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HIGH ALTITUDE COLOR PHOTOGRAPHY AS A TOOL FOR REGIONAL* ANALYSIS: AS DEMONSTRATED FOR SOUTHEASTERN FLORIDA

L. Alan Eyre
Laboratory Research Associate

By 1969, high altitude aerial photography of the United States had become available, and the opportunity thus opened for more general utilization of this type of imagery. In October of that year a NASA RB-57 overflight at approximately 18 km. altitude was flown over a large area of Southeastern Florida to support Earth Resources Test Site No. 164 at Boca Raton, where the Remote Sensing and Interpretation Laboratory directed by Dr. James P. Latham of Florida Atlantic University's Geography Department is located. The photography included color and color infrared of the tri-county region of southeast Florida: Palm Beach, Broward and Dade counties.

This region has experienced exceptionally far reaching changes in recent years. It includes one of the most rapidly growing urbanized areas in North America, concentrated along the "Gold Coast" but also extending increasingly inland. At the same time it is almost the only region which has undergone very substantial agricultural development on land never before used for this purpose. South Florida, in fact, is virtually the last humid area in the nation to undertake massive development on a regional scale. The availability of high altitude imagery made it feasible to evaluate its potential for quantifying the dimensions of regional change.

The imagery is in the form of 228 mm. by 228 mm. duplicate positive transparencies, which were projected by a Bessler Overhead Projector which was modified for aerial roll film use, and viewed on a rear view screen. Closer examination was accomplished with magnification using a florescent daylight tube illumination system made in the laboratory. Under ideal laboratory conditions, resolution of these color and color infrared transparencies is in the range of 4 meters. Each transparency covers an area of 22.5 km.^{2} at a scale of 1:60,000. (Zeiss RMK 30/23 Aerial Mapping Camera was used to record the imagery.)

*For published article see L. Alan Eyre, "High-Altitude Color Photos", Photogrammetric Engineering, Vol. XXXVII, No. 11, November 1971.

Attention has been focused upon three main aspects of change in the region, which in fact overlap. These are

(1) the transformation of the southeast Florida wetlands, popularly though not entirely accurately known as the "Everglades",
(2) the expansion of agriculture,
(3) the growth of the urbanized area.

The limits of all these three elements in the regional pattern were known from U.S. Geological Survey data obtained in 1956, which used both photogrammetry and the ground surveys for U.S. Corps of Engineers 1:25,000 quadrangles. The development analyzed therefore covered the period of thirteen years from 1956 to 1969.

In 1956 there were 9750 km.^{2} of undrained wetlands within the tri-county region. During the thirteen years the drainage and water regulation work of the U.S. Corps of Engineers and the operations of the Central and Southern Florida Flood Control District with headquarters at West Palm Beach have reduced this by 2600 km.^{2} to 7150 km.^{2}. Of this newly drained area, 6 percent has been built over, 68 percent has been developed for agriculture and 2 percent has been put to all other uses (airfields, mining, recreation, etc.); 24 percent was undeveloped as of October 1969 (Table 1).

The remaining 7150 km.^{2} of undrained wetlands are not homogeneous in character, and the color infrared transparencies were very useful in distinguishing various subtypes. Very striking is the pattern formed by the three Water Conservation Areas (Figure A). These are very large bodies of shallow freshwater, totalling 3275 km.^{2} in all, impounded by leaves, and are used to control the natural flow of water from Lake Okeechobee southwards to the Gulf of Mexico, Florida Bay and the Atlantic Ocean, mainly to prevent flooding. Sawgrass and algae, the vigorous growths of which occur throughout the Water Conservation Areas, can be noted by characteristic streaks and blotches of red on the color infrared. (Figure A) Variations in depth can also be detected where stretches of open water occur.

A second division of existing undrained wetland comprises 2122 km.^{2} of reserved areas under various authorities. These include that portion of the Everglades National Park within Dade County, that part of the Seminole Indian Reservation outside the levee of Water Conservation Area No. 3, the West Palm Beach Water Retention Area and the Corbelt Wildlife Area. The third division comprises those wetland areas not utilized for specific purposes in October 1969. The boundaries between the reserved areas and the undeveloped

TABLE 1

REGIONAL ANALYSIS OF DADE, BROWARD AND PALM BEACH COUNTIES, FLORIDA, USING 18 KM. COLOR AND COLOR INFRARED PHOTOGRAPHY

Major Changes 1956-1969

			km^2
Undrained wetlands, 1956			9750
Drained 1956-1969			2600
(a) Utilized for:	1.	Sugar Cane	1207
	2.	Truck farming (So. Dade)	85
	3.	Grassland	273
	4.	Citrus and undifferentiated	205
Total:		Agriculture	1770
	5.	Sand and Gravel Quarries	41
	6.	Urban expansion	153
	7.	Military, recreation utilities	22
(b) Unutilized or undifferentiated			614
Undrained wetlands, 1969			7150
(a) Water Conservation Areas			1772
(b) Everglades National Park (Dade Co.)			1659
(c) Indian Reservation			212
(d) Corbett Wildlife Area			212
(e) West Palm Beach Water Retention Area			39
(f) Unreserved wetlands			1752
Urban built-up area, 1956			374
Expansion 1956-1969			1032
Urban built-up area, 1969			1406

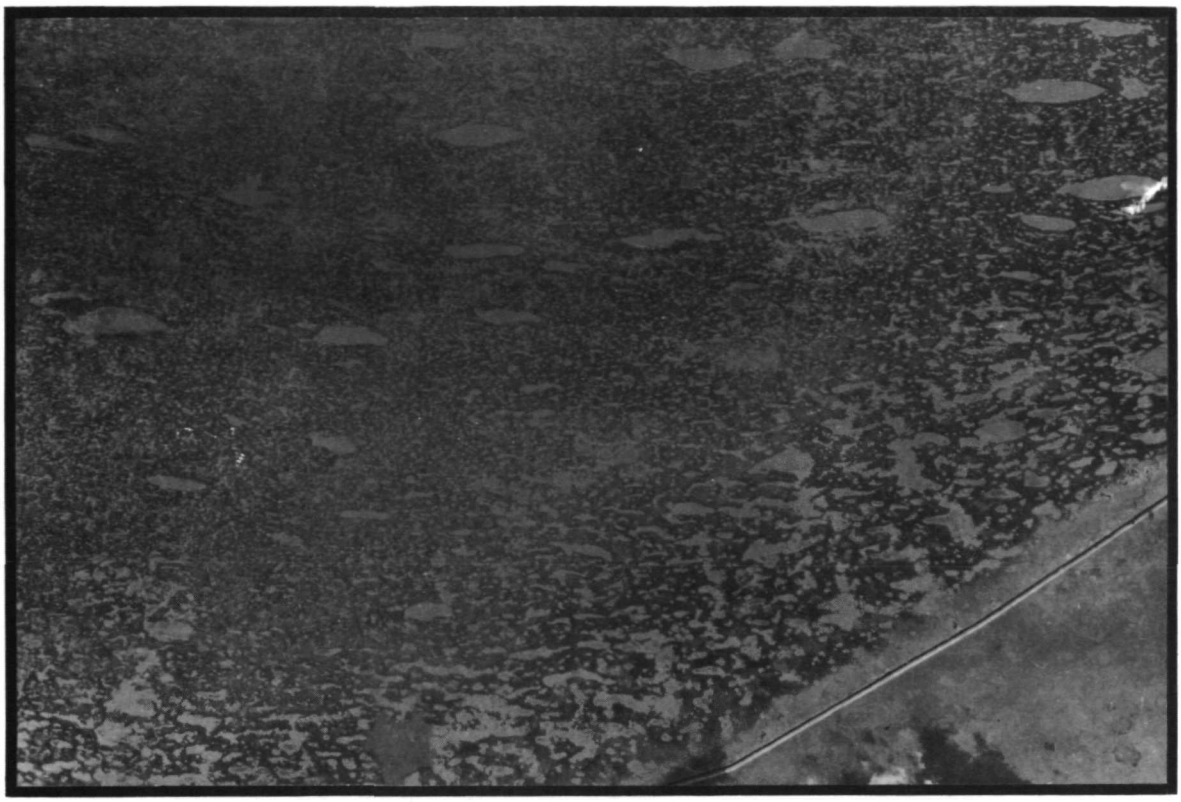

Figure A. - Sawgrass and Algae patterns in water conservation area.

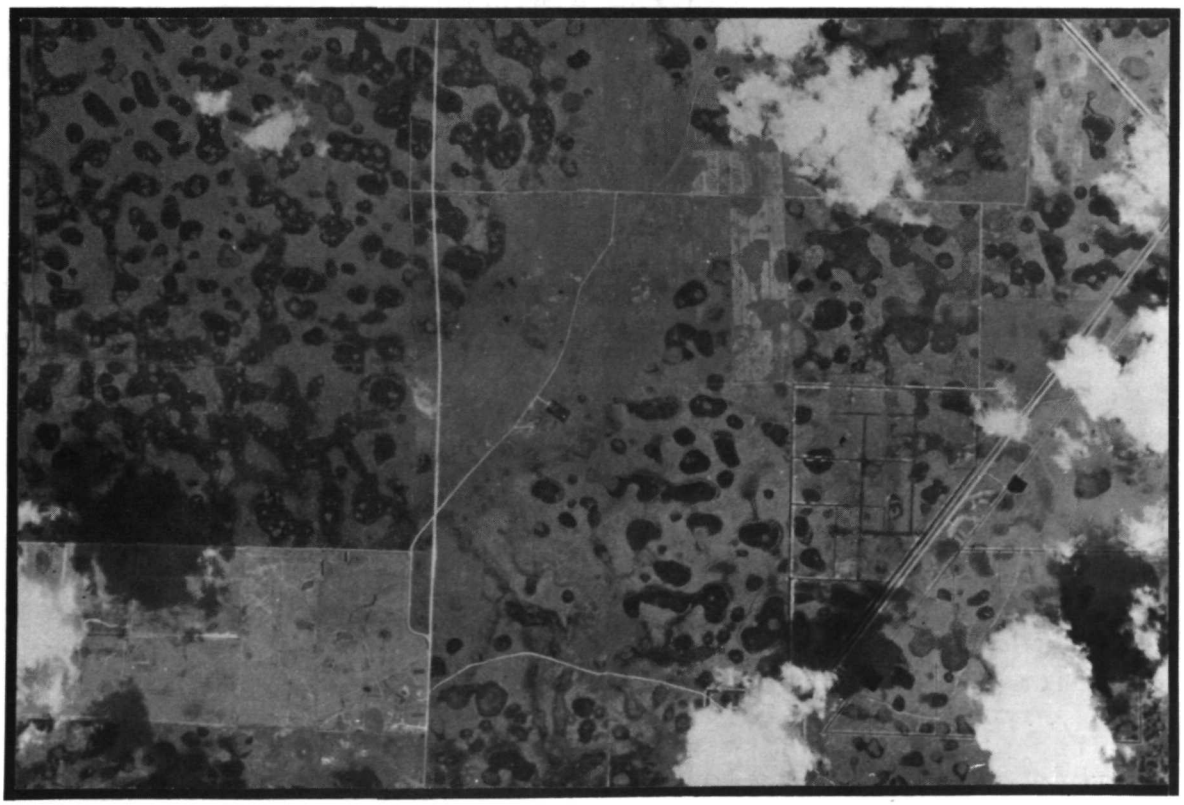

Figure B. - Circular solution features in karst-associated marshland topography.

lands are often quite distinct on the imagery even where their physiographic characteristics are similar.

When the color and color infrared photography are used together, a very detailed picture of this semi-aquatic environment can be obtained, as well as the broad regional physiographic changes from north to south and from the dry coastal ridge inland. This unique environment ranges from marine and brackish mangrove swamp in the extreme south and southeast, through sawgrass with slightly elevated tree hammocks and intervening sloughs, to the so-called "Florida karst" in the north. This last is a curious marshland topography with many low, circular solution features, the details of which are far more apparent from the high altitude photography than on the ground (Figure B).

The expansion of agriculture, almost all by occupance of drained wetland, can be interpreted at a macro level. Four principal types of development can be detected. These are:

(1) Sugar cane
(2) Vegetable and truck farming
(3) Citrus
(4) Grassland

The signatures of the first two on the photography are very distinctive and the expanded acreages of each easily calculated. Between 1956 and 1969 the area under sugar cane increased by 1207 km.^{2}, all of it "reclaimed" from drained Everglades muckland. This expansion is the direct result of the Cuban situation, when sugar supplies to the United States were curtailed after 1959. The industry is highly mechanized, although both domestic migrant and West Indian labor plays a significant role. Major citrus development - also in the forms of large scale enterprises - has entered the area, mainly in Palm Beach Co., since 1956 on drained wetland underlain by the Florida karst topography. Some citrus developments in a very early stage were difficult to differentiate from some other possible land uses. For this reason citrus had to be included with an undifferentiated category in Table 1. The truck farming is primarily in South Dade Co. Here, although 85 km.^{2} was taken in from the wetlands, 212 km.^{2} were lost to urban development, a trend which is continuing.

The fourth category, grassland, posed a difficult problem of interpretation. There are three types of grass cover in this region, all derived from drainage of the wetland. These are pasture, sod and "natural" herbaceous cover developing from former wetland now

drained but unutilized. In the dry season the last category would probably be distinguishable, but in October the rains give an almost uniform red to all grasses on the color infrared. The pasture is used as open, but improved, range for cattle, and the presence of faint tracks and watering points sometimes can give indication of this land use. Large sod farms cultivate St. Augustine grass for trucking to gardens in nearby urban areas: from 18 km., however, this specialty is not easily distinguishable from improved pasture or fodder crops. In the case of the drained but unutilized areas, the semi-aquatic sawgrass vegetation quickly gives way to a variety of seasonal scrub and bunch grasses and low ligneous plants, with the gradual invasion of larger shrubs and palmetto. Most of the unutilized areas are being held as speculation in anticipation of large scale urban development. Even immediately adjoining the Everglades National Park, thirty-eight miles from Miami and eight miles beyond the present limit of suburbia in Dade Co., land is being subdivided for sale as homesites. On some lands of this type an extensive type of low-density livestock rearing is practised as a temporary utilization. There were a little over 600 km.^{2} of drained former wetlands not visibly utilized in October 1969.

The expansion of the urban area has been in two directions: a linear development which has linked all the coastal townships along a ninety-mile section of the Atlantic shoreline into one continuous conurbation, and a westward expansion into the drained wetlands. The latter movement is particularly characteristic of Dade and Broward counties. With lower altitude photography such as the NASA 1.5 km. and 4.5 km. coverage of Test Site 164 considerable potential for infilling of small plots of vacant land can be observed*, but on the high altitude imagery the limits and extension of the urbanization is very sharply defined. The type and density of the development can also be estimated within reasonable limits. From a 1956 area of 374 km.^{2}, the Dade-Broward-Palm Beach urban complex has exploded 280 percent in thirteen years to occupy a total land area in 1969 of aver 1400 km.^{2}.

One trend is of particular interest: the tendency for middle-income residential development (identified by lot size and subdivision design on the photography)

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*See L. Alan Eyre, An Investigation by Remote Sensing of Vacant and Unutilized Land in an Urbanized Coastal Area of Southeastern Florida, contract No. 14-08-0001-10936, Technical Report No. 3, Florida Atlantic University, 1969.

to expand westwards in Broward Co. into former wetland drained by the U.S. Corps of Engineers as far as the levee of the Water Conservation Areas 1 and 2. (Figure C) The continuous eighty-mile long eastern levee of the Conservation Areas forms a unique barrier to expansion of a major metropolitan region. With the Everglades National Park blocking expansion to the south, and the ocean on the east, this "island" of development is hemmed in on all sides except at a ten-mile wide neck near Boynton Beach.

Expansion is "open" only from this point northwards. Under these conditions it is apparent that enormous demographic and economic pressures will be built-up during the 1970's upon the remaining agricultural areas of the tri-county region and westward into Collier Co. beyond the Conservation Areas. More seriously, they will also be brought to bear upon large undeveloped but ecologically vital tracts of the Everglades National Park.

Since water is particularly emphasized on the color infrared, it is possible to identify the principal features of the complex hydraulic system operated by the Flood Control District. This vast system, which extends from Orlando, Fla. to the Keys and includes hundreds of miles of canals with associated sluices, pumping stations and spillways, maintains more or less effective control over the entire water regime of a shallow basin 50,000 km.^{2} in extent. From the high altitude photography, the effects of pollution can be observed upon this enormous, slow-moving mass of water at several places. Particularly evident are the vivid red of water hyacinth infestations, excessive algal growth in semi-stagnant areas and several major pollution features in Lake Okeechobee. At some localities specific effects of canalization such as silt transportation and deposition can be noted.

In the kind of regional overview obtainable from imagery at this scale, it is possible to recognize by characteristic signatures unusual features which occur at widely separated localities and calculate the area they occupy. In the case of the region under discussion such features include drilling rigs, missile launch sites, commercial nurseries, sand and gravel quarries, golf courses and junk yards. Gravel pits and golf courses both occupy an unusually large area in the tri-county region (Figure D).

With this October 1969 photography covering both an urbanized region of two million people and one of the few major agricultural developments of the past decade,

Figure C. Residential expansion into former wetlands.

Figure D. Functional mixed land use changes.

its potential for detailed spatial analysis of the April 1970 Census of Population is considerable. It appears from the imagery that the great expansion of agricultural land in Palm Beach Co. has not been accompanied by any corresponding dispersal of rural settlement. Not only is the development capital intensive and associated with very large land holdings, but the universal availability of road transportation has enabled almost all the increased population to be accommodated in and around the existing centers such as Belle Glade and West Palm Beach.

This evaluation is of a preliminary nature, and only on the broadest scale. It is obviously possible to analyze landscape with this type of photography at a much more detailed level than that reported in this particular study. However, almost the only comparable tool up to the present for providing a broad synoptic picture for regional analysis by photogrammetry has been the black and white photo-mosaics prepared by the U.S. Department of Agriculture. Results using this new 18 km. photography are clearly superior because of the degree of resolution, the combined power of color and color infrared interpretation, and the large area covered by each frame. However, the greatest advantage of this high altitude imagery is undoubtedly the time-saving element, since it is possible to delineate and identify major geographic patterns over thousands of km^2 very rapidly.

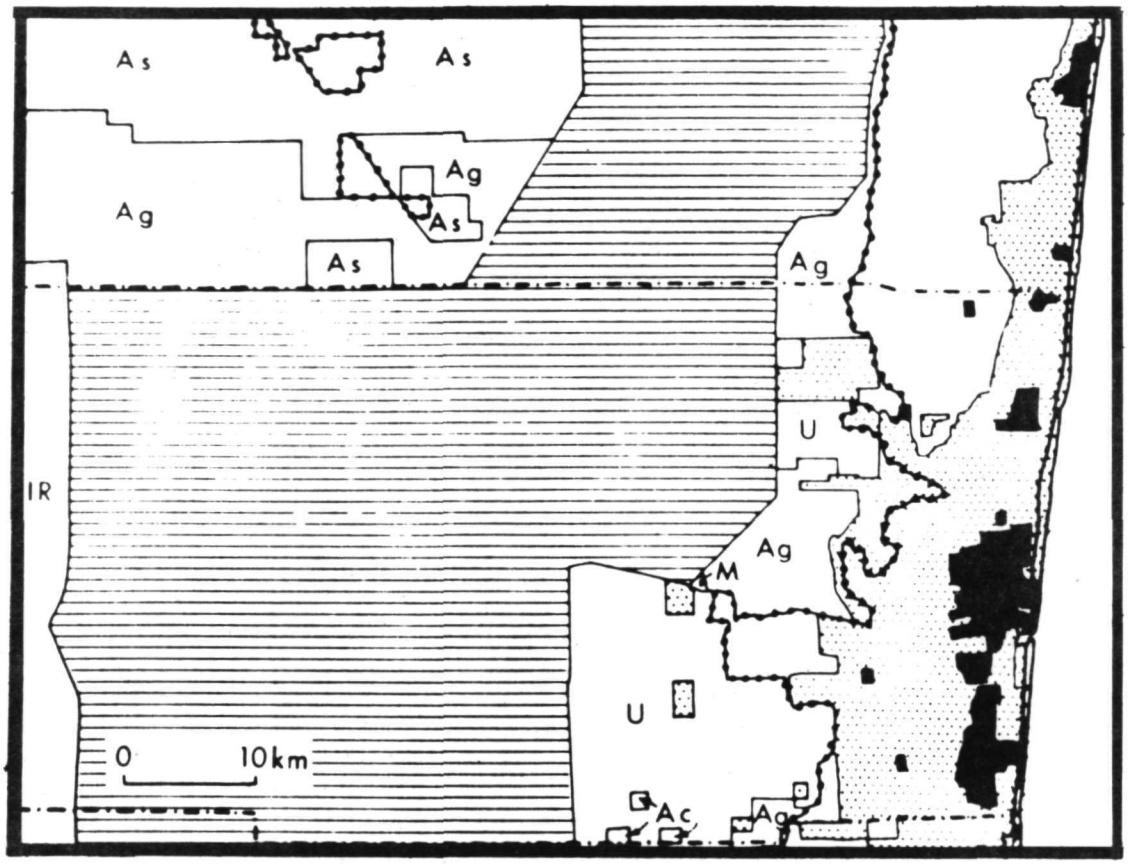

Figure E. A portion of the regional analysis made of Dade, Broward, and Palm Beach counties, Florida, from 18-k photography at the Remote Sensing Laboratory, Florida Atlantic University. Heavy dotted line indicates limits of drained area in 1956, with built up area solid black. Stippled, built up area 1969; hatched, water storage; utilization of land drained since 1956 is shown, - As, sugar cane; Ag, grassland; Ac, citrus; U, unutilized; M, Mining and quarrying.