IRRIGATION WATER PLAN IN THE DEVELOPMENT OF TUKAD SABAH RIVER BASIN IN BALI ISLAND, INDONESIA

By
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A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree, Master
of Natural Resource Management

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ABSTRACT

The Tukad Sabah study area is located on the north coast of Bali Island, Indonesia, to the west of the district capital of Singaraja (Fig. 1.1). The area presently supports coconuts, with dryland under cropping, and some single-cropped sawah (basin irrigated rice) supplied from seasonal rivers and springs. According to climate conditions, the study area is generally suitable for the cultivation of a wide range of tropical crops.

The Tukad Sabah has a total basin area of 85 km^2, but the study area only comprises 1500 hectares of it. The study area is located in a region undergoing an extension of the original irrigation scheme, from Umadesa weir to Tukad Grokgak (Fig. 1.2). The basin area has an average annual flow of 5.50 cumecs and mean annual rainfall of 1270 millimetres, of which 86 percent falls in the six month wet season (November to April).

The main objective of this practicum is to develop a water requirement plan for crop irrigation, by using water from Tukad Sabah river. To achieve this objective, the study attempts to estimate the design flow of Tukad Sabah river,calculate each prospective crop's irrigation requirement, and to develop the most beneficial cropping pattern (the cropping pattern yielding the greatest return to the farmer) for the study area.

Since available flow discharge data are limited, long-term records of rainfall were utilized to generate flow data. The design flow of Tukad Sabah was derived by adjusting minimum average monthly flows on the basis of annual rainfall, to estimate flows with 80 percent probability of being exceeded. A peak design flow of 6.33 cumecs and a low flow of 1.29 cumecs was determined (Table 3.6).

Crop irrigation requirements were calculated by summing crop consumptive use and field loss less effective rainfall, multiplied by efficiency factors for water use. (Tables 4.9, 4.10, and 4.11). Average water requirements for the main crop (rice) and dryland crops were determined at about 22 mm/day and 4 mm/day, respectively.

The most beneficial cropping pattern in the study area was determined, based on the calculation of net crop return for six selective crops grown on open sawah and under coconuts. In open sawah, a rice-tobacco crop rotation was shown to give the highest economic return (628.2 thousand rupiahs/ha/annum) followed by a rice-rice rotation (of 301.1 thousand rupiahs/ha/annum). Under coconuts, the highest economic return was derived from a rice-groundnut-groundnut rotation (283.0 rupiahs/ha/annum). However, a use of cropping pattern based on rice is recommended for the following reasons:

- Production of tobacco, which yields the highest economic return, is restricted by monopsonistic marketing.
- The majority of farmers prefer to grow rice if sufficient water is available.

- Indonesian government policy encourages production of rice since rice must be imported to fulfill the domestic demand.

Using the calculated data, a water requirement plan is established for the study area by matching demand and supply on the basis of monthly water distribution (Table 6.3). In open sawah west of the study area, two crops of rice could be cropped with palawija in the dry season. The main constraint to double-cropping of rice in the dry season is the small flow of water from Tukad Sabah during July to September. Farmers within the study area should start land preparation for rice earlier (ie. October) than at present, in order to allow cultivation of a dry season rice crop before the water supply becomes inadequate. A system of rotational irrigation should be practised by area farmers to spread out the peak water requirement throughout the year.

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GLOSSARY

The following acronyms are used in this report:

P3SA - Proyek Perancangan Pengembangan Sumber-sumber Air (Water Resources Planning and Development Project)

LRD - Land Resources Division, UK Ministry of Overseas Development

HYV - High Yielding Variety (rice)

BIMAS - Bimbingan Massal (Mass Guidance)

IPEDA - Iuran Pembangunan Daerah (District Development Tax) Land Tax

IRRI - International Rice Research Institute, Los Banos, Philippines

USDA - United State Department of Agriculture

The following is the administrative hierarchy within the island (Province of Bali:

Kabupaten - regency (Buleleng)

Kecamatan - sub-regency (Seririt)

Desa - village (Kalisada)

Banjar - sub-village (Tegallengah)

The following Indonesian words are commonly used in this report:

Subak - irrigation organization/association

Sawah - bunded fields used for irrigated rice cultivation

Padi - rice crop or rice on the stalk

Palawija - crops grown on sawah in rotation with rice

Gabah - unhusked rice grain

Gotong royong - system of self-help in maintaining irrigation works and for community work in the fields.

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CHAPTER I

THE PROBLEM AND ITS SETTING

1. Statement of the Problem

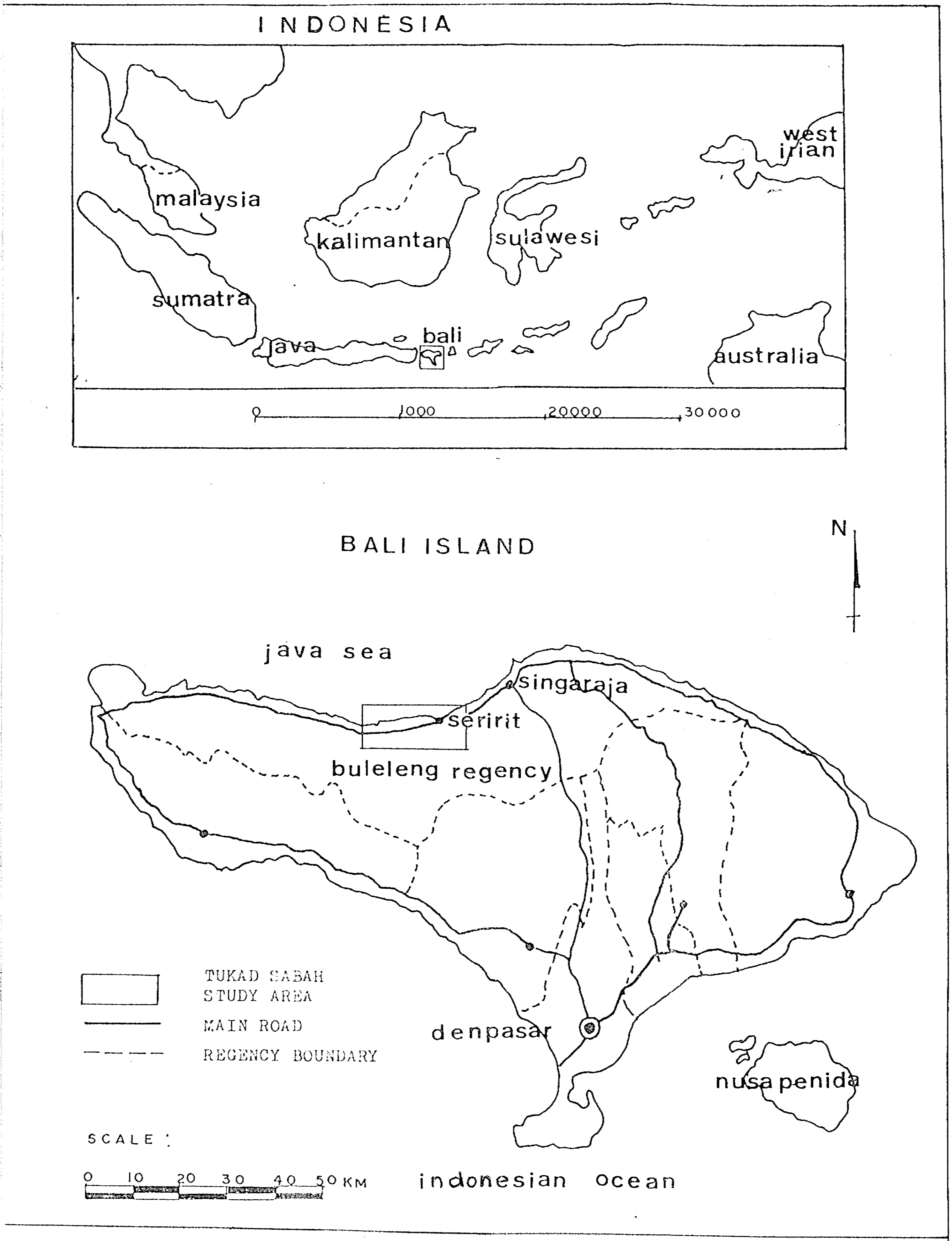
Agricultural production on the northern part of Bali Island, Indonesia, is limited due to a scarcity of water for irrigation. Unlike the southern region of the island where water resources are abundant and agriculture is well-developed, northern Bali is a dry area which receives minimal rainfall from May to October. This seasonal lack of water causes rivers to dry up, and results in a reduction in crop yield by as much as 50 percent.

In attempting to remedy this situation, the Indonesian government has been implementing irrigation projects on major rivers in Northern Bali. One such project is located on the Tukad Sabah River (Fig. 1.1).

The irrigation development of the coastal plain to the west of Tukad Sabah River was initiated in 1965 with design and construction of Umadesa Weir, located approximately 6.5 km upstream of the mouth of the river (Fig. 1.2). The head regulator of Umadesa Canal was designed to convey water to the east bank of the Tukad Gemgem River at a rate of 2.5 cumecs.

Large quantities of sediment enter the head regulator causing siltation, however, which restricts the rate of water discharge. The subsequent build-up of water in the canal can result in flooding onto adjacent agricultural lands, which can lead to crop damage. Flooding is thought to be partly caused because of an incorrect design width for the canal, as it appears very narrow in rel ion to the width of the river.

FIG 1.1


I N D O N E S I A
malaysia
kalimantan
sulawesi
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sumatra
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BALI ISLAND
N
java sea
singaraja
seririt
buleleng regency
denpasar
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TUKAD SABAH STUDY AREA
MAIN ROAD
REGENCY BOUNDARY
SCALE :
0 10 20 30 40 50 KM
indonesian ocean

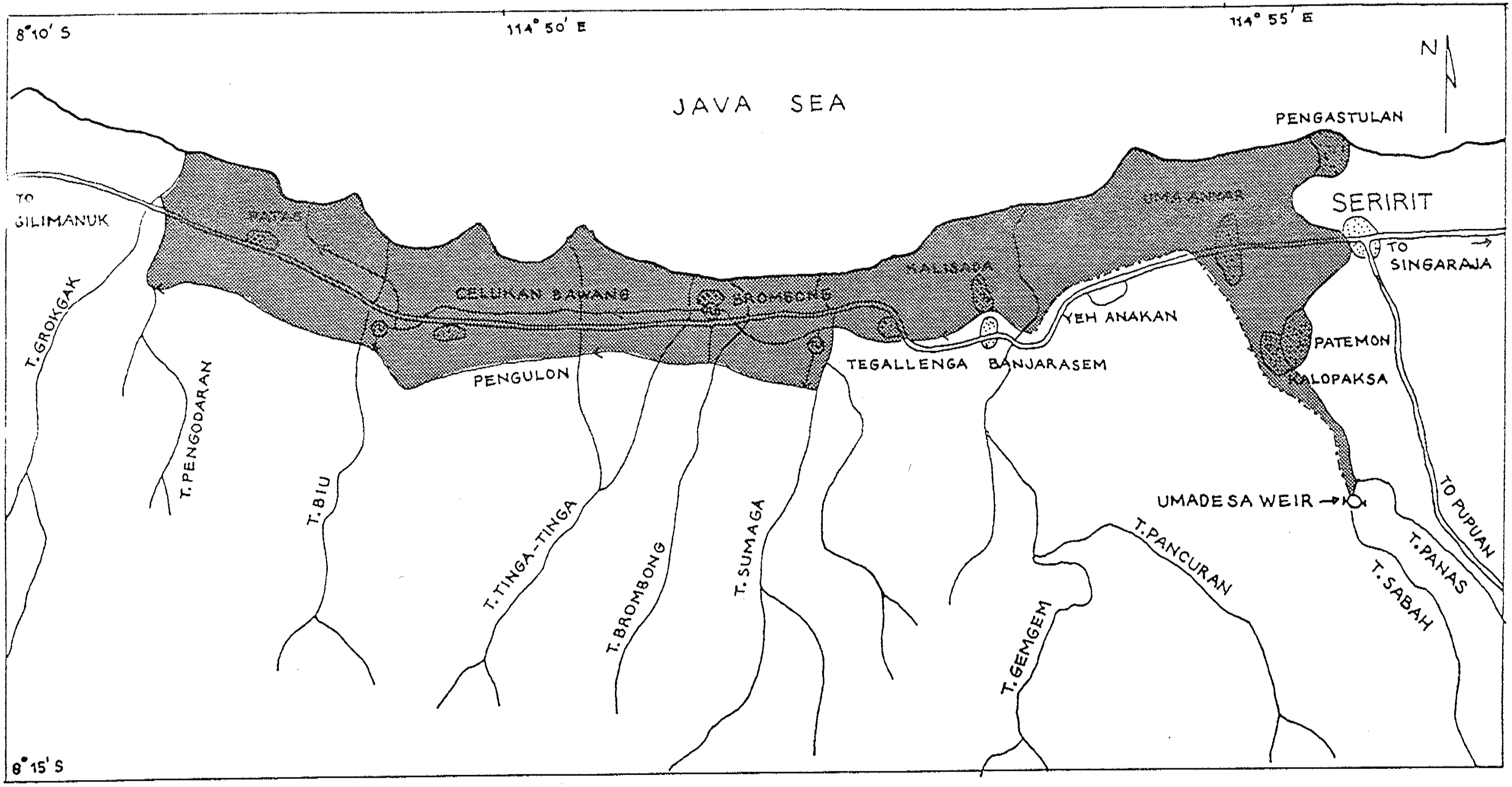


FIG. 1.2

TUKAD SABAH STUDY AREA

In order to prevent future flooding and to extend the irrigated area, the capacity of Umadesa Canal needs to be altered. The local government authority is currently preparing an engineering plan for this development. The purpose of this practicum is to determine irrigation water requirements for the surrounding agricultural land. This information can then be used as a basis for determining a new design capacity for Umadesa Canal.

2. Objective

The main objective of this study is to develop an irrigation requirement plan for agricultural land in the vicinity of Umadesa Canal on the Tukad Sabah River. Since the study will deal only with the use of water for irrigation, the plan has been designed to make water available among various combinations of crops during one crop calendar year. Crops selected are those that give the greatest return to the farmer. To achieve this main objective, the following sub-objectives will also be met:

2.1 Sub-objective one

To estimate the design flow of Tukad Sabah River in order to determine the amount of water available for crop consumption.

2.2 Sub-objective two

To determine specific crop irrigation requirements for each crop capable of being grown in the study area.

2.3 Sub-objective three

To develop a cropping pattern which would maximum the return to the farmer.

3. Assumptions

3.1 Present utilization of Tukad Sabah River for irrigation purposes will continue into the future.

3.2 No charge for water will be imposed, as water for irrigation purposes is free to the farmer based on current government policy.

3.3 In planning cropping patterns, reasons other than economic, may dictate the use of rice instead of other crops.

3.4 The present irrigation demand will be met first, and any remaining flow is considered available for this irrigation developments.

4. Delimitations

4.1 This study will examine the use of water only for irrigation purposes since the flow of Tukad Sabah River is relatively small.

4.2 This study will not develop or evaluate any engineering plans for this river.

4.3 This study will not consider the availability of water from ground water sources within the basin area because of the lack of data.

4.4 Except in the conclusions,this study will not consider any social implications of the proposed irrigation plan.

5. Definition of Terms

5.1 Consumptive use or crop requirement is the amount of water needed for crop growth.

5.2 Irrigation requirement is the consumptive use minus precipitation available for crop consumption. In other words, it is the quantity of water that must be delivered by irrigation to the farm land in order to ensure crop production.

5.3 Field loss is the amount of water lost on farm lands and in irrigation canals due to the deep percolation through the plough pan, seepage in ditches and canals, leakage through and around headgates and other structures, and consumptive use by phreatophytes (USDA, 1970, pg.49).

5.4 Effective rainfall is the amount of rainfall which can be used by a crop (FAO, 1975, pg.18).

5.5 Irrigation efficiency is a constant or a factor which indicates operational water losses created during delivery of water by sluicing, breaks in conduits, and diversion or deliveries in excess of demands.

5.6 Double mass curve is a graph used to check the consistency or the reability of precipitation records under consideration (Booy, 1975, pg. 41).

5.7 Frequency analysis is the expression of hydrologic data on a probabilistic basis. It is standard practice to design on the basis of discharge rates of a given return period - that is, the period in years on the average during which a given discharge rate can be expected to be exceeded (Gray, Donald M., 1975, pg. 12.1).

5.8 Crop calendar is the period during which a crop is grown.

5.9 Cropping pattern is the pattern of crops grown in a crop calendar year.

5.10 Crop budget is a financial analysis pertaining to the amount of monetary return to a farmer for each type of crop grown in a unit of land.

5.11 Financial price or market price is the price at which goods are exchanged in the market, or the current ruling price in the market.

5.12 Accounting price or shadow price is the price which is imputed as the true marginal value of a good or opportunity cost of a resource.

6. Methodology

6.1 The Data

Secondary data processed by agencies in Indonesia were used in this study (e.g. hydrological, climatological and agricultural records as well as background information of the study area).

6.2 Specific Methodologies

The methodology employed in devoloping an irrigation water requirement plan can be described as three major steps.

Firstly the study calculated the amount of water available in the Tukad Sabah River to supply water for crop consumption. To estimate the reliable flow in the river, long-term rainfall records were utilized to generate flow data. For the purpose of design, the minimum average monthly flows were adjusted on the basis of annual rainfall to determine an estimate of flows having 80 percent or 90 percent probability of being exceeded. Data required for this step include flow discharge and rainfal l records.

Secondly, in order to determine the amount of water demanded, water requirements for each prospective crop which could grow in the study area were calculated. This involved a summation of evapotranspiration and field loss, subtracting the effective rainfall, multiplying the result by an efficiency factor for water use (FAO, 1975, pg. 12). Evapotranspiration or crop consumptive use is calculated by multiplying estimated evaporation by crop co-efficient (Gray, 1973, pg. 3.52). Data required in this step are rates of evaporation, percolation, precipitation, and crop co-efficients.

Thirdly, the most beneficial cropping pattern which could be applied in the study area was determined. In this step, net benefit of each crop was calculated based on a crop budget analysis. The economic return by rotation for all possible crop combinations in a crop calendar year was determined by using the above results. Data required in this step include crop prices, crop yields, agricultural inputs and its prices, farm labour, wages, crop calendar, cropping pattern, crop areas, and land use.

The irrigation plan for the study area was established by matching water supply and demand on the basis of monthly distribution.

7. The Importance of the Study

Improving irrigation in the Tukad Sabah River Basin is being considered by the local Public Work Office. A preliminary engineering study has been completed, and currently an engineering plan is being prepared by the above office. This practicum supplements this engineering plan. It provides the basis for:

7.1 Determination of the design discharge of the irrigation canal and the other irrigation structures that will be proposed in the engineering plan.

7.2 Estimations of the land area that can be irrigated by this irrigation project.

7.3 Efficient distribution of the irrigation water in time over the area.

7.4 Deciding on the most beneficial cropping pattern that could give greatest return to the farmer.

CHAPTER II

DESCRIPTION OF STUDY AREA

1. Study Area Boundaries

The Republic of Indonesia is composed of the major islands of Sumatra, Kalimantan, Sulawesi, Java, West Irian and thousands of smaller islands. It has a population of 135 million (1977) on a land territory totalling 1,900,000 km^2. Bali Island is one of the smaller islands situated in the tropical zone (8°S) immediately east of Java Island. Bali has an area of 5,560 km^2 and a population of 2.4 million (1977).

The area for this study is a narrow coastal plain, located in Northern Bali, bounded to the east by the Tukad Sabah River and the small market town of Seririt, to the west by the Tukad Grokgak River and to the south by the foothills of the Patas Mountains. It lies within an existing irrigation area, originating from Umadesa Weir of the Tukad Sabah River which is being extended and remodelled (Fig. 1.2).

According to a proposed plan (Public Work Office, 1977), a low level contour canal extending from Umadesa Weir, largely following the alignment of the existing canal to the Tukad Gemgem will be built. Thereafter, the command area would be divided into two parts: a gravity supply system commanded by an extension of the main conveyor; and a pumped supply system involving the construction of three low lift pump stations located at Sumaga, Brombong and Pengulon. The total size of the irrigated area is 1460 ha of which 1090 ha represent the total net irrigable area. (Table 2.1).

For planning purposes each of the systems is further divided into irrigation units (see chapter 6.1).

2. Geomorphology

Mountains in the central part of Bali Island have created numerous rivers which flow to the sea in a radial pattern. Deep valleys are formed by the swift river currents, until the rivers emerge onto the coastal plain.

The alluvial deposits of the study area form a gentle planar to slightly convex slope from sea level to a height of about 40 metres. Interspersed over this area are small steep-sided knolls and ridges, running almost to the sea, and bounded by the Jembrana volcanics which rise steeply to the south. The study area is extensively dissected by seasonal rivers and watercourses. Heavy vegetation generally covers the banks of the rivers.

To the south, hills of volcanic origin supply soil parent material for the coastal plain. These soils have been formed by alluvial action and have a variety of textural profiles. Most soils are medium textured, but there are also frequently bands of sand or coarser material in the subsoil. Within 100 metres of the coast, soils are very sandy, as this region is essentially a raised beach. Drainage of most soils is poor and in the wet season is a constraint to growing certain annual crops.

TABLE 2.1

IRRIGATED AREA AND NET IRRIGABLE AREAS
(HECTARES)

Canal System	Irrigated Area	Net Irrigable Area
Gravity	673	499
Sumaga Pump	102	77
Brombong Pump	258	168
Pengulon Pump	427	346
TOTAL	1460	1090

SOURCE: Public Work Office - Bali.

Mechanical analysis of these alluvial soil showed that they have a high silt content. They are generally neutral in reaction, have a very high cation exchange capacity, and high levels of most plant nutrients (LRD, 1976)

The soils of the study area are considered suitable for a wide range of crops but their loamy textures and the presence of sandy or gravelly layers near the surface would result in high rates of percolation. This could be reduced in time,however, with deposition of silt from irrigation water and formation of a plough pan. Percolation rate is in the range of 16 to 24 mm/day.

Most of the area lying in the alluvial deposits is backed by the hills of the Jembrana volcanics, and consists of lavas, breccias, tuffs, and associated rock. Just west of the Tukad Sabah there is an outcrop of the Asah formation (comprised of lavas, breccias, pumiceous tuffs and calcareous crack fillings), which accounts for soil variation in the area (Purbo Hadiwidjojo, 1971).

3. Hydrology

3.1 River Systems

Many water courses are found in the study area. Most only flow in the wet season except for a few which are spring fed. The major water sources are the Tukad Sabah and Tukad Gemgem Rivers.

The catchment area of Tukad Sabah above the Umadesa Weir is 82.3 km^2 and the length of the river is 24 km. The Tukad Panas is a tributary of the Tukad Sabah and the confluence is just downstream of Umadesa Weir. The catchment area of Tukad Panas is 40.6 km^2 and the length of the river is 20 km.

The Tukad Gemgem and its tributary, the Tukad Pancuran are immediately to the west of Tukad Sabah (Fig. 2.1). They generally flow year round although in the dry season flows are small. The total catchment area is 51.6 km^2 and the maximum length is 12.8 km.

3.2 River Flow

In order to record flow discharge of the Tukad Sabah River, three gauging stations (2A, 2.B1 and 2.B2) have been established by P3SA (Fig. 2.1). Each station consists of staff gauges positioned at weir structures, or at reasonably uniform reaches of the river. Station 2.B1 is situated immediately upstream of Umadesa Weir. A calibration relationship based on flow measurements taken at regular intervals has been established for each station.

Station 2.B2, however, was destroyed in 1976 so that these records were not used. In March 1976, Station 2A was also destroyed during a flood. Because the flood, changed the shape of the river drastically near this station, further readings showed an erratic flow pattern. Therefore, station 2.B1 was chosen as the best representative of flow in the Tukad Sabah.

Monthly records at 2.B1 were available from the end of 1973 to present (Table 2.2). Staff gauge readings were taken by a local resident at 0600, 1200 and 1800 hours.

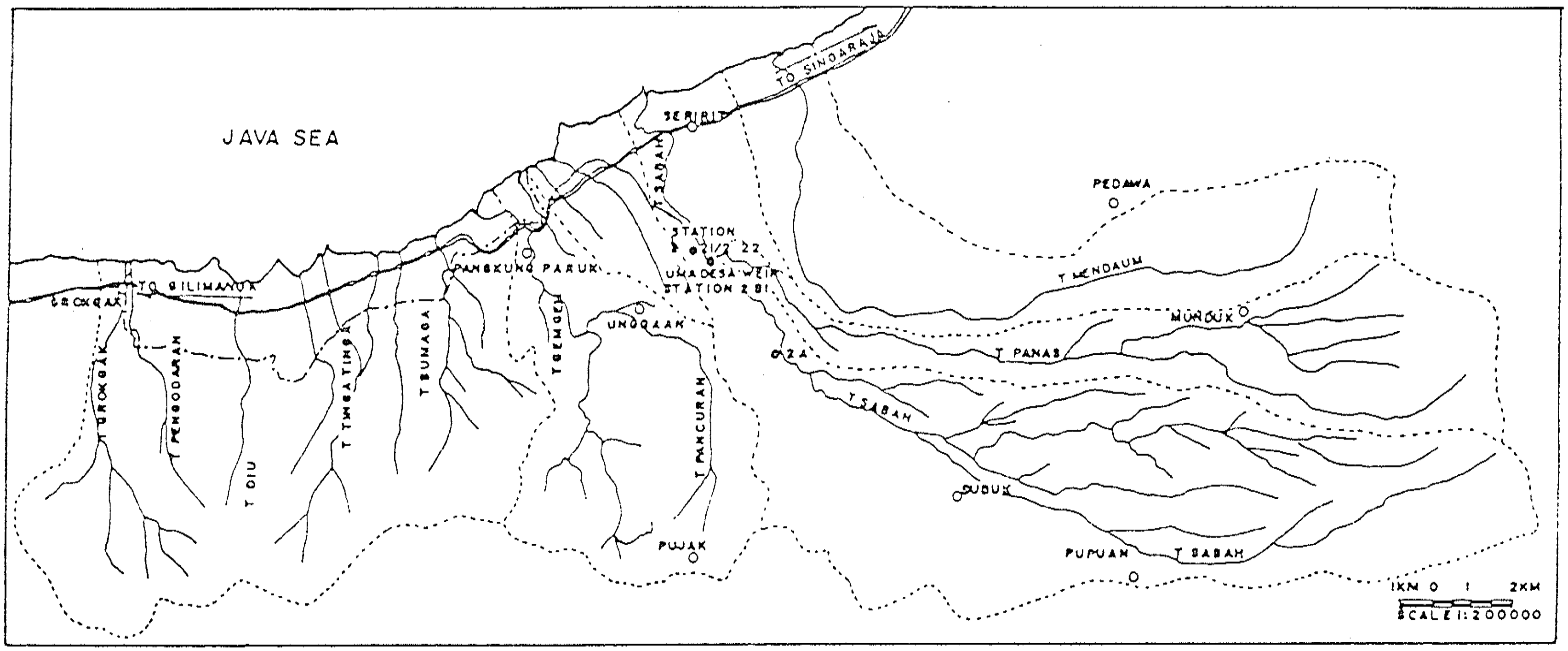


FIG. 2.1
CATCHMENT AREA AND RIVER SYSTEM

LEGEND

— — — —	CATCHMENT AREA BOUNDARY
—·—·—	PROJECT AREA BOUNDARY
○	RAIN GAUGE
o	STAFF GAUGE

SOURCE : PUBLIC WORK OFFICE BALI

TABLE 2.2

TUKAD SABAH MONTHLY FLOW AT UMADESA WEIR (2B1)

	FLOW (cumecs)			
MONTH	1974	1975	1976	1977
January	6.65	9.00	6.60	6.85
February	6.60	6.85	7.65	7.85
March	4.21	6.30	8.40	11.30
April	3.45	6.60	5.80	7.73
May	2.16	5.80	6.60	8.10
June	2.16	5.50	6.60	5.20
July	2.41	6.30	2.16	4.75
August	2.16	2.41	1.66	5.80
September	2.16	3.96	3.20	5.00
October	2.16	3.45	5.80	5.25
November	3.45	4.75	6.05	6.60
December	3.20	6.60	5.25	5.80

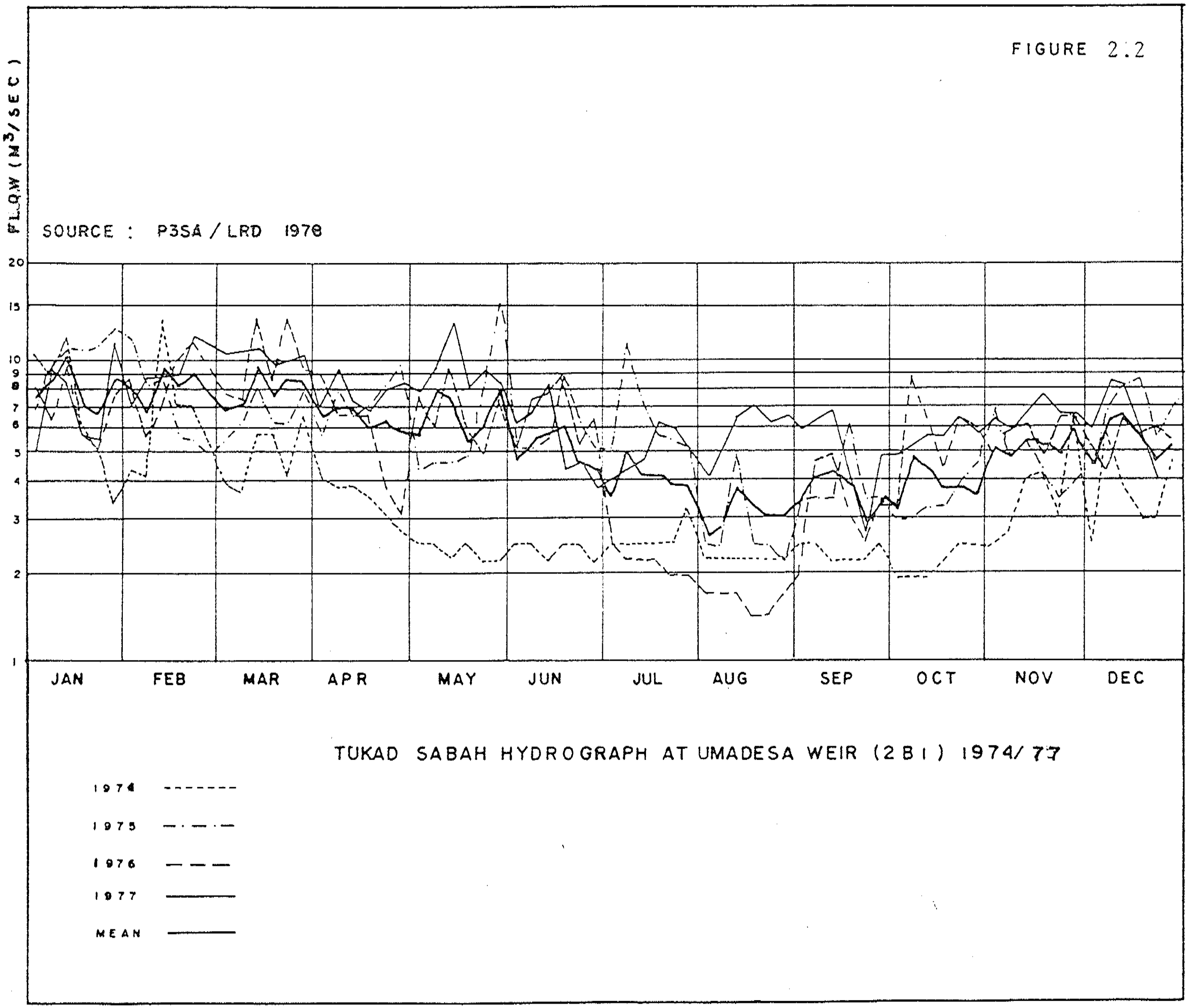
SOURCE: P3SA Office, Singaraja - Bali.

An automatic stage recorder was installed at station 2B1 and weekly charts were then available in August 1977. During the wet season, rain storms often occured in the early afternoon, so that peak flow was reached in the evening and would have subsided by the following morning. A hydrograph reading, taken during a small flood,showed that peak flow was reached at 2100 hours, but subsided nine hours later. Thus, a gauge reading made at 1800 hours and another the following morning at 0600 hours would only record a small part of the flood run off. It is unlikely that this flood water could have been used for irrigation, however, since it was of short duration and occured mainly at night. Non-recording of these peak flows is, therefore, of little importance for the purpose of planning this irrigation project.

The flow in the Tukad Panas is measured just upstream of its confluence with Tukad Sabah at a permanent weir site, but only one year of records is available.

Gauging stations have similarly been established by P3SA on the Tukad Gemgem, but again the period of records is limited to less than two years. For the purposes of planning, it is assumed that flows of the Tukad Gemgem are fully utilized for irrgation of agriculture, and therefore there is no part of the reliable yield (base flow is less than one cumec) that can be injected into the canal system. This also applies to flows in all seasonal rivers in the project area between the Tukad Gemgem and the Tukad Grokgak. Hence the major source of water is the Tukad Sabah. The 5 day records are plotted in Figure 2.2.

FIGURE 2.2



TUKAD SABAH HYDROGRAPH AT UMADESA WEIR (2B1) 1974/77

The existing flow diverted into the Umadesa irrigation canal has been recorded at two staff gauge stations 2.21 and 2.22. Station 2.21 was immediately downstream of the canal head regulator but in 1976 was moved to a position downstream of the Kalopaksa tunnel because of sediment accretion.

3.3 Rainfall

Intermittent rainfall records totalling almost 50 years were available for two rainfall stations (Munduk and Pupuan) on the perimeter of the catchment area. (Fig. 2.1). There are nine other rainfall stations in the catchment area, but their recording period are not consistent. Records fall into three distinct periods:

(1) Those before 1940 taken during the time of the Dutch administration.

(2) Those from 1950 to 1972 taken by the Indonesian Agricultural Service.

(3) After 1973 taken by the Survey Section of P3SA Bali (Bali Water Resources Planning Project) at Singaraja.

No records are available for the period 1941 to 1949 during the Japanese occupation and the immediate aftermath. In the first period, there are records for three stations (Grokgak on the coastal plain, Pupuan and Munduk). After 1950, a further station was established at Seririt. In 1973, P3SA establihsed five new stations; Pangkung Paruk in the Tukad Gemgem headwaters, Unggahan and Bujak in the Tukad Pancuran headwaters, Subuk in the Tukad Sabah headwaters and Pedawa to the east of Tukad Panas. (Fig. 2.1).

A summary of the rainfall stations including elevation and period of records is given in Table 2.3.

Fig. 2.3 shows the mean monthly rainfall distribution for the stations at Seririt, Munduk, and Pupuan. Mean annual rainfall on the coastal plain is about half that occuring in the headwaters area. The annual distribution distinctly falls into a wet season (November to April) and a dry season (May to October). Mean annual rainfall is 1270 mm of which 86 percent falls in the wet season.

Double mass plotting was carried out to assess the general reliability of the rainfall data for Pupuan (Fig. 2.4). The recorded rainfall at the stations of Grokgak, Pupuan and Munduk were aggregated and the individual records of Munduk and Pupuan plotted separately against the total. The records at Pupuan were found to be the most consistent and were assumed to represent the conditions in the Tukad Sabah headwaters. The monthly rainfall records for Pupuan are given in Appendix I.

4. Climatology

The climate of the study are is generally suitable for the cultivation of a wide range of tropical crops. The climate pattern is dominated by the division of the year into wet and dry seasons.

4.1 Temperature

In the study area, average temperature fluctuations throughout the year are very small (Table 2.4). The mean daily temperature is 27°C. Diurnal temperature differences are much

TABLE 2.3

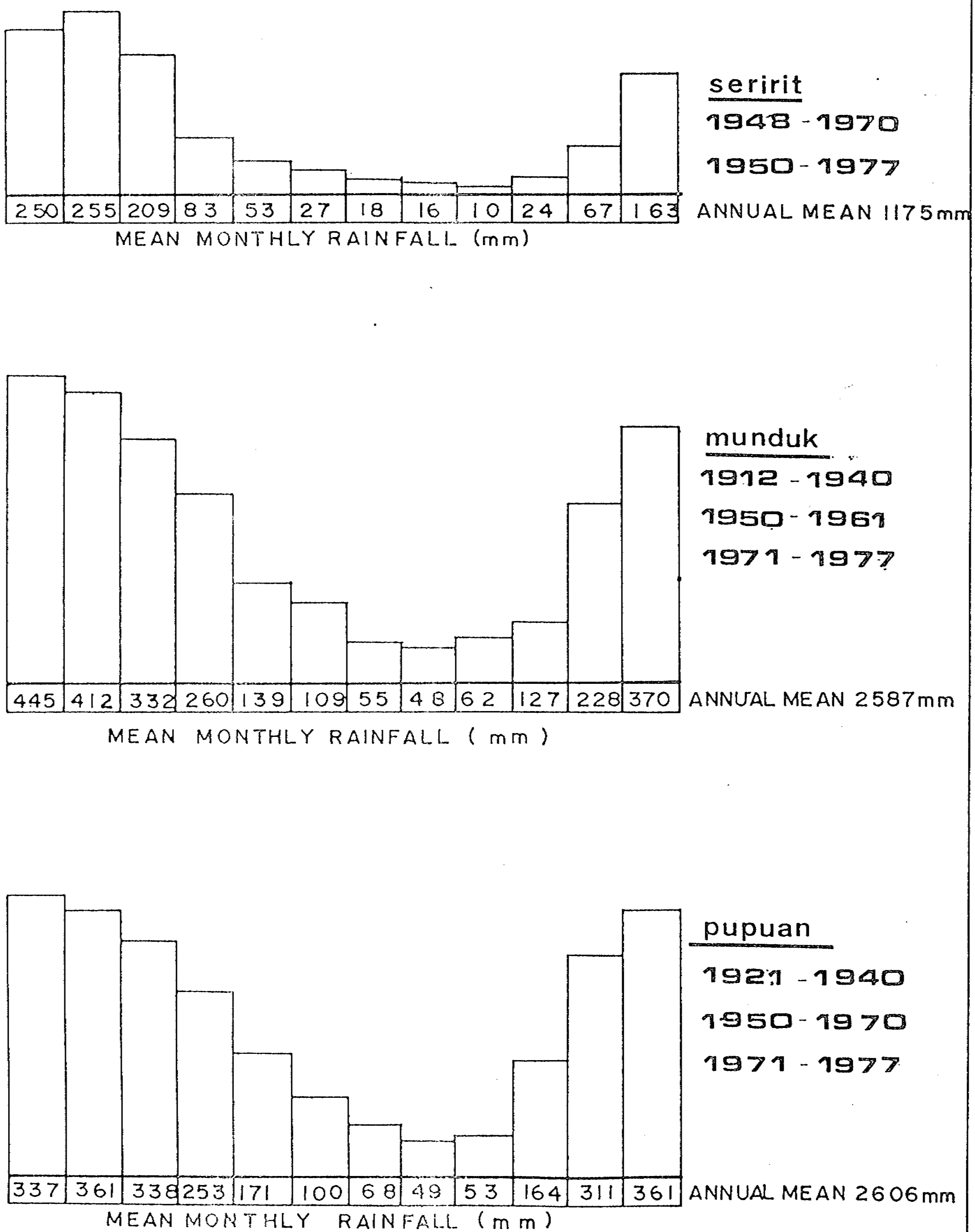
DETAILS OF RAINFALL STATIONS

NAME	ELEVATIONS (metres)	PERIOD OF RECORDS
Seririt (Bubunan)	10	1950-1970,1971-1977
Pangkung Paruk	40	1973-1977
Unggahan	120	1973-1977
Pujak	800	1973-1977
Subuk	310	1973-1977
Pupuan	800	1921-1940,1950-1970 1971-1977
Munduk	730	1912-1940,1950-1961, 1971-1977
Pedawa	670	1974-1977
Grokgak	45	1929-1940,1950-1977

SOURCE: P3SA - Bali, Location of raingauge see Fig. 2.1.

FIG 2.3

SUMMARY OF MONTHLY RAINFALL (m.m)



DOUBLE MASS GRAPH FOR PUPUAN

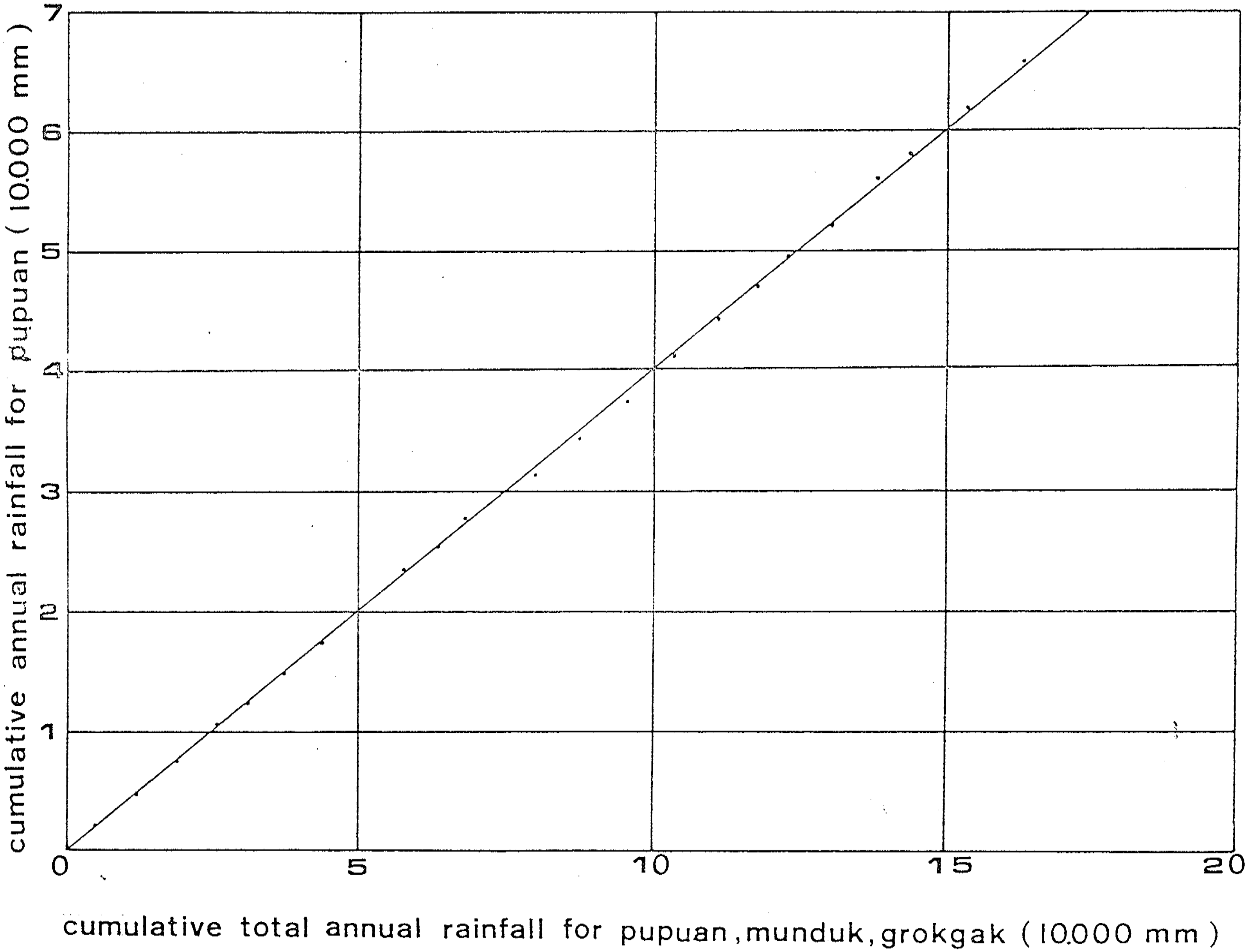


FIGURE 2.4

greater and are greatest during the dry season, which is typical for an equatorial situation. At no time of year would extremes of temperature have any marked effect on the suitability of the area for most tropical crops.

4.2 Hours of sunshine

There is a range from four hours of sunshine per day in the wet season to more than eight hours per day during the driest months. (Table 2.4) The relatively low levels of sunshine during the main rice growing season, January to April, might be reflected in a comparison of the yields of rice grown in wet and dry seasons. However, there is no reliable data on which to base this comparison and it does not appear to be a significant factor in the minds of local farmers.

4.3 Relative humidity

Relative humidity for the study area is in the range of 70 to 80 percent throughout the year (Table 2.4). It is highest during the wettest months and lowest in the dry season. Conditions during the wet season undoubtedly favour the incidence of plant diseases, and thereby constrain satisfactory cultivation of a number of crops susceptible to fungus diseases.

4.4 Wind velocity

Wind velocity seldom reaches speeds which would cause serious damage to agriculture (Table 2.4). Combined with heavy rain in the wet season wind sometimes results in lodging of the rice crop near harvest time especially with long-strawed, traditional varieties.

TABLE 2.4

SINGARAJA CLIMATOLOGICAL STATION, SUMMARY OF DATA
(1973 - 1977)

MONTH	Temperature °C			Sunshine			Open Water Evaporation	
	Average daily	Maximum daily	Minimum daily	Av.hours per day	Rel.Humidity %	Av.wind speed km/hour	Class A Pan mm/day	Penman estimate
Jan.	27.0	29.6	24.4	4.19	80.4	4.0	4.9	5.3
Feb.	27.0	29.6	24.2	4.69	82.0	2.8	5.2	5.1
Mar.	27.3	29.9	24.0	4.88	79.5	2.3	5.1	5.3
Apr.	27.4	30.7	23.8	7.30	77.4	3.1	5.4	5.7
May	26.8	30.8	23.5	7.00	79.2	2.0	4.8	5.2
Jun.	26.8	30.7	22.4	8.21	75.2	2.9	5.5	5.2
July	26.4	30.2	22.2	8.62	72.8	3.1	5.5	6.1
Aug.	26.8	30.5	22.1	8.80	71.1	3.7	6.2	6.1
Sept.	27.6	31.1	23.4	7.66	72.1	3.5	6.5	6.3
Oct.	28.4	31.5	24.1	7.46	71.9	3.2	6.0	6.8
Nov.	27.9	31.1	24.4	6.16	73.2	3.4	5.7	6.3
Dec.	27.7	30.6	24.3	4.44	75.1	3.3	5.2	5.7

SOURCE: P3SA Singaraja Climatological Station.

4.5 Evaporation

Table 2.4 presents data for open water evaporation rates. The data were obtained from work done by the P3SA Bali, which compared evaporation from Class A Pan with figures obtained from calculations using the Penman method. The differences between the figures are not fully explained, but are partly attributed to experimental error and partly to the proximity of the climatological station to the sea. In the latter case, the generally lower rates of evaporation recorded from the Class A Pan could be due to loss of energy advecting from the land to the sea. Lateral energy movement might be expected since the land would heat more rapidly than the sea during the day, and cool more rapidly at night.

Both sources of data are based on rather short term records but since it provides a more conservative basis on which to estimate crop water use, the Penman figures for evaporation will be used for this study.

5. Agriculture

Agriculture is the dominant sector in the economy of the study area. Of the total population, about 90% live in a rural area, and about 80% of the total labour force are farmers.

Because of the warm climate, a wide variety of crops are grown throughout the year. A highly diversified and complicated cropping pattern is also practiced. Techniques such as relay planting and inter-cropping of dry land farmed crops are common. Rice is the base crop, and the others which correspond with the rice growing period are also planted. Water is an important factor in deciding the cropping together with the limitations in topography and land capability.

Terracing of steep terrain, as the result of population pressure and land constraint, is also common. Farm machinery is not used on terraced land, but oxen, the draft animals on the farm, and human labour are used.

5.1 Irrigation System

Utilization of land and water resources in Bali, is very intensive, and their use is coordinated by an irrigation association called "subak". The small, terraces of rice fields are irrigated by long subak canals. Most of the subak systems were built long ago, but are kept in use through careful maintenance. A system generally consists of an intake (undation type), a simple temporary weir (built of bamboo and boulders, situated sufficiently upstream at a higher elevation) and long and unlined canals which convey water by gravity to reach land on the ridges. Diversions or main canals are often shared by more than one subak. Subak facilities are built and maintained by the subak members, who share the cost and labour required in proportion to their farm size. The Indonesian government contributes materials, but only in the case of the Umadesa weir does it play a direct role in operation and maintenance of the system.

During the dry season, water in the rivers is fully utilized. Since the irrigation areas are much larger than the assured water supply in the dry season; irrigation water must be stored during the wet season. During the dry season, the scarce resource is then over-appropriated, and water allocation becomes complicated. When water is in short supply, in flow of water to each farm is controlled by the subak officers so that each farm gets the same volume of water according to unit area. In the dry season and in time of water shortage, a rotational system of irrigation is practised in most subak, indicating that farmers are familiar with this form of discipline.

Water service is generally efficient in a subak system. The government policy is to maintain the subak with necessary assistance and support. New irrigation facilities are turned over to subaks upon completion of construction, and new subaks are established for new development areas. Government thus indirectly subsidizes irrigation projects of the small land holders.

To obtain information on the present extent of irrigation and the type of farming practised, a survey was conducted by P3SA Bali in 1976 of 12 subaks in the study area vicinity. These subaks having an area of 743 ha are located between Tukad Sabah in the east and Tukad Grokgak in the west (Table 2.5 and Fig. 2.5).

About 156 ha of these subaks fall within the study area boundary, comprising the subaks of Pengulon (60%), Tegallengah (100%), Banjar Munduk (88%), and Kalisada (100%).

The six subaks east of Tukad Gemgem are irrigated from the Tukad Sabah, five of them from the Umadesa weir and canal. They are considered to be outside the study area because

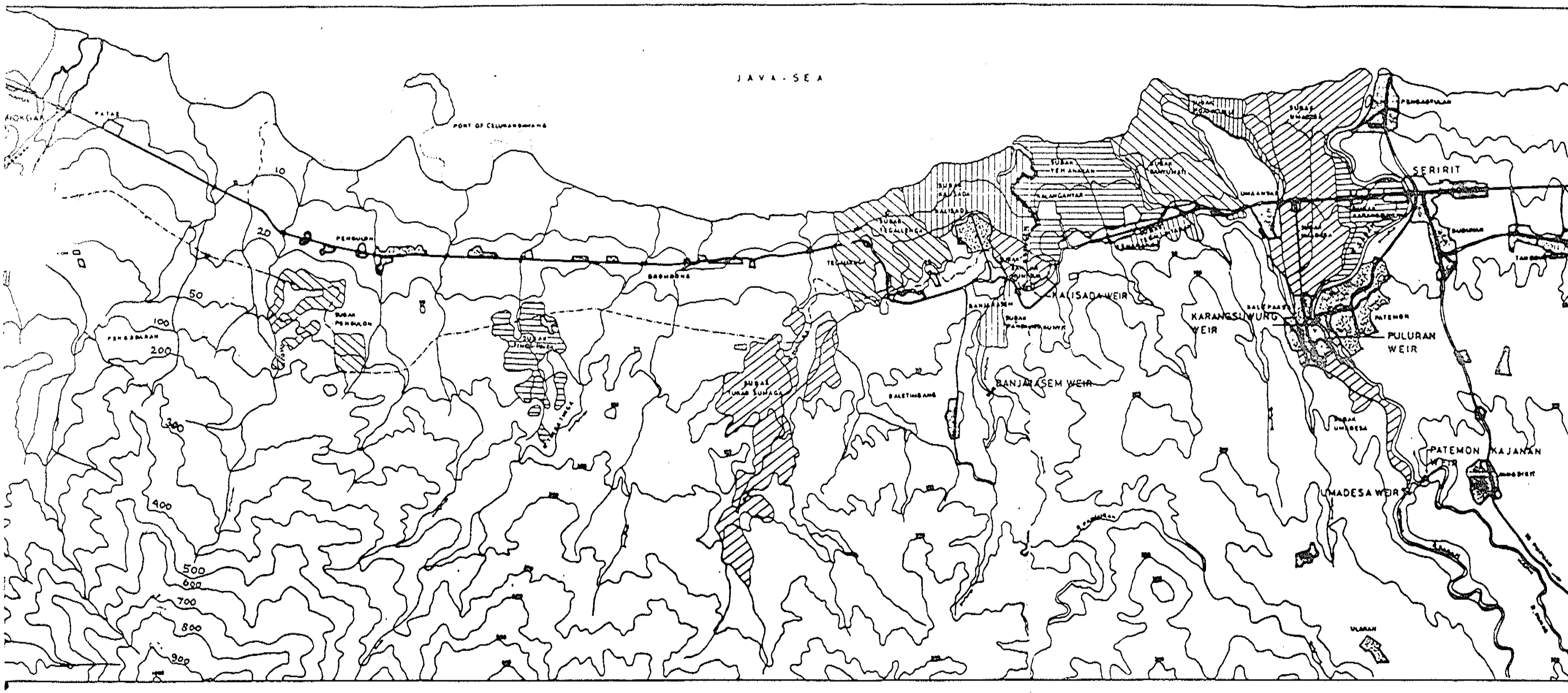


FIG. 2.5 EXISTING SUBAK

SCALE: 1:100,000
SOURCE: Public Work Office, Bali, LRD (1976)

TABLE 2.5

SUBAK AREA AND WATER SOURCE

Name of Subak	Water source	Total Area (ha)	Project area (ha)
Pengulon	T.Biu	26	16
Tinga-tinga	T.Tinga-tinga	39	2
Tukad Sumaga	T.Sumaga & springs	102	-
Tegallengah	T.Sumaga & springs	53	53
Banjar Munduk	T. Gemgem	17	15
Kalisada	T.Gemgem	70	70
Yeh Anakan	T.Sabah*	81	-
Tegal Intaran	T.Sabah*	25	-
Banyumati	T.Sabah*	87	-
Ponjok Cukli	T.Sabah*	18	-
Umadesa	T.Sabah*	190	-
Karang Suwung	T.Sabah	35	-
		743	156

* From Umadesa weir

SOURCE: P3SA, Subak Survey, 1976.

implementation of the project would bring no benefit to them. However, their irrigation requirements will be met first before water can be allocated to areas further to the west. These six subaks have water available for two crops of rice per annum, their usual cropping pattern, but a few farms grow tobacco instead of a second crop of rice.

All subaks west of Tukad Gemgem grow rice in the wet season but only limited area of sawah can be irrigated for a second rice crop. Palawija crops, mostly groundnuts, are grown in the dry season with limited irrigation.

In all subaks surveyed, the timing of land preparation for the rice crop is determined by the availability of a reliable supply of water and is strictly controlled within the subaks. In the wet season a continuous flow of water is allowed in the canals and through the sawahs. There is no attempt to impound water in the sawah basins and thus make use of rainfall. As the wet season ends and river flows decrease, shortages of water sometimes occur,rationing has to be imposed.

5.2 Land Use

Seven categories of land use in the study area have been distinguished (Table 2.6 and Fig. 2.7).

About 92 percent of the study area is presently under agricultural production, and the remaining 8 percent is occupied by villages, roads, rivers and other non-agricultural land classes.

Nearly 80 percent of the study area is planted with coconuts, on average 120 trees per hectare. The major category

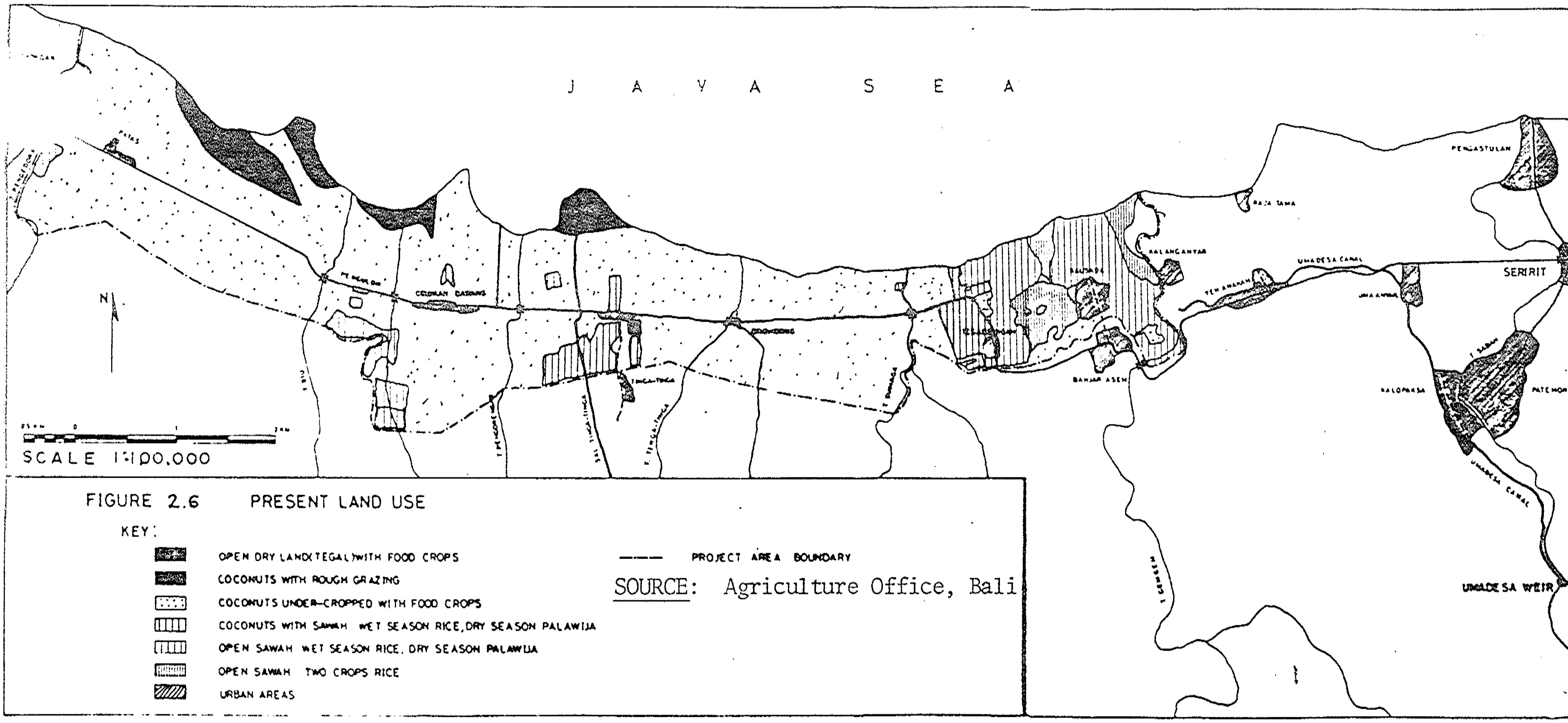


FIGURE 2.6 PRESENT LAND USE

SOURCE: Agriculture Office, Bali

TABLE 2.6

PRESENT LAND USE

CATEGORY	Area (ha)	Percent
Agricultural		
Open dryland with food crops	8	0.5
Full stand coconuts with rough grazing	72	5.0
Full stand coconuts with food crops	1015	70.0
Full stand coconuts with sawah rice and palawija	56	4.0
Open sawah one crop rice/year and palawija	138	9.0
Open sawah two crops rice/year	53	3.5
Sub-total agricultural	1342	92.0
Urban and Other Non-agricultural		
Village areas, roads, rivers, etc.	118	8.0
TOTAL STUDY AREA	1460	100.0

SOURCE: Agriculture Office

of agricultural land use, accounting for 70 percent of the study area, is coconuts undercropped with food crops. This type of agriculture stretches from the western boundary of the study area to Tegallengah in the east. Near the coast, in the western half of the study area, some of the coconut crops are not undercropped but remain in permanent grass land which is used as rough grazing for cattle and buffalos.

In Tegallengah, Tinga-tinga and to a lesser extent at Celukan Bawang and Pengulon, some land between coconut trees has been developed as sawah. This is a recent development and it seems likely that the above average rainfall during the last five years has encouraged farmers to utilize additional flows of water which exceeded requirements of established subaks. However, much of this category of land is not yet admitted to the subak areas, indicating that the subaks feel that it is still too marginal to be offered benefits of membership. A very small area, 0.5 percent, is open dry land. This is mostly around Tinga-tinga.

About 12.5 percent of the study area, nearly all in the eastern end, is under open sawah. It is located in the subaks of Pengulon, Tinga-tinga, Tegallengah, Banjar Munduk and Kalisada. While most of the sawah in these subaks can only be planted with rice in the wet season (December - April), about 53 hectares in Tegallengah and Kalisada subaks are irrigated from the Tukad Gemgem to support a second crop of rice in the dry season. The rest of the open sawah is planted with palawija crops, principally groundnuts, in the dry season.

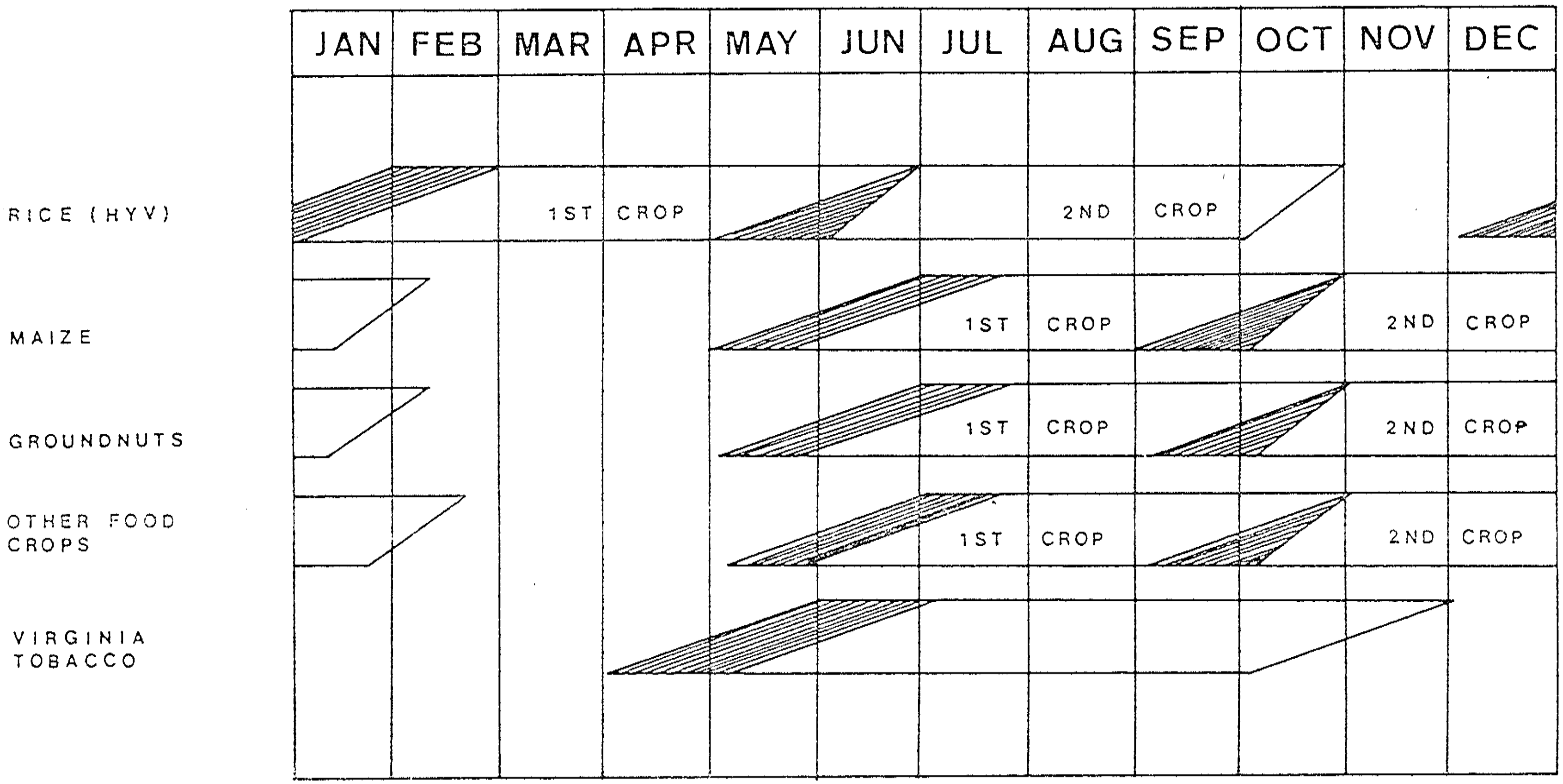
Palawija crops can generally be irrigated with the limited amount of water available. In Pengulon, Tinga-tinga and Tegallengah, two successive palawija crops may be grown.

5.3 Crops and crop calendar

Before discussing the present cropping pattern in the study area, it is necessary to define the periods during which each crop is grown. These vary according to the situation, the cropping periods in sawah are somewhat different from those on dry land.

In the sawah areas (Fig. 2.7), the availability of water determines the timing of land preparation for rice. This process rarely starts before December, and sometimes continues into February. A period of 30 days is sufficient for this operation, and seed beds are prepared and sown during this time. Transplanting takes place from January to March. The length of time till harvest depends on the type of rice grown. High yielding varieties (HYV) mature in about 120 days, traditional varieties take about 140 days or longer. A second crop of rice sometimes follows, but land preparation must be done promptly. It is generally not possible to plant a second crop of rice after a June harvest, however, because of a lack of water. The second harvest generally takes place in October. Even if a crop can be grown or harvested later than this, the onset of rains can upset harvesting and drying operations.

Where it is not possible to grow a second rice crop, palawija crops are grown. Palawija crops such as groundnuts,



SOURCE : AGRICULTURE OFFICE - BALI

KEY:

LAND PREPARATION

CROP CALENDARS
SAWAH AREAS

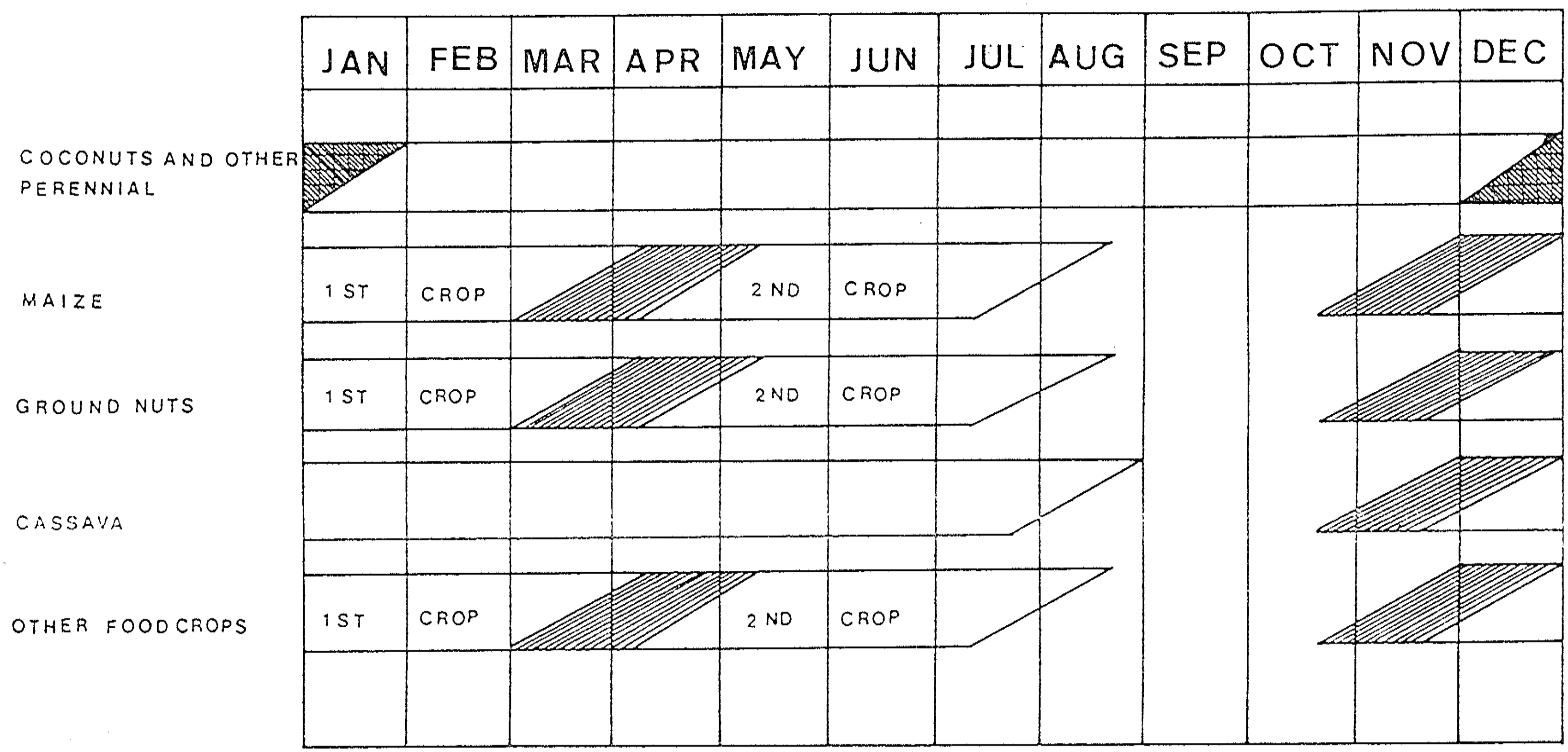
FIG.2.7

maize, grain legumes, and other food crops generally mature in 100 days or less after sowing. A period of 20 days is allowed for land preparation for these crops which are planted in the period of May to July. A second palawija crop may follow the earlier plantings, but it will get less irrigation and its harvest period will extend into the wet season. Production of a second palawija crop is not very common in the study area.

A recent development has been the introduction of virginia flue-cured tobacco as a dry season crop on sawah areas. This crop is grown under the supervisor of the British American Tobacco (BAT) who provide capital, working capital, and inputs of all necessary materials on credit, and buy the cured leaf at the end of the season at an agreed price. Where Virginia tobacco is grown under a BAT scheme, it follows the first rice crop and is transplanted in May to June. Land preparation takes about 30 days. During this period, seed beds are prepared and sown. Seedlings are planted after 6 weeks. Harvesting of the tobacco starts in August and can extend into November.

In the dry land areas (Fig. 2.8), replanting of coconuts and other annual crops such as bananas, is generally done in January to make use of reliable rainfall at that time.

Maize, groundnuts, cassava, and other food crops are grown on most farms in the coconut areas. Land preparation and planting is done in November to December, and a second crop is planted in March to April. This crop can be started



SOURCE: AGRICULTURE OFFICE BALI

KEY

LAND PREPARATION

PLANTING PERIOD PERENNIAL CROPS

CROP CALENDARS
DRYLAND AREAS

FIG. 2.8

earlier than in sawah areas because it does not depend to such an extent on reliable rainfall. Thus, two cropping periods are possible for these crops. Cassava is generally planted at the start of the wet season and is harvested seven to eight months later. Groundnuts comprise the principle cash crop. Other crops are grown primarily for home consumption and any surplus is sold locally. Yields are generally very low. Nearly all farms which grew coconuts also grow some bananas, which are an important source of food for livestock in the dry season. Fruit production is of secondary importance.

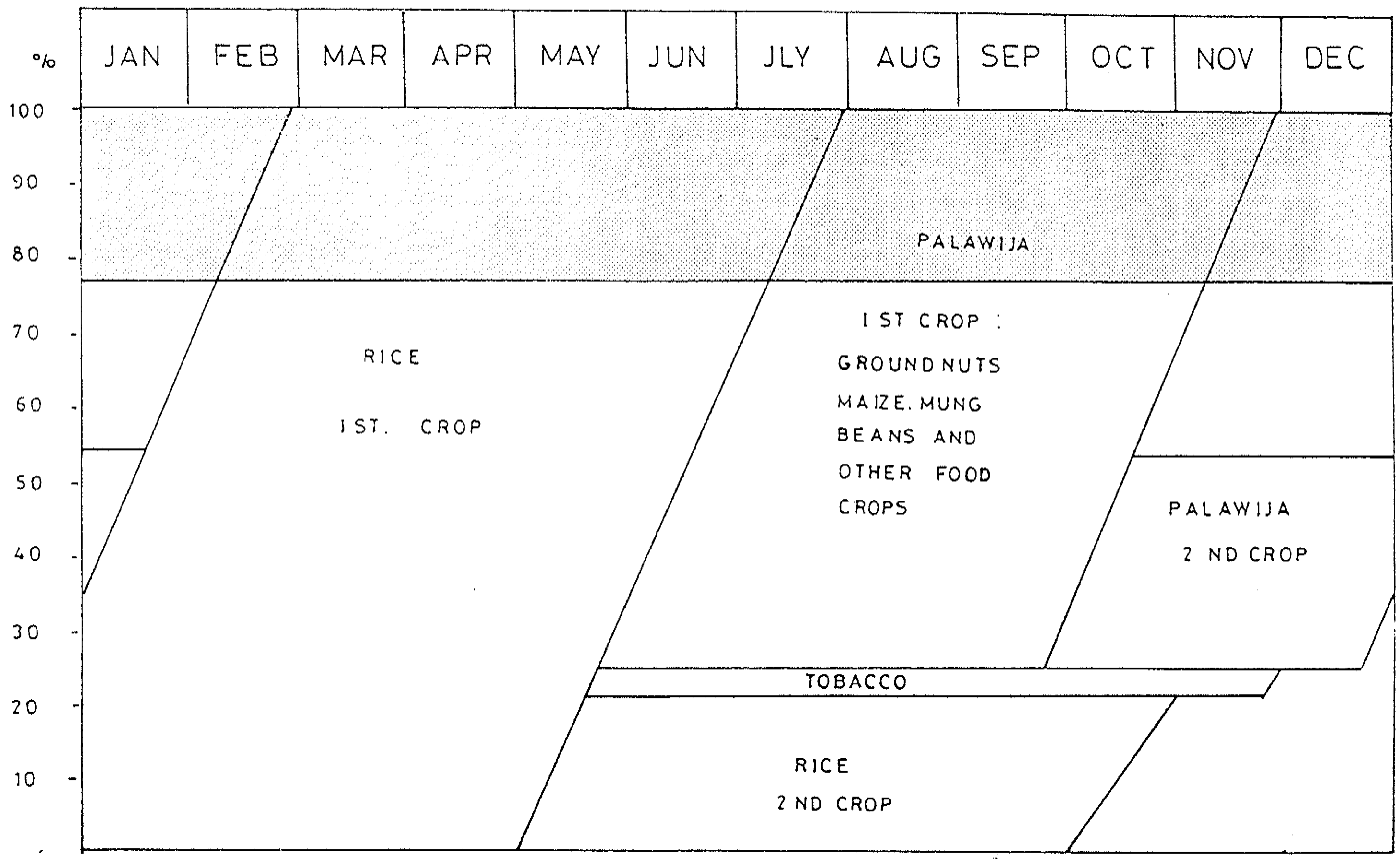
5.4 Cropping patterns

Fig. 2.9 and 2.10 show two generalized cropping patterns followed in sawah and dry land coconut areas, respectively.

The total area of sawah land is 247 ha, which includes 56 ha (23 percent) of sawah grown under coconuts. The area having a second rice crop is 53 ha, (21 percent) and the remainder of the sawah land is planted in palawaja crops. Thus 79 percent of the sawah is planted under palawija crops from May to November (Table 2.7) but only 34 percent is planted with a second palawija crop, mostly maize, from September onwards.

The present cropping pattern for dryland areas is shown in Figure 2.10 . About 99 percent of these areas are planted with coconuts, 6 percent are used for rough grazing under coconuts, and the remainder, including 8 ha of open land, is planted twice a year with food crops. The principle crops

FIGURE 2.9 PRESENT CROPPING PATTERN.
SAWAH AREAS



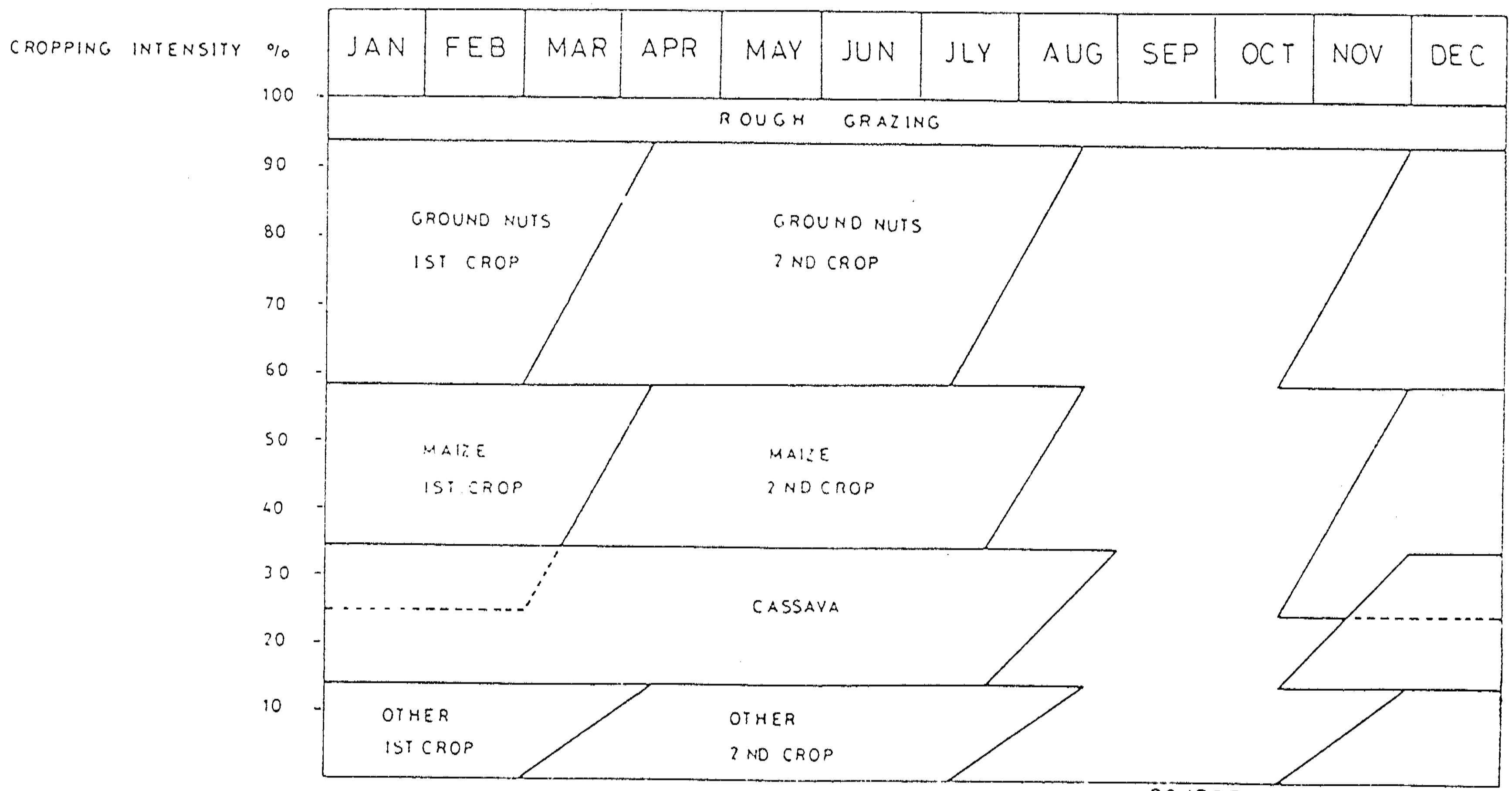
SOURCE : AGRICULTURE OFFICE
BALI,
LRD SURVEY.

KEY :

SAWAH UNDER COCONUTS

FIGURE 2.9

FIGURE 2.10 PRESENT CROPPING PATTERN.
DRYLAND AREAS



SOURCE :- AGRICULTURE OFFICE BALI

LRD SURVEY

KEY :

------ MAIZE INTERCROPPED WITH CASSAVA

NOTE :

99 PERCENT OF TOTAL AREA PLANTED WITH FULL STAND COCONUTS PLUS BANANAS ON FOOD CROP AREAS

TABLE 2.7

SAWAH AREAS, PRESENT CROPPING PATTERN

CROP	First	%	ha	Second	%	ha	Third	%	ha
	Cropping Period								
Rice	Dec-Jun	100	247	May-Oct	21	53			
Maize				May-Nov	4	10	Sept-Jan	27	67
Groundnuts				May-Nov	53	131			
Mungbeans				May-Nov	16	40			
Other food crops				May-Nov	4	10	Sept-Jan	7	16
Tobacco				May-Nov	2	3			
TOTAL		100	247		100	247		34	83

SOURCE: LRD Survey, 1976, Agriculture Office, 1977.

TABLE 2.8

DRYLAND AREAS, PRESENT CROPPING PATTERN

	Cropping Period					
CROP	First	%	ha	Second	%	ha
Maize	Nov-Apr	33*	360	Mar-Aug	23	250
Groundnuts	Nov-Apr	37	405	Mar-Aug	37	405
Cassava	Nov-Aug	20	220			
Other	Nov-Apr	14	150	Mar-Aug	14	150
Rough grazing	All Year	6	70	All Year	6	70
TOTAL		110	1205		80	875

* Half first maize crop interplanted in cassava.

SOURCE: LRD Survey, 1976, Agriculture Office, 1977.

grown are groundnuts,maize and cassava, the first two being cropped twice (Table 2.8). Other crops which make up 15 percent of the undercropped area include mungbeans, cowpeas, lablab, sweet potatoes, cocoyams, and other vegetables. Apart from cassava, the rest can be grown at least twice during the year. In addition every farm in the under cropped area had bananas planted among coconut trees.

6. <u>Socio - Economic Factors</u>

The total population in the study area is estimated at almost 21 thousand, equally divided between females and males. Both females and males participate in the labour force and have the same degree of importance. Eighty percent of the active population is employed in primary activities. Coconut production is most important, followed by other land mixed farming and rice cultivation. Fishing as a full time occupation, provides employment for less than 3 percent. Distribution of employment, by activity, is closely related to the land use pattern. The production of lime from coral is the most important secondary employment activity, followed by copra drying, brick and tile production, and rice milling. About eight percent of the active population is in tertiary activities with retailing being of greatest importance, followed by government employment, working in bicycle and vehicle repair workshops, or as casual labourers.

The average farm size in the study area is relatively small. Rice farms have been shown to average about 0.88 hectares, and coconut farms are larger, the average farm size being 1.89 hectares (LRD, 1976). These farm sizes are units of land ownership and where the land is rented there is often more than one tenant per farm.

Tenancy systems are complex and provide little legal security for the tenant. In practice, agreements are generally long standing and there appears to be little abuse of trust. On rice field areas, the system known as "nandu" is most common, in which the owner and tenant share all costs and returns equally for all crops. On coconut farms, the landlord pays all costs and receives all revenue from the coconut crop, and he also pays the land tax. Replanting of coconut trees is usually done by the tenants, for which he receives a token payment. The tenant is responsible for all crops grown in addition to the coconuts, and receives all the revenue from them.

The irrigation association at the village level is the subak, which is an economic-based, communal organization of farmers. They serve their own needs for diversion and conveyance of irrigation water to farms. The subaks have a long and successful history in achieving that goal. The religious aspect of subak organization is very strong and members make contributions towards various temple ceremonies connected with the rice crop. They also contribute their labour on a "gotong royong" (mutual help) basis for maintenance and repair of canals and other irrigation infrastructure.

CHAPTER III

ESTIMATED DESIGN FLOW

The purpose of this chapter is to estimate the amount of water available for crop consumption within the study area. The availability of water at the intake gate to the irrigation system can then be related to the total demand for water by various crops at various stages of growing.

In order to estimate the quantity of water available, analysis was carried as follows:

- Rainfall data analysis
- River flow data analysis
- Correlation analysis of rainfall and river flow

The potential or expected water availability will be calculated based on the four year river flow data for Tukad Sabah River. These data will be correlated with the available long term rainfall data at Pupuan. Since the water for irrigation must be a dependable flow, it is necessary to estimate the minimum flow. An 80% probability is usually used for this purpose based on a frequency analysis (NEDECO, 1973 & Bailey, 1973).

1. Rainfall Analysis

To establish a frequency analysis, the annual rainfall recorded at Pupuan over 46 years was ranked in descending order of magnitude. The probability and return period were calculated using Weibul Method (Booy, 1975). This method could be formulated as:

TABLE 3.1

ANNUAL RAINFALL AT PUPUAN BETWEEN 1921-1977
(JAN.-DEC.)

Rainfall (mm)	Cumulative Probability (%)
4659	2.13
3687	4.26
3595	6.38
3590	8.51
3481	10.64
3348	12.77
3213	14.89
3199	17.02
3170	19.15
3133	21.28
3031	23.40
2942	25.53
2930	27.66
2863	29.79
2833	31.91
2824	34.04
2818	36.17
2809	28.30
2682	40.43
2655	42.56
2650	44.68
2648	46.81
2527	48.94
2481	51.05
2470	53.19
2449	55.32
2439	57.45
2406	59.57
2392	61.70
2338	63.83
2338	65.96
2277	68.09
2271	70.21
2244	72.34
2136	74.47
2126	76.60
2100	78.72
2065	80.85
2028	82.98
1963	85.11
1944	87.23
1936	89.36
1928	91.49
1899	93.61
1837	95.74
1016	97.87

SOURCE: Appendix I.

$\frac{m}{n+1} \times 100\%$ to calculate probability, where m is the ranking number and n is the number of years.

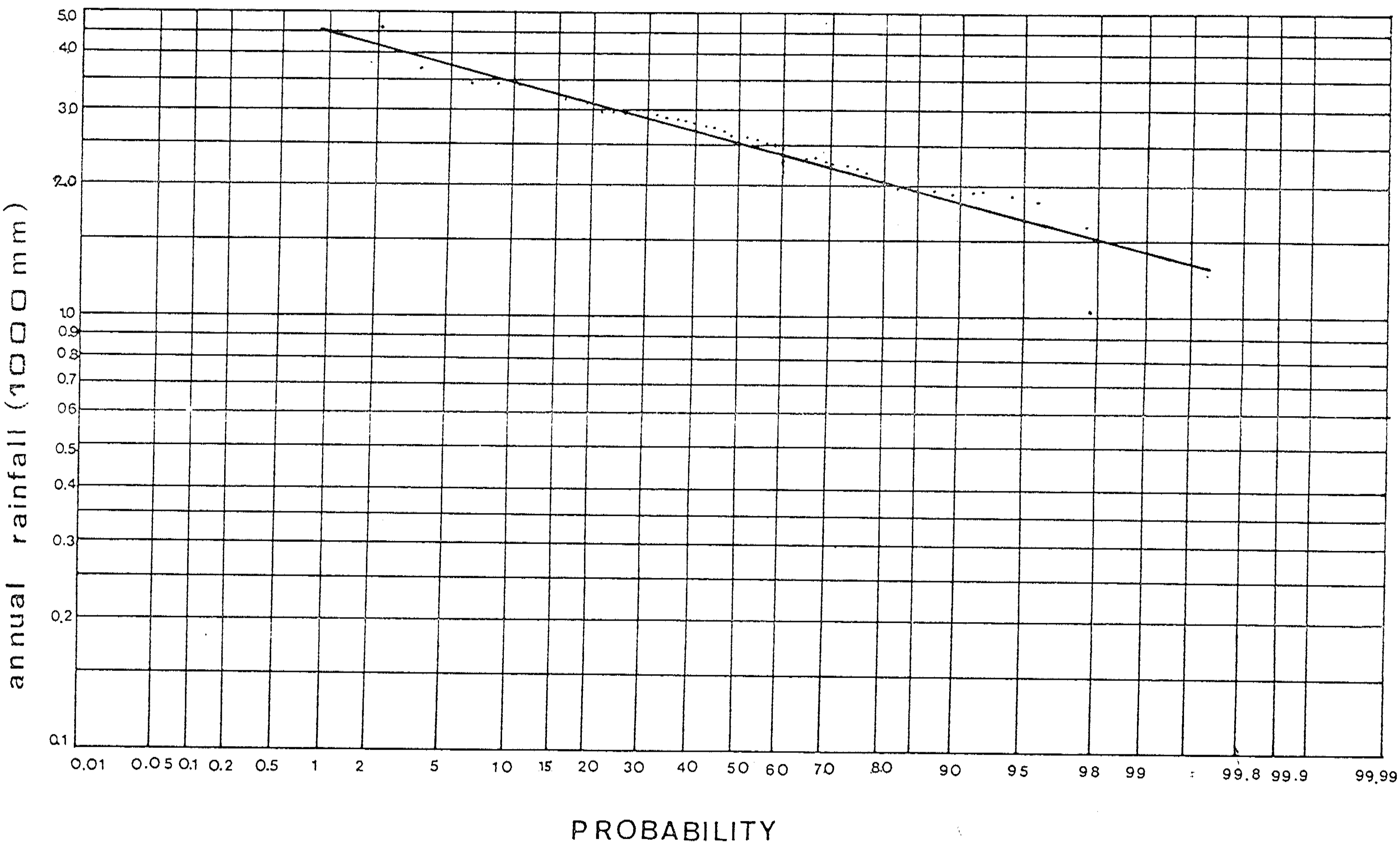
The result of calculations is shown in Table 3.1. The data, plotted on log probability paper, are shown in Fig. 3.1. Based on these results, the design estimate in which there is a 20 percent probability of a lower total annual rainfall occuring is selected as 2080 mm. The probability of rainfall in the years for which run off records are available was determined from Fig. 3.1 and is presented in Table 3.2. This table will be used to examine the correlation between rainfall and run off as discussed in section 3.3.

TABLE 3.2

ANNUAL RAINFALL PROBABILITY

Probability (percentage)	Year	Annual Rainfall (millimetres)
13	1975	3348
17	1977	3199
20	1 in 5 high	3155
23	1976	3031
29	mean 1974/1977	2878
50	median	2505
80	1 in 5 low	2080
91	1974	1928

SOURCE: Based on Table 3.1 and Figure 3.1



PROBABILITY OF RAINFALL AT PUPUAN

FIG.3.1

2. River Flow Analysis

Flow duration records of Tukad Sabah (2.B1) and Umadesa Canal (2.21/2.22) were plotted for 5-day and monthly records and the results are shown in Table 3.3.

TABLE 3.3

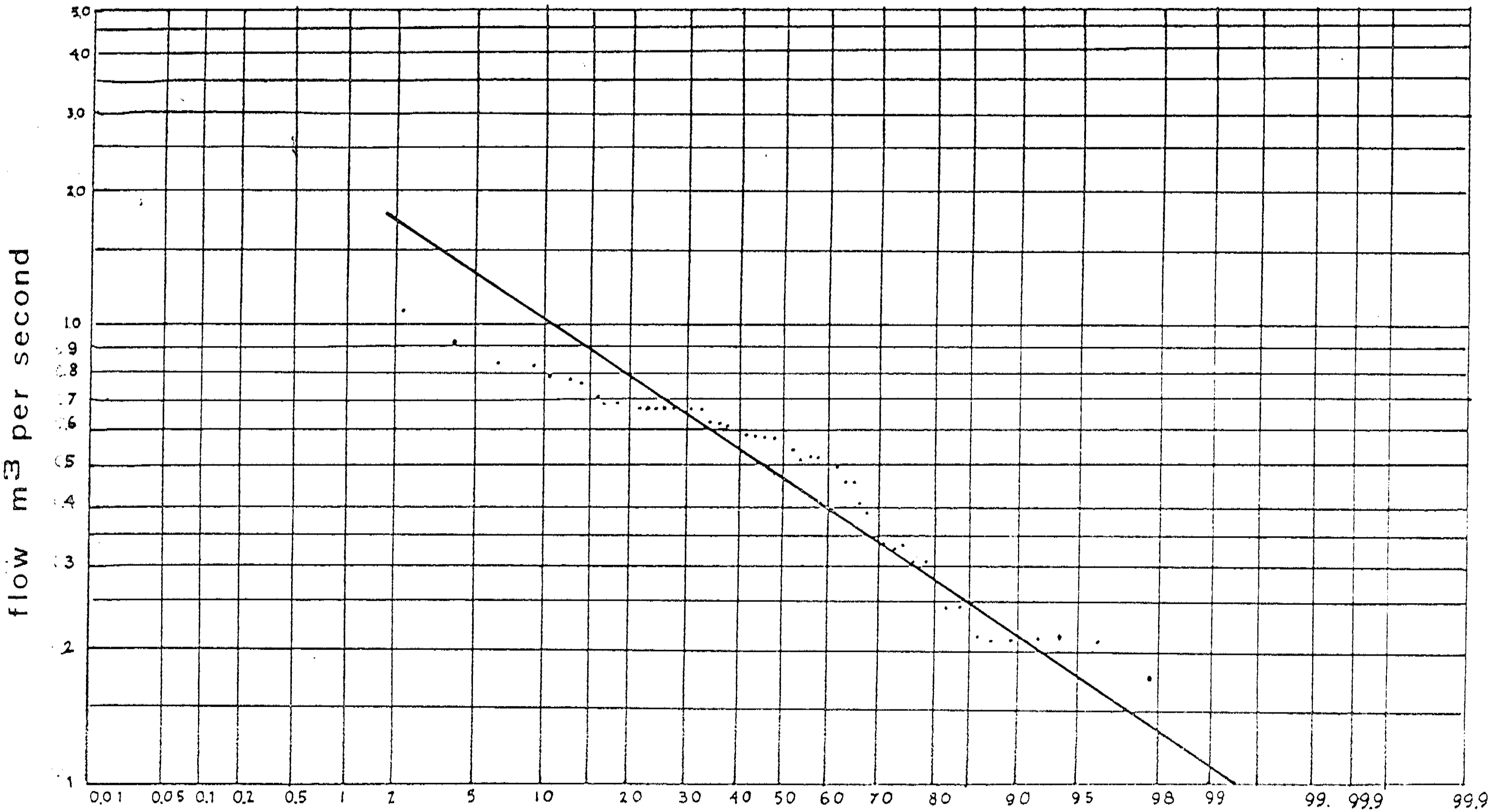
FLOW DURATION

		Flow(cumecs)	
Station	Probability(%)	5 day	Monthly
2.B1	80	2.75	2.75
	90	2.16	2.16
2.21/2.22	80	1.30	1.25
	90	1.20	1.15

The difference between the mean 5-day flows and the mean monthly flows are small. The surplus flows available, neglecting annual distribution in the 4 years of record availability, would be about 1.45 cumecs at 80 percent probability assuming that the flow to the existing Umadesa irrigators would be maintained. Since the record period is so short, however, this minimum flow could not be guaranteed and should not be used for planning purposes. Also the minimum flow occurs in August, and the guaranteed flows throughout the remaining months of the year are required for agricultural planning.

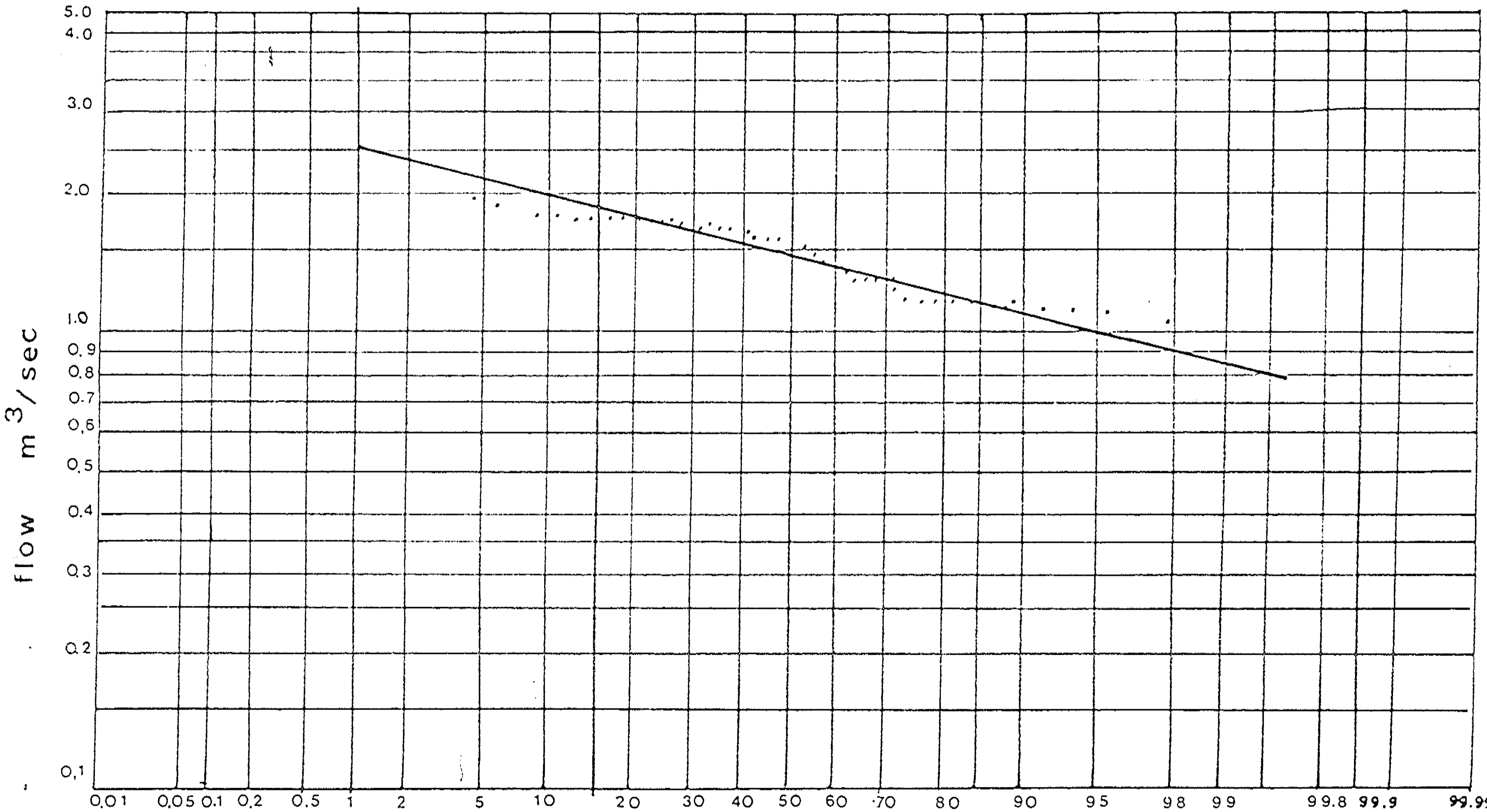
3. Correlation Between Rainfall & River Flow

In order to improve the estimate of reliable flow in the Tukad Sabah, available long term rainfall records could be



PROBABILITY OF MEAN FLOW AT UMADESA WEIR

FIG.3.2



PROBABILITY OF FLOW IN UMADESA CANAL

FIG.3.3

utilized to generate flow data. The flows recorded at Station 2.B1 at Umadesa Weir during 1974 to 1977 could be correlated to rainfall recorded at Pupuan during the same period. A monthly comparison and annual correlation are shown in Fig. 3.4 and Fig. 3.5 respectively. From these figures, it appears that there is no simple correlation between rainfall and recorded flows. Moreover, the period of record is far too small for a correlation analysis.

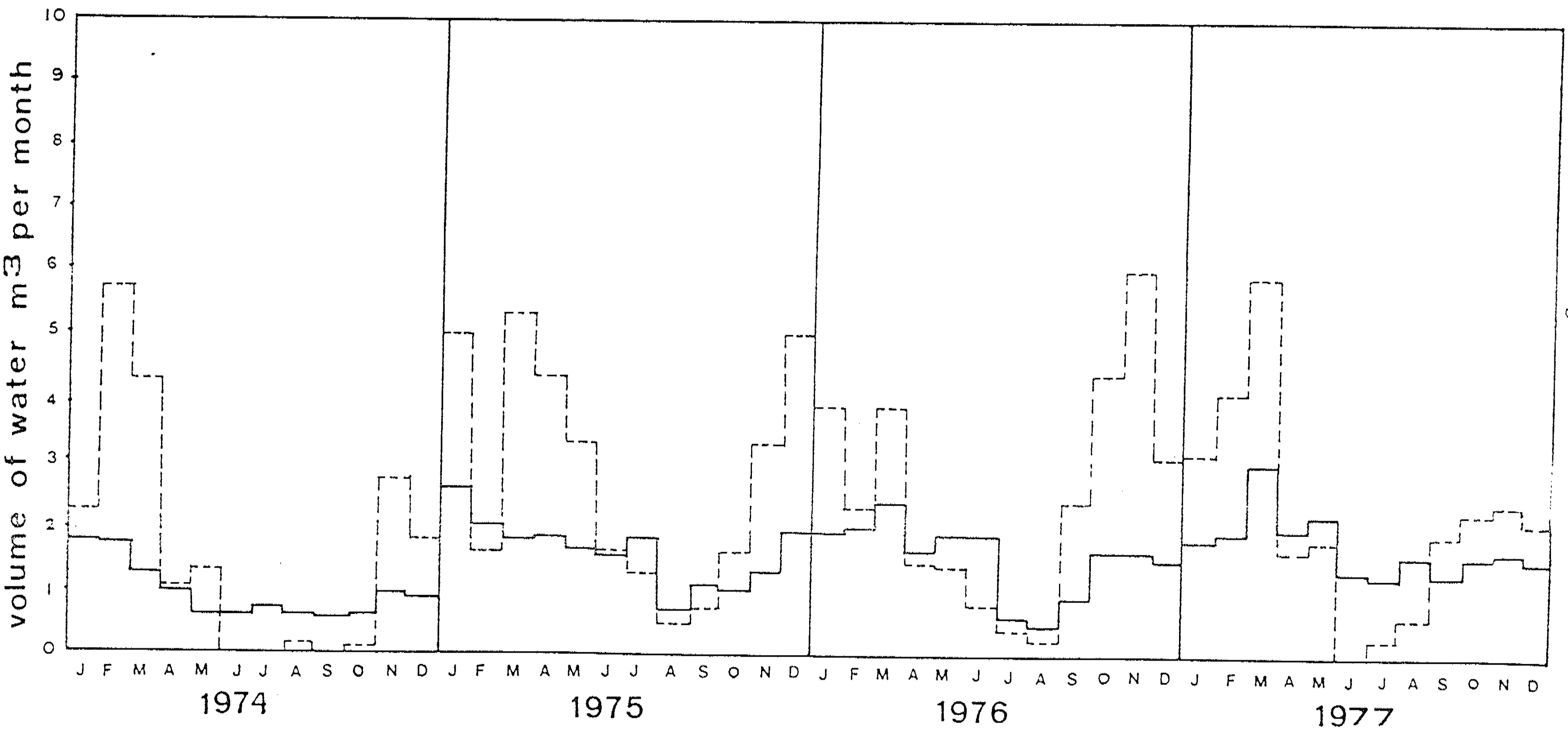
From purely statistical correlation of monthly riverflow and monthly rainfall, a correlation coefficient of 0.67 was derived. Although this correlation coefficient is relatively high, based upon the nature of the problem in a hydrological sense, correlating monthly flows with the rainfall in the same month is not advisable since riverflow is dependent not only on the rainfall in that month but also on the rainfall in the preceding months, rainfall intensity, storm duration and more importantly the antecedent soil moisture of the basin (Darrell R. Weyman 1975, p. 37).

A simplified relationship was therefore adopted in which the minimum monthly flows recorded from 1974 to 1977 were adjusted on the basis of annual rainfall.

4. Estimated Design Flow

Annual rainfall in 1974 was 1,928 millimetres, whereas the mean annual rainfall for 1974 to 1977 was 2,878 millimetres. To determine monthly flows for the design estimate of annual rainfall of 2,080

FIGURE 3.4

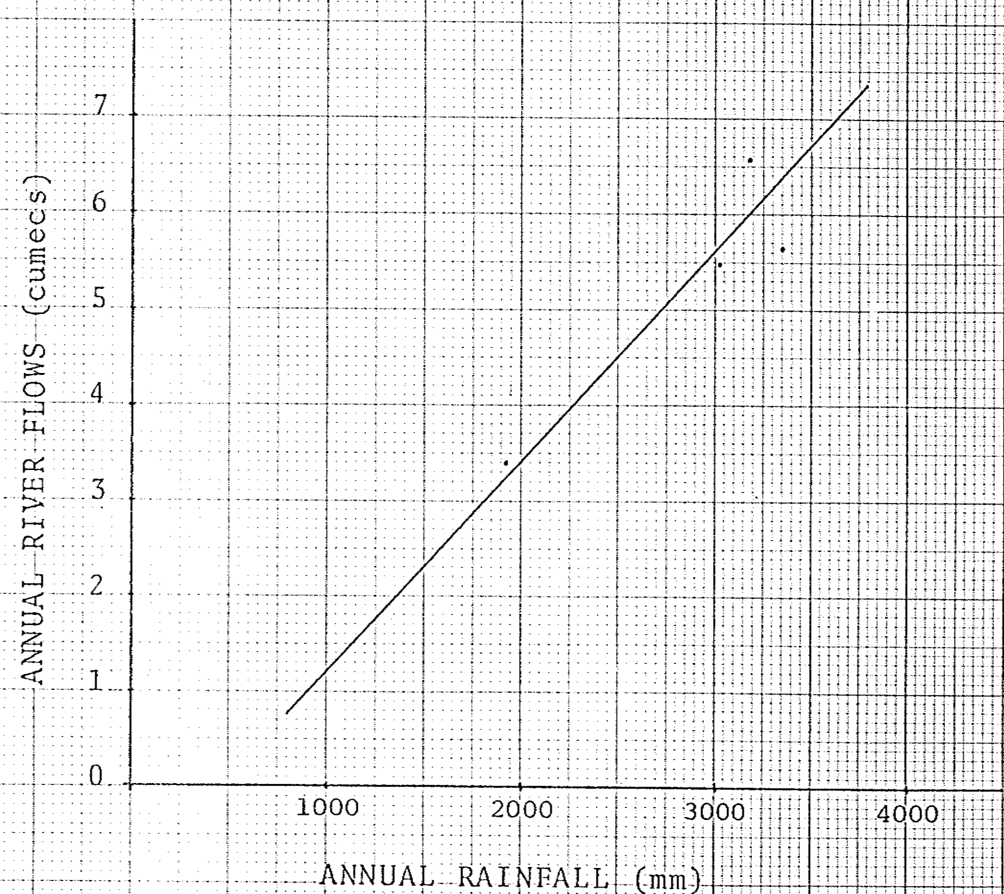


comparison of monthly rainfall and run-off

YEAR	1974	1975	1976	1977
RIVER FLOW (cumecs)	3.40	5.63	5.48	6.69
RAINFALL (mm)	1928	3348	3031	3199

FIG. 3.5

CORRELATION BETWEEN RAINFALL & RIVER FLOW



millimetres, the minimum monthly flows are increased by a fractional increment of 0.16 $\left(\frac{1928 - 2080}{1928 - 2878} = 0.16\right)$ of the difference between the minimum and mean monthly flows shown in Table 3.4.

A similar process was carried out for Tukad Panas, as shown in Table 3.5 The annual rainfall in 1977 was 3199 millimetres. Hence to determine the monthly flows for the design estimate of annual rainfall of 2080 millimetres the mean monthly flows in 1977 were multiplied by a fraction of 0.65 to get the design monthly flows $\left(\frac{2080}{3199} = 0.65\right)$.

The requirements of the downstream irrigators supplied from Puluran weir of Tukad Panas have been ascertained by averaging the stream flow measurements made by P3SA over four years (1974 to 1977) (Table 3.5).

The requirements of downstream irrigators can be supplied during part of the year, from the Tukad Panas, as its confluence is situated just downstream of the Umadesa weir diversion. Tukad Panas cannot satisfy the existing irrigation demand at the Puluran weir during the months of July to February inclusive (Table 3.5). Supplementary release would therefore have to be made from Umadesa weir (Table 3.6). After the supplementary releases have been deducted, the flow remaining at Umadesa weir is considered to be available for irrigation development in the study area which includes the existing area of sawah on the west bank of the Tukad Sabah presently irrigated from Umadesa weir. The monthly distribution of the design flow is given in Table 3.6.

TABLE 3.4

ESTIMATED FLOW IN TUKAD SABAH AT UMADESA WEIR
(cumecs)

(1) Month	(2) Minimum 1974/77	(3) Mean 1974/77	(4) Difference (3) - (2)	(5) Increment 0.16x(4)	(6) Estimated (2) + (5)
Jan.	6.05	7.16	1.12	0.18	6.23
Feb.	6.60	7.32	0.72	0.12	6.72
Mar.	4.21	7.58	3.37	0.54	4.75
Apr.	3.45	5.90	2.45	0.39	3.84
May	2.16	5.68	3.52	0.56	2.72
June	2.16	4.86	2.70	0.43	2.59
July	2.16	3.95	1.76	0.28	2.44
Aug.	1.66	3.02	1.36	0.22	1.88
Sept.	2.16	3.59	1.43	0.23	2.39
Oct.	2.16	4.18	2.02	0.32	2.48
Nov.	3.45	5.21	1.76	0.28	3.73
Dec.	3.20	5.22	2.02	0.32	3.52

SOURCE: Based on Table 2.2 and Table 3.2

TABLE 3.5

ESTIMATED FLOW IN TUKAD PANAS
(cumecs)

(1) Month	(2) Mean 1977	(3) Estimated 0.65x(2)	(4) Existing Demand[1]	(5) Deficit (4) - (3)
Jan.	1.53	0.99	1.45	0.46
Feb.	2.00	1.30	1.64	0.34
Mar.	4.70	3.06	1.60	-
Apr.	3.95	2.57	1.33	-
May	4.30	2.80	1.34	-
Jun.	1.65	1.07	1.07	-
Jul.	1.20	0.78	1.18	0.40
Aug.	1.28	0.83	1.42	0.59
Sep.	1.53	0.99	1.51	0.52
Oct.	1.45	0.94	1.39	0.45
Nov.	1.36	0.88	1.38	0.50
Dec.	0.99	0.64	1.32	0.68

[1] Tukad Sabah downstream irrigators, source P3SA.

TABLE 3.6

DESIGN FLOW IN TUKAD SABAH
(cumecs)

Month	Estimated	Downstream Irrigators	Design
Jan.	6.23	0.46	5.77
Feb.	6.72	0.34	6.38
Mar.	4.75	-	4.75
Apr.	3.84	-	3.84
May	2.72	-	2.72
Jun.	2.59	-	2.59
Jul.	2.44	0.40	2.04
Aug.	1.88	0.59	1.29
Sept.	2.39	0.52	1.87
Oct.	2.48	0.45	2.03
Nov.	3.73	0.50	3.23
Dec.	3.52	0.68	2.84

CHAPTER IV

THE CROP IRRIGATION REQUIREMENT

This chapter will deal with irrigation water demand for each prospective crop in the study area. This irrigation requirement will be done for two major crop categories, those grown on flooded areas (i.e. rice) and those grown on the dryland areas (i.e. groundnuts, tobacco, etc.).

In determining water requirements for irrigation, (IR), the following formula will be used: (FAO paper no. 24, 1975 and Kuijper, 1976, pg. 346).

$$IR = (CU + FL - ER) \times EF$$ where,

IR is irrigation requirement

CU is consumptive use by crop

FL is field loss

ER is effective rainfall

EF is efficiency factor for water use.

Each of these factors is considered in turn.

1. Crop consumptive use

The consumptive use of the crop depends on several factors which can operate independently or in combination to influence the amount of water consumed by a particular crop. Their effects are not necessarily constant but may differ with locality and fluctuate from time to time. Important influences are climate, water supply, and plant growth characteristics.

Crop consumptive use includes not only the water transpired by the plant but also water lost from the soil surface by evaporation. In the case of irrigated rice, consumptive use begins before the crop is transplanted, when the fields are flooded before and during land preparation. The calculation of consumptive use by crops is commonly made by relating it to the daily rate of evaporation from an open water surface, determined either by calculation from climatological data (e.g. Penman), or by direct measurement (e.g. Class A open water Pan). Both methods of measuring evaporation from open water were used by P3SA. For this study, evaporation figures obtained from Penman calculations will be used (Table 4.1).

Studies of the water use by growing crops and observing daily rates of evaporation enable coefficients to be established which relate crop consumptive use to evaporation. These coefficients vary from crop to crop and to a lesser extent, between localities. The LRD team determined crop coefficients for irrigated rice, the principle crop in the study area. For the other crops, coefficients have been calculated according to a method developed by FAO (1975) (Table 4.2).

Once the figures for evaporation rates and crop coefficients were obtained, crop consumptive use or the evapotranspiration was calculated by multiplying those two numbers as presented in the calculation of irrigation requirement shown in Table 4.9 (Gray M. Donald, 1973). For the design of irrigation

TABLE 4.1

EVAPORATION ESTIMATES (Eo) FOR EACH MONTH

MONTH	mm/DAY	mm/MONTH
Jan.	5.32	165
Feb.	5.08	142
Mar.	5.31	.65
Apr.	5.74	172
May	5.22	162
Jun.	5.23	157
Jul.	6.11	189
Aug.	6.11	189
Sep.	6.32	190
Oct.	6.80	211
Nov.	6.28	188
Dec.	5.74	178
TOTAL	-	2108
MEAN	5.77	-

SOURCE: P3SA - Bali, 1978, and refers to Table 2.3.

TABLE 4.2

CROP COEFFICIENTS BY 10-DAY PERIODS

CROP:	Rice	Maize	Groundnuts	Tobacco
CROP LIFE (days):	120	90	100	120
PERIOD	Coefficient (f)			
Land Preparation	0.87			
0 - 10	0.87	0.30	0.30	0.30
11 - 20	0.90	0.30	0.30	0.30
21 - 30	1.03	0.55	0.40	0.36
31 - 40	1.22	0.80	0.60	0.55
41 - 50	1.27	0.95	0.85	0.70
51 - 60	1.27	1.00	0.95	0.92
61 - 70	1.26	1.00	0.95	1.00
71 - 80	1.18	0.95	0.95	1.00
81 - 90	1.09	0.70	0.87	Irri-
91 - 100	1.00		0.65	gation
101 - 120	Crop			stopped
121 - 130	matures			before
131 - 140	on			1st
141 - 150	residual			reap-
151 - 160	water			ing

SOURCE: LRD, "Development of the Water Resources of Bali: A Master Plan", 1976.

FAO, "Crop Water Requirements", 1975.

Bailey, "Water Utilization and Management", 1973.

systems, or distribution systems, estimates of crop consumptive use are made for short time periods (5 to 30 days) (USDA, 1970). For this study, a 10 day period has been selected as most appropriate.

2. Field loss

In the case of flood-irrigated rice, field losses consists of water lost by deep percolation through the plough pan and by leaks or seepage through small dikes (FAO, 1975).

Most estimates made of field loss for irrigated rice in Indonesia have been based on studies of percolation using infiltrometer rings or lysimeters. Values of 0 to 3 mm/day have commonly been derived for irrigated rice areas on Java Island and elsewhere (NEDECO, 1972). In the study area, figures in this range were obtained by LRD from field tests on irrigated rice near Umadesa weir (LRD, 1976). However, LRD studies also included measurements of total inflow and outflow from the 400 hectares irrigated by Umadesa weir, and field losses of 14 mm/day and more were recorded.

Since conventional measurements of vertical percolation gave values of 0 - 3 mm/day, the difference between this and the figures above indicates that excessive water losses must occur laterally through small dikes and then vertically within the small dikes to groundwater. The mechanism by which this happens is not clear and should be studied further. During field testing however, observers noted that many holes were made daily on small dikes by crabs and rats. Auger borings made in the sawah land revealed layers of sandy or coarser material within one metre of the surface. Water reaching these layers would quickly percolate to groundwater. Plastic sheet was used to line the small dikes and this test indicated that a large amount of water was lost through the dike walls. Plastic lining, however, does not provide a practical solution to the problem.

On newly developed sawah (such as that under coconuts) water losses by vertical percolation will be considered until a plough pan is formed. Thus, a field loss estimate of 15 mm/ day has been adopted for this study.

In the irrigation of dryland crops, field losses will be much less significant. Irrigation water is applied periodically to replace the available moisture in the soil according to crop needs. Any water which infiltrates below the crop root zone is considered lost to deep percolation, but should be relatively small. Current recommendations are that this should be included in the irrigation efficiency factor (ANON, 1974).

3. Effective rainfall

The engineer engaged in estimating irrigation water requirements of a crop is confronted with the problem of determining what portion of total consumptive use will be furnished by effective rainfall and what portion will have to be supplied by irrigation, since not all of the rain which falls on a crop can be used by it.

Very light precipitation which barely penetrates the soil will be rapidly lost to evaporation. In the case of heavier rainfall, there will be losses through surface run-off and deep percolation into the soil beyond the crop root zone. The amount (ainfall which can be used by the plant is termed "effective rainfall" (FAO, 1975).

For agricultural planning purposes, records from the two rainfall stations nearest the study area, Grokgak and Bubunan, have been selected. (Tables 4.3 and 4.4).

The station at Grokgak is just south of the western end of the study area and at 45 m elevation. The rainfall at this elevation is likely to be somewhat higher than that within one kilmetre of the coast. The Bubunan station, about two kilometres east of Seririt, is at 10 m elevation and has an average annual rainfall about 200 mm lower than that at Grokgak. The influence of the wide plain of the Tukad Sabah probably results in a lower precipitation at Bubunan than might be expected on the narrower coastal strip of the study area. It thus seems reasonable to take an average of the two stations as being representative for the study area.

The annual distribution of rainfall (Fig. 4.1) shows the very marked dry season from May to November with hardly any rain falling between June and September. Significant rainfall does not begin until December and the rainy season reaches its peak in February, tailing off in April and May. Rain usually falls in heavy showers of short duration, generally in the afternoon. After heavy storms, water run-off is rapid and river beds, which are dry for most of the year, show signs of flash flooding.

The 80 percent probability rainfall for the Grokgak and Bubunan stations is presented in Table 4.5. The mean of the two sets of figures has been taken as the 1 in 5 dry year

FIG.4.1

MONTHLY MEAN RAINFALL

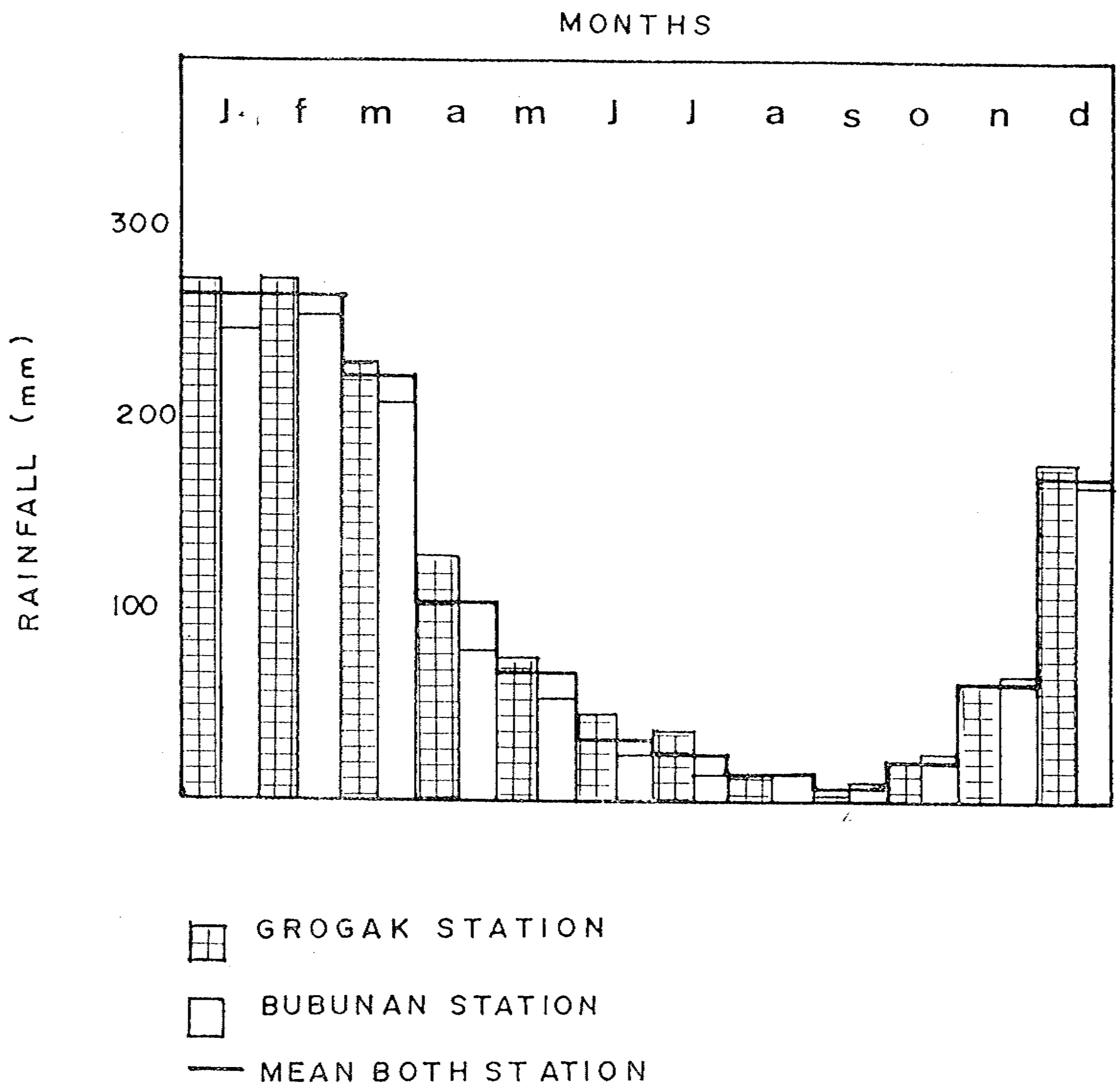


TABLE 4.3

RAINFALL DATA, GEROKGAK STATION NO. 43b. ALTITUDE 45 M A.S.L. 1929-1940 and 1950-1977

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
						Millimetres							
1929	287	100	458	12	0	22	0	0	0	0	1	242	1122
1930	119	882	320	200	0	0	0	0	0	0	0	92	1613
1931	105	149	151	209	86	26	0	10	11	46	32	113	938
1932	137	251	264	71	85	175	0	0	0	0	84	241	1308
1933	172	222	242	264	38	63	0	48	3	37	61	272	1422
1934	309	353	233	267	73	16	26	9	0	6	-	28	-
1935	161	117	210	160	2	54	0	0	0	8	13	92	817
1936	277	288	226	210	55	44	20	11	14	11	84	239	1479
1937	371	111	423	210	68	189	9	0	17	0	9	556	1963
1938	341	306	40	38	149	55	62	1	4	0	131	222	1349
1939	365	343	293	182	13	31	193	73	37	30	2	101	1663
1940	503	138	265	65	33	2	2	0	0	0	3	328	1339

(Continued)

-: data not available

TABLE 4.3 (Cont.)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
						Millimetres							
1950	50	208	172	75	21	0	27	0	0	0	23	118	694
1951	188	265	113	141	88	184	0	30	0	0	34	59	1102
1952	211	334	109	199	86	236	45	0	0	66	79	219	1584
1953	351	175	54	5	2	14	30	98	0	0	52	74	855
1954	220	251	166	111	110	7	0	0	7	79	117	110	1178
1955	194	157	301	153	129	0	23	7	0	0	35	67	1066
1956	275	201	252	204	98	129	8	9	0	26	37	363	1602
1957	298	140	328	47	228	68	287	31	0	6	413	136	1982
1958	277	346	230	46	37	133	55	104	0	0	48	342	1618
1959	150	247	244	182	102	56	209	102	0	0	6	311	1609
1960	151	310	254	109	169	55	155	24	0	25	43	170	1466
1961	588	451	277	102	127	19	18	0	0	0	3	163	1748
1962	371	281	182	84	100	12	3	0	0	0	100	40	1173
1963	377	227	90	168	28	0	0	0	0	2	2	96	990
1964	404	385	126	286	20	35	5	0	0	0	73	198	1532
1965	333	248	226	43	57	0	0	0	0	0	14	265	1186
1966	101	302	342	97	52	16	0	31	0	134	126	96	1297
1967	229	62	348	70	0	1	10	0	0	0	16	54	790
1968	252	504	374	248	36	12	0	0	0	39	24	145	1634
1969	536	266	134	49	7	0	0	0	0	20	21	174	1207
1970	371	301	39	132	160	107	79	30	3	20	74	217	1533
1971	215	310	223	95	13	15	1	0	2	5	21	63	963
1972	80	271	177	204	58	3	12	0	10	8	49	181	1053
1973	342	407	282	32	117	51	0	0	0	89	129	72	1521
1974	225	254	343	29	68	0	0	0	0	1	13	216	1149
1975	539	277	210	78	351	55	182	7	66	3	68	250	2086
1976	270	352	298	50	50	12	0	0	20	25	158	108	1343
1977	337	285	316	143	252	0	4	3	8	133	67	347	1895
Total	11083	11077	9335	5070	3168	1897	1465	628	202	819	2265	7180	52869
No of yrs.	40	40	40	40	40	40	40	40	40	40	39	40	39
Mean	277	277	233	127	79	47	37	16	5	20	58	180	1356

SOURCE: P3SA Office, Singaraja - Bali.

TABLE 4.4

RAINFALL DATA, BUBUNAN STATION NO.438 g, ATTITUDE 10 M A.S.L. 1950-1977

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
						Millimetres							
1950	48	137	120	38	47	0	25	0	0	0	40	58	513
1951	276	431	59	0	78	0	0	12	28	0	0	-	-
1952	257	154	105	37	10	183	10	0	0	25	88	132	1001
1953	215	157	4	16	7	2	0	4	0	0	15	47	467
1954	231	183	253	60	11	0	0	8	0	78	261	80	1165
1955	309	192	326	66	59	0	0	0	0	0	15	78	1045
1956	332	255	267	83	98	48	0	10	23	33	52	363	1564
1957	18	101	130	5	68	44	94	36	0	47	291	93	927
1958	277	297	210	24	7	148	40	294	18	3	38	318	1674
1959	110	242	110	52	38	0	131	30	0	4	43	307	1067
1960	130	186	271	130	45	45	28	21	0	0	26	32	914
1961	265	324	321	48	75	92	55	0	0	0	28	242	1450
1962	220	378	181	117	126	7	5	0	0	10	127	35	1206
1963	239	266	52	41	20	6	6	0	0	0	31	63	724
1964	289	154	52	101	10	86	18	14	0	2	5	268	999
1965	357	221	250	6	1	0	0	10	1	0	25	176	1047
1966	49	551	551	31	52	12	0	1	0	94	186	30	1557
1967	213	98	290	31	23	0	0	0	0	19	3	186	863
1968	143	373	293	116	0	9	0	0	2	0	57	351	1344
1969	565	-	201	84	25	0	0	0	0	2	12	206	-
1970	334	188	66	155	189	0	41	2	6	5	34	238	1258
1971	61	288	280	152	5	13	0	0	0	48	95	87	1029
1972	222	279	73	301	42	16	0	0	24	18	52	236	1263
1973	269	335	242	69	162	16	0	0	33	102	56	77	1361
1974	335	280	229	37	31	1	0	2	0	39	49	250	1253
1975	720	251	360	116	226	6	24	3	111	62	88	169	2136
1976	352	484	305	82	22	0	0	2	35	52	90	140	1564
1977	135	148	287	309	119	0	0	0	20	59	79	211	1367
Total	6971	6953	5888	2307	1596	734	477	449	301	702	1886	4473	30758
No of yrs.	28	27	28	28	28	28	28	28	28	28	28	27	26
Mean	249	258	210	82	57	26	17	16	11	25	67	166	1183

- : data not available

SOURCE: P3SA Office, Singaraja - Bali.

rainfall in the study area.

TABLE 4.5

80 PERCENT PROBABILITY RAINFALL FOR GROKGAK & BUBUNAN STATIONS AND MEAN FOR THE STUDY AREA (millimetres)

Month	Grogak	Bubunan	Mean for Study Area
Jan.	118	166	142
Feb.	159	159	159
Mar.	104	147	126
Apr.	16	60	38
May	6	14	10
Jun.	0	0	0
Jul.	0	0	0
Aug.	0	0	0
Sep.	0	0	0
Oct.	0	0	0
Nov.	4	0	2
Dec.	76	84	80
TOTAL:	483	630	555

SOURCE: Based on Tables 4.3 and 4.4.

The consumptive use of water for irrigated rice is so high that rainfall can only contribute a fraction of total water requirements. For other crops, effective rainfall in the dry season is virtually nil. Effective rainfall has thus been calculated only for rice using a simple method suited to the data available.

Where rice is grown under permanently flooded conditions, rain falls directly onto a water surface. There would thus be no direct loss of rain through deep percolation into the soil and even the smallest shower will contribute somewhat to the total amount of water. The system of irrigation normally practised in the study area involves water flowing continuously from canals to basins, and between basins, from the highest to the the lowest level. At the lowest end of the system, water is lost to drainage.

Under these circumstances, rainfall will merely flow through the system and contribute nothing to the overall water supply, assuming that the water in each basin is at its optimum level. The continuous flow system is acceptable providing that the source of water is sufficient to maintain the flow throughout the cropping period. Where water is in short supply, the continuous flow system is very wasteful, and when water has to be pumped, expensive. An alternative to this system is to supply water to each farm or irrigation area by rotation according to actual crop needs. This implies that the farmer must accept water on certain days and impound it in his sawah basins. The irrigation period is related to estimated total consumptive use and this is discussed later. In planning irrigation needs, it has been assumed that a rotational system of irrigation will have to be practised, firstly because the amount of water available at the Umadesa weir is limited and secondly, where water is to be pumped, running costs must be minimized. These constraints are magnified by the exceptionally high consumptive use requirements of irrigated rice in North Bali. The rotational system is significant here because it enables a certain amount of rainfall to be impounded in the sawah basins and thus contribute effectively to consumptive use requirements.

How much rainfall can be impounded will depend on the water level in the basins at any given time and on the maximum water level maintained. For these calculations it has been assumed that the maximum depth of water that can be impounded in a basin is 100 mm after which it will overflow. Average consumptive use of water for rice is taken as 22 mm/day (Table 4.9). Thus after three days, water will have been depleted to 34 mm, a minimum acceptable safety margin. The field will then be filled up again by applying 66 mm of water over a 24 hour period. In short, rotational irrigation will be practised on a three day cycle.

Under these conditions, rainfall will immediately flow out of the full basins (the basins which have been irrigated first) but 22 mm will be maintained over one third of the area (the basins which have been irrigated one day before) and a further 44 mm over one third of the area (The basins which have been irrigated two days before). All rainfall in excess of 44 mm/day will be lost through run-off. Thus the maximum amount of rainfall which is effective is equivalent to 22 mm (1/3 x 0 mm + 1/3 x 22 mm + 1/3 x 44 mm) for the whole area. On every day that rain fell, the amount that would be retained in the basins is calculated and records as effective rainfall (ER).

To relate this to the study area, a model 1 in 5 dry year was prepared by taking the actual daily rainfall records for

TABLE 4.6 DAILY RAINFALL DISTRIBUTION FOR COMPOSITE 1 IN 5 DRY YEAR (GROKGAK STATION) AND CALCULATION OF PERCENTAGE RAINFALL EFFECTIVE FOR RICE.

Month (and Year of records)
(millimetres

	JAN		FEB		MAR		APR		MAY		JUN TO NOV	DEC	
	AR 1 (1960)	ER 2	AR (1955)	ER	AR (1969)	ER	AR (1976)	ER	AR (1971)	ER	AR	AR (1953)	ER
1	10	6.7	5	3.4	15	10.0	0		0		0	0	
2	0		6	4.0	1	0.7	0		0		0	6	4.0
	0		7	4.7	10	6.7	0		0		0	0	
4	0		1	0.7	15	10.0	0		6	4.0	0	0	
5	0		9	6.0	9	6.0	0		0		0	0	
6	0		43	21.7	10	6.7	0		0		0	0	
7	0		4	2.7	3	2.0	0		0		0	0	
8	0		46	22.0	3	2.0	0		0		0	0	
9	0		0		39	20.3	2	1.3	0		0	0	
10	0		0		6	4.0	42	21.3	7	4.7	0	0	
11	0		4	2.7	4	2.7	0		0		0	0	
12	0		0		1	0.7	0		0		0	0	
13	0		0		0		0		0		0	0	
14	2	1.3	0		0		0		0		0	0	
15	1	0.7	0		7	4.7	0		0		0	0	
16	0		0		0		6	4.0	0		0	0	
17	6	4.0	0		0		0		0		0	0	
18	6	4.0	0		0		0		0		0	29	17.0
19	0		0		1	0.7	0		0		0	0	
20	0		0		0		0		0		0	0	
21	0		2	1.3	0		0		0		0	11	7.3
22	81	22.0	0		0		0		0		0	5	3.3
23	0		5	3.3	0		0		0		0	20	13.3
24	8	5.3	0		0		0		0		0	0	
25	18	12.0	0		3	2.0	0		0		0	0	
26	0		0		0		0		0		0	0	
27	0		25	15.7	0		0		0		0	0	
28	0		0		0		0		0		0	0	
29	19	12.7	-		0		0		0		0	0	
30	0		-		3	2.0	0		0		0	0	
31	0		-		4	2.7	-		0		0	0	
Total	151	68.7	157	88.1	134	83.9	50	26.6	13	8.7	0	74	46.9
	45		56		63		53		67			63	

1 : actual rainfall
2 : effective rainfall

SOURCE: P3SA Office, Singaraja, Bali.

months which most nearly equal the 80 percent probability rainfall on a monthly basis. Because the daily rainfall records for Bubunan are not complete, the data for the Grokgak station were used (Table 4.6).

Under ideal conditions, rainfall could never be more than 67 percent effective using this system (NEDECO, 1972). The percentage rainfall effective in each month was then related to the 80 percent probability rainfall for the study area as shown in Table 4.7.

TABLE 4.7

80 PERCENT PROBABILITY MONTHLY RAINFALL AND EFFECTIVE RAINFALL (FOR RICE)

Month	80% Probability Rainfall (AR) in mm[1]	Effective Rainfall (ER) mm	Effective Rainfall (ER) %[2]
Jan.	142	64	45
Feb.	159	89	56
Mar.	126	79	63
Apr.	38	20	53
May	10	7	67
Jun.	0	0	0
Jul.	0	0	0
Aug.	0	0	0
Sep.	0	0	0
Oct.	0	0	0
Nov.	0	0	0
Dec.	80	50	63
TOTAL	555	309	
AVERAGE			58

[1] From Table 4.5.

[2] From Table 4.6.

In order to relate the amount of effective rainfall to the watering period, effective rainfall for each month (80 percent probability rainfall x monthly percentage effective) was plotted and ten day periods extrapolated (Fig. 4.2) and (Table 4.8).

TABLE 4.8

EFFECTIVE RAINFALL FOR RICE (80% PROBABILITY) BY 10 DAY PERIOD (MILLIMETRES)

MONTH	PERIOD 1	2	3	TOTAL
Jan.	19	21	24	64
Feb.	29	30	30	89
Mar.	30	28	21	79
Apr.	10	6	4	20
May	4	2	1	7
Dec.	6	20	24	50
ANNUAL TOTAL				309

SOURCE: Fig. 4.2.

Effective rainfall for dryland crops will generally be more than that for rice. However, since it is anticipated that during the wet season rice will be grown on all the sawahs and dryland crops will only be grown on sawahs in the dry season, effective rainfall during that period (May - November) will be almost nil.

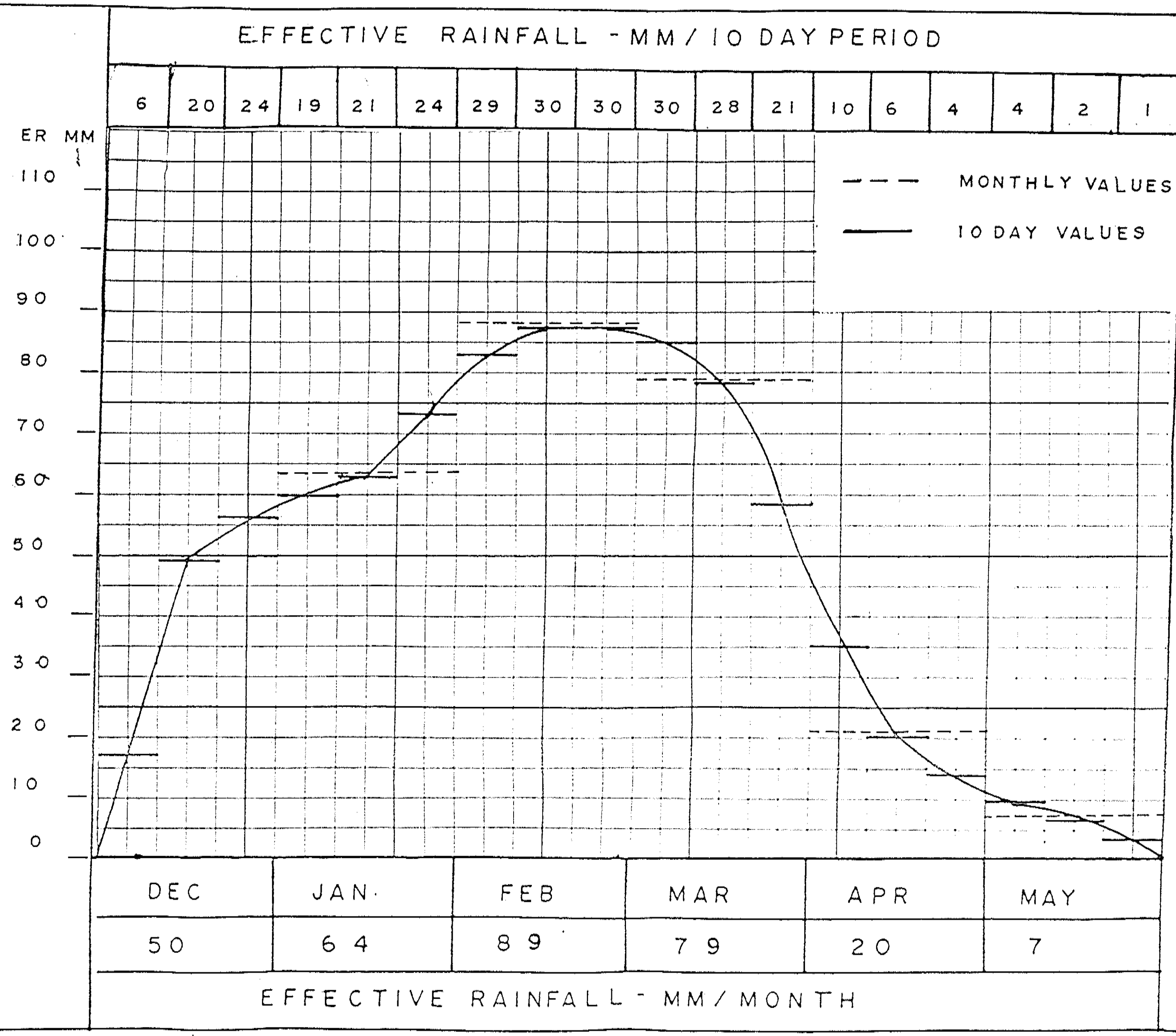


FIG. 4.2 EFFECTIVE RAINFALL - RICE.

FIG. 4.2

4. Efficiency factor

Operational water losses are created during the delivery of water by sluicing, breaks in the conduits, and diversion or deliveries in excess of demand. Canal operational losses are dependent on various conditions which may be quite different from project to project. Efficiency factors for water use are determined by the amount of water lost during operation.

Water deliveries, in excess of the scheduled rate of flow, result in excess deliveries to turnouts and spills at wasteways. Also, when demand for water abruptly decreased due to general rainfall, water is often discharged from waste-ways before the flow in the system can be reduced. These losses are sometimes termed regulatory losses. They are often substantial even for the most efficiently constructed and managed system. On large projects, with normal management, regulatory losses have run from 5 to 30 percent of the amount of water diverted. On carefully managed projects, these losses can usually be held below 10 percent. (USDA, 1970, pg. 60).

Gate leakage on large canals is usually not significant as the volume of flow decreases and the number of gates increase, however, this loss may become greater. Estimates of this value will vary widely depending on the type of gates, maintenance program, and the degree of enforcement of regulations.

There are no data on irrigation efficiencies in Indonesia, but most estimates split the system into two parts: the major network upstream of the tertier gate, and the tertiary network, downstream of the tertier gate. This latter part corresponds to the intra-subak network.

Main and secondary canal water losses are assumed to be 6 percent, a figure which is derived from the following formula:

Losses = 0.004 QL , where

Q = discharge in cubic metres per second

L = length of canal in kilometres.

This formula is based on a loss of 2.5 cumecs for each million square metre of wetted perimeter of canal (Hunting Technical Services, et. al., 1971, p. 58).

Losses below the tertier gate vary according to the crop grown. For flood-irrigated rice, they are estimated at 10 percent which includes losses in the tertiery and farm supply channels and any run-off due to overflowing of the basins (LRD, 1976). This level of efficiency is high at the tertiery level, but it is assumed that the need to schedule movement of water to the field will encourage careful usage on the farm. Overall efficiency for rice is thus taken to be 85 percent.

For palawija crops, even less is known about efficiency factors but literature (ANON, 1974, p. 56 and Bailey, 1973, p. 174) cites figures of 65 to 80 percent, which includes deep percolation and run-off. In sawah basins, the higher figure should be attainable and it has been accepted for this study. For palawija crops, the overall efficiency factor is 75 percent.

5. Irrigation before planting

Because of high field losses anticipated in the study area, the period of land preparation for rice should be kept at a minimum (30 days). Various estimates have been made for the amount of water required during land preparation, but a figure of 200 mm in addition to evaporation and field losses is considered reasonable (ANON, 1974, and NEDECO, 1973, p.102). It will vary according to the state of the field prior to ploughing. Dry or deeply-cracked soils require more water than soils which have been kept moist during rice harvesting. In calculating irrigation requirements for rice in this study, this water is considered to be applied uniformly at a rate of 6.7 mm/day (Table 4.9).

For palawija crops, the soil of the study area is loamy and should be cultivable in the dry state without prior irrigation. However, where the soil has dried out, pre-irrigation is allowed for, to refill the profile to field capacity. For alluvial soils of the study area, field capacity is about 40 percent by weight and available water about 120 mm/metre depth. Pre-irrigation of a completely dry soil would require about 200 mm of water to bring it to field capacity (Withers,B., 1974, p. 64).

6. Irrigation cycles

For rice, the present irrigation cycle is generally designed to allow a continuous flow of water through the sawah basins, with excess water eventually draining to the sea. Because water in the Tukad Sabah is limited in the dry season and water requirements of rice are high , it is necessary to conserve as much water as possible. A rotational system of irrigation must therefore be introduced throughout the year.

For palawija crops, water storage capacity of the soil is the critical factor. There is no specific data for soils in the study area, however, loamy soils, available moisture would be about 120 mm/metre. Under sawah conditions, an impermeable layer is formed at about 500 mm depth which prohibits root penetration. Available water would thus be 60 mm. If average evapotranspiration for palawija crops is taken as 6 mm/day, water should be applied every ten days. This implies that all the available moisture is taken up by the plant,however, which conflicts with the recognized irrigation practice of not allowing available moisture to fall below 50 percent (Whiters and Vipond, 1974, p. 56). This reduces the irrigation cycle to 5 days for palawija crops which varies from present practice, where a 10-day cycle is used.

The assumptions made above about depth of the root zone are speculative and should be the subject of future field study. Experiments done at the Soil Research Institute in Bogor, Indonesia (Keersebilck, et.al., 1975, p. 32-34) have shown that deep tillage of a paddy soil improves the performance of palawija crops immediately, and ultimately improves the yield of rice crops.

To simplify the calculations of irrigation needs, a ten-day cycle has been adopted, but in practice it would seem likely that water should be applied every five days. This would not significantly increase the total amount of water required for palawija crops.

Table 4.9 CALCULATION OF IRRIGATION REQUIREMENTS FOR RICE (HYV)

MONTH	DECEMBER 1	DECEMBER 2	DECEMBER 3	JANUARY 1	JANUARY 2	JANUARY 3	FEBRUARY 1	FEBRUARY 2	FEBRUARY 3	MARCH 1	MARCH 2	MARCH 3	APRIL 1	APRIL 2	APRIL 3
FIELD OPERATION	LAND PREPARATION													HARVEST	
Evaporation (Eo) mm/10 days (Table 4.1)	57	57	57	53	53	53	51	51	51	53	53	53	57	57	57
Effective rainfall (ER) mm/10 days(Table 4.8)	6	20	24	19	21	24	29	30	30	30	28	21	10	6	4
Field loss (FL) mm/10 days	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Crop coefficient (Table 4.2)	0.87	0.87	0.87	0.87	0.90	1.03	1.22	1.27	1.27	1.26	1.18	1.09	1.00	-	-
Evapotranspiration (Et = Eo x f) mm/10 days	50	50	50	46	48	55	62	65	65	67	63	58	57	-	-
Pre-saturation mm/10 days (Pre)	67	66	67	-	-	-	-	-	-	-	-	-	-	-	-
Consumptive use (Et+Fl+Pre) mm/10 days	267	266	267	196	198	205	212	215	215	217	213	208	207	-	-
Irrigation requirement (CU - ER) mm/10 days	261	246	243	177	177	181	183	185	185	187	185	187	197	-	-
Irrigation requirement (IR) mm/day	26.1	24.6	24.3	17.7	17.7	18.1	18.3	18.5	18.5	18.7	18.5	18.7	19.7	-	-
Irrigation requirement litres/sec/ha	3.0	2.8	2.8	2.0	2.0	2.1	2.1	2.1	2.1	2.2	2.1	2.2	2.3	-	-
Requirement at the water source l/sec/ha = IR x efficiency factor (1.18)	3.5	3.3	3.3	2.4	2.4	2.5	2.5	2.5	2.5	2.6	2.5	2.5	2.7	-	-

MONTH	MAY 1	MAY 2	MAY 3	JUNE 1	JUNE 2	JUNE 3	JULY 1	JULY 2	JULY 3	AUGUST 1	AUGUST 2	AUGUST 3	SEPTEMBER 1	SEPTEMBER 2	SEPTEMBER 3
FIELD OPERATION	LAND PREPARATION													HARVEST	
Evaporation (Eo) mm/10 days (Table 6.4)	52	52	52	52	52	52	61	61	61	61	61	61	63	63	63
Effective rainfall (ER) mm/10 days(Table 6.11)	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Field loss (FL) mm/10 days	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Crop coefficient (Table 6.5)	0.87	0.87	0.87	0.87	0.90	1.03	1.22	1.27	1.27	1.26	1.18	1.09	1.00	-	-
Evapotranspiration (Et = Eo x f) mm/10 days	45	45	45	45	47	54	74	77	77	77	72	66	63	-	-
Pre-saturation mm/10 days	67	66	67	-	-	-	-	-	-	-	-	-	-	-	-
Consumptive use (Et+Fl+Pre) mm/10 days	262	261	262	195	197	204	224	227	227	227	222	216	213	-	-
Irrigation requirement (CU - ER) mm/10 days	258	259	261	195	197	204	224	227	227	227	222	216	213	-	-
Irrigation requirement (IR) mm/day	25.8	25.9	26.1	19.5	19.7	20.4	22.4	22.7	22.7	22.7	22.2	21.6	21.3	-	-
Irrigation requirement litres/sec/ha	3.0	3.0	3.0	2.3	2.3	2.4	2.6	2.6	2.6	2.6	2.6	2.5	2.5	-	-
Requirement at the water source l/sec/ha = IR x efficiency factor (1.18)	3.5	3.5	3.5	2.7	2.7	2.8	3.1	3.1	3.1	3.1	3.1	3.0	3.0		

7. Irrigation requirements for rice

Where water is available, rice can be planted at any time of the year, although it is best to avoid a harvest in the wetter months. Two sample calculations of irrigation requirements for rice are shown in Table 4.9, and the total water requirements for the crop according to month of planting are shown in Table 4.10

TABLE 4.10

IRRIGATION REQUIREMENTS FOR RICE ACCORDING TO TIME OF PLANTING (AT WATER SOURCE)

MONTH OF LAND PREPARATION	MONTH OF CROPPING PERIOD (1)				
	0 (2)	1	2	3	4 (3)
Jan.	3.3	2.2	2.6	2.8	2.7
Feb.	3.2	2.4	3.0	2.8	2.7
Mar.	3.2	2.7	3.0	2.8	2.8
Apr.	3.5	2.7	3.0	3.1	2.8
May	3.5	2.7	3.1	3.1	3.0
Jun.	3.5	2.8	3.1	3.1	3.0
Jul.	3.7	2.8	3.2	3.2	3.0
Aug.	3.7	2.8	3.2	3.1	2.7
Sep.	3.7	2.8	3.2	2.7	2.5
Oct.	3.8	2.8	2.7	2.6	2.4
Nov.	3.7	2.5	2.7	2.5	2.4
Dec.	3.3	2.4	2.5	2.5	2.7

Note: Irrigation requirements in litres/second/hectare

(1) for 120-day HYV
(2) assumes 30 days for land preparation
(3) first 10-day period only, crop matures on residual moisture.

The maximum water requirement occurs during the month of land preparation (Month 0 in Table 4.10). In the first month after transplanting, water requirements are much less, but increase during crop life to reach a peak in Month 3. In Month 4, water is only supplied during the first 10-days, thereafter the crop matures on residual moisture. Water requirements are greater during the dry season when there is no rainfall and rates of evaporation are generally higher.

In Table 4.9, two rice crops in succession (with the first harvest at the end of April) followed immediately by land preparation for the second crop in May are shown. While this is possible, it is not generally practised at present, and the normal interval between successive crops is about 6 weeks. During this period, straw is burnt, the field is flooded, and other land preparation activities are carried out.

8. Irrigation requirements for dry land crops

Sample calculations of irrigation requirements for groundnuts and tobacco are shown in Tables 4.11 and 4.12 respectively.

The irrigation requirements for groundnuts according to selected months of planting are shown in Table 4.13. Tobacco is usually planted over a limited period (May to June). Groundnuts are assumed as the preferred palawija crop if tobacco cannot be grown.

Actual irrigation requirements for various cropping patterns and their relation to the availability of water at the water source are presented in the next Chapter.

TABLE 4.11

CALCULATION OF IRRIGATION REQUIREMENTS FOR GROUNDNUTS

MONTH	May			JUNE			JULY			AUGUST		
10-DAY PERIOD	1	2	3	1	2	3	1	2	3	1	2	3
FIELD OPERATION	PLANTING									HARVEST		
Evaporation (Eo) mm/10 days (Table 4.1)	52	52	52	52	52	52	61	61	61	61	61	61
Effective rainfall (ER) mm/10 days (LRD,1976)	5	2	1	0	0	0	0	0	0	0	0	0
Crop coefficient (f) (Table 4.2)	0.3	0.3	0.4	0.6	0.85	0.95	0.95	0.95	0.87	0.65	-	-
Evapotranspiration (Et=Eo x f) mm/10 days	16	16	21	31	44	49	58	58	53	40	-	-
Irrigation requirement (IR=CU - ER) mm/10 days	11	14	20	31	44	49	58	58	53	40	-	-
IR mm/day	1.1	1.4	2.0	3.1	4.4	4.9	5.8	5.8	5.3	4.0	-	-
IR litres/sec/ha	0.13	0.16	0.23	0.36	0.51	0.57	0.67	0.67	0.61	0.46	-	-
IR x Efficiency factor (1.33)= Requirement at the water source litres/sec/ha	0.17	0.21	0.31	0.48	0.68	0.76	0.89	0.89	0.81	0.61	-	-

TABLE 4.12

CALCULATION OF IRRIGATION REQUIREMENTS FOR TOBACCO

MONTH	JUNE			JULY			AUGUST		
10-DAY PERIOD	1	2	3	1	2	3	1	2	3
FIELD OPERATION	TRANSPLANTING							FIRST REAPING	
Evaporation (Eo) mm/10 days (Table 4.1)	52	52	52	61	61	61	61	61	61
Effective rainfall (ER) mm/10 days (Table 4.7)	0	0	0	0	0	0	0	0	0
Crop coefficient (f) (Table 6.5)	0.30	0.30	0.36	0.55	0.70	0.92	1.00	1.00	-
Evapotranspiration (CU) (Et=Eo x f) mm/10 days	16	16	19	34	43	56	61	61	-
Irrigation requirement (IR=CU - ER) mm/10 days	16	16	19	34	43	56	61	61	-
IR mm/day	1.6	1.6	1.9	3.4	4.3	5.6	6.1	6.1	-
IR litres/sec/ha	0.19	0.19	0.22	0.39	0.50	0.65	0.71	0.71	-
IR x Efficiency factor (1.33) Requirement at the water source - litres/sec/ha	0.25	0.25	0.29	0.52	0.67	0.86	0.94	0.94	-

TABLE 4.13

IRRIGATION REQUIREMENTS FOR GROUNDNUTS ACCORDING TO MONTH OF PLANTING (AT WATER SOURCE)

MONTH OF PLANTING	MONTH OF CROPPING PERIOD(1)			
	1	2	3	4
	litres/sec/hectare			
Apr.	0.12	0.65	0.76	0.61
May	0.21	0.68	0.89	0.61
Aug.	0.27	0.84	1.00	0.68
Sep.	0.28	0.89	0.92	0.45

(1) figures given are those for the mid-month 10 day period.

(2) first 10 days only.

CHAPTER V

THE MOST BENEFICIAL CROPPING PATTERN

This chapter attempts to use economic criteria to determine the most beneficial cropping pattern for the study area (i.e. The cropping pattern which will give the greatest return to the farmer). Theoretically, irrigation should be used to produce the crop generating the greatest return per unit of area and unit of time (James & Lee, 1971 ,p. 303). However, no matter how great the returns, a cropping pattern should not be suggested unless it is practicable. This is especially true in the study area, where considerations besides economics (attitude of the farmer, government policy) might play a strong role in determining the kind of crops to be grown by farmers.

To derive appropriate results from an economic analysis, three distinct scenarios must be considered (eg. the present situation, future without project, and future with project). As well, the price to be used in the calculations should be based on the financial price (market price), as well as the accounting price (shadow price). Due to time constraints, however, the economic analysis presented in this study is limited to one scenario (present situation) and one price level (financial or market price). Implications of this will be discussed later.

The economic analysis attempts to calculate a crop budget in order to establish the return from each crop. A distinction is made between crops grown in open sawah or under coconuts and, the following crops are considered practical:

rice, groundnuts, maize, tobacco, cassave, coconuts and bananas. The return of each crop is established by calculating the gross revenue less total costs of each crop. The unit used is rupiahs per hectare per season. The gross revenue is obtained by multiplying crop production per hectare and its price per unit of production. The total cost is derived by summation of all costs involved in the production of each crop per hectare (e.g. material cost, labour cost, depreciation cost, fixed cost). The return from each crop is applied to calculate the net return by cropping pattern per hectare per year.

1. Calculations of Gross Revenue for each Crop

Present crop yields are based on information obtained from the local agriculture office and subak survey carried out by LRD. A summary is presented in Table 5.1, and more explanation is given in Appendix II.

Gross revenue based on Table 5.1 are presented in Table 5.2.

2. Calculation of Total Cost for Each Crop

Physical input requirements for individual crops grown in open sawah or under coconuts were derived from the work of LRD (1976), Van der Goot (1973) and surveys conducted in the study area. Data are summarized in Tables 5.3 to 5.9. Table 5.10 shows the prices of inputs.

In general, yields are closely related to fertilizer use. Seed rates are assumed to be at near optimum levels already.

TABLE 5.1

PRESENT CROP YIELD & CROP PRICE

Crop	Units	Crop yield(per ha) Open sawah	Under coconut	Crop Price (rupiah)[1]
Rice	kg dry gabah	4000	2400	51
Groundnuts	kg dry shelled nuts	660	480	150
Maize	kg dry maize	500	300	43
Tobacco	kg flue cured	1500	-	485
Cassava	kg wet unpeeled	-	4000	13
Coconuts	nuts	-	4350	32
Bananas				
-bananas	stems of fruit	-	120	210
-pseudostems	number	-	200	49
-leaves	bundles	-	40	17.5

Source: Agriculture Office & Trade Office - Bali.

TABLE 5.2

GROSS REVENUE OF CROP

Crop	Gross Revenue Thousand Rupiahs/Hectare/Crop	
	Open sawah	Under Coconut
Rice	204.0	122.4
Groundnuts	99.0	72.0
Maize	21.5	12.9
Tobacco	727.5	-
Cassava	-	52.0
Coconuts	-	139.2
Bananas		
- Bananas	-	25.2
- Pseudostems	-	9.8
- Leaves	-	0.7

Labour requirements have been divided into those which can be met from within the family or by the traditional self-help co-operative system, called "gotong royong". Where this is inadequate or inappropriate, hired labour is used. Labour requirements shown are on a per crop season basis.

Animal power for land preparation and other types of cultivation is usually supplied by Balinese cattle working in pairs. Internal transport, (transport within the farm) may be by manual labour or animal power (buffalo cart). Tillage operations are usually done by the farmer with his own animals or on a "gotong royong" basis, but buffalo carts may be hired on a per load or daily basis.

Based on the valuation of input quantities and their prices as summarized in the previous tables, costs of production for each individual crop are shown in tables 5.11 to table 5.17.

Under financial price terms, the value of labour cost is only calculated for hired labour (Mh & Fh) and family labour (Mf, Ff and Ma) is not treated as a cost. The cost for the usage of animal power is also not treated as a cost, since the animals belong to the farmer. Fixed cost eg. IPEDA tax, subak charges and depreciation are not included yet in the following cost calculation.

TABLE 5.3

RICE: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION Open sawah	Under coconut
MATERIALS			
Seed	kg	45	45
Fertilizer: Urea	kg	100	60
TSP	kg	30	20
Insecticide	litres	1.5	1.0
Rodenticide	grams	100	100
LABOUR			
Nursery	mandays Mf	7	7
Land preparation	mandays Mf	15	15
	mandays Ma	35	35
Pulling & bundling seedlings	mandays Mf	15	15
Transplanting	mandays Fh	20	20
Weeding	mandays Mf	40	32
	mandays Ff	5	4
Applic. of pesticide	mandays Mf	2	2
fertilizer	mandays Mf	2	1
Irrigation	mandays Mf	12	12
Harvesting	mandays Mf	2	2
	mandays Ff	2	2
	mandays Mh	23	14
	mandays Fh	23	14
Threshing	mandays Mh	13	8
	mandays Fh	13	8
Internal transport	mandays Ma	5	3
	mandays Mf	10	6
TOTAL	mandays	244	200
ANIMAL POWER			
Nursery	pr. of oxen	3	3
Land preparation	pr. of oxen	35	35
Transport	buffalo cart	5	3
TOTAL		43	41

Labour Category: Mf, Ff: Family labour, male & female inc. gotong royong activities.
Mh, Fh: Hired labour, male & female.
Ma: Ploughmen and buffalo cart operators

TABLE 5.4

GROUNDNUTS: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION Open sawah	Under coconuts
MATERIALS			
Seed	kg dry shelled nuts	100	100
Fertilizer: Urea	kg	-	-
TSP	kg	-	-
Pesticide	litres	-	-
LABOUR[(1)]			
Land preparation	mandays M	40	30
Sowing	mandays M	4	4
Weeding	mandays F	15	10
Irrigation	mandays M	2	-
Harvesting	mandays M	10	7
	mandays F	12	9
Threshing	mandays Fh	22	16
Drying	mandays F	2	2
Internal transport	mandays M	3	2
TOTAL		110	80
ANIMAL POWER			
Land preparation	pair of oxen	40	30
Internal transport	buffalo cart	1	1
TOTAL		41	31

[(1)] All family labour except for threshing which is done by hired female.

Source: LRD, 1976
Interviewing with farmers.
Agricultural Office.

TABLE 5.5
MAIZE: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNIT	PRESENT SITUATION Open sawah	Under coconut
MATERIALS			
Seed	kg dry grain	20	20
Fertilizer: Urea	kg	-	-
TSP	kg	-	-
Pesticides	litres	-	-
LABOUR(1)			
Land preparation	mandays M	10	20
Sowing	mandays M	4	4
Weeding	mandays M	4	8
Ridging	mandays M	-	-
Applic. of fertilizer pesticides	mandays M	-	-
Irrigation	mandays M	2	-
Harvesting	mandays M & F	8	6
Shelling	mandays F	10	8
Internal transport	mandays M	2	2
TOTAL		40	48
ANIMAL POWER			
Land preparation	pair of oxen	10	20
Weeding	pair of oxen	4	-
Ridging	pair of oxen	-	-
Internal transport	buffalo cart	1	1
TOTAL		15	21

(1) Family labour only

SOURCE: LRD, 1976.
Interviewed with farmer.
Agricultural Office.
Van der Goot, 1973.

TABLE 5.6
TOBACCO: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION Open sawah	Under coconut
MATERIALS			
Seed	grams	5.0	Not grown
Fertilizer:NPK	kg	300.0	
Ammonium nitrate	kg	5.0	
Insecticide	kg	3.5	
Fungicides	kg	0.5	
String	balls	3.5	
Plastic sheeting	sheets	2.0	
Kerosene	litres	3000.0	
LABOUR			
Nursery and seedling	Mf	20	
production	Ff	10	
Land preparation:			
Cutting stubble	Mf	8	
Ploughing	Mf	28	
Planting	Mh	20	
	Fh	20	
Replanting	Mf	2	
Applic. of fertilizer	Mf	10	
pesticides	Mf	3	
Ridging	Mf	8	
Weeding	Mf	60	
	Ff	20	
Irrigation	Mf	6	
Topping	Mf	6	
Suckering	Mf	6	
Harvesting	Mf	10	
Internal transport	Mh	15	
	Ff	10	
	Fh	15	
YIELDS	kg dry leaf	1500	
LABOUR			
Tieing and	Mf	12	Not grown
Loading barn	Ff	13	
Curing	Mf	40	
Unloading barn &	Mf	12	
Grading	Ff	22	
Binding & storage	Mf	2	
	Ff	8	
Baling	Mf	6	
	Ff	2	
TOTAL		394	
ANIMAL POWER			
Ploughing	pair of oxen	28	
Ridging		8	
TOTAL		36	

SOURCE: BAT, [illegible]raja Office.

TABLE 5.7

CASSAVA: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION Open sawah	Under coconuts
MATERIALS			
Stem cuttings	number	Not grown	10,000
LABOUR (1)			
Land preparation	M		20
Planting	M		5
Weeding	F		30
Harvesting	M		6
	F		6
Internal transport	M		20
	F		20
TOTAL			107
ANIMAL POWER			
Land preparation	pair of oxen		20

SOURCE: Van der Goot (1973).
Interviewing with farmers.

(1) All family labour.

TABLE 5.8

COCONUTS: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION
MATERIALS		
Seedlings		8
LABOUR		
Holing & Planting	Mf	1
Harvesting	Mh	15
Field collection	Mh	6
	Fh	12
	Mh	6
	Fh	6
TOTAL		46
ANIMAL POWER	buffalo cart	6

Sources: LRD (1976)
Interviewing with farmers.

TABLE 5.9

BANANAS: INPUTS AND LABOUR REQUIREMENTS
(per hectare)

ITEMS	UNITS	PRESENT SITUATION Under Coconuts
MATERIALS		
Planting materials	suckers	10
LABOUR(1)		
Holing & Planting	mandays M	1
Harvesting bananas	mandays M	2
	mandays F	2
Cutting pseudostems	mandays M	8
Internal transport	mandays M	12
TOTAL		25

SOURCE: LRD (1976)
Interviewing with farmers.

TABLE 5.10
AGRICULTURAL INPUT PRICES USED FOR COST CALCULATION
(1978 PRICES)

ITEM	UNIT	PRICE (rupiah)
Seed	kg	1.5 times harvest value
Coconut seedling	No.	25
Fertilizer: Urea	kg	50
TSP	kg	50
Insecticide/Fungicide	litre	1230
Rodenticide	kg	2300
String	balks	425
Plastic sheeting	No.	700
Kerosene	litre	37.5
Hired labour (male or female)	mandays	350
Subak & religious charges	hectare/annum	2500
Ipeda tax: sawah class I	hectare/annum	7625
sawah class II	hectare/annum	5490
sawah class III (dry land)	hectare/annum	1525
Interest working capital	12 percent on hired labour and materials for 4 months per crop.	
Depreciation	hectare/annum	5000
Animal power	pair of oxen & plough or cart	400

SOURCE: Agriculture Office Denpasar - Bali.
Trade Office, Denpasar - Bali.
BAT Office, Singaraja - Bali.

TABLE 5.11
COST CALCULATION FOR RICE HYV
(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION Open sawah	Under coconuts
MATERIAL COSTS		
Seed	3.4	3.4
Fertilizer: Urea	5.0	3.0
TSP	1.5	1.0
Insecticide	1.8	1.2
Rodenticide	0.2	0.2
SUB-TOTAL	11.9	8.8
LABOUR COST		
Family - Male	-	-
- Female	-	-
Hired - Male	19.6	14.7
- Female	12.6	7.7
SUB-TOTAL	32.2	22.4
OTHER COST		
Animal power	-	-
Interest on working capital	1.8	1.3
SUB-TOTAL	1.8	1.3
TOTAL COSTS	45.9	32.5

TABLE 5.12
COST CALCULATION FOR GROUNDNUTS
(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION Open sawah	Under coconuts
MATERIAL COSTS		
Seed	22.5	22.5
Fertilizer	-	-
Pesticides	-	-
SUB-TOTAL	22.5	22.5
LABOUR COSTS		
Family	-	-
Hired - female	7.7	5.6
SUB-TOTAL	7.7	5.6
OTHER COSTS		
Animal power	-	-
Interest on working capital	1.2	1.1
SUB-TOTAL	1.2	1.1
TOTAL COSTS	31.4	29.2

TABLE 5.13
COST CALCULATION FOR MAIZE
(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION Open Sawah	Under coconuts
MATERIAL COSTS		
Seed	1.3	1.3
Fertilizer: Urea	-	-
TSP	-	-
Pesticides	-	-
Sub-Total	1.3	1.3
LABOUR CORS		
Family	-	-
Hired	-	-
Sub-Total	-	-
OTHER COSTS		
Animal power	-	-
Interest on working capital	0.1	0.1
Sub-Total	0.1	0.1
TOTAL COSTS	1.4	1.4

TABLE 5.14
COST CALCULATION FOR TOBACCO
(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION Open sawah	Under coconuts
MATERIAL COSTS		
Seed	2.5	Not grown
Fertilizer: NPK	15.0	
Amonium nitrate	0.3	
Insecticides	4.3	
Fungicides	0.6	
String	1.5	
Plastic sheeting	1.4	
Kerosene	112.5	
Sub-Total	138.1	-
LABOUR COSTS		
Family	-	
Hired - male	12.3	
- female	12.3	
Sub-Total	24.6	-
OTHER COSTS		
Animal power	-	
Depreciation (1)	61.5	
Interest on working capital	6.5	
Industrial tax	3.5	
Company tax	4.5	
Government tax	3.6	
Sub-Total	79.6	-
TOTAL COSTS	242.3	-

(1) Specific to tobacco production.

TABLE 5.15

COST CALCULATION FOR CASSAVA
(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION Open sawah	Under coconut
MATERIAL COST		
Stem cuttings	-	25.0
LABOUR COSTS		
Family	-	-
Hired	-	-
OTHER COSTS		
Animal power	-	-
Interest on working capital		1.0
Sub-Total	-	1.0
TOTAL COSTS		26.0

TABLE 5.16

COST CALCULATION FOR COCONUTS

(thousand rupiahs/hectare/crop)

ITEM	PRESENT SITUATION
MATERIAL COSTS	
Seedlings	0.2
LABOUR CORS	
Family	-
Hired - male	9.5
- female	6.3
Sub-Total	15.8
OTHER COSTS	
Animal power	-
Interest on working capital	0.6
TOTAL COSTS	16.6

TABLE 5.17

COST CALCULATION FOR BANANAS UNDER COCONUTS

(thousand rps/ha/crop)

ITEM	PRESENT SITUATION
MATERIAL COSTS	
Planting material	2.5
LABOUR COSTS	
Family	-
Hired	-
OTHER COSTS	
Animal power	-
Interest on working capital	0.1
TOTAL COST	2.6

3. Crop Budget

Table 5.18 contains budgetary statements in the present situations showing the net return for individual crops.

TABLE 5.18
NET CROP RETURN
(thousand rupiahs/crop/ha)

CROP	SITUATION Open sawah	Under coconut
1. Rice		
- gross revenue	204.0	122.4
- cost	45.9	32.5
- net return	158.1	89.9
2. Groundnuts		
- gross revenue	99.0	72.0
- cost	31.4	29.2
- net return	67.6	42.8
3. Maize		
- gross revenue	21.5	12.9
- cost	1.4	1.4
- net return	20.1	11.5
4. Tobacco		
- gross revenue	725.5	Not grown
- cost	242.3	
- net return	483.2	
5. Cassava		
- gross revenue	Not grown	52.0
- cost		26.0
- net return		26.0
6. Coconuts		
- gross revenue	Not grown	139.2
- cost		16.6
- net return		122.6
7. Bananas		
- gross revenue	Not grown	35.7
- cost		2.6
- net return		33.1

The highest net return is from tobacco but marketing constraints (i.e. monopsonistic buyer) will likely limit the area to be devoted to this crop (Appendix II). Rice is ranked second, followed by coconuts, groundnuts, bananas, cassava and maize, respectively.

4. The Most Beneficial Cropping Pattern

Net return by cropping pattern is shown in Table 5.20 for the main crop combinations, based upon the net crop returns presented in Table 5.18 and fixed costs from Table 5.19. Fixed costs consist of IPEDA tax and subak charges where relevant, and depreciatory costs as shown in Table 5.10. Fixed costs do not include any project charges at this stage of analysis.

Of the various cropping patterns examined, the highest economic return is obtained from a rice-tobacco rotation (628.2 thousand rupiahs/ha/year), followed by a rice-rice rotation (301.1 thousand rupiahs/ha/year). Both of these cropping patterns occur in open sawahs, however, and open sawah presently accounts for less than 15 percent of the agricultural land in the study area. Under coconuts, a rice-groundnut-groundnut rotation yields 283.0 thousand rupiahs, but this form of land use accounts for less than 5 percent at present. The most common rotation (bananas and food crops under coconuts), occupying about 75 percent of the project agricultural land area, is estimated to provide a net return of 177.8 thousand rupiahs/ha/year.

TABLE 5.19
FIXED CHARGES BY CROPPING PATTERN: 1978 PRICES
(thousand rupiahs per hectare per annum)

CROPPING PATTERN	OPEN SAWAH	UNDER COCONUT
Rice, rice	15.1	-
Rice, tobacco	15.1	-
Rice,groundnuts	13.0	15.1
Rice, groundnuts,groundnuts	15.1	15.1
Rice, maize	13.0	13.0
Rice, groundnuts, maize	15.1	15.1
Bananas. food crops	-	6.5

SOURCE: Table 5.10

TABLE 5.20
NET RETURN BY CROPPING PATTERN: 1978 PRICES
(thousand rupiahs per hectare per annum)

CROPPING PATTERN	OPEN SAWAH	UNDER COCONUT
Rice, rice	301.1	-
Rice, tobacco	628.2	-
Rice, groundnuts	212.8	240.2
Rice, groundnuts, groundnuts	278.2	283.0
Rice, maize	165.2	211.0
Rice, groundnuts, maize	230.7	251.7
Bananas, food crops	-	177.8

Calculations are based on Tables 5.18 and 5.19.

From a strict economic point of view, it is clear that rice - tobacco rotation should be proposed as the favoured rotation in the study area. The potential for this cropping pattern is strictly limited by marketing consideration. The only buyer for tobacco is BAT, hence it is in a monopsonistic buying position. As a monopsony corporation, BAT would be able to manage its operation in order to maximize its profit with a relatively smaller total input at a lower price per unit than if the corporation operated competitively. As BAT would not likely increase its scale of operation, it is likely no reason for BAT to buy more tobacco from the farmer than its present requirements.

The incentive to grow rice is much higher than for any other crops, if irrigation water can be provided. Farmers perceive water at a zero cost, and treat it as a free good. Because rice and its agricultural inputs are subsidized in Indonesia, the price is artificially supported or otherwise affected by government policy. This is designed to ensure a large volume of rice production, since rice is still imported to fulfill domestic demand thus financial prices used in this calculation are likely quite distorted as a result of these activities.

Considering the above reasons, it is quite reasonable to assume that the cropping pattern applied in the study area will be based as much as possible on rice. A further study based on the accounting price of crops might be required for comparison with this study.

Because water requirements for groundnuts are substantially lower than for rice in the dry season, the return to water from groundnuts would be correspondingly higher than those from double-cropped rice. In theory therefore, where water is limited, the rice-groundnuts-groundnuts combination should be preferred to the double rice crop. However, it is again unlikely that many farmers,given water, will prefer to grow groundnuts in the dry season rather than a second rice crop. Groundnuts have been included in the dry season only insofar as they are necessary to allow the limited water supplies to be extended to the whole study area.

Comparing crop returns from open sawah to those obtained under coconuts, there appears to be no immediate advantage in clearing coconuts to create open sawah. This supports the view of farmers interviewed in the study area, who felt that the coconut cover crop should be maintained in conjunction with the irrigation scheme. In the more distant future, conversion to open sawah would still be possible if changing physical or economic conditions warranted it.

CHAPTER VI

IRRIGATION WATER PLAN

In managing the distribution and allocation of irrigation water to individual farmers, a number of relatively complex decisions are required. One recent writer in describing the Indonesian situation has divided these decisions into two categories: those involving planning, and those involving operation:

> Planning decisions deal with estimating potential water availabilities and determining cropping systems to make optimum use of expected water supplies. Operational decisions refer to the management of water for irrigated areas already planted, especially under circumstances in which actual water supplies are less than expected. (Pasandaran, 1976, p. 2).

Basically, the availability of water at an intake gate to an irrigation system must be related to the demand for water throughout the system. The level of demand, in turn, depends on the needs of various crops at various stages of maturation. This chapter will summarize results to propose an irrigation water plan in order to match the crop demand for water with available supply for one crop calendar year in the study area. In addition, according to the authority cited formerly:-

> During the wet seasons, the principal issue in water management is whether available water supplies are adequate to enable all irrigation units within an irrigation system to be simultaneously planted. During the dry seasons, the principal issue is determining the relative areas to be planted to rice and secondary crops... (Pasandaran, 1976, p. 3 and p. 15).

Clearly crop yields obtained from irrigated land, depend very much on how available water is allocated to each field, and matched with crop rotations

1. Irrigation units

For planning purposes, the study area has been divided into units formed by natural east-west boundaries and by the lines of the proposed canals for the north and south boundaries. Where there is a proposal to pump water, the upper canal alignments formed the boundaries of irrigation units.

These irrigation units could be used as a basis for extending the boundaries of existing subaks or creating new ones, since the subak system is likely to operate in this area as it does in all irrigated areas in Bali.

The proposed irrigation units are shown in Table 6.1, and the proposed canal lines, irrigation units and land considered suitable for irrigation are illustrated in Figure 6.1.

2. Water Supply

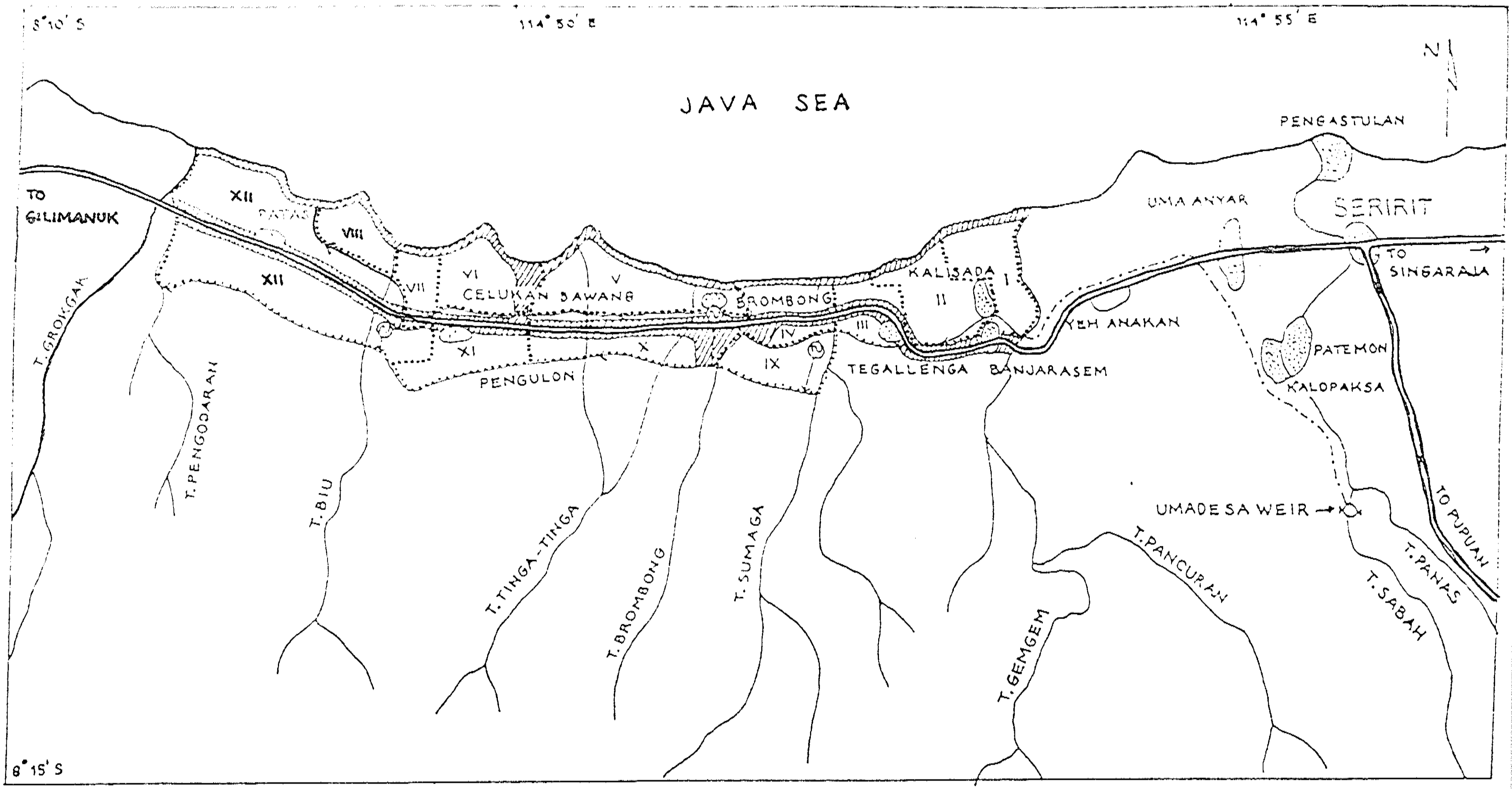
The main source of irrigation water will be the Tukad Sabah. However, irrigation units I and II are already under sawah and have another source of irrigation water for rice growing in the wet season, that is from Tukad Gemgem.

It is suggested that irrigation units I and II should continue to utilize water from Tukad Gemgem, and only draw water from the new gravity canal when their present supply is inadequate. Potential flows of Tukad Gemgem were available from calculation done by P3SA-Office, but were based on less than two

Table 6.1 Land Classification & Irrigation Unit (ha)

Irrigation Unit	Sawah	Coconut	Dry-land	Total	Not Irrigable	Urban	Total	Study Area
Gravity Canal								
I	88.0	-	-	88.0	10.0	2.5	12.5	100.5
II	68.7	11.1	-	79.8	7.1	13.1	20.2	100.0
III	6.4	49.6	-	56.0	5.3	8.7	14.0	70.0
IV	1.0	54.3	-	55.3	9.1	9.6	18.7	74.0
V	1.0	101.5	-	102.5	17.0	3.5	20.5	123.0
VI	-	76.7	-	76.7	5.2	12.1	17.3	94.0
VII	-	44.9	-	44.9	6.1	1.0	7.1	52.0
VIII	-	51.3	-	51.3	7.7	-	7.7	59.0
Gross Area	165.1	389.4	-	554.5	67.5	50.5	118.0	672.5
Net Area*	148.6	350.5	-	499.1	-	-	-	499.1
Pumping Canal								
IX	-	86.0	-	86.0	3.5	12.5	16.0	102.0
X	1.0	108.1	1.6	110.7	31.3	26.0	57.3	168.0
XI	6.0	69.5	-	75.5	8.0	6.0	14.0	89.0
XII	19.5	357.5	5.0	384.0	19.5	23.0	42.5	426.5
Gross Area	26.5	623.1	6.6	656.2	62.1	76.5	129.8	786.0
Net Area*	23.8	560.8	5.9	590.5	-	-	-	590.5
Study Area								1458.5
Gross Area								1210.7
Net Area								1089.6

*Gross area le[illegible]han 10 percent for irrigation infrastructures
Sources: La[illegible] Map Figure 2.6 and Aerial Photo Interpretations P3SA Bali



.... IRRIGATION UNIT BOUNDARIES

—·—·— REMODELLED CANAL

PROPOSED NEW CANAL

ROAD

RIVER

PUMP STATION

VILLAGES

UNIRRIGABLE AREAS

1KM 0 1 2 3

SCALE 1 : 75,000

FIG.6.1 PROPOSED IRRIGATION SCHEME

SOURCE : PUBLIC WORK OFFICE BALI

years of records. (table 6.3) For Tukad Sabah, as discussed in Chapter III, on allowance has been made to satisfy the present requirements of the subaks, which rely on water from Puluran and Karangsuwung weirs, downstream of the Umadesa Weir. The design flow has been presented in Table 3.6.

3. Allowance for present demands on Umadesa Canal

The Umadesa canal, at present, supplies water to five subaks with a total area of 400 ha. The irrigation system provides sufficient water for this area to be planted with rice at least twice a year. On a few farms, however, tobacco is grown instead of a second rice crop. Since none of these subaks will benefit from the project from an economic point of view, they are not considered to be part of the study area.

A future cropping pattern is proposed for these five subaks (Table 6.2). This pattern allows two crops of rice over much of the area, continuous rice cropping on one-third of the area, and an increase in the area under tobacco.

4. Proposed irrigation water plan for the study area

As discussed in Chapter V, where rice is already grown, the aim should be to provide irrigation for a second rice crop. Where the present farming pattern is based on dry land crops the aim should be to provide irrigation for rice at least once, and prefereably twice per year. Priority is given to the areas irrigated by the proposed gravity canal, since high water requirements for rice would be very costly if they were met by pumping.

Table 6.2 Proposed Future Cropping Pattern for Five Subaks Commanded by the Present Umadesa Canal.

Wet Season		Dry Season		Late Dry Season	
Crop	Ha	Crop	Ha	Crop	Ha
Rice	130	Rice	130	Rice*	130
Rice	140	Rice	80		
		Tobacco	60		
Rice	130	Rice	130		
Total	400		400		130

*Third rice crop continuous into following year.

Table 6.3 WATER PLAN FOR THE PROJECT AREA (cubic metres per second)

Line		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Design flow Tukad Sabah	5.77	6.38	4.75	3.84	2.72	2.59	2.04	1.29	1.87	2.03	3.23	2.84
2	5 Subaks under present Umadesa Canal = 400 ha												
2a	Rice/Rice/Rice - 130 + 130 + 130	0.35	0.32	0.31	0.46*	0.35	0.38	0.40	0.37	0.48*	0.37	0.48*	0.32
2b	Rice/Rice - 140 + 80	0.33	0.35	0.35	0.38	0.28*	0.22	0.25	0.24	0.24			0.46*
2c	Rice/Rice - 130 + 130	0.43*	0.29	0.34	0.37	0.35	0.46*	0.37	0.40	0.40	0.38		
2d	Tobacco - 60						0.017*	0.040	0.056				
3	Total	1.11	0.96	1.00	1.21	0.98	1.08	1.06	1.08	1.12	0.75	0.48	2.78
4	Balance flow from Tukad Sabah	4.66	5.42	3.75	2.63	1.74	1.51	0.98	0.21	0.75	1.28	2.75	2.06
5	Design flow Tukad Gemegem	1.57	2.80	4.10	2.90	2.80	0.52	0	0	0	0	0	1.33
6	I.U. I and II = 150 ha												
6a	Rice/Rice - 150 + 130	0.41	0.37	0.35	0.46*	0.35	0.38	0.40	0.37			0.55	0.37
6b	Tobacco - 20						0.006	0.013	0.019				
7	Total	0.41	0.37	0.35	0.46	0.35	0.39	0.41	0.39	0	0	0.55	0.37
8	Water required from Tukad Sabah	0	0	0	0	0	0	0.41	0.39	0	0	0.55	0
9	Balance flow in Tukad Sabah	4.66	5.42	3.75	2.63	1.74	1.51	0.57	0	0.75	1.28	2.20	2.06
10	I.U. III to VIII = 350 ha												
10a	Rice/Rice - 175 + 175	0.45	0.41	0.56*	0.47	0.52	0.50	0.50			0.66*	0.50	0.47
10b	Rice/GN/GN - 175 + 175 + 175	0.41	0.43	0.43	0.47	0.036*	0.12	0.16	0.11	0.05*	0.16	0.16	0.58*
11	Total	0.86	0.84	0.99	0.94	0.56	0.62	0.66	0.11	0.05	0.82	0.66	1.05
12	Balance flow in Tukad Sabah	3.80	4.58	2.76	1.68	1.18	0.89	0	0	0.70	0.46	1.54	1.01
13	I.U. XII = 345												
13a	Rice/GN - 100 + 100	0.27	0.25	0.24	0.012*	0.065	0.076	0.061				0.37*	0.25
13b	Rice/GN - 100 + 100	0.24	0.25	0.25	0.25					0.028*	0.089	0.092	0.33*
13c	Rice/GN - 145 + 145	0.48*	0.34	0.38	0.41	0.39				0.040*	0.129	0.133	0.065
14	Total	0.99	0.84	0.87	0.69	0.46	0.08	0.06		0.07	0.22	0.60	0.65
15	Balance flow in Tukad Sabah	2.81	3.74	1.89	1.02	0.72	0.81	0	0	0.63	0.24	0.34	0.36
16	I.U. X and XI = 168 ha												
16a	Rice/GN - 168 + 168	0.46	0.42	0.40	0.02*	0.11	0.13	0.10				0.61*	0.42
17	Balance flow in Tukad Sabah	2.35	3.32	1.49	1.00	0.61	0.68	0	0	0.63	0.24	0.33	0
18	I.U. IX = 77 ha												
18a	Rice/GN - 77 + 77	0.25*	0.17	0.20	0.22	0.21				0.02*	0.07	0.07	0.03
19	Balance flow in Tukad Sabah	2.10	3.15	1.29	0.78	0.40	0.68	0	0	0.61	0.17	0.26	0

Notes : * = month of land preparation for rice or planting for other crops
: areas in hectare are rounded

Table 6.3 presents a water plan for the study area. In practise, there should be some phasing of operations within the periods suggested to spread peaks in water demand, especially during land preparation for rice. The design flow for the Tukad Sabah (Table 6.3, line 1) shows the total amount of water available at the Umadesa weir. Lines 2 and 3 show the irrigation requirements derived in section 2 of this chapter. The balance of water from Tukad Sabah is shown in line 4.

For irrigation units I and II, which are mostly open sawah, the proposed cropping pattern allows for two crops of rice on most of the area, with 20 hectares set aside for tobacco. In the wet season, these units are currently irrigated from Tukad Gemgem, and future irrigation needs can be met from that river (line 5). In order to achieve early planting of rice in November and to meet irrigation requirements during the dry season, it would be necessary to extract water from the Tukad Sabah flow (line 8). The balance of flow from Tukad Sabah (line 9) shows the critical constraints to increasing the area under double cropping of rice (i.e. there is no water available in the month of August).

The remaining area to be serviced by the proposed gravity canal (I.U. III to VIII) is considered in line 10. It is almost all under coconuts, thus ruling out the possibility of tobacco growing. In the wet season, rice can be grown in the entire area. In the dry season, there is just enough water available for half the area to be planted with a second rice crop. This objective could only be achieved if land preparation for the wet season rice crop is carried out in October. This means harvesting the wet season crop in February, but disadvantages of this should be off-set by the advantages of growing a second crop of rice. Delays in planting the first rice crop would result in the second crop running into water shortages in August. The other half of the area could be planted with two successive palawija crops in the dry season, and two crops of groundnuts have been adopted as the most attractive palawija.

Thus on irrigation units III to VIII, three crops of rice could be grown in two years. This could be programmed by supplying sufficient water for the second rice crop to half the area in one year, and to the other half in the second year, essentially an arrangement between subaks. Alternatively, a constant flow of water could be maintained to each unit, and the division of water could be an intra-subak arrangement, which is likely preferable.

A third possibility would be to designate irrigation units III and IV and most of V as double crop areas, and not allow sufficient water for a dry season rice crop to reach units further to the west. This would seem to be inequitable and could give rise to administrative and social problem in the future.

Having served all possible gravity areas, the flow from Tukad Sabah is now nil in July and August. Unless a quite impractical cropping pattern is adopted (harvest period in January), there is insufficient water for any further double cropping of rice.

The irrigation units which could be irrigated by pumping irrigation units IX to XII, have been considered in reverse order from west to east. This is because pumping costs are likely to be lower for a larger area. Sufficient water would be available for rice to be grown in the dry season. Farmers would probably try to grow an extra palawija crop in the dry season, and this should be possible in the average year if pumping costs could be justified. Rice-groundnut cropping patterns are proposed for irrigation units IX to XII (lines 13, 16 and 18) and the maximum area of each unit could be irrigated in each case. The present areas of sawah in these units are small and make no significant difference to the calculations.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion

General conclusion

1.1 Expansion of the irrigation program on Tukad Sabah would require changes in present agricultural practises. Limited water resources of the Tukad Sabah would have to be shared over a wider area, which would require adoption of a program of cropping and water regulation. This program will likely affect all subaks currently serviced from Umadesa weir. The task of informing the subaks and supervising these changes would be the responsibility of the present sedahan officers (representative of a group of subak chiefs).

Conclusions dealing with main objective

1.2 The irrigation water plan proposed in this study has revealed that present supplies of irrigation water can be utilized on land under sawah and supplemented, when necessary, by water from the new canal. In the open sawah directly west of Tukad Gemgem, two crops of rice could be grown per year. In the coconut areas further west, only half the farms could be doubled cropped with rice in one year and the other half could be cropped with palawija in the dry season (Table 6.3). The constraint to double cropping of rice in the dry season is the very small flow of water from Tukad Sabah during July to September. In July and August, only the area to be serviced by the proposed gravity canal could be irrigated (irrigation units III to VIII).

1.3 While the cropping pattern proposed for the five subaks east of Tukad Gemgem allows them to continue with their present cropping programs, the subaks located in the study area would have to time their farm operations to meet requirements of the irrigation plan. The existing subaks of Tegallengah, Bajar Munduk and Kalisada would therefore, have to start land preparation for rice earlier than at present in order to allow for cultivation of a dry season rice crop before the water supply becomes inadequate. For the same reason, the subaks comprising irrigation units III to VIII would have to start land preparation in October.

Conclusions dealing with sub-objective 1

1.4 The hydrological analyses in this study are based on four years of flow records at the Umadesa weir and about 30 years of intermittent rainfall records. These data are thus not a very reliable basis for estimating minimum water availability. However, in the absence of better information, design flows for this river have been derived by adjusting minimum monthly flows on the basis of annual rainfall probability of occurence.

Conclusions dealing with sub-objective 2

1.5 Rice production uses the greatest amount of water, with peak requirements occuring during land preparation. If land preparation takes place in the dry season, up to 3.8 litres/sec/ha are required at the water source. During the growing period, requirements range from 2.2 litres/sec/ha in the first month of the wet season to 3.2 litres/sec/ha during the second and third months of the dry season. For dryland crops, irrigation requirements never exceed 1.0 litre/sec/ha at the water source.

1.6 Consumptive use of water by rice is estimated to average 22 mm per day. An irrigation cycle of 3 days is considered necessary to maintain the water level in sawah basins. For dryland crops, a ten-day cycle is generally used, but further investigation is needed to determine the available moisture capacity of soils. Effects of a sawah plough pan on the rooting depth of crops must also be required before recommendations can be made.

1.7 Field losses in sawah rice are exceptionally high, even by Indonesian standards. This is likely caused by lateral percolation of water into small dikes, and then downward, rather than by vertical percolation through the sawah basin floor. For dryland crops, field losses are much smaller and are included in the overall efficiency factor.

1.8 Effective rainfall contributes only slightly to crop water requirements for rice. In the dry season, effective rainfall is nil, and has little influence on dryland crops being grown.

1.9 Irrigation efficiency factors which were adopted appear consistent with current recommendation for Indonesian conditions (e.g. 85 percent for sawah rice and 75 percent for dryland crops).

Conclusions dealing with sub-objective 3

1.10 Of the cropping patterns examined in the present situation, the highest economic return is obtained from a rice-tobacco rotation, followed by a rice-rice rotation. Both of these cropping patterns occur primarily in open sawahs, however, and this type of land use accounts for a small amount less than 15 percent of the study area at present. Furthermore, tobacco production is limited by marketing constraints. Under coconuts, a rice-groundnuts-groundnut rotation yields 2830 thousand rupiahs/ha/year, but this form of land use is also insignificant in the study area. The most common rotation of bananas and food crops under coconuts (occupying about 75 percent of the study are) is estimated to provide a net return of 177.8 thousand rupiahs/ha/year.

1.11 Rice cropping gives the best return of traditional crops grown on a large scale in Bali, in spite of the high irrigation requirement and restricted area of cropping in the dry season.

2. Recommendations

2.1 Flow data for the Tukad Sabah should be reaffirmed before project implementation. The program of river flow gauging and rainfall measurement, established by P3SA, should continue, but accuracy and reliability must be emphasized.

2.2 Because irrigation requirement determined by this study exceeds values used in Indonesia in the past further detailed soil surveys should be carried out to better define boundaries of land unsuitable for irrigation, and to determine more fully the water-related characteristics of soils. Further research should also be undertaken to determine if sealing the small dikes with plastic sheeting will reduce the irrigation requirement.

2.3 The government, through the Public Works Office, should operate and maintain all irrigation infrastructure, but close co-operation with the subaks should be maintained through the Sedahan Agung (subak coordinator). It would also be desirable for operators to be recruited from local subaks to ensure efficient and reliable operation.

2.4 A system of rotational irrigation should be practised throughout the year on all areas irrigated from Umadesa weir.

2.5 Boundaries of the proposed irrigation units could form basis for new subaks but a maximum size of 90 hectares would be recommended from field observations, very large subaks such as Umadesa did not appear to operate satisfactorily from an organizational point of view.

2.6 Comparing returns from open sawah to those from cropping under coconuts, there appears to be no immediate advantage to removing coconut trees to create open sawah. However, if the stand density of coconut trees were halved, yields from rice grown under coconuts would double (IRRI, 1975, p. 24). Farmers interviewed in the study area feel that the coconut cover should be maintained, however.

2.7 Because the economic analysis of this study only dealt with one scenario, the present situation, further study should be undertaken to confirm results presented here, and two other important scenarios, future without project and future with project, should also be analyzed.

In order to fully document economic effects, further study based on an accounting framework (shadow price) should also be considered.

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APPENDIX I PUPUAN MONTHLY RAINFALL RECORDS (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Jan-Dec
1921	241	426	353	285	40	179	50	77	47	138	155	280	2271
1922	326	230	225	462	395	60	10	6	4	405	179	561	2963
1923	441	392	151	210	214	99	196	0	0	24	465	247	2439
1924	254	521	392	247	271	32	34	1	13	248	413	101	2527
1925	412	220	270	198	86	13	38	0	25	39	368	467	2136
1926	277	519	338	117	225	40	0	35	63	42	114	258	2028
1927	372	115	274	399	152	106	41	0	39	48	307	312	2065
1928	152	312	442	367	32	12	0	41	13	33	232	490	2126
1929	393	250	330	133	0	28	0	0	0	18	292	455	1899
1930	202	425	527	458	202	0	20	2	3	104	431	281	2655
1931	177	398	405	366	292	63	0	20	0	147	250	274	2392
1932	695	265	287	235	114	265	10	0	8	89	409	456	2833
1933	366	396	479	209	271	118	0	232	165	49	348	297	2930
1934	428	328	212	348	116	10	48	2	0	82	449	254	2277
1935	229	374	263	215	248	39	0	0	7	173	164	251	1963
1936	372	330	252	215	68	26	36	21	6	248	377	387	2338
1937	388	254	342	430	187	186	48	0	7	36	219	384	2481
1938	434	677	394	107	324	253	354	49	13	108	429	453	3595
1939	483	288	190	388	98	94	269	159	77	79	89	256	2470
1940	427	193	192	176	145	50	2	0	0	79	252	420	1936
1950	327	483	361	163	22	64	49	0	10	73	205	581	2338
1951	259	553	233	306	447	288	5	0	58	0	518	121	2824
1952	435	533	454	156	64	401	158	127	15	472	436	436	3687
1953	375	513	600	269	44	169	20	186	80	80	176	621	3133
1954	887	706	350	76	116	5	7	38	152	287	519	447	3590
1955	-	-	-	356	165	0	0	0	0	10	346	347	-
1956	526	446	163	237	328	223	47	150	65	324	312	660	3481
1957	358	290	168	384	123	188	277	120	147	225	632	258	3170
1958	441	240	211	252	83	273	235	325	99	103	165	391	2818
1959	402	401	120	119	300	50	383	45	0	37	269	524	2650
1960	161	416	309	415	134	195	322	93	16	114	308	459	2942
1961	217	424	570	169	265	211	7	10	115	113	173	535	2809
1962	533	403	232	163	227	36	22	30	12	86	406	74	2244
1963	354	345	255	349	118	9	21	0	0	148	256	245	2100
1964	425	388	323	426	135	116	32	32	82	26	135	528	2648
1965	668	197	264	205	72	15	0	0	0	0	228	295	1944
1966	221	423	545	170	234	66	19	31	6	457	73	204	2449
1967	430	375	194	128	22	10	0	0	15	77	269	317	1837
1968	218	377	242	177	109	105	0	20	20	152	359	627	2406
1969	528	111	401	342	123	0	0	0	156	375	225	421	2682
1970	363	96	366	69	138	266	219	284	62	345	440	565	3213
1971	112	90	339	57	25	8	5	35	61	99	148	37	1016
1972	484	441	470	468	443	95	16	0	272	982	650	338	4659
1973	-	-	-	-	-	-	-	-	-	237	357	154	-
1974	224	574	423	104	131	0	0	14	0	10	368	178	1928
1975	499	159	524	433	331	157	131	30	71	161	332	500	3348
1976	390	229	388	145	142	83	36	24	237	442	604	311	3031
1977	383	493	725	204	217	5	36	80	231	279	289	257	3199

Source: P3SA - Bali

APPENDIX II

CROP DESCRIPTIONS

This appendix contains a discussion of the various crops capable of being grown in the study area. These crops include rice, groundnuts, maize, tobacco, cassava, coconuts, and bananas.

1. Rice

If water is available for irrigation, rice is the preferred crop.

Availability of a reliable water supply during land preparation is the main factor influencing the time of planting. In the study area, where the rainy season usually lasts for five to six months, planting is limited to ensure that harvesting takes place as the weather becomes drier. Even when reliable water supplies are available earlier, farmers may be unwilling to plant their rice if this means harvesting in the wettest months. If more than two rice crops per year are to be planted, however, at least one harvest in five is likely to occur during the wetter months. This could result in crop losses if the grain cannot be dried, a reduction in yield because of sub-optimal radiation during flowering and grain formation. Where possible, this study has avoided this situation in planning cropping patterns. In a few cases, however, it was necessary to recommend earlier planting than usual to allow for a second rice crop before the water supply becomes inadequate.

Present yields in open sawah were based on the subak survey done by LRD. In 1976, a thousand hectares of HYV rice grown in the twelve subaks surveyed gave an average yield of 4,000 kg/ha.

Reduction of yield under a full stand of coconuts (120 trees/ha) was assumed at 50 percent. This is based on information about sawah rice under coconuts which was obtained in the subak survey, and on work done on the effects of shading on rice fields. (IRRI, 1975)

Material inputs are based on BIMAS package recommendations. (Agriculture Office, 1975). Present BIMAS recommendations for HYV's include application of 200 kg/ha urea, but existing rates of application are below this level. Triple Super Phosphate (TSP) is also used at about 30 kg/ha. Less fertilizer is applied for coconuts because a lower yield is expected. Insect pest and diseases caused by fungi, viruses and bacteria are serious problems in rice-growing areas.

Rats are reported to be a problem in most subaks. At present, the BIMAS package also recommends 100 gm of zinc phosphide, an acute poison dangerous to use, and sometimes only partially successful in controlling rodents.

Labour requirements are based partly on the LRD survey of rice farms in the study area and in Negara (Southern Bali) (LRD, 1976) and partly on a report by Van der Goot (1973) who estimated labour requirements for various food crops in Indonesia.

Field operations for rice are carried out using traditional, labour-intensive methods, but the standards of land preparation and crop care are high. Sickles are used to harvest HYV's, and the crop is thrashed in the field by beating on a large stone or log. Apart from weeding, which is assumed to be slightly less under coconuts, the pre-harvest operations have nearly the same labour requirement for open sawah or under coconut.

2. Groundnuts

Groundnuts are currently the most widely grown crop on dry land areas and, as palawija, on sawah areas in the dry season. They are the main source of cash income for farmers in both sawah and dry land parts of the study area. Once family food requirements have been met by rice, maize or root crops, groundnuts provide the principal source of cash income for farmers. It is assumed that groundnuts will continue to be the preferred palawija crop, although future changes in technology, prices, and other factors could result in their being replaced by other crops.

The present yield of groundnuts grown as palawija average 660 kg/ha, (dry shelled nuts) according to the subak survey. For groundnuts grown under coconuts, however, LRD reported an average yield of 480 kg/ha. These are well above the national average of 447 kg/ha (Syarifuddin et.al., 1975). Present yield levels have been assumed as less than these reported, since they may be based on a rather liberal appraisal of the situation. Farmers sometimes assess yields by relating them to the amount of money received for their crops, which could have been sold in the field and harvested by a contractor.

On fertile soils of the study area, groundnut response to fertilizer is not consistent. Trials conducted by LRD in 1975/1976 on groundnuts interplanted in citrus groves showed no significant difference between fertilized and un-fertilized plots (LRD, 1976). At present, no fertilizer is applied to groundnuts grown in the study area, but the BIMAS package recommends application of 50 kg/ha urea and 75 kg/ha TSP.

An important fungal disease of groundnuts is leaf spot, caused by Cerco spora SPP (Agriculture Office, 1978). Where leaf spot becomes serious, application of fungicide may yield loss. This is more likely to occur during the wet season. Insect pests are not currently a problem in groundnuts.

Present standards of land preparation generally keep fields free from weeds. Flooding is the existing irrigation method, and this method should be changed to ridge and furrow irrigation in the future. Groundnuts are susceptible to water logging, and this should be avoided.

In dry land areas where lack of water is the principle cause of low yields, irrigation should increase yields significantly.

3. Maize

In the study area, standards of maize production are very low and brings about a low yield. In the 1976 subak survey, the average yield was 240 kg/ha (dry grain). On farms in coconut areas, the yield reported by LRD was about 100 kg/ha. However, in both these cases, the crop was not usually in a pure, stand and in the sawah areas, was grown at the end of dry season with little irrigation. Present yield levels are thus assumed to be higher. Yield reduction for crops grown under coconuts is assumed to be similar to that which occurs for rice.

National average yield is already reported as 1000 kg/ha, and yields of over 5000 kg/ha have been obtained in trial plots of improved varieties (Syarifuddin et.al.,1975).

Fertilizer and pesticides are not presently used, which may be the cause of low yields in the study. Maize requires high levels of nitrogen to maximize yields. Current BIMAS recommendations are to apply 200 kg/ha urea and 100 kg/ha TSP.

A variety of insect pests of maize have been listed by LRD including stalk bores, army worms, seedling fly, cut worms, corn ear worm and leaf beetles. (LRD, 1976) Control of these pests can be achieved by the use of insecticides, after identification of the insect, and assessment of the severity of attack. In sawah areas, maize is generally grown in the last part of the year following the first palawija crop (groundnuts). As a result, irrigation, if practiced at all, is likely to be inadequate. Even when maize is grown on dry-land areas in the wet season, the rather erratic distribution of rainfall in these months sometimes results in moisture stress at critical times during the growing period. To be useful, irrigation should be regular and applied in furrows, not as an overall flood, and this would involve changes in present cultivation methods. The use of the plough for inter-row cultivation and ridging of the crop is not widespread at present. It could be adopted in the future as an aid to better weed control and irrigation.

Labour requirements are based on farm surveys and estimates made by Van der Goot (1973). Use of animal power for inter-row cultivation is not yet practised, but is especially useful in maintaining furrows in the irrigated situation. Harvesting and selling labour requirements are related to yield.

4. Tobacco

Virginia tobacco has been grown for a number of years in North Bali, but only since 1970 has the area under cultivation expanded significantly. In 1970, the British American Tobacco Co. (BAT) started their operation and they are the only significant buyers of tobacco in North Bali. The crop is exported to Java. Hence, this corporation operates on a monopsonistic basis. Under this situation, the BAT have made a special agreement with farmers, in order to maximize their profit. Farmers grow up to 0.8 hectares of tobacco using inputs and expertise provided by BAT, who also purchase the crop at a guaranteed price. The price is adjusted to make the crop compare favourably with a dry season rice crop, which would usually be grown.

Farmers are selected by BAT, and must own their land, must have at least 0.8 hectares of open sawah (the average farm size in the open sawah in the study area is 0.88 ha), and must have proven technical ability. In addition, the farm should have a source of irrigation during the dry season. The company deals directly with individual farmers and does not operate through the subak organization.

Seeds, pesticides, fertilizers and other inputs are supplied on credit by BAT. Seed beds are prepared in May or June, following harvest of the wet season rice crop. Field preparation consists of ploughing (three times) followed by harrowing. The crop is planted on ridges with six-week seedlings.

At planting, water is applied to planting holes, and the first furrow irrigation is applied two weeks later. Thereafter the irrigation is at two-week intervals up to time of harvest. Weed and pest control standards are high. Plants are topped and suckered to increase leaf size.

Harvesting starts 50 to 80 days after transplanting (i.e. about August). Two or three leaves are picked at a time, starting from the bottom of the plant. A plant should produce 20 to 22 leaves per year.

Yields of tobacco reported by BAT average as much as 1800 kg/ha (dry leaf) during the early years of growing. However, as the area under tobacco cultivation increased, average yields declined to 1600 kg/ha in 1977. Farmers plantmore than their allocated area, however, which tends to exagerate the actual average yield. Therefore, a more conservative yield of 1500 kg/ha is likely for the study area.

Green tobacco leaves are removed to curing barns. These barns are built of brick, have corrugated iron roofs, and ventilators at top and bottom. Heat is supplied by kerosene burners.

Use of fertilizer on tobacco must be carefully regulated to combine optimum growth with leaf quality. The present BAT recommendation is to apply 300 kg/ha of mixed fertilizer to the crop five days after transplanting. A top dressing of ammonium nitrate may be applied 3 to 4 weeks after transplanting if necessary.

Tobacco must be protected against a number of insect pests and diseases. In seedbeds, Blue mould (*Perenospora - tobacina*) is common, and must be treated three times a week with copper oxychloride. Insect pests include leaf worms, bud worms, aphids and army worms. When these are noticed, insecticides such as thiodan (endosulfan) are applied.

Tobacco is a labour-intensive crop, requiring almost twice as much labour as rice. However, the cropping period is longer and the labour input more regular through the growing season than that for rice.

5. Cassava

Cassava is an important crop sown under coconuts, accounting for about 20 percent of the inter-cropped area. It is planted during the wet season, and is frequently interplanted with maize.

The national average yield for cassava is reported to be 7300 kg/ha wet tubers (Syarifuddin, et. al., 1975). Where cassava is grown continuously on the same land for a long period of time without fertilizer, as is the case in the study area, yields decline markedly. The yield for the study area at 4000 kg/ha wet tubers.

Material inputs for cassava are limited to planting material, often obtained from the previous crop. Van der Goot (1973) and information from area farmers specify labour requirements for cassava.

6. Coconuts

At present, coconuts are the most important crop in the study area. They are found throughout the area between Tegallengah and Tukad Grokgak. If the irrigation project is not implemented, they are likely to remain very important, with methods of harvesting and processing continuing as in the past. If irrigation is introduced and the coconut areas are converted to sawah, landowners will likely be unwilling to fall their trees even though shading would be reduced causing yields for annual crops to increase. To overcome this difficulty coconuts should be reduced by 50 percent to 60 trees per hectare. Thinning the trees could result in a slight increase in yield of nuts per tree, but the effect of year-round irrigation on the coconuts is as yet unknown.

Where sawah has been developed under coconuts in the study area, trees appear to be unaffected. In the southern part of Bali, however trees have died when planted with sawah, probably due to water logging. This condition is likely related to soil type and ground water levels. Where groundwater levels are high and the soil becomes saturated, coconut trees (and most other trees) will be affected by waterlogging. If groundwater levels are low (a situation prevailing in much of the study area) and irrigation water is maintained in the sawah basins, coconuts will be unaffected and could benefit from presence of available water in the dry season. However, in the long-term coconuts will gradually disappear from the study area since replanting is not practical under irrigated conditions. Thus, the land under irrigation will eventually be converted to open sawah and this process could be accelerated if trees react unfavourably to irrigation.

Coconut trees usually begin fruiting after 7 years and have a productive life of 50 - 60 years. Average age of trees in the study area is about 27 years (Agricultural Office, Bali, 1978).

Coconuts are harvested every two months. The average yield reported by LRD is 41 nuts/tree/years, or about 4350 nuts/hectare. Assuming that about 5000 nuts produce 1 ton of copra (Purseglove, 1972). This is equivalent to 870 kg/ha/year of copra, somewhat higher than the Indonesians average. (Child, 1974).

The only input required for coconuts is seedlings for replanting. Labour is required for harvesting and husking.

Pests and diseases are not a problem inthe study area, but in some parts of Bali squirrels are major pests.

7. Bananas

Bananas are grown with coconuts on most farms in the study area. Bananas are generally planted between coconut trees with a varying stand density.

On most farms, fruit production is secondary to the use of the banana pseudostem (ie. it is not a true stem of the botanical sense) as food for livestock in the dry season. Although potential fruit production could be two stems/plant /year, some pseudostems are removed before fruiting which reduces the number of stems of fruit harvested. An average of 120 stems of fruit/hectare (from 100 plants) is assumed as the present yield. In addition to pseudostems and fruit, banana leaves are sold for use as wrapping material in the markets.

Bananas have a labour requirement when grown as a minor crop. A national allowance for replanting or new planting is allowed at 10 suckers per hectare, which can be obtained from existing plants.

Irrigation of dryland areas would probably cause death of banana plants through water-logging. This could be critical because of their use as fodder for livestock in the dry season.