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APPLICATION OF GEOSPATIAL TECHNIQUES FOR THE STUDY OF RECREATIONAL QUIATILY IN TOURIST BEACHES

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COASTAL-MARINE INTEGRATED MANAGEMENT

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INTRODUCTION

Within a research program held in Colombia since 2010, the "Index of Environmental Quality in Tourist Beaches" (ICAPTU, Spanish acronym) has been designed to work as a technical instrument that summarizes the criteria for analyzing environmental parameters (Botero, Pereira, & Escudero, Informe del programa de investigación en calidad ambiental de playas turísticas (CAPT) en el Caribe Norte Colombiano 2010 – 2014. Periodo AGO – DIC 2010.Tehnnical report., 2011). This index is thought to become into a management tool for environmental authorities, more effective than the comparison of data with the governmental norms, which might be considered outdated or incomplete. The revised ICAPTU model aims to assess the beach environmental quality through a mathematical expression that weights a set of parameters used as indicators of ecosystem, sanitary and recreational quality (Pereira, 2012).

Considering the elements of beach management cited on Williams and Micallef (2009), the essence of this ICAPTU initiative can be cataloged inside the element "monitoring via collection of data". The same author states that beach management should be founded upon sound scientific information, which is where data collection techniques play an important role in behalf of researchers and/or beach manager's. Regarding data collection, a potential instrument may be found with the Geospatial Techniques, considered as all kinds of techniques useful for produce, organizing, and analysing spatial information, such as geodesy, remote sensing and geographic information systems (GIS) (Klemas, 2011).

The adaptation and integration of this geospatial techniques, here after referred as geotechniques, figure as an asset that contribute to the calibration process required for the parameters to be aggregated in the ICAPTU index. The attributes of these techniques pose a potential application on the parameters considered in the recreational indicator, especially for those related with the presence of human facilities and civil structures on the beach. The application of these techniques on the assessment of the recreational parameters of the ICAPTU index, such as ordering, scenery, security/safety and coastal rigidity, would represent the study object of this exploratory research.

The general objective would be analyze the possibility of applying geospatial techniques, such as remote sensing, GPS and GIS, for the study of recreational quality in tourist beaches within the ICAPTU index. Among the specific targets that contribute to this purpose, they are considered i) to recognize different kinds of sensors and techniques applied on beach management; ii) to identify the adequacy of the most important technique for the assessment of the parameters conforming the recreational indicator of the ICAPTU index and iii) to integrate the information of every geospatial technique identified to the variables of the recreational parameters, analizing its utility for the management approach of the ICAPTU model.

The first chapter of this document would describe the conceptual framework of this research according to the process for updating the ICAPTU model. The second chapter would zoom into the recreational dimensions of the model, which includes the definition of instruments for measuring conditions on the beach that are not usually quantifiable, such as the parameters mentioned above. The third chapter is going to describe the group of geotechniques that has been documented for marine and coastal studies, while the fourth chapter highlights the possibilities presented by such techniques for the assessment of recreational quality on beaches. The final chapter will discuss about punctual situations or experiences where certain geotechniques have proven to be a resourceful asset for beach management.

1. INDEX OF ENVIRONMENTAL QUALITY FOR TOURIST BEACHES - ICAPTU

Uncontrolled tourism development threatens the fragile equilibrium of coastal ecosystems and compromises the environmental services they provide. The beach system especially loses its functionality as a place of leisure and recreation when its natural elements represent a risk for the health of beach users. In Colombia, the lack of a reliable and regular information system that can be used for controlling the environmental and sanitary conditions of their beaches presents a challenge for local environmental authorities. Looking after providing environmental authorities with a management tool more effective than the comparison of data with governmental norms, a partnership of local universities in the Caribbean Coast of Colombia has been working for updating a technical instrument that summarizes the criteria for analyzing environmental parameters. The conceptual framework of this research and its progress is here described.

1.1. Beach Environmental Quality

Considering the social and economic value that beaches represent as destinations of leisure and recreation, there is a significant concern for preserving their fragile equilibrium (Beharry-Borg & Scarpa, 2010; Gavio, Palmer-Cantillo, & Mancera, 2010). Conventional tourism is perhaps the most common use of beaches around the world and as any with many uses of natural resources; it generates negative impacts on the environment which need to be considered by coastal zone managers (Cervantes & Espejel, 2008; Nelson & Botteril, 2002). Beach Environmental Quality (BEQ) thus plays an important role in the scientific community and among coastal zone managers as a tool for monitoring and control. However, this concept is not well defined and is rather conceived by diverse and independent notions, such as safety or health risk to users, aesthetic perception, ecosystem health and/or beach management in general (Delgado, *et al.*, 2009; Espejel, *et al.*, 2007; Nelson, *et al.*, 2000; Costa, *et al.*, 2009; Oigman-Pszczol & Creed, 2007; Pendleton, *et al.*, 2001; Thompson, *et al.*, 2008).

There has been little research specific to defining and assessing the environmental quality of tourist beaches. The parameters that make up the different quality schemes of beaches and coastal areas are very diverse, and so identifying a unified approach to determine the state of a beach can be challenging. However, in recent years the advanced study of BEQ has been led by specialized institutions such as the US Environmental Protection Agency (www.epa.gov) and the Blue Flag program (www.blueflag.org), along with other researchers in Europe (Ariza, et al., 2010; Williams & Micallef, 2009). Special attention is given to the sea water and sand because of the direct contact implied during leisure activities of "*3S*" tourism: sun, sea and sand (Elmanama, *et al.*, 2005; Rangel-Buitrago, *et al.*, 2013; Vogel, *et al.*, 2007).

In Colombia (South America), there have been some efforts to address this issue, though there is a limited knowledge of the environmental quality of the country's beaches due to scarce availability of data and the absence of standardized monitoring mechanisms. Among Latin American countries, Colombia is one of many destinations in the Caribbean with increasing tourist activity and the country's beaches are quickly becoming essential parts of local economies targeting the "*3S*" market (Botero, *et al.*, 2013; Gavio, *et al.*, 2010). Despite negative impacts associated with tourism, presently there is no regulation in Colombia specific to controlling the status of national beaches. Local environmental authorities typically rely on governmental norms for assessing the quality of bathing waters using an out-dated regulation (MinSalud, 1984) though these norms may be considered outdated or incomplete as they contain only a few of the parameters needed for assessing BEQ. The closest efforts to address this issue have been made by the coastal regional environmental authorities and the national marine and coastal research institute, INVEMAR, through the establishment of a surveillance network for the protection and conservation of marine and coastal waters, known as RedCAM (INVEMAR, 2014).

Some approaches to assessing environmental quality tend towards an isolated and detailed study of the natural elements (air, water, sand and ecosystem), which represents a reductionist theory that can limit the process of knowledge; in contrast, a holistic approach seeks to account for multiple factors in order to achieve an understanding informed by a greater range of characteristics within the context of the study subject (Hurtado, 2010). With the objective of evaluating the BEQ in Colombia, the first holistic attempt is here described as part of a project for updating the Index of Environmental Quality in Tourist Beaches (ICAPTU, Spanish acronym). This model was first designed in 2002 to assess the BEQ through a mathematical expression that weighted a set of eleven parameters aggregated into four indicators (Botero, 2002) and has been used as a methodological and conceptual reference for different works at national levels (Ceballos, 2003; ICONTEC, 2007). A key advancement of this program here described is the development of an original conceptual framework for BEQ, along with the redefinition of parameters and indicators within the new version of the ICAPTU index.

1.2. General Methodology

In 2010, a partnership was formulated between the University of Magdalena and the Comfenalco Technological Foundation University to create the Research Program of Environmental Quality in Touristic Beaches of the Colombian Caribbean. Within this research program, currently another four universities have joined as partners while others are projected to join in the near future in an attempt to include all provinces covering the Colombian Caribbean (figure 1).

Figure 1. Study area along the Colombian Caribbean coast (from Botero, Pereira, Tosic, & Manjarrez, 2014)

The recognition achieved by the program relies on the objective of evaluating the BEQ in the study area through a monitoring program, as well as updating the ICAPTU index in order to reach a more comprehensive scope that overcomes the limited focus of the original model. Figure 2 represent the general idea of the methodology that has been followed.

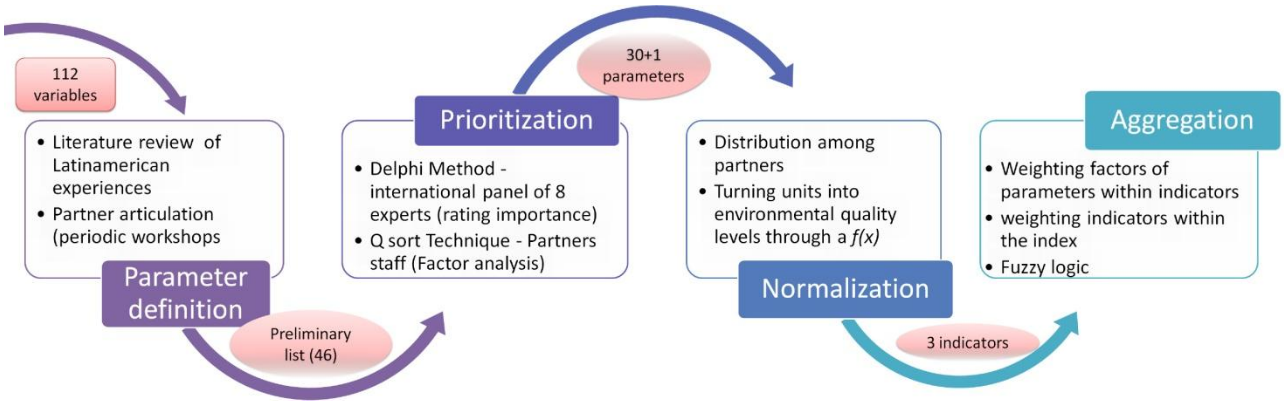


Figure 2. Methodology for ICAPTU update (from Botero, Pereira, Tosic, & Manjarrez, 2014)

The rigor of this research comes from a thorough literature review and the articulation of two expert groups, represented respectively by the members of the working staff of partner universities and members of the Iberoamerican network for beach management and certification (PROPLAYAS). Among the disciplines of the experts involved there are microbiology, oceanography, geology, biology, chemistry, environmental sciences, engineering and tourism management.

The initial review considered 22 scientific papers as well as international official documents in the field of beach quality, taken from areas with similar socioeconomic and ecological characteristics to the study area, which ensures the pertinence and viability of the model. This review focused primarily on environmental issues, rather than tourist issues, and sought to highlight the frequency and relevance of the parameters. The preselected parameters worked also as starting point for establishing a monitoring program that evolves and perfects along the update process of the ICAPTU index (figure 3).

Defining the parameters for ICAPTU was strengthened by workshop discussions between the partner universities; the different disciplines among the working staff ensured an integrated criterion for making an inclusive selection of the preselected parameters. Out of this preliminary collection, the international panel of 8 experts rated the importance of each parameter in order to conclude on a definitive set of parameters. Selected parameters were prioritized using focus group techniques described by Hurtado (2010), such as the Delphi Method (rating importance) and Q sort Technique. The factor analysis of the results allowed the prioritization of the parameters which were then distributed among the universities responsible for their calibration, according to their expertise and strengths.

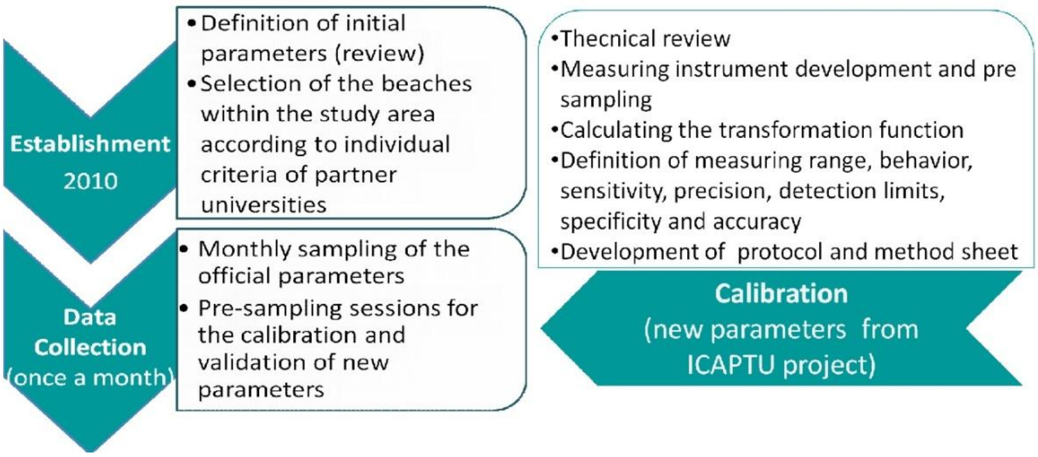


Figure 3. Scheme of the monitoring program for the Research Program on Beach Environmental Quality.

This calibration is a parallel process to the monitoring program, given the necessity to build knowledge on many variables. The parameters measured since the establishment of the program in 2010 did not include the updated list from the index because of the lack of knowledge on many variables. Thus, once each new parameter is supported with a protocol and analytical methodology it can then be officially integrated into the monthly sampling of the monitoring program

1.3. Structure of the new model

Among the advances achieved in the first years of the research program the most relevant finding is the development of an innovative conceptual approach for measuring environmental quality in tourist beaches. The updated ICAPTU model uses a scientific approach focused on decision making goals and the integration of the coastal system. Consequently, traditional methods to measure environmental quality have shifted to taking a multidimensional and holistic approach. As a result, a new scheme was defined for the index that integrates the three dimensions that compose the concept (table 1). Beach Environmental Quality definition within this framework is as follows:

The current state presented by the socio-natural system that characterizes a tourist beach regarding its performance as ecosystem and satisfier of human needs, such as subsistence, leisure and identity. A good environmental quality is considered when the natural system can maintain its structure and function and support at the same time the human activities established in it.

Table 1. New structure of the ICAPTU model (from Botero, Pereira, Tosic, & Manjarrez, 2014). Highlighted recreational parameters detailed in this document.

ICAPTU INDICATORS	DEFINITION (*conceptual framework*)	PARAMETERS	
SEQI - Sanitary Environmental Quality Indicator	Risk probability of human health affected by environmental conditions of the beach (*Health risk*)	Fungi (water)	Vectors (sand)
		Solid Waste (water)	Solid Waste (sand)
		Enterococci (water)	Enterococci (sand)
		Fecal Coli (water)	Fecal Coli (sand)
		Total Coli (water)	Total Coli (sand)
EEQI - Ecological Environmental Quality Indicator	Beach health in terms of the ability to support the vital process of marine life (*Ecosystem health)*	Noise	Toxic Substances
		Hydrocarbons	Dissolved Oxygen
		Sediment Transport	Surrounding Ecosystems
		Organic Matter	Biological Diversity
		Species Abundance	
REQI – Recreational Environmental Quality Indicator	Conditions provided by the beach in order to satisfy leisure necessities of beach users (*Beach management and aesthetics)*	Odor	Noise
		Solid Waste (sand)	Pets
		Fats and Oils (water)	Turbidity (water)
		Safety and Security	Coastal Scenery
		Urbanization	Zoning

The sanitary indicator is focused strictly on sanitary issues, supported by an epidemiological approach, including parameters that measure the adequacy of beach conditions for the safety of human health. The ecological indicator is inspired on an ecosystem health approach (UNESCO, 2006), incorporating parameters that verify the adequacy of a beach for maintaining the ecosystem functions. Finally, the recreational indicator is based on the Human Scale Development, proposed by Max Neef's team (CEPAUR, 1996); it addresses to the conditions of a beach for satisfying tourist's necessity of leisure.

Considering the scientific aim of the holistic research, the proposed definition of Beach Environmental Quality aims to effectively assess the nature of this subject in Colombia. The approach of the three quality dimensions is appealing to the need for studying the coastal system from its complexity, comprehensiveness and within its context, keeping in consideration that the process of knowledge is continuous.

Another important achievement is related to the new list of 30 environmental parameters defined and the fact that it originates from a selective literature review. Both the ICAPTU index and the monitoring program on the Caribbean Colombian are initiatives that go beyond the confirmative research in which theories coming from more developed countries are simply tests. Instead, this model is properly endogenous because the proposed theories and applications are designed to fit the reality of the study area while develop the potential to project toward the Latin-American context.

Finally, during the model's calibration, the research program also gathered a dataset from six tourist beaches in the cities of Santa Marta, Cartagena and Riohacha, allowing the definition of guidelines for designing monitoring platforms. In this sense, the calibration process of the parameters defined in the updated version of the ICAPTU index have progressively structured and systematized the monitoring exercise. The main objective of data sampling and analysis has been to develop a strong conceptual and methodological framework for monitoring beach environmental quality in Colombian beaches. This exercise has also served to identify challenges and opportunities for improving beach quality in a country highly dependent on sun, sea and sand tourism, but unfortunately without the regulations and policies necessary to effectively prevent impacts on the quality of the beaches.

2. RECREATIONAL PARAMETERS OF THE ICAPTU MODEL

Sanitary and ecological parameters are included in many beaches environmental quality programs, because they represent quantitative and tangible phenomenon that can be measured to obtain scientific data. However a beach's use has been established as a core objective of environmental quality form a holistic approach. The Recreational Environmental Quality Indicator is an innovative contribution of ICAPTU because it includes several parameters focused on qualitative data obtained through beach user perception and expert opinions. Almost none of its eleven parameters have been included in any published proposal of beach environmental quality models or approaches.

Although some parameters may be common in environmental engineering studies (e.g. turbidity, fats and oils and solid waste or litter), they are not quite focused on assessing the impact of these elements on beach user's satisfaction during leisure activities. Due to little reference in these matters the development of methodologies and measurement instruments is an essential part on this research field. The methods considered in this research are framed on the methodology designed for calibrating the recreational parameters of ICAPTU within five common stages (figure 4).

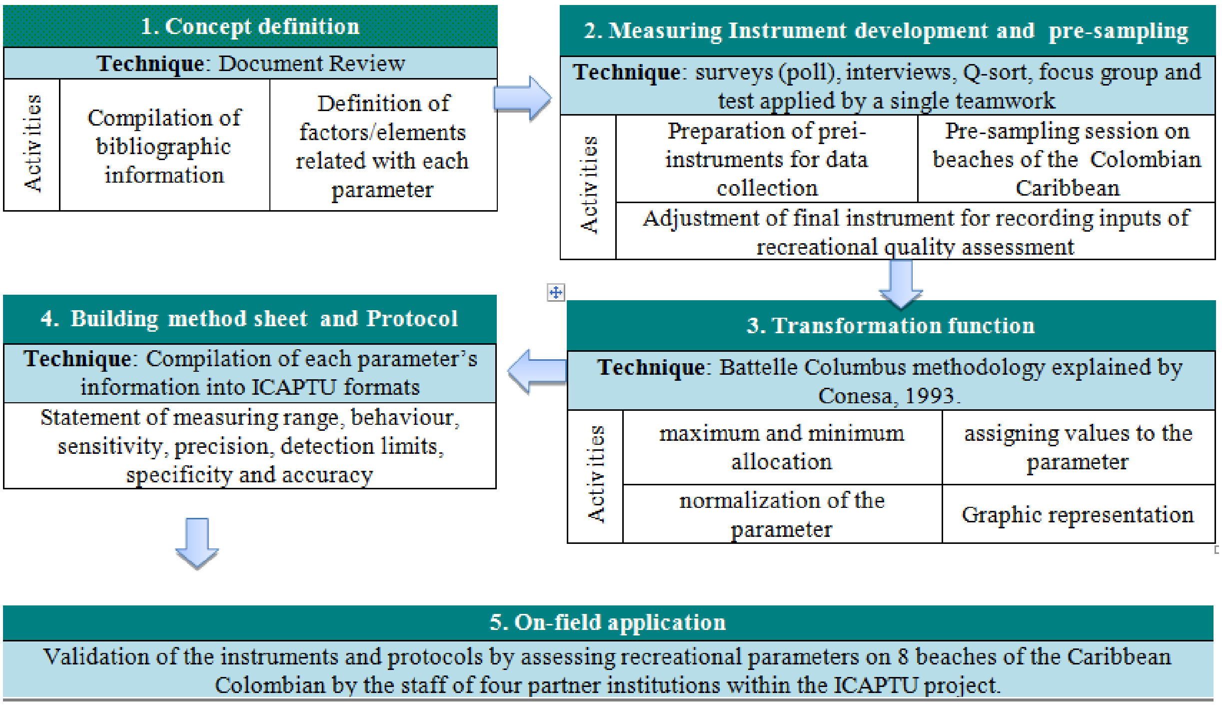


Figure 4. General methodology considered for the calibration process of recreational parameters within the ICAPTU project. Adapted from Botero, et al., 2014.

The following sections describe the application of this process on four recreational parameters: Coastal Scenery, Safety/Secutity, Urbanization and Zoning. The results described focuses on the exercise developed for building up an instrument able to measure each recreational parameter. During the process, different tools were applied and tested in the Caribbean Coast of Colombia, specifically at beaches located in four departments: Riohacha (La Guajira), El Rodadero and Bahia Concha (Magdalena), Puerto Velero, Caño Dulce and Salgar (Atlantico) and Boca Grande (Bolivar) (see figure 1).

2.1. Coastal Scenery

As a recreational parameter, the term of coastal scenery is related with the perception of beach user toward the landscape. The calibration of this parameter is based on the study of a group of researchers from different countries concerning the appreciation and evaluation of coastal scenery (Ergin, *et al.*, 2004; Ergin, *et al.*, 2006). These authors have conducted several studies on coastal scenery for more than eight years, defining elements and methodologies for evaluation. Their experience resulted in an instrument designed to assess the scenic quality of beaches, already applied in Europe, North America, Central America and Oceania (Anfuso, *et al.*, 2014).

This validated instrument assesses the scenic features of the landscape in the sea front according to the preferences of beach users (Ergin, et al., 2003). Since this assessment identifies beach values from a societal approach, the results of this assessment can be used for landscape preservation. In the same way it may also lead to protection initiatives by identifying high quality landscapes, efficient mechanisms to prevent deterioration and those components that detriment the quality (Ergin et al., 2002). However, this instrument has presented limitations in assessing Colombian beaches because the socio-natural conditions of this area are beyond the scope of this model (Botero, Anfuso, Williams, & Palacios, 2013).

The development of this original instrument identified of 26 elements of the coastal landscape, discriminated by physical and human components. The physical elements represent natural and geological features of the beach, while the human elements are those that have been introduced to the landscape through anthropogenic activities. These elements were then categorized according to the preferences of over 1000 beach users interviewed in various European countries and USA. This work included the application of fuzzy logic techniques to reduce subjectivity in the data, so that the final instrument is presented as a checklist that includes five attributes for each element. A weighting matrix was applied for ranking the beaches into five classes, where class 5 represents the best quality of the landscape.

Despite the wide range of countries where this landscape assessment has been applied, an adaptation of this instrument is required in order to suit such assessment to the particular conditions of the Colombian Caribbean coast (Botero, Anfuso, Williams, & Palacios, 2013). Following the methodological framework for parameter calibration described in the figure 4, a set of coastal landscape elements where identified after a literature review about marine and environmental conditions on the study area. These elements were then organized on a checklist that was used on a survey applied to four beaches of different municipalities of the Colombian Caribbean. The non-clustered ordinal data obtained from this sampling sessions were brought under a frequency analysis that identify users' preferences regarding the five categories assigned to each element of the landscape.

From this exercise it was defined a checklist that includes 17 physical and human elements to determine the measurement of the coastal landscape for the beaches on the Colombian Caribbean (table 2). Each element is composed of five socio-natural characteristic of the study area, respectively categorized by the preferences of their users. The categories range from 1-5, where 1 represents the lowest recreational quality and 5 being the highest quality. Also, a transformation function is used to measure environmental quality graphically from the landscape assessment with a weight ranging from 0-1.

Table 2. Coastal landscape elements considered for evaluating coastal scenery on the Caribbean Littoral of Colombia (from Botero, et al., 2014)

Physical Elements	Human Elements
Beach face width	Litter
Sand colour	Sewage
Skyline landform	Land use
Coastal landscape features (arches, caves, waterfalls, island, reefs, etc.)	Built environment
Vistas	Beach Users' Density
Water colour	Recreational Equipment
Vegetation cover	Recreational facilities
	Folklore
	Floating Surfaces
	Facilities

Categorization of coastal landscape elements Example1: **Beach face with**				
Category 1	Category B	Category C	Category D	Category E
< 15 m	**15-30 m**	**31-45 m**	**46-60 m**	**> 60 m**
Weighting factor: **0.08**	Weighting factor: **0.2**	Weighting factor: **0.2**	Weighting factor: **0.12**	Weighting factor: **0.4**

2.2. Safety and Security

Security is one of the fundamental attributes to measure the quality of a tourist destination because it represents one of the aspects that tourists consider when making their choice. Tourists usually prefer a place that can provide greater benefits from the psychological, functional and economic perspective. According to Grûnewald (1998), the main conscious and unconscious needs of the visitor when choosing a destination are the originality, quality, price and above all the safety that the place can provide. In the same sense, Short (1996) argue that environmental characteristics are important in preventing accidents on beaches because these aquatic environments are variable and continuously evolving (Abraldes & Rubio, 2005).

These environments present four major factors that can determine the degree of danger of a beach: the beach morphology, equipment and infrastructure, the rescue and first aid service and circumstantial aspects (Short, 1996). Therefore, a safe beach is defined as the one that provides conditions for the protection of life and physical integrity of users through the following services: a) rescue and first aid, b) emergency care at sea and land, and c) surveillance and monitoring personal protection to safeguard users from common crime and criminal acts. All these services are achieved through a join work among lifeguard corps, health personal, relief agencies and national police.

For reaching the aim of calibrating the safety/security parameter in the beaches of the Northern Caribbean Colombian, it was designed a tool for collecting information about the real threats affecting the study area. This pre-instrument was a structured interview address to the staff responsible of the security issues on the beaches (members of the police, civil defense, Red Cross, lifeguards, doctors and nurses on duty at the medical center closest to the beach). With the information gathered at four beaches in the study area (Riohacha, Puerto Velero, Bocagrande and El Rodadero), a classification of the identified hazards was made according to the damages they cause. These hazards were included in 5 groups: natural, environmental, physical, biological, social and institutional (table 3).

Table 3. Hazard classification of beaches from interviews on the Caribbean coast of Colombian (from Botero, et al., 2014)

Natural	Environmental	Physical	Biological	Social	Institutional
Natural disasters	Microbiological pollution of water	Solar radiation	Invasive species	Criminal activities	Absence of lifeguards
Precipitations	Microbiological pollution of sand	Very high temperature	Marine animals	reckless behavior	Police Absence or insufficient surveillance of authority
Floods	Modification of sediment dynamics	Noise (intermittent or continuous)	Presence of birds and domestic animals	Harassment of street vendors	Absence of emergency and rescue services
Rip currents	Litter and hazard waste	Insufficient lighting on the beach		Ignorance of use regulations	Absence of first aid services
Waves	Atmospheric emissions from vehicles	Water turbidity		Lack of hygiene in food handling	Lack of safety measures and risk management
Landslides	Sewer presence			Increased carrying capacity	Informal provision of tourist services
Coastal erosion					Lack of medical centers nearby
Beach topography					Invasion of public space
Reefs, bedrock, cliffs					Absence of lifeguards

From this pre-sampling session, dully complemented with a detailed literature review, it was developed a measurement instrument to assess real risk on tourist beaches. This tool consists of a quantitative matrix inspired on the methodology for risk assessment at the workplace proposed by the Colombia Technical Guide No. 45. This scheme was adapted for quantifying the risk on the context of tourist beaches, incorporating variables such as the level of impairment (relationship between hazard , its consequences and preventive action), the exposure level (user contact with the hazard), level of probability (likelihood of occurrence of a hazardous event), level of consequence (results in terms of injury or illness after the materialization of risk) and the risk level (combination of probability level with the level of consequence). The above variables are combined to yield a score that indicates which risk level (low, moderate, high or extreme) describes the evaluated beach and the resulting equivalent level of safety/security.

Besides the real risk assessment, the measurement instrument for the parameter of safety/security is complemented through a perceived risk assessment. This section of the instrument was based on the design of a concise survey that allows beach users to assess the risk level of the beach they visit. A small sample of beach visitors are invited to score the risk level (zero, low, moderate, high or extreme) they consider to be exposed to from a list of possible threats.

With the ongoing implementation of this combined instrument, it can be obtained relevant information about both perceived and real risks that arise in the beaches of the Northern Caribbean Colombian. The detailed monitoring of this parameter would be a quality warning system for authorities and managers of the beaches, orientating them on the definition and implementation of appropriate management measures.

2.3. Urbanization

Urban development in the coastal zone seeks for the incentive of foreign investment, job creation, tourism development and the presence of transnational companies (Talesnik & Gutierrez, 2002). Current needs increases the demand for building sophisticated facilities along coastal edges which induce changes in land use, combining outdoor areas with seawalls, sometimes parks, and shops and often malls, as well as cafes and restaurants (Breen & Rigby, 1996; Talesnik & Gutierrez, 2002). Recreational buildings are often located in this edge, such as aquariums, amusement parks and yacht marinas, as well as stablishments for cultural purposes like theaters, concert halls and cinemas (Benseny, 2008).

In this way, traditional activities are replaced by implementation models that come along with the tourism development; thus the urbanization process accelerates and the coastal land configuration is then specialized. Although the rapid development of tourism brings positive economic impacts, when implemented inadequate tourism models, this economic activity becomes predatory of the environment and its resources (Benseny, 2008).

Within the ICAPTU project it has been the parameter "Urbanization" in proposed for assessing the real relationship between the urban coast and the quality of the landscape and environmental resources. To achieve this goal it was applied the methodology of "focus group" described by Hurtado (2010). This exercise of collective intelligence gathered the criteria of experts in the field of construction and environmental sciences, such as environmental engineers, architects and civil engineers to define the concept of urbanization, as well as identify and assess the environmental impacts associated with the construction and civil structures in the beaches of the Northern Caribbean Colombian.

The calibration process began with an active literature review of scientific articles and technical documents related to the term "waterfront" and the impact of coastal structures, as well as related information supporting the research. In order to consolidate an articulated and unbiased definition of "urbanization", there were integrated extracts of the technical review along with the arguments provided by the experts consulted from their owns specialties. As a result, the terms Urbanization was defined as the effect of the construction or civil structures present on the beach, which produces a negative or positive contrast with the landscape and ecosystem functionality when satisfying the human need for leisure. They were also defined and characterized the following typologies of urbanization: 1) Undisturbed natural beaches, 2) Natural beaches or minimally altered, 3) Moderately urbanized beaches or stiffened, 4) Stiffened beaches and 5) Beaches with a high degree of stiffening.

Besides the definition, the calibration process requires the design of an instrument for measuring this parameter in the field. Initially, it was built up a pre-instrument using the effect matrix format described in the simplified methodology of Conesa (2003) for environmental impact assessments (Gómez-Orea, 2007). After filtering the information of the literature review, the matrix collected evidences of the impacts due to infrastructure present on the coast, classifying them within the two dimensions: landscape and environment (table 4). This matrix was the tool used in pre-sampling sessions performed in 4 beaches of the study area, each one from a different municipality of the Caribbean Colombian and representing a different urbanization typology.

Table 4. Impacts or effects associated with the presence of buildings and structures on the beach (from Botero, et al., 2014)

Environmental dimension	Landscape dimension
• Solid waste generation • Atmospheric emissions • Discharges • Migration of species (disturbance) • Habitats (changes and fragmentation) • Changing sediment dynamics • Microclimatic variations • Modified waves • Noise pollution • Soil sealing	• Visual intrusion • Changes in natural morphology • Human concentration • Employment generation • Loss of vegetation cover

The diverse group of experts convened in each beach during the sampling exercise engaged in a discussion session concerning the presence/absence, relevance and improvements of every impact registered on the matrix. When visiting every beach, experts were asked to rate the impacts identified in relation to the 11 evaluation criteria established by Conesa (1993): nature, intensity, extent, moment, persistence, reversibility, synergy, accumulation, effect, periodicity and recoverability. After verifying and evaluating the impacts applicable to the beaches of the study area with the expert team, the formats were adjusted according to the outcomes of the focus group.

As a result, the final instrument for measuring the urbanization parameter in field consists of a list of environmental and landscape impacts with the corresponding importance assessment; these values were calculated from the average of the ratings assigned by each expert during the pre-sampling exercise. Also, given that the urbanization parameter belongs to a recreational indicator, its assessment is complemented by the user’s perception. The checklist describing the final instrument includes an additional “perception” item that represents the value that tourists and visitors give to the type of urbanization characterizing the beach in evaluation.

2.4. Zoning

In order to facilitate the management of beach space, a strategic plan is required concerning beach zoning and the organization of local stakeholders, such as, beach users, peddlers, life-guards, fishermen, etc. Such kinds of studies were carried out in Spain over a decade ago, whilst in Colombia the topic has been developed only in the past few years (Yepes, Sánchez, & Cardona, 2004; Botero, 2008; Herrera, 2010). In this sense the calibration of the zoning parameter for Caribbean Colombian beaches represents an effort for integrating the different dimensions of this concept. Zoning parameter pretends to evaluate the environmental quality of the tourist beaches within its role as satisfier of the human needs for leisure and recreation.

The most known antecedent is a study titled "Beaches: models, types and suggestion for its management", in which two types of spatial arrangement for Spanish beaches were proposed, e.g. lateral and cross-section zoning. This study clearly explained the proper way for establishment of different areas in a beach, according to the main types of usage, which include a variety of activities ranging from recreational and sports to economic or contemplative (Botero, Anfuso, Williams, &

Palacios, 2013). Therefore, the zoning parameter encompasses the spatial arrangement of physical elements and services to reduce the negative interactions amongst them.

This concept also includes all the features and attributes that give the beach the adjective of "organized", such as when vendors at the beach are uniformed in order to make it easy for the users to identify them. Also, beach zoning can be considered as an aggregation of four fundamental components supported on the most important variables in the coastal zone: spatial planning or zoning, regulation order, commercial order and user order.

The methodology used for calibrating the zoning parameter was based on the format provided in the Basic Guide for Certification of Tourist Beaches, proposed by Zielinski & Botero (2012). This document presents the use of checklists for assessing the status of a tourist beaches in an easy, quick and accurate manner. The calibration process included the design of the instrument by which the data were taken to measure the degree of organization of a beach. Initially there were identified those elements or factors that characterizes an organized beach, according to a comprehensive literature review along with field visits. This preliminary list is then evaluated by experts of the Iberoamerican Network of Beach Management and Certification (Proplayas, Spanish acronym) through a virtual tool in the shape of a survey. Using the Q-Sort technique, the zoning factors were organized in an ordinal way, which means ordering them from the "most important" to "least important". As a result there were structured a checklist of the zoning factors with the importance scores established by the expert group.

The final instrument consists of a checklist that gathers the definitive zoning factors distributed in their respective typologies (table 5). Field assessment of the parameters comes when the evaluator registers in this checklist the presence or absence of the elements; then, the interpretation of the information is made out of the protocol and method sheet accompanying the instrument. The maximum environmental quality on a beach occurs when it presents all the zoning elements identified and the minimum quality comes when there is none. Intermediate values correspond to certain configurations of present elements; the values of environmental quality within them vary according to the importance assigned to the checked items.

Table 5. Zoning Factors defined for measuring recreational quality at the Caribbean coast of Colombian (from Botero, et al., 2014)

Spatial organization	Regulations	Commercial organization	Beach users organization
• Green zones • Parking lot • Tourism services area • Public space binding site • Transition area • Users resting area • Users active area • Bathing area • Nautical sports area • Area for vessels transit • Vessel parking area • Promenade • Beach access • Signing • Sports and recreational facilities	• Respect for beach public use • Absence of discharges • Solid waste management • Lifeguard service • Presence of trash cans Cleaning periodically • Non-cemented structures • Ornamentation with native plants • Beach management	• Peddler identification • Forbidden animals at food courts • Clean sales sites • No disturbing advertising activities • Legality of goods • Hygiene and sanitation with products • Access to potable water	• Carrying capacity • Beach information board • Code of conduct • Tourist information points • Safety recommendations

3. GEOSPATIAL TECHNIQUES FOR MARINE AND COASTAL STUDIES

Geospatial Techniques, refers to all available means for generating, organizing, storing and analysing spatial information, which may include advances in geodesy, photogrammetry, geophysics, computer science, statistics, remote sensing and geographic information systems (GIS) (Klemas, 2009; Bishop, *et al.*, 2012). Remote sensing in particular has been largely applied to the study of coastal systems, ranging from observation of physic-chemical (suspended sediments, yellow matter, chlorophyll) and hydrological parameters, through ocean processes affecting the seashore, as well as detecting changes of land use/cover, landscape, or ecosystems (Klemas, 2011).

Now days these applications are going beyond bare-earth representation and considers the effects of human interventions projected on anthropogenic structures, vegetation canopies and short-term changes in terrain (Mitasova, *et al.*, 2012). There are several sensors available for retrieving data, which differ from platform (aircraft, satellite...), mode (active and passive), application (imagers, profilers...) and wavelength range detection (Klemas, 2009).

However this classifications or the kind of resources for dealing with spatial information mentioned above, this section will describe most common geospatial techniques applied for marine and coastal environments. For the purposes of this exploratory research, such techniques would be sectioned in five groups according to the mechanism for acquiring data and/or information. The groups have been catalogued as satellite borne, air borne, in situ measurements, video cameras -as an automatic in situ sensor- and finally the popular geographic information system as the versatile approach for manipulating spatial data.

Along the analysis there must be considered some notions commons to all the categories related with the kind of detail levels among the geographic data, known as resolution; this characteristic may be also tied with the scale of the analysis. There is (a) the spatial resolution which represent the smallest ground surface that can be represented in terms of length by each picture element (pixel); (b) the spectral resolution refers to the amount of specific wavelength interval that can be recorded by a sensor and its width; (d) the radiometric resolution defines the ability of a sensor for distinguishing objects of similar reflectance by having enough values to represent it, such as the 256 values available with 8 bits resolution; and (e) the temporal resolution is related with the frequency of data acquisition from the area of interest (Klemas, 2011).

3.1. Satellite Borne Data Acquisition

Satellite sensors provide means of measuring the electromagnetic energy reflected by an object on the Earth's surface as well as in the atmosphere. They may offer good stability, capability for repeated measurements, potential of global coverage and varying spatial resolution. Geostationary satellites maintain a fixed position over an area of the Earth, being appropriate for continuous monitoring of the environment which counteracts with the low spatial resolution. Satellites which orbit the planet along fixed paths watch over large portions of the globe, but at the cost of long delays between consecutive surveys of the same area (Marcin & Marek, 2012). Some parameters for some satellite missions are summarized on table 6.

Table 6. Comparison of satellite parameters (adapted from Klemas, 2011)

Parameter	Spectral Band	IKONOS	QuickBird	OrbView-2	OrbView-3	WorldView-1	GeoEye-1	WorldView-2	Landdat 7	NOAA
Sensor			BGIS 2000	SeaWiFS					TM	AVHRR
Spatial resolution (m)	Panchromatic	1	0.61	1100	1	0.5	0.41	0.5	15	1100
	Multispectral	4	2.44	n/a	4	n/a	1.65	2	30 - 60	n/a
Spectral range (nm)	Panchromatic	525-928	450-900	n/a	450-900	400-900	450-800	450-800	520-600	n/a
	Coastal blue	n/a	n/a	404-453	n/a	n/a	n/a	400-450	n/a	n/a
	Blue	450-520	450-520	480-500	450-520	n/a	450-510	450-510	450-514	n/a
	Green	510-600	520-600	500-565	520-600	n/a	510-580	510-580	525-605	n/a
	Yellow	n/a	n/a	n/a	n/a	n/a	n/a	585-625	n/a	580-685
	Red	630-690	630-690	660-680	625-695	n/a	655-690	630-690	630-690	n/a
	Red edge	n/a	n/a	n/a	n/a	n/a	n/a	705-745	n/a	n/a
	NIR	760-850	760-890	745-885	760-900	n/a	780-920	770-1040	750-900	725-1100
Swath width (km)		11.3	16.5	2800	8	17.6	15.2	16.4	180	2400
Revisit time (days)		2.3–3.4	1–3.5	1	1.5–3	1.7–3.8	2.1–8.3	1.1–2.7	16	2
Orbital altitud (Km)		681	450	705	470	496	681	770	710	1100

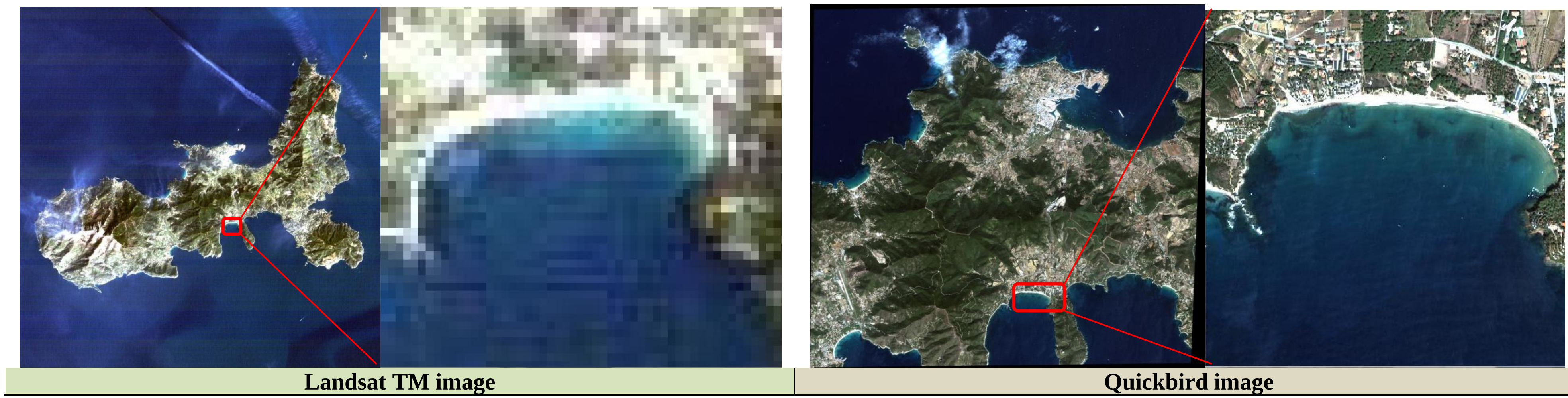


Figure 5. Elba Island (Italy) observed from multispectral imagery with a real color composition through the three spectral bands: red, green and blue (RGB). The original image and the magnified section of the same beach illustrate significant difference in the level of detail according to the spatial resolution of the satellite.

The values in meters for spatial resolution referred in table 6 indicate the ground length in meters represented by each pixel of the image. This means that for a Landsat TM image every pixel of the image represents a cell of 30 m long x 30 m wide of earth's surface, which also means that every object smaller than this dimensions, or even with similar dimension, is going to be represented by a single digital value that would be mixing the reflectivity of all the objects contained in this cell sized pixel. This loss of details is mainly related with how far from the Earth is orbiting the satellite; in the case of Quickbird the orbital altitude is almost half of Landsat, and its spatial resolution is 2,44 m. Images in figure 5 highlight such scale difference by presenting original size multispectral images of both satellites and the same magnification over a portion of the image representing the same beach.

Satellite imagery systems are the most representative technology associated with remote sensing; however this second term is more comprehensive because it implies all techniques for the acquisition of information about an object without making direct contact with it through the use of sensor technologies (Chan, 2011). Aside from on field collection of measurements or samples, most of the upcoming technologies fit such description since they intent to suppress any direct contact with the earth surface. By distinguishing satellite borne among this wide range of technologies it has been summarized a common mechanism in which different data is collected and represented (table 7).

Table 7. Marine and coastal studies based on sensor data retrieved from satellite borne geotechniques.

Sensor data by Spectral range	Coastal Applications	References
Visible and NIR Multispectral Hyperspectral Panchromatic Imagers (film/array)	**Mapping land cover**	Klemas, 2011; Huang & Klemas, 2012; Lipakis, *et al.*, 2007
	Coastal wetlands (mangroves)	Seleh, 2007; Pengra, *et al.*, 2007
	Coastal Forest dynamics	Baskent & Kadiogullari, 2007
	Quality of coastal ecosystems	
	submerged habitats (seagrass, coral reefs)	Klemas, 2011
	Modeling recovering rates	Viedma, et al., 1997
	Monitoring tidal wetlands	Nayak, et al., 1989
	Biological productivity	Klemas, 2011
	Water constituents	
	Chlorophyll	Klemas, 2011
	water pollution (oil spills)	Ahn, *et al.*, 2006
	suspended particles (turbidity)	Klemas, 2011
	dissolved substances	Klemas, 2011
	Geomorphology	
	Shoreline detection	Yang, et al., 2012; Lipakis, et al., 2007; La Monica, *et al.*, 2007; Iandelli & Pranzini, 2007; Crawford, *et al.*, 2013
	Coastal landforms changes	Siddiqui & Maajid, 2004
	Oceanography	
	Open ocean color	Klemas, 2011
	Recreational use	
	Dry beach availability	Yang, et al., 2012

Continuation Table 7

Sensors	Coastal Applications	References
Visible and IR Radiometer	**Water constituents**	Klemas, 2011
	phytoplankton concentration	
	surface water turbidity	
	Oceanography	
	sea surface temperature (SST)	Klemas, 2011; Klemas, 2009
	current patterns	Klemas, 2011; Klemas, 2009
Thermal IR Scanners	**Oceanography**	Klemas, 2011
	sea surface temperature (SST)	
	surface heat flux	
	chart coastal currents	
Microwave Radiometer/ Imager	**Oceanography**	
	sea surface temperature (SST)	Klemas, 2011, Klemas, 2009
	surface heat flux	Klemas, 2011
	Hydrologic parameters	Klemas, 2011
	Environmental conditions	
	sea surface salinity (SSS)	Klemas, 2011; Klemas, 2009
	Soil moisture	Klemas, 2011; Klemas, 2009
	Precipitation by water vapor	Klemas, 2011; Klemas, 2009
SAR Syntetic Aperture Radar	**Water constituents**	
	Oil slicks detection	Brecke & Solberg, 2005; Jensen, 2007
	Geomorphology	
High resolution images	Shoreline detection	Erteza, 1998; Chen & Shyu, 1998; Trebossen, et al., 2005; Wu & Lee, 2007; Cerimele, *et al.*, 2009
	Oceanography	
	Swell patterns	Klemas, 2011
	Internal wave patters	Klemas, 2011

Looking at the first column of table 7 from up to down, the kinds of sensor data representation also show how wavelength range detection increases. The first group, imagers, corresponds to the kind of sensors that generate two dimensional images that can be transformed into maps for enhancing the distinction between on ground features. In this first group there are considered sensors able to collect the reflected solar energy from the Earth surface within the section of the electromagnetic spectrum corresponding to the visible light. This radiance information are collected in several bands able to detect only a section of the electromagnetic spectrum; the narrower the spectral bands the higher should be the amount of bands in order to collect all the information of the visible section of the spectrum (~400-700 nm).

Multi and hyper spectral images are just a collection of images (array) that can be over hundreds of narrow spectral bands. Panchromatic images, on the other hand, come from a single wide spectral band, which allows higher spatial resolution than multi spectral because more radiance energy can be recorded from smaller areas. Images in figure 6 represent section of an Ikonos image taken simultaneously in multispectral and panchromatic bands. The reduction on the level of detail on the true color composition with respect to the panchromatic images explains why the last ones are preferred for identifying the water-land limit; even wet and dry sand can be visually distinguished.

Figure 6. Comparison between multi spectral and panchromatic images taken from Ikonos.

The differentiation of the radiance within several sections of the spectrum, possible with multi and hyper spectral images, allows the identification of features on the ground by the recognition of spectral signatures. The characteristic behavior of certain surfaces along the electromagnetic spectrum allows representing the characteristics of the surface; water for example can be distinguished from any other surface because of low or null values on the infrared (IR) band (figure 7). Such characterization enables technicians to represent the distribution of objects on earth surface onto malleable screens (paper or digital), which can be turned into maps.

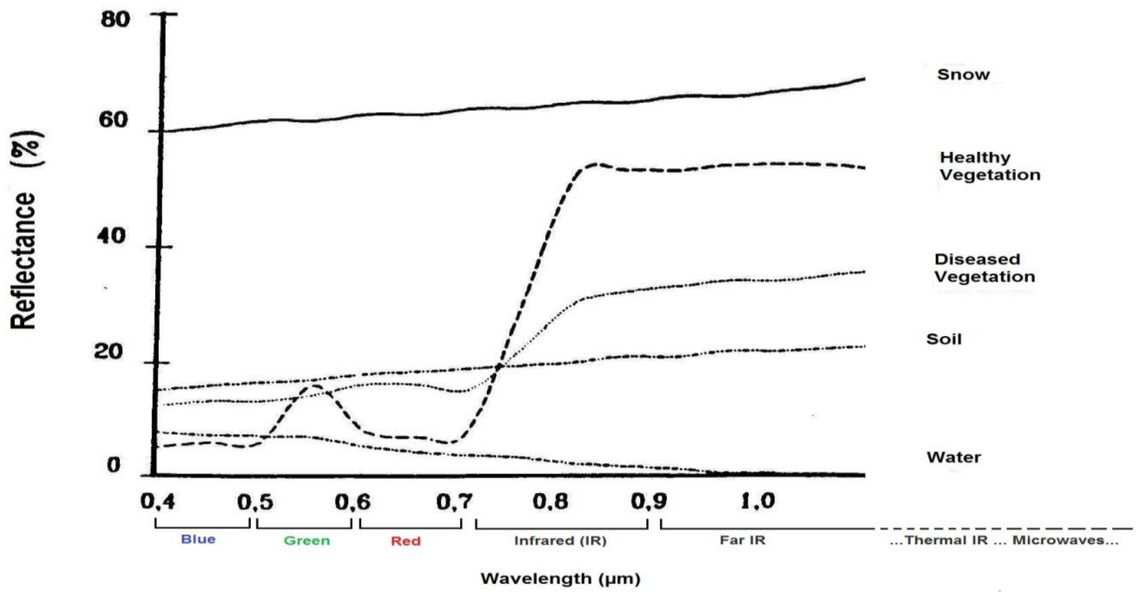


Figure 7. Spectral signature; generic representation o comon terrestrial surfaces.

Among the applications registered on table 7 for the group of imagers, there is the distinction of land cover in coastal areas, the quality of the marine environment in terms of the state indicators of their characteristic ecosystems (healthy vegetation, coverage, abnormalities…); coral reefs and general bottom characteristics requires images with good spatial and spectral resolution (Klemas, 2011). Likewise, very particular applications that take advantage of the level of detail extracted from images to represent water and land attributes are useful for studies in the fields of oceanography and geomorphology.

The next group of sensor data from satellite is radiometers that are mainly referred to sensors detecting on the spectal range of the IR, although they record also in the visible. This kind of data is more appropriate for oceanographic because they are able to differentiate patterns in ocean waters. One example of this on satellite sensor is the Advance Very High Resolution Radiometer (AVHRR) deployed by the north American agency NOAA (National Oceanic and Atmospheric Administration), whose applications works well for meteorological purposes; figure 8 contains the image of the northern Sicily captured within the red band on the sensor, cloud formations are visible in the left side.

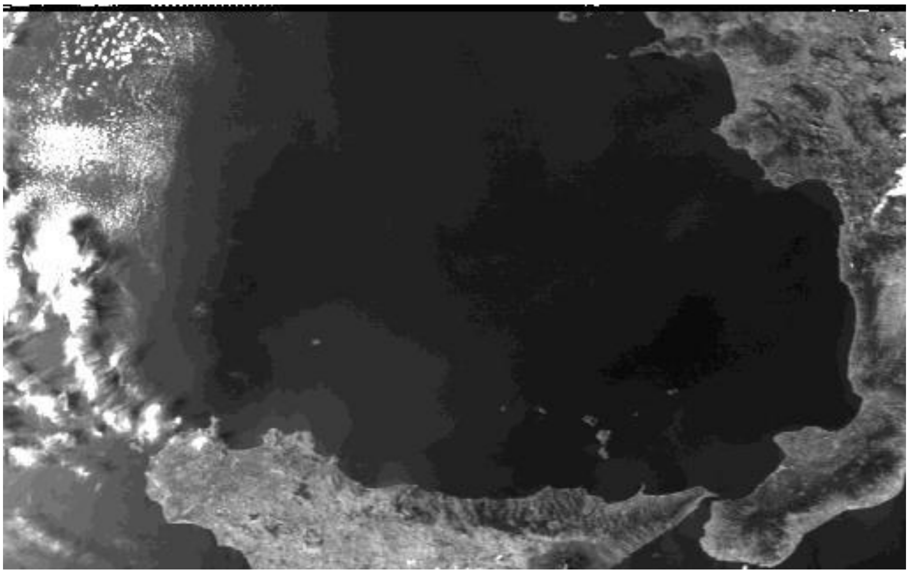


Figure 8. Image of northern Sicily (Italy) captured by NOAA satellite with the band 3 of the sensor AVHRR.

Within the group of thermal scanners, the data is records within the IR spectrum representing changes in temperature; in this case the energy recorded is not the one reflected but the one emitted from objects on the ground that have absorbed the solar energy and re-transmits it in the way of heat. The advantages of thermal measurements within the satellite systems rely in the fact that thermal IR does not require day light for recording signals, unlike sensors working on the visible, so image acquisition is not subjected to the position of the natural illumination. The information recorded with these sensors is especially adequate for oceanographic applications since the physical properties of the water here detected make it possible to represent patterns on the sea surface.

The fourth group on table 7 is classified for the spectral range rather than the data representation. This kind of data register signals with longer wavelength and consequently lower frequency (microwaves); from natural light the amount of energy reflected in these spectral range is much lower that shorter wavelengths so satellite sensor require bigger areas to perceive enough energy able to activate them. Although there are passive sensors recording on this wave range, most common are microwave data obtained from active sensors that instead of waiting for weak sun energy reflected, they send their own signal within this wavelength to ensure sufficient energy intensity for receiving a reflected signal. This characteristic makes data from this sensor mostly adequate for oceanographic application and the observation of environmental conditions through the interpretation of variables like sea surface salinity or temperature (SSS/SST). For instance changes in salinity in the ocean may indicate the presence of fresh water sources like a river plum; these inputs are frequently related with the transport of natural and manmade river-borne pollutants that modify the marine ecosystem (Klemas, 2011).

Synthetic Aperture Radar (SAR) also generates images but belongs to the family of active sensor that works on the part of the electromagnetic spectrum representing microwaves. The spatial resolution of SAR images is about 0,1 - 0,3 m. As for out space platform, this sensor have the same principle of a conventional radar. This family of sensors is better mentioned in the following air borne geotechniques category since the variations of this technology for near shore studies are mostly deployed airborne (Klemas, 2013). Satellite altimetry is specially used for monitoring ocean surface conditions (sea level, tides, currents) because it produces instantaneous measurements of the sea surface heights relative to a reference surface (geoid) (Klemas, 2011). The preferred application of SAR images is related with oil slicks detection and tracking because of the quality of this data source for capturing the roughness of the sea surface under normal and oil slick conditions, allowing even the distinction from different oil densities (Klemas, 2009).

Considering all this possibilities of data capture and representation, there are also multiple processing approaches for deriving useful information within the different applications found. Table 8 summarizes only some of the main processing approaches mentioned for the use of satellite derived data. Several software are used for image processing such as ENVI©, ERDAS© or BILKO©, among others, who are able to deal with the characteristics of spectral information. Independent from the final application, raw data must be radiometric and geometrically corrected as a pre-processing step that can be done either from the supplier of the images or the final users. The first correction reduces the influence of atmospheric distortions and sensor anomalies and the second one make the adjustments to compensate earth's rotation along with the position of the sensors platform by the computation of the unknown parameters of the mathematical functions for the geometric correction model (Lillesand, Kiefer, & Chipman, 2008).

The rectification is another elemental transformation considered as a preparation for future analysis, which implies the translation of the digital image coordinates into geographic coordinates in terms of latitude and longitude. Lipakis, et al (2007) mention some steps for orthorectify an image starting from the acquisition of Ground Control Points (GCPs) for correlating image coordinates and map coordinates, followed by the use of an appropriate digital elevation model. The authors used the orthorectified imagery for extracting the shoreline at different time periods and comparing their relative position. This kind of temporal analysis is common when analyzing the evolution of the water/sand limit and the morphological implications on the beach. Iandelli and Pranzini (2007) compared different processing approaches, including band rapport and normalized difference between digital values of the spectral bands, concluding that the good accuracy of shoreline extraction can't be standardized because determinations are subjected to sedimentary and geomorphological characteristics of the study area, like sand color and beach slopes.

Table 8. Processing approaches commonly used on satellite born data

<table>
<tr><th colspan="2">IMAGES</th><th rowspan="2">Characteristics</th><th rowspan="2">Usual Application</th><th rowspan="2">Processing Approach</th><th rowspan="2">References</th></tr>
<tr><th>Platforms</th><th>Acquisition device/system</th></tr>
<tr><td rowspan="5">Satellite imageries</td><td>Landsat TM</td><td>spat.res: 30 m Multispectral
15 m Panchromatic
revisit: 3 days
rad.res: 8bits(256DN))</td><td rowspan="4">Shoreline detection

Coastal landform changes

Mapping tidal wetlands

Land use/cover map</td><td rowspan="5">- Multiband thresholding for image classification
- Tasseled Cap Transformation
- Band rapports
- Hierarchical classification

- Pan-sharpening
- Normalized Difference Vegetation Index

- Water Index
- Color normalized sharpening (CNS)
- Visual interpretation
- Spectral-value based technique (differencing, image regression, DN value analysis)
- Change vector analysis

- Multi-data composite</td><td rowspan="5">Lipakis, et al., 2007; Iandelli & Pranzini, 2007; Yang X. , 2009; La Monica, et al., 2007; Crawford, et al., 2013; Scherner, et al., 2013</td></tr>
<tr><td>Ikonos</td><td>spat.res: 4 m Multispectral
1 m Panchromatic
revisit: around 3 days</td></tr>
<tr><td>Quickbird</td><td>spat.res: 2.44 m Multispectral
0.6 m Panchromatic</td></tr>
<tr><td>SPOT (Système Pour l’Observation de la Terre)</td><td>spat.res: 20 m Multispectral
10 m Panchromatic</td></tr>
<tr><td>MODIS (moderate resolution spectrometer)</td><td>rad.res: 12bits(4096DN)</td><td>ocean chlorophyll

sea temperature</td></tr>
<tr><td>Radar images (SAR)</td><td>ERS1 and 2

Envisat</td><td>spat.res: 30 m

spat.res: 30-100 m</td><td>Sea Wave length

Shorelines detection</td><td>Interferometric Syntetic Aperture Radar - InSAR</td><td>Massonnet & Feigl, 1998; Burgmann, Rosen, & Fielding, 2000</td></tr>
</table>

Considering a wider scale, to monitor land cover trends and ecosystem changes there have been analyzed time series of remotely sensed imagery. Acquired images will have changes in both time and spectral content so there have been used indexes to reduce the spectral information into one value, like the Normalized Difference Vegetation Index (NDVI); in this way the analysis is simplified to a single variable within a time series (Crawford, *et al.*, 2013; Klemas, 2011). The NDVI, for instance, is a simple algorithm designed for the evaluation of vegetation density and status that appears over the spectral contrast between Red and Near Infrared range. The index expressed as the difference between the red and NIR reflectance divided by their sum. These two spectral bands represent the most detectable spectral characteristic of green plants (Klemas, 2011).

Although the NDVI has been though for discriminating vegetation cover, this ratio also suit for identifying water bodies because the reflectance curve of water shows very low values, which tend to fall as the wavelength raises (figure 7). Water line determinations are usually based on the clear existing difference between the radiometric response of water and that of sand in the red and infrared wavelengths. Like water is the only natural element with this characteristic, it is immediately identifiable in multispectral images, which allows the operator to draw with more certainty over the image the line that represents the limit between water and sand (La Monica, et al., 2007). A continuous concern on near shore changes monitoring relates with the uncertainties derived from the subjectivity of image interpreters, so automatic shoreline detection processes are preferred.

One of these procedure applied by Iandelli and Pranzini (2007) for waterline extraction is graphically simplified in figure 9. In this experience the study site was selected from a high spatial resolution satellite image (frame 1), then sliced in two levels from which the water-land border is extracted with a high-pass filter (frame 2); this is an operation within the digital values of the image inside a matrix used for highlighting differences in opposition to the low-pass filters that intent to smooth or diffuse the differences. After filtering, there is a white image only with the black pixels on the locations defining the water-land border (frame 3), which is after transformed into a vector line adjusted in function of astronomical and baric tides and finally superimposed over the original image (frame 4).

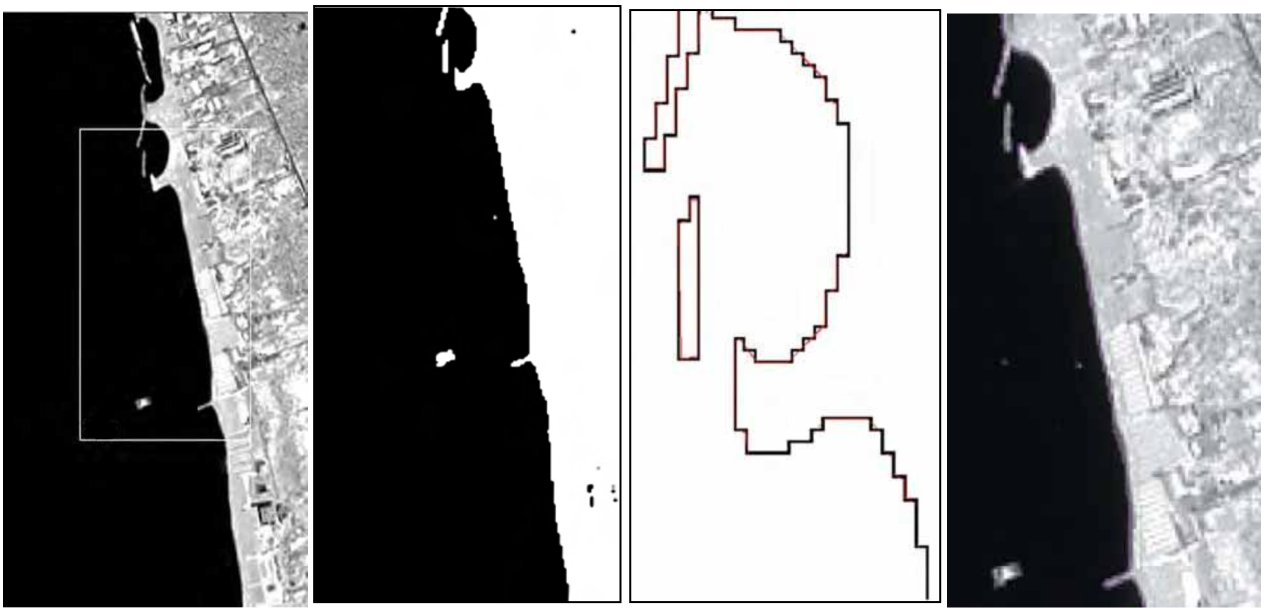


Figure 9. Waterline extraction procedure from an Ikonos image (Iandelli and Pranzini, 2007)

Traditional methods for beach observation include manual or digital photo interpretation and then there are more complex methods for image processing that requires expert operators, like Principal Component Analysis (PCA) and supervised classification for example. This last one considers the use of field data in order to categorize the groups of digital values (pixels) with similar characteristics with the corresponding surface verified on site. Even though this document does not intend to describe each processing approach, the aforementioned have the purpose of pointing out that field data collection is mostly required to calibrate and validate the remotely sensed information, and the accuracy for near shore processes is never better that traditional field surveys.

Ikonos and Quickbird satellite images, for instance, provide not only high-resolution and multi-spectral data, but also the capability for stereo mapping, which allows to get a perception of the surface relief through overlapping images. The cost of these high resolution images becomes excessive if the site is larger than a few hundred square kilometers; in that case, medium-resolution sensors, such as Landsat TM and SPOT, are more cost effective (Klemas, 2013). For larger sites, combining Ikonos and Landsat TM proved cost-effective and user-friendly if the Landsat TM imagery is used to map land cover for the large site and the Ikonos is used for detailed mapping of critical areas identified by Landsat TM (Klemas, 2011). Land cover classification of coastal areas, however may be problematic because it is difficult to obtain cloud-free image scene, the heterogeneity and small spatial size of the surface materials; the presence of complex urban impervious materials and agricultural lands, along with a variety of wetlands and vegetation, leads to significant sub-pixel mixing and a consequent poor distinction between individual features (Yang X. , 2009; Lipakis, et al, 2007).

3.2. Air Borne Systems

Essentially the same kind of data acquired from satellites can also be obtained from aerial platforms, which have been used to observe earth's surface even before satellites could be adequate for this purposes. All kind of sensors can be carried on an aircraft, such as scanners, radiometers, radars or simple digital cameras, which are capable of recording reflected VIS to NIR light. Aerial photography may be considered a technique based on a passive sensor deployed on aerial platforms like an aircraft or a drone (unmanned aerial vehicle). Georeferenced digital cameras providing color and color-IR digital imagery are particularly suitable for mapping coastlines and coastal land cover (Klemas, 2013). Further marine and coastal applications within airborne geo-techniques are listed in table 10, where sensor data has been distinguished according to spectral characteristics and operation.

For a single digital camera operation on an aerial platform, natural color (blue–green–red wavelengths) images can be obtained, as well as color-IR (green–red–near IR wavelengths) imagery when the camera is adapted to different configurations of spectral bands. When multiple cameras are deployed certain filters are used for capturing signals in narrower bands, simulating in this way specific satellite imaging bands. Even more complex sensor can be equipped in an aircraft, like the MIVIS (multispectral infrared and visible image spectrometer). As stated in the previous section, by analyzing the multispectral data it is possible to identify patterns by recognizing the spectral signature of objects or surfaces like water and vegetation. This property has been useful for mapping land and vegetation cover, together with monitoring of coastal ecosystems like wetlands corals and other aquatic flora.

Table 9. Marine and coastal studies based on sensor data retrieved from aerial platforms.

Sensor data	Coastal Applications	References
Photographs (Film/Imager) Multispectral	**Mapping land cover**	Huang & Klemas, 2012
	Quality of coastal ecosystems	
	Emerged wetland	Klemas, 2011
	Submerged vegetation	Klemas, 2011
	Vegetation changes	Crawford, *et al.*, 2013
	Geomorphology	
	Shoreline detection (beach erosion)	Klemas, 2011; Yang, *et al.*, 2012; Ryan, *et a.l*, 1991
	DEM generation	Mills, *et al.*, 2005
	Rip currents identification	Cerimele, *et al.*, 2009; Hapke & Richmond, 2000; Leatherman, *et al.*, 1994
	Recreational use	
	Dry beach availability	Yang, *et al.*, 2012
Radar (Scatterometer Altimeter) Microwave	**Oceanography**	
	Surface wind speed and direction	Ikeda & Dobson, 1995; Martin, 2004
	Significant wave height	Klemas, 2011
	Sea surface height and roughness	Ikeda & Dobson, 1995; Martin, 2004; Klemas, 2009
	Ocean currents and tides	Klemas, 2011
Light Detection And Ranging - LiDAR (Profiler) Visible and IR	**Geomorphology**	
	Digital Terrain and Elevation Models	Klemas, 2013; Bresci, et al., (StCst)
	Shoreline detection	Mitasova, *et al.*, 2012; Jensen, 2007 Lipakis, et al., 2007; Yang, *et al.*, 2012; Brock & Purkis, 2009; Saye, *et al.*, 2005
	map of sedimentary processes	Deronde,*et al.*, 2006
	Beach morphology	Yang, Madden, Kim, & Jordan, 2012
	hurricane induced beach change	Yang, Madden, Kim, & Jordan, 2012
	monitoring beach nourishment	Klemas , 2013; Gares, Wang, & White, 2006
	Environmental conditions	
	flood zone delineation	Klemas , 2013
	human impacts in the coastal zone	Yang, Madden, Kim, & Jordan, 2012
	Recreational use	
	Dry beach availability	Yang, *et al.*, 2012

Another group in table 10 refers to data obtained from active sensors working within the microwave. Radio Detection and Ranging (RADAR) transmits microwave (radio 1-10 cm) signal toward the target surface and measures the backscattered portion of the signal. According to the time delay between the transmitted and reflected signal and the strength of this last one it can be discriminated respectively the distance (range) of the target and the distinction between different targets (figure10). Altimeters and scatterometers are radar variations that don't generate images; they record in one linear dimension the return trip time delay of the backscatter to determine the distance from the signal source, so the output data requires specialized interpretation skills (Klemas, 2011; Klemas, 2009). This characteristic makes them profiling devices whose difference relies on the angle of emission of the signal which influence their main applications. Altimeters are looking straight to the ground surface (nadir) offering height estimations that depict topographic measurements, while the scatterometer has an oblique angle (side looking) which makes it more suitable for oceanographic application because the difference on the returned signal intensity represent physical ocean properties like wind waves and currents' patterns.

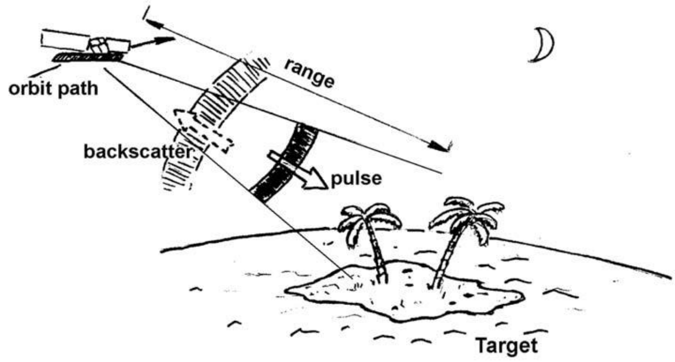


Figure 10. Principle of operation of a radar sensor (from IHO, 2005).

Another group of data obtained from aerial platforms, which also belongs to the category of active sensors, is the Light Detection and Ranging (LiDAR). It operates on the same basic principle as traditional radar, but uses laser as the detection medium. As a profiler, it accurately measures the distance between the instrument and its surrounding environment, and consists of three components: a laser-scanning device, an on-board GPS, and an inertial reference system (Bartlett & Smith, 2005). There can be differentiated terrestrial and bathymetric LiDAR according to the application; the first one is widely applied for topographic surveys in the generation of very precise digital elevation models - DEM (figure 11).

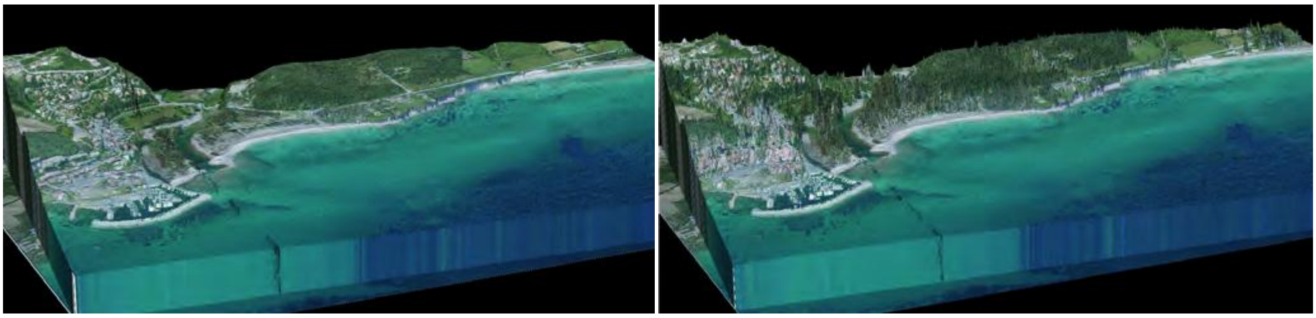


Figure 11. Examples of Digital Terrain Model (left) and Digital Elevation Model (right) (from Balouin, et al., 2013).

When digital representation corresponds to the shape of the ground, like if it were bare soil, there is a terrain model, but when the representation depicts also the elevation of vegetation and other revetments on top of the terrain there is a surface model. LiDAR systems are able to make such distinction by recognizing the difference in the delay of the retoured signal; the first backscattered pulse correspond to the taller surfaces (canopy or building) while the second indicates the ground. In the case of bathymetric LiDAR, the system uses two laser wavelengths: one red (532 nm), reflected by the water surface and one green (1064 nm), which penetrates the water column and is reflected by the seafloor (figure 12). This system is limited by the turbidity, so it is more effective for clear waters in the near shore.

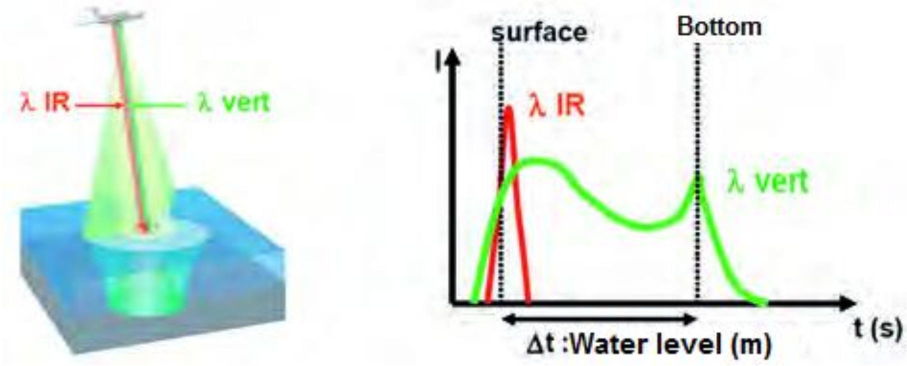
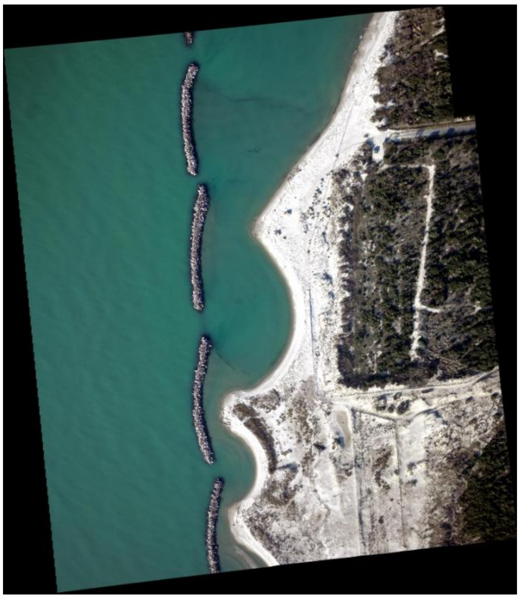


Figure 12. Principle of idrographyc LiDAR (from Balouin, et al., 2013)

Considering that almost the same information retrieved from satellite imagery can be also obtained from aerial platforms equipped with similar sensors, the biggest difference between these two systems rely in the spatial resolution. While the frequency in data acquisition from satellite depends on the orbital characteristics of the mission, aerial photography offers the flexibility of adjusting the time and frequency of data collection. In dynamic environments like beaches that are affected by sea level fluctuations due to tidal changes and surges, aerial photography has proved to be useful for shoreline delimitation (Yang, et al., 2012). Since flights can be programmed to capture images during different tidal conditions, it is possible to define more precisely high and low water level and so deriving conventional proxies for shoreline detection.

Flexibility on the spatial resolution is also possible when dealing with aerial platforms. The altitude of the flight determines the level of details that can be acquired; for mapping large coastal regions aerial photography is usually performed at high altitudes for representations at scale 1:100,000. Medium flights at scales of 1:1200-1:24000 are used for studying coastal ecosystems, while low flights are used to support field data collection for a scale 1:600; images in figure 13 compares the spatial resolution of low and medium height flights. For the evaluation of larger areas, aerial photographs from an airplane are more cost effective than the ones retrieved from small platforms like dirigibles, kitoons of drones (Klemas, 2013).

Photograph taken from a drone (5cm resolution)



Photograph taken fron an airplane (10 cm resolution)

Figure 13. Aerial photography from different platforms.

Compared to normal airplanes, drones offer a useful, safe, and less expensive way for studying remote and small areas. These unmanned aircraft can carry different instruments at a time, like radar and LiDAR or digital cameras and IR sensors. Since the flight range of the drone is limited (~2 km), several displacements on ground are required to completely cover big areas by segmented flights at fixed locations of towed along a transect. This way a small area could monitor from a fixed site as long as needed or large areas can be surveyed by making mosaics of the imagery (figure 14). An aircraft, on the other hand, can cover a larger stretch of coast in a single flight. Thus the output data, of a photographic camera for instance, is indifferent to the platform used, but the detection range and the level of detail required are the ones who influence the decision over one vehicle or another.

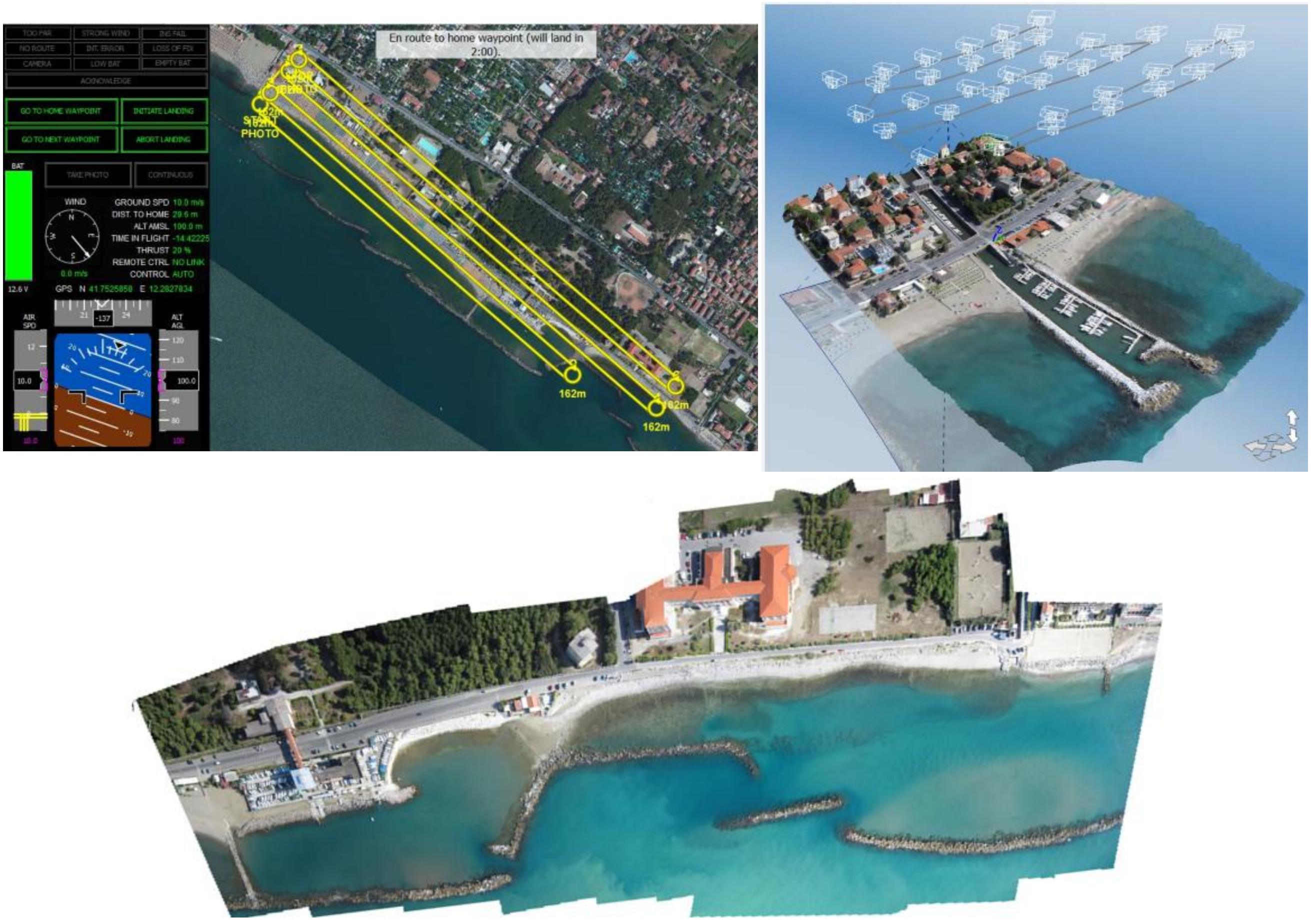


Figure 14. Mosaic of coastal area from the Italian locality of Massa (bottom) with a flight plan (up left) of a drone UAV equiped witha a digital camara that captured a set of digital photos (up right). (from Pranzini, 2012)

Concerning the processing of data obtained from airborne technology, table 11 present common approaches used for the principal applications. Photogrammetry and photo interpretation are the two basic techniques considered for image processing. The first one is defined as the obtainment of spatial measurements and other geometrically derived information from photographs, like distances, areas and elevations ((Lillesand, Kiefer, & Chipman, 2008). This technique allows objects to be described in three dimensions by overlapping images taken from adjacent places (IHO, 2005). Digital photography has the possibility of deriving photogrammetric accuracy and coverage, as well as multispectral data at good resolution, down to a 0.1 m. Thus, it provides photogrammetric positional accuracy with multispectral capabilities for image analysis and interpretation (Klemas, 2013).

Table 10. Processing approaches commonly used on air born data

IMAGES		Characteristics	Usual Application	Processing Approach	References
Platforms	Acquisition device/system				
Aerial photographs	Normal Photographic camera Lens filters for specific wavelengths Multispectral sensor	Resolution according to the height of the flight and defined program Spatial resolution: ~5cm-1m	Land cover distinction Mapping emerged wetland and submerged vegetation vegetation analysis	Similar of satellite imagery with spectral bands - Photogrammetric technique - Manual interpretation - NDVI (for vegetation)	Klemas, 2011; Yang, et al., 2012; Lipakis, *et al.*, 2007; Crawford, Marcucci, & Bennett, 2013; Mitasova, *et al.*, 2012; Massonnet & Feigl, 1998; Burgmann et al, 2000
Radar images	ERS1 and 2 Envisat	spat.res: 30 m spat.res: 30-100 m	Sea Wave length Shorelines detection	Interferometric Synthetic Aperture Radar - InSAR	
Light Detection and Ranging LiDAR		Vertical accuracy: +/- 15 cm	Shoreline detection Relief visualization in 3D Landscape patterns characterization	- Multiple surfaces combination (DEM) - Shading and illuminated surface - Traditional Contour - Interactive 3D visualization	

Several programs are able to make 3D representations of normal photographs, even from online applications (figure 15), but only more specialized softwares are able to integrate geographic data into three dimensional models able to provide accurate measurements. The 3D digital photomodeling technique allows the extraction of geometric information out of a three-dimensional cloud of point taken from photographys with a 60% of overlapping among themselves. Specific softwares for this application are able to find automatically the position of activation points in order to estimate the spatial position of each pixel on the image. For this purpose the geographic coordinates and elevation of the camera need to be recorded with a GPS at the time images are captured (Pranzini, 2013).

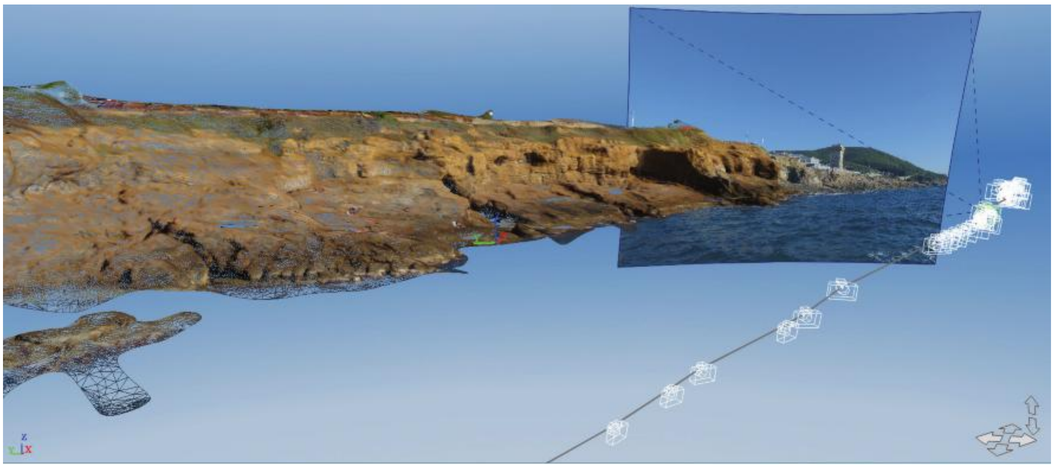


Figure 15. 3D elaboration of rocky shore with conventional digital photos integrated with the online application 123D. (from Pranzini, 2013)

When merging all the images there must be considered ground control points for obtaining an orthorectified mosaic by triangulation. With such precisions these software should be able to extract a cloud of points representing similar elevations and generate level curves, DTM and digital surface model on top of which orthorectified images are superimposed for a three dimensional representation of the surface (figure 16). For clear and shallow waters even photographs from simple digital cameras can be used for photogrammetic analysis within the submerged beach.

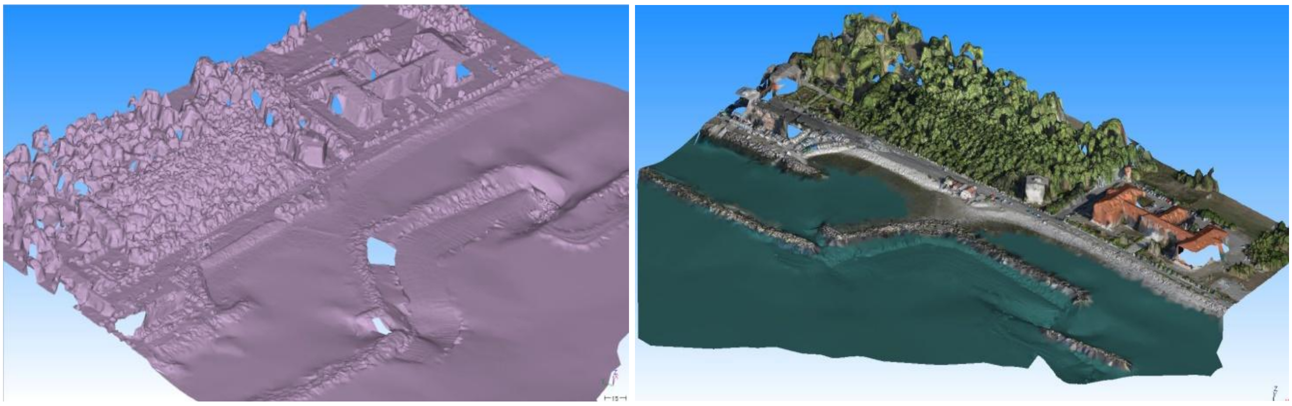
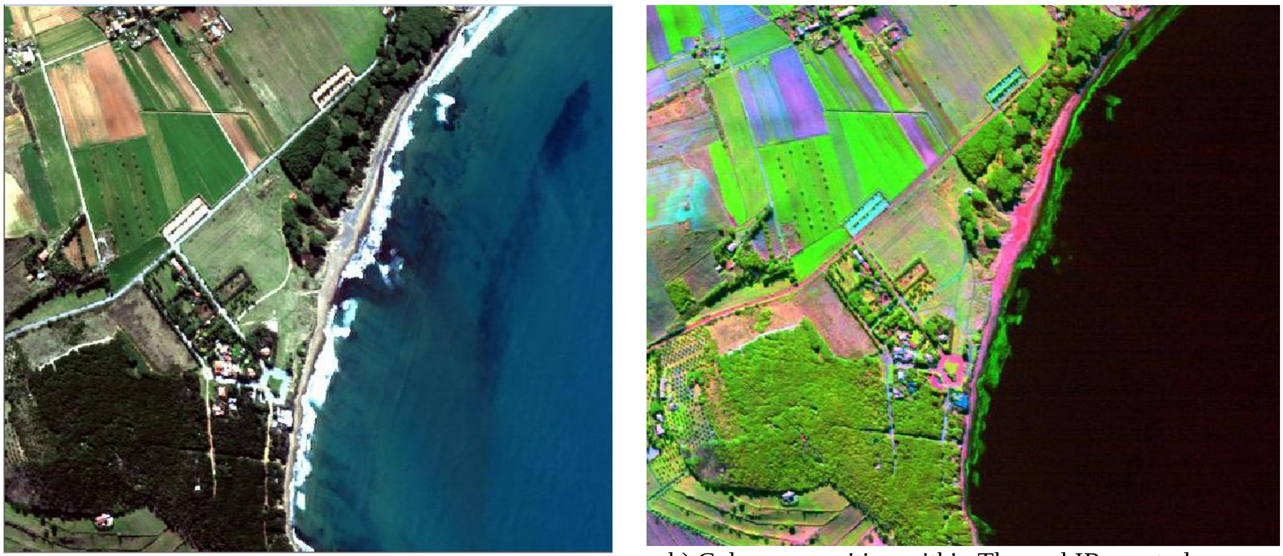


Figure 16. Three-dimensional representation with photogrammetry. DEM (left) and respective 3D representation (right). (from Pranzini, 2012)

Meanwhile, photo interpretation refers to the examination of photographic images in order to obtain a qualitative description of the surface through the identification of objects and features representing its characteristics, use or behavior (IHO, 2005). In simple terms this technique consist on identifying what it is on an image and communicating this information to other; but unlike the daily experience of interpreting common photographs, aerial and space images requires a systematic study that involves different basic characteristics within the image, such as shape, size, patterns, tone, texture and shadow. When interpreting aerial photos there must be considered some difficulties related with the unfamiliar perspectives, like how objects look from above, how are they represented with wavelengths outside the visible portion of the spectrum or different scale and resolution representations of the Earth’s surface ((Lillesand, Kiefer, & Chipman, 2008). So, one approach for analyzing data contained on multispectral images, for instance, consider different configurations of spectral bands in order to deduce phenomena or processes that are not evident at plain sight.

Since aerial photography may simulate satellite imagery with multispectral sensors, the treatment of their images is similar, including pre-processing and orthorectification. The large volume of hyperspectral image data requires the use of specific software packages, large data storage, and extended processing times (Klemas, 2013). The images in figure 17 represent an example of natural and false color composition of aerial imagery acquired with a multispectral sensor. When representing an image it can be combined maximum three spectral bands in the three channels available: Red, Green and Blue (RGB). When making a true color composition, the first channel (R) is assigned to one of the multiples spectral bands that capture the red position of the light, the second channel (G) is assigned to the green portion and the third one (B) to the blue.

When applying a false color composition different spectral bands are assigned to each one of the RGB channels. In figure 17b the RGB composition was assigned to three narrow spectral bands, thermal infrared (TIR), near infrared (NIR) and normal infrared (IR) respectively. This means that red pixels are hot surfaces, green pixels are representing healthy vegetation and blue pixels represent wet surfaces. Being all the bands within the infrared range all pixel representing water are black because the radiance record at this wavelengths for water is zero. With a deep knowledge on the meaning of radiation differences, the availability of multispectral images enhances the identification of near shore phenomena or processes.



a) True color composition

b) Color composition within Thermal IR spectral range

Figure 17. Multispectral images of the Tuscan Region taken from an aircraft with 1m of spatial resolution.

Medium or low-altitude flights have been used for mapping coastal geomorphology, shoreline positions, and dynamic features, including rip currents; LiDAR systems have also been applied with hyperspectral imagers to map wetlands, beaches and coral reefs (Klemas, 2013). However, the principal application of this air borne geotechniques at beaches concentrates in the distinction of the limit between water and sand. Analyzing beach width availability for tourist activity on a barrier island, Yang, et al., 2012 compared shoreline detection by simple interpretation of aerial photographs and LiDAR data (figure 18). This study highlighted that one of the limitations for shoreline delimitation with these techniques relies on the fluctuation of the sea level due to 1) tidal currents, which are influenced by the gravitational attraction of sun and moon; 2) surges, because this effect of low pressure water systems and strong winds blowing on shore increases water levels on the beach and 3) difficulties on representing highly dynamic tidal changes along narrow shorelines.

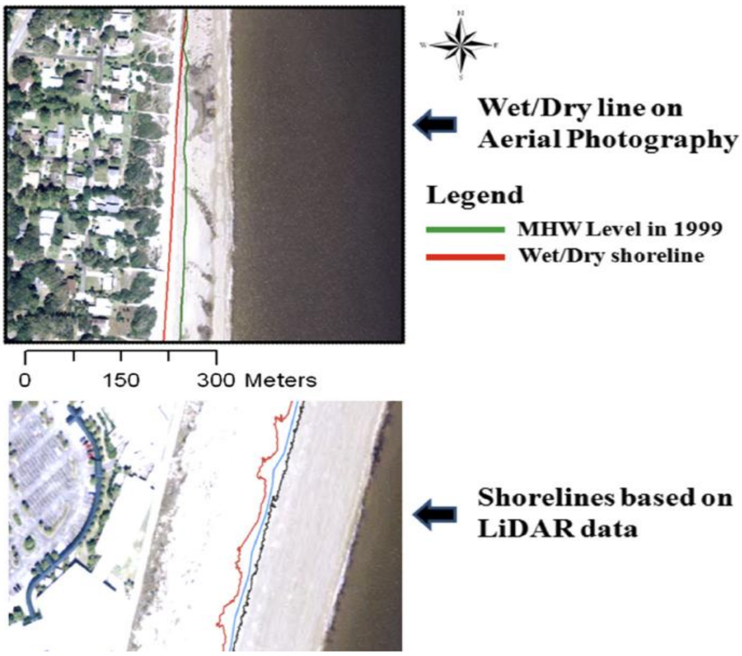


Figure 18. Shoreline detection with airborne techniques for estimating beach width availability. (from Yang, et al., 2012).

3.3. On Field Techniques

Within geospatial techniques, the on field category is here considered as the different kinds of measurements collected with conventional instruments in situ (table 11). Among the multiple applications of these instruments, the field of geomorphology concentrates the more pertinent ones at the beach scale. In situ measurements for monitoring the water surface displacement due to waves along with the associated flows and sediment suspension use instruments like pressure transducers, electromagnetic current meters and optical backscatter sensors (Davidson, *et al.*, 2003).

Table 11. Marine and coastal studies based on sensor data retrieved from in situ geotechniques.

In Situ Instruments	Coastal Applications	References
Laser Scanner	**Geomorphology**	Feagin, *et al.*, 2012
	Digital Elevation Models	Mills, *et al.*, 2005
	Landscape features	Mitasova, *et al.*, 2012; Pranzini & Rossi, 2013
Global Positioning System - GPS	Topographic determinations	Ortega, et al., 2007
	Shoreline position/delineation	Lipakis, *et al.*, 2007; Yang, et al., 2012; Osorio, Medina, & Gonzalez, 2012; Schiaffino et al, BM;J34; Pranzini & Rossi, 2013
	beach profile	Morton et al, 1993 (fron J19)
	Digital Elevation Models	Mills, *et al.*, 2005
Theodolite / Total Station	shoreline delineation	Yang, et al., 2012
	beach profile	Mills, *et al.*, 2005; Pranzini & Rossi, 2013
	Topography (emerged beach)	Pranzini & Rossi, 2013
Acoustic systems		
Multi/single beam, Sonar sound waves	Bathymetric surveys	J021; Mills, *et al.*, 2005; Pranzini & Rossi, 2013

As mentioned before, field surveys are commonly performed for calibrating and validating the measurements obtained by remote techniques because the high accuracy offered by on site instruments, combined with a proper design of the survey, offer a closer representation to the ground reality. The biggest inconvenience with these techniques relies on significant logistic efforts required in terms of personal for data collection and processing, equipment manipulation and coordination of sampling journeys.

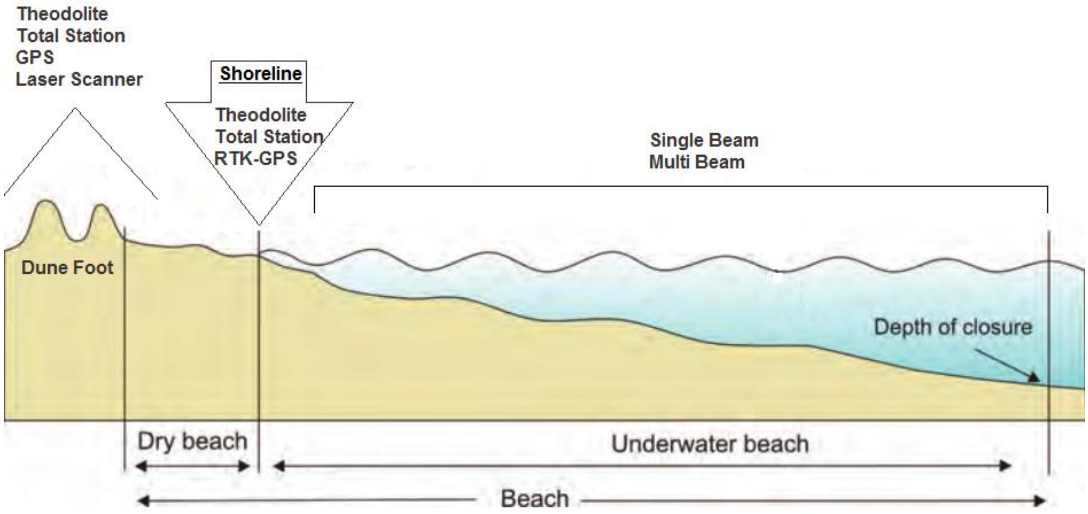


Figure 19. In situ instruments used on beach monitoring according to the profile sections. Adapted from Pranzini & Rossi, 2013

Laser scanner is one of the instruments used on the dry beach zone with great popularity since it allows obtaining accurate representations of the surface, including natural elements, like dunes, cliffs or rocky platforms, as well as artificial structures along the coast, like groins, breakwaters, artificial nourishments, normal buildings and so (Pranzini & Rossi, 2013). This on field instrument allows the acquisition of thousands of points per second with laser technology in order to generate thre-dimentional representations with similar precisions as traditional topographic techniques (Feagin, et al., 2012). This may be considered an active sensor with a similar operating principle as remote technique when the instrument is carried on board of a plane. However, in the on field version the scanner is fixed in land on a tripod or transported on a boat where it can be coupled with bathymetric instruments (figure 20). After the analysis in previous sections it is evident that the results offered by this technique are currently similar to those derived from remote images through photogrammetric analysis.

GPS derived techniques are based on the interpretation of several points located within the Earth's surface in the three dimensions in terms of latitude, longitude and elevation. The operation of this positioning system is based on the receipt of a radio signal sent from a set of artificial satellites; the higher the number of satellite signals received the better is the definition of a location by triangulation. The original system created by the Department of the Defense in the United States is formed by 24 satellites in near circular orbit around the Earth and has been projected to allow at every moment in every part of the world the three-dimensional positioning of objects, including whilst moving (IHO, 2005). Some variations on the operation of this systems offer the conditions for its several applications. Differential GPS and real time kinematic RTK-GPS are bases on the synchronized use of no less than two GPS receivers, one of them working as a still reference station responsible for transmitting corrections to the remote station used for surveying the area. These corrections can be applied in real time or in a post-processing step, once the data has been downloaded from the instruments, which allow the measurements to have a precision in the level of centimeters.

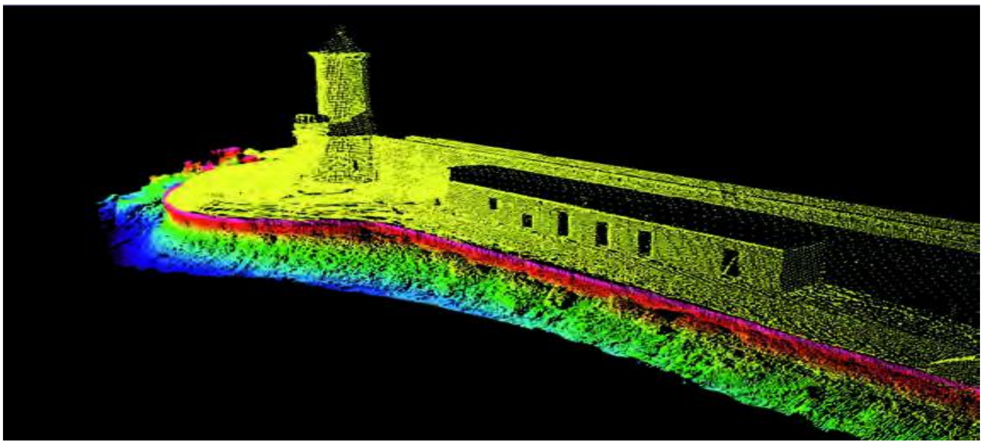


Figure 20. Thre-dimensional representation obtained from laser scanner and multi beam combined survey (from Pranzini & Rossi, 2013)

The kinematic mode of GPS is conceived for continuous monitoring by taking measurement along a trajectory. This characteristic becomes very convenient for extracting the shoreline since the RTK-GPS mode is able to registers the plane coordinates (latitude and longitude) right in the same instant when the instrument is reading a specific elevation. In order to overcome the difficulties in shoreline definition posed by the variability of the instant sea level, surveys are performed regardless the position of the water but considering a trajectory described by an isobaths, collecting the coordinates along a path with the same elevation; zero isobaths is the most appropriate because of its proximity to the end of the dry beach. As depicted in figure 21, the points should be recorded in pairs above and below the chosen isobaths so that the shoreline can be extracted by interpolation of these pairs (Pranzini & Rossi, 2013). In general elevation measurements for beach monitoring purposes can be done with GPS as well as conventional topographic instruments, like theodolite and total stations. However, the information presented within previous sections indicates that any remote or manual instrument should have integrated a GPS device in order to supply the required geographical reference element for geospatial approaches.

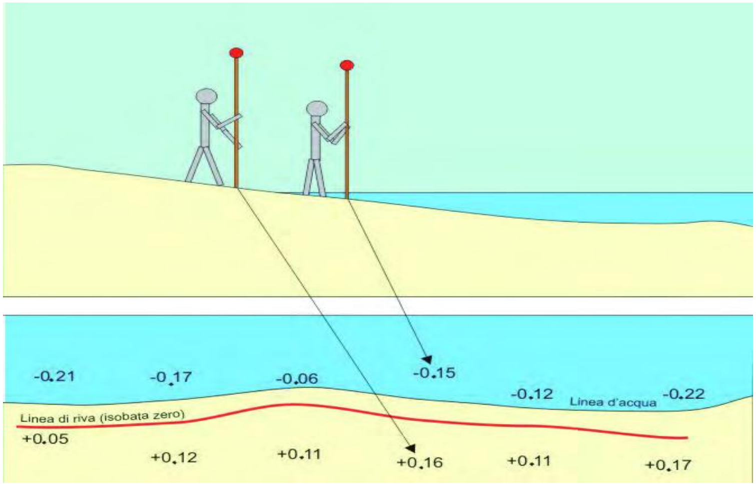
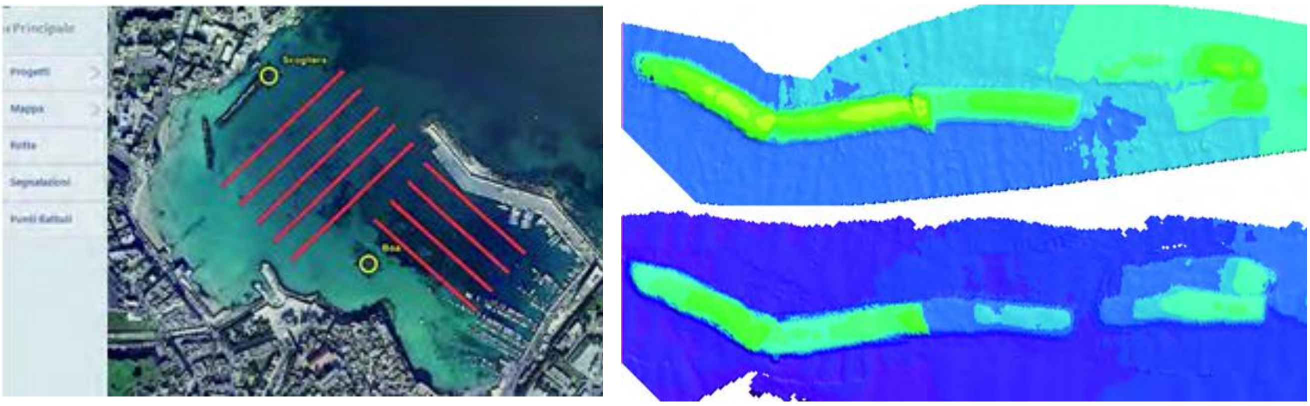


Figure 21. representation of shoreline extraction though a GPS survey (from Pranzini & Rossi, 2013) .

Another important source of data among the group of on field measurements corresponds to acoustic systems that estimate the position of objects from the properties or water for transmitting sound waves. Eco sounding systems works as a profiler sensor that measure the distance of the sea bottom with respect to the water surface from the time lapse between the emission of an acoustic pulse and its returned signal. A sidescan sonar produces images of the sea floor by towing a sonar (tow-fish) equipped with a linear array of transducers that emit, and after receive, an acoustic pulse in a specific frequency range; the data obtained allows to characterize surface sediment and identify sea floor objects (Marcin & Marek, 2012).

Meanwhile, echo sounders systems offer bathymetric data with high precisions (~5 cm) that can be obtained from a single point acquisition along a navigation path (single beam) or from a continuous acquisition of simultaneous pulses covering a stripe (multi beam) (Pranzini & Rossi, 2013). Single-beam measure the water depth directly beneath the vessel through a device (transceiver) that transmits a high frequency acoustic pulse in a beam downward into the water column; the acoustic energy is reflected off the sea floor beneath the vessel and received at the transceiver. The resulting depth values in the form of a point dataset represent accurate and reliable bathymetry, but only along the survey track. Multibeam echosounder produces bathymetric maps by sending out an array of sound pulses in a fan shape and returns depths from underneath the ship as well as from the sides (Marcin & Marek, 2012).

Bathymetric surveys with a single beam usually include the definition of lines orthogonal to the coast for registering the profile of the submerged beach and interpolating points in between the strips for a representation of the area. On the other hand, multi beams allow detecting the real morphology of the seafloor because the wide array of pulses has a wider coverage, saving time for surveying large areas. The bathymetric data processing usually considers a phase of quality control for eliminating statistically invalid data, followed by the creation of a 3D model, the definition of contour lines and the preparation of final maps.



Single beam strip route design — Submerged groins captured on a multibeam survey

Figure 22. Bathymetric survey with echosounder systems (from Pranzini & Rossi, 2013).

3.4. Monitoring Systems by Camera

Coastal monitoring supported by cameras is considered a separate category of geospatial techniques because they comprehend a whole system. The data acquisition mechanism consists of a set of stations located along the coast equipped with a digital and/or video camera. Compared to satellite and aerial imagery technique this system provides better temporal and spatial resolution, because the system continuously captures images at close range. Unlike field surveys that represent beach characteristics by interpolation of data within sampling points, camera systems are able to offer a full real representation of the area and also more frequent measurements than in situ instruments. Coastal monitoring systems by cameras can be more cost effective that satellite, airborne and on field technique separately when high frequency of data acquisition is required.

The extension of the coastal area covered by the system depends on the amount of stations distributed as a network. Cameras are installed at elevated positions with oblique orientation, so the observation range of each station depends on the height and the focal length of the cameras. A camera with 180° of field view is able to cover from 3 km to 6 km of coast; however a range of 2 km has proven to be useful for coastal video systems (Archetti, et al., 2007; Koningsveld, et al., 2007). Every station within the network can be programmed to capture a specific amount of images at citrine intervals of time according to the monitoring requirements.

The study of video monitoring systems for coastal studies is not new; the oldest document found on a literature review dated back to 1993. The application of this technique has always been challenged by the possibility of translating into algorithms the quantitative assessments the human eye is capable of by direct observation (Holman, et al., 1993). In a dynamic environment such as the beach system a single image cannot provide sufficient information for quantifying the processes on the nearshore. All the current applications of the video monitoring system are based on the analysis of five basic types of images generated during a post-processing operation of the original captures of the cameras. These video products are called Snapshot, Time Exposure (or timex), Day Timex, Variance and Time Stack.

Assuming that the camera on a station is programmed to activate every hour and operate at acquisition cycles of 10 minutes, capturing images every 5 seconds. A snapshot would be a simple photograph captured by the camera at a certain instant during the day. The time exposure image is obtained by creating a new image out of the averaged value of each corresponding pixel on the set of snapshots captured during an acquisition cycle. This process eliminates the problem of variability on the shoreline due to instantaneous changes of the water position during the run-up of breaking waves (Schiaffino, et al., 2013). Because of the effect of increases pixel colour intensity, timex images allow to distinguish features such as sand bar topography, shoreline, intertidal beach profile, intertidal beach slope, and morphology formations in beach face (Archetti, et al., 2013).

Day timex are generated the same way as timex images but instead of averaging the images of an acquisition cycle the process is applied to all the snapshot captured in one day. Variance image processing, on the other hand, generates a new image with the standard deviation of the digital value of every corresponding pixel of the images used for the time exposure processing (Archetti, et al., 2007). This image enhances the contrast achieved by timex processing because static pixels are represented in black and moving pixels are white, giving the impression of a negative picture (figure 23). Since changing areas look brighter, like the swash zone, and unchanging regions like the sand look darker, it is possible to identify submerged structures on the foreshore with this images. Even people walking along the beach can be easily identified on variance images.

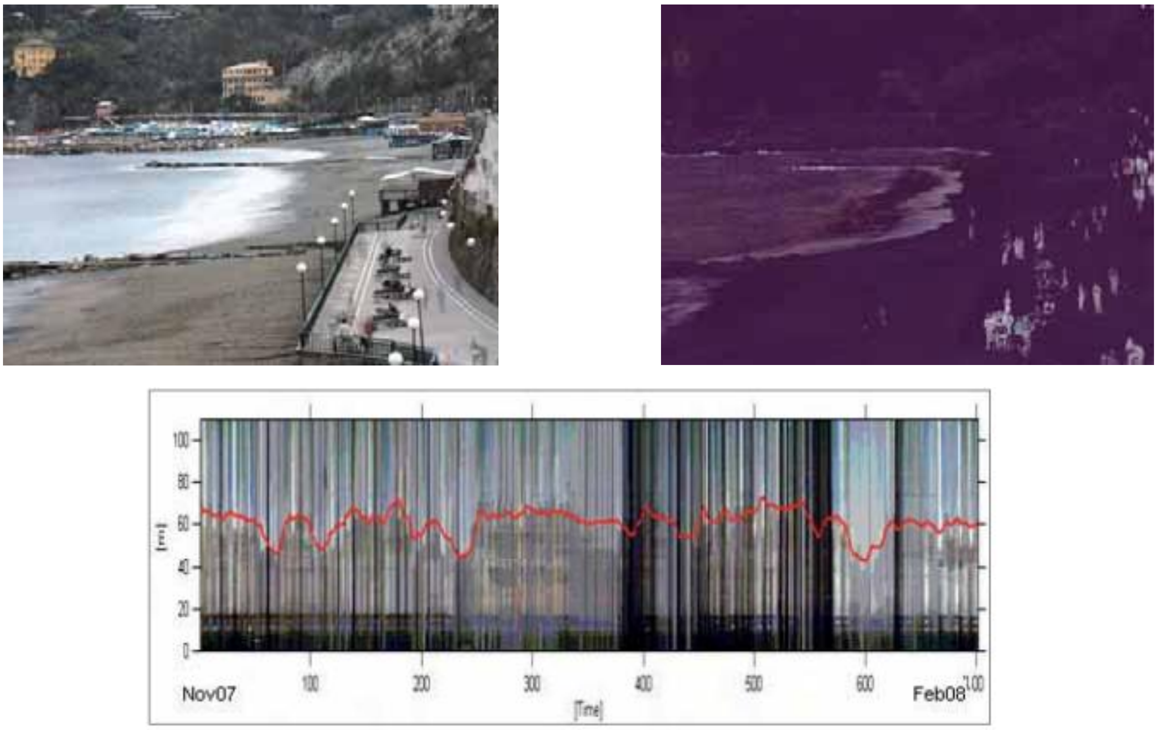


Figure 23. Example of time exposition (timex), variance and a time-stack image with the shoreline delimitation. (from Archetti, et al., 2007 and Archetti, 2007)

Finally, time-stack images are obtained by extracting from a set of images a line of pixels along a predefined array. Each line is placed one besides the other in chronological order so the time is represented in the horizontal axis, while the cross-shore variation in terms of distance is represented on the vertical axis. These images are useful for studying hydrodynamic characteristics on the beach, wave orientation, wave length, run up and cross-shore variation (Schiaffino, et al., 2013).

Table 12 summarizes the principal applications of video monitoring systems for marine and coastal studies reviewed. The higher proportion of researches applying this technique is concentrated on the field of geomorphology. However, diverse analyses of beach geomorphology have been considered for assessing natural conditions affecting the recreational use of a beach, so the amount of researches conducted in this field is small but significant. A less popular application considers the use of reconnaissance cameras for oil slick identification and tracking along with other visible stains on the ocean associated with pollution events (Klemas, 2011). Time exposition and time variance are images specially conceived for making analysis of the shoreline position because they neutralize the variability of the water level on the shore. These characteristics make it easy to identify the limit between sea water and land. This kind of variability on the water level is the main inconvenience facing satellite and aerial technology. These remote technologies are able to capture the instantaneous position of the shoreline, but this limit may have different location instants before or after the capture. Thus shoreline definition from video cameras can ensure a real representation of the shoreline respecting their dynamic. By tracking the temporal and spatial variation of the water-land limit it is possible to analyze beach erosion/accession processes, the evolution of nourishment projects and shore protection structures and seasonal changes associated with the impact of storms (Davidson, *et al.*, 2003; Osorio, Medina, & Gonzalez, 2012; Ojeda & Guillen, 2006). Considering that conventional video imagery only offer measurement on a two- dimensional plane, analysis related on the submerged beach, such as sub and intertidal morphology, requires additional data in order to supply the information for the third dimension.

Table 12. Marine and coastal studies based on sensor data retrieved from in situ automatic acquisition geotechniques.

Coastal Applications	References
Geomorphology	
Shoreline detection	Archeta, 2007; Dessy, et al., 2007; Schiaffino et al, 2007; Archetti & Lamberti, 2007; Schiaffino, et al., 2013; Osorio, Medina, & Gonzalez, 2012; Davidson, *et al.*, 2003
Sub and intertidal morphology	Davidson, *et al.*, 2003; Schiaffino, et al., 2013; Archetti, et al., 2013; Osorio, Medina, & Gonzalez, 2012
beach seasonal changes (storm impacts)	Schiaffino, et al., 2013; Archetti, 2007; Archetti, et al., 2013
Rip currents identification	Koningsveld, et al., 2007; Jiménez, et al., 2007
Submerged bars evolution	Archetti, 2007; Schiaffino, et al., 2013; Lippmann & Holman, 1993; J39
Wave characteristics (direction, period, energy dissipation…)	Chickadel et al., 2003; Archetti, 2007; Kroon, et al., 2007; Lippmann & Holman, 1993
Sediment volumes (beach erosion)	Archetti, 2007; Archetti, et al., 2007; Ojeda & Guillen, 2006
Beach face with and morphology	Schiaffino, et al., 2013; Archetti, 2007
Recreational use	
Beach users density	Sanchez & Taborda, 2013; Jiménez, et al., 2007
Swimming safety	Davidson, *et al.*, 2003; Koningsveld, et al., 2007; Jiménez, et al., 2007

Beach profiles, for example, are defined by relating the position of the shoreline extracted on the images with an elevation model. This means that the position of the shoreline within different times along the day is correlated with the respective water level of the exact time when the images where captured (figure 24). This water level may be obtained by records of buoys surrounding the area or theoretically calculated through models describing hydrodynamic process, such as run-up, storm surge, break-induced wave set-up and swash oscillations, among others. When beaches are not affected by, waves where run-up and set-up is not important, the tide level (with astronomical, meteorological and storm surge effects included) is good enough for defining the water level at any specific time of the day. However, for complex cases of open beaches with a strong tidal influence, the model introduced here should include a robust hydrodynamic model that could describe the physical processes in the near shore and swash zone.

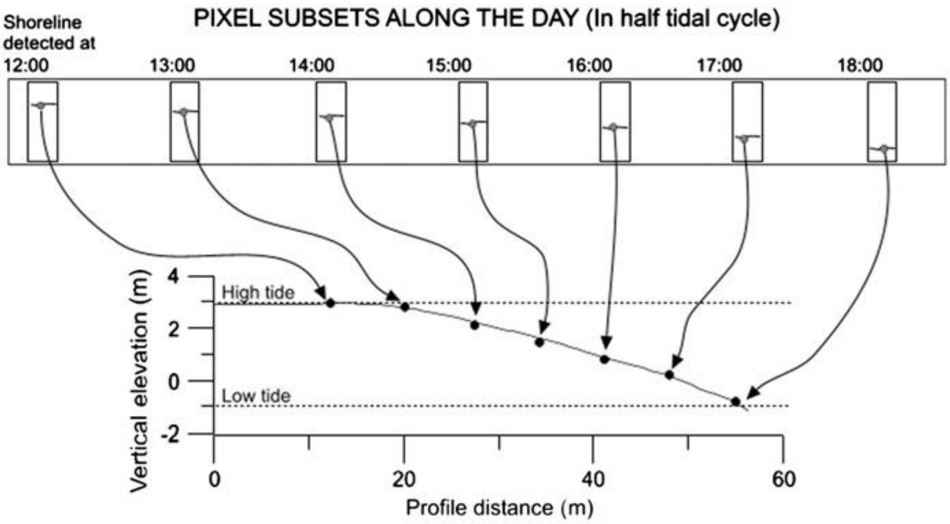


Figure 24. Scheme for defining beach profile estimations with video images (from Osorio, Medina, & Gonzalez, 2012).

Concerning the analysis of rip currents and submerged bars, the determinations are based on the visual interpretation of the images obtained from the video camera system. Someone with sound knowledge on the dynamic of sediments on the near shore is able to identify the location of sandbars by the patterns of water flow on the surface. Variance images also contribute with such observations because these images highlight the section of the water surface experiencing changes, such as the agitation generated on the line where waves break when approaching the coast (figure 25). These lines are usual indicators for the position of submerged sandbars because they set the limit of sediments moving in the near shore.

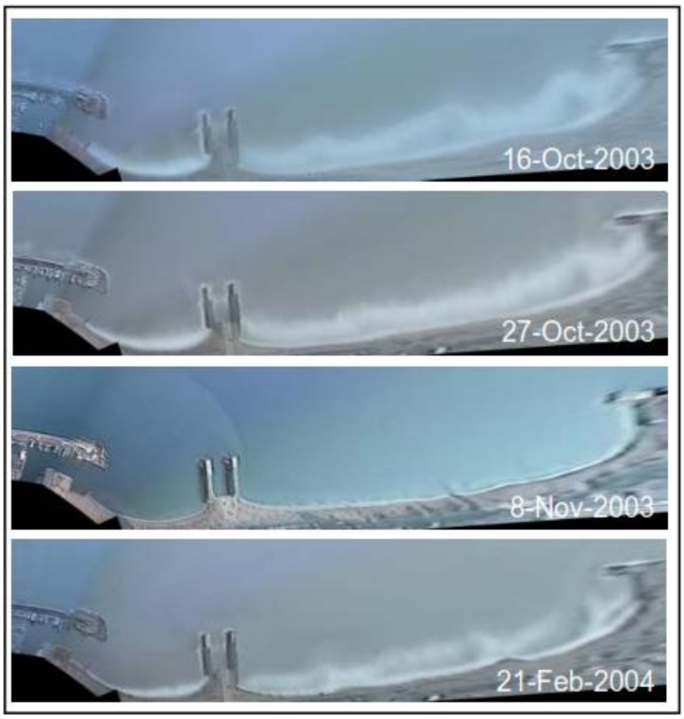


Figure 25. Example of the evolution of a sandbar system deribed from timex images (from Ribas, et al, 2010).

The characteristic water pattern on the surface for a rip can be distinguished on snapshots from a video monitoring system (figure 26). Risk maps on the beach have been drowned based on the visual identification of these currents considered as one of the main natural hazards present on tourist beaches (Jiménez, et al., 2007). This kind of information has been used for educating beach visitors on the identification of dangerous sector of the beach that should be avoided. Beach managers may also use this information for improving the distribution of lifeguard stations, optimizing in this way rescue activities. Since rip currents are dynamic systems, the variation of its locations can be conveniently tracked by with video monitoring systems because of the frequency of observation they offer. Such records can keep risk maps updated, improving management measures for improving beach safety on tourist beaches

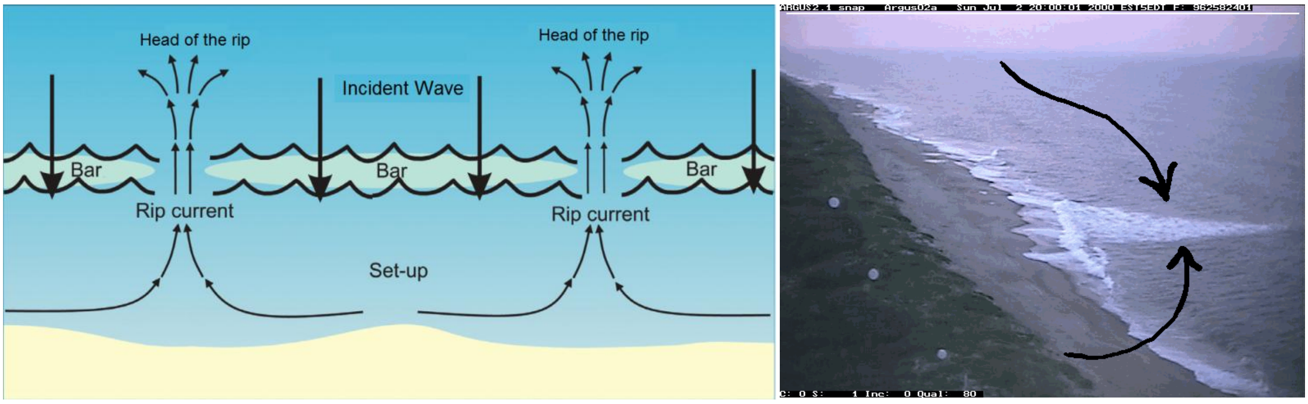
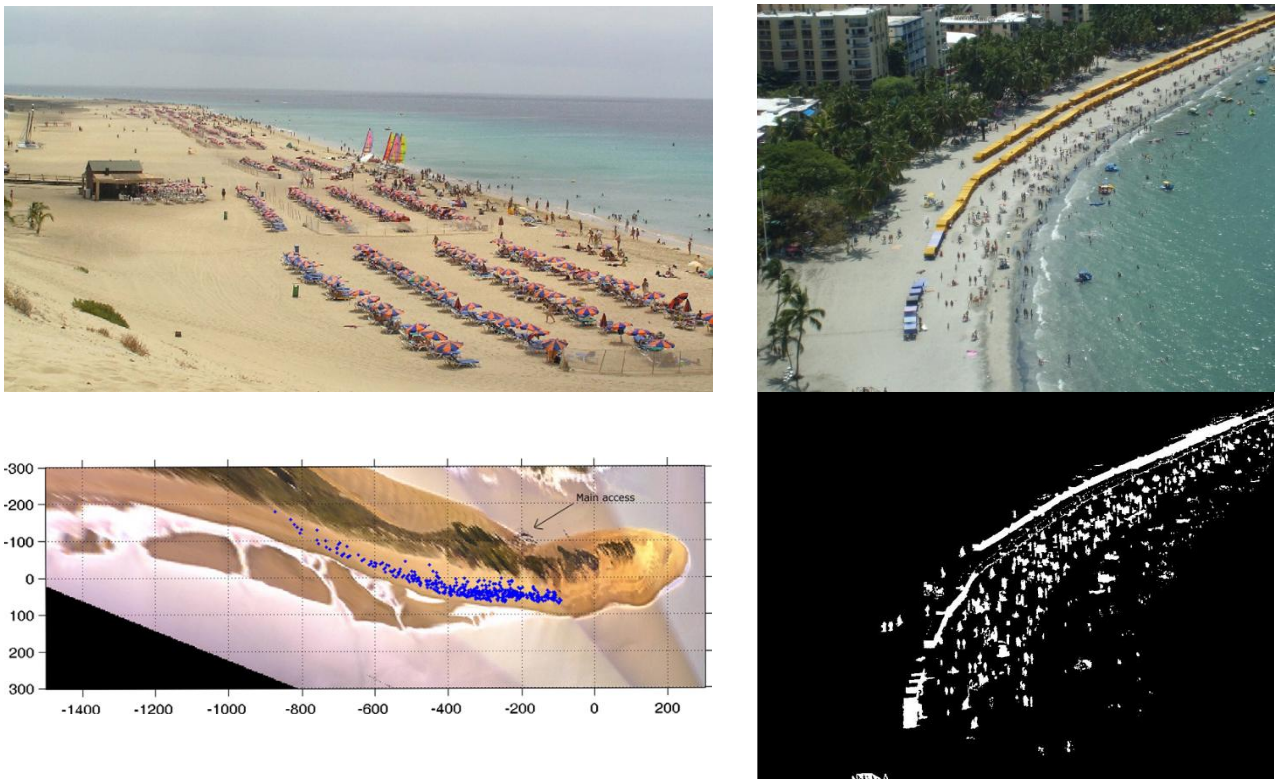


Figure 26. Patter of water flow for rip currents. Conceptual scheme (left) and visual identification from video snapshot (right). Adapted from Pranzini, 2013 and Jiménez, et al., 2007.

Another application of video monitoring systems for recreational uses has to do with the estimation of the amount of beach users. Beach users' density is the measure that defines the square meters available for a tourist on the beach. This measurement needs a proper estimation of the amount of people and the dimensions of the beach (width and length). The procedure for making this estimation on field implies the manual counting of persons in equidistant segments of the beach with known dimensions. This operation requires important resources in personal spending long times on the beach in order to repeat the counting during hours of peak and low occupation (Pereira & Botero, 2014). The quality of data has always big uncertainties that can be overcome by the automation of such process. As mentioned before, video monitoring systems offer good spatial and temporal resolution, so the estimations can cover the entire beach surface occupied as well as all the hours of the day.

One of the mechanisms for these estimations with video camera systems is based on the use of an algorithm that identifies every person in the beach by calculating the difference between a single pixel respects to the mean value of their neighbors (Jiménez, et al., 2007). When the difference exceeds a threshold, the pixel of group of pixels is counted as a person. This estimation has been used to identify the cross and long shore patterns of dispersion for beach users. Even though the former approach has proven to be effective for estimating the density of tourist on Spain, it does not apply on other regions where the model of tourism contain facilities that generate shadows bigger than the size of a person (see figure 27). These elements of occlusion have induced the estimation of beach occupation by tourist instead of the detail of individual users. This estimation calculates then the amount of pixels that represent a person as well as the shadow of the structures or facilities for recreational purposes because these two cannot be discriminated (Sanchez & Taborda, 2013).



Beach user's density defined for a beach in Spain   Measure of beach occupation in a Colombian beach

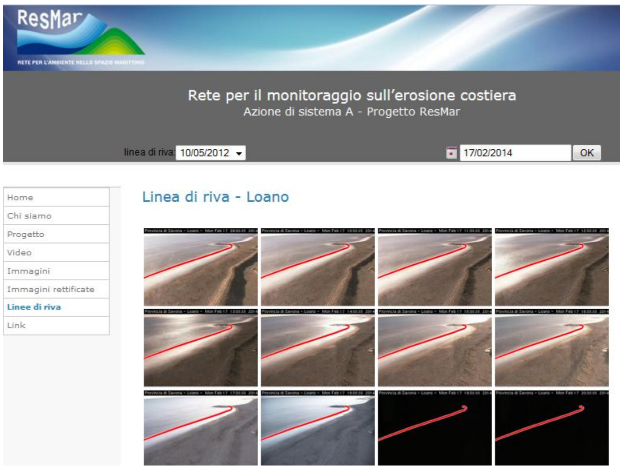
Figure 27. Beach users estimation with images taken with a camera monitoring system (from Jiménez, et al., 2007 and Sanchez & Taborda, 2013).

Besides registering the common processing for the images obtained from video monitoring systems, explained earlier (timex, variance, time-stack), table 13 also considered the customized systems developed within the past years for coastal and management purposes. Argus, EVS and KOSTA are video monitoring stations that are equipped with both hardware and software; the distinction between one and the other rely on the type of camera used. As commercial product, these systems offered a coupled service of data acquisition and processing with a sophisticated program for image processing. All the systems enlisted in the table 13 includes functions for image rectification and georeferentiation through the insertion of ground control points before the image processing phase in order to guarantee accurate measurements out of the images.

Table 13. Processing approaches commonly used on in situ data automatic acquisition by camaras.

IMAGES		Characteristics	Usual Application	Processing Approach	References
Platforms	Acquisition device/system				
Still Cameras	Argus	2km radio, 20 m resolution (1-2m in the shoreline)	shoreline detection Intertidal beach bathymetry	- Snapshots comparison - Time exposition (snapshots average) - Image variance - Time stack	Archeta & Lamberti, 2007; Dessy et al, 2007; Koningsveld, et al., 2007; Ribas, et al., 2010; Jiménez, et al., 2007: www.horusvideo.com
	EVS	10 Mp resolution (video/still cam)			
	Beachkeeper	webcam			
	Horus	Fireware and Web cameras			
	KOSTA	digital cameras			

In the case of Horus, the system encompasses data acquisition from video cameras, software for basic image processing and the visualization of results supported on the web. The system has been developed more like a project of international cooperation than a commercial product. The project was held between two groups of oceanographic engineering and coast from University of Cantabria (Spain) and the National University of Colombia (Colombia). The system has been collecting data from two testing site in Santander (Spain) and one station installed in the touristic district of Cartagena (Colombia). The system offer morphodynamic data (shoreline and sandbar position), hydrodynamic data (wave period and direction) and beach user's information (amount and density) for temporal analysis.



Beachkeeper online presentation of data
http://beachcam.res-mar.eu/

Horus system for online platform
http://www.horusvideo.com/

Figure 28. Online display of data processed by Beachkeeper software and web platform of the Horus system.

Beachkeeper, on the other hand, is only a software designed for the management and elaboration of images acquired by a webcam (Archetti, et al., 2007). This open access program was designed for processing the images that were available in webcams installed by the local administration of the Liguria coast in Italy. These networks of webcams were originally installed as a mean for communicating tourist the conditions of the beach of their interest by offering real time videos available online. The Beachkeeper software was developed with the cooperation of two departments within the Genoa University. The program is supported by Matlab® and it offers the possibility for further development, in case that applications others than the basic image processing can improved (Dessy, et al., 2007).

Finally, the Coast View project is part of a European research program worth to mention in this analysis. The project explored the application of a video monitoring system in support of coastal management issues (Davidson, *et al.*, 2003). This project designed a frame of reference for addressing important management aspects, such as coastal protection and maintenance, navigation and shipping, recreation and tourism and ecosystem protection. Such frame of reference considered the identification of coastal state indicators based on video derived variables. A total of 29 parameters were identified as possible to derive from a video monitoring system, including elements describing the beach state, dine condition, beach safety, beach use, wave climate, shipping activity and algal bloom/seaweed.

Out of this project several experiences demonstrated that video derived parameters are useful for setting coastal state indicators (Koningsveld, et al., 2007). Some of the variables evaluated through video monitoring systems included the momentary intertidal coastal line, the high-water line, sandbars allocation, spit positions, beach with, beach users' density and the spatial distribution of hazards (Kroon, et al., 2006; Smit et al., 2007; Medina et al., 2007; Koningsveld, et al., 2007). However the potential of video monitoring systems was proven useful for coastal management issues, the implementation of a decision making approach based on this system was limited by the resistance of policy makers to modify or replace existent mechanisms (Koningsveld, et al., 2007).

3.5. Geographic Information Systems

Until now, all geospatial techniques identified has been focused on the mechanisms for acquisition and processing of data retrieved from sensors and instruments. Taking into consideration the definition of geospatial techniques described above, *any mean for generating, organizing, storing and analysing spatial information*, it can be stressed that Geographical Information Systems (GIS) deserves special consideration. Within the range of technique, GIS figures as a tool for representing spatial or temporal information in a digital environment. These systems provide a platform for data integration, synthesis and modeling that can be used to support decision making processes (Wang, Zhou, & Yang, 2009).

More than just organizing information digitally, GIS allow the integration of data coming from different sources, which make them appropriate tools for coastal applications. In every one of the previous sections describing technologies for data acquisition, several marine and coastal studies where mentioned repeatedly. Biophysical and socio-economic characteristics of these complex environments can be obtained through remote sensing, field measurements and historical records that have its own geospatial reference system. A GIS is able to store this information, transform it to a unique geometric system, make them accessible as required and process it to generate new geospatial information (Drummond & Tait, 1997).

Several programs have been designed to cover these requirements. While simple software are able to gather, elaborate and display information related to the different disciplines of interest, GIS programs are designed to manage and analyze data with geometric shape and of known position in relation to the Earth surface (Schiaffino, et al., 2013).They contemplate functionalities like display a map with multiple layers, transform between coordinate systems, create and update geographic features or interact with personal and enterprise geodatabases (Marcin & Marek, 2012). Some of these featured technologies include commercial versions, such as the ESRI ArcGIS engine with ArcGlobe, along with several other open source engines, such as Quantum GIS, gvSIG, GRASS GIS, GeoServer, as well as toolkits like Java Geo Tools and the OpeLayers web GIS client library, among many others.

GIS' softwares describe reality through two types of elements: thematic attributes (statistical data elements) and geographical/spatial data. Attributes represent elements that are not geometrical, such as names, measures and properties. Geographical and spatial features are the geometrical elements often employed to describe the same data. Geographical data are strictly linked to the information about Earth surface on real-world scale and in real-world space. Spatial attributes, on the other hand, could consider any information about multidimensional location, including engineering projects, remote sensing or cartography (Schiaffino, et al., 2013).

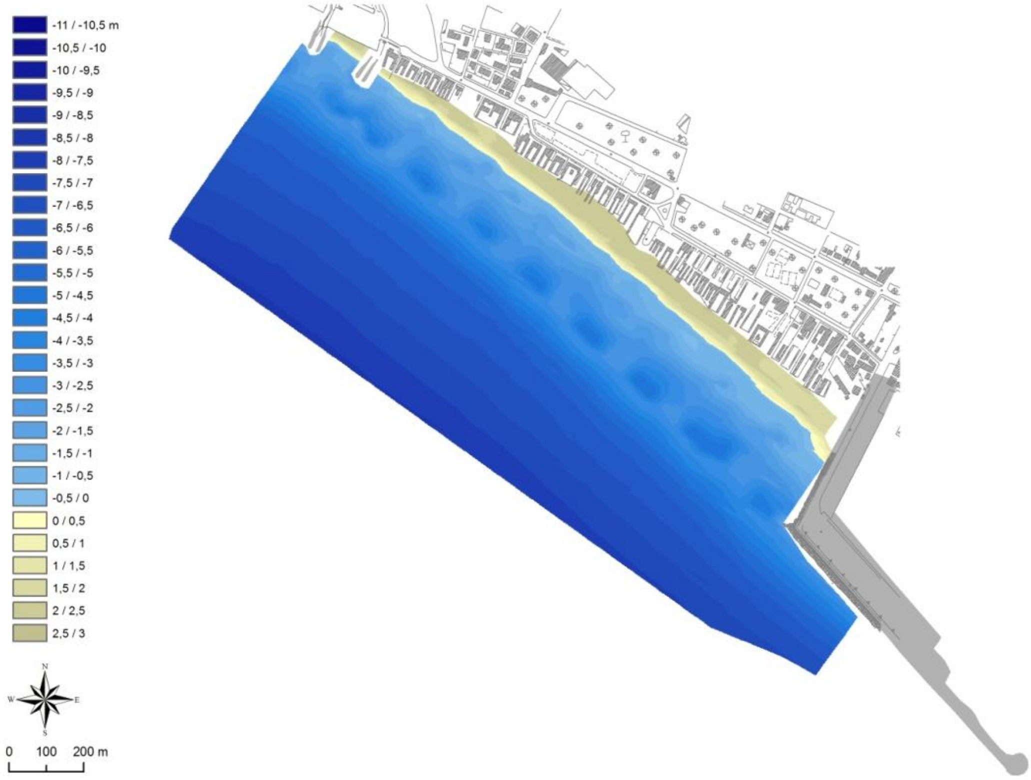


Figure 29. Example of topographic and bathymetric data merged in with a GIS program at Marina di Carrara (Italy).

Geographical features are displayed through vector and raster data; these terms refer to a model for organizing data on the base of geometric shapes. Both approaches allow caricaturing the Earth's surface with a limited number of locations; what makes them different is the sampling strategy they apply (Yang X. , 2009). The principle with the vector approach relies in the collection at intervals of data or information along the length of a linear entity (e.g. roads) or around the perimeter of a surface (e.g. property parcels). These sampling locations are represented by points and when connected they represent a line or polygon feature that approximate the shape of the entity perceived from the real world (Wang, Zhou, & Yang, 2009). The vector strategy is suitable for mapping entities with well-defined edges (e.g. highways, property parcels) through the use of basic elements, such as points, lines and areas.

The raster approach, on the other hand, makes the representation of these physical entities by collecting the information of attributes at fixed intervals. The information gathered is stored on the cells of a grid that may be of different shapes or dimensions. According to the attribute each cell gets a representative value and when all the cells are filled the overview of the grid shows the shapes of the original entities in the real world (Bartlett & Smith, 2005). For example if the cells are filled with values of 1 and 2, where 1 represents the water and 2 the soil, the final grid may be representing a lake, river or sea. The raster strategy is suitable for representing phenomena that lack clear-cut boundaries, such as terrain elevation, vegetation, and precipitation; remotely sensed imagery and digital elevation model (DEM) are often represented into raster (Wang, Zhou, & Yang, 2009).

Raster data are shown to be preferable to vector data for scientific research because they make spatial resolution explicit (Goodchild, 2011). The image in figure 29 represent a raster map build up from bathymetric and topographic data. After transforming the points of both surveys into a single reference system (Gauss Boaga), they were used to create a triangular irregular network (TIN) that delineates quote lines. Such network was then converted into the raster map of the figure.

Many applications of GIS are related with the development of spatial analysis. There are several procedures that can be applied like temporal analysis, pattern analysis and statistical analysis, among others. Several GIS tools have been designed to address each one of these procedures. Among the basic spatial analysis there is the buffering tool that identifies areas within a specified distance of an existing feature; it is particularly useful to depict zones of influence of a phenomenon or to define protection areas. The neighborhood tool generates a new value for each cell based on its original value along with its neighbors; it is appropriate for simulating the propagation of coastal flooding for example. The overlay function enables users to integrate spatial data and attributes from different sources to produce a composite map and to analyze how these attributes relate to each other. Coastal landscapes have been assessed by overlaying raster layers to calculate composite visual indexes (Mitasova, et al., 2012; Crawford, *et al.,* 2013).

Spatial pattern analysis can be performed by a tool of spatial autocorrelation that measures the degree of dependency among observations in a geographical space. Another function for pattern analysis is the quadrat that measures the density of points in a segment by measuring the dispersion among them. Similarly the nearest-neighbor analysis measures the distance between sample points and their nearest neighbor so the spatial pattern can be identified. Landscape metric tool is used to quantify the composition and configuration of a landscape and the spatial interpolation estimates the attribute value in locations where there is no information, which make it useful for environmental modeling (Wang, Zhou, & Yang, 2009; Yang X. , 2009).

Concerning the statistical spatial analysis there is a basic procedure that includes descriptive statistics for studying single variables or the relationship with another and visualizations; causes of long shore sediment transport has been studied with statistic of wind direction and wave height. Regression is another statistical tool on GIS that analyzes numerical data by defining dependent and independent variables. The clustering tool makes groups of observations by measuring their similarities in terms of distance that separate them in a graphic representation. Principal component analysis is another procedure that identifies correlations between variables by projecting the data in a new coordinate system set by the greatest variance (Wang, Zhou, & Yang, 2009).

When dealing with high amounts of data, one of the complications on spatial analysis is related with information redundancy. For studying landscape and landforms, for instance, it is common to find that many of the metrics available may be correlated with each other because they rely on few primary measurements. The best option would be to choose a small group of metrics that capture the mayor properties of a landscape without been redundant. Statistical methods (e.g. principal component analysis) can be used to reduce data redundancy and select a cost-conscious suite of independent metrics (Yang X. , 2009). Many more procedures have been developed for different applications but the ones mentioned before have been considered appropriate for coastal ecosystem research.

The list of applications for GIS may be well extended when considering all its characteristics and also the possibilities posed by upcoming technologies for data acquisition. Table 14 has collected some applications of this technique on marine and coastal studier out of a general review of researches related with diverse geospatial techniques. The fact that GIS is a mean for manipulating data explains that the use of this technique is mostly concentrate on the same applications registered for the techniques of data acquisition.

Just like in the other geotechniques described in previous sections, most of the studies here identified are related with the field of geomorphology and the representation of natural elements of the beach. Among the applications identified the generation of maps out of the information retrieved from multispectral data is very popular. Despite the properties of GIS for integration and synthesis of data from different sensors and sources, remote sensing data acquisition remains a challenge for the scopes of GIS in coastal environments (Marcin & Marek, 2012). This limitation relies on the lack of common standards of data exchange and proper visualization.

Table 14. Marine and coastal studies based on GIS approach

Geospatial Techniques	Coastal Applications	References
Geographic Information Systems	**Mapping land cover**	Goodchild, 2011
	Land development pattern	Crawford, *et al.,* 2013
	Coastal landscape pattern analysis	Yang X. , 2009; Mitasova, et al., 2012
	Geomorphology	
	coastline evolution	Chaaban, et al., 2012
	Digital Terrain and Elevation Models	Chaaban, et al., 2012
	mapping beach morphodynamic	Harris et al, 2011
	Environmental conditions	
	Mapping physical attributes of beaches	Wang, Zhou, & Yang, 2009; Harris et al, 201;
	Mapping cultural attributes	Wang, Zhou, & Yang, 2009
	Mapping risk and vulnerability	Szlafsztein & Sterr, 2007; Schiaffino, et al., 2013
	Recreational use	
	Dry beach availability	Yang, et al., 2012
	Multi Data treatment	
	Integration, synthesis and modeling	Wang, Zhou, & Yang, 2009; Chaaban, et al., 2012; Marcin & Marek, 2012
	Online processing and visualization	Marcin & Marek, 2012; Yang, et al., 2012; Vitale, *et al.*, 2013

Most of the coastal applications have a comprehensive spatial range because they usually analyze interactions and evolutions at an ecosystem scale. One of these wide range applications consider vulnerability and risk analysis respect to coastal hazards, such as coastal erosion or coastal flooding. Figure 30 represent the general scheme proposed by Szlafsztein & Sterr (2007) for assessing and classifying natural and socioeconomic vulnerabilities in the coastal Zone by a GIS based composite vulnerability index. The system integrated separate natural and socio-economic variables to create a single indicator that represent different ranges of hazards. The resulting product of this GIS application was vulnerability maps for the purposes of coastal zone management programs in Bazil. The experience highlighted the importance to complement and update available data in order to improve the reliability of the assessment.

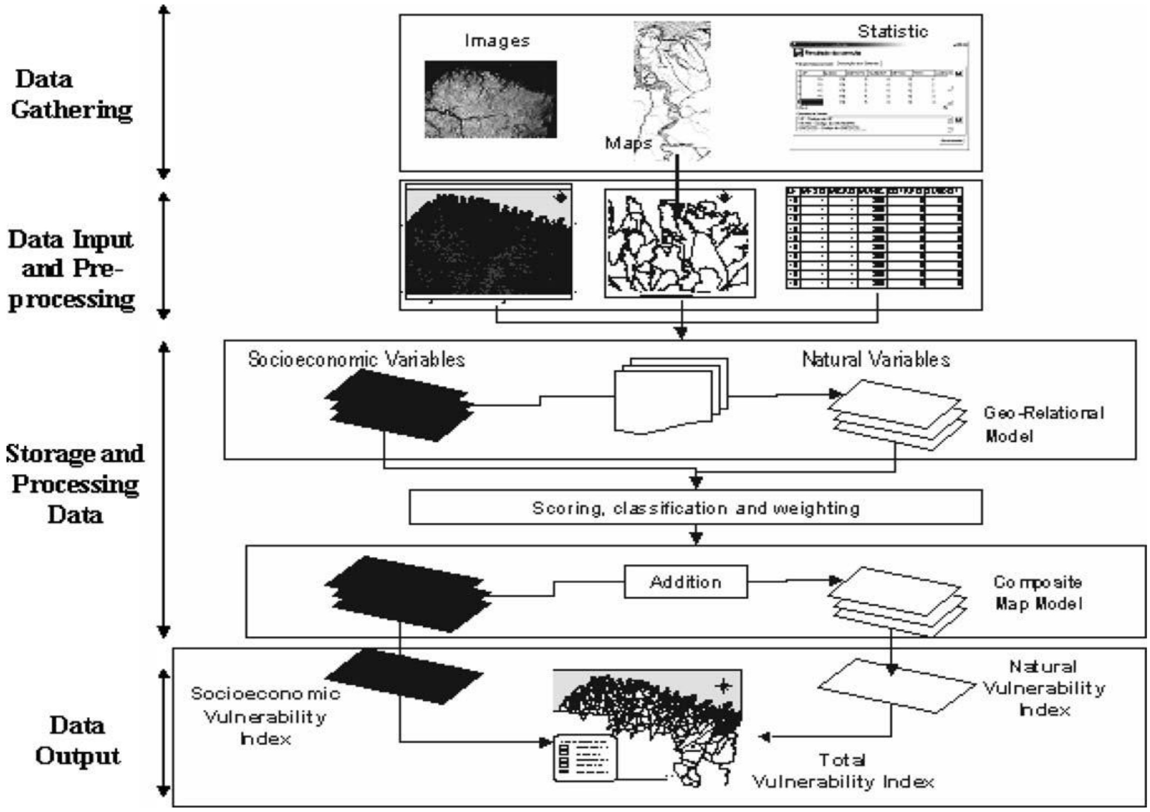


Figure 30. GIS scheme applied to elaborate a composite vulnerability index (fom Szlafsztein & Sterr, 2007)

The beach system is spatially narrower than other coastal ecosystems and it is not always easy to distinguish the limit between one and another. Unlike terrestrial ecosystems, marine and coastal system haven't been mapped with frequency because land cover data are not usually good enough; shoreline classification and mapping is the closest representation retrieved from the sandy beaches data available (Harris, Nel, & Schoeman, 2011) Thus many studies addressed with GIS on these narrow segments has focused on the evolution of shoreline position for monitoring processes of erosion and accretion (Vitale, et al., 2013; Wang, Zhou, & Yang, 2009; Chaaban, et al., 2012; Marcin & Marek, 2012).

One of the models used for shoreline definition is the baseline approach that consists on choosing a baseline approximately parallel to the shoreline and then drawing a set of transects intersecting both the baseline and the shoreline. The extent of retreat can be calculated by measuring the distance between the intersecting points of the transect for every sample and comparing them (figure 31). Chaaban, et al. (2012) developed such analysis supported by aerial photographs by following three basic steps: georeferenciation of images, digitalization of a shoreline, baseline and transect and calculation of shoreline changes. Such experience confirms that GIS provide a flexible mechanism for the identification of coastal vulnerabilities especially when it accomplishes the function of comparing previously georeferenced cartographic data (Schiaffino *et al.*, 2013).

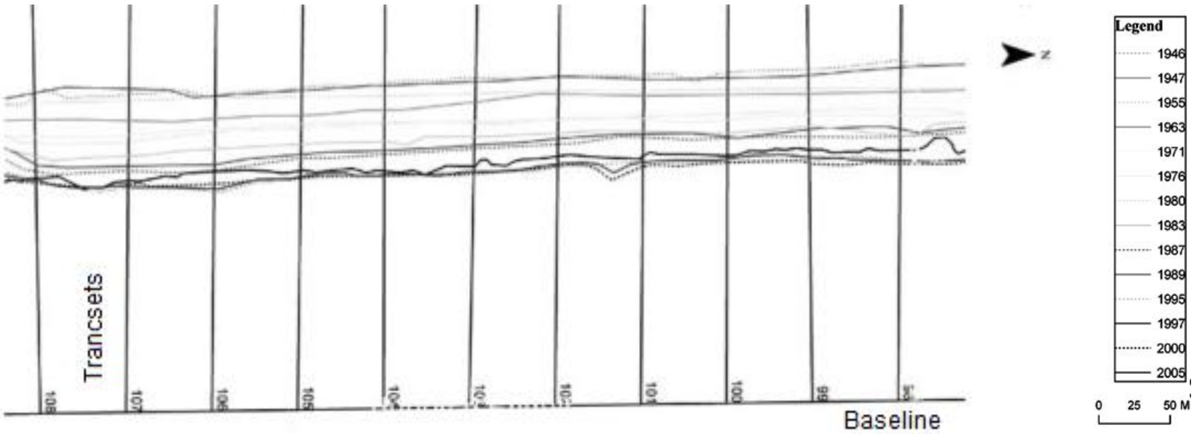
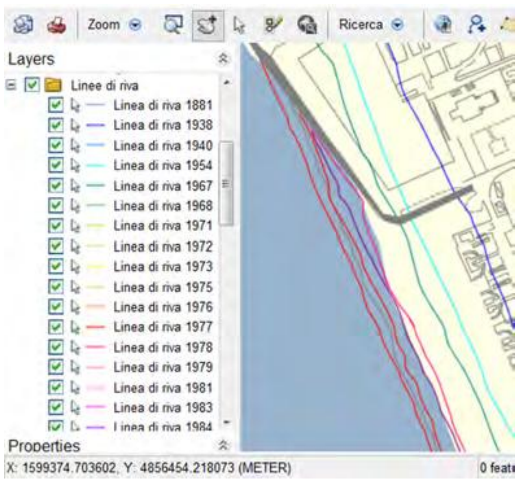
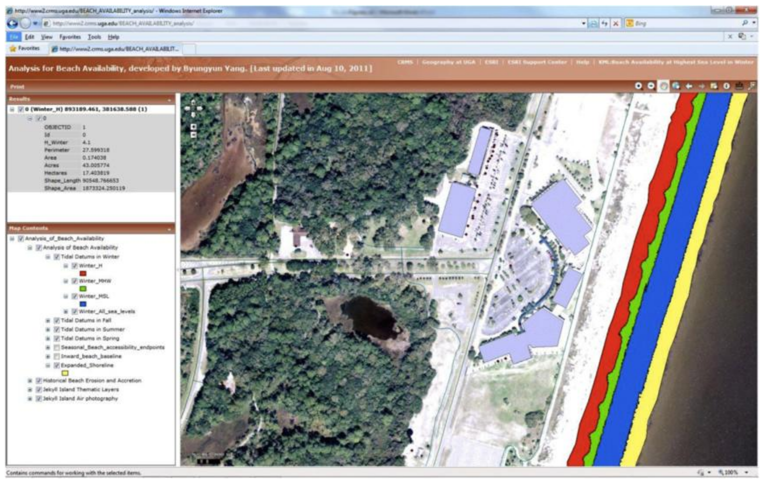


Figure 31. Sampling of digitized shoreline, transects and baseline for studying shoreline evolution within a GIS environment Adapted from Chaaban, et al., 2012.

With a similar approach GIS products have been used to offer online access to the information derived from these analysis. A coastal web-GIS for data share and distribution was developed for the Sardinian and Tuscan coasts of Italy (figure 32). The kind of information displayed in this system includes cartographic data derived from aerial photogrammetric historical sets, sedimentological, geomorphological and hydrodynamic data, and wave and sedimentological models. Yang, et al. (2012) also developed a web application to display the results of beach width availability in a barrier of Jekyll Islan (USA). The study analyses changes the variation of dry beach available for tourist under different tidal conditions. Shoreline is extracted out of aerial photographs and LiDAR data in the range of possible tides. These shorelines are converted into polylines that are all saved in a single geodatabases. This module efficiently manages geospatial data such as shapefiles, satellite imagery, and all GIS data of vector and raster types. Historical records and predictions of shoreline position are available on a web-based GIS application for beach users may corroborate beach availability for tourism and plan their visit (figure 32).



Online presentation of shoreline in Italy



Real-time information into a web-based GIS application

Figure 32.Web based application of GIS for coastal areas (from Vitale *et al.*, 2013 and Yang, et al., 2012)

4. RECREATIONAL QUALITY ASSESSMENT THROUGH GEOSPATIAL TECHNIQUES

Considering the descriptions in the previous chapter, the most popular application of remote sensing and GIS at the beach scale is perhaps the evolution of erosion problems, usually addressed through the use of satellite and video imagery (Pranzini and Wetzel, 2007; Brignone, *et al*., 2012; Kroon, et al., 2007). Further elements on tourist beaches can also be analized with this instrument, such as the presence of human facilities and civil structures concerning zoning and urbanization, landscape and landform features that characterize coastal scenery and rip currents or near shore morphology associated to safety/security issues (Mitasova, et al., 2012; Barrett and Houser, 2012). In this context, geospatial techniques figure as an asset that may contributes to the automation process for assessing recreational parameters within the ICAPTU model.

For this exploratory research, the methodology consisted on the identification of appropriate variable for the assessment of recreational parameters. The description of the parameters under consideration and the elements identified was mentioned in chapter 2. Concerning the possibilities posed by geotechnique it was required to perform a literature review focused on scientific publications that considered the use of different geospatial technologies in coastal environments. The remarks of these studies are documented in chapter 3, where especial attention is given to the application on beaches. This chapter will then focus on pointing out those geospatial techniques that may be useful for measuring recreational quality on beaches.

Along with the literature review, workshops and interviews with experts on the field of some of these techniques were conducted with assistance of the Department of Earth Science from the University of Florence (Italy). The topics addressed considered basic reflection on remote sensing, GIS, automatic monitoring with video camera systems and aerial survey These encounters clarified the use of instruments and computer sciences related with the acquisition and management of geographical data, such was the case of ArcGIS, ENVI and Beachkeeper pluss software, as well as a demonstration of an UAV (drone) for aerial photo survey and mapping. Out of these approximations to geospatial techniques during one month and a half of practical stage in Italy (January and February 2014), the possibilities for their application on recreational quality assessment are here analyzed.

Table 15. Details of visits within the practical stage.

Practical section	ENVI software	ArcGIS software	Beachkeeper pluss software	UAV-Menci demonstration
Date (2014)	10-14-15 January	30th January	6th February	13th February
Host	Florence University	Coastal Research Center (CRN)	University of Genoa	MenciSoftware
City (Italy)	Florence	Cecina	Genova	Arezzo

Initially, the application of ENVI software for coastal analysis was described by members of the research team of the Department of Earth Science in Florence during partial section within three days. This group has collected sufficient experiences dealing with remotely sensed data that has been supported on their active participation on the BEACHMED-e / OpTIMAL Project. Such project is the result of cooperation among nine (9) regional partners of four (4) European nations (Italy, France, Spain and Grece) that focused on the study of Mediterranean coastal areas (Cipriani, 2013).

An important segment of this project was dedicated to the optimization of integrated monitoring technique applied to coastlines, specifically with the use of remote sensing techniques. The only application explored in these experiences was related to shoreline extraction from high resolution imagery, but it has been stressed in previous sections that much more information can be retrieved from this sources (e.g. land use, vegetation cover and hydrodynamic parameters) The analysis of this experience with the research team demonstrated that multispectral image processing software, such as ENVI or ERDAS, are important tools for extracting information out of satellite and airborne sensor data. Their uses allow operators to recognize natural phenomena and processes that are not easy to identify by simple observation of images because this one is limited to the spectral range the human eye can perceive.

The possibility of obtaining multispectral data from satellite and aerial imagery has proved to offer very precise information about specific parameters or variables more suitable for environmental and ecosystem health indicators and with satisfactory precision. Having a look at the variables considered for assessing recreational quality within the four parameters considered in this study, it is evident that most of the assessments are subjects of qualitative rather that quantitative information. This situation stresses the idea that high spectral resolution imagery obtained from satellite and airborne techniques would be overestimated resources for recreational assessment. Besides the costs for monitoring tourist beaches would be very high considering that the spatial resolution of the images required for analyzing these areas are the most expensive in the market (e.g. Ikonos and QuickBird or aircraft flights).

Besides multispectral imagery, aerial borne techniques also considered simpler operations able to provide more quantitative assessments of the beach segment, such as low altitude flights performed by small aircraft, unmanned aerial vehicles or dirigible. This flexible configuration of aerial techniques was observed during the demonstration of an UAV (drone) attended in the locality of Arezzo (Italy). The demonstration was offered by the Italian company MenciSoftware, a developer and provider of software products used in survey, mapping and photogrammetry applications (www.menci.com). The demonstration includes the performance of a drone flight for capturing a set of overlapping images with a conventional digital camera deployed on the light vehicle (figure 33).

The demonstration also presented the possibilities of obtaining digital surface models and digital terrain models. The software introduced by the company offer the possibility of processing the images obtained through photogrammetric technique, including stereoscopic observation and measurements. All these characteristics allow the acquisition of very precise topographic information that favors the analysis and visualization of the area under study. Aside from all the details on precision and accuracy obtained by the digital models derived from this image processing, the greatest advantage of these system is operational. The possibility of plan and adjust the flight path of the vehicle at the users convenience may offer higher frequency and cloud free images. This system may be more cost effective than acquiring images from satellite or high altitude flights when there are required periodic observations of the beach. However, the spatial resolution with this system is not better than video camera monitoring systems.

Figure 33. UAV eBee drone presented on MenciSoftware demonstration.

For a better understanding of the use of video camera for beach monitoring, it was coordinated a visit to the research group that developed the software *Beachkeeper pluss*. This program was developed by researcher of the University of Genoa (Italy) under the framework of the BEACHMED-e / OpTIMAL project. During the visit there where explained the basic functions of the program and the way to insert images for further processing. Compared to other video monitoring systems mentioned in the previous chapter, *Beachkeeper pluss* only manage the step of image processing, while the acquisition can be performed with any mechanism.

Since video cameras systems are installed on the beach for monitoring purposes this technique may be considered within the category of on field measurements; however, this technique is considered separately because they represent an automatic procedure for data acquisition and processing. It offers multiple possibilities but the applications that have been better developed focus on the studying beach morphology. Further trails have been conducted regarding beach user’s density and safety conditions on the beach. This approximations exemplify how appropriate can be video cameras systems for recreational conditions on the beach. Since the stations are properly installed for covering all the area of interest they offer good spatial and temporal resolution, which are particularly important for observing not only physical phenomena on the beach but also human components and interactions.

Finally, a visit to National Research Center (CRN) in Cecina (Italy) was done for analyzing the utility of GIS on recreational quality assessment. The experience of the research team on GIS applications has been focused on the analysis of shoreline evolution for beach erosion monitoring. During the workshop there were explained basic tools of ArcGIS software for data storage, integration and visualization. Applying the georeferencing function it was demonstrated that data from different sources can be merged all together into one single reference system (rectification). Basic tools for drawing points, lines and polygons can be applied on top of an image for making a manual photo interpretation. Among the information considered appropriate for beaches there were considered cartographic maps describing the urban coverage, bathymetric and topographic data describing physical elements, and databases of ecosystem values such as dune systems, seaweed fields or habitats delimitations.

One of the procedures detailed in GIS techniques considers the analysis of redundancy among the available data. Concerning the parameters for recreational quality described in chapter 2 there have been considered many variables under the name of elements, factors, impacts of hazards. The list of variables is long and a periodic evaluation of such variables may become strenuous. Even though further practical work need to be done for validating the measurement instruments of each parameter, an analysis of the pertinence and functionality of all the variables may be beneficial. Tools like principal component analysis and spearman's rank can contribute to make a selection of appropriate metrics. This approach could optimize the recreational quality assessment on beaches by attempting at simplifying data requirements in future evaluations.

Majority of techniques require further research to determine their fitness to each particular parameter of recreational quality. The idea of measuring human values, such as ones included in the recreational parameters considered in this study, is a novel approach within the conceptual framework of the ICAPTU model. One way to improve the rigorous assessment of these unconventional measurements may consider the different ways of making systematic the evaluation. The description of the geospatial techniques considered in this document represents a first exploration in order to systematize recreational parameters with high technologies.

4.1. Coastal scenery

Currently coastal scenery is measured directly on field by a group of experts that mark the characteristics of natural and human elements of a beach out of a checklist with rankings (Ergin et al., 2004). Therefore, elements (variables) of coastal scenery should be measured with optical sensors capable to show differences of colors, shapes and volume on the beach. According to the description of all the categories of geospatial techniques identified in chapter 3, table 16 registers which technique can be used to evaluate every variable considered on the adapted scheme for coastal scenery assessment.

Table 16. Cross matrix of coastal scenery variables and geospatial techniques applicable.

Type of elements	Variable	Satellite	Air	On Field	Camera	GIS
Natural	Beach face width	x	x	x	x	
	Sand colour	x	x		x	
	Skyline landform	x	x	x	x	
	Coastal landscape features (arches, caves, waterfalls, island, reefs, etc.)	x	x	x	x	
	Vistas	x	x	x		
	Water colour	x	x		x	
	Vegetation cover	x	x	x	x	
Human	Litter		x		x	
	Sewage	x	x	x	x	
	Land use	x	x			
	Built environment	x	x	x	x	
	Beach Users' Density				x	
	Recreational Facilities	x	x	x	x	
	Recreational Equipment	x	x		x	
	Folklore				x	
	Floating Surfaces (boat, vessels...)			x	x	
	Facilities	x	x			

Almost all technologies deployed on airplanes or satellites are usefulness for these elements because the images obtained from these platforms may offer qualitative information. Airborne systems can measure same elements that satellite, but the cost of using one or another may be higher of lower depending on the scale required. Satellite systems and high altitude flights may offer similar spatial resolution with similar costs, while low altitude flights can be less expensive but offering representations at lower scales. However large range images may be more cost effective when the study area is extensive, close range ones are more appropriate because tourist beaches are well delimitated in smaller scales.

Some human elements are not possible to identify from satellite imagery because of the limitation of spatial and temporal resolution of images. Litter, for instance, is one element that can be represented at small scales that even high spatial resolution satellites would not be able to distinguish properly. Close rage captures from aerial platforms, like drone or dirigible, may offer better detail on the beach and so differentiate the location and distribution of litter.

Variables associated with the frequency of identification or occurrence in a time scale of hours, like floating surfaces and folklore, are not easy to detect from satellite and aerial imagery. Only instantaneous representations can be obtained from satellite platforms, while the frequency with aerial systems depends on flight programming. The best option for these frequency based evaluations would be video monitoring systems because they allow a continuous observation.

On field techniques are less useful for measuring elements of coastal scenery. From the previous chapter it is already known that field instruments are based on defining positions and deriving elevation models out of bathymetric and topographic measures. Even though coastal scenery is evaluated by direct observations on field, some variables cannot be described by the measurements of the instruments mentioned in section 3.3. Sand and water color, for instance, are not values that can be derived from positions or elevation, different from beach with, skyline and vistas that can be deducted from the relief, or elements that can be delimitated like sewage, buildings and floating surfaces.

Elements categorized by the degree of dispersion or distribution along the beach are not worth to consider with field instruments. Besides the built environment and certain facilities that can be represented from a laser scanner, defining the position of beach users, litter or facilities, for instance, is not operational. In fact, if field measurements require to the presence of personal on the beach to collect the data for further representation, it is better just to make the assessment conventionally.

Meanwhile, video cameras can be used for assessing almost all the elements because these systems are placed directly on the beach. Actually, there are specific applications already developed and systematized for some of these elements, such is the case of beach users density and beach width (Jiménez, et al., 2007; Schiaffino, et al., 2013; Ortega, et al., 2007; Archetti, 2007).There may be some limitations with the human elements of vista and land use related with the position of the video camera stations. In the case of vistas, the conventional oblique orientation of the cameras does not allow to perceive the width of view that can be obtained from a ground location on the beach. However, the positioning of the camera is not standard and when using more than one station, the configuration of the network can overcome this limitation by covering the possible views (figure 34).

Concerning land use, the limitations refer to the conventional location of cameras that orientate the observation range strictly to the sand water interface. Depending on the characteristics of the camera, such as focal length and resolution, zones adjacent to the boundaries of the beach can or cannot be covered by the observation range of the station. Anyway, vistas and land use are some of the landscape elements that don't change in time, so once they are recognized by primary or secondary information they don't need to be reviewed with much frequency.

Figure 34. Scheme of video monitoring network (from Archetti *et al.*, 2013).

GIS was not recognized as a useful technique in this analysis because the scheme of evaluation of coastal scenery conceived for the ICAPTU model doesn't require data integration and further analysis. The only possibility to apply GIS with the current approach of assessment is related with the functionality of data storage. Information registered for coastal scenery can be digitalized in order to make a geographical database that can be used for representing such information in thematic maps. Further studies on this area may consider adjustments to the criteria or categories conceived for each variable in a way that can be computable by GIS tools designed for spatial analysis (e.g. buffering, neighborhood, overlay). Such approximations may concede a systematic management of the information that strengthens the rigor of the assessment.

Summing up, most of the elements characterizing coastal scenery can be measured or analyzed with geospatial techniques; however, the costs of applying these techniques is higher than the conventional evaluation by the visit of an expert to the beach. The advantage can be considered when the assessment is part of a monitoring program, such as is conceived ICAPTU. When the evaluations need to be periodical, that amount of visits from experts can be expensive and time consuming, especially when there are several beaches considered in the monitoring plan. It is worth to mention that some of the elements defined for coastal scenery in the ICAPTU framework are different from the original scheme defined by previous researches (Ergin et al., 2004). Such is the case of folklore, which presented important limitations for the applicability of all geospatial techniques, and beach user's density that is only considered for video camera systems.

4.2. Safety and security

The way to measure the level of security on beaches proposed within the ICAPTU model implies the inspection of the beach from an expert trained on environmental risk assessment. The scheme for the evaluation was inspired on the methodology used on the Colombian technical guide for the identification and evaluation of risks in the workplace, designed by the Colombian Institute of Technical Standards and Certification (ICONTEC, 2010).

The calibration process of this parameter, mentioned in chapter 2, considered the same criteria of the technical guide for making the evaluation but under the specific hazard situations that can be present during leisure activities on the beach. The group of variables defined for this assessment is detailed on table 17, along with the geospatial techniques that have been considered useful for this approach.

The suitability of one technique or another is based on the kind of information that needs to be extracted when inspecting the beach for the safety/security assessment. There are four criteria: presence/absence, level of deficiency, level of exposure and level of consequence. Deficiency levels deal with the relationship between hazards, possible incidents associated to them and the effectiveness of preventive measures. Exposition levels represents how long does a person remain in contact with the source of danger. The level of consequence indicates the outcome in terms of injury of harm that can happened when a hazard materializes.

Deficiency and consequence are related with the nature of the hazard, while the exposition level may be expressed in terms of frequency and probability of occurrence. Thus, appropriate techniques that may improve or ease the assessment are those able to identify the different kinds of hazards and recognize patterns in the temporal frame. The geospatial technique that better fit these requirements is the video camera monitoring system that have already been used for analyzing some of the variables registered on table 17, such as rip currents (Jiménez, et al., 2007; Koningsveld, et al., 2007), coastal erosion (Schiaffino, et al., 2013; Ortega, et al., 2007; Dessy et al, 2007; Archeta & Lamberti, 2007) and waves (Archetti, 2007; Davidson, *et al.*, 2003). It has been told already that camera systems may offer great spatial detail on the beach as well as temporal coverage, depending on the parameters of the cameras and the configuration of the stations or whether or not there is a network of station.

In fact, temporal resolution of video camera systems may even offer an advantage over the current procedure for assessing these parameters. While the inspection of the beach by an expert may collect information perceived during the day of the visit, continuous observations with a camera system may offer more complete information for the assessment. Hazard situations that occur on the studied beach may not be evident during an inspection visit, while multiple observations from cameras, especially in surveillance operation instead of conventional snapshot captures, offer the possibility of making a more rigorous assessment by considering a representative sample in terms of days. Such analysis may influence the frequency of this assessment within a monitoring program, so that instead of making monthly evaluations, the periodicity may be longer and even retrospective analysis can be done for addressing specific beach management issues.

Table 17. Cross matrix of safety and security variables and geospatial techniques applicable

Hazards	Variable		Satellite	Air	On Field	Camera	GIS
Natural	Natural disasters/phenomena (El niño, La niña)		x				
	Hydro-meteorological originated threats	Precipitations	x			x	
		Floods	x	x		x	
		Hurricanes	x				
	Geological originated threats	Coastal erosion	x	x	x	x	
		Seism				x	x
		Tsunamis				x	x
		Landslides/liquefaction				x	x
	Waves		x	x		x	
	Rip currents		x	x		x	
	Beach topography (holes in the sand and steep slopes)			x	x	x	
	Reefs, bedrock, cliffs			x	x	x	
Environmental	Microbiological pollution of water						x
	Microbiological pollution of sand						x
	Atmospheric emissions from vehicles						
	Litter on sand and water					x	
	Hazard waste on sand and water					x	x
	Sewer presence		x	x	x	x	
	Modification of sediment dynamics				x	x	
Social	Criminal activities						x
	Reckless behavior					x	
	Increased carrying capacity					x	
	Lack of hygiene in food handling						
	Harassment of street vendors					x	
	Ignorance of regulations					x	
Biological	Invasive species						x
	Marine animals						x
	Presence of vectors and domestic animals (dogs, birds…)					x	
Physical	Solar radiation						
	Presence of artificial structures		x	x	x	x	
	Very high temperature		x	x			
	Water turbidity			x			
	Noise (intermittent or continuous)						
	Insufficient lighting on the beach					x	
Institutional	Absence of risk management plans (safety measures like signaling)					x	
	Absence of lifeguards (physical security staff on the beach)					x	
	Police absence or insufficient beach patrol of authority.					x	
	Lack of nearby medical centers						
	Absence of first aid, emergency and rescue services at sea and land					x	
	Lack of zoning (public space invasion)			x	x	x	
	Informal provision of tourist services		x			x	

Among the limitations of these systems figures all those variables that are beyond the observation range and scope, especially those related with physical and biological hazards, such as marine and alien fauna and physicochemical variables (turbidity, temperature). The microbiological variables in the group of environmental hazards neither can be detected by cameras or any other group of geotechniques because these component require specific analysis, where only GIS approach can be considered as mean for integration of existing records on a geographical representation of hazards. Meanwhile, insufficient lightning from the group of institutional hazards has been checked only for video camera systems, because stations set for operating also after down may indicate whether the beach is properly illuminated.

Hazards concerning the human component, such as the social and institutional group, are particularly favored by camera systems. Social elements considered in this scheme are related with human habits which represent the vulnerability component of the generic risk definition. The analysis of these elements is more appropriate by observing beach users habits. Camera systems have been already proved to work for studying distribution patterns of beach users on the beach (Jiménez, et al., 2007). Also progresses on the study of beach user's habits have been aided by normal digital videos captured on beaches (Palacio, 2013; Lopes, 2014). Addressing these issues with geospatial techniques may improve the knowledge on this field that is still limited. In such way, the use and implementation of such novel technologies in this area may also compensate the investment required for operating these techniques since their use would enforce monitoring goals as well as scientific advance.

The other geotechniques for acquisition and processing of data within the groups of satellite, airborne and on fields haven't presented significant advantages for the variables of safety and security. The mains reason rely on the limitations that they may offer only instantaneous measures that make it difficult to explore exposure and even identification of some elements. Such assessment wouldn't be representative for the purposes of beach quality monitoring for tourist areas.

As mentioned before satellite imagery may offer good spatial but insufficient temporal resolutions. With or without specific processing images obtained from satellites may work for simple identification of some of the variables checked for this group. Most of them are related with natural or physical hazards, especially for the hydrometeorological and hydrynamic elements that have specific missions targeting these elements. However, the real advantage of these sophisticated means of data acquisition may be misused because multispectral information is not significant for assessing most these variables.

Aerial imagery, on the other side, may offer similar information as satellite for the already mentioned functionalities that they share. Though, more precisions can be obtained for relief derived information, like beach topography, reefs-bedrocks-cliffs and artificial structures, thanks to specialized topographic and bathymetric instruments (LiDAR, Ecosounders) and photogrammetric approaches with close range imagery; the detail of these images distinguish better details like the clarity of water.

Curiously there is one variable in every kind of hazards that have been checked as possible identified from all geotechniques for data acquisition, except for social and biological where only video cameras has been considered. Within natural hazards, the issue of coastal erosion has been studied with all the techniques (Klemas, 2011; Yang, et al., 2012; Lipakis, et al., 2007; Pranzini & Rossi, 2013; Ojeda & Guillen, 2006). Sewer presence, in the group of environmental hazards, artificial structures from the physical ones and lack of zoning from the institutional group can be identified from all techniques since they are relatively easy to distinguish and position from optical sensors and GPS. The first two variables are also considered among the human elements of coastal scenery in the shape of sewage and built environment.

Finally GIS approaches have been checked for some of the variables on the list, specially considered by its functionality on assisting spatiotemporal analysis. By registering a geodatabase of all records available for these variables it can be considered some of the approaches for spatial analysis that may offer further conclusion related with the probability of occurrence and modeling of some events; although such level of detail is not detailed on the current scheme for assessing the parameter of safety and security. Besides, all the variables can be represented on a GIS environment in order to generate thematic maps depicting the spatial distribution of threats on the beach.

4.3. Urbanization

The procedure designed for assessing urbanization as a parameter within the recreational indicator of the ICAPTU model also conceive the visit of an expert to the beach in order to perform an inspection about the evidence of certain impact associated to the degree of urbanization of the beach. The variables considered for the inspection are registered on table 18, under the environmental and landscape dimensions, along with the geotechniques identified as appropriated for the required evaluation. Before checking the presence or absence of these effects, the expert must classify the beach according to four levels of urbanization because every one of the effects is ranked according to the beach typology.

Table 18. Cross matrix of urbanization variables and geospatial techniques applicable

Dimension	Variable	Satellite	Air	On Field	Camera	GIS
Environment	Solid waste generation		x		x	
	Atmospheric emissions					
	Discharges	x	x	x	x	
	Migration of species (disturbance)				x	x
	Habitats (changes and fragmentation)	x	x		x	
	Changing sediment dynamics	x	x	x	x	x
	Microclimatic variations	x	x		x	
	Modified waves	x	x		x	x
	Noise pollution				x	
	Soil sealing					
Landscape	Visual intrusion	x	x		x	
	Changes in natural morphology	x	x	x	x	x
	Human concentration	x	x		x	
	Employment generation				x	
	Loss of vegetation cover	x	x		x	x
Beach Typology	Beach user density	x	x		x	
	Construction density of the built surface	x	x	x	x	
	Shore protection structures	x	x	x	x	
	Mixture of human activities (infrastructure)	x	x	x	x	

The four typologies are: a) *minimally rigid* or altered natural beaches, that characterize beaches by few infrastructure and low contrast between artificial construction and the elements of the landscape; b) *moderately rigid* or urbanized beaches are those who present human settlements with low density, height and extension of the built environment, moderately mimicked in the landscape and variable beach user affluence; c) *rigid beaches*, represented by a lack of homogeneity on the density, height, extension and materials of the built environment; and d) *highly rigid beaches*, characterized by the presence of shore protection structures and robust hotel structure that highly contrast with the original landscape, high density of visitors and they may be also found infrastructure for purposes different of tourism, like port or industrial activity.

The criteria for categorizing the urbanization level are based on the density of beach users and of the constructions on the built surface and particular marks, such as shore protection and mixed human activities. Thus the assessment is based on both, the identification of 15 variables in the environmental and landscape dimensions and the remarks of the beach typology (also enlisted in table 18). Considering first these criteria it can be stated that every view of the beach from above is particularly favorable for defining the progressive levels that characterize every urbanization category. These typology variables are coarser elements to be considered on a preliminary observation of the study area because further details need to be addressed for the other dimensions. All these elements can apply the geotechniques for data acquisition, except in the case on beach users density that have been previously mentioned an inoperative to study with on field techniques.

In general, almost all the variables can be analyzed from the data offered by satellite and aerial imagery and the video camera system. There are two variables that could not be evaluated from any geospatial technique because they represent elements that cannot be perceived optically or by positioning. These two variables, atmospheric emissions and soil sealing are conditions that can be indicated by the presence of traffic flow surrounding or inside the limits of the beach. However, these variables would not be properly assessed without being present on the area where the expert can perceive them by sensitive signal (inference of the impact or texture of the sand), unless there are available records of specialized measures this conditions (gas detector of lab analysis of soil). These variables could be assumed from geotechnique in case that traffic is captured on the images or there are streets or roads right on top of the sand.

Solid waste generation, discharges and human concentration present similar definitions as the variables discussed on the parameter of coastal scenery, referred respectively as litter, sewage and built environment. Human concentration is related with the presence of infrastructure for tourist activity, such as hotel, resorts, restaurants and so. Their proximity to the beach usually calls for bigger amounts of visitors, which also link this variable with user's density. Beach user's density has been discussed widely before, where video camera systems have been successfully used (Jiménez, et al., 2007), instead of high spatial resolution imagery that don't allow as much frequent calculations as video cameras.

Changes in sediment dynamics and changes in natural morphology are variables strongly related. Both of them refer to shifts on beach with due to the presence of structures on the water that alters the natural currents and the sediment deposition in their surroundings. The difference of these elements is basically the approach of the two dimensions (environment and landscape) that were considering during the exercise on environmental impact assessment. The morphological evolution of beaches in this context has been widely analyzed with all the geotechniques considered in this study, including GIS (Yang, et al., 2012; Lipakis, et al., 2007; Pranzini & Rossi, 2013; Chaaban, et al., 2012). 'Modified waves' is another variable considered in the evaluation scheme for this parameter that is linked to the presence of rigid structures on the shore. In the same way that rip currents can be identified by simple observation of satellite, aerial and cameras imagery by the water patterns (Cerimele, et al., 2009; Klemas, 2013; Koningsveld, et al., 2007: Jiménez, et al., 2007), waves can also be detected from such approach.

Microclimatic variations and visual intrusion are two variables related with the presence of constructions of facilities on the beach and its surrounding. Microclimatic variations could be considered as one of these elements only perceived by personal sensations, but this element is well indicated by the shadow effect of buildings or tents. This kind of situation can be easily observed from all kinds of images. Meanwhile, the variables of employment and noise generation bring back to light the versatility of video camera systems because this secondary effect of the level of urbanization in a beach is a human element better characterized by observing frequencies and interactions between users and service providers on the beach. Also, cameras recording as surveillance systems instead of instantaneous image capture can give a sense of the level of noise. Frequent measurements are the strength of video camera systems, characterized by continuous monitoring practices (Schiaffino et al, 2007).

Finally, Migration of species, habitats and vegetation cover are a set of measurements that can be misread if records are not considered. The issue with these variables rely in determine how the flora and fauna have been modified by the presence of buildings and civil structures on the beach. In this sense, comparisons of such natural conditions before and after urbanizing processes have taken place. This kind of spatiotemporal analysis is the domain of GIS. An appropriate example of this application is presented by Crawford, *et al.* (2013) who assessed the impact of residential development on vegetation cover for a coastal barrier in USA. Aerial imagery was used in a GIS environment in other to detect vegetation changes in areas of urban development through the approach of parcel development patters (figure 35).

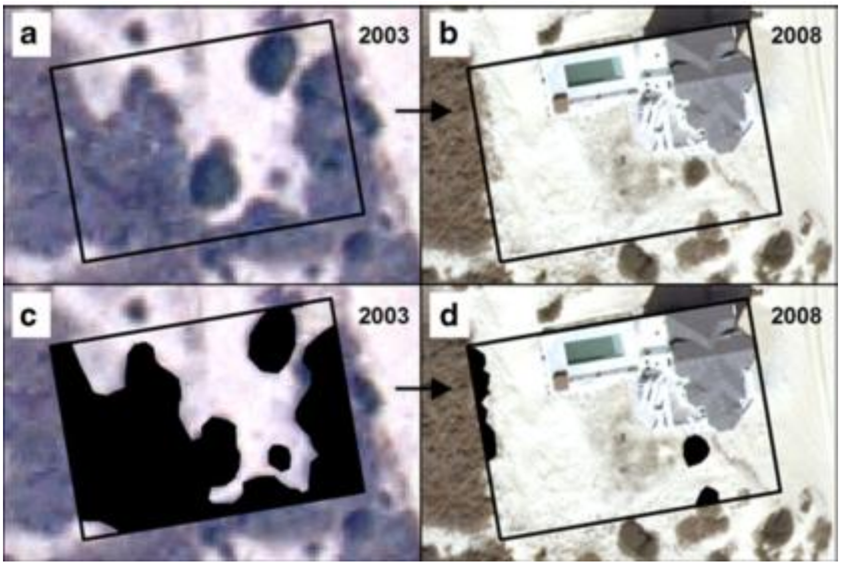


Figure 35. Vegetation change detection in a segment of a coastal barrier in the Outer Bank (USA) between 2003 and 2008: a–b developed parcel ortho imagery, c–d area of developed parcel vegetation cover (black). Adapted from Crawford, et al., 2013

Summing up it is possible to affirm that geospatial techniques can be particularly appropriate for assessing most of the variables of the urbanization parameter. More than just complementing information required for the assessment, deeper study on the applications highlighted may lead to completely evaluate this parameter remotely, without field visits. Also, the convenience of geospatial techniques can optimize time and resources for assessing these parameters when frequent measurements are required for monitoring purposes and in several beaches, as is the projection of the ICAPTU model.

4.4. Zoning

The procedure for evaluating the parameter zoning in the beach is also conceived to be done a field visit of an expert familiar with the concepts of zoning factor. The expert would perform an inspection of the beach and mark in a check list the absence or presence of a set of factors in a check list. Every variable considered on the scheme have a score obtained by the criteria of an interdisciplinary group of experts related with beach management issues, so the final value of a beach in terms of zoning is given by the score obtained from certain configuration of factors identified.

Since the criteria of assessment in these parameter is absence or presence of certain indicators, the systematization of these evaluation presents less difficulties that the former parameters. The variable considered for zoning can be adequately distinguished in a georeferenced plan of the beach. The set of variables organized by zoning factors is indicated in table 19, where the geospatial techniques studied in this document have been considered as applicable for the evaluation.

On field techniques are considered in this section on the basis of its positioning characteristics. Satellite and aerial imagery together with video camera systems are considered by the possibility of making simple interpretation of images. And once again, GIS is considered here as a mean for storing the information gathered and making a visual representation of the patters recognized. So in table 19 GIS is not marked for any variable because none of the data processing approaches offered by the tools of this system would be required in the current mechanism of evaluation.

In the factors considered for spatial organization all the groups of geospatial techniques for data acquisition present possibilities of application. Since this dimension of beach zoning relates with the spatial distribution of activities on water and sand, both images and positioning systems from can be used for delimitating the areas distended for specific uses. On field measurements for georeferenciation and calculation of such areas are though the most inconvenient of all because it would consider extenuated sections on the field with GPS devices and laborious measures. Image interpretation from satellite, air platforms or cameras, on the other hand, may offer a quick and convenient identification of the zones clearly identifiable by delimitation (buoys, fences, marks and so) or diffuse limits posed by patterns of human activities and user’s habits.

Good spatial resolution would be the main advantage of the system to apply, so more convenient and cost effective acquisitions are within aerial imagery wit simple digital camera and video monitoring systems. In the case or tourism service area, for instance, camera systems may present the same limitation as the ones mentioned for the variable of land use in the parameter of coastal scenery. The conventional oblique position of the camera addresses the view range to the sand water interface, for studying this dynamic zone, which may leave out of the observation range the adjacent zone to the landward limit of the beach. This zone of consolidated material is considered as for providing tourist services, characterized for commercial activity.

Table 19. Cross matrix of zoning variables and geospatial techniques applicable.

Factors	Variable	Satellite	Air	On Field	Camera	GIS
Spatial organization	Green zones	x	x	x	x	
	Parking lot	x	x	x	x	
	Tourism services area	x	x	x		
	Public space binding site	x	x	x	x	
	Transition area	x	x	x	x	
	Users resting area	x	x	x	x	
	Users active area	x	x	x	x	
	Bathing area	x	x	x	x	
	Nautical sports area	x	x	x	x	
	Area for vessels transit	x	x	x	x	
	Vessel parking area	x	x	x	x	
	Promenade	x	x	x	x	
	Beach access	x	x	x	x	
	Signing	x	x	x	x	
	Sports and recreational facilities	x	x	x	x	
Regulation	Respect for beach public use				x	
	Absence of discharges	x	x	x	x	
	Solid waste management				x	
	Lifeguard service				x	
	Presence of trash cans/Cleaning periodically				x	
	Non-cemented structures	x	x	x	x	
	Ornamentation with native plants					
	Beach management					
Commercial organization	Peddler identification					
	Forbidden animals at food courts				x	
	Clean sales sites					
	No disturbing advertising activities	x	x		x	
	Legality of goods					
	Hygiene and sanitation with products					
	Access to potable water					
Beach users' organization	Carrying capacity	x	x		x	
	Beach information board					
	Code of conduct for all					
	Tourist information points	x	x	x	x	
	Safety recommendations					

The fact that all variable considered in the spatial organization may be addressed by most of the geotechnique identified confirms the suitability of these techniques for spatial analysis, whether the criteria are qualitative or quantitative. Almost none of the other groups are checked; the variables within the groups of regulation and commercial organization have similar situations with the human component of the other recreational parameters analyzed. The variables that can be identified with geospatial techniques in these groups include absence of discharges that can be related with the variable of sewage from the human elements of coastal scenery and sewer presence from the environmental hazards of safety and security.

“Non segmented structures”, also from the regulation factors of the zoning parameter, is related with build environment from the human component of coastal scenery and the variable of artificial structures from the group of physical hazards of safety and security. Non disturbing advertising activities, from the commercial organization group in table 19, are related with the variable of visual intrusion from the landscape segment of the urbanization parameter. All these similarities among variables of different parameters are curiously in the small group elements within the zoning factors of regulation and commercial organization that can be identified with most of the geotecniques.

Within beach users organization group of variables only carrying capacity and tourist information codes are easy to observe with geotechniques. Carrying capacity, for instance, has a strong relation with beach user’s density, because it refers to the amount of visitors that can be supported by the system without losing quality on the recreational experience and the sustainability of the natural environment (Daza & Botero, 2014). Having a measure of the amount of tourist on the beach and the threshold set by the limitations of the beach system, this variable can be deduced. It has been told already that within geospatial techniques this measure of the amount of people on the beach is one of the few recreational remarks that have been studied.

The group of variables that have no mark in any geospatial technique are mainly those related with the information that cannot be observed from an instantaneous capture of the area and aren’t subject to spatial configurations. Instead, this group of elements require for an expert to collect information on field by experience social interactions on the beach. Such is the case of the variable of beach management because it refers to the existence of a community composed by representative of the stakeholders that willingly take responsibility for managing the beach (Noguera, Botero, & Zielinsky, 2014).

The knowledge of this element is most probable to obtain form interactions with personal on the beach. Similarly can occur with the other variables, such as cleanliness and hygiene of commercial establishments, legality of goods, access to potable water, safety recommendation and code of conduct communication. The majority of variables marked on camera systems within the groups of regulation, commercial and beach user’s organization are considered for the need of frequent samples for evaluation. In these sense, it has been already discussed the advantages of video camera systems for the possibility of continuous monitoring.

4.6. Google Earth for scientific research

Google Earth is a resource of geospatial information that have been used as a mean for making scientific analysis of human and natural elements (Mitasova, et al., 2012; Equipo-Humano, 2007; Harris, Nel, & Schoeman, 2011). Google Earth belongs to the group of Virtual Gloves models that have been developed as online versions since 2004, starting with NASA WorldWind, followed by Google Earth, Bing Maps and Marbel, among many others. These models are 3D representations of the Earth that allow users to change viewing angle and positions in order to move around a digital environment. Originally these approaches have been developed for the general public, but their easy access and reliable information have increased its popularity among the scientific community (Oleda & Mateo-Tomás, 2013). Researchers have found on these resources a mean for interactive representation and communication of geosciences information.

Among all Virtual Glove softwares, Google Earth has obtained great recognition. As free software it allows users to navigate along satellite images all around the world while observing geographic data. Images come from high resolution satellite QuickBird, complemented with additional data offer real representation of elevations and patterns. For instance, the National Science Foundation (NSF) provides browsing access to scientific LiDAR data through Google Earth relief shaded images in the penTopography portal (Mitasova, et al., 2012).

The big amounts of details of natural and human elements represented inlayers overlapped on the all the images around the globe become Google Earth into a global geographic information system presented as service itself. Even temporal analysis can be assisted by the observation of the trend of images available for a single area from different years or months. Further applications can be done by purchasing additional services, such as Google Earth Plus that allows the addition of data imported from GPS or spreadsheets, and Google Earth Pro that offer the possibility of processing external data and measure surfaces.

The helpfulness of this resource has been already demonstrated in marine and coastal studies. Harris, Nel, & Schoeman (2011), for instance, developed a methodology where sandy beaches can be classified remotely from Google Earth or other satellite imagery sources in order to select areas for conservation priority. Purely desktop approach was done for South African sandy beaches, where beach morph dynamics are mapped in ArcGIS software by digitizing the shapeliness onto satellite imagery. A dataset was generated for 45 micro tidal beaches by measuring or coding several physical characteristic from imagery available on Google Earth.

The methodology included the identification of physical attribute of beaches, the statistical grouping of these attributes into a classification scheme, the integration of biological spatial patterns for habitat mapping that reflect shady beach biodiversity and digitalization of shape files to be used in a GIS analysis for systematic conservation planning. Physical attributes identification was done with Google Earth images to recognize the features of the two types of beaches considered, dissipative and reflective. These attributes included surf zone width and type, exposure, number of waves in the surf zone, beach with and slope (figure 35).

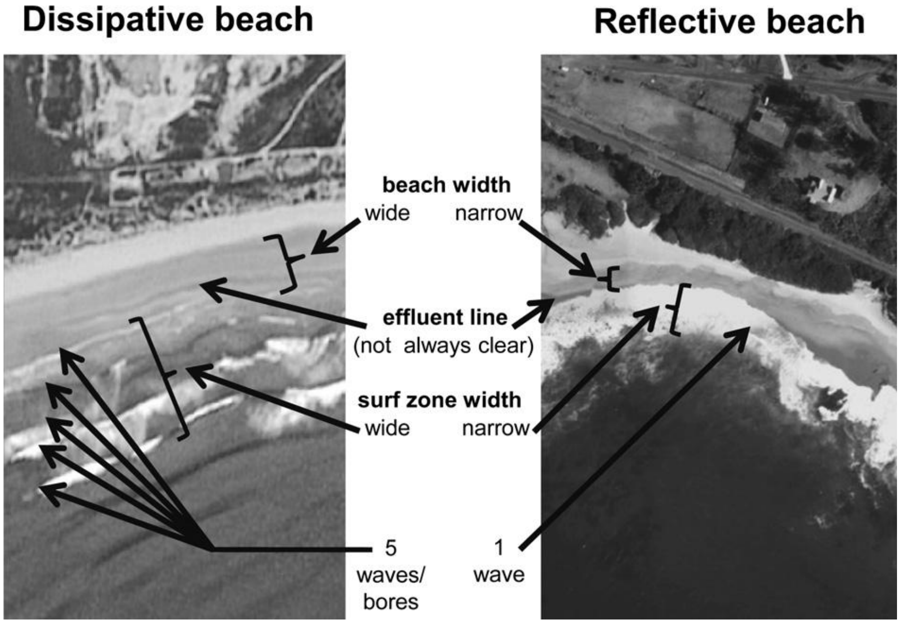


Figure 36. Physical attributes identification on South African sandy beaches classified by the way energy is absorbed by the shore; dissipative of reflective (from Harris, Nel, & Schoeman, 2011).

Patterns in the surf zone were considered on image observations for detecting the presence of offshore sand bars and rips. Surf zone width was defined from the distance between the average landward position of the swash edge in the image and the seaward edge of the white water from the outmost breaker at the backline. Beach width estimation for intertidal coasts was the distance between the portion of the beach site with the lowest position of the swash and the estimated drift line, which is visible as the line of wash up debris presumably along the high water mark. Beach slope was approximated to the distance between the position of the swash edge and the effluent line, which may be the width of the saturation zone.

These are fairly subjective estimates but the work to build up a map representing the distribution of habitats according to the sandy beach classification scheme; the information is worth to consider for conservation planning. This experience shows the potentiality of using simple and accessible geospatial resource, such as Google Earth, for relatively coarse assessments that contribute to management purposes. Such approach can be extrapolated to recreational quality assessments that are also conceived to support management requirements. Some of the physical attributes defined by Harris, Nel, & Schoeman (2011) are included on the variables enlisted for some of the recreational parameters studied. These examples of simple photointerpretation for defining features have a potential application on recreational parameters. Future development of the research of geospatial techniques for BEQ would consider refining these estimations aiming at systematizing the assessment.

One of the variations of the Virtual Globe models worth to mention for the study of recreational parameters is the Street View. This is a characteristic of the Google Maps application and Google Earth software that provide panoramic view at ground level over the streets of a city and their metropolitan surrounding. Similar services have been developed after the version of Google, such as Seety or EveryScape that developed their own mechanisms for recording roads where Google can't reach.

The systems allow users to virtually walk along the streets of a locality with a 360° of horizontal view and 290° of vertical movement. The images are generated from a vehicles equipped with advance technology cameras to generate images. All the photos captured by this system are then merged to generate the panoramic view. Besides main streets, there are also pedestrian zones captured with adapted bicycles.

Figure 37. Google vehicle that capture the images for the Street View service. Source: http://maps.google.com/

These characteristic of Google Maps and Google Earth have been widely used for recreational purposes. Normally users can make virtual visits to tourist attractions around the world and surround cities through streets and parks with great graphical quality. These properties make this service also very appropriate for supporting the assessment of recreational parameters. The observation of images from Street View can offer the kind of qualitative information required to complement recreational quality evaluations. It has been stated that most of the variables of these parameters are based on the qualitative analysis mostly available from optical instruments, such as cameras.

Even though full view of beaches with the Street View service is not guarantee because beaches that are not in front of a street are not covered by the system, with time more beaches can be observed when the coverage of pedestrian zones is improved. Specifically for the urbanization parameter, this resource is appealing because the required data don't rely on precisions like the number of buildings or the kind of materials. This assessment is more related with the perspective of the built environment from its stiffness, distribution and diversity. Such appreciations can be obtained from street view as ancillary data and when beaches cannot be visited.

CONCLUSIONS

Along this document they were analyzed four coarse groups of geospatial techniques used for marine and coastal environments. Three of them focused on mechanisms for data acquisition, including the usual approaches for data processing, satellite systems, airborne platforms and video camera monitoring systems, and finally GIS as the mean for data storage, integration and representation. Now, there are three or maybe four criteria that should be considered when choosing one geospatial technique or another in the study of beach management issues. Scale requirements, frequency of assessments, coast of the technology and state of knowledge of the geospatial techniques are important elements to consider.

Concerning the scale, it must be considered that according to the sensor or device the scale of data collection is different, as well as the scale in which the information is required. The study unit of a beach is initially conceived by the physic-natural dimension and after the socio-cultural and politico-administrative dimensions. The two last ones are the preferred criteria for beach management purposes and the study unit that they comprehend usually doesn't exceed tens of kilometers, with some exceptions. In these sense, satellite and aerial platforms allows data acquisition from different beaches within one region and even a high amount of beaches when the images are taken in sections of several kilometers.

Meanwhile, field instruments or video camera systems offer information from a single beach or adjacent areas. However, it is worth to consider that scale for beach quality assessments should be enough to represent one only one beach at a time. Thus, when studying one beach in particular it should be considered the cost-effective analysis of using images that contains several beach units if the information required is from only one study unit. Images with bigger scales usually lack from precision or detail, and the ones who offer grate precision are very expensive. In consequence for beach management it is better to work on the scale that can offer by video camera systems, by images collected by Unmanned Aerial Vehicles (UAV) or by some of the on field techniques.

Regarding frequency, there are two conditions defining this criterion; there is the frequency of data collection and the other is the amount of information that have been collected over time for a single parameter. In the second case there is much more information about natural and earth sciences than for social sciences that are based on qualitative data. Thus, it is better known the frequency required for measurements in variables related with geological studies, than the one required for social studies. Parameters conforming the recreational indicator in the ICAPTU approach fit better in the field of social studies.

In relation to the frequency of data acquisition, satellite and aerial platforms offer lower frequency because the acquisition is subjected to the pass of the satellite or to the coordination of flight plans. Instead, video camera systems offer higher frequency because they make continuous observations, while the frequency of images taken with UAV can be conveniently adjusted to the needs and for on field techniques it depends on the difficulties to transfer the work team and equipment. In consequence there can be defined three levels of frequency of data acquisition, low frequency from satellites and airplanes, medium frequency from field techniques and UAV systems, and high frequency from video camera monitoring.

With reference to the third criteria mentioned for selecting a geotechnique, costs, it should be taken into account that analysis based on images obtained from satellite and aircrafts are more expensive. The acquisition with these systems depends on the routine of the satellite or the airplane and it is not easy to obtained tailored images, which translate in higher costs. For on field techniques there must be considered the costs for transferring to the area both, personal and instruments. In the case of video cameras the cost of installation may be high but the cost of maintenance and continuous generation of data is reduced, which make it redeemable and also competitive since low resolution cameras are not much expensive for a monitoring system. With these UAV systems, that belong to the airborne category but for close range captures, it is required an initial investment (~15000EUR) that is well amortized with a desirable frequency of use and its possibility to study multiple beaches, instead of just one. This kind of analysis is significant because the cost is always an important criterion within coastal management projects.

Considering the common uses of the geospatial technique identified, most of the literature reviewed was related with studies in the field of geology and earth sciences, along with some variables related with the fields of oceanography and biology. This information has turned out to be very limited for the recreational quality approach of the ICAPTU model. Most of the variables considered in recreational parameters are within social and environmental disciplines that need applied information rather than exact data. Besides, the two occupations for which geospatial techniques are particularly suitable are geology and geography; out of them geology is the one who has make more use of these techniques.

Geographic studies usually don't support their analysis with geospatial technique, which leads to almost no documented experiences of their application. These kinds of experiences would be a better reference for the study of recreational parameters because the kind of data used by social and economic geography is more suitable for the ICAPTU approach. It is encouraged then to consider a geographic approach for further studies on these recreational issues and also to promote the integration of geospatial technique, other than just the application of GIS, for geographic studies.

Another conclusion of this study is related with accuracy requirements on data for recreational parameters. Most of the sensors and instruments described offer data with levels of precision and accuracy that correspond to quantitative analysis rather that quantitative. It doesn't mean that data with high precision, like satellite imagery, cannot be subject of qualitative analysis. However the reductionist approach has lead to consider as valuable only what is quantitative, forgetting that for management purposes qualitative information is more valuable because they indicate processes and change factors conceived from a the perspective of complex systems. In consequence, majority of geospatial techniques can be very useful for recreational parameters, although they require more study on how to apply them and analyze them with the information that is currently being processed.

It is worth to mention in these conclusions that the ICAPTU model propound a measure conceived from applied sciences rather than exact sciences. Therefore, this model is a novel approach to assess environmental quality because it integrates quantitative and qualitative information in order to make them compatible and complementary. Future investigations must be focused on the way to apply the model for making a systematic measure of the parameters of ICAPTU, specially the recreational ones, in order to make them more consistent in terms of the scientific rigor. However, this study represents a first step to recognize among the existent geospatial technique the ones that are worth to consider in further researches.

In regard to the techniques that were found more appropriate for the assessment of recreational parameters in ICAPTU, there outstand images obtained from video camera and UAV systems. Video camera systems are considered suitable because they offer better frequency of data acquisition, lower coasts of installation and better appropriate scale for the study of a particulate beach. Drones or UAV systems are also a promising technique because they allow an economic mean of data acquisition, considering the amortization of the investment, but they are also tied to specific software that facilitate the analysis of the images captured by the drone and the geographic information derived from them. Such analysis consider the generation of digital elevation models, geotagged photos and mosaic of images that allow the observation of phenomena taking place on the beach. Nevertheless, additional studies on the others geotechniques (on field, satellite and airborne) should be done to verify whether they can be optimized or the information that they generate can be applied as it is.

Along this study it was stressed that there is a great amount of variables that ‘repeat’ among two or three parameters. Even this kind of variables is not completely equivalent because the category or criteria of evaluation is different from one parameter to other, they can be measures simultaneously since the same data can feed more than one parameter. This situation reflects that the current scheme of ICAPTU represent a fragmented monitoring program, in which every parameter has its separate protocol, measurement instrument and data structure, but all this structure is not integrated. This is precisely one of the advantages that pose geospatial technique to the research on ICAPTU because each data retrieved from them can feed several parameters automatically. Also GIS would allow not only generate new information, as mentioned in the tables of chapter 4, but to integrate all the information gathered from the different geotechniques , eliminate redundancies and also calculate the values of the parameter out of shared data. This would make it easier and practical to measure the parameters of ICAPTU in a technological way.

Inside the mentions made to online services to support research, such as Google Earth and its characteristic Street View, it is important to highlight that they have a wide coverage and easy access, besides being free. Therefore, this online services would allow complement the measurement of geospatial techniques. Even if they still don’t have sufficient amount of data required to make a complete assessment of any parameter, they allow complementing the information and even making measurements that haven’t been established by the geospatial techniques mentioned in this study. This preview makes it evident that the future of geographic information is toward online services that have been gaining importance progressively. Thus this services should be taken into consideration to focus future researches on geovisores, real time measurements of parameters like beach user’s density or variables that can be analyzed from cameras, drones or any other kind of geotechnique installed on field or able to offer good frequency of measurement.

One of the final conclusions that is particularly address to the interests of the master program that contain this study (*EXPO-Master in Marine and Coastal Integrated Management*) concerns the fact that ICAPTU is conceived to the tourist sector and so the monitoring tools proposed by it should be easily understood by people that is not familiar with technical concepts on geographical information. Likewise it has to be considered that geospatial techniques should support the process of decision making in coastal areas, aiming at the improvement of the integrated coastal management, including tourist beaches. It is also worth to mention that ICAPTU has been thought as a monitoring platform that offer rigorous and frequent information about the state of the beach, allowing that proper decision may be taken opportunely.

Regarding this need for management tools, local research is considered as an important mean to orientate the progress in the administrative sphere. In Colombia, grate impulse is being given the research at regional and local levels supported on the resources available from bonus or royalties derived from the coalmining granted to multinational companies. Such availability of resources is very attractive to politicians and those responsible of the public administrations, which are in charge to present and do the loving of research proposals into the governmental mechanism to adjudge these grants. Beach management is doubtless one of the topics of interest in such administrative atmospheres, both because of the value of the coastal areas as an active and a delicate natural system.

Studies, like the one presented in this documents are pertinent in order to channel research efforts in terms of pertinent and realistic proposals. By doing so, it can be noticeable how some initiative instead of being reliable are just in pursuit of founding and not in local development. It wouldn't be weird that some politician tries to promote some ridiculous project just to obtain the resources, such as pretends establish a mechanism to count the amount of cigarette butt on the beach through satellite imagery. Despite being obvious some of the precisions made in the analysis of this thesis, they need to be document and supported by a scientific process as they has been in order to debate captious ideas like the example suggested.

Finally, it is worth to mention that the practical experience held in Italy in the context of this study have been of great value because it allow a better understanding on the technical and operational principles of the geospatial techniques and also generate the opportunities to make contacts with research groups related with coastal issues and with wide experience in geospatial techniques. The insights obtained with this experience are worth for further research stages where these understandings are going to be tasted in the Colombian reality, enforcing knowledge transfer processes. In these way currents progresses on the study of coastal systems in Colombia may be strengthen by potential applications that complement this study field. Such is the case of the research line of Tecno-ICAPTU that is focused on the development of electronic devices that facilitate urinary field measurements of parameters within the sanitary and ecosystem dimension of the ICAPTU model.

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