The tropical zone is the area of the Earth between the Tropics of Cancer (23°27'N) and Capricorn (23°27'S). However, the concept of tropical countries has to be understood in a broader sense which takes into account social, climatic and environmental factors. The tropical zone is in fact the richest, the most unknown and the most jeopardized region of the Earth; as a consequence remote sensing has a definitive role to play in this region. Remote sensing in the tropics has many particularities. To begin with, the tropics are the only place in the world where the sun can be seen straight overhead and the solar radiation has a shorter path through the atmosphere. Although geomorphologically the majority of the tropics is in lowlands, its agriculture, with predominant shifting cultivation practices, determines a small field pattern. This fact associated with a severe cloud cover problem claims for a remote sensing system especially designed for the tropical region.

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The tropical zone is the area of the Earth between the Tropics of Cancer (23°27'N) and Capricorn (23°27'S). However, the concept of tropical countries has to be understood in a broader sense which takes into account social, climatic and environmental factors. Socially and economically the tropics are, with few exceptions, synonym of "developing" regions. It corresponds to 38 percent of the land surface of the planet with over 50 percent (45 percent in 1975) of its population. The population growth rates of the tropics are typically twice as much those of the temperate zone. Although food production has almost kept up with population growth, this has been achieved, in many cases, at the cost of bringing into production new lands leaving behind improductive soils. Since temperature does not vary much in the tropics throughout the year (around 26°C), the major limiting factor for agriculture is water. Lack of water limits agricultural production, at least to some extent, to about 70 percent of the tropics. About 42 percent of the tropics has only 4 to 6 months of adequate moisture conditions for crop growing.

The tropical zone is in fact the richest, the most unknown and the most jeopardized region of the Earth; as a consequence remote sensing has a definitive role to play in this region. The length of the growing season and the annual solar radiation available for photosynthesis make it possible for the tropics to have a potential annual yield twice as much that of the temperate zone. Of course other limiting factors such as soil, pests and technology cannot be neglected. Desertification problems, pressure on land use, astonishing deforestation rates, explosive urban growth, and the need for cartographic and thematic information make remote sensing a must tool to help sustaining life in the tropics. It is no wonder why many tropical countries have engaged heavily in remote sensing programs even before solving their problems of social justice.

Remote sensing in the tropics has many particularities. To begin with, the tropics are the only place in the world where the sun can be seen straight overhead and the solar radiation has a shorter path through the atmosphere. Although geomorphologically the majority of the tropics is in lowlands, its agriculture, with
predominant shifting cultivation practices, determines a small field pattern. This fact associated with a severe cloud cover problem claims for a remote sensing system especially designed for the tropical region.

Despite all the catastrophic predictions already made for the tropical region, one cannot loose hope. Increasing yield, bringing new arable lands into sustainable production and decreasing the population growth rate are the challenging solutions for the tropics. In all these integrated actions, remote sensing has an unique role to play in the planning and monitoring of agriculture and urban development in the tropics.

1 - The Tropical Environment

Geographically the tropical zone is that part of the world located between 23° 27' north and south of the equator which corresponds to the area where the sun migrates seasonally and therefore is the only part of the world where the sun can be seen directly overhead.

The tropics comprise approximately 38 percent of the land surface of the Earth and over 50 percent of the population.

Typically, the mean monthly temperature variation is less than 5 C. The tropics receive more incoming solar radiation and therefore have a greater photosynthetic potential than the temperate zone. However, there is a great variability throughout the year in the incoming solar radiation, especially due to cloud cover. During the summer growing season, the monthly incoming solar radiation may be greater in temperate areas than in tropical areas. DeWitt (1967) indicated that the year-round solar radiation of the tropics may result in twice as much the yield-producing potential per hectare per year as that of the temperate zone, assuming no additional limiting factor. Maximum day length variation near the tropics is 2:50 hours and rainfall is the major climatic parameter for agriculture in the tropics.

According to Sanches (1976), there is no moisture limitation in about 28 percent of the tropical area. Moisture limits crop growth from 4 to 6 months in 42 percent of the tropics and from 8 to 12 months in the remaining 30 percent of the tropics.

Geomorphologically, 77 percent of the tropics are in lowlands, with less than 900m elevation. Twenty percent of the tropics range from 900 to 1800m of altitude. Only about 3 percent consists of high mountains (above 1800m).

Agriculture is the major productive activity in the tropics. However, it uses only 10 percent of the tropical land, with 20 percent additionally used as grassland (Sanches, 1976). There is
still a great potential to bring new lands into production in the tropics.

Looking the world as a whole, food production has kept pace with population growth. However, the balance is very frightening, and unless well-established programs for family planning and for increasing food production are implemented, one may face a catastrophic situation. Tropical countries have a decisive role to play in this outcome. For instance, high agricultural technology is being used in many tropical countries, but shifting cultivation is still the major farming system in the tropics.

It is well-recognized that the tropics are very rich in germplasms. Many species are found in the natural environment of the tropics and a great variety of crops is grown in the tropics as opposed to very specialized cropping systems of the temperate zone. Rice, cassava, and corn are the major crops in the tropics in terms of total production.

2 - Remote Sensing in the Tropics

Most developing nations in the tropics do not have efficient conventional data collection systems to provide the basic information necessary for planning a harmonious utilization of their national resources. Several tropical countries present hard-to-access areas and uneven population distribution, with a high population growth rate and a very dynamic environment. All these facts make remote sensing an ideal tool for monitoring their terrestrial resources.

Geological and climatic conditions in the tropics result every year in natural disasters with severe social and economical impacts. Floods, droughts, earthquakes, volcanic eruptions, and frost are examples of these catastrophic events. Desertification is a generalized problem in the tropics, especially in Africa (Grove, 1977).

Agricultural production fluctuates a lot in the tropics due to climatic conditions caused by the great influence of the oceans, the sun migration and the atmospheric intertropical convergence.

Many tropical countries do not have good, routinely operated information systems and, generally speaking, they are poorly mapped. Remote sensing, if properly adopted, can shorten tremendously the time necessary to overcome this situation. In fact, many activities in which remote sensing has a major role are currently underway in the tropics. Many tropical countries operate receiving stations for land observation satellites. Additionally with on board recorders and communication
satellites, such as the Tracking and Data Relay Satellite (TDRS), most tropical areas can be imaged by the currently available orbital systems.

However, there are many limitations to the full utilization of remote sensing in the tropics. To begin with, well-trained manpower is a serious limitation in most tropical countries. This point was clearly emphasized during the international conference "Remote Sensing for Development Experiences with and Requirements for User Assistance in Training", held in Berlin (West) from 1 to 6 September, 1986. Besides human limitations, the tropical environment presents limiting characteristics for the utilization of remote sensing, especially for agriculture. Cloud cover, especially during the summer crop growing season, is the major limiting factor for the utilization of the currently available satellite systems. The agricultural systems in the tropics where shifting cultivation still predominates, determine a small field pattern which claims for high spatial resolution that only recently began to be available. Another major limiting factor is the increasing cost of satellite data, in spite of the myth that satellite data are inexpensive. Also, people trained to make full utilization of satellite data tend to be costly. Finally, in terms of agriculture, it is usually hard to pool together the agricultural information system with the agricultural policy program in less developed countries, as it is the case of several parts of the tropics.

Even though an agricultural information system based on remote sensing can be expensive, it is not as expensive as not having a reliable system. For instance, avoiding just one mistake, such as importing or exporting food wrongly, may pay the whole system (Wigton and Paul, 1984).

2.1 - Latin America (LA)

Several countries in Latin America have engaged in strong remote sensing programs. For example, Brazil is continuously operating a LANDSAT receiving station since 1973 and should be able to receive and process SPOT data in 1987. The Argentine receiving station is currently receiving MSS data, but it is being upgraded to receive TM and HRV/SPOT data. Part of LA is not covered by receiving stations, but negotiations in Ecuador and in Colombia are progressing in the direction of installing a local reception facility. Chile already succeeded in receiving MSS data through their NASA Tracking Station near Santiago.

Meteorological satellite data from GOES, TIROS-N, and METEOSAT are routinely received in several countries.

There is a very active remote sensing society organization
in LA, i.e., the "Sociedad de Especialistas Latinoamericanos en Percepcion Remota (SELPER)" created in Quito, Ecuador, in 1980. Presently, its headquarters is in Brazil. The 1986 SELPER symposium held in Gramado, Brazil, jointly with the Fourth Brazilian Symposium on Remote Sensing had over 800 people registered.

In terms of agriculture, several countries have semi-operational information systems based on satellite data for either constructing a sampling frame, or obtaining crop area estimates. That is the case of Brazil (under implementation), Argentina (Redondo et al., 1984), Chile (Pattillo and Solivelles, 1986), and Ecuador and Colombia (Wigton and Paul, 1984).

2.2 - Africa

To help upgrade the economy of Africa, which is rapidly declining for over ten years, Remote Sensing is seen as a great prospect through possible contributions to the Africa's Priority Programme for Economic Recovery (APPFR), which focuses on food self sufficiency by 1991.

The African Remote Sensing Programme (ARSP) was established with very ambitious goals including three receiving stations which would cover 90 percent of Africa (Olujohungbe, 1986). So, the African Remote Sensing Council (ARSC) was established in 1977, but lack of funds prevents much of the action of this council. Several regional centers were established and currently the centers of Nairobi (Kenya), Ile-Ife (Nigeria) and Ouagadougou (Burkina Faso) are having truly regional participation. Although many facilities are available, these centers are still in the process of establishing their facilities and getting personnel training.

All these centers are, to some extent, involved in training and advisory for agriculture remote sensing projects in several African countries.


Within the scope of the ARSP, there are other centers operating in national levels. An example is the Remote Sensing Center of Cairo, Egypt, which is well-equipped and well-staffed, being involved with many projects in agriculture, land use, water resources, and geology. Another example is the Remote Sensing Centre of Kinshasa, Zaire, which is becoming regionalized.

Morocco has a quite successful agricultural information
system based on satellite data. It has built an area sampling frame and is in the process of introducing digital analysis of satellite data for crop area estimate (Wigton and Paul, 1984).

Under the auspices of the Inter-State Commission to Combat Drought in the Sahel, the AGRHYMET project was started in 1975 to increase food production. The World Meteorological Organization executes this project with the help of many western nations. This initiative is the basis for a crop monitoring and early warning system in the Sahel (US, 1986). Otherwise, NOAA's Assessment and Information Service Center (AISC), supported by USAID, provides a global warning system. This service has contributed to Nepal and Mali by warning crop failure in time to avert famine (US, 1986).

2.3 - Asia

Although many Asian countries are quite involved with national remote sensing activities, including receiving and processing facilities, the Asian Regional Remote Sensing Training Center (ARRSTC) established in Bankok, Thailand, has had a key role in providing technology transfer to tropical countries if Asia, especially through training courses.

This center is in the process of continually upgrading its facilities to become fully capable of providing survey services for countries in Asia. It already trained people from Afghanistan, Bangladesh, India, Indonesia, Iran, Malaysia, Mongolia, Nepal, Pakistan, Philippines, China, Taiwan, Republic of Korea, Sri Lanka, Thailand and Vietnam (Nualchawee, 1984).

In the Indonesia and the Philippines, area sampling frames for agricultural survey have been demonstrated, using remote sensing data. In the Philippine case the frame was based on old aerial photographs; now, for updated information, satellite data need to be introduced (Wigton and Paul, 1984).

Bangladesh operates several weather satellite receiving stations and has facilities for data interpretation, both visually and digitally. It is in the process of finalizing its receiving station for LANDSAT and SPOT. Several projects for agricultural modeling are underway (Khan, 1986).

3 - Satellite System for the Tropics

Considering the fast dynamics of the tropical environment, the severe cloud cover problem and the fact that in the tropics the overlap coverage between adjacent orbits is minimum, it is imperative to design an orbital system that maximizes the frequency of coverage of the region.
The expected temporal resolution of current satellite systems is indeed very poor for the tropical needs. For example, the LANDSAT system with a coverage cycle of 16 days in a region with a cloud cover of +50 percent results in a temporal resolution of 32 days. In areas such as the tropical Amazon, the situation is still worse. Mauricio (1986), modelling historical data of cloud cover, predicts with 90 percent of probability of success that it is necessary 221 days to obtain an image (200 x 200 km) with less than 30 percent of clouds in a climatic region such as the Amazon, during the summer time, for a satellite with a 15 days coverage cycle. Similarly, it would take 4650 days to get a good image during the winter time for the same region. The current SPOT satellite system, although it may improve the situation of temporal resolution for specific sites (and applications), has for complete coverage a repetitive cycle of 26 days with cloud-free conditions.

Really, for monitoring the jeopardized tropical environment, a specialized system with a payload based on microwave imaging sensors, or on an orbital platform which maximizes revisit capabilities in an equatorial or semi-equatorial orbit configuration, is needed. An example of such a system is the Tropical Earth Resources Satellite (TERS) concept, jointly proposed by the Netherlands and the Indonesia (van Konijnenburg and Irsyam, 1984). Another example is the ERS-1 (European Remote Sensing Satellite - 1), scheduled to be launched in 1989 with a radar imaging system on board (Duchossios, 1984).

Presently, due to its high repetitiveness, the NOAA AVHRR system is having such a great impact for monitoring the tropics, in spite of its low spatial resolution (Domerge, 1986).

4 - SPOT and Agriculture in Tropical Countries

Since its conception, SPOT has raised much interest in the tropical countries. This is evident by the number of SPOT data distributors and tropical countries engaged in the process of installing ground stations for direct reception and processing of SPOT data. By having participated in the PEPS (Programme d'Evaluation Prélinaire SPOT) International Scientific Committee, we could appreciate how strong is the interest of the international community in assessing the capability of SPOT in helping the solutions of the agricultural sector of the tropics.

Out of the total of 311 proposals received by the PEPS Secretariat, 19 had "agriculture in the tropics" as the main topic of interest. These proposals came from all continents which intercept the tropics.

High spatial resolution was the most emphasized
characteristic of SPOT, followed by revisit (to decrease repetitive cycle) and stereoviewing capabilities. Rice appeared frequently as the target crop and semiarid test sites were of major interest.

The principal investigators of these proposals come either from developing countries (6 proposals) or developed nations (9 proposals) and from international centers in Africa and Asia (3 proposals). Although many tropical countries have presented proposals of high scientific level, the teams responsible for the majority of them are less experienced and less equipped than the teams from developed countries.

5 - Final Remarks

Although remote sensing has been demonstrated to be very useful and essential to help to solve many problems associated with agriculture in the tropical region, there are several limitations for the full utilization of this technology in the tropics, such as lack of trained personnel, inadequacy of the current satellite systems (temporal and spatial resolution) and, finally, lack of funds to adopt the technology in an operational fashion. Notwithstanding, we do hope that all these problems will be solved through the cooperation among the nations involved, both from the technology generating side and from the user side, certainly with the support of international organizations.

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