"Wetlands: water, life, and culture"
8th Meeting of the Conference of the Contracting Parties
to the Convention on Wetlands (Ramsar, Iran, 1971)
Valencia, Spain, 18-26 November 2002

COP8 DOC. 35
Information Paper
English only

The use of Earth Observation technology to support the implementation of the Ramsar Convention

1. This information paper, prepared by the Earth Observation Applications Department of the European Space Agency (ESA-ESRIN, Frascati, Italy), presents the preliminary results of the Treaty Enforcement Services using Earth Observation (TESEO) project on wetlands, carried out by the European Space Agency (ESA) within the framework of the ESA's General Studies Programme (GSP). It is summarised from the preliminary report of this project[1], due to be completed in late 2002, and addresses the following questions:

   i) how can EO contribute to the achievement of the objectives of the Ramsar Convention?
   ii) what are the information needs of the international and national bodies involved in the implementation of the Ramsar Convention? and
   iii) how can EO contribute to fulfil those needs?

2. The paper also includes information on availability, uses, advantages and drawbacks of different Earth Observation sensors for application to wetland issues, which supplements that provided in COP8 DR 6 on a Framework for Wetland Inventory.

3. The TESEO project is intended to the capabilities of existing and near-future Earth Observation (EO) technology to support the implementation of four international treaties of critical importance for the environment: the Convention on Wetlands (Ramsar, Iran, 1971), the UN Convention to Combat Desertification, the Kyoto Protocol to the UN Framework Convention on Climate Change, and the Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78).

4. With this effort, ESA hopes to gain a better understanding of the user requirements in terms of information products and services, so as to prepare future user-driven activities and Earth Observation missions.

5. The TESEO wetlands project has undertaken an analysis of the information needs of the Convention, and those users who implement it; a review of the ways in which existing Earth Observation technology and sensors can contribute to these user needs, and how upcoming technologies and information from EO sensors may enhance this contribution; and it is developing and testing novel applications of EO data and information for wetland assessment, monitoring and management. These novel applications are being trialled on

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1 B. Ryerson, F. Ahern, C. Gosselin, O. Miralles, D. Ball and A. Goldsmith, *Preliminary Analysis Report*, TESEO study on Wetlands, Technical Report, April, 2002.

three Ramsar sites: Coto de Doñana (Spain), Mer Bleu (Canada) and Djoudj National Park (Senegal).

The Ramsar Convention and Earth Observation

6. Achieving the Vision of the Ramsar Convention ("the conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world") through the application of the Convention's *wise use* concept, the identification, designation and sustainable management of Wetlands of International Importance (Ramsar sites) and international cooperation is a complex and challenging task. It requires that all the national and international bodies involved in the implementation of the Convention have access to suitable information to better understand wetland areas, their processes and their significance in the global environment, to manage efficiently wetland areas so that they may yield the greatest continuous benefit to present and future generations, to inform the general public and policy makers of the importance of wetlands and promote their conservation and protection worldwide. Existing and future Earth Observation technology may play an increasingly important role in supporting these activities.

7. Over the past few decades, Earth Observation technology has proved to be an increasingly powerful tool to monitor and assess the Earth surface and its atmosphere on a regular basis. EO satellites, with increasing capabilities in terms of spatial, temporal and spectral resolution, allow, day-by-day, a more efficient, reliable and affordable monitoring of the environment over time at global, regional and local scales. This makes EO technology a fundamental support to the Convention's Contracting Parties and other related national and international bodies involved in the implementation of the Ramsar Convention.

8. Three main areas where EO technology may contribute particularly significantly to achieving the objectives of the Ramsar Convention can be highlighted:

   i) **Increasing scientific and technical knowledge about wetlands.** The collection and analysis of short-term and long-term data and information to better understand wetlands and their physical, biological and chemical components, such as soil, water, nutrients, plants and animals and the interactions between them, the status and trends in the health of wetlands, and the influence of wetlands in the global environment. Earth Observation technology may be of particular importance for the acquisition of information on wetlands in remote and inaccessible regions.

   ii) **Supporting the efficient management of wetland areas.** The collection of short-term and long-term data and information to allow the efficient inventory, assessment and monitoring of wetland sites, in the context of their catchments and basins, as well as to provide support to the development and implementation of restoration or rehabilitation plans.

   iii) **Contributing to improve the performance of the Convention.** EO technology may be used to contribute to and enhance reporting mechanisms under the Convention and, through assessment of overall status and trends in the health of wetlands, to better assess the success of the Convention as a tool for sustainable development. It may also contribute to the creation of common data sets and information systems and may help in harmonizing methodologies, procedures and formats for the gathering and analysis of information required for better decision-making, including harmonised information gathering and reporting between different multilateral environmental agreements.

The information needs of the Ramsar user community

9. Actors involved in the implementation of the Ramsar Convention, those who may be able to take advantage of EO technology to meet their needs, range from the Convention's bodies such as the Bureau and the Scientific and Technical Review Panel, international agencies, National Convention Focal Points and scientists to non-governmental organizations, wetland managers and local communities. However, the type of information required by these different categories of users may vary significantly depending upon their role within the implementation of the Convention.

10. Table 1 gives an overview of the requirements and needs, in terms of information products and services, of the user community (i.e., national and international bodies involved in the implementation of the Ramsar Convention and other related organizations). In this table, users have been categorised in terms of the spatial scale of their role: global, regional, national or local. Moreover, user requirements have been split into two main groups: global and local. This responds to the logic that regional and national organizations usually meet their information needs by aggregating local information, whereas, on the contrary, some requirements of "global" organizations cannot be easily fulfilled by a simple collection and aggregation of local data.

11. EO technology can provide significant support to user organizations in fulfilling some of the information requirements shown in Table 1:

    i) For global information needs, the global nature of EO data renders EO technology a unique tool to provide global information to users on a regular basis.

    ii) Concerning the information needs at local scale, EO technology represents an efficient source of continuous and synoptic information not only for the wetland sites themselves but also at the scale of the entire basins that supply water to the wetlands. This provides novel capabilities to users, who may take advantage of EO technology, for instance, to extend inventory information and monitoring activities throughout the catchments of wetlands (as a tool to identify and monitor threats upstream in the catchments that could potentially damage the wetland site).

12. It is worth noting that in some cases, managing large wetland sites and the corresponding catchment area needs inventory, assessment and monitoring of a huge geographic area (for example, the over 6 million hectares of the Okavango Delta Ramsar site, Botswana). Even though Table 1 treats all 'sites' in the local information category, in these cases of very large 'sites' this requires collecting and analysing information at national and even regional scale which, in many cases, can only be done effectively by using EO technology.

How can Earth Observation support end-users through providing their information needs?

13. An overview of the capabilities of existing EO technology to fulfil user requirements, drawn from the analyses made by the TESEO wetlands project, can be outlined as follows:

14. So far, EO data has been used cautiously as a source of information for conservation activities in wetland areas. Most applications to date concern wetland research activities rather than operational applications. This limited use of Earth Observation for wetland conservation and wise use purposes appears to be a consequence of a combination of several factors, including:

    i) the cost of the technology;
    ii) lack of capacity in the necessary technical capabilities;
    iii) the unsuitability of currently available EO data for some basic applications (e.g. insufficient spatial resolution);
    iv) the lack of clear, robust and efficient user-oriented methodologies and guidelines for using this technology; and
    v) the lack of a solid track record of successful case studies that can form a basis for operational activities.

15. Despite these drawbacks, existing EO technology does have several advantages over other methods of data acquisition, which makes EO a powerful complement to the more traditional conservation activities and methods such as field collection of data. Advantages of EO include: large area coverage, frequent visiting times, continuous and synoptic information, and reduced cost compared with airborne imagery (e.g., aerial photography).

16. The next generation of EO satellites will have improved technical capabilities, including higher spatial resolutions, more frequent visiting times, and improved spectral features, which will provide the user community with enhanced information quality with which to pursue the objectives of the Ramsar Convention.

17. The TESEO wetlands project has made an analysis of the main capabilities of EO technology to fulfil user requirements, summarised below.

18. The analysis has addressed two main issues:

    i) the degree of maturity of different EO applications in the context of wetlands; and
    ii) the advantages/drawbacks of different EO sensors to fulfil user information needs.

19. Table 2 provides an overview of the degree of maturity of existing EO technology to provide users with the required information. The table also includes some information about the most suitable sensors amongst those currently available for use for different purposes of wetland inventory, assessment and monitoring. A more detailed description of the technical characteristics of each of the sensors mentioned in Table 2 is provided in Table 3.

20. Table 4 provides an analysis of the main advantages and disadvantages of the most suitable sensors for use in the context of wetlands. The table also identifies the applications for which these sensor are particularly well suited. As well as data collected by satellite-based sensors, airborne sensors are also included, since these are currently one of the most widely use sources of information for wetlands management in many parts of the world.

21. The analysis demonstrates the considerable potential of EO technology to support the user community in pursuing the objectives of the Ramsar Convention. However, to turn

this potential capability into operational applications, it is still necessary to bring together more closely the Ramsar and EO communities in order to increase mutual understanding and knowledge. To carry out this task, a number of issues should be urgently addressed:

i) Strengthening the communication between the Ramsar Convention and the EO community[2];
ii) Reviewing the data cost policy, specially in developing countries;
iii) Fostering capacity building and training activities among the user community, especially in developing countries;
iv) Fostering the integration of EO-derived products and services within the user internal working procedures (e.g., the use of EO data in combination with traditional approaches);
v) Creating a solid track record of successful case studies;
vi) Developing clear user-oriented guidelines for the use of EO data within the Ramsar Convention;
vii) Developing advanced sensors with improved capabilities (specially, spectral and spatial resolutions);
ix) Developing novel user-tailored EO applications;
x) Developing robust automatic or semi-automatic data processing methodologies, which minimise the need for intervention by an human operator; and
xi) Improving the promotion of the capabilities of EO technology within the Ramsar user community;

Conclusions and future developments

22. The past few decades have seen a great development of the EO technology, not only of sensor capabilities but also in data processing techniques and user-driven applications. However, despite these significant developments, EO is still an experimental rather than an operational tool. In this context, ESA is carrying out different programmatic activities aimed at supporting the user community in the transition from an experimental use of EO to the fully operational integration of EO technology within the user daily working procedures. The TESEO initiative is part of these activities.

23. The final results of the TESEO wetlands project, along with the other TESEO projects concerning desertification, forestry and the Kyoto Protocol and marine pollution, will contribute to better defining novel user-oriented applications to be developed within ESA application programmes (e.g., Data User Programme). They will, if appropriate, contribute to further consolidation in the ESA's GMES Service Element, which is the ESA contribution to the joint European Union/ESA GMES (Global Monitoring for Environment and Security) initiative.

24. With further refinement of the user requirements and under the leadership of the Ramsar Convention, ESA may consider the financing of the development of a dedicated service aimed at matching the information needs of the Ramsar Community. These activities

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[2] In the context of the TESEO initiative, a User Forum has been included in the ESA's TESEO portal (http://earth.esa.int/TESEO). In this web-based Forum, users will find the main results of the TESEO project, surveys aimed at getting a better understanding of user information needs, and a direct way to communicate and collaborate with the ESA's TESEO team.

represent an important component of the ESA technical, financial and human effort intended to better bridge the gap between the user and EO communities.

25. The next generation of EO satellites will provide novel and advanced capabilities to monitor wetlands worldwide on a regular basis. The success of such new technology will depend on the capability of the different actors involved in the space sector (i.e., space agencies, value-added companies, research institutions) to develop user-driven cost-effective operational applications. This should form the basis of achieving the necessary transition from a financing scheme based on research and development programmes (e.g., ESA's Data User Programme, and the European Union's 5th Framework Programme) to a user-based financing scheme, where users (e.g., national environmental ministries, local administrations) support the full cost of the operational use of EO.

Relevant Web sites

26. The following Web sites provide further information about the European Space Agency and its work, the ESA TESEO projects including its User Forum, and ESA's Data Users Programme:

ESA web site:	http://www.esa.int
TESEO project:	http://earth.esa.int/teseo
ESA's Data User Programme:	http://earth.esa.int/DUP
ESA's GMES Service Element:	http://earth.esa.int/gmes

Table 1. Overview of Ramsar Convention and wetland user information needs and requirements[3]

Scope	End-user	Requirements[4]
Global	Ramsar Bureau; UN agencies (e.g., UNEP); International NGOs (e.g., WWF); International Research Org. (e.g., IGBP); International Developing Agencies (e.g., WRI); Scientific community;	Global extent of wetlands ant their temporal variations (seasonal, multi-year) as an input for global environmental models (carbon, methane production, etc.); Global monitoring of wetlands with respect to global environmental changes; Global inventory of wetlands[5];
Regional	Regional policy makers (e.g., EC); Regional Developing Agencies (e.g., the African Development Bank); Regional Environmental Agencies (e.g., EEA);	Inventorying and base mapping[6]: • Wetland boundaries (e.g., size and variation); • Land cover/use of the wetland site and the corresponding catchment area; • Digital Elevation Model of the wetland site and the corresponding catchment area; • Water regime, (e.g., periodicity, extent of flooding); • Water chemistry (e.g., salinity, colour, transparency); • Soil features (soil type, depth, etc.); • Biota (vegetation zones and structure, wildlife); • Location of potential threats to the wetland (in the wetland site and the
National	National Focal Points; Related National Ministries; National Implementing Agencies; National NGOs;	

3 Adapted from (Ryerson et al., 2002)

4 Requirements have been split into two main groups: Global and Local. This responds to the fact that regional and national organizations generally meet their information needs by aggregating local information. In contrast, some information requirements of "global" organizations cannot be derived by using only local information.

5 By aggregating local information (see "inventorying and base mapping" below).

6 Regional and national inventories are based on the aggregation of local information. Therefore, in the table we report the information needs at local level.

Local	Scientific community[7]; Local administrative authorities; Local wetland managers; Local basin authorities; Local NGOs; Land owners; Local communities; Farmers associations[8]; Fishing associations;	corresponding catchment area); • Additional information: e.g., infrastructures, land ownership, administrative boundaries); Assessment activities: • Estimation of biological (e.g., vegetation condition), physical (e.g., water table), and chemical parameters (e.g., salinity), which characterise the ecological condition of a wetland; Monitoring activities: • Identification and monitoring of changes in the biological, physical, and chemical condition of the wetland site (e.g., changes in vegetation extend and/or condition, water table, water turbidity, etc.); • Identification and monitoring of threats in the wetland site and the corresponding catchment area, which may affect the wetland condition (e.g., alien species, overgrazing, urban expansion, agricultural activities, industrial pollutants, etc.). • Rapid reaction to catastrophic events (e.g., floods, pollution emergencies); Implementation of management (e.g., rehabilitation) plans: • Base information for planning and decision making (e.g., base maps); • Information to monitor the efficiency of the undertaken actions (on a case by case basis); • Environmental Impact Assessment (on a case by case basis);

Table 2. Degree of maturity of EO to match wetland user requirements

Information products[9]	**Maturity**	**Suitable sensors[10]**
	Global Information	
Global extend of wetlands as an input for global environmental models (carbon, methane production, etc.);	*Experimental*	*Medium resolution optical and SAR (e.g., ATSR, MERIS, ASAR-wide swath mode)*
Global monitoring of wetlands with respect to global environmental changes;	*Experimental*	*Medium resolution optical and SAR (e.g., ATSR, MERIS, ASAR-wide swath mode)*
Global inventory of wetlands[11];	*Semi operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
	Local Information	
Inventorying and base mapping:		
• Wetland boundaries (e.g., size and variation);	*Operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
• Land cover/user of the wetland site, and the	*Operational*	*Very high and high resolution optical and SAR sensors (e.g.,*

[7] The scientific community has been included under both global and local subdivisions, to distinguish between the research activity focusing on understanding global issues (e.g., influence of wetlands in the global environment) and the research work aimed at better understanding wetlands and their processes.
[8] Note that some of the requirements mentioned in Table 1 under a certain category (e.g., Local) may not fulfil the information needs of some of the corresponding users: (e.g., farming organizations may not require a wetland inventory, but rather only information about potential threats that may affect their activity).
[9] The generation of many information products (e.g., land-cover mapping, water quality parameters, etc.) requires the combined use of both EO data and ground measurements.
[10] See Table 3 for a detailed description of the sensors;
[11] By aggregating local information (see "inventorying and base mapping" below).

corresponding catchment area;		*Landsat-7, SPOT-4, ASAR)*
• Digital Elevation Model of the wetland site and the corresponding catchment area;	*Operational*	*SAR sensors (e.g., ERS-1, ERS-2)*
• Water regime, (e.g., periodicity, extend of flooding);	*Operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
• Water chemistry (e.g., salinity, colour, transparency);	*Experimental*	*Hyper-spectral and superspectral optical sensors (e.g., Hyperion, ASTER, MERIS)*
• Soil features (depending on vegetation cover);	*Experimental*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
• Biota (only vegetation zones and structure);	*Operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
• Location of potential threats in the wetland site and the corresponding catchment area;		
○ Mapping alien species ○ Mapping urban areas ○ Mapping agricultural areas	*Operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
○ Mapping areas affected by overgrazing	*Experimental*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*
○ Mapping industrial pollution sources and damaged areas	*Experimental*	*Hyper-spectral and superspectral optical sensors (e.g., Hyperion, ASTER , MERIS)*
• Additional information: ○ Infrastructures (e.g., roads)	*Semi operational*	*Very high and high resolution optical and SAR sensors (e.g., Landsat-7, SPOT-4, ASAR)*

Information products	**Maturity**	**Suitable sensors**
Assessment activities:		
• Estimation of biological, physical, and chemical parameters, which characterise the ecological condition of a wetland;		
○ Vegetation condition;	*Same as above*	*Same as above*
○ Water chemistry;	*Same as above*	*Same as above*
○ Water regime;	*Same as above*	*Same as above*
Monitoring activities:		
• Identification and monitoring of changes in the biological, physical, and chemical condition of the wetland site:		
○ Changes in vegetation condition;	*Same as above*	*Same as above*
○ Changes in water chemistry;	*Same as above*	*Same as above*
○ Changes in water regime;	*Same as above*	*Same as above*
• Identification and monitoring of threats in the wetland site and the corresponding catchment area, which may affect the wetland condition:		

○ Changes caused by alien species;	*Same as above*	*Same as above*
○ Expansion of urban areas;	*Same as above*	*Same as above*
○ Expansion of agricultural areas and shifting cultivation;	*Same as above*	*Same as above*
○ Expansion of the area damaged by overgrazing;	*Same as above*	*Same as above*
○ Variations in the extend of industrial pollution and damaged area;	*Same as above*	*Same as above*
• Rapid reaction to catastrophic events (e.g., floods, pollution emergencies);	*On a case by case basis*	*On a case by case basis*
Implementation of restoration or rehabilitation plans:		
• Base information for planning and decision making;	*On a case by case basis*	*On a case by case basis*
• Information to monitor the impacts of the undertaken actions;	*On a case by case basis*	*On a case by case basis*
• Environmental Impact Assessment	*On a case by case basis*	*On a case by case basis*

Table 3. Overview of available relevant EO sensors and technical characteristics[12].

Sensor	**Spatial Resolution**	**Swath Width**	**Spectral features**	**Visiting time & Archive**
		Very High Resolution Optical Multispectral Satellites:		
IKONOS (Space Imaging, Commercial)	1m panchromatic 4m multispectral	60km	4 spectral bands; Range 0.45 - 0.88μm;	1-3 days Data not routinely collected
		High Resolution Optical Satellites (multispectral, superspectral and hyperspectral):		
EO-1 ALI (NASA)	10m, panchromatic 30m, multispectral	37km	10 spectral bands; Range 0.48 - 2.35μm;	Experimental Data not routinely collected
TERRA ASTER (NASA)	15m - 90m	60km	14 spectral bands; Range 0.52 -11.65μm;	Experimental Data not routinely collected
EO-1 HYPERION (NASA)	30m	7.5km×100km	220 spectral bands; Range 0.4 - 2.5μm	Experimental Data not routinely collected
Landsat 5TM & 7ETM (NASA)	30m (126m Thermal IR)	185km	7 spectral bands; Range 0.45 - 2.35μm;	16 days Archive available since 1984
SPOT series (SPOT Image, Commercial)	10m, panchromatic 20m, multispectral	60km	4 spectral bands; Range 0.50 - 1.75μm;	26 days Archive available since1990
SPOT-5 (SPOT Image, Commercial)	HRG 20m, SWIR 10m, multispectral 5m, panchromatic 2.5m, supermode pan HRS – for stereo acquisitions 10m, panchromatic	60km 120km	4 spectral bands; Range 0.50 - 1.75μm;	26 days Operational since 2002 Archive no yet available

12 Only the most relevant EO sensors are included.

		High Resolution Synthetic Aperture Radar (SAR) sensors:		
ENVISAT ASAR (ESA)	6m - 100m	50km - 500km	C Band Multi-polarisations	3 days; (35 days with the same geometry) Not yet operational
ERS-1 & 2 (ESA)	24m	100km	C Band VV polarisation	3 days; (35 days with the same geometry) Archive available since 1991
RADARSAT-1 (CCRS)	10m - 100m	50km – 500km	C Band HH polarisation	3 days; (34 days with the same geometry) Archive available since 1995
RADARSAT-2 (CCRS)	6m – 100m	50km – 500km	C Band Multi-polarisations	3 days; (24 days with the same geometry) Not yet operational

Sensor	**Spatial Resolution**	**Width swath**	**Spectral features**	**Visiting time period**
		Medium Resolution Optical Super-spectral Sensors:		
ENVISAT MERIS (ESA)	300m	1150km	15 spectral bands; Range 390nm - 1040nm;	3 days; (35 days with the same geometry) Not yet operational
TERRA MODIS (NASA)	250m	2330km	36 spectral bands Range 0.62 – 16.385µm;	2 days Archive available since 2000
		Coarse Resolution Optical Multispectral Sensors:		
NOAA AVHRR (NASA)	1.1km	2399Km	5/6 spectral bands Range 0.58 – 12.50 µm	1 day Archive available since 1979
ERS-1 & 2 ATSR (ESA)	1km	512km	7 spectral bands; Range 0.55µm - 12µm;	3 days; (35 days with the same geometry) Archive available since 1991
ENVISAT AATSR (ESA)	1km	512km	7 spectral bands; Range 0.55µm - 12µm;	3 days; (35 days with the same geometry) Not yet operational
OrbView-2 SeaWiFS (NASA)	1.1km	2800km	8 spectral bands; Range 0.402 – 0.885 µm	1 day; (16 days with the same geometry)

Table 4. Advantages and drawbacks of EO sensors[13]

Advantages	Drawbacks	Main applications

[13] Adapted from (Ryerson et al., 2002)

Airborne Sensors (aerial photography, hyperspectral):		
• High spatial resolution • Widespread use, widely understood; • Many supply companies available; • Technology for base mapping is widely available;	• High cost; • Small width of coverage; • Logistical and political impediments in many parts of the world; • Acquired by order (no frequent or periodic acquisition); • Lack of solid automatic techniques for data analysis (in many cases, photo-interpretation is required); • No systematic archive data available; • Not suitable for large or remote geographic areas; • Acquisition depends on weather conditions; • Complex data analysis techniques for hyperspectral imagery (experimental);	• Creation of high resolution base maps; • High resolution Land cover/use and change; • Vegetation condition and type (especiall with hyperspectral sensors: e.g., AVIRIS); • Water chemistry (only with hyperspectra sensors: e.g., AVIRIS); • Water regime;
Very High Resolution Optical Multispectral Sensors:		
• High spatial resolution • Can be acquired without special permission; • Images are digital; • Stereo imagery available; • Technology for base mapping is similar to the one used with Aerial photography; • Allows frequent or periodic acquisitions; • Archive data will be available;	• High cost; • Relative small width of coverage; • Lack of solid automatic techniques for data analysis (photo-interpretation is required); • Not suitable for large geographic areas; • Depends on cloud cover; • Archive data is not yet available (very recent technology)	• Creation of high-resolution base maps; • High resolution Land cover/use and change; • Water regime; • Vegetation condition and type;
High Resolution Optical Sensors (multispectral, superspectral and hyperspectral):		
• Frequent global coverage; • Global archive available; • Good discrimination of many surface features; • Solid methodologies for automatic data analysis available; • Low cost; • Suitable for large geographic areas (e.g., wetland site and catchment area); • Existing and widely known archive data for multispectral sensors;	• Spatial and spectral resolution prevents very accurate mapping and fine discrimination of vegetation and water quality indices; • Depends on cloud cover; • Complex data analysis techniques for hyperspectral imagery (experimental); • Archive data is not yet available for superspectral and hyperspectral sensors (very recent technology);	• Creation of base maps; • Land cover/use and change; • Vegetation condition and type; • Water chemistry (only very few parameters); • Water regime; • Potential threats (not suitable for some industrial pollution) • Soil features (depending of vegetation cover); • Mapping infrastructure (e.g., roads);

Advantages	Drawbacks	Main applications
Medium Resolution Superspectral Sensors:		

• Frequent global coverage; • Spectral resolution allows water quality and accurate vegetation condition applications; • Solid methodologies for automatic data analysis available; • Low cost; • Suitable for large scale mapping (e.g., national, regional and global scales); • Archive data will be available;	• Small spatial resolution prevents local scale mapping; • Depending on could cover; • Archive data is not yet available (very recent technology)	• Land cover/use and change at national, regional and global scales; • Vegetation condition and type at national, regional and global scales; • Water chemistry at large scale (e.g., coastal areas, large water bodies);
	Coarse Resolution Optical Multispectral Sensors:	
• Frequent global coverage; • Solid methodologies for automatic data analysis available; • Low cost; • Suitable for large scale mapping (e.g., national, regional and global scales);	• Small spatial resolution prevents local scale mapping; • Spectral resolution prevent the identification of several features; • Depends on cloud cover;	• Vegetation condition and type at national, regional and global scales;
	High Resolution SAR Sensors:	
• Not depends on cloud cover; • Frequent global coverage; • Global archive available; • Good discrimination of many surface features (also emergent vegetation in wetlands); • Solid methodologies for automatic data analysis available; • Low cost; • Suitable for large geographic areas (e.g., wetland site and catchment area); • Archive data available and well known; • Allow accurate DEM and subsidence monitoring;	• Poor discrimination of vegetation type; • Geometric distortion of topography; • Information in image may be affected by meteorological conditions (e.g., wind over wetlands may hinder the accurate mapping of the water table);	• Creation of base maps; • Land cover/use and change (especially in combination with optical data); • Water regime; • Potential threats (not suitable for industrial pollution) • Soil features (depending of vegetation cover); • Mapping infrastructure (e.g., roads); • DEM; • Subsidence;