# HIGH LEVEL EDUCATION ON IMAGE PROCESSING, REMOTE SENSING AND GIS: CASE FC-IA/UNAM, MEXICO.

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**ABSTRACT:**

Some innovative courses (1 undergraduate, 4 graduate) on Image Processing, Remote Sensing and GIS are presented. The students become incorporated in research projects dealing with real problems. The different levels of integration between Teach and Research are discussed. The mentioned courses are optative in the Physics Department Undergraduate & Graduate Programs of the Faculty of Sciences (FC) at the Autonomous National University of MEXICO (UNAM) from 1984. The new stage of these experiences is being developed from 1991, in collaboration with the Institute of Astronomy of our University.

**Key words:** Courses, Remote Sensing, Image Processing, GIS, UNAM, MEXICO.

## I. INTRODUCTION.

Image processing is a common area of interest for many disciplines like: Medicine, Optical & Electron Microscopy, Astronomy, Space Physics, Remote Sensing, GIS, IR Photomicrography, Normal & IR Aerial Photography, Global Change, among others.

The courses on Image Processing, Remote Sensing and GIS must consider an Interdisciplinary approach because the students belong to a multidisciplinary set of technical and scientific areas (Physics, Biology, Engineering, Geography, Computer Sciences, Anthropology, Archeology, Geophysics, etc.).

The group of the Interdisciplinary Laboratory at the Faculty of Sciences (UNAM) was developing research on Water Quality with Remote Sensing Methods from 1976 (Ruiz-Azuara & Lemus, 1977; Ruiz-Azuara & Lemus, 1978; Lemus et al, 1980; Ruiz-Azuara et al, 1983; Ruiz-Azuara, 1985a; Ruiz-Azuara, 1985b; Aguirre et al, 1989; Ruiz-Azuara et al, 1989; Pérez et al, 1989; Ruiz-Azuara & Pérez, 1992).

Some specific undergraduate and graduate courses were introduced in the Physics Department of the Faculty of Sciences from 1984, in relation with these activities.

The new courses were:

1. Workshop on Remote Sensing.
2. Optical Remote Sensing for Hydrobiological Parameters.
3. Scientific Seminar on Remote Sensing.
4. Microwave Remote Sensing.
5. Digital Image Processing.

The first course was offered to undergraduate level. The other four, correspond to the graduate level.

In 1991, a new component was incorporated. Our group started a collaboration in a very ambitious project leaded by Dr. G. Köenisberger, actual Director of the Institute of Astronomy (UNAM). The collaboration of our group in project DGAPA-IA IN-303389 is concerned with courses on Digital Image Processing and related fields. With this project both sides, the Faculty of Sciences and the Institute of Astronomy, get benefits.

It is important, for the astronomers, to receive students of Physics interested in Astronomy with a solid background on Image Processing. The Interdisciplinary Laboratory gets support for its infrastructure and fellowships for young people interested in the different activities involved.

In this paper we described the pedagogical considerations, the general methodology developed and some of the main results that were achieved during 18 years, with emphasis in the relation between teach & research and the connection with real problems. From 1984, mainly the teach and research themes were related with natural resources (water and vegetation) and urban zones.

## II. METHODOLOGY.

The dynamics of the Image Processing, Remote Sensing and GIS courses were based in the former experiences with courses on Introduction to the Scientific Research. It was introduced by the author at the Interdisciplinary Laboratory from 1974 (Ruiz-Azuara et al, 1977; Ruiz-Azuara et al, 1982). Themes related with IR Photography and Remote Sensing generalities were included from 1974.

The general scheme of those courses is shown in the Figure 1.

The traditional class of theory was converted in a Seminar transforming the passive traditional student, that usually acts as a receptor only, into an active member that is receptor and emitter during the class, discussing lessons previously prepared.

The traditional laboratory also modified its philosophy letting the student to choose or modify the practical activities. It was called Free Laboratory.

All these actions can be successful if the student has the advice of specialized persons. In our case they were: the theory and laboratory Professors, the Assistant Professors and the Specialist External Adviser.

The traditional exams were substituted by the continuous evaluation including: home-works, free reports of exercises and laboratory activities, discussion of articles from journals, etc. At the end of the term, a final paper was submitted to the Group Symposium.

The diffusion of the obtained results, initially was done through the publication of internal reports, bulletins and the journal titled: Laboratorio Interdisciplinario. For economical restrictions, the publications could not follow. Then, the students were invited to submit papers to the National Congress of Physics (or International for the graduate students involved in their Master or Ph. D. Thesis).

All the mentioned activities required of a General Coordinator to be complementary and formative for the student. Usually, the Professor of theory played the role of the General Coordinator.

Motivation was one of the main points considered from the beginning. Lectures were organized when the term started to show the students possible subjects for their courses. The lecturers were well known specialists.

The fundamental idea behind this scheme was to create a special academic environment where the student creativity could be stimulated and oriented or supervised.

The general methodology was applied to each particular subject taking into account its specific characteristics. Our group offered courses on: Scientific Methodology, Scientific Photography, Polymers, Remote Sensing, Digital Image Processing (including themes of Geographic Information Systems), during the last 18 years.

## III. RESULTS.

Besides the long term courses, the author taught also a number of Short Courses, for actualization, in Mexico City and in different States of our country. More than 1120 students, professors and professionals were involved in all these activities. The zones or areas of influence of the mentioned courses, the States of MEXICO related with its students, are shown in the Figure 2.

The participants in the Courses on Remote Sensing and related fields, belong, mainly, to Educational and Governmental Institutions but also to Research Institutes or Private Companies.

The courses are alive, suffer changes to include new approaches, new sensors, new satellites, new hardware and software.

### III.1 Long Term Courses.

The actual version for the long term courses on Image Processing, Remote Sensing and GIS is the following:

III.1.1 Workshop on Remote Sensing.

It is a general, introductory course with 60 Hours for Theory and 100 Hours for Laboratory, taught for the first time in 1984 as a Pilot Group with Graduate and Undergraduate Students. From this experience, two courses were offered; this one, III.1.1, undergraduate and the III.1.5, graduate.

The program has five parts:

I. Fundamentals of Remote Sensing.

1. Introduction.
2. Electromagnetic Radiation.
3. Systems of Remote Sensors.
4. Remote Sensing Programs and Series of Satellites.
5. Data processing in Remote Sensing.
6. Corrections of the Digital Images.
7. Geographic Information Systems and Remote Sensing.
8. Ground Truth Data.
9. Fundamentals of Image Analysis.

II. Remote Sensing Applications.

1. Meteorology and Climatology.
2. Marine Environment.
3. Water Resources.
4. Land Use.
5. Geology.
6. Engineering.
7. Agriculture.
8. Forest Resources.
9. Archeology.
10. Urbanism.

III. Remote Sensing in MEXICO.

1. History of Remote Sensing in MEXICO.
2. Actual situation.

IV. Laboratory practices on Spectral Radiometry, Digital Image Processing and GIS.

1. UV-VIS-IR Radiometry.
2. Use of Maps of States of MEXICO made with Satellite Images.
3. Image Digitization (with tablet and scanner).
4. Landsat (MSS & TM) and SPOT Images.
5. Meteorological Images.
6. Radar Images.
7. Digital Image Processing:
   - -Display.
   - -Histogram.
   - -Simple Atmospheric Correction for Water Resources.
   - -Filtering.
   - -Classification: Different Algorithms.
8. Analysis of the images.
9. Geographic Information Systems.

V. Research related with the Use of Remote Sensing on Problems of National Interest.

In the term November 1991 - March 1992, the collaboration with the Institute of Astronomy started and we included specific activities related with Reduction and Image Processing in Astronomy. They were:

1. Lectures on Image Processing in Astronomy and Natural Resources.

2. Visit to the National Astronomic Observatory in Tonanzintla, Puebla.

3. Design of New Practices with Astronomical Images, for example, M51.

4. Design of introductory practices running in Workstations with the Program IRAF.

5. Design of new practices showing the main aspects of the image reduction by using IRAF.

6. Lectures on CCD's.

Bibliography:

The main bibliography suggested for this course is included in the next references: Holz Ed., 1973; Colwell Ed., 1983; Ruiz-Azuara, 1984; Ruiz-Azuara, 1985c; Sabins Jr, 1987; Castleman, 1979; Baxes, 1984; Ripple Ed., 1989, Muller Ed., 1988 and articles from PE&RS, RSE among other Journals.

III.1.2 Optical Remote Sensing: Theory and Water Resources Applications.

It is a theoretical Interdisciplinary graduate course oriented to a Water Resources. All the themes are covered in 104 hours. It is required for the next experimental course, III.1.3, devoted to a real problem of national interest. It was offered for the first time in 1985.

The program has the following themes:

A. Theory: General Aspects.

I. Introduction.

1. Main Aspects of Remote Sensing.
2. Hydrobiological parameters: General Aspects.
3. Radiative Transfer: Fundamental Concepts.

II. Scattering and Absorption of a Wave by a Single Particle.

III. Characteristics of Discrete Scatterers in the Atmosphere, Ocean, and Biological Materials.

IV. Inherent Optical Properties of Sea Water.

V. Radiative Transfer Theory.

B. Optical Remote Sensing: Specific Topics.

I. Methodology and Requirements of Remote Sensing Data Collection.

II. Interaction of Electromagnetic Radiation With the Earth's Atmosphere.

III. The Interaction of Electromagnetic Radiation With The Earth's Surface.

IV. Spectral Signatures and Their Correction for Atmospheric and Noise Effects.

V. Calibrations.

VI. Shallow Waters and Hydrology.

VII. Marine Biology and Water Quality.

VIII. Oceanography.

The diversity of backgrounds of the graduate students forming the group, i.e., Physicists, Biologists, Oceanologists, Engineers, or Ecologists, is considered when the themes for Seminars are distributed. Then, each one helps the others to understand those themes that know better. In this way, a positive interaction among the members of the group is stimulated. Each member learns to respect people with others' specialties.

Bibliography:

The main bibliography consulted for this course is listed in the following references: Ishimaru, 1978; Slater, 1980; Jerlov, 1976; Chandrasekhar, 1960; Egan, 1985; Nihoul Ed., 1984; Colwell Ed., 1983; Asrar Ed., 1989 and articles from PE&RS, RSE among other Journals.

III.1.3 Optical Remote Sensing: A real Case.

It is an advanced graduate course. It works like a Research Seminar or a Professional Workshop. There are some requirements that the applicant should fill:

a) The Former Course III.1.2

b) To have some experience on Digital Image Processing, equivalent to the background obtained during the course III.1.5.

c) To be involved in a Natural Resource Project corresponding to a Mexican Area of interest or to be interested in collaborate with the Projects that we are running.

d) To know Statistical Analysis.

It is a very special course that needs support from the Grants corresponding to our Research Projects. Sometimes there are Master o Ph. D. Thesis involved. It was offered for the first time in 1989, incorporating the students of the 1988 course III.1.2 to our research project Grant P218CCOC880375, supported by CONACYT.

Objective:

To apply the theories studied in the course III.1.2 to a certain Natural Resources or Phenomena by using Remote Sensing and GIS Methods.

The program includes the following aspects:

I. Site Selection.

II. Specific Problem Definition.

III. System Optical Properties.

IV. Ground Truth Data (with Field work and Bibliographic Search).

V. Selection of the Remote Sensing Data and Acquirement (if it is necessary).

VI. Data Analysis.

1) Field
2) Remote.

VII. Analysis of the Results.

1) Statistical.
2) Classified Images.
3) Simple and Multiple Regression Models.
4) Modeling.
5) Thematic Maps.
6) Others.

VIII. Conclusions and Publications.

The course takes approximately 104 class hours. Formally, but usually it takes much more due to the field work.

Bibliography:

The basic bibliography is the same that in course III.1.2. The recent papers (published in the main Journals related with Remote Sensing, GIS and the specific subject, i.e., Ecology) are fundamental.

III.1.4. Microwave Remote Sensing.

It is an introductory graduate course on Microwave Remote Sensing with 56 hours for Theory and 48 hours for Seminar and Practical Activities.

The program is:

I. Introduction.

II. Microwave Interaction with Atmospheric Constituents.

III. Passive Microwave Radiometry.

IV. Radar Fundamentals and Scatterometers.

V. Imaging Radar Systems.

VI. Advanced Systems.

VII. Analysis of Radar Imagery.

It was taught for the first time in 1989, to prepare young people for the new microwave sensors aboard of satellites (i.e., ERS-1 from ESA, among others). Images of SEASAT and for SAR airborne sensors are used in the exercises.

Bibliography:

The references used in this course are listed under the next names: Ridenour Ed., 1965; Kerr Ed., 1965; Ulaby, Moore & Fung, 1981; Ulaby, Moore & Fung, 1982; Ulaby, Moore & Fung, 1983 and Colwell Ed., 1983.

III.1.5. Digital Image Processing.

It is an Interdisciplinary Graduate course with 40 hours of Theory and 48 hours for Laboratory.

The themes are:

A. Theory

I. Fundamental Concepts.

1. Introduction.
2. Digital Images.
3. What is Image Processing?
4. What is Classification?
5. Mathematical Basis for Image Processing.
6. Mathematical Basis for Classification.

II. Digital Image Processing.

1. Fundamental Elements.
2. Digitizing Images.
3. The Gray Level Histogram.
4. Contrast and Dynamic Range Indication.
5. Spatial Filtering.
6. Image Restoration.
7. Spatial Registration.
8. Geometrical Manipulation.
9. Color Processing.

III. Pattern Recognition & Classification.

1. Image Segmentation.
2. Multispectral Classification.
3. Classification Training.
4. Atmospheric Correction.
5. Multispectral Ratios.
6. Principal and Canonical Components.
7. Vegetation Indexes.
8. Spatial Information: Texture.
9. Classification Algorithms.
10. Post-classification Considerations.

B. Laboratory

I. Computer Practices.

1. Digitization.
2. Gray Level and Color Display.
3. Algebra of Images.
4. Enhancements.
5. Extraction of Information.
6. Classifications with Different Algorithms.
7. Geographic Information Systems.
8. Editing Images.
9. Printing Images.

II. Seminar on Digital Image Processing Applications.

1. Natural Resources.
2. Astronomy.
3. Medicine.
4. Urbanism.
5. Environmental Impact.
6. Agriculture.
7. Global Monitoring.
8. Pollution.

9 to 12. Free themes for student proposals.

Bibliography:

The suggested references for this course are listed under the next authors: Schowengerdt, 1983; Castleman, 1979; Ruiz-Azuara, 1990; Ruiz-Azuara & Pizá, 1990; Colwell, 1983; Muller Ed., 1988; Baxes, 1984; Sabins, 1987; Ripple Ed., 1987 and article from the PE&RS, RSE and others Journals.

This course was taught for the first time in 1990. It is offered from the Graduate Program on Physics. From 1991, our course was included also in the Geophysics Graduate Program sponsored by the Institute of Geophysics of the UNAM and for CCH (Colegio de Ciencias y Humanidades). This program pays the salary of one Assistant Professor.

III.1.6 Sede Ensenada.

The main Mexican Astronomic Observatory is located in San Pedro Martir, Baja California Norte. In Ensenada, Baja California Norte, the Institute of Astronomy of the UNAM has installations also. For the term August - December 1992, the Digital Image Processing Course for graduate level will be offered in the CICESE Research Center, located also in Ensenada. Then, some of the activities of the Interdisciplinary Laboratory (related with the project IN-303389) will start in the Ensenada Area (during the Research Stay of the author in

CICESE) from August 1992.

The activities related with the undergraduate level, with the course III.1.1, are being planned in the Autonomous University of Baja California, Sede Ensenada, starting the next year, in January 1993.

III.1.7 Teach & Research Integration:

The integration of the student with the research projects considers different levels:

i) Use of images of the research project for the laboratory practices, including the ancillary data existent. All these images correspond to Mexican Areas under study for Mexican research groups.

ii) Students participate in one aspect of our research project, for example, Image Classification, Map digitization or a Small Computer Program for Radiometric Data Analysis.

iii) Students incorporate Remote Sensing in their Master or Ph. D. Thesis. We help students to obtain sub-images of Landsat Images, existing in one Governmental Institution, for the region where they are doing their Master Thesis or Ph. D. Thesis. The Institution is The Mexican Institute of Water Technology (IMTA).

**III.2 Institutions or Programs Involved.**

Our group is very small; during the last years we were only 3 members supported by the Physics Department. Now, we are only 2 members because the other got a fellowship to the Great Britain.

All the activities mentioned, including the Long and Short Term courses, the Research Projects and the preparation of didactic materials required a big effort and the collaboration of different Institutions. In the Figure 3, we show a scheme of these relations.

In this section we would like to mention them and say Thanks.

III.2.1. Hardware and Software Facilities.

At the beginning, before 1985, the actual National Institute of Statistics, Geography and Information (INEGI) gave us facilities with Computer Time for the ELAS software that they had installed.

After 1985, in the IBM Scientific Center of MEXICO we could develop part of our project with the HLIPS software.

From 1987, we initiated the implementation of our Research in a Microcomputer system in collaboration with a small Private Consulting Company, EMAYEV (Estudios del Medio Ambiente y Electro-Vehículos S.A. de C.V.).

III.2.2. Hardware & Software Acquisition.

Microcomputer practices were included, in the Interdisciplinary Courses, from 1990. The software facilities were provided by EMAYEV and the microcomputer, by the Coordination of the Scientific Research of the UNAM.

In 1991, with the support of Grants corresponding to three UNAM projects; PADEP (Programa de Apoyo a Divisiones de Posgrado) FC-9108; Eclipse 11 de Julio de 1991, and the mentioned DGAPA (Dirección General de Personal Académico) IA-IN303389, we obtained two more microcomputers and accessories. Also we bought software. A workstation where the IRAF will run was also bought but it is not received yet.

III.2.3 Fellowships.

The project IN-303389 included fellowships for young people to collaborate with our group. New members, 4, are participating in the different activities related with support to the students (preparation of new practices, mainly related with Astronomy, Lectures, and supporting our projects on Data Analysis), from 1991. Our colleagues were: Antonio Valencia, María Ladrón de Guevara, Elena Nikiforova and Bertha Vazquez.

III.2.4 Image & Sub-Image Facilities

In our Research Projects, we need to buy the "simultaneous" multispectral images. The work of the students, may need satellite sub-images from a different region of MEXICO with no money to buy them. We had found support for different Institutions. MSS Landsat sub-images, as it was mentioned before, were obtained from The Mexican Institute of Water Technology (IMTA). Meteorological Images, GOES or TIROS images, are provided by The National Meteorologic Service (SMN). SPOT IMAGE & CONACYT gave us some slides and Demonstrative CCT's to use in the courses. Kosmokarta gave us one printed image of a zone of Mexico City.

**III.3 Zones of MEXICO under study.**

III.3.1 Interdisciplinary Laboratory Studies.

The States of MEXICO with zones considered in our projects (with aerial and spatial multispectral imagery), are shown in the Figure 4.

III.3.2 Zones related with Students Projects.

The States of MEXICO with zones of interest for our undergraduate and graduate students, are shown in the Figure 4.

**III.4 Professions or Areas of interest covered by the Undergraduate and Graduate Students.**

The approximate percentage of different professions of the 1120 participants, including students, professors or other professionals is shown in the Figure 5.

**IV. CONCLUSIONS.**

The activities mentioned in this paper were always focused from the physical point of view. At the same time, our work was immersed in a multidisciplinary environment. In this sense, it is possible to say that during the last 18 years, a "small multifaceted seed" was sown. Fortunately, it is growing. Now, many of our former students are working on different places of our country, from Baja California Norte to Chiapas. Most of them, know about the capabilities of Remote Sensing and Geographic Information System Methods. Also, they know how difficult is to use them in a developing country.

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## VI. FIGURES.

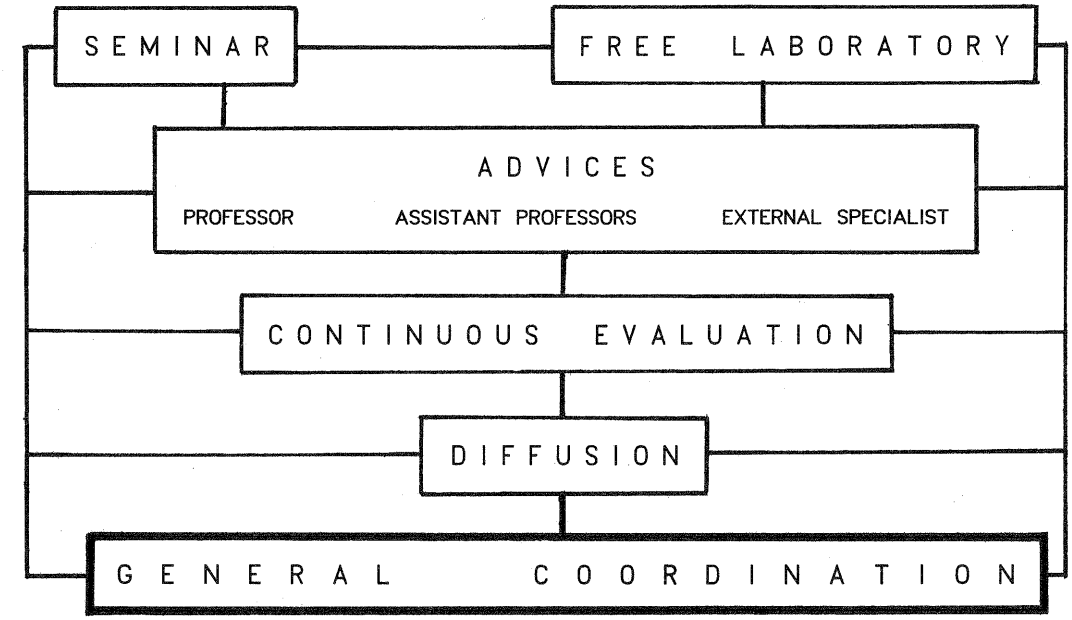


**Figure 1.- Course Dynamics.**

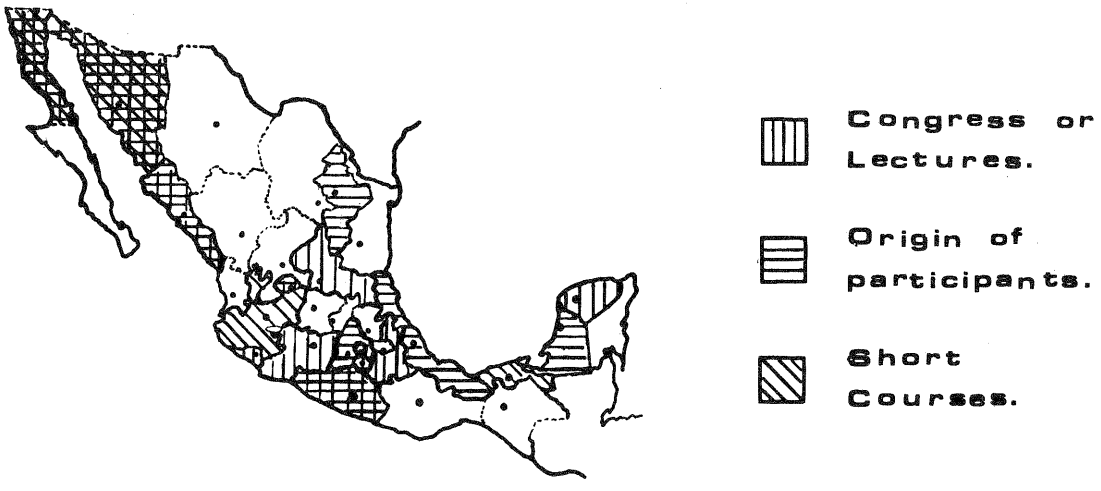


**Figure 2.- States of MEXICO with Areas of Influence**

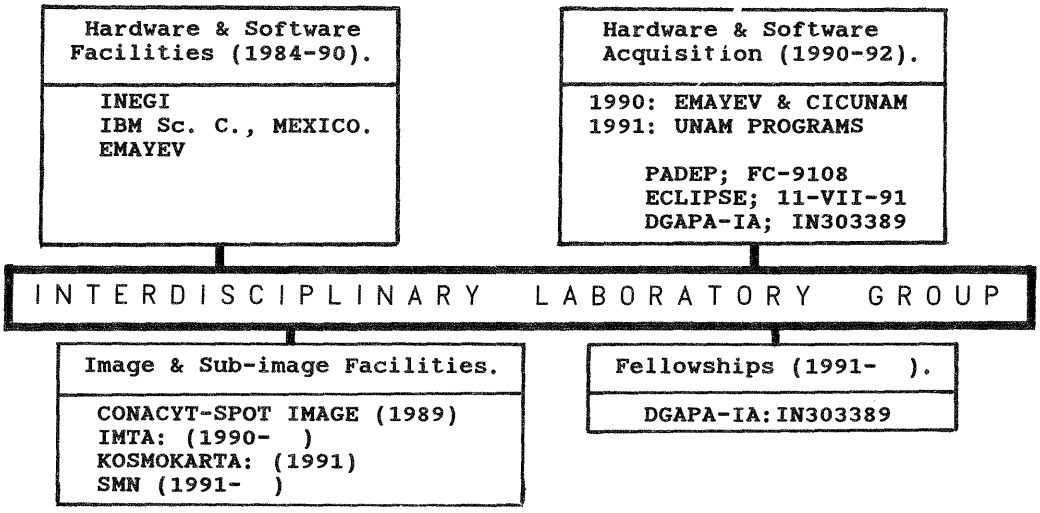


Figure 3.- Institutions or Programs Involved.


Figure 4.- States of MEXICO with zones under study

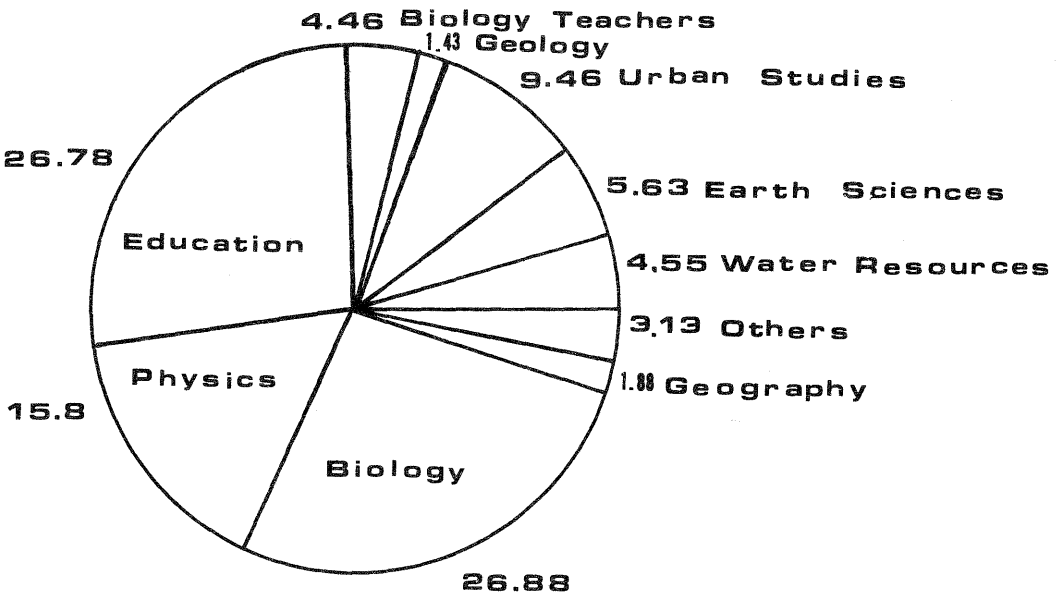


Figure 5.- Professional Areas ( % )