of the eastern mountain range) The quebrada (small stream) is dried up in dry season.

(4) Tibacuy

- The climate is warm and mild.

- In the sub-project area, coffee is main by cultivated.

3.2 Irrigation Plan

3.2.1 Irrigation Area

(1) Study procedure for plan formulation

Due to scarcity of available water resources and large seasonal fluctuation of stream discharge as water resources, when establishing the irrigation plan the irrigation area will be determined paying particular emphasis to the following items, namely;

- Water resources should be utilized as effectively as possible.
- Facilities should be constructed as economically as possible.

Then, the study of irrigation area is carried out in the following three steps.

For first step:

- Possible irrigable area by gravity
- Area of which construction cost will be less than about US$1,500 per ha

Considering the above items, the irrigation area is selected.

For second step:

The more similar in the seasonal change of irrigation water demand under the proposed cropping pattern to the stream discharge of water resources, the cheaper and more economical is the construction cost of reservoirs (if possible) and irrigation facilities, particularly a driving channel.

Therefore, the study is carried out in order to establish a profitable cropping pattern of which seasonal change in water demand is similar to the related stream discharge and which has no problem in farm management.

For third step:

If irrigation facilities are planned taking the less frequent drought year, construction cost of the irrigation facilities becomes large and it is uneconomical.

Therefore, though it is one of the ideas that the plan is established in basis of basic year with hydrological probability, however, in this study the irrigable area is determined by trial so that the maximum benefit is expected for long range of years (past ten years) examining the excess and shortage of available water resources for the said period.

The process of the study is described in (3) 3) of this section. The cropping pattern, irrigation water demand, irrigation canal system, scale of the facilities and benefit which are the prerequisites of the study, are interrelated mutually in each sub-project area. Hence, except part in connection with irrigable area, the above-mentioned items are explained by each sub-project area in the latter part of the report.

(2) Possibility of driving channel and irrigable area

Approximately 2,500 ha of farmland including coffee plantation in the project area are cultivated as mentioned in 2.4 Land Utilization.

On the other hand, available water amount for irrigation purpose is limited. Therefore, all of the cultivated land in some river basin cannot be fully irrigated. Accordingly, for the first step the irrigable area is selected to limit the area as follows:

- The existing cultivated land and coffee plantation

- The cultivated land which located in the lower elevation and to which irrigation water can be distributed by gravity, and the area where the water resources facilities such as reservoirs and driving channel can be constructed economically.

- The cultivated land of which area is concentrated in one location (more than 3.0 ha).

Furthermore, detailed explanation of each sub-project area is as follows:

San Pedro de Iguaque

Total area of existing cultivated land is 1,184 ha.

Out of the total area, 704 ha of cultivated land which is located in the area with elevation of more than 3,100 ha cannot be economically irrigated by a driving channel because the area is located in higher elevation than that of the related streams (water resources) and construction cost of the possible water resources such as reservoir or pumping facility and so on becomes large.

- The cultivated land of 120 ha is located in downstream area of Q. Soavita. Average discharge of Q. Soavita in drought month is estimated at 12.0 l/s, of which 11.0 l/s has been already diverted to the Chiquiza and Sachica area.

- The existing farmland of 46 ha is located in the watershed of

Q. Los Robles. However, available stream discharge is quite a little.

- In addition, it is no economical to irrigate the scattered small scale farmland of 21 ha in total due to long distance of a driving channel.

In view of the foregoings, the area of 293 ha which is obtained to reduce the total area of 891 ha as mentioned above from the total area of 1,184 ha, will be the sub-project area to be studied for its irrigation plan.

Santa Sofia

Total area of the existing cultivated land is 360 ha.

- However, the existing farmland of 49 ha which are scattered in right bank terrace of Q. Salitrillos, is located in opposite side of Agudelo Abajo, a part of the sub-project area. It is not almost economical to irrigate the farmland of 49 ha due to high construction cost of reservoirs and/or pumping station which will probably be necessary for irrigation.

- In addition, it is not economical to irrigate the scattered small scale farmland of 72 ha due to long distance of a driving channel.

In view of the foregoings, the area of 239 ha excluding total area of 121 ha as mentioned above from the total area of 360 ha will be the sub-project area to be studied for its irrigation plan.

Caqueza

Total area of the existing cultivated farmland s 589 ha.

- The farmland of 124 ha is located in the area of which elevation is higher than EL.2,000 m and also higher than that of stream to be water resources for irrigation. Therefore, it is impossible to irrigate the area of 112 ha except 12 ha which is commanded by the existing reservoir by gravity.

- The existing farmland of 41 ha is located in eastern bank of Chorro El Capellania which is running through the eastern side of the sub-project area. However, discharge of Chorro El Capellania cannot be used for irrigation due to its small watershed and depletion of discharge during dry season.

- The existing farmland of 19 ha is located in the most upstream area of Q. Blanca. However, discharge amount of the stream is quite a little and there is appropriate site for storage reservoirs.

In view of the foregoings, the area of 417 ha excluding 172 ha as mentioned above from the total area of 589 ha will be the sub-project area to be studied for its irrigation plan.

Tibacuy

The existing farmland including coffee plantation is 347 ha.

- The coffee plantation of 24 ha which is located in the area higher than EL.1,800 m cannot be irrigated due to its high location.

- The coffee plantation of 70 ha is located in the watershed of Q. Bosa. However, discharge water of Q. Bosa has already been taken for the domestic and drinking water and no more available water for irrigation is remained in the stream.

Therefore, the area of 253 ha excluding 94 ha as mentioned above from the total area of 347 ha will be the sub-project area to be studied. In Tibacuy area, the farm managed by

FEDECAFE which is a pilot farm for the project is included. Therefore, grassland of 5 ha which will be converted to the field is included to the sub-project area totalizing at 258 ha.

Total irrigable area summarized by four sub-project areas is 1,202 ha and is shown in Table 3.2.1 (3-3, Irrigable Area).

Table 3.2.1 Irrigable Area

Name of sub-project area	Area of existing farmland	Irrigable area	Remarks
San Pedro de Iguaque	1,184	293	
Santa Sofia	360	239	
Caqueza	589	417	
Tibacuy	347	253	(includingcoffee of 210 ha)
Total	2,476	1,202	

Note: Irrigable area is that of cultivated land which can be irrigated by gravity. However, necessary water amount for irrigation is not always secured. (This means the irrigable are is not the final project area. Refer to Table 3.1.5)

(3) Discharge of the stream as water sources and irrigable area

1) Selection standard

The following selection standard is used as the second and third steps to determined the actual irrigable area of each sub-project area.

- Investment efficiency (benefit/cost) is important. However, priority is given to a scheme of which benefit is maximum as a whole area.

- Priority is given to expansion of cultivated land during dry season (increasing the working opportunity). However, depending on condition of available water amount, a scheme in which emphasis is put in increase of yield, is adopted.

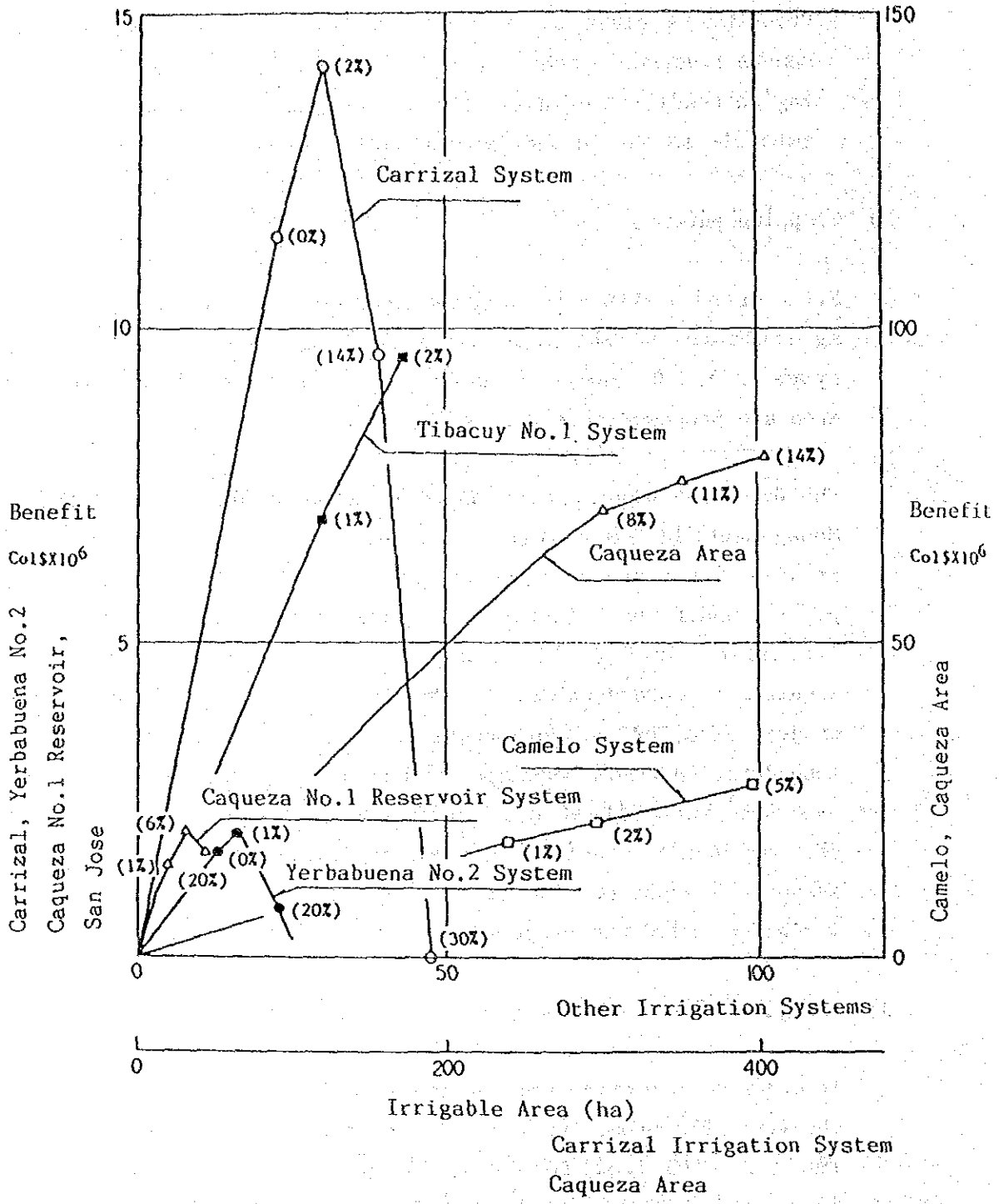
2) Cropping pattern

From stand point of various circumstances surrounding the agriculture as well as locality of the sub-project areas, two types (A and B types) of cropping pattern in each sub-project area are proposed considering the farm management.

The detailed description on this issue is shown in 3.4 (Farm Management) of the report. As mentioned in 3.4, in sub-project areas of San Pedro de Iguaque, Santa Sofia and Tibacuy, cropping pattern under which increase of production can be anticipated by irrigation during dry season (January, February, July and August), is more economical. On the other hand, in Caqueza sub-project area, dry season occurs once a year and continues for a long duration (from December to March). It is not economical to overcome such situation. Therefore, in Caqueza area, a plan that emphasis is put in supplemental irrigation during rainy season, is adopted. The cropping pattern which is object to be irrigated under the project is shown in Figure 3.4.1.

3) Irrigable area and sufficiency of irrigation water

In order to determine the irrigable area, the relationship among the irrigable area, available water amount for irrigation (1974-1983 last 10 year records), amount of water shortage and decreased yield is studied on the representative irrigation systems of each sub-project area. The results of the study are shown in Fig. 3.2.1 (Relationship between Irrigable Area and Benefit).



Note: Number in the parenthesis indicates a decrease production ratio. (Average for 10 years)

Fig. 3.2.1 Relationship between Irrigable Area and Benefit

For example; for irrigation plan in Carrizal area, water shortage is not occurred in case of 90 ha of irrigable area and the total value of benefit amounts to 11,4 million pesos. If the irrigable area is 120 ha, the water shortage is inevitable, and the decrease rate of production will be 2%. However, the benefit becomes to be 14,2 million pesos. Furthermore, assuming that irrigable area is 155 ha, the decrease rate of production by water shortage is 14% and the total value of its benefit amounts to 9,5 million pesos. Its benefit is smaller than the case of 120 ha. From the above-mentioned matters, it is obvious that the benefit in case of 120 ha is maximum.

For another example, on the Caqueza area, in case of increasing the irrigable area from 300 ha (8%) to 350 ha (11%) and 403 ha (14%) more, the total value of its benefit amounts to 71,0 million pesos, 75,7 million pesos and 79,9 million pesos, respectively. Furthermore, the enlargement of irrigable area shows a tendency of an increase in the benefit, but the irrigable area is fixed at 403 ha due to no more farmland in the irrigation system of Caqueza area. As the results of the above-mentioned study, irrigable area with the maximum benefit is adopted in each irrigation system as shown in Table 3.1.4 (Irrigable Area).

Based on the results of the above-mentioned study, the case in which the benefit is maximum is adopted, and shown in Table 3.2.2.

Table 3.2.2 Irrigable Area in Typical Systems

Sub-project area	Irrigation system	Irrigation area (ha)	Remarks
San Pedro de	Carrizal	120	
Iguaque	Yerbabuena No. 1	16	
Santa Sofia	Camelo	74	Total area
Caqueza	Negra, Blanca	403	"
	Reservoir No. 1	8	
Tibacuy	San Jose No. 1	43	Total area

In order to make clarify the relationship between the above-mentioned irrigation area and benefit, the relationship between water shortage and decrease in production is used by the following manners. On the other hand, the method of calculation in case of Carrizal is explained in Annex D.5 (Relationship between Irrigable Area and Benefit in Irrigation System).

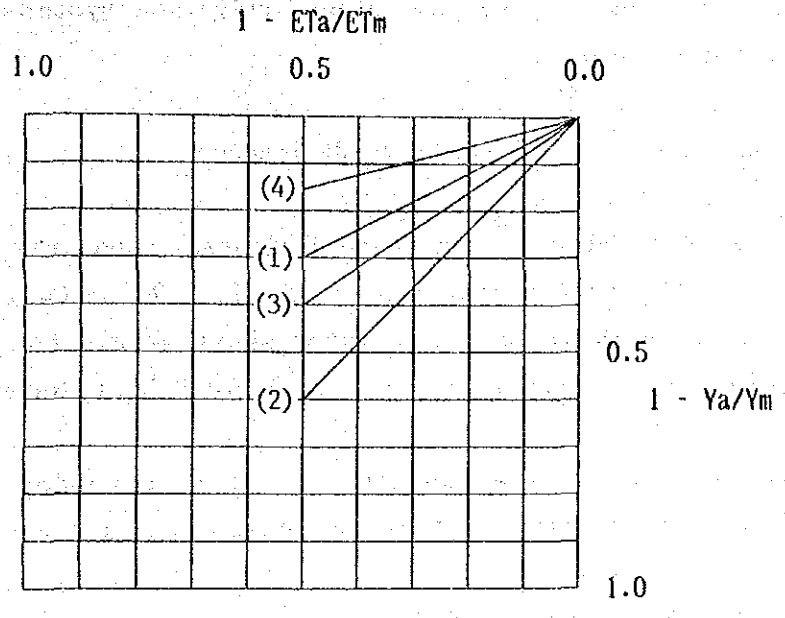
In this study, it is premised to construct reservoir in the project area such as; a reservoir (Storage capacity : 40,000 m^3) in Carrizal irrigation system, a reservoir (Storage capacity : 13,500 m^3) in Yerbabuena No. 2 irrigation system of San Pedro de Iguaque, and reservoirs of Caqueza No. 1 (Storage capacity : 10,000 m^3) and No. 2 (Storage capacity : 4,000 m^3) in Caqueza irrigation system.

Results of the study on these reservoirs are shown in theparagraph 3.2.2 (San Pedro de Iguaque) and 3.2.4(Caqueza).

Water shortage and response yield

Based on the FAO Irrigation and Drainage Paper No. 33 (Yield response to water), the ratio between the water shortage and decrease of yield in growing stage basis, taking into account the kinds of crops proposed under the project is determined and shown in Fig. 3.2.2.

Fig. 3.2.2 Relationship between Water Shortage and Yield



Note (1): Sowing Growing Period
(2): Flowering Period
(3): Maturing Period
(4): Ripening Period
ETa: Irrigated Water Amount
ETm: Maximum Irrigation Water Amount
Ya : Actual Yield
Ym : Maximum Yield
Applied range is 1 - ETa/ETm < 0.5
Ym : Estimated Value of Maximum Yield

San Pedro de Iguaque	(Cropping Pattern	A)	467,000 Col.$/ha
Santa Sofia	(- ditto -	A)	636,000 Col.$/ha
Caqueza	(- ditto -	B)	669,000 Col.$/ha
Tibacuy	(- ditto -	A)	761,000 Col.$/ha

(4) Proposed irrigation area

The determining method of irrigation area (optimum scale) in typical irrigation system of each sub-project area is mentioned in the foregoing paragraph, but the other irrigation systems are used the following manners;

- Yerbabuena No. 1 of San Pedro de Iguaque

In case of 26 ha (the area to be irrigated) depending on irrigation water which diverts from a site of E.L. 2,987 m (watershed area : 2.341 km^2) of Q. Yerbabuena, water shortage did not occur during past 10 years as shown in Annex D, Table D.3.(2) (Water Balance).

Therefore, the irrigation area cannot be extended due to small difference of elevation between benefited area and water source.

From the above-mentioned, proposed irrigation area in Yerbabuena No. 1 irrigation system is fixed at 26 ha.

In addition, as to the other irrigation systems in Santa Sofia area, the ratios of the irrigable area against the watershed of each diversion weir are as follows:

Irrigation systems		
Piedras	:	19%
La Laja	:	24%
Palonegro	:	16%

As a result of the study on the Camelo irrigation system (a ratio of irrigation area for watershed = 27%), it is desirable for all irrigation systems to irrigate all of the existing farmland.

As to the irrigable area commanded by reservoir in Caqueza area, irrigable area commanded by reservoirs No. 2 and 3 is 4 ha and irrigable area by reservoir No. 4 is 2 ha.

Based on the above-mentioned study, assuming that proposed irrigation area is 1,076 ha in all, the proposed irrigable areas of each irrigation system are determined as shown in Table 3.2.3 (Irrigable Area of Sub-Project Areas).

Table 3.2.3 Irrigable Area of Sub-Project Areas

Sub-project area	Irrigation system	Cultivated land (ha)	Irrigable area (ha)	Remarks
San Pedro de	Carrizal	182	120	Reservoir: 40,000 m^3
Iguaque	Yerbabuena No.1	41	26	Diversion weir: 2 places
	Yerbabuena No.2	70	16	Reservoir: 13,500 m^3
Sub-total		293	162	
Santa Sofia	Piedras	55	55	Diversion weir: 4 places
	La Laja	72	72	
	Camelo	46	46	
	Camelo (Pilot)	28	28	
	Palonegro	38	38	Reservoir: 10,000 m^3*
Sub-total		239	239	
Caqueza	Negra-Blanca	403	403	Diversion weir: 5 places
	Reservoir No.1	8	8	Reservoir: 16,000 m^3
	Reservoir No.2 & 3	4	4	" : 4,000 m^3
	Reservoir No.4	2	2	
Sub-total		417	417	
Tibacuy	San Jose No.1			Diversion weir: 3 places
	Coffee plantation	200	200	
	Ordinary field	43	43	
	San Jose No.2 (Pilot)			
	Coffee plantation	10	10	
	Ordinary field	-	5**	
Sub-total		253	258	
Total		1,202	1,076	

* Future plan

** converted from grassland

3.2.2 San Pedro de Iguaque

(1) Water requirement

1) Evapotranspiration

On the basis of meteorological conditions of the respective areas mentioned in the paragraph 2.2 (Meteorology), Evapotranspiration (ETp) is calculated using the Penman method. Monthly evapotranspiration is as follows;

Jan.	:	2.7 mm/day	Jul.	:	3.3 mm/day
Feb.	:	2.9 "	Aug.	:	3.2 "
Mar.	:	3.2 "	Sep.	:	3.1 "
Apr.	:	3.0 "	Oct.	:	2.9 "
May	:	3.1 "	Nov.	:	2.6 "
Jun.	:	3.1 "	Dec.	:	2.4 "

(refer to Annex A.1.9 and Annex D Table D.1(1) Evapotranspiration)

2) Consumptive use

Referring to the Cropping pattern proposed in consideration of the local conditions of the respective areas (see the paragraph 3.4.2 Cropping Pattern), Monthly consumptive use is worked out applying the evapotranspiration of 1) above mentioned. For the calculation, following conditions are provided.

- Irrigation period for the respective crops is shown in Annex D, Fig. D.1.
- Crop efficiency is accorded with FAO manual No. 24.
- To determine the crop efficiency, irrigation interval is assumed 7 days.

Results of the calculation are shown in the following Table 3.2.4 (Monthly Consumptive Use).

Table 3.2.4 Monthly Consumptive Use in San Pedro de Iguaque

Month	Consumptive use (mm/day)	Consumptive use (mm/month)	Month	Consumptive use (mm/day)	Consumptive use (mm/month)
Jan.	2.4	75.6	Jul.	2.7	83.8
Feb.	2.3	63.4	Aug.	2.3	69.1
Mar.	2.3	71.3	Sep.	2.3	67.8
Apr.	2.4	72.0	Oct.	2.4	73.7
May	2.6	88.1	Nov.	2.4	71.8
Jan.	3.0	88.9	Dec.	2.1	64.9

3) Net water requirement

Net water requirment of the sub-project area is calculated by the above-mentioned comsumptive use. The following items are considered to the calculation.

- Gropping pattern of this sub-project area is applied to A type on the examination based of the paragraph 3.4.2 (Cropping pattern).
- Effective rainfall is defined that water amount which can be held the soil within the effective root zone during rainfall to the maximum amount of total readily available moisture (TRAM: 44 mm) is effective.

Based on the above-mentioned definition, the results calculating the monthly net water requirement for past ten years are shown in Annex D, Table D.2 Net Water Requirement. As noted in the Table, the maximum effective rainfall is 42.3 mm/month in June, 1982 and the maximum of average monthly effective rainfall for the past ten years is 29.2 mm/month in January.

(2) Irrigation canal system

In the sub-project area, two streams of Carrizal and Yerbabuena can

be utilized for irrigation.

Considering the distribution in location of the existing farmland and the condition of the related streams (location, longitudinal profile and discharge), irrigation water is taken at the site with elevation of 3,100 m (area of watershed is 5.6 km^2) of Q. Carrizal and is distributed to the farmland(120 ha) extending in both bank side of downstream of Q. Carrizal. Additionally, at the site with elevation of 3,160 m (watershed area is 3.1 km^2) in the upstream of Q. Carrizal, construction of a storage reservoir is proposed (refer to (5) reservoir plan mentioned later).

For Q. Yerbabuena, two irrigation canal systems are proposed. One is that irrigation water is taken from the site with elevation of about 2,990 m (watershed area is 2.34 km^2) and is delivered to the farmland of 26 ha which is located in left side bank of downstream area (No. 1). Another is that at elevation of 3,170 m (watershed area is 0.61 km^2) in upstream of Q. Yerbabuena, there is a site suitable for reservoir though it is small scale, from which irrigation water is taken and distributed to the farmland (16 ha) in Patiecitos located in left side bank area with elevation of 3,000 m to 3,100 m (No. 2). (refer to map of general plan and Annex D, Fig. D.3 (1) Irrigation Canal System)

As the topographic characteristic of the sub-project area, the distance between the intake site and the benefited area is long (3-4 km) and difference in elevation between the site and the area is small. Therefore, structure of driving channel should be open canal type in order to make its construction cost economical.

(3) Diversion water requirement

Taking into account the irrigation canal system and structure of the driving channel (mostly open canal), the results of computing diversion water requirement adopted 80% of irrigation efficiency including conveyance efficiency are as follows: Maximum diversion water requirement in monthly average occurred in June 1982,

Carrizal irrigation canal system (120 ha) 24.5 l/s
Yerbabuena canal system, No. 1 (26 ha) 5.3 l/s
- ditto - No. 2 (16 ha) 3.3 l/s

Total annual diversion water requirements in irrigation canal system basis are as follows:

Carrizal : 338,000 - 487,000 m^3/year
Yerbabuena No. 1 : 73,000 - 105,000 "
Yerbabuena No. 2 : 45,000 - 65,000 "
(refer to Annex D, Table D.5 (1)-(3) Water Balance)

(4) Available water amount at diversion site

Available water amount in monthly basis of each irrigation canal system as mentioned in the previous section (2) is estimated.

The discharge condition in the sub-project area (monthly discharge per km^2) is as described in 2.2.2 (4). Estimation of available water amount in each streams, based on which the discharges in each diversion site for the past ten years are estimated and shown in Table 3.2.5 (Available Water Amount in Each Stream).

Table 3.2.5 Available Water Amount of Each Stream in San Pedro de Iguaque

Irrigation system	Watershed area(km^2)	Water source run-off(m^3/year)	Droughty discharge(l/s)
Carrizal	5.60	505,000 - 637,000	11.2 - 32.5
Reservoir site	3.10	279,000 - 352,000	
Yerbabuena 1 (Pilot)	2.34	211,000 - 266,000	6.2 - 18.0
Yerbabuena 2	0.60	54,000 - 68,000	1.2 - 3.5

(refer to Annex D, Table D.5 (1)-(3) Water Balance)

In the sub-project area, a part of stream water is being taken for domestic livestock. However, it is not an acquired water right which is registered in INDERENA.

(5) Water balance

Based on the diversion irrigation water requirement and available water amount, study results of water demand and supply of each irrigation canal system for the past ten years is as described in Annex D, Table D.3.

- For Carrizal system, water amount of 21,000-81,000 m^3 (5-17% of water demand) in annual basis is lacking.

- For Yerbabuena system No. 1, there is no water shortage.

- For Yerbabuena system No. 2, water amount of 5,000-19,000 m^3 (9-29% of water demand) is lacking yearly.

The above-mentioned water shortage in Yerbabuena system is mitigated due to construction of new reservoir (refer to (6)).

(6) Reservoir plan

1) Reservoirs in Q. Carrizal

Considering the results of the above-mentioned water balance study, occurrences of irrigation water shortage area as follows:

From December 1974 to January 1975 : about 48,000 m^3
From December 1976 to June 1977 : about 66,000 m^3
From December 1977 to January 1978 : about 46,000 m^3
From December 1979 to January 1980 : about 36,000 m^3

As mentioned above, it is preferable to construct a reservoir of which storage capacity is 66,000 m^3. However, in case of Q.

Carrizal, such amount of water cannot be stored during wet season in drought year. Therefore, the storage capacity of the reservoirs is determined by water amount(40,000 m^3) which can be stored fully at the end of raining season (twice a year) for seven years in the past ten years.

In operation of the reservoir in Q. Carrizal, it is neccesary to control released water amount to meet excess or shortage of the intake water amount at the diversion site because the reservoir is located in upstream of the diversion site. Therefore, carefully operation of the reservoir is needed.

On the other hand, the relationship between depth and storage capacity of the proposed reservoir is as shown in Annex D, Fig. D.6(Reservoir). From this relationship, water amount of 40,000 m^3 can be stored at depth of 2.5 m. Therefore, the storage capacity of the Carrizal reservoir is determined at 40,000 m^3.

2) Reservoir of Yerbabuena No. 2

Because size of the reservoir is small (watershed area is 0.6 km^2) and its location is relatively close to the benefited area, it is considered preferable from stand point of water management to directly connect the reservoir to the pipeline networks in the benefited area by pipeline.

Therefore, it is possible in operation of the reservoir to store all amount of discharge during the period when irrigation is not necessary.

Taking 1976 and 1977 when rainfall is less for 10 years from 1974, water balance study is carried out in case of 16 ha of irrigation area. The study result show that capacity of the reservoir is limited to 13,500 m^3 by a constraint of permissible storage capacity and then it can not be stored water even the storage capacity makes bigger than this amount. Inthis case, water shortage of 9,800 m^3 from March to June 1977

occurs, but it is not occured in the remainnig year. Therefore, it can be said that limit of the reservoir capacity is about 13,500 m^3.

On the other hand, considering the topographic condition, total reservoir capacity of 13,500 m^3 at depth of 1.5 m can be stored as explained in Annex D, Fig.D.6.

In view of the foregoings, the storage capacity of Yerbabuena is determined at 13,500 m^3.

(7) Facility plan

1) Reservoir

Considering topographic and geological conditions of the dam sites of the above-mentioned Carrizal and Yerbabuena reservoirs, a fill type of dam (earth fill dam) is suitable and their construction materials can be obtained from neighboring mountainous area.

In course of the study, number of reservoirs are preliminary examined. The study results are shown in Annex D, Fig. D.6.

Based on the above-mentioned study, in order to secure the storage capacity studied in the previous section (5), scale of the reservoirs are determined as follows:

- Carrizal reservoir

Height of dam body	:	4.0 m
Length of dam crest	:	85.0 m
Type of dam	:	Fill type with sloping core
Storage capacity	:	40,000 m^3
Area of full water surface	:	24,000 m^2

- Yerbabuena No. 2

Height of dam body	:	2.5 m
Length of dam crest	:	100.0 m
Type of dam	:	Homogeneous type
Storage capacity	:	13,500 m^3
Area of full water surface	:	10,500 m^3

2) Diversion weir and main driving channel

For selection of the diversion weir site,distance to the benefited area, difference in elevation between the site and the benefited area, discharge and river bed condition of the stream are considered.

Main driving channel of Carrizal and Yerbabuena No. 1 irrigation systems are generally of open canal because of long distance and small gap in elevation. Contrary, main driving channel of Yerbabuena No. 2 is of pipeline.

Structure and scale of the diversion weir sites and the main driving channels of each irrigation system are shown in Table 3.2.6 (Summary of Diversion Weirs and Main Driving Channels).

Table 3.2.6 Summary of Diversion Weirs and Driving Channels in San Pedro de Iguaque

Sub-project area	Irrigation system	Diversion weir		Main driving channel	
		Designed amount of intake water (l/s)	Structure, Scale (m)	Structure Scale	Length (m)
San Pedro de Iguaque	Carrizal	24.5	fixed type H=2 L=4	stone pitching open canal	4,000
				PVC 4"	800
				PVC 2"	750
	Yerbabuena No. 1 (Pilot)	5.3	fixed type No. 1 H=2.1 L=3.5 No. 2 H=2 L=3	stone pitching open canal	2,470
				ϕ 4 mm	1,250
	Yerbabuena No. 2	3.3	Reservoir V=13,500 m^3	PVC ϕ 2-1/2"	1,650

3) Farm pond

In order to regulate an unbalance in hourly basis of water amount which is caused by difference in timing between supply water from water source and irrigation water demand in the benefited area per day, it is necessary to construct a certain number of farm pond (tanks) in each irrigation system.

Location and scale of the farm pond are proposed in Table 3.2.7 (Capacity of Farm Ponds), considering topography of the benefited area, distribution in location of cultivated land and management of on-farm facilities.

Storage capacity of the farm pond is determined in such conditions that operation hours of sprinkler per day is 18 hours even in the season when irrigation water demand reaches maximum (refer to preliminary design of pilot area of Volume IV, for details).

Table 3.2.7 Capacity of Farm Pond in San Pedro de Iguaque

Irrigation system	Capacity (m^3)	No. of unit	Remarks
Carrizal	130-180	8	
Yerbabuena No. 1 (Pilot area)	39- 63	5	See Vol. IV Diseño Preliminar
Yerbabuena No. 2	13,500	1	Utilization of reservoir

(refer to Annex D, Fig. D.3 Irrigation System)

4) Water distribution system

Water distribution system capacity is determined supposing that follow-on irrigation is carried out by the establishment of rotation block for each terminal irrigation system. As to examination of the system capacity is considered on the following condition.

- Water distribution system capacity is set up maximum value of crop consumptive use, considering the cropping pattern.

- Design irrigation interval is 7 days for this sub-project area, considering the soil and root zone of cultivated crop for respective area.

- Irrigation time for one day shall be 18 hours on maximum period (refer to Volumeu IV. Diseño Preliminar).

In San Pedro de Iguaque area it is impossible to reserve a sufficient water to irrigate all the arable land except Yerbabuena No.1 irrigation system (see the paragraph 3.1.3), therefore, the following three alternatives for water distribution are proposed:

i) To focus on the arable land close to water source.

ii) To distribute the water to the existing arable land of individual farm household.

iii) To gather the irrigation land along the distributing canal which runs vertically in the project area. (Replace the grassland with upland field as well as exchange the right for cultivation of some farm households.)

Alternative i) is the least expensive in the project cost, but unfair for the water distribution occurs without the exchange of arable land (right for cultivation) among the farm households.

Alternative ii) brings comparatively fair distribution but the project cost will be high.

Alternative iii) is intermediate of i) and ii).

The comparison of the project cost for three alternatives is summarized as the Table 3.2.12 (Comparison of Construction Cost). The cost should be discussed on the inside of farmer's association for individual water network.

Table 3.2.8 Comparison of Construction Cost for Alternative Plans

(unit: 1,000 Col.$/ha)

Irrigation system	Alternative 1)	Alternative 2)	Alternative 3)
Carrizal	165	204	166
Yerbabuena No. 2	296	419	342

5) Irrigation facilities on farm

In order to effective utilization of water resources, irrigation manners on farm has an advantage of the sprinkler system in farmland due to be possible to use a natural pressure on account of topographic condition as slope area.

Test of basic intake rate conducted in the field shows such large value as 181 and 464 mm/hr. However, for type of sprinkler set, slow-rotating, full-circle type, low pressure (nozzle pressure: 1.0-1.5 kg/cm^2 and sprinkling intensity is 1.83 mm/hr) type is adopted because natural water pressure enough for sprinkler head cannot be obtained in most of the area in addition considering to variety of crops and soil erosion.

Area of one rotation block is determined at 1.12 ha, considering the conditions that area irrigated by one set of sprinkler (two sprinkler head) is 0.08 ha, two times setting day, and seven days rotation interval.

3.2.3 Santa Sofia

(1) Net water requirement

Using same standard as San Pedro de Iguaque, net water requirement necessary for the cropping pattern as proposed in 3.4 (Farm Management) of the report is calculated. The calculation results are 43.44 mm/month in September 1976 for the maximum. (refer to Annex D, Table D.3 (2) Calculation of Net Water Requirement)

(2) Irrigation system

In the sub-project area, four streams of Q. Piedras, Q. La Laja, Q. Camelo, and Q. Palonegro can be used for irrigation.

In all stream basins except Q. Palonegro, pipeline mode is adopted

for main canal because the cultivated land is located close to the streams. In Q. Palonegro basin, open canal mode is selected due to long distance of the main driving channel. Elevation and watershed area of each irrigation system and irrigable area are shown in Table 3.2.9 (Irrigation System).

Table 3.2.9 Irrigation System in Santa Sofia

Irrigation system	Diversion weir site		Irrigable area (ha)
	Elevation (m)	Watershed area (km)	
Piedras	2,400	2.97	55
La Laja	2,460	3.03	72
Camelo	2,400	3.74	74
Palonegro	2,470	2.44	38
Total			239

(refer to Annex D, Fig. D.3 Irrigation System)

A site suitable for reservoir with capacity of about 10,000 m^3 is located in right side bank of downstream of Q. Palonegro. However, construction of this reservoir is not included in the project because water amount taken from the diversion weir is enough to irrigate the proposed area of 38 ha as explain later. Considering the future when water demand is increased, the main canal route is laid out to go through the proposed reservoir site.

(3) Diversion water requirement

Based on the study results described in (1), 1), diversion water requirements of each irrigation system are estimated. The study results show that the maximum diversion water requirement occurs in September 1976 as follows:

Piedras	:	11.5 l/s
La Laja	:	15.0 "
Camelo	:	15.4 "
including pilot area	:	5.8 "
Palonegro	:	8.4 "

In this case,irrigation efficiency including conveyance efficiency is adopted at 80% for Palonegro where the driving channel is long and the farmland is scattered, and 85% for the other irrigation system (refer to Annex D, Table D.5 (4)-(7) Water Balance).

(4) Available water amount at diversion weir site

Based on the run-off per 1 km^2 of the project area as described in 2.2.2 (4) of the Report, available water amount is estimated at diversion site of each irrigation system. The study results are shown in Table 3.2.10 (Available Water Amount of Each Irrigation System).

Table 3.2.10 Available Water Amount of Each Irrigation System in Santa Sofia

Irrigation system	Water source		
	Watershed area (km^2)	Run-off (m^3/year)	Monthly discharge (l/s)
Piedras	2.97	810,000-1,267,000	7.1- 93.3
La Laja	3.03	812,000-1,221,000	5.0- 92.9
Camelo	3.74	803,000-1,379,000	2.1-110.6
Palonegro	2.44	558,000- 934,000	2.5- 73.2

(refer to Annex D, Table D.3 (4)-(7) Water Balance)

Furthermore, the water use plan is taking into consideration the following water amountresistered to INEDERENA as drinking water in this sub-project area.

La Laja	:	2.26 l/sec.
Camelo	:	6.88 l/sec.
Palonegro	:	3.40 l/sec.

(5) Water balance

Comparison of the diversion water requirement and available water amount in monthly basis of each irrigation system for the past ten years is carried out. The results show that;

- There is almost no water shortage in Piedras and La Laja irrigation systems.

- In Camelo irrigation system, five times of annual water shortage with extent of 2,000-16,000 m^3 (0.9-8.4% of the diversion water requirement) occurs.

- In palonegro irrigation system, three times of annual water shortage with extent of 1,000-3,000 m^3 (1.1-3.6% of the diversion water requirement) happen.

  In any irrigation systems, it is considered that such amount of water shortage can be allowable.

(6) Facility plan

Fixed type of diversion weir is adopted for each diversion weir (4 places) due to shallow foundation rock at the site of the stream. For main canal of the Palonegro system, open canal with wet masonry lining is selected because it is economical. For the other systems, pipeline (PVC pipe) is adopted considering its advantage for easy operation and maintenance and short length of the water way.

The farm pond, considering the topography and distribution pattern of the farmland, is basically constructed at rate of one place per

5-15 ha, aggregating to 19 places as shown in Table 3.2.12 (Irrigation Facilities in Santa Sofia) (refer to Annex D, Fig. D.3 Irrigation System).

Capacity of terminal facilities is determined with under such conditions that:

- for sprinkler head, slow-rotating, full-circle type, medium pressure (nozzle pressure: 2 kg/cm^2), and sprinkling intensity of 1.93 mm/hr is chosen,
- operating hour of sprinkler is 17.8 hours (8.9 hours by two times) when the maximum water amount for irrigation is necessary,
- rotation interval of irrigation is 7 days.

In this case, capacity of farm pond should be 8.6 m^3 per ha. The irrigable area by one set of sprinkler (two sprinkler heads) is 0.176 ha (0.088 ha x 2) per day. Thus, area of one rotation block is 1.23 ha. Outline of each facility is summarized in Table 3.2.11 (Irrigation Facilities).

Table 3.2.11 Irrigation Facilities in Santa Sofia

Irrigation system	Diversion weir		Main driving channel		Farm pond(tank)	
	Designed amount of taken water (l/s)	Structure, scale	Structure, scale	Length (m)	Capacity (m^3)	Place
Piedras	11.5	fixed type H = 2 L = 3.5	PVC 4" 2.1/2" 2" 1.1/2"	1,400 300 800 700	45-180	4
La Laja	15.0	fixed type H = 2 L = 3.5	PVC 4" 3" 2.1/2"	700 1,100 600	15-180	5
Camelo	15.4	fixed type H = 2 L = 3.5	PVC 4" 3" 2.1/2" 2"	 300 300 400	92-270	4
Palonegro	8.4	fixed type H = 2 L = 3.5	stone pitching PVC 3" 2.1/2" 1.1/2"	1,750 1,000 1,000 1,500	15- 85	6

3.2.4 Caqueza

(1) Net water requirement

New water requirement (monthly average) of the sub-project area is calculated for the cropping pattern (B type) proposed in 3.4 (Farm Management) of the report for the past ten years. The results show that the maximum water requirement is 48.6 mm/month in November

1980, and the maximum monthly average for the past ten years is 35.10 mm/month in November (refer to Annex D, Table D.2 (3) Calculation of Net Water Requirement).

(2) Irrigation system

Two streams of Q. Negra and Q. Blanca can be used for irrigation in the sub-project area. Additionally, the stored water of four reservoirs which are newly constructed or rehabilitated, and spring water (one place) are also available for irrigation.

Considering the distribution pattern of farmland, irrigation water is planned to be taken from three sites in Q. Negra and two sites in Q. Blanca.

Considering the topography and distribution pattern of the farmland, pipeline is selected for the main canal in the sub-project area. In layout of the pipeline, an idea that if the more water than necessary amount is taken from the stream, the excess water is released to the original stream and reused at diversion weir downstream, is incorporated.

The relationship between diversion weir site and its benefited area is shown in Table 3.2.12 (Irrigation System in Caqueza).

Table 3.2.12 Irrigation System in Caqueza

Irrigation system	Diversion weir site		Irrigable area (ha)
	Elevation(m)	Watershed area (km)	
Negra	2,030	1.38	
	1,880	1.30	
	1,770	0.97	403
	1,880	1.37	
	1,670	1.13	
Reservoir No. 1	2,150	0.05	8
" No. 2, No. 3	2,050	0.10	4
" No. 4	1,800	0.10	2
Spring	1,870	-	(Within irrigation system by diversion weir)

(Annex D, Fig. D.3 Irrigation System)

(3) Diversion water requirement

Taking irrigation efficiency of 85% including conveyance efficiency, the computation results of diversion water requirement are shown in Table 3.2.13 (Diversion Water Requirement in Caqueza).

Table 3.2.13 Diversion Water Requirement in Caqueza

Irrigation system	Irrigable area (ha)	Annual gross requirement (m)	Monthly mean maximum gross requirement (l/s)
Negra Blanca	403	908,000-1,153,000	88.9 (Nov. '80) (for 5 places)
Reservoir No. 1	8	18,000- 23,000	1.8 (")
" No. 2, 3	4	9,000- 11,000	0.9 (")
" No. 4	2	5,000- 6,000	0.4 (")

(refer to Annex D, Table D.3 (8)-(11) Water Balance)

(4) Available water amount at intake site

Based on run-off per km^2 of watershed in the area as described in 2.2.2 (4) of the report, the available water amount is estimated. The results of the estimation are shown in Table 3.2.14 (Available Water Amount in Caqueza).

Table 3.2.14 Available Water Amount in Caqueza

Irrigation system	Water source		
	Watershed Area (km^2)	Run-off (m^3/year)	Monthly discharge (l/s)
Negra Blanca	6.15	1,484,000-3,679,000	3.24-286
Reservoir No. 1	0.05	12,000- 30,000	0.03- 1.7
" No. 2			
" No. 3	0.05	12,000- 30,000	0.03- 1.7
" No. 4	0.05	12,000- 30,000	0.03- 1.7

(refer to Annex D, Table D.3 (8)-(11))

Note :

In the sub-project area, the swamp (1.0 ha) is located in the left shore of EL 1,870 m of Q.Negra, where approximately 2 l/s of water will be available by collecting the water through the connecting channel (open channel).

(5) Water balance

The water balance study of the diversion water requirement and available water amount in monthly basis and in irrigation system basis is carried out for the past ten years. The results show that:

- In the Negra and Blanca irrigation systems, water amount of 33,000-276,000 m^3 (3.6-26.0% of diversion water requirement) is short in irrigation year round.

- In case that no reservoir is provided, water amount of 2,000-11,000 m^3 (12.7-48.4 of diversion water requirement) for No. 1 reservoir system, and 1,500 m^3 (14.0% of diversion water requirement) in November and December 1978 for No. 2 and No. 3 reservoir system are short. However, there is almost no shortage in other years. For the No. 4 reservoir system, there is no shortage.

(6) Reservoir plan

Caqueza No. 1 reservoir is used under such condition that discharge water of the stream, when it is excess in wet year, is stored in the reservoir and carried over to be used in the next year because of the following reasons:

- Watershed area is small (0.05 km^2)

- Though the scale of the reservoir is small, the storage capacity is large compared with embankment volume of the dam which means high efficiency.

- Reservoir can be operated to connect directly to the pipeline

system in the benefited area.

According to the water balance study after October for irrigable area of 8.0 ha, the maximum water shortage is 10,000 m^3 occurs in March 1980.

On the other hand, in terms of topographical condition, water amount of 10,000 m^3 can be stored with water depth of 1.5 m as illustrated in Annex D, Fig. D.8.

In view of the foregoing, the capacity of No. 1 reservoir is determined at 10,000 m^3.

Following the same procedure, storage capacity of No. 2 reservoir is determined at 4,000 m^3 and 2,800 m^3.

(7) Facility plan

Though a certain amount of water cab be stored in every existing reservoirs (water depth of 0.5-1.0 m), dam heights of reservoir No. 1 and No. 2 are increased to make the biger capacity, and earth fill type is adopted for design of the dam body. It is not necessary to increase of the present capacities of the reservoirs No.3 and No.4 but dam body is strengthened.

Outline of the dam body which are newly constructed or rehabilitated is shown in Table 3.2.16 (Irrigation Facilities in Caqueza).

Considering the geological condition of the stream bed, the five proposed diversion weirs are of fixed type. Pipeline system is suitable for main canal due to steepness of its gradient and concentration of the farmland.

Because natural pressure can be utilized in terms of topography, the terminal facilities of irrigation system are determined based on the following conditions.

- Sprinkler head of slow-rotating, full-circle type with medium pressure (nozzle pressure : 2 kg/m^2, sprinkling intensity : 1.93 mm/hr) is adopted and irrigable area of one set of sprinkler (two sprinkler head) is 0.088 ha.

- Operation hour when the maximum water amount is necessary, is 17.7 hour (5.9 hours per one set of sprinkler, three times setting).

- Rotation interval for irrigation is five days

Therefore, necessary capacity of farm pond is 7.8 m^3 per ha and area of one rotation block is 1.32 ha (0.088 ha x three times x 5).

Outline of the above-mentioned facilities are shown in Table 3.2.15 (Irrigation Facilities in Caqueza).

Table 3.2.15 Irrigation Facilities in Caqueza

Irrigation system	Diversion weir (reservoir) Designed amount of intake water (l/s)	Structure, scale	Main driving channel Structure, scale	Length (m)	Farm pond (tank) Capacity	Place
		No. 1-5	stone pitching	1,300	70-220	29
Negra	89.0	fixed type	PVC 4"	2,300		
Blanca		H = 1.5	3"	350		
		L = 3-4	2.1/2"	2,100		
			2"	1,250		
			1.1/2"	350		
Reservoir No. 1	earth fill		H = 3.5 m, L = 35 m			
" No. 2	"		H = 2.5 m, L = 30 m			
" No. 3	"		H = 1.7 m, L = 20 m			
" No. 4 (reinforced)	"		H = 1.0 m, L = 30 m			

(8) alternative

As one of the alternatives, utilization of discharge water of the Palmar River is considered. This alternative is not included in the project due to water right. However, the discharge water of the Palmar River can be diverted to the highest elevation area in the northern part of Caqueza sub-project area with gravity through a intake weir (EL. which will be constructed at Puebro Viejo 2,300 m and 60.5 km^2 of catchment area) and a driving channel with length of 8,500 m. When this scheme comes into use, about 600 ha of all farmland in Caqueza area including the area which is excluded from the sub-project area. From these matters, it is desirable to make dfforts the regulation of water right in future.

3.2.5 Tibacuy

(1) Net water requirement

In this sub-project area, field and coffee plantation are irrigated. Based on the cropping pattern proposed in 3.4 (Farm Management) of the report, monthly water requirement of field is calculated for ten years from 1972 to 1981, following the same procedure as that in San Pedro de Iguaque (instead of seven days, provided five days in Tibacuy for rotation interval of irrigation).

The calculation result is shown in Annex D, Table D.2 (4). According to the result, the maximum water requirement is 51.50 mm/month in August 1976 and the maximum monthly average for the past ten years is 41.60 mm/month in August.

Coffee plantation is normally irrigated just before flowering stage. The consumptive water amount in monthly basis are 3.1 mm/day in April, 3.0 mm/day in May, 3.0 mm/day in october and 2.6 mm/day in November. However, for supplemental water amount, 1/2 of consumptive water amount is taken because these months are fallen in rainy season.

(2) Irrigation canal system

In this sub-project area, only Q. San Jose (including branch streams) can be used for irrigation.

Considering distribution pattern of the farmland and topography of the area, four diversion sites, namely two site in upstream and downstream of main stream of Q. San Jose and one site each in Matejunca and Lamina which are branch streams of Q. San Jose are selected.

The relationship of the diversion site and the benefited area in each irrigation system is shown in Table 3.2.16 (Irrigation System in Tibacuy).

Table 3.2.16 Irrigation System in Tibacuy

Irrigation system	Diversion weir site		Irrigable area (ha)
	Elevation (m)	Watershed area (km^2)	
San Jose	1,820	1.82	
	1,820	0.91	
	1,820	0.87	243
San Jose No. 2	1,701	1.85	15

(3) Diversion water requirement

Taking 85% for irrigation efficiency including conveyance efficiency, diversion water requirement is calculated. The result shows that the maximum diversion water requirement in monthly average for 243 ha of three systems located in higher area and for 15 ha of San Jose No. 2 system are 50.90 1/s and 3.12 1/s, respectively (refer to Annex D, Table D.3 (12), (13) Water Balance).

(4) Available water amount at diversion weir site

Based on run-off per km^2 of watershed area as described in 2.2.2 (4), the available water amount is estimated. The result shows that:

- 1,056,000-2,919,000 m^3/year for San Jose No. 1 irrigation system (higher area, three diversion sites, watershed area: 3.6 km^2)
  2.16-228.2 1/s for discharge in monthly basis

- 445,000-1,401,000 m^3/year for San Jose No. 2 irrigation system (watershed area is 1.85 km^2)
  0-114.2 1/s for discharge in monthly basis

Provided that in San Jose No. 2 system, available water amount is to be the water amount deducting the existing water right of 3.11 l/s which was registered in INDERENA from actual stream discharge.

(5) Water balance

Based on the diversion water requirement and the available water amount, the water balance study in monthly basis is carried out for each irrigation system for the past ten years. Result of the study shows that:

- For San Jose No. 1 system (three diversion sites in higher area), there is no water shortage for five years among ten years. However, for the remaining five years 58,000 - 92,000 m^3 (9.7 - 15.5% of diversion water requirement) is lacking.

- For San Jose No. 2 system, in 1972 and 1974 water shortage of about 7,000 m^3 and 10,000 m^3/year respectively (16.3 - 26 % of necessary diversion water requirement) each occurs. However, there are no water shortages for the remaining eight years.

(6) Facility plan

The fixed type of diversion weir is adopted in every sites due to shallow bed rock.

The existing diversion weir through which currently FEDECAFE is taking drinking water should be rehabilitated and used for the diversion weir of San Jose No.2 irrigation system because transportation of construction materials for the rehabilitation of No. 2 diversion weir is easy.

Pipeline system is selected for rest of the area because steep slope can be utilized and the farmland is concentrated.

Using same sprinkler set as that of Santa Sofia, operation of the sprinkler is designed to be 5.9 hours per one set, three times setting per day, 18 hours for sprinkling per day, five days for rotation interval. The capacity of terminal facilities are also designed under the above-mentioned condition. Therefore, 8 m^3 per ha is necessary for capacity of farm pond. The area irrigable by one set of sprinkler set (two sprinkler heads) is 0.264 ha per day. Area of the rotation block is 1.32 ha.

In coffee plantation, over top-of-tree irrigation method is adopted, because construction cost of drip irrigation method is expensive though it is preferable. For irrigation of coffee plant, small size of low angle sprinkler type (nozzle pressure : 2.0 kg/cm^2, sprinkling intensity : 1.6 mm/hr) is used. Working hour of sprinkler per day is 22.0 hr (10.8 hr x two times), and rotation interval for irrigation is five days.

Therefore, irrigable area by one set of sprinkler (eight sprinkler heads) is 0.16 ha per day and area of one rotation block is 0.8 ha.

Farm pond (tank) for irrigation of coffee plant is shared with irrigation of upland field (8 m^3 per ha).

Outline of irrigation facilities are summarized in Table 3.2.17 (Irrigation Facilities in Tibacuy).

Table 3.2.17 Irrigation Facilities in Tibacuy

Irrigation system	Diversion weir (Reservoir)		Main driving channel		Farm pond(tank)	
	Designed amount of intake water (l/s)	Structure scale	Structure scale	Length (m)	Capacity	Number of Place
San Jose						
No. 1-3	50.9		PVC 6"	1,150	50 - 200	16
No.1		fixed type	4"	2,450		
		H = 2	2.1/2"	400		
		L = 3	2"	400		
			1.1/2"	300		
San Jose		fixed type	PVC 1.1/2"	295	40	3
No.2	3.1	H = 2.0				
(Pilot)		L = 4.5				

3.2.6 Selection of Pilot Area

Among all sub-project areas, in Caqueza and Tibacuy a certain number of farmers are undertaking irrigation using sprinkler during period when no rain days are continued. However, rest of the farmers have almost no experience in irrigation.

Therefore, it is no easy for the concerned farmers to response to the rapid change of farm management when new irrigation facilities are introduced at one time in the large area, through they should follow the new farm management.

In order to solve this problem, it is necessary to select a representative irrigation system among all irrigation systems as a pilot area. In the pilot area, irrigation facilities should be provided in advance of the other area, public and private organization should be integrated and established for water management and farming technology suitable to cultivate method under irrigation, and the effect of the

irrigation should be demonstrated to the concerned farmers.

In order to take necessary action to solve the problems which might happen in course of the project implementation, cooperation of the concerned farmers is indispensable. Considering the above mentioned issues, the following three areas seem to be suitable for the pilot area.

San Pedro de Iguaque	: area of 26 ha in Yerbabuena irrigation system
Santa Sofia	: area of 28 ha along two streams of Tambor and Cruz in Camelo irrigation system
Tibacuy	: 15 ha of demonstration farm in FEDECAFE

The preliminary design of irrigation facilities in the above-mentioned pilot areas are shown in Volume IV.

3.2.7 Problems of Intake Water Plan in Monthly Average Discharge

In course of the feasibility study, water balance is studied using monthly average values in both of available water amount and diversion water requirement. However, these values, particularly discharge amount, are always fluctuated.

On this matter, the stream discharge in Caqueza and Tibacuy area estimated by observed discharge of the other streams is examined as follows;

The discharge during dry season (November to February in Caqueza, January, February, July and August in Tibacuy), by which the irrigable area is limited in water balance study, is examined for the past ten years. Variation of the monthly discharges when the available water amount is almost equal to the diversion water requirement are shown in Table 3.2.8 (Variation of Monthly Mean Discharge in Dry Season). As noted from the Table, the average discharge of every five days is some-

times dropped to 71% of the monthly average discharge.

In design of the project, such water shortage occurs once each in Caqueza and Tibacuy for duration of ten years from 1974 to 1983 (except the month when water shortage happens in study carried out by monthly average discharge). As mentioned above, when the water balance study is carried out using the discharge in monthly basis, a certain degree of error should be presupposed.

3.3 Soil Conservation

There is not a large-scale erosion district in the sub-project areas. Consequently, soil erosion of cultivated land and grassland in the sub-project areas is not remarkable at this stage.

However, if soil erosion will make progress, which exists in the lower part of Q. Los Robles and Q. Soavita in San Pedro de Iguaque and in the right lower part of Q. Palonegro in Santa Sofia, it is in danger of occurring on cultivated land. In those soil erosion areas, it is necessary to afforest and grow grass in order to recover vegetation.

Farmer and organization concerned as one body have need of pushing forward the countermeasures of soil conservation in slope areas, and it is necessary that each farmer gives careful consideration to the following points at least in farm management.

. Cancellation of fallow land and bare land (culture of effective crops such as green manure and so on for keeping and increasing the soil productivity, and afforestation)

. Adoption of conservation cropping (contour cropping, belt cropping, non-tilled cropping)

Moreover, in regional unit (water-use organizations, municipalities), complete equipment of farm drain, road drainage, farm road and so on and/or their everyday maintenance will be necessary (refer to the paragraph 2.4.2).

The area where must be considered a countermeasure immediately is as follows.

(1) The area to be conducted a contour line cultivation and the provision interception canals and ditches by each farm unit.

- San Pedro de Iguaque

- San Pedro de Iguaque
  Zone of CBef2 and Cbf3 is shown in Fig. 2.3.1 (Soil Distribution Map) (530 ha).

- Santa Sofia
  Zone of Side2, Slef2 and Slef4 is shown in Fig. 2.3.2 (Soil Distribution Map) (480 ha)

- Caqueza
  Zone of Gref2 is shown in Fig. 2.3.3 (Soil Distribution Map) (115 ha).

- Tibacuy
  Zone of BLefzp is shown in Fig. 2.3.4 (Soil Distribution Map) (495 ha).

  (Total 1,620 ha)

(2) The area to be carried out an installation of interception canals and ditches, an afforestation, the pavement of road surface (for the purpose of erosion protection), etc. by farmers or rural community.

The areas shown in Fig.3.3.1 (1)-(4) (Land Conservasion Plan) are as follows:

San Pedro de Iguaque	: 10 places	5,300 m
Santa Sofia	: 11 places	7,000 m
Caqueza	: 5 places	2,000 m
Tibacuy	: 7 places	2,700 m
Total	: 33 places	17,000 m

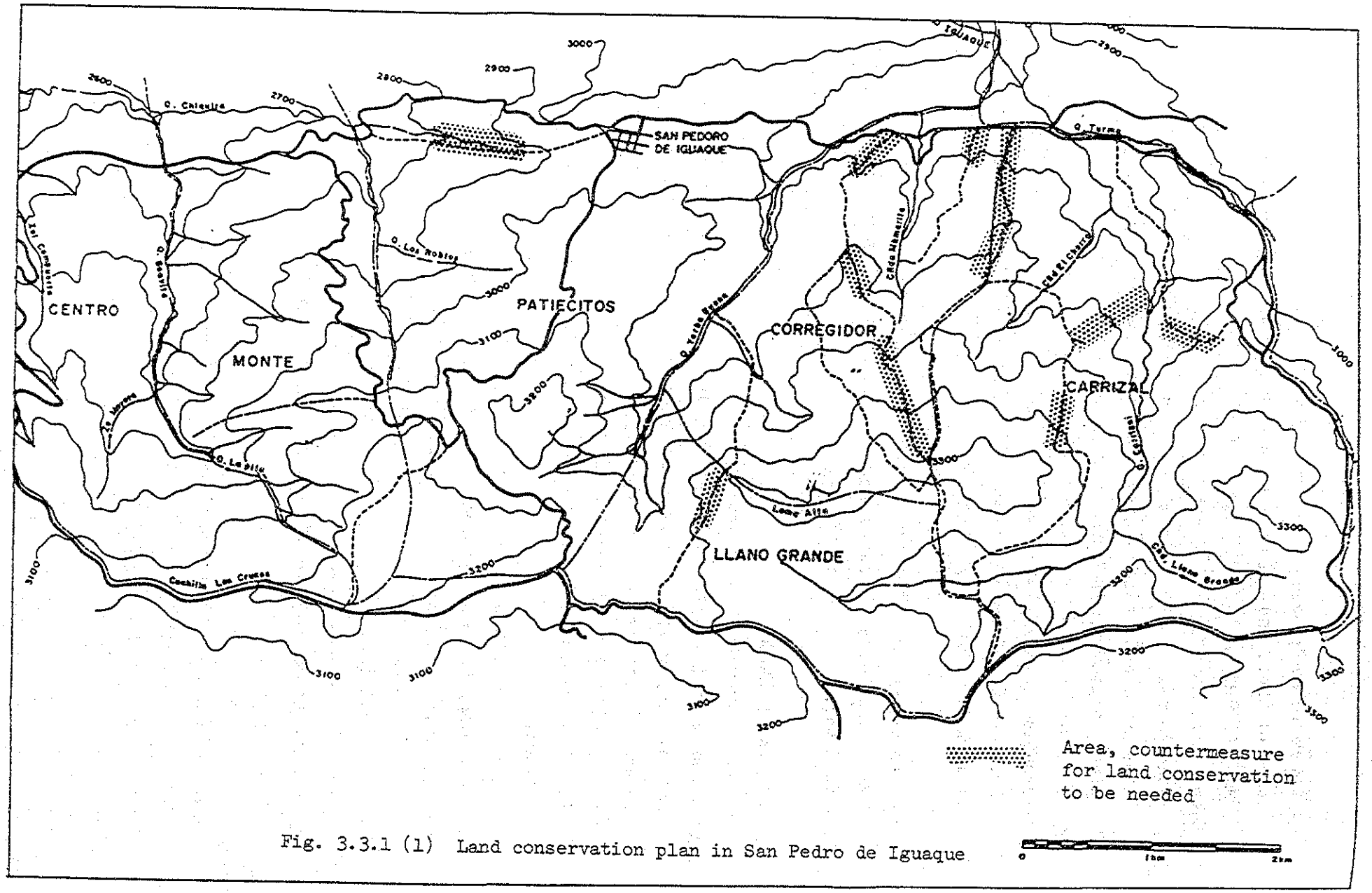


Fig. 3.3.1 (1) Land conservation plan in San Pedro de Iguaque

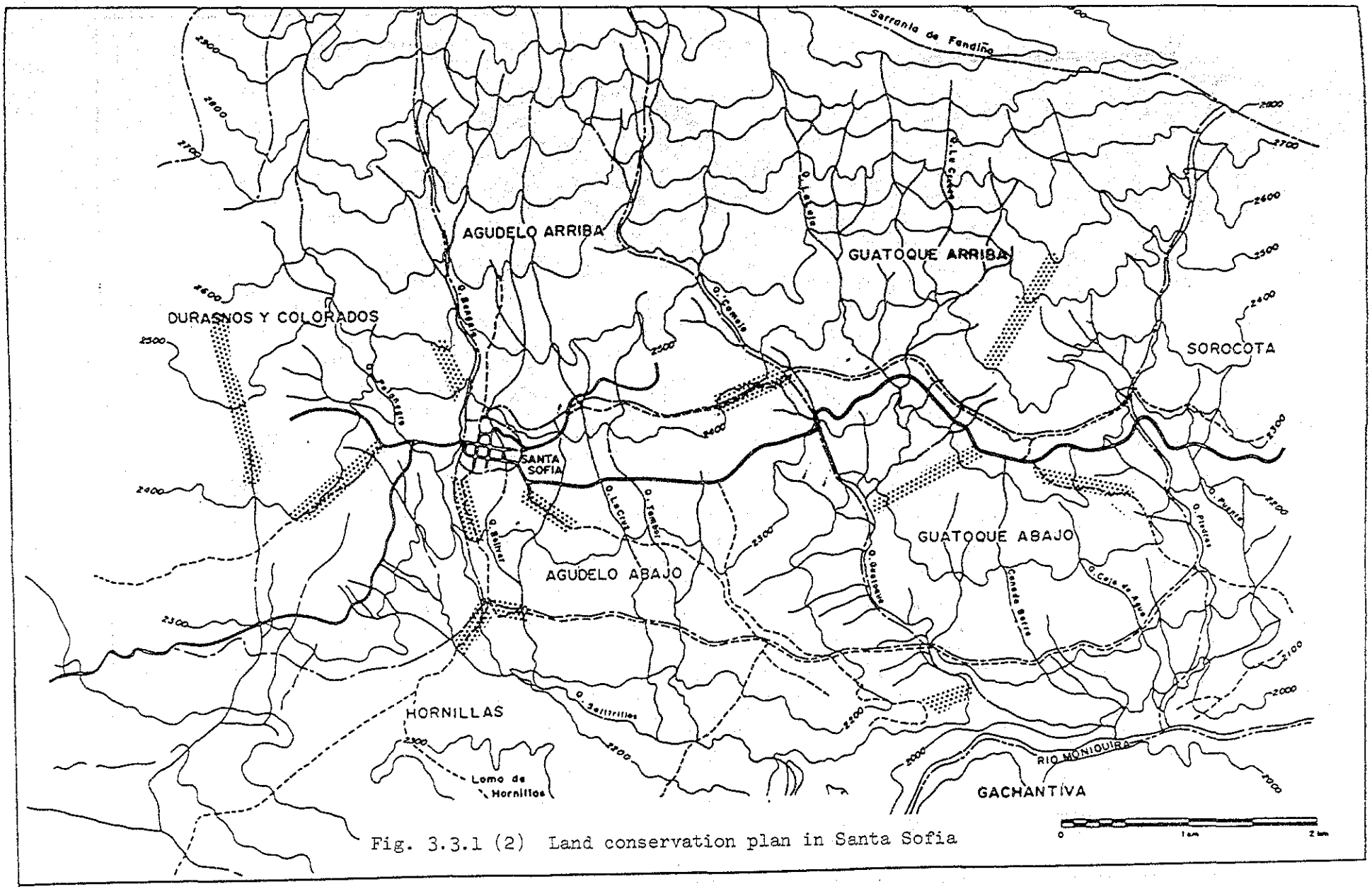


Fig. 3.3.1 (2) Land conservation plan in Santa Sofia

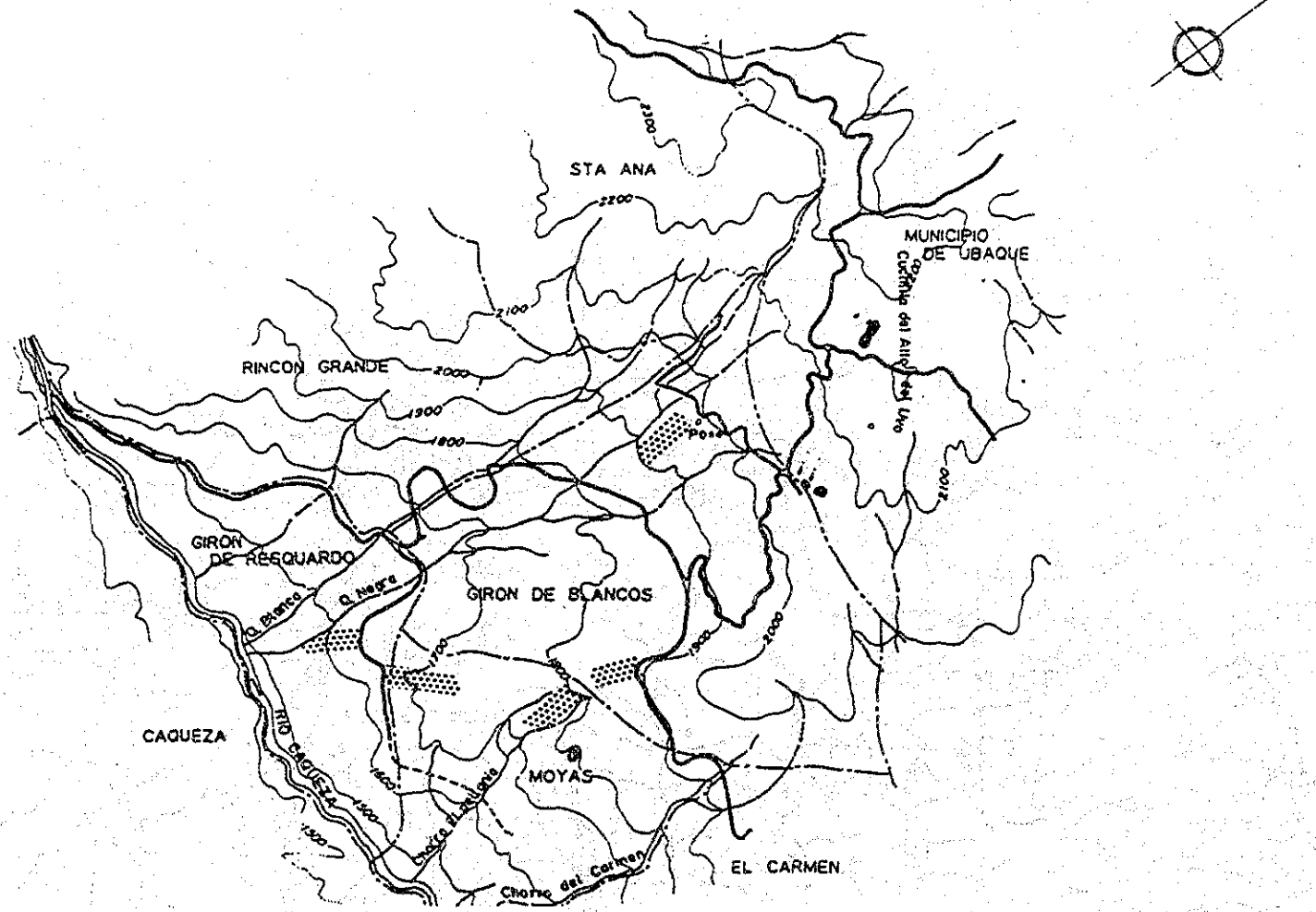


Fig. 3.3.1 (3) Land conservation plan in Caqueza

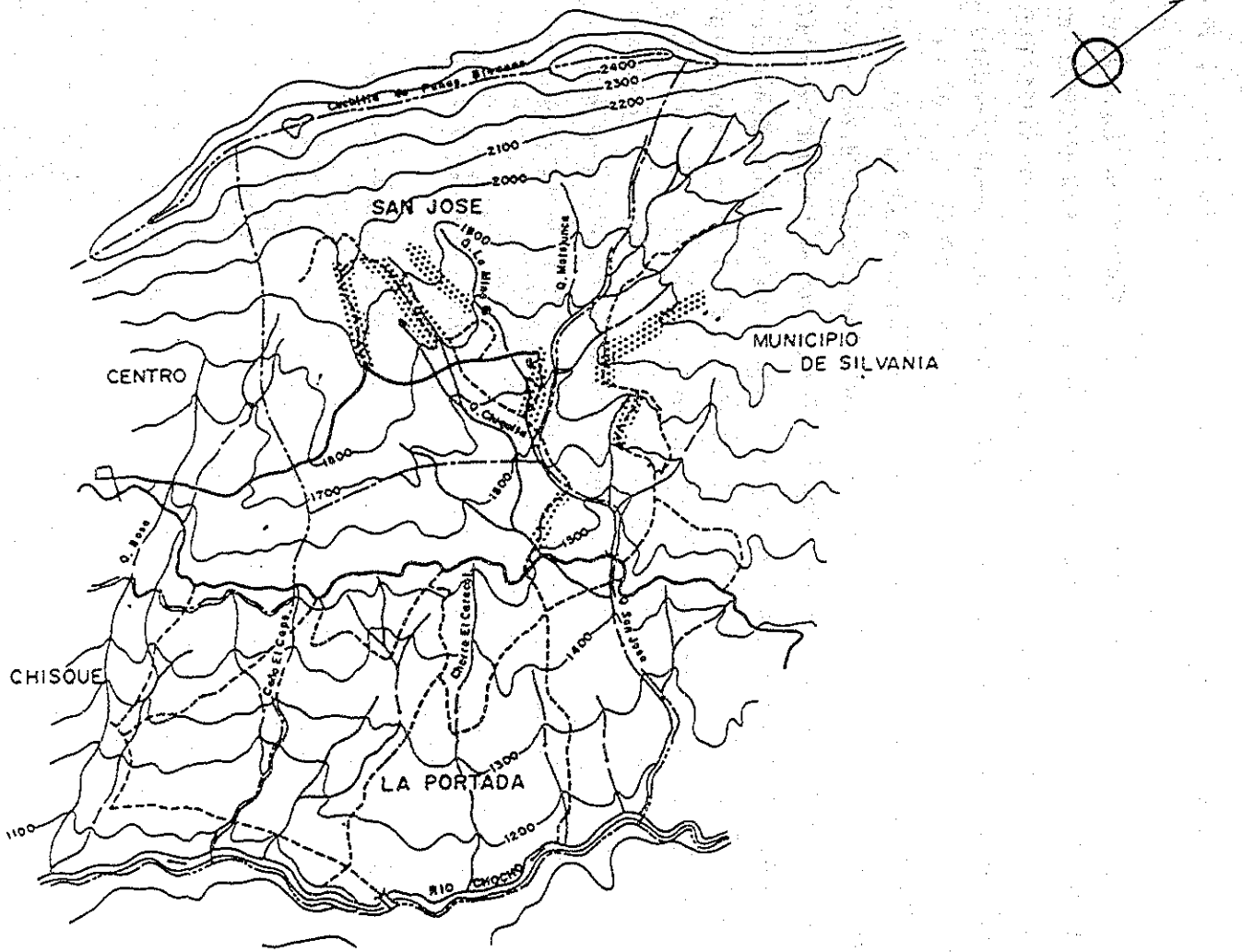


Fig. 3.3.1 (4) Land conservation plan in Tibacuy

3.4 Agricultural Management

3.4.1 Selection of Crops

Crops under irrigated land have been selected in due consideration of natural and socio-economic conditions of each sub-project area; especially, climatological conditions, profitability and availability of transport infrastructures for products have been taken into account.

The Table 3.4.1 (Proposed Crops to be Introduced in Sub-Project Areas) summarizes selected crops for each sub-project area. In the course of selecting proposed crops, information obtained form ICA - Hortalizas, Manual de Asistencia Tecnia which involves recommended crops by land elevation was referred to as presented in Table 3.4.4 (Recommended Crops according to Temperature).

Table 3.4.1 Proposed Crops to be Introduced in Sub-Project Area

Sub-project Area	Cold to Cool Are		Cool to Warm Area	
Crops	San Pedro de Iguaque	Santa Sofia	Caqueza	Tibacuy
Upland Crops				
Potato	O	O		O
Mize	O	O	O	O
Wheat	O	O		
Onion		O	O	O
Welsh Onion	O			
Garlic		O		
Broadbean	O	O		
Kindneybean		O	O	O
Pea	O	O	O	O
Snapbean			O	O
Tomato			O	O
Cucumber			O	O
Beet	O	O		
Carrot	O	O		
Arracacha		O	O	O
Pumpkin				
Fruits				
Curuba		O		
Peach		O		
Guava		O		
Apple		O		
Black berry				O
Quito orange				O
Tree tomato				O
Soursop				O
Cooking banana				O
Papaya				O
Orange				O
Coffee				O

3.4.2 Cropping Patterns

It is proposed that some of lands involved within irrigable area may not be irrigated due to the availability of irrigation water. In this connection, two cropping patterns have been proposed: one in fields where irrigation water is easily available and the other in field where irrigation water is not easily available (refer to Annex C.1 Cropping Pattern). The former patterns (type A) have been established with emphasis laid on abstracting highly profitable crops among selected ones and putting their harvest time in which highest farm-gate price is expected. In this case, cropping period will not be constrained in terms of water availability. On the other hand, crops for the latter patterns (Type B) have been selected based on their adaptability to arid land and profitability, and sowing time has been set forth at the early stage of rainy season. In any of pattern, consideration has been given to elevating cropping intensity as well as avoiding continuous cultivation of a single crop in the same land. These patterns are expected to be realized without employing outside hired labor as much as possible.

Cropping pattern of sub-project area is summarized below.

- San Pedro de Iguaque

  Type A: Profitable crops such as beet, welsh onion, carrot and broad bean are introduced instead of wheat.

  Type B: Broad bean and pea are increased.

- Santa Sofia

  Type A: Garlic as profitable crop is newly introduced instead of potato and sugar cane, and the cropping of pea are increased.

  Type B: Garlic, broadbean and arracacha (Peruvian carrot) are newly introduced.

- Caqueza

Type A: Cucumber as profitable crop is newly introduced.
Type B: Arracacha (Peruvian carrot) is introduced.

- Tibacuy

Type A: Onion, pumpkin and cucumber are newly introduced considering the stability of earnings due to close the markets.

Type B: Onion and arracacha (Peruvian carrot) are introduced.

After evaluating their effects from the viewpoint of water use appropriate patterns suitable for irrigable fields have been established.

Concerning the both type, A and B,it has compared the irrigable area (the area to be fully irrigated) by the stream water of 1.0 1/sec. in normal year (the average monthly discharge in drought season is compared and), on the other hand, when the irrigation water is fully secured, the comparison of the benefit between two types, A and B of the cropping pattern is made.

In this case, even if the benefit per ha in a project area is low, it can be taken up the project area when its irrigable area by the discharge of 1.0 1/sec. is large. Accordingly, a pattern to make larger the total value of expectable benefit is adopted.

Irrigable area by 1 1/sec. of water amount in drought season

Results of the calculation of water requirement for the both cropping pattern are shown in Annex D, Table D.2 (Net Water Requirement).

The proposed irrigable area by 1 1/sec. in the month which is critical factor to determine the irrigable area comparing the varia-

tion of monthly water requirement area in sub-project with available monthly discharge, is shown in Table 3.4.2 (Irrigable areas under the Different Cropping Patterns).

Table 3.4.2 Irrigable Areas under the Different Cropping Patterns

Sub-project area	Cropping pattern		B / A
	A type	B type	
San Pedro de Iguaque	7.4 ha/Jan.	5.5 ha/Jul.	0.74
Santa Sofia	8.6 ha/Aug.	4.5 ha/Jan.	0.52
Caqueza	4.6 ha/Mar.	20.1 ha/Jan.	4.40
Tibacuy	5.5 ha/Aug.	4.3 ha/Jul.	0.78

Note: 1. Calculation of the type A of cropping pattern in San Pedro de Iguaque

In case of type A, the peak of average water requirement during 10 years after 1974 occurs in January (refer to Annex D, Table D.2(1) Net Water Requirement).

Average monthly net water requirement : 29.20 mm/month
Average daily net water requirement : 0.94 mm/day
Average daily diversion water requirement : 1.18 mm/day
= 0.136 1/sec/ha
(Irrigation efficiency : 80% is used.)

Average monthly available water amount of water source during 10 years after 1974 is to be minimum in January as shown in Annex A, Table A.2.6 (Unit Monthly Discharge).

Accordingly, critical factor to irrigable area is discharge in January.

As mentioned above, the irrigable area by discharge of 1.0 l/sec is established as follows;

1.0 l/sec ÷ 0.136 l/sec/ha = 7.4 ha

2. Calculation of the type B of cropping pattern in San Pedro de Iguaque

Water requirement and available water amount in drought season in case of type B are as follows ; In case of type B, peak of water requirement arises in drought season of July.

Average monthly net water requirement	:	38.7 mm/month
Average daily net water requirement	:	1.25 mm/day
Average daily diversion water requirement	:	0.18 1/sec/ha

(Irrigation Efficiency : 80% for A)

The irrigation area will be determined by the discharge in July. Namely, the irrigated area by discharge in July of 1.0 1/sec is calculated as below;

$$1.0\ 1/s \div 0.18\ 1/sec/ha = 5.5\ ha$$

Benefit by cropping pattern

On the other hand, when the irrigation water is fully secured, the comparison of the benefit between two types (A and B) of the cropping pattern is shown in Table 3.4.3 (Comparison of Benefit in Each Cropping Pattern).

Table 3.4.3 Comparison of Benefit in Each Cropping Pattern

Unit: 1,000 Col.$/ha

Sub-project area	Cropping pattern		A / B
	A type	B type	
San Pedro de Iguaque	127	90	1.4
Santa Sofia	309	210	1.5
Caqueza	350	290	1.2
Tibacuy	237	130	1.8

Based on the above-mentioned two kinds of the comparison study, in case of irrigation, A type in which the benefit per unit area (ha) is bigger and also the irrigable area by 1.0 l/s in dry season is slightly big, is preferable to be adopted for San Pedro Iguaque, Santa Sofia and Tibacuy areas. On the contrary, for Caqueza area, though the benefit per ha is low (A/B = 1.2), B type in which large irrigable area (4.4 times) can be taken is preferable to be adopted.

Therefore, concerningthe cropping pattern byirrigation, the cropping pattern B is adopted for Caqueza area and the cropping pattern A for the other three sub-project areas.

Irrigation manner for coffee production in Tibacuy has been set forth in such manner as to irrigate the fields before flowering period of plants. It is expected that irrigation will produce a good effect on the growth of plants, because no rainfall day to continue more than ten days often occur even though in rainy season on which flowering period of plants fall (as described in the paragraph 2.2.1 (6) 3) Continuous no rainfall days).

3.4.3 Farming Program of Model Farmer

(1) Farm size

As given in Table 3.4.5 (Average Farm Size per Farmer), small farmers with holdings of farm less than 10 hectares represent the greater portion of the total number of farms in all of four sub-project areas. Most of these small farmers operate both upland crop and animal husbandaries.

There are many small farmers within the Project area and emphasis of the Project has been laid on improvement of productivity on these small farmers. In this connection, thes small farmers have been picked up as a model farmer of the Project.

In sum, the farm sizes for model farmer of each sub-project area have been determined as given below, which coincide with the average farm sizes of small farmers with farm holdings less than 10 ha.

San Pedro de Iguaque	:	3.0 ha
Santa Sofia	:	2.4 ha
Caqueza	:	1.4 ha
Tibacuy	:	2.0 ha

The farming program for these model farmers has been presented as explained hereinafter.

1) Area by land use

The Study area was delineated according with water availability in rivers and tributaries, water intake sites, viability to locate driving channel, etc. Land distribution by land use has been proposed as a result of the field survey on farmers and land use study.

2) Size of a family

Assuming that there will be no substantial change, the size of a family (eligible for farming) and the head of animals have been proposed on the basis of the field survey on farmers.

3) Cropped area

The ratios of irrigable land to the total farmland are as follows:

San Pedro de Iguaque	:	60%
Santa Sofia	:	100%
Caqueza	:	100%
Tibacuy	:	100%

Forty percent of the total farmland at San Pedro de Iguaque will not be benefited by the irrigation water, so "cropping patterns in fields where irrigation water is not easily available" (see the paragraph 3.4.2 Cropping Patterns) have been applied to these lands. The rest of farmland will be applied "cropping patterns in fields where irrigation water is easily available". (A type)

Table 3.4.6 (Farm Operation of Model Farmers) summarizes farm operation proposal for model farmers.

Crop intensify with Project will be improved as shown below:

	Without Project	With Project
San Pedro de Iguaque	110%	157.5%
Santa Sofia	110%	187.5%
Caqueza	100%	160.0%
Tibacuy	160%	220.0% excluding coffee

(2) Cropping techniques

The major portion of farming activities is presently carried out by manpower; only harrowing leveling and transportation of crops are made by animals. In view of the Project area being extended over complicated topography without providing adequate infrastructures, and assessing farmers' financial capabilities, it is not viable to accomplish the mechanization of production activities in short run. Consequently, recommendations for the improvement of current cropping techniques have been presented in due consideration of current cropping techniques of farmers.

1) Annual crops

a) Introduction of improved varieties and renewal of seeds

Renewal of seeds should be made at least once in every two or three years. Recommended varieties are presented in Annex C.4.3.1 (Annual Crops).

b) Improvement of soils and application of fertilizers

The soil analysis of the present study revealed that soils extended in the study area are represented by high acidity and less content of nourishment.
Considering actual cropping technique of farmers, it is not practical to recommend farmers to carry out at every cropping opportunities an application of soil improvement inputs and organic materials to all of crops to be cultivated. In this regards, it is recommended that an application of above-mentioned inputs crops as potato, onions, tomato at the initial stage of the Project and to all crops within a couple of years.

c) Disease and Pest control

It is observed that vegetables including new varieties of crops introduced in project are often damaged by pest. The main pesticides for major crops and other chemicals recommended by ICA and their volume to be applied per day are shown in Annex C, Tables C.4.5 (Main Diseases and Insects) and C.4.6 (Application Volume of Insecticide and Fungicide per Crop).

They are given in an instance of the diseases such as; black scurt and late flight for potato, damping off and rust for leguminosae, alternaria leaf spot and gray mold for onions, damping off and wilt for tomate, etc., and of the insects such as; black cutworm and potato tuberworm for potato, black cutworm and stem miner for leguminosae, onion maggot and thrips for onions, black cutworm and stem miner for tomate, etc.

It is recommended that the frequency of pest control would be increased by once or twice more than the actual level, and the instruction by ICA is strongly desired on the application of agricultural chemicals.

d) Weeding

After evaluating monthly labor requirements (see Annex C, 4.4), it has become concluded that all of farming activities could be achieved only by family labor, so hand weeding is recommended.

e) Others

With a view to conserving soils it is recommended no to carry out vertical farming to ridge which is practiced in some fields but to realized counter farming as much as possible.

The result which sorted out these improvement points is

presented in the Table 3.4.7. The labor force and agricultural inputs are shown in Annex C, 4.3 and 4.4.

2) Coffee

a) Renewal of plants and introduction of improved varieties

As minimum plants with more than 20 years should be renewed periodically and improved varieties recommended by FEDECAFE should be introduced.

b) Application of fertilizers

Few farmers apply fertilizers at present. It is recommended that an application of fertilizers at least once or twice annually would be carried out so as to increase the productivity (the yield in this area is about 60% s low as that in major coffee production region of the country).

c) Weeding and shading tree

The growth of coffee plant is related largely with the control of weeds, so it is required to carry out weeding at least twice a year. And the planting density of shading tree is required to be determined in accordance with the technical assistance of FEDECAFE.

d) Pest control

Recently the occurrence of "Roya" has been reported and as measure to control this disease FEDECAFE has distributed pesticide to farmers free of charge. It it recommended that technical assistance by FEDECAFE would be carried out with respect to opportunity and volume of pesticide application.

Though the farming technique is planned in line with the above-

mentioned improvement, it is necessary that the farmer's intention on farming practices be promoted and the extension services, be strengthened. In this plan, it is not considered to organize the cooperatives in sub-project area, but the establishment of agricultural cooperative taking advantage of an opportunity to the project implementation, and of the system which can be received positively the extension services are proposed.

(3) Production volume

The Table 3.4.8 (Production Volume) represents targets of production volume by model farmer of each sub-project area for without Project, initial year and target year with Project.

3.4.4 Production Plan in Sub-project Areas

(1) Projection of Crop Yield

Crop yield will be elevated owing to the supply of irrigation water and improvement of cropping technique. Nevertheless, the improvement of cropping technique depends on such uncertain factors as the level of technical assistance by public institutions, the degree of learning technology by farmers, etc., so the peak crop yields have been established in consultation with the FAO's Manual (Irrigation and Drainage Paper No. 33 - Yield Response to Water) which guides how to determine crop yield in case of irrigation water being supplied to satisfy the requirements, and referring to the actual levels estimated as a result of field survey on farmers (see Annex C.2 Production Volume). Then, on the basis of established cropping patterns supply and requirement of irrigation water were estimated; this estimation intimates that there will be some years in which the supply of irrigation water will not satisfy the requirement. Consequently, after taking account of damaged rate the target crop yields have been revised as given in Table 3.4.9 (Crop Yield with Project).

The target crop yield can be attained only when farmers will get a mastery of irrigation techniques which is followed by the following procedure.

First step (Initial year)	:	Increase in the yield is not feasible because of unskilled irrigation techniques.
Second step (Secondary and third year)	:	Regarding 70-80% of the target yield as their irrigation techniques improve.
Third step (Forth year and onward	:	Farmers get a mastery of irrigation technique and target crop yields will be attained according with farmer's willingness for increasing productivity (though further improvement of productivity is expected with the advance of cropping technology, which is not taken into account here).

(2) Crops Production Plan in Project Areas

In accordance with irrigation water development plan, irrigable areas for each sub-project area have been determined as follows:

San pedro de Iguaque	:	162 ha (including 26 ha of pilot area)
Santa Sofia	:	239 ha (including 28 ha of pilot area)
Caqueza	:	417 ha
Tibacuy	:	48 ha (including 5 ha of pilot area)
Coffee	:	210 ha (including 10 ha of pilot area)
Total	:	1,076 ha

Cropping patterns for these irrigable areas have been applied those illustrated in Fig. 3.4.1 (Cropping Calendar); based on these patterns cropped area under irrigation have been obtained and production volumes have been calculated multiplying cropped areas by the above-mentioned target crop yields.

The results of the above-mentioned calculation are as follows;

Sub-project area	Cropping rate (%)	Increased production (ton)	
		Cereals and leguminosae	Others
San Pedro de Iguaque			
Without Project	110	84	1,356
With Project	163	246	3,684
Santa Sofia			
Without Project	111	224	1,470
With Project	189	556	2,443
Caqueza			
Without Project	100	1,077	1,178
With Project	160	2,211	6,045
Tibacuy			
Without Project	110	159	364
With Project	122	572	1,261
Total Without Project	107	1,544	4,368
With Project	158	3,585 (Increase of 232%)	13,433 (Increase of 308%)

Note: Refer to Table 3.4.10 Production Plan of Sub-project Areas.

Table 3.4.4 Recommended Crops According to Temperature

Temperature	Land Elevation (m)	Recommended Crops
Warm	1,000 - 1,800	Pepper, Tomato, Cucumber, Kidneybean, Lettuce, Cabage
Cool	1,800 - 2,800	Cauliflower, Cabbage, Broccoli Brussels Sprouts, Lettuce, Carrot, Beet, Radish, Onion, Celery, Chard, Spinach, Pumpkin
Cold	3,000 - 3,500	Broadbean, Artichoke, Kale

Source : "HORTALIZAS" Manual de Asistencia Tecnica - ICA

Table 3.4.5 Average Farm Size per Farmer

Item / Area	Less than 10 ha				Average Farm Size per Farmer
	No. of Farmers	Percentage (%)	Hectarage of Farmland	Percentage (%)	
San Pedro e Iguaque	778 Farm	85 %	2,322.8 ha	37 %	3.0 ha
Santa Sofia	2,006	95	4,818.7	69	2.4
Caqueza	738	97	1,024.4	72	1.4
Tiacuy	423	89	849.4	42	2.0

Note: Including coffee in Tibacuy (refer to Annex C.4.1-4).

Table 3.4.6 Farm Operation of Model Farms

Items	Sub-Project Areas	San Pedro de Iguaque	Santa Sofia	Caqueza	Tibacuy
No. of Family		6	6	6	4
(Eligible for farming)		(4)	(3)	(3)	(3)
Total Farm Area (ha)	Upland	2.0	0.8	1.1	0.5
	Pasture	1.0	1.5	0.3	0.5
	Orchard	-	0.1	-	0.1
	Coffee Plantation	-	-	-	0.9
	Total	3.0	2.4	1.4	2.0
Cropped Area (ha)	Potato	1.0 (0.4)			0.1
	Wheat	0.1 (0.1)	0.1		
	Maize	0.25 (0.1)	0.1	0.22	0.1
	Beans	1.05 (0.6)	0.7	0.66	0.5
	Onions	0.3 (0)	0.6	0.44	0.2
	Vegetables, etc.	0.45 (0)		0.44	0.2
	Total	3.15 (1.2)	1.5	1.76	1.1
Livestock (head)	Cattle	4	6	2	3
	(Calf)	(2)	(3)	(1)	(2)
	Sheep	5	2	2	
	Hog	2	2		
	Ass or Horse	1	1	1	1
Existing Commercial Crops		Potato, Welsh Onion, Broadbean, Pea	Onion, Kidneybean, Pea, Garlic, Fruits	Onion, Snapbean, Tomato, Kidneybean, Peruvian Carrot, Pumpkin	Coffee, Snapbean, Onion, Kidneybean, Tomato, Cucumber, Fruits, Pumpkin

Note: 1) No. of family member (working force), total farm area and head of livestock are obtained according to the result of the survey to farmers.

2) Cropped area is based on the projected cropping patterns.

3) Figure in parenthesis for San Pedro de Iguaque indicate cropped area in fields where irrigation water is not easily available.

Table 3.4.7 Farming Practices and Improvement Proposals (1)

Farming Activites	Actual Practices	Improvement Proposals
Raising of Seedling	Manual near houses	Renewal of seed and selection of appropriate seed should be considered.
Land Preparation	By a couple of draft animal	To follow the actual practice
Harrowing & Levelling	Ditto	Ditto
Soil Improvement	Application of chemicals by hand (mainly lime)	To follow the actual practice. It is recommended that chemicals should be applied at the internal of once in every two or three years for such basic crops as patato, onions and tomato.
Applicaiton of Organic Matters	Sawdust and excrements are mainly applied by hand.	Ditto
Applicaiton of Fertilizers	Manual	To follow the actual practice subject to increment of 20 - 30% in quantity.
Seeding	Manual	To follow the actual practice, renewal of seed and selection of appropriate seeds should be considered.
Weeding	Manual with a hoe	To follow the actual practie, but the frequency of weeding should be intensified (once or twice more).

Table 3.4.7 Farming Practices and Improvement Proposals (2)

Farming Activites	Actual Practices	Improvement Proposals
Pest Control	Manual with a sprayer	To follow the actual practice, but techincal assistance on application time and selection of insecticide is desired. To intersify the frequency of application in once or twice more.
Harvesting	Manual with a sickle and a hoe	To follow the actual practice.
Collection and Packing	By threshing machine for wheats (on contract basis) Manual for other crops.	To follow the actual practice.
Transportation	By animals (horse, ass, etc) or trucks on contract basis.	Co-operative system should be established.

Table 3.4.8 Production Volume

(1) San Pedro de Iguaque

Unit:ton

Crops	Without Project	With Project
Potato	16.8	19.0
Wheat	0.39	0.21
Maize	0.65	0.44
Broadbean		1.57*
Pea		1.42
Welsh onion		9.0
Beet		4.5
Carrot		2.3

* Production of Broadbean mixed with maize is included

(2) Santa Sofia

Unit:ton

Crops	Without Project	With Project
Potato	2.6	
Wheat	0.04	0.21
Maize	0.22	0.18
Kidneybean	0.22*	0.48*
Pea	0.26	1.0
Onion		6.8
Garlic		1.4
Cassava	0.8	
Sugar cane	1.5	

* Production of Broadbean mixed with maize is included

(3) Caqueza

Unit:ton

Crops	Without Project	With Project
Maize	0.88	0.46
Kidneybean	0.6*	0.23
Pea	0.45	0.25
Snapbean	0.9	4.4
Onion	1.4	7.04
Tomato	1.7	4.4
Arracacha		2.2
Pumpkin		2.29*

* Production of Kidneybean and pumpkin mixed with maize are included

(4) Tibacuy

Unit:ton

Crops	Without Project	With Project
Potato	0.65	1.9
Maize	0.13	0.18
Kidneybean	0.2*	0.28
Pea	0.31	
Snapbean	1.2	3.3
Onion		3.4
Tomato	1.5	2.1
Cucumber		1.7
Pumpkin		1.12*
Coffee	0.9	1.17

* Production of Kidneybean and pumpkin mixed with maize are included

Table 3.4.9 Crop Yield

Unit : ton/ha

Crop	San Pedro de Iguaque		Santa Sofia		Caqueza		Tibacuy	
	Without Project	With Project	Without Project	With Project	Without Project	With Project	Without Project	With Project
Potato	12	19	13	19				19
Maize	1.3	2.2	1.4	2.2	2.2	2.6	1.4	2.2
Wheat	1.3	2.1	1.4	2.1				
Onion			12	17	14	16	12	17
Welsh Onion		30						
Garlic				7				
Broad Bean		2.1		2.1				
Kidneybean				1.0	1.1	1.3	1.0	1.4
Pea		3.3	2.2	3.3	3.0	3.4	2.6	3.8
Snapbean					9	10	8	11
Tomato					17	20	15	21
Cucumber						15	12	17
Beet		15		15				
Carrot		15		15				
Arracacha						10		
Pumpkin						13		14
Cassava			10				10	
Sugar cane			15				15	
Coffee							1	1.3

Note : The crop yields with Project have been established subject to giving the following reduction factors to the peak yields in the fulfillment of irrigation water.

San Pedro de Iguaque	5%
Santa Sofia	5%
Caqueza	15%
Tibacuy	5%

Table 3.4.10 Production plan of the Sub-Project Area (1)

(1) San Pedro de Iguaque (Irrigable Area : 162ha)

Crops	Cropped Area (ha)		Production Volume (ton)	
	Without Project	With Project	Without Project	With Project
Potato	113	81	1,356	1,539
Wheat	24		31	
Maize	41		53	
Maize(& Broadbean)		20		35
Broadbean		20		76*
Pea		41		135
Welsh onion		41		1,230
Beet		41		615
Carrot		20		300
Total	178**	264**		

* Production of broadbean mixed maize is included.
** Cropping Ratio; Without Project: 110%, With Project: 163%

(2) Santa Sofia (Irrigable Area: 239ha)

Crops	Cropped Area (ha)		Production Volume (ton)	
	Without Project	With Project	Without Project	With Project
Potato	60		780	
Wheat	9	30	13	63
Maize(& Kidneybean)	60	30	67	53
Kidneybean	45	119	65*	143*
Pea	36	90	79	297
Onion		119		2,023
Garlic		60		420
Cassava	24		240	
Sugarcane	30		450	
Total	264**	448**		

* Production of Kidneybean mixed maize is included.
** Cropping Ratio; Without Project: 111%, With Project: 189%

Table 3.4.10 Production Plan of the Sub-Project Area (2)

(3) Caqueza (Irrigable Area: 417ha)

Crops	Cropped Area (ha)		Production Volume (ton)	
	Without Project	With Project	Without Project	With Project
Maize(& Kidneybean)	190		334	
Maize,(Kidneybean & Pumpkin)		83		173
Kidneybean	57		230*	86*
Pea	57	83	171	282
Snapbean	38	167	342	1,670
Onion	38	167	532	2,672
Tomato	38	84	646	1,680
Arracacha		83		830
Pumpkin				863*
Total	418**	667**		

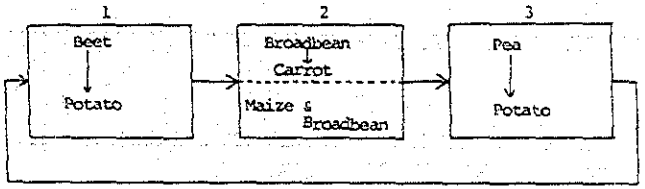
* Production of Kidneybean and pumpkin mixed maize are included.
** Cropping Ratio; Without Project: 100%, With Project: 160%

(4) Tibacuy
(Irrigable Area : Without project 48ha, With 48ha coffee Area : 210ha)

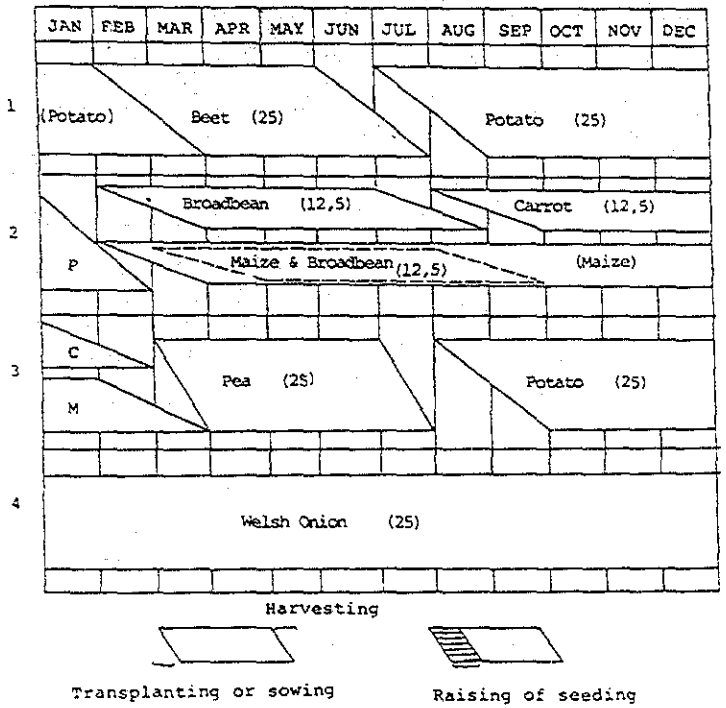
Crops	Cropped Area (ha)		Production Volume (ton)	
	Without Project	With Project	Without Project	With Project
Potato	4	10	52	190
Maize(& Kidneybean)	10		11	
Maize(& Pumpkin)		10		18
Kidneybean	10	119	18*	27
Pea	10		26	
Snapbean	13	29	104	319
Onion		19		323
Tomato	9	10	135	210
Cucumber		9		153
Pumpkin				112*
Cassava	4		40	
Sugarcane	9		135	
Sub-total	69	106		
Coffee	210	210	210	273
Total	287**	316**		

* Production of Kidneybean & pumpkin mixed maize are included.
** Cropping Ratio; Without Project: 110%, With Project: 122%

o Cropping Rotation

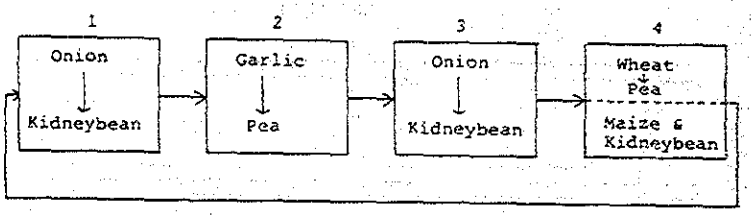


o Cropping Calendar (Type A)



(1) San Pedro de Iguaque

o Cropping Rotation



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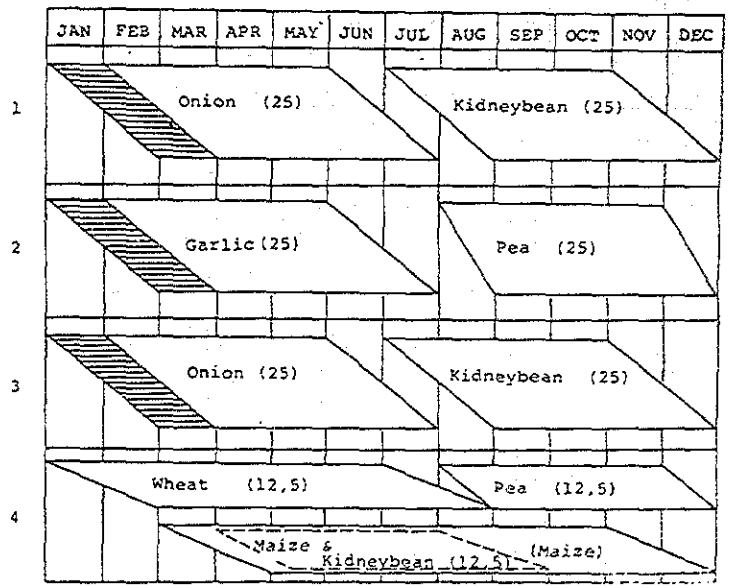
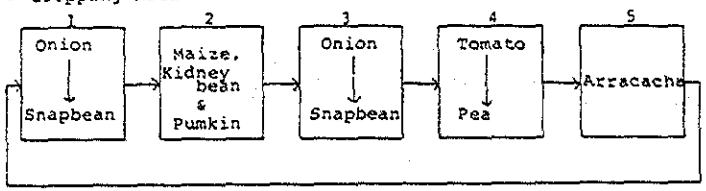


(2) Santa Sofia

Fig 3.4.1 Cropping Calendar

o Cropping Rotation



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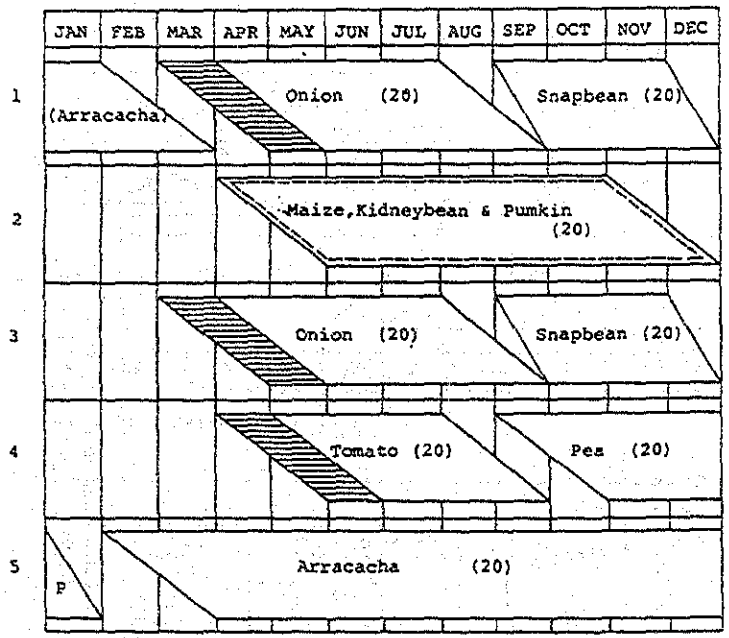
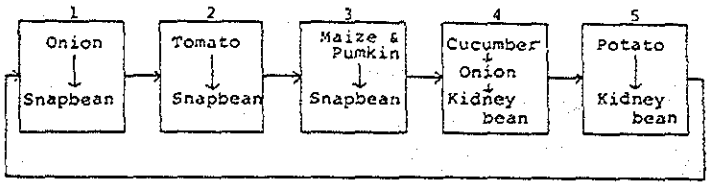
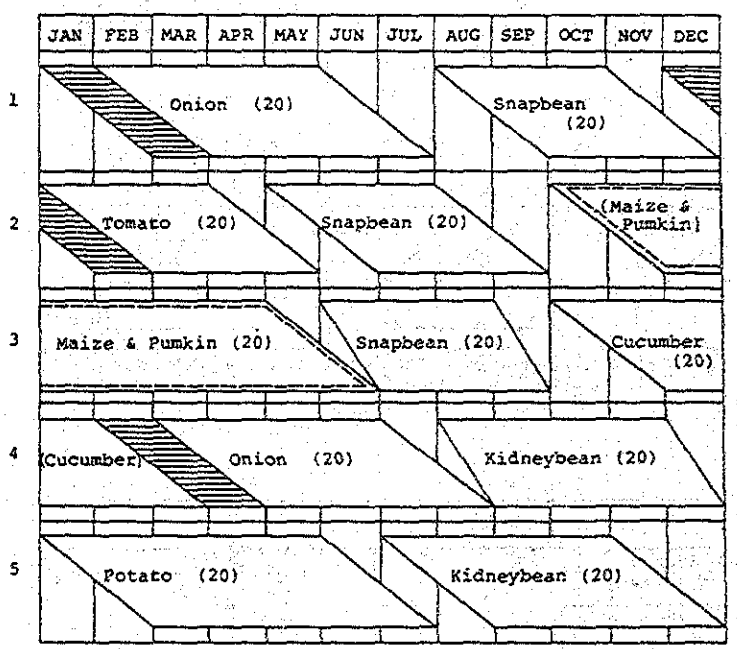


(3) Caqueza

o Cropping Rotation



o Cropping Calendar (Type A)



(4) Tibacuy

3.5 Agricultural Economy

3.5.1 Economic prices of Agricultural products

Farmgate prices of agricultural products in the sub-project area are estimated on the basis of wholesale prices in CORABASTOS in Bogota D.E. and some expenditures from farmgate to market in Bogota D.E. On the other hand, as for following agricultural products, import and export parity prices are adopted to economic farmgate prices.

Import parity price :	Maize
	Bean
	Wheat
	Pea
Export parity price :	Coffee

Table 3.5.1 (Estimated Value of Farm Products) shows economic agricultural gate prices of agricultural products. Besides, these economic prices are yearly average prices on the basis of past trend of prices of agricultural products (they are constant prices as of June 1986).

Furthermore, harvesting period of agricultural products (Without Project and With Project), seasonal fluctuation period of wholesale prices in CORABASTOS and peak transaction period of agricultural products in CORABASTOS are presented in Fig. 3.5.1 (High Transaction Season in CORABASTOS and Harvesting Period of Farm Products in Sub-Project Area). As shown in this figure, it is assumed that agricultural products under with project condition will be marketed effectively during the period of higher price compared with under without project condition.

3.5.2 Production and Shipping Volume of Agricultural Products

Table 3.4.8 (Production Plan of Sub-Project Area) shows anticipated production amount of products in the project area under with project

condition. Table 3.5.2 (Total Production Value of Sub-Project Area) shows production value of agricultural products based on economic prices of agricultural products mentioned hereinafter.

Future production value at full development stage will increase Col.$367,625,000 from Col.$670,826,000 under without project condition.

The increased value per ha at full development stage will be expected as below:

San Pedro de Iguaque	Col.$284,000
Santa Pedro de Iguaque	Col.$467,000
Caqueza	Col.$369,000
Tibacuy	Col.$250,000
Total average	Col.$342,000

Agricultural products from the Project area except for home consumption in farmers will be marketed mainly to Bogota.

Under with Project condition, volume and value of shipping of agricultural products are shown in Table 3.5.3 (Shipping and Dealing Volume (CORABASTOS) of Agricultural Products).

As mentioned in Table 3.5.3, marketed portion from the Project area except for onion, beans and tomato is very small compared with amount of transaction in CORABASTOS where deals with about 70% of whole marketed amount of agricultural products in Bogota D.E.

3.5.3 Production cost

Table 3.5.4 (Production Cost) shows the production costs of agricultural products under with project and without project condition.

Economic prices for agricultural inputs are calculated by multiplying shadow exchange price factor to the import portion of agricultural inputs.

3.5.4 Net Benefit

After having the estimated of net benefit by each sub-project area based on the value and cost of production as stated above, the annual increased net benefit with the Project implementation is Col.$200,000,000 in the whole sub-project area. (refer to Table 6.2.1 Benefit of Sub-Project Area)

3.5.5 Farm Household Economy

Concerning model farmers (refer to Table 3.4.6 Farm Operation of Model Farms), the study results of their agricultural income in case of the without project and the without project are shown in Table 6.6.1(Increased Income of Model Farmers).

The agricultural income shall be increased annually from Col.$ 4,100 - 20,000 to Col.$ 100,000 - 250,000 (refer to Annex C, Table 4.12 Profit and Loss and Table C.4.13 Cash Flow of Model Farmers).

As the results, net income of beneficiary will increase widely under with project condition, then the elevation of farmer's living standards will be expected.

Besides, monthly working rate of family labor force under with project will reach to 60%-80% in San Pedro de Iguaque, 40%-60% in Santa Sofia, 30%-70% in Caqueza and 45%-60% in Tibacuy, so that the working opportunity will increase compared with that of under without project (20%-60%) and farmers will be able to work constantly all the year round (refer to Fig. 2.7.1 Monthly Labor Force).

Table 3.5.1 Estimated Value of Farm Products

Products	Estimated Value (Col.$/Kg)
Potato	17/1
Maize	28/2
Welsh onion	17/1
Pea	106/1
Beat	21/1
Carrot	14/1
Kidney bean	148/2
Wheat	35/2
Onion	31/1
Garlic	103/1
Tomato	33/1
Cucumber	15/1
Pumpkin	18/1
Peruvian carrot	22/1
Coffee	892/3

Note: /1 : Financial farmgate price
/2 : Import parity price (Annex C Table 3.3)
/3 : Export parity price (Annex C Table 3.3)

Table 3.5.2 Total Amount of Productioin by each sub-project Area

Products	San Pedro de Iguaque		Santa Sofia		Caqueza		Tibacuy		Total	
	W/O	W/P	W/O P	W/P	W/O P	WP	W/O P	WP	W/OP	W/P
Potato	23,134	26,163	13,205	-	-	-	950	3,101		
Maize	1,750	-	-	-	-	-	-	-		
Wheat	745	-	351	2,211	-	-	-	-		
Maize/Beans	-	2,511	7,170	5,019	29,461	-	1,517	-		
Maize/Benas/Pumpkin	-	-	-	-	-	33,360	-	-		
Maize/Pumpkin	-	-	-	-	-	-	-	2,419		
Welsh	-	20,655	-	-	-	-	-	-		
Beans	-	8,991	7,801	30,951	25,149	48,039	4,739	9,936		
Beat	-	9,113	-	-	-	-	-	-		
Carrot	-	4,253	-	-	-	-	-	-		
Onion	-	-	-	62,977	16,288	82,733	-	10,118		
Garlic	-	-	-	43,080	-	-	-	-		
Sugar cane	-	-	2,237	-	-	-	619	-		
Cassava	-	-	1,936	-	-	-	348	-		
Tomato	-	-	-	-	21,054	55,044	4,257	6,653		
Peruvian carrot	-	-	-	-	-	18,348	-	-		
Cucumber	-	-	-	-	-	-	-	2,248		
Coffee	-	-	-	-	-	-	140,490	182,700		
Total	25,629	71,686	32,700	144,238	91,952	237,524	152,920	217,275	303,201	670,823
Increasedamount		46,057		111,538		145,572		64,455		367,628

Note) W/O P : Without project
WP : With project
Details are presented in Annex C, Table C.5.3 - C.5.6.

Table 3.5.3 Shipping and Dealing Volume (CORABASTOS) of agricultural products

Products	Shipping Volume										Dealing volume (CORABASTOS)		
	Without Project (ton)					With Project (ton)					CORABASTOS	Ratio (%)	
	San Pedro de iguaque	Santa Sofia	Caqueza	Tibacuy	Total	San Pedro de iguaque	Santa Sofia	Caqueza	Tibacuy	Total		Without Project	With Project
Potato	1,326	672		31	2,029	1,509			179	1,688	183,336	1.1	0.9
Maize	43	31	289	4	367	25	17	128	11	181	15,578	2.4	1.2
Onion			509		509		2,014	2,816	339	5,169	36,444	1.4	14.2
Welsh onion						1,269				1,269	52,527	-	2.4
Pea		75	164	24	263	138	302	284		724			
Snapbean		61	223	17	301		139	79	28	246			
Broadbean						75				75	44,530	2.2	9.6
Kidneybean			335	102	437			1,830	346	2,176			
Pumpkin								910	117	1,027			
Tomato			632	133	765			1,582	218	1,800	50,003	1.5	3.9
Cucumber									160	160			
Carrot						297				297	68,510	-	1.3
Beet						612				612			
Garlic							420			420	-	-	-
Peruvian carrot								893		893	-	-	-
Cassava		218		36	254						15,109	-	1.7
Sugar cane		450		135	585						-	-	-
Wheat	31	4					54			54	-	-	-
Coffee				210	210				294	294	-	-	-
Total	1,400	1,511	2,152	692	5,755	3,925	2,946	8,852	1,692	17,085			
Increase volume						2,525	1,435	6,370	1,000	11,330			

Table 3.5.4 Production Cost (with and without project) - Estimated Value -

Unit: 1000 Col.$/ha

Products	San Pedro de Iguaque	Santa Sofia	Caqueza	Tibacuy
Potato	284 (198)	- (201)	-	284 (201)
Maize	- (48)	-		-
Maize/Beans	100	131 (105)	- (106)	- (105)
Welsh onion	408 -	-		
Beans	79 -	79 (51)	102 (87)	110 (77)
Beat	137 -	-	-	-
Carrot	144 -	-	-	-
Wheat	- (47)	62 (48)	-	-
Onion	-	240	239 (182)	240
Garlic	-	314	-	-
Maize/Beans/	-	-	-	-
Pumpkin	-	-	168	-
Peruvian carrot	-	-	110	-
Pumpkin/Maize	-	-	-	114
Tomato	-	-	321 (251)	330 (246)
Cucumber	-	-	-	221
Coffee	-	-	-	134 (67)
Cassava	-	- (16)	-	- (16)
Sugarcane	-	- (34)	-	- (34)
Coffee	-	-	-	134 (67)

Note: Figures in parentheses is indicate the production cost under without project condition.

Table 3.5.5 Farm Management Balance of Model Farmer

Unit: 1,000 Col.$

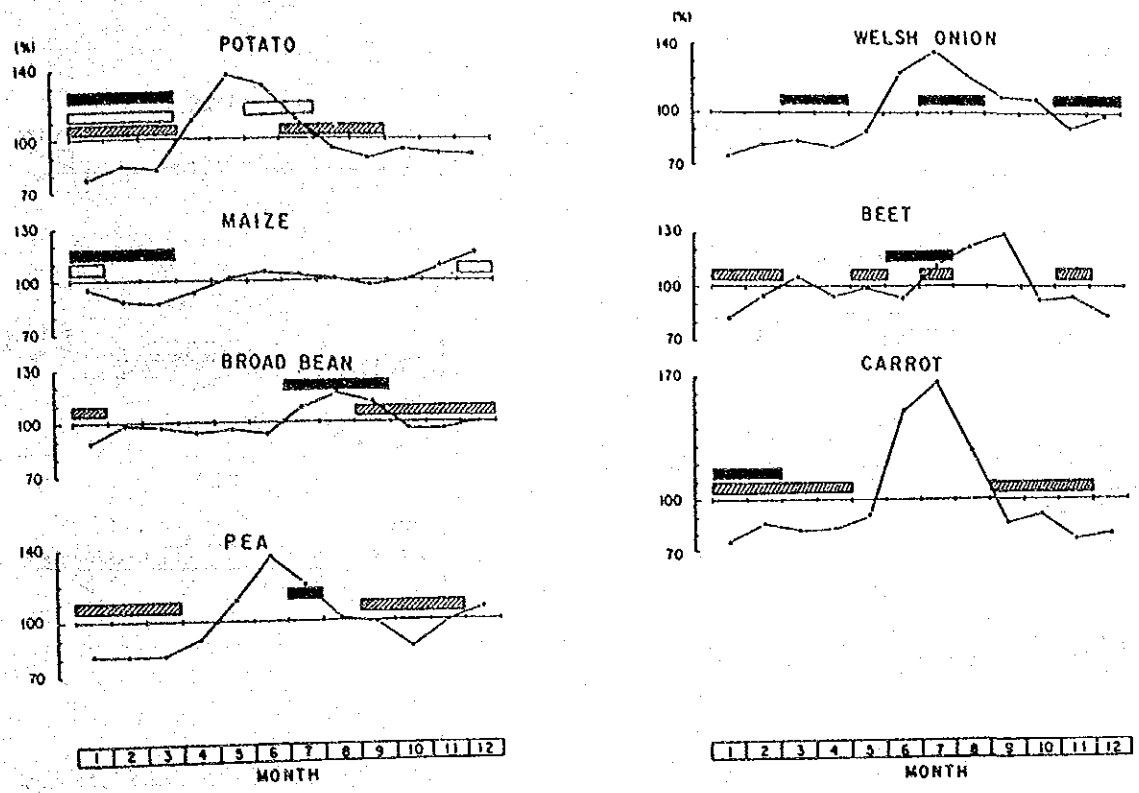
Sub-project area	Without Project	With Project	Increased value
San Pedro de Iguaque			
Gross income	426	858	432
Expenditure	420	690	233
Net profit	6	168	199
Net income	106	415	199
Santa Sofia			
Gross income	272	668	396
Expenditure	268	418	103
Net profit	4	250	293
Net income	57	500	293
Caqueza			
Gross income	303	721	418
Expenditure	296	482	137
Net profit	7	239	281
Net income	210	491	281
Tibacuy			
Gross income	340	668	328
Expenditure	320	488	121
Net profit	20	180	207
Net income	260	467	207

Note: 1. Gross income : Including income from livestock farming in San Pedro de Iguaque, and income from fruits in Santa Sofia.

2. Expenditure : Interest of agricultural credit, O/M cost and depreciation of sprinkler set are excluded.

3. Net income : Deducted value from agricultural income to production cost.

Sub-Project Area: SAN PEDRO DE IGUAQUE



Sub-Project Area: SANTA SOFIA

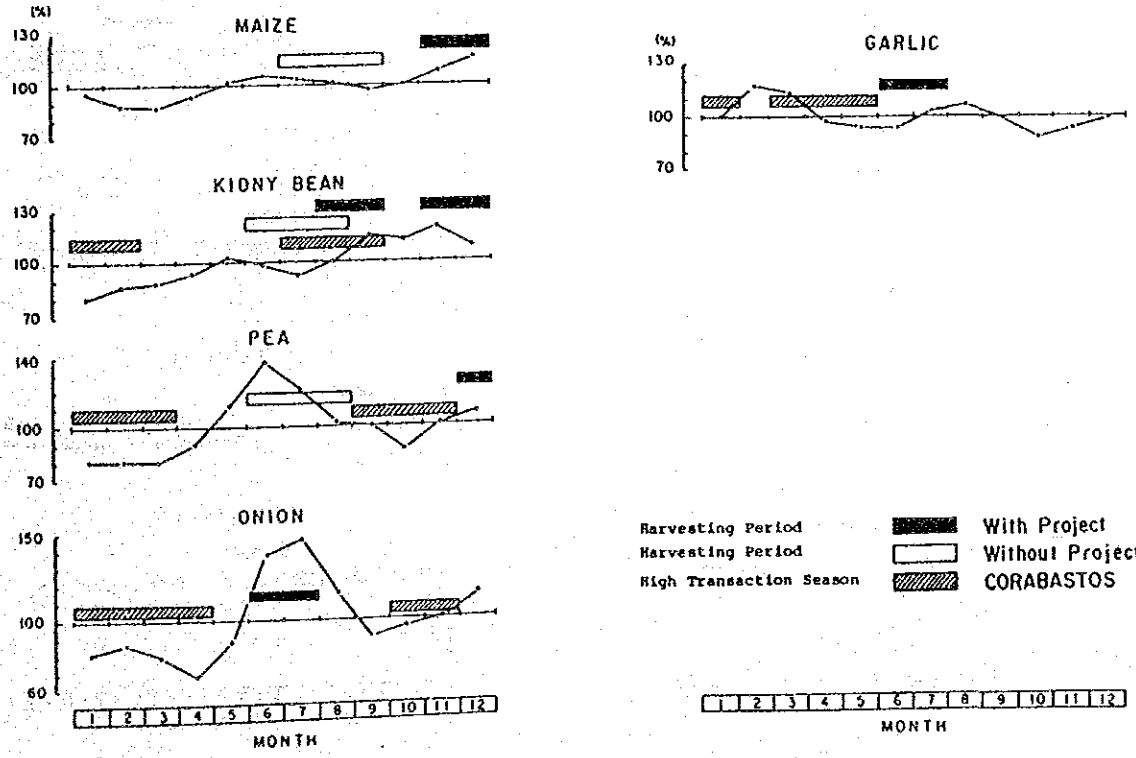
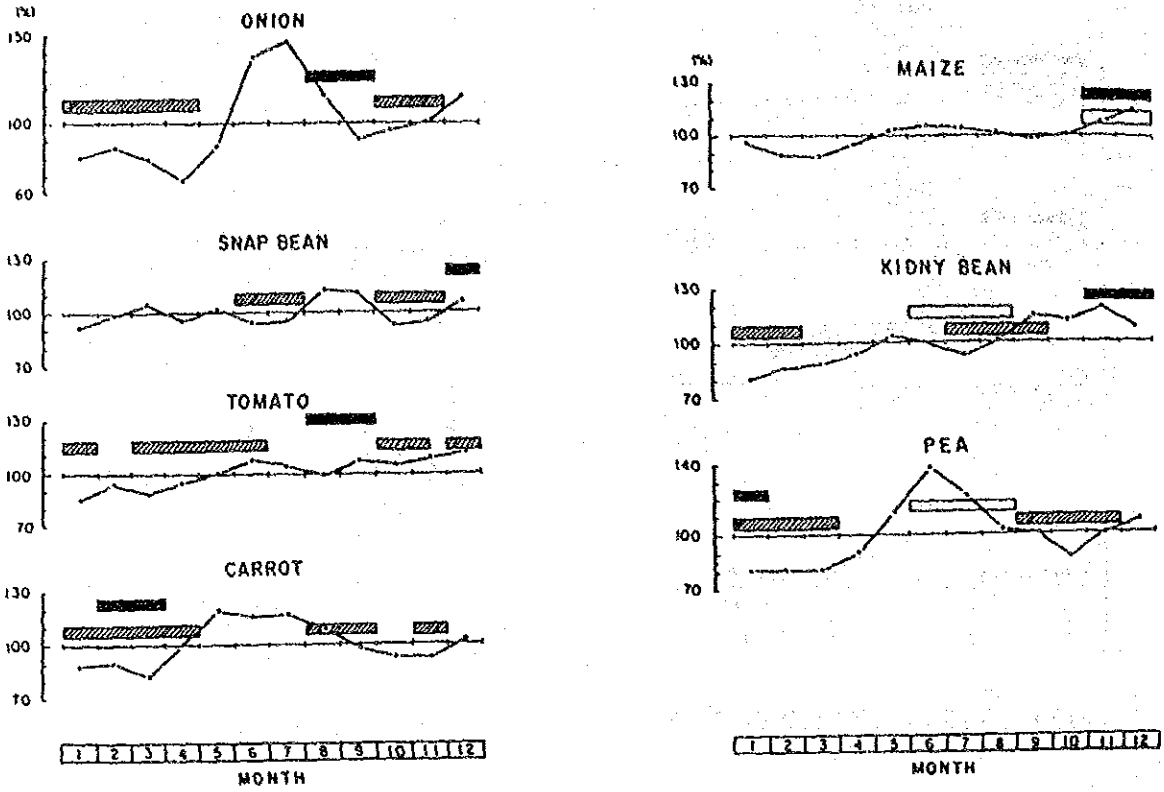


Fig. 3.5.1 (1) High Transaction Season in Corabastos and Harvesting Period of Farm Products in Sub-Project Area
(100 = average of monthly wholesale price)

Sub-Project Area: CAQUEZA



Sub Project Area: TIBACUY

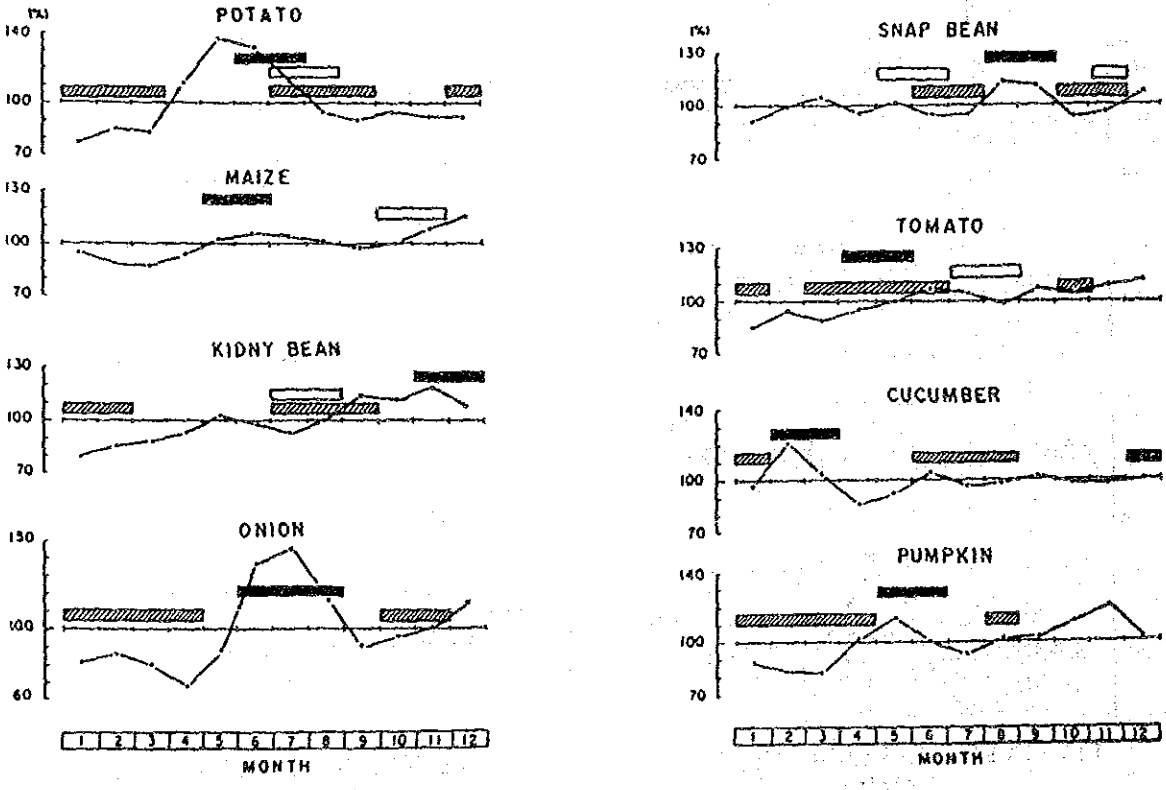


Fig. 3.5.1 (2) High Transaction Season in CORABASTOS and Harvesting Period of Farm Products in Sub-Project Area
(100 = average of monthly wholesale price)

CHAPTER 4. PROJECT IMPLEMENTATION

CHAPTER 4. PROJECT IMPLEMENTATION

4.1 Organization and Schedule of Project Implementation

4.1.1 Organization of Project Implementation

The Small Scale Irrigation Project in Slope Area is a special project and is executed under a full and direct responsibility of HIMAT which is one of the agencies in the Ministry of Agriculture.

The HIMAT will be a capable authority in managing the project planning, legal procedure of the project, contracting and supervision of construction, etc. and will secure the cooperation of other related agencies during the project implementation.

Division de Proyectos Especiales of HIMAT will take responsibility for administration of the special project. Seccion de Lagos y Riego en Ladera makes management and special assistance required for construction works.

Direccion Regional of HIMAT will be in charge of construction works of the project; as evaluating bid, letting contracts and supervision.

The project consists of four sub-project areas, namely San Pedro de Iguaque, Santa Sofia, Caqueza and Tibacuy areas. The following Direccion Regional will carry out the implementation of these sub-project areas. Direccion Regional No. 4, stationed in Duitama, Departamento de Boyaca will be in charge of the San Pedro de Iguaque and Santa Sofia areas. Direccion Regional No. 20, stationed in Bogota, D.E will in charge of the Caqueza and Tibacuy areas.

In addition, since the project is a special project, the water user's association (Junta de usuarios) in the project area will participate in construction of civil works through the gratuitous offer of the land required for the project and the services of labor and transport in the sub-project area.

The organization chart of project implementation is shown in Fig. 4.1.1.

4.1.2 Implementation Schedule

Construction of each sub-project will be implemented separately. Prior to commencement of the whole project, construction of the pilot area will be carried out in the sub-project areas of San Pedro de Iguaque, Santa Sofia and Tibacuy.

However, construction works of the remaining area is desirable to be commenced following the pilot area because of urgency of the project, feasibility and viability which have been clarified through this study and ready availability of the project fund.

The construction schedule is proposed considering the following items in addition to the above mentioned.

- In order to expedite the implementation of the project, administration and supervision of the project shall be executed by HIMAT.

- The construction works will be carried out on a contract basis, but a portion of labor (for light works) will be offered by the beneficiaries.

- Construction work of the intake weir in every sub-project areas should be undertaken during dry season (low flow season).

- The construction of new reservoirs of two in San Pedro de Iguaque area and four in Caqueza area are proposed. Some of the reservoir area are owned by non-beneficiaries. Accordingly, the time for the negotiations on the land acquisition of the reservoir area will be needed.

The proposed implementation schedule is shown in Fig. 4.1.2.

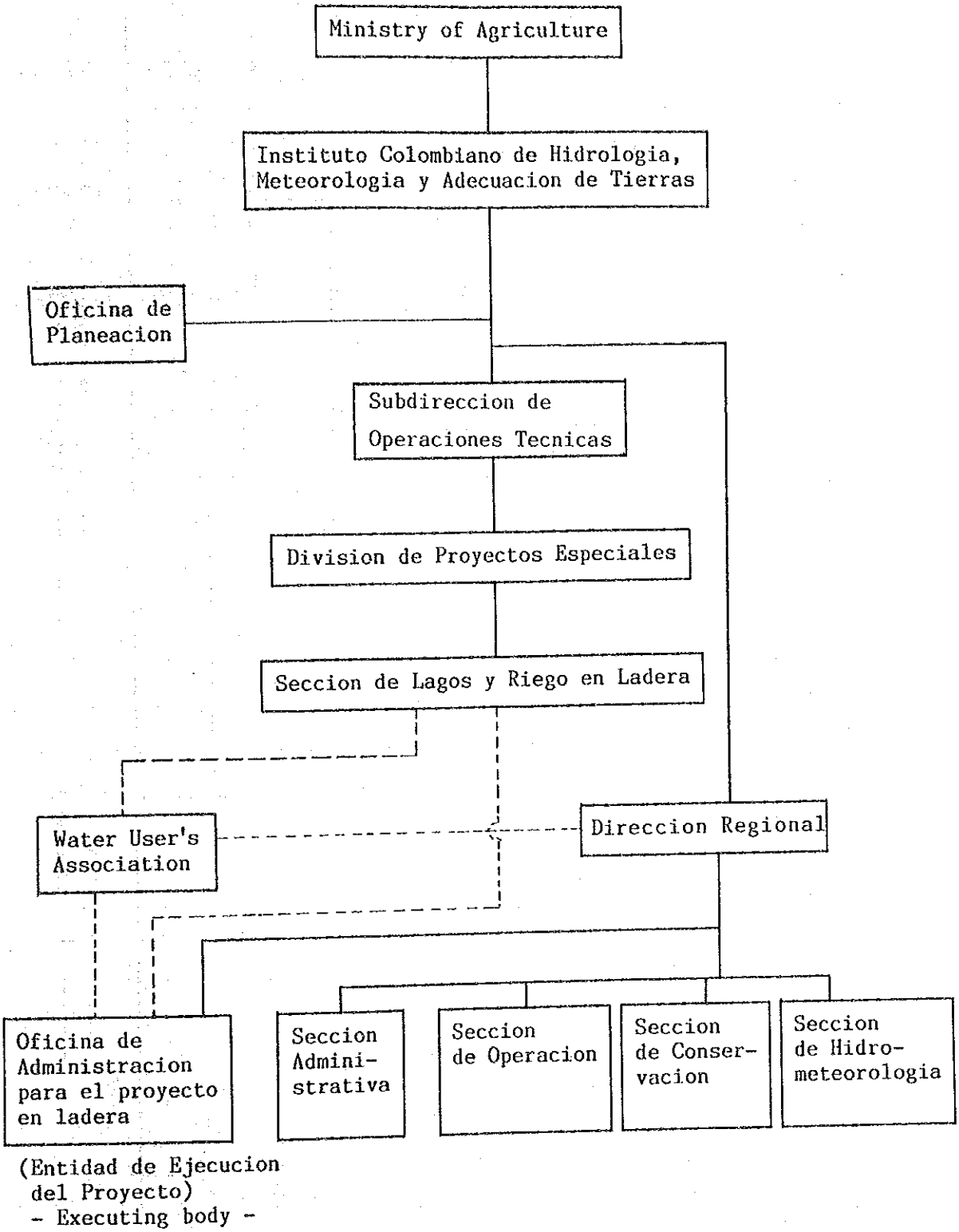
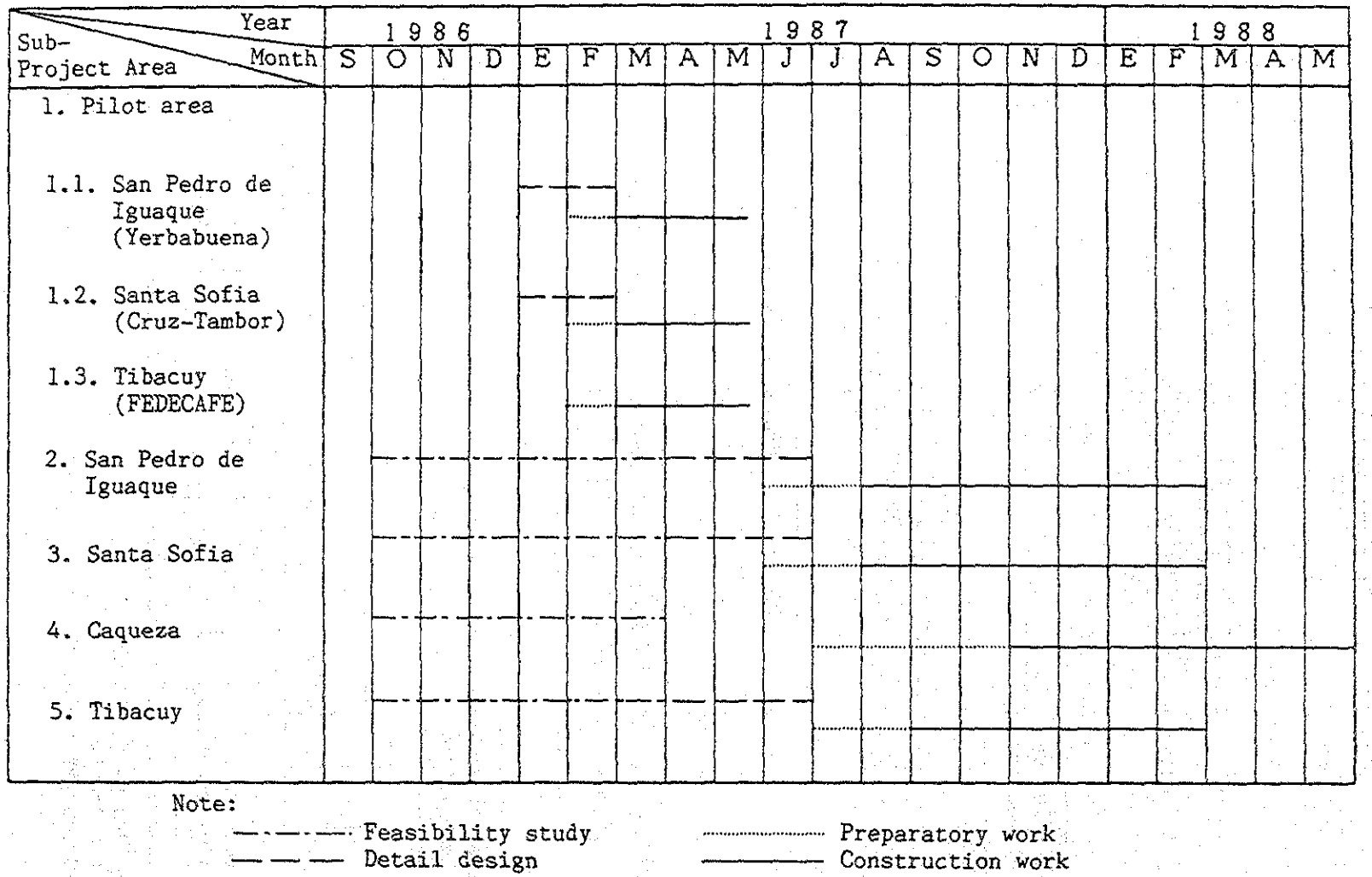


Fig. 4.1.1 Implementation Organization of Project

Fig. 4.1.2 Construction Schedule



4.2 Construction Procedure

4.2.1 San Pedro de Iguaque

This sub-project area is divided into Yerbabuena No.1 (Pilot area) and other irrigation systems, of which construction will be executed separately. Major construction works in each irrigation system are described in the paragraph 3.2.4. Special attention to the construction works should be paid for the following items.

- *Land acquisition*

  The land required for the proposed facilities located in the project area, will be offered by the beneficiaries without any payment. However, the land of facilities which is located outside of the project area such as diversion weirs, reservoirs, main driving channels, regulating reservoirs (or tanks) and borrow pits of embankment material and aggregate should be acquired from the concerned land-owners beforehand in order to expedite the construction.

- Borrow-pit of embankment materials

  Embankment materials of dam is preferable to be obtained from reservoir area, but the soil of high water contents can not be used. There are many cracks in a bed rock at the dam site of Q. Carrizal.

  When selecting the embankment materials for the impervious zone of the dam, quality of materials should be fully examined by the soil tests.

- Temporary works

  The proposed dam site is accessible by the existing roads, but no roads to diversion weir and along main driving channel are available. Therefore, the access road to the site of these facilities must be provided. Furthermore, as for the embankment works, reasonable layout of temporary works should be considered so as to avoid hampering traffic of the existing roads.

- Construction period

  Due to small-scale of the facilities in every irrigation systems, construction works can be complete in a short period. However, the construction works of diversion weir and embankment should be executed during dry season, after adjusted with those of other works. (see Fig. 4.2.1(1))

4.2.2 Santa Sofia

The construction works for this sub-project area will be executed separately as Camelo No.1 (Pilot area) and other area (irrigation system). Major construction works in each irrigation system are described in the paragraph 3.2.3.

Special attention to the construction works should be paid for the following items.

- Land acquisition

  As described in the paragraph 4.2.1.

- Temporary works

  Owing to no existing road to the proposed site of main structures such as diversion weir, main driving channel, etc., the appropriate scale of roads for construction work of those facilities are necessary. Besides, full consideration should be given to keen smooth traffic of the existing roads where irrigation facilities are constructed crossing the existing roads and to avoid disturbing supply of a drinking water taken at downstream when works are carried out in the streams.

- Construction period

  Due to small-scale of the facilities in every irrigation systems, construction works can be completed in a short period. However, the construction works of diversion weir and embankment should be executed during dry season, after adjusted with those of other works. (see Fig. 4.2.1(1))

4.2.3 Caqueza

Construction works for Caqueza sub-project area will be executed, dividing into areas commanded by the stream and three reservoirs. Major construction works in each irrigation system are described in the paragraph 3.2.4.

Special attention to the construction works should be paid for the following items.

- Land acquisition
  Because the four reservoirs' area are located in the private land. The cooperation of the private land owners is dispensable.

- Borrow-pit of material
  The embankment materials of dike will be obtained from the neighboring area of reservoirs. The area of the borrow-pit will be vast because of shallow soil layer. The material to be used as core zone of embankment is necessary to make tests of grain size analysis, permeability, etc.

- Temporary works
  Most of the construction works will be carried out inside the sub-project area. The existing roads can be used for transportation of the construction materials.

- Construction period
  The sub-project area is favorable for the construction works, because the climate of the area has longer dry season than the other sub-project areas. However, it is necessary to give some allowance for the construction period (preparatory stage) due to the large size of the area and construction of the four reservoirs. (see Fig. 4.2.1(3))

4.2.4 Tibacuy

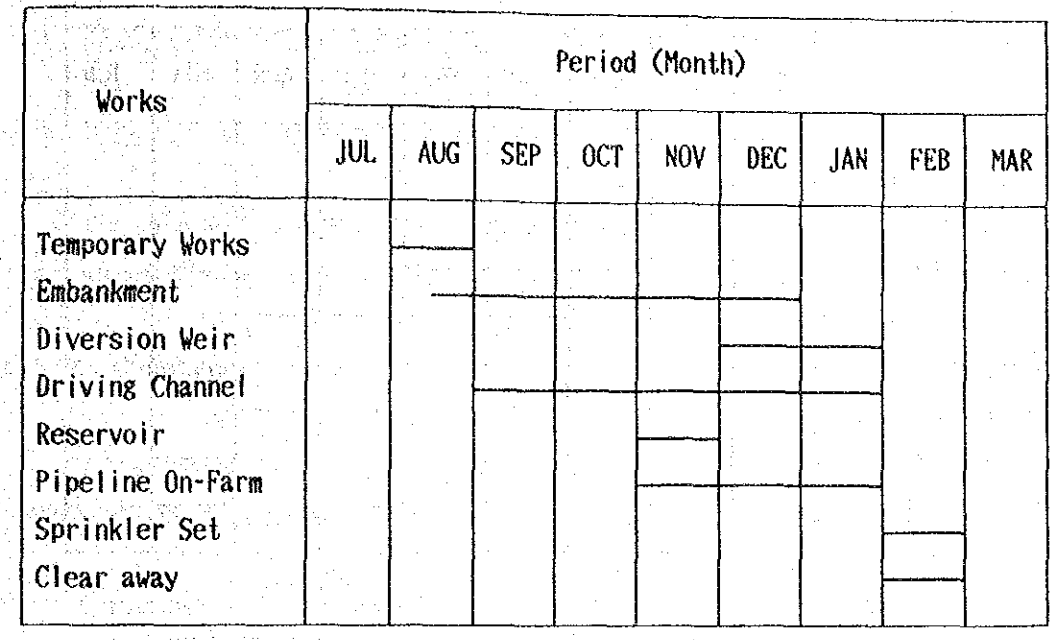
The construction works for Tibacuy sub-project area will be executed separately as San Jose No.1 and No.2. (Pilot area)

Major construction works in each irrigation system are described in the paragraph 3.2.5.

Special attention to the construction works should be paid for the following items.

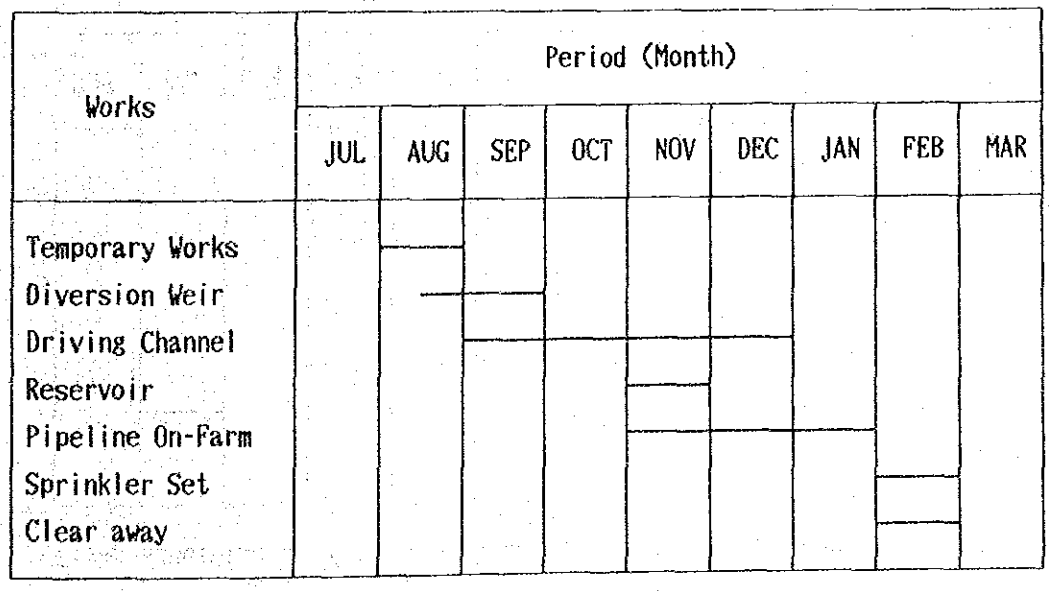
- Temporary Works
  Most of the construction works will be carried out inside the sub-project area and the existing roads can be used for transportation of the construction materials.
  However, construction of new access roads to the intake site is necessary.

- Construction Period
  In order to execute the construction of the four diversion weirs in dry season, the construction schedule of the four diversion weirs should be adjusted with other construction works. (see Fig. 4.2.1(4))



Note : Yerbabuena No.1 (Pilot area) is the same as AnnexIV ,Preriminary Design

Fig. 4.2.1(1) Implementation Schedule, San Pedro de Iguaque



Note : Camelo No.1 (Pilot area) is the same as AnnexIV ,Preriminary Design

Fig. 4.2.1(2) Implementation Schedule, Santa Sofia

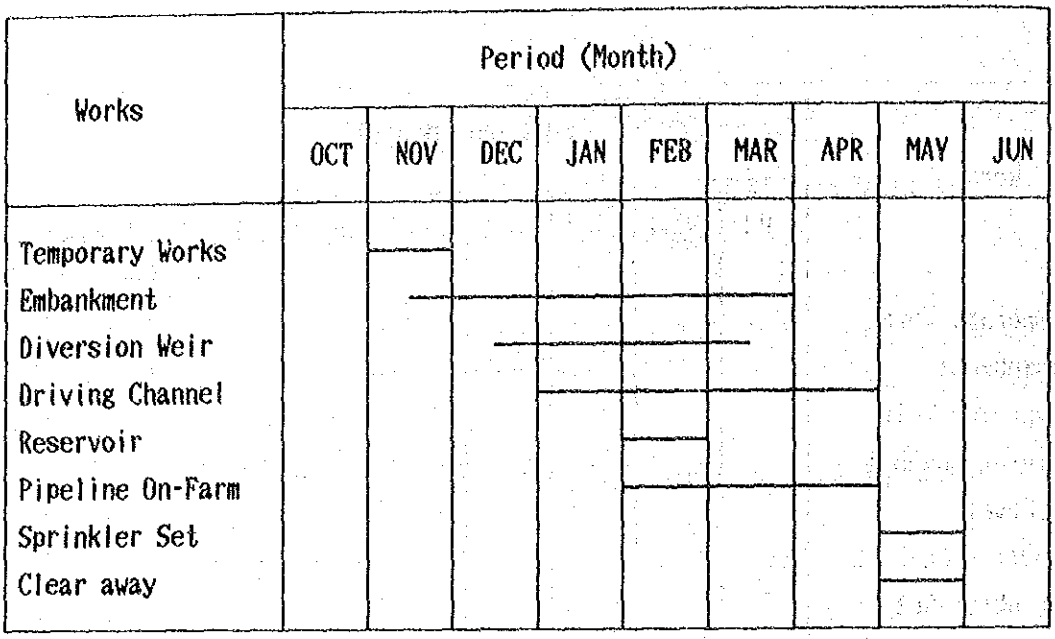
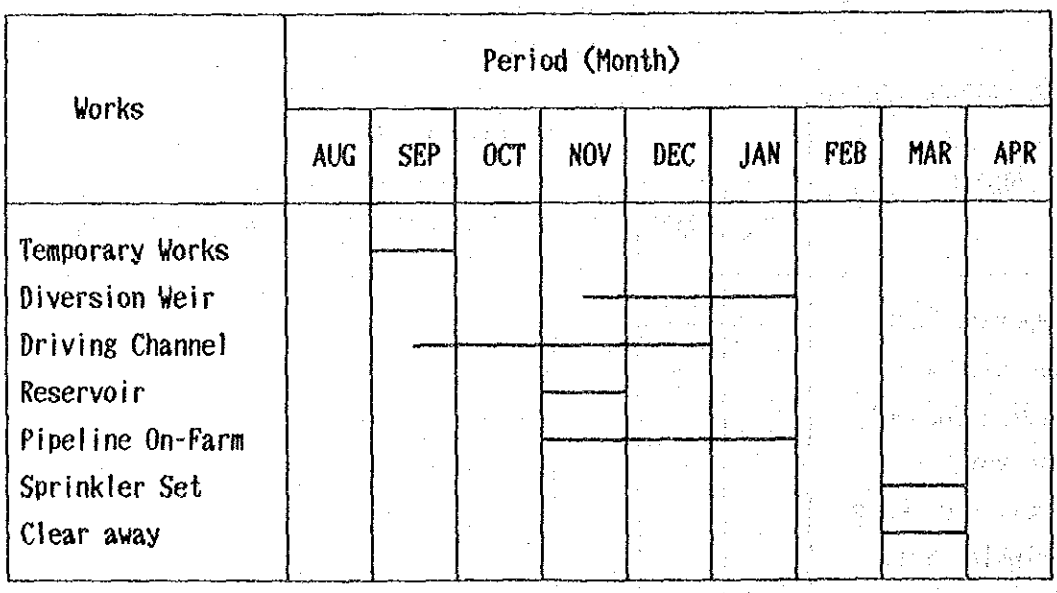


Fig. 4.2.1(3) Implementation Schedule, San Pedro de Iguaque



Note : San Jose No.1 (Pilot area) is the same as AnnexIV ,Preriminary Design

Fig. 4.2.1(4) Implementation Schedule, Santa Sofia

4.3 Estimation of Project Cost

4.3.1 Basic Year of the Project Cost

The project cost was estimated at the prices of labor and materials etc. as of the end of June 1986 consented by HIMAT.

4.3.2 Construction Cost

Referring the construction costs of the similar projects the construction cost was estimated including the physical contingency (15%).

Construction costs of each sub-project area are as follows:

Table 4.3.1 Construction Cost of Each Sub-Project

Sub-Project Area	Irrigable Area	Actual Construction Cost		Construction Cost*	
		mount	per ha	Amount	per ha
San Pedro de Iguaque	162	27,412	169.7	33,251	205.3
Pilot area	(26)	(6,113)	(235.1)	(7,825)	(301.0)
Santa Sofia	239	39,320	164.5	41.363	177.3
Pilot area	(28)	(4,600)	(164.3)	(5,012)	(179.0)
Caqueza	417	54,708	131.2	62,388	149.6
Tibacuy	258	34,392	133.3	40,072	155.3
Pilot area	(15)	(1,957)	(130.5)	(2,306)	(153.7)
Total Cost	1,076	155,832	144.8	178,074	165.5
	(69)	(12,670)	(183.6)	(15,143)	(219.5)

Note: * The cost of the laborers offered by the beneficiaries is included in the construction cost.

4.3.3 Project Cost

The project cost was estimated including the costs for detailed design and administration in addition to the above-mentioned construction cost. The total project cost will be Col.$186,012,000.

The project cost of each sub-project area will be as follows:

Table 4.3.2 Project Cost of Each Sub-Project

Sub-project area	Project Cost	Irrigable area ha	Project cost per ha
- San Pedro de Iguaque (Pilot area)	Col.$35,519,000 (Col.$ 8,797,000)	162 (26)	219,300 (338,300)
- Santa Sofia (Pilot area)	Col.$44,631,000 (Col.$ 5,984,000)	239 (28)	186,700 (213,700)
- Caqueza	Col.$63,684,000	417	152,700
- Tibacuy (Pilot area)	Col.$42,178,000 (Col.$ 3,278,000)	258 (15)	163,500 (218,500)
Total (Pilot area)	Col.$186,012,000 (Col.$ 18,059,000)	1,076 (69)	172,900 (261,700)

Note : Construction costs of diversion weir and main driving channel for 74 ha of Caqueza sub-project area are included in the constructin cost of the pilot area due to be constructed as of constructing the facilities of the pilot area.

CHAPTER 5. OPERATION AND MAINTENANCE

CHAPTER 5. OPERATION AND MAINTENANCE

5.1 Organization

The operation and maintenance (refer to O/M hereafter) for the irrigation facilities will be carried out by the water users' association (Asociacion de Usuarios del Sistema) which is established under the law. The ownership of the irrigation facilities which have been constructed under the project will be transferred to this association after completion of the project.

The water users' association will be established at each sub-project area and consists of the beneficiaries of the project who will elect a certain number of representatives in proportion to the area of each irrigation system. The association assembly is formed by the representatives. The President, Secretary and Treasurer are assigned among the representatives. (refer to Fig. 5.1.1 Organization Chart of Water User's Association)

Among the transferred irrigation facilities, the major facilities will be maintained by the association under the guidance of HIMAT and the on-farm facilities will be maintained at the beneficiaries' expense. The association will decide and manage irrigation water distribution for the concerned farmers, collection of O/M cost and labor required for O/M.

A water man (canalero) who is entrusted by the association will execute O/M works.

For the purpose of smooth implementation of the project, the following agencies will cooperate.

(1) Direccion Regional of HIMAT

The Direccion Regional will give instruction and advice for the O/M of irrigation and drainage systems, administration of water users' association, irrigation technology, etc.

(2) Regional Experimental Station

The regional experimental station which governs the sub-project area, has responsibility to give technical assistance and extension services for the farmers.

Especially, the regional experimental station will conduct the technical instruction of farm management for the small scale irrigation project in slope area.

(3) Caja Credito Agrario

The office of Caja Credito Agraria provides the farm credit for individual farmers and cooperatives in the sub-project area.

(4) Other agencies

The INDERENA is in charge of an administration for rational utilization and conservation of natural resources and coordinates water utilization.

5.2 Operation and Maintenance Plan

5.2.1 Operation and Maintenance of the Facilities

The facilities should be maintained to be the most functionable condition. The facilities will be constructed at as low cost as possible. Therefore, special attention must be paid for O/M of the facilities. Items to be considered for O/M of the facilities are as follows:

(1) Reservoir

- Subsidence of embankment after its completion.
  If Subsidence is occurred practically or be founded out un-uniform settlement, it shall be rehabilitated under instruction from HIMAT.
- Erosion of for the outside slope of the embankment, possibly caused by heavy rainfall.
  It shall check up on the situation of erosion at the end of the rainy season, then severely eroded place shall be rehabilitated.
- Sliding upstream slope of embankment at drawdown of water surface.
  It shall not be released suddenly a large amount of water from reservoir.
  After check up on the upstream slope of the embankment at the empty time of reservoir, the eroded place shall be rehabilitated.
- Malfunction of spillway caused by sedimentation and/or landslide.
  It shall be made a rule to inspect a function of spillway before set in the rainy season.
  It shall be patrolled at frequent intervals in time of a long rain and/or a heavy rain.
- Sedimentation in the reservoir.
  It shall be removed the sedimentation in the empty time of the reservoir.

- Leakage from dike body.

  If it gains in volume of a leak and/or turns into muddy water, the farmers association shall be received promptly instruction from HIMAT.

- Daily maintenance of dike body

  It shall be taken measure in an early stage so that bushes and weeds do not take root into the soil.

- Fish farming

  It shall be smoothly operated to manage a reservoir without an obstacle by fish farming.

(2) Diversion weir

- Sedimentation at upstream of the weir.

  At the end of every rainy season, the sedimentations which is accumulated at upstream of the weir shall be removed by open the scoring sluice.

- Scouring at the tail end of rear apron.

  It shall be rehabilitated promptly when the scouring is found out through an inspection of the tail end of rear apron after flood.

- Sedimentation in the sand trap basin.

  It shall be made an endeavor to sand removal with pay attention at all times so as to be not sedimented up to the height of pipe inlet.

  Specially, it shall be patrolled frequently in the rainy season.

- Choking the screen.

  The screen shall be cleaned a little earlier with pay attention at all times so that fallen leaves, polyethirene films, etc. make the cause of channel.

(3) Open canal

- Broken of stone pitching.

  If the fall off the stone occurs even one piece, it shall be repaired rapidly.

- Scouring at the tail end of the canal spillway.

  The inspection of the channel spillway shall be conducted twice a year, then the scored place must be rehabilitated using small size broken stone or cobble stone.

- Sedimentation in the sand trap box of the canal.

  After every rainy season, the sand removal from sand trap box shall be done.

- Sedimentation in the drain pipe at the crossing point with open canal.

  The drain pipe shall be inspected previously after flood and/or before set in the rainy season and the sedimentation shall be removed.

- Choking the screen.

  The inspection and cleaning of the screen shall be made a rule to conducted once a month.

(4) Pipeline

- Leakage from the pipe joint.

  The place to be loaded as under a road shall be inspected whether there is any infiltrated water at the place. The inspections shall be made in the dry season.

- Function of valves.

  The valve shall not be operated suddenly. If the handle of value does not move smoothly, it shall be operated carefully without full force. If the floating value has gone wrong, it shall be repaired after the closing of sluice valve at the inlet tank.

- Choking of the entrance screen.

  The tank shall be made to empty twice a year, then it must be cleaned a choking of the entrance screen.

(5) Sprinkler sets

- Self keeping.
  The sprinkler set shall be kept safety by the farmers during unused period, without leave in the farmland.
- Choking of nozzle.
  If a nozzle is choked, it shall be done the washing of nozzle. It must be paid attention to clear a nozzle by metaric matelial due to be threatened with damage of nozzle.

5.2.2 Water Management

(1) Operation of reservoir

- All reservoirs constructed under the project should be full of storage water at the end of rainy season. After then, the minimum stored water amount should be defined at end of every months. If the stored water is more than the said minimum water amount, the excess water can be discharged. However, after the stored water decreases up to the minimum water amount, no more water discharge is allowed.

- Regarding the Carrizal area, when the stream flow at the diversion weir site exceeds the designated intake water amount, the releasing the water from the reservoir shall be controlled so as to minimize the excess water at the diversion site.

- Having used of water in the reservoirs No. 2 and No. 3 in the Caqueza area, it is favorable to operate the reservoir No. 2 (in the upstream side) is empty at all times.

(2) Water management of on-farm facilities

- The water from its source is stored fully into the pond (or tank) during night time and combined water from the pond and water source is used in day time.

- The irrigation interval is proposed as follows:

San Pedro de Iguaque:		7 days
Santa Sofia	:	7 days
Caqueza	:	5 days
Tibacuy	:	5 days

- The daily irrigation hour in the maximam season of irrigation water amount is fixed on about 18 hours (about 22 hours in case of coffee). The spray water amount and the spray intensity in each rotation block should be observed as designated.

5.3 Operation and Maintenance Cost

Referring to the irrigation project of Saldana District of HIMAT, the O/M cost of the irrigation facilities is estimated as follows; (5% for construction cost)

San Pedro de Iguaque	10,263 Col.$/ha
Santa Sofia	8,208 Col.$/ha
Caqueza	7,414 Col.$/ha
Tibacuy	7,027 Col.$/ha

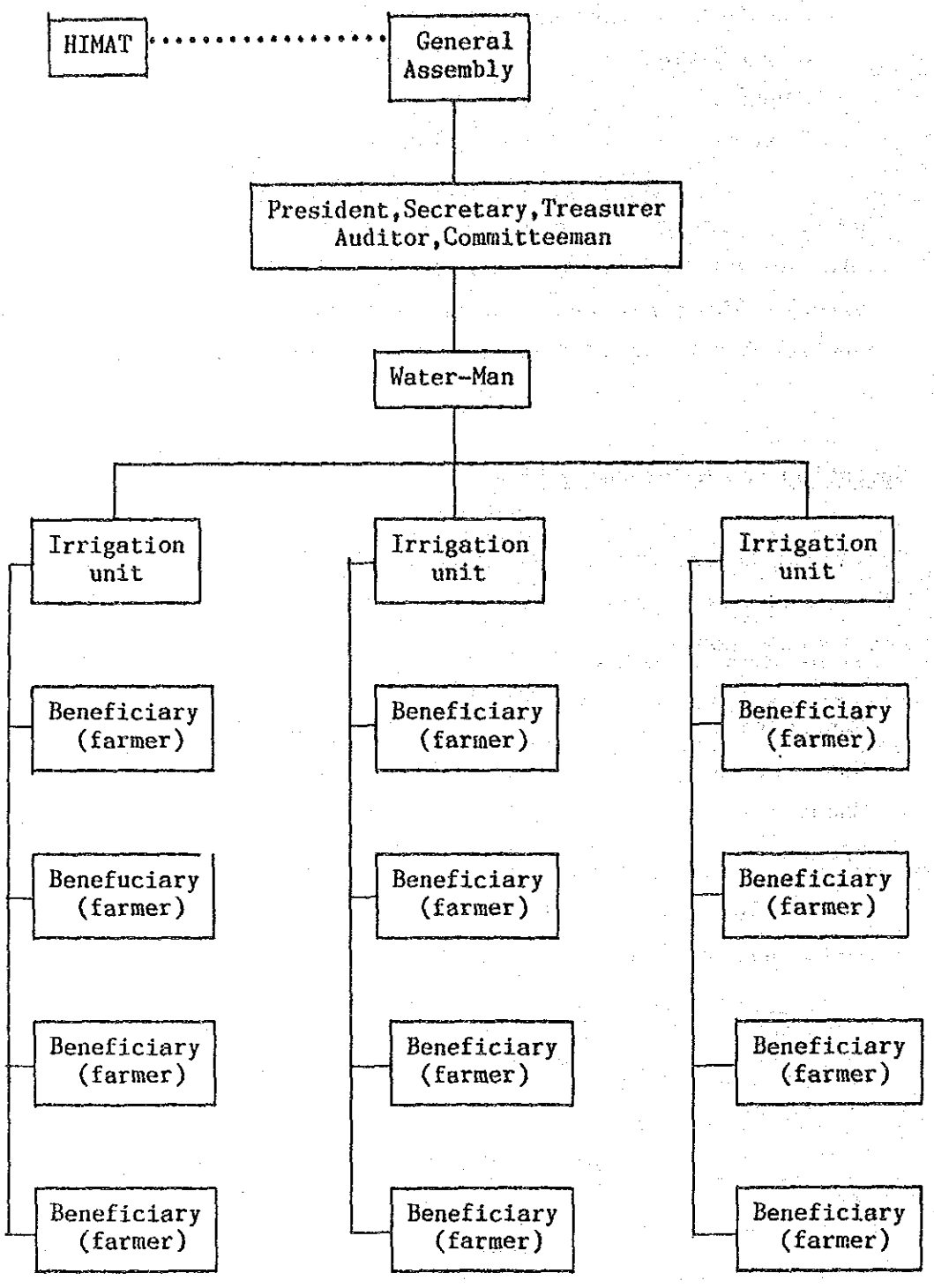


Fig. 5.1.1 Organization Chart of Water User's Association

CHAPTER 6. PROJECT EVALUATION

CHAPTER 6. PROJECT EVALUATION

6.1 Economic Evaluation

The evaluation was carried out using the indicators as follows:

- Net Present Value (NPV)
- Economic Internal Rate of Return (EIRR)
- Benefit Cost Ratio (B/C)

The following parameters are employed in the economic evaluation of the project.

(1) The term of evaluation is set up as 30 years after commencement of the project. The replacement cost of the irrigation facilities is calculated assuming that the facilities are replaced at the time when durable life of the facilities is terminated within 30 years.

(2) The Colombian Peso is used for economic evaluation. The following exchange rate is used.

US$1.00 = Col.$193.76 as of June 1986 (average of month)

(3) The target yield accrued to the project will be reached at the fourth year after completion of the project.

(4) Farm gate price is adopted for the price of agricultural products as economic price. The parity prices are applied for the some crops. (refer to the paragraph 3.5 Agricultural Economy)

(5) The price of input materials for agricultural production which are presented by HIMAT taking into consideration the price lists in the first half of 1986 prepared by Caja Credito Agraria, is used.

(6) For the economic price of labor wage and imported commodities applied is a multiplier of the Shadow Exchange Price Factor

indicated in the document of the World Bank "Estimating Shadow Prices in Colombia".

(7) The wage for family is low level due to over supply of labor force in and around the project area, and it seems that these situation may be remained unchanged in future, even after completion of the project. Hence the minimum wage of Col.$300 per day is applied for the project evaluation.

(8) Interest of credit for farming is not included in the production cost for calculation of the internal rate of return.

(9) Annual production cost is equal to the cost in target year after the following year of the completion of construction.

6.2 Benefits

6.2.1 Direct Benefit

The project benefits are evaluated subject to the increase value which represent the difference of the net profits between "With Project" and "Without Project".

The benefit in each sub-project area is estimated as follows:

Table 6.2.1 Benefit in the Sub-Project Areas

Sub-project area	With Project	Without Project	Increment Benefit
San Pedro de Iguaque			
Gross Production Value	71,686 (11,506)	25,629 (4,114)	46,057 (7,392)
Production Cost	54818 (8,799)	25,547 (4,100)	29,271 (4,699)
Net Profit	16,868 (2,707)	82 (14)	16,786 (2,693)
Santa Sofia			
Gross Production Value	144,238 (16,898)	32,700 (3,831)	111,538(13,067)
Production Cost	69,729 (8,170)	24,210 (2,836)	45,519 (5,334)
Net Profit	74,509 (8,728)	8,490 (995)	66,019 (7,733)
Caqueza			
Gross Production Value	237,524	91,952	145,572
Production Cost	115,342	49,564	65,778
Net Profit	122,182	42,388	79,794
Tibacuy			
Gross Production Value	217,375 (12,312)	152,920 (6,690)	64,455 (5,622)
Production Cost	47,138 (3,319)	21,011 (670)	26,127 (2,649)
Net Profit	170,237 (8,993)	131,909 (6,020)	38,328 (2,973)
Total			
Gross Production Value	670,823 (40,916)	303,201(14,635)	367,622(26,081)
Production Cost	287,027 (20,288)	120,332 (7,606)	166,695(12,682)
Net Profit	383,796 (20,428)	182,869 (7,029)	200,927(13,399)

Note: The values of the Pilot Area show in the parentheses and is including in figures.

Accordingly, annual benefit per ha in target year is estimated as follows:

Unit: 1000 Col.$

Sub-project area	Annual Benefit	per ha
San Pedro de Iguaque	16,786	104
Santa Sofia	66,019	276
Caqueza	79,794	191
Tibacuy	38,328	148
Total	200,927	187

6.2.2 Indirect benefits

If the project is implemented in these sub-project areas, it will give me an impact on the regional economy as described below.

- Increase of dealing volume of commercial enterprises by increase of crop production.

  Increase of outputs Dealing volume in ton 11,330 ton (refer to Annex C, Table C.5.9 Marketed Amount and Total Amount of Transaction in CORABASTOS)

- Increase of working days on farm

  per farmer 107 man-days - 405 man-days (refer to the paragraph 3.5.5 Agricultural Economy)

- Increase of farm input

Fertilizer	1,641 ton/year
Organic fertilizer	427 ton/year
Soil conditioning material	505 ton/year

  (refer to Annex C, Table C.5.13 Amount of Farm Input in the Project Area)

- Increase of the purchasing capacity of farmers and stabilization of farm household economy.

6.3 Costs

6.3.1 Project Cost

If the project is carried out as originally scheduled, annual disbursement of construction cost will be as follows: (refer to the paragraph 4.3.3 Project Cost)

Table 6.3.1 Annual Project Cost

	San Pedro de Iguaque	San Sofia	Caqueza	Tibacuy
1987	27,502(8,779)	33,024 (5,984)	19,106	30,581 (3,278)
1988	8,017	11,607	44,578	11,597
Total	35,519	44,631	63,684	42,178

Note: The values of the Pilot Area show in the parentheses and is included in figures.

6.3.2 Operation and Maintenance Cost

The annual cost of operation and maintenance after completion of the project is estimated as follows (refer to the paragraph 5.3 Operation and Maintenance Cost):

San Pedro de Iguaque	Col.$1,662,000	Caqueza	Col.$3,119,000
Santa Sofia	Col.$2,118,000	Tibacuy	Col.$2,003,000

6.3.3 Cost of Replacement and Repairs

Due to keep away mal-function of the facilities, the replacement and repairs of the facilities are required as follows: