No. 2

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

INSTITUTO NACIONAL DE RECURSOS HIDRAULICOS (INDRHI)
THE DOMINICAN REPUBLIC

THE FEASIBILITY STUDY
ON
THE LIMON DEL YUNA AREA AGRICULTURAL DEVELOPMENT PROJECT

FINAL REPORT

VOLUME II : ANNEX I

NOVIEMBRE 1995

PACIFIC CONSULTANTS INTERNATIONAL
KOKUSAI KOGYO CO., LTD.

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The following foreign exchange rate is applied in the study:
US$1.00=RD$12.87 (as of March 1995)

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ANNEX A: NATIONALS SOCIO-ECONOMIC BACKGROUND

A.1 Macroeconomic Overview

The Dominican Republic occupies two-thirds of the Española Island with a total area of 48,442 km^2. According to the official data of the 7th National Census for Population and Living, the country had a population of 7,089 thousand in 1993 and it is estimated that about 55% of the same lived in urban area. The inter-census growth rate between 1981 and 1993 was 1.6 % per annum.

According to the preliminary figures prepared by the Central Bank, the Gross Domestic Product (GDP) of the Dominican Republic in 1993 was RD$ 4,228.7 million at the constant price of 1970, which had been grown at an annual average rate of 1.6% for the period 1989-93. The sectors which had contributed greatly to GDP formation were: manufacture (18.3%), agriculture and livestock (13.2%), commerce (12.7%), government (8.8%) and construction (8.0%). On the other hand, the sectors which registered higher growth rate for the same period were communications (13.8%) and electricity & water (11.8%), while such sectors as mining and construction had a negative growth (Refer to Table A.1.1).

The current account within the balance of payment corresponding to the year of 1993 showed a deficit of US$ 299.6 million to have been caused by a negative performance of the trade balance (US$ -1,606.9 million). In this country the trade balance has been consistently negative and the amount of the deficit has increased recently due to correlated effect of the decline of exports in value terms and the expansion of imports. The deficit in the trade balance in 1993 was expanded by 55% in comparison with that in 1989. The shrinkage of exports stemmed from the continuous depression of such traditional exports as sugar, coffee and cacao in the international markets. The net international reserves as of the end of 1994 was estimated to be a deficit of US$ 464 million. The Dominican Republic was the only country among Latin-American countries which had reduced external debt during 1994 with a balance of US$ 3,992 million at the end of December 1994, as contrasted with US$ 4,552 million at the same period of the previous year.

The exchange rate of the Dominican peso against US dollar had been stable during 1994, with a variation of only 3% (from US$ 1 = RD$ 12.50 to US$ 1 = RD$ 12.87) and the inflation rate to cover the same period was around 13%.

A.2 Performance of the Agricultural Sector

As indicated in the Table A.1.1, the agricultural sector including forestry and fishing is the most important sector except the manufacture within the context of the GDP formation. Despite the fact, for the last four years 1989-1993, the agricultural sector had attained an accumulated growth as low as only 0.3% per year, the figure far inferior to that of the total GDP (1.6%). As a consequence of this unfavorable performance, the share of the agriculture sector within the total GDP had fallen from 13.8% in 1989 to 13.2% in 1993.

This deteriorated performance experienced by the agricultural sector may be explained by various reasons, of which the following may be stressed: 1). Discouragement among farmers in conducting crop cultivation due to deterioration of international price for traditional exports and reduction of the preferential quota for importation of sugar in the United States, 2) Inappropriate use of land and water resources, 3) An absence of adequate cropping technology, 4) Inconsistency of governmental policies (provision of agricultural credits, agrarian reform and marketing and prices, among others), and 5) low level of investment assigned to the sector.

Agricultural exports contribute greatly to generating foreign exchange of the country; in 1993, the total value of foreign exchange was US$ 511.5 million, of which US$ 185.9 (36.3%) million was covered by four traditional agricultural exports (sugar, coffee, cacao and tobacco). Due to depressed prices at international market as explained before, a foreign exchange earning of these four exports was reduced to about half of the level registered ten years ago (1984).

Regarding production tendency by crop for the last ten years (1984-1993) a brief explanation is made as given below.

Production of paddy showed an irregular accomplishment characterized by the ups and downs in its harvest level; a comparison of production amount had disclosed that there was a drop by 10% in 1993 in comparison with in 1984 as a consequence of a transition from 357.6 thousand tons in 1984 to 319.6 thousand tons in 1993, although a peak production was registered in 1992 reaching 405 thousand tons.

Maize and sorghum are considered to be important crops for feeding animals and both of them are decreasing their production recently; the production of these cereals in 1993 was around half of their accomplishments in 1984.

So far as traditional exports (sugarcane, coffee, cacao and tobacco) are concerned, there was a tendency peculiar to each crop; sugarcane continued to have reduced its production for the decade and its 1993 level was equivalent to only 47% of the 1984 level. Tobacco, on the other hand, attained the maximum output in 1990 with 39.1 thousand tons, but it was precipitated to such a low amount as 20.4 thousand tons in the next year, and this inclination was followed by succeeding years of 1992 and 1993 with decreasing production of 17.6 thousand and 13 thousand tons, respectively. Production of the remaining traditional exports (coffee and cacao) had gone up and down year by year during the period 1984-93, but their annual output never registered below the 1984 level.

Other crops which are worth to be referred are plantain, onion and pepper for their ascending tendency in the decade (1984-93).

The livestock production of is represented by chicken, beef, milk and eggs, which accounted for 50.9%, 17.6%, 17.2% and 13.2% of the total value in livestock production in 1993. In the Dominican Republic, poultry farming has been expanded for the last ten years, while cattle farming has been stagnated; the production of chicken and eggs is increased by 297% and 232% between 1984 and 1993 and that of been and milk showed such a slight increase as 112% and 121% for the same period (See Table A.2.2 and Fig. A.2.1).

A.3 Policies on Agricultural Development

A.3.1 Comprehensive Agricultural Policies

In 1990, the Government of the Dominican Republic, forced by the depression of the national economy which was the outcome of the deficiency in trade balance, an accumulation of external debt and galloping inflation, adopted a series of measures aiming to take up immediately an adjustment program for the healthy performance of the national economy, and this governmental action was reflected on the agricultural development policies.

Since then, structural reform programs comprised the reduction of the public investments, elimination of subsidiaries generalized to consumption goods, abolition of controls over prices of various agricultural products, liberalization of interests among banking institutions, exoneration of taxes on traditional exports, and less participation of the public sector in the course of the marketing process have been put in force.

The effect of these structural reform programs are reflected in the agricultural sector in such manner as an expansion of marketing opportunity, stabilization of prices for products and inputs, increase of salaries among rural population, deregulation in productive process, promotion for more participation of the private sector in marketing of agro-products and planning for sectional policies, and strengthening efficiency of ago-industrial enterprises.

A.3.2 Policies on Production

In view of attaining target output of agricultural products, policies on production are directed to rational use of available resources. More specifically, within the context of the policies on production, attention shall be paid to satisfy domestic demands for foodstuff, to strengthen storage capacity of products, and to generate more foreign exchange through exportation of both traditional and non-traditional agricultural products. In due compliance with these policies, priority in agricultural production is given to the crops which tend to satisfy domestic demand, to serve food security and to contribute foreign exchange earning. And, so far as cereal production is concerned, major endeavor shall be made toward stable production of rice and increase of sorghum production so that the pressure on demand of wheat and maize may be released.

With regard to rice production, the nuclear policy shall be to accomplish self-sufficiency of the grain and in line with this policy, emphases shall be laid on facilitating farmlands improvement works to cover the whole country, on rehabilitating existing infrastructures to irrigate and drain paddy fields, on securing finance arrangement to such activities as sowing and harvesting and marketing, and on maintaining appropriate and profitable farm-gate prices. To intensify rice production, the Dominican government plans to increase rice production in the Lower Yuna region by means of implementation of the AGLIPO II & III projects.

A.3.3 Policies on Prices and Marketing

During the decade of 80', the marketing policies in the Dominican Republic are featured by an aggressive intervention of the public sector; the Government took part in marketing channels of agricultural products by means of establishing supporting price, application of subsidiary and exoneration of taxes. Nevertheless, since 1990, in line with structural reform programs mentioned in A.3.1, the government has undertaken liberalization measures for marketing and pricing of agro-products. Up to 1987, the National Agency for Prices Stabilization (INESPRE) established supporting prices for a wide variety of crops, but from the next year on, with a progress of liberalization program within the domestic market, the control and establishing prices have been eliminated for the majority of crops, and as a consequence, supporting prices are applied for only four crops composed of red haricot bean, garlic, onion and potato.

Despite the fact mentioned above, there still remain some room for the government to control and supervise marketing of rice. This implies that, in response to the petition made by both farmers and rice mill owners, the government through the National Rice Commission persists to intervene in marketing channel of rice and in the light of it the organization sometimes publicize reference price of paddy so that the transaction between farmers and buyers may be made on the basis of the same (the most recent publication of this price was made in October 1993).

A.3.4 Policies on Irrigation

One of the critical constraints on the agricultural development in the country is the limited extension of irrigated lands. Within the context of agricultural development policy, higher priority in allocating budget is given to irrigation sub-sector; during 80' about 70% of the total budget for the agricultural sector are assigned to water resources development projects including irrigation projects. It is registered that physical area for irrigated lands account for 248 thousand ha, which is equal to approximately 10% of the total arable lands of the country and almost half of potentially irrigable lands. On the other hand, for the period 1984-1993, an actually irrigated area over the country went down from 237 thousand ha in 1984 to 187 thousand ha in 1993, a slump by nearly 20% (PLAN OPERATIVA 1994-SEA). In addition, it is reported that the efficiency of water use does not reach 40%, calculated in terms of conduction, operation and application to farmlands (PLAN NATIONAL DE ORDENAMIENTO DE LOS RECURSOS HIDRAULICOS, OEA-INDRHI). This situation may be arisen from: 1) deficiency of water in time of necessity; 2) inadequate system for operation and maintenance of existing infrastructures;

3) lack of tertiary facilities; 4) absence of drainage works at farms; and 5) existence of fallow lands.

Under the circumstances cited above and taking account of the importance of water resources to accomplish agricultural output constantly, the efforts of the public agents shall be oriented to expansion, re-arrangement, intensification and more efficient management of irrigation system. In this sense, the attention of the governmental policies shall be paid to making investment in new irrigation works, maintenance and effective use of existing infrastructure, and more rational use of water resources.

Another important trend relevant to irrigation system of the country is to turn over the responsibilities and undertakings of irrigation works from INDRHI to water users' association. The background for promoting this turn-over policy is that, in spite of the government effort to invest in irrigation projects, the benefits generated by these projects were not as high as those expected at planning stage, and that this deficient generation of benefits is mainly caused by inadequate operation and maintenance of completed irrigation works. Under these circumstances, INDRHI, with an assistance of USAID and for the purpose of strengthening O/M services, has implemented "On-Farm Water Management Project" and the turn-over of the irrigation works from INDRHI to water users' association has been put in effect in a total of nine (9) irrigation projects throughout the country.

A.4 National Production, Supply and Demand of Rice

A.4.1 Production

According with the information of the Rice Research Center (CEDIA) (See Table A.4.1), planted and harvested area, output and unit yield of rice for the year of 1993 were: 86,793 ha, 88,336 ha, 317,073 ton and 3.59 ton/ha, respectively. The principal rice production area of the country is concentrated in the northern part of the country; the sum of rice production in the regions of Northern-Central, Northern-East and Northern-West accounts for 86.5% of the national output in 1993. The share of the AGLIPO area was around 15%.

The greater majority of the cropping system is represented by direct seeding and transplant under irrigation, meanwhile only 3% of the total output was through ratooning method. Harvest at uplands was as few as 1% of the total. The unit yield varies by planting system in such manner as : 3.65 ton/ha (direct seeding or transplant under irrigation), 2.40 ton/ha (ratooning) and 1.76 ton/ha (upland).

The development of rice production is one the important agricultural policies and, in proof of the same, a considerable portion of INDRHI's budget for public works are allocated to construction, improvement and rehabilitation of irrigation system; in IAD's agrarian reform lands nearly half of cultivated area is covered by rice. On the other hand, almost

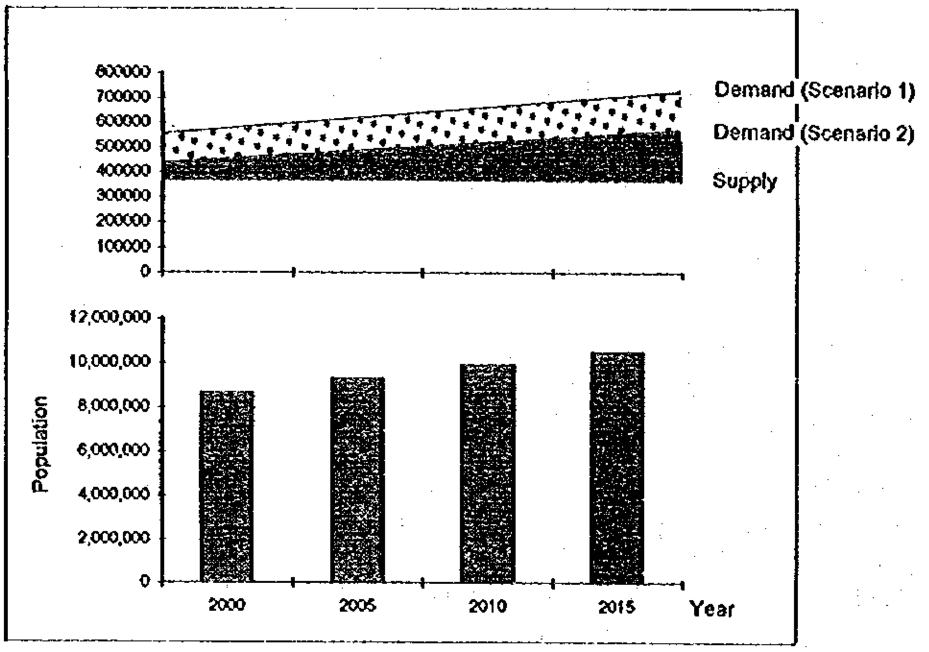
80% of agricultural credit of the Agricultural Bank (BAGRICOLA) are disbursed for rice cultivation.

A.4.2 Supply and Demand

Rice is a vital foodstuff consumed by the Dominican people representing approximately 6.7% of the total household expenses and 15% of the household expense for foodstuffs. Regrettably information on consumption of rice per-capita is not available, thus an analysis on consumption trend of the Dominican people was made referring to data of apparent consumption per-capita; according to this data, the Dominican people consumed 54.4 kg of rice yearly, equivalent to 149 g/day, as an average quantity for the decade (1984-1993), which is far lower than the recommended quantity (190 g/day) to satisfy the calorie-protein requirements (information of ONAPLAN).

For the last 15 years, the population of the Dominican Republic has expanded with an annual rate of 2.35%/year, but is estimated that this growth rate would be decelerated in the coming future; the Latin American Center for Population projects that the total population of the country for the coming 20 years will increase with such modest rhythm as 1.4% per year (Boletin Demográfico, Chile, 1987), thus the country will have an approximate population of 10,480,000 for the year of 2015. Supposing that the production and consumption level will be maintained status quo (Scenario 1) it would have a deficit of 304,000 tons of rice in 2015 to meet the proposed demand anticipated by expansion of population, while if the consumption level for rice would be raised to the above-mentioned recommended level (Scenario 2), the deficit of rice would be expanded to 386,000 tons.

Projection for Growth of Population and Supply and Demand of Rice in the Dominican Republic



A.5 The AGLIPO Project Area

The AGLIPO area consists of three sectors: Aguacate-Guayabo, Limón del Yuna and El Pozo, which are extended over lower basin of the Yuna River-the 2nd largest river of the country. Endowed with favorable natural conditions such as climate, soils and topography, this area is considered to be an optimum area for rice production, thus paddy has been cultivated for long years. On the other hand, in view of promoting rice production there, the Government of the Dominican Republic has put into force an agrarian reform project since 1962 at El Pozo, since 1967 at Limón del Yuna and since 1969 at Aguacate.

The AGLIPO area is located within swampy lands and had been subject to frequent damage by flooding of the Yuna River every year. As a result, the Government of the Dominican Republic had aimed to formulate flood control project; detailed design for the project had been completed, but vast project cost had constituted bottleneck for implementation of the project. Meanwhile, damages by flooding has been alleviated remarkably in recent years owing to the construction of Rincon and Hitillo dams upstream of the Yuna river.

Under the circumstances, the Dominican Government had decided to develop the area with emphasis laid on construction of irrigation facilities so that increased and sustainable rice production would be attained. As a first phase of the project, El Pozo sector was taken up, because the sector was socio-economically the least developed area among three sectors of the AGLIPO area; construction of irrigation facilities was completed in 1990. Subsequently, the Aguacate-Guayabo sector will be benefited by development of irrigation system and detailed design for the system will be proceeded in 1995. Limón del Yuna sector is the only sector among AGLIPO area which had an irrigation system at initial stage of the agrarian reform project, but structural deterioration of the system becomes prominent recently, so rehabilitation and intensification of the system is required for stable production of paddy

The AGLIPO area is one of the major rice production area accounting for 15% of the national output and the importance of the area for rice production will be strengthened in line with the development of irrigation systems at both Aguacate-Guayabo and Limón del Yuna sectors. Actual situation and future forecast of rice production for three sectors of the AGLIPO area is as summarized below.

Unit: ton

	Actual	Year 2000	Year 2005	Year 2010	Year 2015
El Pozo	42,000	55,200	67,500	75,000	75,000
Aguacate-Guayabo	10,200	19,600	54,000	71,000	75,000
Limon del Yuna	32,500	57,600	72,000	83,000	88,000
Total	84,700	132,400	193,500	229,000	238,000
Increased Output	0	47,700	108,800	144,300	153,300

In addition, the most modern and the largest rice processing facilities is under construction within the area with operation envisaged within 1995. In this regards, the AGLIPO area is expected to play a role not only as the major rice production area but also as the leading agro-industrial area.

ANNEX A : TABLES

Table A.1.1 Gross Domestic Product by Sector of Origin

Unit: In million of RD$, constant price of 1970

SECTORS	1989		1990		1991		1992*		1993*		Anual Growth Rate
	Value	%	Value	%	Value	%	Value	%	Value	%	Average (89-93)
Agriculture**	548.7	13.8	501.6	13.3	522.9	13.7	554.5	13.5	556.1	13.2	0.3
Mining	139.3	3.5	111.6	3.0	111.5	2.9	90.9	2.2	57.2	1.4	-20.0
Manufacture	701.1	17.7	671.9	17.8	684.4	18.0	760.9	18.5	773.9	18.3	2.5
Construction	347.5	8.8	280.8	7.4	245.9	6.5	305.9	7.5	338.3	8.0	-0.7
Commerce	531.3	13.4	487.7	12.9	497.5	13.1	533.3	13.0	537.0	12.7	0.3
Hotels, Bars & Rest.	163.3	4.1	157.3	4.2	167.5	4.4	191.1	4.7	230.2	5.4	9.0
Transport	262.8	6.6	252.8	6.7	261.7	6.9	299.1	7.3	313.4	7.4	4.5
Communications	69.2	1.7	78.7	2.1	89.7	2.4	102.7	2.5	115.9	2.7	13.3
Electricity & Water	77.7	2.0	78.4	2.1	82.5	2.2	99.7	2.4	121.5	2.9	11.8
Finance	205.6	5.2	220.8	5.9	223.4	5.9	224.3	5.5	222.1	5.3	1.9
Housing	227.9	5.7	228.2	6.0	228.5	6.0	230.3	5.6	232.4	5.5	0.5
Government	349.0	8.8	358.8	9.5	352.0	9.3	366.1	8.9	373.4	8.8	1.7
Other Services	344.7	8.7	344.0	9.1	337.8	8.9	346.2	8.4	357.3	8.4	0.9
Total GDP	3968.1	100.0	3772.6	100.0	3805.3	100.0	4105.0	100.0	4228.7	100.0	1.6

Source: Banco Central de la Republica, Boletin Mensual (Enero-Marzo de 1994)
Note:* Preliminary figure
** includes livestock, forestry and fishery

Table A.1.2 Balance of Payments

Unit: In million of US$

ITEMS	1989	1990	1991	1992	1993
I. CURRENT ACCOUNT	-266.0	-59.2	-107.0	-582.9	-299.6
1. Commercial Balance	-1039.4	-1058.3	-1070.5	-1612.1	-1606.9
1-1 Exports	924.4	734.5	658.3	562.5	511.5
Sugar	193.1	177.5	167.1	143.0	143.1
Coffee	63.8	46.6	43.5	26.1	26.3
Cacao	47.9	46.0	34.8	35.2	36.0
Tobacco	14.2	21.9	19.1	17.1	21.9
Others	605.4	442.5	393.8	341.1	284.2
1-2 Imports	1963.8	1792.8	1728.8	2174.6	2118.4
Petroleum	427.0	521.5	448.5	498.1	463.3
Others	1536.8	1271.3	1280.3	1676.5	1655.1
2. Service Balance	389.0	628.5	577.0	597.4	865.7
Income	1259.8	1356.7	1407.5	1585.5	1880.3
Expenditure	870.8	728.2	830.5	988.1	1014.6
3. Net Transfer	384.4	370.6	386.5	431.8	441.6
II. CAPITAL ACCOUNT	266.0	59.2	107.0	582.9	299.6
1. Capitals except Reservs	148.7	135.0	487.3	706.4	431.4
1-1 Foreign Investment	110.0	132.8	145.0	179.7	182.8
1-2 Medium & Long Term Capital	156.4	54.1	-3.3	-51.5	-41.1
1-3 Short Term Capital	-117.7	-51.9	345.6	578.2	289.7
2. Net Reserves	117.3	-75.8	-380.3	-123.5	-131.8

Source: Banco Central de la Republica Dominicana, Boletin Trimestral (Enero-Marzo 1994)
Note: Figures are subject to rectification

Table A.2.1 Principal Agricultural Exports

Exports	1989			1990			1991			1992			1993		
	Volumen (M.T.)	Value (000 US$)	%	Volumen (M.T.)	Value (000 US$)	%	Volumen (M.T.)	Value (000 US$)		Volumen (M.T.)	Value (000 US$)		Volumen (M.T.)	Value (000 US$)	
Sugar	490,510	157,090	17.0	354,870	142,677	19.4	318,917	132,277	20.1	320,845	114,917	20.4	319,874	111,657	21.8
Coffee	32,386	63,776	6.9	31,854	46,512	6.3	28,239	43,323	6.6	21,524	24,808	4.4	20,473	26,098	5.1
Cacao	40,615	42,962	4.6	45,840	41,257	5.6	40,555	31,276	4.8	43,488	32,024	5.7	43,817	32,947	6.4
Tobacco	8,168	10,562	1.1	15,058	16,163	2.2	10,823	13,694	2.1	9,271	11,295	2.0	12,192	15,208	3.0
Other products	-	649,998	70.3	-	487,929	66.4	-	437,753	66.5	-	379,345	67.5	-	325,614	63.7
Total exports	-	924,388	100.0	-	734,538	100.0	-	658,323	100.0	-	562,389	100.0	-	511,524	100.0

Source: Banco Central de la Republica Dominicana, Boletin Trimestral (Enero-Marzo 1994)

Table A.2.2 Production of Principal Crops during 1984-1993

Unit: ton x 1000

CROPS	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Paddy	357.6	353.3	327.3	364.0	301.9	339.9	306.2	334.0	405.0	319.6
Maize	102.8	73.6	51.9	47.3	63.0	50.6	43.8	47.7	50.9	56.8
Sorghum	47.3	52.0	50.2	53.8	43.5	43.8	23.1	18.3	19.1	21.7
Sugarcane	1323.1	1094.4	986.1	898.8	803.4	712.8	645.7	645.0	658.9	621.1
Tobacco	22.0	28.0	12.9	24.8	28.8	28.8	39.1	20.4	17.6	13.0
Coffee	39.5	57.6	68.8	52.0	55.4	52.6	58.2	49.5	47.4	51.0
Cacao	46.3	46.3	46.3	46.9	61.8	52.9	64.0	49.7	55.2	58.8
Haricot Bean	82.6	67.7	47.6	59.8	90.3	84.3	58.0	88.2	69.3	72.8
Potato	14.1	12.1	14.7	30.2	30.5	42.5	33.6	32.7	38.2	21.6
Sweat Potato	58.1	49.8	38.2	41.6	46.8	35.2	39.0	49.6	58.1	34.5
Cassava	129.3	125.1	117.7	107.9	139.4	129.4	142.5	147.6	157.2	107.8
Yautia	30.2	46.9	36.3	36.9	46.8	60.0	31.6	21.5	31.2	31.2
Onion	17.7	18.8	16.3	14.6	18.5	27.5	16.9	21.6	23.4	28.4
Tomato	117.5	67.2	87.3	116.7	107.6	158.7	129.5	78.4	112.5	94.9
Sweet Pepper	6.9	6.6	6.8	10.2	13.9	9.5	8.0	8.4	14.7	13.4
Squash	12.5	17.4	21.6	18.5	15.7	27.6	17.6	14.6	12.7	9.2
Plantain*	926	972	967	904	909	1141	1166	1430	1221	1406
LIVESTOCK	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Beef	58.9	63.0	63.1	68.9	67.5	79.5	58.5	61.6	64.2	66.1
Chiken	70.0	69.5	88.0	98.5	121.0	157.5	166.3	174.3	203.4	208.1
Milk***	302	321	330	280	300	358	340	369	366	367
Egg****	336	339	252	350	379	600	660	773	771	787

Source: PLAN OPERATIVO 1994, SEA, Febrary 1994
Note:* production in million units
*** in million of unit

Table A.4.1 Production of Rice in the Dominican Republic in 1993

Region	Planted Area(ha)					Harvested Area (ha)			
	Sowing	Ratooning	Upland	Total	%	Sowing	Ratooning	Upland	Total
North Central	16,573	979	-	17,552	20.2	17,528	1,003	-	18,531
North East	32,103	275	-	32,378	37.3	31,918	229	-	32,147
North West	23,855	1,532	197	25,584	29.5	22,976	1,742	195	24,913
North	965	66	-	1,031	1.2	1,311	-	-	1,311
East	1,389	-	176	1,565	1.8	1,701	-	126	1,827
Central	1,790	-	317	2,107	2.4	2,130	-	780	2,910
South West	6,231	-	-	6,231	7.2	6,253	-	-	6,253
South	345	-	-	345	0.4	474	-	-	474
Total	83,251	2,852	690	86,793	100.0	84,291	2,974	1,101	88,366

Region	Production (ton)*					Unit Yield (ton/ha)			
	Sowing	Ratooning	Upland	Total	%	Sowing	Ratooning	Upland	Total
North Central	74,349	2,355	-	76,704	24.2	4.24	2.35	-	4.14
North East	92,438	418	-	92,856	29.3	2.90	1.83	-	2.89
North West	100,040	4,355	243	104,638	33.0	4.35	2.50	1.25	4.20
North	5,044	-	-	5,044	1.6	3.85	-	-	3.85
East	4,750	-	163	4,913	1.5	2.79	-	1.29	2.69
Central	6,782	-	1,477	8,259	2.6	3.18	-	1.89	2.84
South West	23,452	-	-	23,452	7.4	3.75	-	-	3.75
South	1,207	-	-	1,207	0.4	2.55	-	-	2.55
Total	308,062	7,128	1,883	317,073	100.0	3.65	2.40	1.71	3.59

Note: * Production in hulled rice

Ssource: MOVIMIENTO DE SIEMBRA, COSECHA, PRODUCCION Y PRODUCTIVIDAD
DEL CULTIVO DE ARROZ DEL 1ro DE ENERO AL 31 DE DICIEMBRE, 1993
DIVISION PROGRAMACION Y ESTADISTICAS, DEPARTAMENTO DE FOMENTO ARROCERO, SEA

Table A.4.2 Forecast of Balance between Supply and Demand of Rice

Year	Population*	Demand		Supply****	Balance	
		Scenario 1**	Scenario 2***		Scenario 1**	Scenario 2***
2000	8,621,000	597435	550882	365750	-231685	-185132
2005	9,282,000	643243	593120	365750	-277493	-227370
2010	9,903,000	686278	632802	365750	-320528	-267052
2015	10,480,000	726264	669672	365750	-360514	-303922

Note: * Projection prepared by Centro Latinoamerica de Demografia, 1987

** Assuming that the consumption per-capita reaches 69.3 kg/year (190 gr/day) which is recommended amout to satisfy requirement for calorie-protein by ONAPLAN

*** Asuming that the consumption per-capita remains actual level =54.4kg/year (149 gr/day)

**** Average during last 10 years (1984-93)

ANNEX A : FIGURES

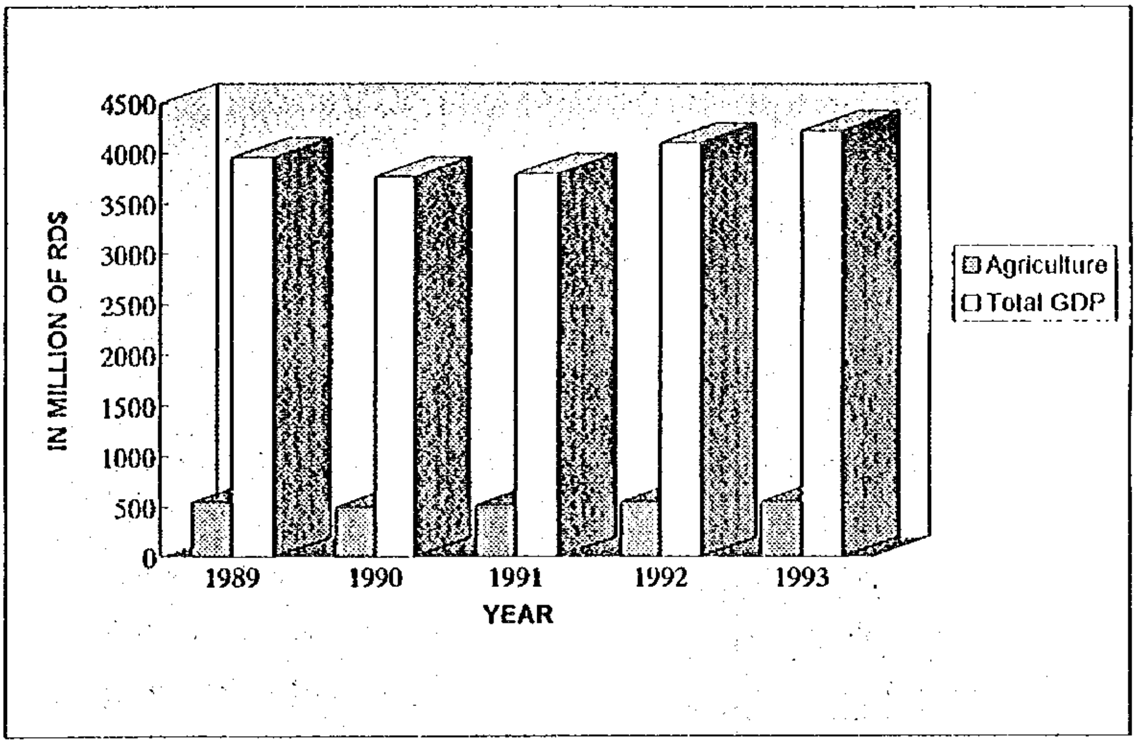


Fig. A.1.1 Total GDP and Agricultural Sector

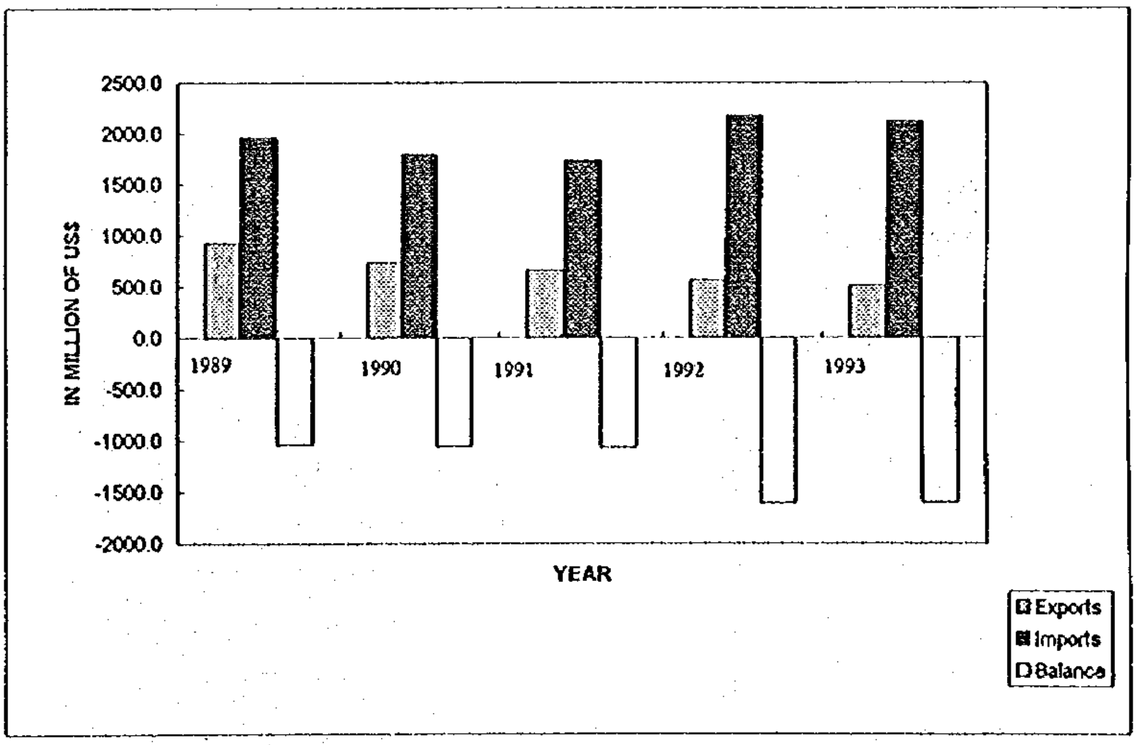


Fig. A.1.2 Commercial Balance

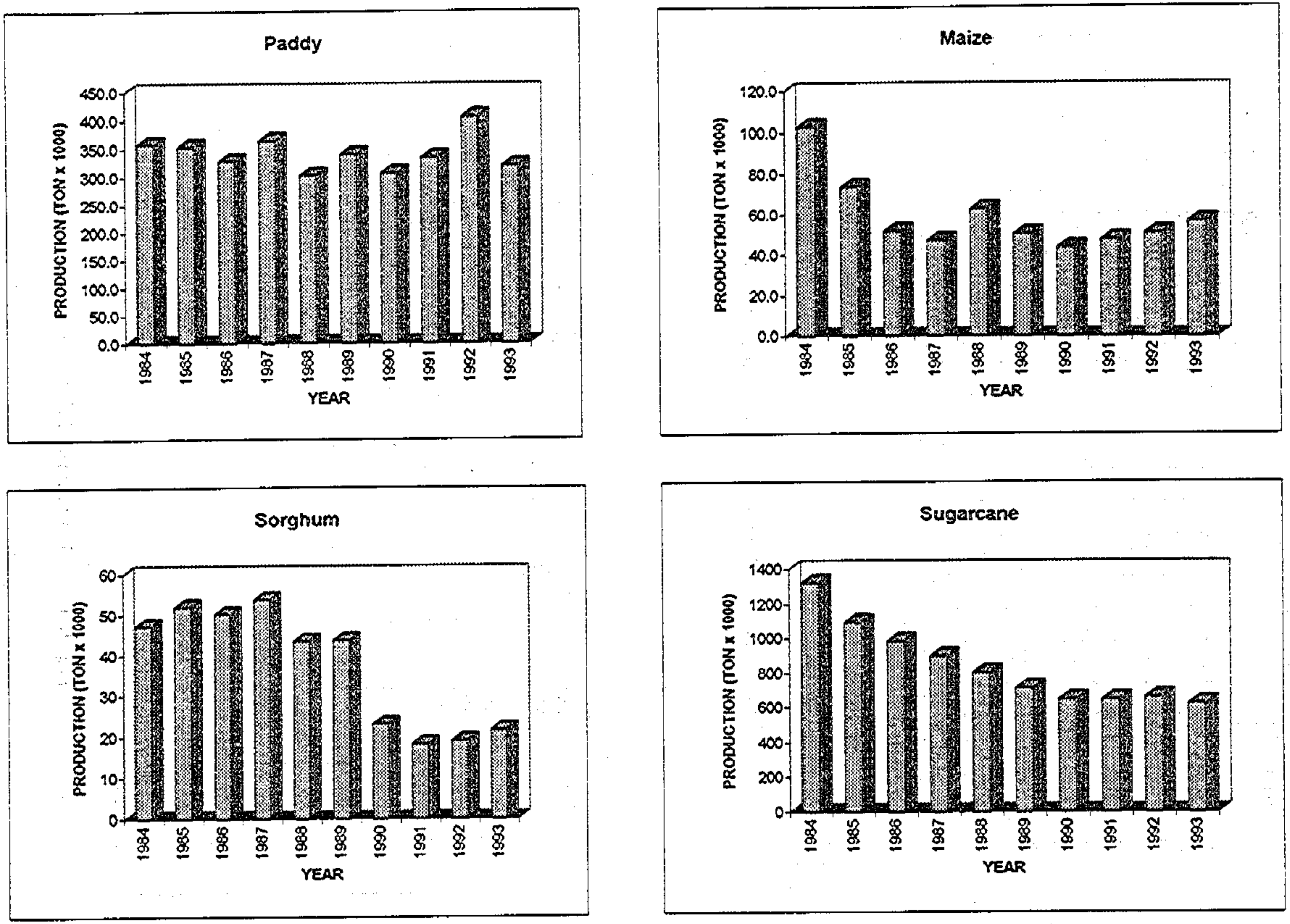


Fig. A.2.1 (I)   Evolution of Production for Major Crops (1984 - 1993)

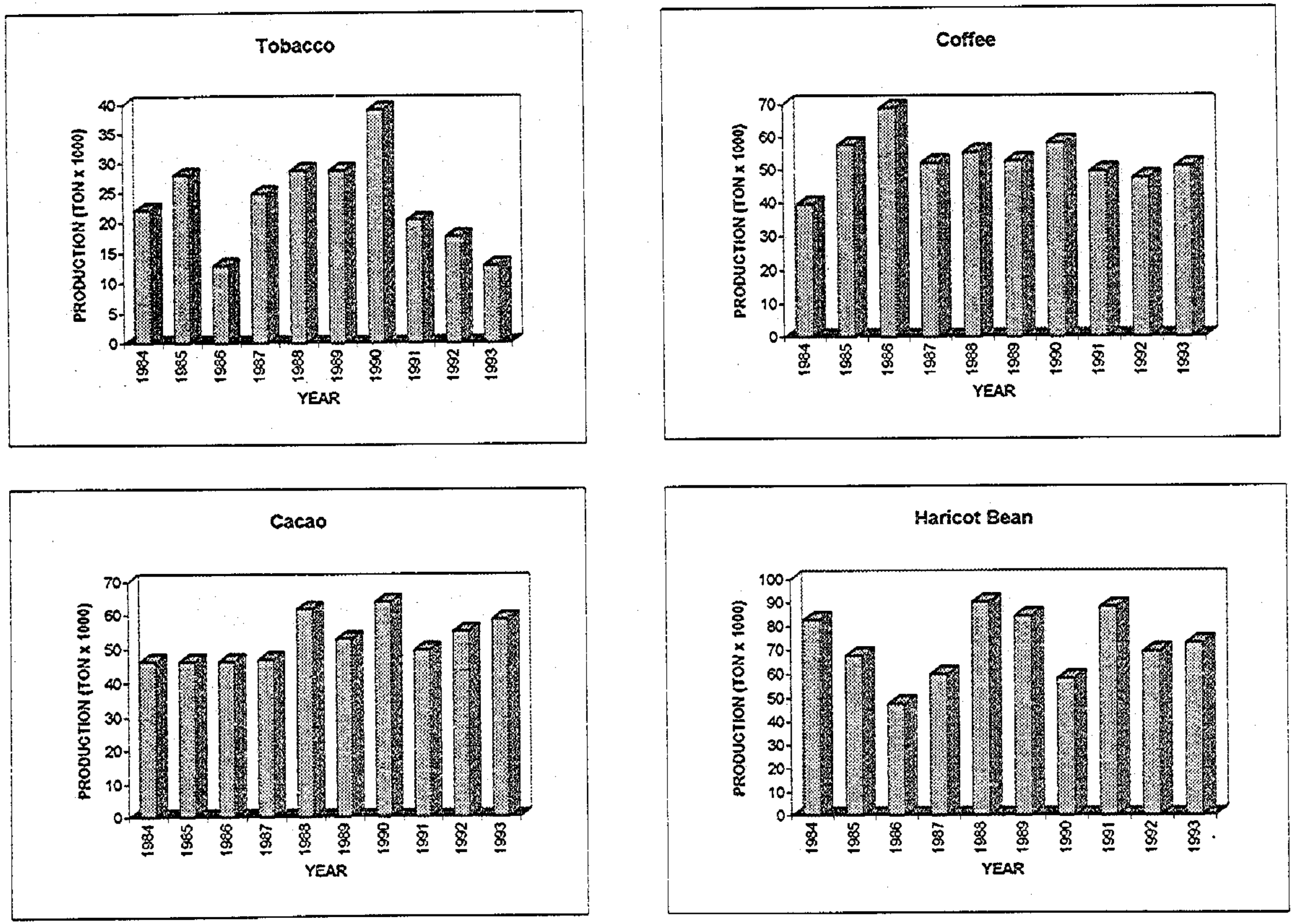
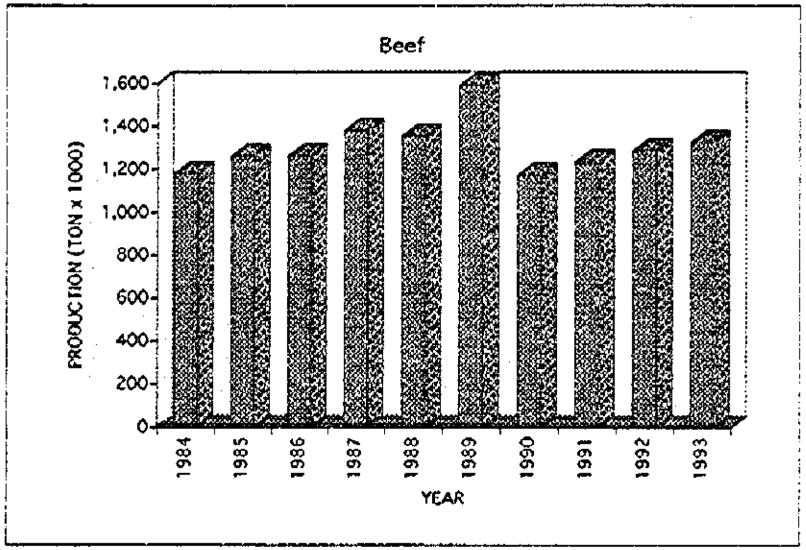
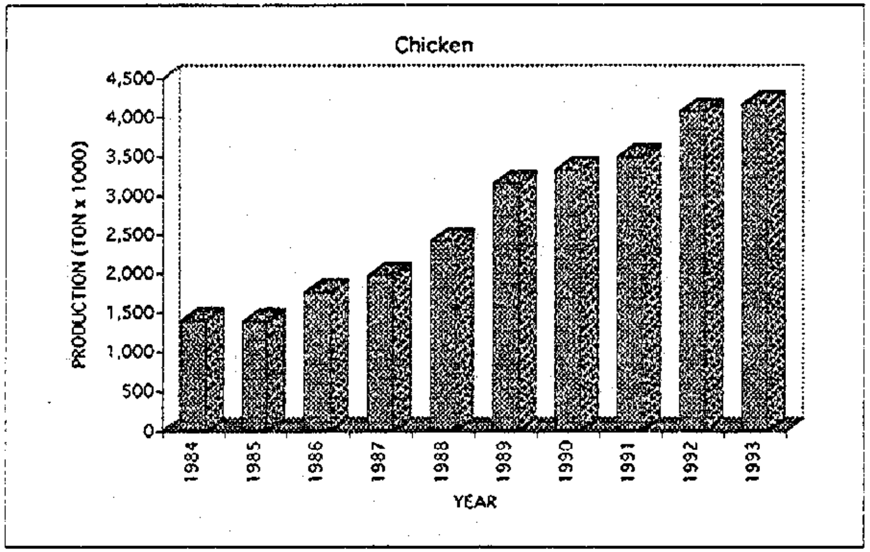
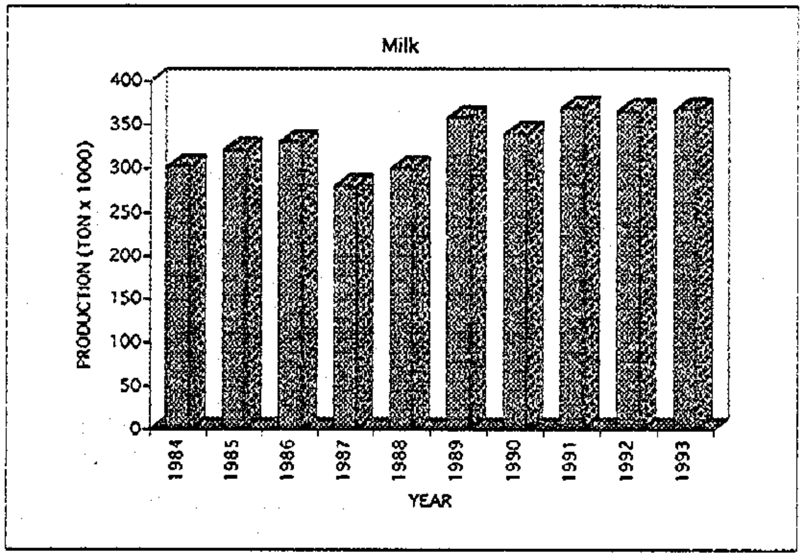


Fig. A.2.1 (2) Evolution of Production for Major Crops (1984 - 1993)







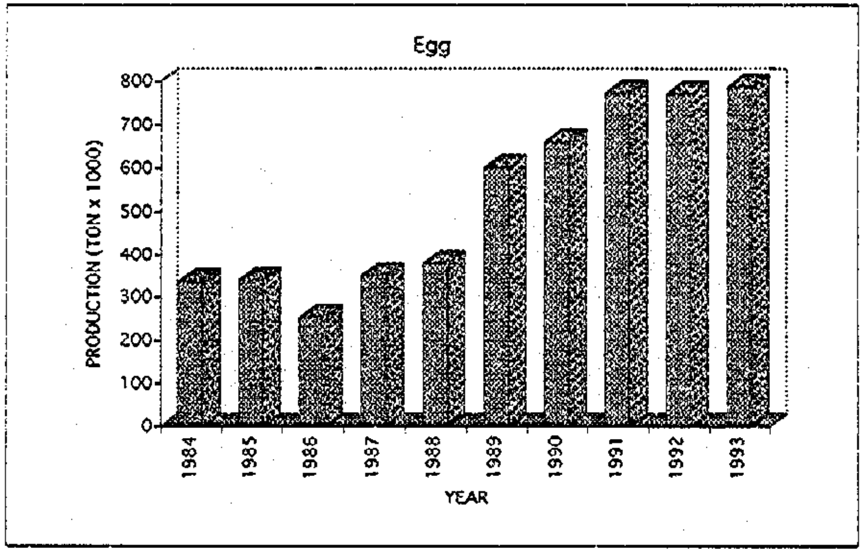


Fig. A.2.1 (3) Evolution of Production for Major Livestock (1984 - 1993)

ANNEX B : METEOROLOGY AND HYDROLOGY

ANNEX B : METEOROLOGY AND HYDROLOGY

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ANNEX B : METEOROLOGY AND HYDROLOGY

B.1 Introduction

B.1.1 Objective of the Study

The main objective of the meteo-hydrological study is to clarify the meteo-hydrological condition in the Study area for the Feasibility Study on the Limon del Yuna Area Agricultural Development Project (hereinafter referred to as "the Study").

The Study area is extended over downstream plain on the right margin of the Yuna river with an approximate area of 120 km^2 and limited by the Yuna river to the north, by Los Haitises Range to the south, by the Barracote river to the east and by the Cevicos to the west. As the drainage condition of the Study area has been influenced of by water level of the Yuna and Barracote rivers, it should be necessary to analyze the entire meteo-hydrological condition of the Yuna river basin for the Study. Further more, the amount of water discharge at the Payabo river is one of the most important elements for the Study, therefore, the hydrological analysis on the Payabo river should also be required.

B.1.2 Summary of Field Works

(1) Data collection

The following meteo-hydrological data were collected:

- Monthly rainfall (54 stations)
- Daily rainfall (2 stations)
- Monthly meteorological parameters (15 stations)
- Monthly mean, maximum and minimum discharge (15 stations)
- Daily mean discharge (3 stations)
- Daily mean water level (3 stations)
- Suspended sediment data (3 stations)
- Spring discharge data (5 springs)

(2) Discharge measurement

The discharge of the Payabo river, the Cascarilla drainage canal and main springs in the Study area were measured during the Phase I and II of field works.

(3) Field investigation

Overall field investigation was carried out during the Phase I and II of field works and some of the analysis results were confirmed based on the site conditions and hearing investigations.

B.1.3 Summary of the Meteorological Study

(1) Climatic condition in the Yuna river basin

The climatic condition of the Yuna river basin can be classified into 2 categories based on its rainfall and mean temperature widely varying 1,500 ~ to 3,000 mm and 20 ~ 30 °C as follows:

- Tropical humidity zone (Eastern part from around latitude 70°)
- Semi tropical humidity zone (Western part from around latitude 70°)

The climate of the Yuna river basin is summarized as follows:

- Annual rainfall 1,500 ~ 3,000 mm
- Mean temperature 20 ~ 28 °C
- Maximum temperature 25 ~ 34 °C
- Minimum temperature 13~19 °C
- Relative humidity 80 ~ 90 %
- Evaporation 1,500 ~ 2,000 mm/year

(2) Climatic condition in the Study area

The climate of the Study area is summarized as follows:

- Annual rainfall 2,070 mm
- Mean temperature 26 °C
- Maximum temperature 33 °C
- Minimum temperature 18 °C
- Relative humidity 83 %
- Evaporation 1,460 mm/year
- Wind velocity 1.1 m/sec

B.1.4 Summary of the Hydrological Study

(1) Rainfall analysis

The correlation coefficient of the monthly rainfall among the 54 rainfall gauge stations was calculated. Considering the location, correlation coefficient and data availability, 8 rainfall gauge stations were selected for the Thiesen Polygon method. Using the monthly rainfall and the Thiesen Polygon method, the average rainfall at the catchment area of Villa Riva, El Limon, Abadesa, the Yuna river confluence with the Payabo river and Payabo river basin was estimated. Approximately 1,700 mm of average annual rainfall was estimated in the catchment area of the Yuna river and around 2,000 mm was estimated for the Payabo river basin.

Using the daily rainfall data at Barraquito and Abadesa, the probability analysis was carried out for the following items and the results are summarized as shown below:

Station	Barraquito		Abadesa	
Return period	1/2	1/10	1/2	1/10
Annual rainfall (mm)	2020	1600	1720	1300
24 hr max. rainfall (mm	102	134	79	109
3 day max. rainfall (mm	143	215	126	167
Number of continuous days without rainfall (less than 0.1 mm)				
Rainy season	8	10	10	17
Dry season	12	18	18	33
Number of continuous days without rainfall (less than 5.0 mm)				
Rainy season	13	17	14	20
Dry season	24	35	31	52

(2) Runoff analysis

1) Water balance in the Yuna river basin

Using discharge data and estimated average rainfall at Villa Riva and El Limon, the water balance in the Yuna river basin was analyzed. Considering the influence of the Rincon and Hatillo dams construction, the analysis period was divided into 3 periods and the results were summarized as shown below:

	Period	Discharge (m^3/s)	Runoff (mm/year)	Rainfall (mm/year)	Runoff Coefficient
Villa Riva	1598~1978	84.7	570	1,596	36%
4,680 km^2	1979~1982	131.3	884	2,027	44%
	1983~1991	90.9	621	1,747	36%
El Limon	1969~1978	79.1	486	1,645	30%
5,130 km^2	1979~1982	135.5	833	2,057	40%
	1982~1993	98.7	607	1,763	34%

2) Low flow analysis

Based on the mean daily discharge data at Villa Riva and El Limon, the annual mean and minimum discharge were analyzed probabilistically and the result is shown as follows:

Villa Riva Catchment Area 4,630 km^2				
Return period	Mean discharge (m^3/s)		Minimum discharge (m^3/s)	
	Before	After	Before	After
1/2	80.15	91.97	11.42	22.19
1/5	60.29	74.95	6.75	16.05
El Limon Catchment Area 5,130 km^2				
Return period	Mean discharge (m^3/s)		Minimum discharge (m^3/s)	
	Before	After	Before	After
1/2	74.38	100.10	12.98	26.39
1/5	64.52	83.90	8.34	16.68

Note : Before and After Dam Construction

Based on the daily mean discharge data at Abadesa and the relationship between the specific discharge and catchment area, the annual mean discharge and the minimum discharge at Abadesa and the diversion point at the Payabo river were analyzed probabilistically as shown below:

Return period	Abadesa		Diversion point at Payabo	
	Mean discharge (m^3/s)	Minimum discharge (m^3/s)	Mean discharge (m^3/s)	Minimum discharge (m^3/s)
1/2	8.80	0.85	12.57	1.46
1/5	6.64	0.53	9.49	0.98

As for the amount of spring water, the expected mean spring water discharge is shown below, based on the a few previous data and the discharge measurement data collected during the Study period.

- Guragao 1.6 m^3/s
- La Cueva 0.5 m^3/s
- El Cercad 0.8 m^3/s
- Lagnita Cristal 1.2 m^3/s
- Laguna Cristal 0.5 m^3/s
- Caño Ponton 0.8 m^3/s

3) High flow analysis

Several flood protection works were carried out at Arenoso, located between Villa Riva and El Limon, during the period 1970 ~ 1992 and the flow capacity of the Yuna river has risen up after completion of the works. It is expected that the flow capacity has risen from approximately 600 m^3/s to 700 m^3/s. The difference in flow between Villa Riva and El Limon has flown to Caño Gran Estero in the Flood Period. Therefore, the limitation of maximum discharge at El Limon depends on the flow capacity at Arenoso and that was estimated in approximately 750 m^3/s from the discharge record. The result of the probability analysis for the high flow at Villa Riva and El Limon was summarized as shown below:

(m^3/s)

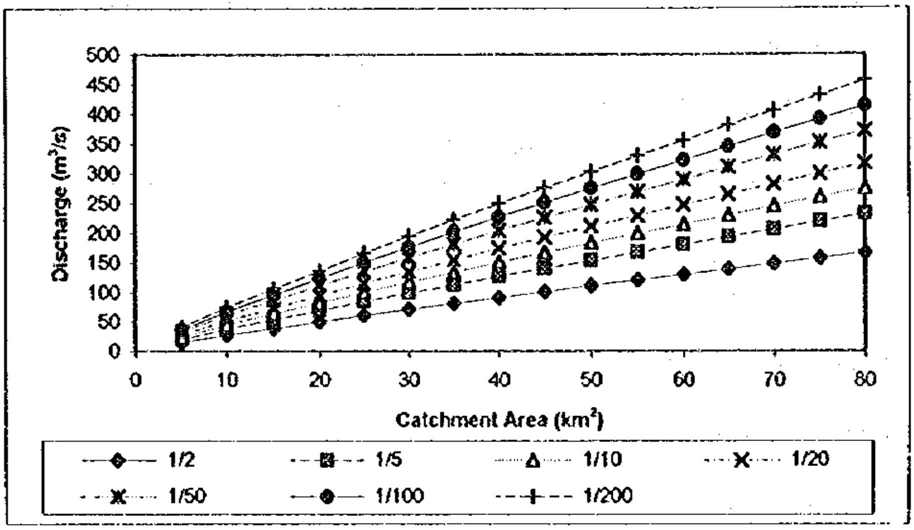
Return period	Villa Riva		El Limon	
	Before	After	Before	After
1/2	630	670	470	530
1/20	1060	930	630	750
1/100	1280	1060	-	-

Note : Before and After Dam Construction

Based on the daily mean discharge data and the relationship between the maximum specific discharge and catchment area, the high flow at Abadesa and diversion point at the Payabo were estimated probabilistically as shown below:

Return period	Abadesa Max. discharge (m^3/s)	Diversion point at Payabo Max. discharge (m^3/s)
1/2	180	200
1/20	380	420
1/100	500	550

Using the Rational formula and the 24 hr maximum rainfall, the flood discharge in the Study area caused by the direct runoff from the rainfall was estimated as shown below:



4) Sediment analysis

Based on the suspended sediment data at Villa Riva, El Limon and Abadesa the sediment runoff was analyzed as shown below:

Villa Riva	$Ss = 2.146 \cdot Q^{1.457}$
El Limon	$Ss = 0.768 \cdot Q^{1.722}$
Abadesa	$Ss = 2.185 \cdot Q^{1.466}$

where Ss : Suspended sediment (t/day)
Q : Discharge (m^3/s)

Using those equations and daily mean discharge data, sediment runoff at those stations was estimated. The sediment runoff at the Payabo river was also estimated based on this result. The result was summarized as shown below:

Villa Riva	290 $m^3/km^2/year$
El Limon	260 $m^3/km^2/year$
Abadesa	200 $m^3/km^2/year$
Payabo	200 $m^3/km^2/year$

(3) Estimation of H-Q rating curve

H-Q rating curves at the discharge measurement point and at the proposed water level gauging stations in which automatic water level recorder was newly installed, were estimated based on the uniform flow equation applying river and canal section data.

B.1.5 Summary of Recommendations

The following considerations were recommended for further meteo-hydrological studies in the Study area.

- Improvement of observation system at Barraquito
- Continuous discharge measurement at the main river and springs
- Improvement of meteo-hydrological observation network in Los Haitises

B.2 Activity of Field Woks

B.2.1 Data Collection

(1) Meteorological data

1) Rainfall data

The monthly rainfall data at 54 rainfall gauge stations in and around the Yuna river basin as shown in Table B.2.1 and Fig. B.2.1 was collected. The summary of rainfall data is shown in Table B.2.2 and annual rainfall distribution at some of the stations is shown in Fig. B.2.2.

The daily rainfall data at Barraquito and Abadesa stations was collected for the hydrological analysis and water requirement analysis in the Study area.

2) Other meteorological parameters

The meteorological data other than rainfall data at 15 meteorological stations in and around the Yuna river Basin as shown in Table B.2.3 and Fig B.2.1 were collected. The summary of meteorological data is shown in Table B.2.4.

(2) Hydrological data

1) River discharge data

The monthly mean, maximum and minimum discharge data at 26 hydrological stations in the Yuna river basin as shown in Table B.2.5 and Fig B.2.1 was collected. The summary of discharge data is shown in Table B.2.6.

The daily mean flow data at Villa Riva, El Limon and Abadesa was collected for the hydrological analysis in the Study area.

2) **River water level data**

The daily mean water level data at Villa Riva, El Limon and Abadesa was collected as well as the coefficients of rating curve and river section data at those stations.

3) **Spring discharge data**

There are several main springs in the Study area and a few water discharge measurement data at some springs were collected. The summary of spring water discharge data is shown in Table B.2.7.

4) **Suspended sediment data**

The suspended sediment data at Villa Riva, El Limon and Abadesa was collected as shown in Table B.2.8.

B.2.2 River, Canal and Spring water discharge measurement

The discharge of the Payabo river, the Cascarilla drainage canal and main springs in the Study area were measured during the Phase I and II of field works. The locations where discharge measurements were carried out are shown in Table B.2.9 and Fig. B.2.3.

B.2.3 Field investigation

Overall field investigation was carried out during the Phase I and II of field works and the following conditions and some of the analysis results were confirmed based on the site conditions and hearing investigations.

- Present flow capacity of the rivers and canals
- Drainage system in the Study area
- Previous flood level and inundation area as well as its period
- Influence of the back water from the Yuna and Barracote rivers

B.3 Availability of Meteo-hydrological Data

The Dpto. de Hidrologia of INDRHI has been processing the data base system for the meteo-hydrological data and most of the meteo-hydrological data was collected from INDRHI. The daily rainfall data from 1981 at some stations which are operated by the Institute of National Meteorology were also collected.

B.3.1 Meteorological Data

(1) Rainfall Data

There are 54 unevenly distributed rainfall gauging stations in and around the Yuna river basin, and at some of the stations the rainfall data has been registered for more than 40 years. Though the daily rainfall has been continuously registered in most of the stations since 1968, frequent interruptions of the records are found. The available data periods of rainfall at these stations are shown in Fig. B.3.1.

(2) Other Meteorological Data

There are 15 meteorological stations in and around the Yuna river basin, and the parameters other than rainfall are recorded. The continuous data is not available throughout an entire record period due to interruption of the observation. The temperature, relative humidity, evaporation and wind velocity data is available for the Study. The continuity of data at these meteorological stations is shown in Fig. B.3.1.

B.3.2 Hydrological Data

INDRHI is responsible for the collection of hydrological data in the Dominican Republic. Daily mean water level and discharge data are available at the INDRHI. The monthly river discharge data of the 26 stations were collected, and the availability of such collected data at these stations is shown in Fig. B.3.1.

B.4 Meteorology

B.4.1 Climatic Condition in the Yuna River Basin

The climate of the Yuna river basin can be classified into 2 categories based on its annual rainfall and mean temperature widely varying from 1,500 to 3000 mm and 20 to 30 °C as follows:

- Tropical humidity zone (Eastern part from around latitude 70°) characterized by around 2,000 mm of mean annual rainfall and more than 25 °C of monthly mean temperature throughout the year.

- Semi-tropical humidity zone (Western part around latitude 70°) characterized by around 1,500 mm of the mean annual rainfall and 20 to 25 °C of monthly mean temperature. Approximately 3,000 mm of annual rainfall can be observed in the mountainous region of the South-Western part of the basin.

  To the West of the border of the Yuna basin, the amount of annual rainfall is comparatively smaller which is more or less 1,300 mm.

The climatic condition of main meteorological stations in and around of the Yuna river basin is shown in Fig. B.4.1.

(1) Rainfall

The highest amount of monthly rainfall in the Yuna river basin that can be found out in May is equivalent to 13 to 15 % of annual rainfall. And in August and November, 10 to 11 % of that is respectively expected On the other hand, in January, February and

March, only 5 to 6 % of that is expected and those three months may be classified as dry season. This tendency can be observed in the entire basin and in most of the country except in the Atlantic Region (North-Atlantic).

(2) Other parameters

Except evaporation, the meteorological parameters other than rainfall are fairly stable throughout the year in all stations and they are summarized as follows:

Mean temperature	20 - 28 °C
Maximum temperature	25 - 34 °C
Minimum temperature	13 - 19 °C
Relative humidity	80 - 90 %
Evaporation	1,500 - 2,000 mm/year

B.4.2 Climatic condition in the Study area

Data from the meteorological station at Barraquito (code 1814) is available for the Study area and the climatic condition at Barraquito is summarized in Table B.4.1.

Around 2,000 mm of annual rainfall is expected and the highest amounts of the monthly Rainfall are expected in May (15% of annual rainfall), in August (10%) and in November (9%). The lowest amounts of rainfall can be observed from January to March, when monthly average rainfall is less than 6 % of annual rainfall.

Approximately 26 °C, 33 °C, and 18 °C of mean, maximum and minimum temperature have been observed without great variation throughout the year. Considering the annual temperature pattern, the differences between monthly temperature and annual mean are less than +/- 15 %.

Approximately 83 % of mean annual relative humidity has been observed and monthly mean relative humidity does not vary throughout the year. According to the record of daily mean relative humidity during the period from 1973 to 1993, 97 % and 71 % maximum and minimum relative humidity was observed.

Approximately 1,500 mm of annual evaporation can be expected. The highest amount of monthly evaporation is expected in May, and the second higher amount in July. The lowest amount of evaporation is observed in December.

Approximately 1.3 m/s of annual mean wind velocity has been observed. The highest monthly mean wind velocity is expected in April and wind velocities in January ~ May are expected to be higher than those in June ~ December.

B.5 Hydrology

B.5.1 General

(1) Drainage System in Dominican Republic

From the view point of hydrology, the drainage systems in Dominican Republic can be divided into 14 zones as shown in Fig. B.5.1 and around 40 % of the catchment area all over the country is covered by the following 4 major basins.

	Catchment Area (km^2)	Total River Length (km)
Yuna basin	5,490	209
Yaque del Norte basin	7,044	296
Yaque del Sur basin	4,972	183
Ozama basin	2,686	198

(2) Drainage system in the Yuna river basin

The Yuna river basin is one of the main drainage systems in Dominican Republic. The Yuna river originates in the Cordillera Central mountain with altitude around 2,000 m and flows down to North-East. At Chacuey Abajo, the Yuna river is confluent with the Camú river which is the main tributary of the Yuna river. Then the Yuna river changes the flowing direction towards the East. At the lower part of Villa Riva and the Haitises National Park the Yuna River diverts to Caño Gran Estero and Barracote river. The drainage system in Yuna river basin is shown in Fig B.5.2 and can be divided into the following 4 main sub-basins.

- Upper Yuna (South-Eastern area in the basin before confluence with Camú river)
- Middle Yuna (Middle part in the basin after confluence with the Camú river)
- Lower Yuna (Eastern part in the basin after diverting to Caño Gran Estero)
- Camú (The basin of Camú river, North-Western part of the Yuna river basin)

1) Upper Yuna sub-basin

The physical characteristics of the upper Yuna sub-basin is summarized below:

Catchment area	1,535	km^2
Main river length	82	km
Average longitudinal slope	1.1	%

The main river profiles are shown in Fig. B.5.3. The longitudinal slope of the Yuna river is quite steep with more than 1% in the mountain side with altitude more than 400 m. It comes down to less than 0.1 % after confluence with the Maguaca river. The Hatillo dam was constructed in 1982 at the Yuna river between the confluence with Maguaca and Maimon rivers and since 1982 the runoff characteristics of the Yuna river basin has been changing. 2,000 mm to 3,000 mm of annual rainfall is expected in this sub-basin.

2) Camú sub-basin

The Camú river originates in the Cordillera Central Mountains and flows down towards the North around 15 km and then changes the flowing direction towards the East. The physical characteristics of the Camú sub-basin is summarized below:

Catchment area	2,355	km^2
Main river length	85	km
Average longitudinal slope	0.36	%

The longitudinal slope of the Camú river is comparatively steep, around 1 % at the mountain side with altitude more than 100 m. It comes down to less than 0.1 % after confluence with the Jima river. The Rincon dam was constructed in 1978 in the Jima river which is one of the main tributaries in the Camú sub-river basin. 1,500 mm to 2,000 mm of annual rainfall is expected in this sub-basin.

3) Middle Yuna sub-basin

The physical characteristics of the middle Yuna sub-basin is summarized below:

Catchment area	790	km^2
Main river length	38	km
Average longitudinal slope	0.078	%

The longitudinal slope of the Yuna river at this area is comparatively more moderate than that of the upper Yuna and Camú sub-basins. Approximately 1,800 to 2,000 mm of annual rainfall is expected in this sub-basin.

4) Lower Yuna sub-basin

The physical characteristics of the lower Yuna sub-basin is summarized below:

Catchment area	810	km^2
Main river length	30	km
Average longitudinal slope	0.025	%

Water of the Yuna river is diverted to the Barracote river except during low flow period and also it is diverted to Caño Gran Estero during the flood period. The Study area is located in this sub-basin and in the Payabo river one and around 2,000 mm of annual rainfall is expected in this sub-area.

(3) Drainage condition in the Study area

The Study area is located in the area where the Yuna river is flowing down on North and West sides, the Barracote river is flowing down on East side and the Haitises National Park is on South side. Approximately 120 km^2 of fertile land is extended in the Study area and the Payabo river which is the main river with 393 km^2 of catchment area, is flowing from South-West to North-East. The drainage condition in the Study area is shown in Fig. B.5.4. The Study area can be divided into 2 zones which are located in Western and Eastern parts with a line connecting the Payabo river and Guaraguao river.

1) Western zone

The main water source in this zone is the Payabo river and all irrigation canals take water from this river. Though some amount of surplus water is drained from the Ponton irrigation canal to the Yuna river directly at the West part of this zone, most of the water is drained to the Payabo river. During the high water level period of the Yuna river, several occurrences of inundation take place during the year due to the poor drainage characteristic of the Payabo river.

2) Eastern zone

There are 5 main springs at the South part in this zone and 4 of them are the main water source not only for irrigation purpose but also for domestic water use. Some amount of irrigation water is directly pumped up from the Yuna river at the North part of this zone. Almost all water in this zone is drained by the Cascarilla drainage canal which is running from West to East in the middle of this zone. The area is flooded several times during the year due to poor drainage capacity of the Cascarilla canal. The longitudinal profile of the Cascarilla is shown in Fig. B.5.5.

B.5.2 Rainfall Analysis

(1) Average rainfall in the entire Yuna river basin

The correlation coefficient of the monthly rainfall among the 54 rainfall gauge stations was calculated and the result is shown in fig B.5.6. Considering the location, correlation coefficient and data availability, 8 rainfall gauge stations were selected for Thiesen polygons method as shown in Table B.5.1 and Fig. B.5.7. Using the correlation equations, the missing data of monthly rainfall at the 8 selected stations were estimated for the period of 1958 to 1993. The result is summarized in Table B.5.2. Using the actual and estimated monthly rainfall, the annual rainfall at 8 stations were calculated as shown in Fig B.5.8. There were dry years every 7 years at the stations except Jima Rincon and La Ceiba before 1978, and after 1978 this tendency was not shown.

Using those monthly rainfall data and the Thiesen Polygon method, the average rainfall at the catchment area of Villa Riva, El Limon, Abadesa, the Yuna river confluence with the Payabo river and the Payabo river basin was estimated as shown in Table B.5.3 and Fig. B.5.9. Approximately 1,700 mm of average annual rainfall was estimated in the catchment area of the Yuna river and around 2,000 mm of that was estimated for Payabo river basin. The tendency of annual rainfall patterns of each catchment area is more/less the same as that mentioned in the paragraph B.4.1.

(2) Probability analysis

Using the daily rainfall data at Barraquito and Abadesa, the probability analysis was carried out for the following Items and results are shown in Table B.5.4.

- Annual Rainfall (being less)
- 24 hr maximum rainfall (excess)
- 3 day maximum rainfall (excess)
- Number of continuous days without rainfall (excess, less than 0.1 mm)
- Number of continuous days without rainfall (excess, less than 5.0 mm)

B.5.3 Runoff Analysis

(1) Water balance in the Yuna river basin

Using discharge data and estimated average rainfall at Villa Riva and El Limon, the relationship between discharge and rainfall was analyzed. Considering the influence of the Rincon and Hatillo dam constructions, the analysis period was divided into 3 periods (before 1978, 1978 to 1982, since 1983). The results are shown in Table B.5.5 and Figures B.5.10, B.5.11 and summarized below:

	Period	Discharge (m^3/s)	Runoff (mm/year)	Rainfall (mm/year)	Runoff Coefficient
Villa Riva	1958-1978	84.7	570	1,596	35.80%
4680 km^2	1979-1982	131.3	884	2,027	43.60%
	1983-1991	90.9	621	1,747	35.60%
El Limon	1969-1978	79.1	486	1,645	29.60%
5130 km^2	1979-1982	135.5	833	2,057	40.50%
	1982-1993	98.7	607	1,763	33.20%

As comparatively large amount of rainfall took place during the period of 1979-1982, the runoff coefficient in that period was higher than that in the other period. Comparing the annual runoff pattern between the periods before and after dam construction, the runoff coefficients in February, June and December have became to high. Especially in February which is the driest month in the year, the runoff coefficient of the period after dam construction has risen to almost twice the previous coefficient. It can be said that this influence is due to dam construction.

(2) Low flow analysis

1) Entire basin

Annual mean and minimum discharge at Villa Riva and El Limon as shown in Fig. B.5.12 is calculated based on the daily mean discharge data. The flow condition has been changing since 1983 as aforementioned, therefore, probability analysis of mean and minimum flow was carried out for data series of the periods before and after dam construction. The result is shown in Table B.5.6 and summarized below:

Villa Riva Catchment Area 4630 km²				
Annual Mean Discharge				
Return Period	Before Dam Construction		After Dam Construction	
	Discharge (m^3/s)	Specific Q ($l/s/km^2$)	Discharge (m^3/s)	Specific Q ($l/s/km^2$)
1/2	80.15	17.13	91.97	19.65
1/5	60.29	12.88	74.95	16.01
1/10	51.25	10.95	67.00	14.32
1/20	44.40	9.49	60.89	13.01
Annual Minimum Discharge				
Return Period	Before Dam Construction		After Dam Construction	
	Discharge (m^3/s)	Specific Q ($l/s/km^2$)	Discharge (m^3/s)	Specific Q ($l/s/km^2$)
1/2	11.42	2.44	22.19	4.74
1/5	6.75	1.44	16.05	3.43
1/10	5.10	1.09	13.55	2.89
1/20	4.03	0.86	11.78	2.52

El Limon Catchment Area 5130 km²				
Annual Mean Discharge				
Return Period	Before Dam Construction		After Dam Construction	
	Discharge (m^3/s)	Specific Q ($l/s/km^2$)	Discharge (m^3/s)	Specific Q ($l/s/km^2$)
1/2	74.38	15.89	100.10	21.39
1/5	64.52	13.79	83.90	17.93
1/10	59.91	12.80	77.33	16.52
1/20	56.39	12.04	72.70	15.53
Annual Minimum Discharge				
Return Period	Before Dam Construction		After Dam Construction	
	Discharge (m^3/s)	Specific Q ($l/s/km^2$)	Discharge (m^3/s)	Specific Q ($l/s/km^2$)
1/2	12.98	2.77	26.39	5.64
1/5	8.34	1.78	16.68	3.56
1/10	6.29	1.34	12.72	2.72
1/20	4.76	1.02	9.91	2.12

Though it is necessary to consider the different period and Number of data series, it is assumed that annual mean and minimum discharge at both stations had been increased comparing with before dam construction. The difference in flows between Villa Riva and El Limon is expected to be coursed by inflow from the Payabo river and outflow to Caño Gran Estero.

2) In the Study area

The Payabo river is the main tributary of the Yuna river in the Study area and the catchment area at diversion point with the Ponton canal is estimated as 345 km². From the result of field investigation, 30 to 60 % of the Payabo river discharge diverts to the Ponton canal and some amount of surplus water is drained from the Ponton canal to the Yuna river directory where it is at around 15 km upper stream from Villa Riva. And this surplus water is counted in the discharge data at Villa Riva. Therefore, it is difficult to estimate the Payabo river discharge using the difference in flows at Villa Riva and El Limon.

There is one hydrological station at Abadesa that is 36 km upper stream from the diversion point and the annual mean, maximum and minimum discharge from 1972 to 1993 at Abadesa is shown in Fig. B.5.13. This figure shows that the amount of maximum discharge had come down since 1980 and more or less 50 m^3/s of annual maximum discharge was observed since 1980. Considering hydrological condition at Abadesa, this value was too small and it seems that there is some problems in the estimation of H-Q rating curve. As for this aspect, now INDRHI is checking the rating curve and expecting to revise the discharge data. Therefore, the data series from 1972 to 1979 was applied for the mean and high flow analysis in this Study. The runoff pattern at Abadesa is shown in Table B.5.7 and around 60 % of annual runoff coefficient at Abadesa was calculated. This runoff coefficient seems to be too high and it is considered that the estimation of average rainfall at Abadesa is a little bit too low. However, relationship between runoff coefficient and estimated average rainfall can be applied for the estimation of runoff pattern at the Payabo river.

Using the discharge data series and estimated average rainfall at Villa Riva, El Limon and Abadesa, the relationship between the annual runoff coefficient and catchment area was estimated as shown in Fig. B.5.14. The equation was analyzed below:

$$Cr = 1.562\ A^{-0.178}$$

where Cr : Annual Runoff Coefficient
A : Catchment Area (km^2)

From this result, 55.3 % of annual runoff coefficient against the estimated average rainfall at the diversion point was estimated. Using the estimated average rainfall at diversion point and estimated runoff coefficient, the annual mean discharge at the Payabo river was estimated as shown in Fig. B.5.15. The monthly river discharge was also estimated and summary of the result is shown in Table B.5.8. Approximately 13 m^3/s of annual mean discharge was expected.

As for minimum discharge, the data series of the period from 1972 to 1993 at Abadesa is available for the analysis. The minimum flow at the diversion point was estimated using specific discharge at Abadesa as shown in Fig. B.5.15. Approximately 1.5 m^3/s of annual minimum flow was expected.

The probability analysis was carried out using those results as shown in Table B.5.9.

As for the amount of spring water discharge, there is a few previous data as shown in Table B.5.10. The spring water discharge has been measured during the Study period as shown in Table B.5.11. The portion of spring discharge at each spring against that of Guaraguao was also calculated as shown in Fig. B.5.16 and this figure shows that the portion might had varied due to influence of rainfall in the rainy season but this might had stabilized in the dry season. The discharge measurement at Guaraguao spring has also been carried out from August 1994 to February 1995 as shown in Table B.5.12 and Fig. B.5.17. Approximately 1.6 m^3/s of mean spring discharge was estimated during this period and 1.3 m^3/s of mean discharge was expected in February. On the other hand, for the estimation of spring water discharge at Caño Ponton, the discharge measurement was carried out as shown in Table B.5.13 in February 1995. Approximately 0.2 ~ 1.1 m^3/s of spring discharge was estimated from this observation.

Considering the previous data and those results, the mean spring water discharge was expected as below:

- Guaraguao 1.6 m^3/s
- La Cueva 0.5 m^3/s
- El Cercad 0.7 m^3/s
- Lagnita Cristal 1.2 m^3/s
- Laguna Cristal 0.5 m^3/s
- Caño Ponton 0.8 m^3/s

(3) High flow analysis

1) Entire basin

Several flood protection works were carried out at Arenoso located between Villa Riva and El Limon during the period between 1970 - 1992 and the flow capacity of the Yuna river has risen up after the completion of works. The mean daily discharge at the Yuna river in 1979 and 1987 is shown in Fig. B.5.18. It is expected that flow capacity has risen from approximately 600 m^3/s to 700 m^3/s. The difference in flow between Villa Riva and El Limon has flow to Caño Gran Estero in the Flood Period. Therefore, the limitation of maximum discharge at El Limon is depending on the flow capacity at Arenoso and that was estimated as approximately 750 m^3/s from the discharge record.

On the other hand, tendency of the flood at Villa Riva has also slightly changed after dam construction. It was assumed that more or less 5 % of peak flood discharge has decreased since 1982. The probability analysis is shown in Table B.5.14.

2) In the Study area

Due to poor operation of the Ponton canal intake facility, it is estimated tha t30 to 60 % of water discharge of the Payabo river has been diverted even during flood period and some of it has drained to the Yuna river directly at Cevicos. Approximately 60 to 80 m^3/s of maximum flow capacity was roughly estimated at the main road bridge of the Payabo river considering river section and longitudinal slope. From the field investigation, more or less the same amount of flood discharge as at the Payabo bridge was estimated at the Ponton canal. Using the mean flood specific discharge at several hydrological stations with more than 100 km^2 of catchment area, the relationship between flood specific discharge and catchment area was roughly estimated as shown in Fig. B.5.19. The equation is estimated as follows:

$$Qf = 88.115\ A^{-0.784}$$

where Qf : Mean Flood Specific Discharge ($m^3/s/km^2$)
A : Catchment Area (km^2)

Approximately 0.9 $m^3/s/km^2$ of annual mean specific flood discharge was estimated at the diversion point of the Payabo river and, using this result and the discharge data at Abadesa, the flood discharge at the Payabo river was estimated as shown in Fig B.5.20. The probability analysis is shown in Table B.5.15.

Concerning to the direct runoff from rainfall in the Study area, the peak flood discharge at each drainage canal was analyzed using Rational Formula as shown below:

$$Qf = f\ I\ A/3.6$$

Where Qf : Peak flood discharge (m^3/s)
f : Flood runoff coefficient (considering the condition of the Study area, 0.75 of coefficient was applied)
I : Rainfall intensity on the duration time (mm/hr)
A : Catchment area (km^2)

Due to a lack of hourly rainfall data, rainfall intensity was estimated using the following formula:

$$I = R_{24}/24\ (24/T)^{n}$$

Where R_{24} : Maximum 24 hr rainfall (mm)
T : Duration time (hr)
n : Coefficient (considering the condition of the Study area, 1/2 of coefficient was applied)

The duration time should be varied depending on the condition of catchment area. Therefore, duration time was estimated using the following formula:

$$Tp = C\ A^{(0.22)}\ I^{(-0.35)}$$

Where Tp : Duration time in minutes (min)
C : Coefficient (considering topographic and land use condition in the Study area, 220 of coefficient was applied)

Using those formula, the relationship between the peak runoff and catchment area was estimated as shown in Fig B.5.21 and Table B.5.16.

Concerning to the direct peak runoff from the Haitises mountain area, runoff and duration time coefficients in the mountain area should be different from those in the Study area. From the result of field investigation, around 7 to 14 hours of direct runoff duration time from mountain area was expected. Though there is no data to analyze direct runoff from mountain area, it is considered that the peak discharge in the Study area might not be influenced by the direct runoff from mountain area considering 7 to 14 hours of time lag. This mechanism is explained in Fig. B.5.22.

(4) Sediment runoff

Using the suspended sediment data at Villa Riva, El Limon and Abadesa, Sediment runoff was analyzed as shown in Fig. B.5.23. The equations are estimated as follows:

Villa Riva	$Ss = 2.146\ Q^{1.457}$
El Limon	$Ss = 0.768\ Q^{1.722}$
Abadesa	$Ss = 2.185\ Q^{1.466}$

Where Ss : Suspended Sediment (t/day)
Q : Discharge (m^3/s)

Using those equations and daily mean discharge data, sediment runoff at those stations was estimated. The sediment runoff at Payabo river was also estimated using the result of sediment runoff analysis at Abadesa. The result of analysis is shown in Table B.5.17.

(5) Estimation of H-Q Rating Curve

Discharge measurement had been carried out at the site as shown in Table B.2.9 and Fig. B.2.3 during the Study period. The automatic water level recorders procured by JICA have been installed at some of the sites and gauging stuff was also installed at every site by INDRHI. The result of discharge measurement during the Study period is shown in Table B.5.18. H-Q rating curve was estimated based on the uniform flow equation applying river and channel section data as shown in Fig. B.5.24.

B.6 Recommendations

The following considerations are recommended for further meteo-hydrological studies in the study Area.

- Improvement of observation system at Barraquito

  The meteorological data at Barraquito station (code no. 1814) should be one of the most important information for the Study. Hence, almost all meteorological parameters are not completed. Considering the data availability for the project, it is necessary to improve the meteorological observation system at Barraquito.

- Continuous discharge measurement at the main river and main springs

  The Payabo river and main springs are significant water sources for the irrigation as well as for domestic use in the Study area. In the present condition, a few data is available for the estimation of water resources potential. For the purpose of clarifying the more exact amount of available water, it is necessary to observe the continuous discharge data at the main water source. Considering this aspect, the continuous observation of water level and discharge measurement at the main water sources should be recommended.

- Improvement of meteo-hydrological observation net work in Los Haitises

  The fluctuation of spring water discharge might be influenced by the meteo-hydrological conditions as well as by geological condition in Los Haitises. However, there aren't any meteo-hydrological observation stations in Los Haitises and quite a few data is available for clarifying the meteo-hydrological conditions in Los Haitises. For the purpose of analyzing the long term fluctuation of spring water discharge, the establishment of meteo-hydrological observation net work should be recommended.