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BACKGROUND AND PRINCIPAL APPLICATIONS OF REMOTE SENSING
IN MEXICO

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16. Abstract Remote sensing, or the collection of information from objectives at a distance, crystallizes the interest in implementing techniques which assist in the search for solutions to the problems raised by the detection, exploitation, and conservation of the natural resources of the earth. In this paper, an attempt is made to present an overview of the studies and achievements which have been obtained with remote sensing in Mexico.			
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BACKGROUND AND PRINCIPAL APPLICATIONS OF REMOTE SENSING
IN MEXICO

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Remote sensing, or the collection of information from objectives /1** at a distance, crystallizes the interest in implementing techniques which assist in the search for solutions to the problems raised by the detection, exploitation, and conservation of the natural resources of the Earth.

In this paper, we attempt to present an overview of the studies and achievements which have been obtained with remote sensing in Mexico.

As a forerunner of this technology, it is known that the first agency whose purpose was the application of photography for photogrammetric work was established as early as 1926, in the then Comisión Nacional de Irrigación [National Irrigation Commission], and that it developed the first plan of this type in 1929. As it has evolved, the application of photography has moved from the use of black-and-white material to color, and currently the taking of conventional aerial photographs is performed in Mexico by about ten individual companies, and it is also relevant to the cartographic work carried out by the Dirección de Estudios del Territorio Nacional [Agency for the Study of the National Territory], a governmental agency which is developing a system of five [types of] maps on a scale of 1:50,000 - topography, /2 geology, land use, edaphology, potential use - and various maps on different scales: climate, touristic maps, etc.

*National Water Resources Planning Commission, Secretariat of Agriculture and Water Resources.

** Numbers in margin indicate pagination in foreign text.

In terms of what is properly called remote sensing - the use of more sophisticated sensors and films, from airplanes and satellites - work was begun in April, 1969 with the accomplishment of one complete mission. These flights corresponded to the third stage of a program of International Cooperation on Remote Sensing established between Mexico and the United States. The mission carried the NASA number 91, and was carried out with the use of a Lockheed Electra airplane of that agency.

The principal objective of Mission 91 was to verify the effectiveness of the new instruments, methods, and systems for the study of natural resources.

The instrumentation employed was:

- 1) Wild RC-8 camera with Aero-neg type 2448 color film.
- 2) Wild RC-8 camera with Ektachrome infrared type 2443 film.
- 3) Multiband system of four KA-62 cameras, with type 3401 Plus-X film (in three) and infrared type 2424 (in one).
- 4) Bichannel optical-mechanical mapper for the 3-5.5 and 8-14 micron bands (thermal infrared).
- 5) Oblique-view [side-looking] radar operating on a frequency of 16.5 GHz.

This mission comprised a flight over six test locations in the central region of our country. These [observations] had the following /3 objectives, in general;

- evaluation of subterranean waters
- determination of thermal anomalies in soils, rocks, and bodies of water.
- mapping of the water contamination caused by urban discharges.
- determination of sludge obstructions in rivers and conduits.
- location of springs and areas of sub-discharges in hydraulic systems.
- detection of insect attack on vegetation.
- working out of a general plan of soils, based on: drainage, salinity, topography, productivity, erosion, and origin.
- a study of land use.

In a general way, the results of Mission 91 proved satisfactory and have borne fruit in the various fields to which they applied. The new sensors and types of film showed themselves to be very useful in this type of study, although it has been impossible, as of this date, to make the technique operational in our country with such a complete array of data acquisition tools.

Work has been going on since 1969 in the Secretariat of Water Resources with multiband camera systems, carrying out specific missions on different scales in zones where they have been required. The airplanes used have been Cessnas, and the cameras have been Hasselblads with objectives having 80 and 50 mm focal length. /4

At the present time it is planned in the Comisión del Plan Nacional Hidraulico [National Water Resources Planning Commission] to use infrared photography for one of the more interesting programs for Mexican agriculture; that of detecting infestations in farmland. This is being done in order to detect hosts of the Mediterranean fly, and there is a project for its application to wheat infestations. Experience and precursors of this work have been obtained in studies on palm trees attacked by insects and studies carried out on citrus plants, where it is possible to detect a number of diseases, to separate species of plants, determine their condition, identify ant-hills, as well as to recognize the species inhabiting them.

The following have been indicated as unquestionable advantages derived from the use of remote sensing in citrus culture:

1) It is possible to study large areas with great speed in order to detect and locate infestations in the vegetation, and to follow their course of development for a more rapid and effective control, as well as to study soil conditions (humidity, salinity, etc.)

2) The costs of detecting and locating the infestations are reduced, as well as the costs of control, whether chemical, biological, or cultural.

3) When limiting the infested areas, for their control, the area of contamination is reduced (in the case of chemical control), avoiding a

/5

greater contamination of the environment and poisoning of insect parasites and predators (biological control).

4) The possibility of identifying species of plants

5) The possibility of inventorying extensive agricultural areas in considerably less time and at less cost than with only field work.

The possibility arose in 1972 of employing information from natural resource satellites, under the terms of the above-mentioned agreement on Mexican-U.S. collaboration. The governmental agencies and universities were able to participate in the capacity of principal investigators in this project. At the conclusions of the experiment, the result was that only two agencies successfully completed the investigations.

With the images from the LANDSAT satellite, then called ERTS, received under the terms of the above-mentioned project, four investigations were completed; one in the Direccion de Estudios del Territorio Nacional [Agency for Studies of the National Territory], which carried out a study in the central zone of the country intended to compare results on land use and on lithological units obtained from aerial and satellite information; and three in the Secretaria de Recursos Hidraulicos [Secretariat of Water Resources], consisting of studies intended to test the efficiency of the methods of remote sensing in different zones of the Republic of Mexico. For this purpose, three test sites were selected whose physiographic and climatic characteristics were distinctly unlike. The zones selected were Papaloapan, Los Mochis and Mexicali. The latter two are important agricultural centers. /6

Papaloapan: comprised the greater part of the basin of the Papaloapan River, and the coastal zone of the Gulf of Mexico. This region exhibits three relevant physiographical characteristics, those of the tropical plains being outstanding.

Los Mochis: Located on the Northwestern coast of the country, it includes 60% of the best-developed irrigation districts in the country. It is a region with a barren, dry climate, the mean annual rainfall being recorded at 850 mm.

Mexicali: Located in the extreme northwestern part of the country, it consists of a delta region (Colorado River), whose characteristic is a desert climate since it is in the zone subjected to east winds. One of the most important irrigation districts in Mexico is found in this zone.

The photographic information received was entirely from the MSS system in black-and-white transparencies, on a scale of 1:1,000,000 in four bands, including an abundant coverage almost every 18 days, from August 1972 to September, 1973.

The method of direct visual photointerpretation in two dimensions was used for quantifying the images, although on some occasions characteristic zones were enlarged with Leitz Wetzlar-Hector transparency projectors with 1:28-300 mm objectives, with which enlargements were obtained up to six times the original size, while still maintaining good resolution, on which work was carried out directly.

/7

Specific studies were prepared within the LANDSAT investigation intended to determine:

- characteristics of present land use
- hydrology
- geological features
- oceanological details

In each of these studies, exploration was in as great a depth as possible, taking into account the availability of time and personnel and the fact that the projects being dealt with were of a general kind, one of the most important objectives being that of demonstrating the applicability of the information to subjects under study in the Secretariat.

Present Land Use. A general plan was obtained, by regions, on a scale of 1:1,000,000, in which zones of irrigated agriculture, natural rainfall agriculture on the plains, natural rainfall agriculture in the mountains, natural pastureland, woods, forests, thickets, sandy areas, bare rock, swamps, mangrove plantations, salty land, bodies of water and eroded zones could all be identified. The cartographic base

plane used was that of the U.S. Air Force, on a scale of 1:1,000,000, which had the convenience of covering the whole country at the same scale as the transparencies.

Hydrology. This study consisted of a mapping of the most relevant characteristics of each zone, including the delimitation of the most important river beds and arroyos. In addition, specific studies were developed on the degradation of bodies of water in some places, correlating precipitation with surface area and monitoring the rate of /8 decrease of that area due to evaporation.

Geology. A structural and general map of the three zones under study was drawn up, permitting the rapid mapping of regional faults.

Oceanology. The use of the LANDSAT images for marine ecological studies has been carried out in two ways:

One which has as its object the determination of the limit and the relative bathymetry of the coastal bodies of water, and the other focussing on obtaining a classification of the nation's coasts for ecological purposes. In the three zones, it was also possible to determine the location and distribution of sedimentary patterns.

The study of the classification of the coasts, which was later extended to the entire national shoreline, on a chart with a scale of 1:2,000,000, contains information on land use from the neighboring border to the coastline, the classification of the coasts in accordance with their structure, the separation of beaches and reefs, and finally the identification of fish ponds.

In the investigation with the LANDSAT information, the following were identified:

- 1) Zones where the specific characteristics of the soil favored moisture and the recharging of aquifers. /9
- 2) The principal bodies of water which predominate in each region,

determining in each of them such characteristics as: different depths, sludge-choked zones, and water qualities.

3) Previously unobserved submarine faults, such as the continuation of the San Andreas fault in the southern portion of the Gulf of California.

4) In the lagoons and on the coasts, zones affected by sludge decomposition were quantified, deducing the possible significance of currents, as a function of the amount of suspended sediments. It was possible to carry out the delimitation of the sedimentary patterns during the four seasons of the year.

5 The detection of a new island, not mapped earlier, in the northern part of the Gulf of California.

6) By means of the LANDSAT images, it was also possible to calculate average areas of the bays and lagoons in the northwest portion of the country.

7) The detection of the reef zones, appraising those which are totally reflecting in Band 5, as well as sand bars.

8) Salt-infiltrated portions within the agricultural zones, quantifying different levels to which they have been affected.

This last point gave rise to a methodology of great economic interest for detecting and classifying (on three levels) the salinity in irrigated terrains.

/10

The map of current land use, prepared by the Plan Nacional Hidráulico, can be considered as the most complete task carried out in the country making use of LANDSAT information.

The map was prepared to meet the requirement for a basis for support of the planning of water and land resources. This information, which is presently being used to define the agricultural frontier of Mexico,

consists of a study of the current use of all the nation's territory at a scale of 1:1,000,000, and another one on potential use covering 45 million hectares.

Later, under the collaboration agreement, information from SKYLAB, the manned space laboratory, was relied upon. SKYLAB collected this information as part of its observations of natural resources on its three missions:

SKYLAB II from May 25 to June 22, 1973.
SKYLAB III from July 28 to September 25, 1973
SKYLAB IV from November 16, 1973, to February 8, 1974.

The Secretariat asked to be considered in the EREP package (Earth Resources Experiment Package Mission) to receive information from the three missions carried out, on photographic film and digital tape, from the various cameras and radiometric sensors. Of the sensors, information was received from the Band L radiometer and the multispectral scanner. The transparencies came from the following cameras:

1) Multispectral system, 70 mm format, with black-and-white, high- /11 resolution color, and infrared color films. These transparencies, on an original scale of 1:2,850,000, were enlarged to different scales by means of cylindrical* projectors to carry out their photointerpretation.

2) Cartographic camera, 11.5 cm format. with high-resolution color and infrared color films. These transparencies, on an original scale of 1:950,000, were also enlarged to different scales and their photointerpretation analysis was carried out, both in projectors and by forming stereoscopic pairs, using a longitudinal overlapping of the exposures (60%).

The results of the SKYLAB investigation by means of photography, broadly speaking, are sketches and drafts: [of] agricultural lands, rocky soil, and bodies of water.

*Translator's note: Sp. "canon" may be misprint for Canon (manufacturer of photo equipment).

In one zone of irrigated agriculture, the SKYLAB information allowed delineation of its limits, portions affected by salinity and zones of possible expansion. It was likewise possible to recognize that the SKYLAB information has a resolution which will permit control of the planted zones. In the coastal zones, SKYLAB-type information, supplemented by periodic sampling, will provide a knowledge of marine currents and the possibility of monitoring the movement of sediments into cultivated tidelands, as well as the collection of larvae [sic]. The stands of mangrove trees were also located and quantified using SKYLAB information.

Alluvial areas were also determined, fans which are not being ex- /12 ploited despite the fact that the subterranean waters are of acceptable quality for agricultural irrigation, according to a geochemical study which has been carried out.

One series of lagoons was studied by means of SKYLAB images, for the purpose of detecting and quantifying aquatic plant growths. Maps were also prepared showing present land use, and using the same information, zones with agricultural possibilities were determined.

Simultaneously, with the receipt of the LANDSAT photographic material, CCT magnetic tapes were received. These tapes permitted the development of SIADIS (System of Automatic Interpretation of Satellite Images*) which was accomplished entirely within the Secretariat.

The automatic interpretation consists in carrying out the identification and classification of terrestrial data by means of computer, which uses the response of the objects to electromagnetic radiation. The interpretation can be supervised or non-supervised, depending on whether or not terrestrial data are included as a previous reference. SIADIS can be used in both interpretations, in any number of bands and with different classification algorithms.

Other efforts within the context of automatic interpretation have been carried out in the country by the now-expired Comisión Nacional

*Translator's note: Acronym is based on the Spanish name of the system.

del Espacio Exterior (National Commission on Outer Space), and the Instituto de Investigaciones en Matemáticas Aplicadas (Institute for /13 Studies on Applied Mathematics) (IIMAS) of the National Autonomous University of Mexico, which has a system operating in an experimental stage.

For about the past two years, the IBM scientific center for Latin America, located in Mexico City, has placed at the disposal of users desiring to develop a joint project, a complete system of automatic interpretation, ERMAN-II, installed in an IBM 360-65 computer with screens to establish a conversational mode and to display the information in color. The three projects developed to date have been carried out in cooperation with the Secretariat of Agriculture and Water Resources.

SIADIS is constrained to operate in keeping with the reality of the country, in terms of both the object of study and the computer available; i.e., it [SIADIS] was designed to operate in modules [and] can be used in medium-sized and small computers if slight modifications are made. The project of developing an automatic interpretation system has been carried out on a CDC model 3300 computer initially, and later on a Ctbor 72 computer.

SIADIS has been applied to LANDSAT information. It has been used in projects exclusive to the Secretariat and in joint projects with other institutions with which there are working agreements. Some of these projects are:

- quantification and detection of aquatic plant growths. /14
- water quality. This makes use of the methodology of classifying water in terms of the quantity of solids in suspension.
- inventory of vegetation in Veracruz. This is of great importance owing to the weak condition of the use of tropical vegetation in the country, and the difficulties imposed by its diversity and continual change. This project of investigation is being carried out under an agreement between the Secretariat and the Instituto de Investigaciones sobre Recursos Bióticos [Institute for the Study of Biotic Resources].

- study of land use and inventory of flood-prone zones in the state of Durango. This has been worked out in collaboration between the Secretariat and the IBM scientific center for Latin America, using information not only from LANDSAT but also from SKYLAB, from the multi-spectral scanner - whose interpretation could be carried out previously, [but] with revision of the data - [and] from conical-to-linear scanning.

At the present time, the broadest project in the Comisión del Plan Nacional Hidráulico consists of completing the national inventory of land use, now on a scale of 1:100,000, by use of the digital LANDSAT information. It is estimated that this inventory will be completed over a period of six months, and is the principal step taken in the direction of using automatic interpretation for national planning.