2.2.2 Climate

There are several classifications of climate applied to Sergipe, such as Koppen, Gaussen, Leite and so on. In general, Sergipe is divided in three classes, semi-arid (Sertao), tropical sub-humid (Agreste) and tropical humid (Leste). Temperature ranging 18 ~ 36 °C shows hot climate, and humidity increases in the direction from inland to sea, ranging 55 ~ 87 %. Annual average rainfall varies from 550 mm to 1,650 mm depending on location but lower in the direction of inland. Annual variation of rainfall is also high. For example, the raingauge station at California irrigation project records 1,000 mm in 1989 but 270 mm in 1993. Wind velocity is categorized light to moderate, except along the coast where sea wind is strong.

In general, climate factors in Sergipe, except rainfall, are suitable for agricultural practices. Seasonal and spatial variations of rainfall require proper selection of crops and cropping calendar for rain-fed agriculture in the tropical humid and tropical sub-humid regions, while irrigation is necessary to grow most of crops in the semi-arid region. If annual fluctuation of rainfall is considered, irrigation should be promoted to ensure and increase productivity even in the tropical humid and tropical sub-humid regions.

Potential evapotranspiration or reference crop evapotranspiration (ETp) is another climate factor to examine necessity of irrigation. ETp was estimated by Penman-Monteith equation, using meteorological data from 7 stations described in Supporting Report C. FAO recommends Penman-Monteith equation as the presently best-performing combination equation instead of Modified Penman equation (traditional approach) which tends to overestimate ETp. The main difference in two equations is that Penman-Monteith equation takes account of stomatal resistance. Results of the estimate are shown in Table-2.2. ETp multiplied by crop coefficient is crop water requirement.

Table-2.2 Potential Evapotranspiration

	Station Name	California	Cotinguiba	Jacarecica	Piaui	Boquim	Jabiberi	Airport
	Altitude (EL. m)	207.0	7.1	161.0	160.0	164.0	177.0	9.5
	Latitude (degree)	9.70	10.27	10.73	10.93	11.14	11.08	10.98
	Longitude (degree)	37.82	36.85	37.33	37.65	37.62	37.95	37.07
	Data Available Year	89-97	90-95	89-97	90-97	75-97	89-97	85-97
		Potential Evapotranspiration (mm/month)						
Month	January	185	170	180	162	150	169	159
	February	169	150	159	143	127	151	143
	March	175	162	166	150	142	160	153
	April	135	127	122	118	108	120	126
	May	113	102	102	100	95	101	116
	June	92	87	85	80	82	81	104
	July	96	94	90	86	85	89	112
	August	120	104	104	97	96	101	117
	September	147	120	120	116	111	122	124
	October	186	144	158	149	136	160	144
	November	186	143	164	153	137	159	147
	December	187	165	178	170	145	173	150
	Total	1,791	1,568	1,628	1,524	1,414	1,586	1,595

Penman-Monteith equation was used in Potential Evapotranspiration calculations with the following values.
for Angstrom's Coefficients: a = 0.25 b = 0.5
degree: degree south for latitude and degree west for longitude
EL.: elevation above mean sea level, Data Available Year: year available for meteorological data
Notice: Sunshine duration was estimated by a relation between barometric pressure and temperature due to no data available for Cotinguiba and Airport.

Annual ETp in semi-arid, tropical sub-humid and tropical humid regions, are approximately 1,800 mm/year, 1,600 mm/year and 1,400 mm/year, respectively. Those figures are consistent with characteristics of climate. ETp decreases in the direction of sea. ETp at the airport is an exception because high wind speed along sea governs drying power of the air. Seasonal variation of ETp is distinct, high in December and January (a dry summer season), and low in June and July (a rainy winter season). This characteristic is applicable regardless of location.

2.2.3 Water Resources Quality

The Study Team conducted quality analysis of surface water and groundwater as discussed in Supporting Report D. Based on the analysis, available water resources for irrigation in terms of quality are summarized as follows.

1) Semi-Arid Region
Surface water, except Sao Francisco River, is contaminated by salt. FAO criteria classify surface water quality in this region as severe hazard in terms of salinity and specific iron toxicity. Groundwater is also not available due to salinity (refer to Supporting Report B). Therefore, water resource available for irrigation is only Sao Francisco River.

2) Tropical Sub-Humid Region
Surface water quality is mostly classified as moderate to severe hazard; however, good quality was observed in several rivers, such as Jabiberi, Fundo, Jacarecica and Vermelha rivers. Meanwhile, groundwater is not available due to quality, except some in the upper reaches of Vaza Barris and Piaui rivers and Boquim Micro-Region, where rate of fresh water is roughly 30 %.

3) Tropical Humid Region
Both surface water and groundwater have no restriction on use.

2.2.4 Sites for Future Irrigation Projects

330,800 ha of the state land have potential for irrigation in terms of soil properties and topographical features. Those areas were re-evaluated by climate and water quality discussed above to determine future irrigation sites by the year of 2020. The result is described in the following section.

1) Semi-Arid Region
One of crucial issues to determine irrigation sites is water resources. Since only Sao Francisco River is available, feasibility of irrigation projects depends on distance between project site and the river. Considering cost for conveyance of water and crop prices, future project sites should be near Xingo dam that has two conduits available for water supply of 20 m^3/s. On the other hand, to conduct water to other irrigable soils located far inland, Eutrophic Red Yellow Podzolic Soil (PE), would be not feasible.

2) Tropical Sub-Humid Region
Propria micro-region has 12,300 ha of irrigable land in terms of soil properties and topography; however, there are already 4 projects implemented and total area of the 4 projects (13,480 ha) exceeds the potential area. Therefore, it can be assumed that there is no area remained for new projects in the lower reaches of Sao Francisco River.

Surface water is available for irrigation only in several rivers, such as Jabiberi, Fundo, Jacarecica and Vermelha rivers, excluding Sao Francisco River. Soils in the upstream of those rivers, Red Yellow Podzolic Soil (PV) and Red Yellow Latosol (LV), have irrigation potential with low salinity, too. Therefore, irrigation is possible by means of water resources development near project sites, such as dam and weir, but area of irrigation is limited by cost of those structures and undulating land. For example, existing irrigation projects (Jabiberi, Pocao da Ribeira and Jacarecica) in those areas are relatively small compared to projects along Sao Francisco River. Meanwhile, some of groundwater with satisfactory quality is suitable for irrigation by individual farmers rather than project scale due to low expected yield.

3) Tropical Humid Region
Rainfall in this region is considered sufficient to grow crops currently cultivated, such as sugarcane, coconut, orange and banana. Orange out of those crops is possible to be irrigated because of higher price compared to other primary crops; however, research results show that orange production in this region can be improved by denser planting but not by irrigation. Therefore, irrigation will not be required as long as crops do not vary.

The overall evaluation of irrigation potential sites is summarized in Table-2.3.

Table-2.3 Irrigation Potential Sites

Watershed	Location	Climatic Region	Scale
Sao Francisco River	upper reaches near Xingo dam	semi-arid	large scale
Japaratuba River	middle reaches	tropical sub-humid	limited scale
Jacarecica River	lower reaches	tropical sub-humid	limited scale
Vaza Barris River	middle reaches	tropical sub-humid	limited scale
Piaui River	lower reaches	tropical sub-humid	limited scale
Real River	lower reaches	tropical sub-humid	limited scale

Irrigation is expected to play an important role in future agriculture in Sergipe; however, since irrigation is intensive agriculture, it requires large investment in facilities and materials. On the other hand, markets require competitive crop prices. Therefore, future project sites were selected from the potential sites by 1) minimizing investment especially water resources development and 2) considering applicability of profitable crops.

Since Xingo dam has two conduits available and the Study Team has proposed Vaza Barris dam for domestic and industrial waters, cost of water resources development can be minimized if irrigation water is conducted from those sources. Therefore, the Study Team proposes two projects, Sao Francisco and Vaza Barris irrigation projects. As a result of water requirement estimate, roughly 16,000 ha and 2,500 ha of lands are irrigable by intake from Xingo dam and Vaza Barris dam respectively.

Fruits for not only raw consumption but also agro-industry should be cultivated in Sao Francisco project because of favorable climate for fruits. Since Vaza Barris project has a good access to Aracaju, which is the largest consumer of agricultural products in Sergipe, cultivation of vegetables in most of land and fruits in steep land is recommended.

Proposed projects by COHIDRO and CODEVASF were also examined and Quixabeira, Ladeirinhas, Jacarecica II, Entre Rios and Estancinha were adopted as future irrigation projects. Factors considered for selection are soil, climate, water quality and possibility of water resources development. Although the study phase varies depending on the project, the further study is required to realize the projects.

Locations of future and existing irrigation projects are shown in Figure-2.2.

2.3 Water Demand for Irrigation

Crop water requirement (ETcrop) is a function of potential evapotranspiration (ETp) and crop coefficient (kc). Penman-Monteith equation was adopted to calculate ETp and kc was obtained from "FAO Irrigation and Drainage Paper 24".

Considering annual variation of rainfall, 75 % probability rainfall was adopted as dependable rainfall. Monthly rainfall for 30 years (1968 ~ 1997) was extracted from 29 rainfall stations selected in the hydrological analysis (refer to Supporting Report C). There are several methods suggested for rainfall probability analysis, such as log-normal, Gamma distribution and so on. Since particular interest of this study is only high frequency, rainfall more than 50 % probability was plotted to obtain regression lines.

Based on 75 % probability rainfall, effective rainfall (water stored in the root zone) was estimated by the relation between ETcrop and rainfall determined by U.S. Department of Agriculture ("FAO Irrigation and Drainage Paper 24"). Net irrigation requirement is obtainable by subtracting effective rainfall from ETcrop.

Since some of soils and waters in Sergipe have salinity problems, it is necessary to include leaching requirement in project water requirement. Leaching requirement is a function of salinity of irrigation water (salinity of water entering root zone) and crop salt tolerance level in the root zone (salinity of water draining from the root zone). Therefore, leaching is not required for projects whose water resources have very low salinity, such as Sao Francisco River. In the case that soils contain high salinity, underground drainage should be considered to collect drainage and prevent upward movement of water even if good quality of irrigation water is available.

Overall irrigation efficiencies adopted are 0.6 for a project consisting of conventional sprinkler and trickle irrigation, and 0.75 for a project of trickle irrigation. Overall irrigation efficiencies take account of conveyance efficiency (pipelines), field canal efficiency (open channel with concrete lining) and application efficiency (sprinkler and trickle irrigation).

Project water requirement is integrated value of net irrigation requirement, leaching requirement and irrigation efficiency. Project water requirements were estimated for proposed projects and results are shown in Table-2.4.

Hargreaves table (1985) is common to estimate irrigation requirement in Sergipe due to lack of meteorological data. Since the Study Team conducted meteorological analysis using the latest data, irrigation requirements of projects proposed by COHIDRO and CODEVASF were also estimated, based on JICA Study Team analysis. For the existing projects, original figures were adopted as project water requirement because irrigation facilities were already installed in accordance with those figures.

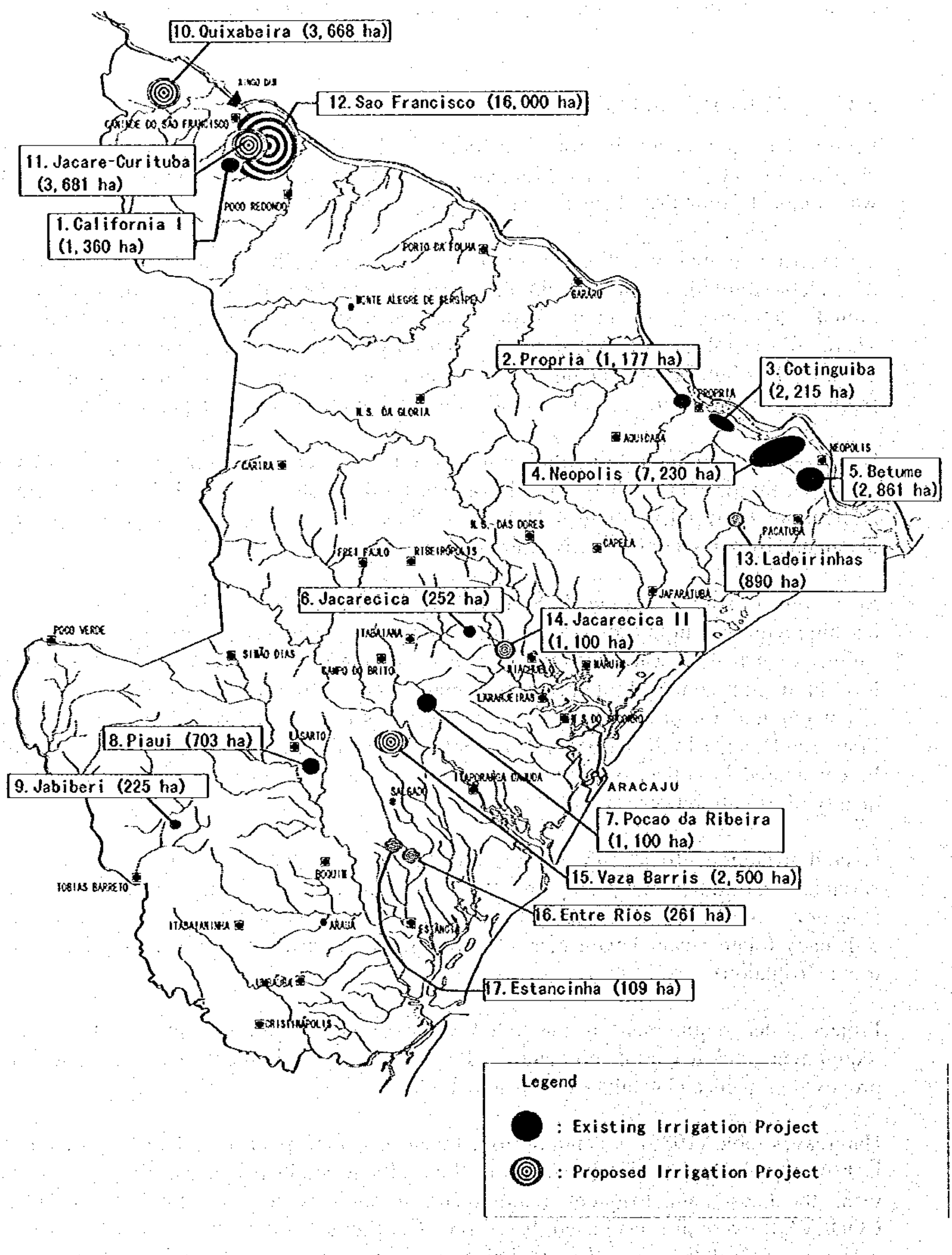


Figure-2.2 Existing and Future Irrigation Projects

Table-2.4 Water Demand of Existing and Future Irrigation Projects

Phase of Project	River Basin	No.	Project Name	Irrigation Area (ha)	Main Crops	Project Water Requirement at Source (m^3/ha/month)												Peak Requirement (million m^3/month)
						Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Existing	SF	1	California	1,360	fruit & vegetable culture	1,150	970	1,400	1,460	1,100	710	590	700	1,070	1,680	1,800	1,670	2.4
	SF	2	Propria	1,177	paddy rice (2 harvests)	2,624	2,368		1,568	880	1,008	1,104	1,696		2,448	2,448	2,592	3.1
	SF	3	Cotinguiba	2,215	paddy rice & vegetables	1,810	1,640	240	810	450	500	550	940	220	1,440	1,470	1,640	4.0
	SF	4	Neopolis	7,230	fruit culture	990	850	570	120			100	340	330	790	910	1,000	7.2
	SF	5	Betume	2,861	paddy rice	2,350	1,300	550	950	1,700	1,500	1,000	750	550	1,000	2,550	2,900	8.3
	Jac	6	Jacarecica	252	Vegetable culture	3,210	2,590	2,520	1,580	90				530	1,680	2,650	3,160	0.8
	VB	7	Pocao da Ribeira	1,100	Vegetable culture	690	810	1,420	870	180			80	310	1,650	2,960	2,020	3.3
	Piaui	8	Piaui	703	Vegetable culture	720	760	1,220	720	190			120	1,200	2,460	2,090	1,620	1.7
	Real	9	Jabiberi	225	fruit & vegetable culture	2,800	2,540	3,390	2,770	810	400	310	650	1,970	4,310	5,530	4,970	1.2
Propose	SF	10	Quixabeira	3,668	fruit & vegetable culture	1,550	730	550	250	750	0	0	0	480	1,300	1,730	2,150	7.9
	SF	11	Jacare-Curituba	3,681	fruit & vegetable culture	1,770	1,130	900	430	730	0	0	0	730	1,480	1,870	2,220	8.2
	SF	12	Sao Francisco	16,000	fruit culture	1,730	1,470	1,150	570	310	0	0	0	490	1,120	1,490	1,750	28.0
	SF	13	Ladeirinhas	890	fruit & vegetable culture	1,930	1,960	1,630	350	150	0	70	630	950	1,630	1,490	1,230	1.7
	Jac	14	Jacarecica II	1,100	fruit & vegetable culture	1,900	1,700	2,300	1,530	700	0	0	0	830	2,180	2,470	2,670	2.9
	VB	15	Vaza Barris	2,500	Vegetable culture	1,400	1,030	1,630	830	470	0	1,520	0	430	2,070	2,630	3,120	7.8
	Piaui	16	Entre Rios	261	fruit & vegetable culture	1,850	1,470	780	0	30	630	0	150	450	730	1,300	1,770	0.5
	Piaui	17	Estancinha	109	fruit & vegetable culture	1,320	930	780	270	0	900	0	430	1,180	1,530	1,150	1,400	0.2

SF: Sao Francisco River, Jac: Jacarecica River, VB: Vaza Barris River
Figures for existing projects: adopted from individual report
Figures for proposed projects: estimated by JICA Study Team
Sao Francisco and Vaza Barris projects: proposed by JICA Study Team
Other proposed projects: adopted from COHIDRO and CODEVASF proposals

2.4 Water Demand for Livestock

As mentioned in projection of future agriculture, livestock population depends on market but average population will be maintained. With this assumption, livestock population in 2020 was estimated as follows, and successively water demand for livestock was calculated. Since the latest year of livestock population data is 1995, it was assumed that the current population (1997) is equal to that in 1995. Cattle, poultry, pig, sheep and goats are major water consumers in Sergipe.

	1997	2020
Cattle	797,000 heads	1,000,000 heads
Poultry	3,041,000 heads	3,100,000 heads
Pig	99,000 heads	100,000 heads
Sheep & Goats	175,000 heads	200,000 heads

Natural pasture contains as much as 80 % of weight as water during the growth period. Therefore, amount of water (liquid phase) supplied to herbivores is a part of total water requirement, which cannot be provided by moisture content of pasture. Pallas Ph. ("Water for Animals", FAO, 1986) estimated the total water requirement and actual water intake of cattle under Saharan conditions. Cattle of 0.7 TLU (Tropical Livestock Unit, 1 TLU = 250 kg live weight) consumes 27 liter/day in total during the wet season; however, within 27 liter/day, 10 liter/day (37 %) is consumed as liquid water. Therefore, it is necessary to consider water intake by means of pasture to estimate water demand of herbivores, such as cattle, sheep and goats,

According to EMBRAPA, the following assumptions can be applied to livestock in Sergipe.

1) Livestock requires dry matter (food) at the rate of 3 % of live weight/day and 3.5 kg ~ 8.5 kg of water/kg of dry matter consumption.
2) 40 % of total water requirement is supplied by pasture.
3) Average livestock weights over whole population are 250 kg for cattle, 40 kg for pigs, 15 kg for sheep and goats, and 1 kg for poultry.

With the assumptions above, water consumption in liquid phase was calculated.

Cattle:	dry matter consumption	250 kg x 0.03 = 7.5 kg
	water consumption	7.5 kg x 5 kg of water = 37.5 kg
	liquid water intake	37.5 x 0.6 = 22.5 kg = 22.5 litters

Since pigs and poultry are not herbivores, it was assumed that there is no water intake by means of food. For the calculation sake, the following figures were adopted.

Cattle:	25 liter/day
Pigs:	5 liter/day
Sheep and Goats:	1.5 liter/day
Poultry:	0.2 liter/day

Current and future water consumption of livestock was estimated by multiplying population by the above rates. As shown in Table-2.5, total water consumption by livestock in 1997 is approximately 21,290 m^3/day and it will increase to 26,430 m^3/day in 2020. Increment is about 24 %.

Table-2.5 Water Demand of Livestock

	Division	Cattle (1995)	Poultry (1995)	Pigs (1995)	Sheep/ Goat (1995)	Cattle (2020)	Poultry (2020)	Pigs (2020)	Sheep/ Goat (2020)
Livestock Population (1,000 heads)									
Micro-region	Sergipana do Sertao do Sao Francisco	131	384	13	12	164	393	14	14
Micro-region	Carira	51	70	3	3	63	71	3	4
Micro-region	Nossa Senhora das Dores	66	83	2	2	83	85	2	3
Micro-region	Agreste de Itabaiana	37	330	6	4	46	336	6	4
Micro-region	Tobias Barreto	75	336	24	86	94	342	25	99
Micro-region	Agreste de Lagarto	95	364	28	37	119	371	29	42
Micro-region	Propria	33	46	4	2	41	47	4	2
Micro-region	Cotinguiba	53	143	1	1	66	145	1	1
Micro-region	Japaratuba	41	78	1	3	51	79	1	3
Micro-region	Baixo Cotinguiba	35	175	1	1	44	178	1	2
Micro-region	Aracaju	15	276	1	1	19	281	1	1
Micro-region	Boquim	104	200	10	18	130	204	10	21
Micro-region	Estancia	64	558	3	4	80	568	3	4
River basin	Sao Francisco	187	446	16	15	233	456	18	17
River basin	Japaratuba	95	168	3	4	120	171	2	5
River basin	Sergipe	125	673	9	7	156	685	7	8
River basin	Vaza Barris	80	530	12	13	100	539	13	14
River basin	Piaui	212	961	39	60	266	979	40	69
River basin	Real	99	264	20	77	124	270	21	88
	State Total	797	3,041	99	175	1,000	3,100	100	200
Water Demand (1,000 m^3/day)									
Micro-region	Sergipana do Sertao do Sao Francisco	3.275	0.078	0.067	0.019	4.100	0.079	0.070	0.023
Micro-region	Carira	1.263	0.014	0.016	0.006	1.575	0.014	0.015	0.008
Micro-region	Nossa Senhora das Dores	1.653	0.018	0.009	0.004	2.075	0.018	0.010	0.006
Micro-region	Agreste de Itabaiana	0.918	0.065	0.027	0.005	1.150	0.066	0.030	0.006
Micro-region	Tobias Barreto	1.863	0.067	0.122	0.130	2.350	0.068	0.125	0.149
Micro-region	Agreste de Lagarto	2.367	0.072	0.141	0.055	2.975	0.074	0.145	0.064
Micro-region	Propria	0.824	0.008	0.023	0.002	1.025	0.008	0.020	0.004
Micro-region	Cotinguiba	1.320	0.028	0.006	0.001	1.650	0.028	0.005	0.002
Micro-region	Japaratuba	1.013	0.015	0.006	0.004	1.275	0.015	0.005	0.005
Micro-region	Baixo Cotinguiba	0.868	0.034	0.006	0.001	1.100	0.035	0.005	0.004
Micro-region	Aracaju	0.386	0.055	0.005	0.002	0.475	0.056	0.005	0.002
Micro-region	Boquim	2.588	0.040	0.049	0.028	3.250	0.040	0.050	0.034
Micro-region	Estancia	1.590	0.111	0.016	0.006	2.000	0.113	0.015	0.008
River basin	Sao Francisco	4.667	0.087	0.084	0.021	5.834	0.090	0.089	0.028
River basin	Japaratuba	2.379	0.034	0.012	0.002	3.003	0.033	0.011	0.009
River basin	Sergipe	3.128	0.134	0.042	0.008	3.914	0.136	0.034	0.015
River basin	Vaza Barris	2.003	0.105	0.058	0.021	2.501	0.108	0.064	0.023
River basin	Piaui	5.290	0.192	0.194	0.092	6.656	0.194	0.199	0.108
River basin	Real	2.462	0.053	0.103	0.115	3.101	0.053	0.105	0.134
	State Total	19.93	0.61	0.49	0.26	25.00	0.61	0.50	0.32

(1995): Figures denote year

APPENDIX-1

Probable Rainfall

Appendix-1 Probable Rainfall

75% probability rainfall was applied to estimate irrigation requirement of proposed projects. Since 8 proposed projects belong to 9 Thiessen polygons out of 29 determined by the hydrological analysis, the probability rainfalls were calculated only for those 9 rainfall stations.

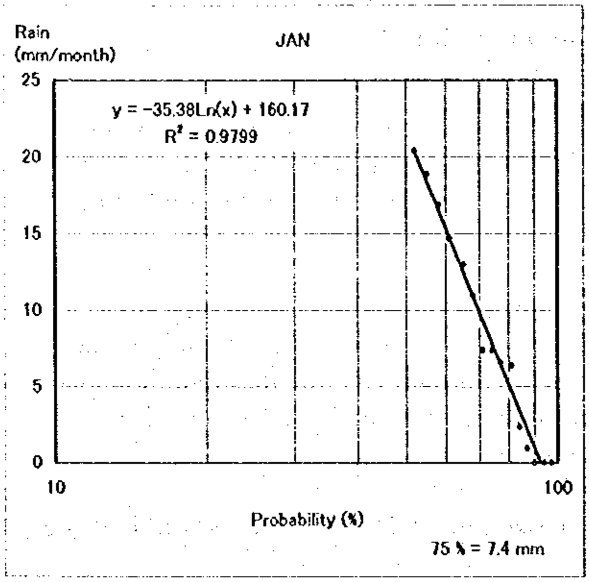
Monthly rainfalls in the last 30 years (1968~1997) were arranged in descending order and plotting position of each rank of rainfall was calculated. There are several methods suggested for rainfall probability analysis such as log-normal, Gamma distribution and so on. Since high frequency is a particular interest, rainfalls more than 50% probability were plotted on log-normal paper in order to obtain regression line.

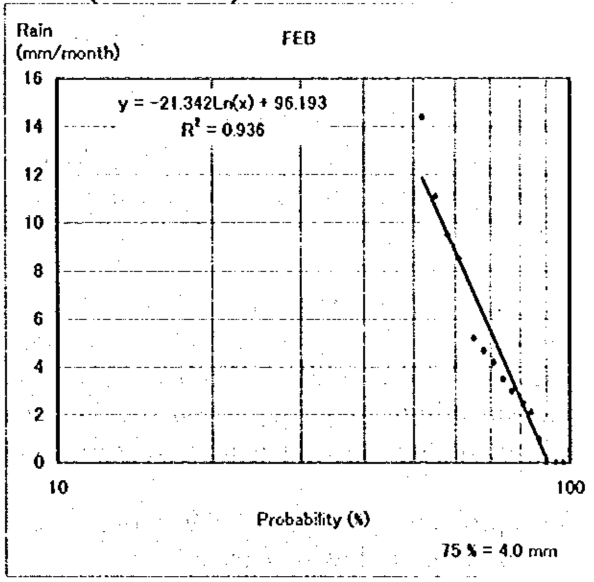
75% probability rainfalls for 9 stations are summarized in Table-1 and regression lines are shown in the following pages.

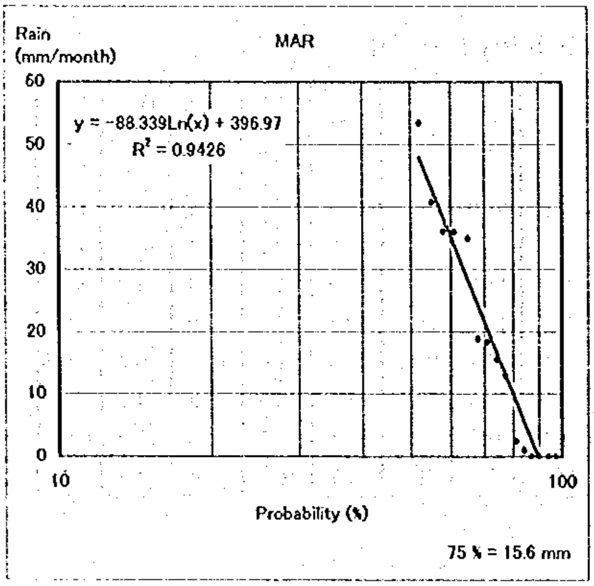
Table-1 75% Probability Rainfall

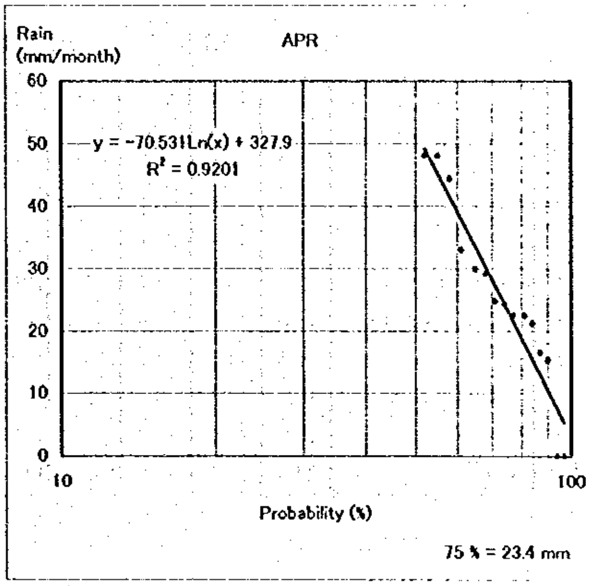
No.	Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1	Caninde de Sao Francisco	7.4	4.0	15.6	23.4	23.6	34.3	31.9	15.2	6.1	0.8	0.2	2.7	165.2
8	Propria	6.2	4.1	24.9	37.4	52.5	76.4	58.0	29.1	14.4	3.3	2.8	5.2	314.3
13	Lagarto	14.7	15.5	41.5	78.0	75.0	107.1	85.4	50.4	18.9	8.1	11.1	10.3	516.0
16	Campo do Brito	12.9	14.6	25.2	72.0	101.0	128.1	113.5	77.0	27.4	4.4	8.4	4.2	588.7
17	Santa Rosa de Lima	11.6	12.4	34.6	57.1	95.5	120.7	118.7	78.9	39.4	7.9	4.9	5.1	586.8
18	Belem	16.6	14.5	44.7	113.2	119.4	156.0	141.1	93.2	47.6	11.4	14.0	6.2	777.9
21	Tobias Barreto	10.2	11.3	29.5	36.6	33.6	52.9	48.6	23.1	13.5	2.5	1.3	14.5	277.6
9	Pacatuba	10.5	14.5	51.7	97.0	103.4	130.9	102.1	57.6	32.1	7.1	8.2	7.0	622.1
28	Estancia	24.0	28.3	57.6	108.2	149.6	164.5	137.8	91.0	47.7	16.9	18.4	14.5	858.5

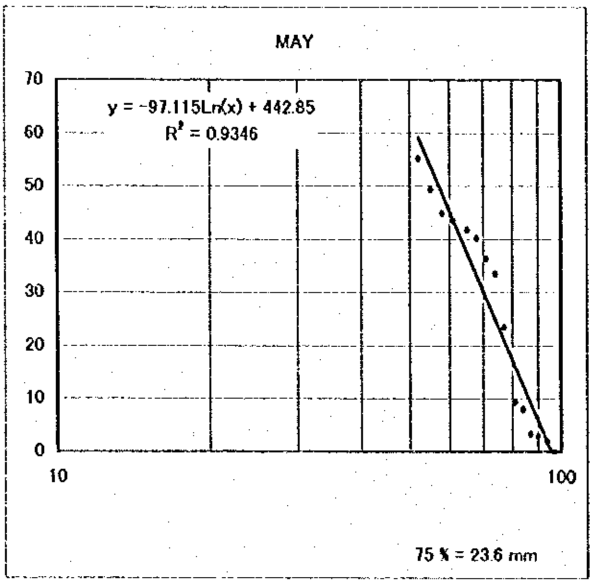
Canindc de Sao Francisco (1968-1997)

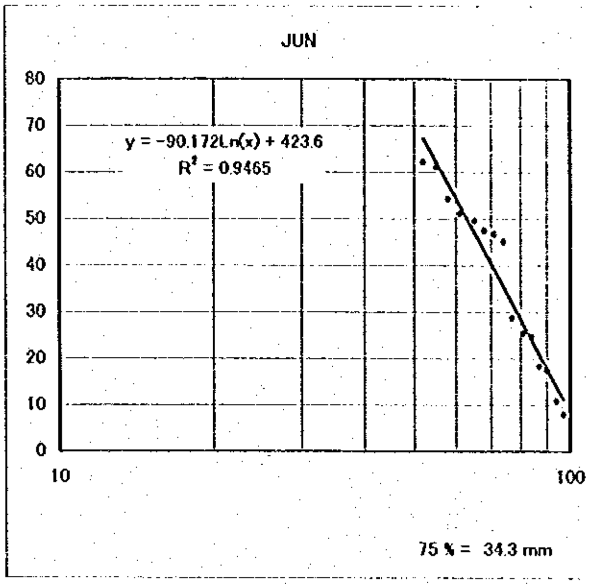




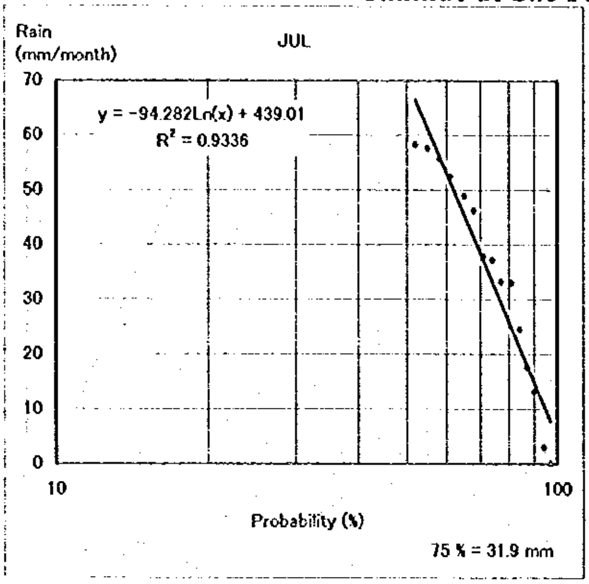


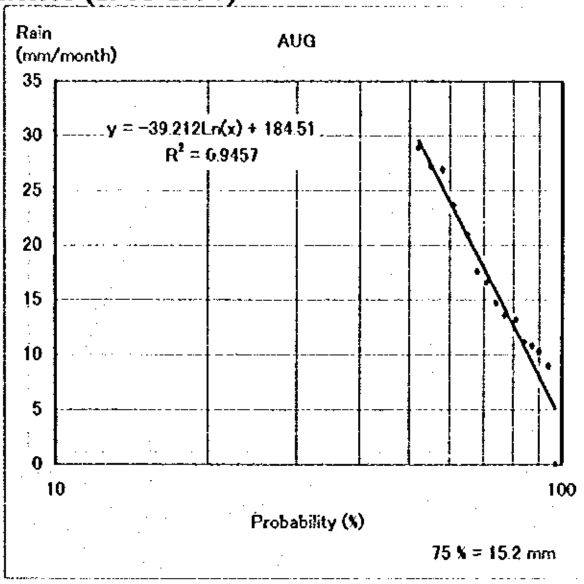


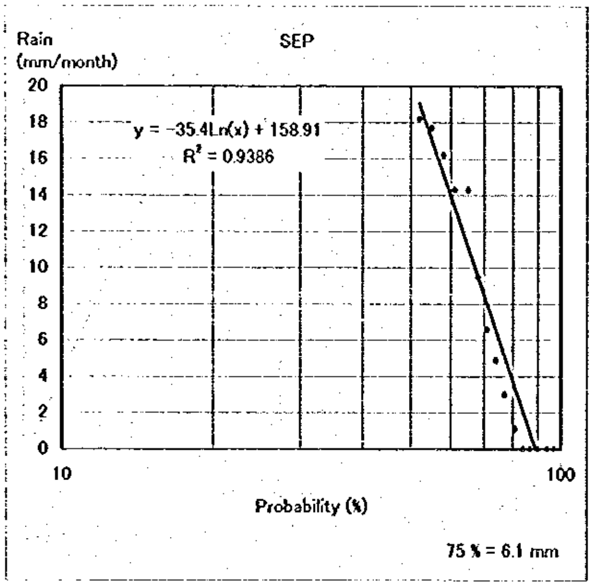


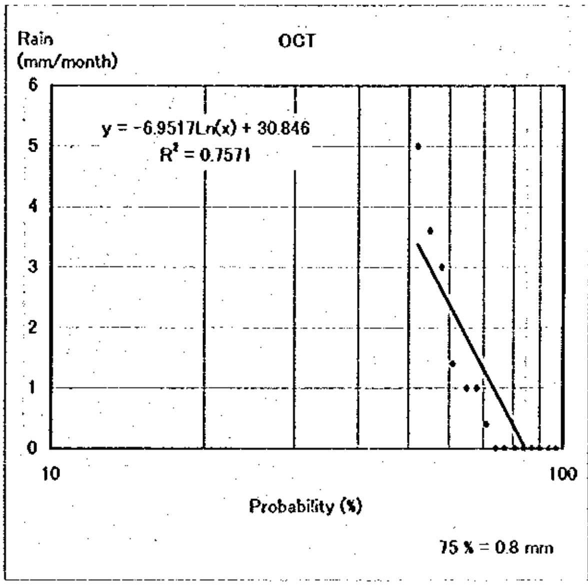


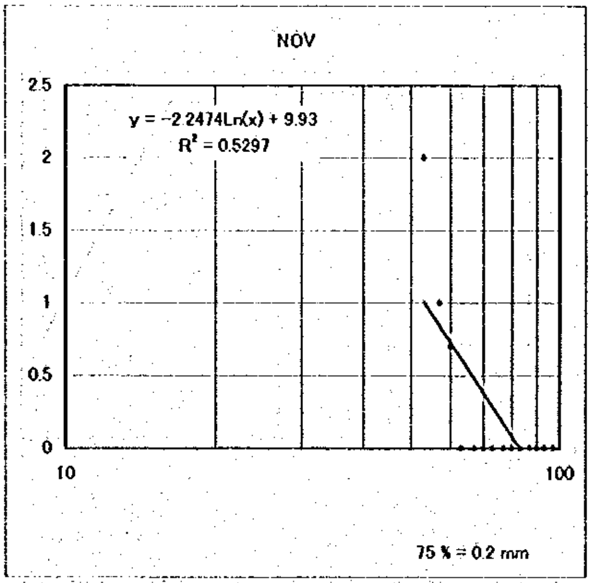
Caninde de Sao Francisco (1968-1997)

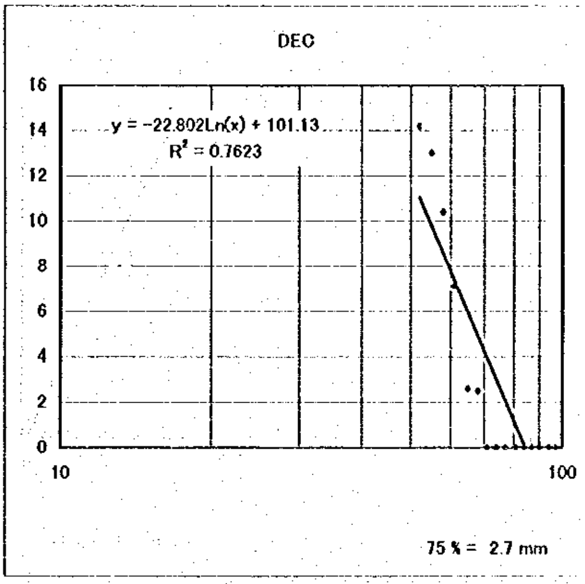




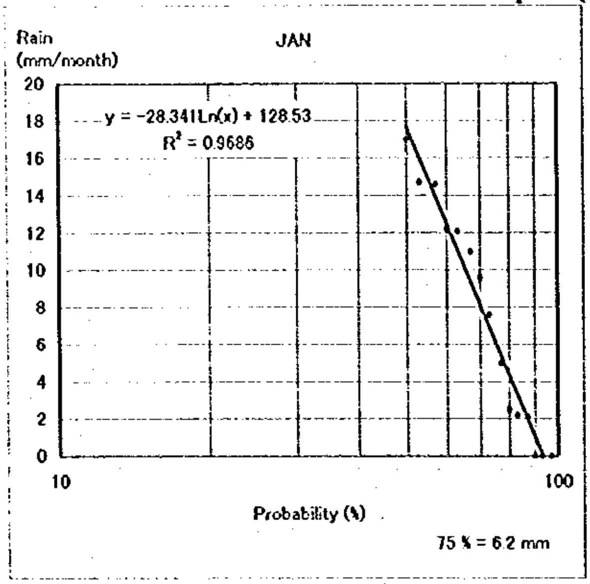


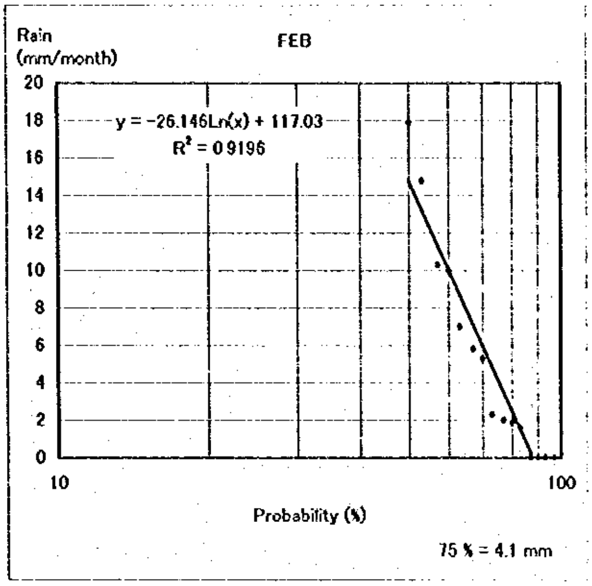


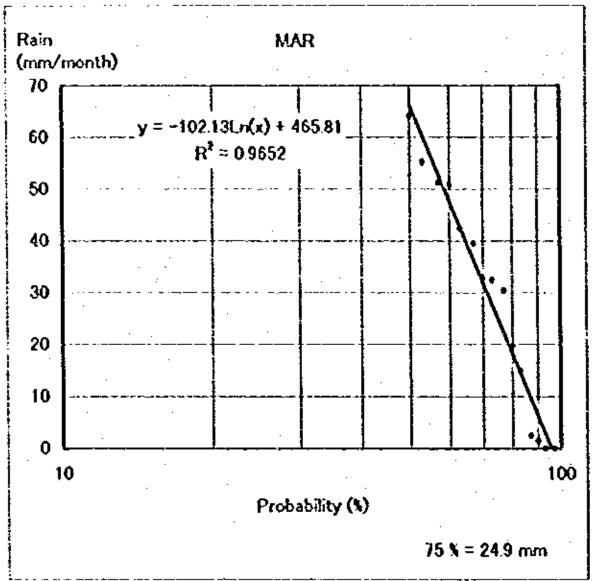


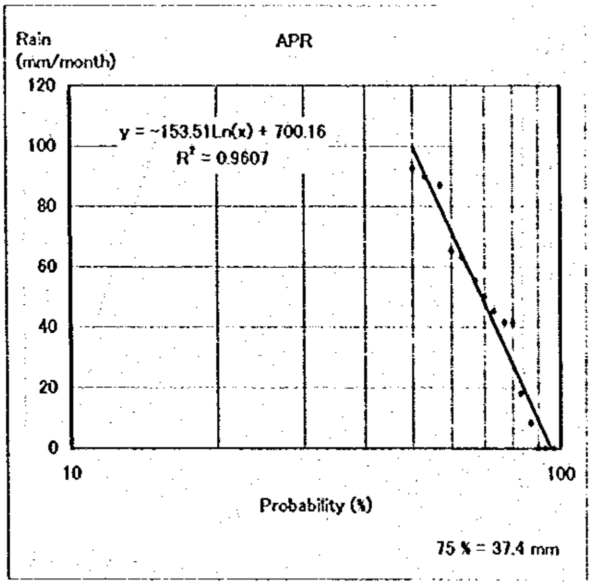


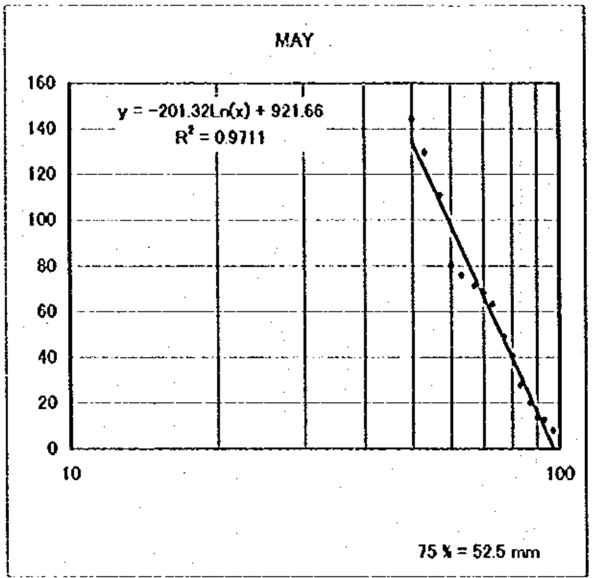
Propria (1968~1997)

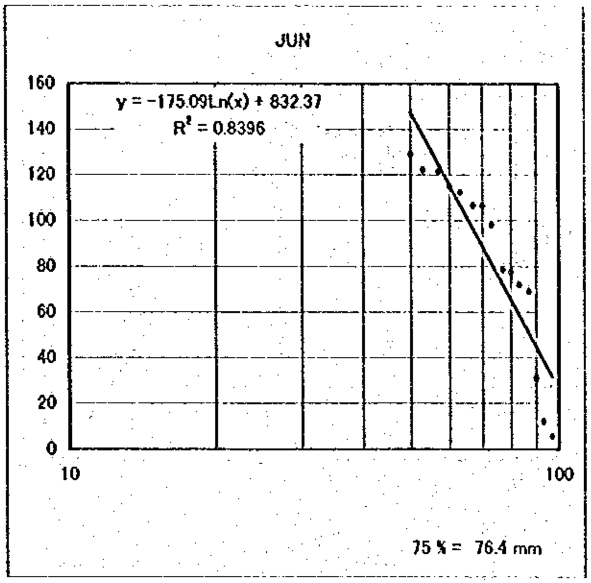












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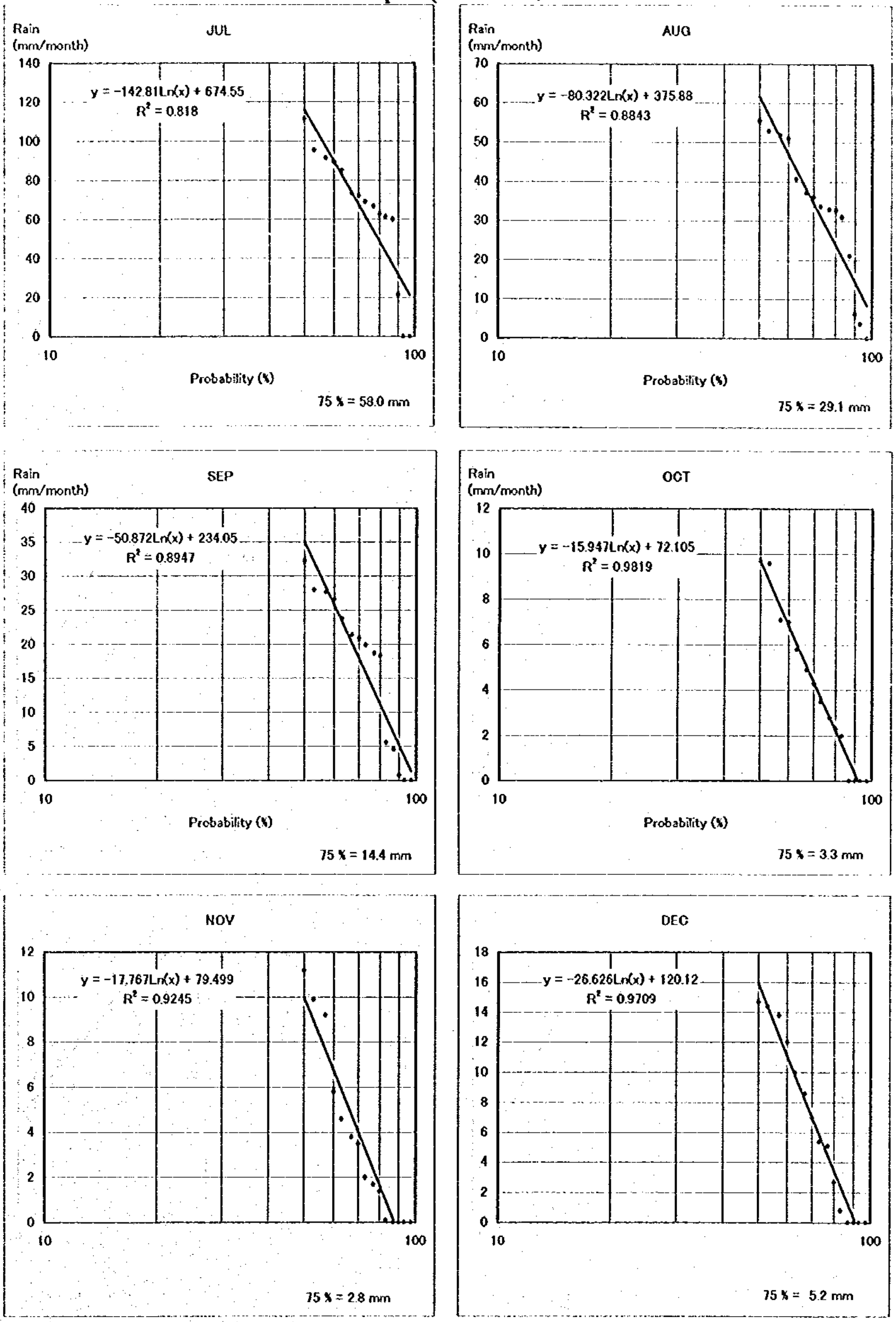
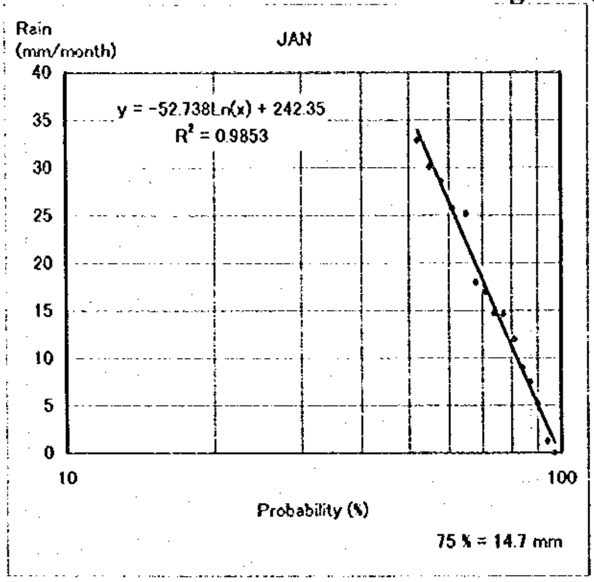
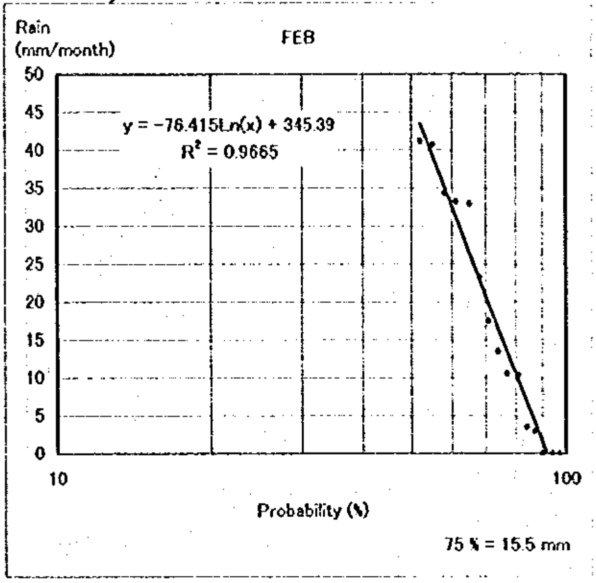
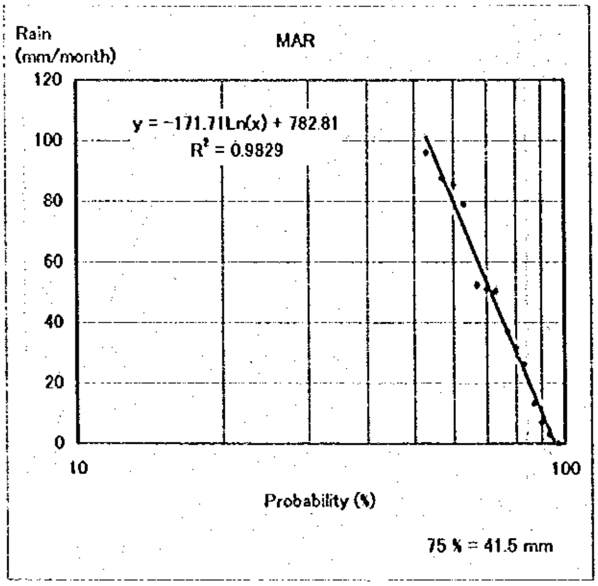
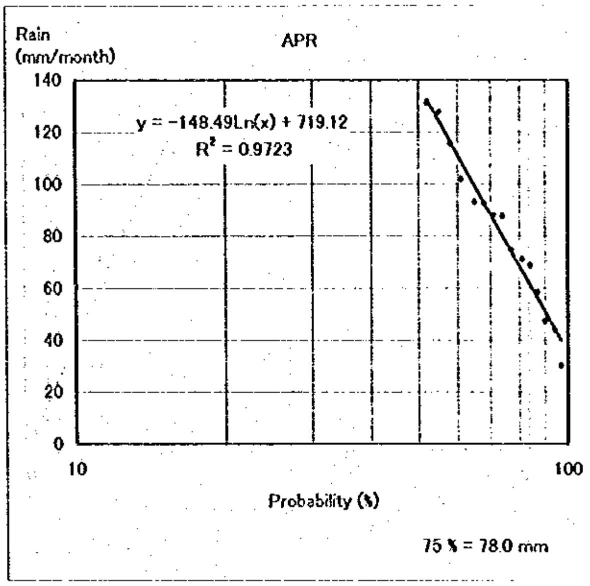


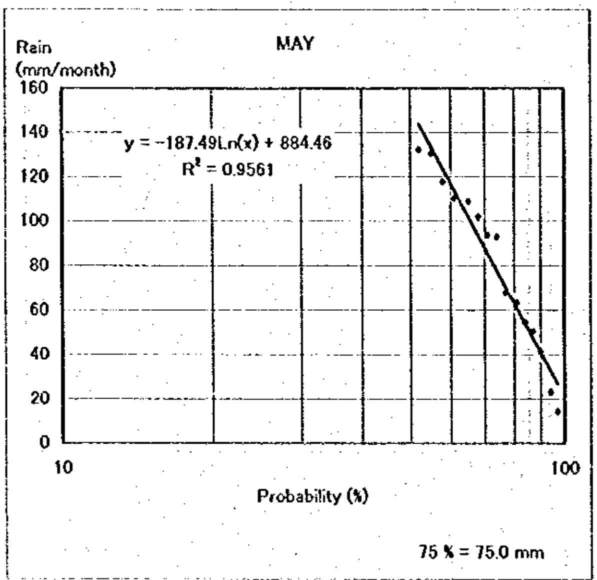
Lagarto (1968-1997)

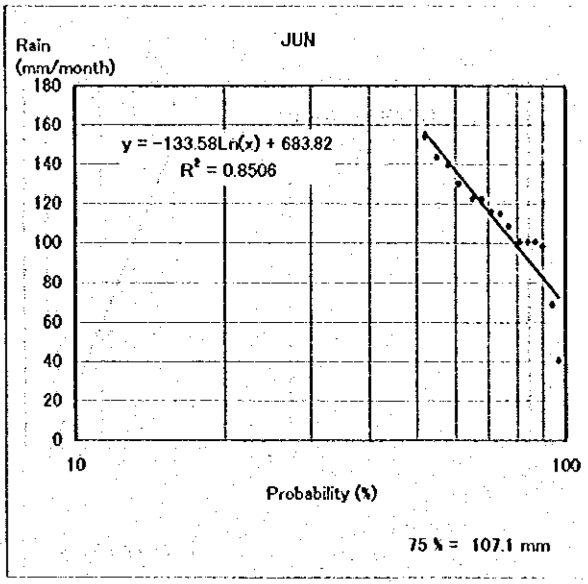












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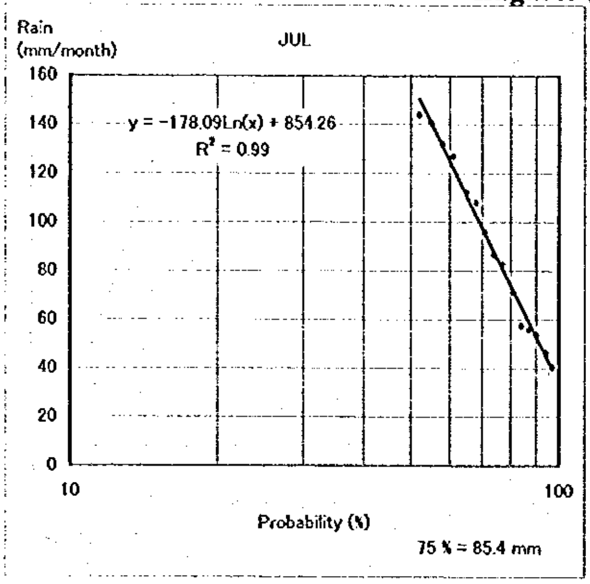

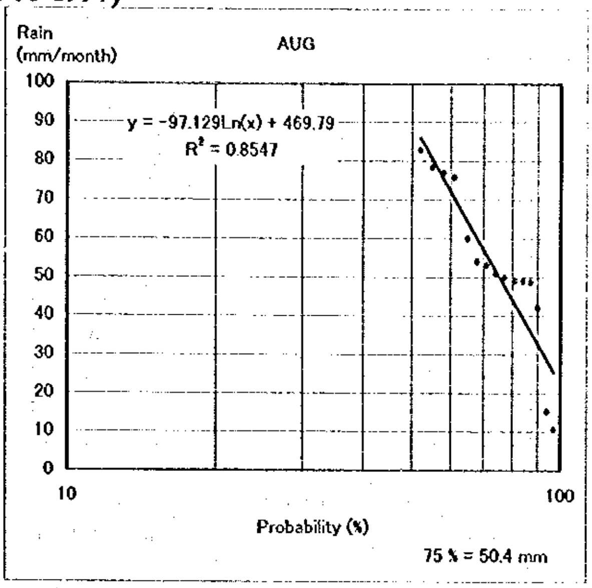

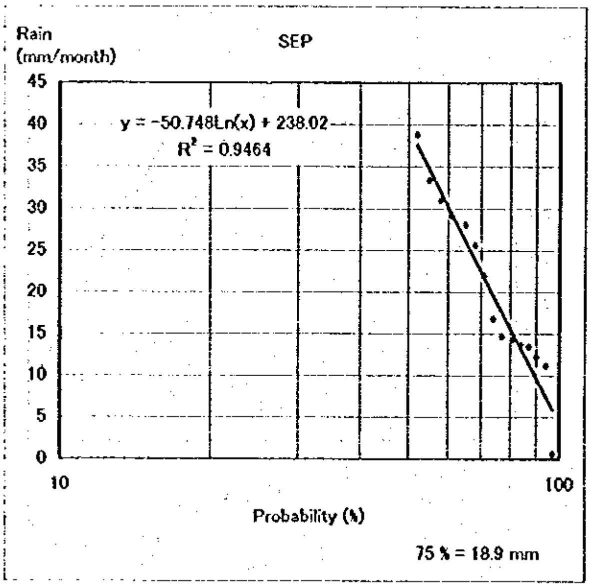

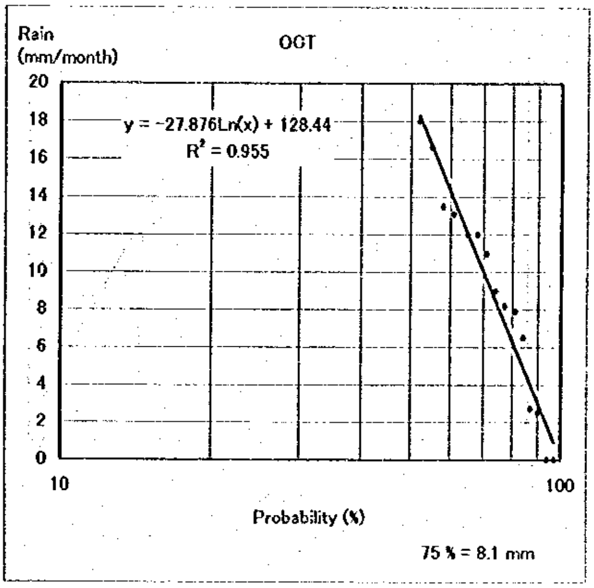

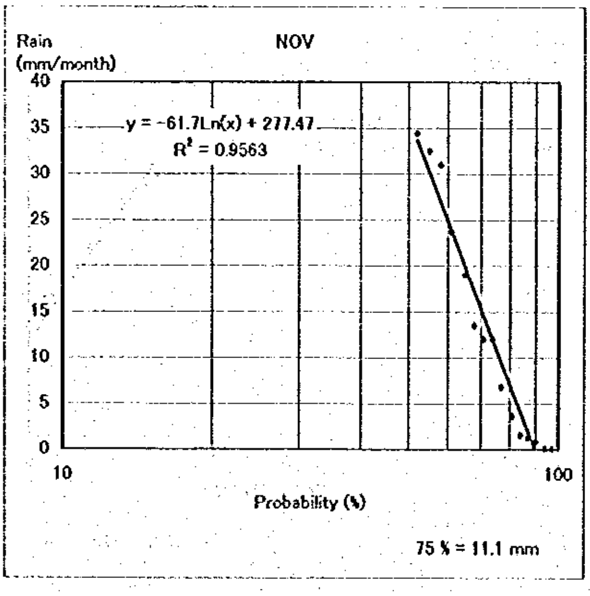

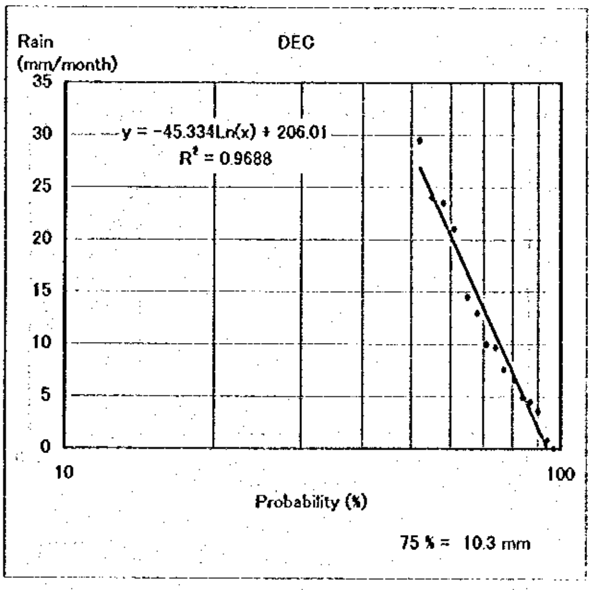

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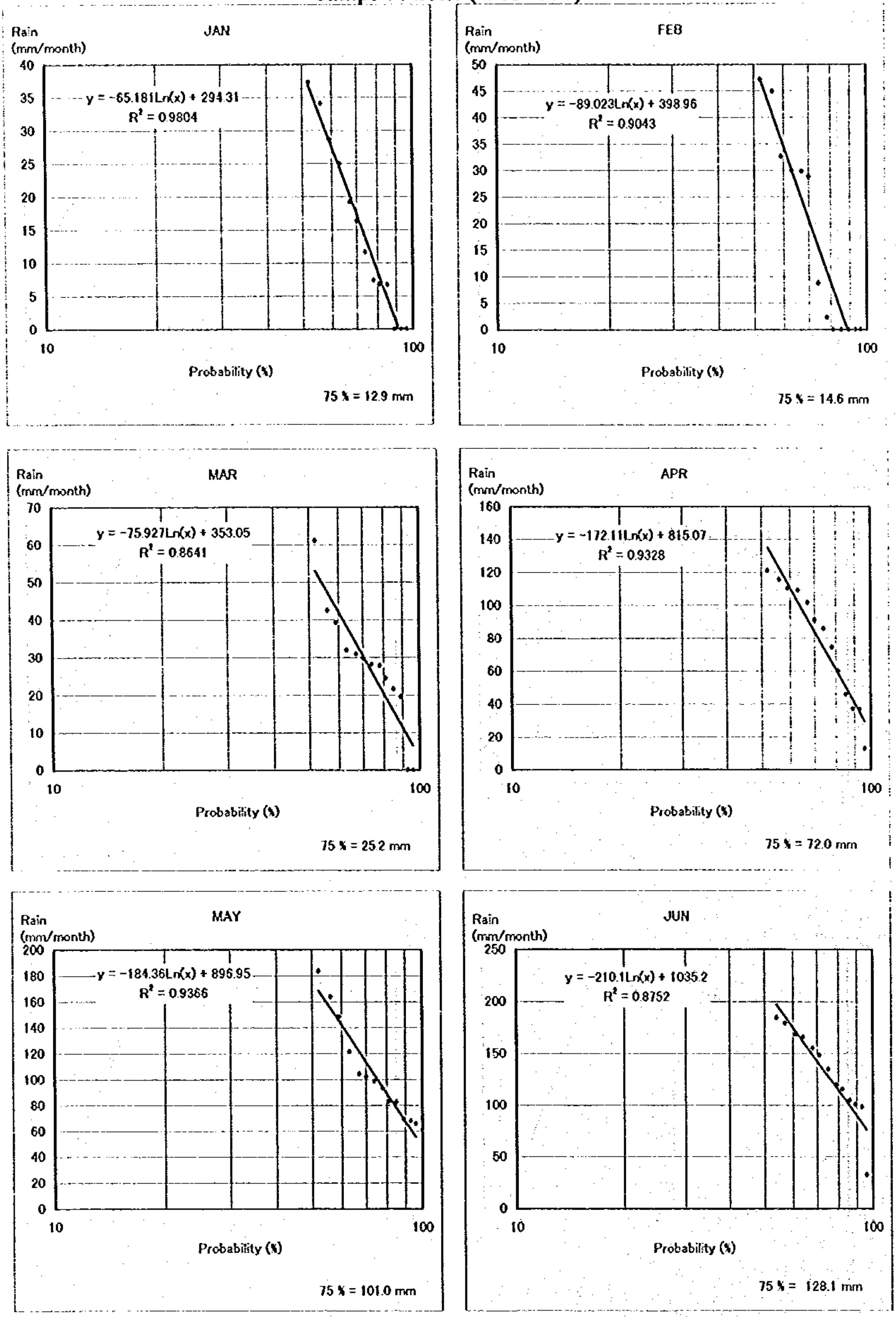

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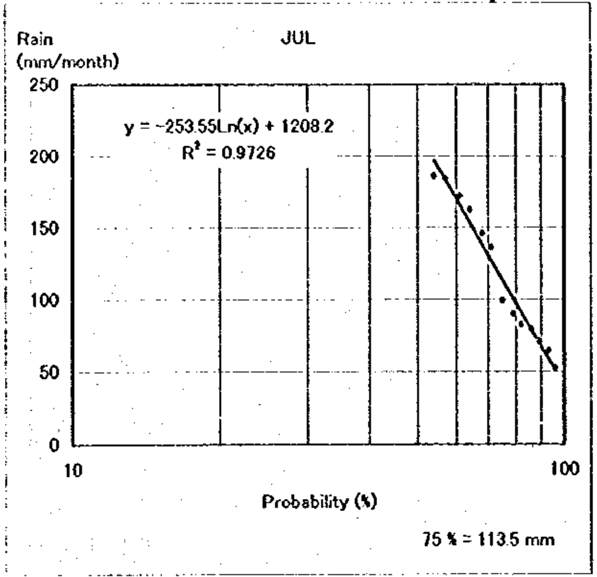
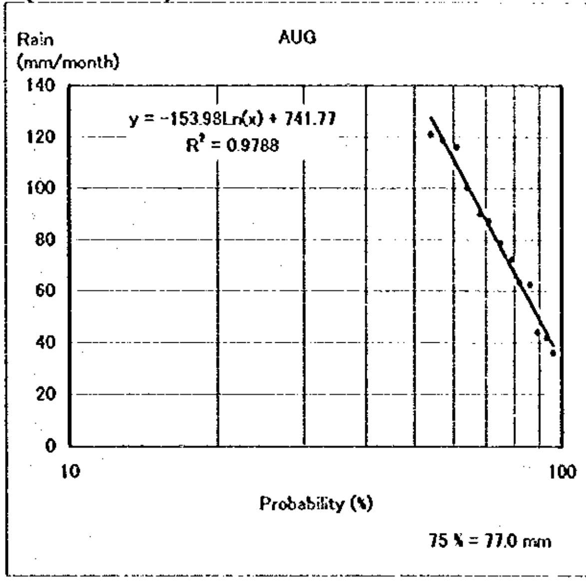
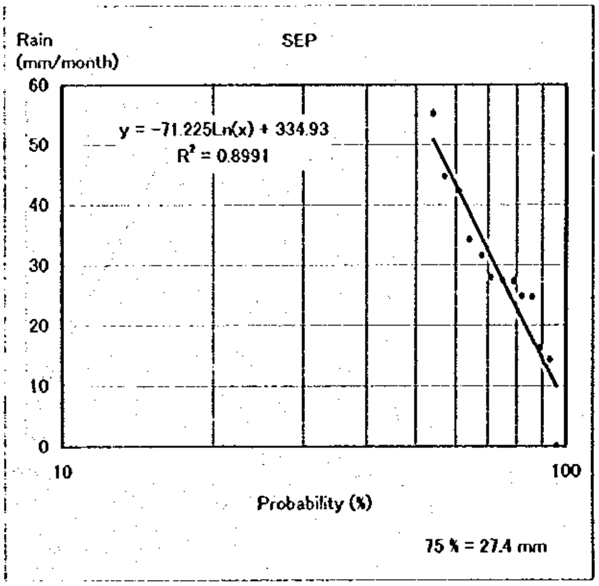
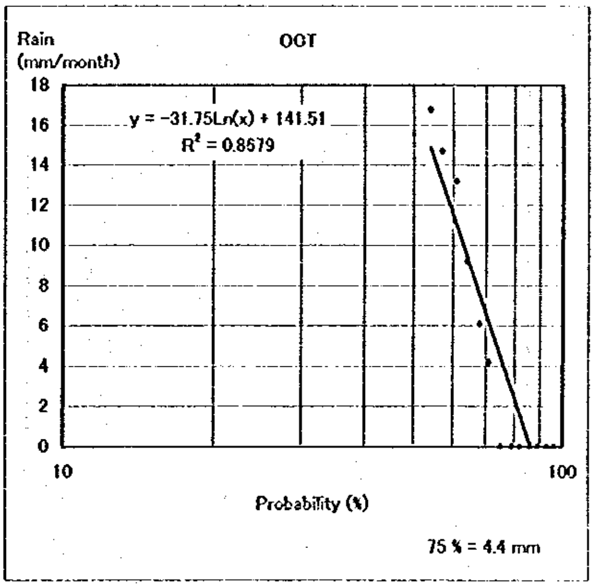
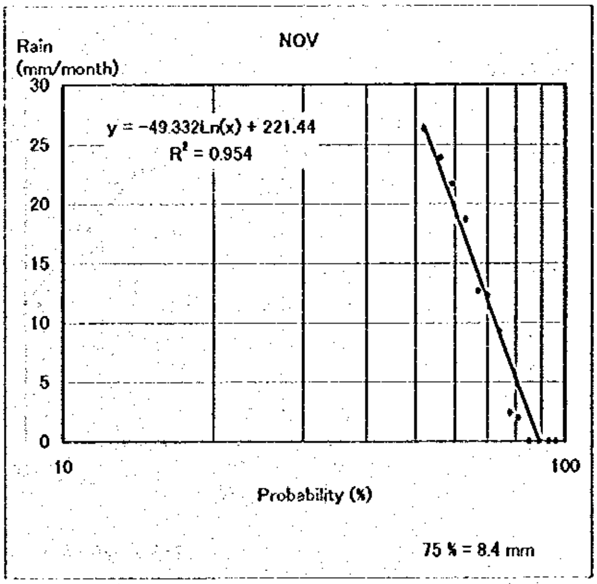
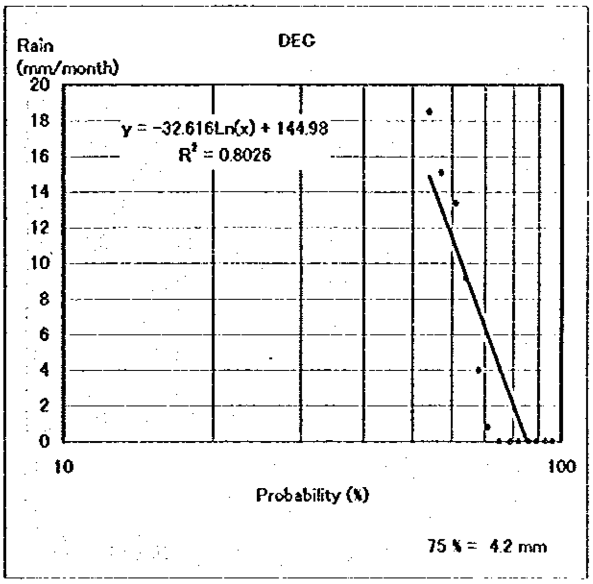




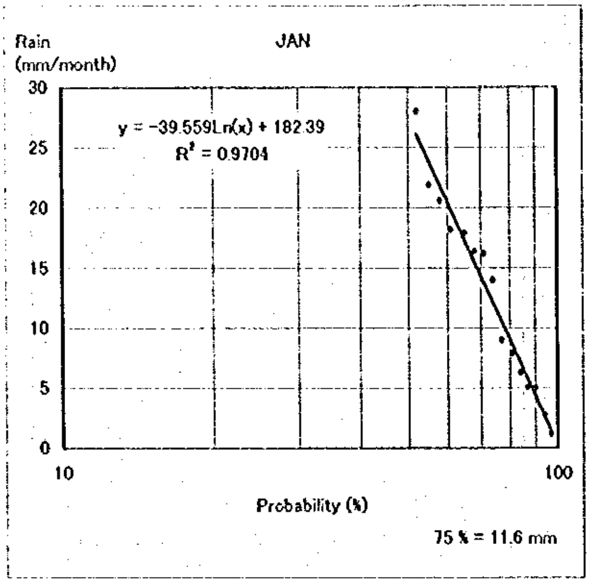


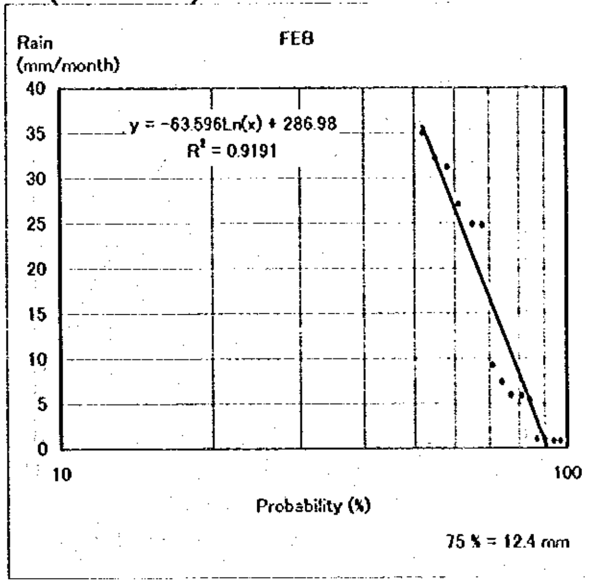


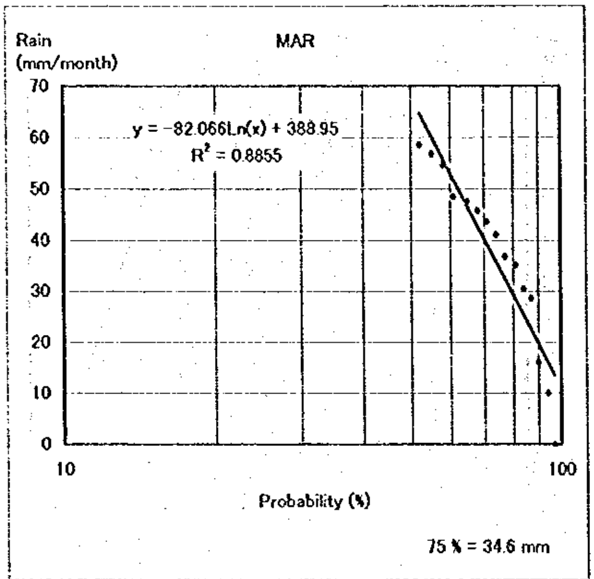


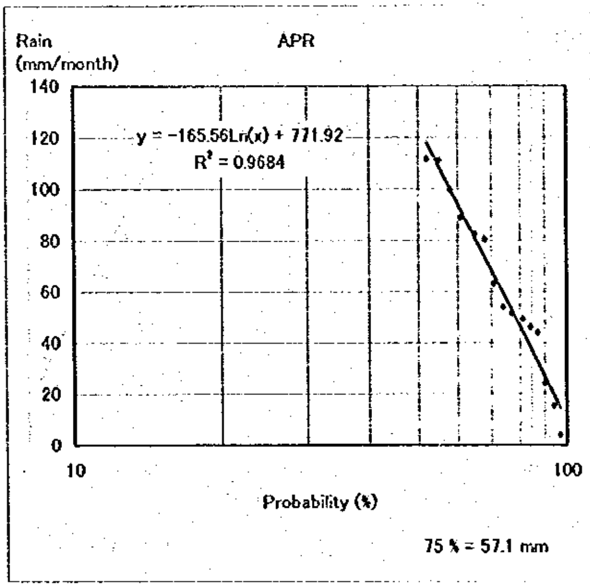


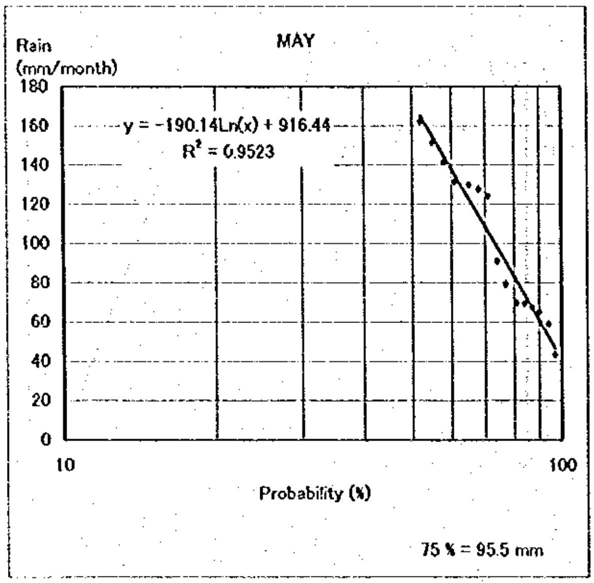
Santa Rosa de Lima (1968-1997)

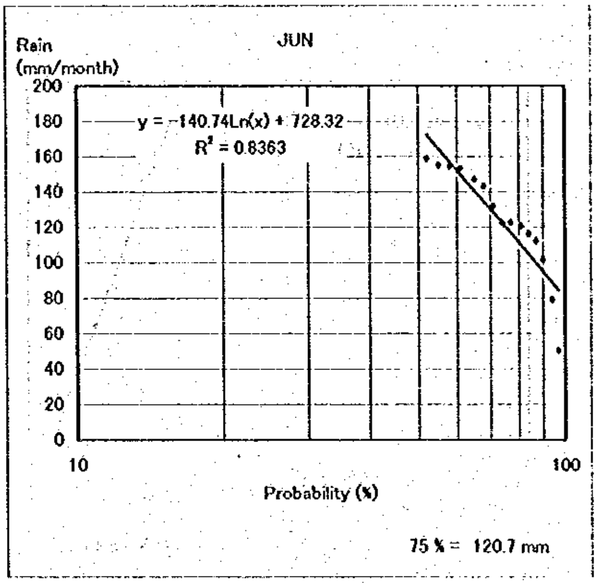




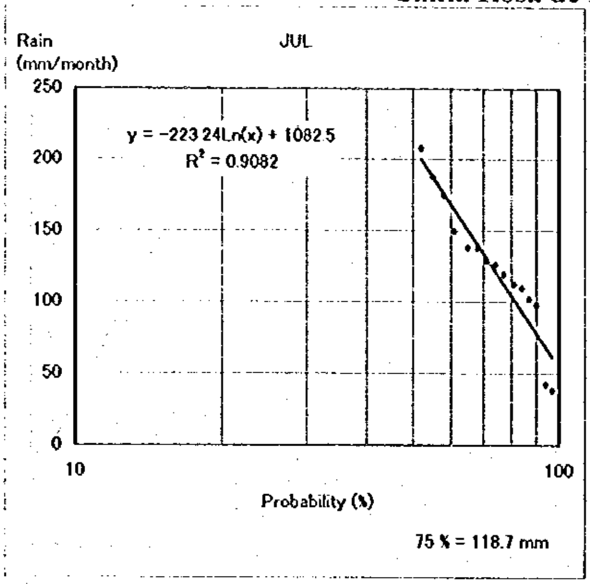


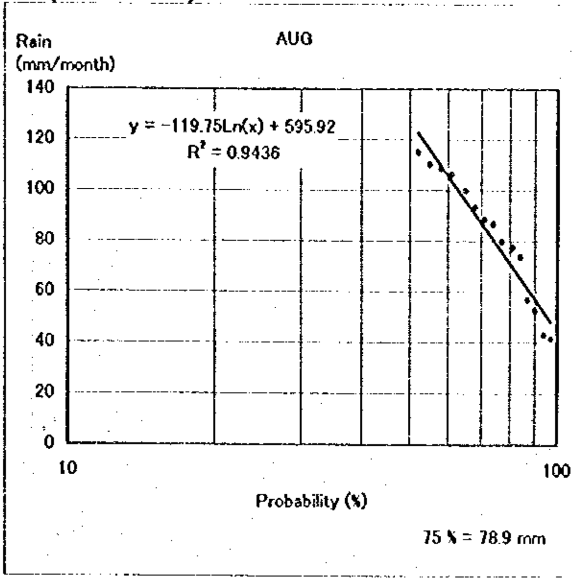


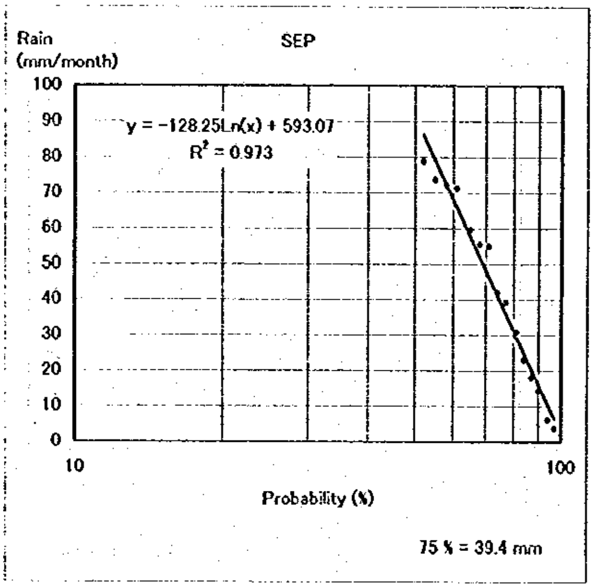


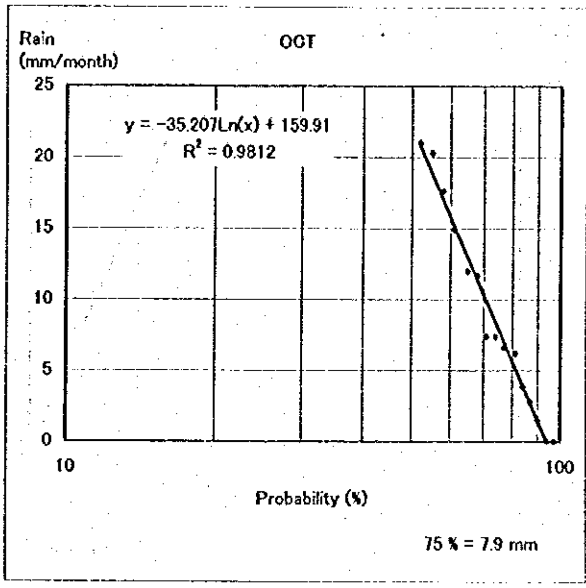


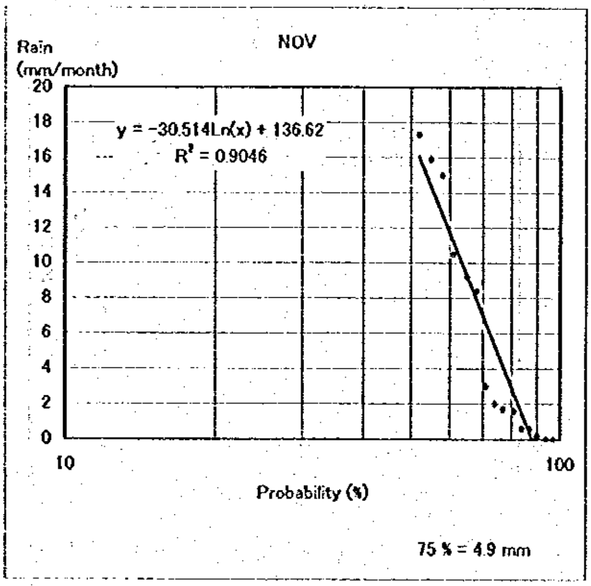
Santa Rosa de Lima (1968-1997)

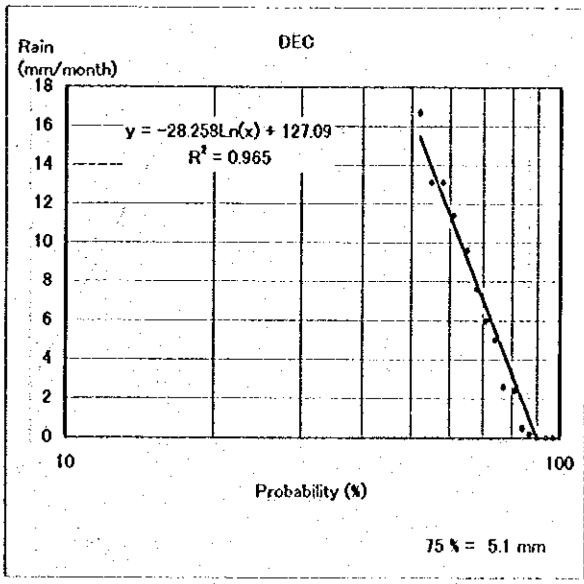




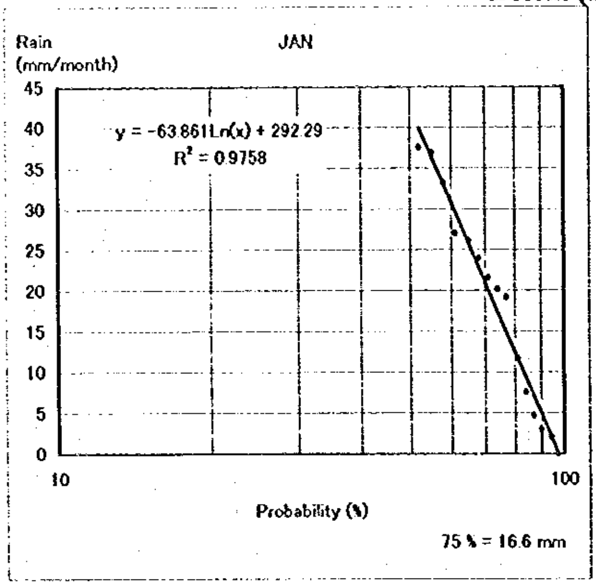


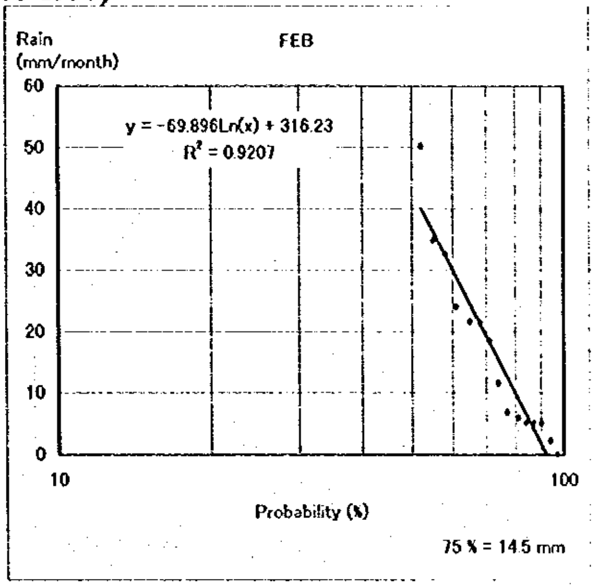


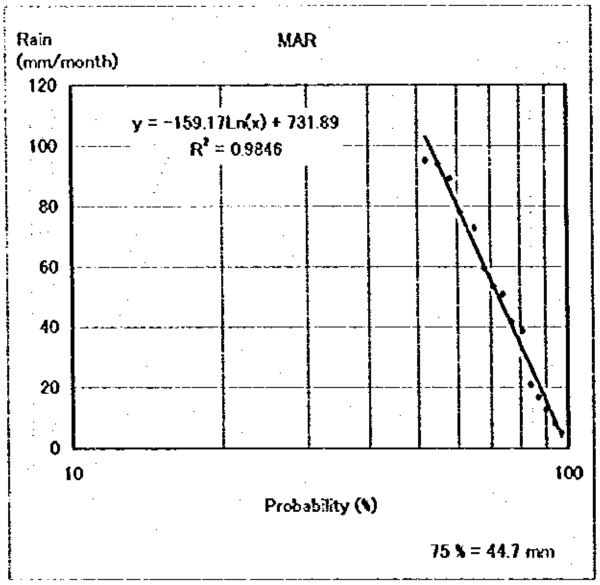


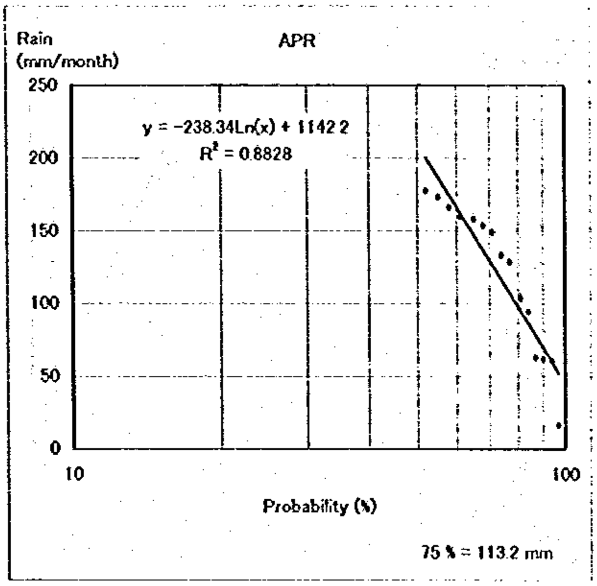


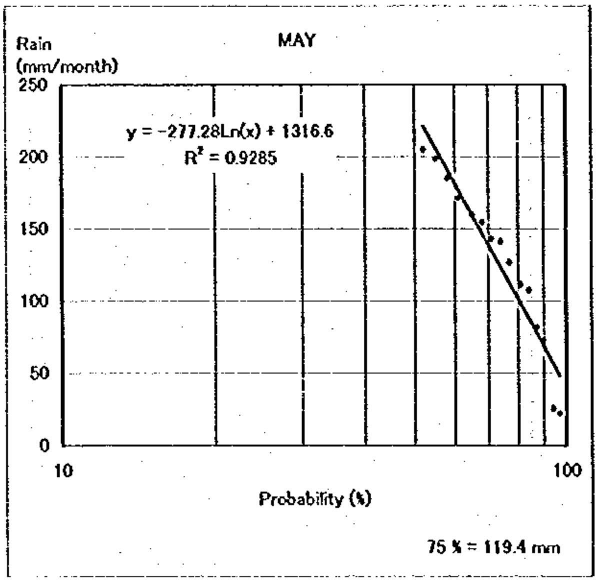
Belem (1968-1997)

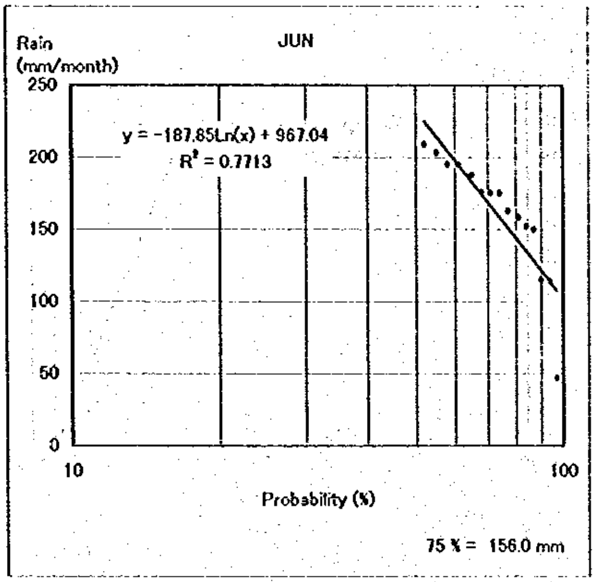












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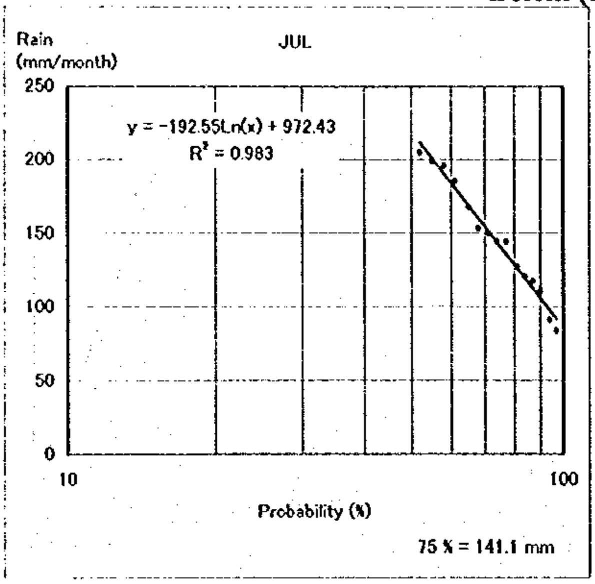
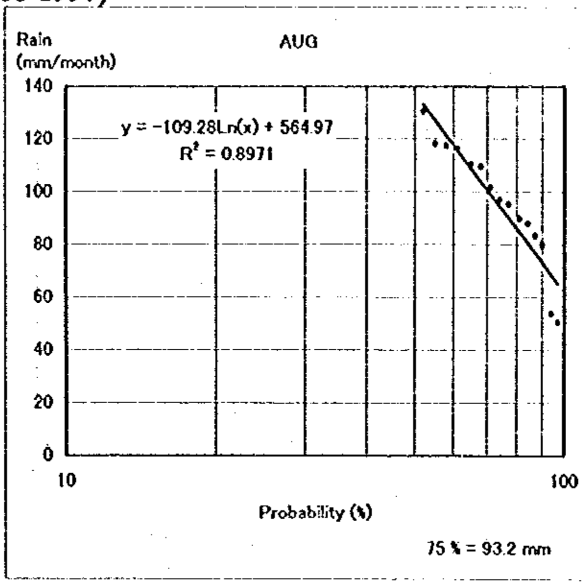
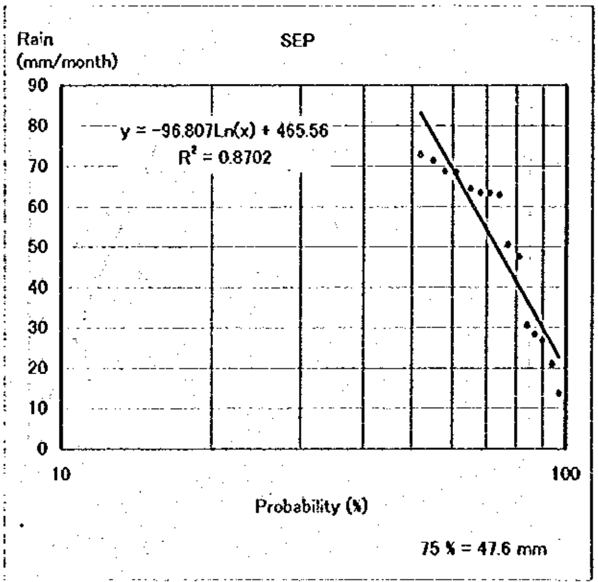
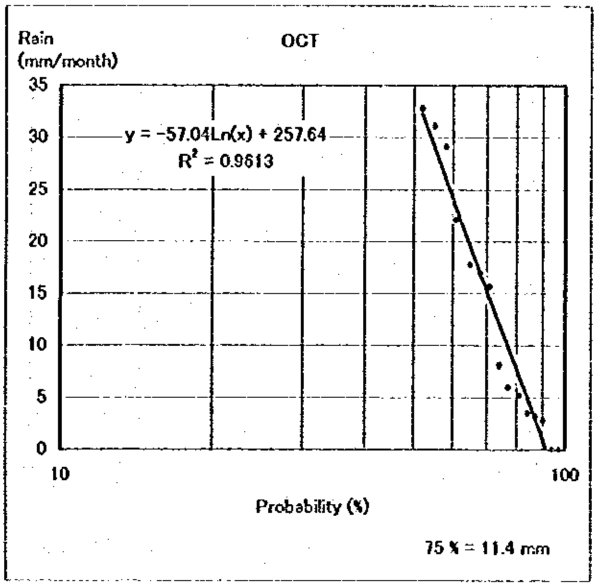
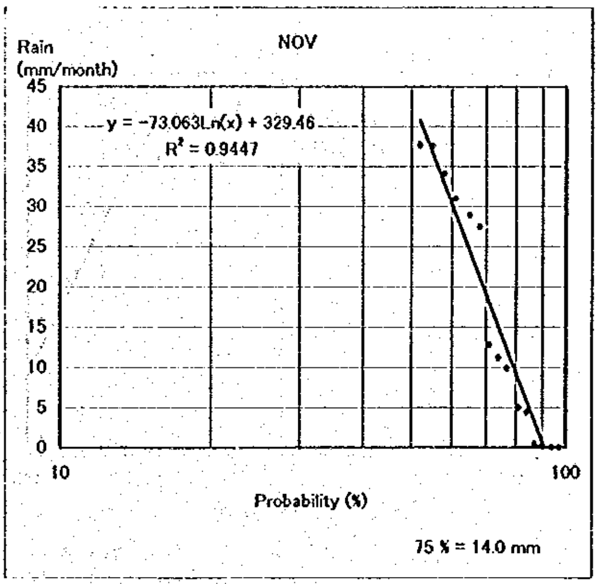
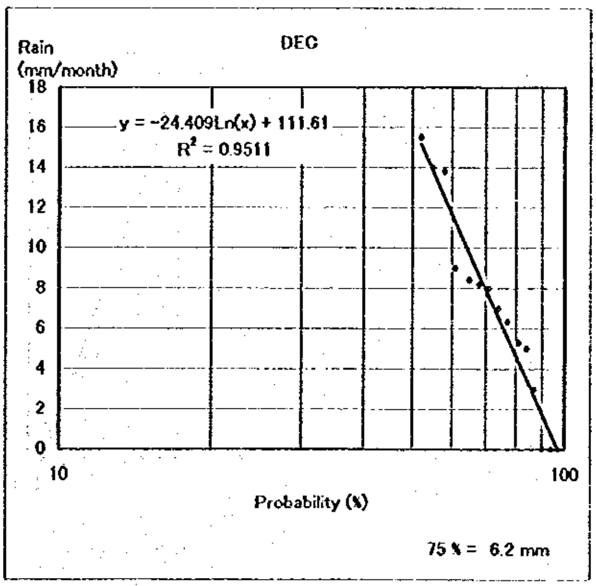




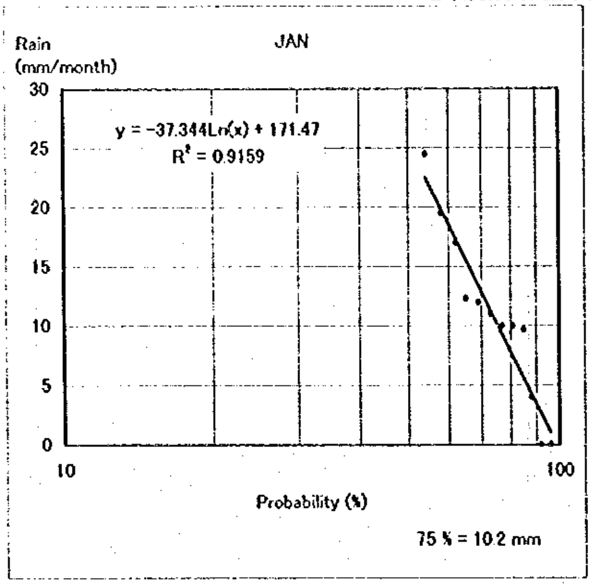


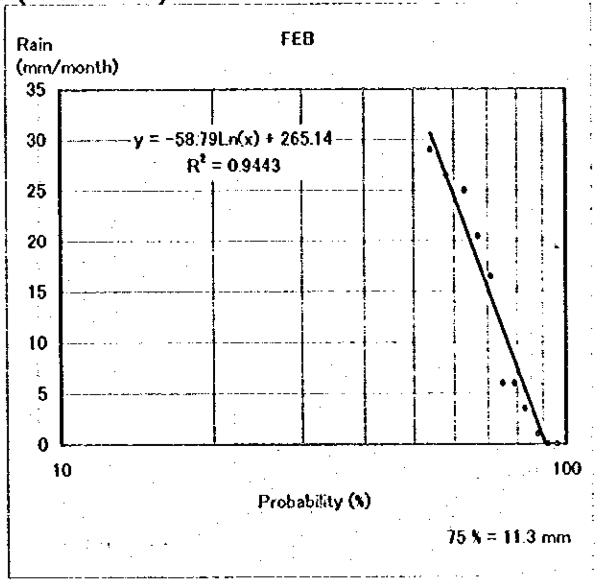


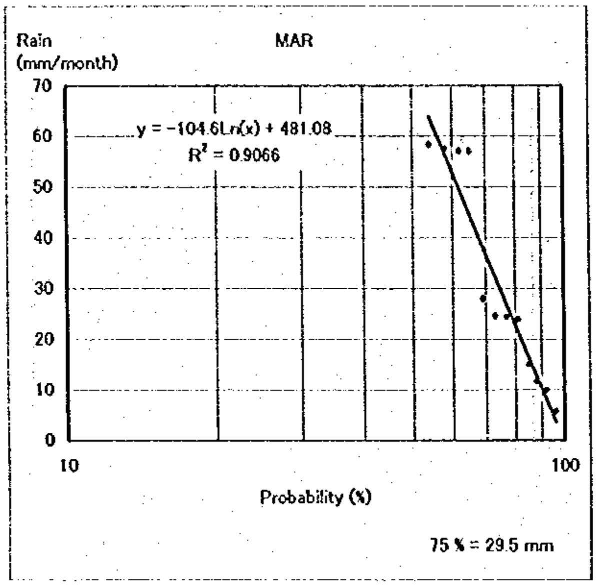


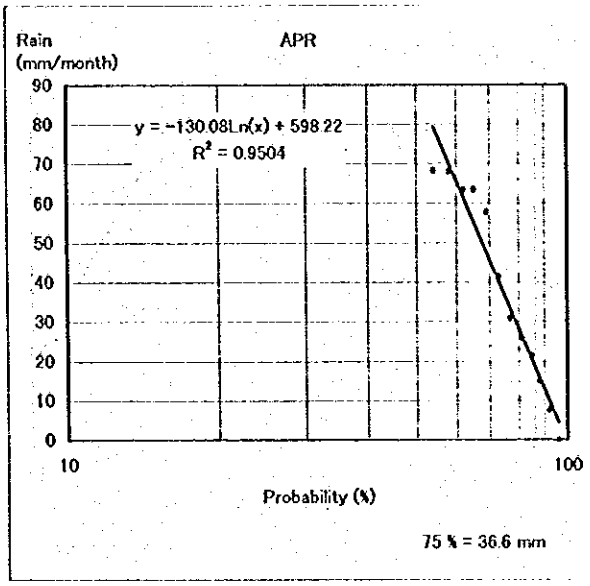


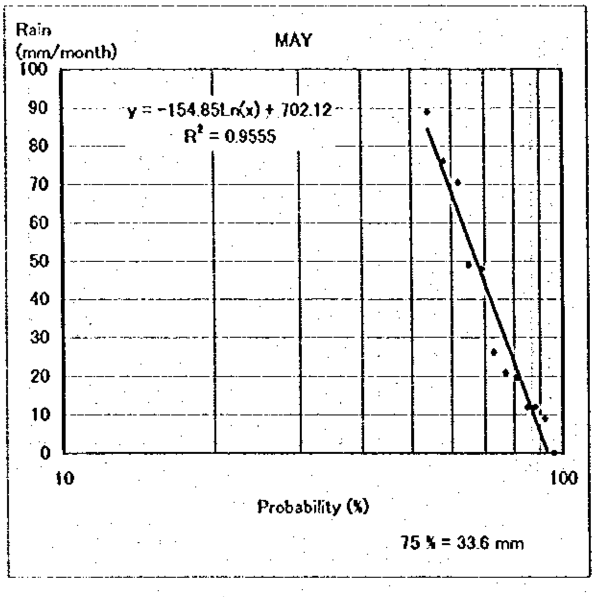
Tobias Barreto (1968-1997)

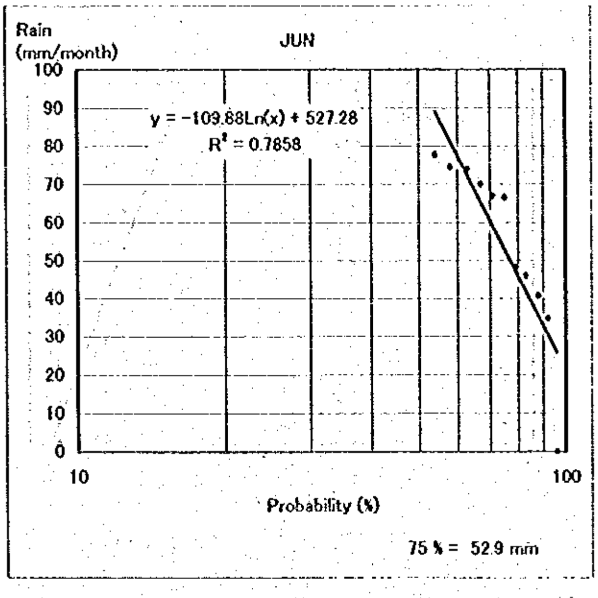




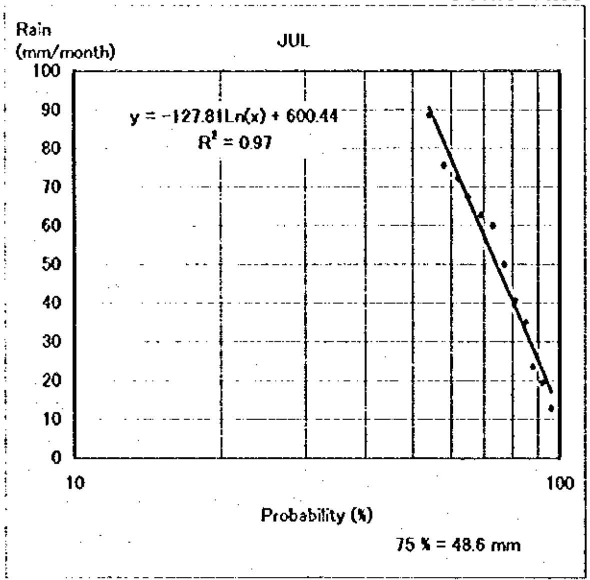


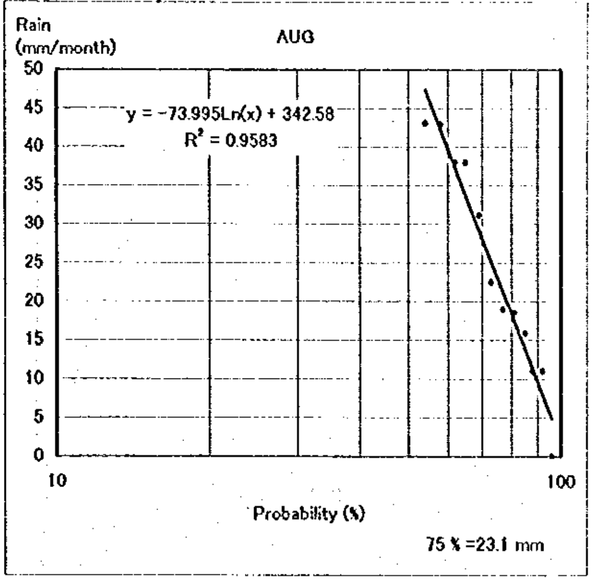


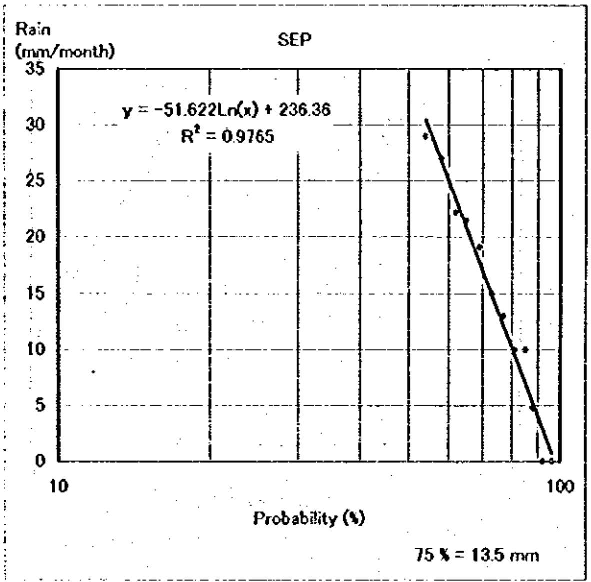


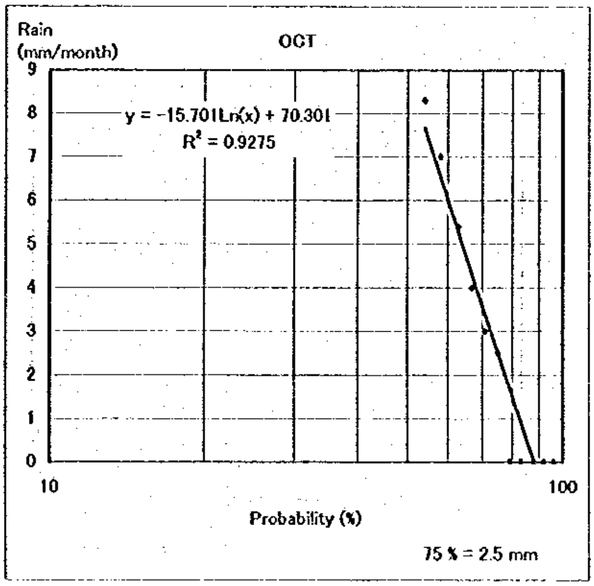


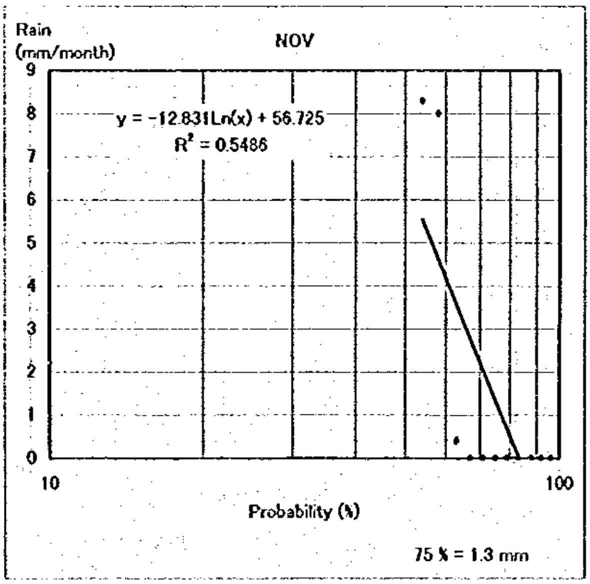
Tobias Barreto (1968-1997)

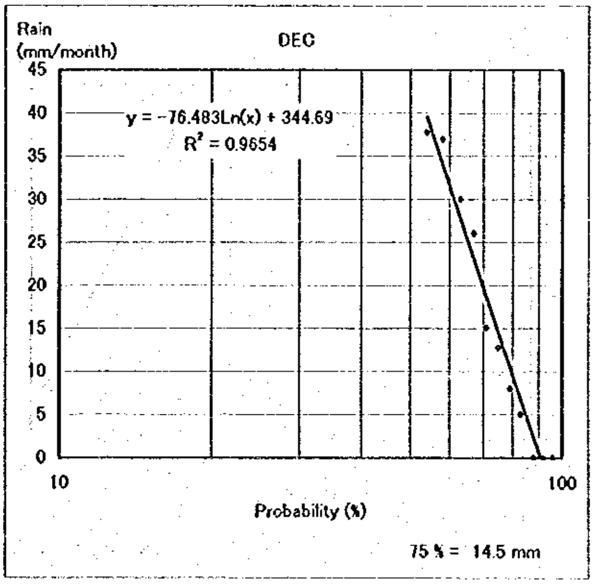




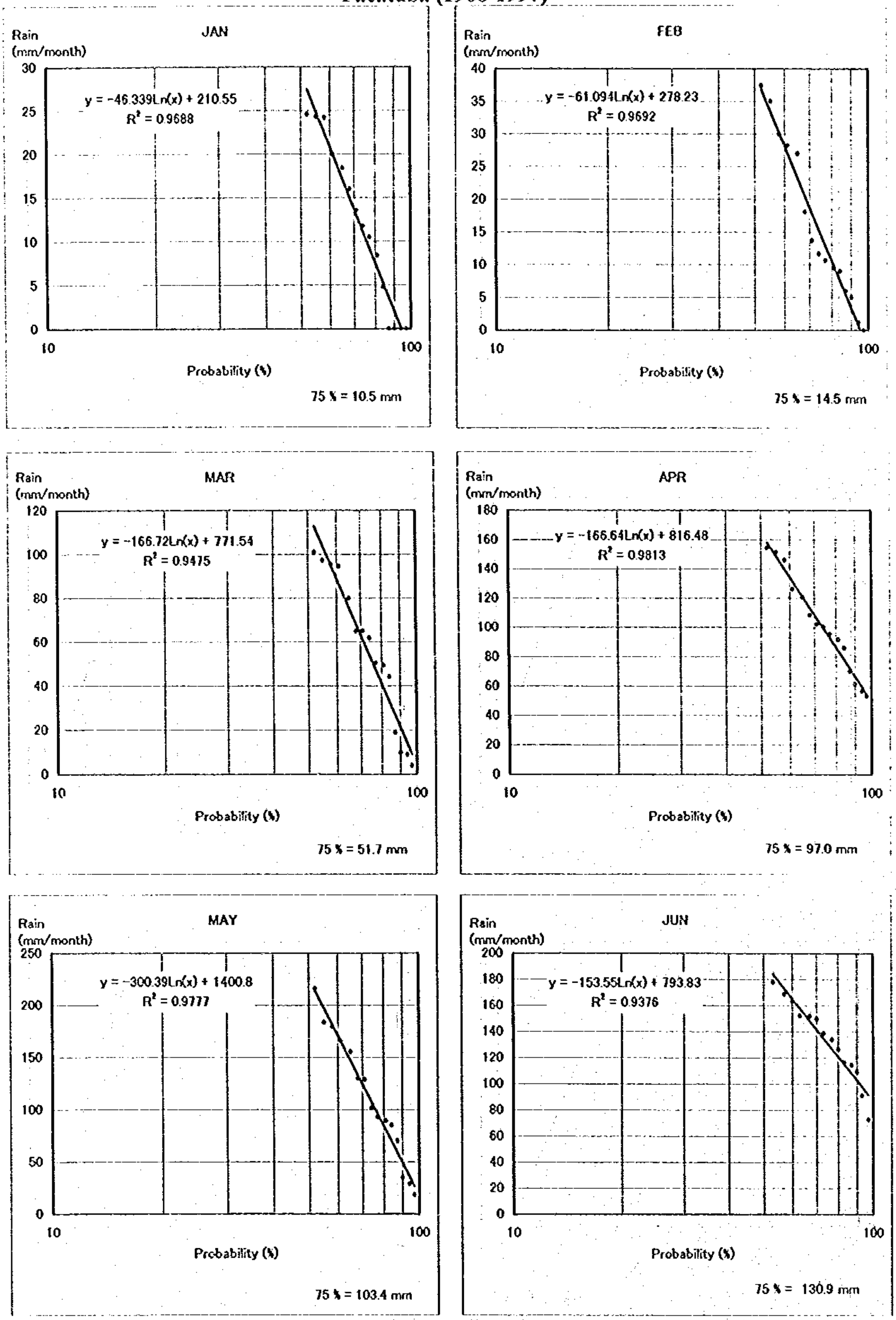




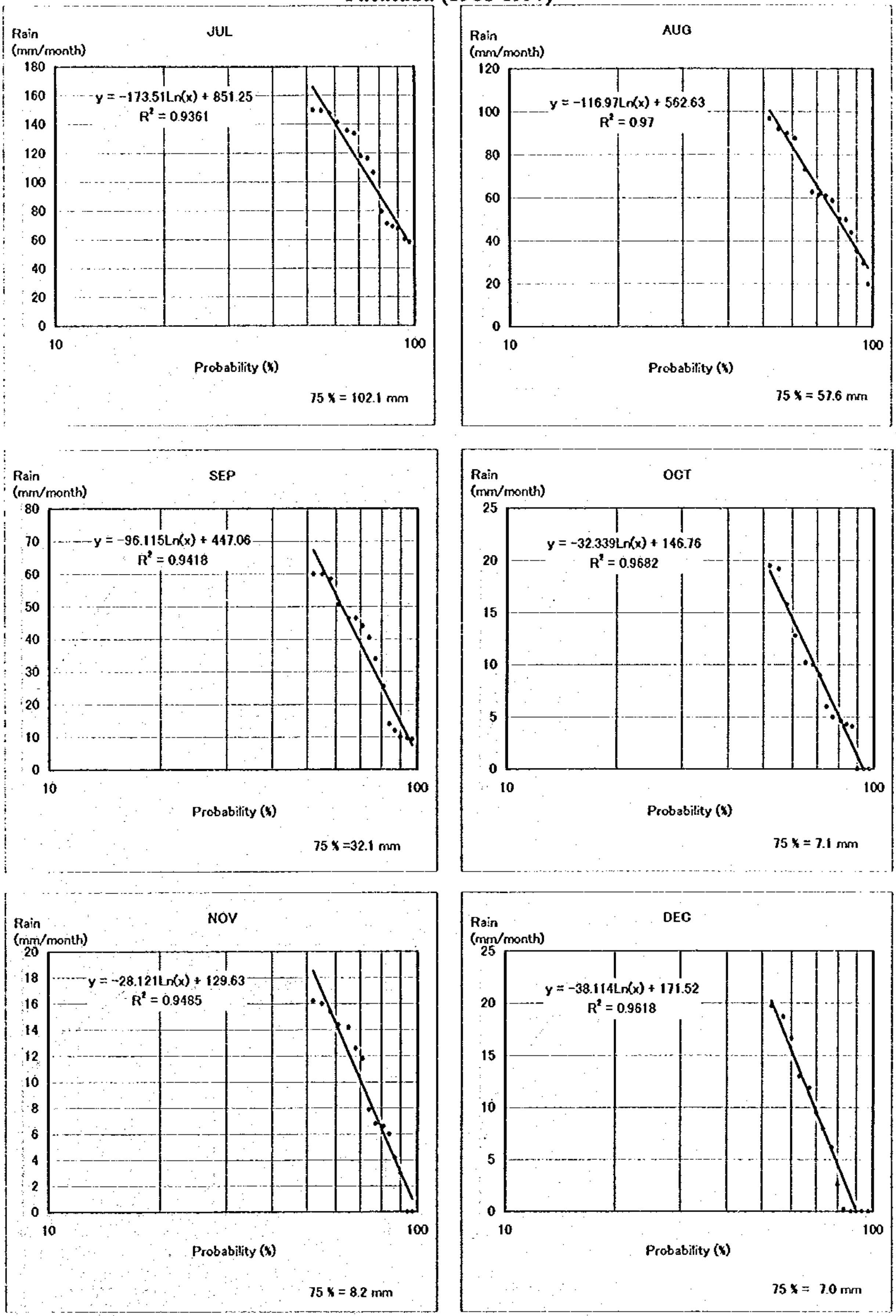




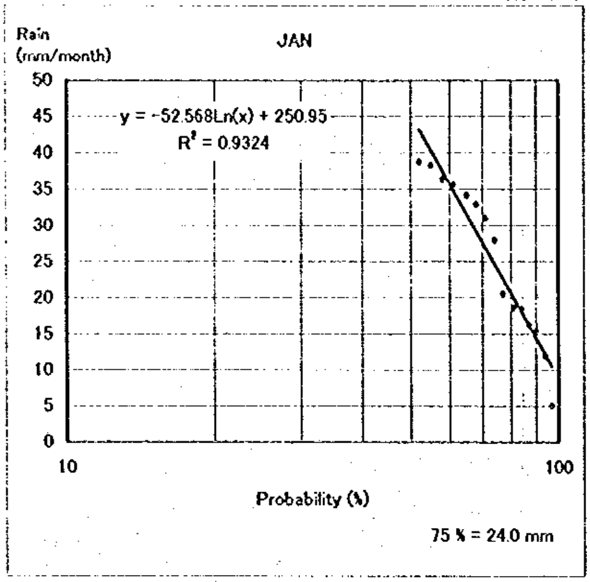
Pacatuba (1968-1997)

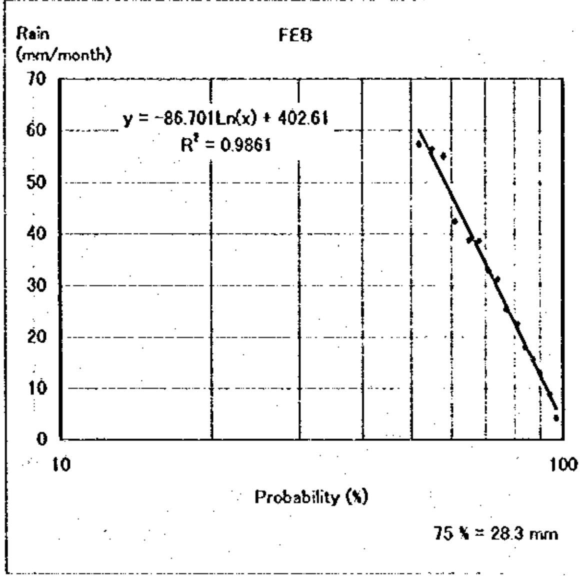


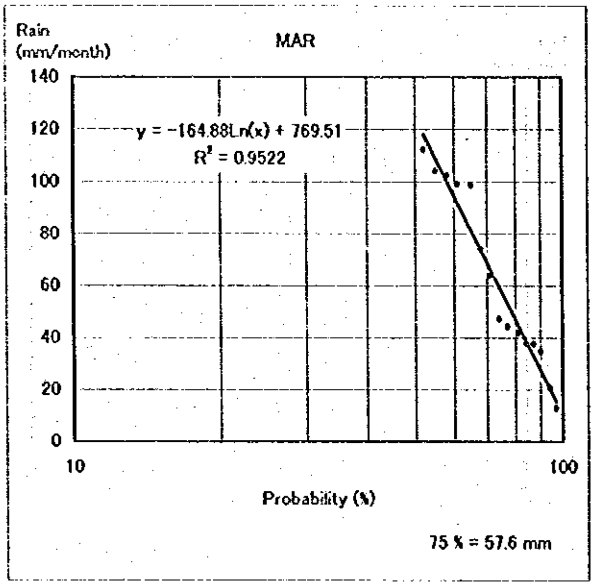
Pacatuba (1968-1997)

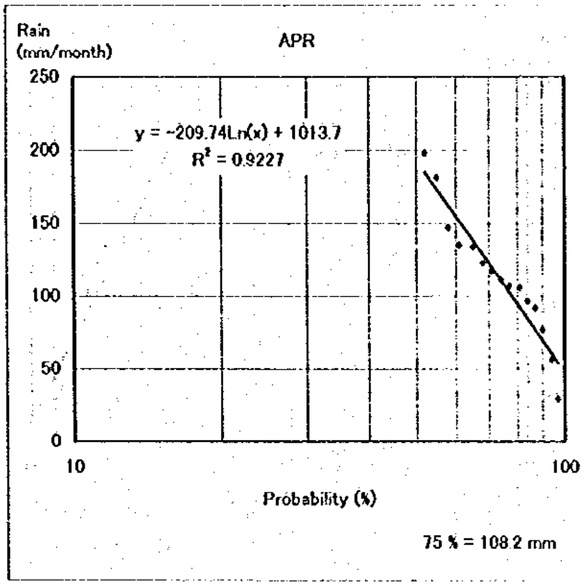


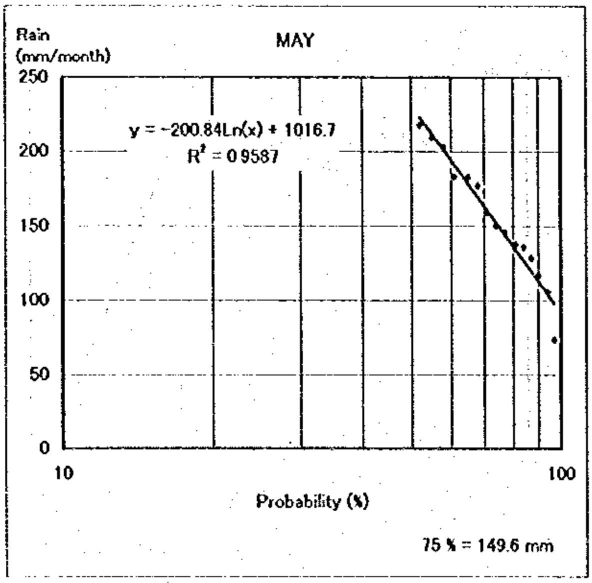
Estancia (1968-1997)

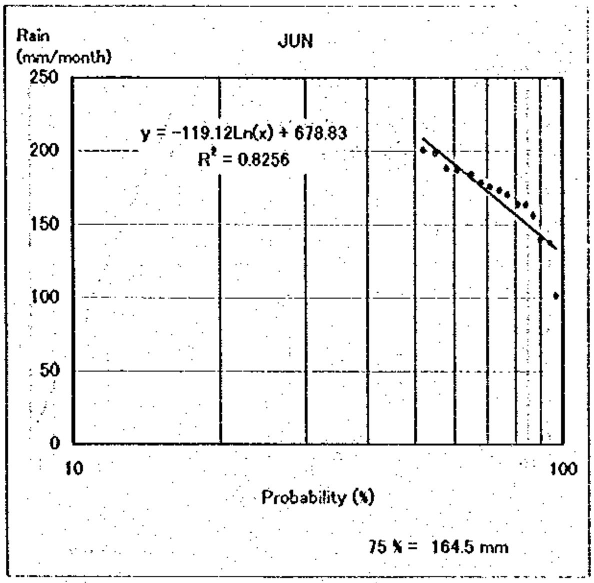




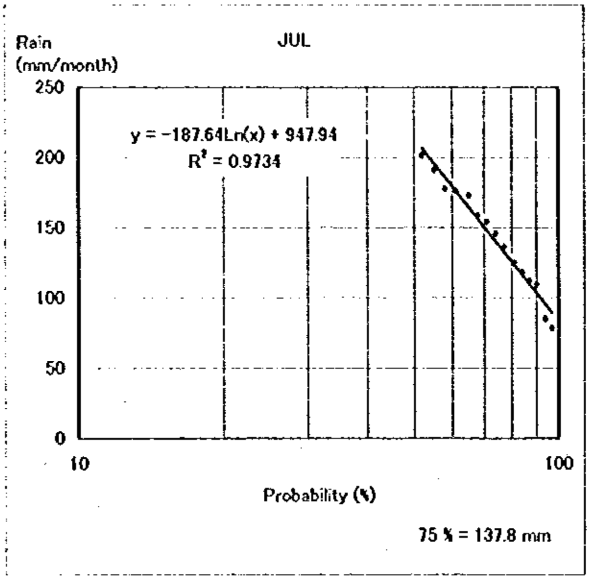


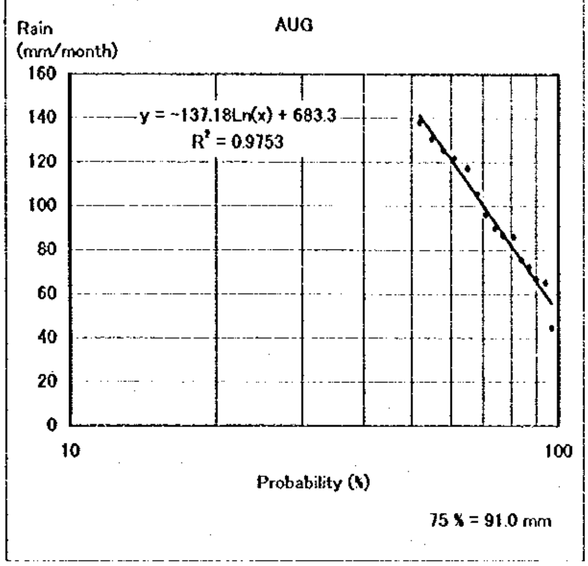


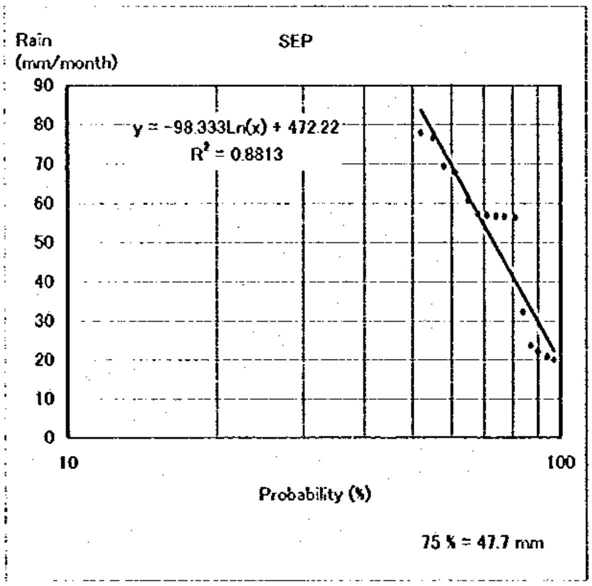


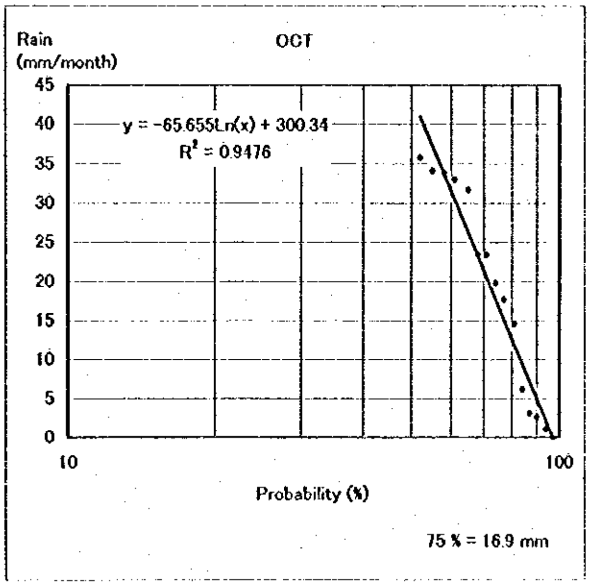


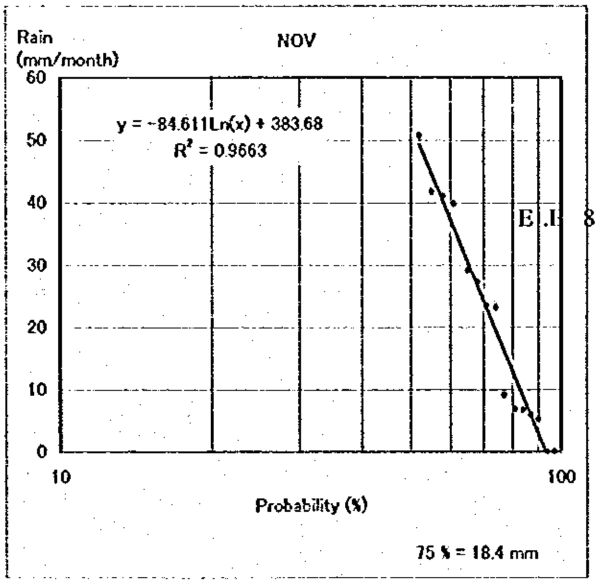
Estancia (1968-1997)

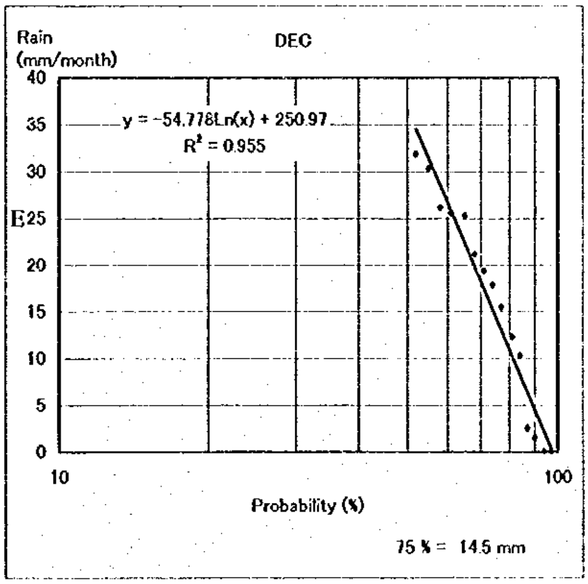












APPENDIX-2

Irrigation Requirement

Appendix-2 Irrigation Requirement

1. Project Water Requirement

No. 10 Quixabeira Project
Soil of Irrigation Project Area: NC
75% Probability Rainfall: based on data from Canindc dc Sao Francisco (No. 1) station
Potential Evapotranspiration (ETp): based on data from California project
Irrigation Area: 3,668 ha
Crop: Fruit Culture and Vegetables (lemon, mango, passion fruit, grapes, maize, cotton, beans, tomato, carrot)
Fruit: 25% of irrigation area, Vegetable: 75% of irrigation area
Overall Irrigation Efficiency (pipelines + sprinkler, drip, center-pivot): 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	7.4	4.0	15.6	23.4	23.6	34.3	31.9	15.2	6.1	0.8	0.2	2.7	165.2
ETo (mm/day)	6.0	6.0	5.6	4.5	3.7	3.1	3.1	3.9	4.9	6.0	6.2	6.0	
ETo (mm/month)	185.0	169.0	175.0	135.0	113.0	92.0	96.0	120.0	147.0	186.0	186.0	187.0	1,791.0
kc	0.50	0.26	0.25	0.23	0.55	0.69	0.90	0.57	0.20	0.42	0.56	0.69	
ETc (mm/month)	92.5	43.9	43.8	31.1	62.2	63.5	0.0	0.0	29.4	78.1	104.2	129.0	677.7
Effective Rainfall (mm)	0.0	0.0	11.0	16.0	17.0	26.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0
In (mm/month)	93.0	44.0	33.0	15.0	45.0	0.0	0.0	0.0	29.0	78.0	104.0	129.0	570.0
Dd (mm/month)													0.0
I (m^3/ha/month)	1550.0	730.0	550.0	250.0	750.0	0.0	0.0	0.0	480.0	1300.0	1730.0	2150.0	9,490.0
P (million m^3/month)	5.7	2.7	2.0	0.9	2.8	0.0	0.0	0.0	1.8	4.8	6.3	7.9	34.9

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
kc was estimated assuming grapes and citrus as fruits, and tomato as vegetables.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season at upstream of Sao Francisco river (SF-1)	EC= 0.01 ds/m Cl = 0.25 me/l	SAR = 0.2 HCO_3 = 0.8 me/l	Na = 0.1 me/l

Source: Water Quality Survey by JICA Study Team

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	severe
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	none

2) Salinity of Soil

EC of Saturation Extract (ECe) of NC1 Class Soil: EC = 2.9 ds/m
Salinity Hazard of NC1 Class Soil: medium to high

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % Yield Potential (ds/m) 100%	90%	75%
grapes	1.5	2.5	4.1
lemon	1.7	2.3	3.3
lettuce	1.3	2.1	3.2
tomato	2.5	3.5	5.0
carrot	1.0	1.7	2.8

Source: FAO Irrigation and Drainage Paper 29

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.01/2.3 = 0
Depth of Drainage Water = 0 mm

As long as water table is low enough, leaching is not required; however, underdrain should be installed to prevent upward movement of water in soil profile.

I. Project Water Requirement

No. 11 Jacare-Curituba Project
Soil of Irrigation Project Area: NC
75% Probability Rainfall: based on data from Caninde de Sao Francisco (No. 1) station
ETp: based on data from California project
Irrigation Area: 3,681 ha
Crop: Fruit Culture (acerora, pine cone, guava, banana, grapes), and Vegetable
(melon, watermelon, tomato, sweet corn, okra, beans)
Fruit: 50% of irrigation area, Vegetable: 50% of irrigation area
Overall Irrigation Efficiency (pipelines + sprinkler, micro-sprinkler): 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	7.4	4.0	15.6	23.4	23.6	34.3	31.9	15.2	6.1	0.8	0.2	2.7	165.2
ETo (mm/day)	6.0	6.0	5.6	4.5	3.7	3.1	3.1	3.9	4.9	6.0	6.2	6.0	
ETo (mm/month)	185.0	169.0	175.0	135.0	113.0	92.0	96.0	120.0	147.0	186.0	186.0	187.0	1,791.0
kc	0.57	0.40	0.37	0.34	0.56	0.62	0.77	0.53	0.30	0.48	0.60	0.71	
ETc (mm/month)	105.5	67.6	64.8	45.9	63.3	57.0	0.0	0.0	44.1	89.3	111.6	132.8	781.9
Effective Rainfall (mm)	0.0	0.0	11.0	20.0	19.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	72.0
In (mm/month)	106.0	68.0	54.0	26.0	44.0	0.0	0.0	0.0	44.0	89.0	112.0	133.0	676.0
Dd (mm/month)													
I (m^3/ha/month)	1770.0	1130.0	900.0	430.0	730.0	0.0	0.0	0.0	730.0	1480.0	1870.0	2220.0	11,260.0
P (million m^3/month)	6.5	4.2	3.3	1.6	2.7	0.0	0.0	0.0	2.7	5.4	6.9	8.2	41.5

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
kc was estimated assuming grapes and citrus as fruits, and tomato as vegetables.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season at upstream of Sao Francisco river (SF-1)	EC= 0.01 ds/m Cl = 0.25 me/l	SAR = 0.2 HCO_3 = 0.8 me/l	Na = 0.1 me/l

Source: Water Quality Survey by JICA Study Team

	Degree of restriction on use (FAO criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	severe
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	none

2) Salinity of Soil

EC of Saturation Extract (ECe) of NC1 Class Soil — EC = 2.9 ds/m
Salinity Hazard of NC1 Class Soil: — medium to high

3) Crops Salt Tolerance

	Crop Salt Tolerance Level ECe for % yield Potential (ds/m) 100%	90%	75%
grapes	1.5	2.5	4.1
lemon	1.7	2.3	3.3
tomato	2.5	3.5	5.0
carrot	1.0	1.7	2.8

Source: FAO Irrigation and Drainage Paper 29

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.01/2.3 = 0
Depth of Drainage Water = 0 mm

As long as water table is low enough, leaching is not required; however, underdrain should be installed to prevent upward movement of water in soil profile.

1. Project Water Requirement

No. 12 Sao Francisco Project
Soil of Irrigation Project Area: NC1
75% Probability Rainfall: based on data from Caninde de S. Francisco (No. 1) station
Potential Evapotranspiration (ETp): based on data from California Project
Irrigation Area: 16,000 ha
Crop: Fruit Culture
Fruit: 100% of irrigation area
Overall Irrigation Efficiency (pipelines + drip): 0.75

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Probability 75 % Rainfall (mm)	7.4	4.0	15.6	23.4	23.6	34.3	31.9	15.2	6.1	0.8	0.2	2.7	165.2
ETo (mm/day)	6.0	6.0	5.6	4.5	3.7	3.1	3.1	3.9	4.9	6.0	6.2	6.0	
ETo (mm/month)	185.0	169.0	175.0	135.0	113.0	92.0	96.0	120.0	147.0	186.0	186.0	187.0	1,791.0
kc	0.70	0.65	0.55	0.45	0.35	0.00	0.00	0.00	0.25	0.45	0.60	0.70	
ETc (mm/month)	129.5	109.9	96.3	60.8	39.6	0.0	0.0	0.0	36.8	83.7	111.6	130.9	799.1
Effective Rainfall (mm)	0.0	0.0	10.0	18.0	17.0				0.0	0.0	0.0	0.0	45.0
In (mm/month)	130.0	110.0	86.0	43.0	23.0	0.0	0.0	0.0	37.0	84.0	112.0	131.0	756.0
Dd (mm/month)													
I (m^3/ha/month)	1730.0	1470.0	1150.0	570.0	310.0	0.0	0.0	0.0	490.0	1120.0	1490.0	1750.0	10,080.0
P (million m^3/month)	29.4	25.0	19.6	9.7	5.3	0.0	0.0	0.0	8.3	19.0	25.3	29.8	171.4

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
kc was estimated assuming grapes for fruit culture.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season at upstream of Sao Francisco river (SF-1)	EC= 0.01 ds/m Cl = 0.25 me/l	SAR = 0.2 HCO_3 = 0.8 me/l	Na = 0.1 me/l

Source: Water Quality Survey by JICA Study Team

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	severe
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	none

2) Salinity of Soil

EC of Saturation Extract (ECe) of NC1 Class Soil: EC = 2.9 ds/m
Salinity Hazard of NC1 Class Soil: medium to high

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % Yield Potential (ds/m)		
	100%	90%	75%
grapes	1.5	2.5	4.1

Source: FAO Irrigation and Drainage Paper 29

4) Leaching Requirement

ECd = 1.5 ds/m was determined as required quality of drainage water, assuming 100% yield of grapes. Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.01/1.5 = 0.007
Depth of Drainage Water = 756*0.007/(1-0.007) = 5.3 mm

As long as water table is low enough, leaching is not required because rainfall is enough for drainage; however, underdrain should be installed to prevent upward movement of water in soil profile.

1. Project Water Requirement

13. Ladeirinhas Project
Soil of Irrigation Project Area: PV, LV
75% Probability Rainfall: based on data from Pacatuba (No.9) station
Potential Evapotranspiration (ETp): based on data from Cotinguiba station
Irrigation Area: 890 ha
Crop: Fruit Culture and Vegetables (grapes, mango, banana, tomato, beans, watermelon, asparagus, red pepper)
Fruit: 67% of irrigation area, Vegetable: 33% of irrigation area
Overall Irrigation Efficiency (pipelines + micro-sprinkler, drip): 0.75

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	10.5	14.5	51.7	97.0	103.4	130.9	102.1	57.6	32.1	7.1	8.2	7.0	622.1
ETo (mm/day)	5.5	5.4	5.2	4.2	3.3	2.9	3.0	3.3	4.0	4.6	4.8	5.3	
ETo (mm/month)	170.0	150.0	162.0	127.0	102.0	87.0	94.0	104.0	120.0	144.0	143.0	165.0	1,568.0
kc	0.90	1.05	1.00	0.72	0.70	0.70	0.65	0.82	0.78	0.85	0.78	0.56	
ETc (mm/month)	153.0	157.5	162.0	91.4	71.4	60.9	61.1	85.3	93.6	122.4	111.5	92.4	1,262.5
Effective Rainfall (mm)	8.0	11.0	40.0	65.0	60.0	65.0	56.0	38.0	23.0	0.0	0.0	0.0	366.0
In (mm/month)	145.0	147.0	122.0	26.0	11.0	0.0	5.0	47.0	71.0	122.0	112.0	92.0	900.0
Dd (mm/month)													
I (m^3/ha/month)	1930.0	1960.0	1630.0	350.0	150.0	0.0	70.0	630.0	950.0	1630.0	1490.0	1230.0	12,020.0
P (million m^3/month)	1.7	1.7	1.5	0.3	0.1	0.0	0.1	0.6	0.8	1.5	1.3	1.1	10.7

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
Crop coefficient and cropping schedule were adopted from original design which is a mixture of the grapes, banana, water melons and beans.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season	EC= 0.07 ds/m Cl = 0.4 me/l	SAR = 1 HCO_3 = 0.1 me/l	Na = 0.3 me/l

Source: Ladeirinhas Project Pre-Feasibility Study

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	severe
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	none

2) Salinity of Soil

EC of Saturation Extract (ECe) of PV & LV Class Soil: EC = negligible
Salinity Hazard of PV & LV Class Soil: very low

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % yield potential (ds/m)		
	100%	90%	75%
grapes	1.5	2.5	4.1
beans	1.0	1.5	2.3

Source: FAO Irrigation and Drainage Paper 29

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 75% yield of beans.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.07/2.3 = 0.03
Depth of Drainage Water = 900*0.03/(1-0.03) 28 mm

Leaching is conducted in June.
It is assumed that "Rainfall *0.8-Effective Rainfall = Contributing to Leaching".
28-(130*0.8-65) = 0 mm

Rainfall is enough for leaching.

1. 1. Project Water Requirement

No. 14 Jacarecica II Project
Soil of Irrigation Project Area: BV
75% Probability Rainfall: based on data from Santa Rosa de Lima (No. 17) station
Potential Evapotranspiration (ETp): based on data from Jacarecica station
Irrigation Area: 1,100 ha
Crop: Fruit Culture and Vegetables (acerora, mango, coconut, banana, tomato, okra, pumpkin)
Fruit: 50% of irrigation area, Vegetable: 50% of irrigation area
Overall Irrigation Efficiency (pipelines + sprinkler, drip): 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	11.6	12.4	34.6	57.1	95.5	120.7	118.7	78.9	39.4	7.9	4.9	5.1	586.8
ETo (mm/day)	5.8	5.7	5.3	4.1	3.3	2.8	2.9	3.4	4.0	5.1	5.5	5.7	
ETo (mm/month)	180.0	159.0	166.0	122.0	102.0	85.0	90.0	104.0	120.0	158.0	164.0	178.0	1,628.0
kc	0.68	0.70	0.98	1.08	1.08	0.80	0.50	0.50	0.65	0.83	0.90	0.90	
ETc (mm/month)	122.4	111.3	162.7	131.8	110.2	68.0	0.0	0.0	78.0	131.1	147.6	160.2	1,223.3
Effective Rainfall (mm)	8.0	9.0	25.0	40.0	68.0	60.0	0.0	0.0	28.0	0.0	0.0	0.0	238.0
In (mm/month)	114.0	102.0	138.0	92.0	42.0	0.0	0.0	0.0	50.0	131.0	148.0	160.0	977.0
Dd (mm/month)													
I (m^3/ha/month)	1900.0	1700.0	2300.0	1530.0	700.0	0.0	0.0	0.0	830.0	2180.0	2470.0	2670.0	16,280.0
P (million m^3/month)	2.1	1.9	2.5	1.7	0.8	0.0	0.0	0.0	0.9	2.4	2.7	2.9	17.9

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
kc was estimated assuming banana as fruit, and tomato as vegetable.

2. Leaching

1) Quality of Water Source

Water quality of Jacarecica II dam reservoir	EC= NA Cl = NA	SAR = NA HCO_3 = NA	Na = NA

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	NA
Infiltration (SAR & EC)	NA
Specific ion toxicity (Sodium)	NA
Specific ion toxicity (Chloride)	NA
Miscellaneous effects (Bicarbonate)	NA

NA: not available
It is assumed that water quality in the dam reservoir has no problem in salinity (EC = 0.01 ds/m).

2) Salinity of Soil

EC of Saturation Extract (ECe) of NC1 Class Soil: EC < 2.0 ds/m
Salinity Hazard of NC1 Class Soil: medium

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % yield Potential (ds/m)		
	100%	90%	75%
grapes (banana)	1.5	2.5	4.1
lemon	1.7	2.3	3.3
tomato	2.5	3.5	5.0
carrot	1.0	1.7	2.8

Source: FAO Irrigation and Drainage Paper 29
It was assumed that salt tolerance of banana is same as that of grapes.

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.01/2.3 = 0
Depth of Drainage Water = 0 mm

Assuming dam water quality is good, no leaching required.

1. Project Water Requirement

No. 15 Vaza Barris Project
Soils of Irrigation Project Area: LVd2
75% Probability Rainfall: based on data from Belem (No. 18) station
Potential Evapotranspiration (ETp): based on data from Piaui station
Irrigation Area: 2,500 ha
Crop: mostly Vegetables, and Fruits in only steep land
Fruit: <5%, Vegetable: >95%
Overall Irrigation Efficiency (pipelines + sprinkler): 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	16.6	14.5	44.7	113.2	119.4	156.0	141.1	93.2	47.6	11.4	14.0	6.2	777.9
ETo (mm/day)	5.2	5.1	4.8	3.9	3.2	2.7	2.8	3.1	3.9	4.8	5.1	5.5	
ETo (mm/month)	162.0	143.0	150.0	118.0	100.0	80.0	86.0	97.0	116.0	149.0	153.0	170.0	1,524.0
kc	0.6	0.5	0.9	1.1	1.1	0.6			0.5	0.9	1.1	1.1	
ETc (mm/month)	97.2	71.5	135.0	129.8	110.0	48.0			58.0	134.1	168.3	187.0	1,138.9
Effective Rainfall (mm)	13.0	10.0	37.0	80.0	82.0	50.0			32.0	10.0	10.0	0.0	324.0
In (mm/month)	84.0	62.0	98.0	50.0	28.0	0.0	0.0	0.0	26.0	124.0	158.0	187.0	817.0
Dd (mm/month)							91.0						
I (m^3/ha/month)	1400.0	1030.0	1630.0	830.0	470.0	0.0	1520.0	0.0	430.0	2070.0	2630.0	3120.0	15,130.0
P (million m^3/month)	3.5	2.6	4.1	2.1	1.2	0.0	3.8	0.0	1.1	5.2	6.6	7.8	38.0

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
kc was estimated assuming grapes as fruit and tomato as vegetable.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season at Belem station (V-3)	EC= 0.5 ds/m Cl = 3.5 me/l	SAR = 2.4 HCO_3 = 1.6 me/l	Na = 2.1 me/l

Source: Water Quality Survey by JICA Study Team

	Degree of restriction on use (FAO criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	slight to moderate
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	slight to moderate for sprinkler irrigation
Miscellaneous effects (Bicarbonate)	slight to moderate

2) Salinity of Soil

EC of Saturation Extract (ECe) of LV Class Soil: EC = negligible
Salinity Hazard of LV Class Soil: extremely low

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % Yield Potential (ds/m)		
	100%	90%	75%
Broccoli	2.8	3.9	5.5
Cabbage	1.8	2.8	4.4
Cucumber	2.5	3.3	4.4
Lettuce	1.3	2.1	3.2
Spinach	2.0	3.3	5.3
Sweet potato	1.5	2.4	3.8
Tomato	2.5	3.5	5.0

4) Leaching Requirement

ECd = 2.5 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops. Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.5/2.5 = 0.2
Depth of drainage water = 817*0.5/(2.5-0.5) = 204 mm

Leaching is conducted in July.
It is assumed that "Rainfall *0.8-Effective Rainfall = Contributing to Leaching".
204 - 141*0.8 = 91 mm

Leaching requirement is 91 mm.

1. Project Water Requirement

No. 16 Entre Rios Project
Soil of Irrigation Project Area: PV
75% Probability Rainfall: based on data from Estancia (No. 28) station
ETp: based on data from Boquim station
Irrigation Area: 261 ha
Crop: Fruit Culture and Vegetables (orange, passion fruit, sweet potato, peanuts, beans, maize)
Fruit: 50% of irrigation area, Vegetable: 50% of irrigation area
Overall Irrigation Efficiency (pipelines + Sprinkler) 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
75 % Probability Rainfall (mm)	24.0	28.3	57.6	108.2	149.6	164.5	137.8	91.0	47.7	16.9	18.4	14.5	858.5
ETo (mm/day)	4.8	4.5	4.6	3.6	3.1	2.7	2.8	3.1	3.7	4.4	4.6	4.7	
ETo (mm/month)	150.0	127.0	142.0	108.0	95.0	82.0	85.0	96.0	111.0	136.0	137.0	145.0	1,414.0
kc	0.87	0.85	0.60	0.60	0.60	0.75	0.60	0.65	0.60	0.40	0.70	0.80	
ETc (mm/month)	130.5	108.0	85.2	64.8	57.0	61.5	51.0	62.4	66.6	54.4	95.9	116.0	953.3
Effective Rainfall (mm)	20.0	20.0	38.0	65.0	55.0	65.0	51.0	53.0	40.0	10.0	18.0	10.0	445.0
In (mm/month)	111.0	88.0	47.0	0.0	2.0	0.0	0.0	9.0	27.0	44.0	78.0	106.0	512.0
Dd (mm/month)						38.0							
I (m^3/ha/month)	1850.0	1470.0	780.0	0.0	30.0	630.0	0.0	150.0	450.0	730.0	1300.0	1770.0	9,160.0
P (million m^3/month)	0.5	0.4	0.2	0.0	0.0	0.2	0.0	0.0	0.1	0.2	0.3	0.5	2.4

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
Crop coefficient and cropping schedule were adopted from original design which is a mixture of the above crops.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season	EC= 0.75 ds/m Cl = 1.2 me/l	SAR = <0.2 HCO_3 = NA	Na = 1.0 me/l

Source: Pre-feasibility Study, Final Report

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	none
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	NA

NA: not available

2) Salinity of Soil

EC of Saturation Extract (ECe) of PV Class Soil: EC = negligible
Salinity Hazard of PV Class Soil: very low

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % Yield Potential (ds/m)		
	100%	90%	75%
orange	1.7	2.3	3.3
sweet potatoes	1.5	2.4	3.8
lettuce	1.3	2.1	3.2
tomato	2.5	3.5	5

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.75/2.3 = 0.33
Depth of Drainage Water = 512 *0.33/(1-0.33) 252 mm

Leaching is conducted in April - July, depending on plots.
It is assumed that "Rainfall *0.8-effective rainfall = contributing to leaching".
252-((109+150+165+138)*0.8-(65+55+65+51))= 38 mm

Therefore, leaching requirement is 38 mm.

1. Project Water Requirement

No. 17 Estancinha Project
Soil of Irrigation Project Area: PV
75% Probability Rainfall: based on data from Estancia (No. 28) station
ETp: based on data from Boquim station
Irrigation Area: 109 ha
Crop: Fruit Culture and Vegetables (orange, passion fruit, beet, beans, maize, tomato)
Fruit: 50% of irrigation area, Vegetable: 50% of irrigation area
Overall Irrigation Efficiency (pipelines + Sprinkler) 0.6

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Probability 75 % Rainfall (mm)	24.0	28.3	57.6	108.2	149.6	164.5	137.8	91.0	47.7	16.9	18.4	14.5	858.5
ETo (mm/day)	4.8	4.5	4.6	3.6	3.1	2.7	2.8	3.1	3.7	4.4	4.6	4.7	
ETo (mm/month)	150.0	127.0	142.0	108.0	95.0	82.0	85.0	96.0	111.0	136.0	137.0	145.0	1,414.0
kc	0.65	0.60	0.60	0.75	0.80	0.80	0.35	0.90	0.95	0.75	0.60	0.65	
ETc (mm/month)	97.5	76.2	85.2	81.0	76.0	65.6	29.8	86.4	105.5	102.0	82.2	94.3	981.7
Effective Rainfall (mm)	19.0	20.0	38.0	65.0	76.0	65.6	30.0	60.0	35.0	10.0	13.0	10.0	441.6
In (mm/month)	79.0	56.0	47.0	16.0	0.0	0.0	0.0	26.0	71.0	92.0	69.0	84.0	540.0
Dd (mm/month)						54.0							
I (m^3/ha/month)	1320.0	930.0	780.0	270.0	0.0	900.0	0.0	430.0	1180.0	1530.0	1150.0	1400.0	9,890.0
P (million m^3/month)	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.2	1.1

ETo: potential evapotranspiration by Penman-Monteith, kc: crop coefficient, ETc: crop water requirement
In: net irrigation requirement, Dd: drainage water for leaching, I: irrigation requirement, P: project water requirement
Crop coefficient and cropping schedule were adopted from original design which is a mixture of the above crops.

2. Leaching

1) Quality of Water Source

Surface water quality during dry season from Report	EC= 0.75 ds/m Cl = 1.2 me/l	SAR = < 0.2 HCO_3 = NA	Na = 1.0 me/l

Source: Estancinha Project Final Report

	Degree of Restriction on Use (FAO Criteria)
Salinity (EC)	none
Infiltration (SAR & EC)	none
Specific ion toxicity (Sodium)	none
Specific ion toxicity (Chloride)	none
Miscellaneous effects (Bicarbonate)	NA

NA: not available

2) Salinity of Soil

EC of Saturation Extract (ECe) of PV Class Soil: EC = negligible
Salinity Hazard of PV Class Soil: very low

3) Crop Salt Tolerance

	Crop Salt Tolerance Level ECe for % Yield Potential (ds/m)		
	100%	90%	75%
orange	1.7	2.3	3.3
sweet potatoes	1.5	2.4	3.8
lettuce	1.3	2.1	3.2
tomato	2.5	3.5	5

4) Leaching Requirement

ECd = 2.3 ds/m was determined as required quality of drainage water, assuming 90% yield of dominant crops.
Since water quality of irrigation water (ECa) is equal to surface water quality, leaching fraction is;

Leaching Fraction = ECa/ECd = 0.75/2.3 = 0.33
Depth of drainage water = 540*0.33/(1-0.33) 266 mm

Leaching is conducted in April - July, depending on plots.
It is assumed that "Rainfall *0.8-effective rainfall = contributing to leaching".
266 -(108.2*0.8-65+150*0.8-76+165*0.8-66+138*0.8-30)=54 mm

Therefore, leaching requirement is 54 mm.

JAPAN INTERNATIONAL COOPERATION AGENCY

STATE SECRETARIAT OF PLANNING, SCIENCE AND TECHNOLOGY
THE STATE OF SERGIPE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF SERGIPE IN THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT SUPPORTING (VOLUME I) MASTER PLAN STUDY

[F] WATER DEMAND PROJECTION

MARCH 2000

YACHIYO ENGINEERING CO., LTD. (YEC)

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THE STUDY ON WATER RESOURCES DEVELOPMENT IN THE STATE OF SERGIPE IN THE FEDERATIVE REPUBLIC OF BRAZIL

SUPPORTING REPORT (F) WATER DEMAND PROJECTION

Table of Contents

List of Tables

List of Figures

CHAPTER 1 WATER USE SURVEY

In order to understand present water use in Sergipe in terms of consumption and supply, water use survey was conducted by the Study Team. The main objective of the survey is to provide supplementary data to 1) water demand projection, 2) economic and financial analysis and 3) social analysis.

Since the data necessary for the analysis was compiled basically from current existing data, the survey focused on collecting information that could not be obtained from existing data.

1.1 Methodology of Water Use Survey

For domestic use, 7 urban areas and 13 rural areas in 15 municipalities were selected. Interviews with questionnaires' forms were made to 20 inhabitants in each area, finally accounting for 140 inhabitants in urban areas and 256 inhabitants in rural areas. The interviews were also made to mayors of 15 municipalities.

Selected areas cover a wide range of natural and social characteristics of Sergipe, such as climatic division, river basin, agriculture practices and so on. Those areas are shown in Table-1.1.

Table-1.1 Survey Area of Domestic Water Use

Meso-region	Micro-region	Municipality	Survey Area (○)		
			Mayor	Rural	Urban
Sertao Sergipano	Sergipana de Sertao do San Francisco	Nossa Senhora da Gloria	○	○	
		Poco Redondo	○	○	
		Porto da Folha	○	○	
	Carira	Carira	○	○	
Agreste Sergipano	Nossa Senhora das Dores	Aquidaba	○	○	
		Nossa Senhora das Dores	○	○	○
	Agreste de Itabaiana	Itabaiana	○	○	○
	Tobias Barreto	Tobias Barreto	○	○	○
	Agreste de Lagarto	Lagarto	○	○	○
Leste Sergipano	Propria	Propria	○		○
	Cotinguiba	Capela	○	○	○
	Aracaju	Aracaju	○		○
	Boquim	Boquim	○	○	
		Itabaianinha	○	○	
	Estancia	Itaporanga d'Ajuda	○	○	
Total	11	15	15	13	7

For industrial use, 55 companies were selected. The variety of business activities and location were considered for the selection. The surveys were conducted with questionnaires forms sent by facsimile.

The respective questionnaire forms are given in Appendix-6.
The respective replies to questionnaires are given in DATA BOOK, DB-5.

1.2 Result of Water Use Survey

Results of the survey are summarized as follows.

1.2.1 Domestic Use

(1) Results of Questionnaires to Mayors

Results of questionnaires to 15 mayors are summarized as follows.

1) Existence of Public Water Supply System
5 municipalities have the system to cover the whole municipality area.
(Poco Redondo, Porto de Folha, Aquidaba, Propria and Aracaju)
10 municipalities have the system to cover only a part of municipality area.
(The rest of the municipalities)

2) Population with and without Public Water Supply System

Table-1.2 Population Served with Public Water Supply System

Unit: %

Municipality	Private Tap	Public Tap	Without System
Nossa Senhora da Gloria	67	14	19
Poco Redondo	90	10	0
Porto da Folha	70	30	0
Carira	70	-	-
Aquidaba	96	4	0
Nossa Senhora das Dores	65	30	5
Itabaiana	73	22	5
Tobias Barreto	67	18	15
Lagarto	65	33	2
Propria	100	0	0
Capela	80	15	5
Aracaju	100	0	0
Boquim	70	20	10
Itabaianinha	50	30	20
Itaporanga d'Ajuda	60	20	20
Average	75	16	9

3) Satisfaction with Water Supply Hours per Day
8 mayors (N. S. da Gloria, Porto de Folha, Carira, N. S das Dores, Tobias Barreto, Lagarto, Itabaianinha and Itaporanga d'Ajuda) out of 15 had unsatisfactory opinion of daily water supply hours, especially those in the Sertao Sergipano Meso-region. They required more supply hours per day.

4) Kinds of Residential Water used by Inhabitants without Public Water Supply System
Well water and rainwater are mostly used in the survey area.

(2) Results of Questionnaires to Urban Inhabitants

Results of questionnaires to inhabitants in 7 urban areas are summarized as follows.

1) Water Consumption
The survey shows only 70 liter/capita/day on average. It is much lower than the actual consumption record of DESO in 1997 that is 109 liter/capita/day in urban area, except Aracaju City.

Table-1.3 Water Consumption (Urban)

Unit: liter/day

Municipality	Household	Per capita
Nossa Senhora das Dores	135	33
Itabaiana	339	92
Tobias Barreto	272	65
Lagarto	417	113
Propria	107	26
Capela	141	36
Aracaju	579	98
Average	**284**	**70**
By River Basin		
Sao Francisco	107	26
Japaratuba	139	35
Sergipe	394	83
Piaui	417	113
Real	272	65

2) Water Supply Hours per Day

More than half of inhabitants are served with water for less than 24 hours per day. Discontinuance of water supply is remarkable in Sertao Sergipano and Agreste Sergipano Meso-regions. It is obvious that inhabitants in that region are unsatisfied with current supply-hours system.

Table-1.4 Percentage of Population by Water Supply Hours

Municipality	24 hours (%)	< 24 hours (%)
Nossa Senhora das Dores	20	80
Itabaiana	45	55
Tobias Barreto	0	100
Lagarto	15	85
Propria	65	45
Capela	100	0
Aracaju	70	30
Average	**48**	**52**
By River Basin		
Sao Francisco	65	35
Japaratuba	73	27
Sergipe	53	47
Piaui	0	100
Real	15	85

3) Water Charge per Month

Average household payment per month is R$ 14.3 and average payment per capita is R$ 3.5. 61% of inhabitants consider that the actual charge is reasonable, while 38% regard it expensive.

4) Household Income per Month

The survey shows R$ 640 on average.

5) Household Size

The survey shows 4.2 persons on average.

(3) Results of Questionnaires to Rural Inhabitants

Results of questionnaires to inhabitants in 13 rural areas are summarized as follows. The survey shows that 51% of interviewees in the rural area engage in agricultural activities.

1) Existence of Public Water Supply System
Coverage ratio of water supply in the rural areas is 55% on average in terms of population. Nearly half of interviewees are not served with public water supply system.

Table-1.5 Population Served with Public Water Supply System (Rural)

Unit: %

Municipality	With System	Without System
Nossa Senhora da Gloria	45	55
Poco Redondo	40	60
Porto da Folha	90	10
Carira	10	90
Aquidaba	90	10
Nossa Senhora das Dores	60	40
Itabaiana	55	45
Tobias Barreto	40	60
Lagarto	90	10
Capela	35	65
Boquim	80	20
Itabaianinha	70	30
Itaporanga d'Ajuda	20	80
Average	55	45
By River Basin		
Sao Francisco	75	25
Japaratuba	45	55
Sergipe	55	45
Vaza Barris	10	90
Piaui	60	40
Real	50	50

2) Water Consumption

Table-1.6 Water Consumption (Rural)

Unit: liter/day

Municipality	Household	Per capita
Nossa Senhora da Gloria	141	34
Poco Redondo	93	19
Porto da Folha	104	21
Carira	159	35
Aquidaba	148	28
Nossa Senhora das Dores	98	21
Itabaiana	217	44
Tobias Barreto	144	31
Lagarto	273	63
Capela	146	26
Boquim	175	42
Itabaianinha	151	30
Itaporanga d'Ajuda	198	36
Average	156	33
By River Basin		
Sao Francisco	120	24
Japaratuba	130	24
Sergipe	170	36
Vaza Barris	160	35
Piaui	210	45
Real	150	30

All rural inhabitants, both with and without public water supply system, consumed 33 liters per day on average. Per capita consumption of inhabitants without the system was 30 liters per day on average.

3) Inhabitants with Public Water Supply System

- Water supply system: 65% of private tap and 35% of pubic tap (Private taps are shared broadly in Sertao Sergipano meso-region, meanwhile public taps serve widely in the rest of meso-regions.)
- Average water supply hours per day: 19 hours for private tap and 18 hours for public tap
- Water charge per month: R$15/household and R$ 2.9/capita

4) Inhabitants without Public Water Supply System

- Carrying hours and distance: Sertao Sergipano meso-region is remarkable compared to carrying distance.

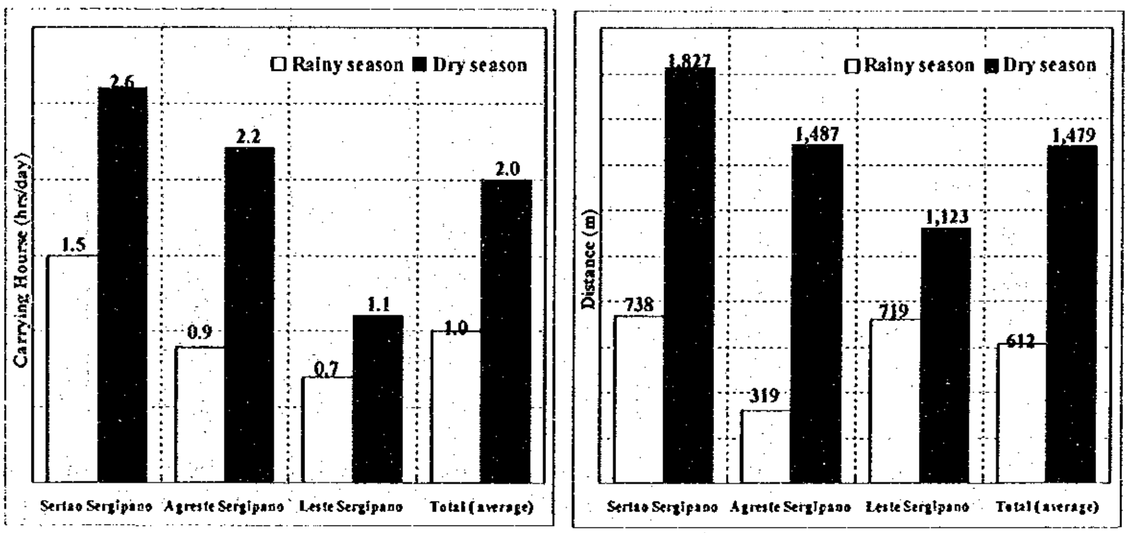

Figure-1.1 Carrying Hours and Distance

- 93% of inhabitants are in favor of future implementation of public water supply project in the area and almost all wished private tap system. Quality improvement is desired in Agreste Sergipano meso-region, while stable supply is desired in the rest of regions, especially Sertao Sergipano meso-region.
- The survey showed 95% of the inhabitants having willingness to pay the following water charge.

Per household	R$ 6.3/month
Per capita	R$ 1.4/month

- Household income was R$270 per month on average.
- Household size was 5.2 persons on average.

1.2.2 Industrial Use

The questionnaire forms were sent to 55 manufacturing companies by facsimile. However, only 18 data were collected. The summaries of the collected data are as follows.

1) The industries are classified to 2 textile, 2 garment, 4 food, 1 brewery, 4 mining non-metal and 5 metal.
2) The size of the companies has a wide range, in terms of monthly turnover from R$ 3,000 to R$ 36,000,000.

Table-1.7 Number of Industries with Questionnaire Collected

Municipality	No. of Company	Textile	Garment	Food	Beverage	Mineral non-metal	Metal
Lagarto	1	—	—	1	—	—	—
Neopolis	1	1	—	—	—	—	—
Siriri	1	—	—	—	—	1	—
Aracaju	8	—	—	—	—	2	5
Araua	2	—	1	2	—	—	—
Itabaianinha	1	—	—	—	—	1	—
Salgado	1	—	—	1	—	—	—
Estancia	2	1	—	—	1	—	—
Itaporanga d'Ajuda	1	—	1	—	—	—	—
Total	18	2	2	4	1	4	5

3) As to source of water used, 5 companies are supplied by public entity only, 8 companies have their own supply and 5 companies use the both. As to the type of source of own supply, 9 companies are getting water from wells and 5 companies from river and lakes.
4) The industries supplied by public entity pointed out instability of supply and expensive charge as major problems and the industries with private industrial water supply system pointed out water quality as the most serious matter.

CHAPTER 2 DOMESTIC WATER DEMAND PROJECTION

2.1 Unit Consumption Rates

A planning standard of water supply system is not available in the state. In a water supply plan of DESO, water demand of various consumers is set up on the basis of the past supply records. According to the water supply plan in Aracaju city, the unit consumption rates were set as follows: 147 liter per capita/day for residential use; 10 liter per capita/day for commercial; and 15 liter per capita/day for public.

The records of DESO's water supply services in 1997 on monthly average for the respective categorized consumers were shown in Table-2.1. Supply record by month in 1997 is given in Appendix-1.

Table-2.1 Water Supply Records by Consumer in 1997

Unit: 1,000 m³/month

Item	Residential	Commercial	Industrial	Public
Urban	4,031	389	308	334
	80%	8%	6%	7%
Rural	190	13	2	21
	84%	6%	1%	9%

Source: Supply records of DESO, 1997

The DESO's supply records give the actual consumption rates at peak period regarding domestic, commercial and public uses as follows.

Table-2.2 Water Supply Records by Region in 1997

Unit: liter per capita/day

Item	Residential	Commercial	Public	Total
Aracaju	122	15	12	149
Urban	109	11	10	130
Rural	80	6	9	95

Source: Supply records of DESO, 1997

According to a DESO's expert, the supply capacity of DESO is not enough to cover the peak demand during the peak period. It is said that the capacity of supply system would be necessary 25% more than the present one. Taking this advice into consideration, the unit consumption rates are set up as shown in Table-2.3.

Table-2.3 Unit Consumption Rates

Unit: liter per capita/day

Item	Residential	Commercial	Public	Total
Aracaju	155	20	15	190
Urban	135	13	12	160
Rural	100	8	12	120

Remark: The unit rates in the report of "Manual Operativo Vol. 2 do PROAGUA" are set up; 150 (liter/day) in the region with population of between 4,000 and 50,000, and 120 with that of less than 4,000.

In rural area where the people are not covered with public water supply system, they get their living water through various sources. The most popular and reliable source is deep wells. The wells are generally provided by COHIDRO at present. According to COHIDRO's staff, the rural people relying on deep wells consume around 30 liter per capita/day on average. However, the unit rate was set up as 70 liter per capita/day in this study according to PLIRHINE (Plano Integdrado do Nordeste do Brasil-SUDENE 1980) in the report of "Diagnostico dos Recursos Hidricos do Estado de Sergipe-Page 22".

Urban area is completely supplied with private tap system at present. As to the rural area, the population size of each village (povoados) in the state was studied at first by the Study Team based on survey results by SUPES in 1985. According to the study, rural area was divided into two types by the size of population as follows: 1) large rural; total of villages with more than 101 inhabitants, and 2) small rural; total of villages with less than 100 inhabitants. Consequently, large rural inhabitants (70% of the rural population) were estimated to be supplied with private tap system and small rural inhabitants (30% of the rural population) were estimated to be served with public tap system.

2.2 Projected Domestic Water Demand

The projected water demand of residential, commercial and public uses by municipality is estimated applying the data mentioned before. The results in summary of both types, trend scenario and strategic scenario, are shown respectively in Table-2.4 and Table-2.5. The projected water demand in urban and rural area of both types by municipality is given in Appendix-2.

2.2.1 Trend Scenario

The state demand in 2020 is estimated at 439,000 m³/day, showing 1.7 times of the demand in 1997. The urban demand in 2020 is estimated at 382,000 m³/day, showing 1.9 times of the demand in 1997, while the rural demand in 2020 is estimated at 57,000 m³/day, showing 1.1 times of the demand in 1997.

Table-2.4 Projected Domestic Water Demand (Trend Scenario)

Unit: m³/day

Year	1997	1998	2000	2005	2010	2015	2020
Sergipe	251,227	256,717	267,699	299,390	337,375	382,921	438,753
Urban	200,510	206,018	217,036	248,360	285,318	329,021	381,944
Rural	50,717	50,699	50,662	51,031	52,057	53,900	56,809
By Micro-region							
Sergipana do Sertao do S.F.	15,201	15,362	15,684	16,789	18,185	19,927	22,078
Carira	7,738	7,865	8,118	8,892	9,821	10,947	12,321
Nossa Senhora das Dores	7,305	7,404	7,602	8,094	8,724	9,515	10,500
Agreste de Itabaiana	18,848	19,428	20,587	25,465	30,736	36,658	43,479
Tobias Barreto	12,558	12,757	13,156	14,211	15,511	17,106	19,069
Agreste de Lagarto	12,080	12,216	12,487	13,213	14,013	14,897	15,876
Propria	11,681	11,900	12,339	13,997	16,175	19,066	22,940
Cotinguiba	5,308	5,355	5,450	5,683	5,955	6,271	6,637
Japaratuba	5,631	5,699	5,834	6,284	6,796	7,389	8,085
Baixo Cotinguiba	10,722	10,918	11,309	12,469	13,923	15,718	17,924
Aracaju	112,534	115,749	122,179	138,995	159,413	183,937	214,329
Boquim	17,704	18,013	18,630	20,240	22,209	24,599	27,505
Estancia	13,916	14,051	14,323	15,061	15,913	16,890	18,010
By River Basin							
San Francisco	30,023	30,411	31,188	33,498	37,183	42,199	47,976
Japaratuba	12,776	13,017	13,498	14,881	16,598	18,684	21,234
Sergipe	133,294	136,964	144,304	166,726	190,301	222,090	256,325
Vaza Barris	22,133	22,570	23,444	25,935	28,953	32,391	36,891
Piaui	38,088	38,572	39,542	41,044	45,304	46,843	52,796
Real	14,913	15,183	15,723	17,307	19,036	20,943	23,531

2.2.2 Strategic Scenario

The state demand in 2020 is estimated at 433,000 m^3/day, also showing 1.7 times of the demand in 1997. However it is estimated to decrease by 6,000 m^3/day compared with the trend scenario (439,000 m^3/day) due to the strategic scenario decentralization in the urban area.

Table-2.5 Projected Domestic Water Demand (Strategic Scenario)

Unit: m^3/day

Year	1997	1998	2000	2005	2010	2015	2020
Sergipe	251,227	256,717	267,699	297,768	334,278	378,618	432,838
Urban	200,510	206,018	217,036	246,738	282,221	324,718	376,029
Rural	50,717	50,699	50,662	51,031	52,057	53,900	56,809
By Micro-region							
Sergipana do Sertao do S.F.	15,201	15,362	15,684	18,443	21,475	24,963	29,095
Carira	7,738	7,865	8,118	8,892	9,821	10,947	12,321
Nossa Senhora das Dores	7,305	7,404	7,602	8,094	8,725	9,515	10,500
Agreste de Itabaiana	18,848	19,428	20,587	27,179	34,093	41,734	50,496
Tobias Barreto	12,558	12,757	13,156	14,211	15,511	17,106	19,069
Agreste de Lagarto	12,080	12,216	12,487	14,721	17,113	19,793	22,894
Propria	11,681	11,900	12,339	15,287	18,505	22,165	26,448
Cotinguiba	5,308	5,355	5,450	6,008	6,666	7,449	8,392
Japaratuba	5,631	5,699	5,834	6,658	7,568	8,611	9,839
Baixo Cotinguiba	10,722	10,918	11,309	12,469	13,924	15,718	17,924
Aracaju	112,534	115,749	122,179	129,131	139,815	154,341	173,328
Boquim	17,704	18,013	18,630	20,240	22,209	24,599	27,505
Estancia	13,916	14,051	14,323	16,436	18,854	21,676	25,028
By River Basin							
San Francisco	30,023	30,411	31,188	36,736	42,859	49,897	58,209
Japaratuba	12,776	13,017	13,498	15,521	17,838	20,569	23,866
Sergipe	133,294	136,964	144,304	157,377	174,534	196,255	223,511
Vaza Barris	22,133	22,570	23,444	26,547	30,103	34,267	39,230
Piaui	38,088	38,572	39,542	44,464	50,095	56,673	64,491
Real	14,913	15,183	15,723	17,122	18,849	20,957	23,531
(Urban)							
San Francisco	18,363	18,879	19,913	26,002	32,558	39,936	48,506
Japaratuba	9,005	9,240	9,712	11,683	13,900	16,465	19,498
Sergipe	124,782	128,416	135,683	148,349	164,742	185,208	210,510
Vaza Barris	15,505	15,943	16,818	19,910	23,434	27,544	32,427
Piaui	23,993	24,447	25,353	30,076	35,451	41,711	49,144
Real	8,862	9,094	9,557	10,718	12,135	13,854	15,944
(Rural)							
San Francisco	11,660	11,532	11,275	10,734	10,301	9,961	9,703
Japaratuba	3,772	3,777	3,786	3,839	3,938	4,104	4,367
Sergipe	8,512	8,548	8,621	9,028	9,792	11,047	13,001
Vaza Barris	6,628	6,627	6,626	6,637	6,669	6,723	6,803
Piaui	14,094	14,126	14,189	14,388	14,644	14,961	15,347
Real	6,051	6,089	6,166	6,405	6,714	7,103	7,588

CHAPTER 3 INDUSTRIAL WATER DEMAND PROJECTION

3.1 Industrial Statistics

There is no statistical information regarding industries in Sergipe State. By the year 1985, IBGE conducted industrial statistics every five years, but it stopped the survey after 1985. There is only one inventory booklet of industrial establishments in the state. They are recorded on the registration list as formal registered establishments on the basis of legal system. The title of the booklet is "Official Registration of Industries in Sergipe 1991/92 (Cadastro Industrial Sergipe 1991/92), CODISE". It was issued in 1992, and afterwards no reports were issued from the agencies. Thus, the version in 1991/92 is the latest information.

3.2 Distribution of Factories and Workers

To estimate the industrial water demand, the following components are indispensable: (1) distribution of manufacturing establishments in target areas; (2) unit consumption rates of the respective industrial types. As mentioned above, the latest information is given by the registration in 1991/92.

The Study Team made a distribution of industrial establishments in Sergipe State as of 1991/92 by municipality. The results were summarized in Table-3.1. There were 1,458 industrial establishments in the state, of which 52 % were located in Aracaju Micro-Region.

Their production and some others changed their products from the registration in 1991/92. Anyhow, there are no other sources except the registration information 1991/92, so the distribution of the respective factories is identified on the basis of this registration information in this study.

The distribution of workers who were employed by the industrial establishments registered officially in 1991/92 was made also. The number of workers was 47,034 in total. The number of workers is a kind of indices showing industrial scale. These figures are only one index at the moment, which shows a production scale of the respective establishments. In this study, this index is used as basic data to estimate water demand of industrial sector.

Table-3.1 Number of Establishments and Workers in 1991/92

Micro-region	Establishments	Workers
Aracaju	756	28,818
Agreste de Itabaiana	131	1,057
Agreste de Lagarto	95	808
Propria	71	1,271
Estancia	67	3,028
Baixo Cotinguiba	33	3,373
Others	305	8,679
Sergipe	1,458	47,034

Source: Cadastro Industrial Sergipe 1991/92, CODI

The number of workers by municipality is given in Appendix-3.

3.3 Unit Consumption Rates

Only DESO's supply records give water consumption data for industry. No other information exists in the agencies concerned so far. The JICA Study Team conducted the interview survey to major industrial establishments regarding water consumption in August 1998. However, as shown in Chapter 2, it could not give the effective information of water consumption. Hence, this study uses what were complied in Japanese units that are given in Appendix-4, because of data availability at present. The Japanese units are given in "Research Report of Unit Rates for Industrial Location in Japan, March 1993, Japan Industrial Location Center". The industrial types are met to the classification of the original source in 1991/92.

In the case of industrial water demand estimation, re-circulation water use is a very important component. An advanced manufacturer usually consider the re-circulation to save water consumption and water costs. Needless to say, the availability of re-circulation technology is indispensable for the manufacturers to introduce a re-circulation system into its production process. In this study, the re-circulation water ratio to total consumption water volume is assumed to be the same level as that in Japan in 1993.

The unit consumption rates for the respective industrial types are usually set as per production value (m^3/R\$ million of production), per factory site (m^3/m^2 of site), value added (m^3/R\$ million of VA), etc. As mentioned above, however, the information of industrial production, site areas and VA is not available. Only the number of employees for the respective factories is available, so this information is applied to estimate the water demand of industries.

3.4 Projected Industrial Water Demand

The water demand of industrial use by municipality in 1991/1992 is estimated applying the data mentioned above. In 1991/92, the industrial water demand was estimated at 151,200 m^3/day. The construction companies were omitted from the list, because they consume water not at the location of the company but at the construction site.

Since 1991/92 up to now, industrial circumstances in each municipality are supposed to be changed in numbers of industries, production scale, type of products etc. So the collected industrial ICMS (a kind of value added tax) amount of 1997 which are considered to express current real industrial activities more precisely than others was surveyed by municipality. Its share by municipality was used in calculation of industrial water demand by municipality in 1997.

The water demand of industrial use by municipality was estimated applying all data mentioned before. The result of both trend and strategic scenarios are summarized respectively in Table-3.2 and Table-3.3. The projected industrial demand by municipality is given in Appendix-5.

3.4.1 Trend Scenario

The industrial demand in 2020 is estimated at 668,500 m^3/day, showing 3.3 times of the 1997 demand. The demand in 2020 in both micro-regions, Aracaju and Baixo Cotinguiba, is estimated at 504,000 m^3/day, showing 4.5 times of 1997 demand and also showing a more accelerated centralization to the both micro-regions.

Table-3.2 Industrial Water Demand (Trend Scenario)

Unit: m³/day

Year	1997	1998	2000	2005	2010	2015	2020
Sergipe	201,869	213,706	237,380	309,090	400,763	518,259	668,514
By Micro-region							
Sergipana do Sertao do S.F.	1,415	1,498	1,664	2,062	2,673	3,457	4,459
Carira	240	254	282	368	477	617	795
Nossa Senhora das Dores	353	374	415	542	703	909	1,173
Agreste de Itabaiana	2,818	2,983	3,314	4,311	5,590	7,229	9,325
Tobias Barreto	1,338	1,417	1,574	2,046	2,653	3,431	4,425
Agreste de Lagarto	12,130	12,841	14,264	18,582	24,094	31,157	40,191
Propria	4,007	4,242	4,712	6,136	7,956	10,294	13,258
Cotinguiba	1,506	1,594	1,771	2,305	2,988	3,865	4,985
Japaratuba	1,700	1,799	1,999	2,604	3,378	4,366	5,632
Baixo Cotinguiba	79,083	83,720	92,994	121,130	157,057	203,102	261,994
Aracaju	73,057	77,341	85,908	111,901	145,089	187,625	242,029
Boquim	1,371	1,451	1,612	2,100	2,723	3,521	4,542
Estancia	22,851	24,191	26,871	35,003	45,384	58,689	75,706
By River Basin							
San Francisco	6,988	7,397	8,217	10,390	13,719	17,741	22,863
Japaratuba	15,794	16,720	18,572	23,869	30,939	40,284	51,965
Sergipe	139,932	148,137	164,547	214,897	278,395	359,724	464,030
Vaza Barris	17,607	18,639	20,704	22,908	29,702	40,505	52,249
Piaui	20,850	22,072	24,517	36,040	46,729	58,340	75,256
Real	699	740	823	986	1,279	1,667	2,150

3.4.2 Strategic Scenario

The demand in 2020 in both micro-regions, Aracaju and Baixo Cotinguiba, is estimated at 437,000 m³/day. It shows 2.9 times of 1997 demand. However, it also shows a decrease by 67,000 m³/day compared with trend scenario demand (504,000 m³/day in 2020). And also the share of both micro-regions in the state demand declines to 65 % in 2020 from 74 % in 1997.

Table-3.3 Industrial Water Demand (Strategic Scenario)

Unit : m³/day

Year	1997	1998	2000	2005	2010	2015	2020
Sergipe	201,869	213,706	237,380	309,090	400,763	518,259	668,514
By Micro-region							
Sergipana do Sertao do S.F.	1,415	1,498	1,664	3,895	7,112	11,655	17,957
Carira	240	254	282	368	477	617	795
Nossa Senhora das Dores	353	374	415	541	701	907	1,170
Agreste de Itabaiana	2,818	2,983	3,314	6,043	9,897	15,257	22,603
Tobias Barreto	1,338	1,417	1,574	2,049	2,657	3,436	4,432
Agreste de Lagarto	12,130	12,841	14,264	20,300	28,383	39,162	53,440
Propria	4,007	4,242	4,712	6,999	10,106	14,298	19,905
Cotinguiba	1,506	1,594	1,771	2,738	4,065	5,871	8,305
Japaratuba	1,700	1,799	1,999	3,034	4,450	6,369	8,946
Baixo Cotinguiba	79,083	83,720	92,994	121,082	156,994	203,019	261,881
Aracaju	73,057	77,341	85,908	103,229	123,534	147,461	175,604
Boquim	1,371	1,451	1,612	2,097	2,721	3,524	4,532
Estancia	22,851	24,191	26,871	36,715	49,666	66,685	88,943
By River Basin							
San Francisco	6,988	7,397	8,217	13,219	20,146	29,637	42,493
Japaratuba	15,794	16,720	18,572	24,830	32,967	43,554	57,278
Sergipe	139,932	148,137	164,547	207,636	261,313	328,499	412,543
Vaza Barris	17,607	18,639	20,704	27,533	36,387	47,873	62,728
Piaui	20,850	22,072	24,517	34,801	48,561	66,900	91,155
Real	699	740	823	1,071	1,389	1,796	2,316

By contrast, the demand of these micro-regions, such as Sertao Sergipano do Sao Francisco, Agreste de Itabaiana, Agreste de Lagarto and Estancia is estimated to increase more than estimated in trend scenario. The demand in 2020 of these micro-regions is estimated respectively 12.9 times, 8.1 times, 4.4 times and 3.9 times of 1997 demand.

APPENDIX-1

Records of Water Supply in 1997

Appendix-1 Records of Water Supply in 1997

Consumer	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Total Volume Supplied (Unit: 1000 m³/month)													
Urban Areas													
Residential	4,256	4,173	4,124	4,186	3,951	3,970	3,801	3628	3907	3978	4104	4297	4,031
Commercial	404	394	382	395	388	374	365	350	423	408	384	397	389
Industrial	334	325	337	290	296	260	266	294	307	339	291	360	308
Public	346	322	335	356	380	303	343	303	343	311	346	319	334
Rural Areas													
Residential	196	199	198	196	176	184	182	173	180	184	202	212	190
Commercial	14	16	14	12	12	12	11	12	11	13	16	17	13
Industrial	2	1	1	1	2	1	2	4	2	2	3	2	2
Public	22	22	17	20	21	21	23	20	22	22	24	21	21
Per Capita Consumption (Unit: lit/capita/day)													
Residential													
Aracaju	121	120	118	115	112	114	107	101	113	113	115	122	114
Urban	109	107	105	107	101	101	96	91	98	100	103	107	102
Rural	80	80	79	77	69	71	70	66	68	69	75	79	74
Commercial (per resident within supply territory)													
Aracaju	13	13	13	13	12	13	12	12	15	14	13	13	13
Urban	10	10	10	10	10	9	9	9	11	10	10	10	10
Rural	6	6	6	5	5	5	4	5	4	5	6	6	5
Public (per resident within supply territory)													
Aracaju	10	9	10	11	12	8	10	9	10	8	10	8	10
Urban	9	8	9	9	10	8	9	8	9	8	9	8	8
Rural	9	9	7	8	8	8	9	8	8	8	9	8	8

Source: Supply Records of DESO, Jan. - Dec., 1997