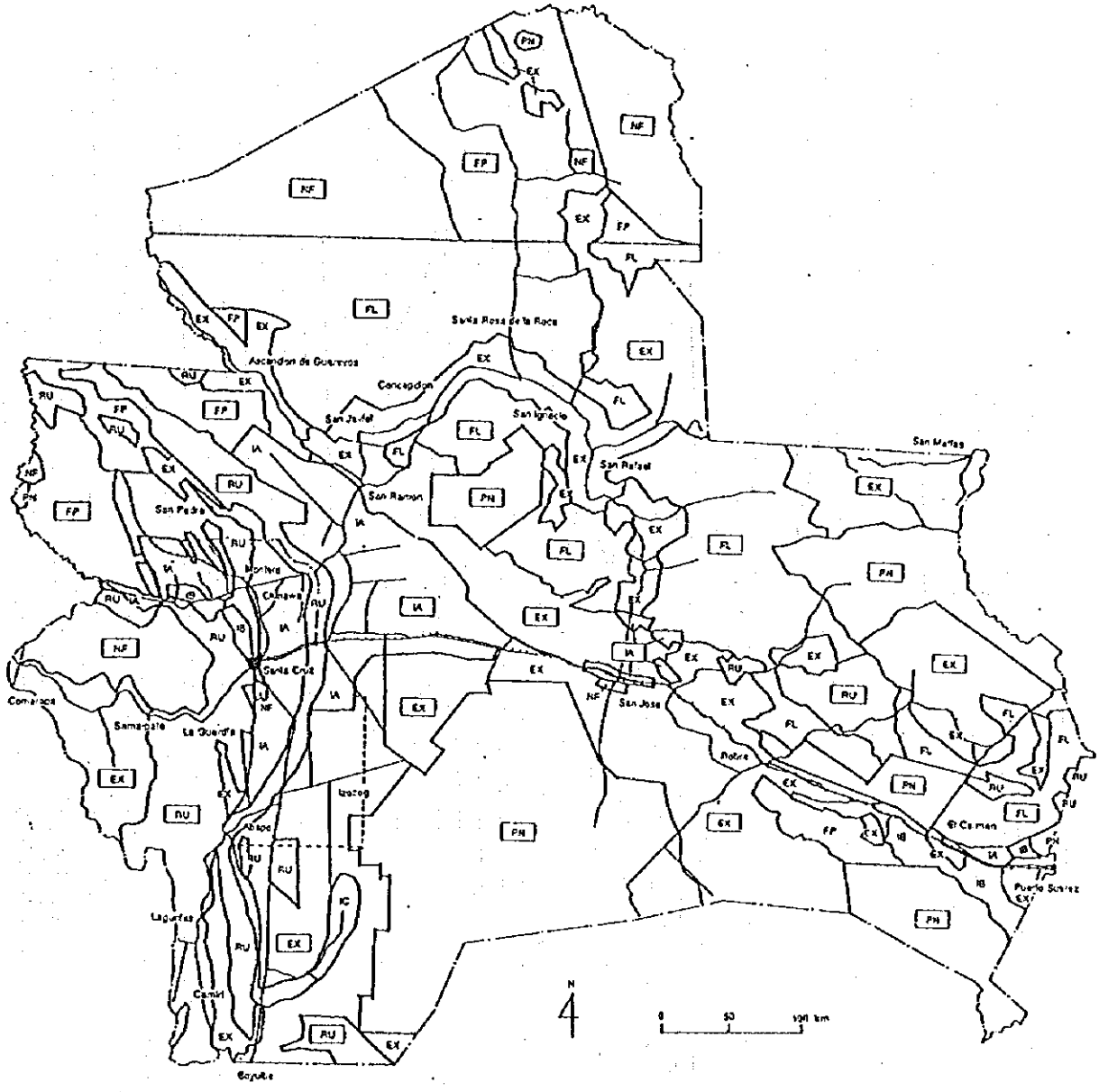
FIGURES

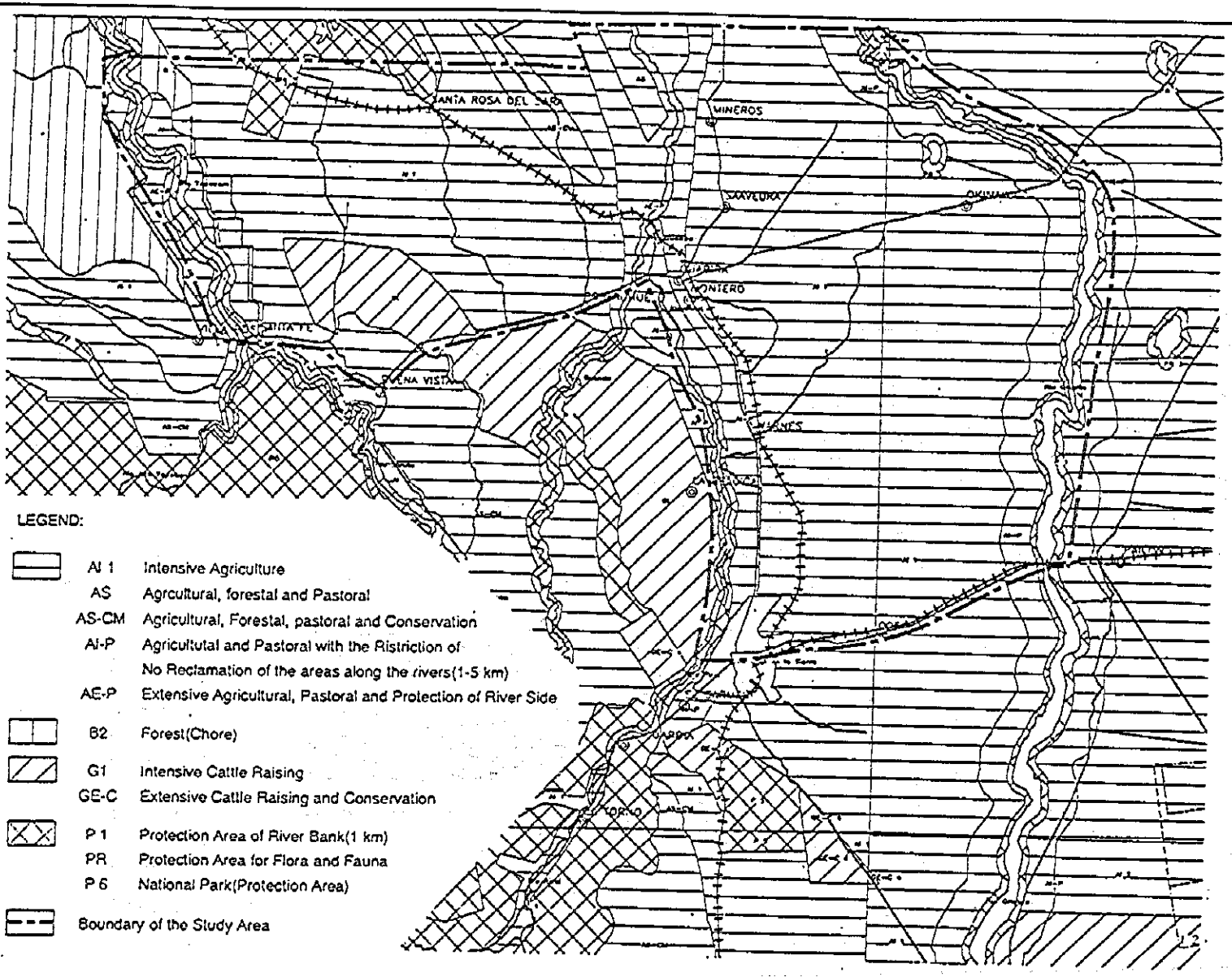


LEGEND:

- Area for Intensive Agriculture/Livestock Use
- IA — Intensive Agriculture Area
- IB — Intensive Livestock Area
- IC — Intensive Agriculture and Livestock Area
- EX — Area for Extensive Agriculture/Livestock Use
- Area for Forestry
- FP — Permanent and Production Forest
- FL — Forest with Limited Livestock
- RU — Area for Restricted Use
- Area for Protection
- NF — Established National Park and Forest Reserve Areas
- PN — Potential Natural Reserve Areas

Source : PLUS, CORDECRUZ

FIG.6.2.1 LAND USE PLAN OF SANTA CRUZ DEPARTMENT(PLUS)



Source : PLUS, CORDECRUZ

FIG.6.2.2 LAND USE PLAN OF THE STUDY AREA(PLUS)

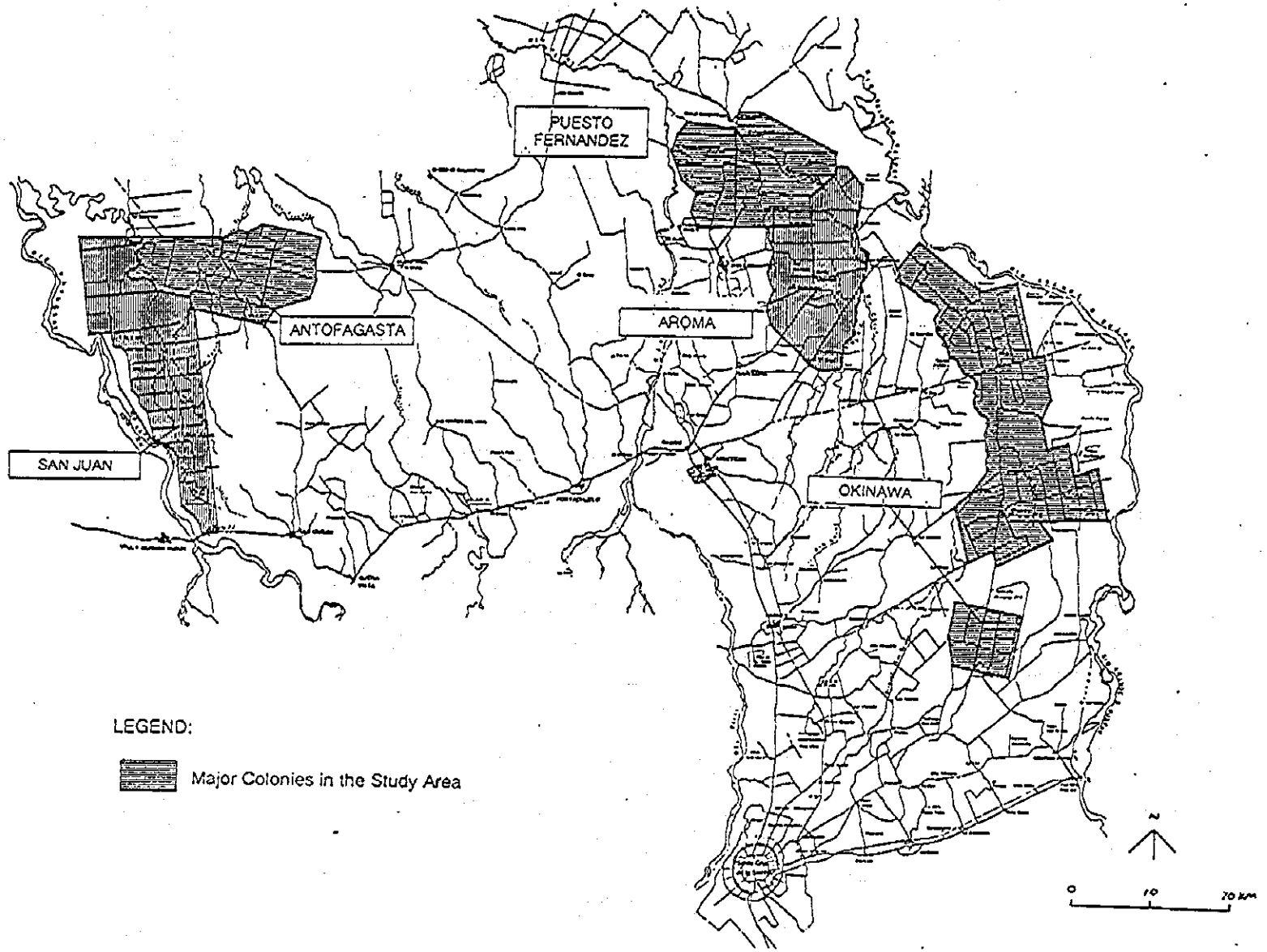
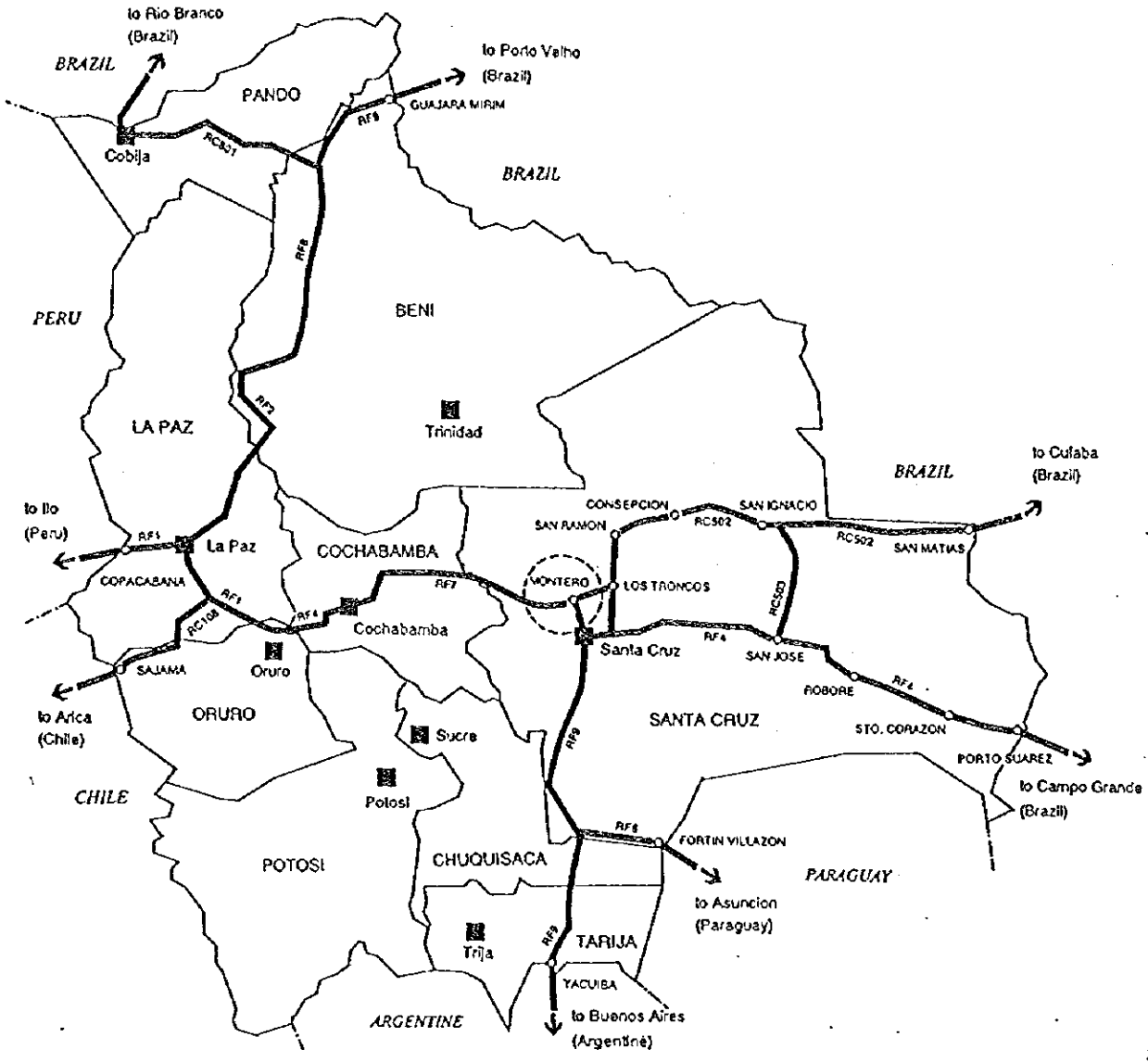


FIG.6.3.1 MAJOR COLONIES IN THE STUDY AREA



LEGEND:

- Export Lanes
- Catital Cities
- Study Area

Source : PGPES, Ministry of Sustainable Development and Environment

FIG. 6.3.2 DEVEOPMENT OF "EXPORT LANES"

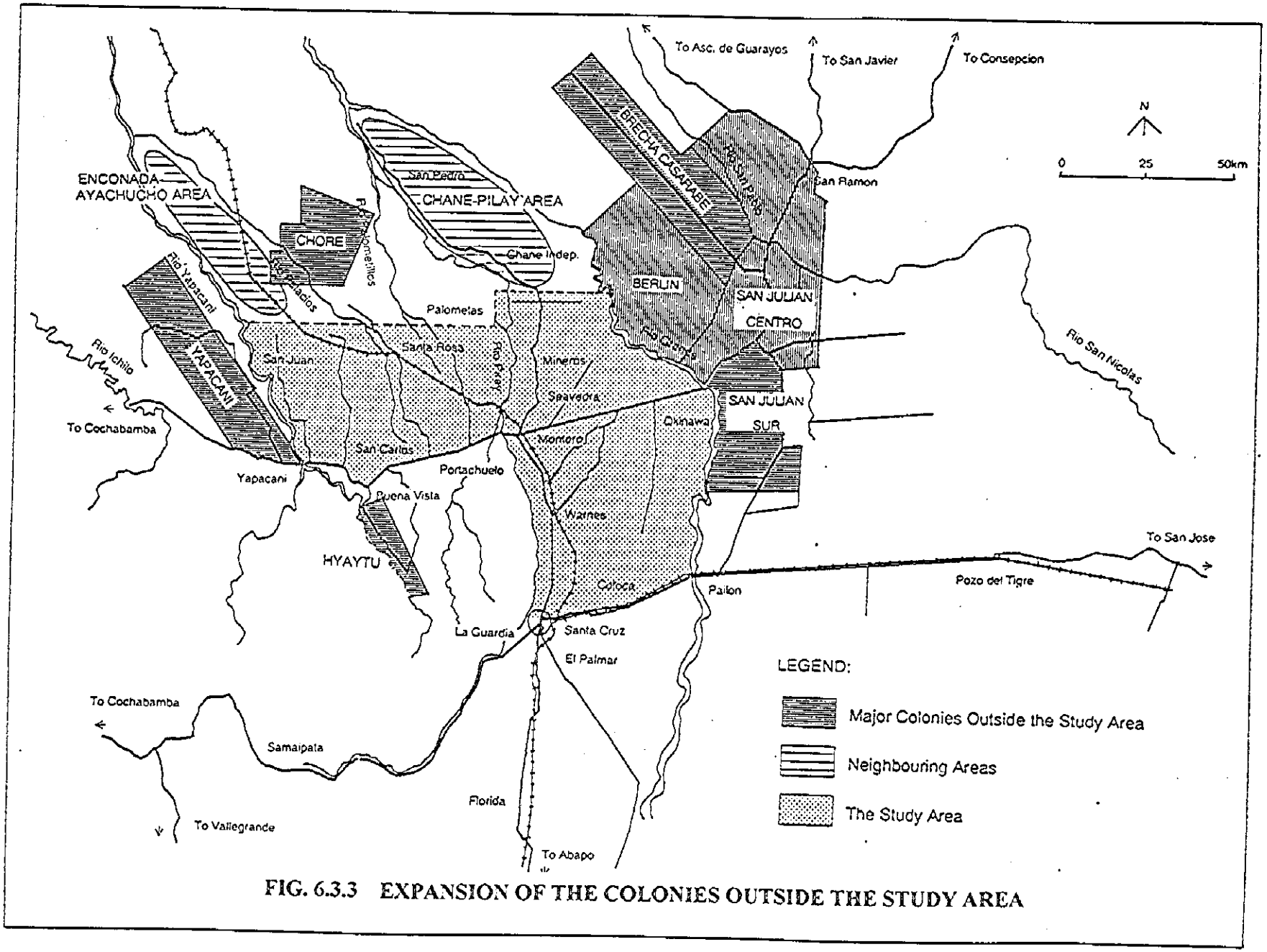


FIG. 6.3.3 EXPANSION OF THE COLONIES OUTSIDE THE STUDY AREA

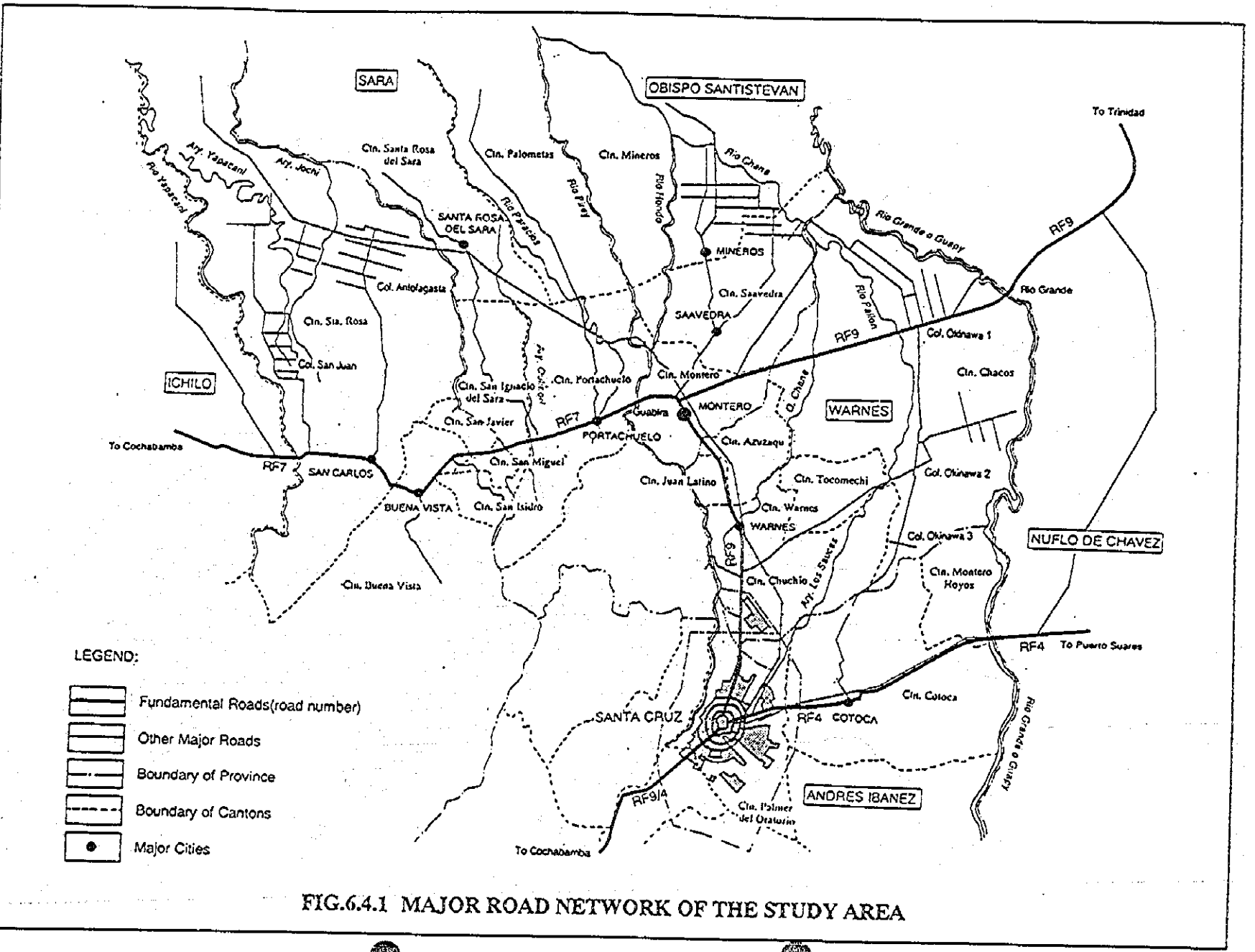


FIG.6.4.1 MAJOR ROAD NETWORK OF THE STUDY AREA

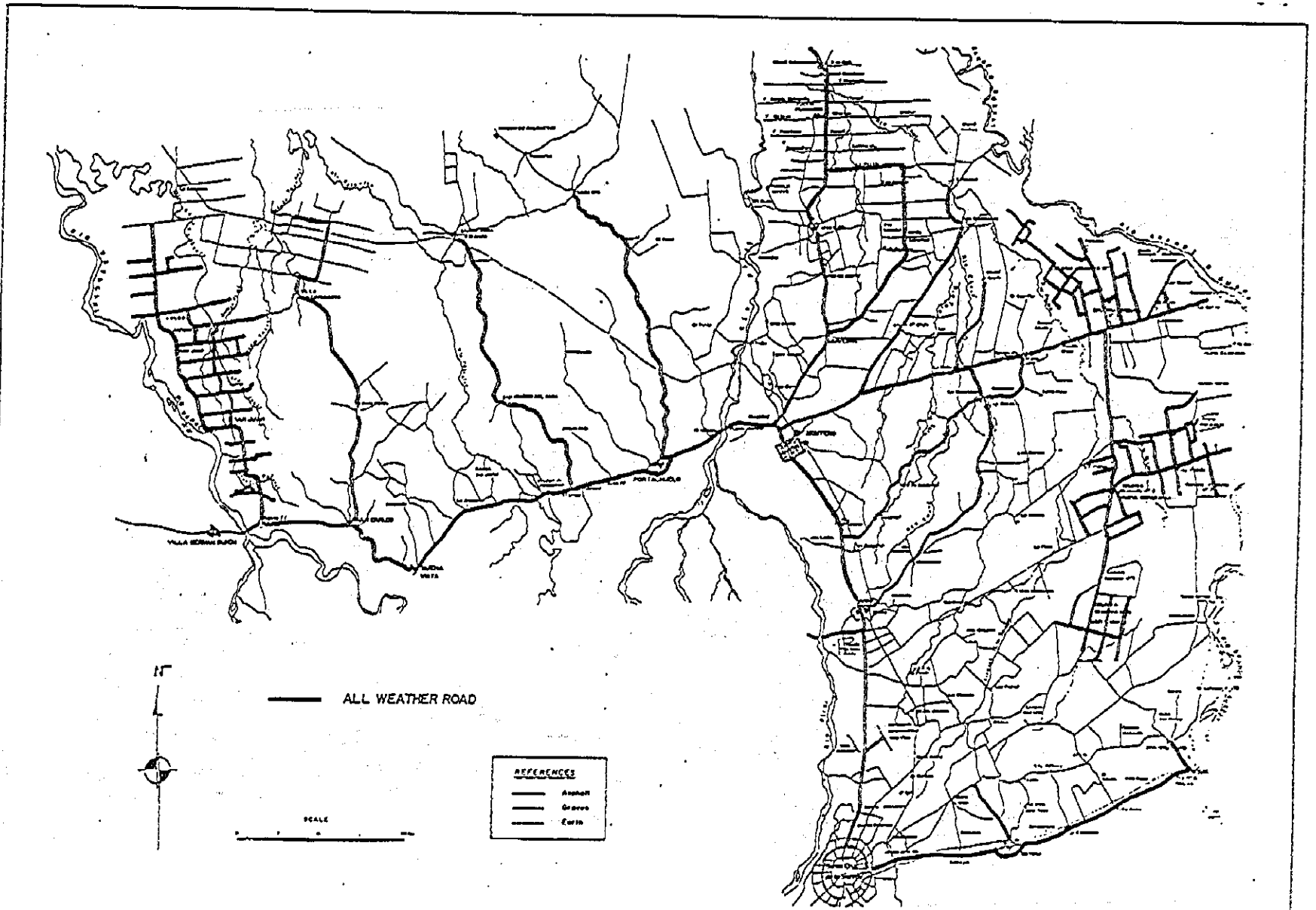


FIG.6.4.2 CONDITIONS OF THE EXISTING ROADS(ALL WEATHER ROAD)

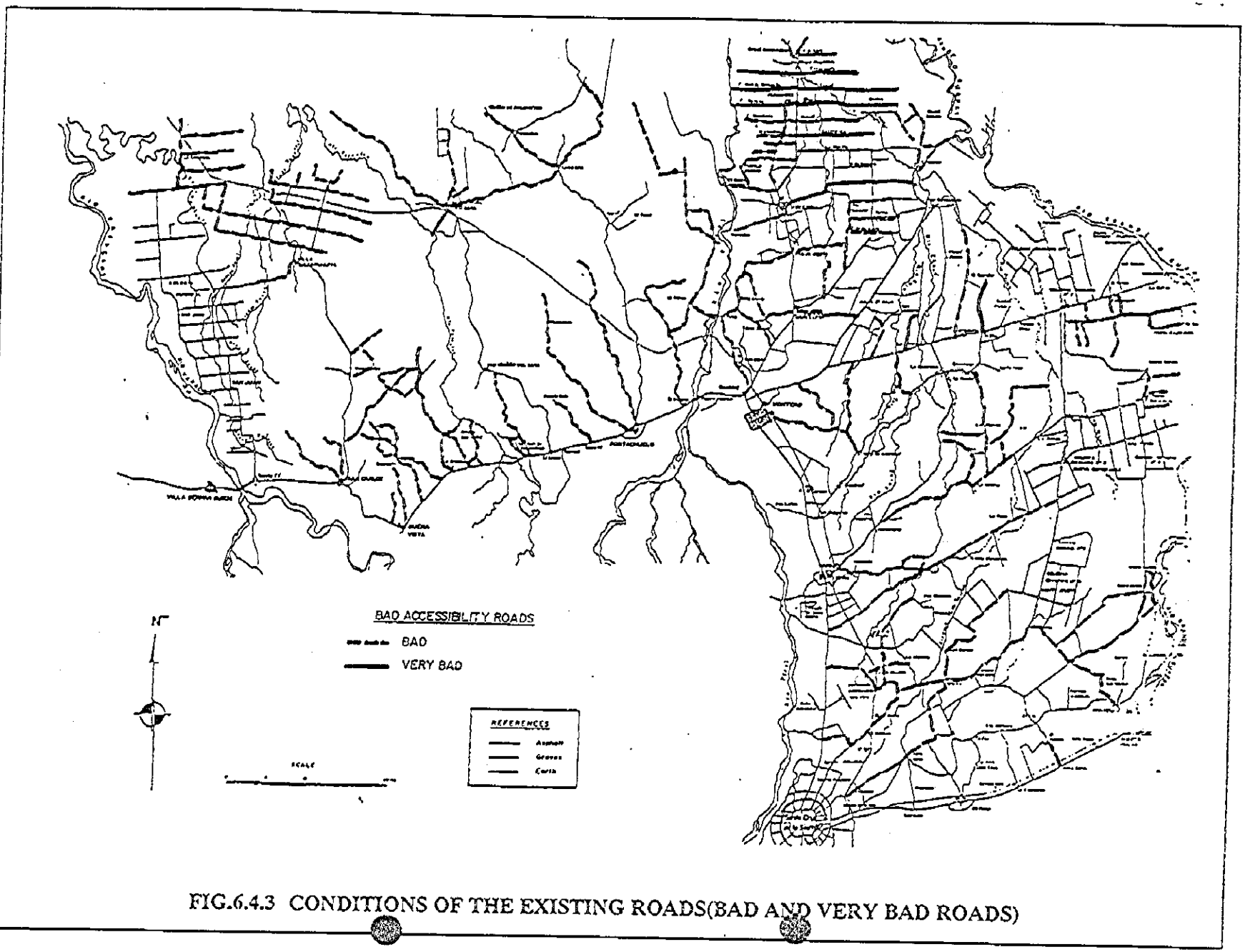


FIG.6.4.3 CONDITIONS OF THE EXISTING ROADS(BAD AND VERY BAD ROADS)

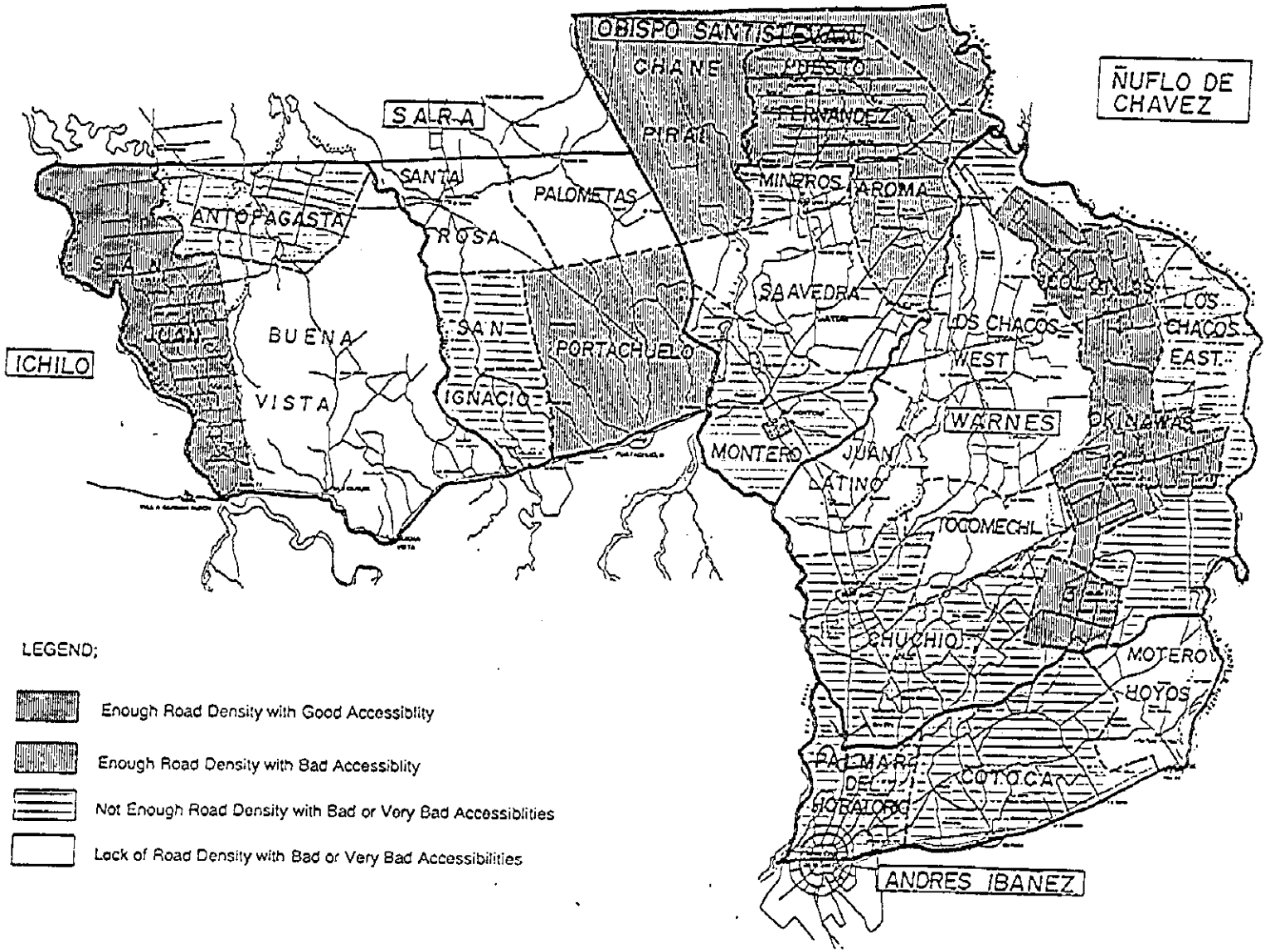


FIG.6.4.4 CONDITIONS OF THE EXISTING ROADS BY CANTONS/SUB-ZONES

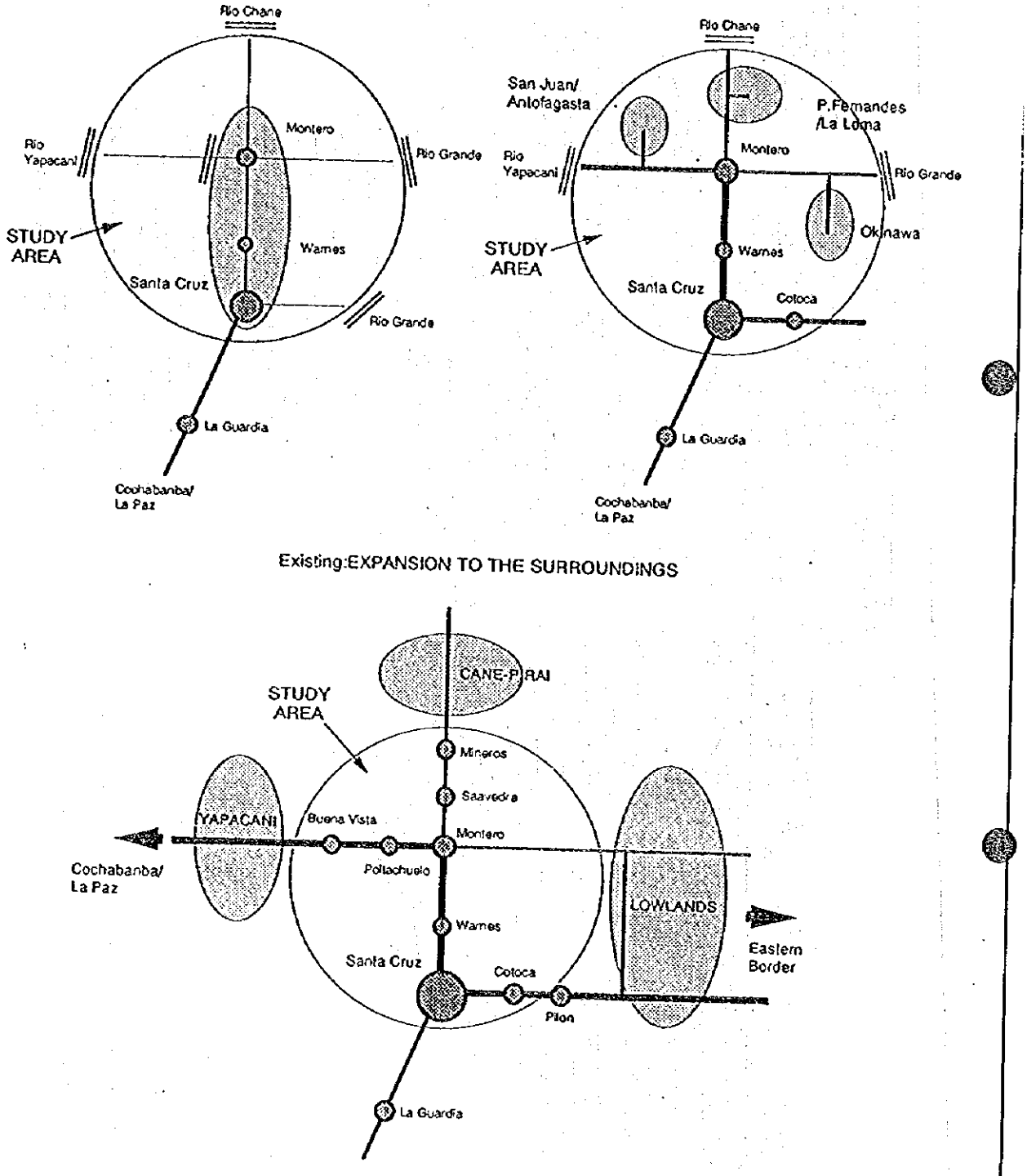


FIG.6.4.5 HISTORY OF THE REGIONAL DEVELOPMENT PATTERNS(1)

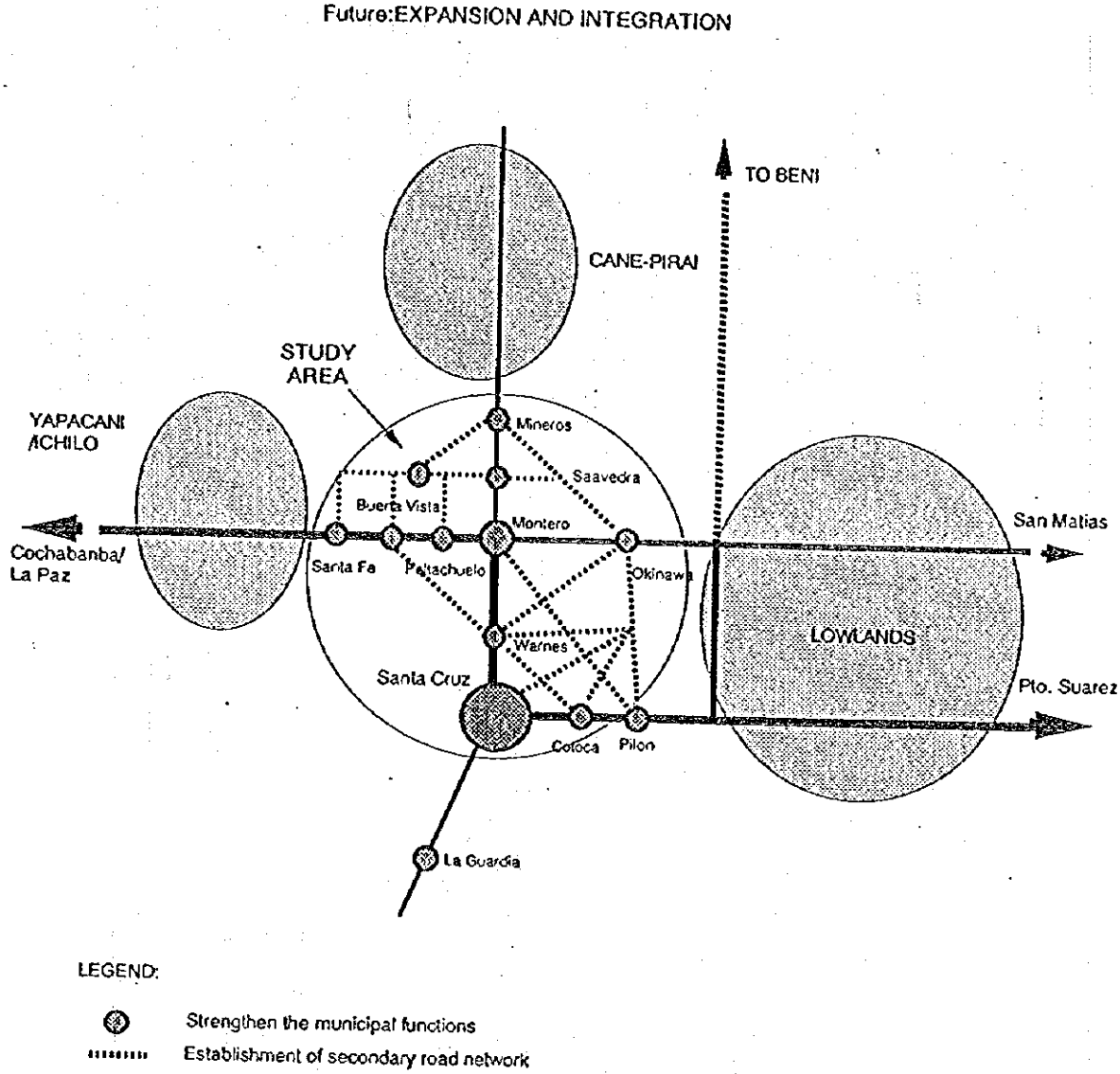


FIG.6.4.5 HISTORY OF THE REGIONAL DEVELOPMENT PATTERNS(2)

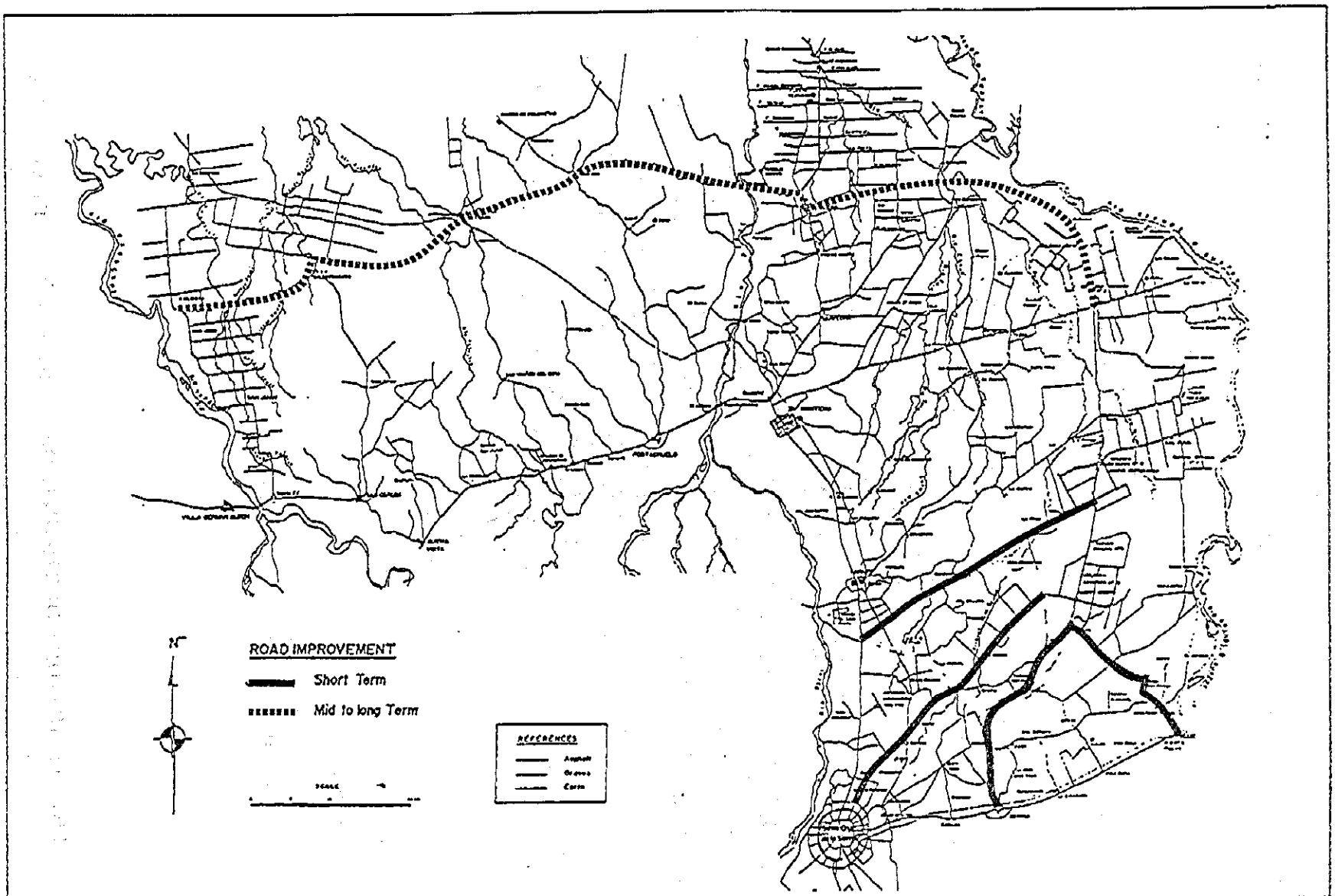


FIG.6.4.6 RECOMMENDED SECONDARY ROADS TO BE IMPROVED

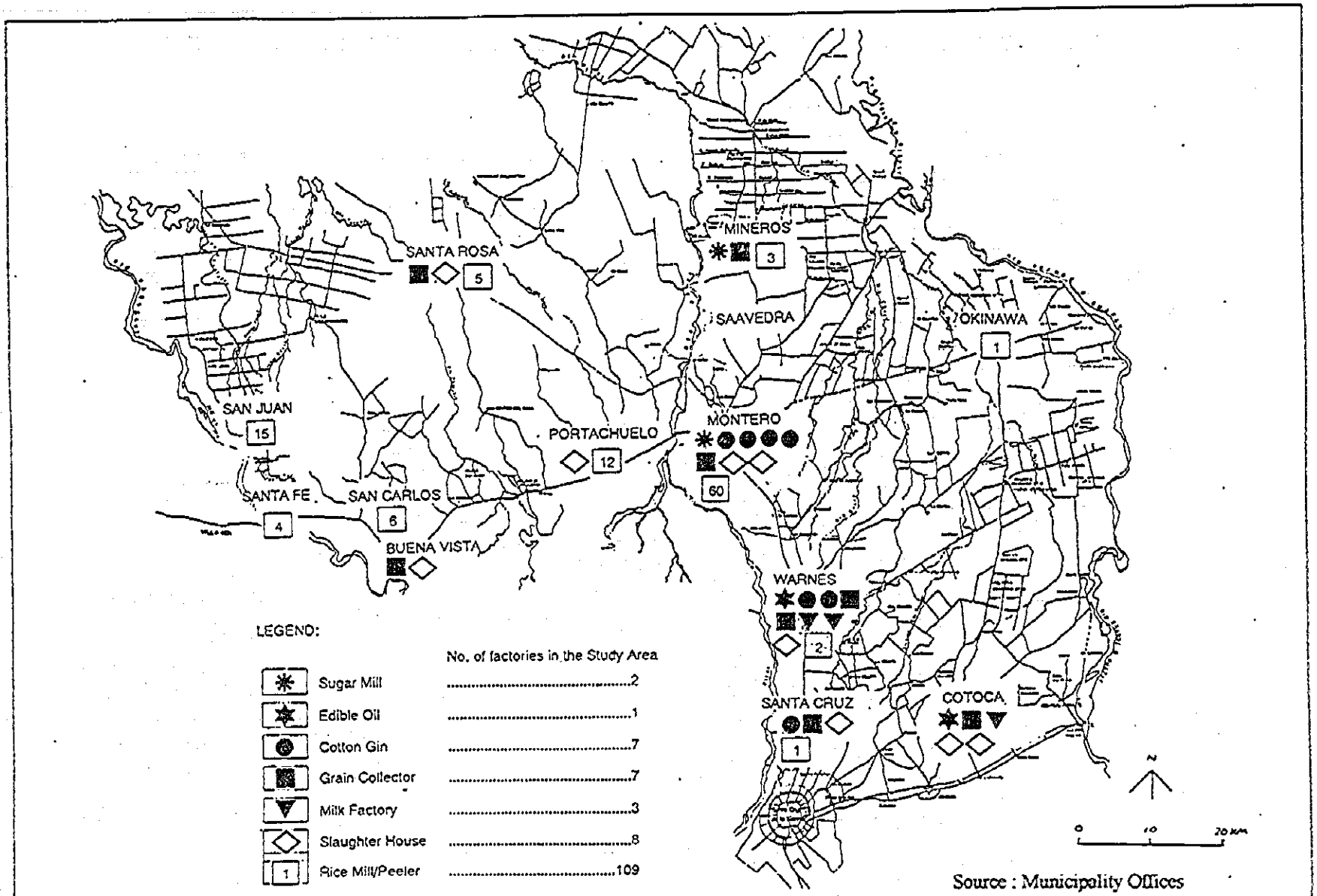


FIG. 6.5.1 LOCATIONS OF THE MAJOR AGROINDUSTRIAL FACTORIES IN THE STUDY AREA

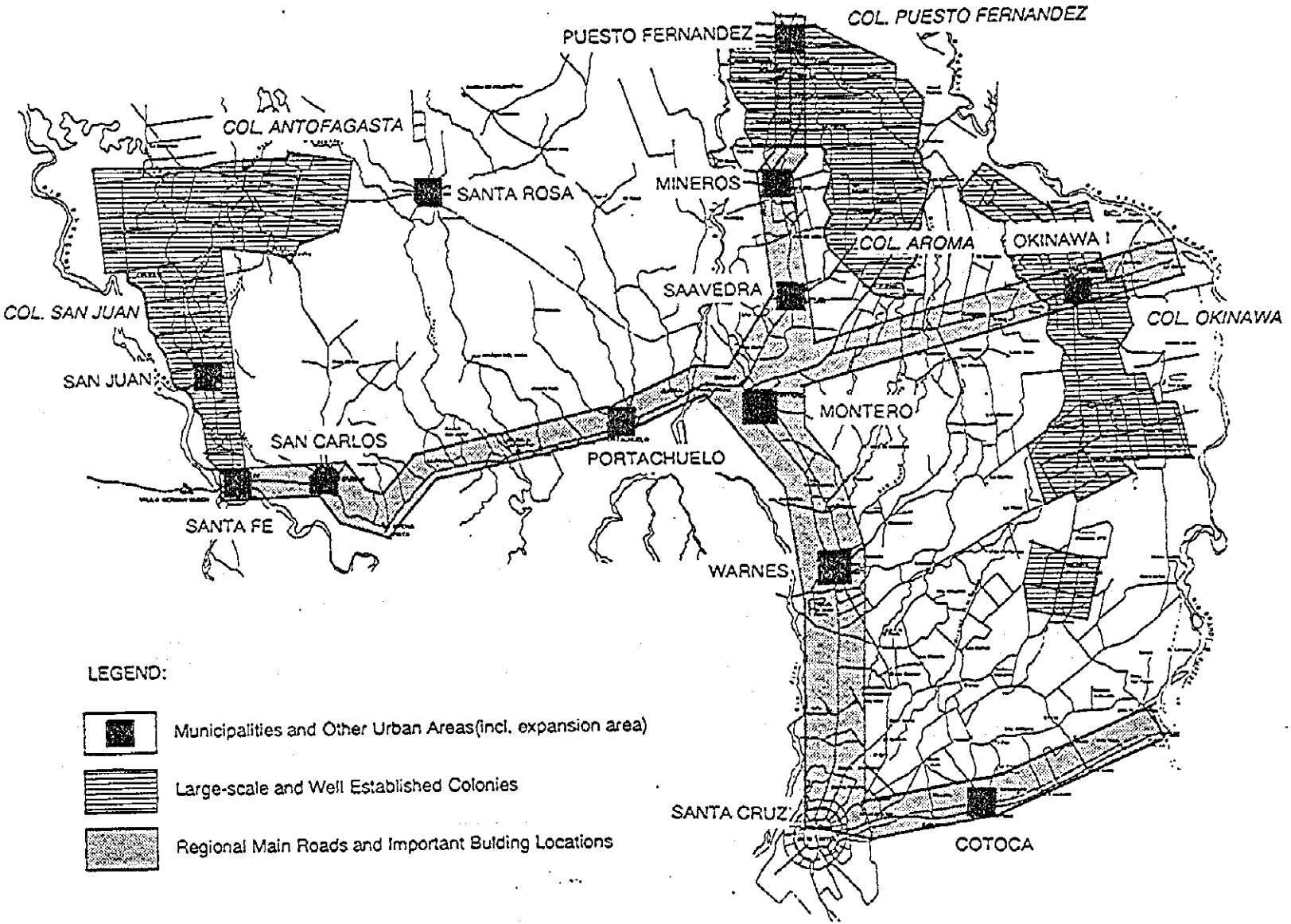


FIG.6.6.1 PRIORITY AREAS FOR FLOOD PROTECTION AND DRAINAGE IMPROVEMENT

CHAPTER 7
AGRICULTURE AND LAND USE

CHAPTER 7 AGRICULTURE AND LAND USE

7.1 General

7.1.1 Role of Agriculture in Economy

The agricultural sector in Bolivia plays an important role in the national economy, which contributes nearly one fifth of the total value added and one fourth of the total foreign exchange earnings. The sector grew 2.5 % per annum from 1988 to 1992 and the share to the GDP was between 17.7 % and 19.0 %, respectively (*Table 7.1.1*).

The principal crops in the Department of Santa Cruz are soybean, sugarcane, rice and maize and they contribute to about 40 % of the agricultural GDP of the Department. The dominant crop was rice until 1988, but soybean after 1988.

The livestock and chicken production also have grown steadily in the period and marked the growth rates of 2.3 % and 5.9 % respectively. However, the growth rate was much less than that of the averages of agricultural GDP in the Department and its share in the GDP has decreased from 34.2 % in 1988 to 27 % in 1992.

7.1.2 History of Agricultural Development in Santa Cruz

Agricultural development of the Department of Santa Cruz can summarize as following stages :

Stage	Period	Main crop
1	1954-1958	Self consumption rice and cattle
2	1958-1969	Rice and sugarcane
3	1969-1974	Cotton
4	1974-1985	Diversification,
5	1985-Present	Soybean

7.2 Existing Situation of Agriculture

7.2.1 Crop Production

The main crops in the Department of Santa Cruz and those in the study area are shown in *Tables 7.2.1* and *7.2.2*, and the indexes of crop production are shown in *Tables E.2.3* and *E.2.4* respectively.

The main crops in the Department of Santa Cruz are soybean, sugarcane, maize and rice that account for about 75 % of the total crop planted area. From 1990 to 1994, the production of crops increased explosively due to the expansion of planted area of soybean, except the summer soybean.

The study area is the agricultural centre of the Department. The crop planted area accounts for 44 % of the whole crop planted area in the Department. The main crops in the study area are soybean, sugarcane and rice. The average annual growth rate of soybean and rice production in ton from 1990 to 1994 recorded lower than those of the Department. However, the share of the crop production is still high (soybean: 37 %, sugarcane: 89 %, and rice: 72 %) and the study area played an important role in the agricultural GDP of the Department.

Among these main crops, soybean is by far the most widely planted, accounting for 47 % of the total main crop planted area in the study area. In the Department, the winter soybean is dominant in the area where are affected by frequent floods and heavy rainfalls in summer, and there are enough rainfall to grow soybean in winter. The winter soybean seed is produced in the area.

The application of improved seeds for the main crops has become popular since the later half of 1980s (See *Table E.2.5* and *E.2.6*). However, the applications of improved seeds do not seem to have contributed to increase in production except for maize and summer soybean in the Department. The effect of improved seeds in the study area was lower than that in the Department. The main reasons are assumed as follows:

1) Soil fertility is decreasing due to the continuous cropping without applying fertilizer,

2) The physical condition of the soil has been distracted due to soil compactness by using heavy agricultural machinery,

3) The forest clearing in the upper reach has likely increased the frequency of floods and the flood damage.

To support item 1), fertilizer is mainly applied to the seed production such as soybean, rice etc., but the application ratio is still very low.

Generally, maize, rice, and cotton are cultivated in summer, and sorghum, wheat, sunflower and kidney bean in winter. The summer crops are harvested in March and April and the winter crops are seeding in April and May, harvesting in September and October.

7.2.2 Livestock Production

The numbers of cattle in the Department and in the study area are shown in *Tables 7.2.3* and *7.2.4*.

The main livestock in the study area is cattle. The study area raised 400,000 heads of cattle in 1994 that accounted for 30 % of the livestock in the Department. The cattle varieties obtained from FEGASACRUZ (Federation de Ganaderos de Santa Cruz) and ADEPLE (Asociacion Departamental de Productores de Leche) are shown as follows:

1) Beef cattle

Variety	Share (%)
-Zebutine crossing	50
-Nelore	20
-Criollo (native)	15
-Others	15

2) Dairy cattle

Variety	Share (%)
-Holstein crossing	80
-Holstein and Brown Swiss	20

The improved pasture area is estimated to be 130,000 hectares according to FEGASACRUZ. The variety of pasture, cultivated in the study area, are Brachiaria, Mutica, Hermatria, Altisima and Brachiaria Humidicola. However, the area has been decreased recently due to the frequent floods and the poor drainage conditions.

The egg production that is mainly in the western part of the study area, becomes one of the main sectors. The area has an advantage of egg production because the area is producing a high quality feed such as the oil cake of soybean.

The swine production accounted for as high as 80 % of the Department. The share may increase higher because currently it has been started also in Okinawa area.

7.2.3 Agriculture Supporting Services

(1) Agricultural research and extension

1) Agricultural research

Agricultural research is mainly carried out by CIAT (Tropical Agricultural Center), which is financed by a trust fund. Main items of the research are on breeding of rice, soybean, cotton and wheat. The results of the research have contributed to the improvement of agriculture by providing new varieties. The selection of citrus also has started recently.

Technical Transfer Department (TTD) of CIAT is responsible for transfer the results of research to the organizations that carry out extension services by organizing seminars, publishing technical guideline, etc.

CIAT receives technical assistance from the UK, JICA and Washington University, and financial assistance for specific projects from USAID and World Bank.

2) Technical extension

There are four types of the organization, i.e., producer's associations, private enterprises, non-government organizations (NGO) and government projects (See Appendix E).

According to the field survey, 44 % of the farmers interviewed, experienced to have received the services. However, most of the small scale farmers had no experience of receiving any services.

(2) Agricultural credit

There are two systems for provision of agricultural credits, formal financing and semi-formal financing systems as follows:

1) Formal financing system

- Banks
- FINDESA (Financiera de Desarrollo Santa Cruz)

2) Semi formal financing system

- FONDECO (Fondo de Desarrollo Comunal),
- PRODEM (Fundacion para la Promocion y Desarrollo de la Microempresa)

There are many organizations that provide agricultural credit. However, there are very few chances for small scale farmers to get loan because they lack guarantee and mortgage.

7.3 Marketing of Main Product

(1) Export

The export trends of main crops from 1984 to 1993 are shown in *Tables 7.3.1* and *7.3.2*. Soybean and sugar contributed much in the foreign-exchange earning, and accounted for 13.0 % of the total export earnings in 1993. The main exporting countries are those in the Andean group such as Colombia and Peru. Since 1985 the export of soybean and sugar have increased at a rate of 38 % per annum. However, the percentages of production exported has decreased from 80 % in 1987 to 50 % in 1993. This reflects increase in the domestic consumption increasing.

(2) Import

The major agricultural import is staple food such as cereal and flour. The import has been increasing since 1990 (*Tables 7.3.3* and *7.3.4*). The imports became 1.5 times of the exports of soybean in 1992. These agricultural products, wheat shares a large part of the imports, are able to be produced in the study area. The expansion of wheat production in the area would contribute in the saving of foreign currency.

(3) Agro-based industry

The agro-based industries in the study area are listed in *Table E.3.5*. In the study area, those industries play an important role not only in economy and employment but also in supporting farming and poultry development.

The processing facilities of the main crops such as edible oil, soybean cake, rice and sugar, can afford to treat more materials. Especially, the running rate of the canned fruits' factories is less than 50 %. Expansion of fruits' production has a high potential in the study area.

7.4 Land Potentiality and Land Use

7.4.1 Land Potentiality

The area by categories and their distribution are shown in *Table 7.4.1* and *Fig. 7.4.1*. The land potentiality is divided into the following five categories:

Category	Land Classification	Criteria
1	II - III	Land suited for agriculture
2	IV	Land marginally suited for agriculture
3	V	Land suited for grazing
4	VI - VII	Land marginally suited for grazing
5	VIII	Land unsuited for any agricultural activity

The land suited for agriculture, category -1, covers 4,431 sq. km that covers 62 % of the study area and the land unsuited for agriculture covers 30 % of the study area. The category-4 and -5 are mostly distributed along river channels and have drainage problems.

According to *Table 7.2.2*, the annual cropping area is estimated to be 2,200 sq. km. The improved pasture area to be 1,300 sq. km, which is equivalent to 80 % of the category-1 area. Therefore, there is still a room to expand an intensive land use such as crop cultivation and improved pasture.

7.4.2 Land Use

A land use map was prepared by the Study Team, based on the LANDSAT data in 1992 and 1994, aerial photographs taken in 1995 and field surveys. The areas by land use and the existing land use are shown in *Table 7.4.2* and *Fig. 7.4,2*. Moreover a summary of land use in 1984 and 1993 is shown in *Table 7.4.3*.

(1) Characteristics of the land use

Main findings from the land use map are summarized as follows:

1) The forest distributes mainly in the unarable land area and along river courses, that are characterized by poor drainage conditions.

2) The secondary forest distributes also in the unarable land area.

3) The farm lands of upland crops and sugar cane are distributed mainly in the arable, but flood hazard area.

4) The poor drainage area classified as unarable land at San Juan, etc., is partly used for upland crops by improving drainage conditions.

5) The low precipitation area, located in the southern part of the study area, is mainly used for grazing.

6) The farm land of sugar cane covers the central part of the study area, in where sugar cane factories are located.

(2) Land use change

The land use data for 1993 was adjusted through the study, because the data did not cover the whole study area and also the land use categories were different from those of the data prepared by the study. The land use data for 1984 was estimated based on the crop planted areas. Major changes in the land use are summarized as follows:

1) The share of each land use by province shows almost no change between 1993 and 1995 except for Ichilo Province.

2) The total agricultural land, including pasture, did not change since 1984. However, the ratio between the farming lands of crops and pasture changed very much during the period. The crop planted area was expanded with decreasing of grazing land.

3) Ibanez Province was different from the others. It might be that the area has not enough precipitation for crop cultivation.

4) The forest areas in the three stages were almost same. It is assumed that the development of agricultural land was finished in the study area by 1984.

5) The secondary forest areas in 1993 and in 1995 are likely corresponding to the idle land in 1984. It is suggesting that the current secondary forest areas were once developed, but later abandoned.

(3) Existing land use by zone

As results of analysis of the existing situations; natural and social condition, the area can be divided into nine zones as shown in *Fig. 7.4.3*. Flood, soil and agricultural structure are given priority for the zoning because these three facters are related each other and affect the existing land use.

Main characteristic of zone and main facters for zoning are summerized as follows;

Zone No	Main Character (Area)	Main Factor
Zone-1:	Low precipitation area (Cotoca)	Rainfall
Zone-2:	Intensive upland field (Okinawa)	Agricultural structure, Flood
Zone-3:	Sugarcane production area (Montero)	Agricultural structure, Flood
Zone-4:	Local colony-1 (Minero)	Agricultural structure, Flood
Zone-5:	New developed upland crop area (Chane)	Flood
Zone-6:	Intensive diversified agricultural area (San Juan)	Agricultural strucure, Flood
Zone-7:	Local colony -2 (Antofagasta)	Agricultural structure, Flood
Zone-8:	Grazing area (Buena Vista)	Agricultural structure, Soil
Zone-9:	Forest area (Sara)	Soil, Land use

7.5 Problem Identification

The questionnaire survey was conducted by the study team in order to supplement the existing data and to identify problems in agricultural sector.

Number of the farmers by holding size in 1984 is shown in *Table E.5.1* and *E.5.2*. The survey results are shown in *Table E.5.3*. The major findings are summarized as follows:

(1) Inundation

72 % of the farmers interviewed have experienced flood damages. Those who suffer from floods yearly, accounted for 93 % of them. Average depth and duration of flooding are 63 cm and 14 days.

Accordingly the floods have affected the crop productivity, the selection of crops and the composition of agriculture in the study area. In order to stabilize the agricultural production and to accelerate the agricultural diversification, optimum countermeasures will be urgent.

(2) Disparity of farmers by farm size

The farm income per farm family is much different due to the farm size. There is a tendency that the smaller farmer yields the lower. According to the survey results, the main reasons are assumed as follows:

- Selection of the same crops among different farm sizes
- No supporting services for small scale farmers
- Low ratio of organized farmers

The ratio of the farmers who belong to a farmer's organization is 73 % in average. The organized large scale farmers are 100 %, but the organized small scale farmers are still low. It is very important for farmers to belong to a farmer's organization in order to get an appropriate technology or to get bargaining power.

(3) Agricultural diversification

Most of the farmers want to continue the same crop cultivation such as soybean, rice, maize and sugarcane. However, there are about 10 % of the farmers who want to diversify their agriculture by introducing vegetables and fruits. Especially those among the farmers of small scale, have an intention to diversify their agriculture.

The colonies of San Juan and Okinawa are accelerating diversification of their agriculture in order to stabilize the income and to sustain the soil fertility by introducing fruits and livestock.

Diversification may be the effective countermeasures for sustainable development of the area.

(4) Low intensity of land use

The fallow and idle lands occupied 16 % of the available land. The efficiency of land utilization, annual cropping area per farm land, is low. Small scale farmers of cultivated their lands less than 110 %. It means that the farmers cultivate their farm lands only once a year.

(5) Degradation of soil fertility

Most of farmers apply insecticide and herbicide, however, only 15 % of the farmers apply fertilizer, mainly to seed production. The ratio of the farmers that apply fertilizer is lower than that of the national average, as shown in *Table E.2.6.*

(6) Comparison of agricultural situation between the flood prone area and the non-flood area

The main findings are as follows:

1) The flood prone area is mainly distributed in the northern part of the study area.

2) The non-flood area produced US$ 153 per hectare, but the flood prone area did only US$ 113 per hectare.

3) On the contrary, crop yield in the flood prone area was higher.

4) Concerning land use, the annual crop area is high in the flood area (56 %) and the pasture is high in the non-flood area (46 %).

5) The ratio of harvest area to seeding area is higher in the non-flood area.

6) As to species, the ratio of beef cattle is high in the non-flood area (85 %), but dairy cattle is high in the flood area.

7) The ratio of application of agricultural inputs such as improved seeds and agricultural chemicals, is higher in the flood area.

8) The ratio of organized farmers is higher in the flood area.

9) The farmers in the flood area have a strong desire for agriculture diversification.

The flood area is characterized as more fertile and application of more agricultural input than the non-flood area. The flood area seems to play a central role in the agricultural production.

7.6 Existing Agricultural Development Policy

The Development Plan of the Department of Santa Cruz was prepared by CORDECRUZ in 1995. The targets and policies concerned to the agriculture sector are summarized as follows:

(1) Target

The GDP growth rate of the whole country is set to maintain 5 % level. The main sectors expected to contribute to the target are mining, agriculture, livestock, timber and agroindustry. In order to achieve it, environmental conservation and sustainable development of resources should be duly considered.

(2) Agricultural policy

The main agricultural policies to achieve the targets are as follows:

1) Enforcement of research and technical extension service to improve human resources,

2) Increment of budget for agricultural research,

3) Improvement of sanitary control for crop and livestock,

4) Improvement of secondary road to secure transportation for agricultural products,

5) Improvement of agricultural credit to medium and small scale farmers,

6) Reforestation in the unarable land to prevent soil degradation.

7.7 Development Plan

The basic development concept for the study is summarized in *Fig. 7.7.1.* The target is to achieve sustainable development by the execution of optimum countermeasures.

7.7.1 Development Plan by Zone

In order to stabilize regional economy, the mitigation of flood and drainage problems of the area is indispensable. At the same time, in order to sustain economic growth, the following measures are necessary.

- Introduction of appropriate crop rotation to sustain soil fertility
- Introduction of high productive crops such as fruits to increase farm income
- Introduction of water tolerant crops and varieties for inundation area

For implementation of the development plan, improvement of agricultural extension services such as technical extension and credit should be necessary. Especially improvements of technical extension services for small scale farmers are essential, because they will play an important role for diversification.

Main existing situation and the development plan by zone are summarized in *Table 7.7.1*, and detail of the existing situation and countermeasures of agriculture explain as follows:

(1) Zone-1: Low precipitation area (Cotoca)

1) Existing Situation

- Pasture is the dominant land use because of low precipitation and sandy soil. The characteristic of agriculture structure is that the area consists of small scale farmers and they run the same agriculture as the large scale farmers, which need a large farm land to get a certain amount of farm income for continuous running.

- Forest distributed along river courses and in unarable land.

2) Counterneasure

- The disparity of farm income among the farming scales is a problem. In order to improve the farm income among the small scale farmers, a high productive crop with labor intensive like fruits should be introduced.

- The expansion of perennial crops in the area will improve the land use condition from flood control aspects.

- Leguminous forage tree such as Leucaena, drought resistance trees, should be introduced for increasing livestock productivity.

- As countermeasures for the shortage of water, drought resistant crops and water resources development for providing supplemental water during seeding stage should be studied.

(2) Zone-2: Intensive upland crop area (Okinawa)

1) Existing Situation

- The dominant land use is upland field. The major crop is soybean, accounting for 70 % of the crop field. The second is wheat in winter and the third upland rice in summer. The crop productivity has been decreasing because of continuous cropping without application of fertilizer. The yield is still high in the Department because of its fertile soil. Forest is distributed only along river courses.

- The area plays an important role in the regional economy through the agricultural production. However, large part of the area suffers from floods and poor drainage

problems. In order to stabilize the agricultural production of the area, it should be indispensable to mitigate flood and drainage problems of the area.

2) Countermeasure

- In order to overcome the degradation of farming conditions, appropriate crop rotation such as the rotation of leguminous crop and gramineous crop should be necessary.

- The area largely depends on soybean. In order to avoid the risk of the price fluctuation, diversification of the agriculture should be required.
  The diversification of agriculture will likely contribute to sustain a high agricultural growth rate of the Department.

(3) Zone-3: Sugarcane production area (Montero)

1) Existing Situation

- The most widespread land use is cropping of sugarcane, because the soil is suited for sugarcane production. Many sugar factories have been established in the zone. The main problems are decreasing of the productivity because of continuous cropping of sugarcane.

- The northern part of the area is suffering from floods and poor drainage problems. In order to stabilize the agricultural production of the area, it should be indispensable to mitigate flood and drainage problems of the area.

2) Countermeasure

- In order to sustain the productivity, appropriate crop rotation should be required.

(4) Zone-4: Local colony-1 (Minero)

1) Existing Situation

- The area consists of small scale farmers, producing rice, soybean and sugarcane. However, the area is affected by floods from the Rio Pirai and Rio Chane and tributaries.

2) Countermeasure

- In order to mitigate the flood problems, it will be necessary to introduce water tolerant variety and crop, because structural measures might not be feasible.

(5) Zone-5: New developed upland crop area (Chane)

1) Existing Situation

- It is a new developed field with fertile soil and the crop productivity is very high, but located in the frequent flood hazard area. The main land use is sugarcane and upland field and the products are soybean and rice.

2) Countermeasure

- It will be necessary to introduce flood tolerant varieties and crops, because the required structural measures will be costly and might not be feasible.

- The area remains high productivity, but there are the same possibilities of decreasing of yield and soil fertility as the zone-2 and -3. In order to avoid the problems, appropriate crop rotation, diversification of agriculture and soil management technology should be introduced.

(6) Zone-6: Intensive diversified agricultural area (San Juan)

1) Existing Situation

- The agriculture in the area is already diversified, however the area has flood and poor drainage problems. The main land use is upland field, accounting for more than 79 % of the area.

2) Countermeasure

- By mitigation of such problems, further diversification by expanding perennial crops will be possible to accelerate sustainable agriculture.

(7) Zone-7: Local colony-2 (Antofagasta)

1) Existing Situation

- The area is suffering from flood and poor drainage problems. In order to stabilize the area, it should be indispensable to mitigate flood and drainage problems of the area.

- The area consists of small scale farmers, producing rice in summer and soybean in winter.

- The area needs to promote diversification their agriculture and.

(8) Zone-8: Grazing area (Buena Vista)

1) Existing Situation

- Most of the area consists of grazing land and forest because of low soil fertility.

- The area has no serious flood problems.

2) Countermeasure

- Agriculture in the area can not change because most of the area is unsuited for crop cultivation. Therefore, improvement of pasture is necessary to increase productivity.

(9) Zone-9: Forest area (Sara)

1) Existing Situation

- The timber resources are going to exhaust in the area because most of useful timber is already cut. However, most of the area can not be used for agricultural activity because soil is unsuitable for crop cultivation.

- There has no serious flood problems.

2) Countermeasure

- Useful timber tree should be reforested to sustain forest industry in the area. Main recommended spices for the reforestation are Mara (*Swietenia macrophylla*), Roble (*Amburana cearensis*), Cedro (*Cedrela Sp.*), Cerebó (*Schizolobium paraibum*) and Ochoó (*Hura crepitans*).

7.7.2 Protection Forest along River Course

The forest has an important role for conservation of soil and water resources and conservation of fauna and flora. The forest area has been decreased by development, however, it should be conserved from both the flood mitigation and environmental protection aspects.

1) Protection forest along the Rio Grande, Rio Pirai and Rio Yapacani

The Forest Regulation (Art. 15) rules that forest should be protected in the area of 500 m wide along the river. It is planned that 1 km wide forest on either bank should be conserved because of flood mitigation and conservation of fauna and flora, as proposed in the Map of Land Use Plan prepared by CORDECRUZ.

2) Protection forest along river course in the tributary area

The Forest Regulation rules that forest should cover at least 20 m wide around the river.

It is planned that 100 m wide forest on either bank should be conserved from flood mitigation and environmental conservation aspects, because average natural vegetation along the small rivers in the study area is about 100 m on either river bank according to the land use survey.

7.7.3 Agriculture Demonstration Center

In Bolivia, there are many areas with severe limitations for crop cultivation like San Juan. Of these areas, San Juan is the most developed area in harmony with natural conditions.

Farmers of the area is well organized and receive enough benefit from the farmer's organization. Farm infrastructures in the area are well improved and managed by the organization, and post harvest such as agro-industry and collecting system are also organized. Cooperation of Sun Juan, therefore, can be said a model of farmers organization.

According to the questioner survey, most small scale farmer are not organized and are not aware of the importance of organization.

Therefore, it is recommend that agricultural center should be established in San Juan to understand importance of organization for small scall farmer as following:

- Management of the organization,
- Activities and role of the organization,
- Distribution of technical information,
- Management of farm infrastrucutres.

7.7.4 Research on Water Tolerant Variety

According to the interview survey results, there are many zones where are damaged by flood every year, namely Zone 4, 5 and 7, and these areas are very difficult to improve the situation.

Therefore, water tolerant variety is necessary to continue agricultural activity in these areas.

Most farmers grow rice during rainy season mainly for self consumption and they leave these field fallow. The yield of rice is very low and others are little.

CIAT has released high yield varieties and has contributed to increase crop productivity. However, water tolerant variety suited for the area is necessary to improve the situation. It is recommended that research on appropriate variety for severe flood areas should be urged by CIAT.

7.7.5 Target of Agricultural Production in the Year 2010

Government set the national economic growth target at a rate of 5 percent per annum for the period from 1995 to 2005. Agriculture of the department played important role in regional economy ; showing high growth rate (8 % per annum during 1988 - 92) and sharing 21 % of GRP in 1992. The study area contributed about 55 % to the Agricultural GRP. Considering these situations the agriculture sector of the study area should continue to play the importance and achieve the target growth rate. Therefore, implementation of the flood control project is important to sustain the economic growth. Implementation of the flood control expect to induce the following effects on agriculture:

1) Expansion of crop planted area or harvested area.
2) Increased of land productivity by introducing high productive crop and improving crop yield.
3) Decreased of post harvest damage by improved road condition..

From estimation of the effects, implementation of the flood control expect to expand 1.2 times of planted area of rainy season in 1994. Otherwise, the area have potential to expand 1.5 times of crop yield; which is ratio of the highest average yield of sugar cane and rice and that of 1994. Therefore, the area have potential to expand 1.77 times (1.2X1.5) of agriculture production by improvement of flood. The expansion of crop production by 2010 equivalents to 3.6 % per annum in growth rate of agriculture production. Furthermore, following effects are expected :

1) Alleviation of post harvest damage.
2) Increasing of land productivity by expanding high productive crop.
3) Expanding crop production in winter season by stability of rainy season's production.

As a result of the assumption, the area is possible to achieve 5 % growth rate per annum after improvement of flood.

TABLES

TABLE 7.1.1 ANALYSIS OF AGRICULTURAL GDP OF BOLIVIA AND SANTA CRUZ

		1988	1989	1990	1991	1992	Average Annual Growth Rate %
National GDP							3.9
Agricultural GDP / National GDP	%	18.7	18.1	18.1	19.0	17.7	2.5
STC GRP / National GDP	%	27.3	27.4	28.2	28.6	28.4	4.8
Agricultural GRP STC / Agricultural GDI	%	27.3	29.5	31.2	34.5	33.9	8.2
Agricultural GRP STC / GRP STC	%	18.6	19.5	20.1	23.0	21.1	4.8
Share of Main Subsector in Agricultural GRP of STC							
Soybean	%	7.5	14.3	10.6	14.2	12.0	22.4
Sugarcane	%	9.2	9.0	11.3	13.8	11.3	15.1
Rice	%	10.2	8.6	10.2	8.2	8.3	3.8
Maize	%	5.1	5.3	3.4	6.2	7.6	20.8
Wheat	%	0.4	1.1	3.0	2.4	4.5	99.0
Livestock	%	29.1	27.0	25.3	21.0	22.5	2.3
Chicken	%	5.1	5.1	5.2	4.1	4.5	5.9
Total	%	66.6	70.3	68.9	70.0	70.8	10.8

Source : CUENTAS REGIONALES, SECTOR AGROPECUARIO 1988 - 1992

TABLE 7.2.1 MAIN CROP PRODUCTION IN SANTA CRUZ

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94
Cotton fiber											
ha	5,741	9,478	10,831	7,463	9,710	1,215	3,555	16,523	26,000	11,400	19,000
qq/ha	8.99	7.01	7.65	8.38	7.26	13.52	12.09	11.20	5.10	14.67	10.00
qq		51,607	66,462	82,876	62,574	70,506	16,425	41,145	185,058	133,640	167,237
Cotton seed											
ha	5,741	9,478	10,831	7,600	9,400	1,200	3,500	16,500	26,000	11,799	19,000
t/ha	0.63	1.01	0.87	0.80	0.80	0.67	0.65	0.60	0.50	0.79	0.70
t	3,617	9,573	9,423	6,080	7,520	804	2,275	9,900	13,000	9,336	133,000
Rice											
ha	60,000	80,000	37,000	50,000	65,000	58,500	73,000	73,000	73,000	85,717	96,500
t/ha	2.11	2.11	2.67	2.68	2.11	2.29	2.50	2.50	2.93	1.90	2.00
t	126,600	168,800	98,790	134,000	137,150	133,965	182,500	182,500	213,890	162,862	193,000
Maize											
ha	50,000	70,000	45,000	32,000	37,500	35,000	52,000	40,000	80,000	83,000	85,000
t/ha	2.05	2.20	2.30	2.30	2.07	2.50	1.10	3.60	2.16	3.60	3.18
t	102,500	154,000	13,500	73,600	77,625	87,500	57,200	144,000	172,800	298,800	270,300
Wheat											
ha	9,000	12,960	10,000	6,500	4,000	13,316	30,219	36,614	63,614	35,115	53,550
t/ha	1.00	1.00	0.47	1.15	0.87	0.81	1.61	1.32	1.52	0.96	1.41
t	9,000	12,960	4,741	7,500	3,500	10,864	48,951	48,400	96,514	33,590	75,505
Frejol											
ha	3,000	5,000	400	670	800	1,500	7,880	18,000	8,000	4,500	5,000
t/ha	1.20	1.20	1.25	1.20	1.20	1.20	1.20	0.70	0.70	0.80	0.76
t	3,600	6,000	5,000	804	960	1,800	9,456	12,600	5,600	3,600	3,800
Sun flower											
ha				40	80	350	10,217	21,500	20,155	23,031	60,000
t/ha				0.60	0.80	0.80	1.16	1.37	1.27	1.22	0.96
t				24	64	280	11,870	29,500	25,572	28,055	57,600
Soy bean (W)											
ha	14,000	12,000	12,358	12,500	20,000	30,000	32,334	45,000	27,600	65,231	89,000
t/ha	1.00	1.01	1.18	1.01	0.70	1.50	1.69	1.60	2.11	1.50	1.50
t	14,000	12,120	14,579	12,600	14,000	45,000	54,781	72,000	58,299	97,847	133,500
Soy bean(S)											
ha	36,316	51,000	50,800	53,878	60,000	110,000	140,000	150,000	164,920	174,923	242,000
t/ha	2.10	1.70	2.50	1.71	2.00	2.20	1.29	2.13	1.52	2.38	2.45
t	76,255	86,790	127,000	92,200	120,000	242,000	180,000	320,000	250,367	415,508	592,900
Sugar cane											
ha	47,727	47624	42,000	40,000	40,000	38,435	47,995	70,000	64,000	64,354	64,354
t/ha	37.48	33.18	24.61	32.24	33.78	35.45	44.16	45.00	40.00	30.73	28.66
1,000 t	1,789	1,580	1,034	1,290	1,351	1,363	2,119	3,150	2,560	1,977	1,844
Sorghum											
ha	6,000	17,000	12,000	6,000	10,500	15,360	24,000	14,500	15,000	35,000	23,500
t/ha	3.00	3.50	3.90	3.00	3.00	2.50	1.50	3.20	2.80	2.79	2.07
t	1,800	59,500	46,800	18,000	31,500	38,400	36,000	46,400	42,000	97,650	48,645
Total											
1,000 ha	238	315	231	217	257	305	425	502	568	594	757

Source: CAO

TABLE 7.2.2 MAIN CROP PRODUCTION IN THE STUDY AREA

	89/90	90/91	91/92	92/93	93/94
Cotton fiber 1)					
ha			1,025	898	5,090
qq/ha			10.82	7.37	11.06
qq			11,091	6,618	56,281
Cotton seed 1)					
ha			1,025	898	5,090
t/ha			0.58	0.51	0.51
t			590	458	2,589
Rice 2)					
ha		50,000	71,717	74,500	69,350
t/ha		2.93	1.90	2.00	2.00
t		146,500	136,262	149,000	138,700
Maize 3)					
ha			7,900	7,900	11,900
t/ha			3.70	3.27	3.60
t			29,230	25,833	42,830
Wheat 4)					
ha	10,684	7,084	10,192	4,600	9,500
t/ha	1.62	1.57	1.53	1.80	1.95
t	17,343	11,089	15,642	8,280	18,525
Sunflower 4)					
ha			2,960	3,670	8,250
t/ha			1.08	1.49	1.09
t			3,208	5,483	9,001
Soybean(W) 4)					
ha	31,579	42,820	24,003	63,643	88,000
t/ha	1.69	1.60	2.14	1.51	1.50
t	53,369	68,512	51,366	96,073	132,000
Soybean(S) 4)					
ha	46,477	44,450	46,535	42,057	57,265
t/ha	1.27	2.13	1.52	2.22	2.37
t	59,026	94,679	70,733	93,435	135,491
Total Soybean 4)					
ha	78,056	87,270	70,538	105,700	145,265
t/ha	1.44	1.87	1.73	1.79	1.84
t	112,394	163,191	122,100	189,509	267,491
Sugarcane 5)					
ha	47,994	69,999	57,152	57,468	57,468
t/ha	44.16	45.00	40.00	30.73	28.66
t	2119420	3,149,960	2,286,080	1,765,995	1,647,036
Total Planted Area					
	158,739	201,506	221,800	254,736	306,823

Source: 1) ADEPA 2) FENCA 3) PROMASOR 4) ANAPO 5) OTAI

TABLE 7.2.3 LIVESTOCK PRODUCTION IN SANTA CRUZ
(Number of Slughtered Head)

	1989	1990	1991	1992	1993	Study Area	
Bovine							
head	144,993	130,631	136,610	139,583	146,444		
t	20,780	33,670	35,640	24,357	26,489		
Pork							
head	35,299	29,612	33,841	36,850	39,039	31,231	
t	2,093	1,857	2,126	2,294	2,495	1,996	1)
Chicken							
head	5,054,000	7,153,582	7,889,393	6,717,915	12,528,391	642,950	
t	5,750	7,154	7,889	11,386	22,551		2)
Chickin (Egg)							
	535,500	731,000	1,170,875	1,095,140	1,027,981	516,850	
t	1,071	1,462	2,342	2,190	2,056		2)
1,000 und	153,950	268,734	360,258	373,510	356,958		
Milk							
Head	55,556	62,659	66,484	66,680	67,324		
1,000 l	78,041	83,232	90,469	93,844	102,669	49,500	3)

Source: CAO 1) ADEPOR 2) ADA 3) ADEPLE

TABLE 7.2.4 NUMBER OF CATTLE IN SANTA CRUZ AND STUDY AREA

(Unt:Head)

Santa Cruz					Study 1)
1989	1990	1991	1992	1993	Area
1,344,267	1,353,072	1,369,986	1,408,960	1,365,801	400,000

Source : Bolivia Anuario Estadistico del Sector Rural 1994
1) FEGASACRUS

TABLE 7.3.1 EXPORT OF MAIN AGRICULTURAL PRODUCTS IN VALUE

(Unit : 1,000 US$)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Sugar	6,649	1,765	4,853	8,565	6,292	19,287	31,710	30,807	25,261	18,485
%	0.9	0.3	0.8	1.5	1.1	2.4	3.4	3.6	3.5	2.5
Cotton	0	0	0	0	0	0	0	13,061	6,533	10,330
%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.9	1.4
Soybean	1,527	5,309	18,741	19,204	20,233	54,280	48,168	69,324	51,504	68,916
%	0.2	0.8	2.9	3.4	3.4	6.6	5.2	8.2	7.2	9.1
Share %	1.1	1.1	3.7	4.9	4.4	9.0	8.6	13.3	11.7	13.0

Source : Bolivia Anuario Estadistico del Sector Rural

TABLE 7.3.2 EXPORT OF MAIN AGRICULTURAL PRODUCTS IN VOLUME

(Unit : 1,000 T)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Sugar	19.0	6.0	17.5	35.1	22.3	42.5	75.5	80.4	72.6	38.7
Cotton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	6.9	6.3
Soybean	12.5	29.3	79.1	84.3	72.2	201.1	184.0	277.9	218.7	260.6

Source : Bolivia Anuario Estadistico del Sector Rural

TABLE 7.3.3 IMPORT OF MAIN AGRICULTURAL PRODUCTS IN VALUE

(Unit : 1,000 US$)

	1988	1989	1990	1991	1992
Cereals	20,775	26,568	23,706	32,170	39,642
Flours	13,562	33,701	25,765	27,358	39,311
Edible oil	4,532	7,961	3,750	3,920	8,266
Milk, egg	4,991	11,775	4,341	9,650	9,318
Tabaco	3,147	3,375	2,709	4,032	2,245
Sub-Total	47,006	83,380	60,270	77,129	98,781
Share* (%)	8.0	13.4	8.6	7.8	8.0

*: Sub-Total / Total Value X 100

Source : Bolivia Anuario Estadistico del Sector Rural 1994

TABLE 7.3.4 IMPORT OF MAIN AGRICULTURAL PRODUCTS IN VOLUME

(Unit : 1,000 Ton)

	1988	1989	1990	1991	1992
Cereals	134.8	153.2	99.3	178.4	254.4
Flours	63.1	118.9	63.6	76.4	131.0
Edible oil	6.6	7.7	3.8	3.7	10.2
Milk, egg	5.0	9.4	3.7	6.5	9.6
Tabaco	1.1	0.8	0.5	1.3	0.5

Source : Bolivia Anuario Estadistico del Sector Rural 1994

TABLE 7.4.1 LAND POTENTIALITY

(Unit : Km2)

Class		Andres Ibanez	Warnes	Sara	Ichilo	Obispo Santistevan	Total
II - III		409	1,392	740	1,003	887	4,431
	%	66	64	63	65	53	62
IV		75	177	161	84	0	498
	%	12	8	14	5	0	7
V		65	435	157	129	86	872
	%	11	20	13	8	5	12
VI - VII		66	156	121	326	156	824
	%	11	7	10	21	9	12
VIII		0	0	3	8	0	12
	%	0	0	0	1	0	0
Unknown		0	0	0	0	530	530
	%	0	0	0	0	32	7
Total		615	2,161	1,182	1,550	1,659	7,167
	%	100	100	100	100	100	100

Source : CORDECRUZ

TABLE 7.4.2 EXISTING LAND USE IN 1995

(Unit:Km2)

	Andre Ibanez	Warnes	Sara	Ichiro	Obispo Santistevan	Total
Upland field	152	867	219	490	110	1,839
	22	37	17	30	8	25
Sugar cane	55	487	12	0	567	1,122
	8	21	1	0	40	15
Pasture	266	481	289	352	287	1,675
	38	21	23	22	20	23
Primary Forest	39	236	466	426	338	1,505
	6	10	36	26	24	21
Secondary Forest	131	261	279	327	75	1,073
	19	11	22	20	5	15
Swamp Forest	0	2	0	4	0	6
	0	0	0	0	0	0
Idle Land	0	0	1	0	7	9
	0	0	0	0	1	0
Urban	53	6	9	4	12	84
	8	0	1	0	1	1
River / Lake	0	1	7	6	14	29
	0	0	1	0	1	0
Total	697	2,341	1,283	1,610	1,411	7,341
	100	100	100	100	100	100

TABLE 7.4.3 SUMMERY OF LAND USE IN 1995, 1993 AND 1984

Land use	Andres Ibanez	Warnes	Sara	Ichilo	Obispo Santistevan	Total
1995 (%)						
Agriculture	30	58	18	30	48	40
Pasture	38	21	23	22	20	23
Forest	6	10	36	27	24	21
Secondary Forest	19	11	22	20	5	15
Idle	0	0	0	0	1	0
Other	8	0	1	1	2	2
1993 (%)						
Agriculture	71	79	26	27	55	54
Forest	29	21	74	73	14	38
Other	0	0	0	0	32	8
1984 (%)						
Agriculture	34	36	15	20	23	25
Pasture	20	38	45	18	38	32
Forest	38	20	21	33	14	23
Idle land	6	4	17	29	23	15
Other	2	2	2	1	1	2

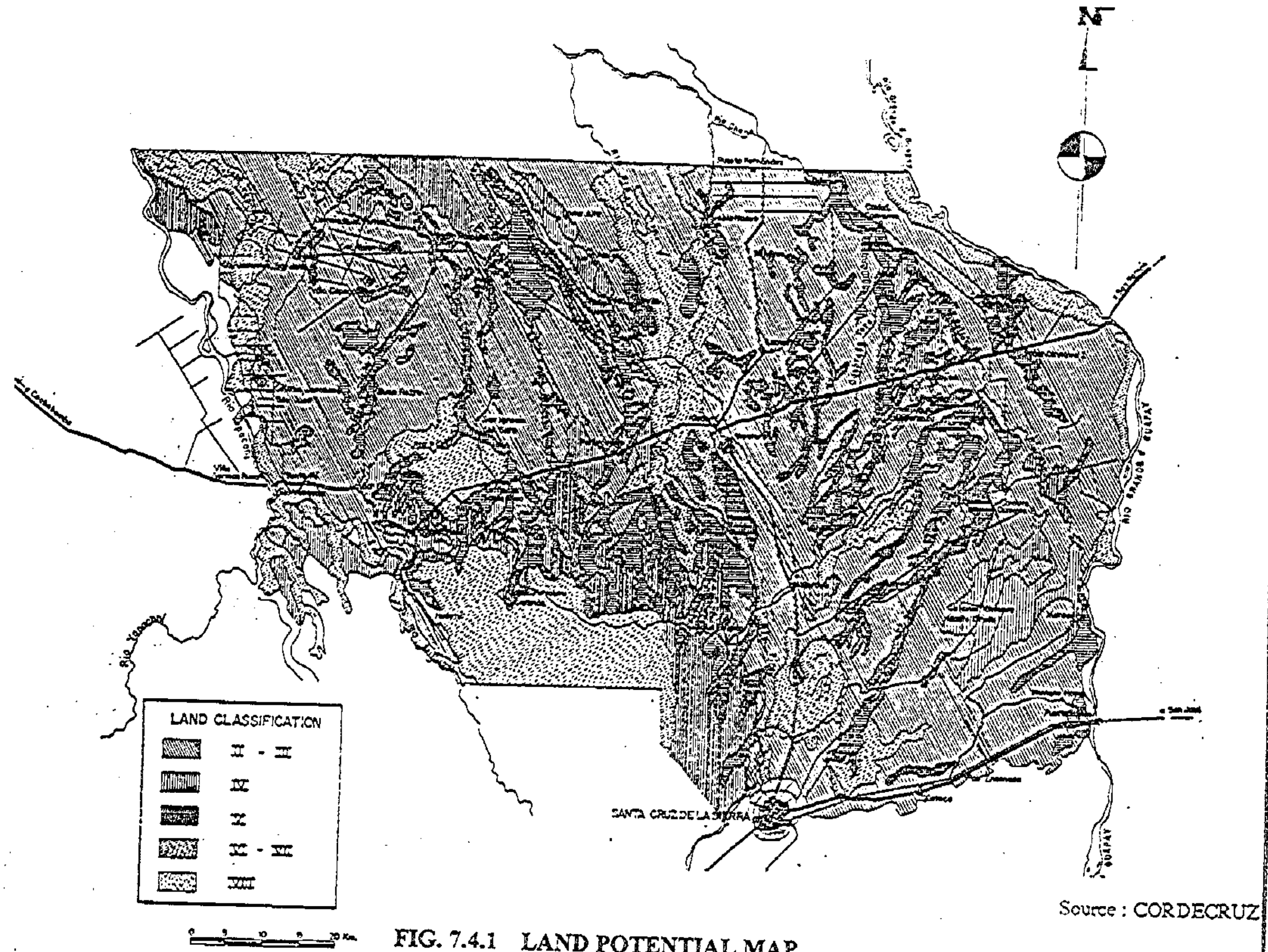
TABLE 7.7.1 SUMMARY OF LAND USE PLAN

Zone	Name	Main production	Natural conditions	Type of inundation	Problem of agriculture	Countermeasure for inundation	Alleviationeffect for inundation**	Countermeasure for agriculture	Target of agriculture development
1	Low precipitation area (Cotoca)	cattle ,cotton, sugar cane, Soybean	soil consisting of sand and silt,Low precipitation (1,300mm)	Uncommon (D)	- Disparity of farm income by size. - Drought	-	-	Introduction of high productive crop for small scale farmer	High productive area
2	Intensive upland crop area (Okinawa)	soybean , rice, maize, wheat, cattle	Fertile alluvial soil, Low precipitation(1,300mm)	Flood and drainage (B,C)	- Degradation of soil fertility	-Protection of overflow -Drainage improvement	A,B	Introduction of appropriate crop rotation and diversification	Diversified crop production area
3	Sugar cane production area (Montero)	sugar cane, cattle	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood and drainage (B,C)	-Decreasing productivity by continuous cropping	-River improvement -Drainage improvement	A,B	Introduction of appropriate crop rotation, diversification	Diversified crop production area
4	Local colony -1 (Minero)	Sugar cane, rice	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood (A)	- Severe flood damage	-River improvement	C	Introduction of water tolerant variety or crop	Stable production area
5	New developed upland crop area (Chane)	soybean, sugar cane, rice	Fertile alluvial soil, Medium precipitation(1,300-1,800mm)	Flood (A)	- Severe flood damage	-Protection of overflow	C,D	Introduction of water tolerant variety or crop	Stable and high productivity area
6	Intensive diversified agricultural area (San Juan)	rice ,egg soybean , cattle, fruits	Poor drainagesoil, High precipitation(more than 1,800mm)	Drainage (B)	- Poor drainage of soil	-Drainage improvement	A	Expansion of perennial crop	Intensive mixed farming area
7	Local colony-2 (Anto Fagasta)	soybean,rice, cattle	Poor drainage, High precipitation (more than 1,800mm)	Drainage (B)	- Poor drainage - Damage of rat	-Drainage improvement	B	Introduction of high productive crop	Stable production area
8	Grazing area (Chane)	cattle ,soybean	Low fertile soil, Medium precipitation (1,300-1,800mm)	Uncommon (D)	- Low fertility	-	-	Introduction of high productive pasture	Intensive cattle raising area
9	Forest area (Sara)	timber,cattle	Low fertile soil, High precipitation (more than 1,800mm)	Partially flood (B,C,D)	- Decreasing of useful timber	-Local drainage improvement	D	Reforestation of useful tree	High productive forest area

* :Severity of inundation=A>B>C>D

**:Alleviationeffects for inundation=A>B>C>D

FIGURES



Source : CORDECRUZ

FIG. 7.4.1 LAND POTENTIAL MAP

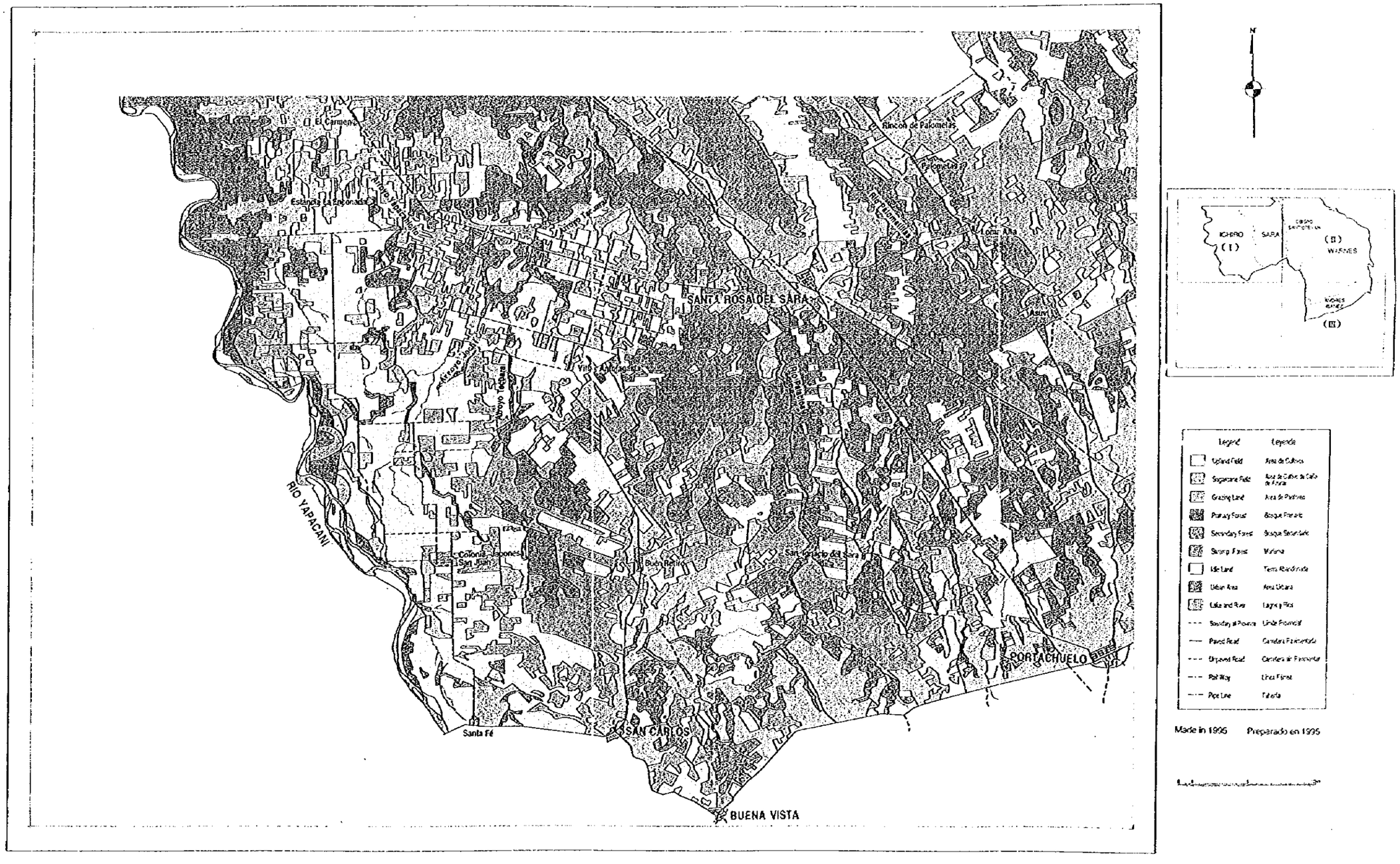
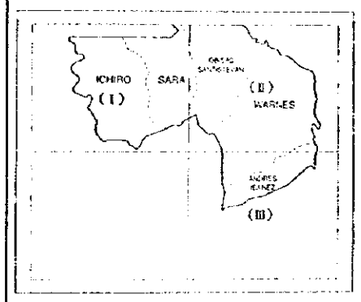


FIG. 7.4.2 LAND USE MAP (I)



Legend

Made in 1995 Prepared on 1995

FIG. 7.4.2 LAND USE MAP (II)

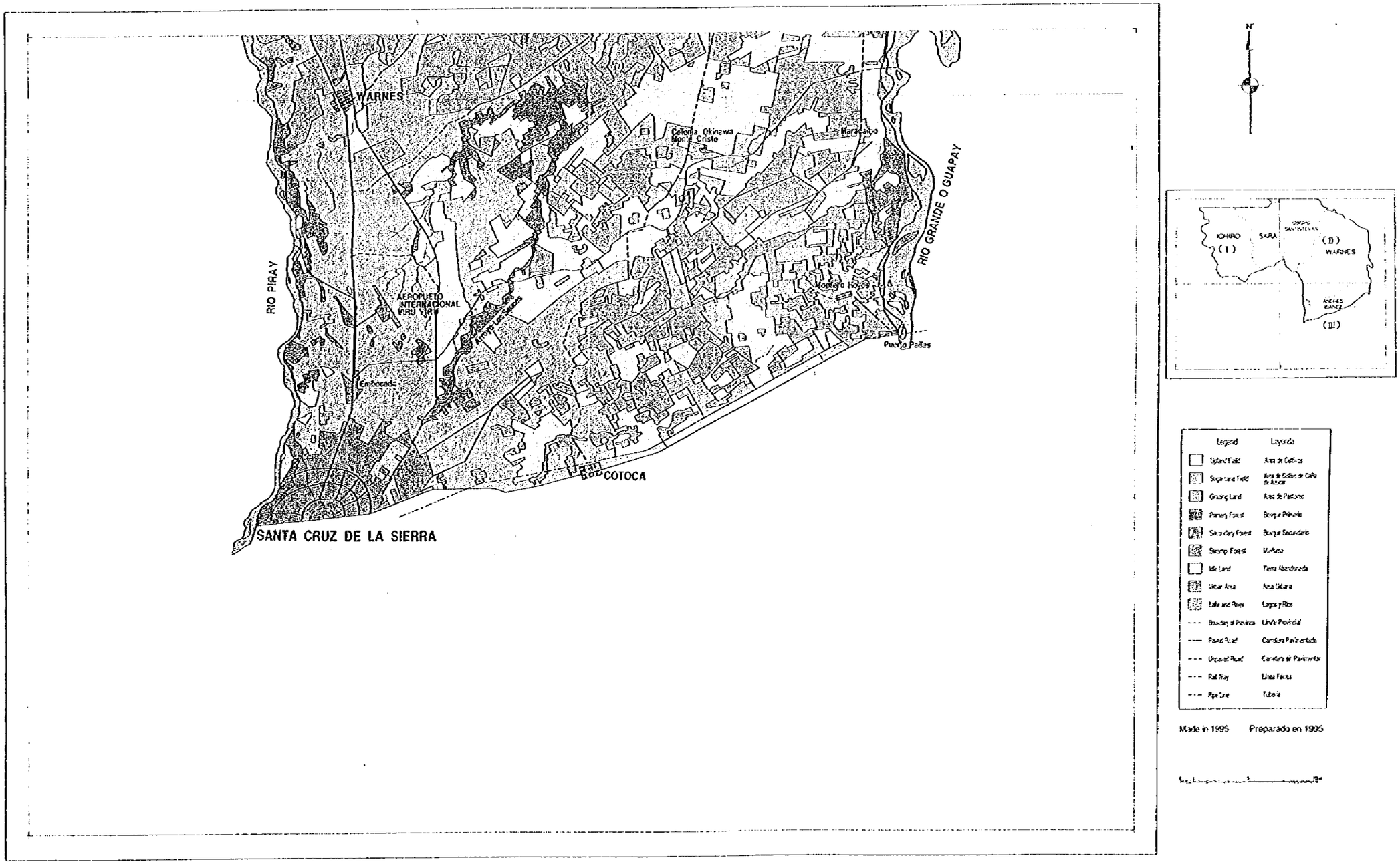


FIG. 7.4.2 LAND USE MAP (III)

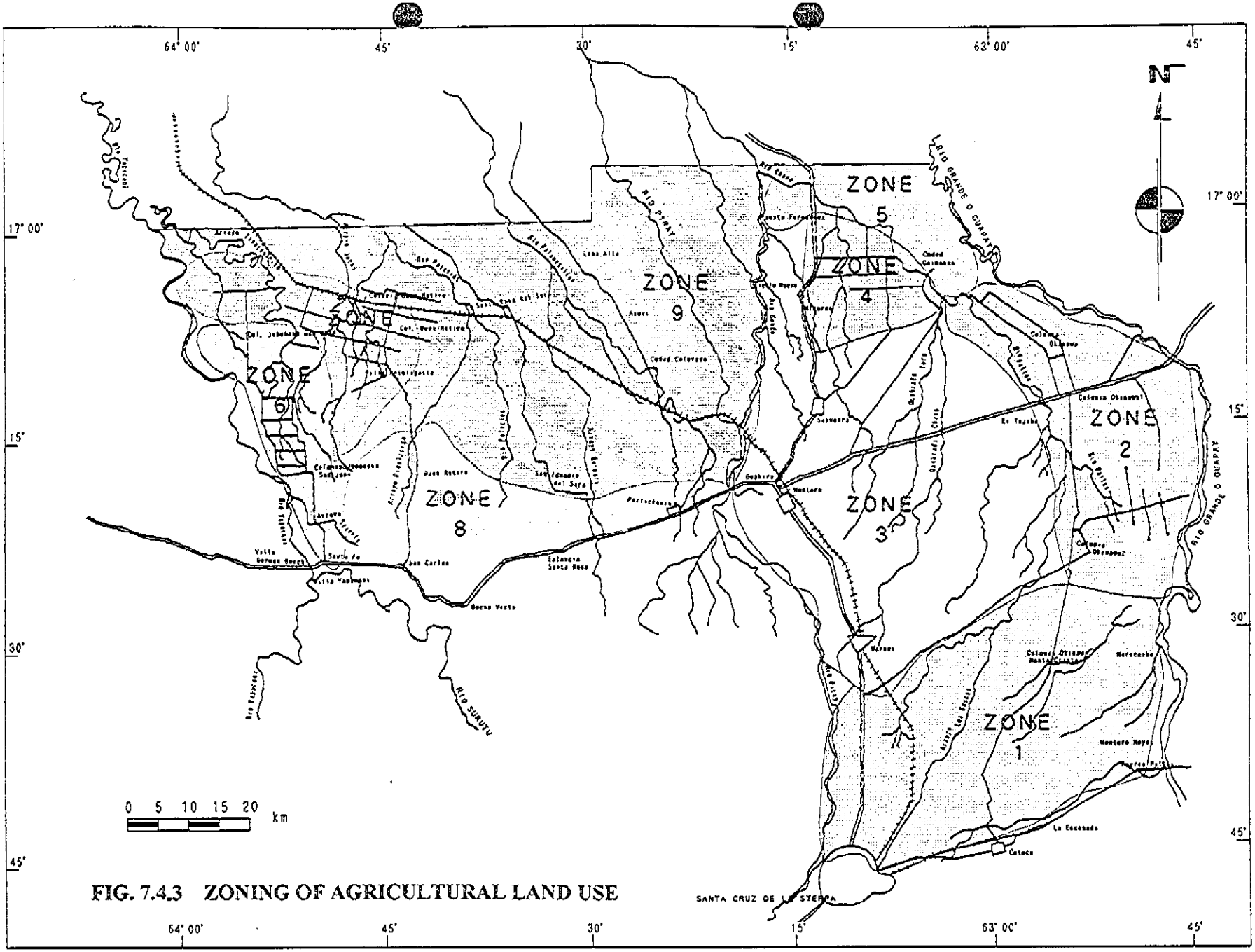


FIG. 7.4.3 ZONING OF AGRICULTURAL LAND USE

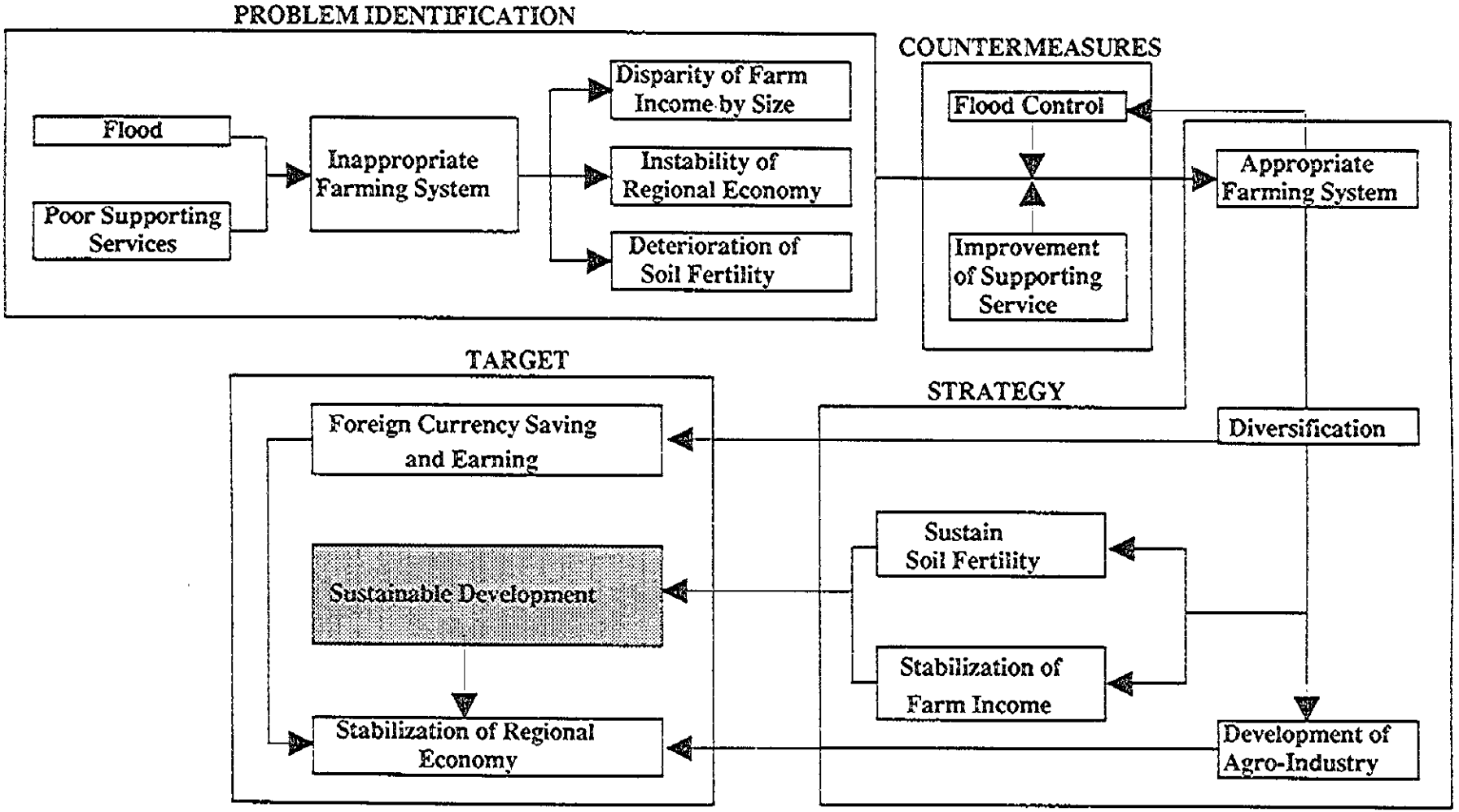


FIG. 7.6.1 BASIC AGRICULTURAL DEVELOPMENT CONCEPT

CHAPTER 8
FLOOD MITIGATION PLAN

CHAPTER 8 FLOOD MITIGATION PLAN

8.1 General

Flood mitigation and drainage improvement measures are usually composed of the two basic measures of structural measures and non-structural measures. In general, structural measures are applied for an area that encounters severe flood and drainage problems, and non-structural measures are applied for an area where such problems are not so significant.

According to the flood damage survey, the flood hazard area of the 1992 floods covers 4,857 km^2, 70 % of the study area. For mitigation of those problems, optimum flood mitigation measures were studied and planned for the study area based on the existing conditions such as flood hazard areas, flood damages, land use, hydrology, river characteristic and the existing flood mitigation plans and facilities.

8.2 Flood Mitigation and Drainage Improvement Measures

(1) Flood Mitigation Measures

The possible structure measures for mitigation of flood problems consist of river improvement works, flood embankment, reservoir or retarding basin, flood bypass and road-cum-embankment.

The non-structural measures consist of such measures as flood proofing of buildings, reduction of flood runoff by land use management, evacuation by flood warning and flood plain management.

(2) Drainage improvement measures

The possible structural measures for improvement of poor drainage conditions are composed of measures such as improvement of drainage systems, improvement of drainage facilities, and development of drainage networks. The non-structural measures are composed of land use management and planting habit management in the poor drainage area.

8.2.1 Flood Mitigation and Drainage Improvement Area

(1) Structural Areas and Non-structural Areas

According to the flood damage survey, the flood hazard areas in the study area were divided by the causes of floods into the following four categories:

Category	Causes of Floods
-1:	Inundation by the Rio Piray, Rio Grande or Rio Yapacani,
-2:	Inundation by own basin runoff with backwater effect of the Rio Piral,
-3:	Inundation by own basin runoff with inflow water from the Rio Pirai,
-4:	Inundation by own basin runoff.

The flood hazard area is mostly composed of agricultural lands, pasture and forest cover. Considering the existing land use, absolute flood mitigation and drainage improvement measures are unlikely feasible in economic, social and environmental terms. In order to pursue reasonable use of the flood hazard area, the existing swampy forest areas and low-lying areas that are supposed to have natural retarding effects, were considered as retarding areas in the basic plan. The flood hazards area were studied and target areas for structural measures and non-structural measures were delineated based on the categories of floods, depth and duration of inundation, as well as land use conditions.

The flood hazard area was divided into the following target areas:

1) Northern Area of the Eastern Part (Chane-Pailon area)

In the eastern part of the study area, downstream areas from the National Road No. 9 belong to the category-2 and -3. These areas are intensive agricultural lands for cultivation of soybean and sugar cane. These areas are affected by annual floods and encountered severe flood damages by the 1992 floods. Structural measures with non-structural measures for flood mitigation and drainage improvement are necessary for this area.

2) Southern Area of the Eastern Part

Upstream areas from the National Road No. 9 of the eastern part belong to the category -3 and -4. These areas are also intensive agricultural lands for soybeans and sugar cane cultivation. Flood damages of these areas are not so severe compared to the northern area because the depth and duration of floods are lesser than those of northern area. Non-structural measures will be applied for these areas.

3) Central Part (Rio Pirai)

Central part of the study area belongs to the category-1. Flood condition of this part is required to be improved by the future flood mitigation plan of the Rio Piray.

4) San Juan and Antofagasta of Western Part (San Juan - Antofagasta)

These areas belong to the category-3 and -4. Colonia San Juan de Yapacani is an intensive diversified agricultural area of rice, egg and soybean. Antofagasta has agricultural development potential and this area is important as a local colony. As these areas suffer from severe flood damage, structural measures with non-structural measures are necessary.

5) Eastern Area of the Western Part (Palacios - Palometillas)

Eastern area of the western part belongs to the category-4. As the land is not used intensively and flood damage is not so severe, non-structural measures will be applied for this area.

Fig. 8.2.1 shows the proposed structural and non-structural areas for flood mitigation and drainage improvements in the study area.

8.2.2 Division of Structural Measure Areas

The target areas of structural measures of flood mitigation are divided by river or drainage basin into seven areas as shown in *Fig. 8.2.2* and *Fig. 8.2.3*. They are as follows;

1) Rio Chane - Pailon Area

a) Rio Chane
b) Rio Pailon
c) Quebrada Chane
d) Chane - Chacras
e) Okinawa Drainage

2) San Juan - Antofagasta Area

a) San Juan
b) Antofagasta

8.2.3 Design Criteria

(1) Design Scale

The design scales of the flood mitigation and drainage improvement measures were decided based on the results of evaluation of beneficial effects in technical, economic and social terms.

Relations between the design scale and the expected beneficial effect (annual average protected area / required excavation volume of river improvement) were studied for the Chane - Pailon Area and San Juan - Antofagasta Area (see *Fig. 8.2.4*). The river improvement works were supposed to be done to contain all of the probable runoff discharges of corresponding design scales without overflow (*Table 8.2.1*). Annual average protected area is the statistical average of the areas, within the design scale, that will be protected by the river improvement. Annual average protected area corresponds to the benefit of flood mitigation and drainage improvement (*Table 8.2.2*). Required excavation volume corresponds to the required energy or cost for the flood mitigation and drainage improvement (see *Table 8.2.3*).

The results of the analysis are as follows;

1) The result of the analysis on Chane - Pailon Area shows that the most effective design scale for flood mitigation measures is between 5-year and 10-year flood frequency.

2) The result of the analysis on San Juan - Antofagasta Area shows that the effective design scale is about 10-year flood frequency.

The design scales for flood mitigation and drainage improvement measures are planned as follows;

1) The design scale of flood mitigation facilities is decided to be 10-year frequency flood.

2) The design scale of drainage improvement facilities is decided to be 5-year storm runoff.

(2) Allowable Inundation Depth

For designing flood mitigation and drainage improvement facilities, an allowable inundation depth of 30 cm is considered based on the study of crop flood damage.

(3) Design of River Cross Section

In order to utilize the natural retarding effect of the flood plain within the allowable inundation depth, the improved river cross sections were set as single excavation channels. Compound cross section, composed of low water channel and high water channel with flood embankments, was not applied for the river improvement in order to avoid drainage problems.

8.3 Facility Planning

8.3.1 Chane - Pailon

Fig. 8.3.1 and *Fig. 8.3.2* show the concepts of alternative facility plans for Alternative I and Alternative II for Chane - Pailon, respectively.

1) Alternative I

Flood mitigation and drainage improvement measures are planned for the target area, including the Rio Chane Area, that is under the backwater effect of the Rio Piray. The target area will be protected from floods by river and drainage improvement measures. Five swampy areas located in the upstream basins from the National Road No. 9 are proposed as the natural retarding basins.

The most downstream reaches of the Rio Chane located between the junction with the Rio Piray and the most downstream road bridge near Puesto Fernandez (length 8.0 km) belong to the flood hazard area of the Rio Piray main stream. River improvement

works for these most downstream reaches are necessary in combination with the flood mitigation of the Rio Piray. The required improvements for these reaches are delineated in this study, but the construction cost and the resultant benefit are not included in the economic evaluation.

2) Alternative II

Flood mitigation and drainage improvement measures are planned for the target area, but without the structural measures to counter the backwater effect area by the Rio Piray.

(2) River Improvement Plan

1) Alternative I

River improvement works are planned for the following rivers (refer to *Fig. 8.3.3* and *Table 8.3.1*);

River Improvement Reach	Length
a) Rio Chane (Jct. Rio Piray to Jct. Rio Pailon):	35.00 km
- Jct. Rio Piray to Downstream Road Bridge:	8.00 km
- Downstream Road Bridge to Jct. Rio Pailon:	27.00 km
b) Rio Pailon (Jct. Rio Chane to Jct. A. Los Sauces):	32.00 km
c) Queb. Chane (Jct. Rio Chane to Road No. 9):	18.00 km
d) Queb. El Toro (Jct. Qda. Chane to Road No. 9):	16.00 km
e) Queb. Las Chacras (Jct. Rio Chane to Road No. 9):	36.50 km

Fig. 8.3.4 shows the design discharge of 10 year floods. *Table 8.3.2* shows the required dimensions of improved river cross sections. *Fig. 8.3.9* shows the longitudinal profile of the river improvement works.

2) Alternative II

The structural measures for Rio Chane is not included in the Alternative II. River improvement works for the other four rivers are as same as the Alternative I.

(3) Drainage Improvement

Drainage improvement is composed of both improvement and new construction of main drains and secondary drains (see *Fig. 8.3.3* and *Table 8.3.1*). Construction works of Alternative I and Alternative II are the same.

	Drainage Improvement	Length/Area
a)	Drainage Main:	36.00 km
b)	Okinawa Drainage Main:	21.00 km
c)	Secondary Drainage:	481.00 km^2

Details could be referred to the Supporting Report G.

8.3.2 San Juan - Antofagasta

Fig. 8.3.5 and *Fig. 8.3.6* show the concepts of alternative facility plans for Alternative I and Alternative II for San Juan - Antofagasta, respectively.

1) Alternative I

Flood mitigation and drainage improvements measures are planned for the target area. The existing drainage facilities in Colonia San Juan de Yapacani are to be rehabilitated.

2) Alternative II

Flood mitigation and drainage improvement measures are planned for the target area, including improvement of existing drainage facilities.

(1) River Improvement Plan

1) Alternative I

River improvement works are planned for the following rivers (refer to *Fig. 8.3.7* and *Table 8.3.1*);

River Improvement Reach	Length
a) Arroyo Yapacanicito (Downstream bridge to existing drainage):	14.10 km
b) Arroyo Jochi (Downstream Swamp to Mid-stream):	12.60 km
c) Arroyo Tacuaral (Downstream Swamp to Mid-stream):	7.70 km

Fig. 8.3.8 shows the design discharge of 10 year floods. *Fig. 8.3.9* shows the longitudinal profile of the river improvement works.

2) Alternative II

The reaches of the river improvement are as same as those of the Alternative I. *Fig. 8. 3.10* shows the design discharge of Alternative II.

(2) Drainage Improvement

Drainage improvements of Alternative I are as follows:

	Drainage Improvement	Length/Area
a)	Main Drainage:	51.30 km
	- Rehabilitation of San Juan Drainage Main:	34.20 km
	- Improvement of Arroyo Tejeria:	7.10 km
	- Main Drainage of Antofagasta:	10.00 km
b)	Secondary Drainage:	212.00 km^2

2) Alternative II

Drainage improvements of Alternative I are as follows;

	Drainage Improvement	Length/Area
a)	Main Drainage:	51.30 km
	- Improvement of San Juan Drainage Main:	34.20 km
	- Improvement of Arroyo Tejeria:	7.10 km
	- Main Drainage of Antofagasta:	10.00 km
b)	Secondary Drainage:	212.00 km^2

Details could be referred to Chapter 9 and Supporting Report G.

(3) Road-cum-embankment

Road-cum-embankment is planned between the Arroyo Yapacanicito Basin and Arroyo Jochi Basin both for the Alternative I and Alternative II. The purpose of the road-cum-embankment is to separate the flood water of these two basins as well as to reinforce the evacuation and transportation route during floods. The length of the road-cum-embankment is 9.0 km.

8.4 Non-structural Measures

Followings are the non-structural measures for flood mitigation as well as for drainage improvement proposed for the study area..

a. Non-structural Measures for Flood Mitigation

-1 Flood warning and evacuation system
-2 Flood proofing of settlement in flood hazard area
-3 Landuse control of retarding basins
-4 Preservation of protected forest along river channels
-5 Landuse management of farm lands in the flood hazard area

b. Drainage Improvement Measures

-1 Landuse management in the poor drainage area
-2 Introduction of water tolerant crop varieties in the poor drainage area

(1) Eastern Part

1) Southern Area

Southern area of the eastern part is mainly composed of the upper reaches of the Río Pailón, Quebrada Chané, Arroyo Los Sauces. Five retarding basins are proposed as a component of the structural measures.

The required non-structural measures for this area are as follows;

a) Conservation of the proposed retarding basins

In order to utilize and maintain retarding effect of natural swampy areas, conservation of the proposed five retarding basins (total area 141.5 km^2) is necessary.

Appropriate regulations with legal basis are required to be prepared and applied for prohibiting any land reclamation which may reduce the retarding effect of the above five swampy areas. If any development activities is necessary, maintaining the existing retarding capacity by considering multipurpose use of the retarding basins will be required.

b) Landuse management to reduce flood runoff

In order to control the rainfall runoff and flood discharge by natural retarding effect, areas with woods and plants as well as undulation are desirable to be kept as much as possible.

Landuse management is necessary for maintaining the areas with natural woods and plants. Furthermore, the necessary guideline is to be prepared to preserve the existing agricultural area against excesive enlargement and development of urbanized area such as Santa Cruz City in future.

c) Flood plain management including improvement of farming system by introducing water tolerant crop variety in the flood hazard area

Especially for the areas that encounter annual inundation, flood plain management is necessary for reducing flood damage caused by inappropriate landuse and farming system. Flood plain management includes activities such as delineation and declaration of potential flood hazard area, guidance on landuse pattern and improvement of farming system such as introducing water tolerant crop variety.

d) Flood warning and avacuation system

Strengthening of meteo-hydrological observation system such as rainfall and water level measurement of rivers is necessary not only for the southern area but also for the whole study area. Flood warning and evacuation system is to be formulated and applied. Flood warning and evacuation system includes followings;

- Meteo-hydrological observation including rainfall and water level measurements
- Broadcasting flood warnings
- Desingation of evacuation shelters and guiding people evacuated from floods

2) Northern Area (Chané - Pailón)

In the Chané - Pailón Area, flood condition of the Río Chané area will not be improved even by the planned structural measures. Non-structural measures are required for the

area including the Río Chané Area. The necessary non-structural measures for Chané - Pailón are as follows;

a) Flood plain management including improvement of farming system in the flood hazard area especially for the Río Chané and the areas along the rivers where inundation would continue to occur.

Even with the implementation of the flood mitigation and drainage improvement measures, there would remain some areas, especially those located along the rivers, where inundation would continue to occur. Furthermore, inundation condition in the Río Chané area will not be improved very much without the river improvement of the Río Piray.

Flood plain management is necessary for the above areas. Flood plain management includes delineation and declaration of potential flood hazard area, landuse guidance and improvement of farming system such as introducing water tolerant crop variety.

b) Flood warning and evacuation system

As the design scale of flood mitigation measures is 10 year return period of floods, wide inundation would occur due to floods larger than 10 year return period. Furthermore, inundation would continue to occur in some areas along the rivers as well as the Río Chané area even by the 10 year floods.

Flood warning and evacuation system is necessary to be formulated and applied. Evacuation roads are also to be included in the system.

c) Flood proofing especially for the Río Chané Area

Even in the area like Río Chané area, where habitual inundation occurs, there exists residential houses. In order to mitigate damage to building from floods, guidance on flood proofing such as raising of foundation of houses and roads is necessary to be introduced. Furthermore, relocation of houses is also to be considered.

(2) Western Part

1) Western Area (San Juan - Antofagasta)

The required non-structural measures for this area are as follows;

a) Conservation of the swampy area at the junction of the Arroyo Jochi and Arroyo Tacuaral

At the junction of the Arroyo Jochi and Arroyo Tacuaral, there is a natural swampy area. Flood waters once enter into the swampy area, from these rivers, exit the downstream reaches. The swampy area acts as one of the hydraulic boundary between the upstream to middle stream and downstream reaches. Furthermore, it acts as a regulating pond for the downstream reaches.

In order to preserve the above functions of the swampy area, appropriate regulation and management with the necessary legal basis are to be undertaken. If any development is necessary in future, maintaining the present retarding capacity and multipurpose use of the area will be required.

b) Landuse management to reduce the flood runoff from upper reaches

In order to control rainfall runoff by using natural retarding effect of the areas with woods and plants, landuse management is necessary to be applied.

c) Flood plain management including improvement of farming system in the flood hazard area especially for the downstream area of the Arroyo Yapacanicito and the areas along the rivers where inundation would continue to occur.

Even if the flood mitigation measures are implemented, some inundation would continue to occur in the upper and downstream reaches of the Arroyo Yapacanicito, Jochi and Tacuaral. Flood plain management is necessary for the above areas.

d) Flood warning and evacuation system

Even with the implementation of the flood mitigation measures some inundation would continue to occur, including inundation of a wide area under larger floods.

Therefore, flood warning and evacuation system is necessary. Evacuation road is also to be included in the system.

2) Eastern Area (Palacios - Palometillas)

The required non-structural measures for the Palacios - Palometillas area are as follows;

a) Flood plain management in the potential flood hazard area

There are some habitual inundation area along the upstream and downstream reaches of the Río Palacios and the downstream reaches of the Río Palometillas. Even though landuse of the eastern part is not so intensive, flood plain management including improvement of farming system is necessary to be introduced.

b) Landuse management

As this area is forest at present, rainfall is retarded naturally. In order to retain this natural retarding effect, landuse management including guidance for conservation of forest cover is necessary. This is also in accordance with the proposed future landuse of this area as forest cover.

c) Flood warning and evacuation system

Flood warning and evacuation system is necessary to be introduced for the potential flood hazard areas.

8.5 Study Items for the Future

In order to promote the flood mitigation and drainage improvement measures proposed in the master plan, the required actions are summarized as follows:

1) Further study for the two priority areas of Chane - Pailon and San Juan - Antofagasta,
2) Flood control studies for Rio Grande, Rio Piray (downstream reaches) and Rio Yapacani,
3) Further study on strategies of non-structural measures such as flood plain management, land use management, conservation of retarding basins, flood warning and evacuation system and flood proofing,
4) Improvement of the hydrological observation network

TABLES

TABLE 8.2.1

DESIGN CROSS SECTIONS OF PROBABLE FLOODS FOR THE DETERMINATION OF DESIGN SCALE

River	Length	2 - Year			5 - Year			10 - Year			20 - Year			50 - Year		
	(km)	Q	W	D	Q	W	D	Q	W	D	Q	W	D	Q	W	D
A. CHANE-PAILON																
1) Río Chane	12.50	950	97.0	6.0	1213	119.0	6.0	1500	142.0	6.0	1777	164.0	6.0	2143	193.0	6.0
	22.50	791	73.0	6.0	978	85.0	6.0	1212	101.0	6.0	1431	116.0	6.0	1718	135.0	6.0
2) Rio Pailon	24.00	591	70.0	5.0	738	84.0	5.0	908	99.0	5.0	1073	114.0	5.0	1278	132.0	5.0
	8.00	663	64.0	5.0	809	75.0	5.0	995	88.0	5.0	1173	101.0	5.0	1404	117.0	5.0
3) Qda. Chane	3.80	407	44.0	4.5	483	49.0	4.5	584	57.0	4.5	681	64.0	4.5	807	72.0	4.5
	14.20	226	36.0	3.5	293	44.0	3.5	353	50.0	3.5	410	56.0	3.5	485	64.0	3.5
4) Qda. El Toro	16.00	328	53.0	4.0	420	64.0	4.0	503	74.0	4.0	583	84.0	4.0	688	96.0	4.0
5) Qda. Las Chacras	20.50	262	44.0	3.0	365	57.0	3.0	440	67.0	3.0	513	76.0	3.0	607	68.0	3.0
	16.00	199	36.0	3.0	270	45.0	3.0	326	52.0	3.0	379	59.0	3.0	449	68.0	3.0
B. SAN JUAN - ANTOFAGASTA																
1) Arroyo Yapacanicito	2.80	141	35.0	3.0	181	42.0	3.0	213	47.0	3.0	244	53.0	3.0	284	59.0	3.0
	11.30	111	29.0	3.0	140	35.0	3.0	165	39.0	3.0	189	43.0	3.0	220	48.0	3.0
2) Arroyo Jochi	8.40	162	30.0	0.5	163	30.0	3.5	194	34.0	3.5	225	37.0	3.5	263	42.0	3.5
	4.20	112	22.0	3.5	148	25.0	3.5	174	28.0	3.5	200	30.0	3.5	232	33.0	3.5
3) Arroyo Tacuaral	7.70	169	26.0	4.0	164	26.0	4.0	194	28.0	4.0	223	30.0	4.0	260	33.0	4.0

NOTE: Q: Design discharge (m3/s)
W: Surface width of channel (m)
D: Depth of channel (m)

TABLE 8.2.2 ANNUAL AVERAGE PROTECTED AREA OF PROBABLE FLOODS FOR THE DETERMINATION OF DESIGN SCALE

1. CHANE-PAILON (Unit: km2)

Area	Design Scale (Year)				
	2	5	10	20	50
1) Rio Chane	93.3	106.0	107.4	107.4	107.4
2) Rio Pailon	107.4	182.6	190.0	197.7	209.3
3) Qda. Chane	56.9	81.1	100.7	112.4	123.2
4) Chane-Chacras	233.1	296.8	318.9	318.9	318.9
Total Protected Area	490.7	666.5	717.0	736.4	758.8
Annual Average Protected Area	245.3	378.7	450.4	487.2	502.3

2. SAN JUAN-ANTOFAGASTA (Unit: km2)

Area	Design Scale (Year)				
	2	5	10	20	50
1) San Juan	60.6	99.4	118.5	132.5	150.8
2) Antofagasta	128.0	160.1	180.8	197.4	217.6
Total Protected Area	188.6	259.5	299.3	329.9	368.4
Annual Average Protected Area	94.3	146.2	176.1	192.6	200.0

TABLE 8.2.3 EXCAVATION VOLUME OF RIVER IMPROVEMENT OF PROBABLE FLOODS FOR THE DETERMINAION OF DESIGN SCALES

River	Length (km)	Excavation Volume (1000m3)				
		2 - Year	5 - Year	10 - Year	20 - Year	50 - Year
A. CHANE-PAILON						
1)Rio Chane	12.50	6,375	8,025	9,750	11,400	13,575
	22.50	8,235	9,855	12,015	13,354	16,605
2) Rio Pailon	24.00	7,200	8,880	10,681	12,480	14,640
	8.00	2,160	2,601	3,120	3,641	4,281
3) Qda. Chane	3.80	599	684	821	941	1,078
	14.20	1,442	1,839	2,137	2,436	2,833
4) Qda. El Toro	16.00	2,880	3,584	4,224	4,864	5,633
5) Qda. Las Chacras	20.50	2,337	3,137	3,752	4,305	5,043
	16.00	1,440	1,873	2,208	2,545	2,976
Total A	137.50	32,667	40,478	48,708	55,965	66,663
B. SAN JUAN-ANTOFAGASTA						
1) Arroyo Yapacanicito	2.80	244	302	344	395	445
	11.30	780	983	1,119	1,254	1,424
2) Arroyo Jochi	8.40	676	676	794	882	1,029
	4.20	221	264	309	338	382
3) Arroyo Tacuaral	7.70	554	554	616	678	770
Total B	34.40	2,475	2,779	3,182	3,547	4,050

TABLE 8.3.1 (1) FLOOD MITIGATION AND DRAINAGE IMPROVEMENT WORKS (1/2)
- ALTERNATIVE I

Project/Sub-project	River Improvement		Main Drainage		Secondary Drainage	Bridge	Culvert	Diversion Weir	Land Acquisition	Retarding Basin
	River	Length (km)	Improve. (km)	Rehabili. (km)	(km2)	(Nos.)	(Nos.)	(Nos.)	(ha.)	(km2)
1. CHANE - PAILON		**137.50**	**57.00**	**0.00**	**481.00**	**21**	**78**	**0**	**1550.0**	**141.5**
1-1 RIO CHANE	Rio Chane	35.00	0.00	0.00	0.00	5	0	0	222.0	0.0
	Acc.0.00 - 8.00 km	8.00								
	Acc.8.00 - 35.00 km	27.00								
1-2 RIO PAILON		32.00	6.50	0.00	50.00	1	8	0	383.0	116.5
	Rio Pailon	32.00								
1-3 QUEBRADA CHANE		34.00	8.00	0.00	0.00	1	0	0	290.0	25.0
	Qda. Chane	18.00								
	Qda. Toro	16.00								
1-4 CHANE - CHACRAS		36.50	21.50	0.00	284.00	12	43	0	445.0	0.0
	Qda. Chacras	36.50								
1-5 OKINAWA DRAINAGE		0.00	21.00	0.00	147.00	2	27	0	210.0	0.0
2. SAN JUAN - ANTOFAGASTA		**34.40**	**17.10**	**34.20**	**212.00**	**6**	**36**	**4**	**487.0**	**0.0**
2-1 SAN JUAN		14.10	7.10	34.20	115.00	3	17	4	174.0	0.0
	Arroyo Yapacanicito	14.10								
2-2 ANTOFAGASTA		20.30	10.00	0.00	97.00	3	19	0	313.0	0.0
	Arroyo Jochi	12.60								
	Arroyo Tacuaral	7.70								

TABLE 8.3.1 (2) FLOOD MITIGATION AND DRAINAGE IMPROVEMENT WORKS (2/2)
- ALTERNATIVE II

Project/Sub-project	River Improvement		Main Drainage		Secondary Drainage	Bridge	Culvert	Diversion Weir	Land Acquisition	Retarding Basin
	River	Length (km)	Improve. (km)	Rehabili. (km)	(km2)	(Nos.)	(Nos.)	(Nos.)	(ha.)	(km2)
1. CHANE - PAILON		**102.50**	**57.00**	**0.00**	**481.00**	**16**	**78**	**0**	**1328.0**	**141.5**
1-1 RIO CHANE		0.00	0.00	0.00	0.00	0	0	0	0.0	0.0
1-2 RIO PAILON		32.00	6.50	0.00	50.00	1	8	0	383.0	116.5
	Rio Pailon	32.00								
1-3 QUEBRADA CHANE		34.00	8.00	0.00	0.00	1	0	0	290.0	25.0
	Qda. Chane	18.00								
	Qda. Toro	16.00								
1-4 CHANE - CHACRAS		36.50	21.50	0.00	284.00	12	43	0	445.0	0.0
	Qda. Chacras	36.50								
1-5 OKINAWA DRAINAGE		0.00	21.00	0.00	147.00	2	27	0	210.0	0.0
2. SAN JUAN - ANTOFAGASTA		**34.40**	**51.30**	**0.00**	**212.00**	**8**	**41**	**0**	**487.0**	**0.0**
2-1 SAN JUAN		14.10	41.30	0.00	115.00	5	22	0	174.0	0.0
	Arroyo Yapacanicito	14.10								
2-2 ANTOFAGASTA		20.30	10.00	0.00	97.00	3	19	0	313.0	0.0
	Arroyo Jochi	12.60								
	Arroyo Tacuaral	7.70								

TABLE 8.3.2 DESIGN CROSS SECTIONS OF RIVER IMPROVEMENT FOR ALTERNATIVE I

River	Length (km)	Water Depth (m)	Width (W.S.) (m)	Bank Slope	Flow Area (m2)	Design Discharge (m3/s)
CHANE-PAILON						
1) Rio Chane	35.00					
Jct. Rio Piray - Jct. Qda. Chacras	12.50	6.0	100.0	1:2	528.0	1500
Jct. Qda. Chacras - Jct. Rio Pailon	22.50	6.0	75.0	1:2	378.0	1212
2) Rio Pailon	32.00					
Jct. Rio Chane - Road 9	24.00	5.0	70.0	1:2	300.0	908
Road 9 - Jct. Arroyo Los Sauces	8.00	5.0	65.0	1:2	275.0	995
3) Qda. Chane	18.00					
Jct. Rio Chane - Jct. Qda. Toro	3.80	4.5	45.0	1:2	162.0	584
Jct. Qda. Toro - Road 9	14.20	3.5	37.0	1:2	105.0	353
4) Qda. El Toro	16.00					
Jct. Qda. Chane - Road 9	16.00	4.0	55.0	1:2	188.0	503
5) Qda. Las Chacras	36.50					
Jct. Rio Chane - Mid-stream	20.50	3.0	45.0	1:2	117.0	440
Mid-stream - Road 9	16.00	3.0	37.0	1:2	93.0	326
SAN JUAN-ANTOFAGASTA						
1) Arroyo Yapacanicito	14.10					
Downstream - Mid-stream	2.80	3.0	35.0	1:2	87.0	213
Mid-stream - Upstream	11.30	3.0	30.0	1:2	72.0	165
2) Arroyo Jochi	12.60					
Down. Swamp - Mid-stream	8.40	3.5	30.0	1:2	80.5	194
Mid-stream - Upstream	4.20	3.5	22.0	1:2	52.5	174
3) Arroyo Tacuaral	7.70					
Down. Swamp - Mid-stream	7.70	4.0	26.0	1:2	72.0	194

Note: 1) Design cress sections are single trapezoidal shapes without flood embankments.