Internal IDRC Report of an Evaluation

"LANDSAT" REMOTE SENSING OF NATURAL RESOURCES : THE BOLIVIAN EXPERIENCE

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CONTENT

INTRODUCTION

A three-man IDRC mission (Tony Price, Bill Bruce and Luis Ramiro Beltrán) was scheduled to conduct in La Paz, Bolivia, a one week evaluation of Project ERTS-DESAGUADERO RIVER-BOLIVIA (3-P-74-0136) in the first week of November 1979. A coupe d'etat shook the country on that very week, preventing the arrival of the evaluators to it. Given the situation, IDRC decided that Price and Bruce went ahead to evaluate comparable projects in Africa while Beltrán would wait in Bogotá a better opportunity to go by himself to La Paz. The closest one came in mid December 1979.

The ERTS Project evaluator had to depend upon only one source of information and opinion for the evaluation: project leader Carlos Brockmann, the director of the Technological Natural Resources Satellite Program hosting the project at the Bolivian Geological Service (GEOBOL), a descentralized agency of the Ministry of Mining and Metallurgy. This restriction was imposed by the limited time available for the inquiry (four days) and by the fact that the political upheaval had made acute the job instability not unusual in the country's public administration. This meant that there was no opportunity for the evaluator to confer either with Brockmann's aids or with appropriate officers in agricultural and mining government agencies that could be regarded as actual or potential users of the information produced by the project. In any case, however, Brockmann would have remained the chief respondent for, evidently, no one in the country is as deeply familiar with the project's nature, performance, limitations and consequences as he is.

The interview sessions were conducted at the GEOBOL offices in an informal manner and without a highly structured data gathering instrument. Each question in the guide was read and clarified. Once the respondent produced each answer, the evaluator often asked for clarifications especially when the response was couched in too technical a language. Once discussion was felt sufficient by both parties, the evaluator recorded the respective answer by typing it in front of the respondent and read it to him at once for verification, seeking to capture with as much fidelity as possible the essence of the statements. Thus, during the total of some 15 hours of interviewing, much more was said than it went recorded in draft writing. Additionally, the evaluator recoursed to scanning pertinent documents and publications from both IDRC and GEOBOL files. Also, in order to be able to grasp at least the essence of remote sensing in general, the evaluator became acquainted with a few basic technical writings on this matter so as to have the indispensable background to

diologue with Brockmann */.

For the convenience of systematic asking and reporting, some minor adjustments were made without altering the evaluation's objectives to the general interrogation pattern prepared in Ottawa. The original set of questions was recomposed in subsets determined by afinity of topic. A few questions containing more than one element were split to make their handling easier. No suppression was made but a few additions were introduced to include some concerns expressed in statements by Woolston and Pitblado **/as well as in an analytical summary of an IDRC sponsored workshop on remote sensing ***/.

The respondent was most cooperative and outspoken. Ha made himself fully and gladly available to the questioning and did not seek to influence the evaluator's own assessments or attempted to deny shortcomings of the project he had designed and conducted. He was polite in reference to IDRC but not insincere.

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*/ Bolivia. Ministerio de Minería y Metalurgia. Servicio Geológico de Bolivia. Programa del Satélite Tecnológico de Recursos Naturales ERTS - Bolivia: procesamiento digital de datos multiespectrales; área Desaguadero. Proyecto experimental. La Paz, GEOBOL, 1977. 58 p. (Contribución especial, serie sensores remotos, no. 01); Bazan, R. Review of the current status and future needs for remote sensing and technology transfer in Latin America. Document presented at the Seminar on Remote Sensing Applications and Technology Transfer for International Development. (Ann Arbor, Michigan, 18-21 Apr. 1979). Howkins, J. Remote sensing: photographing the earth. Intermedia (London) 6(2): 6-8. Apr. 1978; Ploman, E. Remote sensing: the uses of information. Intermedia (London) 6(2): 13-14. 6(2): 9-10. Apr. 1978; Remote sensing: uses around the world. Intermedia (London) 6(2): 11-12. Apr. 1978; IDRC. Remote sensing in the Sudan, Ottawa, IDRC, 1978. 36 p. (IDRC-TS(e).

** / Pitblado, J.R. IDRC Remote sensing projects: proposal for an evaluation. 6 p. (mimeo); Summary notes on Woolston's comments during meeting (mimeo).

***/ Daniels, W. D. Comments on Nairobi evaluation paper. Comments on the Workshop on Remote Sensing Application in Developing Countries, Nairobi, Kenya 6-10 Mar. 1978. (mimeo).

Expectedly, the evaluation was not performed in the terms of a highly "objective" survey based on rigurous quantification of systematically obtained data. It was, obviously and unavoidably, a subjective appraisal based essentially on personal impressions and on an informal judgement of information and opinion directly provided by the respondent in the interview sessions and indirectly supplemented by the reading of pertinent documents by the evaluator. Impressionistic rather than empirical as the assessment admitedly had to be, this report will strive nontheless to control for any possible bias.

The answers recorded are the product of coincident views of Brockmann and Beltrán resulting from their extensive disscussion. In a few indispensable cases, a statement by Brockmann is singled out verbatim and in quotes. But this does not mean that there was any substantive divergence between them. Nevertheless, responsibility for what is said in the present report goes only to Beltrán.

THE PROJECT*/

All technologies for detecting at the distance facts about the earth's surface could well come under the label "remote sensing"; this would, for instance, be the case of radar and air photography. The term is, however, characteristically applied to tele-detection by satellites provided with scanners (radiometers) which operate on several bands (multi-spectral) to measure the radiant energy reflected from Earth and send back to it the respective information in digital form. Such satellites can take those measures cheaper, faster and over much larger surfaces than can any other kind of surveying devises. Also, by being on a continual orbital mission in a sun-sinchronus (near polar) orbit, they can provide periodical information on each spot of land, which greatly favors comparability over time.

At the outset of the present decade, the National Aeronautics and Space Administration of the United States of America (NASA) established its first series of the Earth Resources Technology Satellite (ERTS) which, on achieving succesfully its intended orbit, were renamed LANDSAT. LANDSAT 1 was launched in 1972, LANDSAT 2 in 1975 and LANDSAT 3 in 1978, each with improved capacities compared to its predecessor. LANDSAT 4 is due for launching in 1980 and will be the most advanced and versatile of the series. Data transmitted by these satellites is picked up by special receiving stations, of which three are located in the United States and the rest in Italy, Canada and Brazil. The LANDSAT spacecrafts are regarded experimental by the U.S. and thus are authorized by the International Telecommunications Unit (ITU) to use the spectrum bit of 2290-2300 Megaherz.

IDRC has provided financial assistance to developing countries in Africa, Asia and Latin America to experiment with this remote sensing technology on the basis of U.S. cooperation to facilitate both LANDSAT 1 images and training in the analysis of multi-spectral digital data.

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*/ For detailed information about it, the essential documents are: IDRC. Project abstract: ERTS: Desaguadero river (Bolivia). Ottawa, IDRC, 1975. (IDRC-3-P-74-0136) Bolivia. Ministerio de Minería y Metalurgia. Servicio Geológico de Bolivia; procesamiento digital de datos multiespectrales; área Desaguadero. Proyecto experimental. La Paz, GEOBOL, 1977. 58 p. (Contribución especial, serie sensores remotos, no. 01).

A few Latin American countries established in the present decade remote sensing programs based on satellite-transmitted images (U.S. LANDSAT series imagery) addressed mainly at detecting natural resources */. Brazil is probably the most notorious one but Mexico, Argentina and Peru are also active in this area. Although Bolivia does not have an activity of a magnitude comparable to that of Brazil, it does have a very effectively handled Earth Resources Technology Satellite Program (ERTS) or Programa del Satélite Tecnológico de Recursos Naturales (PSTRN). The program started at the Bolivian Geological Service (GEOBOL) in 1972 through a cooperative agreement between the governments of Bolivia and the United States of America. NASA provided, mostly through LARS-Purdue, technical guidance while AID furnished financial assistance. During its first three years of operation, the program succesfully conducted over 30 research exercises using ERTS data in a conventional manner. Thus by 1975 it had accumulated an experience enabling it to engage in a more ambitious venture: using ERTS data in the non-conventional manner of the computerized process involved in LARSYS III. The project's final report puts it this way: "Although the Bolivian LANDSAT program has been able to apply succesfully the conventional methods of photo-interpretation to map large geographic areas of the Bolivian territory, it has been recognized that the enormous amount of information contained in the different spectral bands of the LANDSAT MSS system could be more effectively reduced and classified utilizing existing computer-aided analysis techniques, such as LARSYS. Therefore, this cooperative research effort was established between the Bolivian LANDSAT program and the Laboratory for Application of Remote Sensing (LARS)at Purdue University, West Lafayette, Indiana, U.S.A.". (See location of Bolivia in Map I attached).

It was within the framework of said ERTS/LANDSAT program that IDRC came to finance in Bolivia in 1975 the DESAGUADERO RIVER project No. 3-P-74-0136 through its Division of Information Sciences (Cartography Program, handled by Robert Le Blond). The following were the chief goals of this project:

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*/ Alternatively, for instance, Bolivia has used this technology to routing a gas pipeline to the Brazilian frontier as well as for mapping land use. Other known applications of remote sensing are urban planning, timber monitoring, navigation and harvest prediction.

1. To contribute to planning for regional development at the Desaguadero River Valley by preparing a set of thematic maps using remote sensing satellite imagery and data.

2. To investigate for sample areas within said jurisdiction the survey and training requirements for computer processing and classification of digital remote sensing data.

3. To set up a program that could enable Bolivia to carry out locally such automated cartography through computer and to train abroad for this purpose professional staff members of GEOBOL.

A more technical definition of the project's aims is the one appearing in its final report:

> The major objective of this project was twofold; first, to perform and evaluate computer-aided analysis techniques (CAAT) using LANDSAT-I multispectral scanner data of the Río Desaguadero area of Bolivia for Geological, Soils and Land Use mapping; and second, to train three Bolivian scientists (an agronomist, a geologist and a geomathematician) in the application of computer-aided analysis of LANDSAT-I multispectral scanner data, so that Bolivia can eventually implement such analysis techniques utilizing computer systems available in Bolivia.*

The Desaguadero River Valley**/ was selected for the study because the Ministry of Planning and Coordination was considering the construction of a dam there that would turn possible the controlled irrigation of the high altitude region located between the departments of La Paz and Oruro in the Western and Andean zone near Peru and Chile so as to seek expanding the country's agricultural frontier. (See maps attached at end of this chapter). On the other hand, mineral prospection was also of natural interest to a country which basically still earns its livelihood from exporting minerals. Consequently, the maps to be obtained were to cover the following thematic areas: regional geology: mineral geology; hydrology; and soils. Special attention was to be given to petrographic factors (diapires and alkaline rocks) determinat of the water's salinity, to the identification of metallogenic zones through geomorphological indicators and to locating suitable lands for agricultural production (see Maps 3, 4).

The project was to last one year divided into the following stages:

1. Preliminary field study addressed at determining, through conventional techniques, the territorial areas on which the non-conventional techniques were later to be applied.

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*/ See Map 2.

**/ Bolivia Ministerio de Minería y Metalurgia. Servicio Geológico de Bolivia. Programa del Satélite Tecnológico ...: procesamiento digital ..., Op. cit. p. 10.

2. Air multispectral photographic survey.

3. Training of Bolivian experts in the United States of America (Purdue) by means of guided multispectral analysis by computer, using LARSYS III, of the Desaguadero images selected.

4. Final verification of computer data with data from direct field observation; adaptation of the computer processing procedures to local requirements, expertise and equipment, and preparation and publication of project's wind-up report.

The total cost of this technology transfer experiment came close to Can$100,000 to which IDRC contributed some 70,000 and GEOBOL the balance.

MAP I

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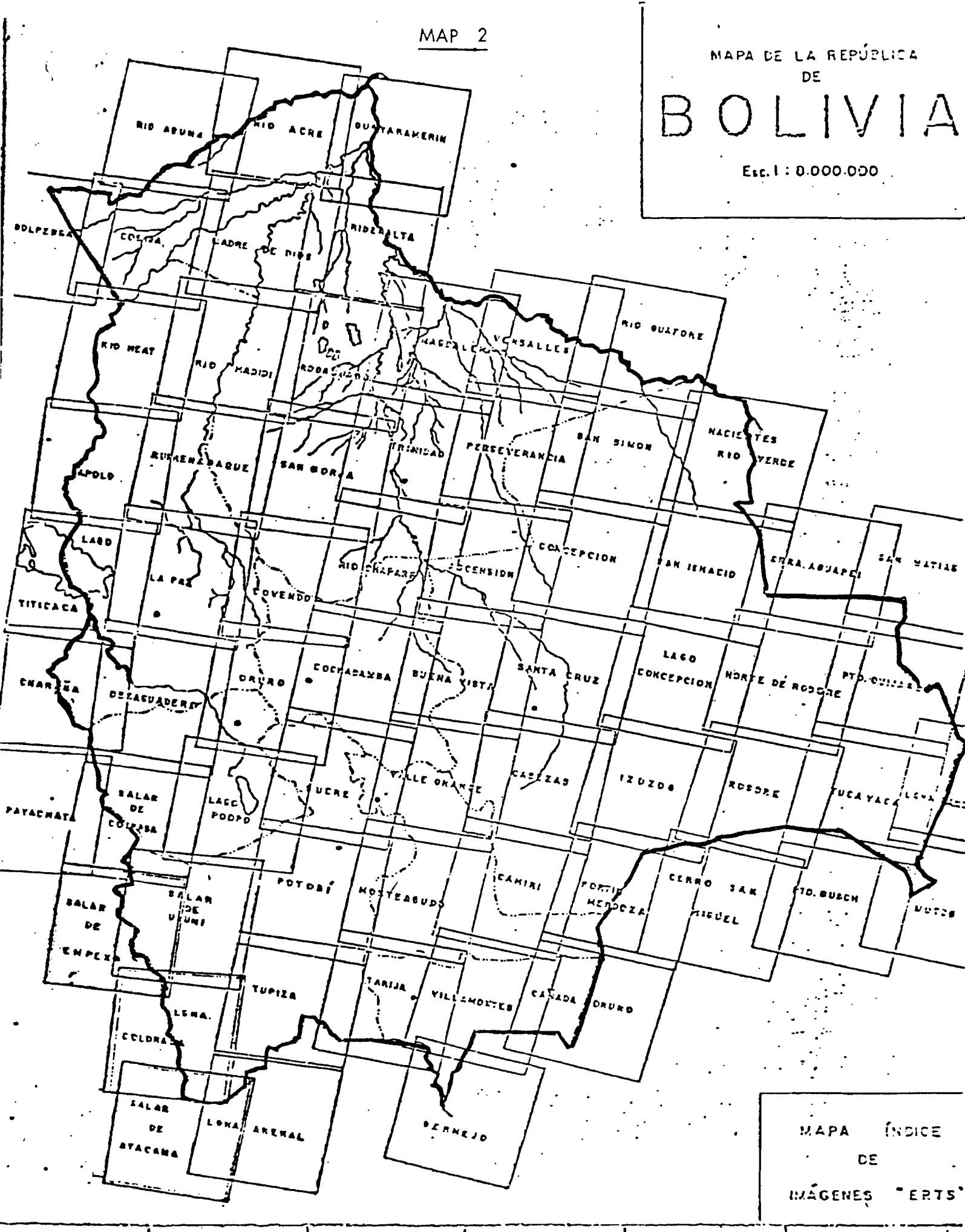
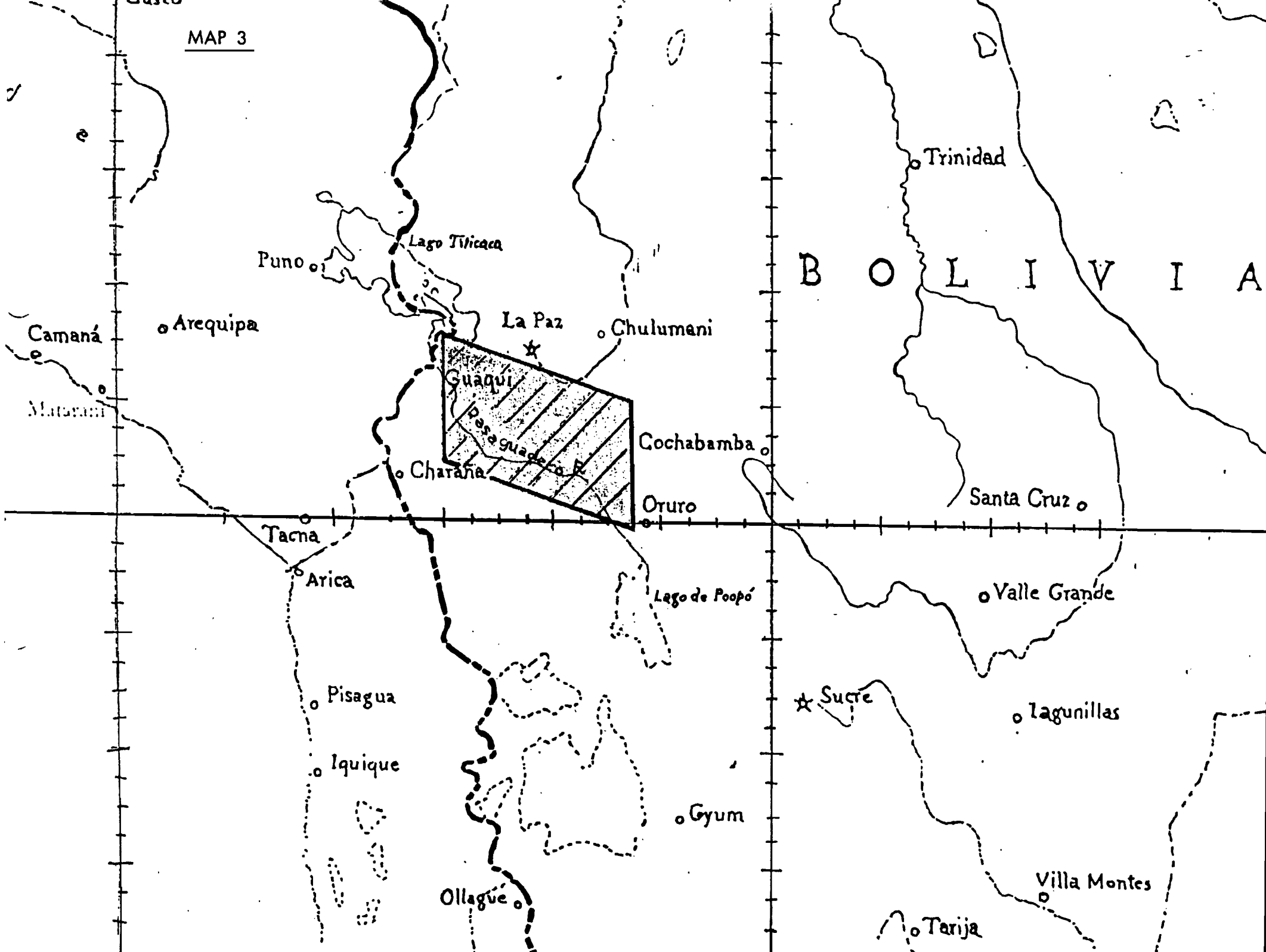
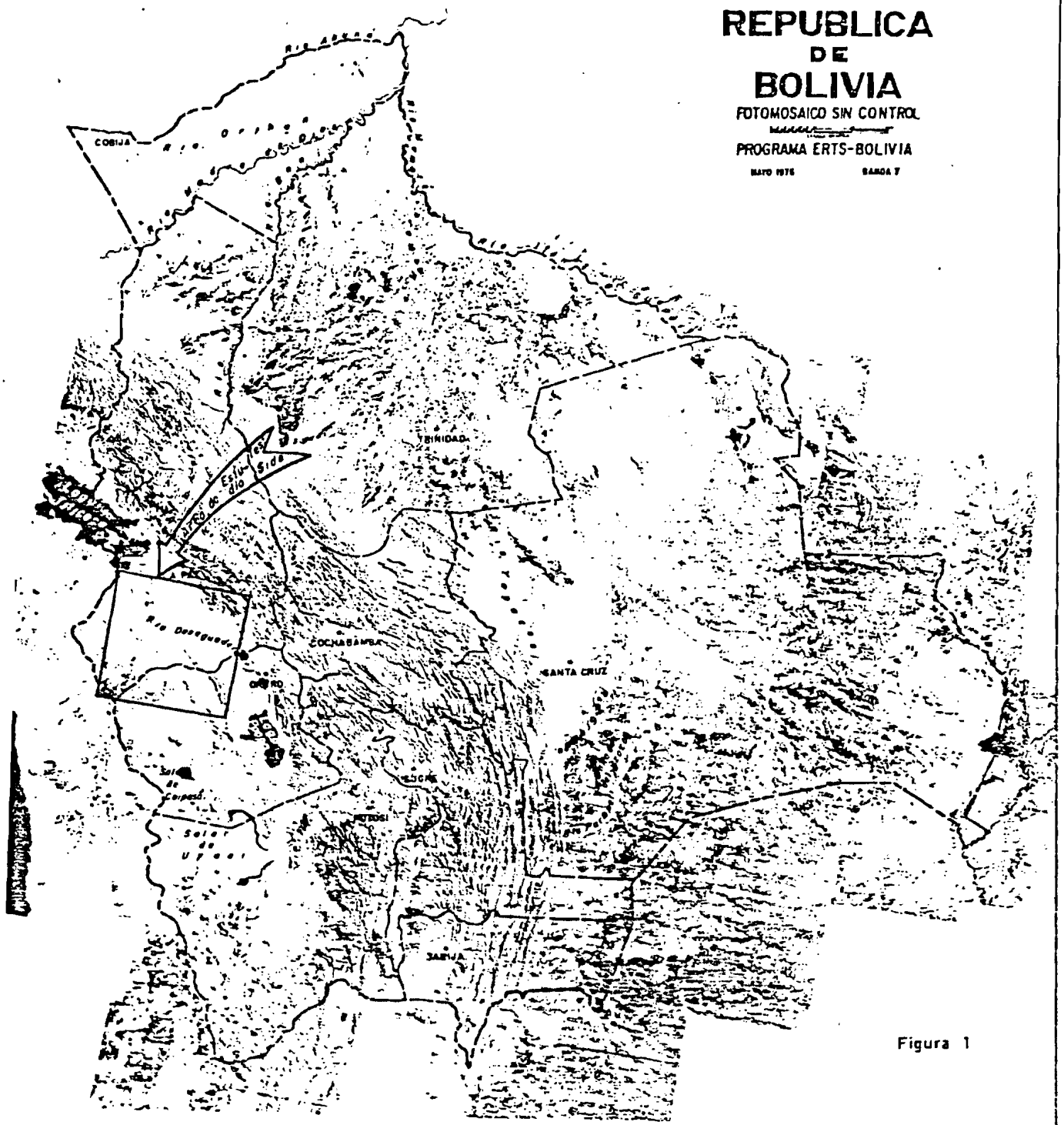
MAP 2


MAPA DE LA REPÚBLICA
DE
BOLIVIA
Esc. 1 : 0.000.000
RIO ABUNA
RIO ACRE
GUAYARAMERIN
COBIJA
MADRE DE DIOS
RIBERALTA
RIO BEAT
RIO MADIDI
RURRENABAQUE
SAN BORJA
TRINIDAD
PERSEVERANCIA
SAN SIMON
RIO GUAPORE
NACIENTES
RIO VERDE
APOLO
LAGO
TITICACA
LA PAZ
COVENDO
RIO MAMORE
CONCEPCION
SAN IGNACIO
SAN MATIAS
CHARAÑA
DESAGUADERO
ORURO
COCHABAMBA
BUENA VISTA
SANTA CRUZ
LAGO CONCEPCION
NORTE DE ROBORE
PTO. SUAREZ
PATACHATA
SALAR DE COIPASA
LAGO POOPO
VILLE GRANDE
CABEZAS
IZOZOG
ROBORE
TUCA YACA
POTOSÍ
MOSTEADUS
CAMIRI
PORTILLO
MENDOZA
CERRO SAN MIGUEL
PTO. BUSCH
SALAR DE UYUNI
SALAR DE EMPEZA
TUPIZA
TARIJA
VILLAMONTES
CAÑADA ORURO
COLORADA
LEÑA
SALAR DE ATACAMA
LOMA ARENAL
BERMEJO
MAPA ÍNDICE
DE
IMÁGENES "ERTS"


MAP 3
Trinidad
BOLIVIA
Lago Titicaca
Puno
Arequipa
La Paz
Chulumani
Camaná
Guaqui
Pesaguas
Cochabamba
Charaña
Oruro
Santa Cruz
Tacna
Arica
Lago de Poopó
Valle Grande
Pisagua
Sucre
Lagunillas
Iquique
Gyum
Villa Montes
Ollagüe
Tarija

MAP 4



Fotomosaico de imágenes LANDSAT cubriendo el territorio boliviano, localización del área de estudio.
LANDSAT photomosaic covering the Bolivian territory. Localization of test site.

THE QUESTIONS

A broad definition of the overall purpose of the IDRC evaluation of the remote sensing projects it has supported in developing countries of Africa, Asia and Latin America was provided by PAP 3-A-79-4057 as follows: "The general objective of this evaluation is to assess the extent to which these projects have met their objectives; to assess the extent to which the projects have built up personnel and institutional capability to independently carry on this activity; and to assess the medium and long term impact of this activity on the development of these countries".

Prepared in Ottawa on July 31, 1979, the following statement stipulated the specific objectives of the evaluation:

1. To determine whether the individual projects have achieved their objectives, and whether the project activities were efficiently and effectively carried out;

2. To assess whether the project objectives were realistic and achievable with the human, institutional and financial resources available;

3. To assess whether these projects have contributed to the development of scientific personnel and institutional capability and whether the capacity now exists to carry this work on with their own resources;

4. To assess whether IDRC's role and involvement in developing and supporting these projects has been appropriate and whether it could be changed to be more useful;

5. To assess whether these projects have made, are likely to make, or could make any useful contribution to the development of the countries involved, whether in the short, medium or long term;

6. To assess whether the results of a project in one country can have any regional benefits;

7. To assess whether there were any general benefits between or linkages between the five projects supported in this programme or linkages created with other countries and organizations involved in the same kind of activity.

8. To assess whether the experience gained in these projects can or has provided any useful guidelines or methodology which can be used in the transfer of this or other technologies to developing countries; and

9. To comment on the appropriateness of IDRC supporting this type of programme and the value of effect of supporting additional projects of this kind in other developing countries.

THE ANSWERS

EFFECTIVENESS

1. WERE THE PROJECT OBJECTIVES ACHIEVED ?

In essence the project had two operational objectives. One was to produce thematic maps of physical resources in the Desaguadero River area. The other was to train scientists in computer-aided interpretation of LANDSAT-1 multispectral scanner data, so that they became able to conduct locally automated cartography by adapting to computers available in Bolivia the LARSYS III.1. digital data processing program. These objectives were tightly interrelated since the product of training was to be constituted by the maps. However, inasmuch as possible, the accomplishment of each of those two major objectives was assessed separately in order to properly record differences which readily became apparent not only between them but also within each.

Accomplishment of Objective 1: Map Production

Indeed, accomplishment of the first objective was sought through a sequence of 5 operations and addressed at 5 thematic areas. In the case of the former set, there were appreciable variations of outcome. And product obtention varied even more distinctly.

The 5 operations will subsequently be enumerated, indicating for each one whether it was a success or a failure:

1. First image selection, through visual photo-interpretation technique, of territory to be studied. Success.

2. Second selection of image covering sample sub-areas of territory. Success.

3. Verification of basic data of the sample sub-areas by aerial and multispectral photography. Failure (Data obtained through this procedure proved not compatible with the digital satellite data. This is partly explained by the fact that multispectral cameras do not have for semi-desertic territories,as that of Desaguadero, the detection capacity that they have for vegetation-covered territories).

4. Verification of the data corresponding to the first image by direct field observation covering the themes or disciplines of immediate concern for the project. Success.

The Head Office derived from said statement of objectives a set of questions for the project institutions to be surveyed. Translated to Spanish, it was sent ahead of time to Carlos Brockmann in Bolivia. The questions were the following:

1. ' Were project's objectives achieved?

2. In the light of human, institutional and financial resources available, were objectives realistic and achievable?

3. Was scientific personnel effectively trained and institutional capability enhanced?

4. Are you now in position to carry on this work with your own resources?

5. What technical and administrative problems were encountered?

6. Was IDRC's involvement appropriate and useful? What might it have done differently, better, etc?

7. What contribution has the project made, or might make, to the development of Bolivia? To your region?

8. What comments do you have on the technologies and methodologies used?

9. What cooperative linkages were made with individuals and institutions in other countries as a result of the project?

10. What are the advantages and realities of regional cooperation in this field?

In turn, as has already been noted in the Introduction, the evaluator of the Bolivian project made some slight changes to the above questions. On the one hand, without affecting intent/content at all, he made separate questions out of those which comprised more than one inquiry element in their statements. On the other, he grouped the questions in four categories, which he identified in the original set of questions, and understood as follows:

Effectiveness. Degree of attainment of objectives in terms of information obtained and training gained in spite of problems encountered in project's performance.

Impact. Benefits produced by the project in terms of manpower expansion, institution building and contribution to national development, as well as in terms of influence beyond the country.

Other Considerations. (This section contained all other original questions not belonging to the Effectiveness and Impact categories).

Supplementary Questions (This section contained a few additional questions stemming from other IDRC pertinent documents. They were presented to the respondent as ancillary and optional but he chose to answer them all as well).

From the viewpoint of simple accomplishment of the professed goal of the project, answers to the Effectiveness section appeared to the evaluator the most important ones. However, from a viewpoint of the intended ultimate effects of IDRC investments, the section on Impact appeared to him at least of equal importance. And, if one had to be chosen over the other, in his judgement the second would have been the crucial one. Responses, however, could be best provided by the subject on the first section since assessing impact should have ideally been done also by respondents other than the project leader and from outside GEOBOL.

5. Multispectral computer-assisted analysis of digital satellite data on the sample sub-areas of the territory. Success.

Operations 1 through 4 were conducive to the culmination of the process: operation 5, out of which the maps emerged. The failure of operation 3 did not prevent such culmination as, although important, it was not a strictly indispensable one. Thus, at the general level, performance was effective. At the specific level, effectiveness varied as it is subsequently explained.

The 5 thematic areas were determined by interests of the Ministries of Planning, Agriculture and Mining. According to the initial plans, four thematic maps were to be produced but, once the project was started, a fifth was added. They were built on the following themes: (1) geology - regional and mineral; (2) geomorphology; (3) hydrology; (4) soils; and - this one being the unplanned addition - (5) land coverage and use. Attempting to build each of these very different thematic maps can be regarded as a sub-objective of the first objective. Such distinction is necessary because it was found that in this case goal attainment - that is, the extent to which the objective was met-varied significantly between maps. Thus the assessment had to be done separately for each and qualification had to be done on a scale rather than dichotomously.

The extent of accomplishment of each sub-objective will subsequently be discussed:

Sub-objective 1: Geology (Regional and Mineral)

The expectation in this case was to be able to differentiate types of rocks and possibly minerals and diapires, hoping to be able to extrapolate from observations of the sample territories to the rest of the image. This expectation was only met in the case of diapires. There are three explanations for the limitation: (1) the satellite used has a low spacial resolution: it does not record surfaces under the size of 230 meters; (2) the amplitude of the satellite's spectral band is larger than certain lower segments of the spectrum which are useful to detect minerals or rocks; and (3) the desert's soil is very thin and lacks a vegetation cover. Mapping diapires was the only intended aim achieved, having some value as it would, for instance, allow to avoid certain areas in road building. Unexpectedly, fractures were found suggesting possible mineralization. In summary, this subobjective was achieved only at a medium level of adequacy. However, the information obtained allowed GEOBOL, as a by-product, to readily refine the existing geological map of Bolivia.

Sub-Objective 2: Geomorphology

The expectation here was to obtain information useful to define land forms. It proved an inadequate expectation as multispectral satellite information gathering does not allow

for recording reliefs (contour variations of land surface in relation to the surrounding land). That is to say, it does not measure heights and, therefore, cannot be used for surveying land forms, which requires altimetry. Thus, this sub-objective was achieved at a low level of adequacy.

Sub-Objective 3: Hydrology

The expectation in this case was to obtain information on water quality; for instance, whether it is clear or muddy. That information which was obtained, however, did not allow to do such definitions. Again, the explanation is low spacial resolution; the rivers are too narrow to be captured by the satellite imagery with depth sufficient to detect water qualities. Such detection would, instead be possible, in mapping large lakes. Hence, this sub-objective was also achieved at a low level of adequacy.

Sub-Objective 4: Soils

The expectation here was to identify types of soils by areas in accordance with a given classification. The expectation was met. The identification was performed to a degree and at a rythm clearly superior to those possible under conventional methods, such as air photography. The main gain was the mapping of saline soils, abundant in the area, including specificationof their characteristics that limit agricultural activity. Had another legend (soil classification) more akin to satellite information been used, the results could have been even better. Thus, this sub-objective was achieved at a high level of adequacy.

Sub-Objective 5: Land Coverage and Use

This was the unexpected addition to the mapping effort. GEOBOL had started in 1975 research to develop a methodology to build a scientific classification on soil coverage and use in Bolivia. At the macro level, this included the following categories: pasture lands; forest lands; cultivated lands; humid or flooded lands; water; barren lands; perennial snow and ice; and, on the other hand, cultural traits: cities, roads, man-made things in general. When analyzing data for the four originally planned maps, the researchers found that each contained, to some extent, some information valuable for land coverage and use concerns. Hence the fifth map, which indeed displays considerable information about pasture, water and barren land, all of direct interest to agricultural development planning. The additional sub-objective was achieved at a high level of adequacy. Furthermore, the possibility exists to extract further information from the data collected by in depth multispectral analysis emphasizing, for instance, lands corresponding to one crop, such as the native quinoa.

The following table condenses the assessment of the extent to which the 5 "sub-objectives" of objective 1 were achieved:

EXTENT OF ACHIEVEMENT	Sub-Objective 1: Geology	Sub-Objective 2: Geomorphology	Sub-Objective 3: Hydrology	Sub-Objective 4: Soils	Sub-Objective 5: Land Cover and Use
High				X	X
Medium	X				
Low		X	X		

Considering that there are two "high" and one "medium" marks over two "low" marks - out of which at least one was attributable to intrinsic limitations of the technology, and not of the researchers - the project can be rated successful.

Evidently, the fruits of the study served considerably more the interests of the agricultural sector than those of the mining sector. As for hydrology, the area of direct relevance to the possible construction of a dam on the Desaguadero, the information obtained was of little usefulness.

In summary, objective 1 (thematic map production to prospect natural resources) taken as a whole (that is, including its 5 sub-objectives) was partially but acceptably accomplished. Everything suggests that, for a learning venture geared at experimenting with the transfer of an advanced and complex technology to a developing country, the Bolivian project did effectively capture the rudiments of it and efficiently produced a fair amount of the information wanted.

Accomplishment of Objective Two: Training of Scientists

Three engineers in the staff of GEOBOL were sent for training to the Laboratory for Remote Sensing Application (LARS) at Purdue University, at Lafayette, Indiana, U.S.A., for on-the-job training of a few months duration. They were a geomathematician knowledgeable of computer programming, an agronomist specialized in edafology, and a geologist. These Bolivian professionals were trained as a basic team to perform computer-aided analysis of LANDSAT-1 multispectral scanner digital data. The expectation was that the training of this team, if successful, was to be applied to a couple of purposes:

(1) immediately, and while in the U.S.,to produce the Desaguadero River area thematic maps intended and (2) subsequently, upon return to Bolivia, to adapt NASA's LARSYS III computer pattern to local computer equipment conditions so that GEOBOL could handle by itself domestically similar digital data processing jobs in the future. Said expectation was fulfilled: the training component of the project proved successful in terms of learning gained, tangible output and the above indicated adaptation.

Learning gained was demonstrated by the fact that the team of trainees was able to satisfactorily do the following:

1. To understand the overall nature of the multispectral computer-assisted satellite data analysis system,a sophisticated and complex technology totally unknown in Bolivia.

2. To build, on the basis of such comprehension, a classification of spectral categories responsive to the requirements of the four original thematic orientations of the project: geology, geomorphology, hydrology and edafology.

3. To properly apply such classification, which they built while at Purdue, to the final production in Bolivia of the intended thematic maps, which they did put out. Furthermore, the scientists trained even grouped by hand certain ambiguous spectral classes which, since GEOBOL lacked then access to appropriate computer facilities, could not be electronically defined .

So successfully did the Bolivian trainees accomplish such ambitious tasks that, in view of it, NASA granted the project leader (Carlos Brockmann, the Director of the ERTS - Bolivia Program) authorization for unlimited and cost-free utilization of the LARSYS III program. This entails a complete method (philosophy and techniques) for the conversion of multispectral remote sensing data into information useful for inventorying and monitoring earth resources. The complete program was sent to Bolivia in magnetic tape, enabling this country to conduct locally automated multi-spectral analysis.

However, the LARSYS III program is designed to be run in an IBM-360 computer, which at the time was not available in Bolivia. In cooperation with USAID, GEOBOL did the conversion of the program to the Digital DEC 10 equipment which was available in the country. This adaptation to national circumstances would have been totally impossible without the decisive contribution of the project trainees that had been to Purdue. (Brazil is the only other country in Latin America that has been able to do such an adjustment to profit from LANDSAT magnetic tapes).

Therefore, everything indicates that objective two - training of scientists - was fully and optimally achieved. This statement is, however, somewhat toned down by the fact that six months after his return from Purdue one of the trainees, (the geomathematician familiar with computer programming) quit GEOBOL due to serious illness. Another staff member was sent to Purdue and thus the loss was rapidly compensated. However, another member of the original Purdue-trained team later left his technical duties to assume an administrative position as a lieutenant of Brockmann. This left on the job only one of the initial three: the edafologist, who is still at it, assisted by still another professional sent to Purdue. All this illustrates how does job instability affect institution building in developing countries.

2. IN THE LIGHT OF HUMAN, INSTITUTIONAL AND FINANCIAL RESOURCES AVAILABLE, WERE OBJECTIVES REALISTIC AND ACHIEVABLE ?

Objective 2 proved to be totally realistic as the training foreseen was fully achieved indeed. Even the project director profitted from some training at Purdue in spite of the shortness of his occasional and informal visits to the GEOBOL trainees there. This proved quite useful for the proper supervision of them by the former.

Objective 1 proved instead, partially unrealistic as some of its sub-objectives were hardly achieved at all in fact. On the one hand, in general, the magnitude of the prospection was too high in relation to the available resources and to the very modest familiarity the GEOBOL staff had then with remote sensing computerized cartography. From the overall Desaguadero area of 220,000 square kilometers, the decision was made to study a segment of 34,000 square kilometers. This proved too large a territory for a small and novel team. It would have been preferable to restrict it to images covering no more than 10,000 Km^2 or perhaps even only 5,000 Km^2. Had this been so, the study would have achieved more depth and higher quality. On the other hand, the scope of the study was also too ambitious. It was not very realistic to aim at serving at once and from start several development sectors through the construction of an assortment of different maps. Considering also the limitations of the technology with the satellite imagery then available, it would have been wiser to skip making geological and geomorphological maps so as to concentrate on making hydrology and soils maps to serve the agricultural sector alone. This would have allowed to get more precise information for those two themes and would have also made possible to obtain more detailed by-product data on land coverage and use.

The disparity between aspirations and capability was much more pronounced in the human resources available than in the case of the institutional and financial ones. Bolivian and IDRC funds were probably well sufficient for the experiment but the goals of it were set at a too demanding level for the size of the staff available and in relation to the high complexity of the endeavour.

3. WHAT TECHNICAL AND ADMINISTRATIVE PROBLEMS WERE ENCOUNTERED ?

Technical Problems

As has already been noted in the preceding section, one problem was given by factors intrinsic to the technology itself: the low spacial resolution and the high amplitude of the spectral band in LANDSAT-1 scanning equipment proved a definite impediment to obtain data on rocks and minerals.

Another technical problem encountered was an ambivalence in the computer-assisted multispectral classification. It was found that one satellite-observed trait corresponded, as recorded by the computer, to two quite different spectral classes. Let us say, for instance, that the spectral class "water" appeared represented in the computer output by about the same trait as that representing the class "shadow" while field verification demonstrated that to each actually corresponded a different trait. This ambiguity caused serious confusion in data interpretation. (It was discovered that it was due to the high altitude of the Bolivian territory under satellite prospection, about 13,000 feet over sea level). In order to overcome the ill effects of the confusion, spectral classes had to be grouped by hand in the "print results", a time-consuming and expensive procedure.

Administrative Problems

The respondent listed the following administrative problems corresponding to IDRC's behaviour:

1. Continuous and increasing losses in money exchanges. Going from Canadian to American and from American to Bolivian proved expensive. Added to fat banking commissions, this reduced appreciably the budget effectively available.

2. Chronic delays in the remittance of payments. Even until this date the last payment has not been made although the project technically expired very long ago. This forced GEOBOL to make transfers to the project of funds in other budgets, harming some of these at times and in any case causing unnecessary complications in accounting.

3. Unilateral and unconsulted modification of the structure of the grant's budget.

As the ERTS Program learned quite late in the game, the project's budget approved in Ottawa and that proposed by GEOBOL were not exact twins. This resulted in perennial differences of charges to divergent items and sub-items, making compatibility with Ottawa almost impossible and causing in La Paz numerous problems in budget control, as well as complicating the preparation of grantee reports. In addition, Ottawa did not timely and clearly provided GEOBOL with specifications of how it wanted the grant accounts to be kept and reported.

The respondent identified as well administrative problems corresponding to the ERTS Program of GEOBOL. He noted that, said program being rather new yet by 1975, it lacked then appropriate administration and accounting systems as well as qualified personnel in these areas. Since the program gets funds from several national and foreign sources, each having different accounting pattern preferences, such a deficiency seriously affected many of the operations - including the Desaguadero project - for a while. Since 1977, the program counts on a competent team and on a universal but flexible accounting and fiscal control system from which diverse client or donor accounts can be well kept without much difficulty and with minimum risk of confusion.

IMPACT

4. WAS SCIENTIFIC PERSONNEL EFFECTIVELY TRAINED AND INSTITUTIONAL CAPABILITY EXCHANGED ?

It has been explained in detail in a preceding section the significant extent and manner in which scientific personnel was trained through the project. As for the enhancement of the institutional capability to conduct other studies of the type characterized by the project, the answer is also affirmative. The scientific staff of the ERTS program has doubled since 1975, passing from 8 to 16 full time professionals and many of them participated in additional Desaguadero type ventures.

Moreover, directly derived from the project's influence, another similar project was established and operated during 1977 with financial support from USAID. It was known as Land Coverage and Use - Buenavista Image and it covered an agriculturally important territory in the humid and fertile Eastern plains of Santa Cruz, in the Bolivian tropics. A set of valuable maps was produced by this project, with preliminary copies having gone to the Ministry of Agriculture and the National Statistics Institute. The final version of the project's overall report is now ready for publication.

The experienced staff trained in the Desaguadero River project had, of course, a strong involvement in the Buenavista project. But newcomers also participated, thus multiplying the learning acquired by the precursors at Purdue. Also, in addition to local in-service training, another couple of GEOBOL scientists have also gone to the U.S. more recently to get training in remote sensing, at no cost to IDRC.

Two staff members of the Program obtained their B.S. degrees in agronomy by submitting to the Universidad de San Simón (Located in the country's second city, Cochabamba) theses fully based on information derived from the Desaguadero River project */.

But an even more telling indicator of the project's impact on institution building is the following spontaneous statement made by Director Brockmann during the interview:

> The Desaguadero project not only had a self-reproducing influence in GEOBOL. Even if we never had again another project like this, we were already enriched by the pioneer experiment beyond the mere aims of this project. It was thanks to it that we came to perceive the ways and means possible to take maximum advantage of satellite magnetic tapes in order to get beyond the general perspective provided by images photographically processed. It was indeed through the Desaguadero project that we embraced the enlightening philosophy and methodology of computer-assisted multispectral analysis of satellite images. So valuable has been the experience we gained in GEOBOL for Bolivia through this IDRC-supported Project that, without it, our Program would not have known how to go ahead.

5. ARE YOU NOW IN A POSITION TO CARRY ON THIS WORK WITH YOUR OWN RESOURCES?

The answer is affirmative but not unqualified.

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*/ Ureña Espinosa, Moisés. Aplicación de imágenes Landsat en estudios de suelos de reconocimiento área Desaguadero. Tesis (Ing. Agrónomo) Cochabamba, Facultad de Ciencias Agrícolas y Pecuarias "Martín Cárdenas", Universidad Boliviana Mayor de San Simón, 1977; Quiroga Quiroga, Samuel. Clasificación taxonómica de suelos utilizando información digital de datos Landsat area Huayllamarca y Eucaliptus. Tesis (Ing. Agrónomo) Cochabamba, Facultad de Ciencias Agrícolas y Pecuarias "Martín Cárdenas", Universidad Boliviana Mayor de San Simón, 1977.

Having conducted in 1977 the Buenavista Image project was in itself an early evidence that the Program did acquire the ability to continue working in studies similar to the Desaguadero one. Similarly, following specific requests from the Ministry of Agriculture but without charging it, the Program conducted small in-depth revisions of segments of the same satellite-taken image from which the Desaguadero image had been derived. Moreover, during 1978-1979, the Program did, under contact with the Development Corporation of Oruro, a study -not equal to the Desaguadero survey but quite similar to it- of the entire territory of this "department" (province). It mapped some 55.000 square kilometers in terms of geology (regional and mineral), geomorphology, soils, hydrology and land coverage/use. In addition, an agreement is in the pipe-line between GEOBOL and the Ministry of Agriculture to conduct, between 1980 and 1982, a statistical survey of crop areas in the Eastern region of Santa Cruz. Finally, a few small and internal studies have been carried out between 1975 and 1979 aiming at improvements of the LARS methodology.

If by "own resources" is meant only the regular GEOBOL budget as determined by the central government's fiscal availability of funds, then the Program could not hope to keep on conducting new and sizable studies similar to the Desaguadero survey. It could, however, keep each of its present staff members productively occupied by sharing in the further and deeper exploitation of the information already accumulated. If, on the other hand, other income is also considered, then the Program is certainly able to go ahead in conducting research perhaps not necessarily comparable to the Desaguadero study but not greatly unrelated to it either. In fact, the regular budget income has normally been strongly reinforced by both local contract and foreign donation income. The fiscal appropriation for the Program has been about US$ 400.000 per annum with at least one half of it being operational capital. Additionally, at least US$ 200.000 were obtained on a yearly average over a 3-year period, from the other two financial sources just mentioned, thus doubling the annual availability of funds not assigned to cover salaries and other basic administrative costs. Presently, the Program has no foreign donation but its local contract income tends to grow significantly. This can, partially but not insignificantly, be attributed to the project's influence. The Desaguadero venture gave prestige and credit to the Program and thus increased the national demand for its specialized services. A clear indicator of this trend is an overall agreement of cooperation in this area of inquiry signed in October of 1979 between GEOBOL and the Ministries of Agriculture/Peasant Affairs, Mining-Metallurgy, Energy/Hydrocarbons, and Planning/Coordination. This instrument will produce, by computerized analysis of multispectral satellite data agricultural development information at a cost estimated at US$ 230.000, of which the Ministry of Agriculture will contribute US$ 130.000 and GEOBOL the balance (see in annex the agreement's text). Had it not been for the Desaguadero Project, GEOBOL would not have been able to undertake such kind of commitments. Brockmann estimates that, during the next five years, local demand for the Program's services will have doubled and GEOBOL will be able to

cope well with it without any major expansion of staff as the productivity of the present personnel will have been optimized by then.

6. WHAT CONTRIBUTION HAS THE PROJECT MADE, OR MIGHT MAKE, TO THE DEVELOPMENT OF BOLIVIA ?

The activities mentioned in answering the previous two questions have already indicated that the project has indeed contributed some information of potential valuable for Bolivia's development plans and octions, especially in the agricultural domain. However, whether such potential is to be realized or not, is something which escapes the jurisdiction of GEOBOL. The project did deliver to the Ministry of Agriculture the information that the latter had asked for in relation to a possible development project in the area of the Desaguadero River, which would probably have had as key component a dam. Contracted at a high cost in US dollars with a European firm, the dam's feasibility study did not come, however, to fruition in terms of a construction plan. In view of it, the Ministry of Agriculture apparently did not sustain its interest in the Desaguadero area, which is essentially composed of dry lands at a high altitude not ideally suited for cultivation. Nonetheless, GEOBOL insisted inasmuch as possible with Agriculture that the information obtained not be left idle. But there was little it could do about it due to the frequent changes in authority structure of that sector essentially explained by the country's lack of political stability. Not surprisingly, the agency capable of obtaining valuable development-oriented information is not endowed at the same time with the power to make sure that other agencies use it readily and properly. In summary, it must be admitted that the main intended beneficiary of the project so far has failed to profit from the land resources information gained through it.

Does this, however, mean that the project has made no contribution to Bolivian development? Not so. As Brockmann has perceptively and honestly explained, several other refined services which GEOBOL's ERTS Program is performing today for the benefit of diverse development agencies would have been just impossible without the project. Through it, scientists were trained, making possible the continuous and expanded utilization of the satellite remote-sensing technique. Moreover, according to Brockmann, even when such technique is not used, the project is acknowledged as having provided inspiration and fresh outlook enabling the entire program to evolve to its present outstanding status in Latin America.

Right now, in fact, two of the main state (provincial) autonomous development corporations - those of Oruro and Santa Cruz - in two very different and large regions of the country (high mountain West and low plains East, respectively), are negotiating new service agreements with the ERTS Program. GEOBOL will assist the former in a deeper analysis of some parts of the province's territory and, at the same time, in building a regular digital data system of information on natural resources. This illustrates the case that initial broader and looser surveys lead to narrower and tighter surveys of the Desaguadero type, showing the recurrent influence of this latter. On the other hand, the Ministry of Planning has profited from what the program already has done in the way of mapping resources in a part of the Santa Cruz Eastern plains in order to be able to redefine the country's regions on the bases of reliable information until then not available. It would, therefore, seem logical to feel that - above and beyond its original and immediate goals - the project has made valuable contributions to Bolivia's development. A closer perception of this, according to Brockmann, shall come in a few more years for the fruits of the project should be seen over a medium term perspective more than on a short-term one.

7. HAS THE PROJECT MADE ANY CONTRIBUTION TO THE REGION'S DEVELOPMENT ?

It has. By the mere fact of successfully experimenting with such a sophisticated modern technology and effectively adapting it to modest local conditions, the Bolivian project set Latin America as the pioneer and leading region on the matter among those in the developing world. But the beneficial Bolivian influence was to achieve higher and clearer expressions. Even before the project came to its termination, Bolivia was already projecting beyond its frontiers the experience gained thanks to it. With IDRC support, the GEOBOL experts gave technical assistance to Chilean counterparts through Project No. 3-A-76-4053. By sharing its learning with them, Bolivians were multiplying the impact of the project readily and significantly. Further and broader sharing of it was achieved through a Latin American symposium and an international seminar on remote sensing which took place in La Paz in 1977 under the leadership of the ERTS Program staff.*

The symposium asked Brockmann to prepare basis for the establishment of an Inter-American Remote Sensing Council; the draft of it is now ready for circulation, its author having counted on cooperation from an FAO expert. The seminar gave an

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* Simposio Internacional de Percepción Remota Aplicada en Demografía y Uso Actual de la Tierra, La Paz, 28-30 Nov. 1977. Memoria. La Paz, AID-GEOBOL, 1977; Seminario de Entrenamiento Regional de Aplicaciones de Percepción Remota (ERTS) por Satélites, La Paz, 1-9 Dic. 1977. La Paz, N.N.U.U., FAO, GEOBOL (ERTS), 1977. (Serie Sensores Remotos, No. 03).

opportunity for an exchange of information about the experiences with remote sensing in several Latin American countries; the Bolivian testimony was the central piece of discussion.

Furthermore, Bolivia seems to be contributing at the world-wide level to the advancement of the discipline. As has been noted elsewhere in this report, the GEOBOL people adapted from IBM-360 to DEC 10 the computer program of NASA LARSYS III.1.; this adaptation was sent into worldwide circulation by NASA itself. Likewise, Bolivians found that Brazil's remote sensing station generates magnetic tapes in a format incompatible with the NASA standard format. The GEOBOL people, with help from AID, made the conversion from the Brazilian computer format to that of NASA and, again, this latter agency plunged it into worldwide availability. As a user of remote sensing information, Bolivia requested all LANDSAT stations in the world to uniform their data formats. As a consequence, an international committee was established to pursue such homogenization.

OTHER CONSIDERATIONS

8. WHAT COOPERATIVE LINKAGES WERE MADE WITH INDIVIDUALS AND INSTITUTIONS IN OTHER COUNTRIES AS A RESULT OF THE PROJECT?

The close connections with NASA, with LARS and with Brazil's Institute for Space Research (INPE) are self-evident. The special ties with Chile have already been stressed. Mention of contacts with AID and FAO has also been made. And the importance of the two international gatherings held in Bolivia was underlined as well. Two other indicators can be added. On the one hand, Bolivians attended the Nairobi seminar. On the other, as reported by Brockmann, Bolivia has been preselected as seat country for a Regional Training Center on Remote Sensing to be established in 1981 through joint financing from the United Nations, the U.S. Agency for International Development and the Inter-American Development Bank.

Bolivia was aware that, under comparable IDRC support, other remote sensing experiments were being conducted in African and Asian developing countries. This coincidence did not amount, however, to an international network type research operation. Thus there was no direct and formal exchange among all these projects.

9. WHAT ARE THE ADVANTAGES AND REALITIES OF REGIONAL COOPERATION IN THIS FIELD?

There are no major regional realities to comment about them yet. But the joint Bolivia-Chile project was an early demonstration of the advantages of at least bi-national cooperation, and learn how to obtain it through remote sensing much faster and cheaper than if they had attempted to do it all by themselves from scratch.

Since, as it has just been mentioned, three international organizations are willing to start soon in Bolivia a training facility for Latin America, it can be assumed that multi-country cooperation - both between developed and developing countries and among these latter - is desirable since it can be productive.

10. WHAT COMMENTS DO YOU HAVE ON THE TECHNOLOGIES AND METHODOLOGIES USED ?

Remote sensing is a technology of great usefulness for developing countries. It allows them to survey their natural resources in a short time and at a low cost. This would not be possible with conventional technologies, such as aerophotography, which are expensive and slow. However, as any technology, remote sensing through satellites has limitations and it works better for certain purposes than for others. Thus it should be regarded as one of the tools in an arsenal from which wise selections must be made in accordance with needs and possibilities.

11. WAS IDRC'S INVOLVEMENT APPROPRIATE AND USEFUL ? WHAT MIGHT IT HAVE DONE DIFFERENTLY, BETTER, ETC. ?

It was both appropriate and useful.

First, it respected local leadership. "As project leader" - Brockmann notes - "I enjoyed absolute freedom to implement the project's plan without interference or imposition from IDRC. Bolivia was trusted. We were not "run by the nose" from above and abroad".

Second, IDRC realistically granted GEOBOL flexibility in the use of the grant. Says Brockmann: "IDRC performed for us -with good will and swiftness - certain tasks which no other international agency would have even considered. For instance, it made on our behalf some direct payments to LARS. This facilitated very much our operations".

Third, as has already been recorded, Brockmann feels that without this IDRC-supported project, its entire program would not have been able to advance as well as it evidently has since 1975.

What might have been done differently is monitoring. A much closer technical and administrative follow-up became evidently desirable. Had it been present, the administrative (mostly budget control) problems mentioned earlier would have been greatly alleviated. Also professional performance during the experiment could have been optimized. Brockmann feels that perhaps it would be convenient in future possible projects in other developing countries to assign to each of them a highly qualified technical consultant, who would at least be in the country frequently and for long periods, something which proved impossible for IDRC staff located far

away and simultaneously involved in many projects in several parts of the world. Such a consultant would not only give timely advice in sittu but act also as a constant monitoring link with IDRC. This comment, Brockmann wishes to make it clear, is in no way detractive of the recognition he has for the confidence and support granted to him and his aids by Robert Le Blond.

SUPPLEMENTARY QUESTIONS

12. SHOULD THE EXISTENCE OF A MULTI-AGENCY USERS COMMITTEE BE TAKEN AS A PRE-REQUISITE FOR THE SUCCESS OF THESE PROJECTS ?

Yes, without such an apriori assurance of interest and commitment on the part of the intended beneficiaries, to conduct one of these studies may well end up as a waste of IDRC's money. The Bolivian experience is in itself an indication of the importance of said-prerequisite. What rescued this project from the ill consequences of the lack of such committee, is that it operated within an already existing broader program by itself sponsored by a number of government agencies. Also, the lack of utilization of its results by the main intended beneficiary, the Ministry of Agriculture, came to be compensated by several unintended but clearly useful by-products of the project.

13. ALTHOUGH REMOTE SENSING MAY BE MUCH MORE PRODUCTIVE THAN CONVENTIONAL METHODS FOR DETECTING NATURAL RESOURCES, IT MAY STILL NOT BE INEXPENSIVE. WHAT DO YOU FEEL ABOUT IT ?

In comparison with conventional technologies, remote sensing can be regarded inexpensive in terms of cost benefit considerations. All expenses from all sources included, the Bolivian project did not cost more than US$250,000: 150,000 in equipment and 100,000 for training abroad. This modest investment endowed Bolivia with full ability to undertake locally further similar research for the years to come. However, considering only immediate applications to development needs, such investment is more than justified for the benefits already provided to the country are sizable. On the other hand, it would be erroneous to rate remote sensing as an extremely complex technology. Scientists in the developing countries certainly have the ability to understand remote sensing without great difficulty, just as they get to master other modern procedures. No more sophisticated equipment than increasingly standard computers are required and, as in the Bolivian case, units already existing elsewhere in the country can be taken advantage of. In summary, the developing countries can afford remote sensing. What they cannot afford is older technologies which consume much money and take years to produce less sharp and reliable information on natural resources.

14. DID THE PROJECT AUGMENT THE INTERNATIONAL NEGOTIATION ABILITY OF YOUR INSTITUTION?

It certainly did at least in some respects. So far, Bolivia has indeed gained unrestricted access to the U.S. information on remote sensing. For instance, NASA's LARSYS III.1 digital analysis program was in principle to be used exclusively within the United States of America. As a result of the project, however, NASA granted Bolivia permission to use it. The adaptation of it to local equipment capabilities was later fed back to NASA. This shows a gain in international negotiation ability. Another indicator is the openness and interest with which NASA has been getting suggestions from Brockmann and his aids in order to improve the remote sensing technology itself. Certain limitations of the first U.S. satellite to obtain information in the conditions of Bolivia seem to have already influenced improvements in the design of future satellites that would overcome most of the shortcomings observed and reported by the Bolivians. The fact that big powers can listen to small countries is most significant so that the former may not keep building technologies that fail to meet the requirements and possibilities of the latter.

15. ARE THERE ANY SUBSTANTIVE DIFFERENCES BETWEEN CENTERS DEVOTED TO REMOTE SENSING TRAINING ?

Differences exist but they are unlikely to be in terms of quality. What seems to basically distinguish one center from another is the special attention each prefers to place on a given discipline. Evidently, LARS at Purdue is the specialized center for agriculture. For mining, EROS Data Center at Sioux City. For cartography, the Geological Survey Center at Reston, Virginia. For geology, ERIM at Michigan. Experiencing with two of them lead to finding one qualitative difference. Whereas training at Purdue was wholeistic (theory and technique) and systematic, it was rather fragmented and somewhat disorderly at Michigan. This was apparently due to the fact that the center at this latter point was not a part of a university and thus it lacked expertise in the planning and conduction of formal training.

16. WHY SHOULD IDRC GET INVOLVED IN REMOTE SENSING WHEN THERE ARE OTHER INTERNATIONAL AGENCIES BETTER EQUIPPED TO SUPPORT ITS USE IN DEVELOPING COUNTRIES?

It is true that agencies such as FAO and AID have been in closer contact with the discipline and can probably allot to it more resources than IDRC. But there are at least two reasons why this latter institution should also be involved in promoting advancements in this field in the developing countries. One is that IDRC specializes in fostering research operations. The other is that, compared to all other agencies, IDRC is "the least bureaucratic and most expeditious". Also it is "the only one that gives the grantee total feedom to decide what they want to do and where they want the external assistance or equipment to come from. Thus it must "stay in the game", except under circumstances as the following:

- When the interested institution has not a both stable and active national committee of users that would ensure taking full advantage of the effort's product.

- When the country concerned fails to have local facilities enabling it to carry out in sittu multispectral analysis by computer. (Bolivia did not have them and thus GEOBOL had to do the image data processing in the U.S. * Learning was indeed gained there but doing the analysis abroad caused serious limitations and inconveniences since field verifications of satellite data were slow and complicated. All types of analysis and verifications should be performed within the country's territory).

- When the main component of the intended inquiry is geological and mineralogical information. (LANDSAT spacecrafts presently available from the first to the third - are not specifically designed to obtain this type of information. This can be compensated by computer analysis procedures more refined than those used in the Desaguadero project. But it seems wiser to wait until the fourth satellite of the series is in operation in 1980 or 1981. This spacecraft will be designed and equipped to obtain geological and mineralogical data as well as other kinds of information).

- When the project's aims are unrealistically overambitious.

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* With additional equipment that will receive soon GEOBOL expects to fully secure such autonomy by the middle of 1980.

SUMMARY

In 1975 IDRC supported in Bolivia, with about Can$70,000, an experiment of transferring to this country an advanced U.S. technology for prospection of natural resources: remote sensing based on computer-analyzed images transmitted by satellites provided with multispectral scanners. The Desaguadero River Project (3-P-74-0136) was conducted by Dr. Carlos Brockmann, the director of the Earth Resources Technological Satellite Program of the Bolivian Geological Service (GEOBOL), a decentralized agency of the Ministry of Mines and Metalurgy. The project had two basic and closely interrelated aims. On the one hand, to produce four thematic maps: geology (regional and mineral); geomorphology; hydrology; and soils. On the other hand, to train Bolivian scientists in remote sensing, with special attention to multispectral analysis of the satellite's digital data processed by computer, and seeking to adapt NASA's computing programs to the kinds of computers available in Bolivia. The main beneficiary of the project was to be the Ministry of Agriculture as, with endorsement from the Ministry of Planning, the former could establish a regional development plan in the Desaguadero valley area if the Bolivian Development Corporation built there a river dam to irrigate an otherwise desertic high-altitude territory.

As the present evaluation found, both those aims were achieved but the extent to which this occurred varied as follows: the training aspiration was fully and optimally met whereas the production of cartographic information was only partially attained. Moreover, while training has fructified and multiplied since 1975 in several ways, the cartographic information obtained for the Ministry of Agriculture soils map has not, so far, been used by it. It did not turn out possible to obtain geological, mineralogical and hydrological information of real usefulness. By contrast, unexpectedly, it turned out possible to produce an extra map on land use and coverage, for which the satellite images of the 35,000 square kilometer segment of the Desaguadero area proved highly informative.

The map making objective proved partially unrealistic. It apparently was too much to expect from a few and unexperienced professionals to build in one year four complex maps of too large a territory. Also limitations intrinsic of LANDSAT spacecraft of the models 1, 2 and 3, as well as observation problems determined by high altitude desertic lands and the narrowness of river courses made practically impossible to obtain valid and sufficient information for the geology, geomorphology and hydrology maps.

Nonetheless, taken as a whole, the Bolivian project did fulfill considerably its aims. It effectively grasped the rudiments of an advanced technology, it

efficiently obtained through it some of the information it wanted (and even some that it did not expect to collect) and it successfully adapted to the country's possibilities said technology by transforming NASA's LARSYS III.1. program from IBM-360 patterns to DEC-10. This experience was not free of problems. On the technical side, the low spacial resolution and the high amplitude of the spectral band in LANDSAT 1 prevented the project from obtaining data about rocks and minerals. On the administrative side, the local lack of proper accounting procedures and IDRC's slowness in doing the grant payments, along with an absence of homogeneity between GEOBOL's and IDRC's budgeting patterns, caused serious difficulties.

The project's impact was assessed on several dimensions. One was the enhancement of the institutional capability for conducting further similar studies. It was found that such strengthening and improvement had occurred to a very appreciable degree in GEOBOL, whose director, Dr. Brockmann, expressed the conviction that, without the project, the ERTS Program containing it would not have found a way to the higher endeavours in which it is now engaged. Relatedly, GEOBOL demonstrated its ability for self-sustained continuity by immediately doing more research as that of the project with its own funds, a large part of which is earned from contracts with many national development agencies resulting from the expanded prestige gained through the project. In fact, several Ministries, descentralized corporations and regional development agencies are increasingly demanding from the program services similar to those provided by the project. Furthermore, the project has also had an impact outside Bolivia in several manners. The most notorious has been an IDRC-supported Chile-Bolivia remote sensing project through which the GEOBOL team shared its experience, acting as teacher of the neighbours. On the other hand, Bolivia hosted two international gatherings on remote sensing, as a result of which Dr. Brockmann was asked to prepare the basis for a Latin American Remote Sensing Council and Bolivia was pre-selected as the seat for a regional training center in this field which will be sponsored by three international organizations as of 1981.

Brockmann regards remote sensing not as a universal panacea but as a very appropriate tool for developing countries as he finds it not so complex, as well as far cheaper and faster than conventional methods for prospection of natural resources, such as air photography surveys. He feels that IDRC's involvement in the project was appropriate and useful, stressing its flexibility and swiftness of procedures and the fact that it does not attempt to exert domination over the grantees. Its monitoring, Brockmann noted, could be greatly improved, by making it closer and more frequent perhaps through recruiting for each project of this type a consultant that would be in constant contact with its operations.

Brockmann recommends IDRC to continue financing similar studies if and when (a) the interested country counts a priori on an inter-institutional committee that would ensure proper utilization of the information to be obtained and (b) has already local facilities for conducting in situ multispectral analysis of digital computer data.

Finally, Brockmann recommends not to ask from present LANDSAT spacecrafts the ability to produce information for geology, mining and hydrology. Thanks in part to the experience with the Bolivian project, the design of LANDSAT 4, to be launched in 1980 or 1981, will allow it to comply also with such requirements.

ANNEX

TEXT OF AGREEMENT BETWEEN GEOBOL AND THE MINISTRIES OF MINING/METALLURGY, ENERGY/HYDROCARBONS, PLANNING/ COORDINATION AND AGRICULTURAL AND PESANTS AFFAIRS.

MINISTERIO DE MINERIA Y METALURGIA
BOLIVIA

Oficinas Centrales:
Av. 16 de Julio 1769
Cables: Minmineria
La Paz - Bolivia

Nº .....

ACUERDO DE COOPERACION TECNICA
INTERMINISTERIAL.

1. ANTECEDENTES.

El Servicio Geológico de Bolivia fué designado como organismo de contraparte e investigador principal del Programa del Satélite Tecnológico de Recursos Terrestres (ERTS-A), creado con el objeto de aplicar las imágenes LANDSAT en el estudio de los recursos del país, para cuyo efecto se elaboró un programa multidisciplinario que cubre las disciplinas de Geología, Hidrología, Pedología, Forestal, Geografía y Cartografía, Evaluación y manejo de Campos Naturales, información que está siendo elaborada en forma sistemática de acuerdo a lo indicado en el Plan Nacional de Desarrollo Económico y Social 1976-1980.

El Anexo A. detalla la experiencia que el Programa ERTS ha obtenido durante los últimos años en aspectos agrícolas, lo que demuestra que el Programa ERTS está capacitado para proporcionar información básica para el desarrollo agrícola del país.

2. MINISTERIOS PARTICIPANTES.

Según el Decreto Supremo de Creación del Programa del Satélite Tecnológico de Recursos Terrestres N°10135 de fecha 1°de Marzo de 1972, establece en su Artículo Tercero la participación de diversos Ministerios que entre otros se encuentran el Ministerio de Planeamiento y Coordinación, Ministerio de Asuntos Campesinos y Agropecuarios, Ministerio de Minería y Metalurgia y el Ministerio de Energía e Hidrocarburos, los cuales intervienen en la suscripción del presente Convenio como partes del mismo y que, por el Artículo Cuarto del citado Decreto Supremo deberán contribuir al Programa del Satélite Tecnológico de Recursos Terrestres, con personal, equipos, materiales y facilidades para la ejecución del Programa (Anexo B).

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Empresas e Instituciones Públicas dependientes: Corporación Minera de Bolivia, Empresa Nacional de Fundiciones, Servicio Geológico de Bolivia, Instituto Minero Metalúrgico, Comisión Boliviana de Energía Nuclear, Banco Minero de Bolivia, SIDERSA, Fondo Nacional de Exploración.

3. OBJETO DEL CONVENIO.

El objeto de este Convenio reviste a que el Programa ERTS proporcionará la información agrícola básica requerida por el MACA a través de sus instituciones especializadas.

Para el cumplimiento del objetivo antes indicado, el Programa ERTS requiere la adquisición de equipos especializados que prestarán los servicios necesarios para el procesamiento digital de datos, que proporcionan la información necesaria para la planificación del desarrollo agrícola del país.

A su vez el Programa ERTS se compromete a poner a disposición del MACA, los programas existentes y los futuros a desarrollarse para el procesamiento digital de información agrícola.

4. JUSTIFICACION DEL CONVENIO.

En el documento actual, el desarrollo de las técnicas de Percepción Remota en Bolivia, se encuentran avanzadas ya que el Programa ERTS dispone de profesionales capacitados para realizar trabajos de investigación y operación para recursos naturales renovables y no renovables.

El Programa ERTS ha implementado un sistema de procesamiento digital de análisis y clasificación de datos multiespectrales conocido como LARSYS que permite identificar en base a parámetros físicos de reflectancia, diferentes clases de coberturas terrestres (vegetación, suelos, rocas, agua y rasgos culturales).

Sin embargo, para optimizar en tiempo, costos y principalmente confiabilidad de los resultados obtenidos, se requiere mejorar y ampliar la capacidad instalada del Programa ERTS en equipo (Hardware) y programas de procesamiento digital de datos (Software).

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El equipo (Hardware) consiste de un dispositivo de presentación digital pictórica que funciona en un modo interactivo, que permite efectuar un realce de la imágen que facilita el análisis de la información para la identificación precisa y rápida de vegetación, suelos, roca y agua.

Con este equipo se incrementa la capacidad interactiva entre el intérprete y el procesamiento de los datos realizados por computadora. Sin embargo, para la presentación gráfica de los resultados finales de análisis y clasificación multiespectral, se requiere del equipo auxiliar impresor en blanco y negro ó color, capaz de generar un producto final. También este equipo auxiliar impresor, tiene la capacidad de imprimir imágenes realzadas digitalmente, aptas para ser utilizadas en interpretación visual.

Para materializar el sistema de procesamiento digital de imágenes se requiere de un minicomputador, que será el dispositivo de interfase entre los dispositivos de mejoramiento y la unidad central de proceso. (Anexo C).

El Programa ERTS ha implementado un sistema de procesamiento digital de datos multiespectrales (LARSYS), que inicialmente se encontraba incompatible con los actuales sistemas de computación existentes en La Paz, para cuyo efecto ha sido necesario efectuar las inversiones necesarias para la implementación de los programas, adquisición de cintas magnéticas y capacitación de personal.

Los requerimientos actuales para el procesamiento digital de datos obtenidos por satélite, hacen necesario la actualización permanente de programas de procesamiento digital.

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Av. 16 de Julio 1769
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Los dispositivos ya justificados anteriormente, requieren de sistemas operativos propios para su funcionamiento, los cuales al ser parte del equipo están justificados.

La capacidad que tiene actualmente el Programa ERTS incrementada con los equipos a adquirirse, servirán para apoyar el desarrollo del Sector Agropecuario, como ser el Levantamiento Integrado del Area San Borja, San Ignacio de Moxos, el cual se desarrollará en forma conjunta al Instituto Boliviano de Tecnología Agropecuaria, el inventario de los suelos salinos y vegetación del Altiplano y el Proyecto Regional (América Latina) de la construcción y uso de un marco de referencia, financiado por USAID/Washington, el cual coordinado con el Programa ERTS y el Departamento de Estadística del MACA se fortalecerán, permitiendo establecer un sistema continuo de datos agropecuarios computarizados (Anexo B).

5. FINANCIAMIENTO.

El financiamiento que comprende este Convenio no cubren los costos que ya han sido realizados por el Programa ERTS, en la fase de implementación del sistema de procesamiento digital de datos multiespectrales, cuyo costo aproximado asciende a la cantidad de $us. 50.000.-

Los montos aproximados de los dispositivos (Hardware) y programa (Software) que forman parte de este Convenio alcanzan a la suma de $us. 230.000.- que desglosados, aproximadamente son los siguientes:

1.	Fase implementada (Programa ERTS)	$us. 50.000.-
2.	Implementación en equipo (Hardware) y programas de procesamiento (Software).	

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Av. 16 de Julio 1769
Cables: Minminería
La Paz - Bolivia

a). Dispositivo de presentación digital pictónica.	$us. 80.000.-
b). Minicomputador de interfase	$us. 40.000.-
c). Dispositivo de impresión.	$us. 60.000.-
Total	$us. 230.000.-

Del total de los $us. 230.000.-, MACA aportará con $us. 130.000.- y el Programa ERTS con $us. 100.000.-, de los cuales $us. 50.000.- ya fueron erogados en la fase de implementación de los programas de procesamiento digital de datos multiespectrales LARSYS 3.1 y las cintas magnéticas de la serie del Satélite LANDSAT 1-2-3.

6. PROPIEDAD.

Los equipos a adquirirse mediante el siguiente Convenio serán de propiedad de las instituciones en forma proporcional de acuerdo a sus aportes, dejando establecido que los mismos forman un sistema de procesamiento digital indivisible, por cuyo motivo, los mismos no podrán fraccionarse si una de las partes diera por finalizado el Convenio.

7. COSTOS.

Los costos que demanden el procesamiento digital de datos serán cancelados por los Ministerios al Programa ERTS en base al costo, hora computación y material a fijarse una vez conocidos los mismos por el Programa ERTS.

8. CAPACITACION.

El Programa ERTS/GEOBOL, mediante este Convenio tendrá a su cargo la capacitación de personal de las diferentes instituciones participantes en el mismo, con el entrenamiento de técnicos en el manejo de los e-

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quipos, durante la ejecución de los trabajos a realizarse. Asímismo, se realizarán cursillos especiales con el fin de capacitar personal en la interpretación visual de imágenes de satélite, fotografías aéreas etc. y en el manejo y uso de la información obtenida por medio de sensores remotos.

9. CONVENIOS.

Para la ejecución del presente acuerdo, se realizarán Convenios especiales entre el Programa ERTS/GEOBOL y los Ministerios participantes, para la ejecución de trabajos específicos elaborados de acuerdo a las políticas de planificación de cada uno de los Ministerios.

En señal de conformidad suscriben el presente Convenio los Señores: Dr. Oscar Bonifaz G., Ministro de Minería y Metalurgia; Ing. Jorge O'Connor D'Arlach, Ministro de Energía e Hidrocarburos; Ing. Carlos Miranda P., Ministro de Planeamiento y Coordinación y Dr. Carmelo Caballero, Ministro de Asuntos Campesinos y Agropecuarios, en la ciudad de La Paz, a los Diez y Seis Días del Més de Octubre de Mil Novecientos Setenta y Nueve Años.

Dr. Oscar Bonifaz G.
MINISTRO DE MINERIA Y METALURGIA

Ing. Jorge O'Connor D'Arlach
MINISTRO DE ENERGIA E HIDROCARBUROS

Ing. Carlos Miranda P.
MINISTRO DE PLANEAMIENTO Y COORDINACION

Dr. Carmelo Caballero
MINISTRO DE ASUNTOS CAMPESINOS Y AGROPECUARIOS

La Paz, 16 de Octubre de 1979.