Use of Remote Sensing in the Long Term Ecological (LTER) Program

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1. Backround of remote sensing data use in the LTER Program.

The LTER program makes extensive use of remote sensing data and depends on their availability in its ecological research. LTER uses data from a large variety of satellite bases, as well as airborne and ground-based sensor system in it research. Photographic remote sensing products (i.e. aerial photographs) are used to some degree for site locations and local vegetation change studies. Aerial data from newer digital sensor systems are becoming more popular for studies of vegetation change at the plot and even individual plant level. Both 1998 and 1999 are important years in the availability of remote sensing data for ecological research, as a number of planned system will be launched to provide a wider variety of data for use in ecological research. Use of data from commercial remote sensing data provider is used to a limited degree within the LTER program, however costs of such data a significant limiting factor to their wide-scale (i.e LTER Network-wide) collaborative use. Data from Positive Systems Inc, from the "ADAR 5000" sensor system has been used by both the H.J. Andrews and Jornada Experimental Range LTER sites for vegetation change research. The entire Sevilleta National Wildlife Reserve LTER was flown early in 1998 at 1m using the ADAR 5000 to produce a composite mosaic image.

Linkages with other agency programs has been crucial for LTER remote sensing research. Collaborations with NASA, Earth Science Enterprise have been extremely important in collaborative exchanges of data, information and expertise. Remote sensing data from agencies such as the CIA promise future access to data not currently available through existing source. Indirect linkages with the USGS, DOE and EPA have also been important for collaborative exchanges related to remote sensing research and monitoring.

2. General Information:

Data Acquisition

Regular acquisition of data from the Thematic Mapper (TM) sensor system of the Landsat series of satellites was seen as an important source of unbiased, systematic, and comparable data for use by the LTER sites. This need was documented in past technology reports known within the LTER Program as the "Shugart Report" and the "Gosz Report". Information regarding this and past recommendations for remote sensing and GIS for LTER sites can be found in the initial document for the "Minimum Standard Installation" know as the MSI. This need was explored further in an LTER funded workshop lead by John Aber, resulting in the initial acquisition plans. Since these data are expensive, proprietary, and difficult to acquire, NET started an initial acquisition of these data for each site in 1991. The details of the acquisition were presented at meetings and published for reference (Proceedings: ERDAS users group - Atlanta, 1991; GIS/LIS, 1991). A special license was arranged to enable a single scene to be used by all LTER sites. This was a large change in the license policy by the commercial vendor EOSAT)now Space Iamgeing/EOSAT), and lead to further changes in data licenses by other groups (such as state-wide TM purchases by GAP researchers). The data acquired were screened for cloud cover (almost 50% of scenes deemed acceptable by EOSAT were returned for reacquisition), sent to the individual sites, and placed online for access through the LTERnet Information Computer System. The copy maintained at the network office has been an important source for intersite research as well as a known location of these data for the sites. NET receives regular requests for replacement copies of the data from individual LTER sites.

High resolution SPOT-HRV data have been acquired for most sites in 1991 with similar license arrangements as those for the EOSAT TM data. These data provide panchromatic 10m resolution data - a substantial improvement over 30m TM data. Again these data were distributed to the sites and placed online.

AVHRR (Advanced Very High Resolution Radiometer) data come in many forms since these data are from a public domain, operational satellite program covering the earth more than once/day. Most useful for LTER research are

those data ingested and processed by USGS/EDC in Sioux Falls, SD. A number of single pass satellite images have been acquired for comparison with other data, but the operational processing of the raw data into 1km vegetation index data (NDVI) has been relatively simple to acquire. Since 1990, these data have been ordered on CDROM, sent to the sites, and preserved offline at NET. Ancillary data comprise most of the CDROM information. The actual NDVI data are relatively small (2-3gb total), and these data have been subset from all CDROMs and placed online. A few AVHRR datasets have been acquired from NOAA (LUQ for instance is only contained in the NOAA data acquisitions), and future plans may involve use of these data for sites outside of the US continent.

Remote sensing information at the national and global scale can be highly specialized and complex, requiring collaboration both commercial and government programs. The LTER Network works with various programs within NASA, the USGS, and commercial data providers such as Space Imaging/EOSAT and Positive Systems Inc.

A good example of interagency collaborations for remote sensing research are with linkages to the NASA programs. More important to the data access has been linking various levels of expertise within the NASA programs with LTER science. An example of this is work within NASA "AERONET" / sun photometer activity, where the technical and scientific expertise of NASA has provided a springboard for important satellite data correction information, and in exchange, an important link by NASA to LTER researchers on the ground. Individual site programs have acquired specialized aircraft and satellite data ranging from digital high resolution ADAR and AVIRIS data, to more standardized datasets from Landsat-TM and NOAA-AVHRR sensors.

All LTER sites were included in work with the NASA global change program. In part of this work, NASA paid for, and provided full Landsat-TM scenes for all of the LTER sites, with most sites receiving multiple scenes during 1992 and1993. More recently additional dataset during 1993, and 1995 have been acquired as part of an atmospheric data correction activity between LTER and NASA for Landsat-TM data. Most sites are also included in the NASA Pathfinder programs, where historic and present Landsat and AVHRR data are acquired for comparison with ground based measurements.

3. Examples of remote sensing data used for ecological research by the LTER Program

Remote sensing data available from satellite systems has been the most important source of data for research in the LTER program. A few of the common types of satellite systems are listed below.

Satellite data:

GOES

Full-earth views of cloud cover from the NOAA geostationary satellites are commonly used for studies of the atmosphere, and to a lesser degree of cloud cover within the LTER program.

NOAA-AVHRR

Data at a resolution of 1km are available daily on a global basis for coarse assessment of vegetation cover. Although the data are more widely used for atmospheric studies as distributed by NOAA, data processed and distributed by the USGS for ground-based studies are used extensively in the LTER program.

Landsat-TM

Landsat Thematic Mapper (TM) remote sensing data is probably the most important medium resolution dataset used in the LTER program. Past license restrictions and cost have limited their availability, but future arrangements will permit their more widespread application. The LTER program has invested significant resources as well as linked with NASA programs for research use of these data. The data provide information over an extent of about 185km, at a spatial resolution of 30meters and broad spectral resolution separated into 7 spectral bands.

SPOT-HRV:

Both 20 meters multi-spectral and 10 meter panchromatic data are used to some degree for applications requiring higher spatial or temporal resolution than Landsat, but the limited spectral content reduce their ability for applications such as land cover classification. Cost and license restrictions from the commercial vendor limit the utility for large scale collaborative work.

ERS and JERS RADAR:

RADAR data is used more recently for its ability to discern features based on their physical structure rather than spectral reflectance. Except for limited "SIR-C/X-SAR" data flown twice in the Shuttle, radar data is currently available through foreign or commercial sources.

A more complete listing of satellite data currently used for ecological research was compiled by the Environmental Remote Sensing Center at the University of Wisconsin, affiliated with the North Temperate Lakes LTER site.

Satellite Name	Source	Launch	Sensors	Types	No. of Channels	Resolution (meters)
Landsat-5	US	1984	MSS	Multispectral	4	82
			TM	Multispectral	6	30
					1	120
IRS-1A	India	1988	LISS-I	Multispectral	4	72.5
			LISS-II	Multispectral	4	36.25
SPOT-2	France	1990	HRV	Multispectral	3	20
				Panchromatic	1	10
IRS-1B	India	1991	LISS-I	Multispectral	4	72.5
			LISS-II	Multispectral	4	36.25
NOAA-12	US	1991	AVHRR	Multispectral	5	1100
ERS-1	ESA	1991	AMI	Radar	1	26
			ATSR	Multispectral	4	1000
JERS-1	Japan	1992	SAR	Radar	1	18
			OPS	Multispectral	7	18 x 24
SPOT-3	France	1993	HRV	Multispectral	3	20
				Panchromatic	1	10
RESURS-O1-3	Russia	1994	MSU-SK	Multispectral	4	170

					1	600
NOAA-14	US	1994	AVHRR	Multispectral	5	1100
IRS-1C	India	1995	WiFS	Multispectral	2	188
			LISS-III	Multispectral	3	23
					1	70
			Pan	Panchromatic	1	5.8
ERS-2	ESA	1995	AMI	Radar	1	26
			ATSR	Multispectral	4	1000
RADARSAT	Canada	1995	SAR	Radar	1	9-100
OrbView-2	US/Orbimage	1997	SeaWiFS	Multispectral	8	1130
(SeaStar)						
IRS-1D	India	1997	WiFS	Multispectral	2	188
			LISS-III	Multispectral	3	23
					1	70
			Pan	Panchromatic	1	5.8
SPIN-2	US/Russia	1997	KVR-1000	Panchromatic	1	2
			TK-350	Panchromatic	1	10

Listed below are a number of remote sensing systems currently planned for launch in the next two years. These systems have been in the planning stages for a long period of time, and will provide unprecedented information for ecological research from their increased spatial coverage and resolution, as well as the temporal resolution (some with daily, global coverage). Except for NOAA, EOS and Landsat data, license restrictions and costs from the commercial and foreign vendors will restrict the utility of some of the data for large, collaborative research programs such as LTER.

Satellite Name	Source	Expected Launch	Sensors	Types	No. of Channels	Resolution (meters)

SPOT-4	France	Launched	VI	Multispectral	4	1150
			HRV	Multispectral	4	20
				Panchromatic	1	10
NOAA-K	US	1998	AVHRR	Multispectral	5	1100
IKONOS	Space Imaging / EOSAT	1998	SpaceImaging	Multispectral	4	4
				Panchromatic	1	1
CBERS	China/Brazil	1998	CCD	Multispectral	5	20
			IRMSS	Multispectral	3	80
					1	160
EOS AM-1	US	1998	ASTER	Multispectral	14	15,30,90
			MISR	Multispectral	4	275
			MODIS	Multispectral	36	########
Landsat-7	US	1999	ETM+	Multispectral	6	30
					1	60
				Panchromatic	1	15
QuickBird	EarthWatch	1998	Multispectral	Multispectral	4	3.2
			Panchromatic	Panchromatic	1	0.82
EROS-A	West Indian Space, Ltd.	1998	Panchromatic	Panchromatic	1	1.5
EROS-B1	West Indian Space, Ltd.	1998	Panchromatic	Panchromatic	1	0.82
IKONOS 2	Space Imaging	1998	Space Imaging	Multispectral	4	4