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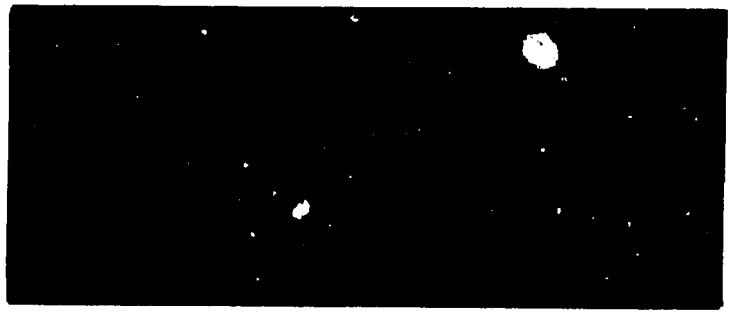

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PARAGUAY

MINIFUNDIA CROP INTENSIFICATION
PROJECT

SOIL FERTILITY REPORT

USAID-CREDICOOP-MASI

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I. INTRODUCTION

The report covers the findings of the MASI Soils Specialist who visited Paraguay during the period August 3 to October 16, 1981. It is the seventh in a series of technical reports prepared by short-term technicians who have served on the Minifundia Crop Intensification Project. Terms of reference for the soils specialist were the following:

1. Determine physical and chemical characterization of project area soils;

2. analyze recommendations currently in use on N, P, K, urea, triple superphosphate and potassium chloride. Make recommendations on the macro-nutrients and probably Ca and Mg;

3. study soil laboratory facilities of the National Agrarian Institute (NAI) and the National University; make recommendations for improvements;

4. make recommendations for fertilizer tests to be conducted at NAI and at farm level;

5. taking into account soil characteristics, make recommendations on factors affecting soil management such as soil preparation, irrigation, conservation methods, methods of fertilizer application and planting systems;

6. study possible effects of irrigation water on soil chemistry;

7. recommend preparation of bulletins, video-tapes and other educational aids related to soil themes; and

8. other related tasks as these might be determined during the course of the study.

The soil scientist will take part in evaluation of soil related aspects of current or planned strategies involving cultivation of tomato, strawberry, banana and pineapple.

During this operation, the soil scientist will work closely with Messrs. Carlos Villalba, CREDICOOP production expert, and with Peace Corps volunteer Eduardo Zappi, both of whom will serve as local counterparts.

Whenever possible, these persons should be trained in the soil aspects mentioned above.

The soil scientist will submit a written report on his work, which he will discuss with CREDICOOP personnel, AID and MASI, three days (working days) prior to his departure from Paraguay.

II. SOME SPECIAL CHARACTERISTICS OF THE CLIMATE IN PARAGUAY

Paraguay has a unique climate. It could not be described as either tropical nor sub-tropical in the conventional meteorological sense. It is a buffer hot inland zone, not very high in altitude, not very rainy, not as humid as the tropics and not too dry. The predominant south and east wind and the geological depression in its geographical location probably have much to do with its zonal climate and consequently zonal flora and cultivation.

The rainfall is not enough, neither in quantity nor in distribution to classify the land as tropical and the monthly evaporation cycle makes the net amount of rain that reaches the soil completely inadequate to classify Paraguay as tropical or sub-tropical. Furthermore, for any form of intensive systematic agricultural development, additional sources of water have to be sought.

The relative humidity in Paraguay is between 65 and 71%, which differs from tropical and semi-tropical areas. In general, moving to the east the average increases. Cloudiness is even averaging 50% all over the country throughout the year; this too is distinct from tropical or sub-tropical zones.

The frequency of days with precipitation during the whole year shows the same pattern as that of relative humidity averaging 6.5 days per month with a little increase towards the east, marking an average of 8.5 days per month. There is micro-variations among the months. The quantity of rainfall in general is different from what is expected for a tropical or semi-tropical

zone. This is probably caused by the wind, elevation and geographical location of Paraguay in the continent.

The average days of frost during the year is zero up to longitude 57° 37' 10" and only about 4.6 days further to the east. Chances of frost are not more than 5% during the months of June and July. Hail days are even fewer (1-3 days per year). Electrical storms are in the soft category, averaging about 26 days per year.

III. SOILS LABORATORIES IN PARAGUAY

There are two main soil laboratories in Paraguay -- one is operated by the National Agrarian Institute (NAI) of the Ministry of Agriculture and is located in Caacupe; the second laboratory, belonging to the Agronomy Department of the National University of Asunción, is situated in San Lorenzo.

Both laboratories do soil fertility analyses for the purpose of making fertilizer recommendations. Most of the samples they analyze are from the first 20 to 30 cm of the soil layer. The upper soil layer determinations are in general the pH, organic matter content, capacity for phosphorus assimilation, potassium and calcium measured in parts per million, the exchangeable aluminum in m.e. 1100 grams; texture (mostly done by feel) relates to the three main separates -- sand, silt and clay.

The NAI Laboratory interprets the analyses in three classes: low, medium and high, while the University Laboratory interprets the analyses in terms of fertilizer recommendation (Kg/ha of N - P_2O_5 - K_2O). A list of existing and needed laboratory equipment is attached as Annex I, Table 1.

A. The Staff

The staff of both laboratories is adequate for the present time. The NAI laboratory is headed by an agronomist who is assisted by two technical assistants. These three specialists can complete up to 200 determinations per day if all equipment functions properly.

The Laboratory of the National University of Asunción at San Lorenzo is directed by an agronomist and employs a laboratory manager and four others. The university laboratory is well equipped although some equipment is in need of repair or replacement. A list of some existing and needed equipment for this laboratory is attached as Annex I, Table 2. The average output of the laboratory is 1500 samples per year.

B. Methods of Analysis

1. Plant Tissue Samples

The addition of plant tissue analysis could be a useful complement to the soil analysis already being done in Paraguay. It would constitute an additional source of information for evaluation of soil fertility. Plant tissue samples could be run with fewer modifications at the laboratory at NAI than at the University laboratory:

Outline of Procedure:

-- A dried plant sample is ground in a parse 1 mm sieve (20 mesh).

-- A one gram sample is then ashed at 500°C., cooled and melted with H_2O and a 2 ml concentration of H Cl, then brought to dryness. Add 25 ml to the H Cl solution and filter.

From the filterate aligmats, samples are taken to determine Ca, Mg, K and N. Analysis is also made for Cu, Fe, Mn and

Zn, all by AA procedures used for soil analysis. P can be read in percent transmission or optical density with spectrophotometer at 680D. Ammonium and nitrogen can be determined by percent transmission or optical density with a spectrophotometer at 630D for a period of 3 hours.

Chemicals and Reagents needed:

The following chemicals and reagents are needed:

phosphorus color reagents

antimony

potassium

tartrate

lanthanum oxide

ammonium molybdate

gelatine and ascorbic acid

alkaline phenol

concentrate H Cl

NaOH

liquid phenal or crystal phenol

clorox (Na ClO)

Standard Solution Preparation Requirements:

sulphuric acid $H_2 SO_4$

2 mg Cu/ml

20 mg Fe/ml (Can be prepared together in the same solution).

15 mg Mn/ml

3 mg Zn/ml

2500 mg K/ml

500 mg Mg/ml (Can be prepared together in the same solution).

1000 mg Na/ml

300 mg P/ml (Can be prepared together in the same solution).

2500 mg N/ml

> 1250 mg Ca/ml Prepared in H_2O solution acidified with a few drops of HNO_3

2. Irrigation Water

a. Collection of Irrigation Water

The minimum quantity of water required for the ordinary chemical analysis of water is about one and a half liters. A representative sample should be obtained. Well water samples should be collected after the pump runs for some time. Not much time should elapse between sample collection and analysis.

b. Reporting Sheet

This contains all necessary information such as date, site, location, description of locality, farm, and elevation. The following values may be useful in determining water quality:

-- pH report to the nearest 0.1 unit

-- Electrical conductivity (EC x 10^6 at $25^oC.$). Report to the nearest 0.1 when less than 100, and to 3 significant figures for values above 100.

-- Dissolved solids. Report in parts per million (p.p.m.) to the nearest whole number.

-- Boron. Electrometric titration method. Report to the nearest 0.01 p.p.m. when less than 10 p.p.m. boron colorimetric method; Report to the nearest 0.1 p.p.m. boron.

-- Lilica. Report in p.p.m. SiO_2 to nearest whole number

-- Fluoride. Report to the nearest 0.1 p.p.m. Fluoride

-- Cations & Anions. Report to the nearest 0.1 meq/L

Boron-Colorimetric Reagent

sodium hydroxide

hydrochloric acid, concentrate

hydrochloric acid, dilute

sulfuric acid, concentrate

carmine solution

standard boric acid solution

Prepare a standard curve from standard boric acid solution -- Calibrate the curve and concentration on the curve. Read unknown against curve.

Dissolved Solids (DS)

Evaporate a known alignate to dryness and report the dissolved solids (DS) to p.p.m.

pH

Use a filterate to determine the pH.

Silica (Gravimetric)

Acidify the sample residue of DS above with hydrochloric acid and evaporate to dryness for about one hour. Moisten with hydrochloric acid, then dissolve in water, then wet filter. Repeat acid and water treatment; wash with hot water. Transfer the residue to a crucible and ignite with a few drops of sulfuric acid and a few milliliters of hydrofluoric acid and evaporate to dryness in a steam bath. The difference between the two weights is the weight of silica.

Parts per million SiO_2 = gm SiO_2 x 10^6 ml in alignate.

All calculations for calcium magnesium, Na and K can be run by the AA from an alignate as the soil extract, or sodium can be determined by the Uranyl Zinc Acetate Gravimetric method, whose reagent use the following:

-- Uranyl zinc acetate:

-- Uranyl acetate, dihydrate (300 gm)

-- Zinc acetate, dihydrate (900 gm)

-- Acitric acid, 30% (270 ml)

-- Distilled water (2430 ml)

-- Ethyl alcohol saturated with sodium, uranyl, zinc, acetate precipitate. Filter before use.

-- Ether anhydrous

Calculation: meq/L of Na = gm sodium, uranyl, zinc, acetate precipitate x 650.16 ml in aliquot. Na can also be determined by flame photometer. K can also be determined by cobaltinitrite gravimetric or volumetric or by flame photometer.

Carbonate and Bicarbonate

Reagents:

-- Phenolphthalein .25% solution in 50% alcohol

-- Sulfuric acid standard 0.050N

-- Methyl orange 0.1 percent in water

Take an aliquot of the sample containing less than 1.0 meq of carbonate and bicarbonate and dilute to 50 ml. Add a few drops of reagent A, and if pink color is produced, titrate with B adding a drop every 2 or 3 seconds until the pink color disappears, then add 1 or 2 drop of C; continue the titration to end point. (This solution is good for Cl determination.)

Calculations are as follows:

CO_3 or HCO_3 MOH = 1000 x normality of acid x titration value

Blank valve (a blank should be run parallel).

Sulfate

Reagents are:

-- Hydrochloric acid concentrate

-- Barium chloride solution 10% (Dissolve 100 gm of Ba Cl_2 $2H_2O$ in 1 liter of water and filter

-- Methyl orange 0.1% in water

Take an aliquot and dilute to a given volume. Add a few drops of reagent C (Methyl Orange) and 1 ml of HCl. Heat to boiling and add an excess of B, drop by drop, with constant stirring. Allow to cool. Reduce volume and filter. Take residue in ashless filter paper. Burn in crucible quite in muffle till constant weight and weigh. Calculations are as follows:

Milli-equivalents per liter of SO_4 = gm Ba SO_4 x 8568.2 ml in aliquot

Chloride

-- Potassium chromate indicator (5 gm per 100 ml filtered).

-- Standard silver nitrate solution 0.05 N

To the solution from the carbonate and bicarbonate determination add 1 ml of reagent A and titrate with B (aliquant should contain less than 2 meq of chloride). Calculations are as follows:

Milli-equivalents per liter of Cl = 1000 x normality of Ag NO_3 x (ml Ag NO_3 - Blank) ml in aliquot.

Fluoride

Use normal "Standard Methods based on American Public Health Association and American Water Works Association" (1946, 39A-2, p. 76 and 39B-2, p. 77).

Reagent

Acid zirconium aligarin reagent. Dissolve 0.3 gm zirconium oxychloride (Zr O Cl_2 $8H_2O$) in 50 ml of distilled water contained into a one-liter glass stoppered flask. Dissolve .07 gm alizarin sodium monosulfonate in 50 ml of distilled water and pour slowly into the zirconium oxychloride solution, while stirring the flask. Prepare a mixed acid solution as follows: Dilute 112 ml concentrate H Cl to 500 ml with distilled water. Dilute 37 ml concentrate sulfuric acid to 500 ml with distilled water. After cooling mix the two acids. To the zirconian alizar in solution in 1-liter flask add the mixed acid solution to the mark and mix. Store in a refrigerator for 60 - 90 days.

Standard Solution Fluoride Solution. Dissolve .221 gm sodium fluoride in distilled water and make up to 1 liter. Dilute 100 ml of the stock sodium fluoride to 1 liter with distilled water. One ml is equivalent to 0.01 mg of fluoride.

To 100 ml of sample and to standards made up to 100 ml with distilled water, add 5 ml of reagent A accurately. Mix and compare sample with standards after standing one hour. Calculations are as follows:

Parts per million F = mg x 1.000 ml in aliquot.

Nitrate

If low Cl content in water, use phenoldisulfuric acid.
If high Cl content in water, use Devarda apparatus.
Nitrogen distilling apparatus with scrubber bulbs.

Reagent

-- Deverda alloy
-- Sodium hydroxide, saturated solution
-- Boric acid 2% solution
-- Standard sulfuric acid solution 0.05 N
-- Bromeresol green, methyl red. (BC G - MR) indicator solution. (Color changes from green in alkali to gray at the end point to red in acid solution.)

Place 50 ml of the sample in Kjeldahl flask and add 2 gms of Devarda alloy. Make up to 300 ml with distilled water then add 2 ml of reagent B, allowing it to run down the side of the flask till it touches the contents. Connect with the distilling apparatus and

rotate the flask to mix. Heat slowly at first and then increase the heat such that a 200 ml of distillate will pass over in one hour. Collect the distillate in 50 ml of C. The ammonia is titrated with D, using indicator E. Calculations are as follows:

Milli-equivalent per liter of NO_3 = 1.000 x normality of acid x (ml acid - blank) ml in aliquot.

IV. WATER

Water is an essential factor for agricultural development in Paraguay. As was discussed earlier, rain water is not adequate to support some crops whose water requirements are above the one meter depth. Irrigation water is therefore a must, especially in areas of intensive agriculture or where crops need over one meter depth of water for their growth. It is evident that crop quantity and quality are directly related to the availability of water.

Eight water samples from different farm wells were taken for analysis during the course of this study, in order to determine their quality. Five of these samples were from different farms at Loreto: one from the farm well of Francisco Jimenez in Itacurubi, 2 water samples from Col Oneida CREDICOOP farms, one from the farm of Daniel Kiscovitch and the last from Pedro Jimenez farm. Water depths varied in all eight wells. It is striking to note the variability of the pH from 8 to 5.7 within very short distances. The hydrogen ion concentration ranges from alkalinity to strong acidity. This has a direct bearing on the fertility of the soil and the fertilizer regime used with the different crops. The sensitive balance of micro-nutrients in this respect has to be judged by the locality as a micro-circumstance and not a macro-generalization.

The ions like the chorors and the sulphates are different and incompatible, showing different trends and no correlation to others. The cations are likewise highly variable. The potassium element shows a very low content except at Itacurubi where Fe is also high.

These patterns of results led to further inquiry as to the quantity and quality fluctuation; unfortunately these could not be answered without at least an annual cycle of periodic analysis. The rate of recharge likewise could not be answered but should be determined in order to budget the available water among the crops intended for cultivation.

A project of water use for agricultural purposes should be considered; classification of water according to international terms should be used. The additional quantity to remedy its salinity, alkalinity or acidity should be determined accordingly. Suitability of the water for domestic consumption must be emphasized.

V. SOILS

A. Origin of Soils in the Concepcion Area of Paraguay

The soils have derived from sedimentary, metamorphic and igneous rocks as described below:

The sedimentary rocks: Land, loam and clay of valley fluvials:

-- j_3a - Mission's land, sand of eolica, land gravel and fluvial silt

-- C_3ag - Left groups - sand, conglomerates, silt, diamicticas and silt

-- Amnz - If a pucumi group; calcareas and dolomitelates and maryasi, Mcososy conglomerate

Metamorphic Rocks:

-- A(A)mng - San Luis Grope - Cartz, metaconglomerate, silts

-- A(A)mnK - Crystal complexes of opac. - gneiss, quartz, micas afibolitas, esquisto

Igneous Rocks:

-- A(Bc)g - Granite of the crystal mixture

B. Parameter for Soil Classification

The main parameters describing Paraguayan soil classification for agricultural use are the following:

1. The profile thickness	very deep, 150 cm and more
	deep, 100-150 cm
	slightly deep, 50-100 cm
	shallow, 25-50 cm
	very shallow, 0-25 cm
2. Surface texture	VH very heavy (clay soil)
	H heavy (clay, loam, F Cl F)
	M medium (clay, fine sandy loam, sandy loam, sandy clay loam)
	L light (fine sandy loam, fine sand, loam)
	VL very light (sand)
3. Permeability	very slow, .27 cm/h
	slow, .27 - .5 cm/h
	moderately slow, .5 - 2 cm/h
	moderate, 2 - 6.4 cm/h
	moderately rapid, 6.4 - 12.7 cm/h
	rapid, 12.7 - 25 cm/h
	very rapid, more > 25 cm/h
4. Physiography	A alluvial flood plain
	B terraces, alluvial
	U high land
	V small valleys

5. Soil Parent Material	1. basaltic
	2. sandy stone
	3. limestone
	4. granite
6. Soil Humidity	W_o below water
	W_1 frequently flooded
	W_2 water table below 1 meter, but not flooded
	W_3 water table generally between 1-3 meters
	P water table is very deep (low)

The class can be determined by all of the above factors and if one or more can be corrected, the soil class is higher. If more severe limitation takes place, it will make the soil class lower and limits its use.

C. Percent of Actual Use of the Land in Paraguay

A UNDP survey divides the actual use of the land in Paraguay into four classes:

- -- Forest land, representing about 70% of total land mass;
- -- Pasture land, constituting about 10-15%;
- -- Forest/pasture mixed land, about 10%; and
- -- Agricultural land, which is also about 10%.

D. Classification of Soils According to Their Potential Use

Soils in Paraguay have eight different classes, according to their potential use. Maps 1, 2 and 3 of Annex II show these classes for the different cooperatives in the project area. The description of these classes and the percentages of each corresponding type of soil is given as follows:

Class I - Can be used for agricultural purposes without any limitations. It does not exist in Paraguay at all.

Class II - Has some limitations which reduce the selection of cultivation as it will require moderate practices of conservation.

Class III- Has severe limitations, which reduce the cultivation. It requires special practices of conservation or both.

Class IV - Has very severe limitations which restrict the cultivation election. It requires very well planned management.

Class V - In these soils, actual conditions are not favorable to cultivation due to high water table, frequent inundation, or both. Could be used for forage, either natural or artificial.

Class VI - Has very severe limitations which render these soils actually inadequate for cultivation. This limits its present use to natural forage only if well drained.

Class VII -Has very severe limitations which restrict its use for cultivation and limits it only to forestry.

Class VIII-Limitations exist which prohibit land use for commercial cultivation, and only allows for recreational parks, fish ponds, etc.

1. Soil Productive Capacity of Northern Paraguay

The productive capacity of the northern part of Paraguay around Concepción is drawn in Map 2 of Annex II. The classes of these soils are as follows:

Class I soils are with no limitations or at most only slight limitations. They are highly productive and may be used for intensive cultivation of a wide range of crops (intensive agricultural use).

Class II are soils with limitations that require fertilizer and corrective amendments in order to maintain their productivity (regular agricultural use).

Class III soils have medium to strong limitations and require amendments and special management in order to maintain limited cultivation (restricted agricultural use).

Class IV (a) Soils of this class are not suitable for agricultural development. These may be used for extensive cattle raising.

Class IV (b) These soils are like Class IV (a) except their use is for a mixture of cattle and forest. They could be used as forage farms in a semi-intensive form in some selected areas.

Class V soils are not suitable for pasture or agricultural development. They have very little use except for natural forests.

2. Soil Productive Capacity and Horizontal Expansion Around Cooperatives (Reference Map 2 of Annex II)

The cooperative and its surroundings are shown in Map 6. Most of the soils belong to Class II, which has moderate limitations. These soils are low in fertility and require normal corrective measures in order to maintain a moderate productive level of cultivation. This is about 15% of total area.

Around these soils one finds group III to the north, and group IV (b) to the east and southwest. These areas comprise about 25% of the total land area. Group III has moderate to severe limitations for agricultural use. These soils will require fertilizer amendments and special soil management in order to broaden the scope of their usage.

The soils to the east and southwest are mainly used now for ranches. They are not useful for cultivation, but can be used for intensive pasture. This is about 40% of the area.

Group IV (b) in the far east of Loreto can be used for a mixture of forests and pasture and in certain areas it can be used as intensive pasture. These soils are shallow and have little relief. They comprise 20% of the land.

3. Extent of Horizontal Expansion Around Quindy and Acahay

Areas of each soil class in the vicinity of Quindy and Acahay are given in Maps 3, 4, 5 and 6 of Annex II. According to the classes of soils in the vicinity of these two cooperatives, and the expected production, one can state that:

a. Roughly 15% of the land is good for normal agricultural use -- any cultivation. Its limitations are moderate. All soils are fertile.

b. About 10% of the land located to the north and south of Loreto has severe limitations.

c. About 35% of the land has severe limitations which restrict cultivation.

   These soils will require fertility corrective measures before they can be cultivated normally.

d. About 40% of the land has restrictive limitations. These soils can be used for forest, pasture, or natural pasture with forest. It is prohibitive at present to use it for agriculture. Some parts of these soils can be used in the future for parks or recreational purposes.

4. Surface Area of Each Soil Class in the Vicinity of Itacurubi

In the discussion of these soils, reference is made to Maps 7, 8, 9 and 10 of Annex II.

a. Soils with one or two reparable limitations are good for agricultural use and they comprise about 15% of the land area. These limitations concern fertility and are manageable under a good production program.

b. Soils with more limitations inhibit their use for common agricultural purposes. Only selected crops can be grown on these lands. The area of this soil class around Itacurubi is about 5%.

c. Soils with severe limitations inhibit their use but are suited to forest or pasture. This area is about 15% of the total.

d. Soils with severe limitations make their development for agricultural purposes impossible and can only be used for natural pasture forest and/or parks or lakes. These areas make up about 65% of the land in the vicinity of Itacurubi.

5. Surface of Soil Classes in Vicinity of Col Ovieda
(Reference Maps 11, 12, 13 and 14 of Annex II)

Soils which show one or two limitations and can be corrected with fertilizer make up about 25% of the land around Col Ovieda. These soils are good for any agricultural use. About 5% of the soils show more limitations to common agricultural practices and are satisfactory for raising cattle. About 25% of the soils have severe limitations, leaving about 45% of the soils with most serious limitations.

VI. FIELD OBSERVATION AND SOIL ANALYSIS

A. Soil Fertility Status in North Paraguay

The northern soils like those of Concepcion and Loreto are described as follows:

1. Texture

The soils have a sandy or sandy loam texture with 70-85% sand, loam ranges between 4 and 13% and the clay varies between 5 and 22% with a very homogeneous profile. However, the moisture content is variable from the surface down to 120 cm depth.

2. pH

The soils show a pH which ranges between 6.5 and 7.5. In some exceptional cases it is as high as 7.8, which could be considered as alkali for these light-textured soils. The acidity still prevails in some of these soils and increases with depth. It is at the surface 6.1 and increases to 5.4 at a depth of 30 cm and maintains this acidic value downward to 120 cm deep in the profile.

3. Organic Matter

The organic matter content is in general low. It is the lowest in the acidic soils and less in the soils of medium neutrality or slight

alkalinity. The bulk of the organic matter content of the soil is found in the upper 30 cm.

4. Nutrients

Soil nutrients are very low. The potassium content throughout the soil above the 120 cm depth is inhibitive to crop cultivation. It is very low at about .08 to 0.06 p.p.m.

Phosphorus content is higher on the surface layer than in the lower layers. But its content is below plant nutritional requirement, ranging from 2 p.p.m. in lower levels to 14 p.p.m. in the upper layer.

Magnesium is also very low, yet it shows a relative balance throughout the profile. Its value ranges between .78 and 0.63 p.p.m.

Soil calcium content reflects the same trend as magnesium, mainly low content all over with relative balance throughout the profile.

In conclusion, soils of the north are considered as poor in nutrients and will need amendments in commercial fertilizers if any crop is to be produced. The type of commercial fertilizer required for these soils should be balanced and complete. There is no need to add gypsum or increase the calcium or magnesium at the beginning since the pH is neutral or a little higher.

B. Soil Fertility Status in the Central Agricultural Zone of Paraguay

Based on soil samples collected in the area of Itacurubi and Col. Oviedo, the fertility of the soils shows the following pattern:

1. Texture

The texture of the soils is sandy loam or sandy clay loam ranging between 62-72% with an average of 75% coarse sand, 12-18% loam and 15-20% clay.

In the upper 0-30 cm the combined percentage of clay and loam can be up to 25%. In the 30 to 60 cm layer it can be as much as 40%, which indicates an increase of about 15% in the fine, active soil separate fraction over that in the upper 0-30 cm layer.

Going lower in the profile, the layer of 60 to 120 cm shows that combined percentage fraction of the soils is between 35 and 40%. Occasionally the clay percentage is twice or three times that of loam content and sometimes these portions are reversed. This of course depends upon the mode of irrigation and the age of the developed profile when the clay migrated downward faster and deposited in the A_2 or B_1 horizon. This phenomenon of advanced degree of development, is not shown in the northern agricultural land (Loreto) as the contents of both loam and clay are almost equal all the way through the profile.

2. Chemical Soil Properties Related to Productivity

The pH of these soils ranges between 6.2 and 5.2. In general, there is no pattern to the acidity throughout the profile from the upper layer down to the lower layers. pH may increase, decrease, or maintain a constant value down to a depth of 120 cm. Probably the type of fertilizer added, quality of irrigation water and crop rotation systems have much to do with this situation. The pH can not be correlated with organic matter content in the soil profile, nor with available potassium, magnesium orphosphorus. Likewise, other fertility factors can not be correlated with clay or lime content. However, some correlation was found with Ca.

3. Organic Matter Content

In general organic matter ranges from 1.5 to 2.5 %, and as expected, is higher in the upper layers. The organic matter content is higher in these central soils than in those of upper Paraguay.

4. The Nutrients

There is a positive correlation between the active soil fraction (lime plus clay content) and the nutrients in general.

The calcium content predominates the cation exchange capacity followed by magnesium and then potassium.

The magnesium content is generally low as it ranges between 0.8 and 0.6 meq per 100 ml.

Potassium is extremely low as its content is in the range of 0.1 to 0.05 and sometimes lower meq per 100 l.

The phosphorus content is almost zero in the upper layers. Above pH 6 phosphorus does not surpass 2 p.p.m. irrespective of layer depth.

5. Conclusion

It is difficult to establish a fertility pattern for the soils in the central or northern part of Paraguay. They can be described as an exhausted, deteriorated media of growth. The essential elements are deficient and their balance is difficult to establish. With very low fertility, the land availability assumes an even greater importance.

Balanced fertilizer is one step in solving the productivity complex. It should always be looked at and interpreted in the global context of factors which affect the uptake of nutrients by plants. The deficiency symptoms may be resolved or corrected only by adding fertilizer, in accordance with soil analyses. The type of crops grown and the cultivation practices followed will also have an effect on the nutrient stock in the soil profile.

Water quantity, quality and frequency of irrigation are also important factors affecting availability of nutrients in this delicate soil. For

example, low water content at low pH will cause even a small quantity of salt to exert a toxic effect on the root zones. Poor fertilizer placement can likewise burn the roots at various soil depths, depending upon soil pH and water availability factors.

a. Typical Physical/Chemical Characteristics of Hydromorphic Soils

Please refer to Table 3 of Annex I, where the difference between phenosol and glypoco humid soils is described physically and chemically.

b. Micro-nutrient Content of Typical Hydromorphic Soils

Please refer to Tables 4 and 5 of Annex I, and Figures 1 and 2 of Annex III. The main points of distinction between the two kinds of soils are well expressed in the content of 2.1 iron (Fe), 2.2 manganese (Mn), 2.3 copper (Cu), and 2.4 zinc (Zn). The submersion of 30or 90 days show these basic points:

Soils have different elements contents;

The superficial soil beds have more micro-nutrient concentration.

The glypoco humid soil has an original content higher in Mn and Zn, similar in Cu and higher in Fe, than the planosol.

The effect of water in submersion is indefinite in the availability of Zn between the soils and the horizons of each profile. Irrigation

and submersion have the tendency to increase the concentration of the elements in the gleypoco humid and in the planosol which will decrease by the submersion. The submersion causes a considerable increase in the Fe concentration and in the planosol and the Mn in the gleypoco humid.

Cultures in these soils can show toxidity in Fe in the planosol, Mn in the gleypoco humid and deficiency of the two in both.

c. Relationship between pH and Micro-nutrients

Figure 3 of Annex III describes these relationships. While molybedeneum increases with pH increase, the other micro-nutrients (Zn, Fe, B, Mn and Cu) decrease. Micro-nutrients are most available when the pH is between 5.5 and 6.5.

d. Fertility Status and Field Observation

A soil sample was taken 30 cm deep just under the roots of a strawberry plant at the NAI experimental Station strawberry trial plots, and another sample was taken far away where there was no fertilizer or plants.

The maximum root extension was 23 cm and the diameter of the root was 24 cm. Plants were planted for the purpose of being transplanted later to the farmer's fields. The following Table summarizes these soil analyses comparisons.

NAI-Strawberry Experiment at Caaupe

Soil Analysis

	Soils away from plants	Soils under plants
Sample Depth	0-30 cm	0-30 cm
pH value	6.3	6.1
O.M. %	3.1	2.6
Ca	4.1	4.8
Mg } meq/100ml	0.76	0.83
K	0.09	0.12
P p.p.m.	12	14

From the analysis of both soil samples one can conclude that there is little difference between the fertilized and the non-fertilized soils at the NAI Experimental Station. The slight difference is an increase in acidity reduction in organic matter content and an increase in the content of calcium.

There is a little more potassium and phosphorus in the upper 30 cm under the plant than in the sample taken 2 meters away at the back of the plot. The NAI soils are generally deficient in nutrients and probably should receive additional fertilizer.

e. Fertilizer Migration in Tomato Field at Quiindy

Tomato was planted in May at the Cooperativa of Anindi and received first application of fertilizer in June. A second application was made in July and a third on the first of August, all in band placement. The amount applied was 150 gm per plant of 25-0-19. The soil sample was taken on 8/7/81. The tomato variety was Nadomi, which is favored over Santa Cruz. Frost which occurred in last July had killed many plants.

Table 6 of Annex I indicates the laboratory fertility results which point out that there was incidence of P fixation in the upper 30 cm and very slight movement downward, indicating that the phosphate placement was not optimum.

Potassium was also found to be in the upper 30 cm layer, but very little was found deeper down the profile; pH was higher as a result of the fertilizer application. Recommendation: increase the dose of P and K and apply locally at 20 cm depth (roots are only down to 23 cm and plants are as high as 58").

f. Fertility Evaluation of Loreto and Soil Profiles

Soils and water samples from Loreto were tested. Figure 4 of Annex III illustrates the location of these small farms, the location of soil profile where samples were taken, and the chemical and fertility data available for these farms. The number of soil and water samples corresponding to these sites is also shown.

VII. FERTILIZERS

A. Definitions and Comparisons

There are two chemical companies in Paraguay -- Agrochemica and Nitrochemica. Nitrochemica sells fertilizer such as 20-5-30, 28-14-14 and 15-30-15.

A combination of potassium and magnesium has proven to be of higher value in production than potassium alone. A high potash (20-5-30) fertilizer is used when plants are maturing and blooming. In this stage plants require smaller amounts of nitrogen than potash and very little phosphorus.

A high phosphorus feed is 15-30-15. It is used as a starter for tomato plants and garden vegetables in general.

The 28-14-14 formula is a high nitrogen fertilizer that should be used during the period of vegetative growth. When plants make their maximum growth they require more nitrogen than phosphorus or potassium.

The 20-20-20 formula is a sixty percent nutrient in a balanced form (1:1:1 ratio). It is the most widely used water soluble formula and can be used in the absence of a specific formula recommendation.

All of the above formulas are water soluble and can be used on all plants. Their solubility is in the range of 250-400 gms per liter of water. Warm water can be used for faster results. They contain a package of micro-nutrients including Fe, .1; Mn, Zn and Cu, .05 each; Bo, .02; and Mo, .0005 per bag. For agricultural crops, the concentrate is diluted at the rate of 5 Kg per 25 liters of water per hectare.

Analysis	Rate of Application
20-5-30	5-10 Kg per hectare
28-14-14	3.5-7.0 Kg per hectare
15-30-15	6.5-13 Kg per hectare
20-20-20	5-10 Kg per hectare

Fertilizer Formula Calculations

In order to determine the amount of a particular fertilizer in a formula, it is necessary to know the part per million (p.p.m.) of that fertilizer. Using nitrogen as an example, one part per million (p.p.m.) means that a solution contains one part of nitrogen in 1,000,000 parts of water by weight. In order to determine the p.p.m. of a solution use the formula:

$$\frac{\text{gms of fertilizer products}}{\text{of water in solution}} \times \text{grade of fertilizer} \times 10 = \text{p.p.m. liters}$$

Formula 20-20-20 contains 20% nitrogen and in order to calculate the p.p.m. of nitrogen in a solution containing 1 gm of 20-20-20 in 100 liters of water, the equation would be:

$$\frac{1 \text{ (gm of product)}}{100 \text{ (liters of water)}} \times 20 \text{ (grade of fertilizer)} \times 10 - 2 \text{ p.p.m.}$$

To determine the number of grams required to make up a 200 p.p.m. solution of nitrogen with 20-20-20 fertilizer in 100 liters solution, simply divide by 200; the answer is 100 gms.

These formulas are very soluble. They contain synthetic, inorganic, and chelated metal complexes used to incorporate trace elements in the formulas to provide micro-nutrients to both acid and alkaline soils. The chelated complex is completely available to the plant and cannot be tied up by either elements in the soil or the phosphate ions in solution.

The Agronomico Co. of Paraguay sells double sulfate of potassium and magnesium grade 00-22-18.

Analysis

Soluble potassium	(K_2O)	22%
Magnesium	(MgO)	18%
Sulphur	(S)	22%
Chemical formula	$K_2 SO_4 .2 Mg SO_4$	
Commercial name	K - Mag	

The fertilizer characteristics:

1. Three elements: potassium, magnesium and sulphur;
2. The nutrients are in an assimilable form (small crystals);
3. It can be mixed with nitrogenous and phosphatic fertilizers;
4. It improves the quality of some products; and
5. Magnesium which is lacking in many soils will, when added to the soil, stimulate phosphorus assimilation.

B. Recommended Usage

-- in soils low in potassium, magnesium and sulphur;

-- for soils low in potassium and magnesium;

-- for soils requiring potassium and sulphur;

-- for soils requiring magnesium and sulphur;

-- for soils low in magnesium or which have been corrected with calcium and not dolomite;

-- for soils where the applications of potassium could induce (agravar o provocar) or provoke a deficiency;

-- for crops which require high levels of both magnesium and sulphur as oil seeds, soya, cotton, coco, african palm;

-- for crops sensitive to chloride such as pineapples and tobacco; and

-- as a supplement of a complete and maintained fertilizer program in soils of high deficiency and/or crops with high requirements of these nutrients.

C. Fertilizer Programs and Recommendations

1. Fertilizers of nitrogen, phosphorus and potassium are evidently needed annually for soils and all cultivations in question.

2. Initial application of lime to correct extreme acidity of many soils is a must, with subsequent application of lime at approximately three-year intervals.

3. All soil analyses have shown that broadcasting fertilizer or incorrect placement of fertilizer in relation to the plant will reduce the effectiveness of fertilizers. Phosphorus fixation is more pronounced when it is broadcasted. It should be applied in bands or placed in zones where the first plant roots develop. However, damage and burn to germination should be taken into account, especially when high rates of fertilizer are applied.

4. In the absence of field tests, it is impossible to know to what extent phosphorus fixation manifests itself in the soil, and especially in predominantly acid soils.

Basic soil fertility research through laboratory and potted plants should be initiated immediately. This will establish the proper foundation for soil analyses and fertility interpretation in the field. The soils to be included in this research are from key soils and classes. Fertility limitations should be outlined within each soil class. Corresponding fertilizer programs should be adapted to the soils according to the different degree of acidity and levels of fertility.

D. Experimental Soil Sampling

Samples to be collected from the following locations

-- Itacurubi

-- Col. Oviedo

-- Aniundi

-- Akai

-- Loreto

Sampling depth. (a) 0 - 30 cm (aA, ^aB, ^aC, ^aD, ^aE)

(b) 30 - 60 cm ($bA + bB + bC + bD + bE$)

Composite sample from five fields in the same location

Total Sample/Location = 10

Total Sample = 50

Dimensions of pit 30 cm x 30 cm x 30 cm

Hectares 10^4 meters

Area taken .09 m^2

Factor per hectare = 10^5

E. Tentative Fertilizer Recommendation

The specific fertilizer recommendation for each area should be based on soil laboratory testing for various crops. Formal fertilizer guides for the various crops should start by experimentation. This will establish rates of application due to the uncertainty of yield response to fertilizer application. Soil test results to date indicate that recommendations should employ ratios in which phosphate predominates, for example - 1:2:1 and 3:3:2 and 3:2:3.

It should be noted that the actual amount of up-take of nutrients will be variable and can only be narrowed down by field trials in different localities for the different crops.

F. Making Composts in the Fields of Paraguay

1. Background

Soils in Paraguay are generally low in nutrients. Higher yields will require, among other adjustments, an increase in nutrients, better nutrient balance and moisture content of the root zone area.

Nitrogen is the most needed element in almost all of the soils of Paraguay. It is essential for all field crops. Importation of nitrogen in different forms from outside the country has almost doubled over the past 10 years and should continue to increase as the demand for improved produce increases.

Organic matter is a natural source not only of nitrogen but also of other essential elements and micro-nutrients needed by all crops. The content of organic matter in Paraguay's soils ranges between low and very low in almost 80% of the cultivated soils. Consequently, hardly any crop can be grown without improvement in the levels of organic material.

Thousands of tons of nutrient elements are waisted yearly on Paraguayan farms as farm manure and waste are left to decompose, disintegrate and evaporate, thus losing its value as a fertilizer material.

2. Composting

Composting can be carried out on any scale ranging from large farms to backyard gardens. Almost any natural organic product can be composted with proper care -- corn stacks, straw, leaves, grass clippings, garbage, etc. The decomposing microbes are not selective.

Compost heaps should be built no more than 180 - 250 cm high so that air can enter at the bottom of the pile. All residues should be cut less than 15 cm in length. Nitrogen fertilizer should be added at the rate of 100 gms per 0.027 m^3 of any material. Moisture content between 50-75% is desirable.

Decomposition is slowed down when the hay is drier. An aerobic condition exists particularly at the bottom of the heap, where it is wetter. Water and nitrogen are best applied in layers as the pile is built up. Excessive moisture should be avoided. The temperature of the pile increases as it heats up, at which time it will hasten the decomposition. The compost should be turned every three or four days.

Usually the compost is complete in three to four weeks. This can be recognized by a cooled pile and by the onset of a darker color. In addition, the texture becomes more crumbly and the pile has less ammoniac odor.

Compost will be very beneficial to soils of Paraguay. Most soils are low in organic matter, and frequent tillage and complete removal of crops has lead to soil deterioration.

Composts, like organic amendments, will improve the soil structure, water penetration, and moisture-holding capacity. This will encourage the return of micro-nutrients which were previously extracted from the soil. However, compost should be considered a complement to, not replacement of, commercial fertilizers. Compost alone does not contain enough nutrients to satisfy the nutritional requirements of growing plants.

G. Basic Research and Experimental Studies

1. Laboratory - Greenhouse - Pot Test

a. Effect of Al and its toxicity on germination and plant growth - the objective is to evaluate the rate of tolerance to all toxicity in different fields for different varieties. The objective is to establish among different plants a tentative level of tolerance to aluminum, and to determine above what level the plant or variety would not grow.

b. Lime requirement and its correlation to soil analysis - the objective is to establish the lime quantity suitable for each soil to bring it to a given pH. All other soil chemical properties should be tested in order to establish a lime criteria for each soil.

c. Lime requirements established by above method and response - crop response is correlated with soil test data, such as O>M, clay content, Al, etc.

d. Phosphorus fixation and available phosphate in relation to fertilizer rate, time of application and soil analysis - evaluate the amount of applied phosphorus and the residual which remains available as affected by rate of P application, length of time following application, and the kind of P extractant to measure residual P.

e. Potassium fixation and available potassium in relation to fertilizer rates and soil analysis

f. Phosphorus correlation - relate soil phosphorus availability to plants. The most important soil test is the one which correlates well with plant response before a reliable prediction can be made for phosphate fertilizer needs.

g. Potassium correlation - relate soil potassium to availability to plants, employing soil tests. It is similar to the above-mentioned experiment.

2. Field Experiments

After the conclusions of the pot tests and greenhouse experiments, the following field experiments should be considered as the most important for banana, tomato, strawberry and pineapple:

a. Fertilizer with irrigation
b. Fixed doses with different time of application
c. Placement of fertilizer
d. Different forms of N or P or K with the other two variables held constant

VIII. STRAWBERRY

A. Growth Pattern

Strawberry plants set in moist soil produce new fine fibrous roots within a few days. Therefore, they can be set in winter, spring and fall. Plants set in spring are subject to loss of water and it is advisable to remove all the leaves or spray plants frequently with water. New leaves appear as soon as the new roots are established. The leaves will be healthy and large if the new root system is extensive.

If the temperature drops and the weather cools in winter and late fall, as in Paraguay, plants should be set with all the leaves on them.

When plants are set out in the spring, runners appear usually from buds in the leaf axils in 30 to 75 days and continue to appear until fall. When days start to shorten (about 12 hours or less) in the fall, the growing points in the crowns of the oldest and largest plants start changing into flowering buds.

B. Requirements for Good Cultivation

1. Climatic Requirements

Daylight periods of 12 hours or less and cool temperature are very important in flower and bud formation. Most of the varieties that give good yield require different day length (the shorter the better) and

cool temperature. The development of flower buds occurs in the oldest and strongest plants first and in the youngest and smallest plants last.

The growing point of the terminal crown changes to a flower bud first, followed by the growing points of lateral crowns. It has been physiologically noted that plants with greater number of leaves will produce a greater number of berries.

The flower clusters appear after the flower buds form because the plants have practically no rest period. In certain cases flower clusters that develop in the warm weather may be killed if the drop of temperature reaches freezing. However, some of the killed buds can rapidly be replaced.

The first flower to open on a cluster is the largest, and the first flower develops into the second largest fruit, and later flowers develop into successively smaller fruit. The flowers are pollinated chiefly by bees. The berries mature about 30 days after bloom. They mature slower in cool weather and faster in warm weather.

2. Soil Requirement

No particular type of soil is best for the varieties of strawberries grown in a given area. Course sand, fine sandy and heavy soils are used extensively. However, medium to coarse textured soils such as sandy loam or fine sandy loam are preferred. Fortunately, these soils are found in abundance in areas designated by CREDICOOP for strawberry plantings.

3. Drainage Requirements

Standing water or poorly drained soil seriously injures strawberry plants and may drown them or so weaken them that their growth is stunted. Soils should be prepared so that water will drain away. If the land where the strawberry is intended to grow is low, then drainage is especially important. It is a common practice to set the strawberry plants on ridges 8 to 30 cm above the furrows that separate them.

Leaf, root and fruit diseases occur more frequently on poorly drained sites than where the drainage is good.

C. Preparation of Land

Land should be thoroughly prepared. It should contain abundant supplies of humus when the plants are set. Humus can be supplied by applying adequate quantities of manure or by growing and turning under one or more green manure crops before the plants are set. Legumes such as clover, soybeans, cowpeas are preferred as green manure crops.

Use a plow to form suitable ridges; the height and weight of these ridges depend upon the character of the soil and on the slope of the fields. Ridges 15 to 24 cm above the bottom of the furrows are usually adequate. The top of the ridges are usually levelled with a plank before planting.

D. Preparation of Mother Plants, Freezing and Storage

Plants are dug in early December, cleaned of old leaves, packed in crates lined with polyethylene film or equivalent material, then placed in cold storage at 32° to 34° F. for about 60 days. This is to insure a cold rest period so that the plants can produce runners. Nurseries are the places for such plants. When these plants are planted they are set 90 cm apart during the winter in rows 120 cm apart to serve as mother plants for further propagation.

E. Field Schedule, Summary of Planting, Transplanting, Propagation

A common schedule for field planting is as follows:

February-March - Cold storage plants or new mother plants are planted.

May-June - The mother plants should have developed enough runner plants to set a larger area of stock plants.

August - Runner plants from the May-June setting should be ready for planting a more extended area of stock plants.

September-October- Plants set in August should have developed large runner plants ready for planting into the fruiting fields. This is usually done during the first half of October.

The exact time for original planting or transplanting of runner plants will vary in accordance with soil and moisture conditions.

By transplanting in May and June it is possible to obtain enough plants to set a four- to five-acre area from a small original stock of 1,000 plants. Usually plants transplanted in this manner have large crowns.

Propagation can be accomplished also from selective native local stock, or from nursery stock obtained from other locations. Some farmers may prefer planting plants for fruit which are obtained each year from a different location or nursery to ensure higher yield than from home-propagated plants. However, unless locally-grown plants are free of nematodes, growers in all areas should obtain (if possible) their stock from other localities or nurseries.

F. Recommended Schedule

General recommendations are summarized as follows:

February-March - Obtain plants from nurseries or from local field known to be free of nematodes. Use them to set permanent fields.

June 15-July 15 - Use the best of the runner plants produced by those set in February and March to set a larger area of stock plants.

October-December - Use the best of the runner plants produced by those set in June and July to set the planting for fruit.

Another alternative method is:

May	- Cultivate and weed out the bearing field or a part of it immediately after the picking season.
June 15-July 15	- Use the best of the runner plants from this cleaned area to set a new planting of stock plants.
October-December	- Use the best of the runner plants from the field set in June and July to set the planting for fruit.

G. Planting Systems

There are two systems for growing strawberries, the hill and the matted row.

1. Hill System

In this system plants are commonly set in late summer or autumn and the crop is harvested during the winter or early the following spring. Usually plants set at that time make no runners and if they do appear they should be removed. When this system is used, one may set the plants in single, double or triple rows.

The plants are usually set about 30 cm apart in rows 90 cm apart. Occasionally, the rows are 100 to 105 cm apart. In many places the double row is preferred. In double row method, the rows on each bed are about 30 cm apart and the alleys between beds are 90 cm wide. With the

spacing commonly used, wide beds on which two rows are set allow more plants to the acre than single rows do. If drainage is good, three or four rows may be set on each bed.

2. Matted-Row System

Under this system, plants are usually set in the winter or early spring. Place them 45 to 100 cm apart in rows 8 to 10 cm apart. The runners are allowed to root. The distance between plants in the row depends on the probable danger of losing plants to drought or insects. If there is little danger one may set the plants 100 cm or more apart and train the runner plants to form a solid mat in the spaces between plants. Where loss is likely, set the plants about 45 cm apart. Filling the empty spaces in the field requires experience and is expensive as a full stand is necessary for a profitable planting.

H. Plants per Acre

The following Table shows the number of strawberry plants needed to set an acre when the plants are spaced according to systems commonly used:

Number of Strawberry Plants Needed to Set an Acre

When Using Different Spacing

Spacing In Row cm	Spacing Between Rows cm	Plants per Acre
Double row		
2.5 by 3.25	90	20,100
Single row		
3.75	60	14,520
2.5	90	14,520
2.5	105	12,446
3.75	75	11,616
5.00	90	7,260
7.5	90	4,840
7.5	120	3,630

I. Care of Plants Before and After Setting

1. Before Setting

Plants should be kept cool when received from nurseries and should be kept in polyethylene bags in the shade if they are going to be planted the same day or the following day. If much time elapses before planting,

open the bundles, separate the plants and heel them in, or place the entire shipment in cold storage at 0° C.

When plants are set in the field by hand one should not drop them far ahead of the setters, especially on dry windy days. Plants should be handled with damp cloths to protect them from drying.

2. Setting the Plants

Set the plant by hand with one of several hand tools. It is very important to set the plants at the right depth and firming the soil well about the roots.

Set the plants so that crowns are even with the surface of the ground after the soil has been packed about the roots. Soil should be properly firmed, otherwise air will get to the roots and they will dry out. On the other hand the soil should not be packed too tightly so as to injure the roots. Some growers step on the soil beside each plant after it has been set to make sure the soil has been properly firmed, but be sure the foot does not injure the plants.

3. Setting with Hand Tools

Growers with small acreages may set plants by hand, using a trowel or punch to open the soil and to press the soil back around the plants. A worker makes an opening about 15 cm deep, inserts the roots and presses the soil back. Two men may work together setting plants with a spade.

One man inserts the spade, forces it forward, and opens a slot in the soil. The second man carries the plant and inserts them in the slots. After the roots are inserted, the first man withdraws the spade and presses the soil firmly about the roots with his foot. Plants can be set rapidly by this widely-used method.

4. After Setting

Flower stems usually appear on winter-set or spring-set plants soon after they are set. Until the plants become well established after transplanting, fruit production is a severe drain on their vitality, therefore, the grower should cut off the flower stems as they appear.

Early formal runner plants produce the most fruit the following year, and removal of lower stems helps to get early runners.

5. Care in Matted Rows

Generally, matted row beds should not be more than 60 cm wide. Many growers find that rows 24 to 38 cm wide are better. Probably this latter pattern suits most Paraguayan soils. Berries are easy to harvest from narrow rows. Unless the plants are well spaced, many berries are likely to be small.

Often it is necessary to thin plants in matted rows during the summer and autumn. All runners extending into the alleys are cut off while cultivating. Surplus runners may be removed also when the field is hoed.

When matted rows are 60 cm wide, growers may run a pull tongue plow equipped with a point 10 to 12 cm wide. Dow the center of each row about the first part of September in the first-year beds, or immediately after harvest in second-year beds. This practice tears up the center plants and cuts the row into two parts; then it might be called a double-matted row.

J. Strawberries as an Intercrop

This practice is used in orchards especially in the first years before trees are mature. Considering that strawberries do not bear well unless moisture conditions are good, they act as indicators of these conditions for the tree crops.

K. Tillage

As a general rule it is necessary to keep down weeds and to maintain the soil in good physical condition until time of planting. As soon as plants are set in the fruiting field, black plastic mulch is applied and no further tillage is necessary.

In areas where weeds grow fast, cultivation should begin immediately after planting. Plants should be tilled each week or 10 days until late autumn or into the winter when the mulch is applied. Hoeing may not be necessary in the spring. New leaves grow slowly from the top of the crown, which causes the crop to grow slowly out of the ground. New roots from the crown grow out at the base of the new leaves. Since dry air and wind may kill these new roots (wind in Paraguay is from the E, NE, SE and sometimes has a velocity of

30 km per hour), it is very important to hoe and cultivate moist soil toward the plants to give the new roots a chance to form.

L. Weed Control

In small holdings, weeds can be controlled by cultivation and hand weeding. In large commercial plantings, the cost of hand weeding is prohibitive. In these cases, one should consider the use of black polyethylene mulch, soil herbicides combined with mechanical cultivation.

Time of application of herbicides depends upon the nature of weeds to control, their intensity, variety of plant, soil texture and composition, the cultural practiced, and climate of the locality. However, all chemicals should be applied according to directions of superior and instructions on the container label.

M. Mulching

The purpose of mulch in strawberry fields is many fold. It keeps the berries clean, prevents decay, conserves soil moisture, protects the flowers from frost and keeps down weeds. The common, widely-used mulching materials are black plastic (1 to 1.5 millimeters thick and wide enough to cover the top), pine needles or wild hay; and any local straw will be satisfactory. Most of the commercial acreage is mulched with black plastic. The plastic mulch is applied when the plants are set or soon after they are set in the plantings for fruit.

IX. BANANA

A. Climatic Requirements and their Effect on Banana Cultivation

Bananas are in general very sensitive to climatic factors. They require average annual temperature of 20° C. and an abundant, well-distributed rainfall of about 200 cm per annum. They are adapted to many equatorial and sub-tropical regions but do not thrive at altitudes above 1,200 meters. Most varieties are liable to low temperature injury, even after a relatively brief exposure. The Cavendish variety is somewhat more cold resistant.

Exposures to cold will adversely affect the rate of growth and productivity of banana. Sometimes one can expect 17 to 30 months to elapse between the appearance of suckers and the harvesting of their bunch. It is also known that banana plantations grown at lower levels may yield up to 40% more than those grown on higher levels (400 meters and above).

An important relationship exists between the temperature and the age of the plant. During the month when the bunch is due for harvesting an average temperature of 25.5° C (78° F) augments its weight. Augmented weight occurs up to 84° F. At higher temperatures, maturation is accelerated but the fruit weight is diminished. During one or two months before harvesting, the optimal temperature is 78° F. Higher or lower temperatures are detrimental to the growth of the fruits.

It has been reported that the optimal conditions for growing banana in Central America is from sea level to an altitude of 750 meters. In Paraguay most of the land is between 200-300 meters.

In favorable regions the rainfall is about 225 cm per year (88 inches) while in Paraguay it varies between 40 and 170 cm with an average from 41-70 cm (Ministerio de Defensa Nacional--Dirección de Metereología). In the eastern part of Paraguay the rainfall is between 140 to 160 cm per year (location of the cultivated areas of CREDICOOP).

Well-distributed rainfall of this low magnitude is very necessary for high productivity. Lower and/or poorly-distributed rainfall must be supplemented by irrigation if high yields are to be obtained. In Paraguay the rainfall is low in general, particularly during the period June to September when rainfall averages below 10 cm per month. For the remainder of the year, the average is between 10 to 15 cm per month. Effective rainfall is even lower since evaporation may account for a 50 to 70% loss of monthly rainfall. Where the rainfall is low, the retention capacity of the soil is especially important and the depth of the soil profile is of prime importance.

As the soils show medium to coarse texture, their water retension capacities will be very low, especially in the upper 60 cm layers indicating that insufficient water will be a principal factor limiting banana growth in Paraguay. Irrigation will be necessary during the entire year with requirements being highest during the period June to September.

B. Morphology and Root Development

The banana is a large herbaceous perennial plant. It consists of a branched underground stem or rhizome, with abundant roots, several lateral buds, and erect leafy trunks which bear the bunches. Roots in rhizomes sprout new

roots high up or on the under side. Later the more superficial of these roots traverse the soil horizontally or penetrate downwards to a varying extent. The underside roots typically grow vertically downwards into the soil. In a well-mulched soil many of the horizontal roots, which usually grow at a depth of two to three inches, come to the surface and give rise to abundant, short, secondary and tertiary roots. These grow under and into the mulch, thus forming a mat of roots. In light to medium loams as in Paraguay, the main roots which are white, fleshy and of considerable lengths typically give rise to short, thin, lateral rootlets. Both roots and rootlets have an abundant development of root hairs.

The organs mainly responsible for the up-take of water and nutrients are in the region just behind the root tip. If the tip of the main root is damaged or is cut off during cultural operations, one or more lateral roots grow out in proximity to the injured region. If an older region of the root is cut, two or more strong growing lateral roots are formed and continue their growth in the original direction of the parent root.

While the horizontal roots are usually close to the surface, they may descend in a well-aerated soil to two feet six inches below the surface. Under favorable conditions, horizontal roots grow at the rate of two feet per month and may extend for distances up to 17 feet from the parent rhizome.

As has been noticed in the fields in Paraguay, in sufficiently moist, open loamy soils the vertical roots may descend to four feet six inches, thus affording an excellent anchoring system, especially for plants growing in a windy situation.

Banana roots are sensitive to adverse conditions such as water-logging, desication, variable soil moisture, excessive clay content and over-compactness and poor oxidation. In these conditions the main roots may remain inextensive and the lateral roots scanty. Individual plants may have a very restricted root system or one greatly reduced by diseases.

In clayey soils, banana roots may encounter considerable difficulty in forcing their way through the soil. Such inadequate root development has important effects on the rate of growth of the plant and its suckers, and on the size and rate of enlargement of the bunch.

In Paraguay, the development of banana roots will not be restricted by soil depth or compactness as soil profiles are homogeneous down to more than four feet. Most of the roots extend into the 60 to 90 cm area. However, the bulk of the roots are in the 30 to 60 cm layer. Most of the soil is homogeneous with medium to light texture, which indicates low to medium water-holding capacity. No sign has been seen so far of water-logging in the banana fields.

Soils as a media for banana cultivation, therefore, can be described as favorable with no apparent physical restriction. Soil fertility, availability of nutrients and soil productive potential are different aspects that affect banana cultivation in Paraguay and will be treated separately.

C. Planting Material

Planting material varies in different parts of the world. In fertile soils, all of the several planting materials give good results provided the

individual sucker or bit is not too small. The poorer the land, the more it requires the use of large planting material such as large bulbs or bits. In general, small suckers give rise to more slow-growing plants which flower later. They yield better bunches, but have lower total yield. The later the planting, the bigger the sucker should be so as to avoid winter injury to the bunches.

It is advantageous to plant so that bunches should be initiated in summer, shot in autumn, and mature in winter. Spring planting, therefore, is the rule - in September and October.

D. Spacing and Pruning

In fairly fertile soils, spacing and pruning are the two most important factors which determine production. Insufficient height may be due to crowded planting of the mother plants or to excessive suckering in the absence of pruning. Wider planting may limit the production in Paraguay. Nitrogen deficiency can develop as a result of wider spacing which allows grass invasion and its competition with the banana (yellowish-green lead blades and reddish pigmentation of petioles). Inadequate height results in a low rate of growth in the suckers, and a slower filling-out and premature ripening of the fruits.

It is important to obtain basic local information on the optimum number of mother plants per acre that can be maintained in a state of maximum growth. Best commercial results as measured by pounds of exportable fruit per acre per annum can probably be obtained by observing the following:

1. Planting the highest population the soil can support using the triangular system of spacing under local environmental conditions.
2. Planting the prescribed number of bulbs or bits per acre.
3. Pruning each mother plant to a single flower. Note: close spacing is expected to give better yield than wider spacing and multiple suckering by each mother plant. Uniformity and good size of finger are expected with this procedure. Increase of about 15% in triangle spacing is expected as compared with the square system.

E. Fertilizers

Fertilizer mixtures in Paraguay are made on trial and error basis. A typical mixture is 10.3 N - 3.4 P_2O_5 - 14 K_2O, to which calcium and ferrous sulfates are sometimes added.

Pot culture and field experiences emphasize the importance of N and K. Low potassium reduces vigor while phosphate is important in root development. Experiments in Central America and Jamaica showed that yield was increased with N application, especially when application was done frequently in small amounts.

Sometimes response was due only to the application of nitrogen and in others it was due to potassium application. Phosphorus will improve production if potassium is adequate; and in the absence of potassium, phosphorus has an adverse effect on production. Potassium increases the grade (number of hands in the bunch), the quality of the fingers, the rate of bunch production, and the population of plants per acre. Nitrogen can also increase the length of fingers and sometimes nitrogen must be accompanied with phosphate.

Sometimes a decline in production can be observed in areas where roots are barred from penetrating the soil as they used to, even though adequate levels of soil nutrients are present within the restricted root penetration area. This calls for a program of good soil management and conservation including the addition of fertilizers. Nitrogen has been emphasized and the banana's response to it is very evident. Potassium is needed for many depleted soils. Phosphorus fertilization is needed when at levels below 10 to 20 p.p.m. The best banana soils are neutral or slightly alkaline. High pH is favored for good banana growth, and it may also prevent certain diseases. For example, when ph is low, it favors the Panama or vascular wilt disease.

Manurial treatments have a favorable effect on the growth of banana during the early months of its life. Subsequent application of fertilizer is not as important as are rainfall and temperature. In short, the early phases of growth largely determine the nature of subsequent developments. Therefore, the nutrients required by banana should be abundantly present in the soil from the time of planting onwards, or during the early crop or the ratoon crop.

F. Nitrogen Deficiencies and Excesses

Nitrogen deficiency causes slow growth. The development of the yellowish-green color in the lamina and more or less deep reddish tinge or pigmentation in the petiole is according to the degree of the nitrogen deficiency. If the deficiency is not excessive, the leaf blades may recover to a normal green color.

The best fruits can be obtained from tall plants with rapid, sustained growth, low phosphate levels (phosphate can cause short and distorted fingers). Early nitrogen application is desirable since this will not only help to overcome nitrogen shortage due to the presence of decomposing plant materials, but also help production by attacking the banana weevil borer.

In Jamaica and Honduras, experiments have proved that nitrogen increases growth substantially. Increases cover number of bunches and total weights per hectare. Several nitrogen sources are good, according to the soil pH and its type. Na NO_3 can sometimes be superior to urea. Iron, manganese, boron and copper show a significant beneficial effect.

The rate of growth in height of the banana stem can be taken as an indicator of good fruiting performance. An increased application of nitrogen results in faster plant growth, greater height of pseudostem at shooting and an increased number of leaves and larger suckers. Weight can commonly be increased up to 12%, and in some instances up to 20%. There is also an expected reduction in the time of maturity. However, it is better to apply phosphorus when potassium is inadequate.

The nutrients required by the banana are mainly taken from the top 30 cm of soil since this layer is enriched and improved in texture by the incorporation of the organic matter. Roots may penetrate more deeply, thus extending the productive life of the area. Leaching of nutrients in deep soils reduces banana growth by lowering organic matter in the soil.

The disappearance of the viable top layer of soil which had acquired a good texture and had been enriched by the incorporation of O and M is important, especially in compact layers where roots can only penetrate very superficially. Hence, root depth is very important in banana cultivation.

Nitrogen deficiency is most noted in soils which are depleted of organic matter or poorly drained. Application of sulfate, ammonia, nitrates, urea, etc., causes improvements in production. Even leached or depleted soils respond to nitrogen application. Excessive nitrogen causes "leaf-break", which occurs at the junction between the leaf stack and the pseudostem.

G. Potassium

Potassium deficiency is shown by premature leaf yellowing, which can sometimes be preceded by marked reduction in growth. Older leaves become yellow at the tips and distal margines. The discoloration spreads rapidly downwards until the whole leaf is withered.

A characteristic feature of potassium deficiency is the failure of affected leaves to collapse at the petiole, but typically stand out from the pseudostem in their normal positions. Usually, these affected leaves are one or two only and are located in the center of the crown, being separated from the lower affected leaves by a few healthy ones. In severe cases a brownish water-soaked tissue develops in the center of the crown. All of this can be noticed at the time of bunch shooting, which makes the affected plants bear very few leaves for the effective filling out of the fruit.

Soil potash is related directly to this condition as is high pH caused by excessive limeing. Drought can bring this about or competition of coco trees previously planted. Massive application of potassium is the remedy and this may be done by applying banana leaf ash and potassic fertilizer.

When potassium is deficient, leaf emergence is progressively slower and the successive leaves are smaller. In pot culture experiments, it has been shown that the youngest leaves remain green while the older leaves lose their color from the margin inwards and a marginal necrosis may develop. Chlorosis may develop very rapidly. The whole leaf may become yellow in a day or two, thereafter driving out and the petiole breaks.

In well-controlled pot experiments a pronounced marginal yellowing or chlorosis appeared in the older leaves, which spreads toward the midrib in a somewhat irregular pattern. The chlorotic areas gradually become necrotic, giving the leaf the appearance of marginal scarring. This irregular pattern of yellowing distinguishes the K deficiency from that of Ca in which the marginal yellowing is regular and remains well defined and localized along the margin. At more advanced levels of K deficiency, the necrotic leaf blades collapse and the midrib becomes burned such that the leaf tip is pointing downwards towards the base of the pseudostem. The highest relationship of K-deficient and control plants was reported to be 2.8:6.6.

Excess of K can cause premature ripening of immature fruits (yellow pulp). This is caused by high K to N ratio from the outset of the vegetative development onwards. A high ratio of K to calcium and magnesium also leads to disturbed metabolism during bunch development. In practice each soil should be treated as a separate unit as there is no rule of thumb for that.

The Ca and Mg ions seem to have direct nutritional value. Also they tend to read just the physiological disequilibrium caused by excess K.

H. Phosphorus Deficiency

This is common in soils known as phosphorus deficient. The banana can develop a bad leaf color and stop growing. Further leaf symptoms include severe marginal scorching, shrinking of the older leaves, and poor leaf development. Rotting will take place at the base of the crown or rhizome. Some of the plants subsequently die.

Symptoms of mild P deficiency can be easily detected. In pot culture experiments, P-deficient plants can be severely stunted and develop a somewhat dingy, dull or dark-green leaf color and subsequently a brown blatching and scorching.

In full nutrition experiments, it has been demonstrated that banana rhizomes can take up sufficient P in seven weeks to carry the plant through its whole cycle. The chlorosis spreads from the distal edge and extends backward over 2/3 of the length of the leaf blade. Islands of green, health tissue may sometimes remain.

The rapid spread of necrosis towards the midrib distinguishes P deficiency from the basic nutrient deficiencies. Necrosis may take place very rapidly with drying out of the leaf tissues and breaking of the petiole at the pseudostem.

I. Magnesium

Mg deficiency as induced in sand culture pot experiments causes leaves to develop a conspicuous interveinal yellow color or chlorosis. They may develop a marginal waviness and a narrowing of the lamina in the more recently emerged leaves. Although the blade is yellow, the midrib remains green. Plants show small rate of growth and ultimate small size. The yellow leaves then turn dark brown and hang down prematurely. Mg-deficient plants develop leaf symptoms resembling the yellow-brown rotting of the rhizome cortex similar to that of bacterial rot.

J. Remedy

Application of 500 to 1,000 kgs per hectare usually results in the return of the off-colored leaves to their normal dark green color and the renerval of vigorous growth.

Magnesium acts both directly and indirectly in the growth and productivity of banana. It is regarded as an indispensable and major nutrient. Apart from its physiological action in photosynthesis, it shares with calcium a particular importance in its effect on the action of potassium. Magnesium exerts an antagonistic relationship with K. The more potassium is absorbed by banana plant, the less magnesium penetrates into the tissue and vice versa.

The importance of this relationship in banana growth leads to the equilibrium between magnesium and potassium. The application of magnesium enhances growth and productivity and causes the blue disease to disappear. Magnesium sulfate is used in this connection.

It has been reported that failure to incorporate magnesium in the soil in sufficient quantities may lead to serious losses in production. The recommendation is to incorporate N, P, K, Mg. This applies especially to poor soils and soils which are naturally deficient in magnesium as the project soils (being derived from acidic parent material) or soils derived from mother rocks poor in basic elements, or soils which have been impoverished in magnesium and have lost their equilibrium.

In some cases, replenishing the magnesium content of the soil is indispensable. It is also needed to safeguard future fertility of the soil. Magnesium also affects the assimilation of phosphorus. Researchers have pointed out that magnesium phosphate is much more mobile in the plant than calcium phosphate.

K. Calcium

There is a close quantitative relationship between the soils calcium content and productivity. This is described as one of the most precise correlations in banana nutrition.

Calcium increases pH value in acid soils. When soil pH is increased from 4.5 to 5.8 or higher, productivity will be increased. The banana plant can accommodate itself to quite acidic soils, but best production can be obtained at a pH above 5.8. Higher pH value (over 6.5) due to excessive calcium and magnesium can be very harmful.

Calcium deficiency causes diffused and well-defined yellow bands along the leaf margins, which turn to a medium brown color as the leaf ages. The symptoms of Ca deficiency are very close to those of K deficiencies. The deficiency symptoms can become apparent on the fourth or fifth oldest leaves such as loss of color in a narrow band along the margins. The inner edge of this band becomes static and then turns to necrosis. The necrotic band remains marginal until the leaf begins to become yellow and senescent. The roots in Ca-deficient plants are short, stubby, very branched and very susceptible to attack by fungi and nematodes.

Like magnesium, calcium is especially important in the later stages in the life of the plant. There is a tendency that calcium may replace magnesium in the equilibrium between the basic elements. Treatment with lime or lime and magnesium affects very substantially the yield by increasing the productivity.

L. Iron Deficiency

Iron deficiency is usually associated with alkaline soils and the symptoms become most evident during periods of drought. They include an interveinal chlorosis of the young leaves, which becomes a general chlorosis if the deficiency is severe. In soil conditions similar to those in Hawaii, iron in banana leaves is only three to four p.p.m. as compared to eight to nine p.p.m. in healthy leaves.

Repeated spray with aqueous ferrus sulfate will remedy iron deficiency. Soil applications of iron compounds are also effective.

M. Zinc

Zn deficiency can be observed in small, Cavendish banana, especially on land that has produced Zn deficiency symptons in citrus. The symptoms include a "bunchy top" development of the crown, and the formation of narrow pointed and chlorotic young leaves. Severe chlorosis is expected to be followed by necrotic spotting. Wilder effect may look like those of nitrogen. When affected plants are treated with various combinations of boron, copper, manganese and zinc, they may only respond to zinc. Soil and leaf spray applications of zinc sulfate are effective under field conditions toxic effect. Sodium chloride above .05% cannot be tolerated by banana, especially in alkaline soils.

Arsenic effect: poor fruit development and chlorotic stripping of the leaves. If arsenic in the parent rocks is over 500 p.p.m., it is dangerous to plants. In the leaves of an affected plant arsine was between 0.25 to 2.00 p.p.m., but no arsenic may yet be found in the fruits.

In arsenic soils tomato plants can accumulate up to 70 p.p.m. in the leaves. Banana is susceptible to the toxic action of arsine and so far no remedial measures have been indicated.

Banana leaf fall occurs to plants grown in depleted areas suffering from general nutrient deficiency. Symptoms are more apparent in the old plants than in the younger ones. It is characterized by premature withering and dying of the leaves in acropetal succession. This is followed by the normal death of the older leaves during the winter season and by spider injury.

Leaf fall is considered to be a physiological disease resulting from the cultivation of banana on worn-out land.

Remedial measures: When plants are adequately manured with a mixture of super-phosphates, muriate of potash, and sulfate of ammonia, leaf fall virtually disappears; whereas in comparable unmanured plants, it is much in evidence.

X. TOMATOES

A. Climatic Conditions

Tomatoes grow under a wide variety of conditions with a minimum of effort, but they do not thrive in very cool weather. They are suited to Spring, Summer and Autumn culture. Usually each tomato plant is expected to grow eight to ten pounds of fruits. In order to spread the tomato harvest over the growing season, simply spread planting dates at two- to three-week intervals.

B. Soil

Tomatoes grow best in fertile, well-drained soils, but they grow almost in any kind of soil. Deep soils like those in Paraguay are expected to help develop a very broad root system in the tomato plant. This is of course if soil is fertile or supported by fertilizers. Tomato roots can penetrate down to six feet. It is important to choose sites that receive direct sun rays all day.

C. Soil Preparation

A cover crop should be grown in the field one year preceding tomato plantings in order to add organic matter to the soil. This is especially important for the sandy soils of Paraguay as nearly all are poor in organic matter. Plow under the cover crop into the soil in early spring before planting.

Tilling the soil will help create a good moisture in the soil layer. To test for moisture in the field, squeeze a handful of soil. If it sticks together in a ball and does not readily crumble under pressure, it is too wet for working. Sometimes the soil is dry enough on the surface, but is too wet in the lower layers for working. Moisture level at which soil can be tested in the field can also be tested by inserting a shovel into the soil. If the soil sticks to the shovel, it is usually too wet to work.

D. Fertilizers

Elements applied during soil preparation will help tomato plants grow rapidly and produce well. The kind and amount one needs depends upon the locality and the natural fertility of the soil.

Since soils in Paraguay are poor in almost all nutrients, the trend should be to use complete fertilizers whenever possible. Generally, a 1:2:1 grade fertilizer is recommended. Use of fertilizer that contains small amounts of micro-nutrients is also recommended. Iron, zinc, manganese, and other minor soil elements are necessary and at present are found in extremely low quantities in the soil.

Fertilizers should be applied either a few days before planting or when the tomatoes are planted. Sometimes the soil will require plowing after fertilizer application.

The optimum soil pH for tomato is between 6 and 6.5. Build up soils to descent level of nutrients as soils are very deficient in general. At

planting time, use 40 to 60 lbs. N/acre; 80 to 150 lbs. P_2O_5/acre; and 80 to 150 lbs. K/acre. Apply as side dressing 20-30 lbs. N/acre in 2 applications of about three weeks apart. The first application should be made when the first cluster forms.

E. Limeing

Use lime when the soil test indicates that it is required. Do not apply lime in larger quantities than the test indicates. Lime is needed as hydrated and air-slacked lime. However, the unburned, finely ground dolomitic limestone is best. Fifty-six pounds of burned lime or 74 pounds of hydrated lime is equivalent to 100 pounds of ground limestone.

Tomato plants also need the calcium provided by lime to help prevent blossom and rot. When using lime, spread it after plowing and mix it thoroughly into the topsoil. It is recommended to apply lime in the Spring season because some of it may be washed out of the soil during the Winter season.

F. Seeding

Work the soil in the field to somewhat granular condition. Sow the seeds in rows 200 to 150 cm apart. Keep the soil moist until the seed germinates. When the seedlings have three leaves, thin them out so they are spaced about 45 to 90 cm apart.

1. Indoor Seeding

Before transplanting to the fields and while preparing the soil, sow the tomato seeds five to seven weeks before the plants are to be transplanted into the field.

The seeds can be planted in pots then transplanted to growing containers. Excessive handling of plants should be avoided since this will retard root development.

To start seeds in pots, use a mixture of sandy soil, peat moss (shredded), vermiculite, or one part compost, one part sand, one part topsoil. The soil must be kept moist and the temperature at 70 to 80° F. at night. The young plants should be exposed to as much sunlight as possible.

2. Transplanting to Field

Plant tomato seedlings into fields when the soil has warmed and there is little threat of frost. Protect plants against frost with plastic covers. Set tomato plants into the field about the same depth as they were in pots or containers.

After replanting, press the soil firmly around the plant so that a slight depression is formed to hold water. Then pour approximately one pint water to which fertilizer has been added around each plant to wash the soil down around the roots. Use one tablespoon of granular (1:2:1) 15-30-15 fertilizer per 1-1/2 gallon of water.

G. Watering

Tomato plants need about 10 cm depth of water per month, and if rainfall is deficient as in Paraguay, this should be supplemented by irrigation. Probably one watering every two or three weeks will be needed.

H. Staking

Staking makes it easier to cultivate and harvest tomatoes and helps prevent fruit rot. Insert the stakes soon after transplanting to prevent root damage. Use wood stakes which are 240 cm long and 3-1/2 cm wide. Push the stakes into the soil about 60 cm. Tie soft twine or strips of rag tightly around the stake 5 to 7.5 cm above a leaf stem, then loop the twine loosely around the main stem not far below the base of the leaf stem and tie with a square knot. Or use plant ties, made of tape reinforced with wire, to fasten plants to stakes. Wire fencing about 6 ft high may also be used to support a tomato plant. Form a circle around the plant with the fence.

I. Pruning

Prune tomatoes once a week. Remove the small shoots that appear at the point where the leaf stem joins the main stem. Do not disturb the fruit buds which appear just above or below the points where the leaves are attached to the leaf stem.

It is best to prune by hand. Grasp the shoot with your thumb and forefinger. Bend the shoot sharply to one side until it snaps; then pull it off in the

opposite direction. Reversing the direction is necessary to prevent injury to the leaf axil or to the main stem.

J. Controlling Weeds

Weeds compete with tomato plants for water, nutrients and sunlight. They also harbor insects and diseases and may be hosts for nematodes.

K. Cultivation

The area around tomatoes should be kept free of weeds. Weeds can be removed by hand or with a hoe or cultivator. Loosen the soil around the root with a hoe or cultivator so water can soak into the soil around the plant and reach the roots.

L. Mulching

Mulches help keep weeds down. They also reduce water loss from the soil and stabilize soil temperature. This is a very important practice needed to be done in all the fields of Paraguay. Straw or leaves or polyethylene sheets may be used as mulch. When using plastic mulch, be sure to treat the soil with a broadcast fertilizer before applying the mulch. If you use organic mulch, it should be at least 5 cm deep on the soil to provide insolation, to hold water and to control weeds.

Herbicides applied to the soil immediately after transplanting effectively controls weeds without injuring the plants.

Annex I

List of Existing and Needed Equipment in the Laboratory of the National Agrarian Institute (IAN) at CAACUPE

Available Equipment

1. Atomic absorption spectrophotometer v. 220/50 c. tropicalized
2. One conductmeter with respective cell
3. One Micro Kjeldahl
4. One Micro Distiller
5. One soil hydrometer (only one)
   (Cat. #14331 513. Fisher -soil hydrometer, Description 1000 - 1,600)
6. One mechanical shaker with 1 vase (scouks)
7. Two digestion sheets
8. Water distiller (10 lt capacity in 1/2 hrs)
9. One deionizer (water)
10. One dryer by forced air (ovens)
    model 176, 12 ov & 240 volt. Fisher, AT. No. 13 - 244 - 176 - 186)
11. One precision scale (Metler)
12. Two torsion scales
13. One flame photometer unit
14. One soil mill
15. Two plant mills
16. Two dispenser alicuotes
17. Four dispenser alicuotes (liluting)
18. Two simple dilutors
19. Two multiple dilutors
20. Two automatic dishwashers
21. One titration shaker
22. Eight carts with glass holders, glasses and ten glass trays each

Glasses in abundance

1. Berlin glasses: 250 - 400 - 600 - 1000 - 2000 ml.
2. Volumetric pipettes: 1 - 2 - 3 - 4 - 5 - 10 - 15 - 20 & 50 c.c.
3. Graduated pipettes: 5/XI/10 ml. 1/10 x 10 x 100 ml.
4. Graduated test tubes: 10 - 25 - 50 - 100 - 500 & 1000 ml.
5. Matraz gauger: 100 - 250 - 500 - 1000 & 2000 ml.
6. Elemeyer: 50 - 500 - 1000 - 2000 ml.
7. Glass flasks of: 50 ml.
8. Three mortars (pounding)
9. Thermometer 20°C ti k50°C and 10°C to 260°C
10. bottles of 2 - 4 - 8 - 16 - 32 oz and 1 gallon

List of required apparatus

1. One atomic absorption spectrophotometer
   Coleman 295. Perkin - Elmer. Fuse with ensamble 1 AMP (fuse 1 AMP with housing assembly)
2. Voltage Regulator for 2500 watts - 220 volts 50/60 Hz - two units.
3. One pH Meter Accumet - Fisher Model 230
   One pH Portable meter. to be used in the field right away.
4. Four sets of electrodes for pH meter
   (4) combination electrodes
   standard glass body
   No. 13 - 639 - 90
   13 - 639 - 91
   Page 895 Fisher Scientific 81 Catalog Complete Chemical Catalog - starts p. 1329.
5. Conductmeter with respective cell - one portable unit for use in the field right away.
6. Two units of Micro Kjeldahl
7. Three units of Mechanical shaker with one vase. (Skourks). Hamilton Beach - NSF Testing Laboratory 512 - Ann Arbor, Mich.

8. Soil hydrometer
   9 - 12 units needed
   Cat. # 14331 5B, Fisher, Soil Hydrometer #e, Descrip. 1,000 to 1,060.
9. Coleman flame Photometer, Model 51 Ca. For determinations Na - K, L plus Ce (Identical to Model 51 except for addition of Ca Filter and including Ca scale 14376-75).
10. Two medium size ovens, one for drying soil samp'es and the other is for soil samples and drying plant samples as well.
    Fisher model 176, 120 V and 240 volt.
    Cat. # 13 - 244 - 176 and 186.
11. One flame photometer unit.
12. (2) Units Stirrer with magnetic stirring
    Cat. Fisher No. 14 . 511 - 100
    Cat. Fisher No. 14 . 511 59

List of Missing Quemicals and Reactives

1. Galatine (USP Baker) 1 lb.
2. Na Dicromate - 3 lbs.
3. Lanthanum oxideL_2 O_3 - 10 lbs.
4. PVP (Pirolidone Polivinil) - 1 lb
5. Phenolphthalein (6 bottles, 8 oz. each)
6. Sulphuric acid
7. Potassium chloride - 25 lbs, Fisher P 215
8. Sodium Bicarbonate - 25 lbs. S 233
9. Natrium oxalat 5 lbs.

Note for Lanthanum oxide: it is from N.Y., 198 Broadway, New York 10038. From 1 - 6, these are the most difficult reactives to find.

List of Missing glasses

1. Berlin glasses 250 ml (6 doz) beakers
2. Berlin glasses 400 ml (3 doz) beakers
3. Berlin glasses 1000 ml (9 units) beakers

Annex I - Table 2

List of Available and Needed Equipment at the Laboratory of the National University of Asunción at San Loreto

Available Equipment

Potentiometer (2)

Conductimeter (1)

Spectrophotometer (2) for colorimetry

Stove (2)

Mechanical shaker for texture (2)

Kieldal Distiller (1)

Water distiller (1) burnt

Precision scale (1)

Common scale (2)

Flame spectrophotometer (1) burnt

We have glass equipment in abundance since 15 to 18 years ago.

Needed Reactives

Sulphuric acid (30 ltr)

K Chloride (30 kg)

Sodium cosotinitrate (3 kg)

Hydrochloric acid (35 ltrs)

Isopropelic alcohol (20 ltrs)

Formaldehyde (10 ltrs)

Indicators (black , Bromotimolozil)

Ferrous sulfate (15 kg)

Ascorbic acid (10 kg)

Annex I - Table 3

Physical-Chemical Characteristics of Typical Soils of the South of Paraguay

Soil	Horiz.	Depth cm.	Texture	pH	M.O %	P	AL	K	Ca	Mg
						p.p.m.				
Plenosol	A_1	0-11	F.Sandy	4.9	0.9	6	1.6	0.1	5,1	.3
	A_2	11-19	"	4.7	0.7	6	2.4	0.2	3.5	.2
	B_2	19-119	"	5.0	1.0	5	4.0	0.1	10.6	.2
Gley Poco Humico	A_1	0-13	F.sandy-clay	5.0	2.4	15	0.2	0.2	9.2	2.6
	B_1	13.30	"	5.3	1.5	7	0.2	0.1	13.2	4.3
	B_2	30-45+	"	5.3	0.6	5	0.2	0.2	5.3	2.0

Reference: Revista Technica
Instituto de Tecnología y Normalización
Año XIV, abril - junio
Asunción, Paraguay No.4

Annex I - Table 4

Micronutrient content in Typical Hydromorphic Paraguayan Soils

Site: Streams and swampy lands

Table SF-4

Element	Soil	Horizon	Depth cm.	Period of Submersion in days 0	30	90
F	Planosol	A_1	0-11	440	950	1250
		A_2	11-19	545	705	990
		B_2	19-119+	220	400	725
Mn				57.5	69.0	61.0
				19.0	20.0	17.0
				4.0	6.0	7.0
Cu				3.0	3.7	9.0
				2.5	3.0	6.5
				3.8	2.4	5.8
Zn				2.5	1.6	2.1
				1.8	2.1	4.4
				2.0	1.0	1.7

Annex I - Table 5

Micronutrient Content in Typical Hydromorphic Soils of Paraguay

Element	Soil	Horizon	Depth cm	Period of submersion 0.0	30	90
F	Gley poco humico	A_1	0-13	265	386	275
		B_1	13-30	55	3.5	14
		B_2	30-45	85	13.0	40
Mn				51	78	80
				111	165	158.5
				20	21.5	22.5
Cu				2.2	6.5	4.5
				3.4	9.0	5.5
				2.5	4.4	3.8
Zn				3.1	3.8	3.5
				4.1	5.0	5.0
				2.7	1.3	2.2

Annex I - Table 6

Fertility Migration under Tomato Plant at Quiindy

Paraguay

Farmer: Mr. Porferomensa

	30 cm. away from the tomato plant				Fertilized spot under tomato plant	
		Depth - cm.			cm	cm
		0-30	30-60	60-75	0-30	30-60
	pH	5.9	5.9	5.9	6.1	6.0
	O.M.%	2.9	1.2	1.1	2.0	1.9
	Ca	4.3	3.1	4.4	5.2	4.4
P.p.m.	Mg meq/100 ml.	.76	.62	.78	.78	.77
	K	.23	.02	.06	.17	.09
P.p.m.	P	3	3		93	5

Location and First Foot Soil Analysis in Banana
Fields - Loreto, Concepción
Paraguay

iscription	Location #1	Location #2	Location #3	Location #4	Location # 5	Location #6	Location #7
pH	6.4	6.1	6.0	6.3	6.	7.4	6.4
M.%	.3	.5	.5	.4	.4		0
Ass. ppm	1.0	1.0	1.0	18	4.		27
Ass ppm	90	28	58	124	94		32
Ass ppm	1020	880	1180	800	720		520
.Ca + Mg meq./100gm	0	0	0	0	00	2040	0
xture	S.L.	S.L.	S.L.	S.L.	S.L.	S.L.	S.L.
te analized	5/29/80	5/23/80				5/11/81	5/23/81

Note: 6 is analyzed by CAL (Industrial Nacional de Cemento- Laboratorio de Suelos Agrícolas).

il mples	1-1	3-1		5-1	2-1+B	4-1
	1-2	3-2		5-2	2-2	4-2
	1-3	3-3		5-3	2-3	4-3
	1-4	3-4		5-4		4-4
ter mple pth		W_2/8m.	W_3/8m Office at Loreto	W 5/4	W_1/71m	W_4/4m

Description of Location #1

Location # 1
Profile # 1

Homogeneous Sandy loam with clay fractions increases with depth.
Fine roots down to 120 cm. Not very much O.M. matter. Moisture 25 - 30 cm. per one meter depth

Soil Fertility Levels - very low in nitrogen and organic matter. Fair in Potassium and relatively sufficient in Calcium and Magnessium, pH is in the normal range.
Good range of stored moisture expected good drainag and no water logging.

Recommendations:

1. Good farm management - 30 cm or more - plowing
   - Fallaw in Summer and level surgace
   - plow under organic matter
   - add farm manure.

   Fertilizer - Nitrogen of no calcium base
   - Phosphorus can be as high as nitrogen
   - Micronutrient not needed at present

Location # 3

Farmers Name: Julián Jimenez

Green Cover

Soil Physical Structure

Deep homogeneous profile

Roots thicker

Medium to fine textured soil has water holding capacity up to 30 %.

Inherent Fertility Levels

Nutrients in the medium levels

pH is below normal

Due to high perventage of o.m.

Almost all of the micronutrients seem to be in sufficient supply.

Recommendations

This field can have a potential of hving water holding capacity up to 35% if o.m. is ploughed under - and it will yield above normal crop.

Level land - plow under green manure. Supplement commercial fertilizer 1.2.1, 1.1.1 , 1.2.2., 2.2.2. ratios. Crop will respond. Then select your best suited ratio.

Location # 5

Owner: Arnaldo Ortiz

Moist homogeneous Deep with mottled clay particles.

Soil Characteristics

Homogeneous medium textured profile
Water holding capacity up to 30 cm/meter depth

Fertility Level

Medium with prospect to high. High in Potassium on to phosphorous. Calcium is about 70 ppm. pH is 6 and there is room for it to increase.

Recommendations

Levelling - o.m. and green manure to be ploughed under.

Commercial fertilizer can be 1:1:1 or 1:2:1 or 2:2:1 for best results.

No micronutrients are needed so far.

Location # 6

Farmer's name: Ninio Vinettes

Salty weeds

Loose surface

Very poor Banana field

Very salty soils in salt marshes

lowest topographic area (depression)

Texture Sandy loam with loose surface particle due to high salt content.

pH is high, above normal. Add calcium sulphate (gypsum) 1/2 = 3/4 Ton/Ac. Plow under to 30 cm deep on a very levelled soil surface. Then irrigate. Repeat if necessary.

Add fertilizer from nitrogeneous base.

Add phosphate as much as N in split - 2 or 3 applications. - localized.

Add potassium 1/2 to as much as nitrogen.

Irrigate grown grass and plow under.

Location # 7 Banana grown Nanicoa

Soil structure

Medium texture with tendency to be coarser at the lower layers. Fine clay close to the depth of the upper 30 cm. Organic matter is very little.

Fertility Levels

pH is best for climate 6 - 7 and for uptake of nutrients. Ratio of phosphorous to potassium is about 1:1 with calcium is below 600 ppm.

Moisture Level

Relatively high in the first foot, thus gives early and balanced good start.

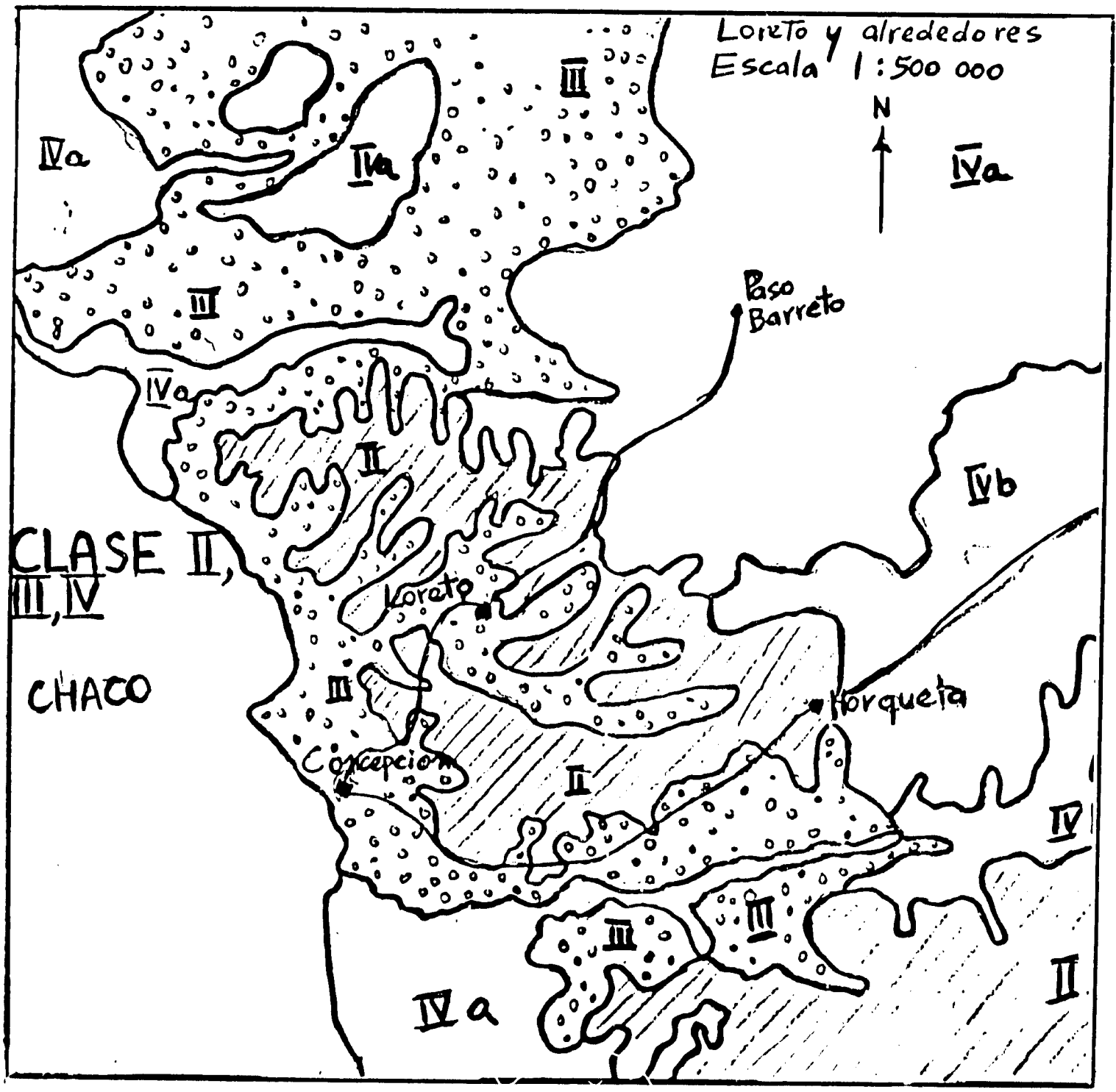
Recommendations

Plow down to 30 cm. Apply farm or green manure.
Level soil surface.
Fallow.
Supplement with commercial fertilizer 1:1:1 and 2:1:1; give large dosis. There is a great chance of response.

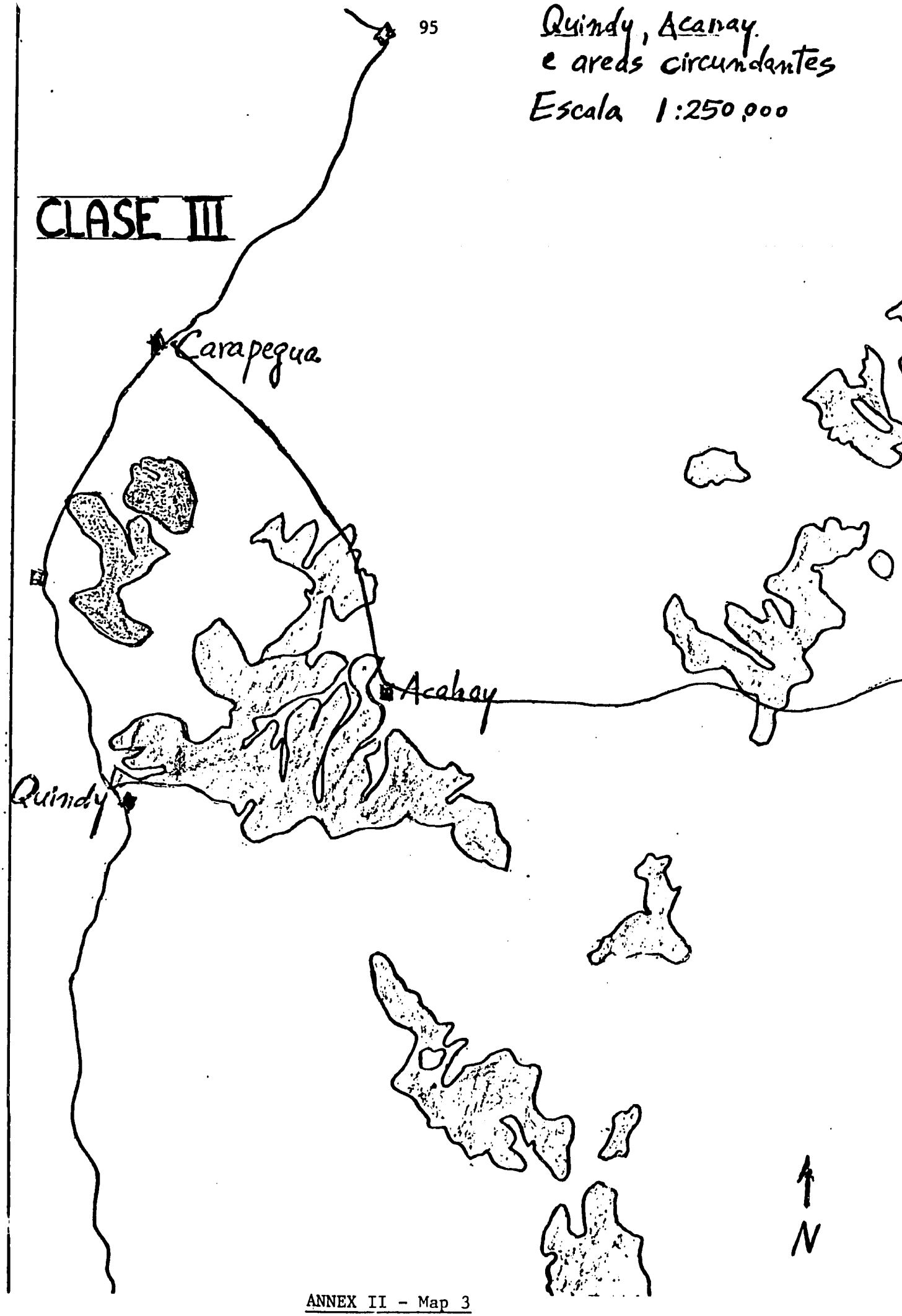
No micronutrient is needed.
Mosture and nutrient uptake will improve with o.m.

Soil Class Groups According to Use Potential

ANNEX II - Map 1



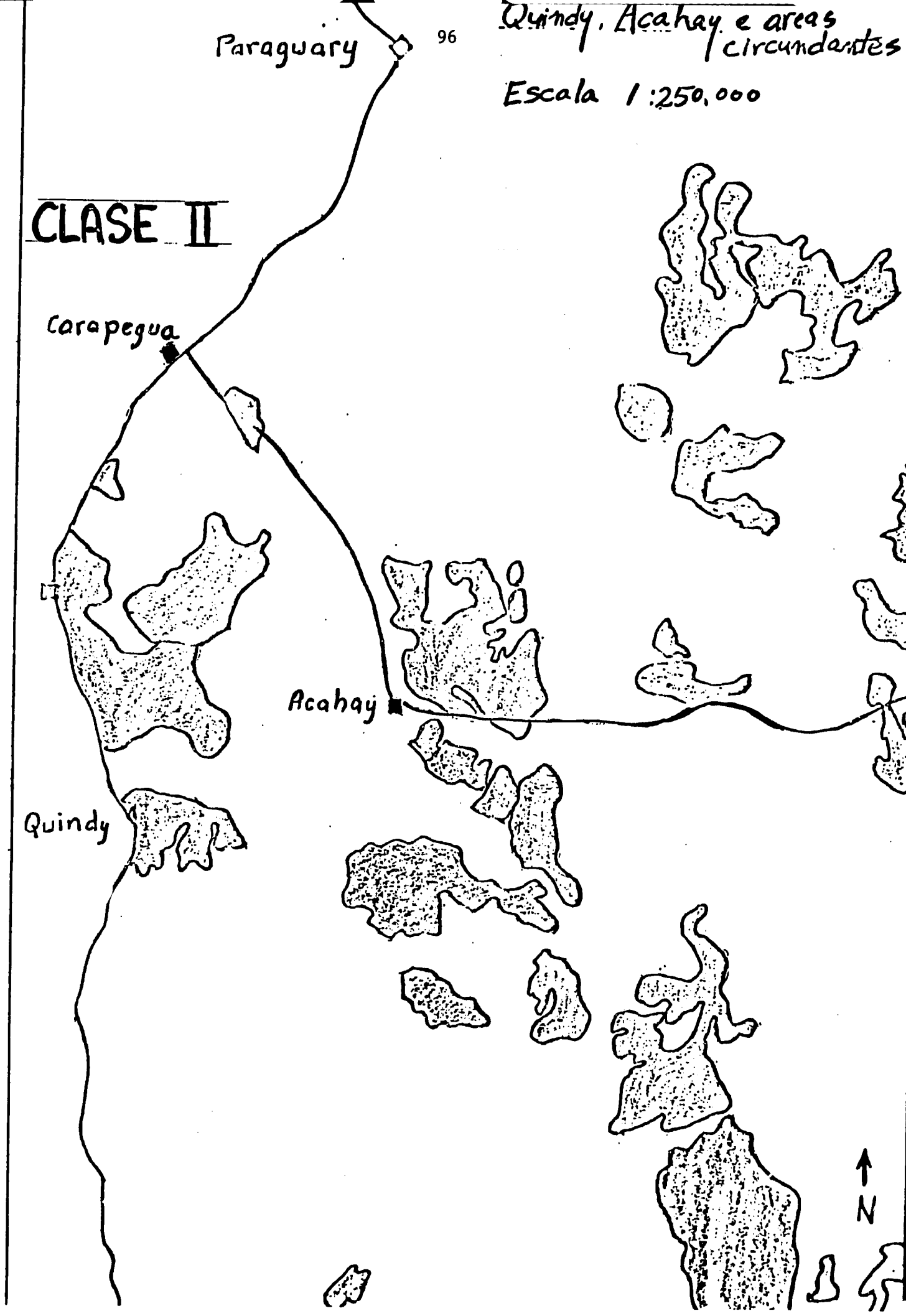
ANNEX II - Map 2

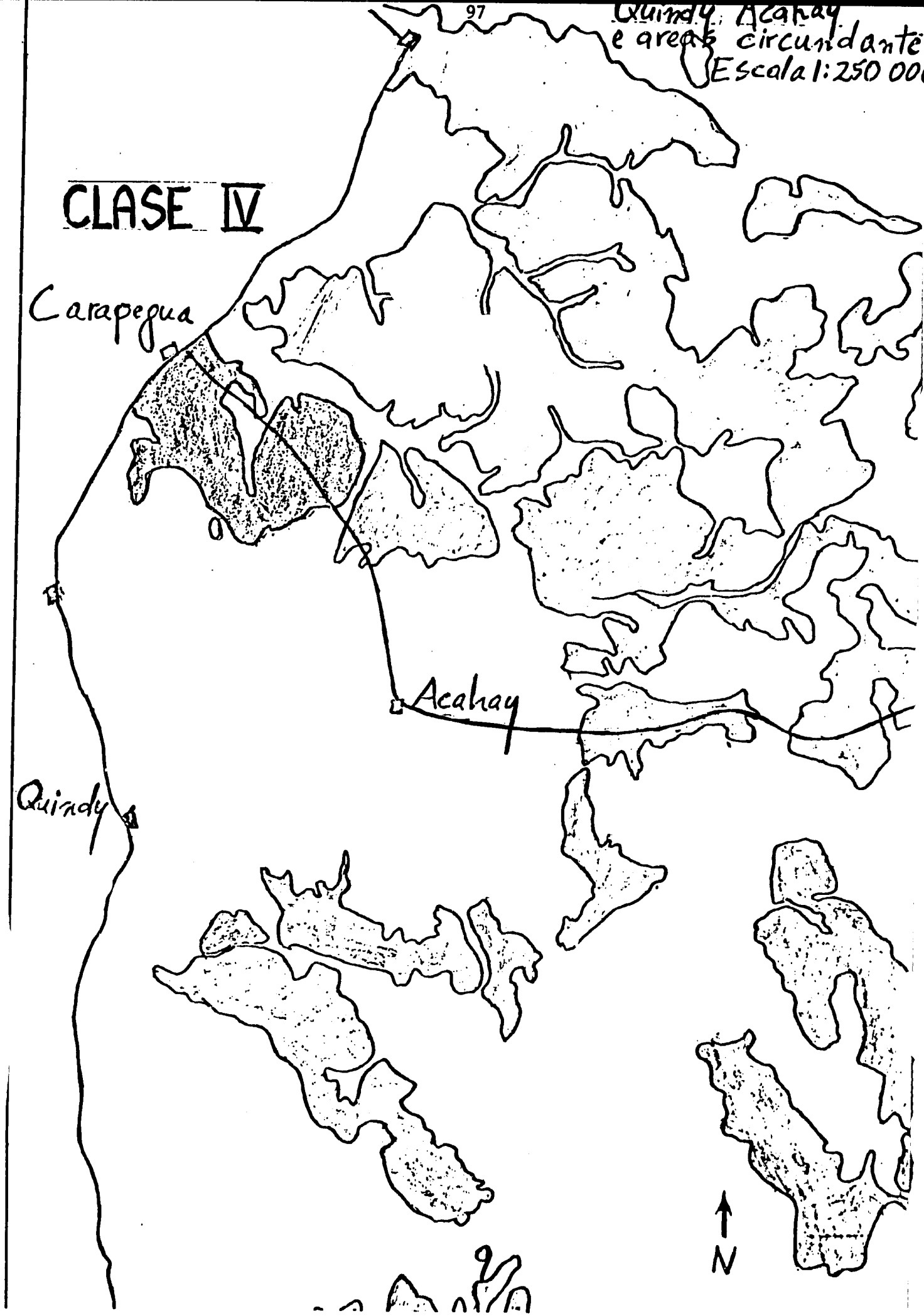


ANNEX II - Map 3

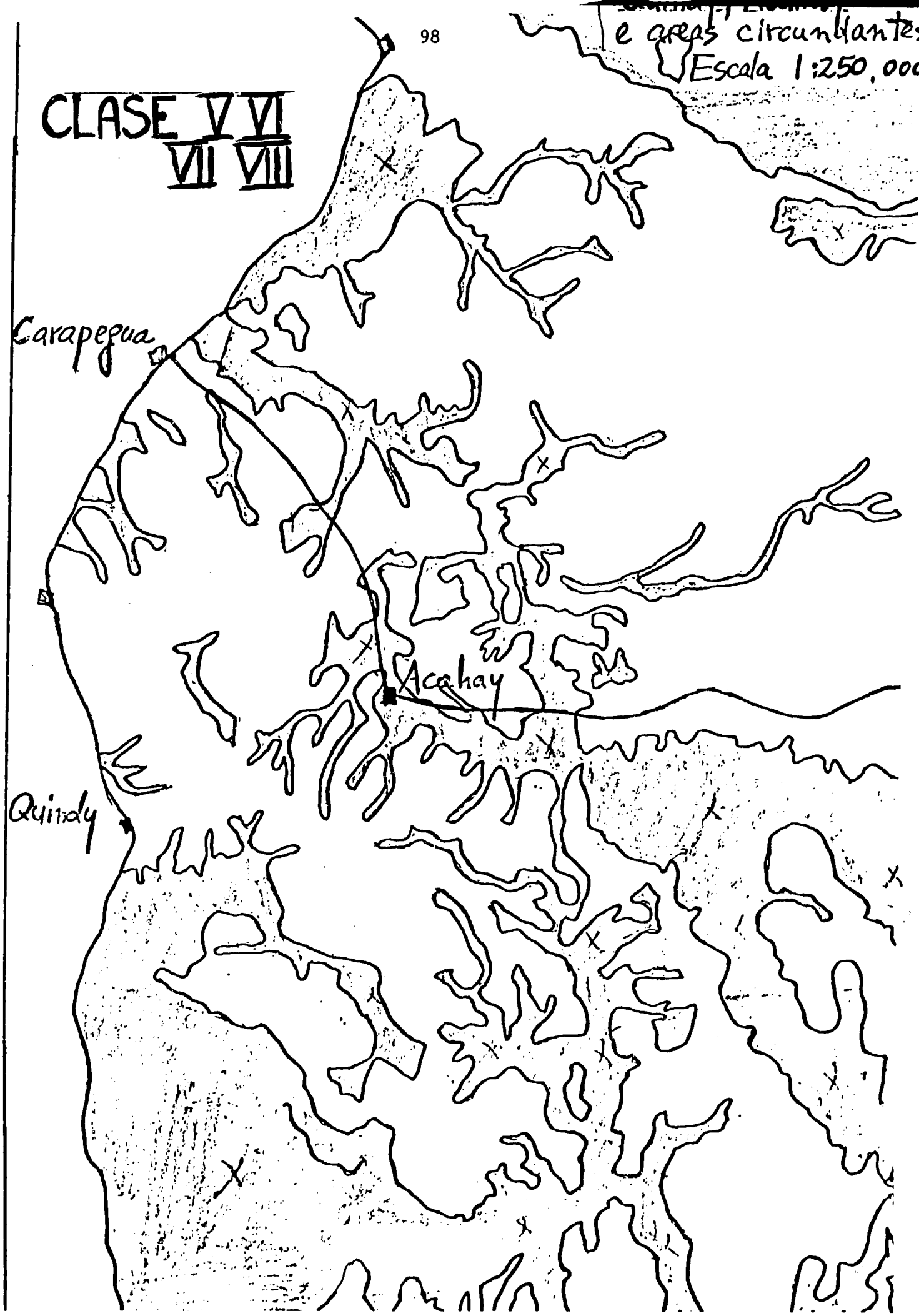
Quindy, Acahay e areas circundantes

Escala 1:250,000

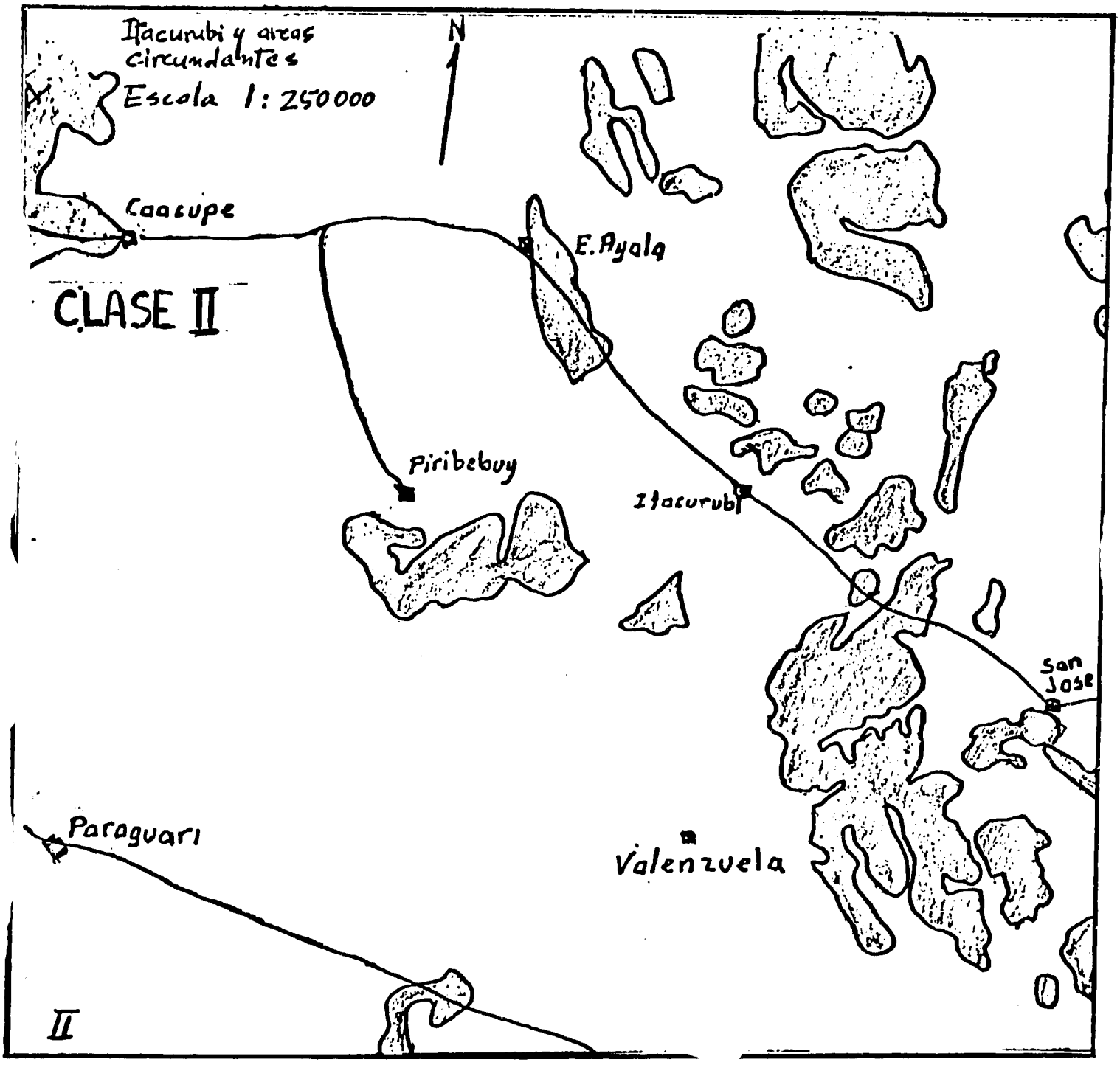




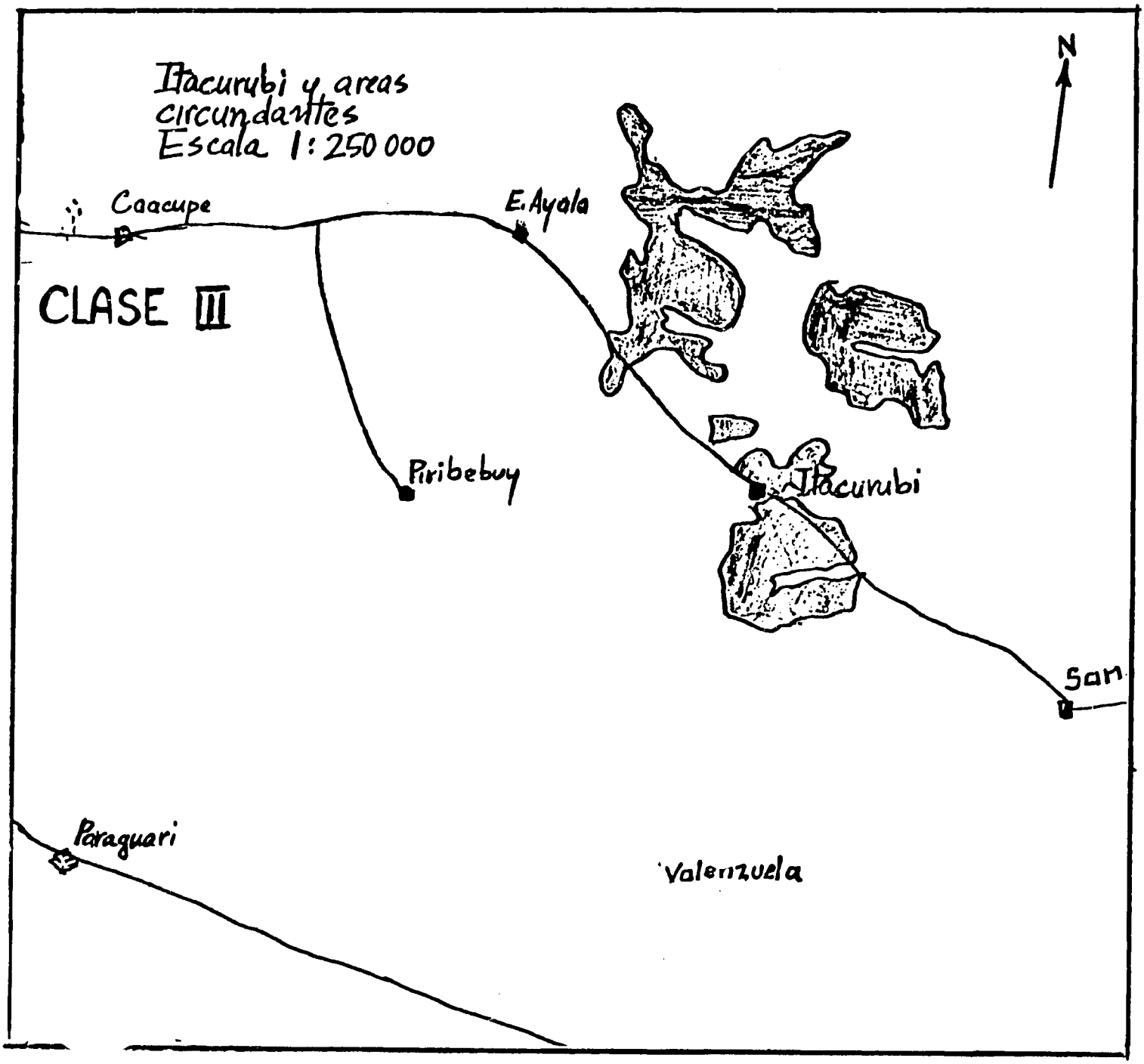
ANNEX II - Map 5



ANNEX II - Map 6



ANNEX II - Map 7



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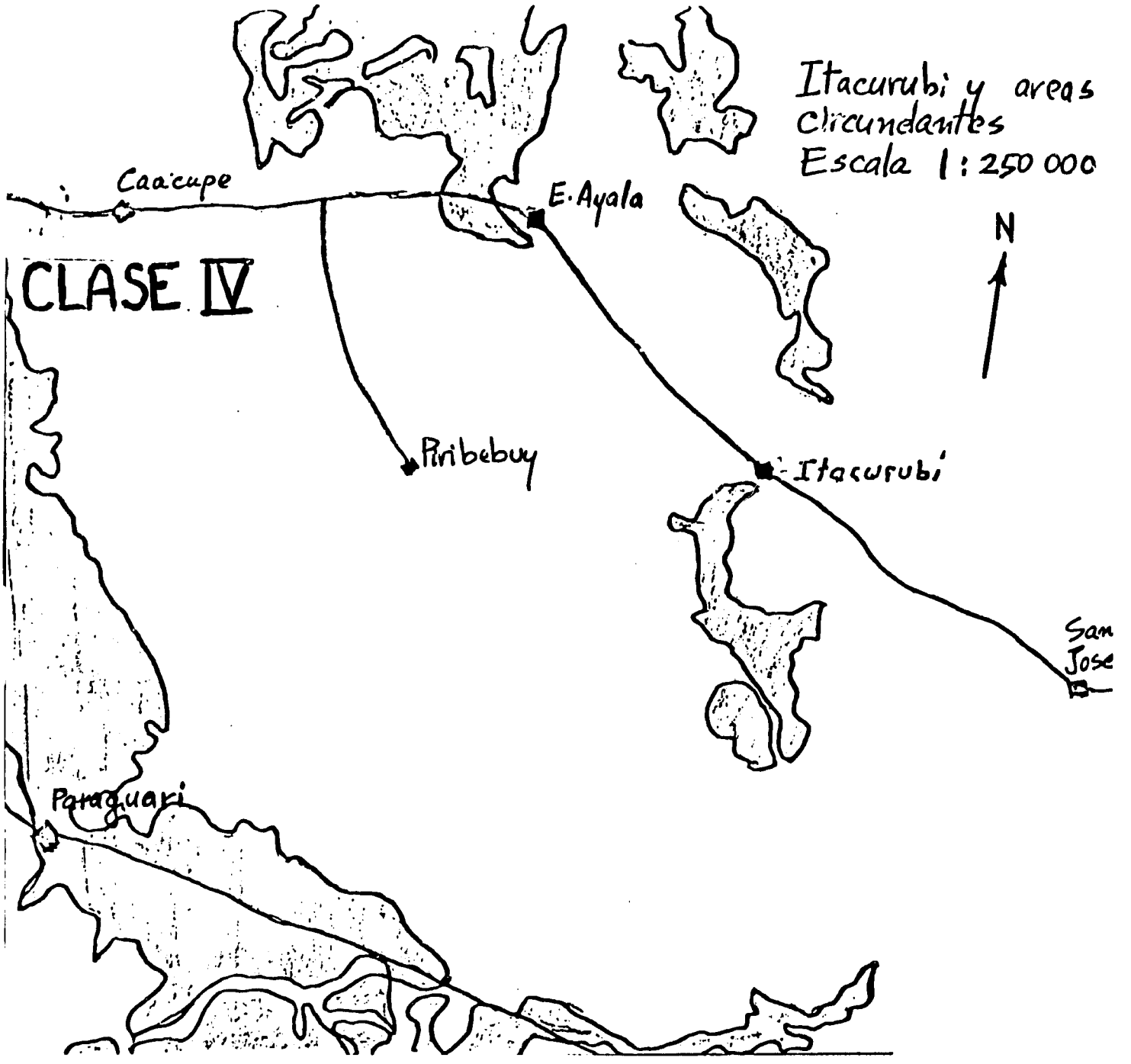
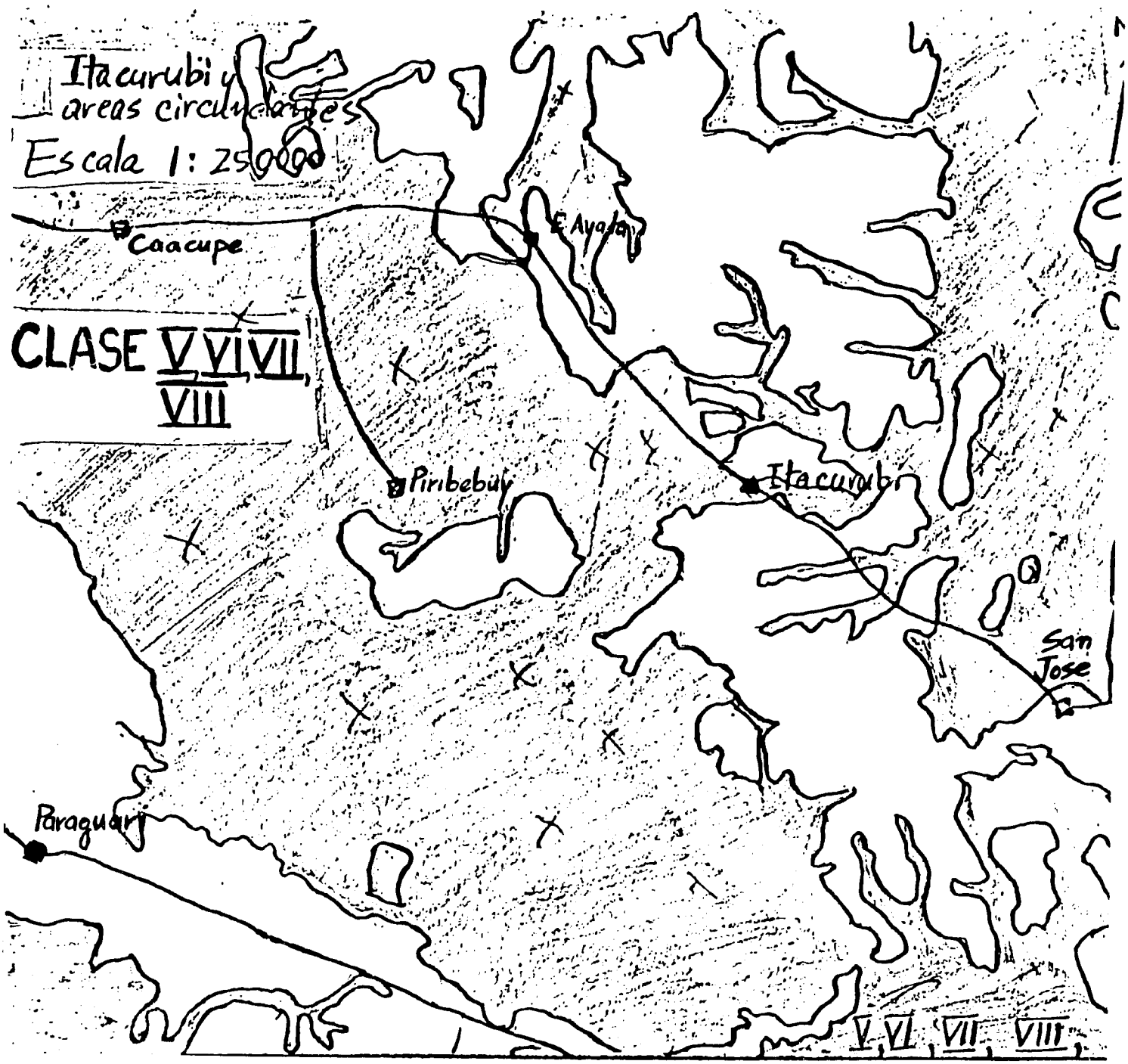
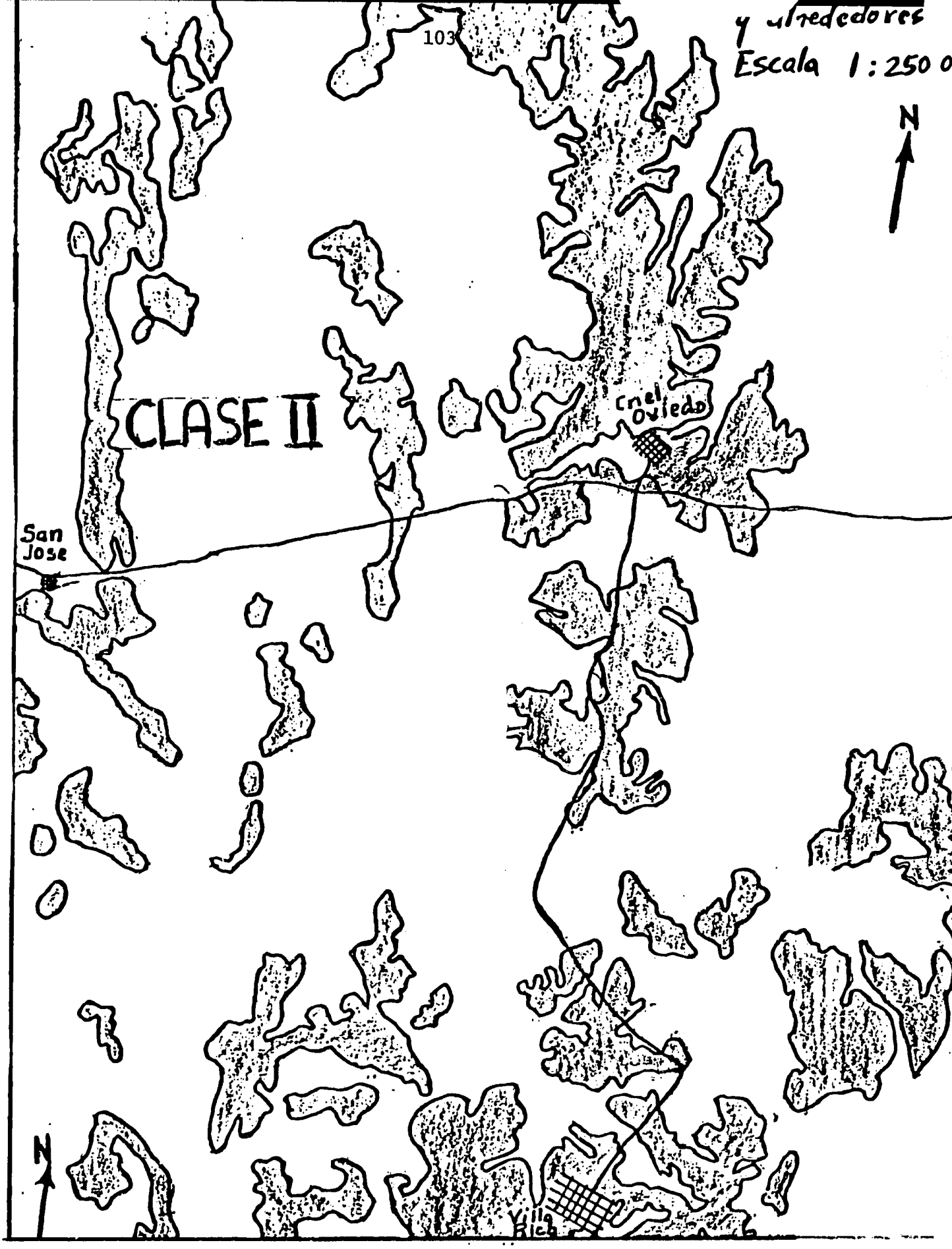


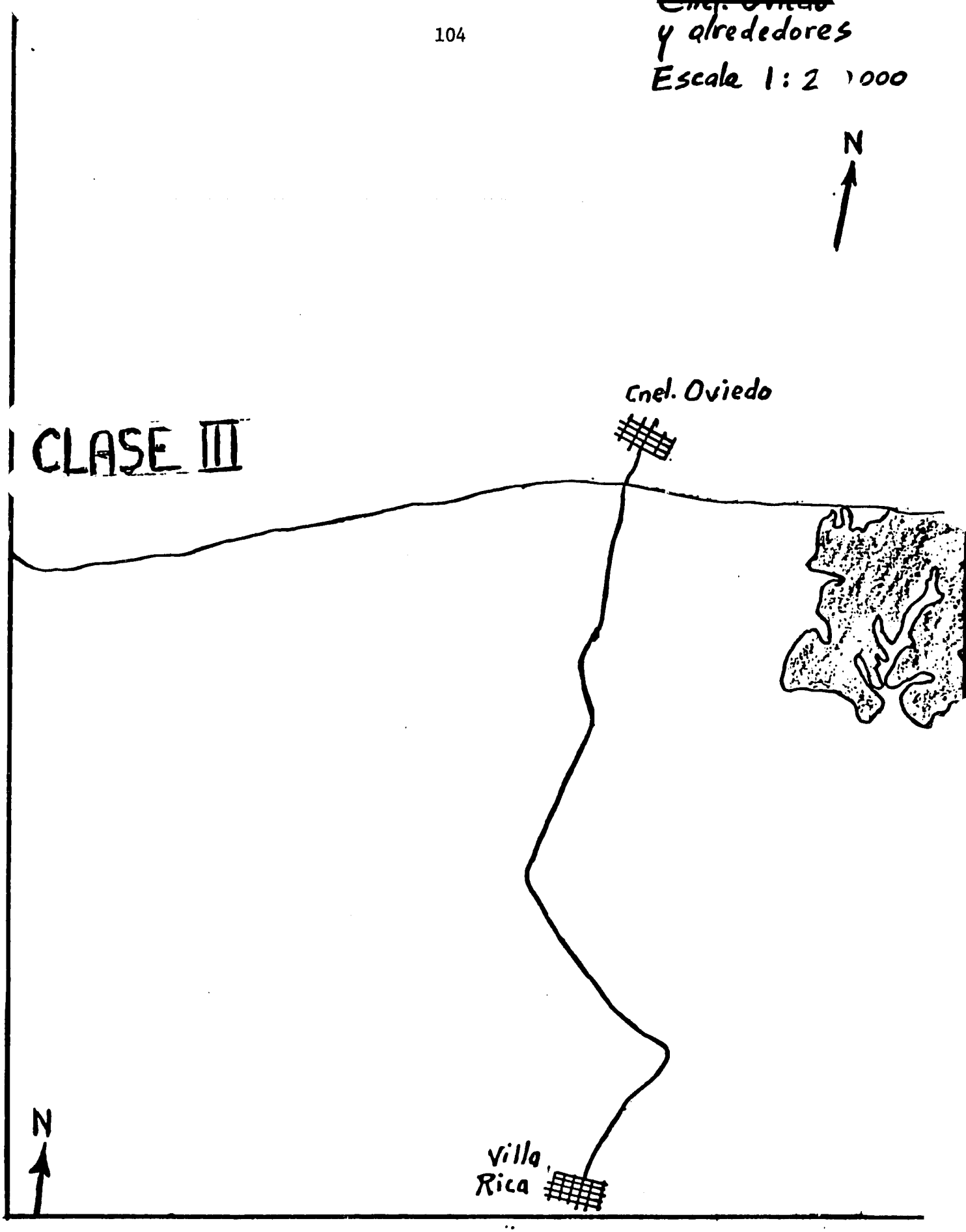
ANNEX II - Map 9



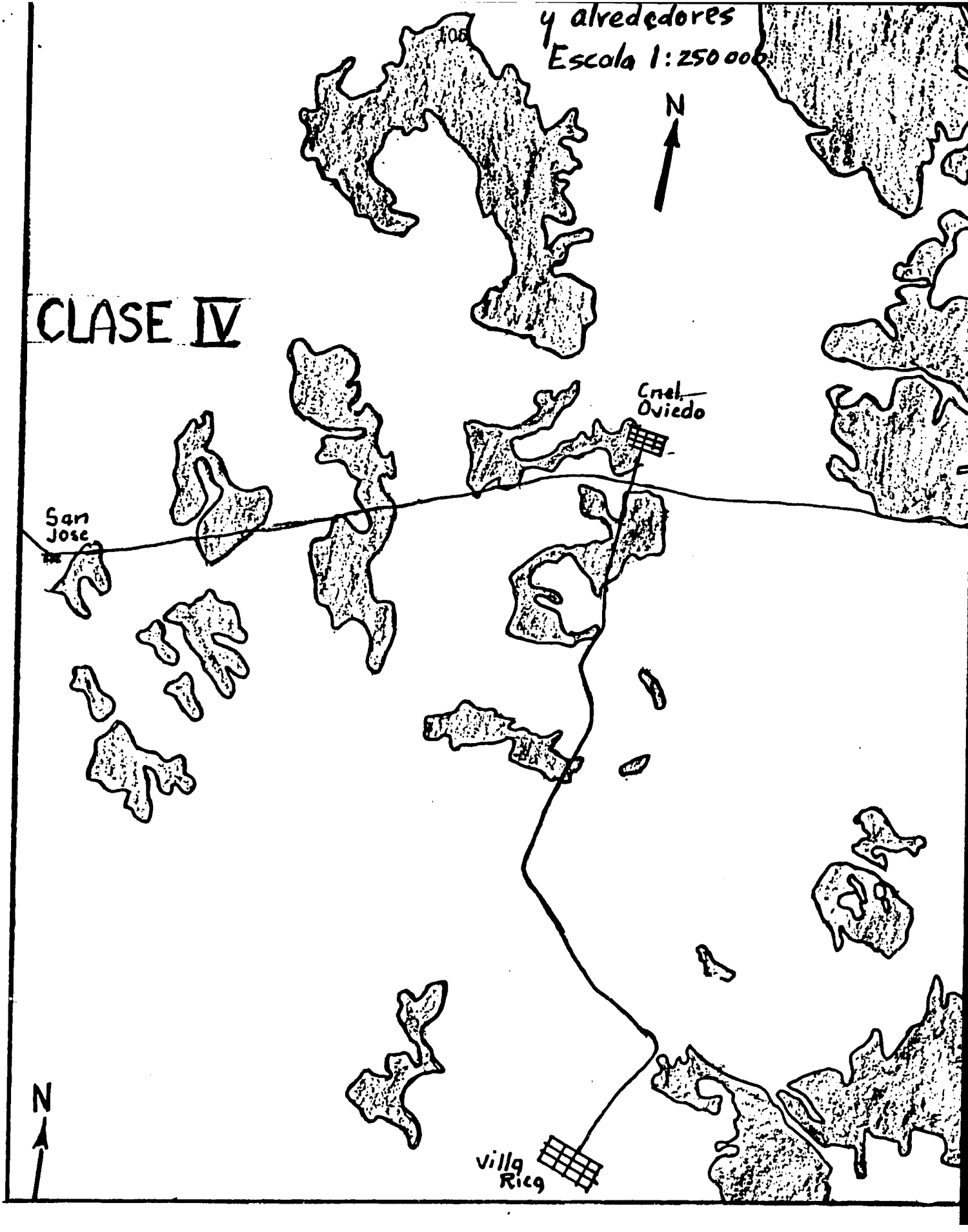
ANNEX II - Map 10



ANNEX II - Map 11

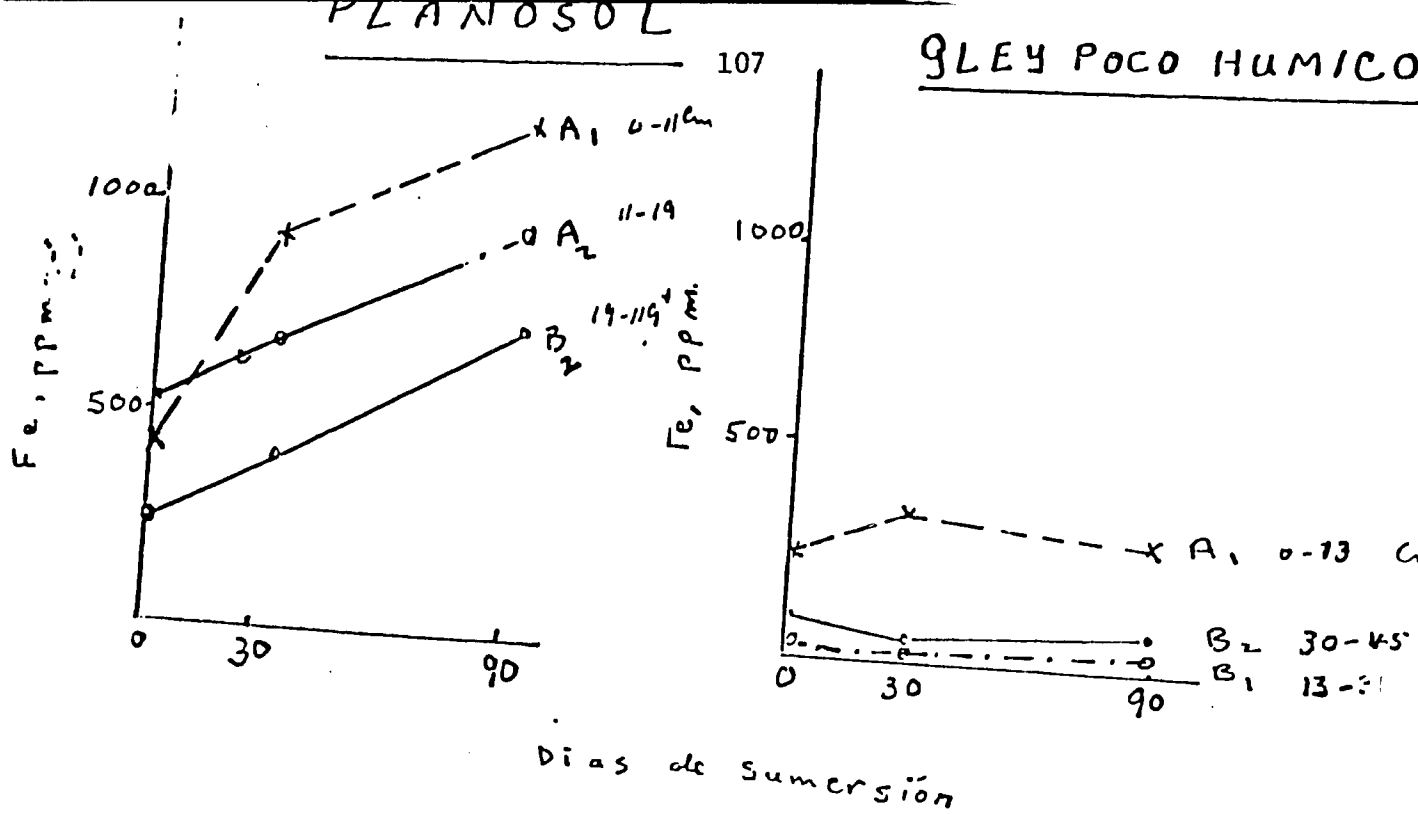


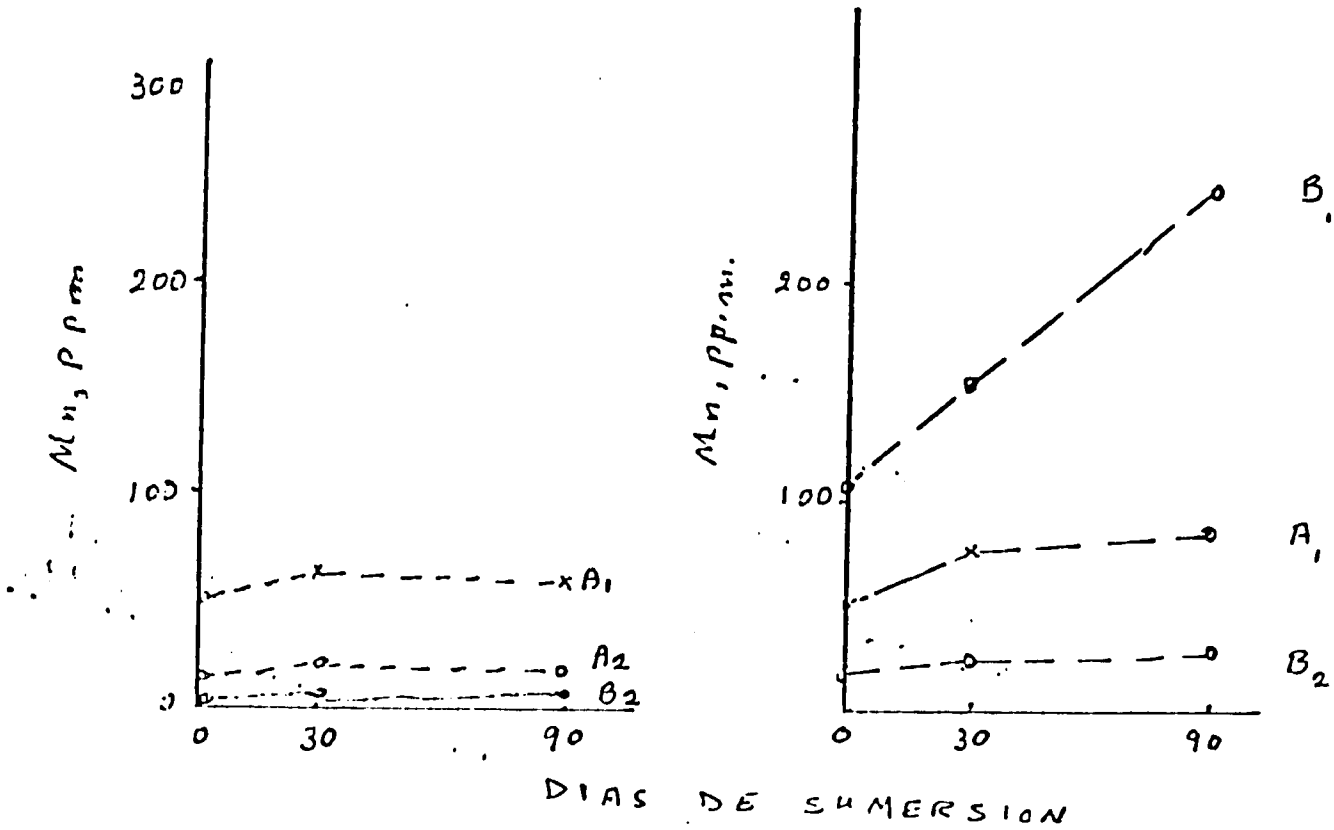
ANNEX II - Map 12



ANNEX II - Map 13

ANNEX II - Map 14



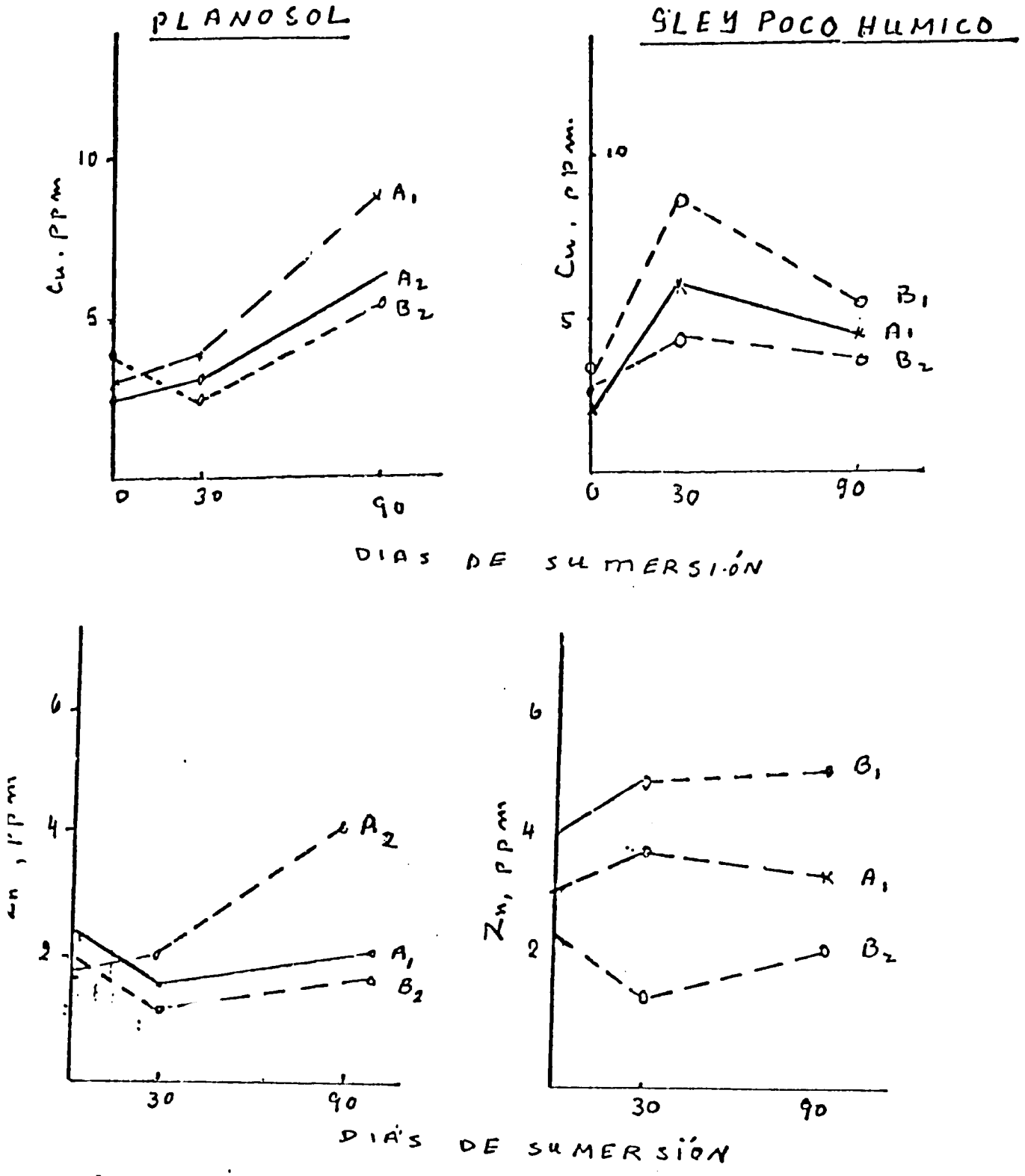


Disponibilidad de Fe y Mn en Suelos hidromorficos sumergidos a dos períodos de sumersión.

Segun: Lic. Jose E. Dias Z

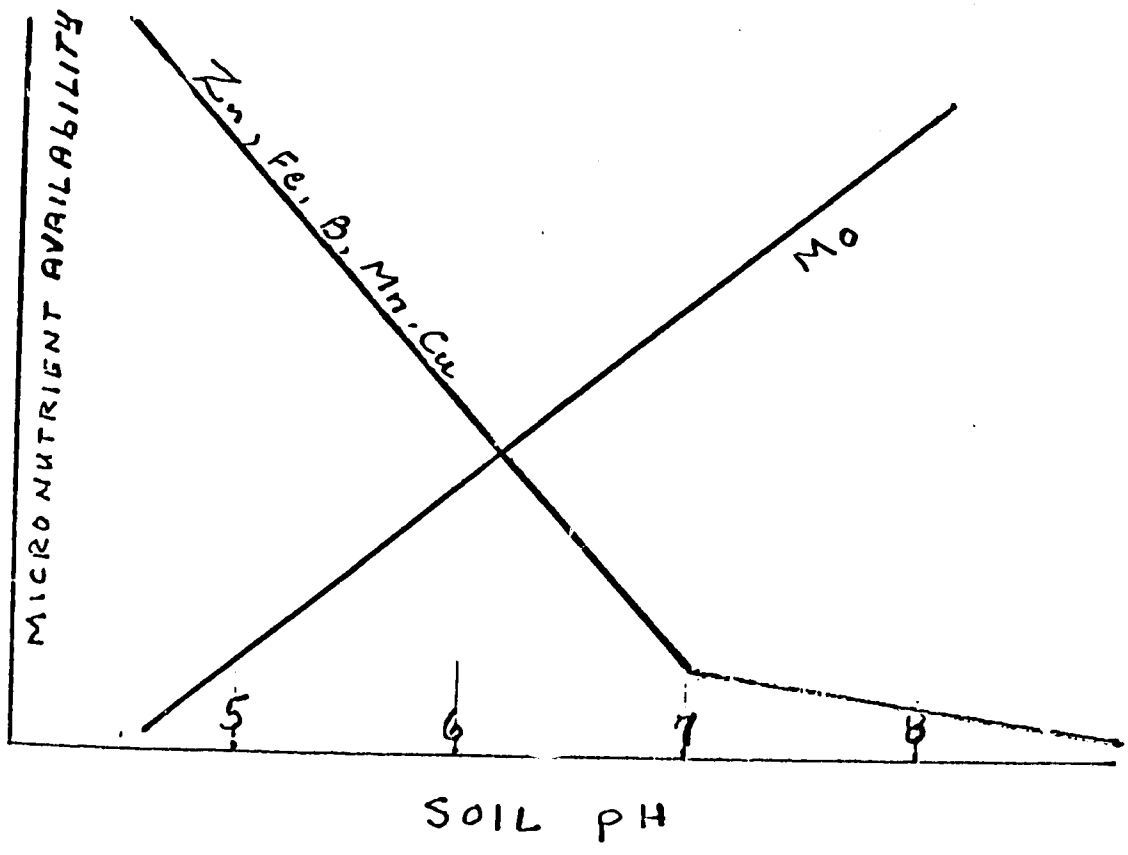
INSTITUTO NACIONAL DE TECNOLOGIA Y NORMALIZACION DE LOS ALIMENTOS. (INTN, 2/79)
ASUNCIÓN. PARAGUAY. 1979

ANNEX III - Figure 1



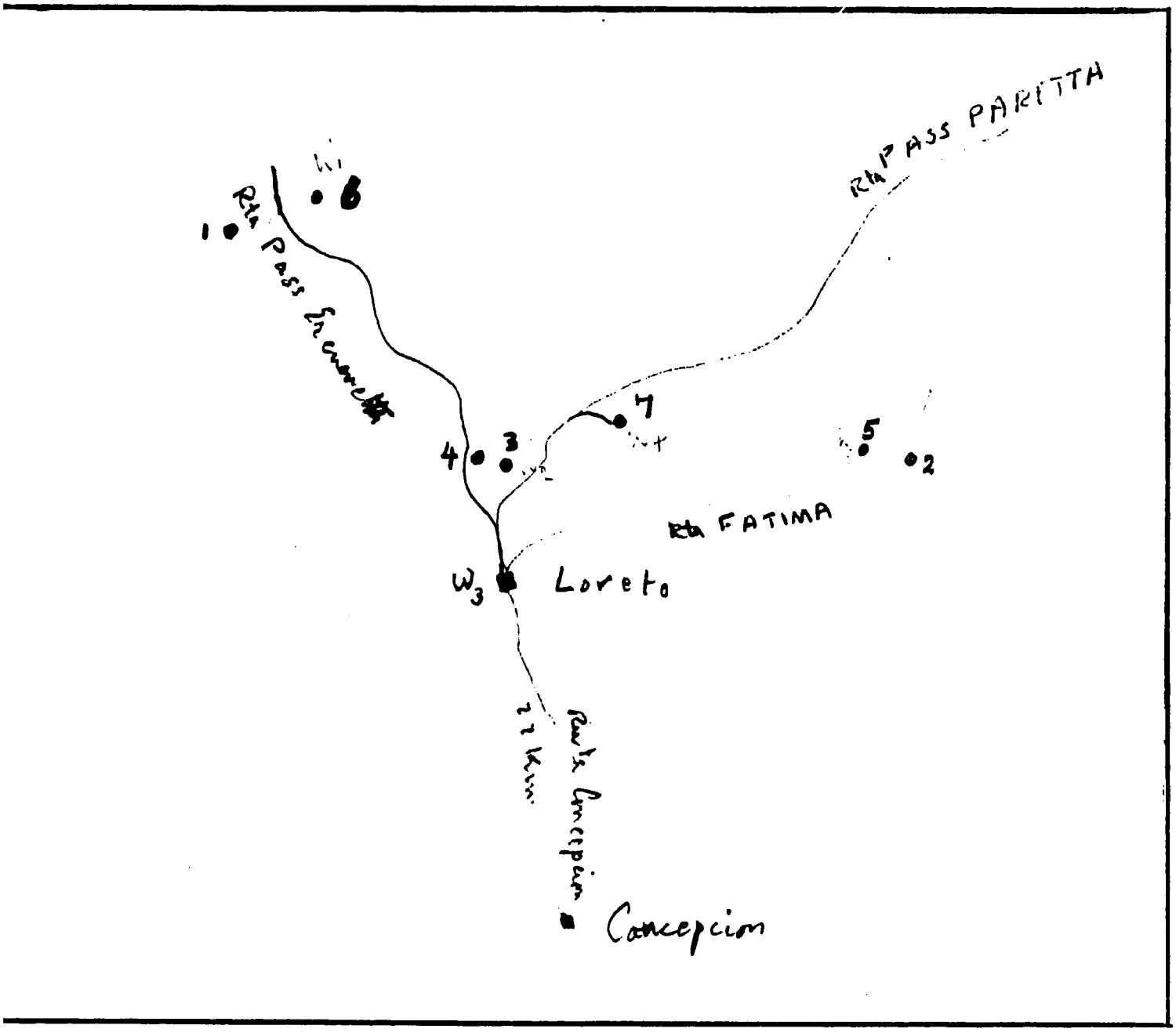
Disponibilidad de Cu y Zn en Suelos hydromorficos sometidos a dos periodos de SUMERSION.

ANNEX III - Figure 2



RELATIVE AVAILABILITY OF MICRONUTRIENTS AND SOIL PH.

ANNEX III - Figure 3



Sketch showing location of small farms visited
Soil profiles & samples taken, and water (W) samples from farm wells; from Loreto Coop., Concepcion, Paraguay (August 1981)

ANNEX III - Figure 4