14th Congress of the International Society of Photogrammetry, Hamburg 1980 .
Commission VII - Working Group VII/2
Presented Paper:

DESERTIFICATION - GENERATING HYPOTHESES FROM AERIAL PHOTOGRAPHS

Author: Laura E. Pla, Departamento de Investigación, Instituto Universitario de Tecnología de Coro, Falcón, Venezuela.

ABSTRACT

Changes occurred between 1946 and 1975 in the vegetation cover of northwestern Falcón State, Venezuela were identified and analyzed using medium scale aerial panchromatic photographs.

A key was constructed with 25 categories based on horizontal distribution of vegetation and percentage plant cover.

Photo interpretation of the 1946 mission resulted in 87 units, which were mapped at a scale of 1:250 000. The same procedure was followed with the 1975 mission. The ground check was done in 1977.

Each unit is described and changes occurred are identified. The twelve most frequent events are pointed out and ten hypotheses are formulated to explain the causes of desertification.

INTRODUCTION

Desertification is the decrease or destruction of the biological potential of the land which in the long run can lead to desert-like conditions. It is a phenomenon involving climate, animal and plant communities, soils and man. Even though desertification can develop from natural causes alone,experience has shown that more often than not it originates under excessive pressure of human use or changes in land use acting on an inherently fragil dryland ecosystem. It is a self-acceleratingprocess and degradation of vegetation, soil and water can easily turn irreversible. Even if the productivity of natural resources is only partially lost, quite often this productivity is totally lost to human use systems. Thus the necessity to diagnose desertification at an early stage and monitor a range of processes involved in its occurrence.

Changes in perennial plant cover during the dry season is an important indicator of desertification. Losses of natural vegetation occur when pastoralists increase their herds or farmers encroach on rangelands or plough land unsuitable for agriculture. This pressure on the land is a consequence of social and economical exogenous factors which arrise from the need to increase production and desertification can be stopped or slowed down only by eliminating the causes of these factors. However, an early detection of degradation through the monitoring of vegetation changes may call the attention to fundamental environmental problems.

A knowledge of the evolution of the vegetation and of the history of management of the area may help not only in diagnosing and arresting the social and economic processes that lead to it, but also in policy-making and planning land use under conservative strategies.

The trends in vegetation changes over long periods can be observed by comparing enclosures with the surrounding areas. However, in most regions, particularly in underdeveloped countries, use and misuse of land has started long before enclosures were considered. On the other hand, the utilization of aerial photographs by specialists such as agronomists, geographers, geologists, has traditionally been limited mostly to existing land attributes mapping. In the present paper, aerial photointerpretation is used to compare the vegetation cover at two periods 29 years apart and draw hypotheses about the causes of desertification to be tested by further research.

Background

There are various methods to compare observations at two different times by photo interpretation and these can be grouped in two approaches: those which compare sample points and those which analize the whole area covered by the aerial photo mission.

Dill (1959) discusses two methods to study land-use changes. At a medium scale (1:20 000) contact copies can be used to measure areal changes in small areas. The study of changes in large areas can be done by comparing photomosaics or photoindices at 1:60 000 scale. The author suggests that the error of measurement in uncontrolled mosaics is smaller than that of extrapolating sample data.

In a study of road and highway construction impact on the environment Wagner (1963) compared aerial photographs taken some years apart. His methods could be used to assess urban and industrial development as well as natural resource changes in an area.

Zeimetz and her group, working for the U.S. Economic Research Service, have developed a method to study the changes occurred in agricultural lands (Zeimetz et al, 1976). The method was applied in 53 States. They used photographs at various scales. Twelve land-use categories were established and the sample sites were statistically selected. The results of the photo interpretation were checked up on the data from the 1960 and 1970 censuses and on field surveys. A similar methodology had been used to assess the trends in land use of the Mississippi Valley (Frey and Dill, 1971).

Recently, new techniques have been developed to compare aerial photographs, such as the densitometric analysis of Brother and Fish (1978).

The Agency for International Development (AID) has started a desert monitoring project using Landsat, in the western Sahel (Paul, 1978). The AID has been working in several countries of America, Asia and Africa in cooperation with local technicians and engineers to study trends in landscape evolution. The major question is what the relation will be between self reliance and performance in the underdeveloped countries (e.g. Smith et al, 1978).

Most of the venezuelan territory (80%) is covered by standard topographic maps at a scale of 1:25 000, with reduced versions 1:100 000 and 1:250 000. The base maps have been compiled from white and black imagery. However, few studies on land use and land cover have been published yet using remote sensing techniques (COPLANARH, 1975; Guevara et al, 1977).

The Study Area

The present study covers an area of approximately 3 920 km^2 in the northwestern corner of Falcón State, Venezuela. It encompasses part of the coastal desert of north South America and the southern Caribbean (Lahey, 1975).

Several authors have described the vegetation and environment of Falcón State (Hueck, 1960; Tamayo, 1964; Ewell & Madriz, 1968; Smith et al, 1973). The methods and classification systems used in each study differ. However, they all agree with respect to the general pattern of vegetation distribution. The coastal fringe is characterized by contracted distribution, in which xerophytic and halophytic species form patches in a matrix of bare ground. Plant distribution becomes even and its percentage cover increases to the south. Vegetation height also increases in this direction and closed forests are encountered next to the southern boundary.

The climate is characterized by remarkable thermal uniformity, with an average yearly temperature of 27-28°C. The only two meteorological stations record average yearly precipitation of 486 mm in the east and 529 mm in the center, with rainy seasons in May and August-November. It has been estimated that the potential evapotranspiration more than doubles the average yearly precipitation (Pla et al, 1978).

The area stretches along two Geomorphic Provinces: The Coastal Plains and The Coastal Piedmont (Matteucci et al, 1979 a). The Coastal Plains are characterized by a uniform topography to the east and the west and an irregular one in the central portion. In the first case, the aluvial plains have been formed by the deposition of materials carried by the rivers ending in the Golfo de Venezuela and are locally gullied by recent erosion. In the central portion the plain has been uplifted and tilted and then dissected by differential erosion. The altitude varies from sea level to 80 m and the slope from 0 to 6%. The altitude increases up to 400 m and the slopes steepen to 25% to the south, in the Piedmont.

MATERIALS AND METHODS

The first step consisted in the development of a descriptive key in order to interpret the categories in the 1946 photographs. The key should permit comparisons of aerial photographs taken 29 years apart. A previous study of the vegetation of Falcón State was used as a basis for the key construction. During this study considerable background experience and general knowledge of the region was acquired, which permited a fair recognition of the vegetation elements and other features of the photographs. However, the vegetation had been classified according to structure, component species periodicity and special morphological characteristics (Matteucci et al, 1979 b). These attributes would not be recognized in the photographs. Since field records for 1946 do not exist, the results had to rely entirely on photo-interpretation. Thus, the categories were transformed taking into consideration criteria easily recognized in the photographs, such as type and percentage plant cover, predominant life form and height. Accordingly, the results of the 1975 photo interpretation were modified to respond to the new key. The classification categories and symbols are shown in table I.

Table I: Classification categories

Cover Type	Symbol
Bare ground	
Sandy areas	DA
Flooded areas	DI
Contracted vegetation	
Low scrub or herbaceous vegetation, patches around 100 m^2	CH
Low woody vegetation (scrub, less than 5 m tall)	
Along water courses	CAA
Patches up to 3 000 m^2	CAM
Homogeneous vegetation (plants evenly distributed)	
Low shrub or herbaceous vegetation	HH
Low woody vegetation (scrub, less than 5 m tall)	
Less than 50% coverage	HAR
More than 50% coverage	HAD
Tall woody vegetation (woodlands or forests, taller than 5 m)	
Less than 50% coverage	HTR
More than 50% coverage	
Open canopy	HTD
Closed canopy	HB
Edaphic formations	
Mangrove forests	M
Galeria forests	G
Agricultural and pastoral lands	C
Urban lands	U

Aerial photo missions 4-4A of 1946 at a scale of 1:40 000 and 0201106 of 1975 at a scale of 1:50 000 were used. Both missions used panchromatic film and were flown in the dry season.

Only the central portion, within the effective area boundary, of the alternate photographs was interpreted and transferred to the base maps at a scale of 1:100 000 by means of a reflecting projector (Kail, model K56). The base maps are compiled by photogrammetric techniques, edited and reproduced by Cartografía Nacional. The minimal area considered was 25 ha. By means of the same projector the maps were reduced to a scale of 1:250 000. Important details which would be lost at this scale were reproduced apart at a larger scale.

The cartographic units resulting in the 1946 map were numbered and a full description was given for each. These units were compared one at a time with the results obtained from the 1975 photo interpretation. The differences encountered with respect to percentage cover, shape and area were pointed out and several hypotheses were presented to account for each one of the changes noted. It is expected that further research will explain the major causes of vegetation evolution in the region and permit the development of conservative management practices on the basis of the past history.

RESULTS

The photo interpretation of the 1946 mission resulted in 87 units which show relative homogeneity attending to texture, tone and pattern. The complete listing of units and their cover type in 1946 and 1975 are given in table II. Their distribution in both years is shown in figures 1 and 2.

TABLE II: Cover type of each unit in 1946 and 1975

U	Cover Type 1946	Cover Type 1975	U	Cover Type 1946	Cover Type 1975	U	Cover Type 1946	Cover Type 1975
1	DI	DI-CH	31	G	G	60	HAD	HAD
2	CH	CH	32	HAR	HAR	61	HAD	HAD
3	CH	CAM	33	HAR	HAR	62	HAD	HAD
4	HH	HH-CAM	34	HAR	HAR	63	HAD	HAD
5	HH	HH-CAM	35	CAA	CAA	64	G	G
6	CAA	CAA	36	HTD	HTR	65	G	G
7	CAA	CAA	37	HTD	HTR	66	HAD	HAD
8	CAA	CAA	38	HTD	HTR-C	67	HAD	CAA-CAM
9	HAR	HAR	39	DA	C-DA	68	CAM	CAM
10	HAR	HAR-DA	40	HB	HTD-C-HB	69	HAR	HAR
11	HAD	HAR	41	HB	HTD-C	70	HAR	HAR
12	CAM	CAM	42	HB	C	71	HAR	HAR
14	HAD	HAD	43	HB	HTD	72	HTD-HB	HAD-HTR-HTD
15	G	G	44	HTD	HTD	73	DI	CAM
16	CAA-CAM	CAA-CAM	45	HTD-HB	HTD-C-HAR	74	HB	HTD-C
17	HAR-HAD-HTD	HAR-HAD-HTD	46	G	G	75	HAD	HAR-HTR
18	HTD	HTD	47	HB	HTR-C	76	HTD	HAR-HTD
19	HAD	HAR	48	HB	HTR	77	HAR	HAR
20	HAD	HAD-HAR	49	HB	C	78	HAD	HAD
21	HAR-HAD-HTD	HAR-HAD-HTD	50	CAM	CAM	79	HTD	HAD
22	HAR-HAD-HTD	HAR-HAD-HTD	51	HTR	HTR	80	HH	CAM
23	HAR-HAD-HTR	HAR-HAD-HTR	52	HB	HTR	81	HTD	HTD-HTR
24	G	G-C	53	HAR	HAR	82	HAD	HTR
25	HAR-HAD-HTD	HAR-HAD-HTD	54	CAR	CAR	83	DA	DA
26	HAD	HAR	55	HAD	HAR	84	HTD	HAD
27	M	M	56	HTD	HTD	85	HTD	CAM
28	HAR	HAR-C	57	G	G	86	HAD	HAD
29	HTD	HTR-HAR	58	HAR	HAR-HAD	87	HH	CAM
30	HTR	HAR-HTR-C	59	HB	C-HB	88	HAD	HAR

The findings from both airphoto interpretation and field study indicate that the major changes occurring in the landscape in the intervening period are:

-Decrease in percentage plant cover in most of the forests (e.g. Units 29 40, 47 and 48). In some units the tree species have almost disappeared, while in other their numbers have decreased (Figure 3).

-Advancement of secondary succession on the formerly cultivated fields (conucos: subsistence seminomadic agricultural settlements), especially to the north of the main road, which was constructed after 1946 (e.g. Units 18, and 20) (Figures 4 and 5).

-Evidence of previous settlements in the occurrence of numerous abandoned houses.

-Southward shifting of the boundary between contracted and evenly distributed vegetation (e.g. Units 16 and 88).

-Loss of small forest communities to the north (e.g. Units 67, 76 and 85).

-Increase in cultivated area from 30 000 to 200 000 ha. This expansion has been at the expense of unused natural vegetation, mainly to the west of the study area, in the vecinity of Dabajuro city (e.g. Units 41, 49 and 59) (Figures 3 and 5).

-Deforestation along the oil pipeline built after 1946. The deforested unit is approximately 100 m wide and thus was not represented on the map at a scale of 1:250 000 (Figure 6).

-Loss of some herbaceous or low shrub vegetation units (e.g. Units 4, 5 and 80).

-Settlement of conucos by almost every water course, on meander scars and at the expense of the galeria forests (e.g. Units 15, 24 and 31) (Figure 7).

-Increase in wasteland area. Bare ground occurs as small patches within units of high plant cover along the boundary between contracted and evenly distributed vegetation (e.g. Unit 10) (Figure 8).

-Accumulations of sediments deposited where streams empty into the Golfete de Coro (e.g. Units 1 and 2).

-Contrary to what was beleived, the coastal sand dunes are not encroaching on the neighbouring shrublands or woodlands. This may be occurring at a very slow rate and in such case it would not be perceptible in 29 years at the scale of the present study.

CONCLUSIONS

From the changes observed through photo interpretation and field work, ten hypotheses are formulated. In each case guidelines are given for their test.

-Ecosystems degradation next to the boundary between contracted and evenly distributed vegetation has been caused by man's activity in the last decades and their recovery would be difficult if not impossible. The test of this hypothesis requires the study of the social subsystem to establish the trends in the land use pattern and management practices. Studies of plant succession in enclosures could give an estimate of the rate of recovery.

-The conversion of agricultural or pastoral lands into wastelands is due to ecosystem mismanagement. The study of the management history in former cultivated and grazing lands and an environmental impact assessment in natural areas of similar physical characteristics would be required in this case.

-Pasture establishment to the west of the study area has not affected the neighbouring forests and the existing management practices are suitable for pastureland conservation. The comparative study of the pasturelands in the area and the monitoring of the neighbouring ecosystems are required.

-In the already exploited forests further harvests could be carried out without their depletion. It would be necessary to conduct a forest inventory to estimate stand volume, condition and growth and to determine the trend in timber yield during the last decades. This information could help in planning corrective measures to ensure sustained production over the long term.

-The denudation of the slopes is due to mismanagement. It would be required to trace back the history of management of these wasteland areas and to determine which would be the most suitable management practices or whether it would be better to protect the hillsides from use.

-Soil slides from denuded slopes will interfere with land use in the piedmont areas. The evaluation of the rate of release of materials from the source or storage sites would be required previous to planning land use in the lower areas. It is pertinent to know whether the rate of removal of material is likely to be affected by land use changes introduced here.

-Extensive use of rangelands by goats leads to ecosystem deterioration. In this region goats are the main protein source for people; however, alterations in the type of pastoralism practised, increase in herd size, changes in trends of market demands, etc. may enhance the pressure on the environment. It would be necessary to monitor desertification of rangelands and to investigate into the optimal carrying capacity of the grazing lands and the most suitable management practices.

-Shifting agriculture leads to denudation of the land. It would be necessary to study the evolution of agricultural lands in each particular unit, since changes toward wasteland may occur directly as a result of human use, indirectly or for reasons not related to man's use, depending on the physical attributes of the land, the microclimatic conditions, the size of the cultivated plot and the nature of the surrounding vegetation.

-In some of the deforested units desertification has reached an irreversible stage. The establishment of enclosures to protect the lower vegetation from trampling and browsing would permit the assessment of the regeneration rate of vegetation and the study of the succession of species that invade the enclosure. The failure to regenerate vegetation at a suitable rate may be a cause of desertification.

-The deterioration of vegetation that has occurred in the study area has been slow because the introduction of advanced mechanized technology has been checked by sociocultural factors. The conversion of marginal drylands from range use to agricultural use is one of the principal causes of desertification. In areas of marginal rainfall, where there is a pressure for the expansion of agriculture, there is a tendency to shift from hand cultivation to mechanized cultivation. An obvious consequence of such changes is the destruction or the degradation of perennial cover and the decrease in vegetation regeneration rate. It would be useful for planning of future land use to determine which is the most adequate agricultural technology to be applied in this semiarid area, or whether in the long run pastoralism would be ecologically more conservative.

REFERENCES

Brother, G.L. & E.B. Fish, 1978. Image enhancement for vegetative pattern change analysis. Photogramm. Eng. & Remote Sensing, 44(5): 607-616.

COPLANARH, 1975. Inventario Nacional de Tierras. Publicación N°44, COPLANARH, Caracas, Venezuela.

Dill, H.W., 1959. Use of the comparison method in agricultural airphoto interpretation. Photogramm. Eng., 25: 44-49.

Ewell, J. & A. Madriz, 1968. Zonas de vida de Venezuela. Ministerio de Agricultura y Cría, Caracas, Venezuela, 264 pp.

Frey, H.T. & H.W. Dill Jr., 1971. Land use changes in the southern Mississippi alluvial valley. 1959-69 Agricultural Economic Report 215, Econ. Res. Ser. USDA, Washington, D.C.

Guevara, G. & F.M. Serrano, 1977. La percepción remota. Trabajo especial de Tesis, Escuela de Geografía, Fac. Humanidades y Educación, Universidad Central de Venezuela, Caracas.

Hueck, K., 1960. Mapa de la vegetación de la República de Venezuela. Boletín N°7. Instituto Forestal Latinoamericano de Investigación y Capacitación Mérida, Venezuela.

Lahey, J.F., 1973. On the origin of the dry climate in northern South America and the southern Carribbean. In: Amiran, D.H.K. & A.W. Wilson (Eds.), Coastal Deserts: their natural and human environments, The University of Arizona Press, Tucson, Arizona, Pages 75-90.

Matteucci, S.D., A. Colma & L. Pla, 1979 a. Relieve y geología del Estado Falcón. Publicación del Instituto Universitario de Tecnología de Coro, Falcón, Venezuela, 89 pp.

Matteucci, S.D., A. Colma & L. Pla, 1979 b. La vegetación de Falcón. Publicación del Instituto Universitario de Tecnología de Coro, Falcón, Venezuela, 292 pp.

Paul, C.K., 1978. Internationalization of remote sensing technology. Photogramm. Eng. and Remote Sensing, 44(5): 625-632.

Pla, L., S.D. Matteucci & A. Colma, 1978. El clima de Falcón, Publicación del Instituto Universitario de Tecnología de Coro, Venezuela, 64 pp.

Smith, R., E. Ferrer & A. Chavez, 1973. La vegetación actual de la región Centro Occidental. FUDECO, Boletín Informativo N°3, Barquisimeto, Venezuela.

Smith, W.P., C.D. Burnside, E.A. Jones & H.G. Jerie, 1978. Photogrammetry in the Third World. The Photogrammetric Record, IX (52): 483-488.

Tamayo, F., 1964. Mapa fitogeográfico preliminar de la República de Venezuela. Ministerio de Agricultura y Cría, Caracas, Venezuela.

Wagner, R.R., 1963. Measure changes in land use around highway interchanges using air photos. Photogramm. Eng., 29: 645-649.

Zeimetz, K.A., E. Dillon, E.E. Hardy & R.C. Otte, 1976. Using area point samples and air-photos to estimate land-use changes. Agricultural Economic Research, 28(2): 65-74.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. Silvia Matteucci for advice and assistance in this study.

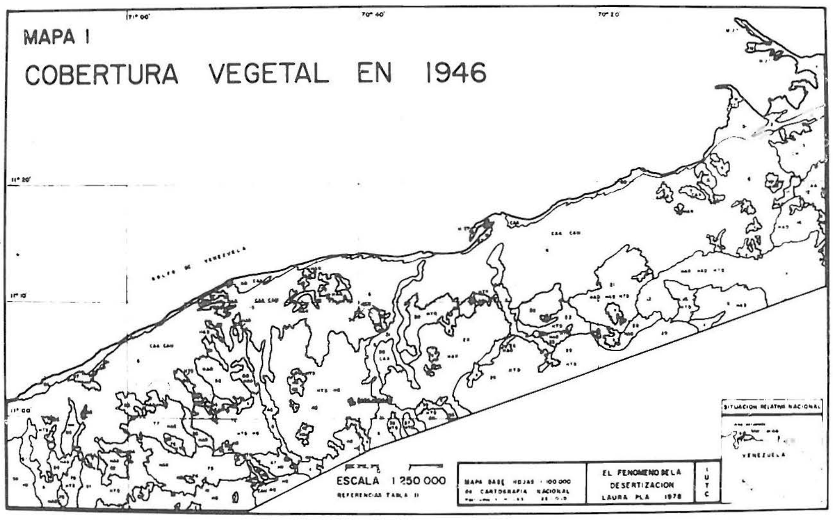


Figure 1: Land cover in 1946
(Definition of symbols in Table I)

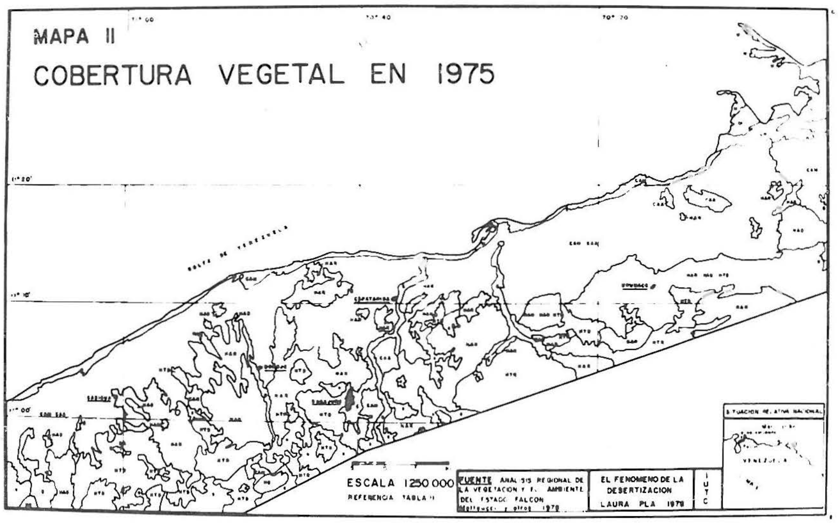
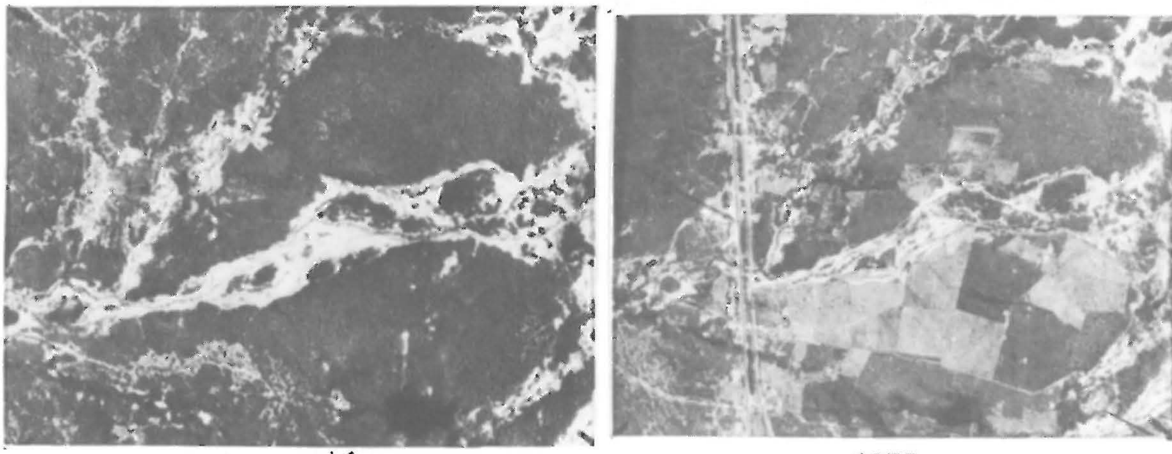
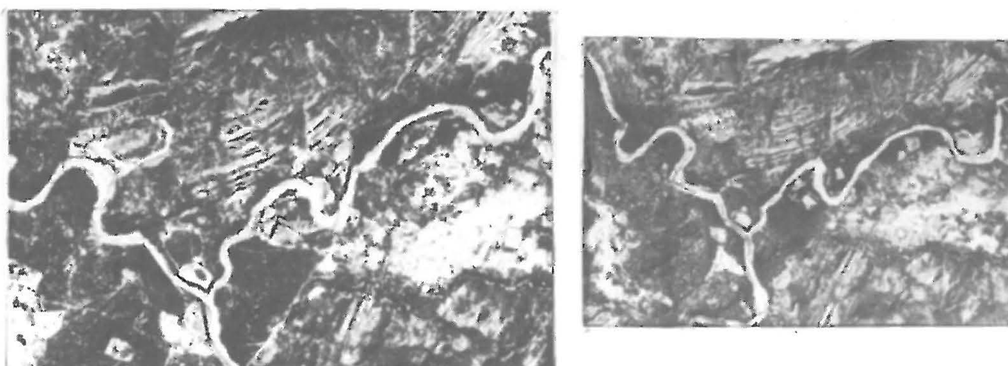


Figure 2: Land cover in 1975
(Definition of symbols in Table I)



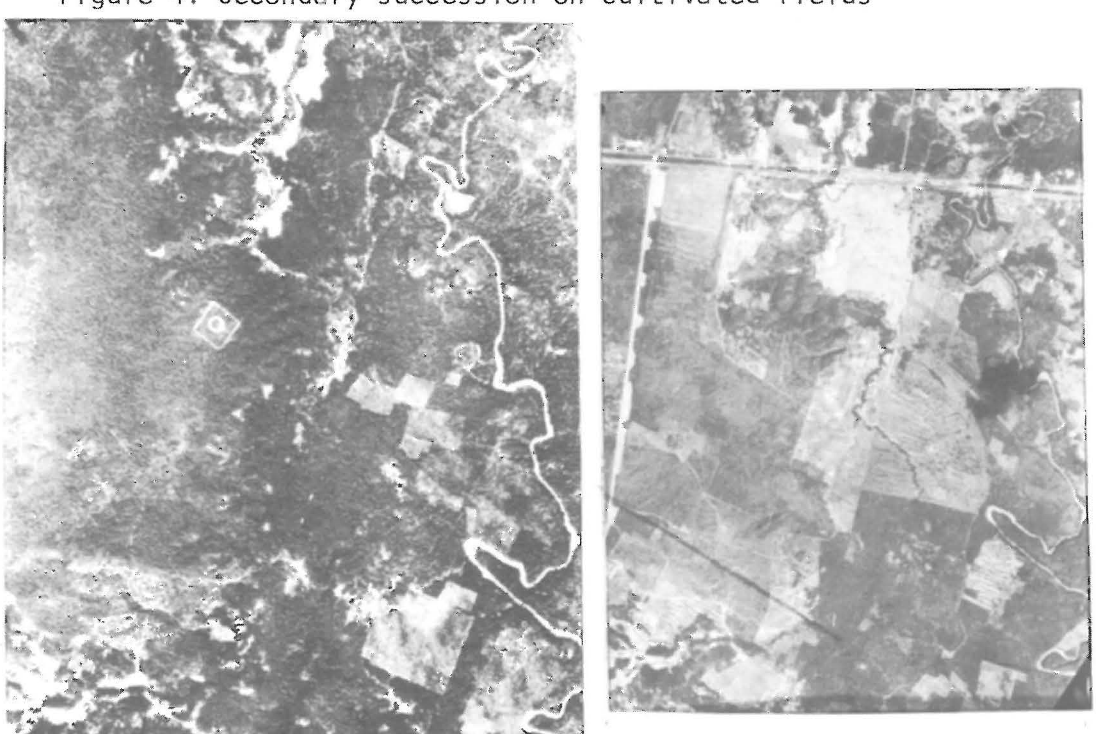
1946 1975

Figure 3: decrease in percentage tree cover



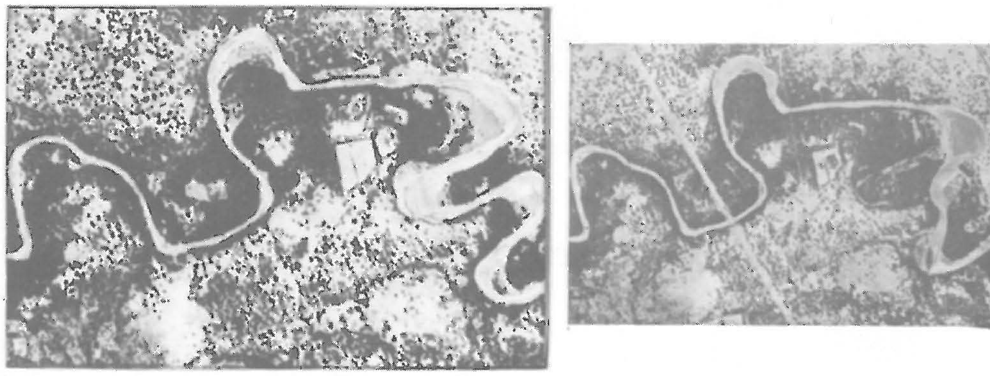
1946 1975

Figure 4: Secondary succession on cultivated fields



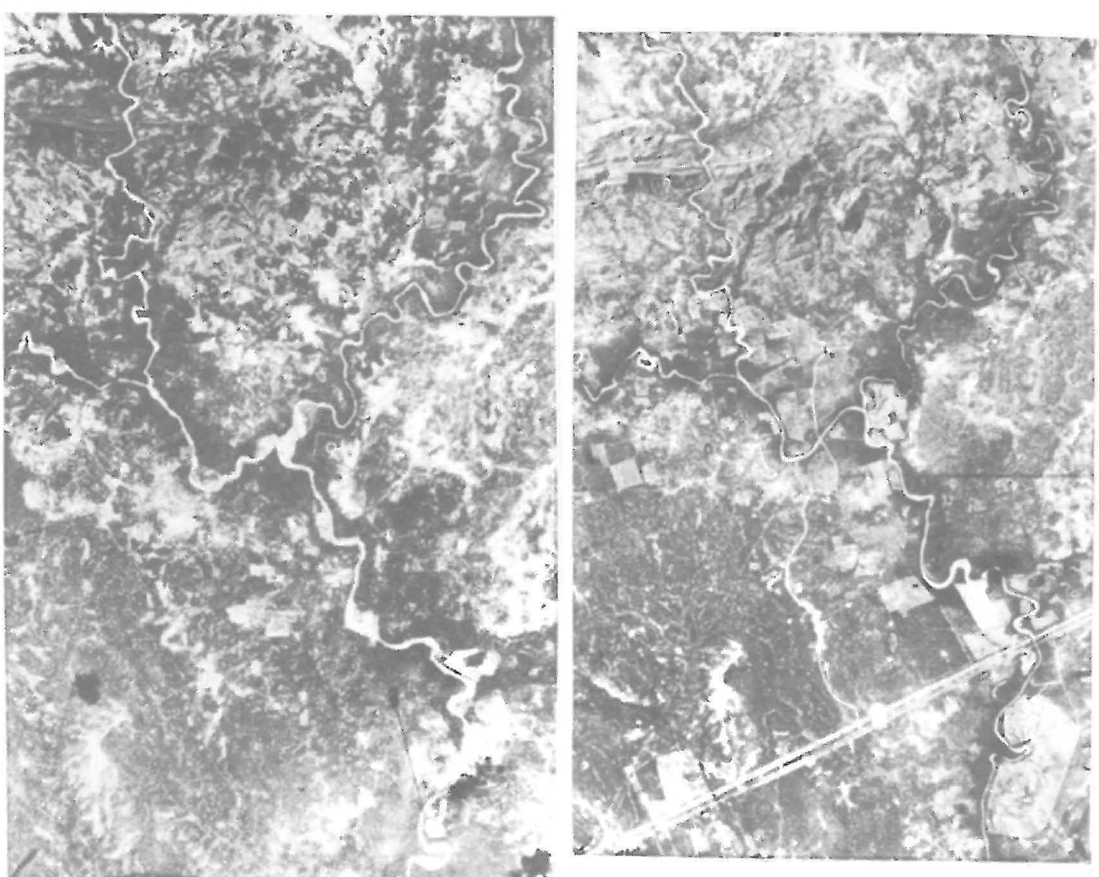
1946 1975

Figure 5: Expansion of agricultural lands



1946 1975

Figure 6: Deforestation along the oil pipeline



1946 1975

Figure 7: Settlement of conucos next to water courses

1946

Figure 8: Detail of Unit 10 at
a scale of 1:20 000
The white areas represent
the present natural vegetation
The black areas represent portions
of lost vegetation.
Dots represent areas where secondary
succession advances on wasteland.