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: Ramsar Theme of the Treaty Enforcement Services Using Earth Observation (TESEO) Project, European Space Agency (ESA)

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I. Introduction

TESEO - Treaty Enforcement Support using Earth Observation - is a project of the European Space Agency (ESA), which aims at exploring the potential of Earth Observation (EO) technology to support in the near future the implementation of international environmental treaties. This activity will, additionally, be an important ESA contribution to the detailed definition and early implementation of the Global Monitoring for Environment and Security (GMES) , an initiative of the EC to coordinate and expand the use of remote sensing for environmental treaties, natural disasters, and humanitarian aid. The overall objective of TESEO consists in exploring the potential of EO, with a focus on future technology, to support key environmental areas of particular interest for establishing European policies for the implementation of the relevant fundamental environmental treaties

- The Ramsar Convention on Wetlands;
- The Kyoto protocol to the UN Framework Convention on Climatic Change;
- The UN Convention to Combat Desertification; and
- International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).

The Ramsar TESEO project is being performed by a team of scientists, technologists and knowledge managers, led by Atlantis Scientific, Inc. of Ottawa, Canada. We are researching and developing Earth Observation applications which can be used for improving support for the management and sustainable use of wetlands within the context of the Ramsar Convention.

By the end of the project, the team will have completed:

- Thorough investigation of the information needs of wetlands managers by working with end users.
- Study of the capacity of EO technology (present and future satellites, models, algorithms and data fusion techniques) to fulfill those needs.
- Exploratory studies of the most appropriate tools and techniques.
- Selection of a few prototype products which provide reliable information in a way that can become operational, and responds to the users' needs.
- Creation and validation of prototype products.

Recommendations to the ESA for future satellite missions that will deliver information of value to this community.

Three test sites are involved in the study: Mer Bleue in Ontario, Canada; Doñana in Andalucia, Spain; and Djoudj wetland near the delta of the Senegal River in Senegal.

2. Description of results

Our team has conducted an exhaustive review of the national and international bodies involved in the implementation of Ramsar Convention, and identified those that may benefit from EO products and services. We identified the actions, provisions and objectives within the Ramsar Convention where EO may contribute. We collected and analysed end user requirements in terms of information products & services. We obtained a group of end users that expressed their interest in participating in the project. These include the Estación Biológica de Doñana (managers of the Doñana wetland in Spain), National Capital Commission of Canada (managers of the Mer Bleue wetland) and World Resources International. We entered into a partnership with the Centre de Suivi Écologique in Senegal to jointly create and test prototype products of the Djoudj wetland in Senegal. We reviewed the cost of EO applications compared to competing sources of information. We created a "user-needs" web site with a survey asking about information requirements of wetlands managers that could be fulfilled more conveniently with EO products. We presented the information needs and products in an easy-to-read chart showing key selection criteria and recommendations.

Exploitation of EO technology for wetlands management consists of the following steps:

- Creation of a base map which includes not only the wetland area, but a regional zone of influence, where human activities can affect (either beneficially or detrimentally) the natural functioning of the wetland within the protected area. The base map will normally contain political boundaries, infrastructure (roads, railroads, canals, settlements, power distribution networks, and other relevant infrastructure), political and administrative boundaries, and a current and accurate depiction of the hydrology of the wetland and area of influence
- Creation of a baseline inventory. Some of the most important types of information include land cover (including detail on vegetation) and land use, at a level of detail adequate to address the essential management issues.
- Capture of essential information on changes that impact the management of the wetland. Land cover and land use change are almost always essential information layers. Many wetlands are hydrologically dynamic. Information about the extent of open water and flooded vegetation is key to wetland managers
- Creation of products which "tell the story" to the public, and to politicians, about the state of the protected wetland, its recent history, threats to its sustainable ecological functioning, and constraints imposed by external realities.
- Creation of products that present alternative management scenarios, and the likely consequences of each scenario. These products will provide the resource managers and decision makers with the information they need to weigh competing interests and reach informed decisions.

We conducted four exploratory studies aimed at exploiting the potential of recently available and future space-borne sensor data. In Mer Bleue, Canada, we investigated the use of multipolarized and fully polarimetric radar data to distinguish water extent from inundated vegetation, and classify gross vegetation types. We also found that radar repeat-pass interferometry holds more promise than was expected for mapping coherence, which can indicate gross vegetation characteristics, and for mapping subtle changes in elevation.

Again at Mer Bleue, we merged high spatial resolution (1m) panchromatic data (airborne photography, re-sampled to simulate the IKONOS sensor) with Landsat colour to produce a highly-interpretable visual product which can be excellent for baseline mapping, land cover and land use classification, and change monitoring, particularly vegetation changes (Figure 1).

Figure 1. Mer Bleu, Canada:
Colour Image Simulating the Use of High Resolution Panchromatic Data (e.g. Ikonos) Merged with ETM+ Multispectral Data (30 m resolution).

This is a remarkable example of the value of merging multispectral colour data with very high resolution panchromatic data. The image exhibits discrimination of small scale and subtle differences in vegetation, including cattails (C), Fen-like vegetation (F), and areas that may be related to poorer (P) and richer (R) nutrient availability.

At Ebro Delta in Spain, two exploratory studies were carried out:

- A study of the changes in the delta resulting erosion, deposition, and sediment transport by marine currents;
- A study of anthropogenic modifications to Canal Vell, an internal marsh in the Ebro Delta which is ecologically significant as a breeding area for several species of birds.

These exploratory studies were particularly important demonstrations of the value of the 30 year archive of Landsat data. The studies showed that Landsat archived and current data can be used for extremely accurate studies of trends in ecological conditions, using photointerpretation and digital classification techniques. A comparison of the advantages and disadvantages of the various kinds of imagery for Ramsar-specific needs can be found in Table 1 and Table 2, respectively.

In terms of relating this information to the needs of wetland managers, the wetland manager is used to dealing with the wetland which he or she can visit, touch, smell, and so on. A photo or an image can be regarded as a first abstraction from that "real world." A map derived from that photo (e.g., a topographic or thematic map) is a further abstraction from the real world. A table of areas derived from that map is yet another abstraction. As one moves farther away from the real world, information is in one sense less believable, and less useful for many applications since not only is some information lost, but the information retained may not be of direct relevance to the potential user. This is especially the case for those dealing with management and monitoring of a resource.

Thus, focusing on the users' perspective, what we wish to do is create the best possible first abstraction or image of the real world, which clearly represents the real world as the user understands it. At this stage, our literature review suggests that optical and radar imagery combined with ancillary data (such as those described above) and integrated in a geographic information system (GIS) is best. Then we want to ensure that we produce tools with which the user can extract required information (areas, lengths of ecotones, etc). Based on past experience we believe that if we skip this first step and go directly to a derived product farther down the abstraction chain, the users will be less prone to accept what is produced and will be less likely to buy into the use of the product, especially if there are any errors in the first derived products that they see. We want them first to understand that the image contains valuable information and then, once they reach that understanding (which they will), we help them extract it with the tools developed or drawn from other sources.

3. Conclusions

The team has summarized the requirements for an operational system with the four adjectives: Reliable, Robust, Affordable, Repeatable. The project web site was used as a mechanism for disseminating progress, and also for posting a user survey in three languages: English, French and Spanish. We received 13 responses from our web-based survey from Canada, Greece, Netherlands, U.S., India, Turkey, Malaysia, UK, Botswana and South Africa. Although the number of responses was small, the respondents showed enthusiastic interest and unanimous willingness for further participation. The responses were from private companies, non-government organizations, National and local governments, and private consultants. Respondents were mainly wetlands managers and researchers. The respondents' organizations are mainly involved with Ramsar sites, either directly managing wetlands or in inventorying wetlands.

In answer to the question about types of information they need, survey respondents identified the following main categories of information:

- Identification and physical description of wetlands.
- Change in vegetation, land use, environmental pressures, dominant vegetation, invasive species, water quality and quantity, preferably on a 2-5 year update frequency.
- Water quality information.

We also created a list of innovative products and services based on EO technology which respond to the user needs analysis and the survey results. We then asked our end user collaborators to comment on the priorities of each product or service from his/her perspective. These products and services are described in Product Description Sheets.

We evaluated all of the 48 proposed products and services according to the following criteria:

- Technical feasibility for EO based products.
- Priority identified by the questionnaire of our end users.
- Practical advantages.
- Contribution to the needs of the Ramsar Convention.
- Contribution to users (our assessment based on knowledge of the technology).
- Novelty.

The result of this evaluation was the selection of the following products which we intend to prototype at our test sites of Mer Bleue, Doñana and Djoudj:

- Water cover and water-cover change;
- Vegetation cover and vegetation cover change;
- Land use and land-use change;
- Exchange of information with other Ramsar sites and with the Ramsar Convention Bureau.

A design for these products was created. Production of prototype products is in progress, and the prototype products will be shown at COP VIII in Valencia (November 2002).

class of sensor	*Aerial photography*			*Hyperspect*	*High Res. Sat.*		*Fine resolution optical satellite*					*Coarse res. optical sstellite*			*Radar satellites*					
mission				*Airborne*	*IKONOS/QuickBird*		*IRS*		*SPOT*		*Landsat*	*OrbView-1*	*NOAA*		*RADARSAT*	*ERS*	*JERS-1*	*ENVISAT*	*RSAT-2*	*ALOS*
sensor	*240 mm camera*				*digital camera*		*LISS*		*HRV*		*TM/ETM+*	*SeaWifs*	*AVHRR*	*MERIS*	*SAR*	*SAR*	*SAR*	*ASAR*	*SAR*	*PALSAR*
spectral mode	*B&W*	*colour*	*CIR*5*		*Pan*	*MS*	*Pan*	*MS*	*Pan*	*MS*	*reflective*	*reflective*	*reflective*	*MODIS*	*C band*	*C band*	*L band*	*pol-C*	*pol-C*	*pol-L*
sensor imaging characteristics																				
swath width (km)	1-10	1-10	1-10	1-10	60	60	60	60	60	60	185	2800	3000	575	50-500	100	75	50-500	50-500	70-360
spatial resolution (m)	0.1-1.0	0.1-1.0	0.1-1.0	1-10	1	4	10	20	10	20	30	1100	1100	300	10-100	25	18	6-100	6-100	10-100
image repeat with pointing (days)	1	1	1	1	5	5			5	5	N/A	1	1	3	3	31	N/A	3	3	3
image repeat with identical geometry (days)	1	1	1	1	N/A	N/A	24,25	24,25	26	26	16	16	N/A	35,16	24	31	44	35	24	46
Application	***Advantages for each application***																			
Base Mapping																				
Creation of base map information	SPC	SPD	SPD		SP*3		S	S	S		C									
Inventory																				
Boundary and area	SA	SPD	SPD	D	S	SD	S	SD	S	SDA	DCPA	DCPW			DTW	DT	DT	DTW	DTW	DTW
Geomorphic setting	D	D	D		D	D	D	D							DTW	DT	DTW	DTW	DTW	DTW
Land cover - Vegetation type	S	SDP	SDP	SD	S	SD	S	SD	SA	SDA	DCA				T	T	T	T	T	T
Vegetation condition	S	S	SDP	DS	S					SDA	DCA				FT	T	T	FT	FT	FT
Land use	SDPCA	DSP	DSP	DS	S	SD	S	SD	SA	SDA	DCA				FT	T	T	T	T	T
Water level	S	S	DSP	DS			S		SA	SA	CA				FD*1T	D*1T	D*2T	FD*1T	FD*1T	FD*2T
Chlorophyll and suspended sediment concentration, turbidity		DS		DS		S						DCPAW		DCPW						
Geog. context for mgmt. planning	SDPCA	SDP	SDP	DS				SD		SDA	DCPA			DCPW	TW	T	T	TW	TW	TW
Identification of current or potential problems	SP	SDP	SDP	SD	S	SD		SD		SDA	DCA									
National, regional, continental, and global inventories of wetlands	S	S	S								DCPA	DCPW		DCPW	TW	T	T	TWA	TWA	TWA
Assessment and Monitoring																				
Changes in area	SDAC	SDP	SDP	SD	S	S	S	S	SA	SDA	DCA				D*1	D*1	D*2T	D*1	D*1	D*2T
Changes in vegetation type	S	SDP	SDP	SD	S	SD	S	SD	SA	SDA	DCA				T	T	T	T	T	T
Changes in vegetation condition	S	S	SDP	SD	S	SD	S	S	SA	SA	DCA									
Change in land cover	S	SDP	S	SD	S	SD	S	S	SA	SA	DCA				FT	T	T	FT	FT	FT
Change in land use	SDPCA	SDP	S	SD	SP	SDP	SDP	SP	SPA	SPA	DCA				FT	T	T	FT	FT	FT
Changes in water level	S	S	SDP	SD	S		S		SA	SA	CA				SDPFT	DPT	SDPT	SDFT	SDFT	SDFT
Changes in chlorophyll, suspended sediment, turbidity	S	SDP		SD								DCPAW								
Regional climatic change	S	S	S	SD							A		AFTW	DFSCW	TW	T	T	TA	TA	TA
impact assessment	S	SD	SDP	SD	SF	SDF	SF	SDF	SFA	SDFA	DACW									
Identify wetlands needing restoration	S	S	SDP	SD	SF	SDF		SDF		SDAF	DACW				FT	T	T	TA	TA	TA
Cost effectiveness of restoration	SDPCA	SDP	S	SD	SP	SDP	SDP	SP	SPA	SPA	DCA				FT	T	T	FT	FT	FT
Characterization of New Sites																				
Identification of potential new Ramsar sites	S	SDP	SDP	SD	S	SD	S	SD	SA	SDA	DCA				FT	FT	FT	FT	FT	FT
Provision of case studies of new sites	S	SDP	SDP	SD	S	SD	S	SD	SA	SDA	DCA				TW	T	T	T	T	T
Public Information, Training and Characterization																				
Information for training to inventory, monitor, and manage wetlands	S	SDP	SDP	SD	SP	SDP	SP	DP		DPA	DCPA	CPW		CPW	TW	T		TW	TW	TW
Case studies to build awareness in the community	S	SDP	SDP	SD	SP	SDP	SP	DP		DPA	DCPA	CPW		CPW	TW	T	T	TWA	TWA	TWA

Advantages (codes)

good **D**iscrimination of desired features; good **S**patial resolution; low **C**ost per km2;straightforward **P**rocessing for this application; good **A**rchive; **F**requent revisit; reliable **T**iming of data acquisition; **W**ide area coverage

Notes

*1: Good discrimination of emergent herbaceous vegetation; *2: Good discrimination of flooding under forest canopies;
*3: Can be acquired in stereo and processed with analytical stereo mapping tools; *4 Good for rapid assessment of coastal water quality changes; *5: CIR cannot be used for any water-based information.

class of sensor	*Aerial photography*			*Hyperspect*	*High Res. Sat.*		*Fine resolution optical satellite*					*Coarse res. optical sstellite*			*Radar satellites*					
mission				*Airborne*	*IKONOS/QuickBird*		*IRS*		*SPOT*		*Landsat*	*OrbView-1*	*NOAA*		*RADARSAT*	*ERS*	*JERS-1*	*ENVISAT*	*RADARSAT*	*ALOS*
sensor	*240 mm camera*				*digital camera*		*LISS*		*HRV*		*TM/ETM+*	*SeaWifs*	*AVHRR*	*MERIS*	*SAR*	*SAR*	*SAR*	*ASAR*	*SAR*	*PALSAR*
spectral mode	*B&W*	*colour*	*CIR*		*Pan*	*MS*	*Pan*	*MS*	*Pan*	*MS*	*reflective*	*reflective*	*reflective*	*MODIS*	*C band*	*C band*	*L band*	*pol-C*	*pol-C*	*pol-L*
sensor imaging characteristics																				
swath width (km)	1-10	1-10	1-10	1-10	60	60	60	60	60	60	185	2800	3000	575	50-500	100	75	50-500	50-500	70-360
spatial resolution (m)	0.1-1.0	0.1-1.0	0.1-1.0	1-10	1	4	10	20	10	20	30	1100	1100	300	10-100	25	18	6-100	6-100	10-100
image repeat with pointing (days)	1	1	1	1	5	5	5	5	5	5	N/A	1	1	3	3	31	N/A	3	3	3
image repeat with identical geometry (days)	1	1	1	1	N/A	N/A	24,25	24,25	26	26	16	16	N/A	35,16	24	31	44	35	24	46
Application	***Drawbacks for each application***																			
Base Mapping																				
Creation of base map information	ROW	ROAW	ROCW	PROCAW	WC	WC						DS	DS	DS	D	D	D	D	D	D
Inventory																				
Boundary and area	ROW	CROAW	CROAW	PWROCA	WC	WC						DS	DS	DS	D	D	D	P	P	P
Geomorphic setting	ROW	ROW	ROW	PWROCA	WC	WC						DS	DS	DS						
Land cover - Vegetation type	DROW	ROCAW	DROCAW	PROCA	C	C	D		D			DS	DS	DS	D	D	D	P	P	P
Vegetation condition	DROW	ROCW	ROCAW	PROCA	C	C	D		D			DS	DS	DS	D	D	D	P	P	P
Land use	ROW	ROCAW	ROCAW	PROCA	C	C	D		D			DS	DS	DS	D	D	D	P	P	P
Water level	DROW	ROCAW	DROCAW	PROCA	C	C	D	D	D	D		DS	DS	DS	C				C	
Chlorophyll and suspended sediment concentration, turbidity	DROW	ROCAW	ROCAW	AROC	DC	DC	D	D	D	D		S	DS	S	D	D	D	D	D	D
Geog. context for mgmt. planning	RW	ROAW	ROAW	PAWROC	WC	WC						DS	DS	DS	D	D	D	P	P	P
Identification of current or potential problems	DRW	DRCA	RCA	WROCA	C	C					S	DS	DS	DS	D	D	D	P	P	P
National, regional, continental, and global inventories of wetlands	ROCW	ROCAW	ROCAW	PWROCA	WC	WC	W	W	W	W		DS	DS	DS	D	D	D	P	P	P
Assessment and Monitoring																				
Changes in area	RW	RCAW	RCAW	PAROC	AC	AC	A	A				DS	DS	DS	D	D	D	P	P	P
Change in land cover	DRW	RCAW	RCAW	AROC	AC	AC	DA	A	D		S	DS	DS	DS	D	D	D	PA	PA	PA
Change in land use	RW	RAW	RAW	AROC	AC	AC	DA	A	D		S	DS	DS	DS	D	D	D	PA	PA	PA
Change in water level	DRW	RCAW	RCAW	AROC	AC	AC	D	D	D	D	D	DS	DS	DS						
Changes chlorophyll, suspended sediment, turbidity	DRW	RW	DRAW	RCP	DC	DC	D	D	D	D	S	S	DS	S	D	D	D	D	D	D
Regional climatic change	DRCW	DRCAW	DRCW	ROC	AC	AC	A	A				A	D	A	D	D	D	P	P	P
impact assessment	DRW	RCAW	RCW	RCOP	AC	AC	D	S	D	S	S	DS	DS	DS	D	D	D	P	P	P
Identify wetlands needing restoration	DRW	RCAW	RCAW	ROC	AC	AC	D	S	D	S	S	DS	DS	DS	D	D	D	PA	PA	PA
Routine provision of condition for monitoring & mgmt	DRW	RCAW	RCAW	ROC	CW	CW	D		D		S	DS	DS	DS	D	D	D	P	P	P
Rapid reaction condition assessments	DRW	RW	RDW	ROC	CW	CW	D		D		S	DS	DS	DS	D	D	D	P	P	P
Change in biological, and physical condition	DRW	RAW	ROAW	PROC	CW	CW	DA	A	D		S	DS	DS	DS	D	D	D	PA	PA	PA
Cost effectiveness of restoration	RW	RAW	RAWD	AROC	AC	AC	DA	A	D		S	DS	DS	DS	D	D	D	PA	PA	PA
Characterization of New Sites																				
Identification of potential new Ramsar sites	DRW	RAW	RAWD	ROC	CW	CW	D		D			DS	DS	DS	D	D	D	P	P	P
Provision of case studies of new sites	DRW	RAW	RAWD	ROC	C	C	D		D			DS	DS	DS	D	D	D	P	P	P
Public Information, Training and Characterization																				
Information for training to inventory, monitor, and manage wetlands	RW	RAW	RAWD	ROC	C	C	D		D			DS	DS	DS	D	D	D	P	P	P
Case studies to build awareness in the community	RW	RCAW	RCAW	ROC	C	C	D		D			DS	DS	DS	D	D	D	P	P	P

Drawbacks (codes)

poor **D**iscrimination of desired features; high **C**ost per km2; complex **P**rocessing for this application; no or limited **A**rchive available; **R**equire permision to obtain data (all airborne); data difficult or costly to **O**btain; small **W**idth of coverage