Six Ramsar remote sensing case studies were developed in 2002 as part of the NASA Socioeconomic Data and Application Center's (SEDAC) Ramsar Wetlands Data Gateway, developed in support of the Ramsar Convention on Wetlands of International Importance. That web service has been discontinued but the case studies are available from the documentation page for SEDAC's Sea Level Rise Impacts on Ramsar Wetlands of International Importance, v1 (2000–2010) data set at https://doi.org/10.7927/H4CC0XMD

Global: Remote Sensing for Ramsar Sites

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I. Introduction

The Earth Satellite Corporation, together with Isciences LLP, produced a report in early 2002 entitled *Monitoring Environmental Agreements: Ramsar Convention Feasibility Study*. The purpose was to examine the utility of remote sensing imagery for wetland identification and delineation. The feasibility study also evaluated current and forthcoming imagery in terms of its utility for monitoring vegetative health, drainage and infilling, encroachment by agriculture, and pollutant discharges. This study did not focus on a single wetland, but rather on a number of pilot applications. These included the Quill Lakes in Saskatchewan, Canada; Donana and Marismas wetlands in Andalucía (southern) Spain; Lake Naivasha in Kenya; and the Shadegan Marshes and the Mudflats of Khor-al Amaya & Khor Musa in western Iran near the Gulf.

The study also outlined potential techniques to enhance data delivery using an Internet-based mapping system that would provide access to critical data for Ramsar sites, such as, location, boundary and baseline land cover.

2. Methods and result

The imagery used in the feasibility analysis focused on Landsat MSS, TM and ETM data. These platforms were chosen for their ability to provide consistent historical datasets for the temporal analysis of wetland change over the period studied. The focus on Landsat data was also due in part to availability as well as its affordability. For the purpose of the feasibility analysis, the dates of imagery ranged from 1974 through 2000 with the primary focus being placed on data gathered in the last 15 years.

Remote sensing techniques were demonstrated for identifying wetlands and documenting current conditions (necessary to determine wetlands appropriate for potential suitability for Ramsar site designation) and to evaluate change from prior conditions (for potential inclusion in the Montreux Record of threatened sites). EarthSat has developed an imagery-based technique to measure the degree of change called Cross-Correlation Analysis (CCA) (US patent # 5719949). There are two general types of Cross-Correlation Analysis: one evaluates a satellite image against polygons delineating the historical land use or land cover; the other uses two different dates of imagery and compares spectral difference between the two. CCA assigns a statistical measure of the degree of change to each data point or pixel. Both methods provide quantification of the likelihood of change in land use. CCA presents a methodology for detecting change without requiring specific knowledge about the study area although, as with all interpretation, an experienced analyst will make more informed decisions about setting the thresholds that define significant change (see Figures 1 and 2).

The main purpose of this study focused on satellite imagery and monitoring techniques on a site-by-site basis. One of the important lessons discovered through this investigation was the potential use of imagery in conjunction with GIS datasets (infrastructure and settlements) to investigate the interconnectivity of wetland sites within a larger geographic region. This type of regional analysis would greatly enhance capabilities to assess and understand the environment as a whole instead of an isolated entity. On a regional scale the impacts of wetland degradation as related to migratory bird flights could be closely monitored.

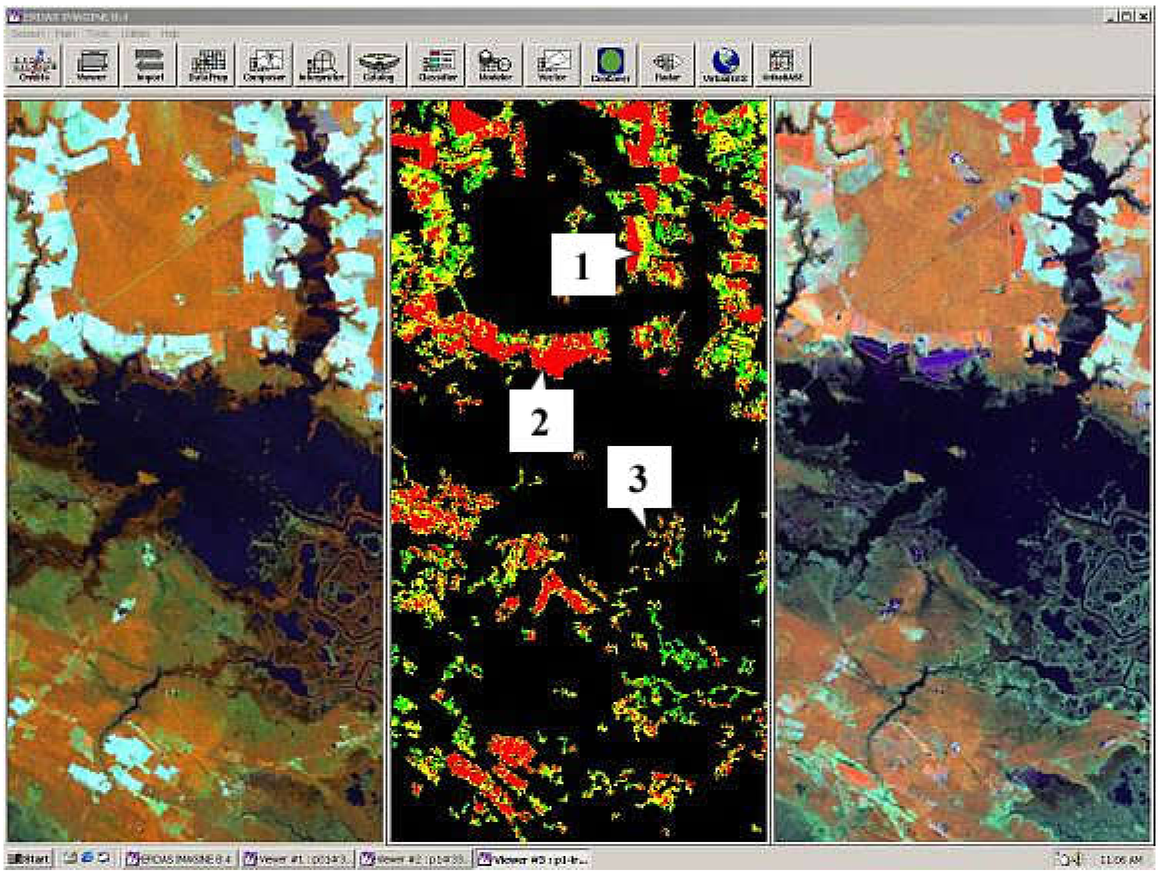

Figure 1. *Chesapeake Bay, Virginia, USA, in close proximity to the Ramsar site of the same name. The figure shows Landsat imagery for 1988 (left) and 1998 (right). Areas of potential change identified by cross-correlation analysis are in the center image. Red areas indicate the highest probability of change; yellow areas have a lower probability; green indicates moderate probability. Notes in the central image indicate: (1) conversion of forest to agriculture, (2) conversion of wetland vegetation to shallow water, and (3) decrease in wetland vegetation.*

Remote sensing, with supporting ground truth data, can identify wetland areas and monitor the general health and extent of wetland vegetation. The hydrologic environment can be monitored and mapped using various remote sensing techniques and allows for the quantification of the water resources supporting wetlands. Distribution of algal blooms, invasive species, and overall water quality measures may be able to be obtained from remotely sensed data and that in turn can be used to estimate the carrying capacity of a wetland to support bird and fish species. Remotely sensed data can be used to monitor international flyways to check on the health and status of wetlands along the routes that are important to migratory water birds. The digital nature of remote sensing data allows for the analysis and manipulation of the observations to identify and measure changes in wetlands due to encroachment, pollution, and urbanization or expansion due to sea level rise. Although remotely sensed data can not replace in-field measurements and observations, it can provide a uniform base layer and cost effective (and consistent) means for monitoring the over 1,000 Ramsar listed sites. Table 1 provides a matrix of the remote sensing instruments currently or soon to be available with spectral ranges and detection capabilities of interest to the Ramsar convention.

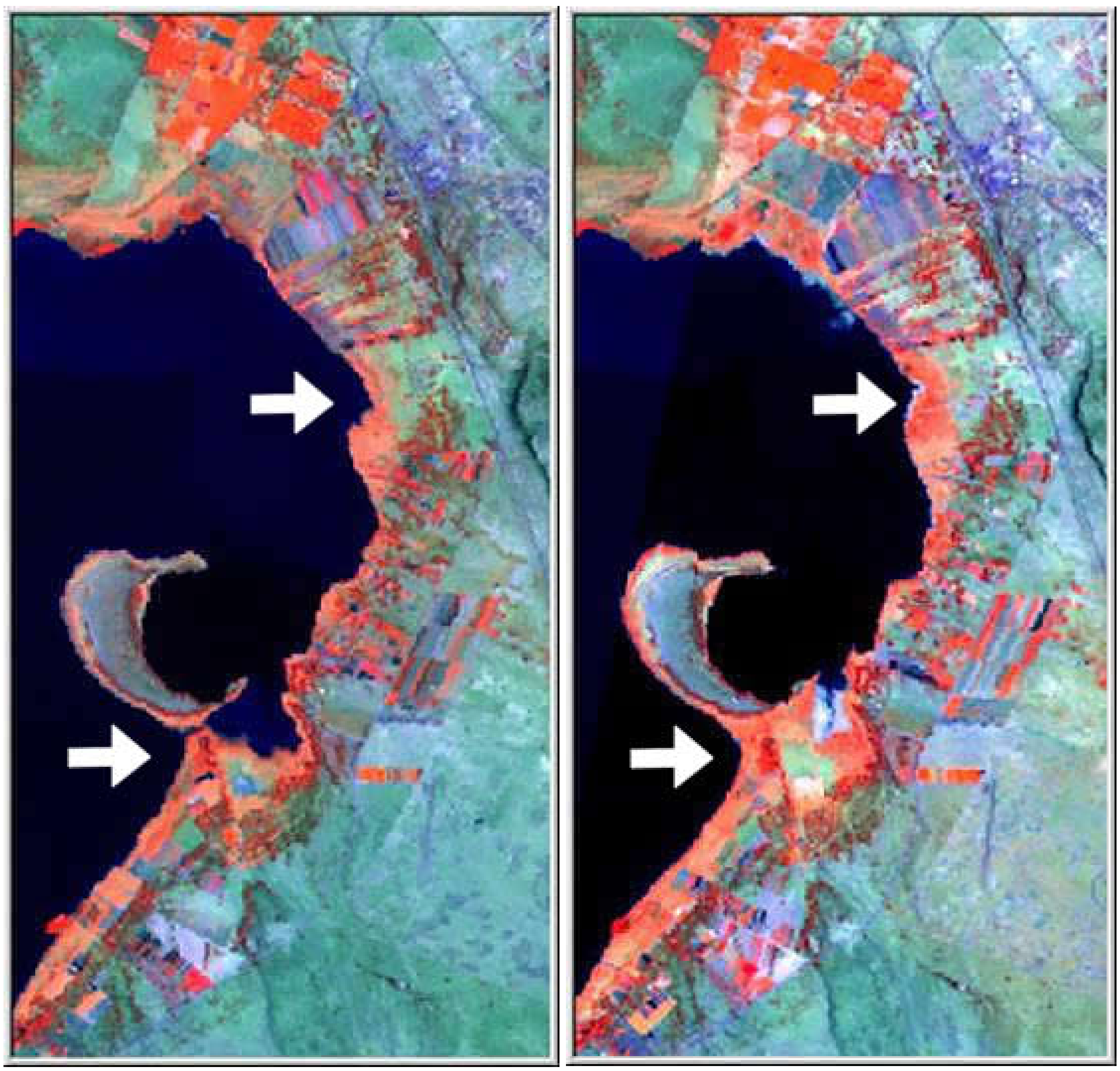

Figure 2. *Lake Naivasha, Kenya. Landsat imagery from January 1986 (left) and February 1987 (right). Lake Naivasha supports a diversity of natural and human activities and was one of the Ramsar Wetland*

Conservation Award winners in 1999. The dramatic change between the two Landsat images, taken 13 months apart during the growing season, may be related to natural fluctuations in the hydrologic cycle. These images demonstrate the importance of understanding the environment when defining a significant threshold of change.

The remote sensing imagery used in the feasibility analysis focused on moderate (30 meter) resolution Landsat data. Wetlands of limited extent, less than 50 hectares, will not be adequately imaged using Landsat alone. Currently, there are less than 20 such sites on the Ramsar list. However for these smaller wetlands an alternative image base of finer resolution, IKONOS at 1-meter or aerial remote sensing at 0.3-meter resolution may be required. Higher resolution data such as IKONOS or aerial data are much more limited in coverage, have a higher overall cost, and do not have an easily usable historical database. Many areas, including Ramsar sites, have not yet been imaged using space-based 1-meter platforms and scheduling a satellite to obtain an image on a given day is costly and time consuming. However, with sufficient lead-time, small wetlands can be targeted for data collection.

Identifying threats to a wetland and remediation planning often requires more specific knowledge about a wetland than can be derived from imagery alone. In many instances the ecological conditions of a wetland are being affected by political and economic factors as well as development trends and population shifts. Since most threats to wetland health are likely to originate outside of the wetland, monitoring for wise use includes observation of the surrounding watershed and the socio-economic factors that may affect it.

Currently, the technical capability, base data and online mapping capacity are all sufficiently developed to build a Ramsar monitoring system for all existing Ramsar sites. Table 1 demonstrates that many sensors are already available for measuring important wetlands-relevant parameters.

3. Conclusions and future directions

EarthSat's ongoing efforts in the field of environmental remote sensing are multi-faceted. Under current contracts with NASA, EarthSat is providing global orthorectified Landsat datasets in three epics c. 1980, c. 1990 and c. 2000 through the GeoCover program. The expected availability for the 1980 and 1990 datasets is December 2002 and the 2000 datasets in the summer of 2003. In addition to the GeoCover program, EarthSat is deriving a worldwide 13-class land cover dataset based on the orthorectified 1990 and 2000 Landsat data. The GeoCover LC will be the first consistently prepared, moderate-resolution land cover (LC) database for the world. This information will provide a baseline for scientists and decision-makers to track environmental changes worldwide.

New hyperspectral sensors with over 200 bands will eventually allow a users to differentiate between land uses to a much finer degree and to monitor vegetative health in greater detail. Impacts on vegetation due to air pollution, reduced water quality, and encroachment of urbanization will be observable within the next five years. However, it should be noted that with this increase in definition will come added reliance on the skill of the image analyst, and may also increase the subjective nature of the analyst's opinion on land use changes.

Advances in radar technology will allow for finer resolution monitoring of water resources. Currently the RADARSAT satellite records reflected microwave data at resolutions varying from 8 meters to 100 meters. Microwave radiation is attenuated by water and, using existing radar satellite data, soil moisture can be monitored in shallow soil profiles as well as pooled on the surface. [see table 1].

Table 1. Application of Satellite Remote Sensing To Ramsar Wetland Treaty Monitoring
Sensor Spectral Ranges and Criteria Monitored

Satellite Platform

	Wavelength	*AVHRR*	*SeaWifs*	*MODIS*	*Landsat*	*IRS*	*Spot*	*IKONOS*	*OrbView*	*Radarsat*
Ultra	*Micrometers*									
Violet	*Range*									
	0.4		EUA	EUA						
	0.45		EUA	EUA	EUA / DI		EUA / DI	EUA / DI	EUA / DI	
Visible	*0.5*		VH / WI	VH / WI	VH / WI	VH / WI	VH / WI	VH / WI	VH / WI	
Range	*0.55*		WD	WD	WD	WD	WD	WD	WD	
	0.6	WD	WD	WD	WD	WD	WD	WD	WD	
	0.65		VH	VH	VH	VH	VH	VH	VH	
	0.7		VH	VH	VH	VH	VH	VH	VH	
	0.75	VH	VH	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	
	0.8	VH	VH	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	
	0.85	VH	VH	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	
	0.9	VH	VH	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP	DI / WI / IP		
Reflectived	*0.95*	VH		VH	VH	VH				
Infrared	*1*	VH		VH	VH	VH				
	2			VH	VH	VH				
	3	VH		VH						
	4	VH		VH						
	5			VH						
	6			IP						
	7			IP						
	8			IP						
	9			IP						
	10			IP						
Thermal	*11*	EUA		EUA	EUA / IP					
Infrared	*12*	EUA		EUA	EUA / IP					
	13			EUA						
Spatial	**Resolution**	**1km**	**1km**	**250 - 1000**	**15 - 30m**	**5 - 30m**	**10 - 20m**	**1 - 4m**	**1 - 4m**	**8 - 100m**
	Centimeter									
	Range									
	1									
	2									
	3									WI
	4	Data from ERDAS Field Guide (1999) a 700+ page reference for								
Radar	*5*	use of ERDAS Imagine 8.4 softwar								
	6									DI
	7	Other data from:								
	8	http://modarch.gsfc.nasa.gov/modis/instrument/modis_spec								
	9	http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/BRS_SRVR/seawifsbrs_info								EUA
	10									

	Key
WI	Wetland Identification
WD	Wetland Delineation
VH	Vegetative Health
IP	Industrial Pollution
DI	Drainage Infilling
EUA	Encroachment Urban Agricultural