another. It will be much easier to maintain an organized irrigation and drainage system within a boundary. Overall, it will be much easier to apply modern cultivation techniques in an undivided large plot than numerous small plots.

Household

The Canalscape will provide a highly organized household pattern. Raising the existing platform (height will be determined based on the land type and depth of flooding) will protect it from flood water (Fig. 22, p.47). In the proposed village pattern, a cooperative society cultivates and harvests crops centrally. It will use one specialized platform (Farm House, Fig. 20, p. 45) for crop processing. In the existing platform every household keeps a large open yard to process the crop (Fig. 10, p. 20). So, the new pattern will create more open spaces within each platforms where vegetable production or poultry farming can be done or a small cottage industry can be established (Fig. 22, p. 47). In this way generation of income sources can be increased and utilization of unemployed people (women, elderly, and so forth) in production can also be accomplished. By shaping the platform more regularly, erosion problems can be solved. The Canalscape will also ensure an organized plantation of different trees, which will not only provide economical benefits but also protect the households from environmental hazards. Since every platform will be designed specially for living, new types of housing can be implemented that will accommodate more families in one platform. Because more than 90 percent of houses in the village are singled storied, there is a great possibility to decrease the number of the total houses by increasing the number of two or three storied houses. This will discourage families from building new platforms, thus minimizing the use of cultivable land for housing.

Proposed Canals and Roads

The Canalscape will provide a highly organized transportation system by connecting every road and waterway. By creating a continuous road system along the canals, the Canalscape will also ensure widespread travel and communication both inside and outside of the village. The main purpose of canalscape is to distribute canals and roads in such a way that the road system will not block the water flow. Every road will be the boundary between canals and patches of cropland, and will act as an embankment to keep flood water from entering from canals to the crop fields (Fig. 21 and 24, p. 46 and 50). Control of flow through this embankment will also provide an effective drainage and irrigation system. Canal depth will be increased, and the excavated soil will be used to build the road system. The Canalscape will connect every household into an organized transportation network (Fig. 20, p. 45).

Agriculture

In the Canalscape, when borders of the small plots will be removed, a large area of land will be opened facilitating proper agricultural management. Different patches of large plots will also facilitate following a definite cropping pattern under the community farming system. This will help to maintain the soil fertility level and will also reduce the invasion of different insects and diseases from one plot to another. Since the community farming system ensures a combined agricultural practice, the benefits will be much greater than scattered cultivation techniques. The Canalscape will facilitate proper irrigation and drainage systems throughout the year. Deepened canals and newly built reservoirs (adjacent to every raised platform, Fig. 20-22, p. 45-47) will hold excessive floodwater during the dry season. This will also create more space (fresh water) to culture fish. Since different patches of crop field are bordered by embankments, transplanted fish can be cultured along with rice or jute. Each year natural flooding adds silt into the crop field which makes the soil fertile. This can also be accomplished through controlled flooding depending on need. Pearce (1991) said, "Famine was predicted after the floods in 1987 and 1988; in fact, record crops followed, largely because the floods left behind moisture, fertile silt and algae." For the Canalscape system the crop field is recommended to be flooded during the peak of the flooding season. It also supports the idea of controlling the flood during the first few months of monsoon to provide a flood-free environment for the rice seedlings to grow up to a certain level (Saleh, 1991). The filter (between crop field and road system) will bring about some filtering effect to reduce the residual effects of pesticides. Highly mechanized farming systems reduce a large amount of labor; however, in Bangladesh there is also a large number of unemployed people in the rural area. The Canalscape would introduce a blend of indigenous and modern techniques to utilize a vital resource (labor) to sustain the development. However, the Canalscape concept strongly suggests the proper use of other components for cultivation, such as modern varieties of crops, fertilizer, irrigation, and so forth. Livestock and poultry farming will be encouraged on every platform, providing job for the unemployed people especially for the women and the elderly. The canalscape will open a large area where different economical and native plants can be planted. The purpose of this community pattern is to make every village economically sound and independent, thus providing a necessary foundation for national development by efficiently utilizing every possible acre of land and organizing the excessive population into a resource under a definite plan.

Environment

The Canalscape will provide a necessary facility to control primary and secondary floods to protect crops. By using a simple water control gate or siphon tube (Yoder, 1995a), the water level in the field can be regulated. During the peak of flooding, the floodwater will be allowed to enter the crop field, that will protect the road system by reducing water pressure due to secondary flooding and will also increase the fertility of the crop field. In every village, a large area (flooded area) could be designed for natural flooding, that will reduce the water pressure during sudden flooding and over bank flooding (Fig. 20, p. 45). These flooded areas among several villages can be connected for further benefit. Deep water rice, along with fish, can be cultured in those flooded areas. The canalscape will create large native forest lands (Fig. 20 and 21, p. 45 and 46). These patches of forests will be a refuge for wildlife. Plantations in conjunction with the road system (Fig. 22 and 24, p. 45 and 50) will connect different patches of forests providing linkages or corridors for wild life movement. The forest will also act as windbreaks to protect the crops from storms. Since the road system will also act as an embankment, plantation of trees might be harmful because of plant root damage, however, a country like Bangladesh cannot spare idle land. In such a situation, trees will be planted on the dry side of the secondary road (between road and crop field). Since primary roads are wider than secondary roads, plantation will be done on both sides of the primary roads. Periodical harvest of trees can reduce the damage due to root growth. Chowdhury (1995) said that the possible root damage by planting trees on levees/roads could be ignored for a project like Canalscape. According to him the benefit from afforestation is very high, so, if there is any damage it can easily be repaired. However, different plant groups can be selected according to the spreading nature of their root system and soil binding capacity. Date palm (*Phoenix sylvestris*) is one of the several species of plants which can bind the soil. Root spreading can be limited by a) root type consideration during plant selection, and b) providing some physical barriers. Canal banks can be protected from erosion through proper techniques. In Bangladesh, cattle usually graze on the canal bank. Permanent structures along the canal bank would disturb this use, and this kind of construction would be expensive. Since cattle grazing on the canal bank disturbs the growth of grasses and increases erosion (Chowdhury, 1995), fodder crops which can withstand water, such as napier grass or para grass, can be planted on the wet side of the levee and can be harvested for cattle (Pradhan, 1992). By harvesting grasses from canal banks people can prevent cattle grazing in these areas, thus protecting the canal bank. Moreover, the organized plantation of trees will protect households and crops from storms. Figure 26 shows a pattern of air flow around a shelterbelt. Planting a large number of valuable trees not only helps the environment but also ensures economic benefit.

People and Rural Economy

The new community pattern will encourage the people to use minimum land for living and maximum land for cultivation. It will also provide a new housing pattern which will take considerably less area. Proper research might find affordable multi-storied housing suitable for the rural environment. The community farming system and cooperative society will utilize every man and woman in all possible ways. It will provide a personal farming system within each platform (vegetables, poultry, livestock, fisheries etc.) along with community farming for every household. The cooperative society will establish cottage and different small-scale industries to create more jobs. The society will provide necessary inputs and training. The community will establish its own marketing system. Finally, this community pattern will ensure the participation of all people in their own and national development.

Education

Under the new community system, every village will have at least one well-organized primary school. The community farming system will ensure that every child goes to school. In every three villages (depending on the population of those villages) there will be at least one high school. Communities of those villages will share the expenses with the government to run the school. In every ten villages (depending on the population of those villages) there will be at least one college. Communities of those villages will share the expenses of that

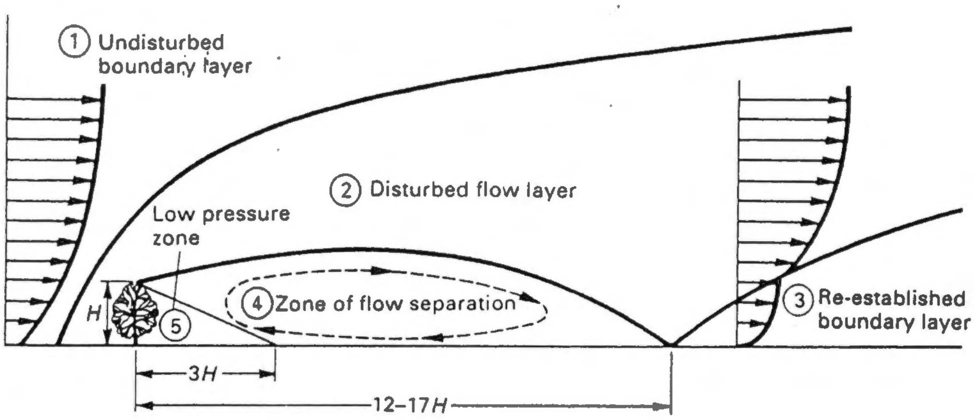


FIG 26: PATTERN OF AIR FLOW AROUND A SHELTERBELT
Source: Coppin and Richards, 1990

college along with the government. Up to high school level (10th grade) education will be free. The Community will provide several grants and scholarships for the students to go to college. The Community will provide vocational training according to its needs and will absorb the trained people into its different institutions such as, school, bank, farm, different processing industries, and so forth. It will also provide mass literacy programs for adults.

CHAPTER IV

IMPLEMENTATION OF CANALSCAPE INTO A MODEL VILLAGE

To test the conceptual village pattern at the field level an example village has been chosen, based on the availability of necessary information. Information about this village has been collected from published literature, a recorded interview, and brief surveys by some volunteers.

A Village Profile

The name of the village	Choto Kalampur
Union	Sutipara
Upazila/Thana	Dhamrai
District	Dhaka
Total Land	663.74 acres
Cultivable land	515 acres
Fallow land	.90 acres
Total Culturable land	515.90 acres
Area Under Houses, School, and bazar	147.84 acres
Area Under Forest	Nil
Soil Type	Sandy Loam
Total Population	3640
Male	1875
Female	1765
Literacy	21.9%
Male	30.3%
Female	12.6%
Schools	
Primary	1
High school	2
College	1
Islamic School	1
Bank	2
NGO	2
Total Households	649

(Source: Upazilla/Thana Statistics, 1994, collected by Saifuddin ,1995b)

Choto Kalampur is located approximately 35 miles from Dhaka city, and is easily accessible via the Dhaka-Aricha Highway. The highway has dissected the village into a northern and a southern part. The south part is totally lacking of roads and vulnerable to frequent flooding. Almost 79.5 percent of cultivable land floods occasionally or regularly, while 20.5 percent never floods. The village is bordered by 10 other villages and the river Banshi on its north side. The river runs approximately 1.7 km through the village. There are 1.6 km of canals on both side of the Dhaka-Aricha Highway, and almost 0.4 km of waterway at the middle of the village next to the primary road. Moreover secondary roads have been clustered in the central part which cover less than 20 percent of the total area. The primary occupation of 68 percent of households in this village is agriculture. Figure 27 shows the households and physical infrastructure of the village Choto Kalampur, while figures 28 and 29 show a typical rural household and non agricultural activities of that village.

In 1984, R.M. Ahsan and S.H. Hussain investigated the rural landscape of the present village, which they later published (Ahsan and Hussain, 1988). Most of the information about the physical, environmental, and social aspects has been adapted here from their study. Data were gathered through questionnaires, observations, and interviews of people by the investigator. A questionnaire was designed to obtain information such as land level, flood-ability, irrigation, location of plots, cropping patterns, crop yields, and so forth. On the basis of this questionnaire and field observation, land use maps were made. Investigation was carried out on 10 percent of total households throughout the year in 1984, with households selected on a stratified random basis. Because of its importance for the present study, the micro-level environment of this village has been illustrated here under different categories.

Environment

Situated approximately 20 feet above sea level, Choto Kalampur has a mean January temperature of 60 degrees F and a mean July temperature of 82 degrees F. The soil is generally referred to as the Brahmaputra Tract, which is grey in color without a developed profile, and light loam to clay loam in character. The amount and timing of the yearly rainfall

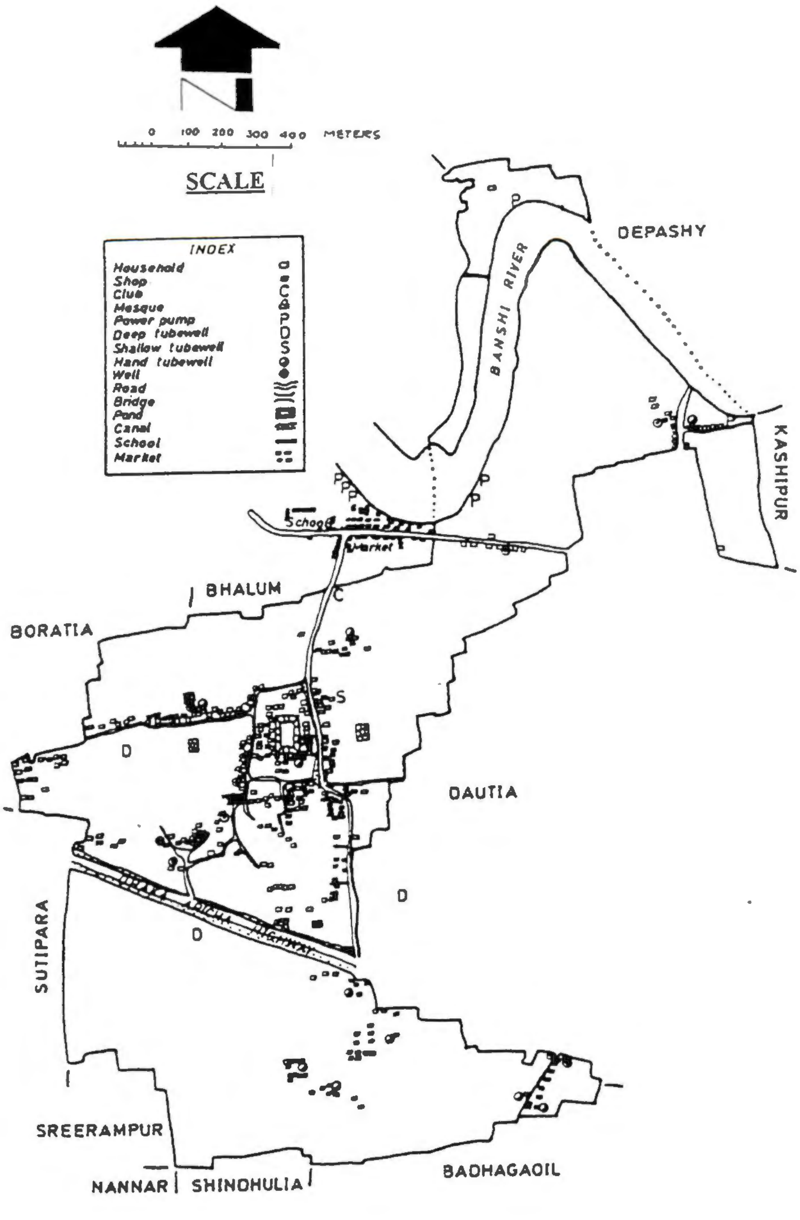


FIG 27: HOUSEHOLDS AND PHYSICAL INFRASTRUCTURE OF CHOTO KALAMPUR
Source: Ahsan and Hussain, 1988

FIG 28: A TYPICAL HOUSEHOLD OF CHOTO KALAMPUR
Source: Saifuddin, 1995a

FIG 29: OFF-FARM ACTIVITIES OF CHOTO KALAMPUR
Source: Saifuddin, 1995a

are critical to the well being of farmers. If there is a drought during the dry season and the sparse rains do not come, the farmers can lose their whole crop. If the monsoon is early and heavy, there is too much water and the rice crop may be destroyed. If the monsoon is heavy and lasts into October, another rice crop and the jute crop may be destroyed. Table 10 shows a comparison between flooding events and different cropping seasons for the village.

If a farmer can apply fertilizer to the crop it is fair to think, in general, the rainfall, temperature, and soils are adequate to produce enough food to at least maintain a subsistence level of living. But unfortunately, these factors are only a few of the variables affecting agriculture. Land distribution, irrigation, technology, social organization, political factors, and even religions are but a few factors affecting agriculture.

Distribution of Land

On average, a farm household of Choto Kalampur includes approximately 1.62 acres of land, compared with the national average of 1.67 acres (BBS, 1993). As studied by Ahsan and Hussain (1988), fragmentation of land is one of the most striking characteristics of the landscape of Choto Kalampur. Figures 30 and 31 show the fragmentation of land and condition of crop field during dry season. Small farm households own, on average, nine plots of land per household. Large farm households own an average of twenty-five plots of land per household, but an individual large farm household may own up to thirty-seven plots. These plots are scattered throughout the countryside, which is another limiting factor for successful agricultural practices. Some of the land owned and farmed by the residents of this village is located in different villages. One plot of a household's land may be only two minutes walking distance from the homestead, while another, seventy minutes walking distance from the house. The latter one is a potential time and energy liability. Figures 32 and 33 show the fragmentation of land and distance of each plot from the households.

Relative elevation of plots is another important feature which influenced the planning of agricultural activities of this village for the year. About 20 percent of the land in Choto

TABLE 10: A COMPARISON BETWEEN FLOODING EVENT S AND DIFFERENT CROPPING SEASONS

FLOODS AND THEIR OCCURANCE

Floods Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Flash Floods (Primary)				*	*							
Monsoon Floods (Primary and Secondary)						*	*	*	*			
Overbank Floods (Secondary and Tertiary)							*	*	*			
Storm Surges (Tertiary)				*	*					*	*	

CROPPING PATTERN

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Early Kharif	Jute			///	///	///	///	///	///	///			
	Aus			///	///	///	///	///	///				
Late Kharif	B. Aman			///	///	///	///	///	///	///	///	///	///
	T. Aman	///					///	///	///	///	///	///	///
Rabi	Boro	///	///	///	///	///					///	///	///
	IRRI Boro	///	///	///	///	///	///						///
	Wheat	///	///	///	///					///	///	///	///
	Mus-tard	///	///	///						///	///	///	///
	Potato	///	///	///	///				///	///	///	///	///

AVE ANNUAL RAINFALL DISTRIBUTION OF DHAKA DISTRICT FROM 1986-1989

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	35.5	19	43	202	263	379	450	314	388	199	62	13

Source: BBS, 1993; Barrett, 1990; Ahsan and Hussain, 1988.

FIG 30: FRAGMENTATION OF LAND IN CHOTO KALAMPUR
Source: Saifuddin, 1995a

FIG 31: CONDITION OF CROP FIELD DURING DRY SEASON IN CHOTO KALAMPUR
Source: Saifuddin, 1995a

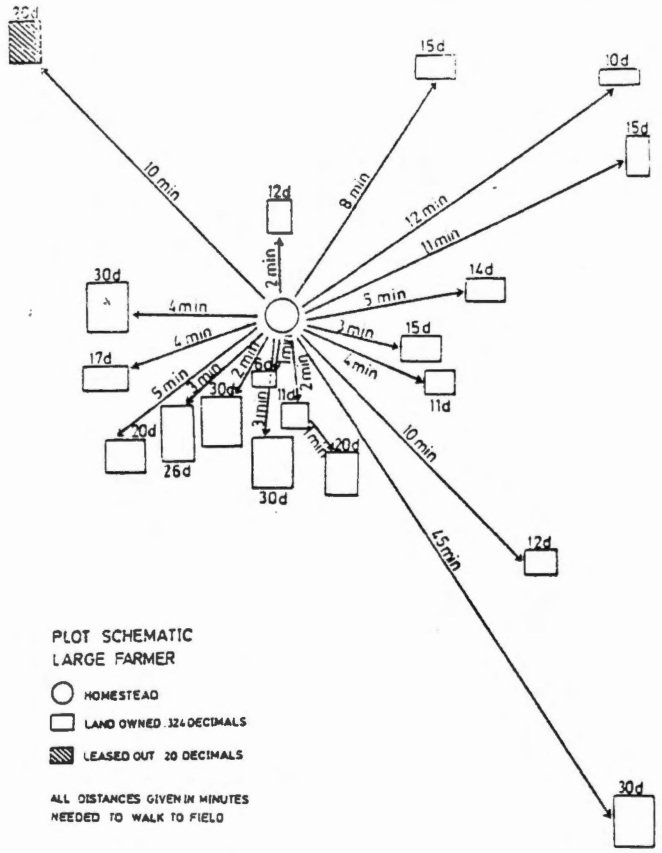


FIG 32 : SCHEMATIC PLOT DISTRIBUTION IN CHOTO KALAMPUR(LARGE FARMER)
Source: Ahsan and Hussain, 1988

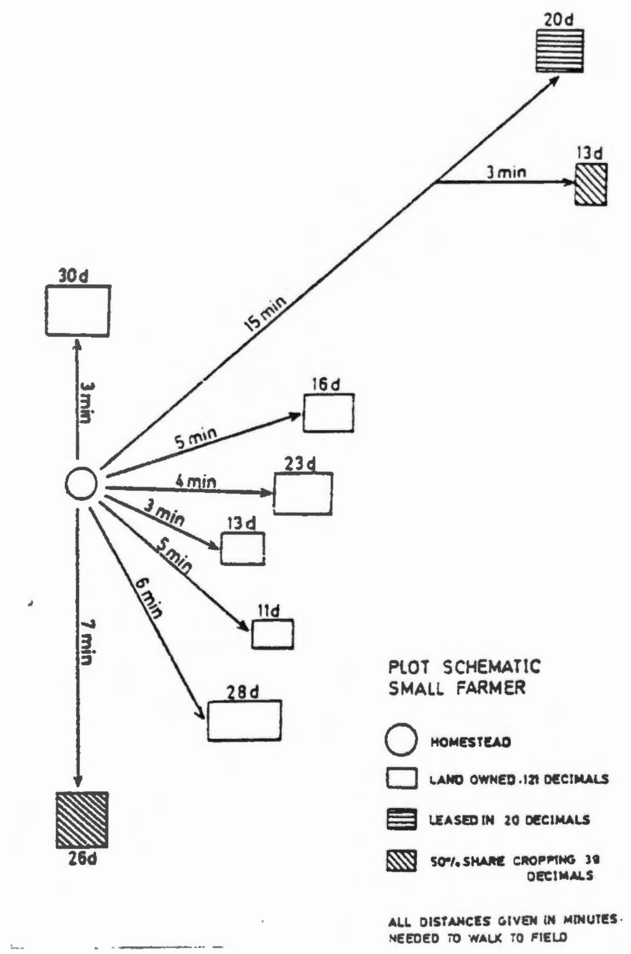


FIG 33: SCHEMATIC PLOT DISTRIBUTION IN CHOTO KALAMPUR (SMALL FARMER)
Source: Ahsan and Hussain, 1988

Kalampur is "high", which seldom floods during the heavy monsoon or rainstorm, and 24 percent of the land is 'medium high' which occasionally floods up to 3 feet. Fifty percent of the land is "medium low" and six percent is "low", which flood regularly during rainy seasons (Fig. 34). It has been recorded that the medium low lands often flood to a depth of 6 feet. Since the land is scattered throughout the community, susceptibility to flooding is another variable that farming households have to deal with when making cropping decisions.

Farming System

The farming system in Choto Kalampur is very much influenced by the irrigation system. Without irrigation, drainage control, and flood protection, the farmer is limited to one to two crops a year. Only 19 percent of the plots are under irrigation, which takes place during the early kharif period. Effectively there is no irrigation system in the southern part of the village, since the water comes from a canal located north of the highway. It takes 12 hours of continual pumping before the water reaches the fields. Analysis by the investigators revealed that 64 per cent of plots receive no fertilizer.

Ideally, the farm family harvests three major crops a year, but the crops are usually not grown on the same plot of land. It was found that part of the land is triple cropped, while other parts of the land may be double-or single-cropped. Some part of the land may lie fallow for part of the year. As such, a farm family may own two acres of land, but the family does not necessarily get two acres of triple cropping out of the land each year. On an average, 58 percent of the land is double-cropped. Approximately 14 percent of the land is single-cropped while multiple intensities (triple-cropped) land use is about 27 percent. Figure 35 shows the cropping season for Choto Kalampur throughout the year. Partially because of land fragmentation and partially because of unequal distribution of wealth, land is frequently sharecropped.

In general, the yields of the major crops in Choto Kalampur are below the national average. The average yields for the local variety Aus is 6.51 maunds (one maund = 37.32 kg)

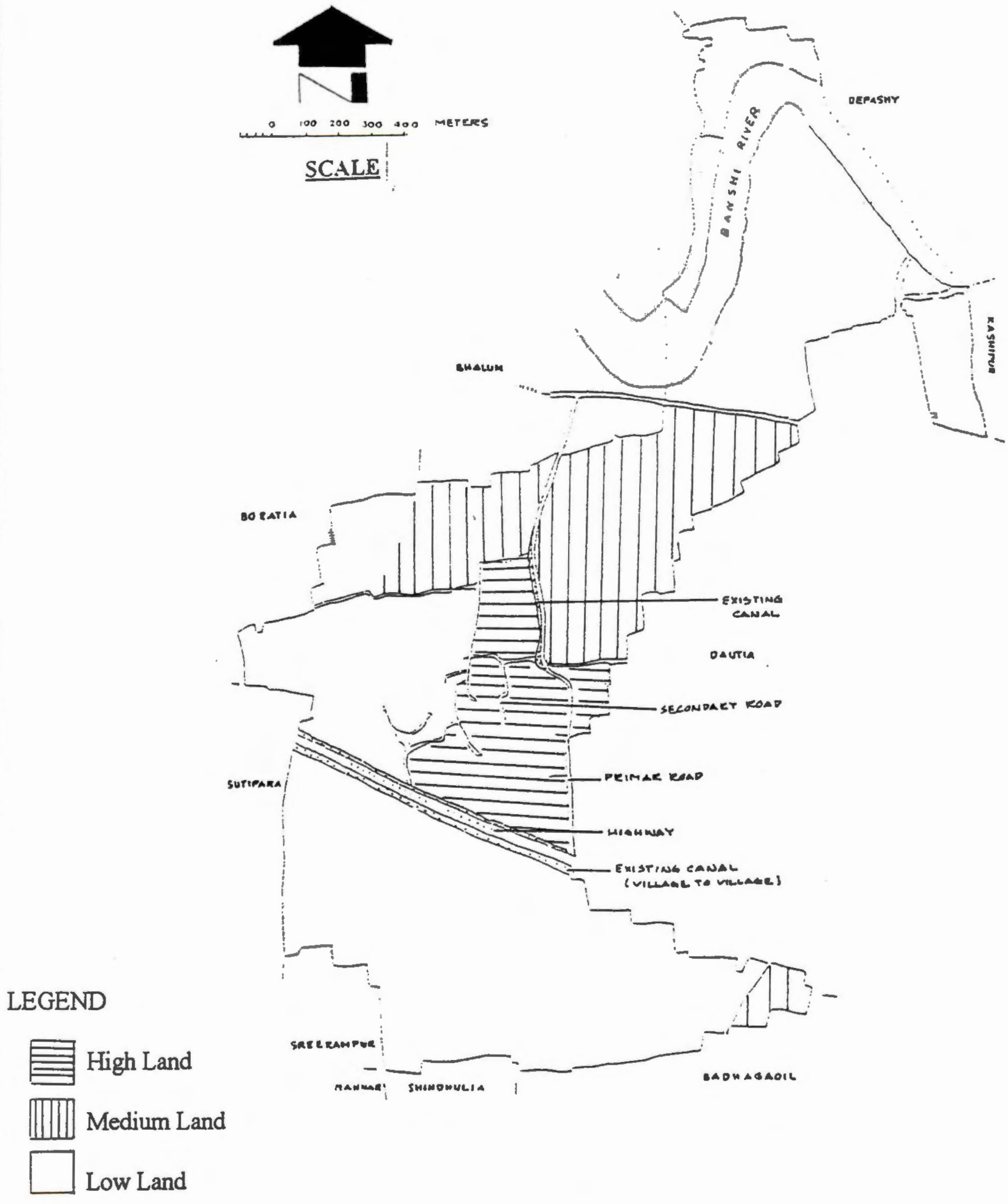


FIG 34: AVERAGE FLOODING SITUATION OF CHOTO KALAMPUR
Source: Ahsan and Hussain, 1988

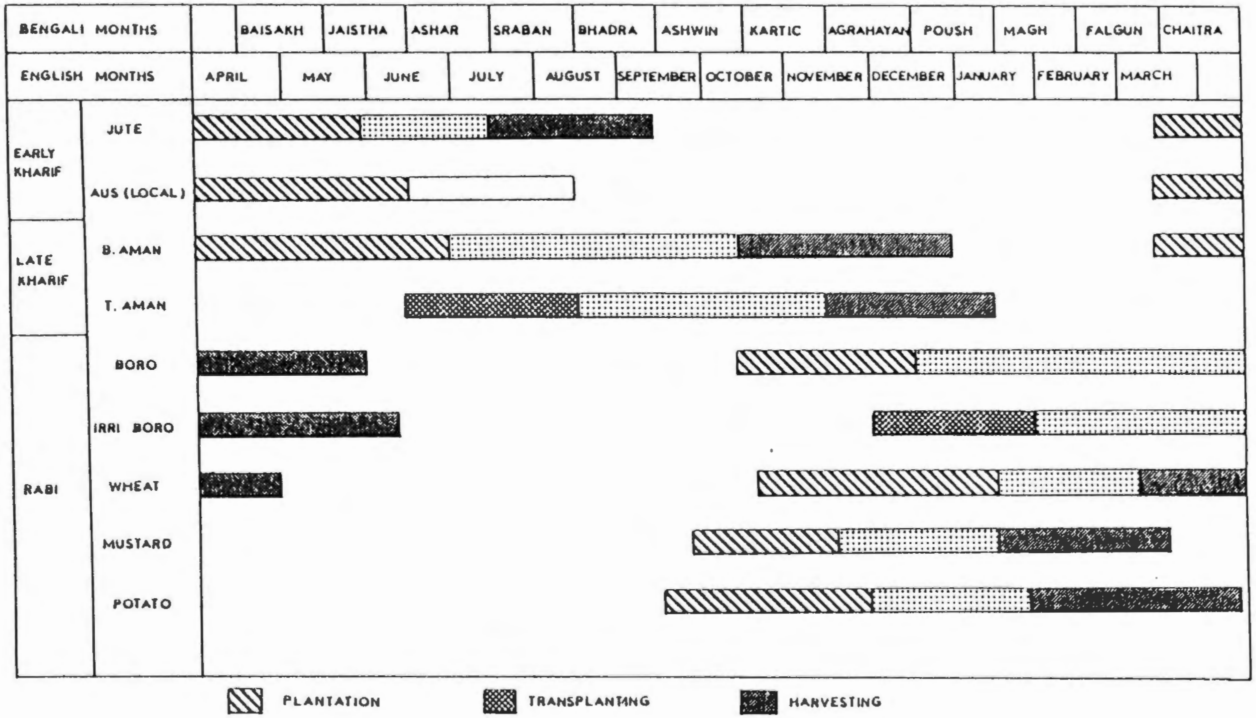


FIG 35: CROPPING SEASON OF CHOTO KALAMPUR

Source: Ahsan and Hussain, 1988

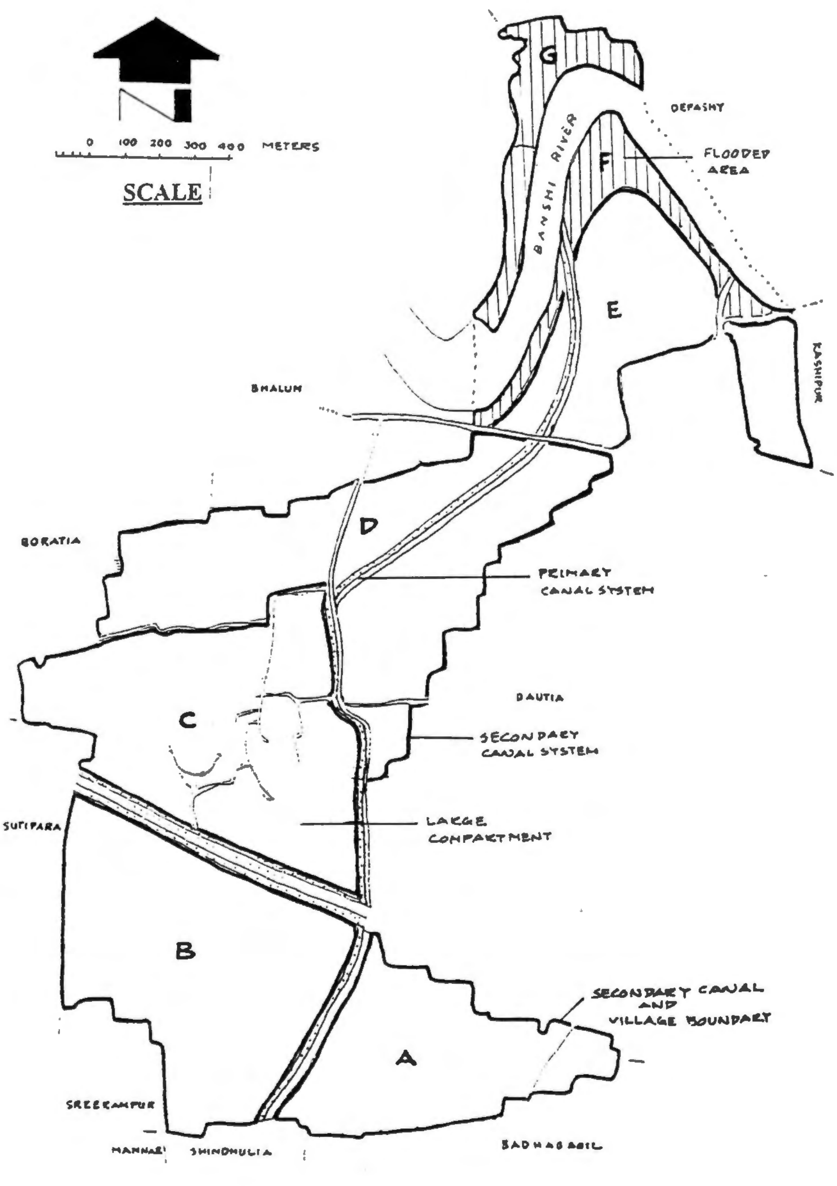
per acre while the national average is 11.46, for local Aman the yield is 5.0 maunds per acre compared the national average of 13.56. Jute is the only crop that has a higher yield than the national average. The average jute yield is 25.33 maunds per acre, whereas the national average is 15.75.

Very limited information has been found from published literature and brief survey about other agricultural practices such as forestry, fishery, livestock, and so forth. A detail survey of the socioeconomic conditions of Choto Kalampur is essential for the proper implementation of the Canalscape. In this investigation, an attempt has been made to compare the existing and modified conditions of the rural landscape, and to show the benefit from this project.

Suggested Landform Modification For Choto Kalampur

The total area of the village has been divided into seven compartments (Fig. 36), which are surrounded by a secondary canal system with a 10-foot wide road on both sides of the canal. A primary canal will run from the southern end to the northern end, and drain the entire area to the river Banshi. To calculate the size, shape, and covered area under primary canal system the total area of the village has been divided into three drainage basins such as AB (A+B), CD (C+D), and EF (E+F) (Fig. 36). Sine there is no primary canal in compartment G, a secondary canal system will drain that area. A 15-foot wide primary road will run along with the primary canal, while a 10-foot wide secondary road will run along the other side of the canal. Again, a 10-foot wide secondary road system will further divide the seven compartments into 21 small compartments (Fig. 37) to create the infrastructure of the "Canalscape."

The calculation for the flood water level has been done according to a 20-year return period of this region. A Flood Management Model of this region has cited the maximum depth of flood water during a 20-year return period between 6 and 9 feet (FPCO, 1994). The

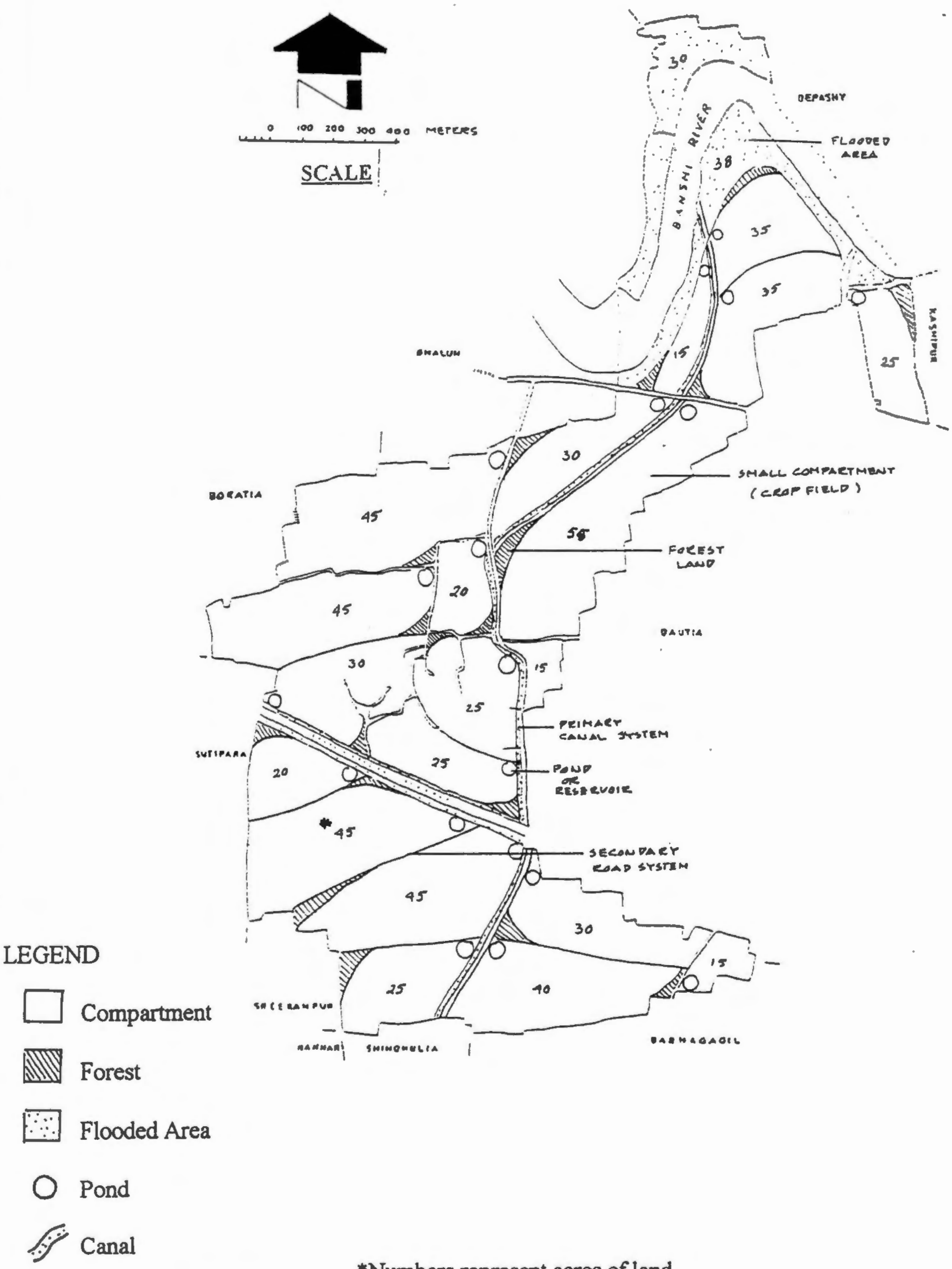


LEGEND

Temporary Flooded Area

Canal

FIG 36: IMPLEMENTATION OF CANALSCAPE INTO THE EXISTING LANDSCAPE OF CHOTO KALAMPUR



*Numbers represent acres of land

FIG 37: IMPLEMENTATION OF CANALSCAPE INTO THE EXISTING LANDSCAPE OF CHOTO KALAMPUR

intention of the present investigation is to prevent floodwater entering from the crop field for a certain period at the beginning of the flooding season (during primary and secondary floods). Since the water level ranges between 3-4.5 feet (occasionally up to 6 feet) during the regular flooding season in Choto Kalampur, an average 6 feet flooding depth has been chosen for the present study. An average 4-foot levee height has been designed for both the primary and secondary canal systems. The levee height has been chosen according to the assumed flooding depth of that village. The levee (submersible embankment) height on both sides of the river will be 2 feet to allow natural flooding (overbank flooding) to compartments F and G (Fig. 36, p.74), to reduce the water pressure into the other compartments, and to provide storage for excess water during secondary floods.

Methods

Design of the canal system has been calculated based on two equations. The first is based on a simple mass balance, or continuity equation:

$$Q = vA$$

Where,

$Q =$ Flow Rate $(ft^3 / sec = cfs)$

$v =$ Flow Velocity $(ft / sec = fps)$

$A =$ Channel Cross Sectional Area (ft^2)

The other equation is an empirical one known as Manning's Equation (Schwab et al.,1993). This equation is of the form

$$v = \frac{1.49}{n} R^{\frac{2}{3}} s^{\frac{1}{2}}$$

Where,

v = Velocity (fps)

R= Hydraulic Radius (ft) = A/P (where P = wetted perimeter in ft)

s = Channel Slope in ft/ft

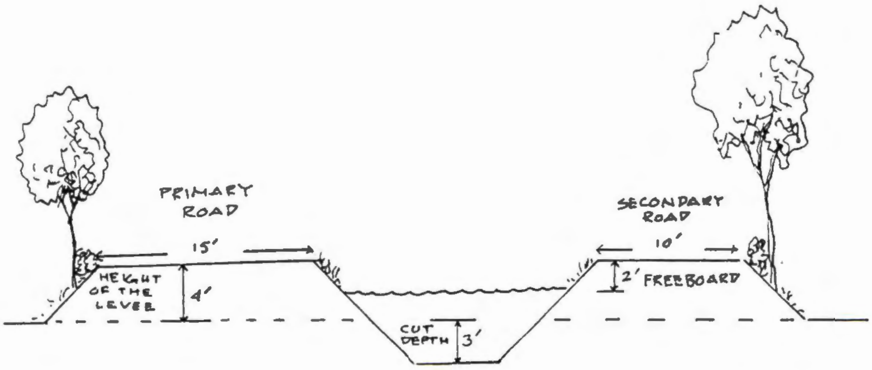
n = Manning's Roughness Factor for channel

<u>Different numerical values assumed in the design process are:</u>

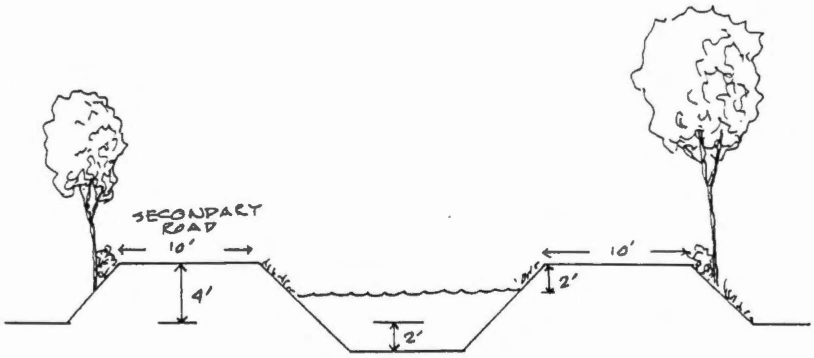
Channel Slope (%)	= .5%
Channel Manning's Roughness	= .024 (Chow, 1959)
Maximum Permissible Velocity (fps)	= 7 (Schwab et al.,1993)
Water Depth to Remove (ft)	= 6
Time for removal (hrs)	= 72
Top width of Levee (ft)	
Primary (Major) Road	= 15
Secondary Road	= 10
Free Board to Allow (ft)	= 2
Channel Cut Depth (ft)	
Primary Canal	= 3
Secondary	= 2
Side slopes of canal	= 1:1 (45^0)

Figure 38 and 39 shows the proposed sketch and geometry of the canal and road systems.

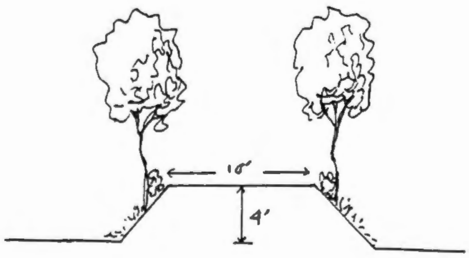
The attempt made to calculate canal sizes and shapes used by the project to control flooding does not intend to be a complete hydrologic analysis, but rather a simple proof of the concept in determining the approximate land area occupied by the Canalscape. According to the basic hydrological equations, a program was written to calculate canal sizes and the land area occupied by the Canalscape (Yoder, 1995b). For the purpose of this program a trpezoidal shape has been chosen for channel with a specified bottom width and a sideslope steepness defined by Z = run/rise (Fig. 39). The sideslope steepness is determined by ease of



a: PRIMARY CANAL SYSTEM



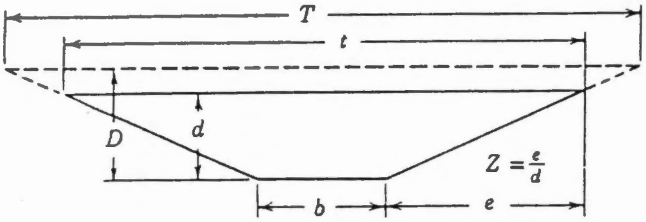
b: SECONDARY CANAL SYSTEM



c: SECONDARY ROAD SYSTEM

Note: Canal widths not to scale

FIG 38: PROPOSED CANAL AND ROAD SYSTEMS



Cross-Sectional Area a	Wetted Perimeter, p	Hydraulic Radius $R=\frac{a}{p}$	Top Width
$bd + Zd^2$	$b + 2d\sqrt{Z^2+1}$	$\frac{bd + Zd^2}{b + 2d\sqrt{Z^2+1}}$	$t = b + 2dZ$ $T = b + 2DZ$

TRAPEZOIDAL CROSS SECTION
Note: Freeboard = *D-d*

FIG 39: GEOMETRY OF THE PROPOSED CANAL SYSTEM
Source: Schwab et al., 1993

construction and by slope stability criteria. The assumed sideslope steepness for both primary and secondary canal system is 1:1 or, 45^0. A value of 0.024 for n (Manning's roughness) has been determined according to the type of bottom and vegetation in the channel. To run the program the likely channel slope of the village Choto Kalampur has been assumed as 0.5%. The normal procedure is then to pick the flow depth, and to alternatively solve the two equations. The flow velocity at which these converge is then compared to the maximum permissible velocity which will not cause erosion within the channel. If the flow velocity is too high, a larger channel depth is selected, and the process is repeated. If the flow velocity is much lower than permissible, a narrower channel width is selected to reduce channel size. The program has been set up to automate this procedure. It selects a channel width, converges on a flow velocity, and then adjusts the channel width to get a flow velocity equal to 90 percent of the maximum permissible velocity. The entire process is based on knowing the flow rate Q. The program calculates it from the depth of water to be removed, the time over which it must be removed, and the area of the enclosure. In addition, it calculates the land area lost to levees, based on the general shape and the channel width determined above. This assumes that the general enclosure shape is elliptical. The land area taken by the canal/levee is then calculated by multiplying the entire levee width by the enclosure perimeter length.

Results

The preceding equations and conditions were applied to the example village Choto Kalampur, which resulted in the following findings.

Primary Canal System

To calculate the size and shape of the primary canal system which runs from the southern to the northern end of the village and ends at the river Banshi, the entire area has been divided into three different drainage basins such as AB (A + B), CD (C +D), and EF (E + F) (Fig. 36, p. 74). Table 11 has depicted the covered area under levee and channel in those drainage areas.

TABLE 11: AREA UNDER PRIMARY CANAL SYSTEM

Drainage Area (acre)	length of canal (ft)	Total Canal and Levee width (ft)	Covered Area (acre)
221 (AB)	1680	46.50	1.79
221+295 (AB + CD)	4560	66.50	6.96
221+295+148 (AB + CD + EF)	1800	76.99	3.18

Total primary canal length: 8040 ft

Total area covered by primary canal system (Canal and associated Roads and levees): 11.93 acres or, 1.8% of total land area.

Secondary Canal System

The secondary canal system encircles each smaller drainage basin, creating 7 compartments (Fig. 36, p. 74).

Total area covered by secondary canal system: 47.23 acres or 7.11% of total land area.

Secondary Road System:

This road system does not have canals with it, and has further divided the seven large compartments into 21small compartments (Fig. 37, p. 75). Since the secondary canal system has already been designed to drain each of those 7 compartments, the purposes of this road system are (a) to provide extensive transportation inside the village, (b) to create more area for plantation of trees, (c) to increase the effect of the shelter belt, and (d) to make cultural operation (both crop production and fish culture) easier by providing smaller patches of land. By avoiding canals along with this road system, the wastage of valuable land has been reduced.

Total area under secondary road system:	5.05 acres or, .76% of the total area

Flooded Area

To flood compartments F and G (Fig. 36 and 37, p. 74 and 75) during continuous rainfall and sudden water flow from the river during the early flooding season, a two-foot high levee is recommended.

Area covered by this levee:	2.51 acres or, .38% of the total area
Total area covered by canal and levee (road):	11.93 + 47.23 + 5.05 + 2.51= 66.72 acres or, 10.05% of the total land
Existing road and canal (approximately):	6.64 acres or, 1% of the total land
Net area covered by new canal and levee:	66.72 - 6.64 = 60.08 acres or, 9.05 % of the total land
Total area covered by forest land besides homestead plantations:	7 acres or, 1.05% of the total land
Total area covered by pond inside smaller drainage basin:	3 acres or, .45% of the total land
Total area covered by the newly designed Canalscape:	60.08 + 7+ 3 = 70.08 acres or, 10.55% of the total land
Total land area of Choto Kalampur:	663.74 acres
Area unavailable for cultivation:	147.84 acres or, 22.27% of the total land
Total culturable area:	515.90 acres, or, 77.73% of the total land
Area available for cultivation:	515.90 - 70.08 = 445.82 acres or, 67.18% of the total land

Linear Length of Area Along the Canal and Road System for Plantation

Along the primary canal system	24,120 ft
Along the secondary canal system	79,200 ft
Along the secondary road system	33,420 ft
Total linear area available for plantation	136,740 ft

Cost analysis

In this section an attempt has been made to rationalize the loss of crop land due to the structure of the Canalscape. Although the loss of 70 acres of land might seem unreasonable initially, the ultimate economical benefit (calculated) from this structural change will determine the credibility of this project. The modified landform will create the opportunity to sustain an improved and balanced environmental condition. The land that will be taken away from traditional crop cultivation, may not be a net loss. It can be compared with energy transformation from one stage to another where net energy loss is zero. In the present study the land that has been taken away is actually the transformation of land from one use to another. Simple calculations have been made to show the difference in net economical benefit with or without this structural change. Moreover, different social and environmental impacts of Canalscape have been discussed in the next section.

Approximate Cost Due to Structural Establishment and Crop Loss

Structural establishment

Cost of earth work (Source: Matin,1995)

(Canal digging and levee making)

TK. 225,000/km for 15' wide (top width), and 4' high levee.

TK. 150,000/km for 10' wide (top width), and 4' high levee

TK. 75,000/km for 10' wide (top width), and 2' high levee

($1 = approx.TK. 40, 1 km = 0.6214 mile)

Average annual maintenance cost (Source: Matin, 1995)

(Canal digging and levee repairing)

TK. 1,000/ km

A. <u>Cost for Primary Canal System</u>

A 15' wide primary road, and a 10' wide secondary road (Fig. 38a, p. 78) will run on both sides of a 2.68 km primary canal.

Cost for 15' wide road (levee):	TK. 603,000
Cost for 10' wide road (levee):	TK. 402,000
Total:	TK.1,005,000

B. <u>Cost for Secondary Canal System</u>

A 10' wide secondary road (Fig. 38b, p. 78) will run on both sides of a 13.20 km secondary canal.

Cost for 26.40 km road (levee): TK.3,960,000

C. <u>Cost for Secondary Road System</u>

These roads will divide the 7 large compartments into 21 small compartments. A 10' wide secondary road (Fig. 38c, p. 78) alone will run for 5.57 km.

Cost for 5.75 km road (levee): TK. 835,500

D. <u>Levee on River Bank</u>

A 10' wide and 2' high levee will run on both sides of the river (1.7 km on the south side and .9 km on the north side of the river).

Cost for 2.6 km levee:	TK. 195,000
Total structural cost:	TK.5,995,000

If we consider this structure will remain intact for a minimum period of 20 years, the annual cost may be counted as

Tk. 299,750

Maintenance cost

Total maintenance cost of
40 km of road (levee)
@ 1000/km TK. 40,000

The levee will be built by the excavated soil from canal digging. The canal depth might be increased if there is shortage of soil. Since the river becomes almost dry during winter, excavation of soil from the river bed is also a possibility. Again, the Canalscape suggests a network of canals for surface irrigation during dry season. Therefore, the depth of canal will also depend on the water requirement and the depth of the water table of that particular village.

Total Annual Cost: TK. 339,000

Loss from Crop Production:

A total of 70 acres of land has been consumed in the proposed Canalscape Project.In Choto Kalampur,

14 percent of land is under single crop cultivation
58 percent of land is under double crop cultivation, and
27 percent of land is under triple crop cultivation

On an average, the cropping pattern of land in Choto Kalampur is double-cropped (Ahsan and Hussain, 1988). It can be assume that the present 70 acres of land were double-cropped intensity before structural transformation. According to Ahsan and Hussain the most common cropping pattern of this village is:

Rabi (Winter)	Kharif (monsoon)
Boro Paddy	Jute
	T. Aman

Even though the production of these crops except jute was below the national average for this village, we will count the national average for our calculation. Production cost and market price has also been calculated according to the national average of 1991-92 (BBS,1992).

Boro Rice(HYV)

Yield/acre: 46 maunds, one maund (md) = 37.32 kg = 82.29 lbs

Price/mds: TK. 212

Total production cost/acre:	TK.	9,523
Total gross income/acre:	TK.	9,752
Total net income per acre:	TK.	229
Total net income for 70 acres:	TK.	16,030

For kharif season, we will assume both Jute and T. Aman will be cropped in the 70 acres of land.

Jute

Yield/acre: 25.33 mds (national average, 18.8 mds)

Price/mds: TK. 143

Total production cost:	TK.	6,105
Total gross income:	TK.	6,782
Total net income per acre:	TK.	677
Total net income for 35 acres:	TK.	23,350

T. Aman(HYV)

Yield/acre: 38.9 mds

Price/mds: TK. 245

Total production cost:	TK. 7,156
Total gross income:	TK. 9,530
Total net income:	TK. 2,374

Total net income in 35 acres: TK. 83,090

Total annual net loss from 60 acres of land converted from cropping: **TK. 122,470**

Total Annual Expenditure and/or Loss:

Structural Cost:	TK. 339,750
Crop Loss:	TK. 122,470
Total :	**TK. 462,220**

Income Generation Through Canalscape Implementation

Fishery

Total available land for cultivation: 445.82 acres

If it be considered that at least half of this area will be used for fish cultivation in conjuction with rice or jute during the monsoon (6 months), the net income under fish cultivation can be calculated from Table 12. According to this table, a net profit of TK. 2,731 (TK. 7,811 including the profit from rice) can be achieved from one acre of land. The production of rice has been calculated separately.

Total annual net income: **TK. 608,770**

TABLE 12: COST ANALYSIS OF FISH CULTURE WITH RICE /hac*

Different Phases/ Items	Cost (TK**)	
	Fish Culture with Rice	Fish Culture after Rice
1. Land Preparation 2.Ploughing/ Fertilizer 3. Rice Cultivation 4.Fish Culture 5. Irrigation 6. Land Value 7. Interest on credit @ 15%	550 4,068 5,030 4,580 1,000 1,875 (6 months) 1,283	460 4,068 5,260 7,352 1,500 3,750 (12 months) 3,359
Miscellaneous @ 5%	919	1,287
Total Cost	19,305	27,036
Income		
Price of Rice @ Tk. 6,500/ton Price of Fish a. Sarputi @ Tk. 45/ Kg. b. Mirror Carp @ Tk. 40/ Kg. c. Rohu @ Tk. 50/ Kg	 28,600 @ 4.4 ton 6,480 @ 144 Kg. 3,520 @ 88 Kg. 	 28,600 @ 4.4 ton 7,020 @ 156 Kg. 7,480 @ 187 Kg. 12,500 @ 250 Kg.
Gross Income	38,600	55,600
Net Profit	19,295	28,546

Source: Majid et al., 1992
* 1 hectare = 2.47 acres
**1US Dollar = Approx. 40 Taka

Forestry

Plantation on the levee

In the present Canalscape design for Choto Kalampur village a 136,740 linear foot or 45.58 km of land has been created where plantation of trees and shrubs will be accomplished. According to Chowdhury (1995) and Siddiqui and Ali (1994) an afforestation model has been prepared (Fig. 40). Total production and recovery rate (net production or income) has been calculated according to the conversation with M. B. Chowdhury (1995), and available information. Table 13 shows different types of trees and their purposes. From figure 40 the number of trees under different categories have been calculated, which are:

Fruit Trees:	5,470, @ 4 tree /100 ft.
Soft wood Trees:	2,735, @ 2 tree /100 ft.
Fuel/Fodder Trees:	4,102, @ 5 tree/ 100 ft.
Bushes (Pulses):	136,740 linear feet

Fruit Trees:

Example: Date Palm

Purposes:

Juice, fruit, fuel, handicraft

Yield/tree: 5 kg 'GUR' (Molasses)/yr

Total gross income
@ TK. 30/ kg Gur : TK. 820,500/yr

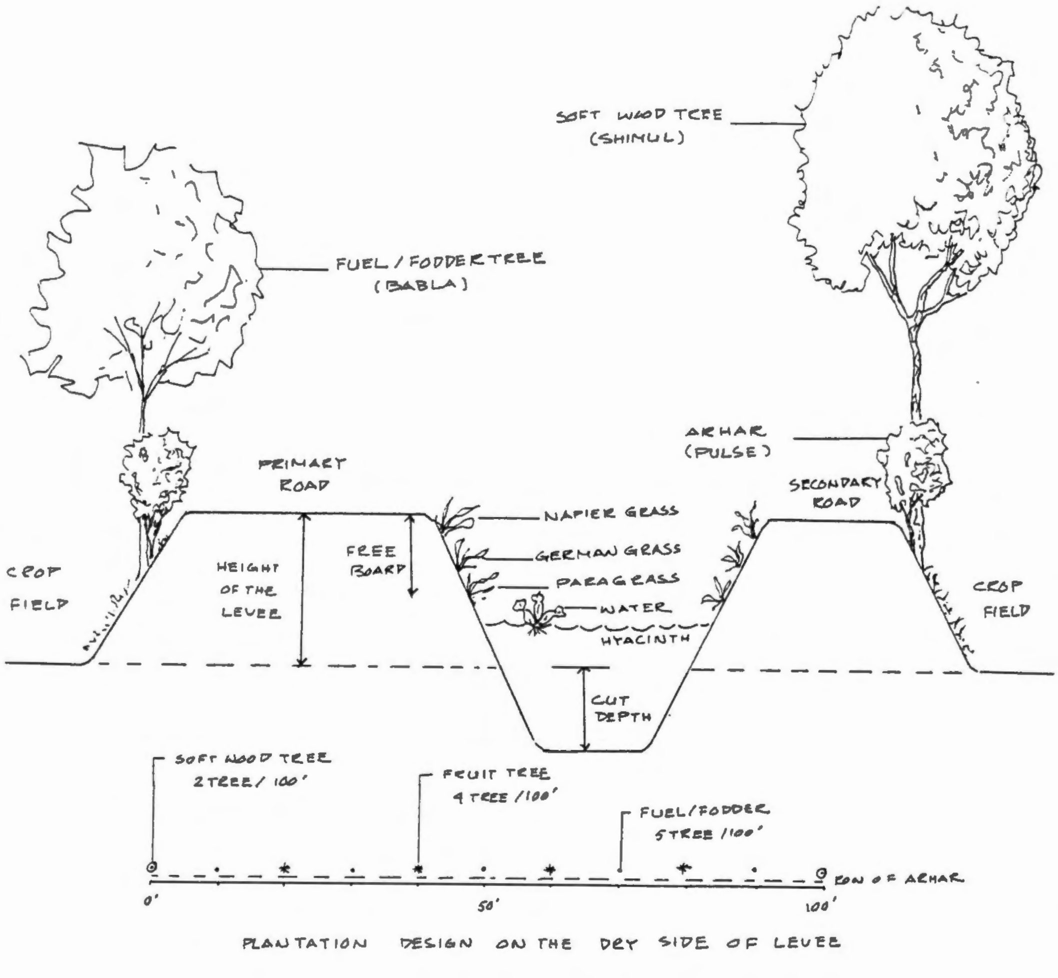
(1 kg = 2.20 lbs)

If recovery rate is 70 percent (Chowdhury, 1995),

Total net income: TK. 574,340/yr

Assume a tree will be profitable from the 4th to 30th year period

Total annual net income: TK. 568,016



(Note: Sideslopes are exaggerated for illustrative purpose)

FIG 40: AN AFFORESTATION MODEL FOR CANALSCAPE
Source: Chowdhury, 1995; Siddiqui and Ali, 1994

TABLE 13: DIFFERENT TYPES OF PLANTS AND THEIR CHARACTERISTICS

PLANTS		CHARACTERISTICS			
Common Name	Scientific Name	Timber	Fodder	Fuel	Fruit
Arjun	*Terminalia arjuna*	*		*	
Mahagoni	*Swietenis mahagoni*	*		*	
Sissoo	*Dalbergia sissoo*	*	*	*	
Tatul	*Tamarindus indica*	*		*	*
Shimul	*Salmalia malabaricum*	*			*
Chatian	*Alstonia scholaris*	*			
Date Palm	*Phoenix Sylvetris*			*	*
Babla (Babul)	*Acacia nilotica*	*	*	*	
Epil epil	*Leucaena leucocephalla*	*	*	*	
Arhar	*Cajanus cajan*		*	*	pod
Black gram	*Phaseolus mungo*		*		pod
Napier grass	*Pennisetum purpureum*		*		
German grass	*Echinochloa crus-galli*		*		
Para grass	*Brachiaria mutica*		*		

Source: Siddiqui and Ali, 1994; Pradhan, 1992

Soft Wood:

Example: Shimul

Purposes: Matches, packing boxes, fuel

Net return from one tree in a 10- year period:	TK.	1,600 (Mahat, 1993)
Annual net return/tree:	TK.	160
Total annual income:	TK.	437,600

Fuel/Fodder:

Example: Babla

Purposes: Fuel, fodder, timber

Total gross income for a 7- year period

@ TK. 100/pole:	TK.	410,200
@ TK. 50/tree for fuel:	TK.	205,100
Total:	TK.	615,300

Annual gross income:	TK.	87,900
Annual net income:	TK.	65,925

Recovery rate 75 percent
(Chowdhury, 1995)

Pulse:

Example: Arhar (Pigeon pea)

Purposes: Beans, fodder, fuel

According to Figure 40 (p. 90), a row of Arhar will be planted densely in the upper two foot slope of the levee. Assume that 1kg of pulses will be harvested from each 5 linear feet of bushes in each season.

Pulse

Total Yield:	27,348 kg
Price:	TK. 10/ kg (BBS, 1992)
Total gross income:	TK. 273,480

Fuel

Yield:	1 kg/ linear foot	
Total Yield:	3664 mds	
Price/mds:	TK. 30	
Total gross income:		TK. 109,920
Total:		TK. 383,400
Total net income:		TK. 287,550

Recovery rate 75 percent
(Chowdhury, 1995)

Total income from Plantation on levee:

Fruit trees:	TK. 574,350
Softwood trees:	TK. 437,600
Fuel/Fodder trees:	TK. 67,900
Pulse/Fuel:	TK. 287,550
Total:	**TK. 1,367,400**

Forest Land

A total of 7 acres of high land in each compartment along with the canals and roads have been created for forest areas (Fig. 37, p. 75). This space might be utilized for the native species which are already on the brink of extinction. Besides, this land may also be occupied by seasonal cash fruit crops (papaya, banana, and so forth) or long-term plantation for softwood trees (Shimul, Chatian, and so forth) or timber trees (Mahagoni, Shagoon, and so forth). Table 13 (p.91) presents a list of plants which can be planted in this area. It is assumed the people in that village will choose softwood trees for a moderately quick return (10 years).

After 10 years 300 trees can be harvested from each acre of land (Mahat, 1993).

Total no. of trees: 2100

From table 14, the net income from 7 acres of soft wood plantation in a 10-year period can be calculated, which is

	TK. 3,350,760
Net yearly outcome:	**TK. 335,076**

Total Net Income Through Structural Transformation:

Fisheries:	TK. 608,770
Plantations on levees:	TK. 1,367,400
Forest land:	TK. 335,076
Total:	**TK. 2,311,246**

<u>**Total Annual Net Outcome:**</u>

Total Income:	**TK. 2,311,246**
Total Expenditure and/or, loss:	**TK. 462,220**
	TK. 1,862,916

As suggested before, the implementation of the Canalscape proposal has to be done by voluntary participation of the people in that village. So, it is fair to think the occupied 70 acres of land will be donated by the villagers. But for contrast we will consider these lands as rented, and the cost might be calculated in the following way.

Total Rental Cost: @ TK.3000/acre/yr	TK. 210,000
Total Net Annual Outcome:	**TK. 1,652,916**

According to the previous calculation, if the total 60 acres of land is under double-crop cropping pattern, the total annual outcome from this amount of land is

TK. 122,470

TABLE 14: ESTIMATED COST AND RETURN PER ACRE MATCH WOOD PLANTATION FOR COMMERCIAL PLANTATION

ITEMS	TK.*
Cost Components (Cumulative) A-10-Year Period	
Land	30,000
Operation	8,820
Organization	45,000
Total	83,820
Estimated Return	
15 cft./tree 10 cft. Match wood @ 300 trees	450,000 @ Tk. 150/cft.
5 cft. Packing @ 300 trees	112,500 @ Tk. 75/cft.
Total	562,500
Net Return / acre/ 10 year	478680
Net Return / acre / year	47,868
Net Return /tree /year	160

Source: Mahat, 1993

*1 US Dollar = Approx. 40 Taka

If we consider the total amount of culturable land (445.82) after the implementation of Canalscape will be utilized as double-cropped pattern, the total possible annual outcome might be

TK. 779,993

Total Annual Possible Outcome of Choto Kalampur Village: **TK. 2,432,909**

Total Increase in Productivity: **212 percent**

It is imperative to mention that the total TK. 902,464 (TK. 779,993 + TK. 122,470) has been calculated for a double-cropped cropping pattern in Choto Kalampur context according to the average national production. In their investigation Ahsan and Hussain (1988) found that the average crop production in this village was less than 50 percent than that of the national average. They pointed out several problems, and some of those were

1. Fragmentation of lands.
2. Lack of proper irrigation and drainage.
3. Lack of input (credit, seeds, fertilizer, and so forth)
4. Limited use of fertilizer.
5. Limited use of modern varieties.

In Choto Kalampur more than 50 percent of crop land gets flooded regularly during the monsoon season. Table 10 (p. 66) shows a relationship between flooding events and the cropping pattern of this village. Since most of the modern varieties cannot withstand flood water, the farmers have no option but to choose low yielding local varieties. Eventually they depend mostly on the HYV boro rice (winter season crop) to produce the major portion of their annual production. Moreover, modern varieties need proper fertilization, irrigation, drainage, and crop protection practices. Unfortunately, due to the fragile economic condition, the farmers can barely follow proper cultivation techniques.

Again, the main purposes of the Canalscape are, (i) to provide controlled flooding, (ii) to protect crops, and (iii) to increase the total production. The Canalscape suggests to open the crop field for cultivation during the first few months of the monsoon. If the flood water can be prevented entering from the crop field during the early stage, the aman rice can be grown successfully. However, flooding condition in the crop field during the late stage of maturation of this rice is important as well. So, it can be said that by utilizing the aman season (also aus season, which is affected by the early monsoon floods as well) a triple-cropped cropping pattern would be possible to introduce. It is necessary to mention that during this investigation it has been found that net income from one acre of aman (HYV) is TK.2,374 whereas from boro (HYV) it is only TK.229. However, farmers of Choto Kalampur cannot produce HYV aman because of flooding. The communal farming system will ensure effective cultivation techniques to increase the total production. Ahsan and Hussain (1988) also noticed the lack of an income generating farming system. The previous cost analysis strongly reveals the possibility to balance the farming system with environment toward a sustainable economy.

Most of the values which have been calculated during the analysis of cost return are close-approximation. Information from the interviews with Chowdhury (1995) and Matin (1995) have given a significant amount of depth in the cost analysis process. Both of these persons have served the government of Bangladesh in their appropriate fields.

The figures of total return might seem too good to be true, but the fact is undoubtedly impressive. If only 50 percent of this increased productivity can be realized, it will not be quite so impossible for the poorest majority of a poor nation to change their fate. Perhaps, the myth of 'Sonar Bangla' (Bengal, filled with gold) might become true once again.

Environmental and Social Impact of Canalscape in Choto Kalampur Context

Issues

At the beginning of this project the proposal of Canalscpe was sent to different professionals for their analysis and comments on the project. A critical analysis of the proposal was conducted by Dr. M.F. Ahmed, a professor of environmental engineering, Bangladesh University of Engineering and Technology, and is presented in Appendix B (Ahmed, 1994). Along with complimenting the project's merits, some of the major concerns were:

- The project will require large-scale displacement and relocation/resettlement of the population which the people will not accept readily until some visible positive impacts of such changes are demonstrated by pilot projects.

- The canal and reservoir system will not provide adequate storage and conveyance capacities for the huge amount of flood-water to be handled in deep flooded areas, particularly in F_3 type land (water depth 180-300cm, Fig. 1, p. 4). On the other hand, there may not be any available water in canals in dry seasons in F_0 and F_1 type of lands, especially in low watertable areas.

- If naturally stable slopes are provided to canals and roads/embankments, a large proportion of the total agricultural lands within the project area will be required for the canal-embankment system.

- The embankment will facilitate controlled flooding of agricultural lands but it will also prevent drainage of rainwater from agricultural lands to the canals. Again the buried water control and drainage structures shown in the proposal are likely to be difficult to maintain.

- Experience from the compartmentalization in coastal areas shows that canals carrying water with a high sediment load are silted up and bed level rises quickly to a level even higher than the ground level inside the embanked area, causing enormous problems.

Addressing the Previous Issues along with other Environmental and Social Issues

Primarily, it seems that the project will take away a large amount of land area from cultivation. Indeed, the structural framework of Canalscape will occupy a reasonable amount of land, but at the same time the Canalscape will create more different functional areas and opportunities. Again, the area occupied by the Canalscape will vary from region to region according to the flood depth. In F_0 (high) and F_1 (medium) type land construction of levees might not be necessary, whereas F_2 (low) and $_3F$ (very low) type will require levee construction to control the floodwater. Levees are not only controlling floodwater in this project, but also creating a vast transportation network. The land of Choto Kalampur is in between F_2 and F_3 type. For a 20-year return period the flood depth of this area will be maximum in between 6 feet to 9 feet (FPCO, 1994). To hold the flood water in extreme situations, this village needs a total of 70 acres of land, which is 10.55 percent of the total land area. Again in Choto Kalampur, 58 percent of land is double cropped, 14 percent single cropped, and 27 percent of land is under triple-cropped cropping pattern. It is considered that to increase total production of Bangladesh, there is no other way but to transform all of the land under triple-cropped cultivation in a year. If a triple-cropped cropping pattern is assumed for this village, it can be said almost 30 percent of the land of Choto Kalampur has never been cultivated. Since the Canalscape will increase the intensity of use of land, the uses of 10.55 percent land under permanent structure may not be as unreasonable as it appears to be. In Choto Kalampur, where people constantly fight for their livelihood, where they barely have enough input for successful agricultural production, where the production of most of the crops are much less than the national average, it is obvious that the people should not suffer more.

The vast network of canals will hold and carry away the excess water which previously flooded the crop field. If the cropping pattern of this village (Fig. 35, p. 72)is considered carefully, the necessity of keeping the excess water away from the cropfields for a certain period of time can be identified. When flash flooding occurs during the pre monsoon months of April and May, there is always a major crop (Boro rice) in the field that is ready to harvest. This type of flood is caused by localized rainfall in the nearby river catchments. The floods often rise quickly and fall rapidly, with high water velocities that can cause damage to crops and properties. Since the existing canals of Choto Kalampur occupy less than .5 percent of the total land area (Fig. 22, p. 56), and the river is at one end of the village, even a rainfall of small duration can cause harm to the standing crops. A 15.88-km long canal network will provide the necessary space to control this sudden flow of water. In addition, between June and September monsoon rain flooding occurs, which is caused by localized high intensity or long-duration rainfall. One of the major crops of Choto Kalampur is aman rice, which is cultivated during this period and grows with the floodwater. Even though this variety can withstand floodwater, during the early stage of its growth it needs to be protected from excessive water. It is quite common in Bangladesh for a farmer to repeatedly transplant aman rice after it is destroyed by a sudden flood.

Monsoon season is the main season for summer crops, when 80 percent of the rice crops (aus and aman) are grown. In Bangladesh the spread of modern varieties (MVs) has mainly been limited to dry season crops; use of modern varieties is much more common in wheat and boro rice production than in other rice crops (aus and aman). So it is quite important to increase the production of aus and aman rice by using modern varieties to meet the future demand. Unfortunately, only 20 percent of agricultural land is suitable for MV-aman under rain-fed conditions and 26 per cent under irrigated conditions (FAO, 1988). This is because most of the new varieties developed so far are relatively short-stemmed and thus less suited to heavily flooded monsoon areas. In Choto Kalampur only local varieties have been cultivated. Inevitably the production of aman rice in this village is only 5 mds per acre (Ahsan and Hussain, 1984) whereas the national average for that year is 18.1 mds/acre for local and 40.5 mds/acre for HYV (High Yielding Variety). There is a great possibility to cultivate modern aman varieties in this village if the depth of water during its growing period can be reduced. The main purpose of making compartments in Canalscape is to control the water depth according to the necessity. In the northern side of the village 68 acres of land has been designed to be flooded during overbank flooding from the river to protect the internal area from sudden or prolonged water pressure (Fig. 36 and 37, p. 74 and 75). A 2-foot levee has been designed on both sides of the river that will allow the local aman rice or jute to grow safely during their critical early stage.

In 1989 a Flood Action Plan was launched by the World Bank and the government of Bangladesh, which suggested to embank three of the major rivers of Bangladesh at a cost of $ 5 billion. However, researchers and environmentalists cast serious doubt on this costly project (Pearce, 1991). According to Barrett (1990), embanking the rivers has some major technical and social problems.

- Embankment will restrict the spread of water over the floodplains and eventually the volume of water will increase during the peak of floods, which will also increase the erosive power of water.

- If rivers are embanked, sediments will not be laid down on the floodplains, so the fertility benefits would be lost.

- The implication for local fisheries must also be assessed. Minkin (1981) reported that 60 percent of 251 identified fish species in Bangladesh are floodplain dependent. Without doubt, embanking the major rivers in Bangladesh would radically change the present environmental balance.

- An estimated three trillion tonnes of sediment flows annually over the borders of Bangladesh. If sediments were to accumulate in the confined riverbeds, this would necessitate massive annual dredging operations or else the construction of higher and higher embankments.

- Major improvements in rural infrastructure over the past few decades, most notably in road building, have further restricted water flow. Frequently, insufficient cross-drainage structures have been provided.

Boyce (1990) mentioned that large embankments of Bangladesh might be susceptible to breaches due to earthquakes in this region. According to him an active fault line lies along the northern edge of the delta, at the foothills of the Himalayas. In his studies Saleh (1991) questioned the technical feasibility and environmental viability of the conventional flood control embankments. He mentioned that these embankments damage the historic environmental balances critical to the human life in the delta, but benefit from their massive investments by providing flood protection benefits only in relatively rare years of high floods.

Instead of the construction of large conventional embankments, Saleh (1991) suggested small submersible embankments to protect crop fields only for a period of time. Submersible embankments are designed to delay the onrush of floodwater untill June only. According to Saleh the delayed flooding allows the farmers to harvest their winter crops without damage, and facilitates the initiation of the following aman crop. Improvements in flooding conditions bring about an increase in the level of input use and switching over low yield local varieties to high yielding varieties of rice. Since these embankments do not eliminate flooding during the monsoon, there is no change in the regional flood status and minimal impacts on the agroecosystem. A comparative economic analysis of submersible embankments and flood control embankments has shown that submersible embankments have a much higher benefit to cost ratio and internal rate of return than flood control embankments.

Some researchers suggest that the risks of devastation can be reduced by building 'compartments' rather than expensive embankments. If there are high discharges of water coming downstream, then the authorities can decide to flood a particular compartment in order to protect downstream areas (Pearce, 1991). However, it will be hard to justify flooding some areas to protect others. If the people of a particular village cultivate their crop under a cooperative system, they can sacrifice some areas to protect the others for the benefit for all. Pearce also cited that one of the experts dismissed the embankments proposed in the flood plan by World Bank as "extremely unlikely to be justifiable investment" for Bangladesh. He proposed a switch from "hard" engineering to "soft" engineering. He also mentioned that people in this region have adopted many ingenious ways of living through the floods. During the early stages of the World Bank's proposal to implement embankments an American technical group also suggested coping with rather than combatting the floods, and stressed the need to improve dry-season agricultural productivity by irrigation to reduce the reliance on the flood-season crop (Barrett, 1990). According to Saleh (1991) it is unreasonable to construct huge embankments when the events of severe floods are rare. In Choto Kalampur context, the maximum flood water depth for a 20-year return period is between 6 feet and 9 feet, and the maximum water depth during regular flooding season is between 4.5 and 6 feet. Therefore, a 6 feet water depth has been considered during the design process of the Canalscape. During severe flooding season all of the compartments could be kept open for flooding, except a few that are occupied by the households. In Choto Kalampur, the compartment C represents the main household site (Fig. 36, p. 74). It is possible to separate the households and the crop fields among compartments. A specific compartment within each village can be encircled by larger embankments to protect the households. It would also be easier to pump out the water from a single compartment during the severe floods than a larger area.

The Canalscape concept suggests natural flooding of the crop field during the peak flooding period when the relative danger of crop loss will be reduced. It also stresses the importance of compartmentalization to create flexibility in land uses. The Canalscape will facilitate plantation of grasses on the wet side of the levee to reduce the erosion of the canal and will provide pond areas in each compartment to reduce sedimentation problems for the canals. If the canal itself can be protected from erosion, and if the water coming off of the fields can be detained for some period of time in the pond area at the lower point in the field, a significant reduction of sedimentation problems would be possible (Yoder, 1995a). However, the canals, roads, and ponds have to be maintained regularly. It is strongly recommended to spend a portion of the annual profit in maintaining the infrastructure. Canal digging programs in every alternate year to remove deposited silt from ponds and canal bases will not only keep the structure viable, but also will generate a source of income for the rural people. Rahman et al. (1984) say that canal digging programs solve the twin problems of drought in the dry season and flood in the rainy season and make way for producing at least one more crop in the dry season with irrigation. Table 15 shows the impact of canal digging programs on crop production. Moreover, by digging the soil from the canals and ponds people can meet their need for soils in repairing their households.

Indeed, there is a potential problem in drainage from the crop field to the canal during the constant monsoon if the water level of the canal remains higher than that of the crop field. Even though this situation might harm the feasibility of this project, it is quite possible to adjust according to the situation. According to water depth and duration of rainfall, canal depth may be increased for that particular region. Again, the Canalscape concept suggests to cope with the flood *in lieu* of stopping it completely. However, drainage of the cropfield depends entirely on the purposes or uses of that particular cropfield during the peak of the monsoon. The Canalscape concept includes an organized rice-fish culture pattern to increase the total production during the monsoon. In that case higher water depth in crop fields will be desirable. Moreover, after a certain period in their life cycles aman rice and jute can easily withstand water. Therefore, the drainage problem expected in the period of July-August might not be as significant as it seems to be. Another weakness of the project noticed by Ahmed was the potential for siltation problems with the proposed underground structures. In this context, Yoder (1995a) stressed the possibility of above ground structures built into the levee, or the use of flexible hose for siphons. In fact, the proposed Canalscape has the flexibility for any kind of improvement according to the situation. Traditionally, farmers of Bangladesh use different indigenous methods for irrigation and drainage purposes. These techniques may be

TABLE 15: IMPACT OF CANAL DIGGING ON CROP PRODUCTION (A SAMPLE OF 50 FARMS AND 10 LANDLESS HOUSEHOLDS FROM 4 VILLAGES)

Cropping Pattern Before and After Canal Digging

Crops	Area (acres)		Change (acres)	Contributory Change (%)
	Before	After		
HYV Aman	78.63	99.18	+20.55	+10.17
Local Aman	18.62	4.62	-14.00	-6.73
	3 .39	13.33	+9.99	+4.94
Wheat	3.35	3.16	-0.19	-0.09
Potato	39.69	70.19	+30.50	+15.09
HYV Boro	9.66	2.33	-7.28	-3.60
Local Boro	29.89	23.22	-6.67	-3.30
	12.13	3.75	-8.33	-4.15
Aus	5.13	4.50	-0.53	-0.31
Jute	1.63	1.31	-0.32	-0.16
Pulses				
Vegetables				
Total	202.12	225.69	+23.57	+11.66

Cropping Intensity Before and After Canal Digging

Farm Size Groups	Total Cultivated Lands (acres)		Total Cropped Land (acres)		Cropping Intensity (%)	
	Before	After	Before	After	Before	After
Marginal	3.82	2.50	8.38	5.50	219.37	220.00
Small	10.09	11.91	17.88	21.31	177.20	178.93
Medium	44.09	46.39	80.91	90.46	183.51	195.00
Large	68.69	74.93	94.95	108.42	138.23	144.70
All Farms	126.69	135.73	202.12	225.69	159.54	166.28

Yield of Crops Before and After Canal Digging

Crops	Total Yields (maunds*)		Yield per acre (maunds)		Change in Total Yield (%)
	Before	After	Before	After	
Aman	2869	3320	29.74	30.99	+ 12.23
Boro	1951	3184	37.94	42.59	+ 63.20
Wheat	52	233	15.91	17.54	+357.69
Potato	47	51	14.51	16.80	+ 8.51
Aus	617	505	20.38	20.40	- 18.15
Jute	185	58	14.27	15.29	+ 68.65
Pulses	76	76	15.66	15.68	- 3.95
Vegetables	850	730	500	553	- 14.12

Source: Rahman ,et al., 1984 (+) Indicates Increase (-) Indicates Decrease

* 1 maund = 37.32 kgs

applied with modern power pumps. If the Canalscape can generate income sources, it can also provide mechanical means to drain a particular compartment. The same thing could be said about irrigation. Water depth in the canal during the dry season totally depends on the water table of that area. If in any case water does not seem to be available in the canal, irrigation can still be provided through power pumps, which is the practice now.

As mentioned before, the Canalscape objective is to transform the land into different uses rather than consuming it. The dry side of the levee could be used for raising trees while the wet side could be utilized for forage production. Figure 40 (p. 90) shows the detailed utilization of the levee area. The pond in each small compartment will help to drain the water properly from cropfield to the canal and store water for the dry season. Moreover, these ponds could be used as harvesting sites for fish during fish culture with rice. These ponds and drains will ensure the movement of fish in case of shallow water depth. Two different designs for fish cultivation techniques with rice within each compartment has been shown in Figure 41. In Bangladesh, the direction of the prevailing wind during the pre monsoon season mostly starts from the southeast. The small compartments have been designed in such a way that the narrower width of these compartments will be in the same direction as the prevailing wind. The average width of the narrower side of the compartments is between 600 feet to 750 feet. If the average height of the plantation of trees along with the canal system is 35 feet to 45 feet, these crop fields could be saved from the destruction or severe damage during seasonal storms. Figure 26 (p. 59) shows the pattern of air flow around the shelterbelt. The Canalscape not only improves transportation through both roads and waterways but it also ensures a proper orientation of roads and waterways for continuous water movement rather than blocking it.

Since a field level investigation in the village Choto Kalampur has not been done, possible impact of the Canalscape on other income generating sectors was not possible to measure. However, the new community pattern will create different opportunities to improve the livelihood of the people in that village. Wallace et al. (1987) argued that a small land area

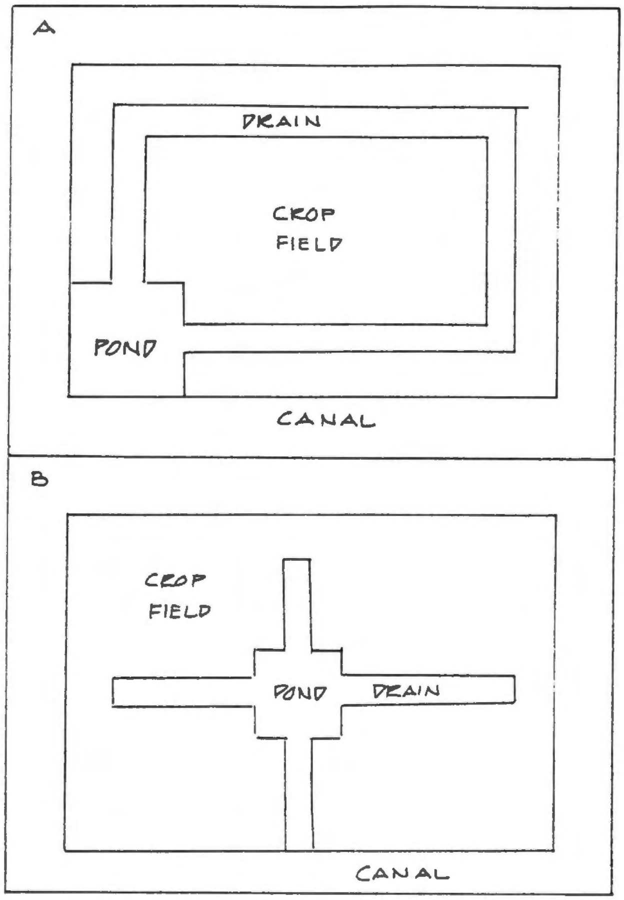


FIG 41: TWO DIFFERENT ARRANGEMENTS OF FISH CULTIVATION TECHNIQUES WITH RICE
Source: Kabir et al.,1993

in Choto Kalampur village costs more to cultivate than a large area. They mentioned a .16 acre land cost 555 taka to produce jute, whereas a .32 acres cost only 585 taka. This is one of the several examples why the small and poor farmers in Bangladesh cannot produce a crop profitably.

Since the cooperative society under the Canalscape project encourages common cultivation for the entire village, problems due to the fragmentation and scatteredness of crop land, and lack of resources can potentially be avoided. Ahsan and Hussain (1988) described the limitations of farmers in the village Choto Kalampur in using the optimum inputs (modern varieties, fertilizers, irrigation, and so forth) in crop cultivation. They also mentioned that the fate of the farmers of that village could be changed, if the farmers would have the opportunity to use those inputs properly. The cooperative farming system shows a way to improve the personal economy for both the rich and the poor farmers. Since the Canalscape would open a vast network of waterways, duckery could be another source for income generation. Chowdhury (1995) stressed the importance of duck farming together with poultry to increase households income. He also mentioned that by planting fruit and other beneficial plants on each platform, people could potentially double their income.

The social impact of this project might be enormous if it can be implemented properly. The social reform recommended in this investigation is essentially an organized community pattern. The success of the Canalscape project is highly dependent on its appropriate implementation and proper management. The participation of the local people is required for the success of such a project. Motivation, proper education, and demonstration of the results would help to initiate this. Local government, non-government organizations, and village social groups all have to work together to make this project functional. Although the Canalscape suggests the an initial social reform, this also has to be prioritized by the local people. People have to choose for themselves whether they want better organization. The cost analysis shows that the economical benefit from Canalscape not only proves the feasibility of this kind of project, but also strongly recommends a model demonstration to motivate the resourceless poor majority who need the improvement most.

This project may seem overwhelming and ambitious at first, but recognition of a problem often generates thinking that can result in a satisfactory solution. Bangladesh is facing a crisis, and solutions may not be obvious; however, involvement in the problem and a search for solution is practicable. For Bangladesh, different solutions must be considered to solve the multifaceted problem. This study may not be the only solution, but it might help to find the root of a common solution to improve the fragile environmental and socioeconomic conditions of Bangladesh.

CHAPTER V

SUMMARY

Statement of the Problem

Bangladesh is a country confronted with numerous problems. To plan any kind of development program to improve the existing conditions and to sustain the growth of rural Bangladesh, the following points have to be taken into consideration.

- Environmental problems
  - Excessive floods.

    Flood is one of the major problems in Bangladesh. The present project is mainly concerned about primary flooding (flash flooding) and secondary flooding (monsoon rain flooding) which delays crop planting and sometimes causes serious damage to the crops. These floods are easier to manage than tertiary floods (overbank floods and storm surges). If primary and secondary floods can be controlled, it will be a significant advantage.
  - Drought.

    During pre and post monsoon seasons drought limits agricultural production.
  - Damage due to seasonal storms.

    During the pre monsoon season seasonal storm cause damage to crops and people. Any barrier that can reduce the wind speed will be beneficial for standing crops.
  - Rapidly decreasing forest areas.
  - Potential problems with water quality due to agricultural practices.
- Different physical and social problems related to land use
  - Lack of roads.

    Most of the roads (secondary roads) in the rural areas are not high enough and get flooded during monsoons. Disorganized road systems also block the natural water flow.

- Lack of canals to remove excess water during monsoons and to hold water during post-monsoon season.
- Lack of sources of inland fresh water for fish culture and household uses.
- Lack of proper irrigation and drainage.
- Poor yield.
- Fragmentation of lands.
- Problems with land ownership.
- Scattered farming.
- Lack of wood for fuel and buildings
- Other sources of protein.
- Lack of proper income generation systems.
- Child labor.

  To help their families children in the rural areas have no choice but to give up education.
- Lack of an organized social structure.

  In a nation with enormous poverty, an extremely large population, and many natural calamities, it is obvious that every small unit of that country has to have some self-reliance in solving some of their problems rather than depending solely on the government.

Purpose and Research Question

The main purposes of the Canalscape projects are

- Flood control.
- Crop protection.
- Increased production.
- Income generation.
- Environmental protection
- Social and cultural improvement

- Sustainable development.

Problems of Bangladesh are multifaceted and correlated to each other. One problem cannot be solved without considering other. Again, one solution cannot be applied to different problems. The proposed village pattern is one of the several ways through which the socioeconomic condition of Bangladesh can be reformed. The primary concerns of this investigations are

- Is the conceptual design of Canalscape feasible?
    - Physically/Technically
    - Economically, and
    - Environmentally
- Does this approach sustain the growth or generate resources?
- How does this project get implemented?

<u>Design Process</u>

Conceptual Framework

Bangladesh is predominantly an agriculturally dependent country. In the rural areas, inhabited by the majority and the poor people of the nation, agriculture provides the major source of livelihood. Resource-poor farmers constitute the bulk of the farming community in Bangladesh. Marginal (.5 to 1.25 acres) and small farmers (1.25 to 2.5 acres) together with landless households constitute more than 70 percent of farm families. With increasing population and fragmentation of land, small farmers are becoming marginal.

Farming in Bangladesh is mainly subsistence level. Farmers produce diversified products to meet their home consumption requirements and other household needs. Most farms raise field crops, homestead vegetables and trees, cattle, poultry, and occasionally fish. Off-farm and non-farm activities are pursued to supplement cash requirements. Intensive use of land and the interaction of multiple farm components and activities make the farming systems of Bangladesh highly complex.

The primary idea behind the implementation of the Canalscape is to reshape the rural landscape and rejuvenate the farming system which the Banladeshis have used for a long time. The Canalscape suggests to cope with the problems rather avoiding them. Interaction between the land and environmental resources and human settlement is the key. The necessity of the physical structure is quite clear. It will hold an organized community in a relatively safe environmental condition.

Canalscape

The Canalscape is a modification of landform to protect the crops and people from controllable floodwater (primary and secondary floods), to make every village accessible to all parts of the village and the country, and to generate resources to improve the economic and social conditions. In Bangladesh not all lands are prone to flood. Although primarily the Canalscape suggests a design to hold the excessive water, the basic concept is the transformation of the uses of the land. The modification of landform has been outlined to support a new cooperative community by absorbing it into a safe environmental condition.

Benefits of canalscape

By implementing the concept of canalscape in its existing landscape, Bangladesh can achieve an environmentally safe physical structure which will ensure an organized and productive farming system.The Canalscape primarily suggests,

- A comparatively safe environment for both crop and human welfare.
- Proper utilization of resources to increase production.
- A continuous flow of income by multiplying resources.
- Sustainable growth in the society by providing an effective organizational structure.

Implementation

In this investigation, the village Choto Kalampur is just an example to prove the concept's feasibility. An extensive survey at the field level would help to find an ideal location to test this idea. The Canalscape design of Choto Kalampur has been primarily accomplished based on actual available information. A physical survey of that area might change the design. In considering the existing landform and existing features (houses, roads, canals, and so forth) of that village the basic pattern of the Canalscape has been modified. Since the Canalscape is itself a flexible design, this design has to be implemented according to the needs of that particular village. During the design process the following components have been taken in consideration.

- Depth of floodwater.
- Duration of flooding event.
- Physical infrastructure of the village.
- Cropping pattern.
- Distribution of land.
- Social structure.

In calculating the area under the Canalscape simple hydrological equations have been followed. Moreover, an attempt has been made to prove the feasibility of the structural transformation of land.

Major Findings

Problems of Choto Kalampur

- Floods

  More than 50 percent of the cropfield is flooded in an average depth of 4.5 feet.Because of flooding problems, farmers cultivate low yielding local aman rice during monsoon season. Moreover, early flooding destroys the crop.
- Fragmentation of lands.

Lands are fragmented and scattered throughout the village.

- Lack of inputs
- Lack of proper irrigation and drainage.
- Lack of enough income generating sources.
- Low yield

  Production of most of the crops are below national average.

Possible Results from the Canalscape Implementation

In the present investigation the village Choto Kalampur has been chosen to test the feasibility of such a project. Different selected facts of this village are:

<u>Before Canalscape Implementation</u>

Total land	663.74 acres
Cultivable land	515 acres
Fallow land	.90 acres
Total culturable land	515.90 acres
Area under houses,school, market, roads, and canals	147.84 acres
Area under existing roads and canals	Approx. 6.64 acres or 1% of total land
Area under forest	Nil

<u>After Canalscape Implementation</u>

Net area covered by canal and levee (road)	60.08 acres or, 9.05% of total land
Total area covered by forest land besides homestead plantation	7 acres or, 1.05% of total land
Total area covered by ponds inside each small compartment	3 acres or, .45% of total land
Total area covered by Canalscape	70.08 acres or, 10.55% of total land

Total area available for cultivation	445.82 acres
Total linear space along levee for plantation	136,740 ft.
Total no. of trees @ 1tree/10 ft.	13,674
Total area under plant coverage	45.58 acres or, 6.86% of total land
Total length of canals	15.88 km
Total lenght of roads	37.51 km

The possible economical benefits from the Canalscape implementation are:

Without Canalscape

If the total cultivable crop land of Choto Kalampur can be cultivated under a double-cropped cropping pattern, the annual total possible outcome is

TK. 779,993

With Canalscape

Cost due to structural establishment and crop loss

Structural cost	TK. 339,750
Crop loss	TK. 122,470
Total annual loss	TK. 462,220

Income generation through the Canalscape

Fishery	TK. 608,770
Plantation on levee	TK.1,367,400
Forest Land	TK. 335,076
Total	TK 2,311,246

Income from crop production	TK. 779,993
Total possible annual outcome	TK.3,105,129

Annual rental cost for 60 acres of land	TK. 210,000
Total annual net income	TK. 2,432,993
Total increase in productivity	212 percent

Conclusion and Recommendations for the Future Study

The purpose of this study was to evaluate a new approach related to the development and improvement of rural Bangladesh. At the time of this research, different organizations along with local government were participating in the rural development of Bangladesh in different ways. This research is the initial step in planning a process for potential implementation of a pilot Canalscape program in cooperation with the government and the local people.

In designing the Canalscape idea in Choto Kalampur, approximately 10.5 percent of the land in that village was found to be required to build the physical structure. Although it seems a reduction of valuable crop fields, which Bangladeshis can barely spare, in terms of total production it is just a transformation of uses. In the Choto Kalampur context, the cost analysis shows a potential 212 percent increase in productivity. Even though this figure might not be fully acceptable statistically, most of the values used in calculations are approximate. Besides the positive environmental and social impacts, this project implies a strong economic outcome. Most importantly, this proves Canalscape's feasibility for a field level demonstration.

This investigation needs extensive research work and a combination of skilled professionals and financial support. Support of different international and non-governmental organizations along with the local government would greatly accelerate such a program. The present study is an initial step in the implimentation of such a project in the rural areas of

Bangladesh. Different ranges of numeric examples have been used in the text. Again, each region has its own unique characteristics. A single plan would probably not be appropriate for every region of the country. In that case, it is hard to deal with fixed values. Changes may be made according to the existing conditions and information.

To justify the necessity of such a project, a model demonstration is obvious. Further invesigation for such a demonstration might consider the following steps to initiate a pilot program.

1. Develop a concept proposal (accomplished in this study).
2. Consult with international organizations for their support.
3. Seek help from local government officials and local organizations in collecting research materials.
4. Complete necessary surveys and collect different information for research and feasibility purposes to modify the proposal into a pilot program.
5. Submit the proposal to the concerned organization for their continuous support.
6. Talk with the local government officials for their help in conducting the project.
7. Select two villages in different parts of Bangladesh.
8. Motivate and seek cooperation from the people of those villages for a model demonstration.
9. Initiate documentation concurrent with the program for use in potential expansion of the project.

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APPENDICES

APPENDIX A

A COMPUTER PROGRAM FOR CACULATING LAND AREA OCCUPIED BY CANALSCAPE

```
#include  <stdio.h>
#include  <string.h>          /* for strcpy()... */
#include  <ctype.h>           /* for iscntl(), isupper(), etc */
#include  <math.h>

enum      {TRAPEZOIDAL = 1, TRIANGULAR, PARABOLIC};

void      main()
{
          char      shapeStr[50], inputStr[10];
          int       shape, times, times2, redoFlag;
          float     flowRate, roughness,
                              maxDepth, Z,
                              slope, velocity1, velocity2,
                              maxVelocity, checkVelocity,
                              areaAcres,
                              leveeWidth, freeboard, totalLeveeWidth, cutDepth,
                              width, depth, manningsConst,
                              lowWidthGuess, highWidthGuess,
                              lowDepthGuess, highDepthGuess;

RESTART:
          highWidthGuess = 100.0;
          lowWidthGuess = 0.0;
          times2 = 0;
          printf("\n\n\n\nchannel slope (%%): ");
          scanf("%g", &slope);
          printf("channel Manning's roughness: ");
          scanf("%g", &roughness);
          printf("max. permissible velocity (fps) = ");
          scanf("%g", &maxVelocity);
/*
          printf("channel shape (trapezoidal,triangular, or parabolic): ");
          scanf("%s", shapeStr);

          if (strcmp(shapeStr, "trapezoidal") != 0) shape = TRAPEZOIDAL;
          else if (strcmp(shapeStr, "triangular") != 0) shape = TRIANGULAR;
          else if (strcmp(shapeStr, "parabolic") != 0) shape = PARABOLIC;
          else printf("don't understand the channel shape");
*/
          shape = TRAPEZOIDAL;

          if (shape == TRAPEZOIDAL) {
                    printf("minimum bottom width (ft) = ");
                    scanf("%g", &lowWidthGuess);
                    printf("Z = ");
                    scanf("%g", &Z);
          } else if(shape == TRIANGULAR) {
                    printf("Z = ");
                    scanf("%g", &Z);
          } else if (shape == PARABOLIC) {
                    printf("max depth (ft) = ");
          scanf("%g", &maxDepth);
```

```
}

printf("\nflow rate -- enter 0 if want calculated -- (cfs):");
scanf("%g", &flowRate);
if (flowRate < 0.0001) {
        float       waterDepth, removalHours;
        printf("water depth to remove (ft) = ");
        scanf("%g", &waterDepth);
        printf("time for removal (hrs) = ");
        scanf("%g", &removalHours);
        printf("area(acres) = ");
        scanf("%g", &areaAcres);
        flowRate = waterDepth * areaAcres * 43560.0 /
                        (removalHours * 3600.);
        printf("\nflow rate = %6.3f cfs", flowRate);
}

checkVelocity = 0.9 * maxVelocity;
manningsConst = 1.49 * sqrt(slope / 100.0) / roughness;

do {
        width = (highWidthGuess + lowWidthGuess) / 2.0;
        highDepthGuess = 15.0;
        lowDepthGuess = 0.0;
        times = 0;
        do {
                double    area, wetPer, hydRad;
                depth = (highDepthGuess + lowDepthGuess) / 2.0;
                if (shape == TRAPEZOIDAL) {
                        area = (width * depth) + (Z * depth * depth);
                        wetPer = width + (2.0 * depth *
                                        sqrt((Z * Z) + 1.0));
                } else if (shape == TRIANGULAR) {
                        area = Z * depth * depth;
                        wetPer = 2.0 * depth * sqrt(Z * Z + 1.0);
                } else if (shape == PARABOLIC) {
                        float       topWidth = width;
                        area = 2.0 * topWidth * depth / 3.0;
                        wetPer = topWidth + (8.0 * depth * depth /
                                        (3.0 * topWidth));
                }
                hydRad = area / wetPer;

                velocity1 = flowRate / area;
                velocity2 = manningsConst * pow(hydRad, (2.0 / 3.0));
                times++;
                if (velocity1 > velocity2) lowDepthGuess = depth;
                else highDepthGuess = depth;
        } while ((fabs(velocity1 - velocity2) > 0.001) && (times < 50));
        if (times >= 50) {
                printf("\n\n#1: 50 iterations with no solution");
                return;
        }
        times2++;
        if (velocity1 > maxVelocity) lowWidthGuess = width;
```

```
			else highWidthGuess = width;
		} while ((fabs(velocity1 - maxVelocity) > 0.001) && times2 < 50);
		if (times2 >= 50 && width > (lowWidthGuess + 0.001)) {
			printf("\n\n#2: 50 iterations with no solution");
			return;
		}
		printf("\nbottom width = %6.2f ft, depth = %6.3f ft, velocity = %6.3f fps\n", width, depth, velocity1);
		if (areaAcres < 0.00001) {
			printf("area(acres) = ");
			scanf("%g", &areaAcres);
		}
		printf("\ntop width of levee (ft): ");
		scanf("%g", &leveeWidth);
		printf("freeboard to allow (ft): ");
		scanf("%g", &freeboard);
		printf("channel cut depth (ft): ");
		scanf("%g", &cutDepth);
		totalLeveeWidth = (2.0 * leveeWidth) + width + (2.0 * Z * (depth + freeboard)) + (2.0 * Z * (depth
freeboard - cutDepth));
		printf("\nwidth of channel and levees = %6.2f ft, levee height = %6.2f ft\n",
			totalLeveeWidth,
			depth + freeboard - cutDepth);
		printf("\ntertiary canal (Y/N)?: ");
		scanf("%s", inputStr);
		if (inputStr[0] == 'Y' || inputStr[0] == 'y') {
			float	axisRatio, ellipseA, ellipseB, ellipsePer,
					leveeArea;
			printf("Ratio of long ellipse axis to short: ");
			scanf("%g", &axisRatio);
			ellipseB = sqrt(areaAcres * 43560.0 /
					(3.1415926 * axisRatio));
			ellipseA = axisRatio * ellipseB;
			ellipsePer = 2.0 * 3.1415926 *
				sqrt((ellipseA * ellipseA +
					ellipseB * ellipseB) / 2.0);
			leveeArea = ellipsePer * totalLeveeWidth;
			printf("\nlevee area = %6.2f acres, percentage = %6.2f %%\n",
				leveeArea / 43560.0,
				100.0 * leveeArea / (areaAcres * 43560.0));
		}
		printf("\nRestart (Y/N)?: ");
		scanf("%s", inputStr);
		if (inputStr[0] == 'Y' || inputStr[0] == 'y') redoFlag = 1;
		else redoFlag = 0;
		if (redoFlag == 1)
			goto RESTART;
}
```

Source: Yoder, 1995b

APPENDIX B

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
Environmental Engineering Division, Department of Civil Engineering

TO: Mr. A. B. M. Mohiuddin
The University of Tennesssee
Knoxville, Tennessee

From: Dr. M. Feroze Ahmed
Professor of Civil/Environmental Engineering
BUET, Dhaka-1000

Comments on Canalscape : A proposal to Modify Landform and Community Pattern of Rural Bangladesh

Canalscape : a proposal to modify the existing landform in relation to environment and to develop an ideal community pattern for the sustainable development presents an innovative thought on landuse and community living in Rural Bangladesh. In the past similar proposal for constructing wide flood protection embankments on both sides of the major rivers to achieve flood control within river basin and establishing linear settlements on the embankments were discussed. The idea came from the community living of food affected people on embankments and roads during high floods. Community living in proposed fringes has several advantages over present form of scattered living over a wider area in Bangladesh. The advantages such as community participation in improved modern agricultural practices, industrial activities, fish culture, dairy and poultry farming, afforestation and good access to education, healthcare, water supply and sanitation and cultural activities have been well identified. The conceptual model describes the outlines of the methodologies of achieving proposed village pattern and community involved economic activities and management of infrastructure facilities. The proposed landuse pattern and community living are to be well supported by adequate reasons for such changes.

Some technical and social aspects needed to be well addressed are as follows:

1. The project will require large scale displacement and relocation/resettlement of population which the people will not accept readily until some visible positive impacts of such changes are demonstrated by pilot projects. It is indeed an induced change, whatever blending is done with the natural system, it will have many environmental and social implications. These are to be considered carefully.

2. The canal and reservoir system will not provide adequate storage and conveyance capacities for the huge amount of flood water to be handled in deep flooded area, particularly in F_3 type land (water depth 180-300 cm.) . On the other hand there may not be any water available in canals in dry seasons in F_0 and F_1 type of lands specially in low water table area (presently 35 % of the area is under low water table category).

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3. If naturallyy stable slopes are provided to canals and roads/embankments, a large proportion of the total agricultural lands within the project area will be required for the canal-embankment system .

4. The embankment will facilitate controlled flooding of agricultural lands but it will also prevent drainage of rain water from agricultural lands to the canals. Again the buried water control and drainage structures shown in the proposal are likely to be difficult to maintain. Even open water regulating structures in Bangladesh face enormous operating problems due to siltation.

5. The canalscape and major land distribution system shown in Fig.1 resembles flood control or controlled flooding by compartmentalization or existing polders in the coastal area in a reduced scale. Experience shows that similar canals carrying water with high sediment load are silted up and bed levels rise quickly to a level even higher than the ground level inside the embanked area causing enormous drainage problems. The erosion/sedimentation behavior of silt laden flood water is very difficult to understand. The reservoir proposed in the system may help to reduce silt load of the flood water to a certain extent.

6. Many of the pesticides used in the agricultural lands soon enter into bio-fabrics specially into fatty tissues in different species of animals. The air pollutants removal potentials of many plants are known but the capacities of plants to absorb/adsorb pesticide residues are not yet known.

However, the above mentioned points, I hope, will help development of the project On sound social and environmental footings.. There is nothing to be discouraged, innovative ideas reveal alternative solution to existing problems. The proposal bears good merits to be tried in selected areas as pilot project. In some areas, I believe, canalscape has good prospect to change the fate of rural people in Bangladesh.

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APPENDIX C

SELECTED BASIC FACTS ABOUT BANGLADESH

Geographical Location:	Between 20°34' and 26°38' north latitude and 88°01' and 92°41' east longitude
Boundary:	North: India West: India South: Bay of Bengal East: India and Burma
Area:	56,977 sq. miles or 147,570 sq. km.
Administrative and other units:	
Population:	111.4 million
Urban:	12.8 million or, 11.49%
Rural:	98.6 million or, 88.51%
Annual growth rate:	2.17%
Literacy rate (7 years and above):	32.4%
Main seasons:	Winter (November-February) Summer (March-June) Monsoon (July-October)

Number and area of households:	
Number and area of households	13,817,646
Number of nonfarm households	3,772,347
Number of farm households	10,045,299
Number of small farm households (.05 to 2.49 acres)	7,065,957
Number of medium farm households (2.50 to 49 acres)	2,483,210
Number of large farm households (7.50 acres and above)	496,132
Area operated by households (acres)	23,019,885
Area operated per households (acres)	1.67
Area operated per farm households (acres)	2.26

SELECTED BASIC FACTS ABOUT BANGLADESH (CONTINUED)

Homestead area:	
Homestead area	965,986
Homestead area per households (acres)	0.07
Homestead area per farm households (acres)	0.08
Percent of household area to uncultivated area	33.75
Cultivated area:	
Cultivated area (acres)	20,157,564
Per farm cultivated land	2.00
Per capita cultivated (acres)	0.25
Agricultural labor:	
No. of agricultural labor households	5,495,300
Percent of agriculture lobor household to total households	39.8%
Area under forest (1991):	7,178 sq. mile or, 12.60% of total land
Area under farm forest area (1988):	1,178 acres
Per capita GDP (Gross Domestic Production) in 1991-92 at current market price: (BBS, 1993)	Taka 8,137

(1 US dollar = approx. 40 taka)

APPENDIX D

WEIGHTS AND MEASURES

1 acre (ac)	0.40468 hectares 100 decimals
1 hectare (ha)	2.4711 acres
1 maund (md)	82.29 pounds (Ibs) 37.3261 kilograms (kgs)
1 metric ton	1000 kgs 26.79 maunds
1 Crore	10 million
1 mile	1.609 kilometer (km)
1kilometer	0.6214 mile
1 inch	25.4 mm
1 square mile	258.9 hectares 640 acres 2.589 square kilometers

APPENDIX E

GLOSSARY

Aman:	Rice planted before or during the monsoon (which begins June) and harvested in November or December.
B. Aman:	Broadcast aman.
T. Aman:	Transplanted aman.
Aus:	Rice planted during March and April and harvested during July and August.
B. Aus:	Broadcast aus.
T. Aus:	Transplanted aus.
Boro:	Rice planted in winter and harvested during April to June.
Kharif:	Wet season.
Kutcha Road:	Earthen road.
Pucca Road:	Brick soling road.
Rabi:	Dry season.

VITA

A.B.M. Mohiuddin was born in Dhaka City, Bangladesh on September 20, 1964. He is the eldest son of Mr. and Mrs. Abdul Matin. He grew up in Dhaka City, where he attended his high school and college. He received his Secondary School Certificate (S.S.C.) from Dhaka Board of Education in 1980. After receiving the Higher Secondary School Certificate (H.S.C.) from the same board of education in 1982, he attended Bangladesh Agricultural University, Mymensingh and received the degree of Bachelor of Science in Agriculture in 1986 (final examination for the academic period of 1982-1986 held in 1989).

Following graduation he entered the Department of Horticulture, Bangladesh Agricultural University, where he received his Master of Science degree in 1992. During 1990-1991 the National Fellowship for Science and Technology Foundation awarded him a Fellowship. In August 1992 he began graduate studies at the University of Tennessee, Knoxville and acquired a Master of Science degree with a major in Ornamental Horticulture and Landscape Design in August 1995.

He is a member of Bangladesh Society for Horticultural Science and Crop Science Society of Bangladesh. While attending in Bangladesh Agricultural University he was engaged in different cultural activities and held several offices. He is an amateur sculptor and musician. He is also a member of Pi Alpha Xi, Alpha Beta Chapter, an honorary society for students in floriculture, landscape, and ornamental horticulture.