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REMOTE SENSING FROM ARTIFICIAL EARTH SATELLITES

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SENSORS ON BOARD SATELLITES ORBITING THE EARTH EVERY 103 MINUTES, 550 MILES ABOVE US, MONITOR SRI LANKA'S RESOURCES; OFFERING A NEW CAPABILITY TO BOOST OUR ECONOMY.

PI - A.T.M. Silva

The first artificial satellite Sputnik I, was launched into orbit around the earth by the U.S.S.R.in 1957. Since then, hundreds of satellites have been placed in earth orbit by a number of nations. Many of these have specialised scientific or strategic objectives. Manned space flights and specialised unmanned missions to parts of our solar system also are contributing to our knowledge of the space surrounding our planet. Some of these satellites and missions are concerned with the study of the earth's surface from space. These missions carry equipment, such as cameras, which observe and record radiation from the earth's surface and have obtained useful images of the earth from distant positions in space. The advantage of this technology known as Remote Sensing, is to detect, measure and monitor the properties and features of the earth without the slow and costly necessity of detailed ground or aerial surveys. The modern satellite sensors record data over a broad range of the electromagnetic spectrum - providing information which is not available to the unaided eye, or to the conventional aerial camera.

MULTISPECTRAL OBSERVATIONS.

The spectrum of electromagnetic radiation extends from extremely short wavelengths such as Gamma and X-rays through the Ultraviolet, visible, near and far-infra-red to microwaves and long radio waves. The human eye is sensitive to a narrow band of visible light. This is a very small part of the entire radiation spectrum. All objects or surfaces on the earth reflect or radiate energy in both visible and non-visible bands. That is, there is a very wide distribution of available radiation from the earth's surface but only a small band of this radiation is discernible to the human eye or affects conventional photographic films. Radiation intensities at different wavelengths vary depending on the type of surface or object. The spectral distribution and intensities of the different bands vary with surface type and orientation.

SENSORS.

Modern satellites carry electronic sensors to measure and record broad portions of the electro-magnetic spectrum, yielding images in both the visible and non-visible ranges. This approach, known as Multi-Spectral Scanning, attempts to identify surface features by their unique combinations of radiance values recorded in each band. The combination of recorded values characteristic of each surface is the "Spectral Signature" of that surface type. This approach is utilised by the American Earth Resources Technology Satellite (ERTS). ERTS I was placed in orbit by the National Aeronautics and Space Administration (NASA) in 1972. ERTS 2 became operational in January, 1975. The satellites have since been re-named LANDSAT 1 and 2 respectively.

LANDSAT.

The LANDSATs circle the earth in a near-polar orbit at about 550 miles above us. The orbit, altitude and attitude of the satellites are maintained through sophisticated remote control devices. Each satellite carries a scanning device with a cluster of detectors sensitive to one of four different bands of radiation.

The near-polar orbit in combination with the earth's rotation about its axis produces sequential coverage in N-S strips over the earth's surface. This system is designed to bring the satellite over the same area at the same time of the day once every 18 days. Therefore, four simultaneous images in four spectral bands are obtained for the particular areas of the earth's surface. Radiance values in each of the bands is recorded and transmitted to receiving stations on earth. These are recorded on magnetic tape and later, either processed by computer, or imaged and photographed on a Cathode ray tube display. Most of the globe can be imaged every 18 days. The near-polar sun-synchronous orbit enables the satellite to cross the equator at the same local time on each orbit of the earth. Hence, the imagery is taken at the same sun angle providing similar shadow effect and illumination in sequential images. LANDSAT completes 14 orbits a day at a rate of about 103 minutes per orbit, passing N to S on the sunlit side and S to N on the dark side.

The earth rotates about 26° ~~during each orbit or~~ an equivalent of about 2,900 Km at the equator. A mirror scans an East-West strip of 185 Km. allowing for entire equatorial surface coverage in 18 days. Adjustment of the Satellite's orbit to provide a small angle with the Earth's polar axis accounts for slight wobbling (precession) of the axis and for systematic coverage in N-S strips. Every 19th day coverage is repeated. Therefore, imagery of any part of our country can be obtained at 18 day intervals.

IMAGERY

After the sensor values obtained by the satellite are telemetered to the ground receiving stations and recorded on tape, these values can be computer processed to correct for the distortions caused by earth's rotation during the scanning period and other systematic errors in the system. To produce an image, the scanning process is reversed by using a light beam on a TV-like display to simulate the satellite-recorded signal values. Through this process a photographic image of a 185 Km. square area in each multispectral band is obtained. Images in different bands enhance different types of terrain detail. For example, a near infra-red band enhances the appearance of water bodies, while a red band enhances that of vegetation. The combination of different bands gives a wide variety of information. Either individual single band black and white images or colour composites are produced. The colour composites are obtained by projecting two or more bands through different colour filters onto colour film. Complementary to this visual imagery, are the Computer Compatible Tapes (CCT). Digital computers utilizing CCTs automatically analyze the spectral data and through ground verification or from aerial photos, identify different types of terrain surface.

The image geometry of the 185 Km Square ground scene as recorded from 550 miles above the surface provides a good orthographic projection. Further rectification through the system correction and the use of ground control results in an excellent image geometry.

APPLICATIONS:

The practical applications of this technology are not entirely unknown. However, the speed, relatively low cost, and continuous updating ability of the satellite systems provide broad applications. Basic advantages are in the increased accuracy and speed of collecting data that is already being gathered through different survey organisations utilising cumbersome, costly and traditional methods.

For example, current estimates of crop acreages are often based on accumulation of the farmer's subjective yield estimates or on rough estimates given by Grama-Sevakas or Cultivation Committees. LANDSAT data offers objective recurrent measurements in 18 day cycles of total acreages under each crop as well as records of the seasonal variations. Accurate current information systems on crop production would enable the Government to plan Trade Policies with greater certainty. Timely knowledge of food import needs would result in efficient use of scarce foreign exchange, minimization of erratic changes in the imports and in the efficient use of storage facilities. Prediction of crop production is being developed in other countries utilising LANDSAT Imagery.

The schedule given at the end of this paper lists possible applications of Earth Satellite Imagery in Sri Lanka. It should be noted that many user organisations may be involved in obtaining current information from this new technology. Hopefully, the speed and low cost of the satellite data will enable more careful planning of development and improvement of our economy. This schedule gives an idea of the wide scope of applications and the possible advantages of exploiting this new capability.

LIMITATIONS:

The fact that the observation of the ground is done at a distance of about 550 miles imposes certain limitations in image resolution. The multispectral scanner system observes radiance values for roughly square areas of approximately 1½ acres on the ground.

This resolution area is called a picture element or "pixel".
In a typical 185 Km. square frame there are more than 7 million such pixels, each having a radiance value observation in each of the four bands. Therefore, the number of quantitative values and possible combinations is immense and is far too unwieldy for human analysis. However, the photographic images generalizing this information in each band has inherent advantages and limitations. It offers a synoptic view of a large area of the earth's surface, affording a medium for generalization, which is not possible with small area coverage. But the small scale, the congestion of millions of units of information on a small area and the degradation caused by normal photographic processes result in decreased resolution. The largest scale upto which this visual imagery can be enlarged is in the order of 1 to quarter million.

On the other hand, original data in the form of computer compatible tape (CCT) can be "looked at" on any scale. That is, except for the 1½ acre resolution limitation, the digital values can be read virtually at ground scale. However, detailed processing, analysis and interpretation of many millions of such digital values and combinations of values is a tremendous task, requiring large computer capacities - currently beyond those available in Sri Lanka. However, it is ~~clear~~ known that techniques are being developed to simplify the procedure for digital analysis. Already we have submitted proposals for such a pragmatic approach to digital image processing to obtain information on crop yields, water stress etc., for agricultural management. Such information is likely to be slower, and perhaps, of lesser resolution than those obtainable through the sophisticated and expensive processes. But it is hoped that it will be a reasonable compromise considering the size, economic development and the capital outlay capability of this country.

The most successful applications of such satellite imagery, whilst using both visual and digital forms, have been conducted in areas where large extents of homogeneous land-use patterns and well-planned human activity exist. In this respect, our own development and land use pattern is very much different and consists of mixed cultivations of very small size. Due to this, we can foresee many difficulties in adopting simplified techniques to resolve and interpret our crop patterns.

However, investigations are being made to develop techniques of making use of this new capability of obtaining information which is likely to yield economic benefits to our country.

POSSIBLE BENEFITS OF SATELLITE IMAGING APPLICATIONS IN SRI LANKA AND RELEVANT USER ORGANISATIONS.

Satellite Data Type (Reference: An economic evaluation of the utility of ERTS data for developing countries by Lowe, Summers & Greenblat-ERIM Report)	Applications and benefits	User Organisation	Non-recurrent (N R) or Recurrent (R R) (and frequency in number of days)
1. Soil types Soil permeability	Agricultural planning and management; Crop diversification; maximisation of Agricultural output; investigation of crop compatibility for particular areas to formulate agricultural policy when combined with Land Use and Hydrology Maps (3) and (4).	Ministry of Agriculture and Lands; Ministry of Plantation Industries; Ministry of Planning and Economic Affairs; Ministry of Plan Implementation; Dept. of Agriculture; Agriculture Research Organisations; Land Commissioner; Land Reform Commission.	N R
2. Geology	Geological Mapping; 1st Stage in Mineralogical Exploration - vide 5.	Geological Survey Dept., and Client Depts.	N R
3. Land Use	National policies on land use, when combined with soil maps (1) and Hydrology (4) Land preservation. Data on Urban growth. Expansion of transportation systems with physical land structure and terrain information.	Ministry of Planning & Economic Affairs; Ministry of Agriculture & Lands; Ministry of Plantation Industries; Ministry of Irrigation, Power & Highways; Dept. of Forestry; Dept. of Wild Life; Dept. of Agriculture; Agriculture Research Organisation; Town & Country Planning Dept., Land Commissioner; Land Reform Commission.	R R (36)

Satellite Data Type.	Applications and benefits.	User Organisation	Non-recurrent (N R) or Recurrent (R R) (and frequency in number of days)
4. Hydrology	Agricultural planning and Water management; when combined with Land Use (3) and Soil types (1) helps investigate crop suitability for particular areas and to formulate policies to maximise total output.	Ministry of Agriculture & Lands; Ministry of Irrigation Power & Highways; Dept. of Agriculture; Agriculture Research Organisations; Ministry of Plantation Industries; Land Commissioner; Land Reform Commission.	R R (36)
5. Mineralogy	Systematic intranational mineralogical exploration to determine areas which initially appear promising in terms of mineral deposits - for subsequent detailed investigation. Complete roster of mineral bearing sites for development as resources permit. Import substitution.	Ministry of Planning & Economic Affairs; Ministry of Plan Implementation; Ministry of Industries & Scientific Affairs; Petroleum Corporation; Cement Corporation; Mineral Sands Corporation, and other Organisations under the Ministry of Industries & Scientific Affairs.	N R
6. Water Resources	Recurrent reporting of agricultural, weather, water-supply data; drought effects and evolving of possible changes in regional irrigation schedules; water flow and variation within a one-year period and planning of major hydrological structures.	Ministry of Irrigation, Power & Highways; Ministry of Agriculture & Lands; Water Resources Board.	R R (36)

Satellite Data Type.	Applications and benefits.	User Organisation	Non-recurrent (N R) or Recurrent (R R) (and frequency in number of days)
7. Agriculture & Crop Forecasting	Total acreage cultivated and distribution among various major crops; soil moisture; crop vigour; water stress. Crop Forecasting :- Assists formulating State trade policies; Advance knowledge of import needs; pricing policies; Consumer-market structure; Acreage estimates by crop and method for unit-yield surveys after on-site sampling; Early detection of disease and water-stress and monitoring of remedial measures; Drought-effects for possible adjustments to irrigation schedules; Import substitution; Export of excess produce; chanelling of foreign exchange for vital needs.	Ministry of Agriculture & Lands Ministry of Trade; Ministry of Planning & Economic Affairs; Import & Export Controller; Marketing Dept., Co-operatives; Paddy Marketing Board; Flour Milling Corporation.	R R (36)
8. Forestry	Estimating timber stands; prevention of over-logging; monitoring of illicit logging, fire damage, disease, encroachments; evolving policies for timber industry.	Forest Dept., Timber Corporation.	R R (36)
9. Soil Erosion	Control of Soil erosion, Control of river/harbour silting ; monitoring sea erosion; monitoring effectiveness of preventive measures.	Ministry of Irrigation Power & Highways; Ministry of Shipping & Tourism; Ministry of Home Affairs and Public Administration; Port Commissioner; Tourist Board.	R R (36)
10. Environmental Pollution	Monitoring of Industrial and Agricultural Pollution and Preventive measures.	Ministry of Planning; Tourist Board; Local Authorities	R R (72)
11. Cartography	Planimetric mapping and revision on smaller scales; thematic mapping.	Survey Dept., Ministry of Education; Tourist Board.	R R (360)

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