respectively of the analysis object area, showing that there was hardly any change. Forests distribute sparsely on the mountain slope land at the east of analysis object area, while they are observed in bulk on the flat land in the south.

4) The plateau grassland was 41,000 ha. (19% of the analysis object area) in 1970's and 28,600 ha. (13% of the same) in 1980's, which correspond with 22% and 15% respectively, showing a trend of substantial decrease. The plateau grassland distribute concentratedly at the highland of mountainous zone in the east.
5) The grazing/grass land was 81,000 ha. (38% of the analysis object area) in 1970's and 92,000 ha. (43% of the same) in 1980's, occupying the largest share in the area. They correspond with 43% and 49% respectively of the analyzed area showing a trend of substantial increase. The grazing/grass land distributes extensively covering almost all of the low land in the west of analysis object area.
6) The agricultural forest was 22,500 ha. (10% of the analysis object area) in 1970's and 25,300 ha. (12% of the same) in 1980's, which correspond with 12% and 14% respectively of the analyzed area, indicating a trend of slight increase. The agricultural forest is concentrated at the low land in the north edge of the analysis object area.
7) Although the bare/waste land distributes among the grazing/grass land, its area is quite small, and no change is observed to it.
8) Farm land, city/town and snow/ice field are not observed in this analysis object area.

(7) Cauca

1) Since Cauca state has large area and low population density, there still remains the forest in the mountain zone (especially in the south). As the analysis object area is located centering around the mountain zone, the forest and and plateau grassland occupy the large part of it. Also, around the state capital Popayan, gazing/grass land is dominant, sharing substantial portion in the analysis object area.
2) The analyzed area in Cauca was 586,300 ha. in 1980's and 362,400 ha. in 1980's which are 98% and 60% respectively of the analysis object area of 599,800 ha.
3) The forest was 360,100 ha. (60% of the analysis object area) in 1970's and 191,900 ha. (32% of the same) in 1980's, occupying the substantial portion of analysis object area. In the ratio against the analyzed area, they are

respectively 61% and 53% indicating a trend of substantial decrease. In the north part of analysis object area, the forest distribute mixed with other land use on the slope land of altitude 35,000m or less along the main ridge of mountain range. In the south, the forests are covering all over the mountains of low altitude (1,500 - 3,000m).

4) Plateau grassland was 59,500 ha. (10% of the analysis object area) in 1970's and 28,600 ha. (6% of the same) in 1980's, both of which are 10% of the analyzed area, and no change is observed. The plateau grassland scatters at the highland of altitude 3,500m or more along the ridges of mountains such as Mt. Neva del Tolima.
5) Grazing/grass land was 137,000 ha. (23% of the analysis object area) in 1970's and 109,400 ha. (18% of the same) in 1980's, which correspond with 23% and 30% respectively of the analyzed area, showing acute increasing trend. It distributes along the ridges of mountain range which runs through the center from south to north, as if to entering inside the forest from low land.
6) Agricultural forest was 21,400 ha. (4% of the analysis object area) in 1970 and 16,500 ha. (3% of the same) in 1980's, which correspond with 4% and 5% of the analyzed area showing a trend of slight increase. It distributes at the south part of the area as if to fill the clearance between grazing/grass land and forest.
7) Bare/waste land scatters among the forest, but its area is as small as 1% of the analysis object area. There is no change between 1970's and 1980's.
8) Snow/ice field distributes slightly at the mountain top of Neva del Tolima.
9) Farm land and city/town are not observed in the analysis object area.

(8) Huila

1) Similar to Cauca state, Huila has low population density and the agricultural production is also low. Furthermore, as the analysis object area is located at the mountainous zone in the south-west edge of state, most of the land use is occupied by forest and grazing/grass land (mostly by forest).
2) The analyzed area of Huila was 115,600 ha. in 1970's and 58,700 ha. in 1980's, which are 87% and 44% respectively of the analysis object area.
3) Forest was 103,900 ha. (78% of the object area) in 1970's and 48,600 ha. (37% of the same) in 1980's, which correspond with 90% and 83% of the analyzed area, showing a trend of fair decrease. The forest occupies

almost of the analysis object area, except a part of low land.

4) Plateau grassland scatters at the mountain ridges at the south edge of the analysis object area, but its area is very small (1% of the analysis object area).
5) Grazing/grass land was 10,800 ha. (8% of the analysis object area) in 1970's and 9,900 ha. (7% of the same). But in comparison with the analyzed area, they represent 9% and 18% showing a double increase. It distributes in bulk at the north edge and south-west edge of the area.
6) Agricultural forest, farm land, city/town, bare/waste land and snow/ice field are not observed in this area.

(9) Narino

1) Similar to Cauca and Huila, Narino also has low population density, and there are reserved forests in the mountain area. The analysis object area is located at the mountain zone which includes high mountain peaks exceeding 4,000m, and the total area is occupied by forest, plateau grassland and grazing/grass land (mostly by forest).
2) The analyzed area in Narino is 116,800 ha. in 1970's and 63,400 ha. in 1980's, which corresponds with 94% and 51% respectively of the analysis object area of 123,800 ha.
3) The forest was 96,100 ha. (78% of the analysis object area) in 1970's and 45,700 ha. (37% of the same), which correspond with 83% and 73% respectively of the analyzed area, indicating that the forest is decreasing.

   The forests distributes at the areas excepting grazing/grass land at the low land in the south, plateau grassland and bare/waste land.

4) Plateau grassland was 5,000 ha. in 1970's (4% of the object area) in 1970's and 4,100 ha (3% of the same) in 1980's, which are 4% and 6% respectively of the analyzed area, showing almost the same level. The plateau grassland distributes as if to enclose the mountain top of Mt. Dona Juana.
5) The grazing/grass land was 13,100 ha. (10% of the object area) in 1970's and 11,300 ha. (9% of the same) in 1980's, which correspond with 11% and 18% of analyzed area, indicating substantial increase. It distributes concentrating at the mountain zone in the center of the area.
6) Bare/waste land distributes only on the mountain top of Mt. Dona Juana, occupying 2% of the analysis object area.
7) Agricultural forest, farm land, city/town and snow/ice field are not

observed in this area.

(10) Putumayo

1) Population density is extremely low in Putumayo, and the area where agricultural products are grown is limited to only a part of the state. As the analysis object area is located on the deep mountain area of the mountain zone in the north-west of the state, most of it is occupied by forest.
2) The analyzed area in Putumayo was 13,000 ha. in 1970's and 9,600 ha. in 1980's, which are 86% and 66% of the analysis object area.
3) This area shares only a small portion of the total analysis object area, and the all of the analyzed area is forest.

6.3. Situation of vegetation

In contrast with the land use classification image, only the items concerning vegetation are picked up and forest is subdivided into natural forest and man-made forest in the vegetation classification image. We determined the items of vegetation classification to be the 5 categories of forest (natural), forest (man-made), plateau grassland, grazing/grass land and others.

Table 6.3 and Table 6.4 show the list of area by the vegetation classification items. In the Tables 6.3 and 6.4, natural forest and plateau grassland are grouped as natural vegetation, and man-made forest and grazing/grass land are grouped into man-made vegetation to show the situation of natural and man-made vegetation.

We will explain the situation of vegetation in total area and in each state.

(I) General situation

1) Against the total analysis object area of 1,918,300 ha, the analyzed area excluding the area covered by clouds was 1,640,000 ha. in 1970's and 1,269,200 ha. in 1980's, which are similar to 6.2. "Situation of land use."
2) The natural forest was 806,300 ha. in 1970's and 484,100 ha. in 1980's. They are respectively 43% and 25% of the analysis object area, and 49% and 38% of the analyzed area, indicating the decrease of natural forest.
3) Man-made forest was 43,900 ha. in 1970's and 46,800 ha. in 1980's. They are respectively 2% and 3% of the analysis object area, and 3% and 4% of the analyzed area. Therefore, it can be said that the man-made forest is

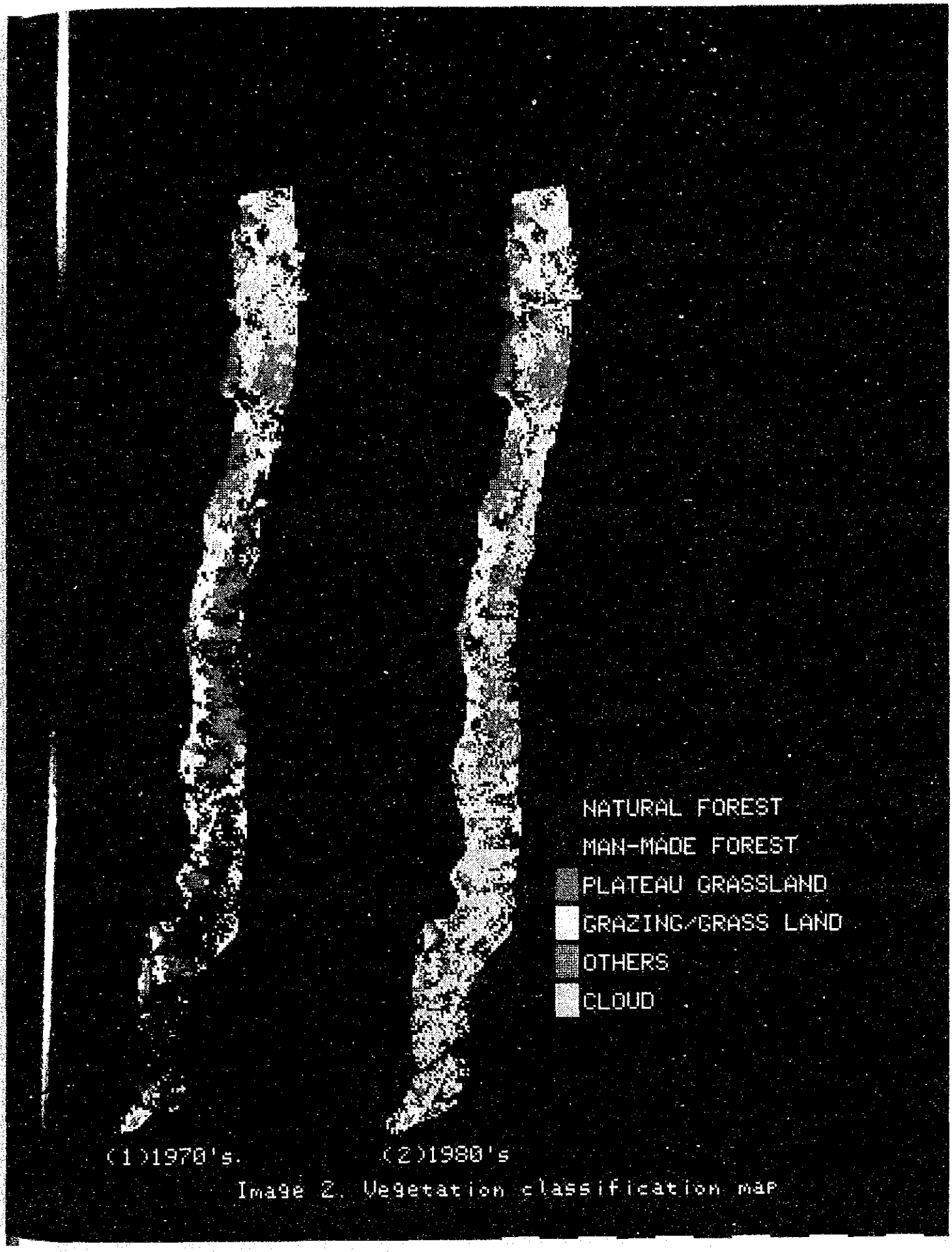


Image 2. Vegetation classification map

Table 6.3. List of area by vegetation classification items (1980'S)

Upper column:area(ha)
Lower column:ratio(%)

State / Item	Antiquia		Caldas		Risaralda		Quindio		Tolima		Velle del Cauca		Cauca		Huila		Narino		Putumayo		Total	
Natural forest	14,900		37,800		13,700		20,800		126,600		31,300		348,200		103,900		96,100		13,000		806,300	
	16	23	15	26	20	26	17	22	42	48	15	17	58	60	78	90	78	83	86	100	43	49
Man-made forest	0		4,200		1,100		0		600		22,500		15,500		0		0		0		43,900	
	0	0	2	3	2	2	0	0	0	0	10	12	3	3	0	0	0	0	0	0	2	3
Plateau grass land	0		13,900		14,200		2,000		89,000		41,000		59,500		900		5,000		0		225,000	
	0	0	6	9	21	27	2	2	29	34	19	22	10	10	1	1	4	4	0	0	12	14
Grazing/ grass land	38,900		68,300		5,800		30,800		42,700		81,000		137,000		10,800		13,100		0		428,400	
	43	62	28	47	9	11	25	33	14	16	38	43	23	23	8	9	10	11	0	0	22	26
Others	9,700		22,200		17,700		41,000		5,500		11,100		26,100		0		2,600		0		135,900	
	11	15	8	15	25	34	34	43	2	2	5	6	4	4	0	0	2	2	0	0	6	8
Analyzable area excluding clouds	63,500		146,400		52,600		94,600		264,400		186,900		586,300		115,600		116,800		13,000		1,640,000	
	70	100	59	100	77	100	78	100	87	100	87	100	98	100	87	100	94	100	86	100	85	100
Cloud	27,700		102,000		14,900		26,100		38,500		29,200		13,500		17,200		7,000		2,200		278,300	
	30		41		23		22		13		13		2		13		6		14		15	
Total	91,200		248,400		67,400		120,700		302,900		216,100		599,800		132,800		123,800		15,200		1,918,300	
	(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)	

Natural forest	14,900		51,700		27,900		22,800		215,600		72,300		407,700		104,800		101,100		13,000		1,031,300	
	28		42		80		43		83		41		73		91		89		100		69	
Man-made forest	38,900		72,500		6,900		30,800		43,300		103,500		152,500		10,800		13,100		0		472,300	
	72		58		20		57		17		59		27		9		11		0		31	
Vegetation total	53,800		124,200		34,800		53,600		258,900		175,800		560,200		115,600		114,200		13,000		1,503,600	
	100		100		100		100		100		100		100		100		100		100		100	

Table 6.4. List of area by vegetation classification items (1980'S)

Upper column:area(ha)
Lower column:ratio(%)

State / Item	Antiquia		Caldas		Risaralda		Quindio		Tolima		Velle del Cauca		Cauca		Huila		Narino		Putumayo		Total	
Natural forest	12,900		49,000		13,800		22,600		71,500		29,300		181,100		48,600		45,700		9,600		484,100	
	14	21	20	24	20	26	19	22	24	43	14	16	30	50	37	83	37	72	63	100	25	38
Man-made forest	0		7,400		1,400		0		1,300		22,300		14,400		0		0		0		46,800	
	0	0	3	4	3	3	0	0	0	1	10	12	3	4	0	0	0	0	0	0	3	4
Plateau grass land	0		15,500		12,700		2,200		61,900		28,600		37,200		200		4,100		0		162,400	
	0	0	6	8	19	24	2	2	20	36	13	15	6	10	0	0	3	6	0	0	8	13
Grazing/ grass land	34,800		97,300		6,900		37,200		27,600		92,000		109,400		9,900		11,300		0		430,000	
	42	64	39	47	10	13	31	37	9	16	43	49	18	30	7	17	9	18	0	0	22	34
Others	9,300		34,700		18,200		39,500		7,500		14,100		20,300		0		2,300		0		145,900	
	10	15	14	17	27	34	32	39	3	4	7	8	2	6	0	0	2	4	0	0	7	11
Analyzable area excluding clouds	60,600		203,900		53,000		101,500		169,800		186,300		362,400		58,700		63,400		9,600		1,269,200	
	66	100	83	100	79	100	84	100	55	100	87	100	60	100	44	100	51	100	66	100	65	100
Cloud	30,600		44,500		14,400		19,200		133,100		29,800		237,400		74,100		60,400		5,600		649,100	
	34		18		21		16		44		13		41		56		49		37		35	
Total	30,600		248,400		67,400		120,700		302,900		216,100		599,800		132,800		123,800		15,200		1,918,300	
	(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)		(100)	

Natural forest	12,900		64,500		26,500		24,800		133,400		57,900		218,300		48,800		49,800		9,600		646,500	
	25		38		76		40		82		34		64		83		82		100		58	
Man-made forest	38,400		104,700		8,300		37,200		28,900		114,300		123,800		9,900		11,300		0		476,800	
	75		62		24		60		18		66		36		17		18		0		42	
Vegetation total	51,300		169,200		34,800		62,000		162,300		172,200		342,100		58,700		61,100		9,600		1,123,300	
	100		100		100		100		100		100		100		100		100		100		100	

increasing slightly.

4) As plateau grassland and grazing/grass land have been already described in the paragraph of land use (see 6.2), the explanation of them are omitted here.

5) When the ratio of natural vegetation and man-made vegetation are compared, the natural vegetation shared 69% and man-made vegetation 31% in 1970's, while in 1980's, the natural vegetation is 58% and man-made vegetation is 42%. Therefore, it can be said that natural vegetation is decreasing and man-made vegetation is increasing.

The situation of each state will be described in the following:

(II) Situation by states

To compare the situation of vegetation by each state, we show the "comparison of vegetation area by each state" in Fig. 6.3 and Fig. 6.4.

(1) Antiquia

1) The analyzed area in Antiquia was 63,500 ha. in 1970's and 60,600 ha. in 1980's

2) Out of this, the natural forest is 14,900 ha. (23% of the analyzed area) in 1970's and 12,900 (23% of the same) in 1980's, and therefore, it can be said that there was no change in the natural forest.

3) Grazing/grass land was 38,900 ha. (62% of the same) in 1970's and 38,400 ha. (64% of the same) in 1980's, showing a slight increase.

4) With respect to the ratio of natural vegetation and man-made vegetation, the share of natural vegetation was 28% and that of man-made vegetation was 72% in 1970's, which changed to 25% of natural vegetation and 75% of man-made vegetation. Therefore, it can be said that the natural vegetation is decreasing and man-made vegetation is increasing, although its extent is slight.

(2) Caldas

1) The analyzed area in Caldas was 146,400ha. in 1970's and 203,900 ha. in 1980's.

2) Natural forest was 37,800 ha. (26% of analyzed area) in 1970's, and 49,000 (24% of the same) in 1980's, indicating a slight decrease.

3) Man-made forest distributes at Pensylvania and Manizales, and was 1,100 ha. in 1970's and 7,400 ha. in 1980's. They are 3% and 4% respectively of analyzed area, showing that man-made forest is increasing slightly.

4) Grazing/grass land was 68,300 ha. (47% of the same) in 1970's and 97,300 ha. (47% of the same) showing no change against the analyzed area.

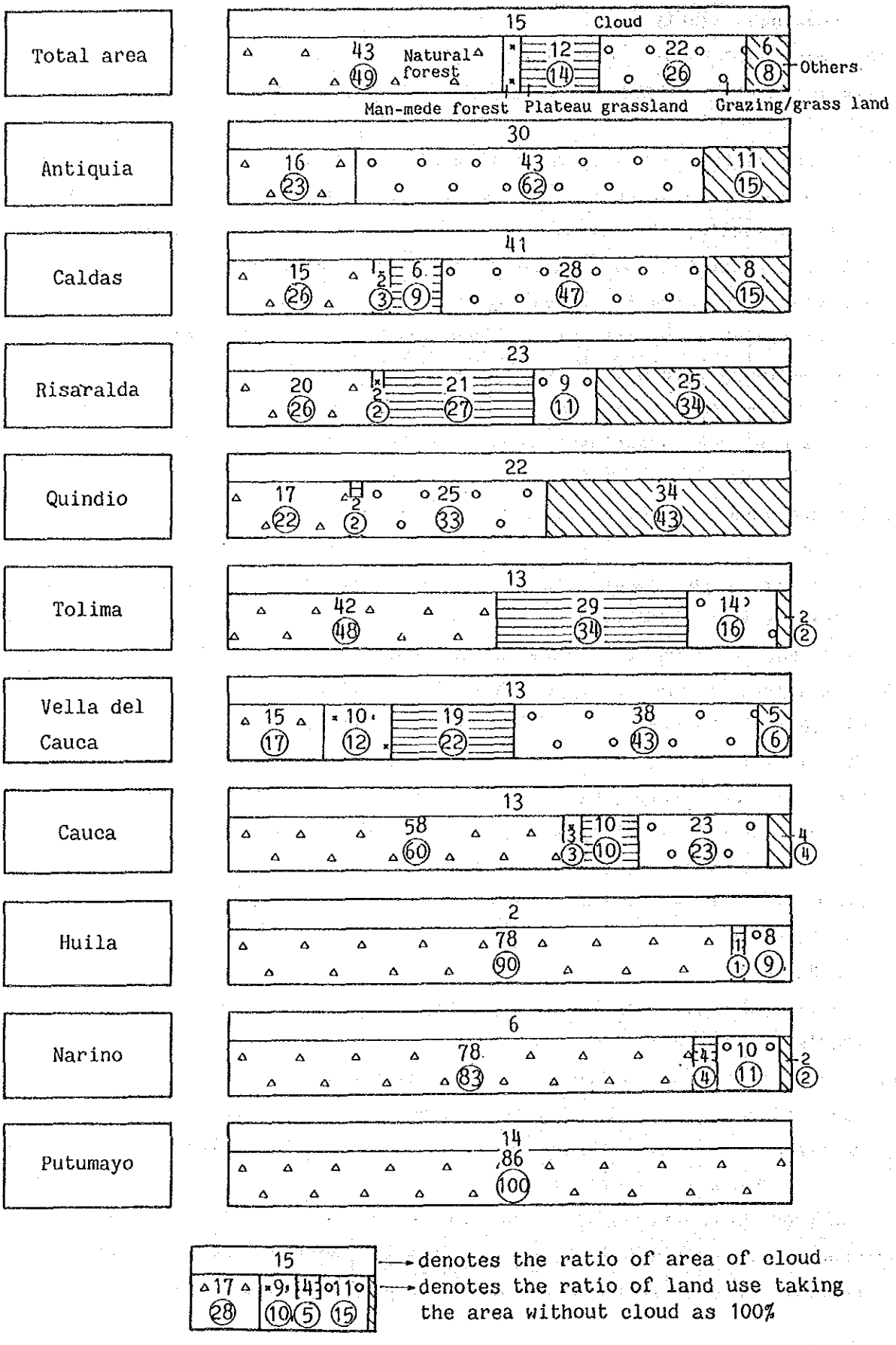


Fig. 6.3. Comparison of the area of vegetation by states (1970's)

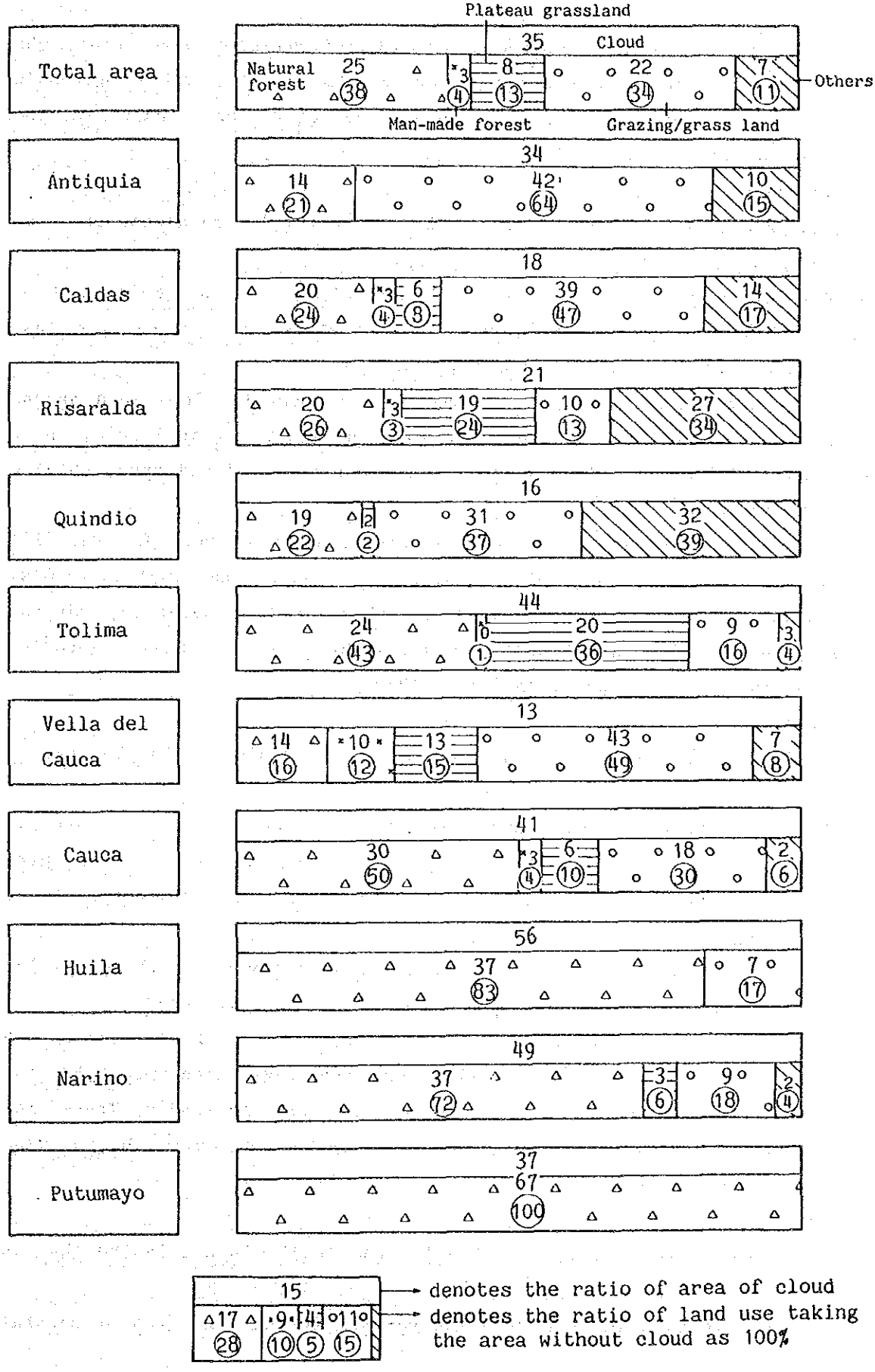


Fig. 6.4. Comparison of the area of vegetation by states (1980's)

5) With respect to the ratio between natural and man-made vegetation, the natural vegetation was 42% and man-made vegetation 58%, while in 1980's the natural vegetation was 38% and man-made vegetation 62%, indicating the decrease of natural vegetation.

(3) Risaralda

1) The analyzed area in Risaralda was 52,500 ha in 1970's and almost the same area of 53,000 ha. in 1980's.

2) Natural forest was 13,700 ha. in 1970's and 13,800 ha. in 1080's. Both of them are 26% of the analyzed area, and therefore, it can be said that there is hardly any change in the natural forest.

3) Man-made forest is frequently observed at the mountain slope land around Pereira. Its area was 1,100 ha. in 1970's and 1,300 ha. in 1980's, which correspond with 2% and 3% respectively against the analyzed area, showing a slight increase.

4) An increase is observed to the grazing/grass land as it was 5,800 ha. (11% of the analyzed area) in 1970's and 6,900 ha. (13% of the same) in 1980's.

5) With respect to the ratio of natural and man-made vegetation, natural vegetation was 80% and man-made vegetation 20%, while natural vegetation was 76% and man-made vegetation 24% in 1980's.

(4) Quindio

1) The analyzed area in Quindio was 94,600 ha. in 1970's and 101,500 ha. in 1980's.

2) All of the forests in this area are natural forest, and its area was 20,800 ha. in 1970's and 22,600 ha. in 1980's. It can be said that there is almost no change as both of these area correspond with 22% respectively of the analyzed area.

3) Grazing/grass land was 30,800 ha. (33% of the analyzed area) in 1970's, and 37,200 ha. (37% of the same), indicating a slight increase.

4) Natural vegetation was 22,800 ha. (43% of the same) in 1970's and 24,800 ha. (40% of the same) in 1980's, while man-made vegetation was 30,800 ha. (57% of the same) in 1970 and 60% in the same term in 1980's. Therefore, it can be said that natural vegetation is decreasing while the man-made vegetation is increasing.

(5) Tolima

1) The analyzed area in Tolima was 264,400 ha. in 1970's and 169,800 ha. in 1980's.

2) Most of the forests in this area are natural forest. The area of natural

forest was 126,600 ha. in 1970's and 71,500 ha. in 1080's, occupying 48% and 43% respectively of the analyzed area.

3) Man-made forest distributes on side slope land at the north side of Mt. Nevado del Ruiz. Its area was only 600 ha. in 1970's but it increased to 1,300 ha. in 1980's.

4) Grazing/grass land was 42,700 ha. in 1970's and 27,600 ha. in 1980's, showing large difference. But when they are seen as the percentage against the analyzed area, both of them represent 16%, therefore, it is considered that no significant change has taken place.

5) With respect to the kind of vegetation, the area of natural vegetation was 215,600 ha. in 1970's and 133,400 ha. in 1980's. When these areas are compared with the analyzed area, they are 83% and 82% respectively, showing a slight decrease. On the other hand, the man-made vegetation is increasing slightly from 17% to 18%.

(6) Velle del Cauca

1) The analyzed area in Velle del Cauca was 186,900 ha. in 1970's and 186,900 ha. in 1980's.

2) Natural forests mainly distribute at mountain ridges. The area of natural forest was 31,300 ha. (17% of the analyzed area) in 1970's and 29,300 ha. (16% of the same).

3) Almost no change is observed to the man-made forests between 1970's and 1980's, and its area was 22,500 ha. (12% of the same) and 22,300 (12% of the same) respectively.

4) Grazing/grass land shows fairly increase as seen in 81,000 ha. (43% of the same) in 1970's and 92,000 ha. (49% of the same) in 1980's.

5) With respect to the kind of vegetation, the natural vegetation was 72,300 ha. (41% of the same) in 1970, and 34% in 1980's, while man-made vegetation was 103,500 ha. (59% of the same) in 1970's and 114,300 ha. (66% of the same) in 1980's. Therefore, natural vegetation is decreasing while man-made vegetation is increasing.

(7) Cauca

1) The analyzed area in Cauca was 586,300 ha. in 1970's and 362,400 ha. in 1980's.

2) The natural forest was 348,200 ha. in 1970's and 181,100 ha. in 1980's, representing respectively 60% and 50% of analyzed area. The natural forests are fairly decreasing. They mainly distribute on the mountain ridges and south part of analyzed area.

3) Man-made forest is concentrated on the mountain slope land at the east of Popayan. Its area was 15,500 ha. in 1970's and 14,400 ha. in 1980's. They correspond with 3% and 4% respectively of the analyzed area, showing a fair increase.

4) Grazing/grass land was 137,000 ha. in 1970's and 109,400 ha. in 1980's, which correspond with 23% and 30% respectively of the analyzed area, showing a tendency of increase.

5) With respect to the ratio of natural and man-made vegetation, it was 73% of natural vegetation and 27% of man-made vegetation in 1970's, which changed to 64% of natural vegetation and 36% of man-made vegetation, indicating the decline of natural vegetation.

(8) Huila

1) The analyzed area in Huila was 115,600 ha. in 1970's and 63,400 ha. in 1980's.

2) For both decades, all of the forests are natural forest in this area, mostly distributing on the mountain slope lands. The area of natural forest was 103,900 ha. (90% of the analyzed area) in 1970's, and 48,600 ha. (83% of the same) in 1980's, occupying the most of the analyzed area, but a decline is observed to it.

3) Grazing/grass land was 10,800 ha. (9% of the analyzed area) in 1970's and 9,900 ha. (17% of the same) in 1980's, indicating the trend of increase.

4) Natural vegetation decreased from 91% in 1970's to 83% in 1980's, while man-made vegetation increased from 9% in 1970's to 17% in 1980's.

(9) Narino

1) The analyzed area in Narino was 116,800 ha. in 1970's and 63,400 ha. in 1980's.

2) Natural forest was 96,100 ha. in 1970's and 45,700 ha. in 1980's, which represent 83% and 72% respectively of the analyzed area, indicating a fair decrease.

3) Grazing/grass land has increased from 13,100 ha. (11% of the analyzed area) in 1970's to 11,300 ha. (18% of the same) in 1980's.

4) With respect to the kind of vegetation, natural vegetation had decreased from 89% in 1970's to 82% in 1980's. In contrast, the man-made vegetation increased from 11% in 1970's to 18% in 1980's.

(10) Putumayo

1) The analyzed area in Putumayo was 13,000 ha. in 1970's and 9,600 ha. in 1980's

2) All of the forests in this area are natural forests. Furthermore, all of the analyzed area both in 1970's and 1980's are natural forest, and no change is observed there.

3) Therefore, all of the vegetation in this area are natural vegetation, and no change is observed between the two decades.

6.4. Secular change of land use/vegetation

We summarized the secular change of land use and vegetation in the analysis object area basing on the land use/vegetation secular change image made in Chapter 5. The situation in the total object area is described in the following. Table 6.6 shows the list of secular change of land use and vegetation.

The areas where the secular change was analyzed are the portions which were not covered by clouds in both periods, which are shown in Table 6.5. Against the analysis object area of 1,918,300 ha., the area of secular change analysis is 978,300 ha. (51% of the object area).

Table-6.5. Analyzed area of secular change and Area of secular change

State name	Study area(ha)	Analyzed area of secular change		Area of secular change	
		Area(ha)	Ratio(%)	Area(ha)	Ratio(%)
Antiquia	91,200	47,400	52	4,200	9
Caldas	248,400	168,900	68	6,3.0	4
Risaralda	67,400	45,200	67	2,000	4
Quindio	120,700	56,700	47	3,000	5
Tolima	302,900	224,100	74	200	0
Velle del Cauca	216,100	129,600	60	2,000	2
Cauca	599,800	221,900	37	14,700	7
Huila	132,800	66,400	50	300	0
Narino	123,800	71,800	58	0	01
Putumayo	15,200	8,000	53	0	0
Total area	1,918,300	1,040,000	54	32,400	3

The figure in ( ) denotes the ratio (%) against the analysis object area. The "Secular change area" means the area where secular change analysis was possible.

The situation of the secular change is described in the following.

(1) General situation

The secular change between the two periods (about 10 years) of 1970's and 1980's shows in general that the natural forests were largely changed into

Table 6.6. List of secular change of land use and vegetation

Unit: ha.

1980's / 1970's		Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/waste land	Snow/ice field	Total
Forest	Natural	———			20,400	4,000					24,400 (75)
	Man-made		———		400						400 (1)
Plateau grassland				———	1,300						1,300 (4)
Grazing/ grass land			1,500		———						1,500 (5)
Agricultural forest					3,200	———	200	1,600			5,000 (15)
Farm land						100	———				100 (0)
City/town								———			
Bare/waste land									———		
Snow/ice field										———	
			1,500		25,300	4,100	200	1,600			32,700

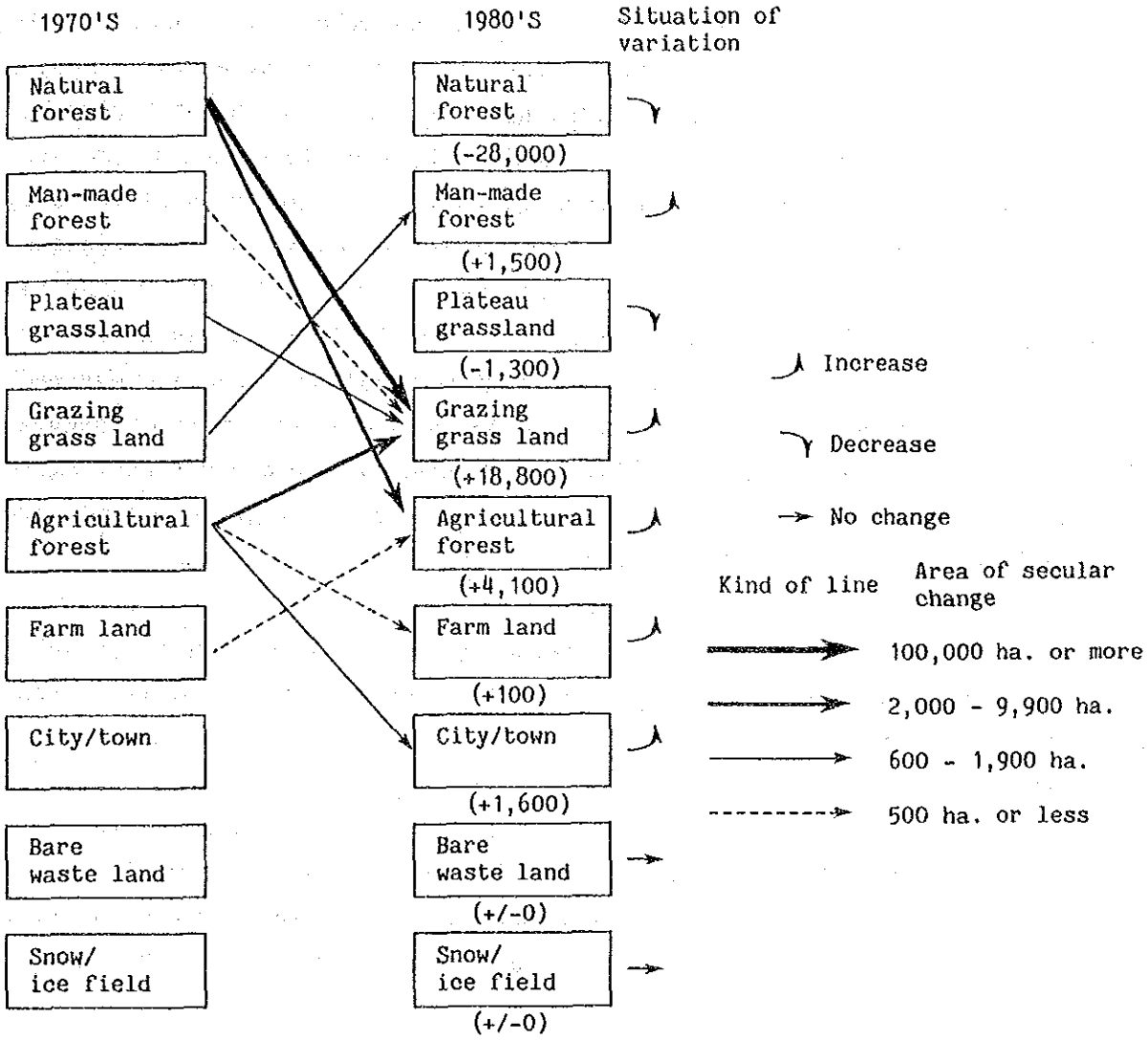


Fig. 6.5. Secular change of land use and vegetation (Unit:ha.)

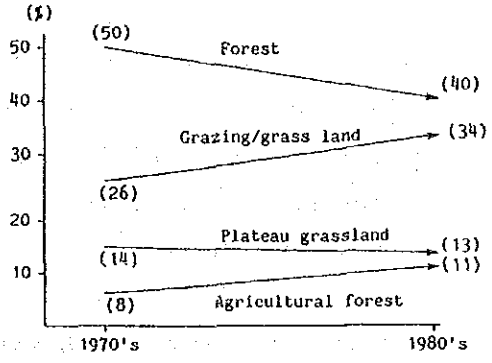


Fig. 6.6. Secular change of land use

grazing/grass land or agricultural forests. On the other hand, however, the increase of man-made forest is observed in some part. The area where secular change observed in this study was 32,700 ha., out of which 76% of 24,400 ha. was related to the change of forest. These changes of forest mean that the natural forests were changed into grazing/grass land or agricultural forests. The next frequent was the conversion from agricultural forests to grazing/grass land, farm land or city/town, and such area totaled to 5,000 ha. occupying 15% of the total area where the secular change was observed. Following this was the conversion from grazing/grass land to man-made forests, which amounted to 1,500 ha., or 5% of the total area of secular change. Besides these, 1,300 ha. (4%) was changed from plateau grassland to grazing/grass land, 400 ha. from man-made forest to grazing/grass land, 100 ha. from farm land to agricultural forest.

(2) Situation of each state

Secular change of land use and vegetation by each state is shown in Table 6.6 - 13. The situation of secular change of land use and vegetation in each state is described in the following.

1) Antiquia

Agricultural forest changed to grazing/grass land at the mountain slope land at the east side, and the natural forest to agricultural forest or grazing/grass land at the slope land in the west. The natural forests decreased by 2,800 ha. or 22% of the total natural forest of 12,900 ha. in this area.

2) Caldas

The natural forest changed to grazing/grass land at the area close to the mountain top in the north, and the agricultural forest to grazing land in the west. 4,000 ha. of natural forest and 1,700 ha. of agricultural forest were converted into grazing/grass land.

3) Risaralda

The conversion from agricultural forest to city/town is observed at Pereira located at the west of analysis object area. In the mountain area in the south, 400 ha. in total of forests were changed into grazing/grass land. However, However, as large part of the forest was covered by the clouds, the change which may have taken place there is unknown.

4) Quindio

The change from forest to agricultural forest or grazing/grass land is observed at the slope land at south side. 3,000 ha. out of 22,600 ha. of

natural forest has decreased.

5) Tolima

In general, the area where secular change is observed is small. Only that 200 ha. of natural forest has changed to grazing/grass land at the mountain slope.

6) Velle del Cauca

1,900 ha. of forest (natural forest 1,500 ha., man-made forest 400 ha.) has changed to grazing/grass land around the mountain ridge and slope land. There are some areas which have been changed from farm land to agricultural forest at a part of slope land near the river low land.

7) Cauca

Except the southern area, secular change is observed all over the area. At the slope land of the east side of mountain, most of the changes are the conversion from forest (natural) to grazing/grass land. Also, the change from forest (natural) to grazing/grass land is observed at the west side slope land. On the other hand, there are some places which changed from grazing/grass land to man-made forest by afforestation. In total, 11,900 ha. of natural forest has changed to grazing/grass land. 1,500 of grazing/grass land has changed to man-made forest.

8) Huila

The change from forest (natural) to grazing/grass land is observed only to a small area (300 ha.) in the secular change analysis area.

9) Narino and Putumayo

No secular change has been observed within the secular change analysis area.

Table 6.7. List of secular change of vegetation (Antiquia)

(Unit: ha.)

70's \ 80's	Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest: Natural	———			1,600	1,200					2,800 (67)
Forest: Man-made		———								
Plateau grassland			———							
Grazing/ grass land				———						
Agricultural forest				1,400	———					1,400 (33)
Farm land						———				
City/town							———			
Bare/ waste land								———		
Snow/ ice field									———	
				3,000	1,200					4,200 (100)

Table 6.8. List of secular change of vegetation (Caldas)

(Unit: ha.)

70's \ 80's	Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest: Natural	———			3,900	100					4,000 (67)
Forest: Man-made		———								
Plateau grassland			———							
Grazing/ grass land				———						
Agricultural forest				1,800	———	200				2,000 (33)
Farm land						———				
City/town							———			
Bare/ waste land								———		
Snow/ ice field									———	
				5,700	100	200				6,000 (100)

Table 6.9. List of secular change of vegetation (Risaralda)

(Unit: ha.)

70's \ 80's		Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest	Natural	———			400						400 (200)
	Man-made		———								
Plateau grassland				———							
Grazing/ grass land					———						
Agricultural forest						———		1,600			1,600 (80)
Farm land							———				
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
					400			1,600			2,000 (100)

Table 6.10 List of secular change of vegetation (Quindio)

(Unit: ha.)

70's \ 80's		Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest	Natural	———			500	2,500					3,000 (100)
	Man-made		———								
Plateau grassland				———							
Grazing/ grass land					———						
Agricultural forest						———					
Farm land							———				
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
					500	2,500					3,000 (100)

Table 6.11. List of secular change of vegetation (Tolima)

(Unit: ha.)

70's \ 80's		Forest		Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
		Natural	Man-made								
Forest	Natural	———			200						200 (100)
	Man-made		———								
Plateau grassland				———							
Grazing/ grass land					———						
Agricultural forest						———					
Farm land							———				
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
					200						200 (100)

Table 6.12 List of secular change of vegetation (Velle del Cauca)

(Unit: ha.)

70's \ 80's		Forest		Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
		Natural	Man-made								
Forest	Natural	———			1,500						1,500 (75)
	Man-made		———		400						400 (20)
Plateau grassland				———							
Grazing/ grass land					———						
Agricultural forest						———					
Farm land						100	———				100 (5)
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
					1,900	100					2,000 (100)

Table 6.13. List of secular change of vegetation (Cauca)

(Unit: ha.)

70's \ 80's		Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest	Natural	———			11,900						11,900 (81)
	Man-made		———								
Plateau grassland				———	1,300						1,300 (9)
Grazing/ grass land			1,500		———						1,500 (10)
Agricultural forest						———					
Farm land							———				
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
			1,500		13,200						14,700 (100)

Table 6.14. List of secular change of vegetation (Huila)

(Unit: ha.)

70's \ 80's		Forest: Natural	Forest: Man-made	Plateau grassland	Grazing/ grass land	Agricultural forest	Farm land	City/town	Bare/ waste land	Snow/ ice field	Total
Forest	Natural	———			300						300 (100)
	Man-made		———								
Plateau grassland				———							
Grazing/ grass land					———						
Agricultural forest						———					
Farm land							———				
City/town								———			
Bare/ waste land									———		
Snow/ ice field										———	
					300						300 (100)

7. Analysis of study result

7.1. Outline

Analysis was made and regional characteristics were summarized basing on the investigation results as stated in the above.

First of all, analysis was made to grasp the regional characteristics of land use, vegetation and especially forest in the analysis object area, basing on the study results of Chapter 6.

The analysis object area is located at the Central Andes Mountain Range in the Republic of Colombia, and it is the place where there is much cloud throughout the year.

The influence of the clouds was not very small also on the LANDSAT data. As a matter of course, much attention was paid to the volume of clouds when acquiring the LANDSAT data, and we retrieved the existing data in an effort to obtain the data which were less influenced by the cloud as much as possible. As a result, however, we were compelled to use the analyzable area as shown in Table 7.1.

7.2 Influence of cloud volume on the accuracy of investigation

The analysis object area of this study has much cloud all though the year. The cloud volume in the LANDSAT data we used for this study is as shown in 1.5. Among them, there was even a data which has 50% of cloud volume within one LANDSAT secene (180 square kilometer). In implementing the study, we tried to obtain the data with less cloud volume as much as possible by checking the cloud volume by the Quick Look Picture (see Fig. 7.1). If, however, the clouds were unavoidable over the object area in the available data, we selected the data which had the least volume of cloud.

The LANDSAT data we obtained for this study were those which had least volume of clouds among available data. Table 7.1 shows the cloud volume in the analysis object area by each state. In this table, we showed the cloud volume and analyzed area by the decades of 1970's and 1980's. In addition, we show the area for which the secular change of land use and vegetation was analyzed by overlaying images of two different periods.

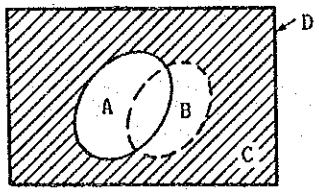
As a result, it was proven that, out of analysis object area of 1,918,300 Km^2, the cloud occupied 278,300 ha. or 15% of analysis area of land use and vegetation in 1970's, and 649,100 ha. or 35% of analysis area in 1980's.

Fig7.1. Quick-look picture of LANDSAT image

Table 7.1. Area of analysis

State nama	Area impossible fo analyze				Analyzed area of secalar change		Study area
	A		B		C		D
	1970'S		1980'S				
	Cloud volum(%)	Area (ha)	Cloud volum(%)	Area (ha)	Cloud Volum(%)	Area (ha)	Area (ha)
Antiquia	30	27,700	34	306,00	52	47,400	91,200
Caldas	41	102,000	18	44,500	68	168,900	248,400
Risaralda	22	14,900	21	14,400	67	45,200	67,400
Quindio	22	26,100	16	19,200	47	56,700	120,700
Tolima	13	38,500	44	133,100	74	224,100	302,900
Velle del Cauca	13	29,200	14	29,800	60	129,600	216,100
Cauca	2	13,500	40	237,400	37	221,900	599,800
Huila	13	17,200	56	74,100	50	66,400	132,800
Narino	6	7,000	49	60,400	58	71,800	123,800
Putumayo	14	2,200	37	5,600	53	8,000	15,200
Total area	15	278,300	34	649,100	54	1,040,000	1,918,300

Note1. Relation of each area is schematically shown as follows:



Note2. Analyzed area of secular change means the area Wheve there were no clouds in both of two period and where the analysis of secular change was possible

As seen in Table 7.1, the area where secular change analysis was possible varied by states, and for example, the analysis was possible to 74% of the object area in Tolima. Following this, analysis was possible at 68% of Caldas, 67% of Risaralda, and 60% of Velle del Cauca. On the other hand, there were states where the analyzable area was quite limited such as 37% of Cauca.

In implementing the analysis of secular change, it is desirable that there are no clouds at all over the object area in both two periods.

We looked into the cloud volume list of LANDSAT data on the 4 scenes which cover the analysis object area observed from 1972 to 1988, and found that the data with 40% or less of cloud (cloud volume per one scene) were only 14 scenes. The observation times during this period amounted to 165 scenes. Therefore, the scenes with less cloud were only 8.5% against 165 scenes. In our present study, we selected the best data which could support our study among the data with cloud volume of 40% or less, namely analyzable area of more than 60%.

However, no matter how high the ratio of analyzable area is, there would be some cases where analysis is difficult, or even meaningless, according to the position of the cloud.

For example, analysis would be impossible if only the area where no secular change is considered is free from the cloud, or if the area where the secular change is likely to occur is covered by cloud.

Therefore, with respect to the reliability of analysis result, its accuracy is largely dependent on the ratio of analyzable area and the location of the cloud. Table 7.2. shows the judgment concerning the possibility of analysis due to the influence of clouds in our present analysis.

Table 7.2. Judgment on the possibility of analysis

State name	Object area (ha.)	Analyzable area (%)	Area of secular change analysis (ha)	Possibility of analysis
Antiquia	91,200	52	47,400	Analyzable ratio is 52% but clouds cover ridges where grazing/grass land distributes, with less influence for analysis on secular change of forests
Caldas	248,400	68	168,900	Secular change analysis on forest is possible seeing from analyzable ratio. Clouds are positioned over ridges and the influence on the analysis is less
Risaralda	67,400	67	45,200	"
Quindio	120,700	47	56,700	Analyzable area is 47%, but clouds cover only grazing/plateau/grass land which are less influential for forest secular change analysis
Tolima	302,900	74	224,100	Forest secular change analysis is possible seeing from analyzable ratio. Clouds exist on less influential area.
Velle del Cauca	216,100	60	129,600	Same as above. Clouds are concentrated on part of slope and ridges where grazing/plateau/grass land distributes
Cauca	599,800	37	221,900	Analyzable ratio is 37%, but clouds cover only less influential areas
Huila	132,800	50	66,400	Analyzable ratio is 50%, but this state shares only a small portion of the object area, and no secular change is considered as the forest is reserved.
Narino	123,800	58	71,800	"
Putumayo	15,200	53	8,000	"
Total area	1,040,300	54	1,040,000	---

As seen in the above Table, it was considered that analysis was possible at Tolima, Caldas and Velle del Cauca because the ratio of analyzable area is relatively high. Although the ratio of analyzable area was fairly low in Antiquia, Risaralda, Quindio and Cauca, they were considered analyzable because the clouds were located over the area which is less influential in

investigating the secular change of forests. Furthermore, although the analyzable ratio is 50% or less in Huila, Narino and Putumayo, they were considered less influential because their share in the analysis object area is marginal and forests were reserved in these states.

7.3. Situation of land use/vegetation

The following consideration was made to summarize the situations of land use and vegetation in the analysis object area.

(1) Relationship between land use/vegetation and altitude

Traversal section diagram was constructed at the measuring lines as shown in Fig. 7.2 to grasp the relation between land use/vegetation and altitude. The traversal measuring lines were selected from the representative ground points from the land use classification image within the analysis object area. Fig. 7.3 shows the schematic diagram by each traversal measuring line. The land use was interpreted from this diagram by each altitude, and summarized as shown in Table 7.3.

From this Table, the land use in the analysis object area is summarized as follows in general:

* At the highland of altitude 4,000m or more, there exists snow/ice field.
* At attitude 3,000 - 4,000m, plateau grassland distributes
* At altitude 2,000 - 3,000m, forest distributes
* At altitude 1,000 - 2,000m, grazing/grass land distributes
* At altitude 1,500 or less, agricultural forest distributes.

While the tree line is at about 3,000m, the grazing/grass land is expanding up to 2,500m or even to 3,000m as seen in measuring line 1 and 3. Therefore, it can be said that the range of forest is further narrowed down. This tendency is conspicuous in the north part of analysis object area.

With respect to the present state of forest distribution, the upper limit namely the tree line is at around 3,000m, and at upper than this line, forest cannot exist taken place by plateau grassland and then snow/ice field. On the other hand, as seen in measuring lines 1 and 3, the grazing/grass land is expanding to altitude 2,500 or nearly to 3,000m, narrowing down the area where natural forest may grow. It is considered that this trend will further promoted in the future undermining the area for the forest to grow. At the lower altitude than the places where grazing/grass land can survive, there are grown the agricultural forests.

Table 7.3. Land use by measuring lines

Land use / Measuring line	Snow/ice field	Plateau grassland	Forest	Grazing/ grass land	Agricultural forest	Remarks
1	-	Highland of 3000m or more	2000-3000m at Caldas side	Mountain slope land of 2000m or less at Tolima side	Slope land of 1500 - 2000m	State border of Caldas and Tolima
2	Mountain area of 4000m or more	Mountain slope of 3000 - 4000m	Mountain slope of 1500 - 3000m	-	Gradual slope of 1500m or less	State border of Risaralda and tolima. There is Mt. Nevada Tolima of 5215m
3	-	-	Mountain slope of 1500 - 2000m	Mountain slope of 2000-3000m	Slope land of 1500m or less	State border of Quindio and Tolima
4	-	Highland of 3500m or more	Mountain slope of 2000 - 3500m in V.D. Cauca and of 3500m or more in Tolima	Mountain slope of 1000-2000m in V.D. Cauca	-	State border of V.D. Cauca and Tolima
5	-	Highland of 4000m or higher	Mountain slope of 3500 - 4000m. Also, at 3000m or less at west side and 2500-3500m at east side of mountain.	Mountain slope of 2500m or less. Also, at 3000-3500m at west side of mountain	-	Cauca State
6	-	Highland of 3000m or higher	Mountain slope of 3000m or less	-	-	State border of Narino and Cauca

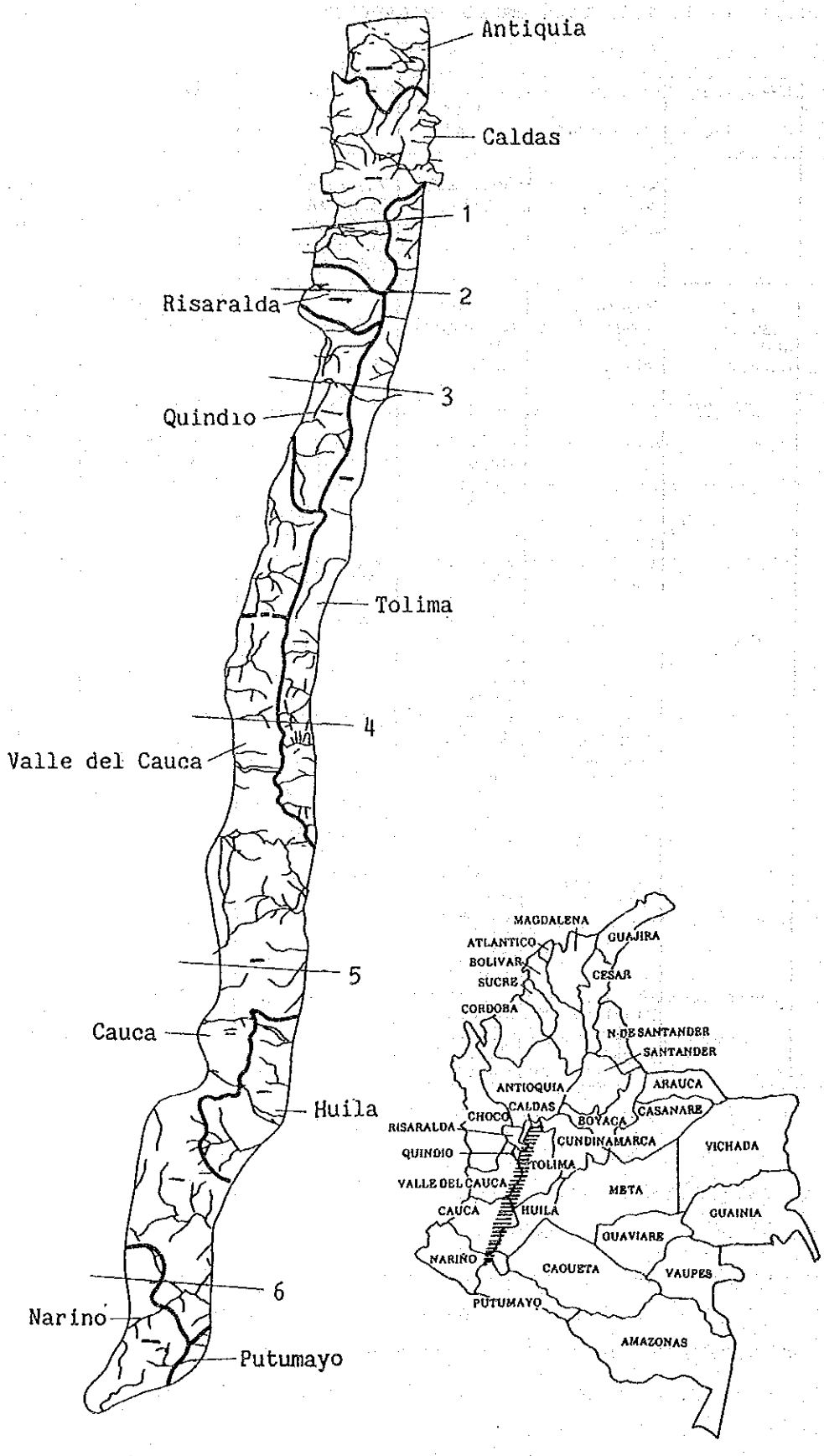


Fig. 7.2. Measuring line of traversal section map of land use

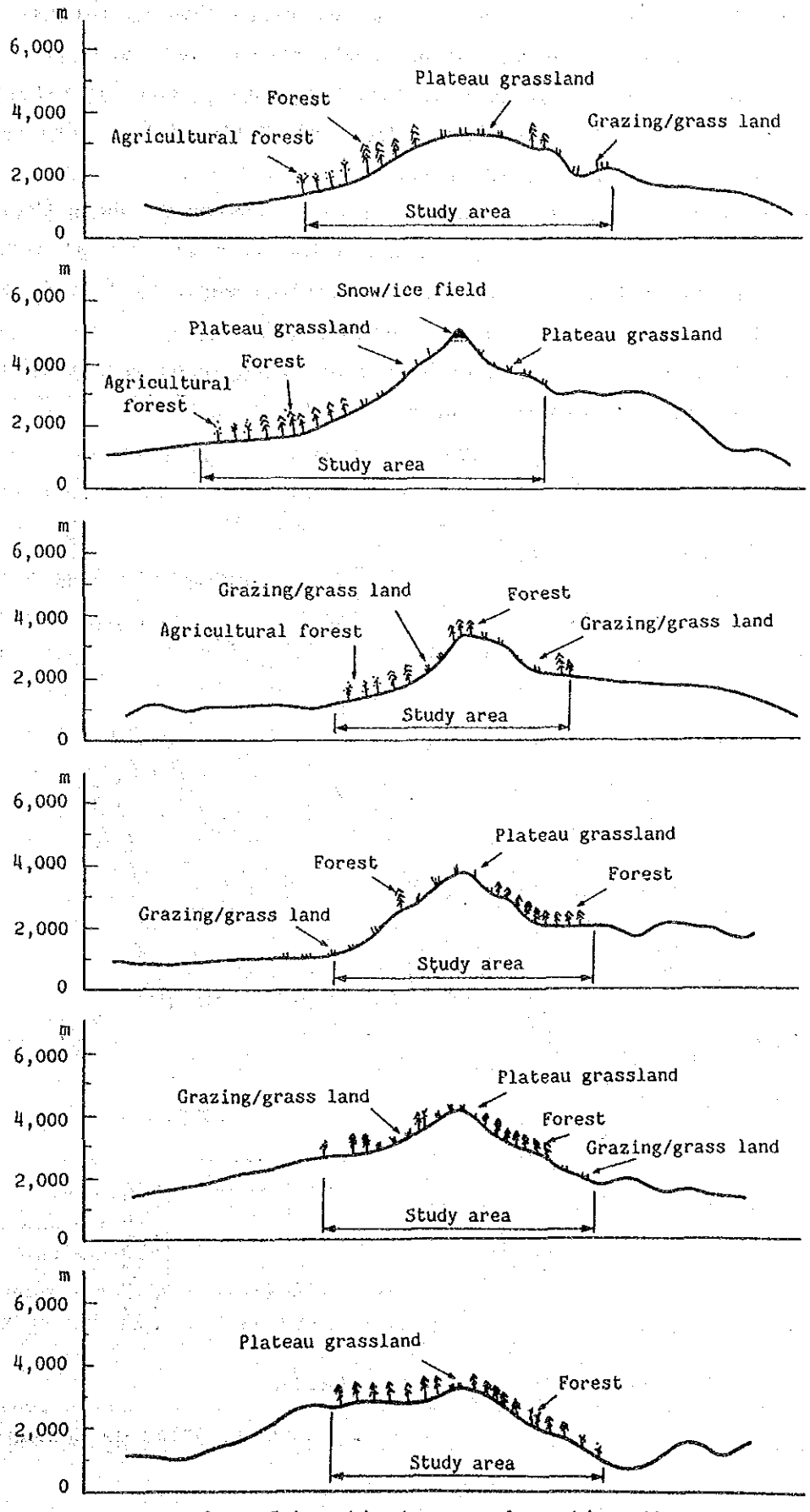


Fig. 7.3. Schematic traversal section diagram

Expansion of grazing/grass land into the nurturing land of natural forest is conspicuously observed on the slope lands at the west side of Central Andes. For example, this trend is especially eminent in the central part of analysis object area (Risaralda, Quindio and Velle del Cauca) at the measuring lines of 3, 4 and 5 in Fig. 7.3.

Also, north and south sides of object area are compared, while this trend is clearly observed in the north, the nurturing land of natural forest is reserved relatively well in the south (foe example, measuring line 6, etc.)

(2) Relationship with the land use in peripheries

The trend of land use at the peripheries of object area was grasped using the existing land use maps as referential materials.

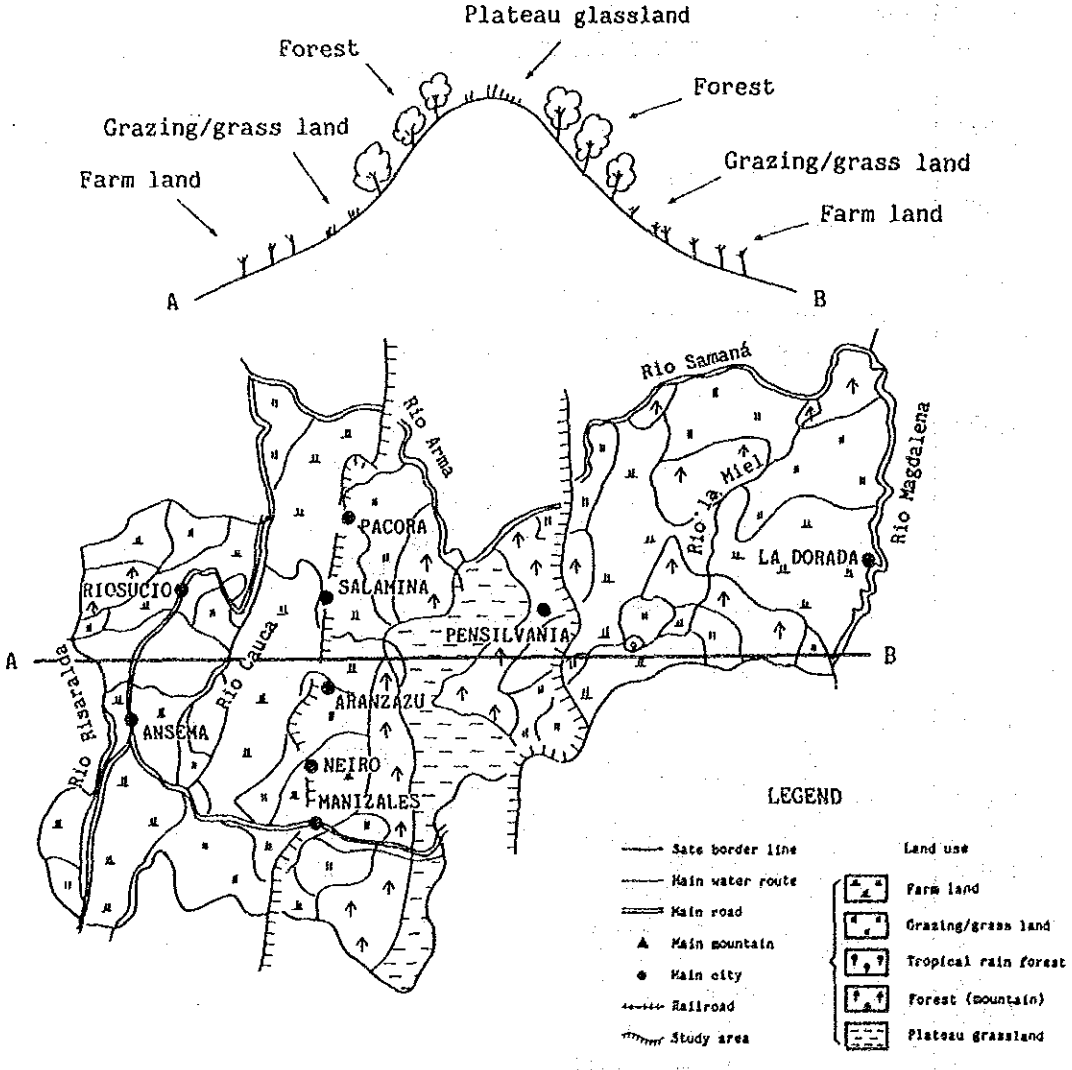


Fig. 7.4. Land use map of Caldas

Source: Atlas de Colombia

The state of Caldas is located at the north part of the analysis object area, and is a center of population concentration, having major cities such as Manizales and Pensylvania. With respect to land use, there are plateau grassland at the mountain ridges in the object area, and forest, grazing/grass land and farm land distribute towards the mountain foot. (Fig. 7.4)

The schematic traversal diagram of the same point in land use classification image of present study is as shown in Fig. 7.5. It has become clear that the forest distributes at the mountain ridge and slope land on the east side, the land up to relatively high altitude is used as grazing/grass land, and agricultural forest distributes at the mountain foot.

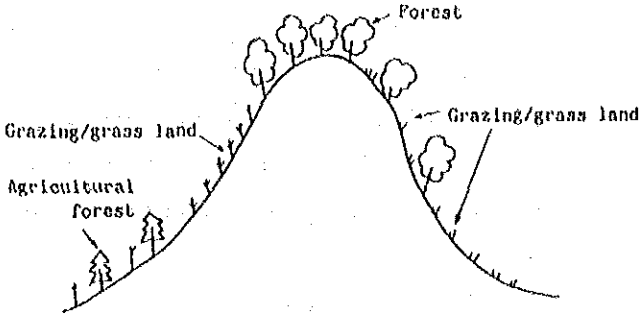


Fig. 7.5. Schematic traversal section diagram

Therefore, the results of image we created and the existing land use map show the identical tendency. The same tendency is observed whole through the object area, but the land use is done at higher altitude and at more acute slope land at the north part and central part which have relatively high population.

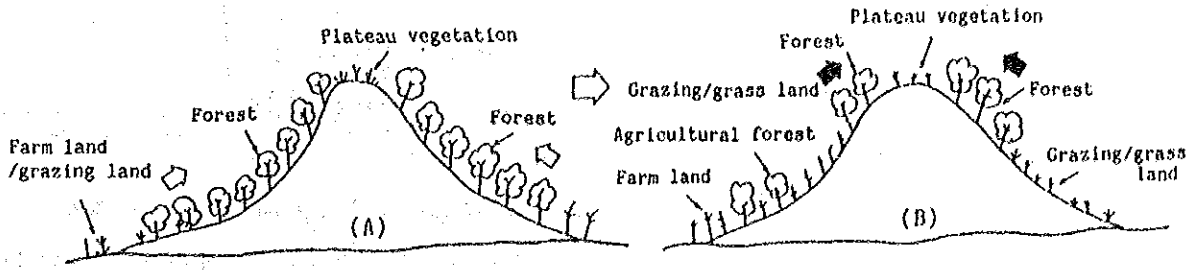


Fig. 7.6. Schematic diagram of conversion of forest

When the conversion of forest is schematically drawn integrating these trends, it would be as shown in Fig. 7.6. Namely, farming and grazing which had been done on relatively flat land, moved up from flat land to mountain foot, from mountain foot to slope land at mountain breast, and eventually to the acute slope land at the mountain breast along with the increase of population. As the result, the forest has decreased because it was converted and is not restored by afforestation. This tendency is more conspicuous in

north than in south in the analysis object area.

Now, we will discuss the relation between the land use and the periphery of cities where population concentrates. The cities/towns and the roads which connect them distribute in the analysis object area as shown in Fig. 7.7.

The land use at the west side slope land is more active comparing with those in east side as the cities and towns as well as the roads are more developing at the west side of the object area.

Fig. 7.7 was constructed by combining the land use map made in the present study and the existing materials. They almost coincided each other with respect to the distribution of farm and agricultural forests such as coffee plantation, well expressing the results of production activities including agriculture.

As is clear from this map, the land use is more diversified in the south than in north, giving more pressure on the forests.

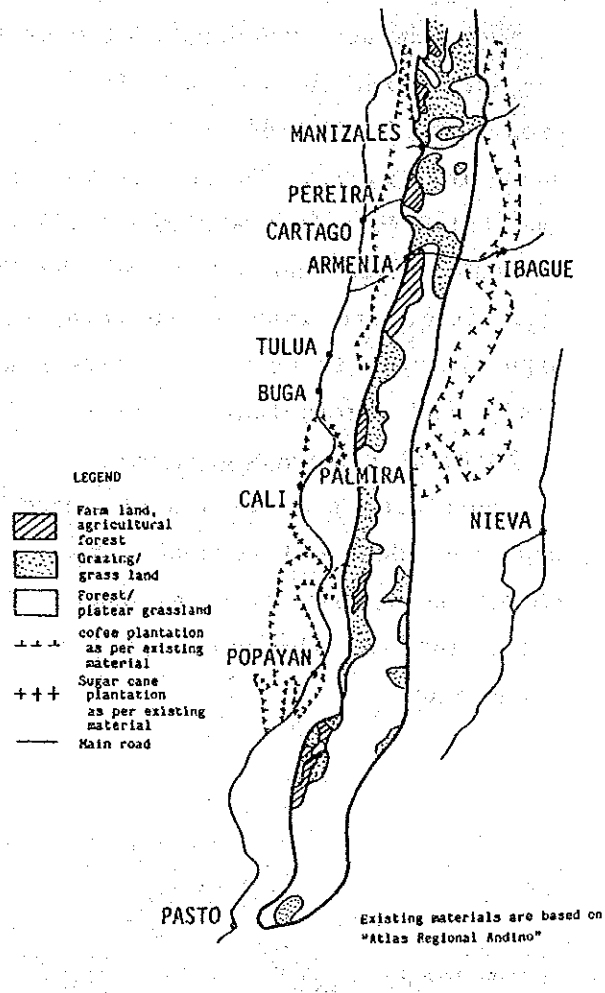


Fig. 7.7 Schematic diagram of land use (Analysis result of present study is roughly shown as for farm land, agricultural forest, forest and plateau grassland)

(3) Secular change of land use and vegetation

The pattern that natural forest is converted into grazing/grass land or agricultural forest was most dominant in the secular change of land use and vegetation. This tendency was conspicuous in each state of Antiquia, Caldas, Quindio and Cauca. Especially in Cauca, 11,900 ha. of natural forest has been changed to grazing/grass land. This area corresponds with 3.4% of the area of natural forest as of 1970's.

In general, the secular change is more conspicuous at the east side slope land of Central Andes Mountain Range especially in Caldas, Velle del Cauca and Cauca comparing with the slope lands of west side.

This active secular change in the west side is considered to be due to the peripheral environment, namely it is reflecting the development of cities, towns and roads as stated in (2) above. Fig. 7.8. shows the schematic diagram of these secular change.

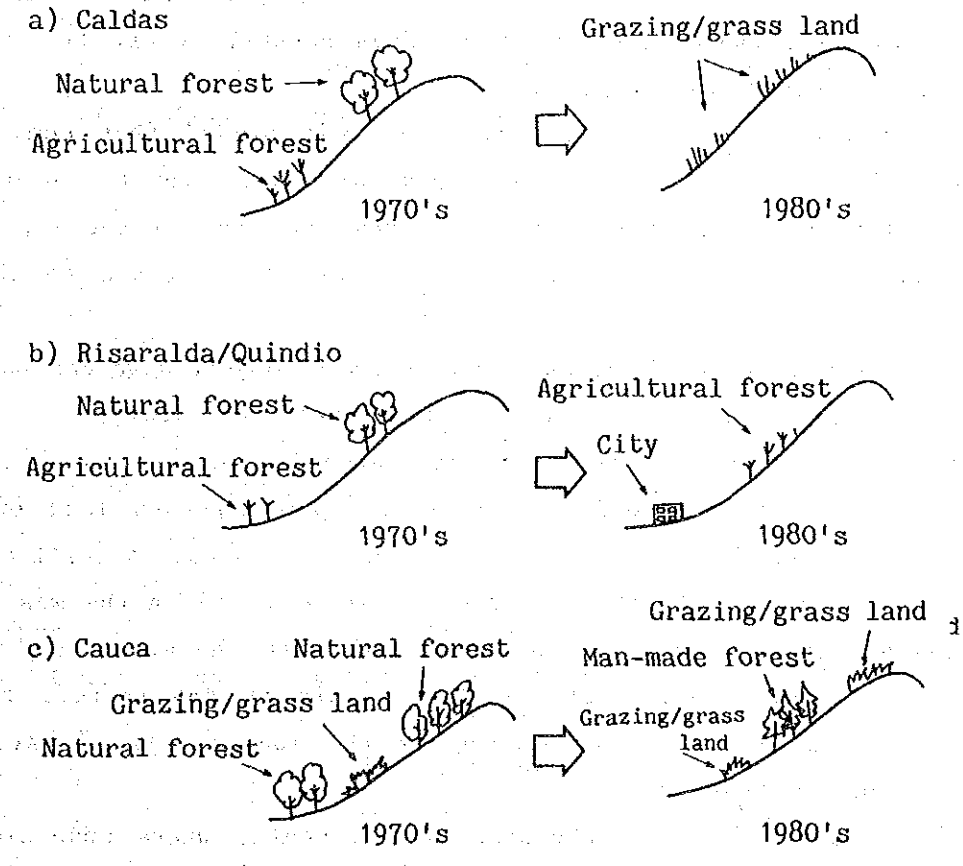


Fig. 7.8. Schematic diagram of secular change

a) is an example of the state of Caldas where natural forest and agricultural forest have changed to grazing/grass land. Both the agricultural forest at the mountain foot and the natural forest near the mountain top changed to grazing/grass land.

In this area, even the acute slope near the mountain ridge is used as grazing/grass land, showing a typical example of this trend.

b) is an example of central part of the analysis object area where agricultural forest was converted into cities, and natural forest was changed to agricultural forest. The agricultural forest shifted upward along with the expansion of cities, undermining the natural forest which was located at the mountain breast of relatively high altitude, resulting in the decrease of natural forest.

c) is an example of Cauca State where natural forests near the mountain top and at the mountain foot were converted into grazing/grass land, and grazing/grass land at the mountain breast was changed to man-made forest. This is an area where expansion of grazing/grass land is developing in general, and where the conversion from natural forest to grazing/grass land is outstandingly active.

It was made clear in 6.3 "Result of the study" that conversion from natural forest to grazing/grass land or agricultural forest is most conspicuous in the secular change of land use and vegetation, but on the other hand, in a part of the area, increase is observed to the man-made forest.

The regional characteristics in the analysis object area can be summarized as follows basing on the analysis result of (1) - (3) above.

1) The north part of the area centering around Caldas is the area which has been developed from olden time, where grazing/grass land expands over close to mountain ridges, and the decrease of forest is still continuing.
2) In general, more diversified land use is observed in the west side slope land of central mountain range comparing with the east side. Especially, there are more farm lands in Cauca basin at the center. Furthermore, agricultural forest is developing at the mountain breast slope land of altitude 1,800m or less.
3) Forests are relatively abundant in the south, where undeveloped forest expands over the wide area.
4) In the analysis object area, the forest in Caldas which has state capital (Manizales City) in it is considered to play important roles such as

waterhead reservoir, prevention of soil erosion and prevention of flood.

Conclusion

(1) This study was carried out in an aim to grasp the present state and changes of land use and vegetation through the analysis of LANDSAT data for providing basic materials for formulating forest management plan guideline and model plan for the Central Reserved Forest of Colombia.

(2) The identification items of land use classification image are 9 categories of forest, plateau grassland, agricultural forest, farm land, city/town, bare/waste land, snow/ice field and cloud. According to the land use classification of 1980's, the forest was 28% and grazing/grass land was 22% of the analysis object area of 1.9 million ha. which includes the study area.

(3) The identification items of vegetation classification image are 6 categories of natural forest, man-made forest, plateau grassland, grazing/grass land, others and cloud. According to the vegetation classification of 1980's, the man-made forest was 3% of the analysis object area.

(4) The most conspicuous change among the secular change of land use and vegetation was the conversion from the natural forest to grazing/grass land.

(5) As a result of this study, it has become clear that change of forest is more conspicuous in the north of analysis object area which includes study area, and that the intensive area in Caldas State has high urgency in formulating the forest management plan.

(6) It was possible to grasp the situation of present state and secular change of land use and vegetation from the macro viewpoint by this study. This was first possible through the remote sensing analysis.

(7) Although some parts of the LANSAT data were covered by clouds and there were some area which were not analyzable in present study, it was possible to clarify the general trend and overview.

(8) The result of present study will be used as the materials for discussing the direction of forest management plan in intensive area and eventually in model area.

ANNEXED MATERIALS

1. Study team
2. About remote sensing
3. Photograph of the site
4. False color image
5. Secondary ground cover classification

1. Study team

Study team of the first study year

Item of investigation	Name	Main duties
Field survey	Iwao NAKAJIMA Kazuyoshi KAGEYAMA	Study period: Fe. 14 - Mar. 25, 1989 (40 days); creation of image identification standard, ground cover classification
Analytical works in Japan	Masahiro SETIJIMA	Image interpretation, analysis of ground cover classification

Study team of the second study team

Item of investigation	Name	Main duties
Analytical works in Japan	Iwao NAKAJIMA	Remote sensing, analysis plan, supervision
	Ryuji MATSUOKA	Image interpretation, report preparation
	Masahiro SETOJIMA	Analysis of ground coverage classification, report preparation
	Mamoru TAKAHASHI	Analysis of secular change, report preparation

I. THE REMOTE SENSING

1. Outline

The remote sensing refers to a technique which collects data on subjects and phenomena reflecting or radiating electromagnetic waves by using sensors mounted on a platform such as an aeroplane and a satellite to provide information about the subjects and phenomena.

The remote sensing can provide data on information in a wide region within a short period of time and thus offer high efficiency in understanding temporal changes. These data are processed and analyzed for various types of surveys.

Platforms for data collection may be a satellite, an aeroplane, or a special ground vehicle. These platforms depend on the range of the survey to be conducted and the type of sensors to be used.

Sensors used in the remote sensing include camera, scanner and TV camera. Remote sensing utilizes a wide range of waves from γ rays and millimeter waves to centimeter waves. The ranges used most commonly are the visible light range and the near-infrared and thermal infrared range.

Collected data are processed to analog data such as photos and digital data for analysis by a computer. Analog data such as photos provide easy understanding of the location and distribution of subjects. On the other hand, digital data which are subjected to image processing such as automatic classification by a computer and image stressing can be changed to different types of image, and so can provide different aspects of the subjects.

2. Principle

Any kins of subjects (substances) carry inherent reflection characteristics of electromagnetic waves depending on their kinds, and the intensity of the reflected electromagnetic waves is measured for every wave length from a satellite or an aeroplane to identify substances on the earth surface. This is the principle of the remote sensing.

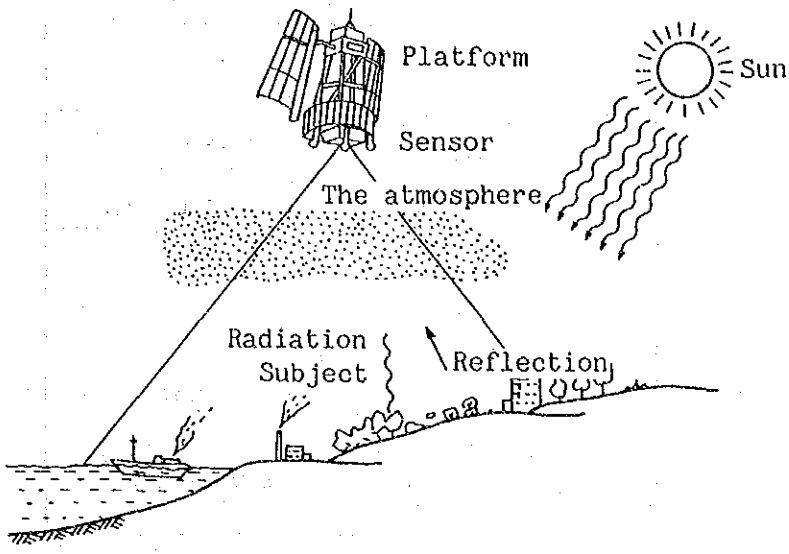


Fig. 1 Data collection by remote sensing

Electromagnetic waves are termed in accordance with wavelength bands. The wavelength region used in the remote sensing covers the range from ultraviolet rays to microwaves.

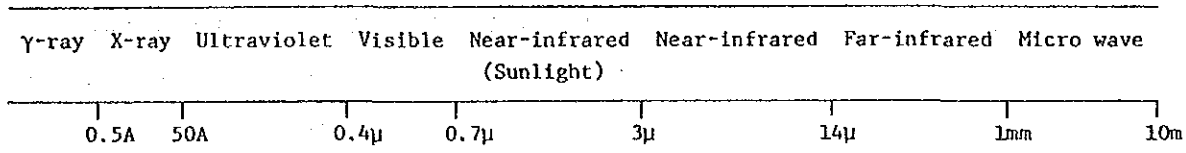


Fig. 2. Spectrum of electromagnetic waves

Visible rays are electromagnetic waves in the visible range; blue color has shorter wavelength, while red color has longer wavelength. Further longer wavelength is in the infrared region. Infrared rays are classified into near-infrared, medium infrared and far infrared (thermal infrared) depending on wavelength. Longer wavelength rays than infrared rays belong to so called electric waves, which are represented by microwaves.

The electromagnetic waves reaching the earth surface in the wavelength bands used in the ordinary remote sensing are used only for observation of the earth surface.

Figure 1.3 shows schematically characteristics of reflection spectra of representative substances on the earth surface.

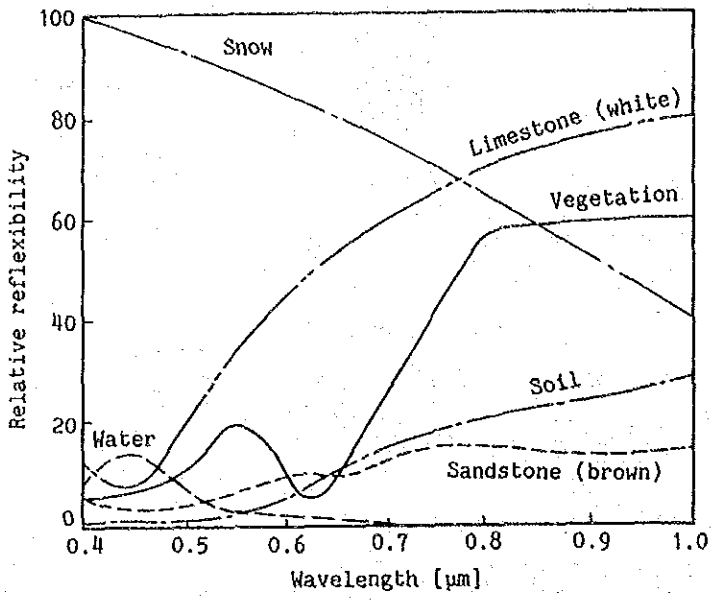


Fig. 3. Distribution of general reflection spectra
(From U.S. Geological Survey)

3. Flow of Analysis

The remote sensing is subjected to analysis consisting of (1) data collection, (2) data processing/analysis, and (3) application to survey.

(1) (2) (3)

Data collection → Data processing/analysis → Application to survey

(1) Data Collection

1) Purchase from major agencies concerned

--- 1 LANDSAT Satellite data --- . EOSTA Ltd. (U.S.A.)
. Receiving centers in major countries

2 NOAA Satellite data --- . NOAA (U.S.A.)

3 SPOT Satellite data --- . SPOT IMAGE Ltd. (France)

2) Data collection by photography/observation

--- Data at the level of aeroplane --- Aerial photography surveying companies

(2) Data Processing/Analysis

1) Data processing techniques
   ① Computer processing-based technique (Digital processing technique).
   ② Photo processing technique (Analog processing technique)
2) Data analysis techniques
   ① Analysis based on dialogue between an analysts and an image analysis system by computer
   ② Interpretation by analyst's eyes --- Interpretation by eyes using photos (for instance, extraction of geological structures)

(3) Application to Survey

   ① Use as preliminary information for a survey
   ② Use to check and correct in a field survey
   ③ Use to prepare necessary thematic maps

4. Remote Sensing Data

4.1. Types of Platforms

Currently used platforms are grouped into (1) satellite, (2) aeroplane, and (3) ground.

(1) Satellite

Table 1 summarizes the details of major satellites used for earth observation.

Table 1. Details of major satellite used for earth observation

Satellite for earth observation	Year of launching	Country of launching	Major mounted sensor	Wavelength range	Resolution (m)	Observation width (km)	Orbital height (km)	Observation period (day)	Covered field
				μm					
LANDSAT No. 1	1972.7 (Functional stoppage)	USA	MSS	0.5- 0.6 0.6- 0.7 0.7- 0.8 0.8- 1.1	80	185	920	18	Cover the earth and widely used for both land and water areas.
No. 2	1975.1 (Functional stoppage)								
No. 3	1978.3 (Functional stoppage)								
LANDSAT No. 4	1982.7 (Functional stoppage)		MSS	The same with the above	The same with the above	180	700	16	The same with the above
No. 5	1984.3		TM	0.45- 0.52 0.52- 0.60 0.63- 0.69 1.55- 1.75 10.40-12.50 2.08- 2.35	30 120 30	180	700	16	The same with the above
SPOT No. 1	1986.2	France	HVR	0.51- 0.73 0.50- 0.59 0.61- 0.68 0.79- 0.86	10 20	60	830	26	The same with the above Preparation of geographical maps is possible because of stereo visibility

(2) Aeroplane

1) Bimotored aeroplane --- MSS for aeroplane mounting
2) Single-engined aeroplane --- Aerophotos
3) Helicopter --- Oblique photos
4) Model plane/Model helicopter --- Very low

(3) Ground Platform

1) Crane vehicle · Observation of reflection-characteristics and radiation
2) Cherry picker characteristics of substances.

4.2. Types of Sensors

Figure 4 shows the relation between the ranges detected by currently used sensors and electromagnetic waves.

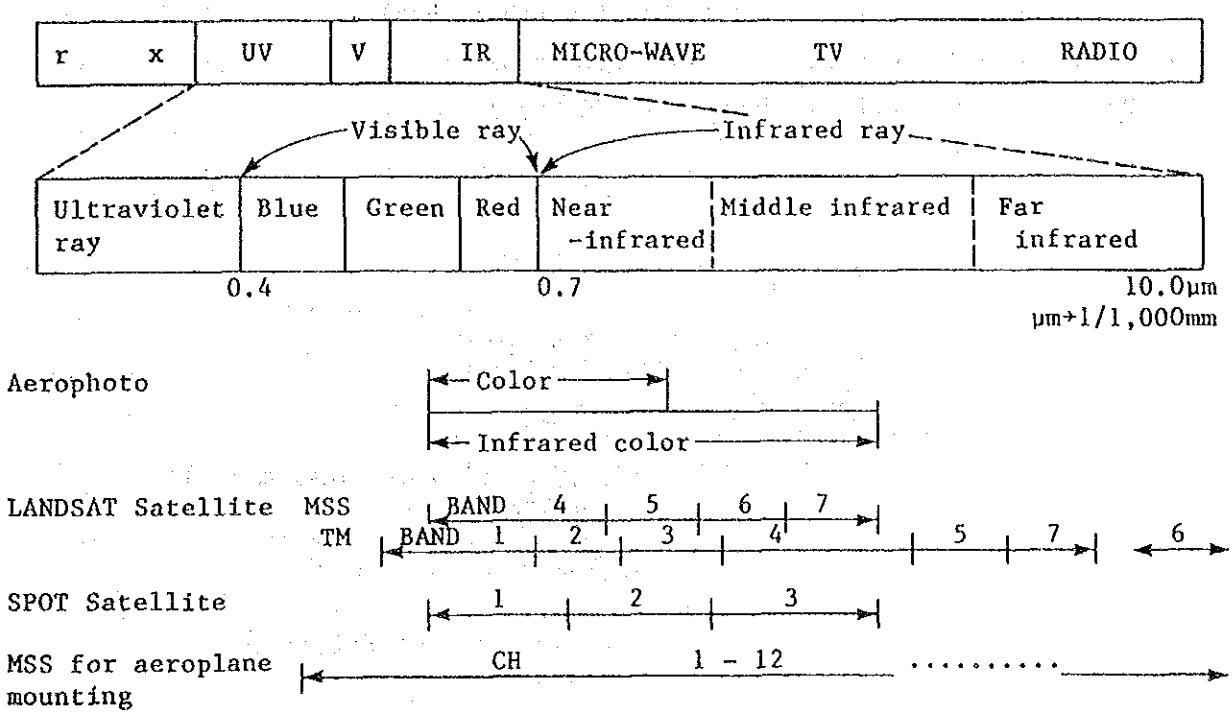


Fig. 4 Sensors and ranges of electromagnetic waves

(1) Camera

Aerophotos are grouped as follows, according to combinations with films and filters to be used:

1) Panchromatic photo --- The visible ray range is recorded in a panchromatic film.
2) Color photo --- The visible ray range is recorded in a color film.
3) Infrared color photo --- Of the visible ray range, green and red lights and near infrared rays are recorded in a color film.

(2) MSS of LANDSAT Satellite

A MSS is a scanning type radiometer called Multispectral Scanner (MSS), which records visible rays (green and red rays) and near-infrared rays with 4 different wavelength bands. MSS is the sensor mounted on LANDSATs No. 1 through No. 5, and records 180km x 180km as one scene, with the minimum resolution of approximately 80m x 80m. Its appearance is shown in Figure 1.5.

1) Band 4 = 0.5 - 0.6 μm (Green light of visible rays
2) Band 5 = 0.6 - 0.7 μm (Red light of visible rays)
3) Band 6 = 0.7 - 0.8 μm (Near-infrared rays)
4) Band 7 = 0.8 - 1.1 μm (Near-infrared rays)

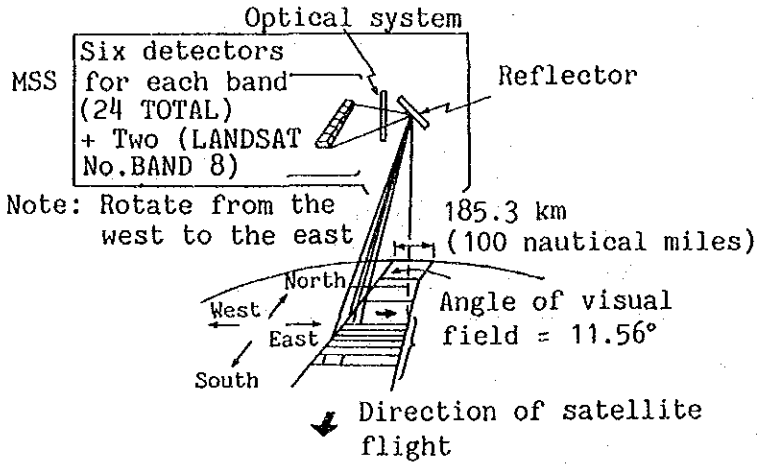


Fig. 5 Appearance of LANDSAT MSS

(3) TM of LANDSAT Satellite

A TM called Thematic Mapper (TM) is a scanning type radiometer similar to MSS, and records visible through far (thermal) infrared rays with 7 different wavelength bands. It has been mounted on satellites after No. 4. TM records 180km x 180km as one scene, with the minimum resolution of 30m x 30m. Its appearance is given in Figure 6.

1) Band 1 = 0.45 ~ 0.52μm (Blue light of visible rays)
2) Band 2 = 0.52 - 0.60μm (Green light of visible rays)
3) Band 3 = 0.63 - 0.69μm (Red light of visual rays)
4) Band 4 = 0.76 - 0.90μm (Near-infrared rays)
5) Band 5 = 1.55 - 1.75μm (Middle infrared rays)
6) Band 6 = 10.40 - 12.50μm (Far infrared rays)
7) Band 7 = 2.08 - 2.35μm (Middle infrared rays)

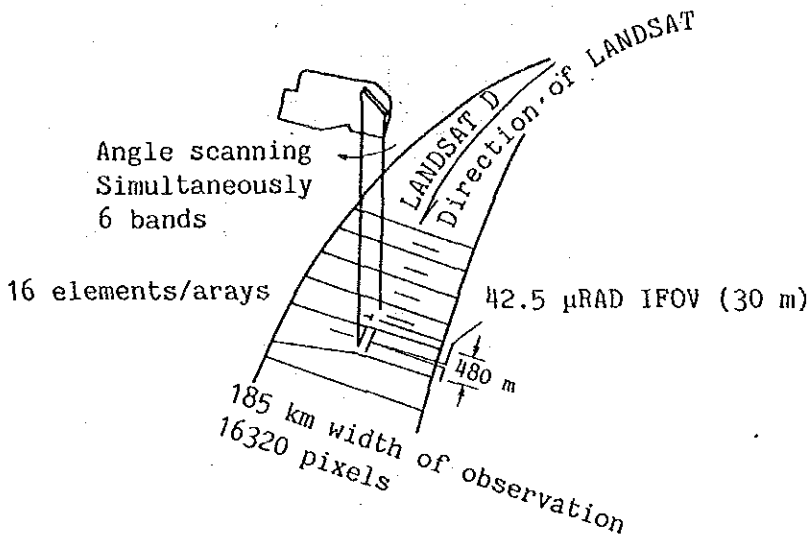


Fig. 6. Appearance of LANDSAT TM

(4) HVR of SPOT Satellite

This is a sensor mounted on SPOT Satellite launched by France. HVR is an abbreviation of High Resolution Visible imaging instrument. HVR produces two types of data.

1) Panchromatic mode; Record 0.51 - 0.73μm with black-white single band
2) Multispectral mode; Band 1; 0.50 - 0.59μm
Band 2; 0.61 - 0.68
Band 3; 0.79 - 0.86

Rhw minimum resolution is approximately 10m x 10m, and 20m x 20m for the panchromatic mode and for the multispectral mode, respectively. The most marked characteristic of HVR is provision of stereo visibility.

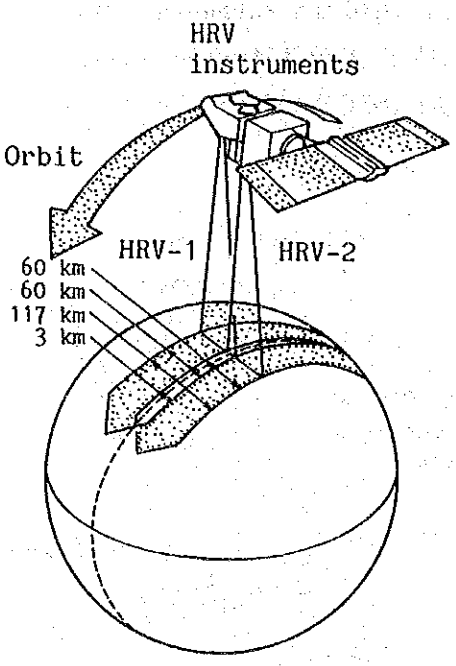


Fig. 7 Appearance of SPOT HRV

(5) MSS for Aeroplane Mounting

This is a MSS of a similar type with MSS of LANDSAT mounted on an aeroplane. The MSS records visible rays through far (thermal) infrared rays from low altitude in higher precision than that of LANDSAT MSS. Figure 1.8 gives its appearance. This sensor is used in a wide area including water temperature survey and geothermal survey.

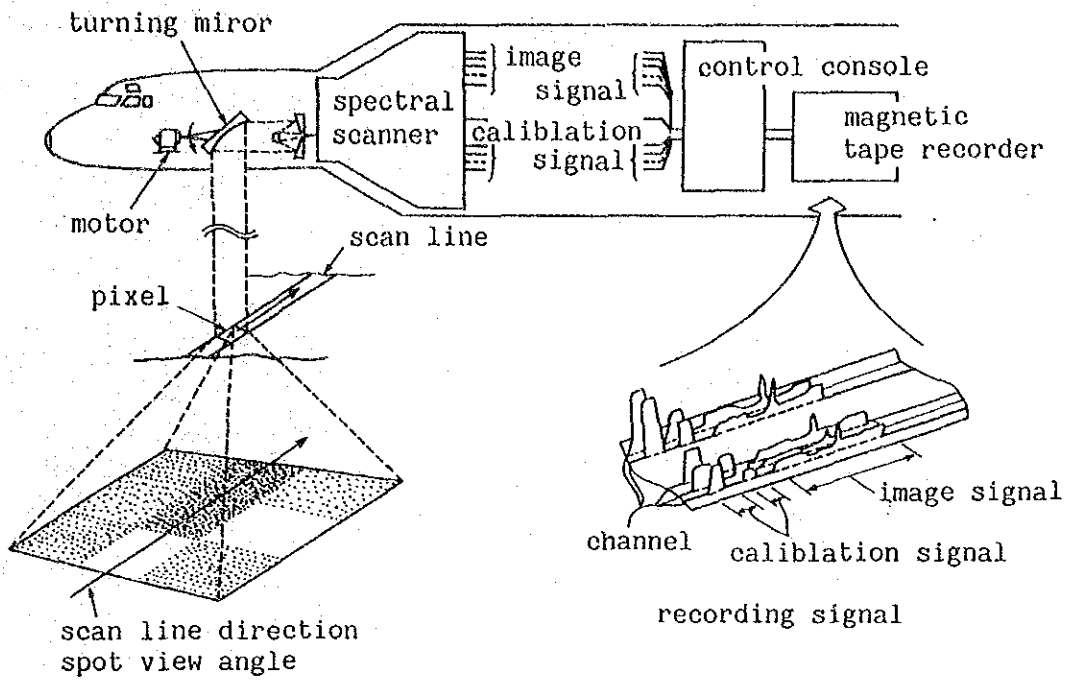


Fig. 8 Appearance of MSS FOR aeroplane mounting

4.3. Data Collection

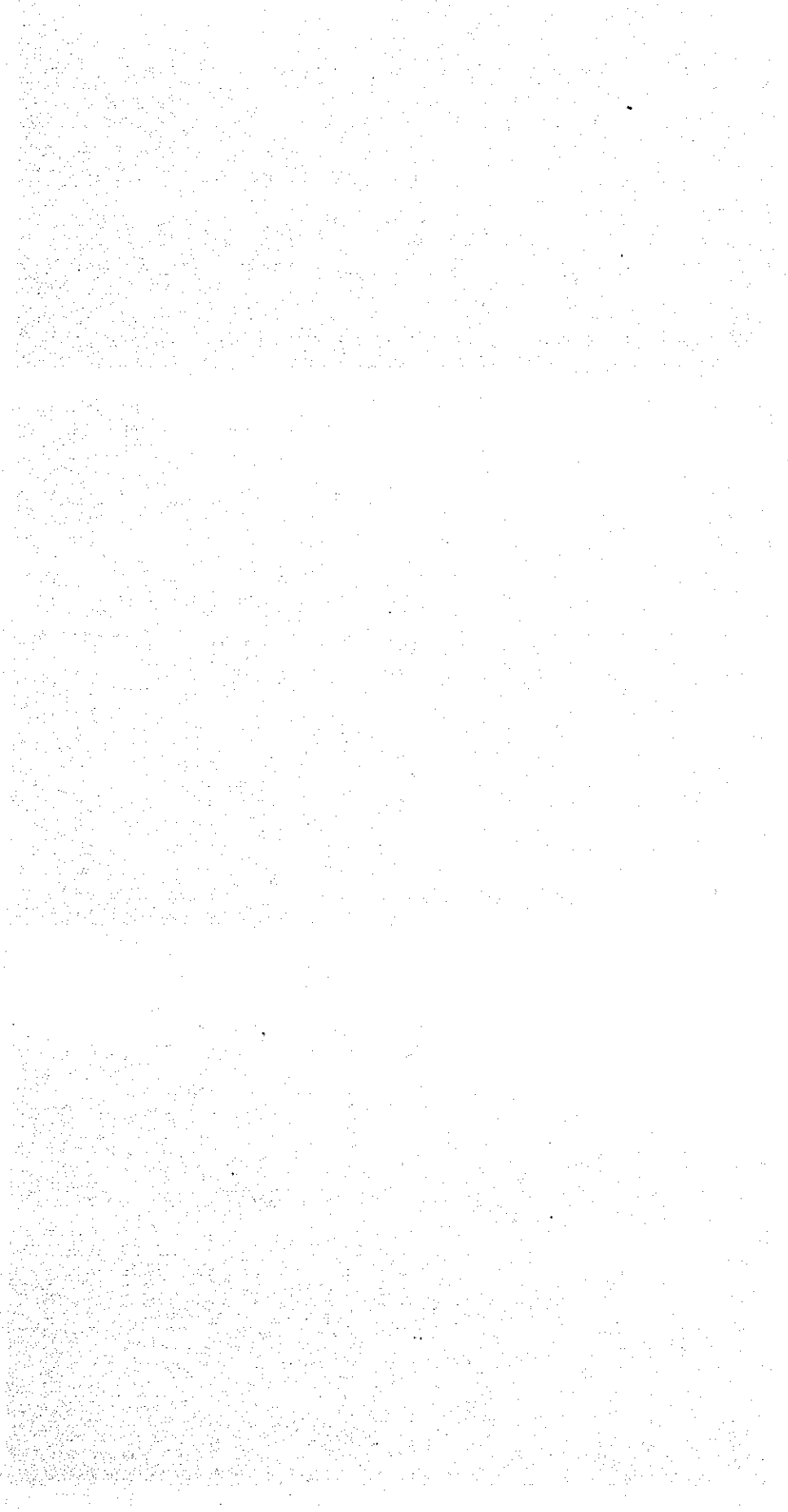
(1) Visible ray data --- Data in the wavelength range equal to our vision in daily life - (Example) Red light data of visible rays are best to analyze a polluted water pattern.

(2) Near-infrared ray data --- Suitable to measure vitality of vegetation and water areas on the earth surface

(3) Middle infrared data --- It is said to be best to analyze degrees of rock alteration and geological structures and distinction between vegetation and non-vegetation

(4) Far infrared ray data --- Used to catch thermal distribution such as terrestrial heat and water temperature

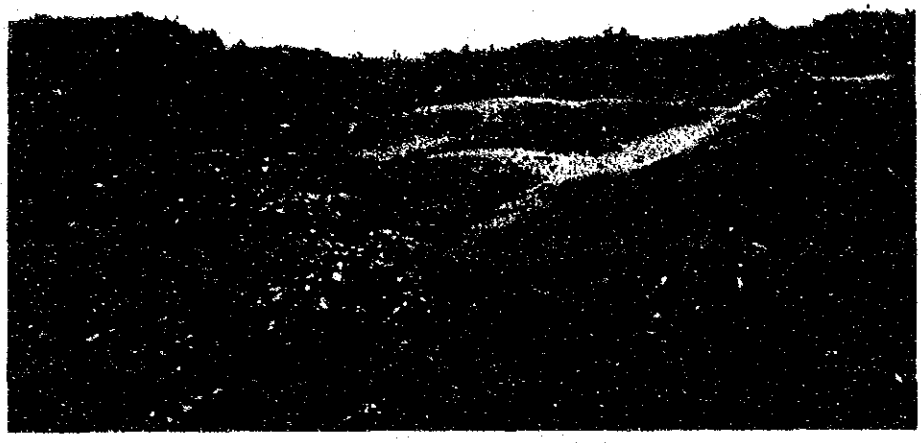
3. Photograph of the site



Natural forest
This is a picture of natural forest seen around Manizales waterhead forests

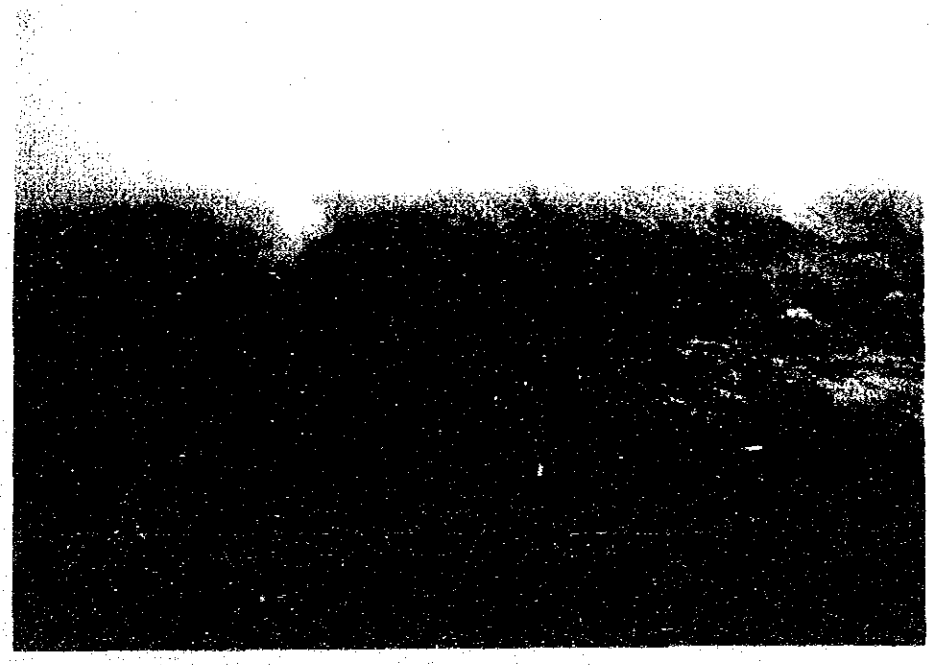
Man-made forest
This is a picture of aliso forest seen in Salamina region

Forested woods
This picture shows the forested woods seen on the mountain slope land near La Palma. Forestation of pine trees, ect. is done actively.



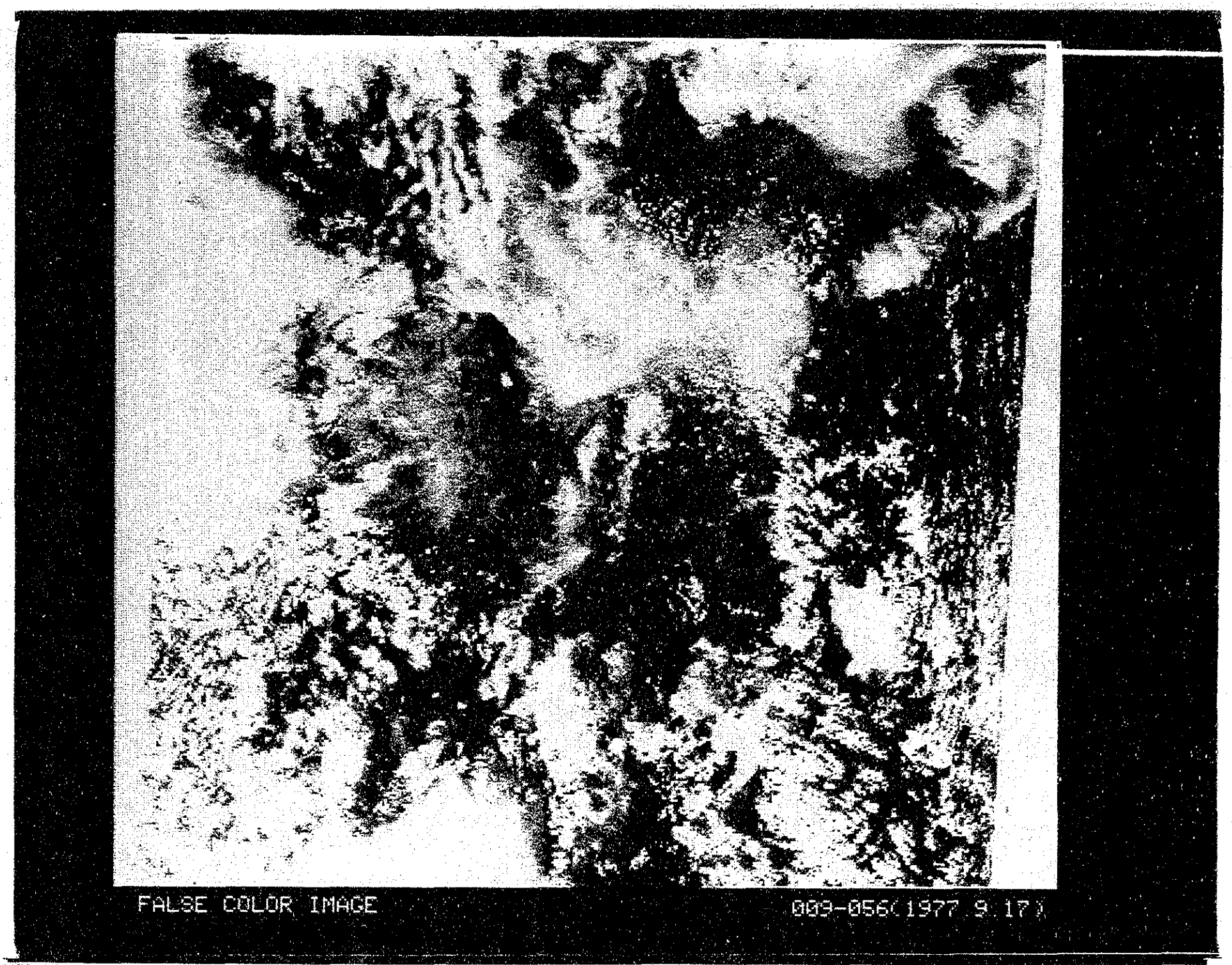
Grazing/grass land
This picture shows the grazing/grass land seen in the mountain area near Neira. The grassland expands over to the mountain top, and forests are only seen at the ridges.

Farm land, agricultural forest
This is a picture of farm land and agricultural forest seen on the mountain slope land around Salamina region. Panera is forested.



Plateau grassland
This is a picture of plateau grassland seen around the Mt. Nevado del Ruis.

4. False color image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FALSE COLOR IMAGE
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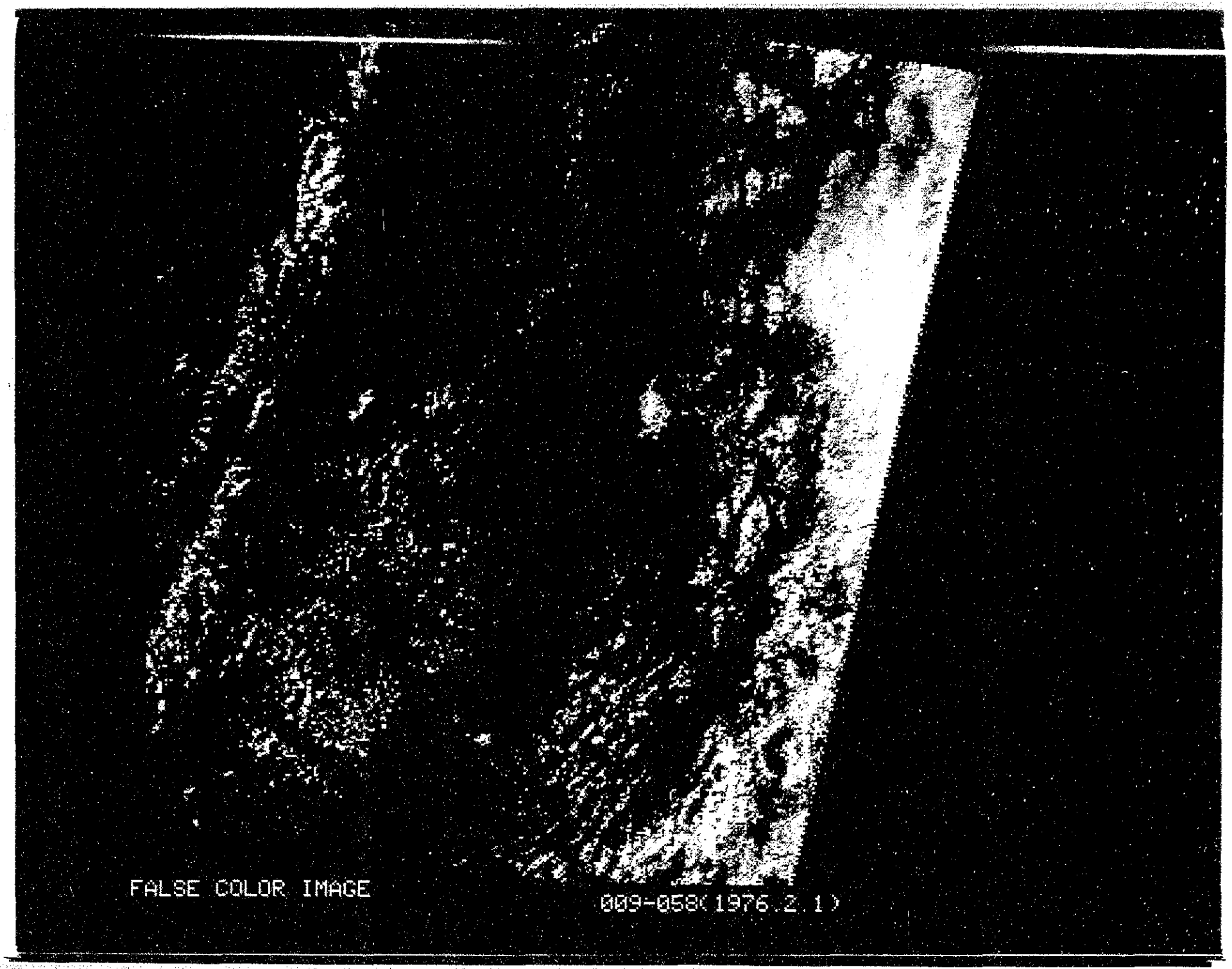
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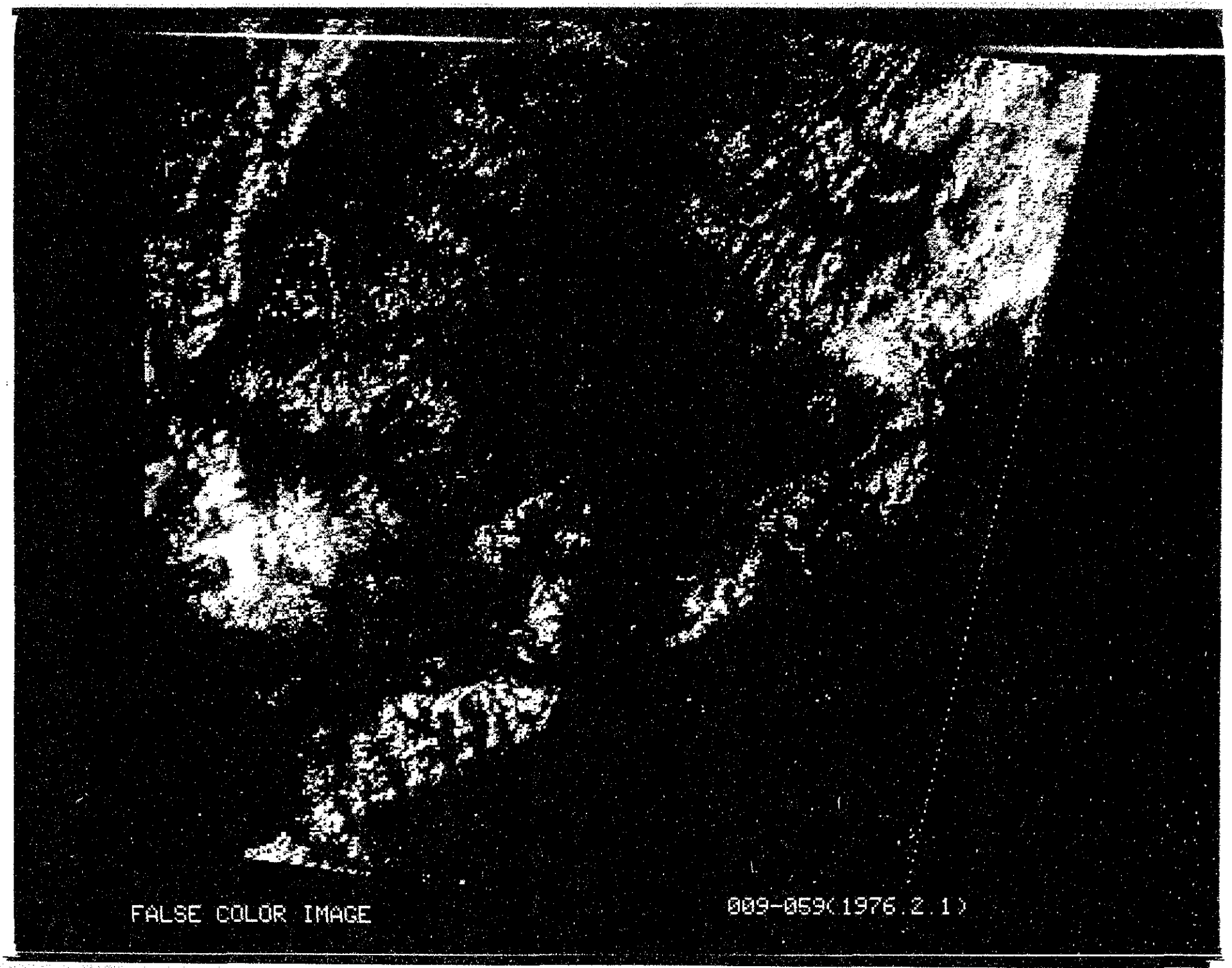
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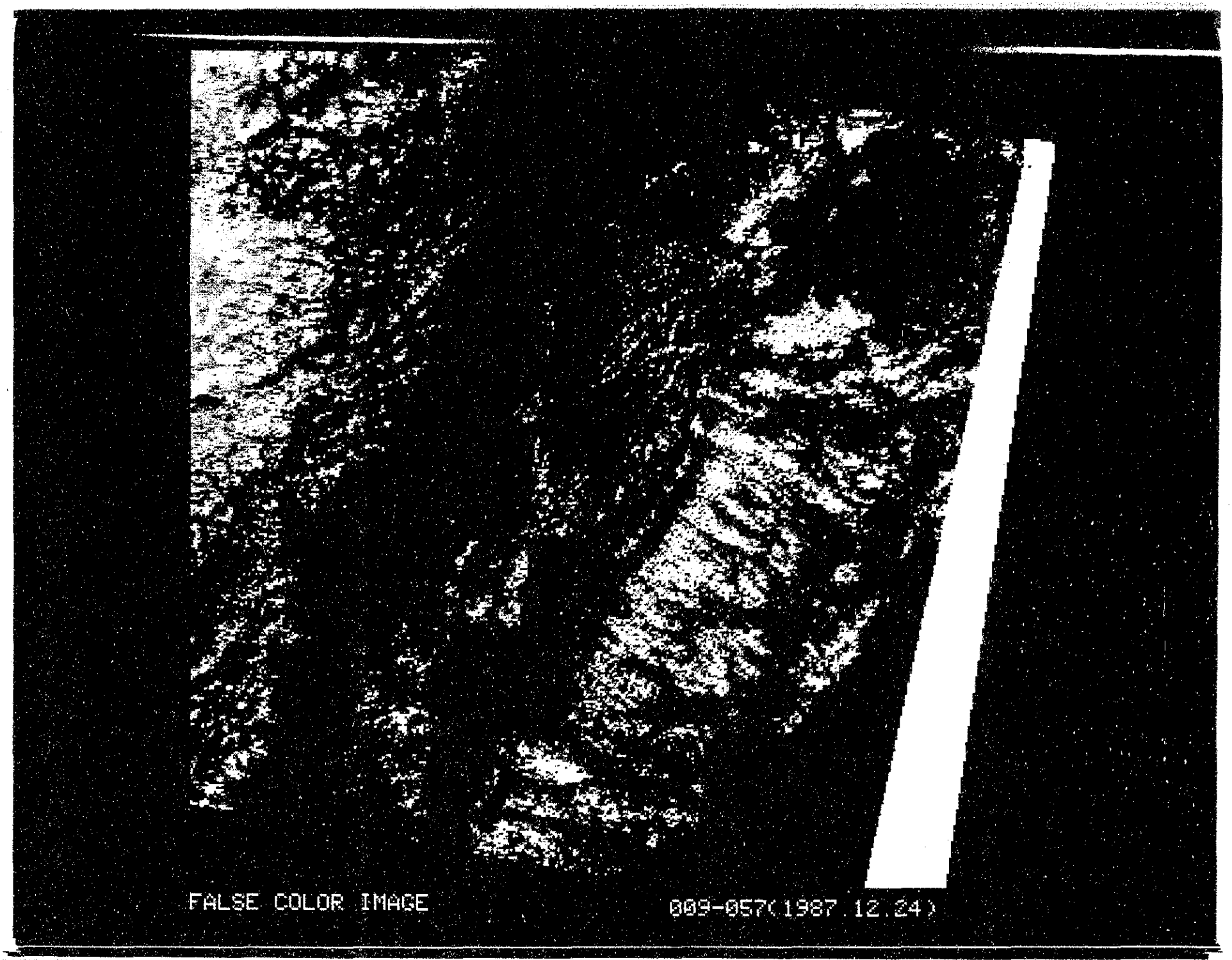
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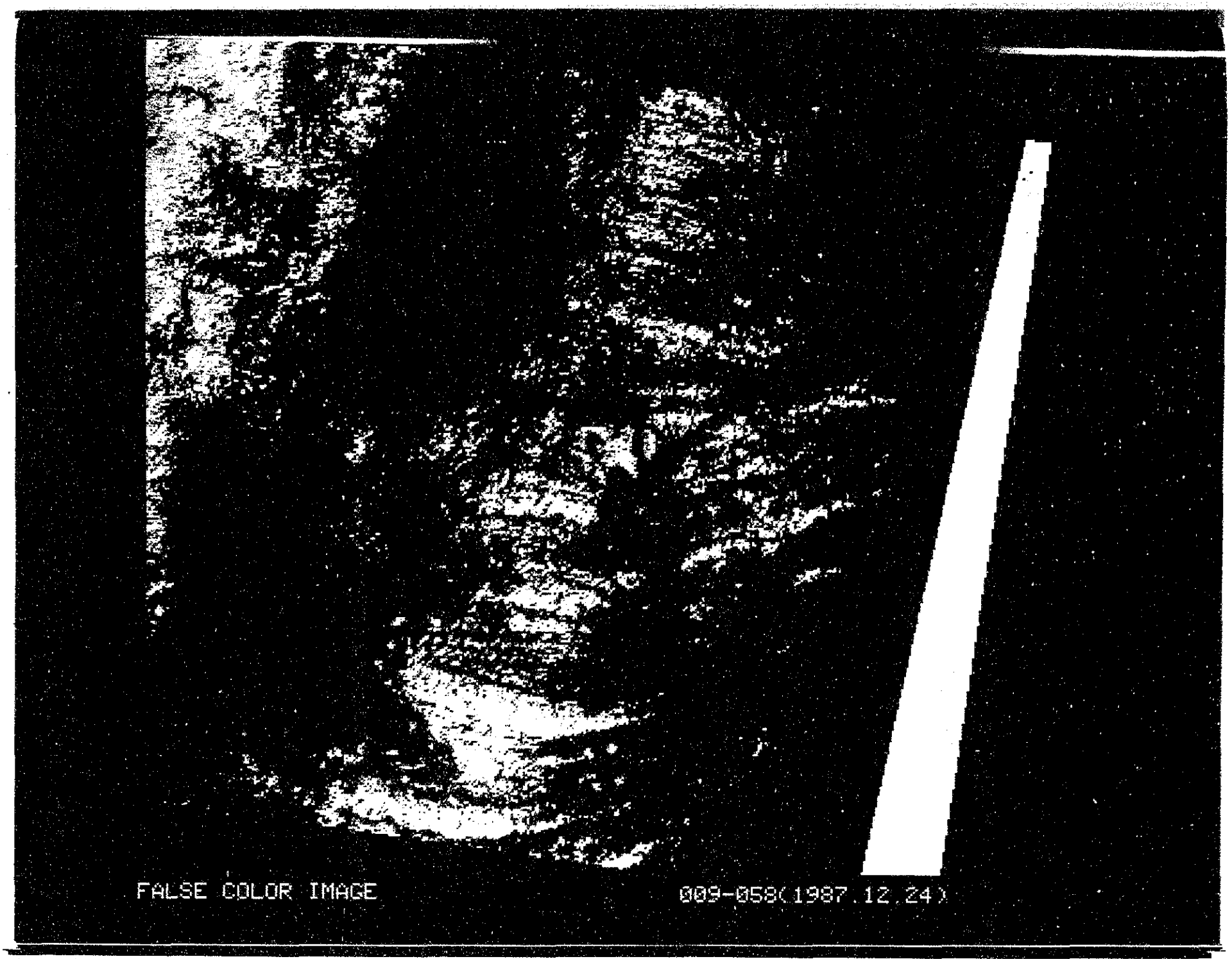
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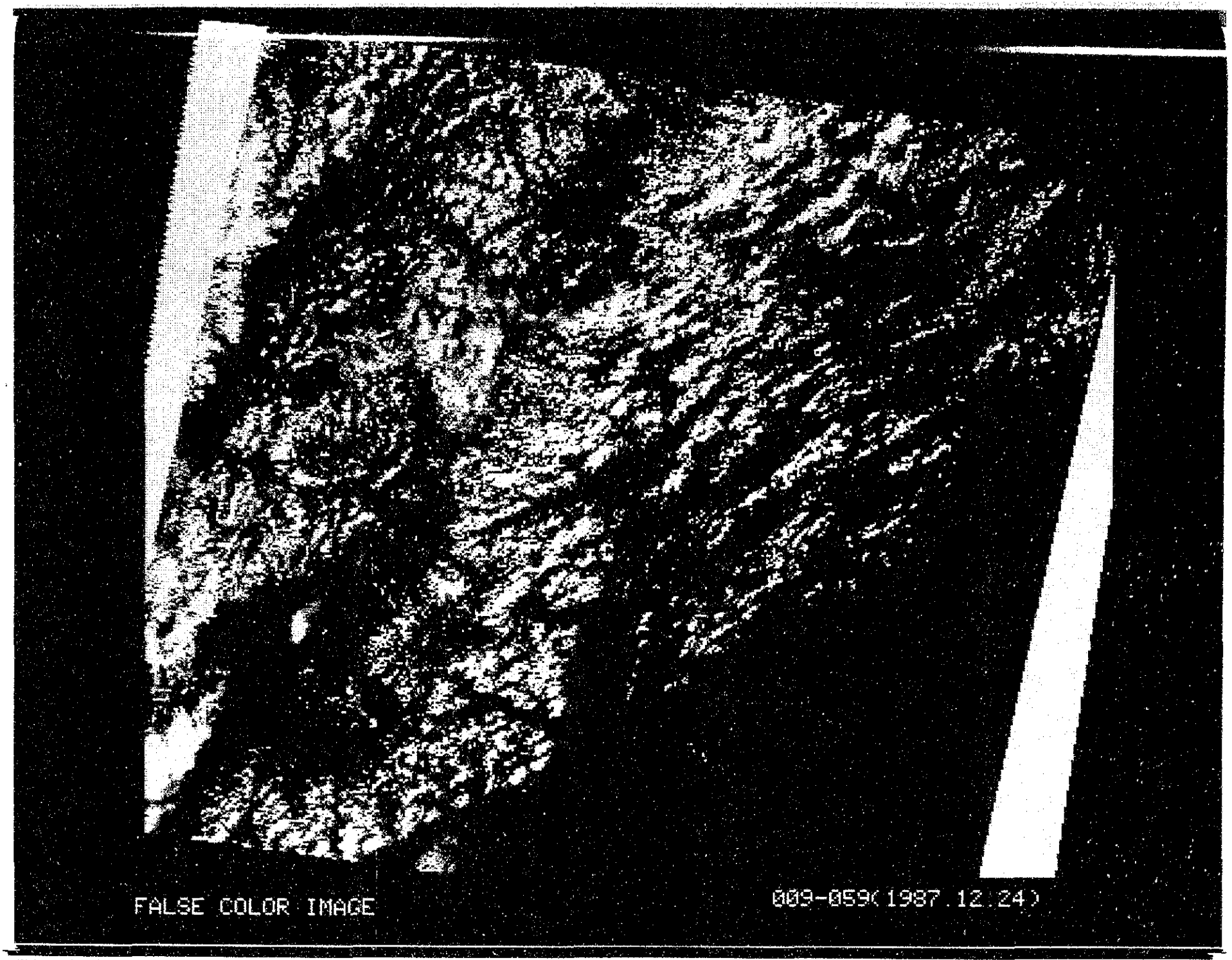
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