ISN-30896
PN-AAN-409 /62

CLIMATE AND FLUVIAL MORPHOLOGY IN THE CHAPARE REGION, BOLIVIA

Report to USAID, La Paz 53
28 January 1983

Consultant: Gregory L. Morris
Hydrologist

National Counterparts:

Lucio Juarez Castillo
Consulting Geologist

Luis Carlos Sánchez
Hydrologist
CORDECO

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SUMMARY CONCLUSIONS AND RECOMMENDATIONS

1) Seven existing climatological stations should be upgraded to support planned agricultural trials, and a microcomputer should be used to for data storage, retrieval, and analysis. This program will require one technician, one microcomputer, mescellaneous meterolotical equipment, and access to a vehicle. Five year cost, including technical assistance, is estimated at $ 60,000.

2) Approximately $ 800,000 will be required for extending the main spans on four failed bridges in the Chapare. This project should be contemplated as part of the caminos vecinales II project. Financing for the 5th damaged bridge has already been obtained.

3) The upper watershed (above 500m MSL) should be protected against any type of development due to the high erosion hazard. There is little erosion hazard on the flat alluvial lands in the Chapare area.

4) The rivers in the Chapare flood, erode their banks, and change course from time to time as a result of natural geologic/hydrologic processes. Development to date has probably had little effect on these processes. It is not feasible to control these processes. Rather, development should be avoided in areas known to have historically been subject to flooding and erosion. Maintenance of riverbank vegetation will help retard the rate of river erosion and meander.

5) Agricultural development is not forseen to have an impact on river navigability.

6) A rural electrification project for the Chapare has been prepared by Empresa Nacional de Electricidad for financing by BID.

7) Large scale drainage projects should not be contemplated in the Chapare area. However, small on-farm drainage ditches may improve crop production in some areas. Small on-farm systems of contour dikes could be constructed in many aereas for paddy rice production. Field trials would be required to determine economic feasibility.

8) Reliable public water supplies do not exist in the Chapare. A separate rural sanitation project is being developed by USAID to provide public water supply.

INTRODUCTION

This report summarizes the climatological data available for the Chapare area from Servicio Nacional de Meterología e Hidrología (SNMH) in Cochabamba. River geomorphology is briefly described, as are the problems of washed-out bridges and culverts. Recommendations for management are also included.

The report was prepared based on five days in the Chapare area, two days in the Santa Cruz - Yapacaní area, plus about 1.1/2 weeks in Cochabamba.

METHODOLOGY AND DATA SOURCES

CLIMATIC DATA

Original climatic data were obtained from the monthly tabulation sheets prepared by the Servicio Nacional de Meterología e Hidrología (SNMH) in Cochabamba. Additional data may be available through the central SNMH offices in La Paz; time limitations did not permit a review of the data available in La Paz.

Although there are a total of 9 climatological stations in the Chapare, the data coverage is relatively poor. The data series are incomplete, and only a few years of data are available from for most stations. Also, the quality of data at many stations is poor. There are approximately a dozen additional stations located in the upper watershed areas with usable data. Observations concerning the available data are summarized below.

Precipitation

Rainfall gages are not always read on a daily basis. Visits to the La Jota and Chipiriri Stations revealed that the station technicians were not present to record data on the weeked of 15 January, resulting in erroneous recording of the heavy rainfall

on 14 January which washed out five bridges and several culverts. It is reportedly a common practice for technicians to leave these stations unattended over the weekend, from Friday noon until Tuesday noon. Thus, while the data on total rainfall is probably accurate, the reported daily values are subject to errors and should be used with caution for predicting maximum daily precipitation.

Temperature.

While it is expected that the data on temperature is generally accurate, there are nonetheless obvious errors in the recorded low temperatures. Freezing and below freezing temperatures have been erroneously recorded at some stations (e.g. -2.2 deg. C at La Jota). The type of vegetation in the Chapare area indicates that freezing temperatures do not occur. Similarly, at the CIMCA experimental station further south (where colder temperatures are expected), freezing temperatures have never been recorded.

Mean temperatures have been computed as the average of the daily high and low temperatures. The mean values of the most extreme temperature in each month in each year have also been shown. In some cases the accuracy of these extreme values is questionable. Reported freezing temperatures have been omitted in computing the minimum values.

Pan evaporation.

Data on pan evaporation is sparse in the Chapare area, and comparison of the daily change in water depth in the pans against the daily precipitation revealed that much of the available data are erroneous (for example, the pan evaporation data from Puerto Villarroel has been completely discarded because of large discrepancies in the reported daily reainfall and the change in pan water level). The data which has been used in this report is the most reliable data available.

GEOLOGY AND FLUVIAL MORPHOLOGY

Summary information on the regional geology has been obtained from existing reports, interpretation of the observed outcrop areas, and the previous experience of the Bolivian counterpart. Conclusions concerning the fluvial morphology have been made based on visual interpretation of the rivers, interpretation of the 1:50,000 scale mapping (to obtain data on river length and slopes), and available aerial photography from 1963, 1973 and 1979.

Conclusions concerning the failure of bridges and culverts, and recommendations for protection of these structures in the future, have been a based on the inspection of each structure. Most structures failed on 14 January, and were visited on 15 and 16 January.

EXISTING CONDITIONS

SUMMARY CLIMATIC CHARACTERISTICS

Rainfall and Evaporation

High rainfall is the most conspicuous aspect of the Chapare climate. The wet season extends from October through March, the southern hemisphere summer, with January and February being the wettest months.

The area of highest rainfall is near the base of the Andean foothills, at elevations in the range of 400m to 1000m. Chipiriri (411m) and Satun Chato (397m) are the wettest stations, each with an average hydrologic year[1/] precipitation of about 4900mm (193 in/yr). A maximum hydrologic year precipitation of 6900mm

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1/ A hydrologic year beginning in October and ending in September has been used in this report, since the end of the calendar year falls in the middle of the wet season.

(271 in) has been recorded at Chipiriri. Rainfall decreases toward the north (away from the mountains) and toward the east (toward Puerto Villarroel).

Rainfall data is collected at all climatic stations, and has been analyzed by Pinto (1982) to convert the short term records available at most stations to long term means by constructing correlations with long term index stations. These values have been used to construct an isoheytal map showing contours of equal annual rainfall for the Chapare area (Figure 1). Precipitation is strongly influenced by orographic effects as illustrated in Figure 8.

The climatic characteristics of several stations in the Chapare area are summarized in Figures 2 through 5. Due to the limited record at the various stations, it was not possible to construct climatological graphs for all stations using the same period or of record and the same paramenters. Monthly rainfall and pan evaporation have been reported for those stations for wich some pan evaporation data are available, and where a rapid perusal of the data did not reveal obvious errors. The Chapare area is extremely wet: rainfall exceeds evaporation during most months at most stations. There are periods of more rain or less rain in the Chapare, but no true dry season.

For the purpose of comparison with the Chapare región, climatological data has been obtained from Colonia San Juan de Yapacaní and from the CIMCA agricultural experiment station near Montero, both in the Department of Santa Cruz. Yapacaní is considerably drier than the Chapare, with a long term average rainfall (1960-78) of 1900 mm/year. There are five months at Yapacaní when the pan evaporation [1/] is equal to or greater than rainfall; this does not occur in the Chapare (Figure 6 and 7).

1/ The pan evaporation data at Yapacaní was reported by to have problems with undercounting, according to the CORDECRUZ technicial in charge of compiling the data reported by that station.

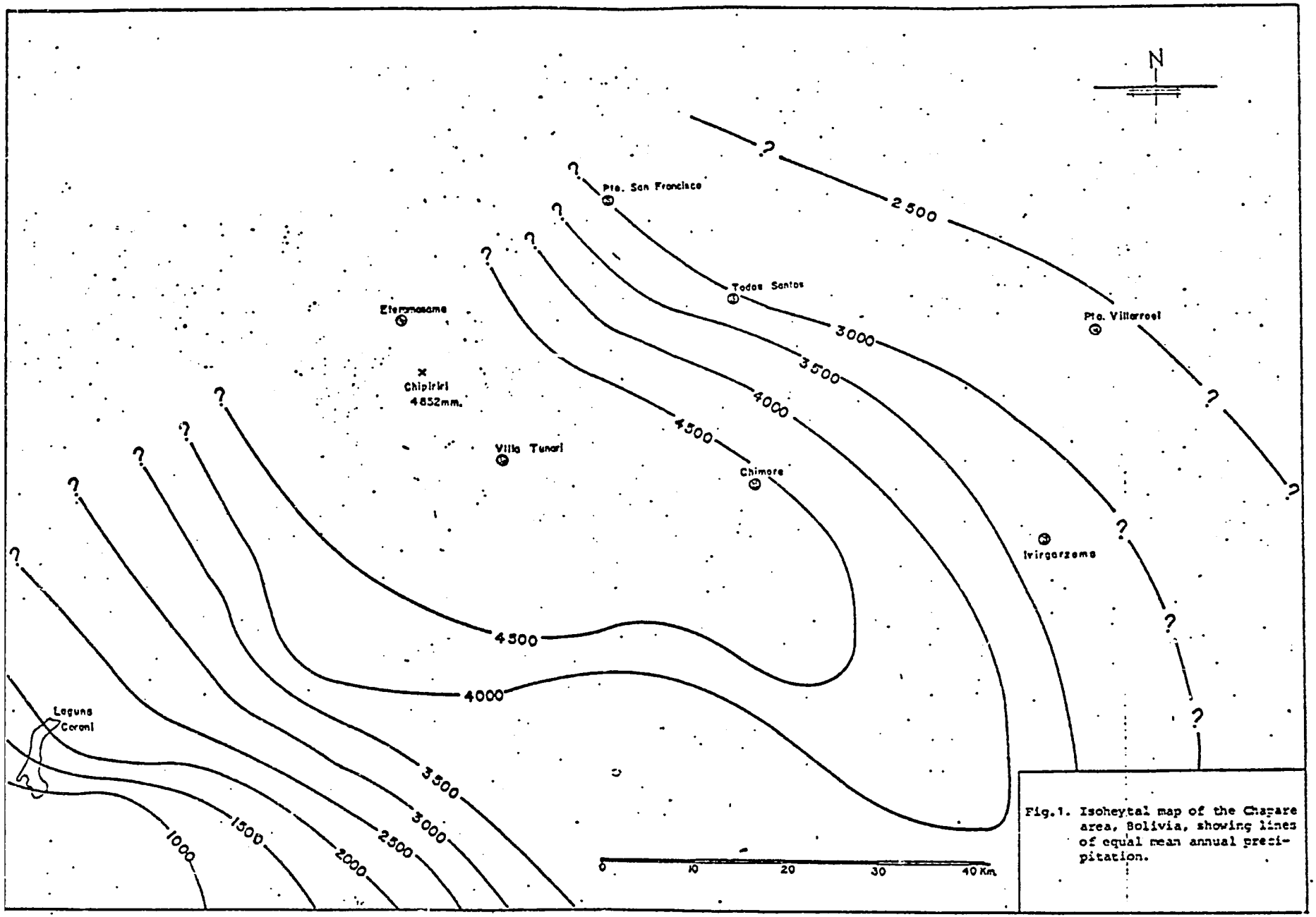

Fig. 1. Isoheytal map of the Chapare area, Bolivia, showing lines of equal mean annual precipitation.

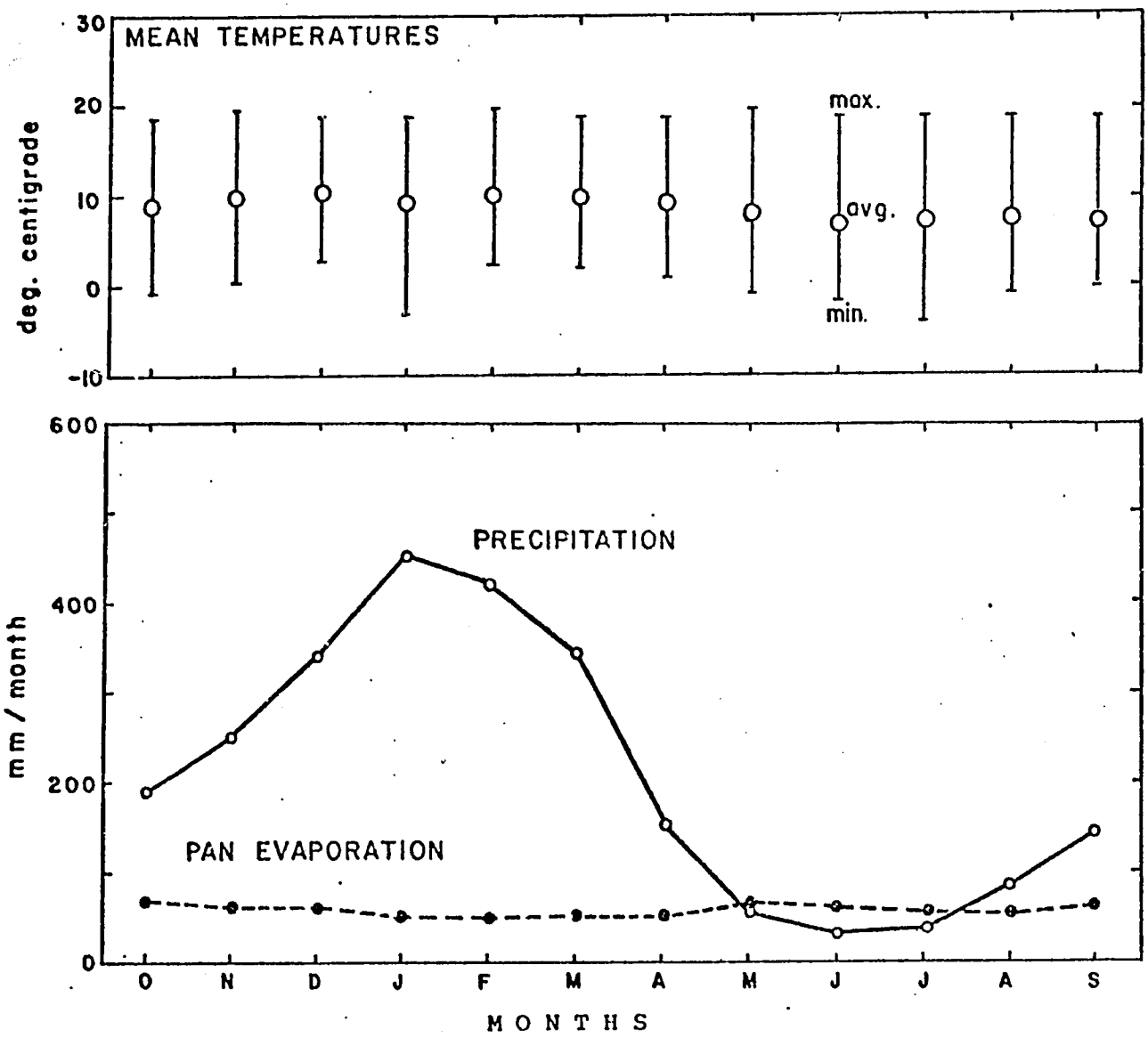

Fig. 2. CORANI. This station is located at the Corani reservoir in the mountains south of the study area, but within the upper watershed of the Chapare River. It is one of the most reliable climatological stations in the area and has a continuous climatological record since 1959.

Elevation: 3240 m Mean Annual Precipitation: 2451 mm

Mean Annual Pan Evaporation: 696 mm

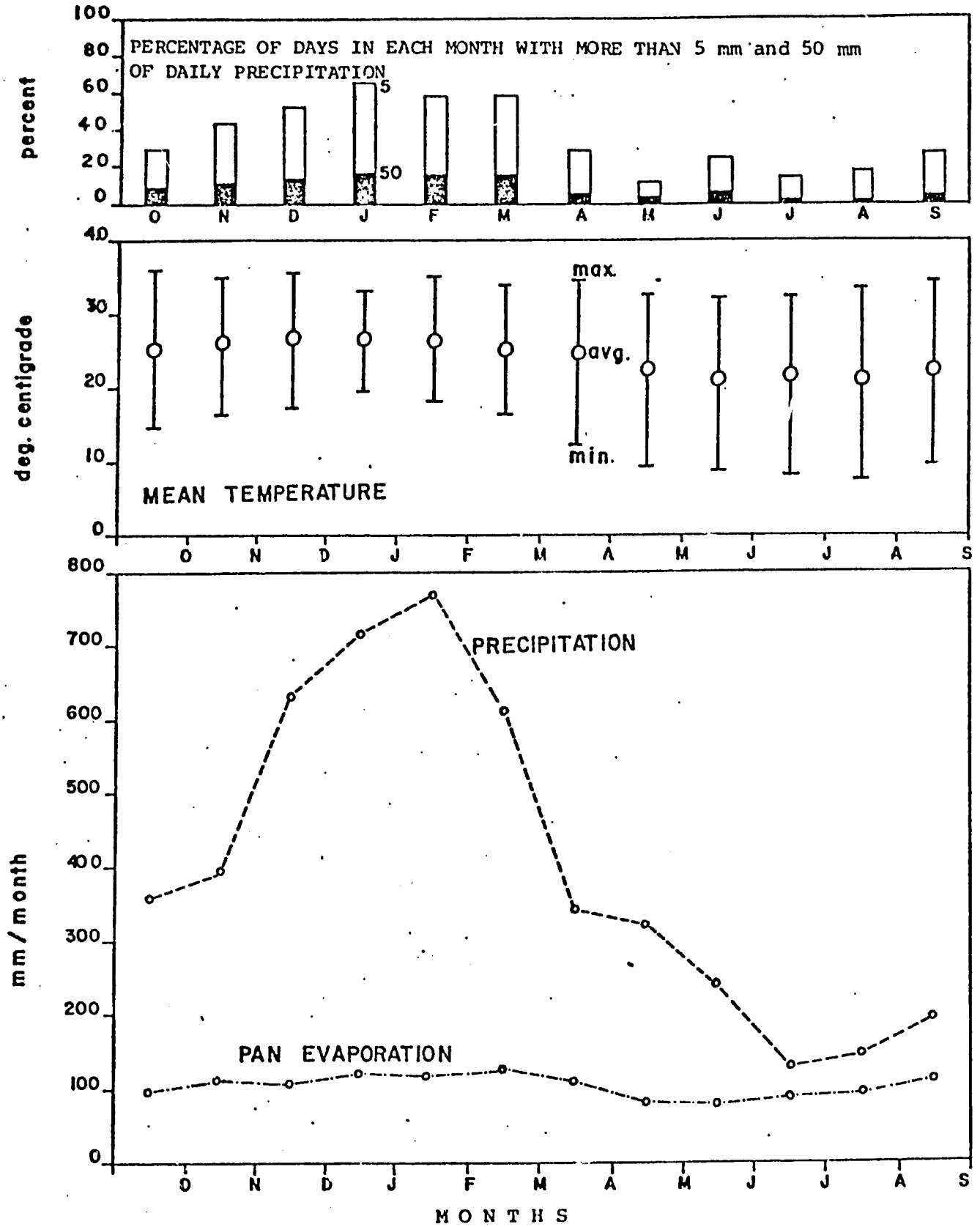

Fig. 3. CHIPIRIRI. This station is located at the Chipiriri agricultural experiment station. Precipitation data are available for 1965-1979, but pan evaporation data from only 1973-74 has been used due to the unreliability of more recent data. Temperature data for the period 1974-81 has been used to compute the mean temperature for each month and the mean of annual extreme values for each month.

Elevation: 411 m Mean Annual Precipitation: 4852 mm

Mean Annual Pan Evaporation: 1248 mm

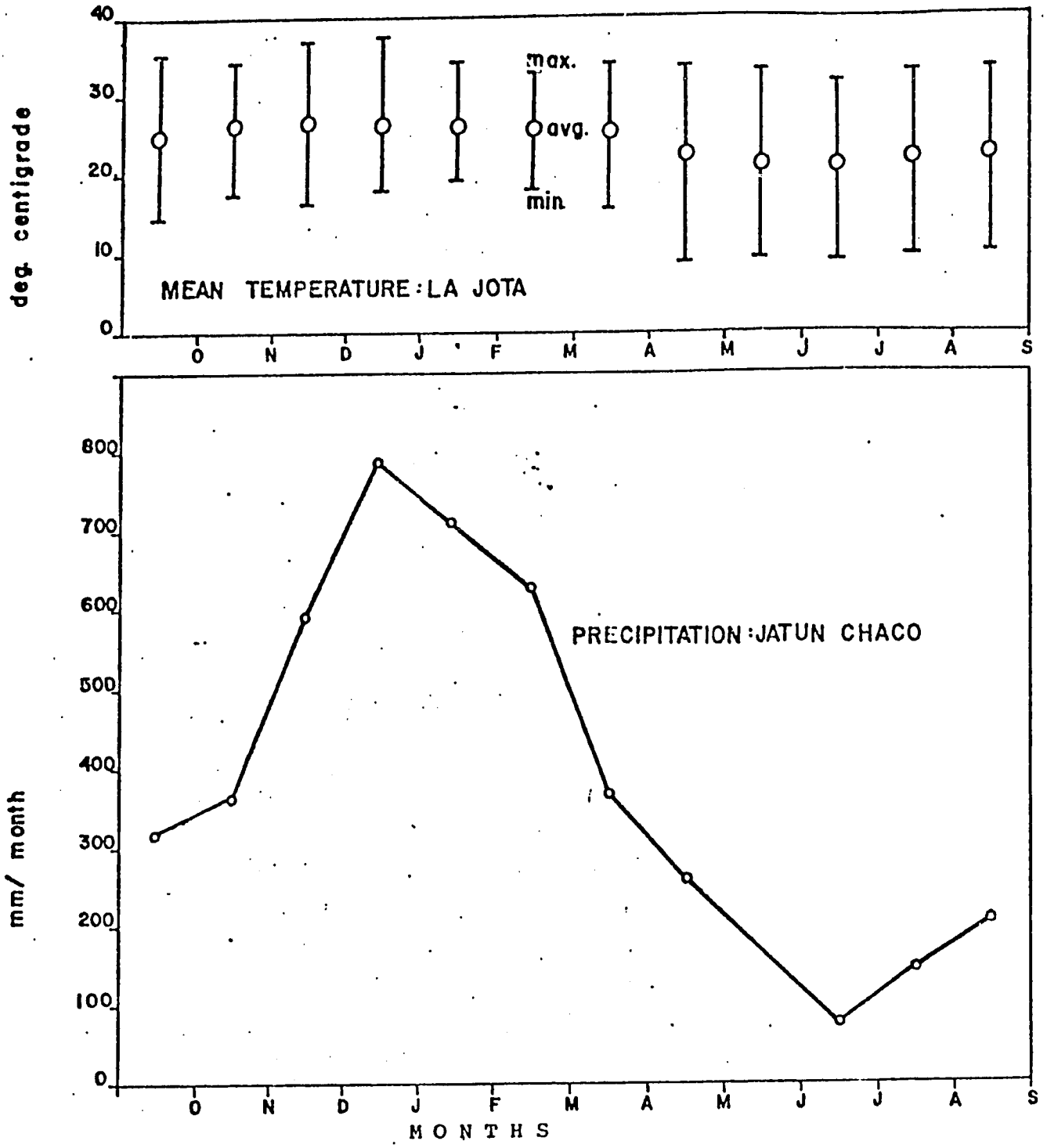

Fig.4. LA JOTA. Temperature data (1978-82) is summarized for the La Jota agricultural experiment station.

JATUN CHACO. Rainfall data for 1969-79 is plotted, instead of using the short 3-year record at La Jota. Jatun Chaco is only 9 km. distant from La Jota. Temperature data are not available at Jatun Chaco, and evaporation data are not available for either station.

Elevation: 397 m Mean Annual Precipitation: 4645 mm

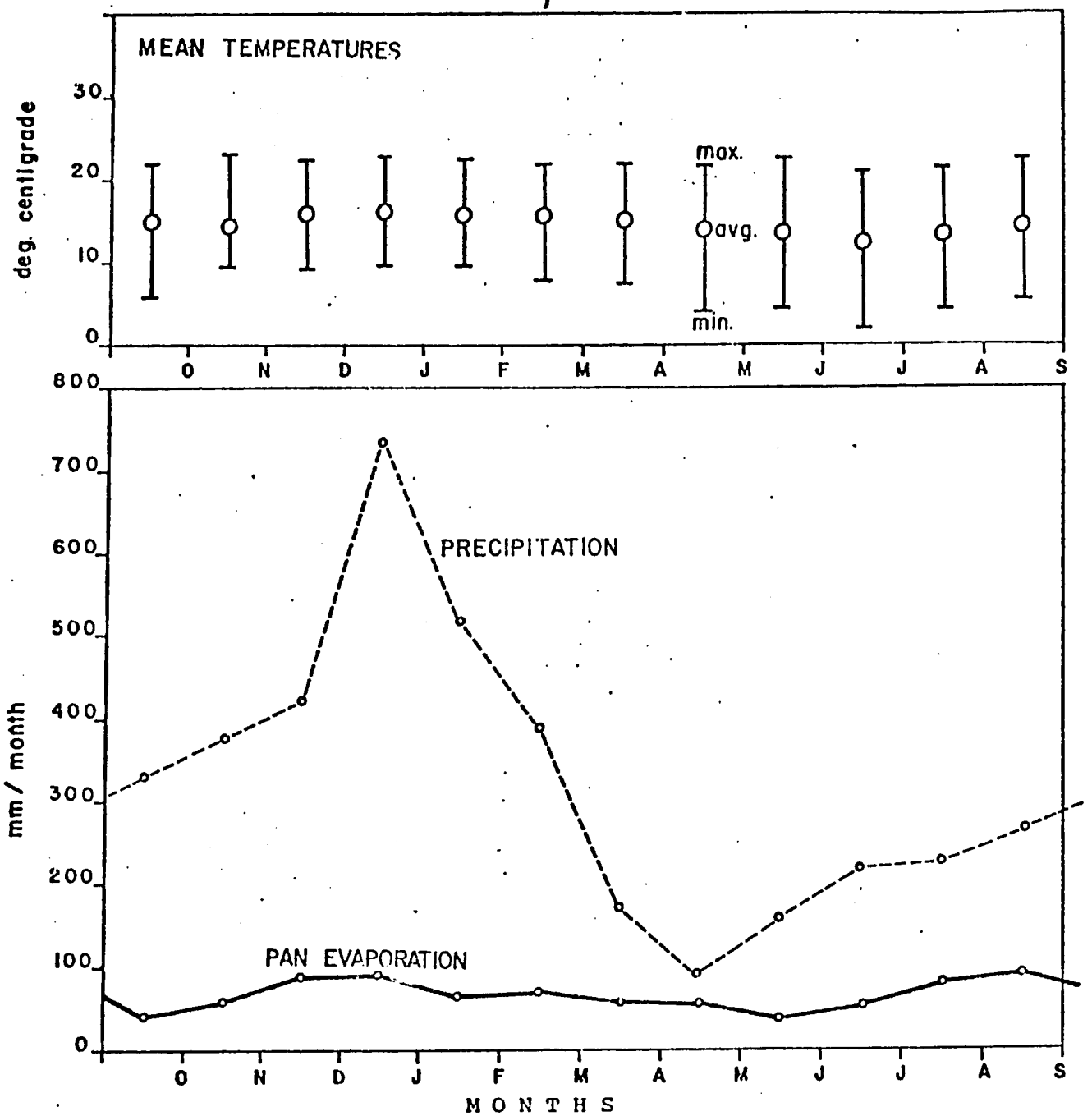

Fig. 5. SEHUENCAS. This station is located in the mountains south of the are- being considered for agricultural development. Data have been shown for this station because the amount of precipitation is characteristic of the values found elsewhere along the foothills of the southern boundary of the study area, and the pan evaporation data from this station appear to be reliable. Data are available for the period 1973-79.

Elevation: 1980 m Mean Annual Precipitation: 3747 mm

Mean Annual Pan Evaporation: 725 mm

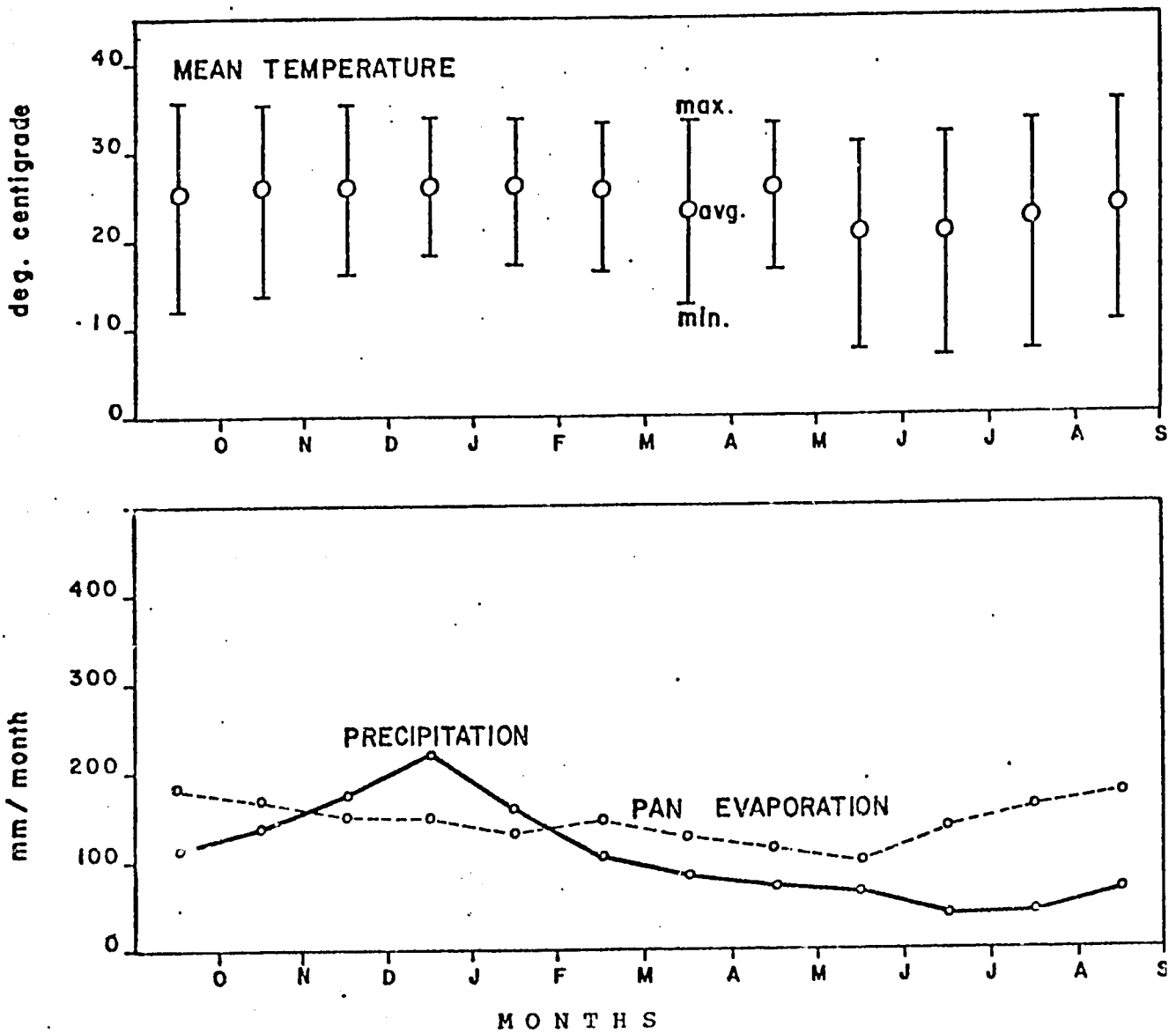

Fig. 6. CIMCA. These climatological data are from the CIMCA agricultural experiment station near Montero in the Santa Cruz area. Precipitation and temperature data are available from 1951 to present, and pan evaporation data from 1972 to present. This is a highly reliable station and it is located in a zone of recognized agricultural potential which lies southeast of the Chapare area. There is a marked contrast between the precipitation:pan evaporation relationship at this station as compared to the stations within the Chapare area.

Mean Annual Precipitation: 1253 mm

Mean Annual Pan Evaporation: 1739 mm

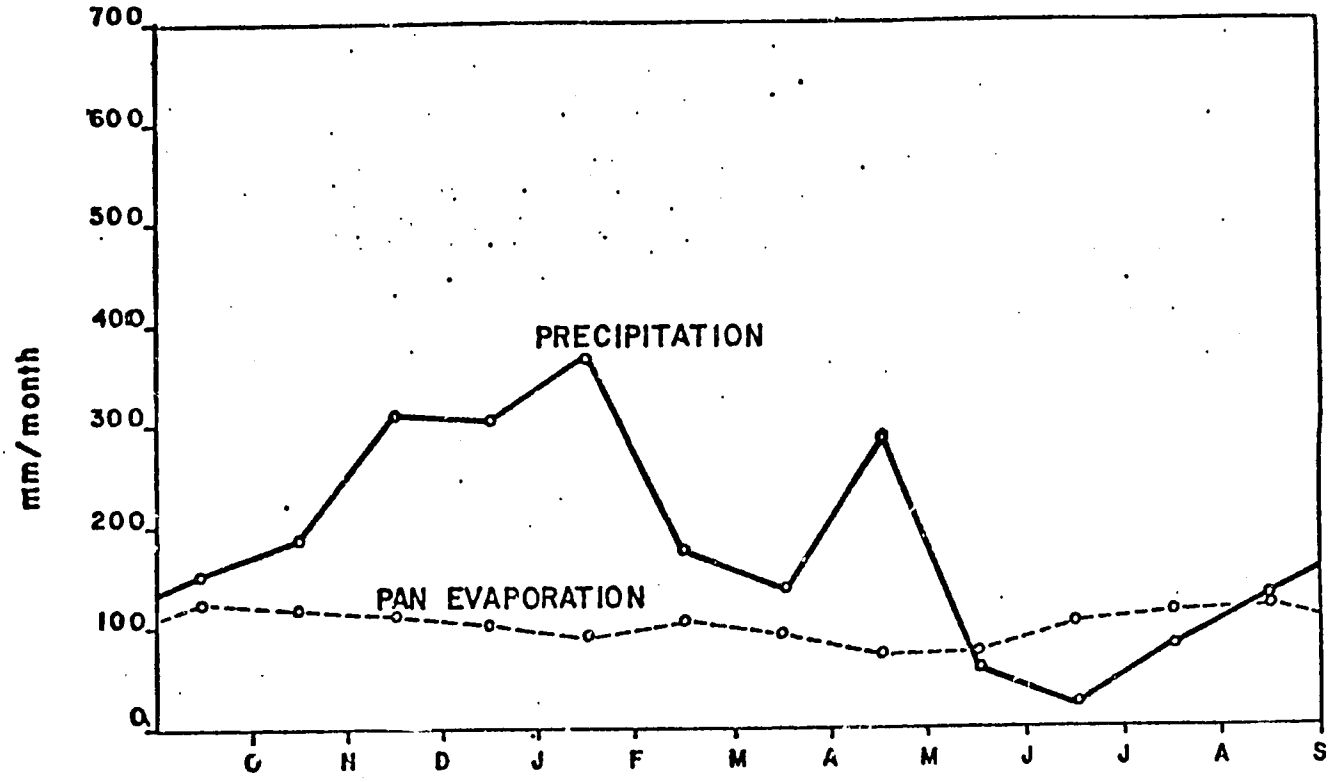

Fig.7. YAPACANI. Precipitation and evaporation data from Colonia San Juan de Yapacaní are averaged over the period 1978-81. The CORDECRUZ technician in charge of tabulating data reported by this station indicated that the pan evaporation data may tend to be underecounted due to data collection error. Of all the stations east of the Ichilo River, Yapacaní is closest to the Chapare (approx. 100 km southeast of Pto. Vollarroel).

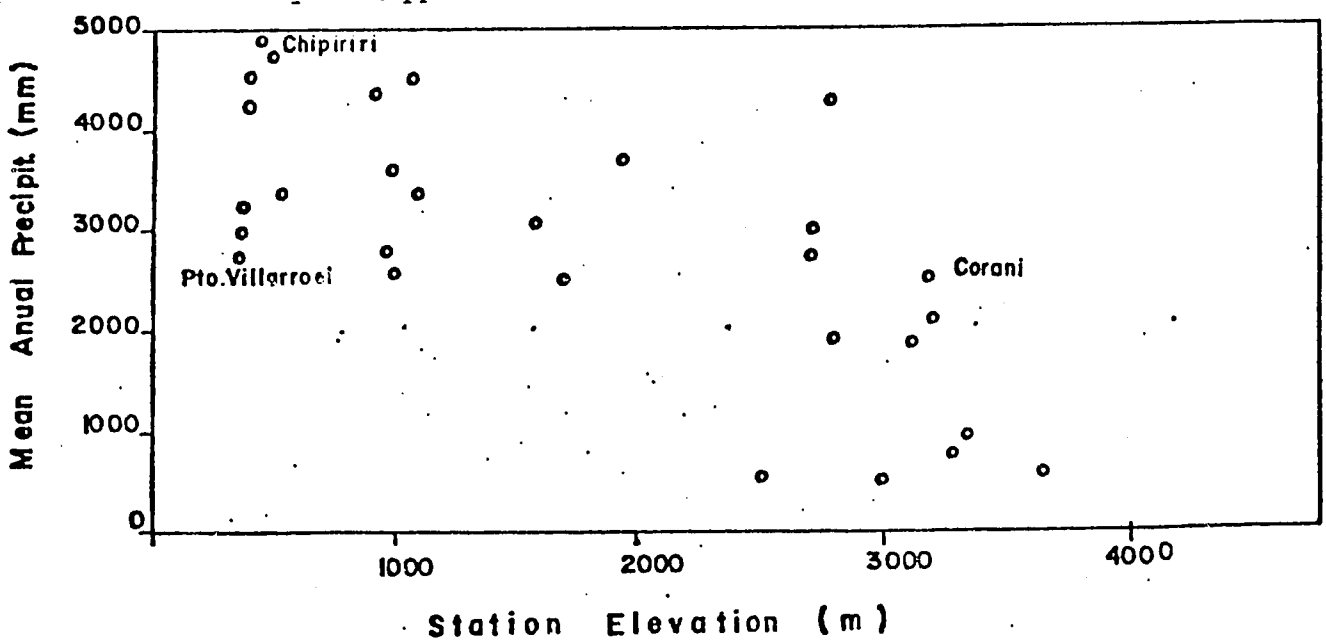

Fig.8. Variation in mean annual precipitation, as a function of elevation in meters above mean sea level, for stations in the Chapare area. Note that although rainfall at Puerto Villarroel is considerably less than Chipiriri, they are at nearly the same elevation. At a given elevation, rainfall tends to decrease as one moves east..

Temperature.

Data on temperature for several stations are summarized in Figures 2 through 5. Temperature data is also summarized for the CIMCA experimental station near montero in the Santa Cruz area (Figure 6). Freezing temperatures do not occur in the Chapare area (as mentioned earlier, the several instances of recorded freezing temperatures are attributed to measurement error). Increased moisture during the wet season has a moderating influence on the temperature; there is a reduced range of temperatures in the wetter months as compared to the drier monts.

Days with Rainfall.

The number of days with rainfall have been computed for the several stations (Figures 3 and 4), showing the number of days with greater than 5mm (0.2 inches) as well as the number of days with greater than 50mm (2 inches). Pan evaporation on dry days averages on the order of 4 mm, a value of 5mm/day of rainfall has been selected to indicate those rainstorms which can offset daily evaporation. The value of 50mm has been used to indicate major rainstorms. Because the number of days in each month varies, days of rainfall has been computed as the percent of the days in each month.

Wind

Reliable wind data are not available for any station in the Chapare. What data are available indicate that there is relatively little wind, and the winds which occur during the daylight hours come from the north. No data on winds during the nighttime have been collected. Ing. Antonio González, climatologist at the CIMCA experimental station, reports that breezes do occur during the nighttime in the Montero area, and that these are generally from the south in contrast to the northerly winds which occur during the day. It is not known whether this same condition obtains in the Chapare area.

GENERALIZED GEOLOGY

Description

The region under study includes the foothills of the eastern Andean slope and the adjacent alluvial plain. The eastern Andean slope is characterized by a rapid change in elevation, from 300m MSL on the alluvial plains to 4700mm MSL in the Cordillera.

This zone consists of sedimentary rocks ranging in age from Cambrian to Tertiary, and its stratigraphy comprises one of the most complex geologic series in Bolivia. These sedimentary deposits may attain a thickness of greater than 2000m and consist principally of shales, although bands of quartzite and deposits of dolomitic limestones occur in some areas. These shales and their derived soils are typically unstable and tend to erode rapidly when vegetative cover is removed. The instability of these soils is readily evident in the road washouts and landslips which occur between Corani and Villa Tunari. In some sections this road crosses areas of highly unstable mudstones which produce large quantities of finely-divided sediments when eroded.

At the base of the Andean foothills, at an elevation of approximately 400m to 500m MSL, the topographic gradient flattens and the shales are covered by alluvial materials. Coarser materials have been deposited closer to the foothills, and finer-grained sediments have been transported and deposited at progressively greater distances from the mountains. Although there are considerable variations in the local soils, in general the sandy and better drained soils (coarser sediments) are found closer to the foothills, while the heavier soils (finer sediments such as silts and clays) tend to be found at greater distances from the mountains.

Development Potential

Agriculture. Sloping soils above an elevation of approximately 500m are entirely unsuitable for development of any type due to the highly unstable nature of the soils and their parent materials. Agricultural development in these areas will greatly increase erosion and sedimentation of the rivers.

Limestones. Two deposits of dolomitic limestone occur in the area of Limbo. One deposit is located near km 125 on the old road from Cochabamba to Villa Tunari, and the other near km 145 on the new road from Cochabamba to Villa Tunari near the point where it crosses Río Putintiri. Another area of dolomitic limestone is located in the region of El Palmar, approximately 27 km distant from Villa Tunari on the old Cochabamba road.

It may be economically feasible to mine these deposits to supply limestone for agricultural use to increase soil pH, which tends to be acidic throughout the Chapare region.

Salt. A salt spring with an orifice approximately 10 cm in diameter discharge into the Río Cachí Mayu (salt river) in the El palmar area. This suggests than that a salt deposit may exist which could be developed to supply salt for livestock or other uses.

FLUVIAL MORPHOLOGY

Characteristics of the rivers in the Chapare area change dramatically as one travels downstream from the upper watershed to the alluvial plain. Three types of river channels may be described based on concepts of fluvial morphology. Starting in the mountains and moving downstream the successive rives reaches may be classified as: (1) non-alluvial channel, 2) alluvial bed load channel, and (3) alluvial suspended load channel (Mac Brown, 1981).

Non-Alluvial Channels

The non-alluvial river channel has rigid channel boundaries: its course is controlled by the shape of the Valley which has been carved into the parent rock. The river can change its course only by the slow erosion of the geologic parent material, and the river course is often controlled by lines of faulting (containing rocks less resistant to erosion), rather than the hydraulic action of the river itself.

Non-alluvial channels are found in the upper watersheds of the rivers in the Chapare area. Heavy sediment loads are contributed by landslips, and these non-alluvial channels export sediments to the alluvial reaches further downstream.

Alluvial Channels

In an alluvial channel the river has movable boundaries composed of erodable alluvial materials such as sand, gravel, silt, and clay. The course of the river is not controlled by solid geologic boundaries. Rather, the river tends to alter its course through the processes of erosion and sedimentation caused by the hydraulic action of the flowing current. Because most erosion and sedimentation occurs during floods, its is possible for rivers in this area to change course literally from one day to the next. Perhaps the best example of this phenomena was the formation of the Río Veinticuatro in 1946, when the Río Chapare changed its course.

Rivers transport sediment using two mechanism (see Fig. 9) Most sediment are transported in suspension; silt and clay particles are eroded and suspended in the water column by turbulence and are carried downstream. Larger particles such as sand and gravel are too large to be carried in suspension, but can be transported downstream as "bed load", being rolled or bounced along the river bottom when the current velocity is high enough.

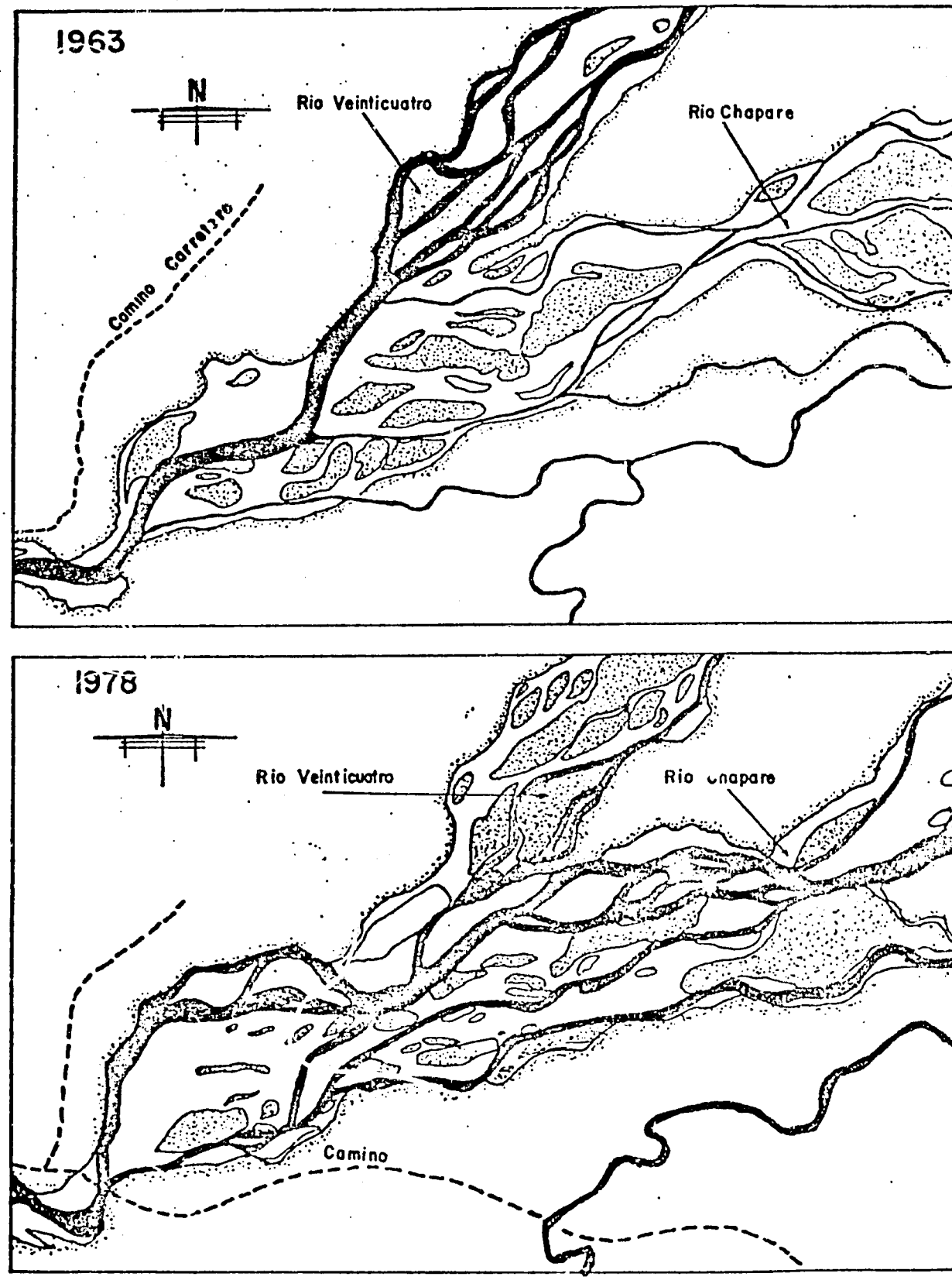

Fig.9. The Veinticuatro River was formed in 1946 when the Chapare River altered its course. Since then the relative volumes of water carried by the Chapare and Veinticuatro has varied, as illustrated by 1963 and 1978 air photos. A larger flow was carried by the Río Veinticuatro in 1963, and by the Chapare in 1978. The Chapare continues to have the larger flow of the two rivers.

The two general types of alluvial channels are distinguished by the nature of sediment transport. In the alluvial "bed-load" channel, sediment transport as bed load is significant (over 10% of the total sediment transport). In the alluvial "suspended-load" channel, bed load transport is negligable.

Alluvial Bed Load Channel.

Alluvial bed load channels have a heavy load of coarse sediments which restricts the ability of the river to erode the channel bed, even though current and erosive force is greatest at the botton of the channel. Rather, the rivers tend to be shallow and erode laterally, and often have a braided pattern. All of the major bridges in the Chapare cross bed load type channels, and the lateral erosion of these channels has been the cause of bridge failures.

In the Chapare area bed load channels correspond to braided sections of the rivers. Comparison of air photos from 1963 and 1979 indicate that this is a zone of sediment deposition because:

1. The bed-load type channel regime is advancing downstream, filling in the deeper suspended-load channels with coarse sediments (see Figure 10).
2. Braided river sections tend to be wider in 1979 than in 1963, indicative of a net accumulation of sediment (as opposed to a net loss of sediment due to scour).

The coarse sediments which are being deposited in this zone are derived from two sources, landslips in the mountainous areas and erosion of the river-banks. Human activity in the upper watersheds does not appear to be responsible for significant sediment contributions, since little agricultural or other activity is evident in the mountainous areas. Furthermore, aerial photographs reveal that there was much more agricultural activity in upper watersheds during 1963 than in 1979. However, photographs for some areas show a substantially greater incidence of landslips in 1979 than in 1963 (see Figure 11).

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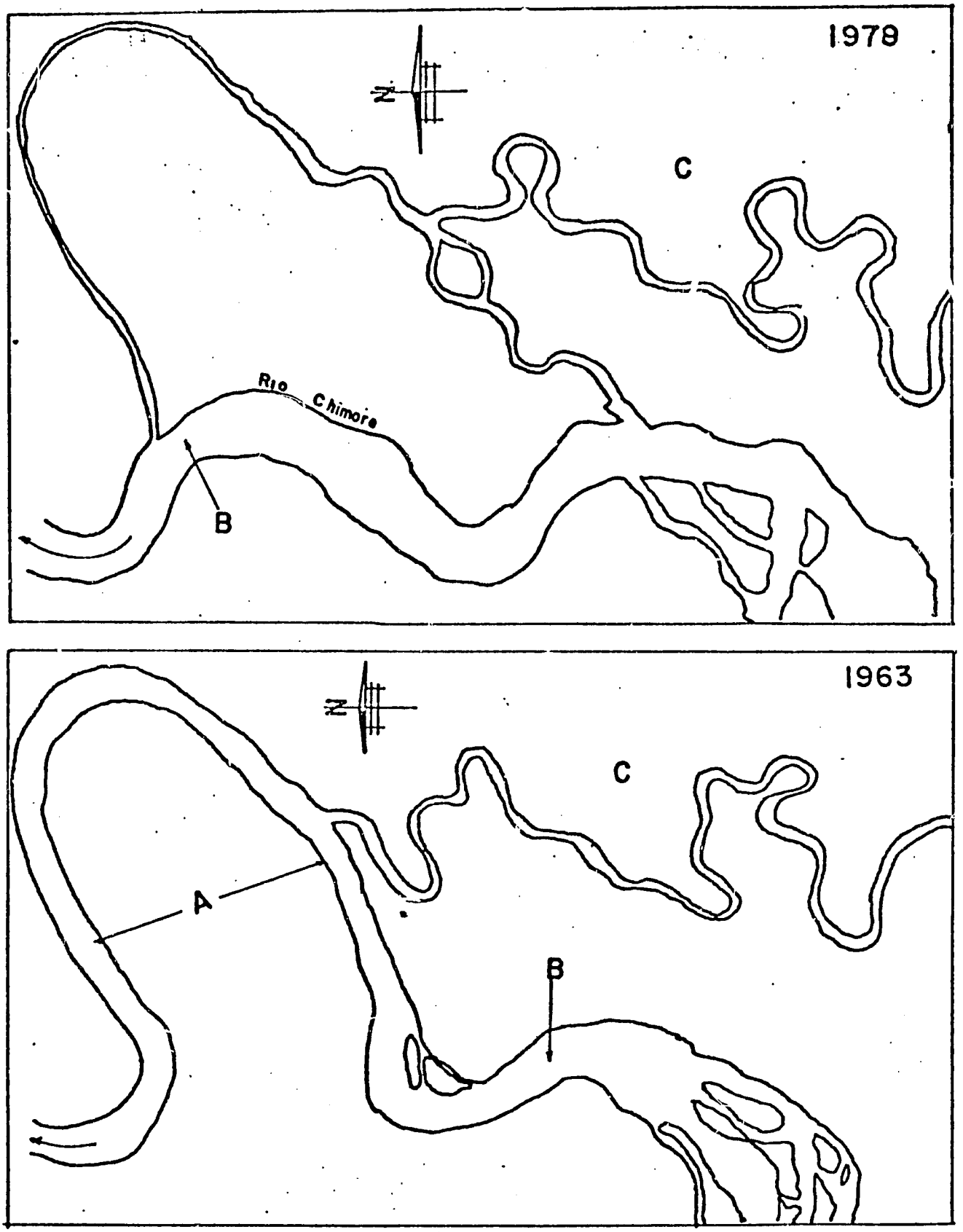


Fig.10. Changes in the course of the Chimoré River between 1963 and 1978, based on air photos, showing: (A) meander which has been abandoned, (B) movement of braided section of the river further downstream, filling in the alluvial suspended-load channel with coarse sediments, and (C) numerous changes in the course of the meandering tributary.

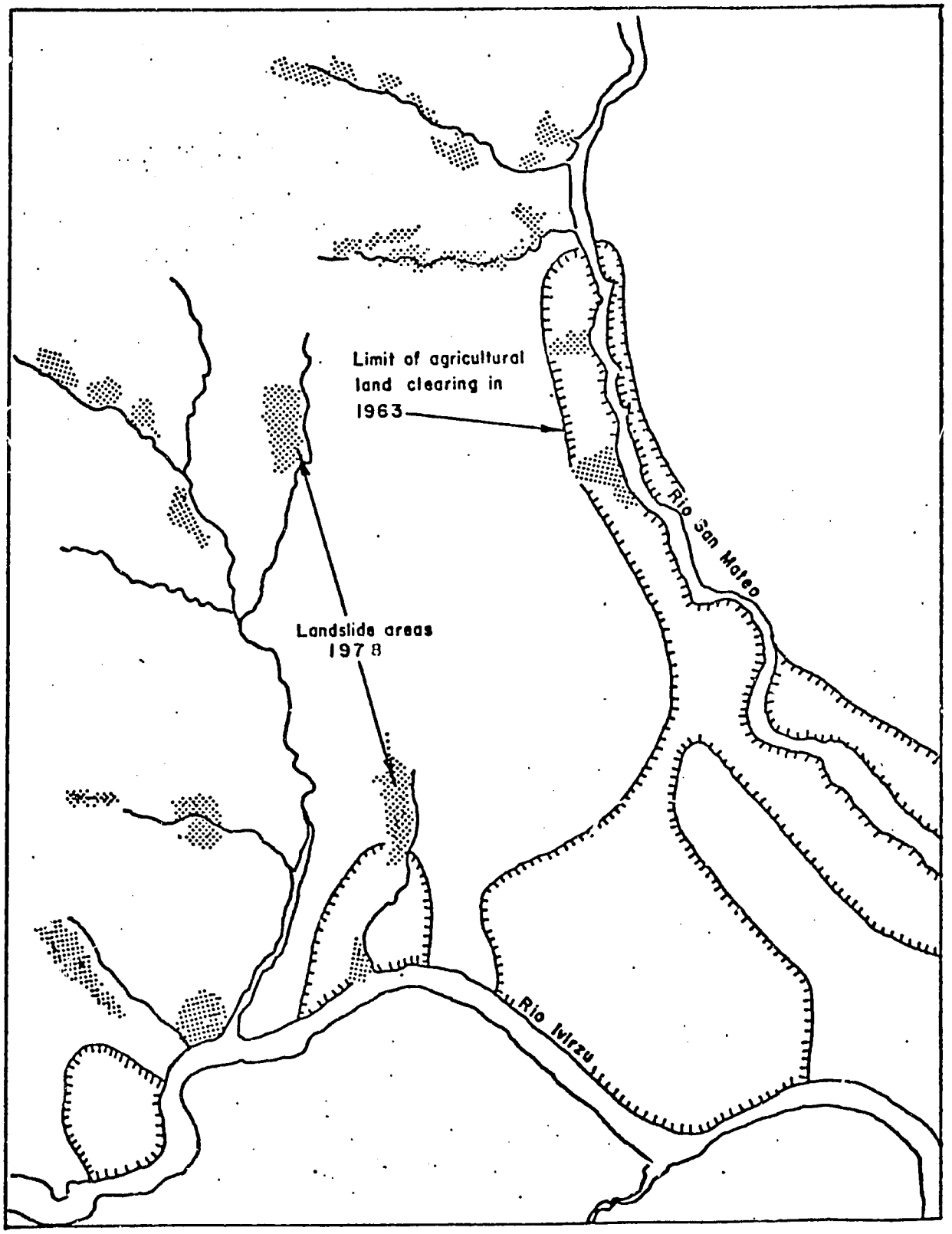


Fig. 11. Diagram based on 1963 and 1978 air photos showing areas where approximately one-half or more of the land was cleared for agricultural use in 1963, and which had reverted to forest by 1978. Also shown are landslide areas which appeared in the 1978 photos, but not in 1963. Note that there is little correlation between the area of landslides and the area of agricultural development in this particular area.

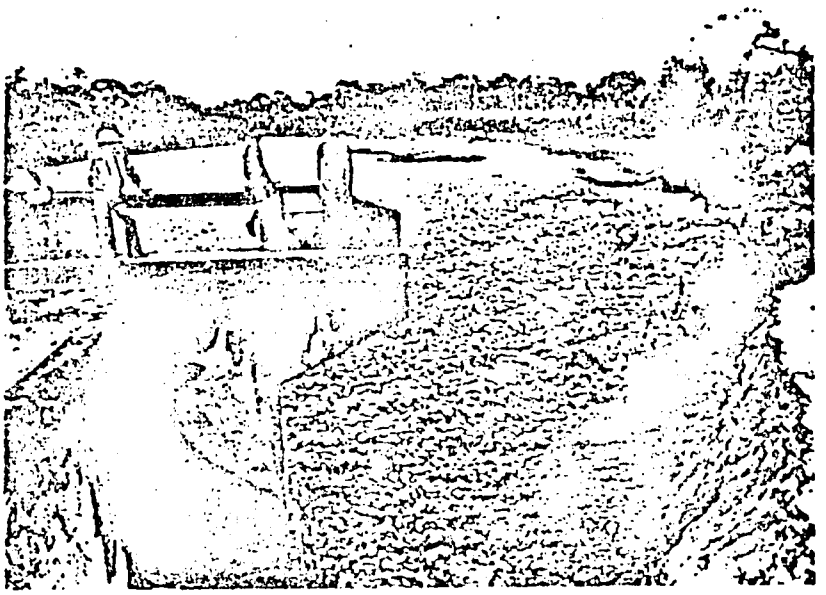
Alluvial Suspended Load Channel

The alluvial suspended load channel occurs furtherest downstream and is characterized by deep mandering channels which have developed in alluvium containing fine-grained sediments (i.e. silt and clay). Because flow velocity in rivers is faster at the bottom that at the riverbanks, there is a natural tendency for rivers to cut relatively deep channels rather than to erode laterally. These river channels are important from the aspect of navigation and fisheries.

Meandering rivers are continually eroding the banks on the outer edges of river bends, and sediments are continually being deposited as point bars on the interior side of bends. New channels are cut across meanders from time to time, and the old meanders tend to either fill with sediments or remain as "oxbow" lakes. The erosion processes occur very rapidly in the Chapare, and major changes in river courses are evident in comparing 1963 and 1979 air photos (see Figure 9). Todos Santos was formerly the principal commercial center in the Chapare, based on river traffic from the Beni. However, changes in the course of the Chapare River and flooding in 1967 virtually destroyed the town, and commercial river traffic moved to Puerto Villarroel (MASI, 1979).

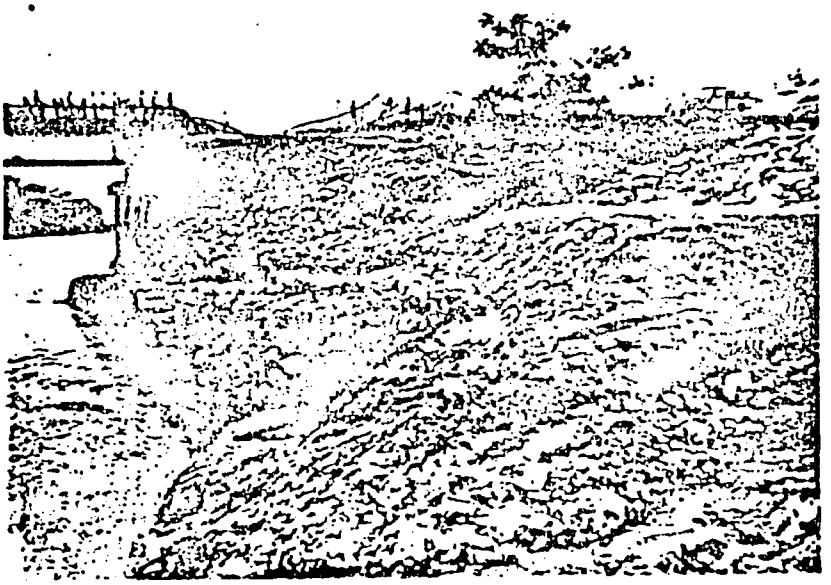
BRIDGES AND CULVERTS

As a result of heavy rainfall on January 14, the following five bridges failed: Eteresama, Vinchuta, Eñe, Chimoré, and Ivirgarsama. Photos 1 through 4, which were taken on 15 and 16 January, illustrate the problems at four of these bridges. All bridge failures were caused by erosion of the abutments. Bridge abutments are located in zones of active riverbank erosion, and the abutments and approach causeways had inadequate protection (or no protection at all) against hydraulic scour. Erosion of the abutments at the Matamojo and Mariposas bridges has also occured and will lead to failure in the future if not controlled.



1. ETERESAMA

Photo 1. Erosion of bridge over Rio Eteresama (view looking upstream). Steel Pilings supporting this abutment are exposed (not shown in photo). Note that the entire left bank of the river at this point is being actively eroded.



2. VINCHUTA

Photo 2. Erosion of bridge across Rio Vinchuta (view looking downstream). The gabions which have been installed do not extend to the bridge pilings, and also are not high enough to prevent erosion.

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Photo 3. Erosion at Rio Eñe bridge, view looking upstream.

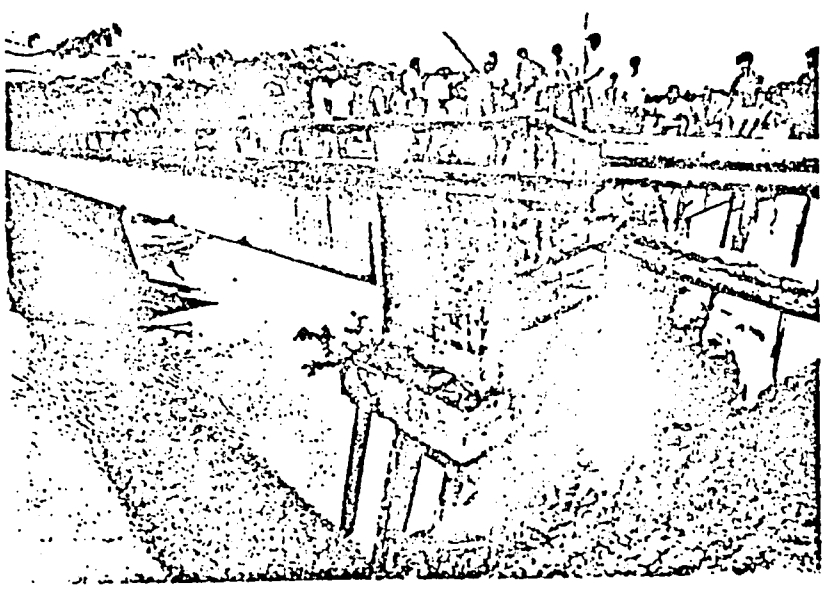


Photo 4. Bridge across Rio Icersama, view looking downstream. Note that several pilings are simply hanging in mid-air. Approximately 50 loaded trucks crossed this bridge a few hours after this photo was taken, crossing the eroded section on the temporary log span which is seen under construction in this photo. The truckers subsequently dismantle this bridge and dragged the logs to the next washed-out brid (Rio Chimoré) to repeat the bridge-building process.

Although all bridge spans reamain intact at this time, erosion from the January 14 storm was sufficiently severe to pose a structural hazard to all of these bridges. The structural hazard is particularly severe at the Icersama bridge: pilings supporting the abutment are completely exposed, and several of the piles are hanging in mid-air. Settlement of this span is already occuring and additional scour could cause the main span to collapse. This could effectively isolate Ivirgarsama and Pto. Villarroel from truck traffic, since the river bed consists of sand (trucks will become stuck) and the river is too shallow for a ferry operation.

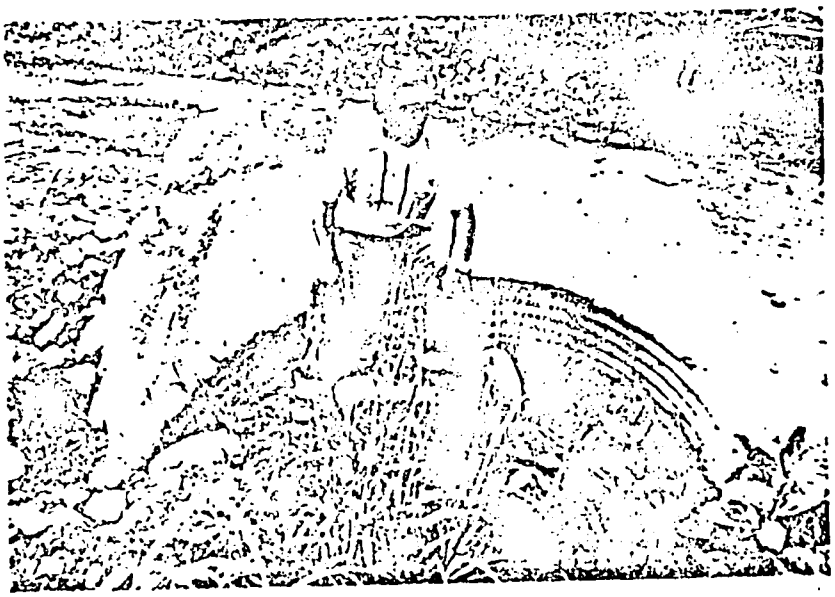
The Servicio Nacional de Caminos has been placing fill in the eroded sections as a repair measure. Fill placed at the Río Eñe bridge following the December flood was completely washed out on January 14. Without protective structures which are installed to sufficient depth to prevent undermining by scour, (such as well-placed gabions of properly sized stones) these bridges will continue to wash-out with every major rainstorm. A more permanent solution would be to extend the bridge spans across the eroded areas.

The Servicio Nacional de Caminos already has financing available to repair the Chimore bridge. As a very rough estimate, it would cost approximately $US 320,000 to construct adequate gabions at the four other failed bridges. Extension of the bridge spans at these same four sites would cost on the order of $US 800,000. The latter solution is recommended. (Cost estimates obtained from Ing. Conrado Camacho, Servicio Nacional de Caminos, Cochabamba).

As a rough count, approximately 10 culverts failed between Ivirgarsama and Eteresama, Two principal caused of culvert failure were observed. First, footings of the downstream headwalls have not been constructed to sufficient depth. As a result scour has undercut the footing and caused collapse and progressive erosion of the culvert (See photos 5 and 6). This problem

5.

Photo 5. Failure of culvert between Villa Tunari and the Rio Vinchuta.



6.

Photo 6. Photo of portion of downstream retaining wall protecting the downstream face of this culvert against erosion. Note that this headwall was embedded no more than 2 feet into the soil (stained concrete on left side of photo). Water undercut the headwall and caused collapse of this culvert.

would be solved by constructing deeper footings.

Second, some culverts have become clogged with debris causing water to overflow and erode the road. This can be remedied by installing a concrete road section (swale) at culverts where this has been a problem, thereby permitting floodwaters to overflow the road without washing out the road and culvert.

ISSUES AND RECOMMENDATIONS

CLIMATOLOGICAL STATIONS

Although there are several climatological stations in the Chapare, the data from these stations are unreliable. Several stations are regularly unattended over the wekends, and in other instances data are obviously in error. There is little quality control on the field data which is being collected, and much of the data which has been collected has not been tabulated into a reliable and usable format.

Quality control measures should be implemented at all stations. Specifically, (1) field technicians should be properly trained and supervised, (2) data should be collected on a daily basis, (3) any station not meeting quality control standards should be eliminated since there is little sense in collecting erroneous data, (4) existing data should be tabulated (preferably using a computerized data base), the data should be checked for quality, and records with obvious errors should be eliminated.

As a minimum, stations should be maintained at the following sites to support proposed agricultural production models: Chipiriri, Senda B, Valle Ivirsu. The following data should be collected at these stations: daily precipitation, pan evaporation, relative humidity, maximum and minimum temperatures,

hours of sunlight, and wind speed and direction should be recorded using a recording anemometer.

FAILURE OF BRIDGES

Five bridges were washed out on 14 January, and the structural integrity of all of these bridges is threatened. In every case these bridges have washed out due to inadequate protection of the bridge abutments against lateral erosion and scour. These bridges will continue to wash out every time there is high water, and structural collapse could occur, unless major repairs are undertaken.

It will be necessary to install gabions or other structures to protect bridge abutments and approach causeways from erosion. Cost of this project is approximately $US 320,000 for four bridges. A more permanent measure would be to extend the bridge spans; this would cost approximately $US 800,000 for four bridges. This should be included as a component of the USAID financed Caminos Vecinales II project. Separate financing has already been obtained by Servicios Nacional de Caminos for the Chimoré bridge.

Approximately 6-10 major culverts have been destroyed by flooding. When these culverts are replaced, they should be constructed to prevent failure by scour and overflow (as explained previously in the text).

EROSION

Erosion rates are high in the upper watershed within the Chapare region due to high rainfall and naturally unstable sedimentary rocks. All lands in this area above approximately 500 m MSL elevation should be strictly protected to prevent an increase in the naturally high erosion rates.

Erosion is not anticipated to be a significant problem in the areas of flat topography, which comprises the largest portion of the Chapare region.

FLOODING AND EROSION BY RIVERS

It will not be feasible to control the flooding and meandering of the rivers in the Chapare area, both of which occur as a result of natural hydrologic/geologic processes. The only feasible strategy will be to avoid development in areas which are most prone to flooding and erosion by rivers, and to adjust agricultural production cycles to minimize the potential for damage. Riverbank vegetation should be maintained to help impede riverbank erosion.

Through a more detailed study it would be possible to identify areas with high flooding and erosion potential. However, the scale of the project contemplated does not warrant a study of this type. Rather, knowledge of local residents on areas historically subject to flooding should be used as the primary source of information.

NAVIGATION

The Ichilo River is the principal navigable river in the región, and Puerto Villarroel is the principal port. The Ichilo is navigable as far upstream as Pto. Grether. The other rivers in the area are also navigable in their meandering downstream reaches (alluvial suspended load channels, as described previously).

None of the contemplated agricultural activities is expected to have a significant effect on river navigability.

HYDROPOWER

A rural electrification project for the Chapare has been developed by Empresa Nacional de Electricidad S.A. for financing by BID. This project contemplates extension of lines to the Chapare from the existing electrical grid, rather than construction of new hydropower generation facilities in the zone (Empresa Nacional de Electricidad S.A., 1982).

ON-FARM WATER MANAGEMENT

The topography of farms in the Chapare is extremely varied.

Nonetheless, two water management techniques may have promise on some farms.

The combination of high rainfall and limited topographic relief over large areas results in poor drainage. The production of some crops on some farms could undoubtably be facilitated by providing drainage ditches. However, large scale drainage systems are not appropriate in the Chapare; it is expected that they would rapidly become clogges with sediment and vegetation. Any drainage works should be oriented to small on-farm ditches.

Extreme moisture, plus the limited topographic relief, suggests that the production of paddy rice would be feasible by constructing systems of contour dikes. The exact layout would vary from one paritiular farm to another. Several model farm experiments could be implemented to demostrate and refine water management techniques for paddy rice production in the Chapare, and to evaluate economic feasibility. Because significant investment in dikes will have been made, and since areas most suitable for paddy rice will be limited, rice cultivation will be required in successive years on the same field and will require fertilizer inputs. At present no paddy rice is produced in the Chapare because farmers feel that existing rainfall inputs are adequate. Fertilizer is also no normally applied to rice in the Chapare.

PUBLIC WATER SUPPLY

A high incidence of sanitation related diseases are reported in the Chapare. Public water supply facilities are available only at the principal settlements in the Chapare region, and the quality of water from the existing water supply systems in suspect. In some areas (e.g. Ivirgarsana) a shallow public water supply well has been recently contructed at the center of town. Unfortunately, this also corresponds to the area of greatest contamination, which may prejudice the quality of the well water. Rural settlements tend to lack water supply or other sanitation facilities of any type.

Groundwater is the preferred source of water supply, because a properly developmed groundwater source provides good protection against bacteriological contamination. Geologic conditions, suggest there is a good potential for development of groundwater supplies in the zone nearer the foothills. However, moving north toward Pto. San Francisco and Todos Santos poorly-permeable clays tend to predominate, making the development at groundwater much more problematic in this area.

Implementation of water supply projects in the Chapare are proposed as a separate USAID financed Rural Sanitation project.

PROGRAM COMPONENTS

Separate projects are being a developed for electrification, public water supply, and road/bridge reconstruction. Therefore, no program components are identified for these activities.

It will be important to obtain reliable climatological data from areas where agricultural trials are being undertaken. This will not only be important to interpret results of agricultural trials in the Chapare, but will also provide the climatological data base necessary to extrapolate results to other areas.

Climatological stations already exist in areas where agricultural trials are being recommended, but the accuracy of the data from these stations is limited by the lack of maintenance of the equipment and the lack of supervision and quality control. Also, existing facilities in the Servicio Nacional de Meteorología e Hidrología are inadequate to process and analyze climatological data on a timely basis.

To overcome these bottlenecks, and in order to obtain reliable climatological data in a format which can be readily analyzed, it is recommended that a climatologist be hires and be supported by a microcomputer and with access to a vehicle. This climatologist should work in conjunction with SNMH and CORDECO, but should

remain directly responsible to the organization which actually administrates the Chapare project. The data collection and analysis methods developed in this project would be transferred to SNMH over the duration of the project.

The following seven climatological stations would be upgraded:

Chipiriri	Puerto Villarroel
Senda-B	Eteresama
Villa Tunari	Todos Santos
Valle Ivirsa	

Additional equipment would be purchased as need to collect the following data at each station: (1) total daily precipitation, (2) precipitation intensity, (3) relative humidity, (4) high & low temperature, (5) pan evaporation, and (6) wind speed and direction.

Techinical assistance would be provided at project initiation to help design data reporting procedures and computerized data-management techniques which are compatible and efficient. The proposed project budget is included as Table 1.

Table 1. Proposed climatological data collection budget ($US).

	COST PER YEAR					
	1	2	3	4	5	TOTAL
1. Climatologist ($250/mo)	3,000	3,000	3,000	3,000	3,000	15,000
2. Micro computer	5,000					5,000
3. Use of vehicle (10,000 mi/yr at $.25)	2,500	2,500	2,500	2,500	2,500	12,500
4. Climatological equipment (7 stations, $2,500 ea.)	17,500					17,500
5. Technical Assistance	10,000					10,000
	38,000	5,500	5,500	5,500	5,500	$60,000

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