AIT Series

Trends in earth observation

Volume 1

Earth observation advancements in a changing world

Edited by Chirici G. and Gianinetto M.

Earth observation advancements in a changing world

Edited by

Gherardo Chirici and Marco Gianinetto

AIT Series: Trends in earth observation

Volume 1 - Published in July 2019
Edited by Gherardo Chirici and Marco Gianinetto
Published on behalf of the Associazione Italiana di Telerilevamento (AIT)
Via Lucca 50
50142 Firenze, Italy

ISSN 2612-7148
ISBN 978-88-944687-1-7
DOI: 10.978.88944687/17

All contributions published in the Volume "Earth observation advancements in a changing world" were subject to blind peer review from independent reviewers.

Publication Ethics and Publication Malpractice Statement
Editors, Reviewers and Authors agreed with Publication Ethics and Publication Malpractice Statement

Preface

Since 1986 the Italian Remote Sensing Society (Associazione Italiana di Telerilevamento – AIT) aims to disseminate remote sensing culture, disciplines and applications in Italy. Specifically, AIT's mission is to:

- Create a network of people from Research, Academia and hi-tech Companies interested in analysis, development and application of a wide range of remote sensing methods and techniques;
- Promote and coordinate initiatives to expand the use of remote sensing technologies in Italy and across the European Union;
- Foster the exchange of knowledge and cooperation between its members to "shorten" the chain: research→innovation→new applications/markets→research;
- Support the dissemination of remote sensing methods through the organization of congresses, conferences, working groups, including international thematic courses;
- Represent and take care of scientific and cultural interests in remote sensing for institutions, agencies, companies and similar associations, at national and international level.

Recently, AIT was included in the Italian Copernicus User Forum among the representatives of the IV sector. AIT is also the official Society of the European Journal of Remote Sensing, an open-access scholarly journal published by Taylor & Francis.
Until 1995, AIT was used to organise National Conferences, but in 1997, the Society joined a wider Federal Association (Associazioni Scientifiche per le Informazioni Territoriali e Ambientali - ASITA) related to Cartography, GIS, Topography, Photogrammetry and Remote Sensing, which organises annual national conferences to share and diffuse the Geomatic advancements.

In 2016 AIT decided to bring back its tradition to organize its national conferences with a more distinctive research trait. In addition, always in that year, AIT started to organize its annual International Summer Schools for the exploitation of Copernicus data and programmes.
In this framework, we decided to take the opportunity to create a new book series, officially supported by AIT, entitled *Trends in Earth observation*. These volumes want to present to the readers a snapshot of the state-of-the-art in several different application fields.
I hope that *Trends in Earth observation* can contribute to the scientific progress and the continuous innovation of Earth Observation.

AIT President
Livio Rossi

Contents

Introduction

Earth observation advancements in a changing world

Chirici G., Gianinetto M.

Trends in Earth observation (ISSN 2612-7148) is a new series supported by the Italian Society of Remote Sensing (AIT) which purpose is to provide a new media for publishing the outcomes of high-quality researches. This series accompanies the well-established European Journal of Remote Sensing, which is the official journal of AIT, and shares its blind peer-review process. However, while the journal is general purpose, Trends in Earth observation addresses specific emerging topics organized into thematic chapters.

This first volume of Trends in Earth observation is entitled Earth observation advancements in a changing world and includes 47 contributions from colleagues belonging to 10 different countries, organized in 6 chapters. Compared to similar volumes which often focus on the techniques and methods, Trends in Earth observation also describes case histories. In this sense, it provides the present state-of-the-art of many real-world remote sensing applications.

The first chapter is specifically oriented to agriculture applications of remote sensing and authors present innovative applications for monitoring problems of different cultivations (coffee, rice, olive, maize, tomato, oil palm) in different environmental conditions and with different Earth Observation technologies.

The second chapter covers the very wide area of forest monitoring and environmental studies. Two of the most common issues are the recognition of tree species and/or forest types and the multi-temporal analysis of vegetation trends and disturbances.

The third chapter is focused on disaster risk and geomorphologic applications, also including some applications using UAVs which is a relatively recent new area of remote sensing applications.

The fourth chapter describes applications in the field of water management and protection, with a specific focus on the mapping of water resources with different data and different resolutions.

The fifth chapter addresses the monitoring of coasts and the last chapter reports new advancements in the monitoring of urban environments using either optical or radar images.

We gratefully acknowledge the contributions of all authors and hope you will enjoy reading this first volume of the new series Trends in Earth observation.

UAV APPLICATION FOR MONITORING THE ANNUAL GEOMORPHIC EVOLUTION OF A COASTAL DUNE IN PUNTA MARINA (ITALY)

E. Grottoli*, P. Ciavola, E. Duo, A. Ninfo

Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Via G. Saragat 1, 44122, Ferrara, Italy
(grtdrd, cvp, duonrc, nnfndr)@unife.it

KEY WORDS: SfM photogrammetry, High resolution DEM, DoD, Dune geomorphology, Dune conservation, Incipient dune, Drone application.

ABSTRACT:

Unmanned Aerial Vehicles (UAV) allow to gather detailed topographic data at low cost over large survey areas. The study site, located in Punta Marina (Emilia-Romagna), is one of the few regional coastal locations still characterized by "natural" dunes; in 2015 a preservation scheme was realized to protect the dune system and reduce the erosion and vegetation degradation generated by beach users. Four UAV surveys were performed using a commercial DJI Phantom 3 Professional, a quadcopter equipped with the standard digital camera of 12 megapixels (3.6 mm focal length). Drone surveys were supported by a RTK-GNSS, both for GCP measurements and drone-derived DSM validation. Orthophotos were obtained through photogrammetry processing with a geometric resolution of about 3 cm, generating a DEMs with a cell size of 5 cm. Dune morphology was compared by means of DoD processing to understand the geomorphological evolution and quantify the volume of sediments displaced. The most evident result is related to the growth of a small incipient dune fed by aeolian processes and enhanced by preservation measures (planted vegetation and wooden fence). A cumulative vertical growth of 0.5 m was locally measured after the monitoring period. The role played by the growth of pioneer plants in overestimating volume changes was quantified as +11%. The use of drone-derived images, combined with SfM algorithms, allowed to achieve a centimetric accuracy in the incipient dune analysis. This methodological approach can represent an efficient tool for coastal and landscape managers, both for mapping and risk assessment purposes at small spatio-temporal scales.

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) are today a common tool adopted by geomorphologist to monitor landform evolution in different environments. The geomorphic evolution of coastal zones is often fast and it requires efficient, low-cost and sufficiently accurate monitoring techniques like UAV that can provide a practical option for multi-temporal surveys (Casella et al., 2016, Turner et al., 2016). In a few years, the commercial market growth, combined to the development of SfM (Structure from Motion) photogrammetry, have assigned UAV the role of low-cost and user-friendly tool for surveying and monitoring landforms where short-term evolution is taking place, like in coastal areas.

In sandy coastal zones, dune morphology is constantly changing due to the sand transport capability exerted by forcing factors such as wind, waves and tides. In the current scenarios of sea level rise and worsening of erosion processes along large portions of coastlines, dune conservation and stability represent essential conditions that have to be maintained by local authorities and citizens. Coastal dunes also represent a natural defence from sea flooding and can protect strategic infrastructures and populated urban areas located behind them. The results of a yearly monitoring programme (from March 2017 to April 2018), performed by means of UAV surveys at seasonal intervals, are presented, focusing on the geomorphic evolution of a coastal dune system, recently subjected (2015) to a preservation scheme by local authorities. The most active dune in the study site is the one closer to the shoreline, which was recently artificially vegetated with pioneer plants (2016). Contrarily, the dense vegetation which covers the stabilized rear dune makes the use of drone-derived images difficult to detect geomorphic changes of loose sediments. For these reasons we chose to focus on the geomorphic evolution of the embryonic incipient dune being covered by pioneering vegetation and easily subjected to geomorphic evolution. Although the development of new dunes is well described, we know little about the factors that determine the speed of early dune development (van Puijenbroek et al., 2017). As highlighted by van Puijenbroek et al. (2017), the contribution of vegetation and dune size depends on seasonality and degree of shelter, therefore it seems important to investigate the effectiveness of the preservation scheme recently built for this dune, in order to propose an appropriate management scheme.

2. STUDY AREA

The study area is located on the Northern Adriatic coast, 12 km NE from the city of Ravenna adjacent to the Punta Marina village (Emilia-Romagna, Italy). The monitored dune reaches 6 m in elevation, it is 600 m long and 150 m wide and is separated from sea by a 40 to 60 m-wide sandy beach. It represents part of the 28% of preserved dune systems still surviving along the whole regional coast (Perini and Calabrese, 2010). The area is an alternation of natural elements and human structures such as bathing installations and recreational activities. The beach facing the dune is bounded at its southernmost limit by a 70 m long groin that traps sand from the littoral drift directed northwards. The wave climate consists of small waves from E occurring for most of the time (about 90% of significant wave height is below 1.25 m). The main storm directions are from SE ("Scirocco" wind) and ENE ("Bora" wind): the latter is the strongest wind that generates the most energetic storms. The microtidal range is 30-40 cm at neap tide and 80-90 cm at spring tide. Despite the small tidal range the combination of high tides and storm surges can be significant for morphological changes of the dune and beach system (Armaroli et al., 2012).

* Corresponding author

2.1 Dune preservation project by local authorities

Between May and June 2015, local municipalities built a preservation scheme for the dune in order to reduce the increasing dune trampling produced by beach users and hold back the geomorphic and vegetation deterioration. The project mainly consisted of a 1-m elevated wooden pathways crossing the dune system (Figure 1). A wooden fence was also built few meters distant from the foredune toe to improve the sand trapping and stabilize the entire dune ridge in its seaward-most line. Deployment of sand-trapping fences is a common adjustment that changes the characteristics of the dune ramp and its role in linking sediment transfers from the backshore to the foredune (Jackson and Nordstrom, 2017). Furthermore, 5500 typical dune plants were planted in autumn 2016 to accelerate sedimentation and growth of the incipient dune.

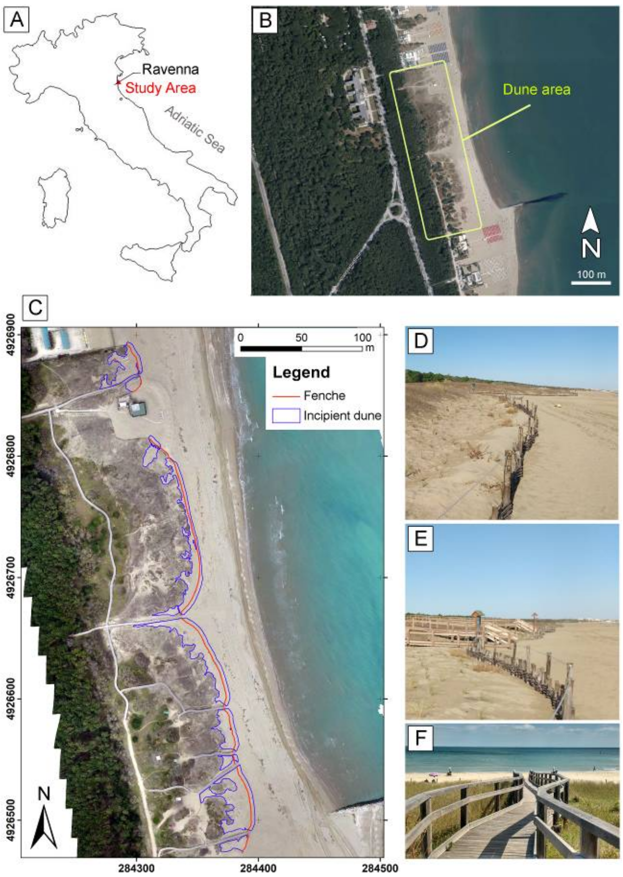

Figure 1 - Study area location (A); monitored dune area (B); overall view of the area of incipient dune (area of interest) and preservation structures (C); frame enlargements of wooden fence and elevated pathways (D, E, F).

3. METHODOLOGY

Topographic surveys have been performed by means of a RTK-GNSS Trimble R6 at the same time of UAV surveys in order to monitor the conservation and geomorphic state of the dune and validate UAV derived results. UAV surveys were carried out with a commercial DJI Phantom 3 Professional, a quadcopter equipped with the standard digital camera of 12 megapixels (4000x3000 resolution, 3.61 mm focal length). As suggested by Duo et al. (2018) the use of automatic flight planning can considerably improve the survey quality due to controlled flight altitude and image overlap. A satisfying overlap between captured images should stay between 70-80% (Dohner et al., 2016; Turner et al., 2016). The flight parameters used for the surveys were: ~ 80 m flight altitude, 72% sidelap, 72% frontlap, fixed focus and automatic pilot mode in order to avoid any shortcoming derived from a manually pilot mode. Those parameters were chosen to have a good compromise between the acquisition time and the cell size resolution (ground resolution of 3.2-3.3 cm) necessary to detect also the subtle morphological changing, as comparably obtained by Giordan et al. (2018). Four surveys were carried out during one year of monitoring (March, September, December 2017 and April 2018; Table 1). Before each flight, twenty ground control points (GCPs), consisting of 60x60 cm wooden squares, painted with a red and white cross, were placed across the study area in order to completely cover the dune system and the facing subaerial beach. GCPs were then measured by means of a RTK-GNSS (range accuracy ~3 cm) linked to the Comacchio GNSS fixed station. The GNSS measurements were performed in geographical coordinates with elevations referred to the WGS84 ellipsoid. Then they were projected to the UTM 33N system with the ETRF2000 geoid.

Survey date	Overlap F/S [%]	Image nr.	Coverage area [Km^2]	Ground res. [cm/pix]
01. 03/03/2017	72/72	297	0.218	3.2
02. 27/09/2017	72/72	154	0.173	3.3
03. 13/12/2017	72/72	150	0.129	3.2
04. 18/04/2018	72/72	150	0.168	3.3

Table 1 - Flight settings of each survey.

The photogrammetric reconstruction (DEM and orthophoto generation) was made in Agisoft PhotoScan Professional. The settings of photogrammetric reconstruction are the following ones: Alignment accuracy (highest); Dense cloud quality (ultrahigh or high); Mesh face count (high); Texture (Mosaic mode).

	Alignment accuracy	Sparse Cloud Points	Dense Point Cloud quality	Dense Point Cloud points	Mesh face count
01	highest	~~113 K	high	~31 M	~6 M
02	highest	~87 K	ultrahigh	~94 M	~19 M
03	highest	~88 K	ultrahigh	~94 M	~19 M
04	highest	~88 K	ultrahigh	~98 M	~20 M

Table 2 - Characteristics of photogrammetric process for each survey.

Since the entire dune area presents high vegetated areas, we only focused on the incipient dune part where the accuracy of drone derived DEMs is sufficient to detect subtle morphological changes. For each survey, a validation of DEM produced by the photogrammetric process was done computing the RMSE (Root Mean Square Error) between its elevation values compared to GNSS measurements along four cross-sections equally spaced along the incipient dune area (area of interest). The DEMs produced for each survey were then analyzed through the Dem of Difference (DoD) method to quantify the amount of sand that fed the incipient dune during the monitoring period. Wave, wind and water level data were retrieved from the closest measuring sites (off-shore Cesenatico, Ravenna and Porto Garibaldi respectively) provided by the regional environmental agency (ARPAe-Dexter database).

In order to compare the incipient dune geomorphic changes, focusing only on natural processes and avoiding artefacts and errors (e.g. shadows), a mask representing the "undisturbed" dune area was digitized in GIS. The mask was created interpreting as landward limit the toe of the stabilized dune from the first orthophoto (March 2017). As seaward limit a vector line was automatically generated, using a buffer distance of 3 m from the wooden fence. The mask was manually refined to remove the largest shadow zones from the orthophotos (mainly generated by walkways) and reshaping the seaward limit where beach portions underwent large human modifications (i.e. beach scraping in winter). This analysis mask was digitized at 1:125 map scale. Stable artificial elements were also excluded from the mask (i.e. roof, walkways, buildings, etc.). The vegetation's contribution to volume variation of the incipient dune was also calculated in a representative portion and resulted to be 9% of the whole incipient dune area. The vegetation's contribution was analysed comparing two DSMs (one with and the other without plants) derived from the drone images, which showed the most increased growth of plants (second survey in September 2017). Plants were excluded from DEM contouring their shape on the orthophoto in ArcGIS software.

4. RESULTS

Orthomosaics obtained from the photogrammetry processing have a grid cell size of ~3 cm, whereas DEMs have a grid cell size of 5 cm. GCPs returned a mean error on their real location (XYZ) below 10 cm for each drone survey (8, 9, 7 and 5, respectively), with a minimum value of 1.8 cm in September 2017 for one single GCP. These values are quite high because include the thick vegetation of the stabilized dune area. In the incipient dune (area of interest) validation of drone-derived DSMs with GNSS measurements returned an error (Root Mean Square Error) between 5 and 7 cm in elevation computed on about 30 points for each survey.
During the monitoring year, all the occurred storms were identified as category I ("Weak"), except one in February 2018 of category II ("Moderate") according to the Mendoza et al. (2011) storm classification (Figure 2). The thresholds for storm identification were those of Armaroli et al. (2012). The storm direction was always from the NE sector and the maximum water level associated to each storm never reached 1 m above mean sea level (Figure 2). Since the lowest measured elevation of the incipient dune is 1.3 m, none of the occurred storms reached the dune foot. Thus, it is reasonable to believe that wind action was the process responsible for the generation and growth of the incipient dune. In particular, between the first and the second survey (from March to September 2017), the wind blew from an E-ESE direction (Figure 2A), being this direction perpendicular to the dune system and inducing the strongest dune growth. In that period there was the greatest vertical growth (mean value 0.1 m), especially in the southern zone where peak values of 0.4-0.45 m were recorded (Figure 3A and 4). The greatest volume increase (+312 m^3) was also measured in this interval (Table 3). Partial erosion affected the incipient dune between the second and the third UAV survey (Figure 3B) with an overall volume decrease of 90 m^3 (Table 3). The period between December 2017 and April 2018, even though remained basically stable as volume variation (only +6 m^3, Table 3), showed a mild increase in elevation and a landward migration of the crest of the incipient dune, especially in the southern zone (Figure 3C and 4). This process is better visible looking at the cumulative DoD (Figure 3D) where the sedimentation portion in the central and southern zone of the incipient dune is marked in Figure 3A with blue if compared to the first time-slice. The landward migration of the incipient dune crest is clearly visible in the profiles in the southern zone in Figure 4, where an overall increase of 0.5-0.55 m in elevation is locally noticeable. As a whole, the volume of incipient dune increased of 228 m^3 after one year. Masking vegetated portions from DoD computation, we found that vegetation overestimates volume increase of about 11% (Table 3). Being the RMSE of four DEMs comprised between 5 and 7 cm an overestimation or underestimation of the actual volume variation has to be taken into account.

	01. March 2017	02. September 2017	03. December 2017	04. April 2018
Incipient dune	5105 m^3	5417 m^3 (+312)	5327 m^3 (-90)	5333 m^3 (+6)
Incipient dune without vegetation	4544 m^3	4821 m^3 (+227)	4741 m^3 (-80)	4746 m^3 (+5)

Table 3 - Volume values of incipient dune measured from each UAV survey. Volume variation compared to previous survey is showed between brackets. Volume values refer to the incipient dune mask visible in Figure 1C.

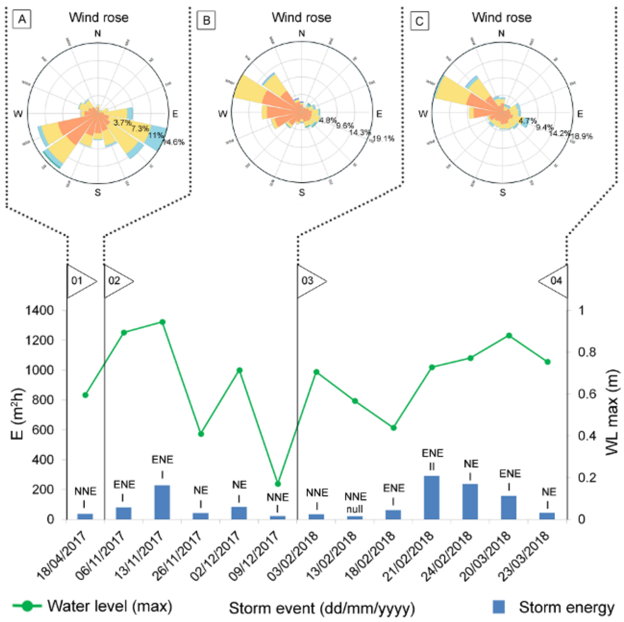

Figure 2 - Climate conditions (wind, storm events and max water level) during the yearly monitoring period: from March to Sep. 2017 (A); from Sep. to Dec. 2017 (B); from Dec. 2017 to Apr. 2018 (C). Storm classes are identified following Mendoza et al., (2011): "null" means under min threshold; "I" means "Weak" energy; "II" means "Moderate" energy. On each storm event the wave direction is also written.

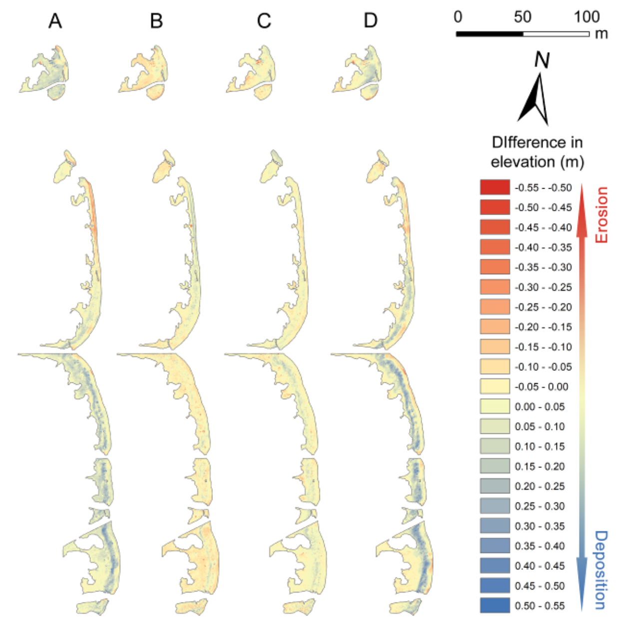

Figure 3 - Geomorphic variation of the incipient dune during the monitoring period: Dem of Difference (DoD) from March to Sep. 2017 (A); from Sep. to Dec. 2017 (B); from Dec. 2017 to Apr. 2018 (C) and cumulative period from March 2017 to Apr. 2018 (D).

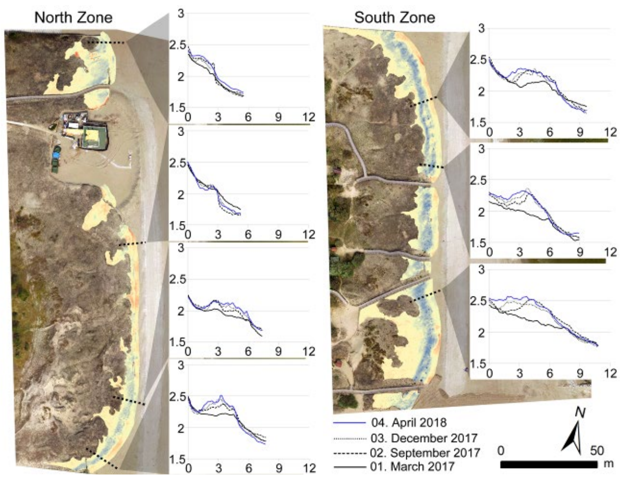

Figure 4 - Cross section variation of the incipient dune at seven locations across the study area. The background DSM is the cumulative DoD for the entire monitoring period: blue color represents sedimentation, red color erosion (see color-scale of Figure 3 as reference).

CONCLUSIONS

During the monitoring period the incipient dune showed the ability to withstand low energy storms and to grow under strong wind action from easterly quadrants in a few months. The buffering role played by the fence and the planted vegetation resulted important for the generation and growth of the dune that locally reached and exceeded 0.5 m of vertical growth. Currently, the incipient dune represents a small sand reservoir ready to feed the beach during a stronger sea storm or potentially able to enlarge the backward foredune during intense and prolonged wind actions from E. With the occurrence of more energetic storms, especially combined with high water levels, the small incipient dune is likely to disappear if not stabilized by vegetation growth or increasing its size further.

Despite vegetation exclusion was a useful test to have an idea on volume overestimation (+11%), to remove plants from the DSM may imply the exclusion of sand amounts placed at plant bases where the accumulation of sediments is more pronounced. We showed that with the right methodological approach (acquisition, processing and accuracy) also low cost commercial UAVs can be used to detect subtle changes of topography and consequently estimate the rate of growth of small landforms with their volume variation. This represents a clear benefit for coastal managers that should take advantage of this low-cost technique for mapping storm impacts (flood limits, damage to buildings or ecosystems, sedimentation and erosion patterns), to improve and update risk assessment at local scale and short-term monitoring of the conservation state of coastal dunes and beaches.

ACKNOWLEDGEMENTS

We are thankful to Yoeri Eijkelhof, Silvia Cilli, Alba María Delfín de la Rosa and Marc Sanuy for their valuable help during the fieldwork activities.

REFERENCES

Armaroli, C., Ciavola, P., Perini, L., Lorito, S., Valentini, A., Masina, M. (2012). Critical storm thresholds for significant morphological changes and damage along the Emilia-Romagna coastline, Italy. Geomorphology 143-144, 34-51, doi:10.1016/j.geomorph.2011.09.006.

Casella, E., Rovere, A., Pedroncini, A., Stark, C. P., Casella, M., Ferrari, M. and Firpo, M. (2016). Drones as tools for monitoring beach topography changes in the Ligurian Sea (NW Mediterranean). Geo-Marine Lett., 36(2), 151-163, doi:10.1007/s00367-016-0435-9.

Dohner, S. M., Trembanis, A. C., and Miller, D. C. (2016). A tale of three storms: Morphologic response of Broadkill Beach, Delaware, following Superstorm Sandy, Hurricane Joaquin, and Winter Storm Jonas, Shore & Beach, 84, 3–9.

Duo, E., Trembanis, A. C., Dohner, S., Grottoli, E., Ciavola, P. (2018). Local-scale post-event assessments with GPS and UAV-based quick-response surveys: A pilot case from the Emilia-Romagna (Italy) coast. Nat. Hazards Earth Syst. Sci. 18(11), 2969-2989, doi:10.5194/nhess-18-2969-2018

Giordan, D., Notti, D., Villa, A., Zucca, F., Calò, F., Pepe, A., Dutto, F., Pari, P., Baldo, M., and Allasia, P. (2018). Low cost, multiscale and multi-sensor application for flooded area mapping, Nat. Hazards Earth Syst. Sci., 18, 1493–1516, doi:10.5194/nhess-18-1493-2018.

Jackson, N. L., Nordstrom, K. F. (2018). Aeolian sediment transport on a recovering storm-eroded foredune with sand fences. Earth Surf. Process. Landforms 43, 1310-1320, doi: 10.1002/esp.4315.

Mendoza, E., Jimenez, J., Mateo, J. (2011). A coastal storms intensity scale for the Catalan sea (NW Mediterranean). Nat. Hazards Earth Syst. Sci. 11, 2453–2462, doi:10.5194/nhess-11-2453-2011.

Perini, L., Calabrese, L. (2010). Le dune costiere dell'Emilia-Romagna: strumenti di analisi, cartografia ed evoluzione. Studi Costieri 17, 71-84.

Turner, I. L., Harley, M. D., Drummond, C. D. (2016). UAVs for coastal surveying, Coast. Eng., 114, 19-24, doi:10.1016/j.coastaleng.2016.03.011.

van Puijenbroek, M. E. B., Nolet, C., de Groot, A. V., Suomalainen, J. M., Riksen, M. J. P. M., Berendse, F., Limpens, J. (2017). Exploring the contributions of vegetation and dune size to early dune development using unmanned aerial vehicle (UAV) imaging. Biogeosciences 14(23), 5533-5549, doi:10.5194/bg-14-5533-2017-supplement.

Earth observation advancements in a changing world

Edited by Chirici G. and Gianinetto M. "***Earth observation advancements in a changing world***" is the first volume of "***Trends in Earth observation***", a new series published by the Italian Society of Remote Sensing (AIT).

This volume, organized in 6 thematic chapters, includes 47 contributions from colleagues belonging to 10 different countries. Compared to similar volumes which often focus on the techniques and methods, ***Trends in Earth observation*** also describes case histories. In this sense, it provides the present state-of-the-art of many real-world remote sensing applications.

Edited by Chirici G. and Gianinetto M.

Gherardo Chirici is Professor of Remote Sensing and Forest Inventory and Director of geoLAB – Laboratory of Forest Geomatics at the Department of Agriculture, Food, Environment and Forestry of the Università degli Studi di Firenze. His main research interests are the application of spatial analysis technology for environmental applications and forest ecosystems monitoring. He is member of the Board of the Italian Society of Remote Sensing, of the Italian Academy of Forest Sciences, responsible for the Forest Geomatics working group of the Italian Society of Forest Ecology and Silviculture and coordinator of IUFRO Unit 4.02.04 – Geographic and management information systems. Co Editor-in-Chief of the European Journal of Remote Sensing, editor of Remote Sensing and Sensors. Prof. Chirici authored more than 200 scientific papers and 3 books.

Marco Gianinetto is Professor of Remote Sensing and Geomatics and head of L@RS – Laboratory of Remote Sensing at the Department of Architecture, Built Environment and Construction Engineering of Politecnico di Milano. His main research interests are in the field of Earth Observation and Spatial Information Technologies for environmental monitoring and land mapping. He is member of the Board of the Italian Society of Remote Sensing. Co Editor-in-Chief of the European Journal of Remote Sensing, Editor for International Journal of Remote Sensing and Journal of Applied Remote Sensing. He was also Editor for International Journal of Navigation and Observation from 2007 to 2018.
Prof. Gianinetto published more than 100 scientific papers and co-authored the study 'Space Market Uptake in Europe' for the European Parliament.

ISSN 2612-7148
9 772612 714859
ISBN 978-88-944687-0-0
9 788894 468700