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MINISTRY OF ECONOMIC PLANNING
GOVERNMENT OF THE REPUBLIC OF GHANA

FEASIBILITY REPORT ON THE AVEYIME SUGAR PRODUCTION PROJECT IN ACCRA PLAINS

ANNEXES

JUNE 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

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MINISTRY OF ECONOMIC PLANNING
GOVERNMENT OF THE REPUBLIC OF GHANA

FEASIBILITY REPORT ON THE AVEYIME SUGAR PRODUCTION PROJECT IN ACCRA PLAINS

ANNEXES

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JAPAN INTERNATIONAL COOPERATION AGENCY

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ABBREVIATIONS

km	kilometer	kW	kilowatt
m	meter	MW	megawatt
cm	centimeter	kVA	kilovolt ampere
mm	millimeter	V	volt
kg	kilogramme	Hz	hertz
g	gramme	mho	reciprocal of ohm
mg	milligramme	PS	Horse power
meq	milligramme equivalent	pH	potential of Hydrogen
km^2	square kilometer	°C	degree centigrade
m^2	square meter	%	percent
cm^2	square centimeter	ppm	part per million
ha	hectare	ft.	foot
kℓ	kiloliter	no(s).	number(s)
ℓ	liter	rpm	revolution per minute
mℓ	milliliter	dia.	diameter
m^3	cubic meter	approx.	approximately
hr(s)	hour(s)	max.	maximum
ℓ/sec/ha	liter per second per hectare	min.	minimum
kg/ha	kilogramme per hectare	US$	U.S. dollar
g/ha	gramme per hectare	US¢	U.S. cent
ℓ/ha	liter per hectare	¢	Cedi
ton(s)/hr	ton(s) per hour	L.S.	lump sum
m^3/hr	cubic meter per hour		
cm/min	centimeter per minute		
ℓ/min	liter per minute		
m^3/sec	cubic meter per second		
Nm^3/min	net cubic meter per minute		
mm/day	millimeter per day		
mg/100g	milligramme per 100 gramme		
meq/100g	milligramme equivalent per 100 gramme		
kg/cm^2G	kilogramme weight per square centimeter		
$cals/cm^2$	calories per square centimeter		
El(s).	Elevation(s) above mean sea level		

CONVERSION TABLE

Length

1 mile = 1.609 km
1 yard = 0.914 m
1 foot = 0.305 m
1 inch = 0.0254 m

Area

1 square mile = 2.59 km^2
1 acre = 0.405 ha
1 square foot = 0.093 m^2
1 square yard = 0.836 m^2

Volume

1 acre foot = 1,233.5 m^3
1 cubic yard = 0.765 m^3
1 cubic foot = 0.0283 m^3
= 28.3 ℓ
1 gallon (English)
= 4.546 ℓ

Weight

1 ounce = 28.35 g
1 pound (English)
= 453.59 g

CURRENCY EQUIVALENT

Currency unit
Cedi (¢), Pesawa (P)
¢ 1.00 = 100 P
¢ 1.00 = US$0.87
US$ 1.00 = ¢ 1.15
US$ 1.00 = ¥ 300
¢ 1.00 = ¥ 261

ANNEX I

METEOROLOGY AND HYDROLOGY

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX I METEOROLOGY AND HYDROLOGY

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Annex I METEOROLOGY AND HYDROLOGY

1.1 Meteorological Data

Meteorological data are available from the Ghana Meteorological Services Department Headquarters which publishes general climatological summaries annually, together with selected list of rainfall data. The location of the observation stations in the Accra plains, and the general pattern of rainfall, as indicated by the average annual isohyets are shown in Fig. I-1. The following meteorological data were used for the present study.

(1) Daily rainfall records at Aveyime, (1953-1974)

(2) Mean, maximum and minimum air temperature records at Aveyime, (1964-1974)

(3) Monthly average relative humidity records at Aveyime, (1964-1974)

(4) Monthly average duration of sunshine records at Aveyime, (1963-1974)

(5) Monthly pan evaporation records at Ada and Akuse, (1965-1974)

(6) Monthly solar radiation records at Ada and Akuse, (1967-1974)

The Aveyime meteorological station is located in the project area. The records have been obtained at this station for more than ten years. They are regarded as representing the project area. Meteorological data at Aveyime are summarized in Table I-1 and Fig. I-2.

1.2 Analysis of Meteorological Data for Agricultural Development

Weather phenomena, such as precipitation, temperature, wind, relative humidity, evaporation and cloudiness affect soil-moisture, available moisture supplied, choice of crops, crop yields, and even the quality of the crop products. Therefore, accurate and proper analysis of the meteorological data is the basis in planning the new agricultural development under irrigation.

1.2.1 Rainfall

The principal climatic factors in the irrigated agriculture are precipitation and temperature. In the tropical regions, adequate amount of light is available for crop growth, and temperature is also sufficient for the normal plant growth. However, precipitation which constitutes the basic source of all water used in crop production varies widely from place to place and year to year. Precipitation data have a direct bearing in planning to meet such problems as drainage of storm water, control of soil erosion, and determination of the quantity of water needed to irrigated crops in addition to that provided by natural precipitation. Therefore, precipitation is of primary importance.

(1) Monthly average rainfall

Records obtained from the Aveyime meteorological station were mainly used for estimation of the rainfall potential in the project area, because it has a record covering a long period of years. In addition, some more gauging stations located in the Accra plains were also used for making comparison of the records with those of the said stations.

The average rainfalls at Aveyime are given in Table I-2 and summarized as shown below.

Average Rainfalls (22 years)

Unit: mm

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
14	34	82	104	137	213	54	25	76	120	69	21	949

As can be seen in the above table, the Accra plains have two rainy seasons and two dry seasons in a year. Precipitation in the major rainy season which begins from April and ends in June is approximately half of the total annual rainfall. Average monthly precipitation is estimated at about 80 mm, which is not sufficient to expect high yields of crops under favourable growing conditions. It is inevitable that supplement of water to crops by irrigation is needed for profitable and economical agricultural development in this area.

(2) Rainfall intensity

The rainfall intensity curves at the Akuse and Ada stations (see Fig. I-3 and I-4), were provided by the Ghana Meteorological Services Department from detailed observation data. The arithmetic mean of the intensities at the two is applied to the project area. Fig. I-5 shows the relationship between the rainfall intensity and the duration thus constructed.

(3) Rainfall distribution affecting farm operations and sugar cane growing

Mean monthly rainy days which affect the planning of farm operations have been estimated as follows (refer to Table I-3):

Unit: days

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1	2	4	6	8	12	5	3	5	8	5	2	61

In the project area, it is envisaged to grow sugar cane. In general, sugar cane needs a lot of water and high temperature during growing period, but needs dry weather and enough drainage during ripening period. In order to obtain high sugar yield from cane, the cane sugar factory should get adequately ripened cane and it should extract sugar before deterioration begins. In other words, only the dry season of the cane is the operation period of the factory.

As can be seen in the above table, in the period from November to April, it is possible to secure about 150 days of actual grinding period for the factory. It will be enough to produce cane sugar economically in the project area.

1.2.2 Temperature

Temperature conditions for the irrigation projects largely determine the type of crops most suitable for profitable production. Common types of farm crops grow in a temperature ranging from at few degrees above freezing to about 45°C. Most rapid growth often takes place at temperatures from 24 to 35°C.

Unit: °C

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	27.9	28.9	29.1	28.4	27.6	26.5	25.7	25.6	26.2	27.2	27.8	27.5
Max.	33.5	34.3	34.2	33.5	32.3	30.4	29.0	29.4	30.4	31.9	32.8	32.8
Min.	22.3	23.5	23.9	23.3	22.9	22.6	22.3	21.8	21.9	22.4	22.7	22.2

According to the records, the annual variation of mean monthly temperatures is approximately 3.5°C, and the annual mean is 27.4°C. The daily range is about 10°C. The mean monthly minimum temperature is 28.1°C. Therefore, it may be said that there is no special problem of temperature in climatic conditions for the growth of crops in the project area. Daily mean, maximum and minimum temperatures at Aveyime are shown in Tables I-4 and I-5.

1.2.3 Light

In general, light conditions over the project area are favourable for the production of most farm crops. Since many crops amply applied with water develop maximum quantity of dry matter under high light intensities, maximum crop yields are often secured on irrigated lands. According to the records (see Table I-6, I-7 and I-8), the annual sunshine hours corresponds to more than 55 % of a year.

1.2.4 Relative humidity

The observed data on the relative humidity at Aveyime are available over 12 years, as shown in Table I-9.

The annual variation of the monthly relative humidity is about 8 %. Remarkably low relative humidity occurs for a few days during December, January and February. The minimum relative humidity in a day occurs in the mid afternoon and the maximum occurs at a night.

1.2.5 Evaporation

Accurate knowledge of monthly evaporation rates is required for the determination of crop consumptive use of water. At the Aveyime Station, evaporation was observed and recorded every day, but the data obtained cover only about two years, which is not sufficient for estimating design consumptive use of water in the project area. On the other hand, the Akuse and Ada synoptic stations give sufficient amount of data concerned (see Tables I-10 and I-11). The proposed project area is at the middle of both Akuse and Ada stations, (Akuse, 30 km west-northwest, Ada, 30 km southeast from the site). The weather conditions of two stations indicate similar seasonal characteristics and they vary gently between Ada and Akuse. Therefore, it is possible to use mean of data of the Ada and Akuse stations for the project area. Monthly pan evaporation values were estimated in the way mentioned above.

Unit: mm/month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Akuse	150	176	206	184	172	123	127	130	140	155	148	131	1,842
Ada	138	153	190	183	172	139	141	147	158	187	173	143	1,924
Aveyime	144	165	198	184	172	131	134	139	149	171	161	137	1,885

1.3 Hydrological Data

Hydrological data on the Volta river are available from the Volta River Authority (VRA) and the Public Works Department, Ministry of Works and Housing.

There are nine gauging stations between the Akosombo dam and the mouth of the river. The year of commencement of observation and locations of the stations are shown in the following table and Fig. I-6.

Gauge Station	Catchment Area	Length of River from Source to Site	Year of Commencement
	km^2	km	
Akosombo (D/S)	393,913	1,402.1	1962
Volta Bridge	394,043	1,407.2	1955
Sench Halcrow	394,097	1,412.2	1954
Kpong	394,133	1,419.1	1951
Amedica	394,276	1,427.2	1963
Obetenya	394,276	1,428.1	1952
Sogakope	394,400	1,486.2	1962
Anyanui	398,373	1,520.5	1962
Ada	398,373	1,515.0	1963

Records obtained from these stations are usable to study hydrologic studies of the lower Volta river. In addition, the tidal records at Ada which are available from the report prepared by NEDECO have been used for the study of possible floodings in the lower part of the Volta river.

1.4 Natural Regime of the Volta River

The Volta river arises from a catchment which extends to about 400,000 km^2, and the natural flows rise to a marked annual flood peak which may vary considerably from year to year in magnitude. This seasonal flood occurs generally in October, after which the flow diminishes fairly rapidly until November and then falls to a minimum between January and May.

The maximum flood peak recorded within living memory was about 14,000 m^3/sec and occurred in 1971. In 36 years of records (1963-1971) the maximum flood was 13,000 m^3/sec (1963), the minimum 2,500 m^3/sec (1958) and average about 6,600 m^3/sec.

Nowadays, with the construction of the Akosombo dam not far upstream from the proposed project area, the natural regime of the river has been remarkably modified. The main purpose of the Akosombo dam is the generation of electric power and all power units at the dam are now under operation.

The regulated power release is 1,090 m^3/sec based on the historical period of record of 35 years from 1936 to 1970/1. Spilling out the flood water from the reservoir will occur every three years or more as will be mentioned in Chapter 1.5.

/1: Food and Agriculture Organization of the United Nations, "Report on Survey of the Lower Volta River Flood Plain", 1963.

1.5 Possible Flood Control

As previously stated, the natural regime of the Volta has been significantly modified by the completion of the large Volta lake. If the flood discharge below the dam could be controled by proper reservoir regulation, much of the areas which extend in the lower plain of the Volta will be usable for agricultural purposes. In fact, a large agricultural development has been worked out at Asutsuare, and several possible economic developments are envisaged in the lower Volta flood plain in future. In planning such agricultural developments, the area chosen for the project should not be liable to flooding from the Volta river.

Originally, the flood routing programme of the Akosombo dam was published by Kaiser Engineers and Contractors in their report of January 1961.

Afterwards, the report/1 on survey of the lower Volta flood plain prepared by the Food and Agriculture Organization of the United Nations recommended that the limitation of the peak outflow of 5,660 m^3/sec (200,000 cusecs), including power release from the Volta Lake, should and could be achieved for the lower Volta flood plain by means of a 15-day flood forecasting system based upon the daily rainfall records of synoptic stations within the catchment together with regular flow records for all the principal tributaries.

And the study on the regulation of the reservoir presented by the Volta River Authority concluded that the Volta River would be regulated by the use of such forecast of inflows and by the application of optimum rule curves, allowing the limit downstream flow of 5,660 m^3/sec throughout the major flood period, August through November.

These recommendations are important for this irrigation project. Our present designs have been based upon the criteria above-mentioned.

It should be clearly understood that the recommendations of this report as to the feasibility and economic justification of the developments proposed are conditional on the operation of the reservoir so as to limit the peak outflow to 5,660 m^3/sec.

Fig. I-7 shows the relation between natural peak inflows and regulated peak outflows studied in detail by Kaiser Engineers/2,/3. These curves are used for our project planning. According to this figure the discharge of 5,660 m^3/sec corresponds to a recurrence interval of 30 years.

/1: Food and Agriculture Organization of the United Nations, "Report on Survey of the Lower Volta River Flood Plain", 1963.

/2: Kaiser Engineers, "Ghana Power Study", August 1971.

/3: Kaiser Engineers, "Akosombo Power Development", October 1963.

1.6 Water Surface Profiles of the Volta River

The water surface profiles of the Volta river is presented in Fig. I-6. The water surface profiles were obtained by a way of adjusting the curves which were taken from two sources, i.e. the Feasibility Report/1 submitted by Nippon Koei in 1967 and the Report/2 submitted by Kaiser Engineers in 1971.

The former includes the water surface profiles, which is based on the river profile survey and the analysing the flow records of the lower part of the Volta. The profile survey of the Volta river was carried out from the existing pumping station at Asutsuare to a point near the Tefle Bridge during 1966. Along with the profile survey, cross-sections of the river were surveyed at five points.

The latter includes the tailwater curves at Akosombo, which is based on records of VRA measurements taken during 1969/70 and the river bottom profiles surveyed. The river profile is shown down to Aveyime.

These curves above mentioned have little difference each other. Combining these curves the curves shown in Fig. I-7 was obtained. They will be the base of the project planning.

According to this figure, the proposed project areas (lowland area) will not be liable to be flooded by the river flow up to 5,660 m^3/sec lying around the Ke Lagoon which will be kept in safety through some protection works against that flooding.

1.7 Effect of the Kpong Project

The Kpong Hydroelectric Development Project/2 is under contemplation on the Volta river, 24 km downstream of the Akosombo dam. The project consists of a four-units powerhouse with a total installed capacity of 144 MW and the overflow type concrete weir with a length of 1,575 m crossing the Volta river on the Kpong rapids. The closure dikes and the river levee are also planned at each side of the concrete weir and along the downstream of the Volta. The location of the project is shown in Fig. I-5.

The regulated power release from the Akosombo will be wholly used for power production at the proposed new powerhouse. And the regulated outflow from the spillway at Akosombo will flow over the proposed concrete weir. The flow conditions, downstream of the new powerhouse, will therefore not change after implementation of the Kpong hydroelectric development project. Consequently it can be concluded that the Kpong hydroelectric development project will not have unfavourable influence on the Aveyime sugar production project.

/1: Nippon Koei Co., Ltd., "Feasibility Report on Sugar and Rice Production Project in Accra Plain", September 1967.

/2: Kaiser Engineers, "Ghana Power Study", August 1971.

1.8 Water Quality of the Volta River and Lagoons

The water quality of the Volta river and lagoons in the project area was investigated at the nine sites from May 1965 to January 1967. The chemical analyses were carried out at the field laboratory and in Japan. The results of analyses are presented in Table I-12.

In general, the quality of water delivered to arable land on an irrigation project should be adequate for continued profitable agriculture, without adversely affecting crop growth, impairing the quality of crop products, or damaging the soil on which crops are grown. The results of analyses indicate that the quality of water of the Volta and lagoons, except the Ke lagoon, is adequate for the purpose above mentioned.

The discussions on the results analyzed are summarized hereunder.

(1) The reaction of river water is alkaline having pH value ranging from 7.0 to 7.8, while lagoon waters have very weak acidity with pH value ranging from 6.4 to 6.8, except water sample of the Ke lagoon with rather strong acidity of pH 5.5.

(2) The electric conductivity of the water of the Volta is nearly 75 micro mho per cm. This value is classified as good for irrigation water by the standard/1 on permissible limits of constituents in water. As for water of the lagoons except the Ke lagoon, the data of the electric conductivity measurement are also classified as good for irrigation by the standard above mentioned. Analysis of salt content (NaCl) in water of the river and lagoons also shows the same result and each water is usable for irrigation without adversely affecting crop growth or damaging the arable land. However, water of the Ke lagoon only would be of doubtful quality in regard to salinity.

(3) The contents of calcium, magnesium, sodium, potassium are insignificant in each sample water. The sodium percentage/2 is less than 60 % in each sample water, and not injurious to irrigated crops.

(4) Regarding anions in water, the contents of acid radicals such as sulfate, chloride, etc. are less than 12 ppm in each sample water of the river and lagoons, except the Ke lagoon. It is concluded that waters are also suitable for irrigation exclusive of water of the Ke lagoon.

/1: Scofield, C.S. "The Salinity of Irrigation Water" Smith. Inst. Rep., 1935, pp. 175-187.

/2: The sodium percentage is the ratio of the total sodium plus potassium cations to the total cations contained in solution, multiplied by 100. The value is computed by the following formula:

$$\text{Sodium percentage} = \frac{(Na + K) \times 100}{Ca + Mg + K + Na}$$

The water with sodium percentage of less than 60 % is suitable for irrigation.

(5) All samples of river water include relatively rich amount of silicic acid and poor amount of iron. These chemical features are the common characteristics of river water in the tropical monsoon climatic regions.

According to the Scofield Standard[/1], each water sample of the Volta and lagoons exclusive of the Ke lagoon is rated as first class with excellent quality or second class with good quality.

The chemical analysis of the Volta river water also shows that the water is usable for domestic purposes without injuring to health of mankind and animals under proper chemical treatments.

[/1]: Scofield, C.S. "The Salinity of Irrigation Water" Smith. Inst. Rep., 1935.

Table I-1. Summary of Meteorological Data at Aveyime

Item	Unit	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Monthly Rainfall	mm	14	34	82	104	137	213	54	25	76	120	69	21	949
Monthly Rainy Days	days	1	2	4	6	8	12	5	3	5	8	5	2	61
Mean Air Temperature	°C	27.9	28.9	29.1	28.4	27.6	26.5	25.7	25.6	26.2	27.2	27.8	27.5	Av.27.4
Maximum Air Temperature	°C	33.5	34.3	34.2	33.5	32.3	30.4	29.0	29.4	30.4	31.9	32.8	32.8	Av.32.0
Minimum Air Temperature	°C	22.3	23.5	23.9	23.3	22.9	22.6	22.3	21.8	21.9	22.4	22.7	22.2	Av.22.7
Monthly Evaporation[1]	mm	144	165	198	184	172	131	134	139	149	171	161	137	1,885
Relative Humidity	%	81	86	74	75	77	82	81	79	78	77	77	82	Av.79
Duration of Sunshine	hours	6.4	6.8	6.9	6.6	6.6	4.5	4.1	4.6	5.1	6.7	7.6	6.7	Av.6.1
Monthly Solar Radiation[1]	cals/cm^2	382.4	446.4	492.3	495.7	488.9	406.6	421.7	423.7	450.4	494.4	491.2	419.7	5,413.4

[1] The mean value of Ada and Akuse stations

Table I-2 Monthly Rainfall Station: Aveyime

Unit: mm

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1953	-	-	-	48	192	95	34	10	1	221	29	1	-
1954	28	110	224	92	120	111	5	0	17	88	26	-	-
1955	-	-	147	-	-	-	78	81	76	212	13	21	-
1956	0	18	145	55	121	178	8	3	32	106	49	26	741
1957	0	-	77	92	205	82	43	18	69	92	74	70	-
1958	0	23	51	79	233	233	0	0	53	200	103	0	975
1959	0	45	50	115	117	256	33	0	129	165	94	33	1,037
1960	39	15	51	91	114	224	26	18	118	168	110	34	1,008
1961	60	22	45	152	30	294	72	0	85	86	97	6	949
1962	38	11	59	78	143	448	116	83	8	86	101	36	1,207
1963	0	41	91	145	92	-	89	-	-	62	98	9	-
1964	3	4	70	204	74	151	64	3	26	32	47	8	686
1965	8	63	67	188	87	270	88	124	39	77	92	32	1,135
1966	19	7	91	53	90	203	73	0	14	141	121	54	866
1967	0	21	92	202	152	303	5	4	89	43	73	9	993
1968	8	28	56	64	94	211	211	91	220	132	54	2	1,171
1969	29	30	107	53	131	257	23	6	32	128	50	10	856
1970	24	28	66	62	283	84	12	2	120	227	44	9	961
1971	1	17	58	56	131	257	23	6	32	128	50	10	769
1972	0	95	36	163	158	156	5	4	89	33	90	54	883
1973	0	51	51	89	143	216	39	78	178	68	86	7	1,006
1974	31	15	89	102	160	230	148	3	173	144	17	5	1,117
Average	14	34	82	104	137	213	54	25	76	120	69	21	949/1

/1: Total of average monthly rainfall

Table I-3. Monthly Rainy Days

Station: Aveyime

Unit: days

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1953	-	-	-	2	7	8	4	1	1	12	3	1	-
1954	2	4	7	5	7	6	1	0	4	10	2	-	-
1955	-	-	5	-	-	-	2	2	4	6	2	0	-
1956	0	1	5	3	3	6	1	1	6	6	2	3	37
1957	0	-	3	4	8	5	4	2	3	3	4	2	-
1958	0	1	2	4	6	4	0	0	4	9	2	0	32
1959	0	2	4	7	8	13	3	0	5	15	8	2	67
1960	1	2	6	6	9	14	3	4	7	8	5	3	68
1961	2	2	5	6	5	15	5	0	4	3	5	1	53
1962	1	1	4	6	12	19	3	2	1	5	5	2	51
1963	0	3	6	5	5	-	7	-	-	6	7	2	-
1964	1	1	3	11	7	13	3	1	4	4	3	1	52
1965	2	3	5	11	6	14	10	10	3	6	9	1	80
1966	1	2	5	5	9	10	3	0	5	9	6	2	57
1967	0	2	4	5	9	17	4	2	9	8	6	2	68
1968	1	2	2	5	8	16	14	12	17	11	4	1	93
1969	1	2	6	8	8	21	7	2	3	10	7	2	77
1970	2	1	4	4	8	7	3	3	8	13	11	1	65
1971	1	2	4	4	8	21	7	2	3	10	7	2	71
1972	0	4	4	9	11	10	2	1	5	5	8	3	62
1973	0	2	5	6	9	9	5	13	9	10	5	3	76
1974	2	3	3	5	13	13	10	2	8	8	7	1	75
Average	1	2	4	6	8	12	5	3	5	8	5	2	61

Table I-4. Daily Mean Air Temperature Station: Aveyime

Unit: °C

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	27.8	29.1	29.4	27.6	25.8	25.8	24.5	24.1	25.4	26.1	27.3	27.4
1965	27.6	28.1	28.7	27.5	27.4	25.9	24.8	24.9	25.8	29.1	27.3	27.1
1966	27.4	28.4	28.9	28.5	27.9	26.7	26.3	25.6	25.9	26.6	27.4	27.3
1967	26.7	28.6	28.6	28.7	27.7	26.4	25.3	25.1	26.1	26.6	27.8	27.9
1968	27.8	-	-	-	-	26.6	26.1	26.2	26.0	26.9	27.5	27.7
1969	28.1	29.5	29.1	29.3	28.9	26.6	25.6	25.9	26.7	27.1	27.8	28.4
1970	28.2	29.5	29.4	29.3	27.2	26.8	25.8	26.5	-	-	27.3	26.7
1971	-	28.5	28.7	28.7	-	-	-	-	-	-	27.5	26.9
1972	28.3	28.8	28.9	28.0	27.8	26.3	26.2	25.9	26.8	28.1	28.7	28.1
1973	29.4	-	29.8	-	28.7	27.2	26.5	26.3	26.7	27.4	28.1	27.8
1974	27.4	29.5	28.9	28.4	26.6	26.5	25.6	25.6	-	-	-	-
Average	27.9	28.9	29.1	28.4	27.6	26.5	25.7	25.6	26.2	27.2	27.8	27.5

Annual Average 27.4 °C

Table I-5. Daily Maximum and Minimum Air Temperature

Station; Aveyime
Unit; °C

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	Max.	33.3	34.5	35.0	32.3	30.3	30.0	28.3	28.2	30.0	31.1	32.7	33.0
	Min.	22.4	23.6	23.8	22.9	21.3	21.7	20.7	19.9	20.9	21.1	21.8	21.8
1965	Max.	33.4	33.6	32.4	32.4	32.3	29.9	28.2	28.8	30.4	31.7	32.7	32.7
	Min.	21.7	22.6	23.4	22.6	22.6	21.9	21.3	21.0	21.1	21.4	21.8	21.6
1966	Max.	33.1	34.3	34.3	34.6	32.9	31.6	27.2	29.9	30.9	31.9	32.8	32.8
	Min.	21.6	22.4	23.6	22.5	23.0	21.9	21.9	21.3	20.8	21.3	22.1	21.7
1967	Man.	33.2	34.4	34.2	33.6	32.2	30.0	28.7	28.4	30.2	31.1	32.8	33.3
	Min.	20.2	22.7	22.9	23.9	23.2	22.8	22.0	21.8	22.2	22.1	22.8	22.6
1968	Max.	33.6	-	-	-	-	30.0	28.9	29.2	29.7	31.3	32.2	32.5
	Min.	22.0	-	-	-	-	23.2	23.2	23.3	22.3	22.6	22.8	22.9
1969	Max.	33.2	34.4	33.6	33.8	33.4	29.7	28.6	29.3	30.8	31.4	32.5	33.4
	Min.	22.8	24.6	24.7	24.8	24.4	23.4	22.6	22.5	22.6	22.7	23.2	23.5
1970	Max.	33.4	34.4	34.0	33.9	31.3	30.8	29.5	30.4	30.9	31.7	32.2	32.8
	Min.	23.1	24.6	24.7	24.7	23.1	22.8	22.2	22.6	-	-	22.3	20.6
1971	Max.	33.6	34.2	34.1	34.1	33.9	29.9	28.9	-	30.2	31.8	32.3	32.3
	Min.	-	22.7	23.3	23.4	-	-	-	-	-	-	22.6	21.4
1972	Max.	33.6	33.8	33.9	32.7	32.3	30.2	29.6	30.2	31.2	32.8	33.5	32.8
	Min.	23.1	23.8	23.8	23.3	23.3	22.4	22.8	21.7	22.4	23.3	23.9	23.4
1973	Max.	35.1	35.3	35.0	34.9	33.4	31.2	30.5	29.9	30.8	31.7	33.4	32.9
	Min.	23.7	-	24.6	-	23.8	23.1	22.4	22.7	22.6	23.0	22.8	22.7
1974	Max.	32.8	34.6	34.2	34.1	31.8	30.6	29.2	30.2	29.7	-	-	-
	Min.	21.9	24.4	23.5	22.7	21.3	22.4	22.1	21.0	-	-	-	-
Average	Max.	33.5	34.3	34.2	33.5	32.3	30.4	29.0	29.4	30.4	31.9	32.8	32.8
	Min.	22.3	23.5	23.9	23.3	22.9	22.6	22.3	21.8	21.9	22.4	22.7	22.2

Table I-6 Duration of Sunshine Station: Aveyime

Unit: hours

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1963	6.4	6.8	6.9	6.6	6.6	4.5	4.1	4.6	5.1	7.7	6.7	7.3
1964	5.4	6.5	8.5	6.6	6.2	3.4	4.2	4.2	5.3	6.4	8.1	6.6
1965	8.6	6.8	7.3	7.5	4.0	4.5	4.1	4.6	5.1	6.7	7.6	6.7
1966	6.4	6.8	6.9	6.6	6.6	4.5	4.1	4.6	5.1	5.0	6.1	6.8
1967	4.7	5.8	5.8	5.9	7.1	5.4	3.5	3.2	5.1	6.1	8.4	7.1
1968	5.6	6.8	6.1	5.7	6.7	4.3	4.1	4.0	3.7	5.0	8.2	6.7
1969	5.1	6.2	6.8	5.8	7.8	4.1	3.3	3.8	4.9	7.9	7.6	6.7
1970	6.4	6.8	6.9	6.6	6.1	4.3	4.8	4.2	5.1	7.2	7.5	6.0
1971	6.8	6.6	7.6	5.4	6.6	4.5	4.1	4.6	5.1	7.1	7.9	6.7
1972	7.1	8.0	7.6	7.6	6.7	5.7	4.0	5.3	6.4	7.2	7.6	6.7
1973	6.6	7.4	5.6	7.3	7.9	4.5	4.1	5.1	5.3	6.7	7.7	6.1
1974	7.7	6.8	6.9	7.4	6.7	4.5	4.9	6.7	5.2	7.9	7.7	6.7
Average	6.4	6.8	6.9	6.6	6.6	4.5	4.1	4.6	5.1	6.7	7.6	6.7

Annual Average 6.1

Table I-7 Monthly Solar Radiation

Station: Akuse

Unit: cals/cm^2

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1967	375.4	427.2	440.1	493.7	486.3	390.2	356.9	336.5	392.0	480.8	499.3	410.5	5088.9
1968	369.8	417.9	469.7	467.8	482.6	421.6	368.0	372.2	409.2	453.6	459.2	412.9	5104.5
1969	361.0	459.2	488.8	448.1	483.2	390.7	362.9	359.2	381.4	483.2	514.7	461.0	5193.4
1970	407.3	442.5	492.5	455.5	438.8	442.5	398.1	385.1	416.6	475.8	468.4	440.7	5263.8
1971	387.0	438.8	498.1	492.5	503.6	394.4	403.6	370.3	429.5	488.8	494.3	433.3	5334.2
1972	390.7	429.5	472.1	492.5	466.6	412.9	372.2	377.7	374.0	425.8	416.6	344.4	4975.0
1973	375.9	407.3	424.0	453.6	485.1	401.8	449.9	375.9	401.8	444.4	464.7	349.9	5034.3
1974	303.6	351.8	442.5	472.1	433.3	366.6	361.0	416.6	381.4	451.8	427.7	370.3	4778.7
Average	371.3	421.8	466.0	472.0	472.4	402.6	384.1	374.2	398.2	463.0	468.1	402.9	5096.6

Table I-8 Monthly Solar Radiation

Station: Ada

Unit: cals/cm^2

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1967	360.5	446.0	454.4	506.4	492.9	414.1	434.3	434.3	489.6	531.5	521.5	432.6	5,518.1
1968	367.2	-	-	-	-	-	-	-	489.7	512.8	503.1	447.5	-
1969	405.2	489.7	518.5	510.9	537.7	420.6	393.7	468.6	476.3	-	533.2	478.2	-
1970	415.5	482.0	550.3	499.0	474.4	461.1	491.5	495.2	525.6	533.2	512.3	453.5	5,893.6
1971	404.2	468.7	552.2	519.9	529.4	389.0	485.8	470.6	519.9	548.4	538.9	476.3	5,903.3
1972	434.5	504.7	546.5	557.9	521.8	438.3	457.3	468.7	506.6	523.7	480.1	377.6	5,817.7
1973	406.1	482.0	487.7	519.9	518.0	406.1	495.2	468.7	514.2	499.0	521.8	425.0	5,743.7
1974	354.8	423.1	519.9	521.8	463.0	345.3	457.3	506.6	499.0	531.3	502.8	400.4	5,525.3
Average	393.5	470.9	518.5	519.4	505.3	410.6	459.3	473.2	502.6	525.7	514.2	436.4	5,729.6

Table I-9 Relative Humidity at 9:00 am. Station: Aveyime

Unit: %

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964	86	81	72	76	79	81	82	78	75	77	71	79
1965	70	75	72	76	76	82	84	81	81	78	79	87
1966	82	74	71	73	-	82	83	79	78	77	76	83
1967	80	79	-	76	77	84	81	83	76	76	74	79
1968	86	-	-	-	-	84	84	84	85	80	80	83
1969	86	75	78	77	76	84	80	78	74	77	81	81
1970	-	79	82	74	80	81	78	76	75	77	80	82
1971	83	74	74	72	72	84	82	82	80	79	76	78
1972	82	74	72	78	78	83	81	76	75	73	76	83
1973	78	73	73	71	74	81	78	79	77	77	75	82
1974	81	76	71	73	80	81	81	75	80	-	-	-
Average	81	76	74	75	77	82	81	79	78	77	77	82

Annual Average 78

Table I-10 Monthly Pan Evaporation Station: Akuse

Unit: mm

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1965	184	192	229	191	179	116	108	107	137	145	145	135	1,868
1966	146	170	221	171	162	108	132	133	129	165	152	122	1,811
1967	140	164	184	182	163	114	115	136	148	154	151	148	1,799
1968	154	196	197	183	155	128	120	114	121	135	135	112	1,750
1969	131	159	203	173	185	129	118	120	133	151	128	126	1,756
1970	-	-	-	167	156	136	121	144	154	153	152	134	-
1971	143	180	198	207	192	123	142	118	148	157	152	144	1,904
1972	166	163	199	177	170	130	132	149	149	180	160	122	1,897
1973	163	185	226	203	193	134	159	133	140	155	155	123	1,969
1974	126	173	199	186	166	115	126	146	136	158	146	142	1,819
Average	150	176	206	184	172	123	127	130	140	155	148	131	1,842

Table I-11 Monthly Pan Evaporation

Station: Ada

Unit: mm

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1965	133	136	192	182	175	132	134	166	182	195	174	127	1,928
1966	122	150	192	183	169	134	155	138	156	197	167	137	1,900
1967	130	139	159	212	162	134	133	128	138	176	158	143	1,812
1968	160	164	179	174	179	130	133	146	149	161	158	137	1,870
1969	124	155	205	186	184	150	141	155	-	188	179	153	-
1970	133	166	207	182	179	166	-	145	167	191	163	139	-
1971	132	145	188	178	176	126	137	129	157	189	174	150	1,881
1972	148	165	185	181	168	144	131	144	158	186	165	128	1,903
1973	142	161	185	163	165	130	148	155	166	194	197	151	1,957
1974	153	144	207	192	160	146	157	168	153	193	190	169	2,032
Average	138	153	190	183	172	139	141	147	158	187	173	143	1,924

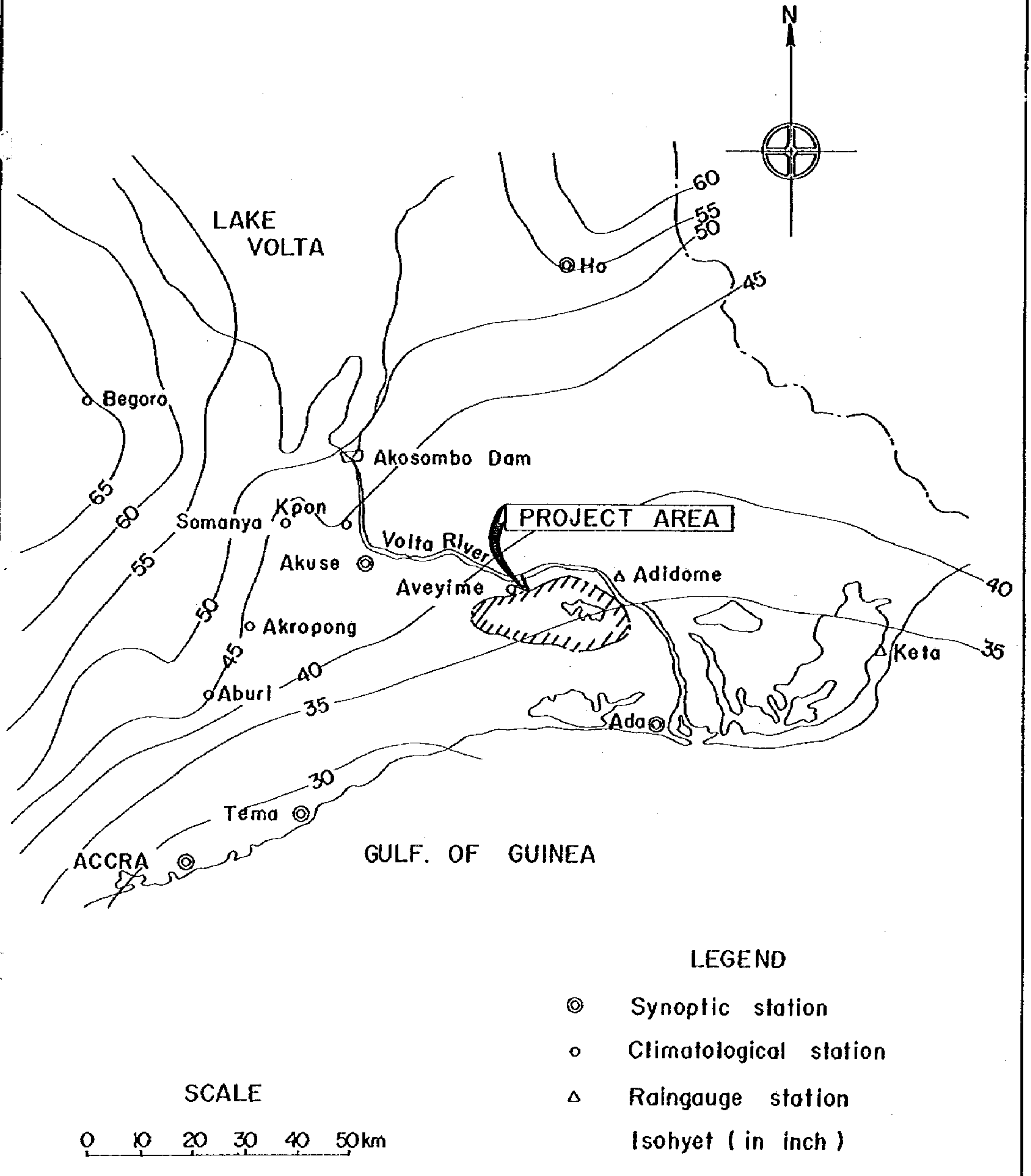
Table I-12 Water Analysis of the Volta River and Lagoons

	Location	Date of Sumpling	[1] Water Depth (ft.)	Muddiness (ppm)	Electric Conductivity (μ℧)	pH	Alkalinity (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Cl (ppm)	SO_4 (ppm)	SiO_2 (ppm)	Fe (ppm)	PO_4 (ppm)	Cu (ppm)	Mn (ppm)	NH_4-N (ppm)	NO_3-N (ppm)	NaCl (ppm)	Evaporation Residum (ppm)
Volta	Ablevenia	Apr.26, 1966	0.5																		3.3	
			3.0																		3.3	
	Aveyime	Apr.26, 1966	0.5																		2.4	
			2.0																		4.1	
			4.0																			
		Sept.13,1966	0.5	2.0	75.2	7.0	35.0	6.8	5.4	3.6	3.8	2.5	0.5	10.9	less than 0.03	less than 0.10	–	less than 0.05	less than 0.15	0.24	4.1	90.0
			7.0	47.5	75.8	7.2	–	–	–	4.0	0.8	–	0.5	12.2	0.27	0.10	–	0.05	0.15	0.27	–	200.0
		July 17,1975[2]	1.0	–	77.0	7.1	–	6.5	5.4	4.2	2.4	4.2	3.24	–	–	–	–	–	–	–	–	
	Battor	Apr. 26,1966	0.5	–																	3.3	
			3.0	–	75.9	6.7	30.0	6.0	6.3	4.0	3.4	2.0	3.3	10.8	0.08	less than 0.10	–	–	less than 0.15	0.08	3.3	130.0
			6.0																		2.4	
			9.0																		4.1	
			12.0																		3.3	
			15.0																			
		Sept. 13,1966	0.5	6.0	74.1	7.2	–	–	–	5.0	0.8	–	–	11.4	less than 0.03	less than 0.01	–	less than 0.05	less than 0.15	0.25	–	190.0
			13.0	90.0	76.1	7.3	36.0	6.8	3.9	4.6	19.8	2.0	2.2	11.0	0.18	less than 0.01	–	less than 0.05	0.88	0.19	3.3	280.0
	Mepe	Apr. 26,1966	0.5																		2.4	
			3.0																		2.4	
			6.0																		3.3	
			9.0																		3.3	
			12.0																		3.3	
			15.0																		3.3	
		Sept. 12,1966	0.5	2.0	76.0	7.1	37.0	7.2	4.4	2.6	1.6	2.0	less than 0.5	10.7	less than 0.03	less than 0.10		less than 0.05	less than 0.15	0.39	3.3	80.0
			10.0	–	–	–	–	–	–	–	14.4	–	–	–	0.18	–		–	0.69	–	–	–
	Melefi	Sept. 10,1966	0.5	6.0	74.4	7.2	40.0	7.2	4.9	3.6	1.6	2.0	less than 0.5	11.5	less than 0.03	less than 0.10		less than 0.05	less than 0.15	0.24	3.3	110.0
			7.0	15.5	74.5	7.0	36.0	6.8	4.0	2.4	1.6	2.5	3.4	11.4	0.05	less than 0.10		less than 0.05	less than 0.15	0.22	4.1	150.0
			15.0	36.0	77.7	7.1	–	–	–	3.2	3.8	–	0.3	10.8	0.03	less than 0.10		less than 0.05	less than 0.15	–	–	130.0
	Tefle	Nov. 28,1966	0.5	–	65.5	7.4	36.2	–	–	2.6	1.2	3.0	2.3	10.8	less than 0.10	less than 0.10	0.011	less than 0.05	less than 0.15	0.01	4.97	80.0
			8.0	–	74.3	7.8	37.8	–	–	2.6	1.6	2.3	2.7	12.6	0.22	less than 0.10	0.011	less than 0.05	0.20	0.08	3.80	140.0
			16.0	–	75.3	7.6	40.2	–	–	3.0	2.0	2.6	2.5	13.5	0.19	less than 0.10	0.011	less than 0.05	0.15	0.07	4.41	80.0
		July 17,1975[2]	1.0	–	86,1	7.7	–	5.9	5.8	4.5	2.3	7.56	3.75	–	–	–	–	–	–	–	–	–
Lagoons	Bla	Jan. 25,1967		–	58.9	6.4	28.6	–	–	5.4	3.0	5.0	3.2	8.3	3.9	less than 0.10	0.01	0.17	0.37	0.16	8.3	800.0
	Aklamadow	Jan. 25,1967		–	59.5	6.7	25.8	–	–	4.2	0.8	5.0	2.6	3.9	0.10	less than 0.10	0.01	less than 0.05	less than 0.15	0.01	8.3	90.0
	Ke	Jan. 25,1967		–	200.0	5.5	28.4	–	–	2.2	2.0	57.0	6.7	22.6	0.50	less than 0.10	0.03	0.20	0.20	0.19	94.6	370.0

[1] : Figures show the sampling depth in feet from the river surface.

[2] : Water samples of the Volta river were taken at Aveyiem and Tefle during this time's survey and were analized in Tokyo for the confirmation of the previous analytical data.

Fig. I-1 NETWORK OF METEOROLOGICAL STATIONS



SOURCE : Average Annual Rainfall
Published by the Survey of Ghana, 1968

Fig I-2 METEOROLOGY AT AVEYIME

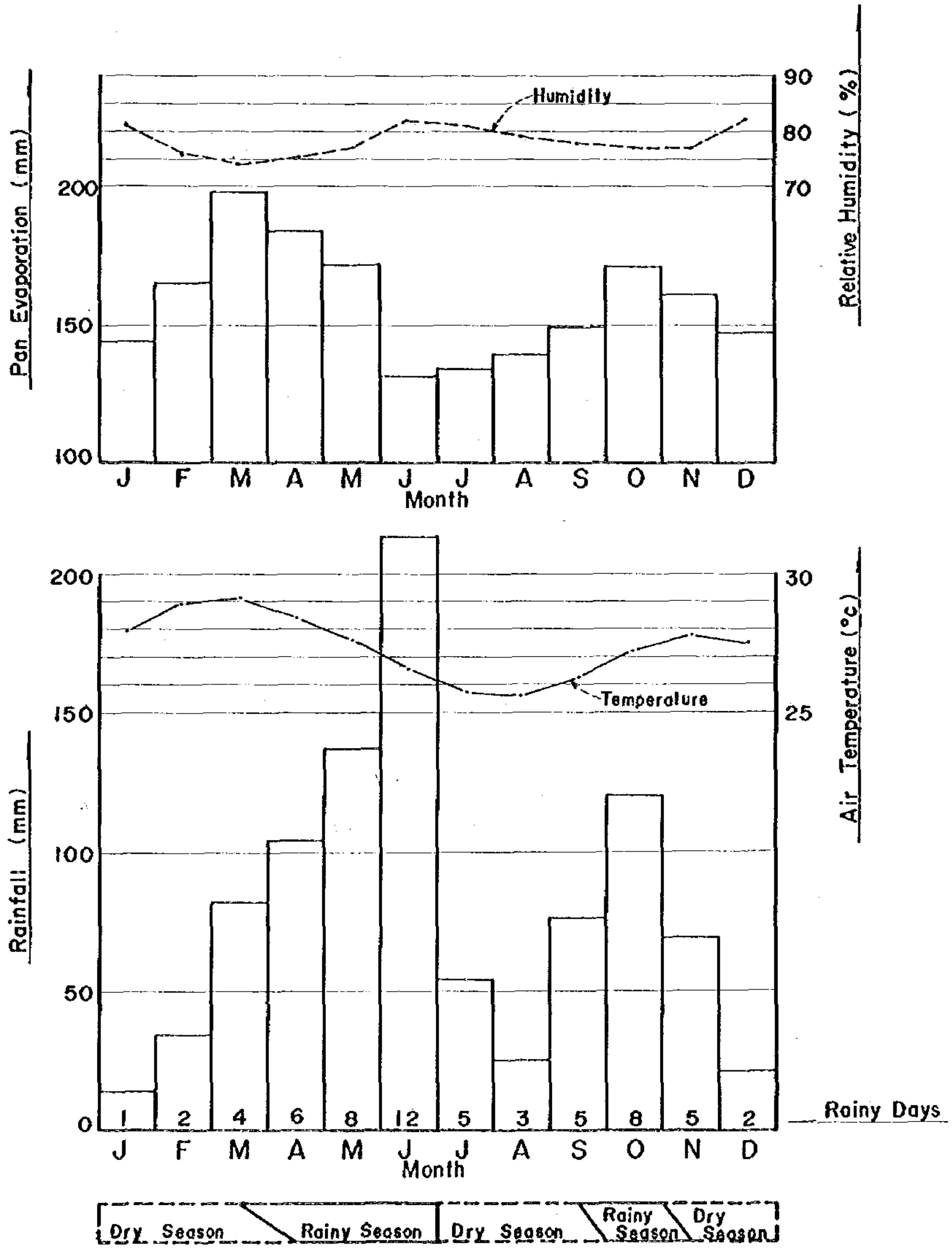


Fig.I-3 RAINFALL INTENSITY CURVE AT AKUSE

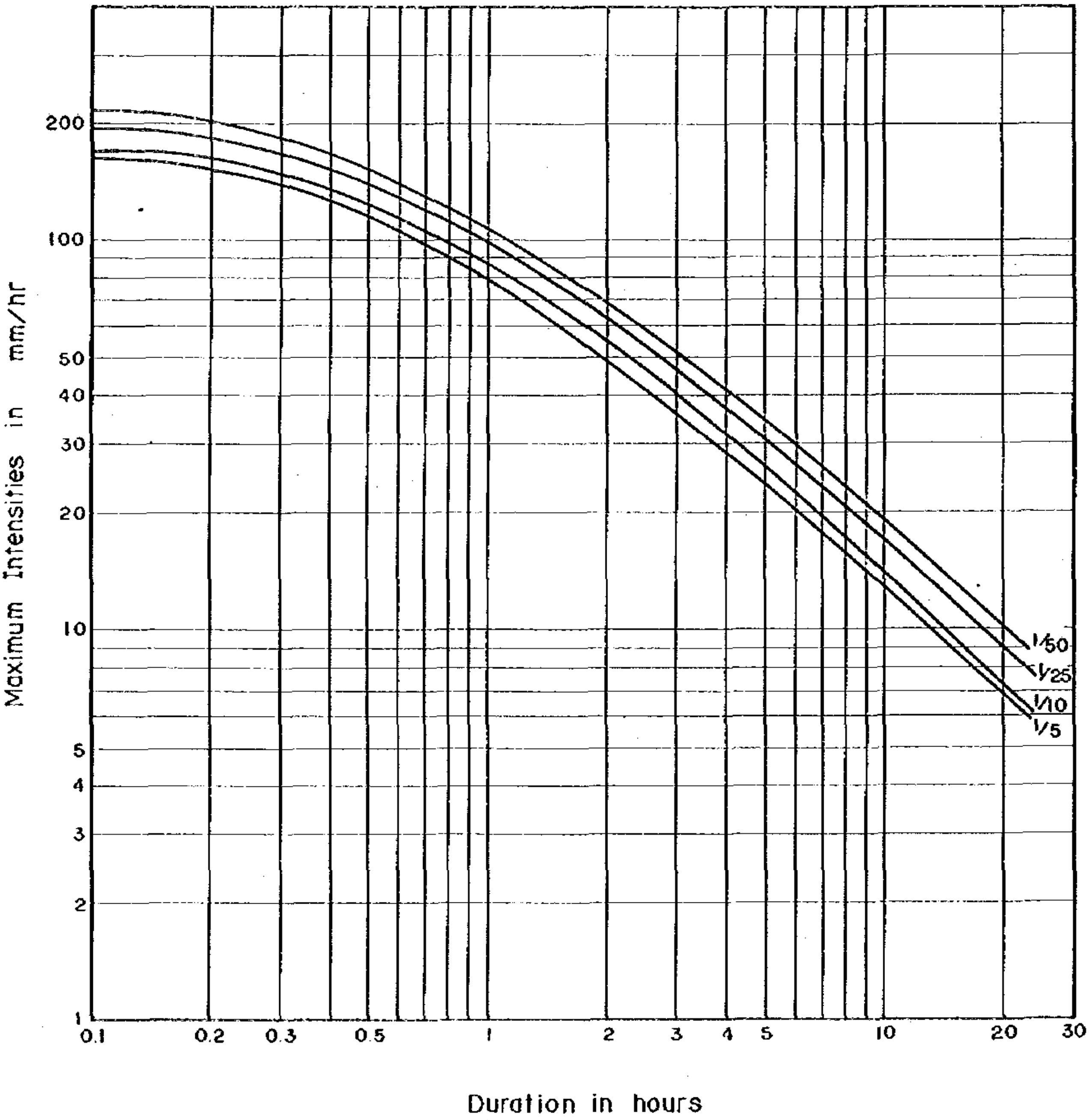


Fig. I-4 RAINFALL INTENSITY CURVE AT ADA

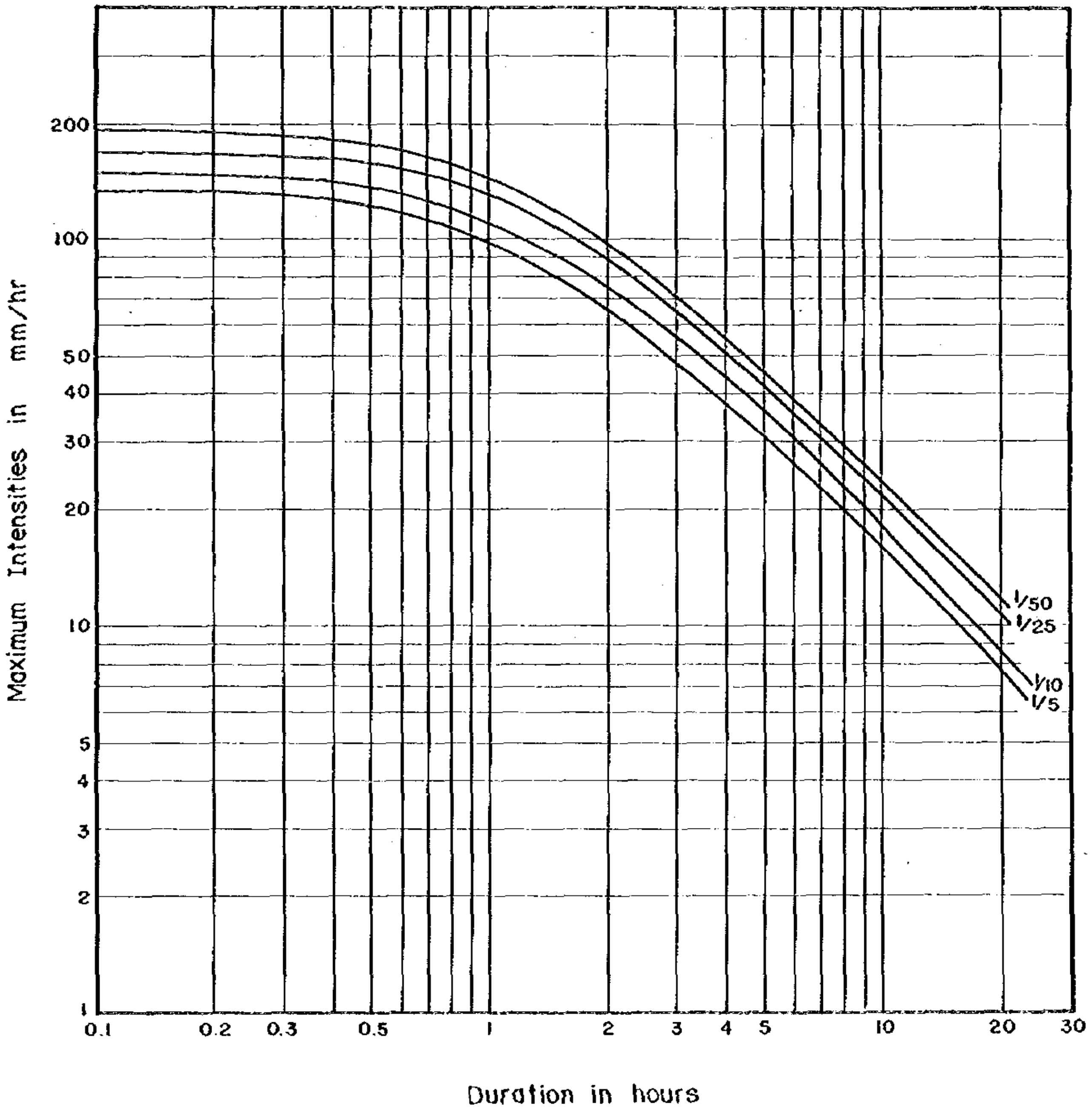


FIg. I-5 RAINFALL INTENSITY CURVE AT AVEYIME

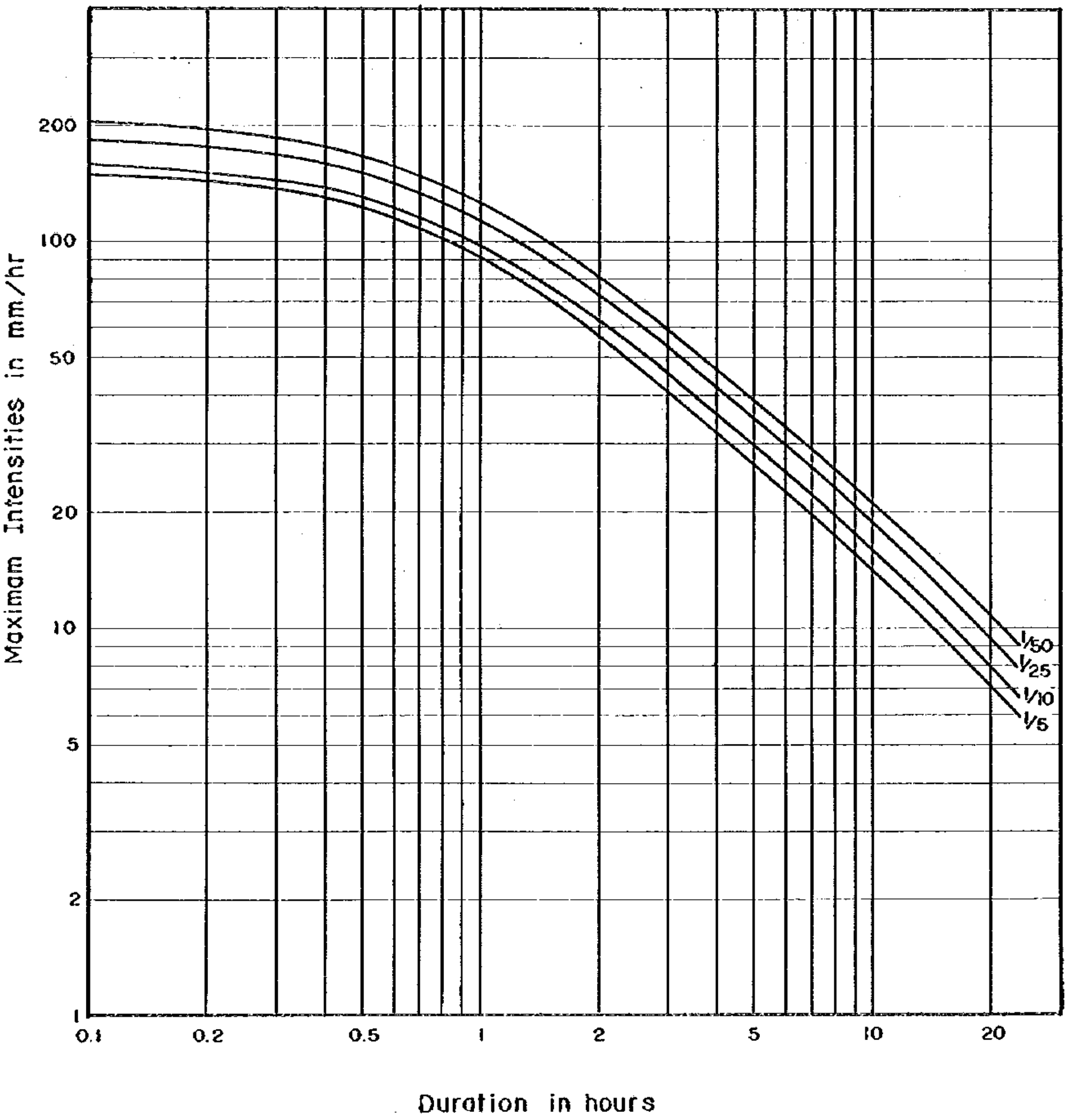


Fig. I-6 WATER SURFACE PROFILES OF THE VOLTA RIVER

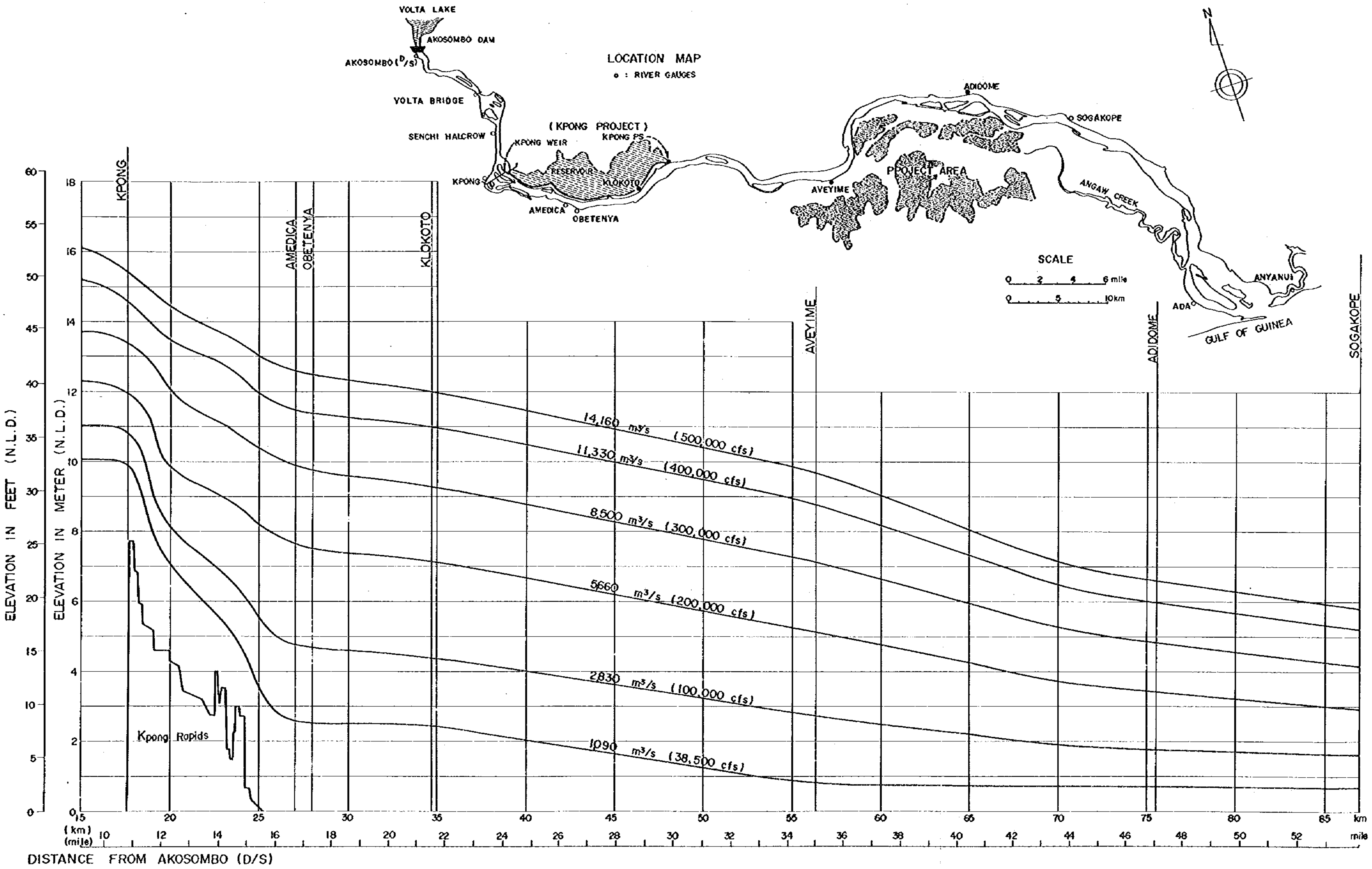
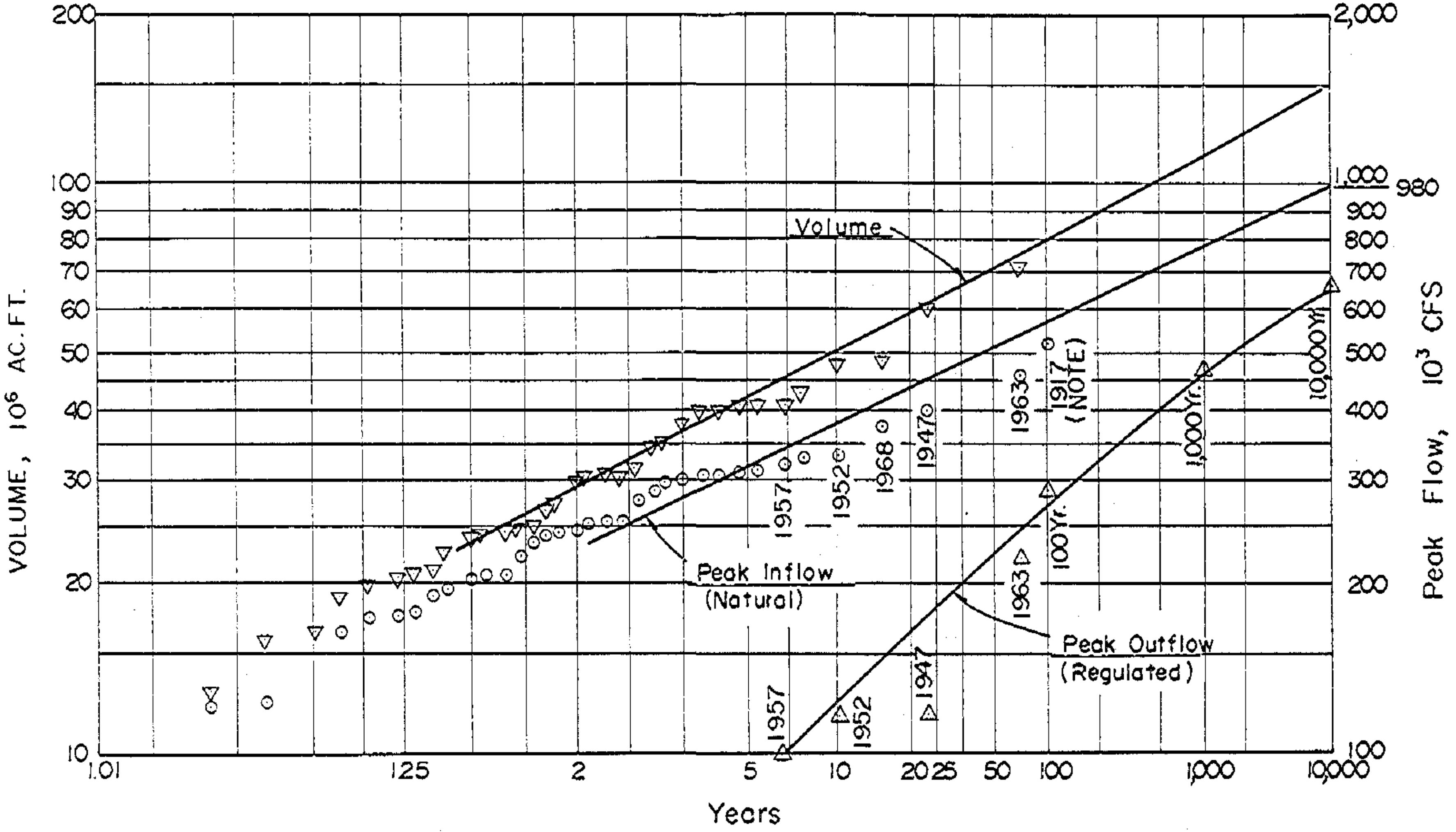


Fig. I- 7 FLOOD CONTROL AT AKOSOMBO



LEGEND

- ⊙ Peak Inflow (Natural)
- △ Peak Outflow (Regulated)
- ▽ Volume (for Month July through November)

NOTE

The flood of 1917 was estimated at 520,000 CFS and was reputed to be the largest since 1868. It was not used in the frequency analysis.

SOURCE

Kaiser engineers international INC., Ghana Power Study, August 1971.

ANNEX II

SOIL STUDY

This Annex II is reproduced from the "Feasibility Report on Sugar and Rice Production Project in Accra Plain" prepared by Nippon Koei Co., Ltd. in 1967.

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX II SOIL STUDY

CONTENTS

LIST OF TABLES

2.1 General

2.1.1 Introduction

There have been several soil survey works performed so far on the Accra plain region. Of these soil studies, the reconnaissance by C.F. Charter and H. Brammer from 1950 to 1962/1, the detailed soil survey of the Volta river flood plain by Th.A.Day in 1963/2, and detailed soil survey of the Kpong Pilot Irrigation Area by H. Brammer in 1955/3 are noteworthy.

However, these soil survey works did not cover our project area sufficiently. Then, the soil survey is carried out in order to reveal the distribution of major soil groups and their essential features necessary for the determination of adapted crops and their profitable irrigation farming practices, and for the evaluation of basic factors of irrigation engineering design.

Broadly speaking, the project area is situated on the right side of the Volta extending from Ajaikope to Tefle. In view of topography, the area consists of low lying lands with elevations of about 1 to 8 m and slightly elevated land of more than 6 m in elevation.

Large part of the project area is underlain by Lower Pre-Cambrian Dahomeyan metamorphic rocks such as gneiss and schists.

The climate of the project area is characterized by two rainy periods and two droughty periods every year. The annual rainfall varies from 84 to 112 cm. The annual mean temperature is approximately 27°C. The relative humidity varies from 80 to 90%.

The flora is classified into the Guinea Savannah Woodland and the Coastal Thichet with Glassland.

The majority of the population are farmers mostly being engaged in shifting cultivation. Cassava is the major crop in this area, and maize, groundnuts and vegetables are planted with poor returns in general.

2.2 Schedule and Procedure

2.2.1 Process of Survey

The soil reconnaissance was carried out over the area of about 24,300 ha on the right bank of the lower Volta with Ke lagoon as its center for two months in March and April, 1965. As the results, the general development of the great soil groups and their essential features were revealed.

/1 Brammer, H. and J.B. Wills: (1962) Agriculture and Land Use in Ghana, Oxford University press, pp 88 - 219, London.

/2 Day, Tha. A.: (1963) Report on Survey of the Lower Volta River Flood Plain, Volume II, Soil Survey and Classification, FAO, United Nations, pp 1 - 66, Rome.

/3 H. Brammer: (1955) Detailed Soil Survey of the Kpong Pilot Irrigation Area, pp 1 - 100, Kumasi.

In succession to the reconnaissance, the detailed survey was performed up to May, 1966. In this survey, the field inspections and observation on soils were done at 470 trenches and pits along with 600 auger tests.

The physical natures and chemical properties of the soils were examined at the field laboratory of the Aveyime Pilot Farm. For these works, about 200 samples were taken from the representative soil layers and horizons to find out the basic data necessary for the design of hydraulic works and irrigation farming practices. Some soil samples were brought to Japan and examined at the soil laboratory of the Tokyo Agricultural University in order to confirm and supplement the results of field laboratory works.

2.2.2 Method for Field Inspection and Laboratory Test

Both the field inspections and laboratory tests were mostly made in accordance with the methods and procedures which were described in the Seventh Approximation of Soil Classification compiled by the Soil Survey Staff of the Government of the United States in 1960. Some of them were modified, however, in compliance with recent experience of our soil study in Japan and in various countries of Southeast Asia under tropical climate. Their essentials are outlined in the following.

(a) Sample preparation

Air dried soil samples were pulverized and passed through a 2 mm wound-hole sieve. The fraction less than 2 mm in diameter was used for laboratory tests except for bulk density.

(b) Granulometric constitution

Particle size distribution analysis by pipette method/1 i.e. dispersion with sodium hexametaphosphate was used.

(c) Physical natures

(1) Specific gravity

Real specific gravity was determined by using picnometer, and bulk density was measured by the actual volume measuring apparatus proposed by K. Yamanaka and S. Misono/2.

(2) Soil colour

Soil colours both in dry and wet conditions more determined by using the modified Munsell Soil Color Chart proposed by the Ministry of Agriculture of Forestry, Japan in 1960/3.

/1 Robinson, G.W.: (1933) Imperial Bulletin of Soil Science, Techn. Comm., No. 26, London.

/2 Misono, S.: (1958) (Japanese) Journal of the Science of Soils and Manure, No. 29, Tokyo.

/3 Koyama, M., and H. Takehara: (1960) (Japanese) Standard Soil Colour Chart, Nippon Shikisai Co., Ltd. Tokyo.

(d) Chemical properties

(1) Soil reaction

PH values of water and 1 Normal KCl solution in contact with sample soils were determined by colourimetric method on the field, and were confirmed by glass electrode apparatus in laboratory. Besides, exchangeable acidity was determined by Daikuhara method/1.

(2) Humus content

Total content was determined by using Tiurin Method/2.

(3) Cation exchange capacity

The modified Schollenberger's method/3 was used.

(4) Exchangeable base

Exchangeable cations were determined as the displaced amounts in contact with 1 Normal ammonium acetate solution/4.

(5) Base saturation degree

The base saturation degree was illustrated by the percentage of the amount of exchangeable bases to the cation exchange capacity.

(6) Total nitrogen

Total nitrogen was determined by Kjeldahl method modified by the Association of Official Agricultural chemists/5.

(7) NH_4-N

NH_4-N was determined by McLeam - Robinson method/6.

/1 Daikuhara, G.: (1914) Bulletin of Imperial Central Agricultural Experiment Station, Japan, No. 2, Tokyo.

/2 Tiurin, I.V.: (1931) Pedology, No. 26, pp - 36 - 47, Moscow.

/3 Schollenberger, C.T. and R.H. Simon: (1945) Soil Science, No. 59, pp 13 - 38, Baltimore.

/4 Peech, M., etal.: (1947) Methods of Soil Analysis for Soil - Fertility Investigations, U.S. Dept. Agr., Circular 757, Washington, D.C.

/5 Association of Official Agricultural Chemists: (1955) Official Methods of Analysis. Ed. 8, pp 30 - 31, Washington, D.C.

/6 Robinson, W.O.: (1939) Method and Procedure of Soil Analysis Used in the Division of Soil Chemistry and Physics, U.S. Dept. Agr. Cir. 139, p. 21, Washington D.C.

(8) NO_3-N

NO_3-N was determined by phenoldisulphonic acid method.

(9) Available phosphoric anhydride

The molybdo-phosphoric blue color method was used.

(10) Phosphatic absorptive coefficient

The mixing method of 100 mℓ of 2.5% neutral ammonium phosphate solution with 50 g of air dried sample soil was used, and the absorbed amount of P_2O_5 in mg per 100 g of soil was shown as the absorptive coefficient.

(11) Cl

Chlorine was determined by AgCl method.

(e) Hydrological characteristics

(1) Field capacity

The field capacity of soil was determined as the moisture in the sample soil which had been taken from the soil layer within the effective rootzone depth on the profile after a certain hours/1 of cylinder infiltrometer trial.

(2) Wilting point

The wilting point of soil was determined approximately as $\frac{1}{1.84}$ times centrifugal moisture equivalent.

(3) Available moisture holding capacity

The available moisture holding capacity was show as the difference between the field capacity and the wilting point.

(4) Cylinder intake rate

The method standardized by the United States Department of Agriculture/2 was used, and the instantaneous intake rate, average intake rate, and basic intake rate were determined by the following formulate.

$$D = CT^{n}$$
$$I = 60Cn\ T^{n-1}$$
$$Iave = D/T = 60CT^{n-1}$$
$$I_B = 60Cn\ (600-600n)^{n-1}$$

/1 Samples are taken after 24 hours in sandy soils, 36 hours in loamy soil, and 48 hours in clayey soils.

/2 Haise, H.R. et al. (1956) The Use of Cylinder Infiltrometer to Determine the Intake Characteristics of Irrigated Soils, U.S. Department of Agriculture, ARS 41 - 7, pp 1-18, Washington D.C.

Where,

D: Accumulated intake in T minutes (cm)

C: Constant, indicating initial intake intercept in unit time (cm/min).

T: Time that water is on the surface of the soil (min).

n: Constant, indicating slope of the logarithmic line of accumulated intake curve that is the value of vertical scaled distance divided by horizontal distance.

I: Instantaneous intake rate of the soil at T minutes after the start of irrigation of the soil (cm/hr).

Iave: Average intake rate during T minutes (cm/hr).

IB: Basic intake rate or final intake rate at the time when the rate of change in intake rate is reduoed to 10% of the rate, i.e. after - 600 (n-1) minutes (cm/hr).

2.2.3 Terminology for Soil Feature Descrimination

(a) Effective soil depth

Term	Range of depth (cm)
Very deep	more than 102
Deep	76 - 102
Medium	51 - 76
Shallow	20 - 51
Very shallow	less than 20

(b) Soil reaction

Term	Range of pH
Strong acid	less than 5.0
Weak acid	5.0 - 6.5
Neutral	6.6 - 7.3
Weak alkaline	7.4 - 8.5
Strong alkaline	more than 8.5

(c) Slope of land

Term	Range of slope
Flat or nearly level	less than 2 %
Gently sloping	2 % - 5 %
Rolling	5 % - 15 %
Hilly	15 % - 25 %
Steep sloping	more than 25 %

(d) Size of soil fraction (According to Atterberg's system)[1]

Term	Range of diameter (mm)
Clay	less than 0.002
Silt	0.002 - 0.02
Fine sand	0.02 - 0.2
Coarse sand	0.2 - 2
Gravel and debris	more than 2

(e) Soil texture

Soil texture was determined on the base of the Textural Standard of the International Society of Soil Science.

(f) Gravel content

Term	Range of gravel content (% by weight)
With few gravel	less than 5
With gravel	5 - 10
Rich in gravel	10 - 20
Very rich in gravel	20 - 50
Gravelly soil	more than 50

2.3 Results of Field Inspections and Laboratory Tests

2.3.1 Discrimination of Major Soil Groups

By means of the identification of diagnostic features of soil profiles observed on the field, the major soil groups are discriminated in accordance with the categories of soil classification as listed in the following.

Major soil groups in the Accra Plain Project Area

(1) Great soil group 1. Acid gleisols

Soil series 1. HAKE series

Soil type 1. Sandy surface-light clayey subsoil type

Soil phase A. Deep, well drained, nearly flat lowland phase

Soil type 2. Clay surface-sandy subsoil type

Soil phase B. Deep, moderately drained, nearly flat lowland phase

Soil type 3. Sandy surface-sandy subsoil type

Soil phase C. Deep, very well drained, nearly flat lowland phase.

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[1] Atterberg, A: (1912) Die Mechanishe Bodenanalyse und die Klassification der Mineralböden Schwedens. Intern. Mitt. d. Bodenk., B.2,S.312-342, Hagen.

Soil series 2. AMO series

Soil type 4. Loamy surface-clayey subsoil type

Soil phase D. Deep, imperfectly drained, flat lowland phase

Soil type 5. Silty clay surface-clayey subsoil type

Soil phase E. Deep, poorly drained, flat lowland phase

Soil series 3. TEFLE series

Soil type 6. Clayey surface-clayey subsoil type

Soil phase F. Deep, very poorly drained, severely floodable, gently sloping lowland phase

Soil phase G. Deep, very poorly drained, slightly floodable, gently sloping lowland phase

Soil phase H. Deep, very poorly drained, moderately floodable, flat lowland phase

Soil series 4. CHICHIWERE series

Soil type 7. Sandy surface-sandy subsoil type

Soil phase I. Deep, well drained, easily tillable, very gently sloping, natural levee phase

Soil phase J. Deep, well drained, easily tillable, gently sloping, natural levee phase

(2) Great soil group 2. Savannah ochrosols

Soil series 5. AVEYIME series

Soil type 8. Sandy surface-loamy subsoil type

Soil phase K. Deep, well drained, nearly flat, slightly elevated lowland phase

Soil type 9. Loamy surface-loamy subsoil type

Soil phase L. Deep, moderately well drained, nearly flat, slightly elevated lowland phase

Soil series 6. ZIPA series

Soil type 10. Sandy surface-loamy subsoil type

Soil phase M. Deep, well drained, mottled, nearly flat, slightly elevated lowland phase

Soil type 11. Loamy subsoil type

Soil phase N. Deep, moderately well drained mottled, nearly flat, slightly elevated lowland phase

(3) Great soil group 3. Tropical grey earths

Soil series 7. AGAW TAW series

Soil type 12. Sandy surface-clay pan type

Soil phase O. Moderately shallow, imperfectly drained, very gently sloping upland phase

Soil type 13. Sandy surface-loamy subsoil type

Soil phase P. Moderately deep, moderately well drained, very gently sloping upland phase

Soil phase Q. Moderately deep, moderately well drained, gently sloping upland phase

(4) Great soil group 4. Regosolic groundwater laterites

Soil series 8. DOYUMU series

Soil type 14. Sandy surface-gravelly loamy subsoil type

Soil phase R. Deep, moderately well drained, easily tillable, very gently sloping upland phase

Soil phase S. Deep, moderately well drained, easily tillable, gently sloping upland phase

Soil phase T. Deep, moderately well drained, usually rocky, very gently sloping upland phase

2.3.2 Demarcation of Soil Groups

Based upon the field inspections of soil profiles and other diagnostic features, the distribution of soil groups and their proportional extent are shown in the following Table II-1 and the boundaries of the soil groups are demarcated in attached SOIL MAP, Drawing No. 000-02.

Table II-1 Distribution and Proportional Extents of Major Soil Groups in Accra Plain Surveyed Area

Great Soil Group	Soil Series	Soil Type	Soil Phase	Area (ha)	Proportional extent (%)
Acid gleisols	HAKE	1	A	220	0.9
		2	B	310	1.2
		3	C	550	2.3
	AMO	4	D	1,490	6.1
		5	E	2,530	10.4
	TEFLE	6	F	2,520	10.4
			G	30	0.1
			H	1,590	6.5
	CHICHIWERE	7	I	370	1.5
			J	20	0.1
Savanna ochrosols	AVEYIME	8	K	310	1.3
		9	L	470	2.0
	ZIPA	10	M	80	0.3
		11	N	380	1.6
Tropical gray earth	AGAWTAW	12	O	4,100	16.9
		13	P	5,030	20.7
			Q	250	1.1
Regosolic groundwater laterites	DOYUMU	14	R	3,370	13.9
			S	600	2.5
			T	60	0.2
Total				24,280	100.0

2.3.3 Profile Features, Physical Natures, Chemical Properties, and Hydrological Characteristics of Major Soil Groups

All the results of field inspections and laboratory tests were collated with one another, and the essentials of profile diagnostics, physical natures, chemical properties are listed by major soil series in Table II-3 and the hydrological characteristics are shown by major soil types in the following Table II-2.

Table II-2 Essential Hydrological Characteristics of Major Soil Groups in Accra Plain Project Area

Soil type	Apparent specific gravity	Field capacity (% by volume)	Wilting point (% by volume)	Available moisture holding capacity (% by volume)	Basic intake rate (cm/hr)
type 1	1.28	20 - 24	11 - 13	9 - 11	4.6 - 5.8
2	1.15	23 - 27	12 - 14	11 - 13	3.0 - 4.6
3	1.27	20 - 25	11 - 13	9 - 12	5.1 - 8.9
4	1.25	25 - 30	13 - 15	12 - 15	2.5 - 4.6
5	1.20	27 - 33	14 - 18	13 - 15	1.3 - 2.5
6	1.12	33 - 40	18 - 22	15 - 19	0.3 - 0.8
7	1.27	20 - 25	11 - 13	9 - 11	5.1 - 8.9
8	1.25	23 - 27	12 - 14	11 - 13	3.8 - 6.4
9	1.20	20 - 26	11 - 14	9 - 12	3.8 - 6.4
10	1.27	23 - 27	12 - 14	11 - 13	2.0 - 5.1
11	1.21	21 - 27	11 - 14	10 - 13	2.0 - 5.1
12	1.28	13 - 19	7 - 10	5 - 9	2.5 - 3.8
13	1.29	17 - 20	9 - 11	8 - 9	2.5 - 5.1
14	1.28	13 - 17	7 - 9	5 - 8	8.9 - 12.7

Table II-3 Profile Diagnostics, Physical Natures and Chemical Properties of Major Soil Groups in Accra Plain Project Area

(1) Sample No.26

Location	0.6 km north of Aveyime
Land category	Shrubby grassland
Topography	Flatland; El. 8 m
Soil group	Acid gleisols, HAKE series

Profile diagnostics

Depth (cm)	Remarks
0 - 13	Gray-yellowish-brown (10 YR 4/3), loamy sand, pH 6.0 in active acidity, frequent rootlets, crumby, moist friable
13 - 30	Brown (7.5 YR 4/6), light clay, pH 6.2 in active acidity, blocky, mottling, sticky
30 - below	Light-yellowish-brown (7.5 YR 5/6), light clay, pH 6.4 in active acidity, blocky, sticky

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 13	-	29.0	56.4	6.1	8.5	2.66	1.32	1.40	trace
13 - 30	-	13.2	21.6	25.0	40.2	2.68	1.14	0.80	0.10
30 - below	-	14.1	21.1	26.2	38.6	2.70	1.15	0.50	trace

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 13	6.0	4.0	4.81	1.53	0.51	0.20	0.06	10.3	69	2.55	1.15	0.20
13 - 30	6.2	4.2	5.76	2.12	0.71	0.25	0.15	13.0	69	1.36	0.26	0.05
30 - below	6.4	4.4	6.12	2.26	0.75	0.30	0.18	14.5	66	0.82	0.10	0.02

(2) Sample No.10

Location	2.4 km northeast of Aveyime
Land category	Shrubby grassland
Topography	Flatland, El. 8 m
Soil group	Acid gleisols, AMO series

Profile diagnostics

Depth (cm)	Remarks
0 - 10	Grey-yellowish-brown (10 YR 4/3), sand clay loam, pH 5.9 in active acidity, frequent rootlets, moist friable, manganese dioxide concretions, many mottling, porous
10 - 25	Brown (10 YR 4/6), light clay, pH 6.0 in active acidity, rootlets, cracking, many manganese dioxide concretion, many mottling, sticky
25 - below	Brown (7.5 YR 4/6), heavy clay, pH 6.2 in active acidity, many mottling, very plastic and sticky

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 10	-	25.6	38.2	15.8	20.4	2.60	1.25	1.42	trace
10 - 25	-	12.5	14.4	31.6	41.5	2.70	1.14	0.56	0.11
25 - below	-	8.5	13.1	30.4	48.0	2.73	1.11	0.60	0.52

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 10	5.9	3.9	3.55	1.68	0.62	0.32	0.08	10.5	59	2.10	1.20	0.15
10 - 25	6.0	3.9	4.22	2.03	0.85	0.55	0.07	12.2	63	1.40	0.35	0.10
25 - below	6.2	4.2	6.67	5.08	1.03	0.93	0.11	18.3	76	0.19	0.20	0.10

(3) Sample No.303

Location	1.6 km east of Dove
Land category	Marshy grassland
Topography	Flat land, El. 5 m
Soil group	Acid gleisols, AMO series

Profile diagnostics

Depth (cm)	Remarks
0 - 13	Brown (7.5 YR 4/3), silty clay, pH 5.5 in active acidity, frequent rootlets, moist friable, many mottling, porous, sticky
13 - 38	Brown (7.5 YR 4/3), light clay, pH 5.9 in active acidity, rootlets, many mottling, blocky, sticky, manganese dioxide concretions
38 - below	Dark-brown (10 YR 3/4), heavy clay, pH 6.3 in active acidity, many mottling, plastic, very sticky, manganese dioxide concretions decreasing with depth

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 13	-	8.6	7.6	47.5	36.3	2.68	1.20	1.86	0.33
13 - 38	-	7.5	18.8	31.5	42.2	2.71	1.18	1.05	0.15
38 - below	-	8.3	13.3	30.6	47.8	2.72	1.10	1.52	1.55

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 13	5.5	3.7	3.84	1.62	0.56	0.44	0.05	12.3	53	1.69	1.34	0.10
13 - 38	5.9	3.7	4.65	2.11	0.83	0.62	0.09	13.1	63	1.05	0.85	0.08
38 - below	6.3	3.8	5.22	3.95	1.21	1.13	0.16	18.2	64	0.25	0.15	0.01

(4) Sample No.441

Location	1.6 km south of Ajaikope
Land category	Marshy grassland
Topography	Flatland, El. 4 m
Poil group	Acid gleisols, TEFLE series

Profile diagnostics

Depth (cm)	Remarks
0 - 20	Dark-brown (7.5 YR 3/4), heavy clay, pH 5.8 in active acidity, very plastic and sticky, cracking, distinct mottling, rootlets, blocky
20 - 46	Brown-grey (7.5 YR 4/1), heavy clay, pH 5.6 in active acidity, very plastic and sticky, cracking, distinct mottling, blocky
46 - below	Brown-grey (7.5 YR 5/2), heavy clay, pH 5.7 in active acidity, very plastic, sticky, mottling, blocky

Physical and chemical features

Depth (cm)	Granulometric component (% by weight)					Specific gravity		Humus (% by weight)	Cl (mg/100g)
	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent		
0 - 20	-	14.7	12.7	3.3	69.3	2.69	1.18	2.12	1.50
20 - 46	-	9.8	12.6	4.5	73.1	2.68	1.13	1.35	1.81
46 - below	-	16.1	13.2	2.3	68.4	2.67	1.12	0.85	2.00

Depth (cm)	pH		Exchangeable base (meq/100g)					Cation exchange capacity (meq/100g)	Base saturation degree (%)	Available P_2O_5 (mg/100g)	Nitrogen (mg/100g)	
	H_2O	KCL	CaO	MgO	K_2O	Na_2O	Mn_2O_3				NH_4	NO_3
0 - 20	5.8	3.6	9.95	4.75	0.46	0.32	0.03	19.9	78	1.32	1.51	0.10
20 - 46	5.6	3.5	7.89	4.50	0.32	0.31	0.08	19.2	68	1.22	1.00	0.05
46 - below	5.7	3.7	7.65	4.75	0.85	0.57	0.15	19.2	73	1.09	0.85	0.01

(5) Sample No.37

Location	0.6 km southeast of Aveyime
Land category	Grassland
Topography	Flatland, El. 9 m
Soil group	Acid gleisols, CHICHIVERE series

Profile diagnostics

Depth (cm)	Remarks
0 - 20	Grey-yellowish-brown (10 YR 4/3), loamy fine sand, pH 6.1 in active acidity, crumbly, moist friable, frequent rootlets, porous
20 - 38	Brown (7.5 YR 4/4), loamy fine sand, pH 5.9 in active acidity, crumbly, moist friable, frequent rootlets
38 - 51	Brown (7.5 YR 4/3), coarse sandy loam, pH 6.4 in active acidity, crumbly, moist friable, mottled with iron flecks
51 - below	Grey-yellowish-brown (10 YR 5/4), silty clay, pH 7.6 in active acidity, blocky, slightly firm

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus (% by weight)	Cl
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent		(mg/100g)
0 - 20	-	39.4	46.3	3.5	10.8	2.64	1.23	1.24	0.05
20 - 38	-	35.8	49.8	3.2	11.2	2.65	1.32	1.08	0.15
38 - 51	-	28.4	38.7	19.5	13.4	2.66	1.28	0.37	0.30
51 - below	-	11.2	13.4	46.5	28.9	2.65	1.18	0.08	0.06

	pH		Exchangeable base(meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCL	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 20	6.1	4.0	3.02	1.72	0.68	0.32	0.05	9.3	62	2.55	1.10	0.20
20 - 38	5.9	3.8	2.88	1.65	0.55	0.42	0.03	10.2	54	1.23	0.85	0.08
38 - 51	6.4	4.0	3.05	2.70	0.60	0.55	0.06	11.6	60	0.58	0.60	0.03
51 - below	7.6	6.2	5.98	3.82	0.86	0.92	0.13	13.5	87	0.55	0.15	0.01

(6) Sample No.125

Location	1.6 km south of Kumepo
Land category	Grassland
Topography	Flatland, El. 10 m
Soil group	Savannah ochrosols, AVEYIME series

Profile diagnostics

Depth (cm)	Remarks
0 - 20	Dark-brown (10 YR 4/6), loamy fine sand, pH 6.0 in active acidity, moist friable, frequent rootlets, non-sticky, structureless
20 - 46	Black-reddish-brown (5 YR 3/4), sandy clay loam, pH 5.8 in active acidity, frequent rootlets, slightly sticky, blocky
46 - below	Reddish-brown (2.5 YR 4/8), light clay, pH 6.2 in active acidity, blocky, sticky, firm

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 20	-	6.8	80.8	4.6	7.8	2.69	1.35	0.92	0.01
20 - 46	-	6.3	69.0	5.4	19.3	2.63	1.35	1.00	trace
46 - below	-	3.2	47.5	5.8	43.5	2.67	1.32	0.82	0.01

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 20	6.0	4.8	1.52	1.15	0.55	0.25	0.05	5.40	65	2.41	0.90	0.25
20 - 46	5.8	4.3	2.00	2.35	0.59	0.31	0.31	9.59	58	1.23	0.49	0.13
46 - below	6.2	4.4	5.75	0.15	0.71	0.41	0.23	12.95	56	1.12	0.12	0.12

(7) Sample No.365

Location	0.5 km north of Jadanrav
Land category	Grassland
Topography	Platland, El. 10 m
Soil group	Savannah ochrosols, ZIPA series

Profile diagnostics

Depth (cm)	Remarks
0 - 30	Brown (7.5 YR 4/3), loamy fine sand, pH 6.1 in active acidity, friable, frequent rootlets, structureless
30 - 56	Grey-reddish-brown (5 YR 3/6), sandy clay loam, pH 5.8 in active acidity, prominent mottlings, rootlets, subangular, blocky
56 - below	Dark-reddish-brown (2.5 YR 3/6), sandy clay loam pH 6.0 in active acidity, prominent mottlings, rare rootlets, firm

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 30	-	7.8	77.3	5.3	9.6	2.58	1.34	0.98	trace
30 - 56	-	6.2	71.4	6.1	16.3	2.62	1.30	0.73	trace
56 - below	-	3.1	53.5	5.3	38.1	2.63	1.30	0.15	trace

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 30	6.1	4.8	3.25	2.13	0.53	0.14	0.08	8.76	70	2.13	0.95	0.35
30 - 56	5.8	4.3	3.12	2.20	0.43	0.10	0.43	8.37	75	1.04	0.51	0.15
56 - below	6.0	4.7	4.76	3.06	0.39	0.10	0.45	10.95	80	0.93	0.43	0.08

(8) Sample No.525

Location	1.0 km north of Lota
Land category	Grassland
Topography	Flatland, El. 11 m
Soil group	Tropical grey earths, AGAWTAW series

Profile diagnostics

Depth (cm)	Remarks
0 - 10	Blackish-brown (10 YR 3/2), loamy fine sand, pH 6.6 in active acidity, moist friable, frequent rootlets, non-sticky
10 - 25	Dark-brown (10 YR 3/3), silty clay, pH 6.3 in active acidity, blocky, very hard, rarely rootlets, sticky, occasional manganese dioxide concretions and frequent calcium carbonate concretions
25 - 76	Yellow-brownish-grey (10 YR 5/1), pH 7.4 in active acidity, blocky, very sticky, very hard, frequent calcium carbonate concretions

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 10	-	42.2	43.6	5.9	8.3	2.61	1.28	1.02	1.00
10 - 25	-	8.8	10.1	47.5	33.6	2.64	1.16	0.84	4.50
25 - 76	-	23.6	25.2	15.7	25.5	2.65	1.17	0.76	12.60

	pH		Exchangeable base (meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 10	6.6	4.8	2.65	1.51	0.35	0.16	0.08	6.7	70	1.63	0.60	0.05
10 - 25	6.3	4.6	4.35	3.25	0.28	0.15	0.11	12.8	63	1.05	1.80	0.04
25 - 46	7.4	5.8	6.32	4.55	0.31	0.45	0.18	12.0	98	0.34	0.04	0.01

(9) Sample No.591

Location	1.0 km south of Tehe
Land category	Grassland
Topography	Flatland, El. 18 m
Soil group	Tropical grey earths, AGAWTAW series

Profile diagnostics

Depth (cm)	Remarks
0 - 5	Blackish-brown (10 YR 3/2), loamy fine sand, pH 6.8 in active acidity, moist friable, frequent rootlets, non-sticky, porous
5 - 25	Blackish-brown (7.5 YR 2/3), fine sandy loam, pH 6.8 in active acidity, slightly sticky, calcium concretions
25 - 50	Brownish-grey (7.5 YR 5/1), silty clay loam, pH 8.5 in active acidity, firm, sticky, manganese dioxide concretions
50 - below	Yellow-brownish-grey (2.5 Y 6/2), clay loam, pH 8.4 in active acidity, firm, manganese dioxide concretions

Physical and chemical features

Depth (cm)	Granulometric component (% by weight)					Specific gravity		Humus (% by weight)	Cl (mg/100g)
	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent		
0 - 5	-	41.6	43.6	5.3	9.5	2.68	1.29	0.83	0.30
5 - 25	-	25.8	46.3	15.5	12.4	2.62	1.22	0.78	0.50
25 - 50	-	12.4	16.6	48.5	22.5	2.67	1.21	0.64	6.60
50 - below	-	18.7	25.9	35.0	20.4	2.71	1.20	0.16	5.40

Depth (cm)	pH		Exchangeable base(meq/100g)					Cation exchange capacity (meq/100g)	Base saturation degree (%)	Available P_2O_5 (mg/100g)	Nitrogen (mg/100g)	
	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3				NH_4	NO_3
0 - 5	6.8	5.2	1.81	1.45	0.18	0.09	0.11	5.0	73	0.64	1.02	0.30
5 - 25	6.8	5.3	4.05	2.87	0.20	0.15	0.13	10.4	71	1.01	0.55	0.06
25 - 50	8.5	6.2	6.88	6.12	0.29	0.28	0.18	12.5	110	2.05	0.22	0.05
50 - below	8.4	7.0	6.75	6.62	0.39	0.32	0.19	14.0	103	2.55	0.10	0.01

(10) Sample No.552

Location	3.2 km southwest of Tehe
Land category	Grassland
Topography	Flatland, El. 27 m
Soil group	Regosolic groundwater laterites, DOYUMU series

Profile diagnostics

Depth (cm)	Remarks
0 - 15	Blackish-brown (7.5 YR 2/2), loamy fine sand, pH 6.6 in active acidity, frequent rootlets, porous, moist friable
15 - 30	Blackish-brown (7.5 YR 3/2), fine sandy loam, pH 7.3 in active acidity, frequent rootlets
30 - 64	Brownish-grey (7.5 YR 5/2), clay loam, pH 7.5 in active acidity, iron and manganese concretions and quartz
64 - below	Grey-yellowish-brown (2.5 Y 6/4), silty loam, pH 7.2 in active acidity

Physical and chemical features

	Granulometric component (% by weight)					Specific gravity		Humus	
Depth (cm)	Gravel	Coarse sand	Fine sand	Silt	Clay	Real	Apparent	(% by weight)	Cl (mg/100g)
0 - 15	-	41.6	44.7	6.4	7.3	2.64	1.28	0.75	1.05
15 - 30	-	28.4	40.5	19.6	11.5	2.66	1.30	0.56	0.60
30 - 64	25.3[1]	22.8	19.6	13.8	18.5	2.70	1.25	0.40	8.50
64 - below	-	19.2	20.0	47.2	13.6	2.68	1.23	0.08	9.20

	pH		Exchangeable base(meq/100g)					Cation exchange capacity	Base saturation degree	Available P_2O_5	Nitrogen (mg/100g)	
Depth (cm)	H_2O	KCl	CaO	MgO	K_2O	Na_2O	Mn_2O_3	(meq/100g)	(%)	(mg/100g)	NH_4	NO_3
0 - 15	6.6	5.1	2.50	1.66	0.12	0.10	0.14	6.8	66	0.58	0.80	0.70
15 - 30	7.3	5.5	4.60	4.43	0.10	1.75	0.03	11.5	95	1.22	0.60	0.60
30 - 64	7.5	6.0	5.63	5.28	0.13	1.10	0.10	13.2	93	2.08	0.50	0.06
64 - below	7.2	6.5	4.90	3.35	0.11	0.92	0.08	10.4	90	1.05	0.10	0.02

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[1] Each fraction is shown as the per cent of bulk soil inclusive of gravel.

2.4 Interpretation of Survey Results

Based upon the results of our survey, the soils developed in the Accra Plain Project area are interpreted hereunder.

2.4.1 Mode of Soil Formation

As regards the maturity of the soils in the Accra Plain Project area, they consist of immature, semi-mature and mature soils developed under the equatorial monsoon climatic conditions.

The immature soils develop on the recent alluvial lowland with elevations less than 6 m along the Volta river from Agdetipo to Dentlokope. The semi-mature and mature soils are the old alluviums, colluviums and residual soils on undulating upland of more than 6 m in elevation.

As to the origin of soils, it may be generally considered that the upland soils are derived from various rocks such as gneiss and schists, while the lowland soils are the fluvial deposits transported by the Volta river.

Regarding the process of soil formation, most soils are in the course of laterization and gleization which range widely in accordance with various factors especially with relief conditions.

The alternations of soil features caused by existing farming practices are scarcely observed in the surved area.

2.4.2 Essential Features of Major Soil Groups

In the soil survey works needed for the planning of an irrigation farming project, the soils should be grouped in accordance with the lowest possible category to which the essential elements of irrigation engineering and farming methods and practices are closely related.

From such a point of view, the soils in this surveyed area are grouped into twenty soil phases in the lowest categories according to the recent United States classification system/1.

These soil phases are grouped together into fourteen soil types, eight soil series/2, and four great soil groups in the higher categories by their diagnostics.

/1: Soil Survey Staff: (1951) Soil Survey Manual, United States Department of Agriculture, Washington 25, D.C.

/2: The nomenclature of soil series in the surveyed area is same as that used in the following reports.
Day, Th.A.: (1961) Report on Survey of the Lower Volta River Flood Plain, Vol. II, Soil Survey and Classification, F.A.O., Rome. Brammer, H. and J. B. Wills: (1962) Agriculture and Land Use in Ghana, Oxford University Press, London.

According to the results of our soil survey, the major soil groups in various categories and their essential features are explained as in the following.

(1) Great soil group 1 Acid gleisols[1]

The soils of this great soil group occupy the nearly flat lowland with elevations between 3 and 9 m in general, and they are mostly the immature fluvial deposits transported by the Volta and its tributaries.

These soils extend over the area of about 9,940 ha corresponding to about 40.8 % of the total surveyed area.

These soils are wet in the rainy season and some parts of them which extend over lowlying land of about 5 m or less are subject to flooding.

These soils consist of deep, various textured surface soils overlying fine textured clayey subsoil in general. The colour of them is commonly grey yellowish brown to brown.

The reaction is weak acid in active acidities[2] and strong in potential acidities[3], and acidity decreases gradually with depth. The humus content varies from 1 to 2 %. They have rather low cation exchange capacities and medium base saturation degree.

In these soils, the water intake rate ranges from low to moderate, and the water holding capacity is relatively high. Therefore, their irrigabilities are fairly favourable. However, they are not always blessed with drainability due to their topographical conditions and textural features.

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[1]: This great soil group may be classified as the introzonal soil order and the hydromorphic soils in the higher categories according to the United States Soil Classification system proposed by C. E. Kellong in 1938, while it may be classified as the Entisols order according to the 7th Approximation of Comprehensive Soil Classification System proposed by the United States Department of Agriculture in 1960.

[2]: Active acidity is shown by the pH value of water in contact with soil sample.

[3]: Potential acidity is shown by the pH value of KCl normal solution in contact with soil sample.

As shown on the SOIL MAP (Drawing No. 000-02), the greater part of about 70 % of this great soil group occupies low marshy land with elevation of less than 6 m. The completion of adapted drainage system along with flood control works is required for the agricultural development of these marshy lands.

These soils are too compact to be cultivated by local hoes in the dry season, except the small portions of sandy soils along the Volta.

These soils are suitable for the cultivation of common tropical crops, especially for paddy rice and sugar cane, by improved farming methods such as irrigation and drainage facilities, use of agricultural machinery, soil conditioner, proper application of fertilizers and chemicals.

This great soil group is subdivided into four soil series, seven soil types by the textural soil class and ten soil phases by the availability for irrigation farming.

Soil series 1. HAKE series

This soil series includes 3 soil types grouped by the textural features within their solum depth, and each of 3 soil types consists of 1 soil phase respectively as in the following.

Soil type 1. Sandy surface - light clayey subsoil type

The soils of this type extend over the natural levee and old alluvial land with area of 220 ha corresponding to about 0.9 % of the total surveyed area.

They have the gray-brown to gray-yellowish brown coloured sandy surface soils of 13 cm in the average depth and the brown to yellowish brown coloured sandy clay or silty clay subsoils of about 15 cm in the average depth overlying the light yellowish brown coloured sandy clay or silty clay textural substratums.

The soils have weak active acidities with pH values between 6.0 to 6.2 and strong acidities ranging from 4.0 to 4.2 in pH value. The available nutrient contents are not so rich. The phosphatic absorptive coefficient is small. The cation exchange capacity shows about 7 to 17 meq/100g of soil and the base saturation degree ranges from 60 to 70 %.

As far as the hydrological characteristics are concerned, the water intake rate ranges from 4.6 to 5.8 cm/hr and the available water holding capacity varies from 20 to 24 % by volume of soil.

This soil type contains only 1 soil phase as follows.

Soil phase A

The soils of this phase are deep, well drained and relatively fertile. They are easily tillable. Special attention should be paid to the application of fertilizers because of low cation exchange capacities of these soils. The flood problem is not so serious. Both the irrigability and drainability are rather favourable. The soils of this phase have high capabilities for irrigation farming.

Soil type 2 Clayey surface - sandy subsoil type

The soils of this type develop over about 310 ha corresponding to 1.2 % of the total surveyed area. They cover the natural levee of the Volta of 6 to 9 m in elevation.

The general features of these soils are nearly alike to those of the soils of the type 1 except the water intake rates, which are generally low on the type 2 soils as compared with the soils of the type 1. This soil type consists of 1 soil phase as follows:

Soil phase B

The soils of this phase are inferior to the soils of phase A in drainability, though both are nearly alike in other natures and properties.

Soil type 3 Sandy surface - sandy subsoil type

The soils of this type develop on the natural levee and slightly elevated low and with area of 550 ha corresponding to about 2.3 % of the total surveyed area.

This soil type contains only 1 soil phase as follows.

Soil phase C

The soils of this soil phase are nearly alike in general features to the soils of the phase B except their favorable drainabilities compared with the soils of the phase B.

Soil series 2. AMO series

This soil series includes 2 soil types, which are distinguishable with each other by the textural features within their solum depths, and each soil type consists of 1 soil phase respectively as stated below.

Soil type 4. Loamy surface - clayey subsoil type

The soils of this soil type develop over the elevated natural levees of the Volta of 3 to 8 m in elevation. They occupy about 1,490 ha corresponding to 6.1 % of the total surveyed area.

They have grey-yellow brown coloured loamy textured surface soil with the average depth of 10 cm and brown to light brown coloured light clayey textured subsoils of 15 cm in the average depth, and the yellow-brown grey to grey brown coloured heavy clayey textured substratums.

The soil reaction is acid with pH values ranging from 5.5 to 6.0 in active acidity and 3.6 to 3.9 in potential acidity. The cation exchange capacity ranges from 7 to 15 meq/100g of soil and the base saturation degree varies from 60 to 70 %. The phosphatic absorptive coefficient ranges from 450 to 600 mg/100g of soil. The available nutrient contents are not so plenty.

As regards the hydrological characteristics, the basic intake rate ranges from 2.5 to 4.6 cm/hr and the available water holding capacity varies from 25 to 30 % by volume of soil.

This soil type consists of only one soil phase.

Soil phase D

The soils of this soil phase D are deep, imperfectly drained and relatively fertile. They are not easily tillable by local hoes. In the practice of farming, therefore, it is necessary to apply the proper amount of organic matters and irrigating water for the improvement of soil textural conditions and soil moisture levels. They have fairly well irrigability, but the drainability is not so favourable. The facilities of drainage are required to take away excess water from soils in the rainy season. Irrigating water should be applied by the basin and furrow methods.

Soil type 5. Silty clay surface - clayey subsoil type

The soils of this type occupy the land of 2,530 ha corresponding to 10.4 % of the total surveyed area. They develop on the flat alluvial lowland in elevation of 3 to 6 m.

They consist of dark brown coloured silty clay textured surface soils with the average depth of 13 cm overlying the brown to grey-yellow brown coloured light clay textured subsoils with the average depth of 25 cm. The content of clay gradually increases with the depth of soil up to the sub-stratums having grey-yellow brown colour and heavy clayey texture.

The soils have weak active acidy with pH value ranging 5.5 to 5.9 and strong potential acidity ranging from 3.6 to 3.9 in pH value. The cation exchange capacity ranges from 9 to 15 meq/100g of soil and the phosphatic absorptive coefficient is about 500 mg/100g of soil. The nutrient contents are fairly rich.

As to the hydrological characteristics, they have moderate water intake rate ranges from 0.5 to 2.5 cm/hr and rather high available water holding capacity ranging from 27 to 33 % by volume of soil.

This soil type contains only one soil phase.

Soil phase E

The soils of soil phase E are deep, poorly drained and fairly fertile. Their general features are nearly alike to the soils of phase D excepting their drainabilities which are remarkably inferior to the soils of phase D.

Soil series 3. TEFLE series

This soil series includes only one soil type which is subdivided into 3 soil phases by the specific soil conditions related to the availability for irrigation farming.

Soil type 6. Clayey surface - clayey subsoil type

The soils of this type occupy the land of 4,140 ha corresponding to about 17.0 % of the total surveyed area.

They develop on the recent alluvial marshy lowland around the Keli lagoon, Ke lagoon, Pilili lagoon, Akalamadow lagoon with elevations less than 6 m with a single exception of the slightly elevated old alluvial land on the south of the Bla lagoon.

They consist of the dark brown to dark gray coloured heavy clayey textured surface soils and the gray coloured heavy clayey textured subsoil overlying the thick, gray-yellowish brown coloured heavy clayey textured substratums. These soils have the heaviest texture of all the soils in the surveyed area and contain clay component of about 70 % by weight of soil. They are acid in reaction and have the active acidity of 5.5 to 5.9 in pH value and the potential acidity of pH 3.5 to 3.7. Their cation exchange capacities range from 10 to 20 meq/100g of soil and the base saturation degrees vary from 50 to 70 %. The contents of exchangeable calcium are rather rich as compared with all the other soil types of the Acid gleisols. The phosphatic absorptive coefficient ranges from 600 to 700.

In regard to the hydrological characteristics, their basic intake rates range from 0.3 to 0.8 cm/hr and their available holding capacities vary from 33 to 40 % by volume. Their drainabilities are poor though they have fairly favourable irrigabilities.

Soil phase F

The soils of the soil phase F are very poorly drained and fairly fertile. They have fine texture containing a large amount of clay of more than about 55 %, so they can be hardly tilled by the use of local hoes. For the irrigation farming on these soils, the use of adapted farm machinery and implements and the improvement of soil conditions by the application of organic matters and soil conditioners are required. Their irrigabilities are rather favourable. The problem of annual flood is serious, and the complete flood control works are indispensable.

Soil phase G

The soils of this soil phase G are distinguished from those of the soil phase F by the slope. Their slopes are greater than 2 % as against the slope of the phase F less than 2 %.

Soil phase H

The soils of this soil phase H are distinguished from those of the soil phase F by the floodability. These soils are more floodable than the soils of the soil phase F.

Soil series 4. CHICHIWERE series

This soil series has nearly uniform textural features within the solum depth and grouped in a soil type which is further divided into 2 soil phases by the specific soil features related to the agricultural usability as shown in the following.

Soil type 7. Sandy surface - sandy subsoil type

The soils of this type develop on the natural levee and old alluvial land of 390 ha in total corresponding to about 1.6 % of the total surveyed area.

They consist of the grayish brown coloured loamy fine sand textured surface soils with the average depth of 20 cm overlying the brownish to yellowish-grey brown coloured fine sand textured subsoils of 18 cm in the average depth. Their substratums consist of gray-yellowish brown to yellow brown coloured coarse sandy loam, silty clay or sandy clay.

The soils have weak active acidity of 5.9 to 6.1 in pH value and strong potential acidity ranging from 3.6 to 4.0 in pH value. Their cation exchange capacities range from 7 to 15 meq/100g of soil and their base saturation degrees varies from 60 to 80%. The phosphatic absorptive coefficient ranges from 400 to 500 mg/100g of soil. The content of available nutrients is poor.

As regards the hydrological characteristics, the basic intake rate ranges from 5.0 to 8.9 cm/hr and the available moisture holding capacity varies from 20 to 25% by volume of soil.

This soil type is composed of 2 soil phases as follow.

Soil phase I

The soils of this soil phase I are deep, well drained and not so fertile. They can be easily tilled. Because of their low clay and humus contents, their cation exchange capacities are low. Their drainabilities are favourable in general. The basic intake rate is so high that the adapted application method of irrigating water should be selected carefully.

Soil phase J

The soils of this phase J are distinguished from those of the soil phase I by their slopes of more than 2% as against less than 2% of the latter soils.

(2) Great soil group 2 Savannah ochrosols/1

The soils cover the gently sloping or undulating upland with elevations ranging from 6 to 18 m. They occupy about 1,240 ha corresponding to about 5.1% of the total surveyed area.

They consist of the dark brown coloured light textured surface soils overlying the reddish brown coloured medium textured subsoil.

The soils have weak active acidities ranging from 5.8 to 6.5 in pH value and strong potential acidities of 3.8 to 4.1 in pH value. Their acidities are generally weaker than those of the Acid gleisols. The cation exchange capacities are generally low, but their base saturation degrees are high in common. The content of available nutrients and organic matters are rather poor.

/1: This great soil group may be classified as the zonal soil order and the Ferralitic soils in the higher categories according to the United States Soil Classification System porposed by C. E. Kellog in 1938, while it may be classified as the Oxisols order and the Ustox suborder according to the 7th Approximation of a Comprehensive Soil Classification System proposed by the United States Department of Agriculture in 1960.

Due to their physical natures and hydrological characteristics in the main, these soils have rather favourable irrigability and drainability as well as tillability. The flood problem is generally negligible.

At present, some parts of these soils are used for the rainfed culture of groundnuts, maize and some other crops. The yields are poor in general.

The soils of this great soil group can be profitably used for the culture of common tropical crops by applying proper irrigation farming methods.

This great soil group is subdivided into 2 soil series, 4 soil types and 4 soil phases in the lower categories as follows.

Soil type 5. AVEYIME Series

This soil series is divided into 2 soil types by the textural features within the solum depth, and each soil type consist of only 1 soil phase respectively as shown hereunder.

Soil type 8. Sandy surface-loamy subsoil type

The soils of this type occupy old alluvial land with elevations ranging from 9 to 11 m.

They extend over about 310 ha corresponding to about 1.3% of the total surveyed area.

These soils consist of blackish brown to reddish brown coloured loamy fine sand textured surface soils with the average depth of 8 cm overlying the reddish brown coloured loamy textured subsoils with the average depth of 25 cm. The contents of clay decrease with the depth up to the sub-stratums composed of dark reddish brown to reddish brown coloured silty clay textured soils.

The soils have weak active acidities with pH values ranging between 5.8 to 6.2 and strong potential acidities ranging from 4.1 to 5.0 in pH value. Their cation exchange capacities range from 5 to 13 meq/100g of soil and the base saturation degrees vary from 55 to 65%. The contents of nutrients are poor in general. The exchangeable calcium increase with the soil depth. The Al_2O_3/SiO_2 ratio is lower than all the other soil types in the project area. The phosphatic absorptive coefficient is about 500 mg/100g of soil. Mottlings are often found in their subsoils.

As regard the hydrological characteristics these soils have rather low basic intake rates ranging from 3.8 to 6.4 cm/hr and rather high water holding capacities from 23 to 27% by volume of soil.

This soil type consists of only 1 soil phase as follows.

Soil phase K

The soils of this phase K are deep, well drained and not so fertile. They can be easily tilled. The capacity to hold the nutritious components is low as shown by their low cation exchange capacities. As regards their hydrological characteristics, they have fairly good irrigabilities. These soils can be used for most tropical crops.

Soil type 9, Loamy surface-loamy subsoil type

The soils of this type are distributed on nearly flat slightly elevated lowland with elevations of 9 to 12 m. They extend over about 470 ha corresponding to 2.0 % of the total surveyed area.

This soil type contains only 1 soil phase as follows.

Soil phase L

The soils of this phase L are distinguished from the soil phase K by their drainabilities which are extremely inferior to those of the soil phase K.

Soil series 6. Zipa series

This soil series is divided into 2 soil types by the textural features within the solum depth, and each soil type consists of only 1 soil phase respectively as shown in the following.

Soil type 10. Sandy surface-loamy subsoil type

The soils of this type develop on nearly flat slightly elevated lowland. They extend over about 80 ha corresponding to 0.3 % of the total surveyed area.

They consist of the brown coloured sandy textured surface soils with the average depth of 30 cm overlying the reddish brown coloured loamy textured subsoils with the average depth of 25 cm.

These soils have rather weak active acidities ranging from 5.8 to 6.1 in pH value and strong potential acidities between 4.3 to 4.8 in pH value. They have low cation exchange capacities ranging from 8 to 11 meq/100g of soil and rather high base saturation degrees varying from 70 to 80%. Their phosphatic absorbtive coefficients are 200 to 400 mg/100g of soil. Their inherent fertilities are poor in common.

As regards their hydrological characteristics, these soils have rather low basic intake rates ranging from 2.0 to 5.1 cm/hr and rather high available water holding capacities varying from 23 to 27% by volume of soils.

This soil type contains only one soil phase as follows.

Soil phase M

The soils of this soil phase M are deep, well drained and not so fertile. They can be easily tilled due to their sandy textures.

Soil type 11. Loamy surface-loamy subsoil type

The soils of this type develop on nearly flat slightly elevated lowland. They extend over about 380 ha corresponding to 1.6% of the total surveyed area.

This soil type contains only one soil phase as follows.

Soil phase N

The soils of this phase N are deep, moderately well drained and not so fertile. They are distinguished from the soil phase M by their drainabilities inferior to those of the soil phase M.

(3) Great soil group 3 Tropical gray earths [1]

The soils of this great soil group develop on gently sloping upland with elevations ranging from 6 to 24 m in general, and they are composed of matured residual soils in general.

They extend over 9,390 ha, or about 38.7% of the total surveyed area.

They are grayish brown to blackish brown in color, and have rather large solum depths consisting of the light textured surface soils overlying the fine textured subsoils. Frequencly hard clay pan layers are found within the illuvial horizons at rather shallow depths.

They have weak active acidities and strong potential acidities. It is worthy to note that the substratums of these soils often show alkaline reaction. This fact can be considered as one of the advantageous features that may be contributable to the improvement of

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[1] This great soil group may be classified as the zonal soil order and planosol in higher categories according to the United States Soil classification System proposed by C.E. Kellog in 1938, while it may be Classified as Alfisols order according to the 7th Approximation of a Comprehensive Soil Classification System proposed by the United States Department of Agriculture in 1960.

surface soil conditions by neutralizing of soil acidities and supplementing alkaline basis. Their cation exchange capacities are not so high, but their base saturation degrees are extremely high in general.

They have relatively low basic intake rates and low to medium available water holding capacities. They are often waterlogged after the showers during the rainy season, but their surface soils dry up in a short time due to their favourable drainabilities.

At present, these soils mostly lie waste and only a samll part is used for semi-nomadic grazing of cattles, goats and other animals by a few existing farmers.

The soils of this great soil group consist of 1 soil series in the surveyed area which is subdivided into 2 soil types, and 3 soil phases in the order of soil classification category as in the following.

Soil series 7. AGAWTAW series

This soil series is divided into 2 soil types by their textural features within the solum depth, and then, they are subdivided into 3 soil phases in the lower soil classification categories concerning the agricultural availability of soils. These soil groups are interpreted as follows.

Soil type 12. Sandy surface-clay pan type

The soils of this type develop on the lower parts of gently sloping lands with elevation of 6 to 15 m. Besides, some lower sloping lands along the Agbo river with elevation less than 6 m are covered by the soil of this type exceptionally.

These soils extend over about 4,100 ha corresponding to about 16.9% of the total surveyed area.

These soils are usually wet in the rainy season and droughty in the dry season.

They consist of the gray-brown coloured loamy fine sand textured surface soils of about 10 cm in thickness and the brown coloured silty clay textured subsoils of about 15 cm in the average depth overlying the thick and very compact sub-stratums with sandy clay texture. Hard clay pan layers are often formed within the subsoils. Such a hard clay pan is considered to disturb the penetration and development of crop roots extremely. Crushing the hard pan is required for the irrigated farming on these soils.

The soils have weak active acidies or nearly neutral reactions with pH values ranging from 6.3 to 6.6, and strong potential acidities ranging from 4.6 to 4.8 in pH values. The contents of humus and available nutrients are poor. Their cation exchange capacities and base saturation degrees are low in the surface soils, but they increase gradually with the soil depths. Remarkable amount of chlorine, which was previously reported by F.A.O. Report/1 and was considered to have been originated from the salt water sprays in the prevailing southerly wind, is found in the deep soil layers, but the amount of chlorine is not so much as that injurious to the growth of crops.

Regarding their hydrological features, the soils have medium basic intake rates ranging from 2.5 to 3.8 cm/hr and rather low available water holding capacities varying from 13 to 19% by volume of soil.

This soil type contains only one soil phase as follows.

Soil phase 0

The soils of this soil phase 0 are moderately shallow, imperfectly drained and not fertile. They are drained rapidly after the end of heavy rains. The clay pans, restricting the development of plant roots, are found throughout the land of these soils. At the practice of land preparation, therefore, it is necessary to crush the hard pan layers and to mix them thoroughly with the soils within solum depth by using adapted farm machinery. These soils are available for the irrigated culture of sugar cane and other crops.

Soil type 13. Sandy surface - loamy subsoil type

The soils of this type develop on the higher part of gently sloping land with elevations ranging from 9 to 24 m.

These soils extend widely over 5,280 ha corresponding to about 21.8% of the total surveyed area.

These soils are moderately well drained in general except in the rainy season. They have the blackish brown coloured loamy fine sand or fine sandy loam textured surface soils with the average depth of 25 cm and the blackish brown to brown grey coloured silty clay loam or sandy clay textured subsoils with the average depth of 25 cm overlying the thick substratums of clay loam textural semi-matured soils. At the deep depth of subsoil layers and substratum, there are compact fragipans in common whose compactnesses are not so hard as the clay pans in the soil type 12.

The reactions of these soils are neutral or weak alkaline with pH values ranging from 6.6 to 8.5 and weak acid in potential acidity of pH values ranging from 5.5 to 6.0. The acidity decreases gradually with the depth of soils. Their cation exchange capacities range from 5 to 15 meq/100g of soil and their base saturation degrees are 70% or more. It is worthy to note that their substratum layers have rather

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/1 Day. Th. A:(1963) Report on Survey of the Lower Volta River Flood Plain, Volume II, Soil Survey and Classification P. 24, Rome.

strong alkaline reaction and high base saturation degree of more than 100%. The content of nutrients and humus are poor. The phosphatic absorptive coefficient range from 300 to 450 mg/100g of soil.

Regarding their hydrological characteristics, these soils have medium basic intake rates ranging from 2.5 to 5.0 cm/hr and rather high available water holding capacities ranging from 17 to 20% by volume of soil.

This soil type contains two soil phases as follows.

Soil phase P

The soils of this soil phase P are moderately deep, moderately well drained and not fertile. They have compacted pan-formation layers in common, so it is necessary to crush them at the practice of land preparation. As these soils are liable to be suffered from drought damages in the dry season and erosion in the rainy season, careful selection of adapted irrigated farming practices should be undertaken for the agricultural use of these soils.

Soil phase Q

The soils of this soil phase Q are distinguished from those of the soil phase P by their slopes of more than 2%.

(4) Great soil group 4 Regosolic groundwater laterites/1

These soils develop on gently undulating upland with elevations of more than 12 m.

The soils extend over about 4,030 ha corresponding to about 16.6% of the total surveyed area.

They consist of the brownish gray to blackish brown coloured coarse sand or loamy sand textured surface soils with the average depth of 30 cm and the brownish grey to yellowish brown coloured gravelly clay loam textured subsoils with the average depth of 25 cm, overlaying loamy substratums with large depth.

The soils have neutral to weak active acidities ranging from 6.6 to 7.3 in pH values and strong to slight potential acidities ranging from 5.1 to 6.5 in pH values. The contents of humus and available nutrients are relatively poor. The phosphatic absorptive

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/1 This great soil group may be classified as the intra-zonal soil order and planosol with gravel in higher categories according to the United States Soil Classification System proposed by C.E. Kellog in 1938, while it may be classified as Alfisols order according to the 7th Approximation of Comprehensive Soil Classification System proposed by the United States Department of Agriculture in 1960.

coefficients range from 350 to 450 mg/100g of soil.
Their cation exchange capacities range from 6 to 13 meq/100g of soil and the base saturation degrees vary from 66 to 92%.

As regards their hydrological characteristics, these soils have rather high basic intake rates ranging from 7.6 to 12.7 cm/hr and medium available moisture holding capacities from 13 to 17% by volume of soil. Their drainabilit es are favourable though they are not blessed with irrigabilities in general.

In regard to their textural features, the subsoils contain gravelly fractions consisting of iron, manganese concretions and quartz with diameters of some 5 mm. The contents of gravels are commonly about 25% or so by weight of soil, and so, they are not so serious hindrance to the plowing and other farming practices.

For the successful management of irrigation farming on these soils, it is most important to improve the soil conditions by applying proper amount of organic matters.

At present, only some parts of this great soil group are used by the existing farmers.

This great soil group consists of 1 soil series in the surveyed area which is composed of 1 soil type and further subdivided into 3 soil phases according to the order of soil classification category as follows.

Soil series 8. DOYUMU series

This soil series consists of 1 soil type having nearly uniform textural features within the solum depth, and the soil type is subdivided into 3 soil phases in the lower soil classification category. All these soil groups are shown as in the following.

a. Soil type 14. Sandy surface-gravelly loam subsoil type

The soils of this soil type 14 have the essential features of the Great Soil Group 4, Regosolic groundwater laterites as described in the preceding paragraph.

This soil type contains 3 soil phases as shown hereunder.

Soil phase R

The soils of this soil phase R are deep, moderately well drained, not fertile and easily tillable.

They have low cation exchange capacities and high erodibilities For the success of irrigation farming on the land of these soils, special attentions should be paid to the selection of adequate water application and cropping practices. These soils can be rather easily used for the culture of the drought resistant crops such as cassava, millet, maize and groundnuts. But the soils can be also available for profitable irrigation farming of sugar cane and other crops by applying proper irrigation farming methods.

Soil phase S

The soils of this soil phase S are distinguished from those of the soil phase P by their slopes of more than 2%.

Soil phase T

The soils of this soil phase T are distinguished from those of the soil phase S by their rich components of rock fragments. These soils are not suitable for irrigation farming due to their rocky and stony features, and they can be used for recreation, wild life, and forest reserve.

2.4.3 Land Capability

Based upon the comparative evaluation on the adaptabilities and availabilities for irrigation farming of major soil groups in the project area, the total land are graded into 5 classes of land capabilities as in the following.

Rating	Remarks for grading
CLASS I	Very suitable for irrigation farming. Deep, moderately to well drained, light to medium textured, a few problems of flooding, easily tillable, relatively rich fertility, fairly good irrigability, no erodibility, high productivity by proper farming management.
CLASS IIa	Moderately suitable for irrigation farming. Deep, well drained, light to medium textured, no problems of flooding, easily tillable, rather low fertility, fairly good irrigability, no erodibility.
CLASS IIb	Moderately suitable for irrigation farming. Deep, imperfectly to poorly drained, medium to fine textured, frequently floodable, uneasily tillable, fairly fertile, good irrigability, no erodibility.
CLASS IIIa	Fairly suitable for irrigation farming. Compact, shallow impermeable layer, unfavourable tillability, no problems of flooding, a few problems of erodibility, moderate irrigability, poor fertility.

CLASS IIIb	Fairly suitable for irrigation farming. Deep, very poorly drained, fine textured, rich fertility, severe problems of annual flooding, unfavourable tillability, good irrigability, no erodibility.
CLASS IV	Usable for irrigation farming. Deep, moderately well drained, light to medium texutred, no problems of flooding, severe erodibility, easily tillable, low fertility, unfavourable irrigability.
CLASS V	Unavailable for irrigation farming, usable for recreation, source of construction materials etc.

The area of each graded class is shown in the following Table II-4, and the distribution of each class is illustrated in Drawing No. 000-03.

Table II-4 Area and Proportional Extent of Each Class of Land by Land Capability in Accra Plain Project Area

Rating		Total surveyed area		Net irrigable area	
		Area (ha)	Proportional extent (%)	Area (ha)	Proportional extent (%)
CLASS	I	1,470	6.1	380	4.6
CLASS	IIa	1,240	5.0	180	2.2
	IIb	4,010	16.5	1,770	21.7
CLASS	IIIa	9,390	38.7	3,800	46.5
	IIIb	4,140	17.1	1,990	24.3
CLASS	IV	3,970	16.4	60	0.7
CLASS	V	60	0.2	0	0
Total		24,280	100	8,180	100

ANNEX III

PLAN OF SUGAR CANE PRODUCTION

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX III PLAN OF SUGAR CANE PRODUCTION

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3.1 General

The annual rainfall in the project area varying between 800 mm and 1,100 mm is not enough for rain-fed culture of sugar cane. Moreover, the distribution of rainfall is erratic and more intense rain than 3 mm/day occurs only in 100-120 days every year. It is, therefore, proposed to grow sugar cane under irrigation.

The sugar factory is operated only during the dry season because of inherent sensitivity of sucrose in sugar cane. In this connection, the long spell of dry season lasting between November to April favours the sugar production in the project area.

As seen in Annex II, Acid gleisol and Tropical grey earth, together being demarcated on 8,590 ha, are suitable for growing sugar cane among the soils which are recognized in the project area.

Herein presented are the plan of sugar cane production under the above-mentioned conditions.

3.2 Proposed Cropping Pattern

3.2.1 Selection of varieties

Investigations to select the suitable cane varieties have been carried out on the fields at Asutsuare and the Agricultural Research Station (A.R.S.) at Kpong in the Lower Volta floodplain. Taking into account the results of the experiments at these fields, six varieties of cane, i.e. B41227, B34104, PR980, CO1001, POJ2878 and POJ3142, were tested by Nippon Koei at the Aveyime pilot farm in 1965-66. The results of the variety trials/1 were as follows:

Table III- 1 Results of Variety Trials

Item	POJ2878	B34104	B41227	POJ3142	CO1001	PR980
Weight (kg/stalk)	1.54	1.51	1.90	1.78	1.45	1.41
Stalks (nos./ha)	58,000	74,800	58,000	52,300	57,500	67,400
Unmillable stalks (%)	4	13	5	31	9	10
Millable stalks (nos./ha)	55,800	65,200	55,100	36,000	52,300	62,700
Cane yield (ton/ha)	84.4	98.8	103.0	63.0	74.8	84.2
Available standard sugar % by test mill juice	14.6	14.6	14.3	15.3	13.0	15.1
Sugar yield (ton/ha)	12.3	14.3	14.8	9.6	9.6	12.6

/1: Nippon Koei Co., Ltd., Feasibility Report on Sugar and Rice Production Project, Appendix IV, 1967

The above table shows that B41227 and B34104 are the highest yielding of the varieties tested. Next to them come POJ2878 and PR980, while CO1001 and POJ3142 deserve consideration.

B41227 is considered the most hopeful among all the varieties tested. This variety has characteristics free from lodging, with better germination and late flowering. Moreover, the stalks of this variety have adequate thickness, and the sugar content is high. Compared with B41227, the variety B34104 has less favourable characteristics such as poor germination, lodging disposition and early flowering. In spite of these demerits, B34104 is recommendable as an early-maturing type of varieties for a large-scale commercial farm because of its high yield and high sugar content. These two varieties are the most promising of those tested, and it is recommended that at the initial stage they should be used on the greater part of the cane field.

In the trials, PR980 has also shown favourable characteristics such as better germination, no tendency to lodge and high sucrose content. The yield of POJ2878 is not so high, but this long established variety, cultivated for longer or shorter periods in almost all of the cane producing countries of the world, is highly resistant to diseases. The cultivation of this variety may be advantageous in case main varieties are attacked by diseases.

In the light of these results, the following allocation of varieties for planting is suggested:

B41227	60 % of the area for middle and late harvesting
B34104	20 % of the area for early harvesting
PR980	10 % of the area for early harvesting
POJ2878	10 % of the area for middle harvesting

Some other varieties have been imported and tested at A.R.S. in recent years. According to the annual reports of A.R.S. (1965-73), CP48-103, CP44-101, CO349 and CO419 seem to be promising for the lower Volta flood plains. Since a variety selected for a certain area does not necessarily show the same result in other areas because of the differences in climatic and soil conditions, the continuation of variety trials at the Aveyime pilot farm is necessary, and as many other varieties as possible should be imported for testing.

3.2.2 Times of planting and harvesting

The time of planting sugar cane has a great influence on production. The time of planting is generally dictated by the climatic conditions, expected time of harvesting and the growing period of the crop.

The climatic conditions of the project area present no problem for growing sugar cane if irrigation water is made available. In the project area, there are two rainy seasons and two dry seasons in a year, the major rainy season being from mid-April to mid-July and the major dry season from early November to the following mid-April. The minor seasons are mid-September to early November (rainy) and late July to early September (dry). For the economical operations of the factory and the cane field, the major dry season from November to April should be the harvesting and milling season. The optimum growing period of the varieties which are proposed in Chapter 3.2.1 is 14-16 months. Therefore, the adequate time of planting should be the mid-August to mid-January, and the planting and harvesting times of each of the selected varieties would be as follows:

Variety	Growing period (month)	Planting	Harvesting
B41227	14 - 16	Oct.15 - Jan.15	Jan. 1 - Apr.15
B34104	14.5	Aug.15 - Sep.15	Nov.15 - Dec.15
PR980	14.5	Sep.15 - Oct.15	Dec.15 - Jan.15
POJ2878	15	Sep.15 - Oct.15	Dec.15 - Jan.15

3.2.3 Crop rotation

In most of the sugar-producing countries, sugar cane is maintained for several years, i.e., a plant cane and ratoons. Generally the yield of ratoon is lower as against that of plant crop, but the cost of cultivation is cheaper because the ratoon crops do not require the land preparation for planting. A study on the relationship between the number of ratooning and net profit would indicate the optimum number of ratoons in a crop rotation.

Table III-2 shows the gross income, cost of cultivation and net income of each of plant crop and its ratoons on the assumption of a straight-line yield decline for repetition of ratoons.

Table III-3 shows average gross and net values of cane production in different crop rotative patterns, being derived from Table III-2.

As seen from this table, it is likely that the 4-year rotation would be the most profitable. It is proposed that the cane cultivation should be stated with 4-year rotative schedule consisting of a plant crop, two ratoons and one-year fallow. Since there have been no field observation on ratoon crops in the project area, the proposed crop rotative schedule is not final and subject to further studies to be made in the proposed pilot farm.

In the proposed crop rotation pattern, one-fourth of the cane fields, 1,875 ha, will be newly planted every year. Harvesting will be executed on the newly planted area of 1,875 ha and the ratooned area of 3,750 ha, annually. After harvesting of second ratoon crop, there would be fallow period of about 9 months. In order to utilize the fallow land and to increase the farm income, it is proposed to grow the short-term cash crops such as groundnuts, maize and vegetables on the settlement farm.

Recaptulating, the proposed cropping pattern is shown in Fig.III-1.

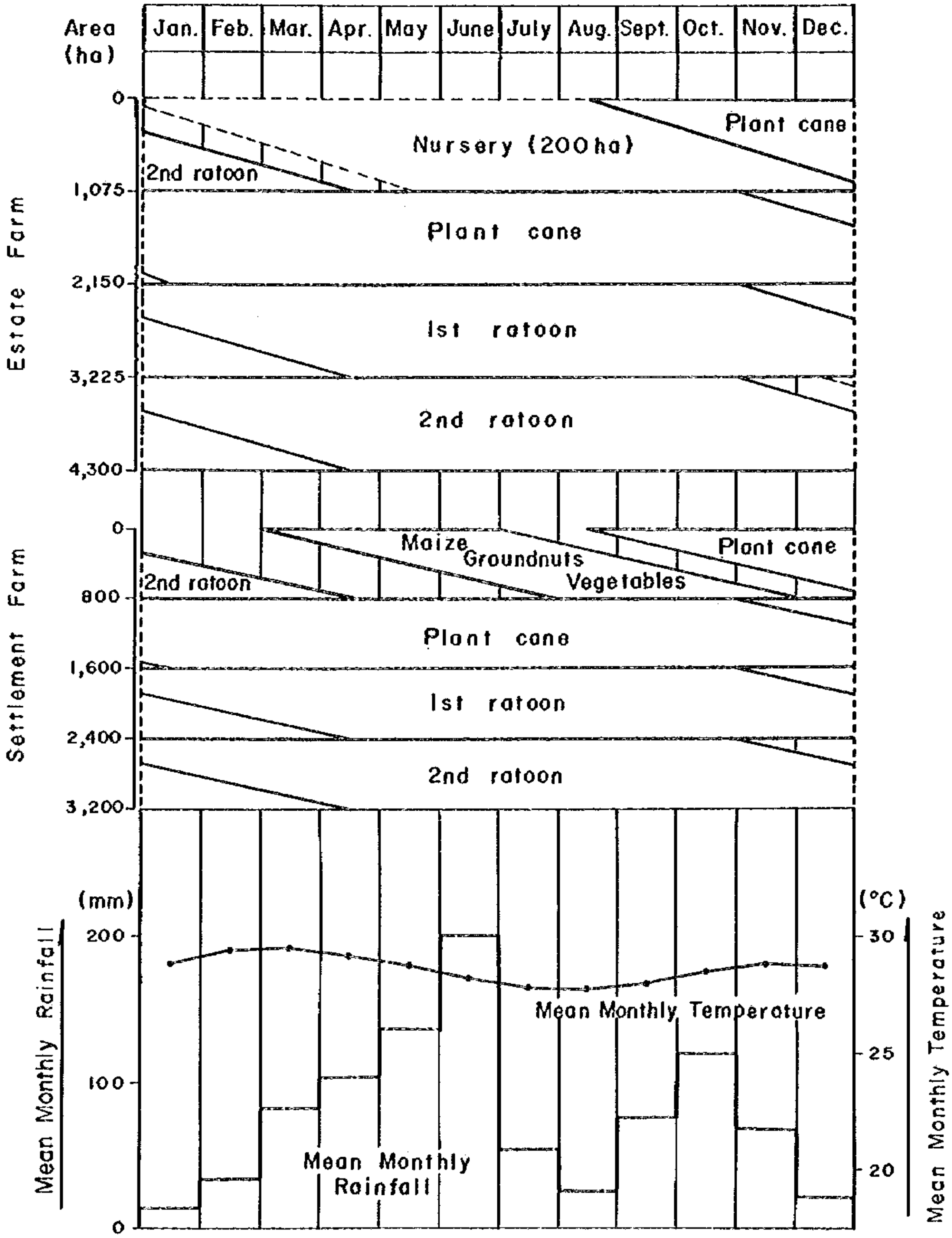
Table III-2 Gross Income, Cost of Cultivation and Net Income of Each of Plant Crop and Ratoons (per ha)

	Fallow	Plant Cane	1st Ratoon	2nd Ratoon	3rd Ratoon	4th Ratoon
I) Gross Income						
- Yield (tons)	-	90	80	70	60	50
- Unit price (US$/ton)	-	17.4	17.4	17.4	17.4	17.4
- Gross income (US$)	-	1,566	1,392	1,218	1,044	870
II) Farming Expenditures						
- Seed cane (US$)	-	80	-	-	-	-
- Fertilizer (US$)	-	78	72	63	54	45
- Agri-chemicals (US$)	-	33	22	22	22	22
- Labour (US$)	-	286	237	225	214	203
- Machinery (US$)	-	359	258	245	233	221
- Farm buildings (US$)	6	6	6	6	6	6
- Miscellaneous (US$)	-	42	30	28	26	25
Total (US$)	6	884	625	589	555	522
III) O&M Cost (US$)	42	83	83	83	83	83
IV) Gross Outgo; II+III (US$)	48	967	708	672	638	605
V) Net Profit; I-IV (US$)	-48	599	684	546	406	265

Table III-3 Comparison of Profitability among Different Crop Rotations (per ha)

	Two Years	Three Years	Four Years	Five Years	Six Years
I) Harvested Area					
- Fallow (ha)	0.50	0.333	0.25	0.20	0.167
- Plant cane (ha)	0.50	0.333	0.25	0.20	0.167
- 1st ratoon (ha)	-	0.333	0.25	0.20	0.167
- 2nd ratoon (ha)	-	-	0.25	0.20	0.167
- 3rd ratoon (ha)	-	-	-	0.20	0.167
- 4th ratoon (ha)	-	-	-	-	0.167
II) Crop Production (tons)	45.0	56.6	60.0	60.0	58.5
III) Gross Income (US$)	783	985	1,044	1,044	1,018
IV) Farming Expenditures (US$)	445	504	526	532	531
V) O&M Cost (US$)	63	69	73	75	76
VI) Gross Outgo; IV+V (US$)	508	573	599	607	607
VII) Net Profit; III-VI (US$)	275	412	445	437	411

Fig. III - 1 PROPOSED CROPPING PATTERN



3.3 Method of Cultivation

3.3.1 Preparation of seed cane

Real seeds of sugar cane are never used for planting the field. The universal planting material for sugar cane is stem cuttings which are called "seeds" in the industry. It is always better to use cutting with more than one bud for planting purpose to ensure that at least one will spout. The most convenient size to handle are stem pieces of 30-40 cm in length (These will have 2 or 3 buds). The best cuttings are derived from the cane plant which is about 6 to 10 months old. Quantity of seed cane required for planting is about 6 tons per ha.

There will be two types of nursery. One will be pure-line reserved nursery which will be established with an area of 30 ha in the proposed pilot farm. On this nersery, the strains of the excellent varieties selected will be carefully maintained under the control of sugar cane agronomist. The other is ordinary nursery on which the seeds maintained on the pure-line reserve farm are planted for multiplication. A part (20 %) of the fallow land in the estate farm will be used as the ordinary nursery.

3.3.2 Cultivation of plant crop

The cane field will be subsoiled immediately after harvesting of second ratoon crop for improving the drainability of subsoils which will have been compacted by heavy tractor operations. After subsoiling, the cane field will be kept fallow for 8 months and after that the cane field will be prepared, for the planting, by ploughing and harrowing. In the proposed cane area, it is suggested that the soils should be ploughed up to the depth of 40 - 50 cm and be harrowed as thoroughly as possible to break down clods remaining on the field. The field preparation for new plant crop will be as follows:

Width of planting furrow:	150 cm
Depth of planting furrow:	25 - 30 cm below ground line
Depth of planting bed:	5 - 10 cm below ground line
Interval of planting:	30 cm

The cane seeds will be sterilized with fungicides prior to the planting to present the crop from diseases. A relatively recent innovation brought about by the gradually increasing cost of labour in many sugar-producing areas is mechanical planting. Many different types of planting machines have been developed for this purpose and are available in the market. Among them, cutter-planter is widely used in the major areas of the sugar belt as the most favourable planting implement. This machine can be accurately adjusted for varying depths of furrow, amount of cover, length of sets and spacing in the row. The first application of fertilizers can be carried out be simultaneously with the planting by an attachment of the planter. This type of machine will be used in this area.

For the development of root system of new plant crop, earthing and banking play important role, especially banking of stools is needed for cane to stand erect. These farm operations will also be mechanized. The first earthing up will be carried out soon after the first application of fertilizers, and the second earthing will take place after the second fertilizing.

Weeds near cane stools must be cleared just before second fertilizing. According to the experiences in the project area, better results in weed control will be obtained if the soils are loosened before earthing. In addition, cultivation of interspace of rows in the period between the earthing up and banking is also effective for weed control.

3.3.3 Cultivation of ratoon crop

Before ratoon cultivation starts, the discarded stalks and the top of cane will be collected and taken out of the field, to avoid distarbance to the subsequent works. After clearing of the field, the cane field will be off-barred by a cultivator as close as possible along the rows, and the bank will be opened up to help stubbles sprout easily; then most of old roots are cut off and the soil is well-aerated to give the buds in the lower soil layer an opportunity to sprout. The dying-off of underground stalks by poor aeration is often the limiting factor for the ratoon crop production.

All the cane above the ground should be harvested, but "high-cutting" of stalks is often observed with the harvesters. New shoots that emerge from the buds on the old stumps are always weak and usually they are sheded out by more vigorous shoots that emerge from the buds lower in the soils. This results the delay in the growing time but it can be prevented by using mechanical stubble shaver. Fertilizer can be applied at the same time from an attachment of the stubble shaver.

The second fertilizing and earthing will be done one month after the opening of banks. As the stricks grow up early in ratoon fields, the times of the second fertilizing, earthing up and banking should be decided according to the growth of the stricks.

3.3.4 Fertilizer Application

(1) Fertilizer requirement

The fertilizer application trials carried out by Nippon Koei at Aveyime in 1965-67, showed fairly high response to application of nitrogen and phosphorus and little or no response to potash. Based on the results of these trials, the standard application level of fertilizers is estimated as shown in Table III-4.

As the fertilizer requirements differ among the different soils, fertilizer application trials should be carried out to determine the optimum quantities of fertilizers in different type of soils.

Table III-4 Standard Application Level of Fertilizers

(kg/ha)

	Description	Plant cane	1st ratoon	2nd ratoon
(1)	Anticipated yeild (ton/ha)	90	80	70
(2)	Total nutrient requirements/1			
	N	85	76	69
	P_2O_5	51	46	41
	K_2O	151	136	122
(3)	Natural supply of nutrients/2			
	N	46	41	37
	P_2O_5	36	32	29
	K_2O	140	127	113
(4)	Nutrient to be needed, (2) - (3)			
	N	39	35	32
	P_2O_5	15	14	13
	K_2O	11	9	9
(5)	Rate of availability (%)	50	20	60
(6)	Nutrients to be applied			
	N	80	70	60
	P_2O_5	80	70	60
	K_2O	20	15	15

/1 : "Manual of Cane Growing" by Norman J. King, p.91.

/2 : Nippon Koei Co., Ltd., Feasibility Report on Sugar and Rice Production Project in Accra Plain, Appendix IV, 1967, p.25.

(2) Time of fertilizer application

In general, a great amount of nitrogen is absorbed by cane mainly at its initial stage of growing and after that the absorption rate gradually reduces. It is reported that heavy application of nitrogen at the later stage of growing will result in lower sugar content. Nevertheless, the application of all the nitrogen requirement at the time of planting may lead to a low rate of utilization of nitrogen because of the loss by leaching and nitrification. It is therefore proposed to apply the nitrogenous fertilizer at three different times; one at planting and the other two later on. According to the experiments/1 at Agricultural Research Station, Kpong, sprit-application of nitrogen, one at planting and another at 3 months later, produced the highest yield. In order to minimize the loss of nitrogen, however, the top dressing at 1.5 months after planting is also recommendable as well as that at 3 months later.

Phosphorus is essential for cell division which is most active in early stage of the plant development, particularly in germination. Phosphorus is stable in the soils and phosphatic fertilizer applied has a longer effect on the plant. Therefore phosphorus should be applied as a basal fertilizer at planting.

Potash is required by cane in a great quantity. However, the functions of potash are not yet fully understood. It is known however that the functions appear to be in connection with assimilation of carbon dioxide and formation and translocation of sugar within the plant. It also apparently control water metabolism in the plant. These mean potash is required in every stage of plant growth. Since much potash is available from the soils of the project area, potash will be applied only in the form of basal fertilizer.

3.3.5 Control of Pests and Diseases

In the pilot farm at Aveyime, damages caused by pests and diseases were negligible. Some damages by termites were observed in the experimental plots near Bla. Application of Aldrin emulsion put an end to the trouble. It may be advisable to apply this emulsion in the furrows, two days before planting.

With the development of the cane sugar industry in the area, the damages suffered from pests and diseases will be increased. In this case, it is necessary to use adequate amount of pesticides and fungicides. Plant protection is more important in the nursery. Careful treatments will have to be carried out, which include spraying MEP emulsion for damage by top and stem borers and two-hours soaking of seeds in 50° hot water for mosaic diseases.

/1: Agricultural Research Station, Kpong, Annual Report, 1970/71 PP.33-34

The proposed agro-chemicals against the pests and diseases are as follows:

	Unit	Plant crop	Ratoon crops
- Insecticides			
Fenitrothion[1]	(ℓ/ha)	2	2
Aldrex-40[2]	(ℓ/ha)	12.5	12.5
- Fungicides			
Thiophanate[3]	(ℓ/ha)	1	-
- Rodenticides			
Zinc phosphide[4]	(g/ha)	70	60

3.3.6 Mechanization

The proposed cropping pattern requires systematic farming practices throughout the year together with efficient water management. In order to maintain the systematic work-flow from soil preparation to harvest-to-mill process and to save the labour requirements, all the farming practices will be mechanized as much as possible.

(1) Mechanized farming practices

The diagram attached (Figs.III-2 and III-3) shows a time schedule of various mechanized farming activities, including transport of cane harvested, and suggestions as to types of farm machinery required for the proposed farm operations on the total area of 7,500 ha.

The 140 PS class crawler type tractor is proposed as the special machinery for breaking up the compacted subsoils caused by heavy tractor operations. The 80 PS class wheel type tractor will be used for rather heavy works such as ploughing, harrowing and ridging. The 60 PS class wheel type tractor will be used for rather light works including planting, plant protection, interrow cultivation, etc. About 60 % of the total required numbers of the 60 PS class tractor will be a high-clearance type for smooth farm operation after cane planting. Every farming practices, except harvesting and transport, will be performed by attaching various equipment to such tractors, as shown Figs.III-2 and III-3.

Harvesting is also mechanized. Various types of machines have been developed for this purpose and are available on the markets. The self-propelled chopper type harvester which is widely used in Australia, among others, is recommended for cane harvesting in the project area, in view of its high efficiency. This type of harvester simultaneously carry out

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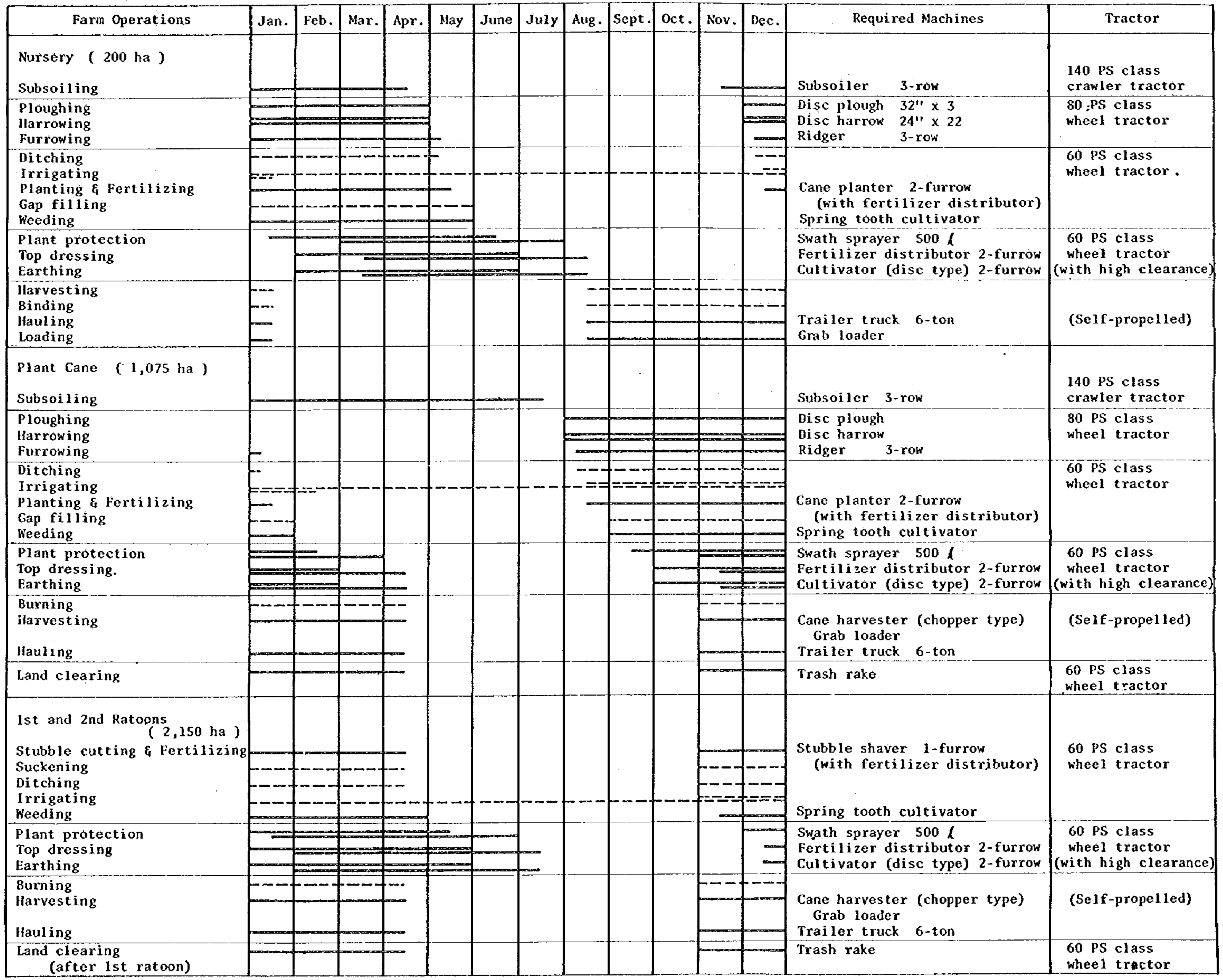
[1] Dimethyle 4-nitro-m-tolyl phosphorothionate
[2] Emulsible concentrate containing 4 pounds of Aldrin per gallon
[3] 1, 2-bis (3-ethoxycarbnyl-2-Thioureido) benzene
[4] Zn_3P_2

Fig. III-2 PROPOSED FARM OPERATION SCHEDULE

(Estate Farm: 4,300 ha)

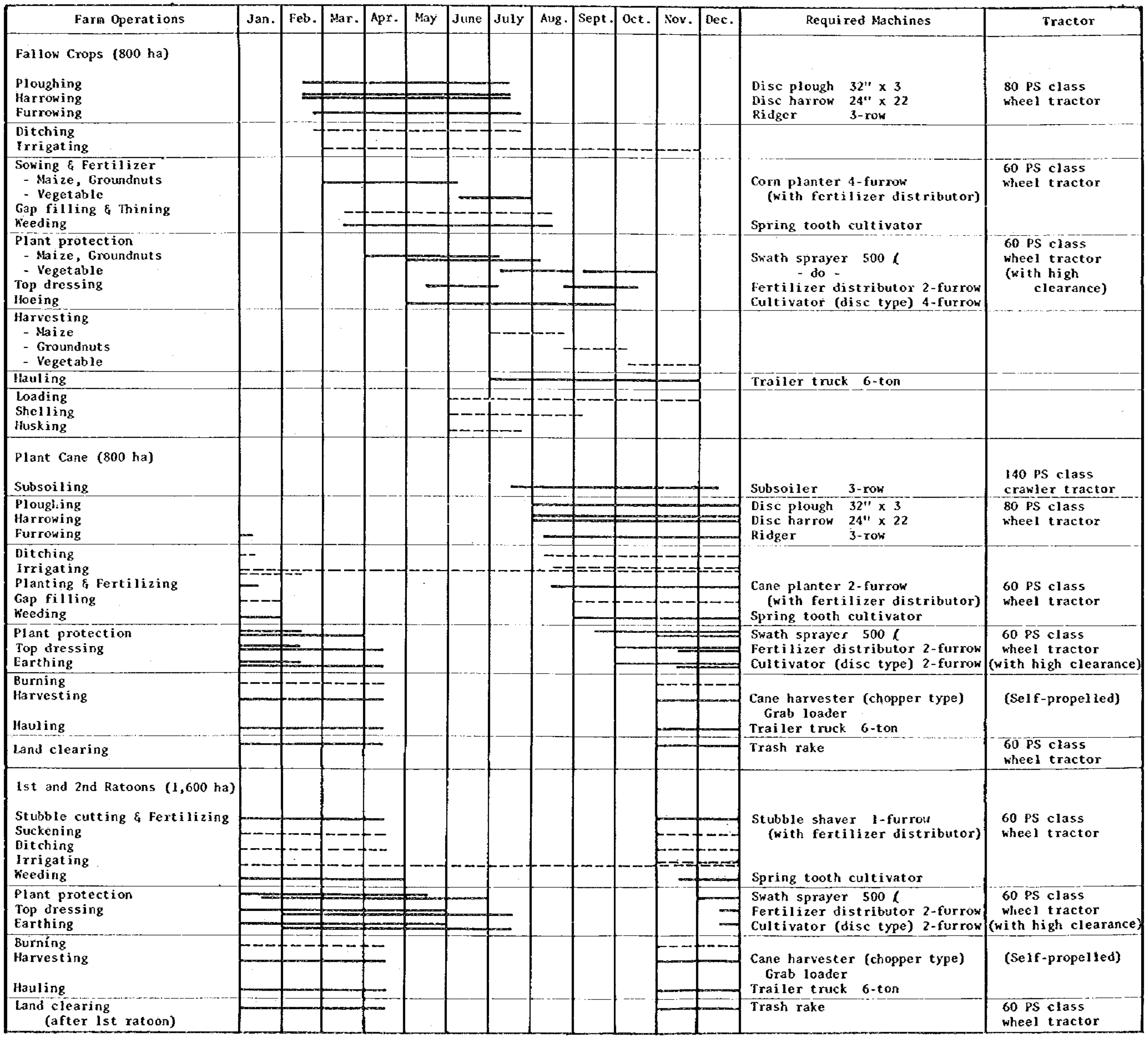


Farm Operations	Required Machines	Tractor
Nursery (200 ha)		
Subsoiling	Subsoiler 3-row	140 PS class crawler tractor
Ploughing	Disc plough 32" x 3	80 PS class wheel tractor
Harrowing	Disc harrow 24" x 22	
Furrowing	Ridger 3-row	
Ditching		60 PS class wheel tractor.
Irrigating		
Planting & Fertilizing	Cane planter 2-furrow (with fertilizer distributor)	
Gap filling		
Weeding	Spring tooth cultivator	
Plant protection	Swath sprayer 500 ℓ	60 PS class wheel tractor (with high clearance)
Top dressing	Fertilizer distributor 2-furrow	
Earthing	Cultivator (disc type) 2-furrow	
Harvesting		
Binding		
Hauling	Trailer truck 6-ton	(Self-propelled)
Loading	Grab loader	
Plant Cane (1,075 ha)		
Subsoiling	Subsoiler 3-row	140 PS class crawler tractor
Ploughing	Disc plough	80 PS class wheel tractor
Harrowing	Disc harrow	
Furrowing	Ridger 3-row	
Ditching		60 PS class wheel tractor
Irrigating		
Planting & Fertilizing	Cane planter 2-furrow (with fertilizer distributor)	
Gap filling		
Weeding	Spring tooth cultivator	
Plant protection	Swath sprayer 500 ℓ	60 PS class wheel tractor (with high clearance)
Top dressing.	Fertilizer distributor 2-furrow	
Earthing	Cultivator (disc type) 2-furrow	
Burning		
Harvesting	Cane harvester (chopper type) Grab loader	(Self-propelled)
Hauling	Trailer truck 6-ton	
Land clearing	Trash rake	60 PS class wheel tractor
1st and 2nd Ratoons (2,150 ha)		
Stubble cutting & Fertilizing	Stubble shaver 1-furrow (with fertilizer distributor)	60 PS class wheel tractor
Suckening		
Ditching		
Irrigating		
Weeding	Spring tooth cultivator	
Plant protection	Swath sprayer 500 ℓ	60 PS class wheel tractor (with high clearance)
Top dressing	Fertilizer distributor 2-furrow	
Earthing	Cultivator (disc type) 2-furrow	
Burning		
Harvesting	Cane harvester (chopper type) Grab loader	(Self-propelled)
Hauling	Trailer truck 6-ton	
Land clearing (after 1st ratoon)	Trash rake	60 PS class wheel tractor

Remarks; ——— machine - - - - - manpower

Fig.III-3 PROPOSED FARM OPERATION SCHEDULE

(Settlement Farm: 3,200 ha)



Farm Operations	Required Machines	Tractor
Fallow Crops (800 ha)		
Ploughing	Disc plough 32" x 3	80 PS class wheel tractor
Harrowing	Disc harrow 24" x 22	
Furrowing	Ridger 3-row	
Ditching		
Irrigating		
Sowing & Fertilizer		60 PS class wheel tractor
- Maize, Groundnuts	Corn planter 4-furrow (with fertilizer distributor)	
- Vegetable		
Gap filling & Thining		
Weeding	Spring tooth cultivator	
Plant protection		60 PS class wheel tractor (with high clearance)
- Maize, Groundnuts	Swath sprayer 500 ℓ	
- Vegetable	- do -	
Top dressing	Fertilizer distributor 2-furrow	
Hoeing	Cultivator (disc type) 4-furrow	
Harvesting		
- Maize		
- Groundnuts		
- Vegetable		
Hauling	Trailer truck 6-ton	
Loading		
Shelling		
Husking		
Plant Cane (800 ha)		
Subsoiling	Subsoiler 3-row	140 PS class crawler tractor
Ploughing	Disc plough 32" x 3	80 PS class wheel tractor
Harrowing	Disc harrow 24" x 22	
Furrowing	Ridger 3-row	
Ditching		
Irrigating		
Planting & Fertilizing	Cane planter 2-furrow (with fertilizer distributor)	60 PS class wheel tractor
Gap filling		
Weeding	Spring tooth cultivator	
Plant protection	Swath sprayer 500 ℓ	60 PS class wheel tractor (with high clearance)
Top dressing	Fertilizer distributor 2-furrow	
Earthing	Cultivator (disc type) 2-furrow	
Burning		
Harvesting	Cane harvester (chopper type) Grab loader	(Self-propelled)
Hauling	Trailer truck 6-ton	
Land clearing	Trash rake	60 PS class wheel tractor
1st and 2nd Ratoons (1,600 ha)		
Stubble cutting & Fertilizing	Stubble shaver 1-furrow (with fertilizer distributor)	60 PS class wheel tractor
Suckening		
Ditching		
Irrigating		
Weeding	Spring tooth cultivator	
Plant protection	Swath sprayer 500 ℓ	60 PS class wheel tractor (with high clearance)
Top dressing	Fertilizer distributor 2-furrow	
Earthing	Cultivator (disc type) 2-furrow	
Burning		
Harvesting	Cane harvester (chopper type) Grab loader	(Self-propelled)
Hauling	Trailer truck 6-ton	
Land clearing (after 1st ratoon)	Trash rake	60 PS class wheel tractor

Remarks; ——— machine - - - - - manpower

both harvesting and loading; The cane field is burned prior to the harvesting. The harvester simultaneously cuts the top and bottom of the cane stalks at the ground level. The cane harvested are lifted by the elevator attached and cut into pieces of 30 cm in length. These chopped stalks are loaded on the trailor running side of the harvester.

Although this harvester has extremely high efficiency for harvest-to-mill process, it cannot harvest the lodged cane which is estimated less than 20 % of the whole quantity of cane to be harvested. The lodged cane will be harvested and bound into bundles of each about 30 kg by manpower, and will be loaded onto the trailer by the grab-loader.

As for the cane transportation system the following three systems are considered: (1) Complete railway system, (2) road and infield railway system and (3) full road system. Out of them, the full road system is recommendable for the reasons given below:

a. Complete railway system requires not only huge amount of railway construction but also much labour force for transloading at the cane yard.

b. Road and infield railway system has more flexibility than the complete railway system and has the merit to enable the harvesting in wet field condition, by introducing portable railways. However, the moving of the rail and equipment from site to site and the transloading of harvested cane on the farm road neighbouring the field are serious disadvantages.

c. Full road system is capable of easy adaptation to any degree of mechanization and avoids the need of the transloading of cane. The full road system will facilitate the access of farm machinery and equipment and the inspection of the cane field.

(2) Farm machinery requirement

Taking into account the climate and soil conditions in the project area, monthly workable days for mechanized farm operations are estimated as shown in Table III-5. Based on the proposed farm operations given in Figs.III-2 and III-3, monthly work quantities and monthly working hours for each farm operations are estimated and summarized as shown in Tables III-6 and III-7. From these tables, the number of machinery required for performing the proposed farm operations is estimated as shown in Table III-8.

3.4 Labour Requirement

There are about 18,000 inhabitants or 1,800 farming farmilies in the project area. Average size of family consists of 10.2 persons and keeps about 2.5 adult-men equivalent labour per day. The project area has therefore total labour force of about 4,500 adult-men equivalent or 1.16 million man-days per annum assuming that there are 258 workable days annually.

Table III-5 Estimate of Monthly Workable Days

Year	Weather Delays /1												Total
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1955	-	-	7.0	-	-	-	3.0	3.5	5.5	8.0	1.0	0	
56	0	1.0	7.5	3.0	4.0	8.0	0	0	0	7.0	3.0	1.0	
57	0	0	3.5	5.5	11.0	4.5	2.5	1.0	4.5	4.5	5.5	4.0	
58	0	1.5	3.5	5.5	8.5	6.0	0	0	3.0	11.0	2.0	0	
59	0	3.0	3.0	3.5	4.0	6.0	1.5	0	2.0	9.5	3.0	1.5	
60	2.0	1.0	3.0	4.5	4.5	10.5	1.5	0	4.5	7.0	6.0	1.5	
61	3.0	2.0	3.0	8.0	2.0	12.5	2.0	0	3.5	3.0	4.0	0	
62	2.0	1.0	3.0	4.0	5.5	17.5	3.5	4.0	0	4.5	5.0	2.0	
63	0	2.0	5.0	7.5	3.5	-	3.5	-	-	2.0	5.5	0	
64	0	0	3.0	5.0	3.0	7.0	2.0	0	1.0	1.5	3.5	0	
65	0	2.0	3.5	9.5	4.5	8.0	5.5	6.5	1.5	3.5	5.0	2.0	
66	1.0	0	3.0	4.0	4.0	8.0	3.0	0	0	4.5	5.5	3.5	
67	1.5	1.5	5.5	1.0	7.0	9.0	1.0	0	1.5	5.0	2.0	0	
68	0	1.5	3.0	4.0	5.0	9.0	7.5	3.0	9.0	6.0	3.0	0	
69	0	1.0	4.0	5.5	7.0	11.0	0	0	4.0	1.0	3.5	0	
70	1.0	1.5	3.5	3.5	12.0	4.0	0	0	3.0	10.5	2.0	0	
71	0	1.0	3.0	3.0	7.0	9.0	1.0	0	1.5	5.0	2.0	0	
72	0	3.5	1.5	9.5	9.0	8.0	0	0	5.0	2.0	4.5	3.0	
73	0	2.0	3.0	5.0	6.0	11.0	2.0	3.0	7.5	2.5	3.5	0	
74	2.5	0	5.0	5.0	6.5	11.0	7.0	0	7.5	4.5	1.0	0	
Total	13.0	25.5	76.5	96.5	114.0	160.0	46.5	21.0	64.5	102.5	70.5	18.5	
Average	1	1	4	5	6	9	2	1	3	5	4	1	
Workable/2 Days	24	24	21	20	19	16	23	24	22	20	21	24	258

/1 : Weather delays (by rain or wet ground)are estimated from the daily rainfall record at Aveyime (1955 - 74) under the following assumption.

Rainfall (mm/day)	Weather delays (days)
0 - 9	0
10 - 19	1.0
20 - 29	1.5
more than 30	2.0

/2 : Workable days (per month) exclude Sunday, National holiday and weather delays.

Table III-6 Work Quantity of Proposed Mechanized Farming

(Unit; ha or tons/month)

Work Item		Monthly Work Quantities												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Subsoiling		180	180	170	160	130	130	150	160	160	160	180	120	1,880
Ploughing		40	120	200	200	160	160	80	380	380	370	380	410	2,880
Harrowing		40	120	200	200	160	160	80	380	380	370	380	410	2,880
Furrowing		170	40	40	40	10	-	-	250	380	370	380	400	2,080
Planting & Fertilizing		230	40	40	40	20	-	-	190	380	370	380	390	2,080
Weeding		1,100	720	800	880	200	160	160	80	380	380	710	1,060	6,630
Plant protection		1,790	1,970	1,820	1,600	1,420	1,060	360	210	300	540	800	1,430	13,300
Top dressing		1,430	2,150	1,800	1,630	1,530	920	410	50	160	460	560	1,090	12,190
Earthing		1,430	2,150	1,800	1,630	1,440	760	380	20	-	380	560	1,090	11,640
Harvesting	(tons)	81,800	81,800	81,800	41,000	-	-	-	-	-	-	81,800	81,800	450,000
Hauling–Seed cane	(")	1,300	-	-	-	-	-	-	1,300	2,500	2,500	2,500	2,500	12,600
–Sugar cane	(")	81,800	81,800	81,800	41,000	-	-	-	-	-	-	81,800	81,800	450,000
–Fallow crops	(")	-	-	-	-	-	-	490	400	250	1,080	1,600	-	3,820
Loading	(")	17,700	16,400	16,400	8,200	-	-	-	1,300	2,500	2,500	18,800	18,800	102,600
Land clearing		680	680	680	350	-	-	-	-	-	-	680	680	3,750
Stabble cutting & Fertilizing		680	680	680	350	-	-	-	-	-	-	680	680	3,750
Furrowing for fallow crops		-	50	160	160	160	160	110	-	-	-	-	-	800
Sowing for fallow crops		-	-	160	160	160	50	-	-	-	-	-	-	530
Hoeing for fallow crops		-	-	-	-	160	160	160	160	160	-	-	-	800

Table III-7 Prospective Working Hours of Tractors and Implements

(Unit; hrs/month)

Tractors and Implements	Monthly Working Hours												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Subsoiler	450	450	430	400	320	320	380	400	400	400	450	300	4,700
Disc plough	130	400	670	670	530	530	260	1,270	1,270	1,260	1,240	1,370	9,600
Disc barrow	90	270	440	440	360	360	180	840	840	830	830	920	6,400
Ridger	140	30	30	30	10	-	-	210	320	310	320	330	1,730
Cane planter	380	70	70	70	30	-	-	320	630	620	630	650	3,470
Spring tooth cultivator	1,570	1,030	1,140	1,260	290	230	230	120	540	540	1,010	1,510	9,470
Swath sprayer	990	1,090	1,010	890	790	590	200	120	170	300	440	800	7,390
Fertilizer distributor	1,790	2,690	2,250	2,040	1,910	1,150	510	60	200	580	700	1,360	15,240
Cultivator	2,380	3,580	3,000	2,730	2,400	1,270	630	30	-	630	930	1,820	19,400
Cane harvester	5,840	5,840	5,840	2,940	-	-	-	-	-	-	5,840	5,840	32,140
Trailer truck	19,400	19,100	19,100	9,600	-	-	80	430	760	930	20,100	19,800	109,300
Grab loader	440	410	410	210	-	-	-	30	60	60	470	480	2,570
Trash rake	970	970	970	500	-	-	-	-	-	-	970	970	5,350
Stubble shaver	1,700	1,700	1,700	880	-	-	-	-	-	-	1,700	1,700	9,380
Ridger/1	-	100	320	320	320	320	220	-	-	-	-	-	1,600
Corn planter/1	-	-	270	270	270	70	-	-	-	-	-	-	880
Cultivator/1	-	-	-	-	200	200	200	200	200	-	-	-	1,000
140 PS class crawler tractor	450	450	430	400	320	320	380	400	400	400	450	300	4,700
80 PS class wheel tractor	360	700	1,140	1,140	900	890	440	2,320	2,430	2,400	2,390	2,620	17,730
60 PS class wheel tractor	4,620	3,870	4,470	3,300	1,110	820	650	640	1,370	1,160	4,310	4,830	31,150
60 PS class wheel tractor (with high clearance)	5,160	7,360	6,260	5,660	5,100	3,010	1,340	210	370	1,510	2,070	3,980	42,030

/1: Implements for cultivation of fallow crops

Table III-8 Number of Tractors and Implements Required

Tractors and Implements	Average Working Hours (hrs/day)/1												Peak Working Hours (hrs/day)	Required Numbers/2 (Nos.)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.		
Subsoiler	19	19	20	20	17	20	17	17	18	20	21	13	21	2
Disc plough	5	17	32	34	28	33	11	53	58	63	59	57	63	6
Disc harrow	4	11	21	22	19	23	8	35	38	42	40	38	42	4
Ridger	6	1	1	2	1	-	-	9	15	16	15	14	16	2
Cane planter	16	3	3	4	2	-	-	13	29	31	30	27	31	3
Spring tooth cultivator	65	43	54	63	15	14	10	5	25	27	48	63	65	6
Swath sprayer	41	45	48	45	42	37	9	5	8	15	21	33	48	4
Fertilizer distributor	75	112	107	102	101	72	22	3	9	29	33	57	112	10
Cultivator	99	149	143	137	126	79	27	1	-	32	44	76	149	13
Cane harvester	243	243	278	147	-	-	-	-	-	-	278	243	278	24
Trailer truck	808	796	910	480	-	-	3	18	35	47	957	825	957	80
Grab loader	18	17	20	11	-	-	-	1	3	3	22	20	22	2
Trash rake	40	40	46	25	-	-	-	-	-	-	46	40	46	4
Stubble shaver	71	71	81	44	-	-	-	-	-	-	81	71	81	7
Ridger/3	-	4	15	16	17	20	10	-	-	-	-	-	20	2
Corn planter/3	-	-	13	14	14	4	-	-	-	-	-	-	14	2
Cultivator /3	-	-	-	-	11	13	9	8	9	-	-	-	13	2
140 PS class crawler tractor	19	19	20	20	17	20	17	17	18	20	21	13	21	2
80 PS class wheel tractor	15	29	54	57	47	56	19	97	110	120	114	109	120	10
60 PS class wheel tractor	193	161	213	165	58	51	28	27	62	58	205	201	213	18
60 PS class wheel tractor (with high clearance)	215	307	298	283	268	188	58	9	17	76	99	166	307	26

/1: Average working hours (hrs/day) = $\frac{\text{Monthly working hours (Table III-7)}}{\text{Monthly workable days (Table III-5)}}$

/2: Required numbers = $\frac{\text{Peak working hours}}{\text{12 hours (2-shift operation)}}$

/3: Implements for cultivation of fallow crops

In the proposed farming practices, such farming works as on-farm irrigation, ditching, gap-filling, pre-harvest burning, harvesting of lodged cane, etc. are planned to be carried out by man-power. The work efficiency of these works is estimated as follows:

On-farm irrigation	20 man-days/ha
Gap-filling	6 man-days/ha
Pre-harvest burning	4 man-days/ha
Cane cutting	1 man-days/ton
Binding of harvested cane	0.6 man-days/ton

Based on this estimate and the proposed farm operation schedule, hand labour requirements for the entire project area of 7,500 ha are calculated at about 503,000 man-days per annum, as shown in Table III-9. This means that almost half of the present working population will have to be engaged in the envisaged sugar industry. The total labour requirements for the estate farm of 4,300 ha are estimated at about 259,000 man-days per annum, of which about 88,000 man-days per annum or 340 adult men per day are to be provided as the permanent labourers as shown in Table III-11. The rest will be seasonal labour requirements for busy farming season. The total labour requirements for the settlement farms are about 244,000 man-days per annum for the total area of 3,200 ha.

The total labour requirements for cultivation of crops proposed for the settlement farm is estimated at about 305 man-days for a standard size of farm holding 4.0 ha per year, whilst available family labour is estimated at 645 man-days per year. The present farm labour force of typical family will fully cover the farm labour requirement. The detailed farm labour requirements for the settlement farm is shown in Table III-10.

The machine operator requirements for the total cane area of 7,500 ha are estimated at 330 men, as shown in Table III-12, based on the working hours of machinery given in Table III-7. These operatons will be mainly recruited from outside the project area, whereas it is desirable to employ the common laboureSS in and around the project area.

3.5 Anticipated Yield

Taking into consideration both the results of the previous experiments conducted by Nippon Koei and other authorities at Aveyime and the envisaged complete irrigation and drainage system, the targeted unit yield of sugar cane per ha is conservatively estimated at 90 tons of plant cane, 80 tons of 1st ratoon and 70 tons of 2nd ratoon. In estimating the target yield, it is assumed that such proposed farming practices as timely planting and harvesting, adequate application of fertilizers, complete plant protection, etc. are assured for the entire cane field under the project.

The unit yield of sugar cane will gradually increase proportionately to the increase of land productivity and the improvement of farming technique. The unit yield during the build-up period is tentatively assumed to be 80 % of the target yield.

Whilst, the sucrose content of cane and the factory yield are estimated respectively at 13.0 % and 10.0 % on an average of all the cane to be harvested during the period of factory operation. As to the molasses percentage, it is roughly estimated at 4.5 % on an average throughout the harvesting based on the sucrose content and the factory yield mentioned above.

Table III-9 Labour Requirement for Cane Cultivation

(Unit ; man-days)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Estate Farm (4,300 ha)													
- Nursery	2,700	600	700	800	900	500	500	2,700	4,800	4,700	4,600	4,600	28,100
- Plant cane	12,500	10,500	10,200	6,200	2,400	2,400	2,400	2,800	4,700	5,000	12,700	12,900	84,700
- Ratoon cane	20,500	21,100	21,800	14,100	5,700	5,300	4,900	4,700	4,300	3,400	19,900	20,200	145,900
Sub-total	35,700	32,200	32,700	21,100	9,000	8,200	7,800	10,200	13,800	13,100	37,200	37,700	258,700
Settlement Farm (3,200 ha)													
- Plant cane	9,300	7,800	7,600	4,600	1,800	1,800	1,800	2,100	3,500	3,700	9,500	9,600	63,100
- Ratoon cane	15,300	15,600	16,200	10,500	4,200	3,900	3,700	3,500	3,200	2,600	14,800	15,100	108,600
- Maize			1,200	2,000	1,000	800	7,700	4,900					17,600
- Groundnuts				200	1,700	1,900	700	4,000	10,300	3,300			22,100
- Vegetables						3,500	6,700	1,300	800	8,400	11,900		32,600
Sub-total	24,600	23,400	25,000	17,300	8,700	11,900	20,600	15,800	17,800	18,000	36,200	24,700	244,000
Total	60,300	55,600	57,700	38,400	17,700	20,100	28,400	26,000	31,600	31,100	73,400	62,400	502,700

Table III-10 **Labour Requirement for Settlement Farm (4 ha)**

(Unit: man-days/month)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Plant cane	11.6	9.7	9.5	5.7	2.3	2.3	2.3	2.6	4.4	4.6	11.9	12.0	78.9
Ratoon cane	19.1	19.5	20.2	13.1	5.2	4.9	4.6	4.4	4.0	3.3	18.5	18.9	135.7
Maize			1.5	2.5	1.3	1.0	9.6	6.1					22.0
Groundnuts				0.3	2.1	2.3	0.9	5.0	12.9	4.1			27.6
Vegetables						4.4	8.4	1.6	1.0	10.5	14.9		40.8
Total	30.7	29.2	31.2	21.6	10.9	14.9	25.8	19.7	22.3	22.5	45.3	30.9	305.0
Workable days	24	24	21	20	19	16	23	24	22	20	21	24	258
Average family labour force/1	60.0	60.0	52.5	50.0	47.5	40.0	57.5	60.0	55.0	50.0	52.5	60.0	645.0

/1: Average farm labour force per family is assumed at 2.5 adult-men equivalent.

Table III-11 Permanent and Seasonal Labourer Requirement of the Estate Farm

Month	Plant and Ratoon Cane (man-days)	Nursery (man-days)	Total (man-days)	Workable Days (days)	Daily Average Labour Requirement (men/days)	Permanent/2 Labourer (man-days)	Seasonal Labourer (man-days)
Jan.	33,000	2,700	35,700	24	1,490	8,200	27,500
Feb.	31,600	600	32,200	24	1,340	8,200	24,000
Mar.	32,000	700	32,700	21	1,560	7,100	25,600
Apr.	20,300	800	21,100	20	1,060	6,800	14,300
May	8,100	900	9,000	19	470	6,500	2,500
June	7,700	500	8,200	16	510	5,400	2,800
July	7,300	500	7,800	23	340/1	7,800/2	0
Aug.	7,500	2,700	10,200	24	430	8,200	2,000
Sept.	9,000	4,800	13,800	22	630	7,500	6,300
Oct.	8,400	4,700	13,100	20	660	6,800	6,300
Nov.	32,600	4,600	37,200	21	1,770	7,100	30,100
Dec.	33,100	4,600	37,700	24	1,570	8,200	29,500
Total	230,600	28,100	258,700	258		87,800	170,900
Plant and ratoon cane						78,300/3	152,300/4
Nursery						9,500	18,600

/1: Daily minimum labour requirement is assumed to be met by permanent labourer.

/2: Permanent labourers (340 adult men) x workable days

/3: 230,600 man-days x $\frac{\text{87,800 man-days}}{\text{258,700 man-days}}$ ≑ 78,300 man-days

/4: 230,600 man-days x $\frac{\text{170.900 man-days}}{\text{258,700 man-days}}$ ≑ 152,300 man-days

Table III-12 Machinery Operator Requirement

Month	Monthly Operator Requirement			Workable Days (days)	Daily Average Operator Requirement (men/day)
	Estate Farm (man-days)	Settlement Farm (man-days)	Total (man-days)		
Jan.	3,910	2,750	6,660	24	278
Feb.	3,990	2,930	6,920	24	289
Mar.	3,880	3,030	6,910	21	329
Apr.	2,330	1,930	4,260	20	213
May	610	760	1,370	19	73
June	360	570	930	16	59
July	170	380	550	23	24
Aug.	350	380	730	24	31
Sept.	520	450	970	22	44
Oct.	640	530	1,190	20	59
Nov.	3,730	2,790	6,520	21	311
Dec.	4,040	2,890	6,930	24	289

Number of operator required 329 ≑ 330 men

3.6 Sugar Cane and Sugar Production Programme

As proposed in Annex IV, the construction of the infrastructural facilities will be commenced in the beginning of the 1977/78 dry season and span over four major dry seasons; completion of the all the civil works is expected by July, 1982. The sugar factory will be installed by the beginning of the 1980/81 dry season.

Taking into account such implementation schedule, sugar cane production programme is formulated as shown in Fig. III-4, and is summarized as follows:

Unit: cane ton

Year	Estate Farm	Settlement Farm	Total
1980/81	104,400	-	104,400
1981/82	211,600	-	211,600
1982/83	258,800	79,200	338,000
1983/84	176,100	170,400	346,500
1984/85	208,000	174,400	382,400
1985/86	230,800	180,800	411,600
1986/87 and after	258,000	192,000	450,000

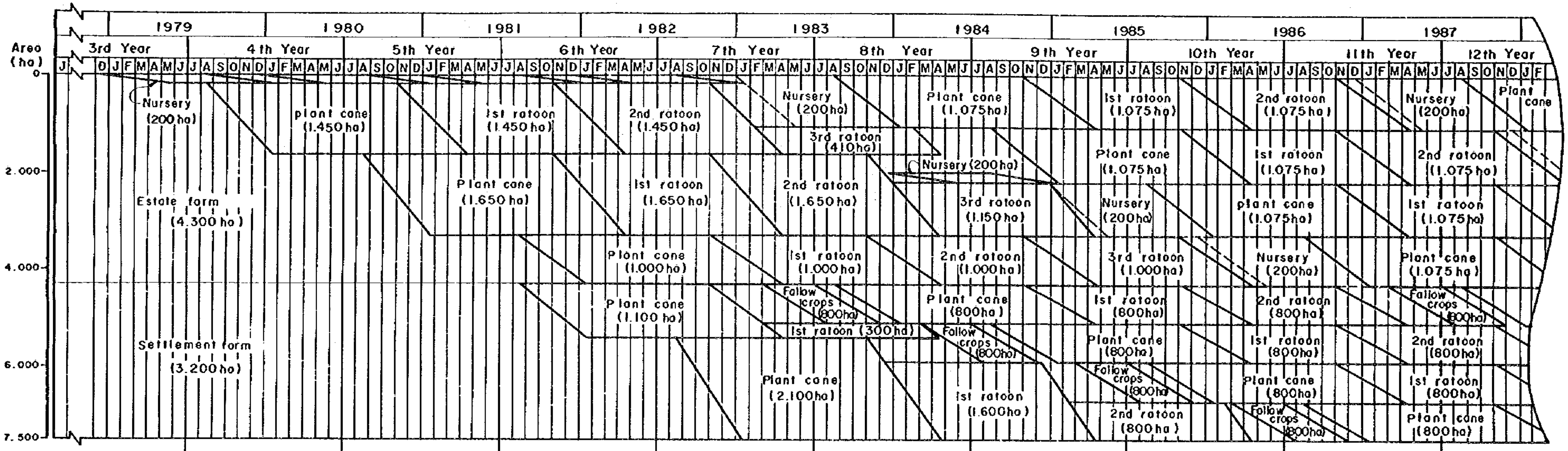
The annual output of the commercial sugar will gradually increase in accordance with the increase in sugar cane production. The commercial operation of the sugar factory will be commenced in 1980/81 dry season with a crushing rate of 1,800 tons per day and a factory yield of 7 %. The crushing rate will be increased to about 2,000 tons per day in 1980/81 and, in 1981/82, it will reach the maximum rate of 3,000 tons per day. The factory yield will be also increased proportionately to the improvement of the factory operation technique. The anticipated factory yields are: 8 % in 1981/82 9 % in 1982/83, and full 10 % in and after 1983/84. The production programme of sugar is summarized as follows:

Year	Cane Production (1000 tons)	Factory Yield (%)	Sugar Production (tons)	Molasses Production (tons)
1980/81	104.4	7	7,300	6,300
1981/82	211.6	8	16,900	11,600
1982/83	338.0	9	30,400	16,900
1983/84	346.5	10	34,700	15,600
1984/85	382.4	10	38,200	17,200
1985/86	411.6	10	41,200	18,500
1986/87 and after	450.0	10	45,000	20,300

3.7 Pilot Farm

Systematic research regarding sugar cane growing as well as training of technical staff should be initiated prior to the full operation of the project. The provision of a pilot farm well equipped and staffed, working in close coordination with the management of the cane field, is one of the essential conditions for the success of the project.

Fig. III - 4 PROPOSED CROP ROTATION PATTERN



Harvested Area(ha)									
(Nursery)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	(200)	
- Plant cane		1.450	1.650	2.100	2.100	1.875	1.875	1.875	
- 1st ratoon			1.450	1.650	1.300	1.600	1.875	1.875	
- 2nd ratoon				1.450	1.650	1.000	800	1.875	
- 3nd ratoon					410	1.150	1.000		
Total		1.450	3.100	5.200	5460	5.625	5.550	5.625	
Sugar Cane Production(ton)		104.400	211.600	338.000	346.500	382.400	411.600	450.000	

The proposed works to be carried out in the pilot farm will be (1) research on mechanized irrigation farming of sugar cane, (2) training of the technical staff and leading farmers in the various fields of mechanized sugar cane cultivation, and (3) multiplication of the improved seed cane.

3.7.1 Site and size proposed

Considering the immediate availability of irrigation facilities and easy access by existing farm road, the site for the proposed pilot farm is selected in the irrigated farm which was originally established by Nippon Koei as a pilot farm at Aveyime with an area of 80 ha. The proposed size of the pilot farm is about 50 ha/1 in due consideration of the proposed works.

3.7.2 Proposed works

The proposed work in the pilot farm will be as follows:

(1) Research work

a) Agronomic research on sugar cane cultivation: The purpose of agronomic research will be limited to the increase of crop yield and the saving in the production cost. The following agronomic trials will be carried out.

1. Variety trials
2. Test on optimum fertilizer requirement
3. Trial on optimum times of planting and harvesting
4. Test on chemical weed control
5. Test on plant protection against pests and diseases
6. Test on optimum ratooning

Particular emphasis will be laid on the variety trials in which response to fertilizer, resistance to pest and diseases, seasonal response and suitability for mechanized harvesting will be investigated for each variety.

b) Research on effective water management: Irrigation water requirement will be exemined on different types of soils. The water management is quite important for cultivation of irrigated sugar cane. A manual for practical water management will be prepared through adequate research work.

c) Research on mechanized sugar cane farming: The research will be designed for the establishment of the most effective mechanization system in the Accra plains; especially working efficiency of each farm machinery on different soil groups will be investigated.

/1: The Aveyime farm is now being used as a rice demonstration farm. The area under the cultivation of rice is about 30 ha. The remaining land of 50 ha is not presently used for any purpose.

(2) Training

The large scale mechanized sugar cane cultivation under the irrigated condition is not familiar for the local farmers as well as the technical staffs in Ghana. The staffs and leading farmers (settler) will be intensively trained for mastering the mechanized sugar cane farming by means of the "learn by doing" technique.

(3) Seed multiplication

The project area covering 7,500 ha will annually require about 11,000 tons of strong and healthy seed cane for planting. The pilot farm, functioning as a pure-line reserve farm, will produce adequate amount of seed cane for its multiplication on the ordinary nurseries.

3.7.3 Proposed organization

The proposed organization for an effective operation of the pilot farm will be set out under the following staff.

1 - Senior Sugar Cane Agronomists
2 - Assistant Agronomists
1 - Irrigation Engineer
1 - Farm Machinery Expert
1 - Senior Officer
1 - Junior Officer (Accountant)
2 - Machine Operator/Mechanic
4 - Foremen

For the successful operation of the Pilot Farm, the technical assistance by foreign experts will be needed for the initial stage of operation. The experts required will be as follows.

1 - Senior Sugar Cane Agronomist
1 - Farm Machinery Expert
1 - Irrigation Engineer

3.7.4 Cost estimate

The initial investment cost for the Pilot Farm is estimated at about US$236,000 as follows:

Item	F.C. (US$)	L.C. (US$)	Total (US$)
1. Rehabilitation of irrigation, drainage facilities, farm road, etc.	13,900	7,700	21,600
2. Buildings including laboratory, garage, etc.	-	63,000	63,000
3. Farm machinery & equipment	110,000	-	110,000
4. Equipment for experiment	21,000	-	21,000
5. Contingency	13,700	6,700	20,400
Total	158,600	77,400	236,000

The annual costs of the operation and maintenance are estimated at US$100,000 equivalent, excluding the cost of consultancy services. The details of the cost estimate are given in the following tables.

Table III-13 Rehabilitation Cost of Pilot Farm

Item	F.C. (US$)	L.C. (US$)	Total (US$)
1. Land Preparation (50 ha)	3,800	2,400	6,200
2. Rehabilitation of canals, drains and roads	1,400	3,000	4,400
3. Replacement cost of pumping facilities	8,000	2,000	10,000
4. Miscellaneous	700	300	1,020
Total	13,900	7,700	21,600

Table III-14 Buildings Required for Pilot Farm Operation

Description	Nos.	Floor area required (m²)	Unit cost (US$/m²)	Amount (US$)
Garage				
For farm machinery and vehicles				
80 PS class tractor	1	16.6		
60 PS class tractor	1	15.4		
Grap loader	1	15.0		
Trailer-truck	1	42.0		
Jeep	2	12.2		
Spare space (20 %)		16.5		
Sub-total		166.7	150	17,500
Garage for farming attachment				
32" x 3 disc plow	1	3.4		
24" x 22 disc harrow	1	12.6		
Ridger	1	4.0		
Spring tooth cultivator	1	3.0		
Swath sprayer	1	5.0		
Fertilizer distributor	1	8.6		
Trash rake	1	5.0		
Spare space (20 %)		8.4		
Sub-total		50.0	150	7,500
Spare parts store room		20.0	200	4,000
Tooling room		40.0	200	8,000
Sub-total		60.0	200	12,000
Laboratory				
Chemical analysis	1	30.0	300	9,000
Crop research	1	30.0	300	9,000
Test mill room	1	20.0	200	4,000
Store room	1	20.0	200	4,000
Sub-total		100.0		26,000
Total				63,310

Table III-15 Farm Machinery and Equipment for Pilot Farm Operation

Description	Nos.	Unit price (US$)	Amount (US$)
Tractor			
80 PS class wheel type tractor	1	12,000	12,000
60 PS class wheel type tractor with high clearance	1	12,000	12,000
Grab loader (Self-propelled)	1	11,500	11,500
Spare parts (20 %)			7,100
Sub-total			42,600
Attachment			
32" x 3 disc plow	1	2,000	2,000
24" x 22 disc harrow	1	1,700	1,700
Ridger	1	800	800
Spring tooth cultivator	1	600	600
Swath sprayer	1	11,500	11,500
Fertilizer distributor	1	900	900
Stubble shaver	1	4,000	4,000
Trash rake	1	2,200	2,200
Spare parts (30 %)			7,200
Sub-total			30,900
Transportation equipment			
6-ton trailer-truck	1	11,000	11,000
2-door jeep	2	7,000	14,000
Spare parts (30 %)			7,500
Sub-total			32,500
Farming tools and others			2,000
Oil supplying equipment			2,000
Total			110,000

Table III-16 Equipment for Laboratory

Description	Nos.	Unit Price (US$)	Amount (US$)
Saccharimeter	1	3,500	3,500
Abbe's Bix meter	1	900	900
Chemical balance	1	300	300
Phamacy balance	1	200	200
Table balance	4	70	280
Platform scale	3	150	450
Electric oven	1	160	160
Electric furnace	1	360	360
Electric vacuum pump	1	200	200
pH meter	1	300	300
Distilling equipment	1	1,200	1,200
Microscope, x 40 - 1,000	1	500	500
Hand refractometer	2	40	80
Soil moisture meter	1 set	4,000	4,000
Tension meter	10 sets	60	600
Electric centrifuge	1	1,200	1,200
Cane test mill with 5 PS diesel engine	1	2,000	2,000
Small aparatus	L.S		1,000
Glass aparatus and others	L.S		500
Transportation charge and others (20 % of the above)			3,270
Total			21,000

Table III-17 Annual Operation and Maintenance Cost of the Pilot Farm

	Item	Amount (US$)
(1)	Personnel cost	36,000
	1 - Senior agronomists	5,000
	1 - Senior officer	5,000
	1 - Irrigation engineer	5,000
	1 - Farm machinery expert	3,000
	2 - Assistant agronomists	6,000
	1 - Junior officer	3,000
	2 - Operators	3,000
	4 - Foremen	6,000
(2)	Labour wages	
	9,400 man/day x 2.2 US$	20,700
(3)	Farm input	7,000
	Fertilizer	4,200
	Agri-chemicals	2,000
	Others	800
(4)	Machinery cost	21,400
	Replacement	10,500
	Repair cost	6,600
	Fuel and oil	4,300
(5)	O & M cost of facilities	12,500
(6)	Miscellaneous	9,400
	Total	100,000

ANNEX IV

DESIGN OF INFRASTRUCTURAL FACILITIES

FEASIBILITY REPORT
ON THE AVEYIME SUGAR PRODUCTION
PROJECT IN ACCRA PLAINS

ANNEX IV DESIGN OF INFRASTRUCTURAL FACILITIES

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