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EARTH OBSERVATION SYSTEMS FOR SMALL COUNTRIES AND REGIONS

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ABSTRACT

Earth Observation (EO) data are useful tools for managing and improving various aspects of regional and national resources. EO programs are often costly to initiate, therefore they are difficult to develop with the limited budget of a small country or region. Several characteristics of EO are considered and applied to three test cases: Catalonia, Spain; Alsace, France; and Mauritius. Results of these test cases show that EO utilization is feasible and beneficial for small countries and regions. The concept of a prototype software "selection" tool is presented to assist regional and national leaders in determining what EO capabilities are useful to them and how to initiate a program.

FULL TEXT

Civil Earth Observation (EO) programs are valuable tools for decision makers at various levels. Examples of such decision makers include resource managers, urban and regional planners, agricultural producers, and disaster first responders. Examples of EO applications include facilitating public services and natural resource management. EO data and information can be especially useful for small countries or regions, assisting their future development. Implementing EO programs can be difficult for regions or small countries because EO data and systems are technically complex and costly.

Small countries and regions looking to establish EO capacity must determine the most cost-effective way of implementing the technology. The options for utilizing EO are either to obtain data from existing EO systems or to develop new systems. Cooperation between regions or small countries can overcome resource constraints and lack of expertise to harness the potential of this powerful technology.

Three test cases—Catalonia, Spain; Alsace, France; and Mauritius—were prepared to illustrate the utility of EO for regions and small countries. The test case sites were chosen for several reasons. First, Catalonia was chosen due to interest expressed by the Aerospace Technology Centre (CTAE), located in Catalonia, in the opportunities for participating in the International Space University Summer Session Project team research. Second, Alsace was chosen because it exhibits some similarities to Catalonia and because the two regions would provide a good illustration of potential collaboration for EO programs at the regional scale. Third, Mauritius proves a useful test case because this island nation has similar spatial scale, economic resources, and resource management needs to Alsace and also commands an extensive economic zone (EEZ) in the surrounding Indian Ocean.

Implementing EO technology requires a systematic progression from data collection to extraction of useful information from these data. This process begins with data collection by the sensor and moves to the data receiving center where the data are stored and distributed. Once the data are distributed, they are transmitted to a processing center where information is extracted by analysis. Once the data analysts have extracted the information from the data, the information is available for use by decision makers in the public and private sectors. The continued development of geographic information systems (GIS) has vastly simplified the display of multiple types of EO information and contributed to the ability to understand and act on them.

During the test case research for the test cases, an information gap was observed . this gap exists between EO providers, who possess the data, and decision-makers, who could apply the information. While preparing the test cases, a prototype software selection tool for organizing and disseminating EO information was developed to close this gap.

Earth observations are a technically complex and costly set of tools that can be instituted effectively for small countries and regions, if developed appropriately. EO developers must assess the applications, needs, technical capabilities, and policy and legal implications of using the technology. Five major, non-exclusive options for developing EO capacity were identified:

1. Buy EO data from existing aerial and spaceborne EO data providers;
2. Establish aerial EO programs;
3. Develop locally owned and operated spaceborne EO systems;
4. Create a data processing center that converts data to information for decision makers; or,
5. Any or all of the above in cooperation with another small country or region.

An understanding of the financial considerations for EO programs is essential to establishing EO programs and systems. A proposed value chain for EO systems, from the EO system provider and to the end users who exploit the information, is shown in Figure 1. The principal concepts applied to the value chain are the EO ventures analyzed, cost estimating methods and financing options.

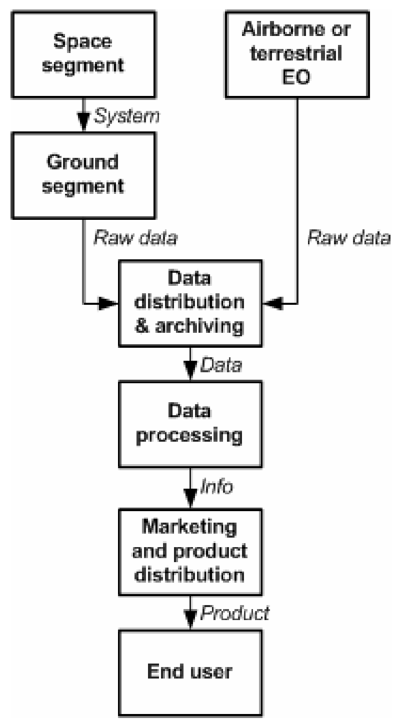

Figure 1: EO Value Chain

When a small country or region develops EO programs, the national and international policies and legal framework for space should be considered in concert with the technological development path and program financing. EO system licensing and data access policies are particularly important because, if ignored, they can obstruct the users' ability to obtain data.

Given this technological, financial, and legal context for EO program development, small countries and regions are often best served by employing a cooperative model, *e.g.*, public-private partnership (PPP). Using a cooperative model, small countries and regions can overcome obstacles and develop EO programs that meet the specific needs of the region.

Case 1: Catalonia, Spain

Catalonia, in northeast Spain, is one of the 17 autonomous communities of Spain. The local economy is highly dependent on tourism and industry. Agriculture, including viticulture and cereals, is also an important factor for the economy. Currently, private industry and academic research centers comprise the extent of EO capabilities in Catalonia; however, interest in expanding EO capability locally has grown recently. This project has identified an opportunity for Catalonia to consider developing a regional EO system to stimulate local industry and to improve the use of EO for current and future applications.

EO can be useful in Catalonia for viticulture, mapping, environmental monitoring, disaster management, and humanitarian aid. Catalonia is currently using EO data for some applications, but the region could further capitalize on EO technology and build capacity in EO system development.

Given the current capacity and the potential budget for EO systems, a small satellite is one viable option for Catalonia. Such a system could satisfy some of the technical EO needs (*e.g.*, high spatial resolution) for the applications identified above. Discussion with CTAE resulted in an estimated budget of 12M€ for the region for the test case.

The most suitable sensors for the applications noted above are multispectral and hyperspectral. A multispectral or hyperspectral aerial system would be especially useful for applications such as viticulture since the spatial resolution is on the order of one meter or less. The Compact Airborne Spectographic Imager (CASI) hyperspectral sensor, for example, is particularly suited to this type of application because its high spectral resolution would assist in qualifying crop health. For applications at this spatial scale, *in situ* data provided by ground-based sensors and airborne systems can also improve the quality of information derived from the data.

These proposed systems would be best developed in cooperation with other regions or countries in order to facilitate technology transfer, to encourage political ties between regions, to improve EO system capabilities (*e.g.*, revisit time), and to offset some of the system construction and operational costs. For Catalonia, mapping, environmental, and disaster management applications would be best served by this type of system.

EO capacity building in Catalonia could result in valuable economic and social spin-offs for the region. High-tech EO systems can be beneficial for the local economy by stimulating economic growth, industry, commercial development, and fostering new ventures in EO. This would occur if Catalonia began developing its own satellites or if the region established other EO competencies. A data processing center, for example, could serve regional data processing needs, stimulate revenues for the region, and provide a mechanism for Catalonia to assist other regions in harnessing the potential benefits from EO. A center of this type could be based on a PPP model. EO capacity building in Catalonia may encourage scientific and technology competitiveness and promote scientific education.

Case 2: Alsace, France

Alsace is a small region located in the north-eastern part of France, at the border with Germany. Its economy is highly dependent on viticulture, forestry, and tourism. EO capabilities have been developed in Alsace through the use of Satellite Pour l'Observation de la Terre (SPOT) data and aerial Institut Géographique National (IGN) data for local applications. Locally, value-added services are also offered by the private sector, so EO information can be accessed and utilized by non-technical users. To capitalize on the full potential of EO, Alsace must identify suitable options for EO development, given its limited budget, and build on the current expertise.

Currently, EO data are used in Alsace for forestry, mapping vineyards, and disaster monitoring; however, there is potential for Alsace to expand its EO capabilities. Precision farming presents a particular avenue for expanding EO capabilities within Alsace since the wine industry is integral to the regional economy. In addition to mapping the vineyards, Alsace could invest in EO systems and data that provide detailed information about grape, vine, and soil health. With this information in hand, wine producers can manage their crops and maximize profits by adjusting the harvesting system to collect the grapes based on their quality.

Purchasing aerial and spaceborne EO data and information from commercial data providers is the most suitable option for EO systems in Alsace. With a severely limited budget available for EO data and information, the best option for the region is to purchase data rather than to build or acquire systems. This option would allow the user to purchase raw data or, where available, the value added information derived from that data. For viticulture, Alsace should consider high spatial resolution multispectral (*e.g.*, Quickbird and Ikonos) and hyperspectral (*e.g.*, aerial sensors) data for mapping, assessing crop health, and disease monitoring. Alternatively, Alsatian companies, like Service Régional de Traitement d'Image et de Télédétection (SERTIT), currently offer EO data and information at various stages of processing. For wine producers, who possess no expertise in the use of EO, buying information tailored to their specific needs is ideal for assisting in viticulture management. However, such information must be sufficiently inexpensive to be a realistic option for individual producers.

A more ambitious EO system could be considered for Alsace if the region cooperates with neighboring regions for that system. Given the limited regional budget, a cooperative venture with other regions having similar EO needs could provide the capital needed to develop and support a dedicated EO system for viticulture. The framework offered by the European Union (EU) provides a means for this type of cooperation. The small satellite systems discussed in the case of Catalonia might be one consideration for such a cooperative venture in Alsace.

In the long term, Alsace may want to consider developing an advanced precision viticulture scheme that includes EO data. As precision viticulture algorithms and techniques improve, Alsace will likely want to establish its own precision viticulture capabilities. This will be helpful in improving crop production in order to compete with the quality and quantity of grapes produced by other wine regions. Also, with recent improvements in spectral resolution, there is great potential for EO to provide increasingly accurate and meaningful information about vine and soil health. The key to the successful use of EO for precision viticulture is to market the technology to wine makers or their professional wine maker associations.

Case 3: Mauritius

Mauritius is a small island country located in the Indian Ocean, east of the African continent. Its economy is highly dependent on sugarcane production, textile manufacturing, and tourism. Mauritius remains a developing country with limited economic resources available to research and development. Despite this limitation, Mauritius has taken the initiative to develop EO capacity specializing in EO applications relevant to environmental resource management and disaster preparedness. It is now appropriate for Mauritius to consider options for further developing its EO capabilities.

EO programs can be a useful tool in improving efficiency and efficacy for managing environmental resources and weather monitoring. Agriculture, coastal zone management, and disaster management warning and mitigation systems present the greatest potential for EO in Mauritius. The country has been successful in using EO for managing natural resources like sugarcane, fisheries, and some coastal zone resources. With increased EO capacity in the country, Mauritius could improve on these applications and extend the use of EO to other applications. Another important consideration for EO capacity building in Mauritius is its use for detailed weather monitoring, specifically for the tropical cyclones that are prone to hit the island.

Under its current budget conditions, Mauritius cannot afford to invest in its own EO system; therefore, a cooperative EO system or purchasing available EO data are the suitable options. The research presented here indicates that US$1.3 million per year is a reasonable EO budgetary allotment for Mauritius over the next three to five years; however, an investment of this size is not sufficient to establish and maintain a sustainable EO system.

The first option for EO in Mauritius is to obtain freely available data. Mauritius can obtain free data from the United States National Oceanographic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR). Although these data are of a low spatial resolution, they could be useful for Mauritius in monitoring fish stocks and large scale environmental change on the island. The U.S.-Germany Shuttle Radar Topographic Mission could also be a source of freely available data that could facilitate topographic mapping, which is useful for assessing landslides in affected areas of the island.

The second option is for Mauritius to purchase commercially available EO data. This option is more suitable for Mauritius, given its limited budget and the need for higher spatial and spectral resolutions for many relevant applications. The medium spatial resolution SPOT and the Disaster Monitoring Constellation (DMC) multispectral sensors have been identified as especially useful for monitoring the forests and the coastline. High resolution Quickbird and Ikonos data are alternative sources of commercially available multispectral data and, although more costly, should be considered by Mauritius for specific needs like urban development. Purchasing data also opens up the possibility for obtaining space-based and airborne data using differing sensors to meet specific application.

The third option for EO capacity building in Mauritius is for the country to cooperate with another country or region in developing an EO system or other capabilities. By pooling resources and capital with another country, Mauritius could establish a dedicated EO system, similar to those provided by firms such as Sunspace in South Africa or Surrey Satellite Technology Limited (SSTL) in the United Kingdom. This type of cooperation is often undertaken by academic institutions; however, Mauritius could also consider developing similar cooperative mechanisms at the state level. Alternatively, Mauritius could coordinate with other countries to establish capabilities in other related EO services (*e.g.*, data receiving or processing centers) that could be offered in exchange for EO data.

EO Decision Software

During the analysis of the feasibility of EO for small regions and countries, a prototype software selection tool, called "SOLST," was developed. SOLST is a proposed system architecture that would use a decision tree structure to identify suitable EO data and system options for EO users. The system architecture for the SOLST prototype is composed of databases of specific information about EO applications, such as data types and availability, estimated costs, and potential collaborators, and was developed in concurrence with the test cases. These databases link together so that multiple outputs can be selected, depending on the level of detail required by the user. The outputs are recommendations for the EO system or data for the region or the application being investigated.

The purpose of the software is to bridge the gap between EO providers and the data and information users. By using a simple software interface to link, EO users can better access comprehensive information and specifications relevant to available EO systems and data without having a considerable technical background. The software recommendations are not intended to replace the technical expertise that is needed to consider possible EO systems. Rather, SOLST could be used, for example, by a regional decision-maker to decide if EO is a potential solution in a region before recommending the activity for further, detailed study.

The SOLST method and prototype, including the databases, the interface, and their linkages, will require frequent updating to be a useful tool. Two potential options for managing database updates are suggested: first, that the system could be updated by a dedicated group of individuals working for an organization that manages the software; or alternatively, the databases could be maintained as open source data that the EO providers and users would be responsible for updating. An open structure such as the latter option would require a group or an individual to control the system and ensure accurate contributions.

Conclusion

Earth observations provide a powerful tool, with great potential for assisting in environmental management and other important applications, for small countries and regions. The utility of EO for such countries and regions, however, rests on the ability of an organizing body responsible for the proposed EO program to identify and select the most suitable options for the region. This selection must fall within the technical and budgetary constraints, which are case specific. Cooperation between countries and regions could provide solutions within these constraints. The three test cases are provided as examples of different ways that EO could be developed for small countries and regions.