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Project Acronym	STREAM
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Project Title	Strategic Development of Flood Management
Priority Axis	2 – Safety and Resilience
Specific objective	2.2 – Increase the safety of the Programme area from natural and man-made disaster

Work Package 4
Work Package Title Development of innovative technologies and systems of flood forecasting and early warning system

Activity Number	4.1
Activity Title	Flood forecasting system
Partners in Charge	PP6 – Consiglio Nazionale delle Ricerche
Partners involved	LP, PP8, PP14, PP15
Status	Final
Distribution	Public

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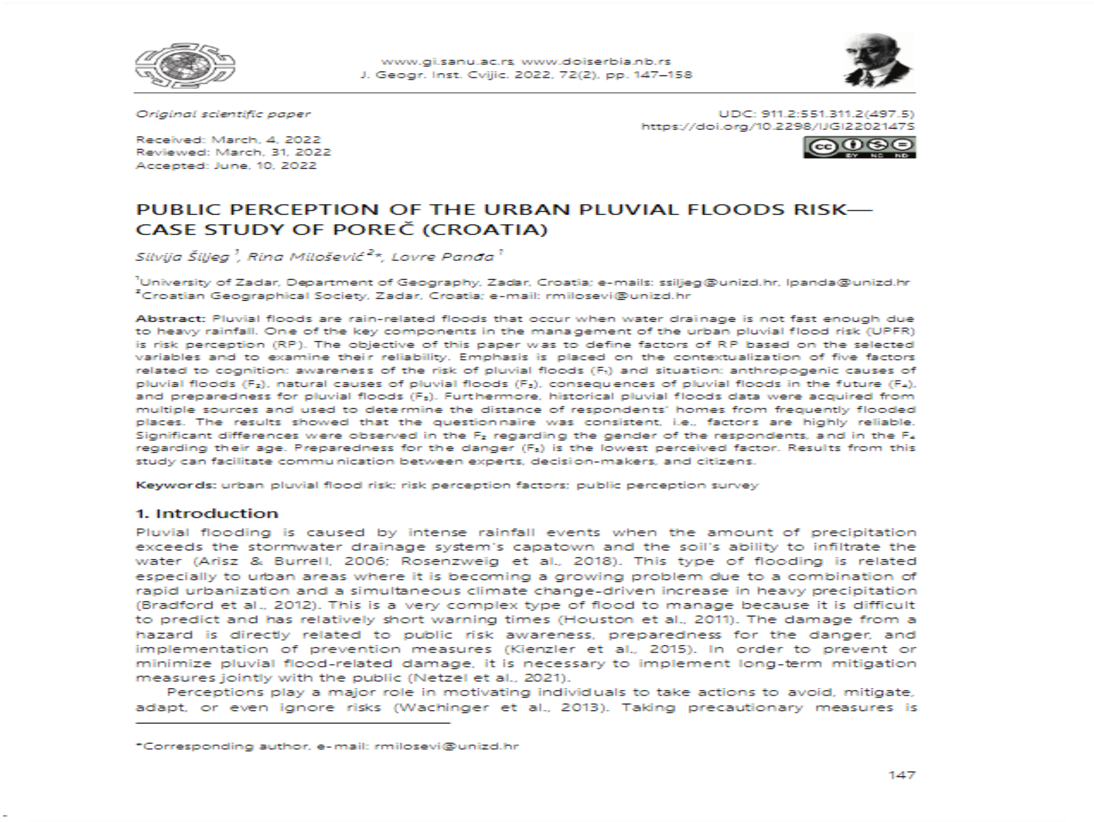
STREAM scientific and technical partners contributed to the dissemination of project achievements to the scientific publications. Some of the project results were included in scientific publications describing the most innovative aspects of the methodological approach used within the project. The scientific partners of the project published a total of 19 articles in scientific journals, 14 more than was prescribed in AF.

PP3



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PUBLIC PERCEPTION OF THE URBAN PLUVIAL FLOODS RISK—CASE STUDY OF POREČ (CROATIA)

Silvija Šiljeg [1], Rina Milošević [2], Lovre Panđa [1]*

[1]University of Zadar, Department of Geography, Zadar, Croatia; e-mails: ssiljeg@unizd.hr, lpanda@unizd.hr
[2]Croatian Geographical Society, Zadar, Croatia; e-mail: rmilosevi@unizd.hr

Abstract: Pluvial floods are rain-related floods that occur when water drainage is not fast enough due to heavy rainfall. One of the key components in the management of the urban pluvial flood risk (UPFR) is risk perception (RP). The objective of this paper was to define factors of RP based on the selected variables and to examine their reliability. Emphasis is placed on the contextualization of five factors related to cognition: awareness of the risk of pluvial floods (F_1) and situation: anthropogenic causes of pluvial floods (F_2), natural causes of pluvial floods (F_3), consequences of pluvial floods in the future (F_4), and preparedness for pluvial floods (F_5). Furthermore, historical pluvial floods data were acquired from multiple sources and used to determine the distance of respondents' homes from frequently flooded places. The results showed that the questionnaire was consistent, i.e., factors are highly reliable. Significant differences were observed in the F_2 regarding the gender of the respondents, and in the F_4 regarding their age. Preparedness for the danger (F_5) is the lowest perceived factor. Results from this study can facilitate communication between experts, decision-makers, and citizens.

Keywords: urban pluvial flood risk; risk perception factors; public perception survey

1. Introduction

Pluvial flooding is caused by intense rainfall events when the amount of precipitation exceeds the stormwater drainage system's capatown and the soil's ability to infiltrate the water (Arisz & Burrell, 2006; Rosenzweig et al., 2018). This type of flooding is related especially to urban areas where it is becoming a growing problem due to a combination of rapid urbanization and a simultaneous climate change-driven increase in heavy precipitation (Bradford et al., 2012). This is a very complex type of flood to manage because it is difficult to predict and has relatively short warning times (Houston et al., 2011). The damage from a hazard is directly related to public risk awareness, preparedness for the danger, and implementation of prevention measures (Kienzler et al., 2015). In order to prevent or minimize pluvial flood-related damage, it is necessary to implement long-term mitigation measures jointly with the public (Netzel et al., 2021).

Perceptions play a major role in motivating individuals to take actions to avoid, mitigate, adapt, or even ignore risks (Wachinger et al., 2013). Taking precautionary measures is

*Corresponding author, e-mail: rmilosevi@unizd.hr

Modelling the publci perception of urban pluvial floods risk (PFR)- case study of Poreč
https://www.researchgate.net/publication/362838266_Public_Perception_of_the_Urban_Pluvial_Floods_Risk_-_Case_Study_of_Porec_Croatia Journal of the Geographical Institute Jovan Cvijic SASA 72(2):147-158

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Automated Coastline Extraction Using the Very High Resolution WorldView (WV) Satellite Imagery and Developed Coastline Extraction Tool (CET)

by Fran Domazetović [1,*], Ante Šiljeg [1], Ivan Marić [1], Josip Faričić [1], Emmanuel Vassilakis [2] and Lovre Panđa [1]

[1] Department of Geography, University of Zadar, 23000 Zadar, Croatia
[2] Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, 15784 Athens, Greece
* Author to whom correspondence should be addressed.

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Abstract

The accurate extraction of a coastline is necessary for various studies of coastal processes, as well as for the management and protection of coastal areas. Very high-resolution satellite imagery has great potential for coastline extraction; however, noises in spectral data can cause significant errors. Here, we present a newly developed *Coastal Extraction Tool* (CET) that overcomes such errors and allows accurate and time-efficient automated coastline extraction based on a combination of *WorldView-2* (WV-2) multispectral imagery and stereo-pair-derived digital surface model (DSM). Coastline extraction is performed and tested on the Iž-Rava island group, situated within the Northern Dalmatian archipelago (Croatia). Extracted coastlines were compared to (a) coastlines extracted from state topographic map (1:25,000), and (b) coastline extracted by another available tool. The accuracy of the extracted coastline was validated with centimeter accuracy reference data acquired using a UAV system (*Matrice 600 Pro + MicaSense RedEdge-MX*). Within the study area, two small islets were detected that have not been mapped during the earlier coastline mapping efforts. CET proved to be a highly accurate coastline mapping technique that successfully overcomes spectral-induced errors. In future research, we are planning to integrate data obtained by UAVs infrared thermography (IRT) and in situ sensors, measuring sea and land surface temperatures (SST and LST), into the CET, given that this has shown promising results. Considering its accuracy and ease of use, we suggest that CET can be applied for automated coastline extraction in other large and indented coastal areas. Additionally, we suggest that CET could be applied in longitudinal geomorphological coastal erosion studies for the automated detection of spatio-temporal coastline displacement.

Keywords: coastline extraction tool (CET); WorldView; multispectral data; thermal imagery

1. Introduction and Background

Coastal zones represent oscillating, highly dynamic environments between the water surface and a certain land surface [1]. Today, coastal zones are economic and population hotspots, highly endangered by various anthropogenic pressures (e.g., excessive urbanization and construction, agricultural exploitation, pollution) [2,3] and natural or climate change-related processes (e.g., sea-level rise, storm surges, coastal erosion, tsunamis, salinization) [4,5,6,7]. Anthropogenic pressures are caused by the nearly 2.4 billion people (40% of the total world's population) living within the 100 km from the coastline [8]. In this manuscript, the precise demarcation line between land and water is defined as a *coastline*. Sometimes, the term *shoreline* is also used, although there are minor differences between them [9,10,11,12]. In simple terms, the coastline is the boundary of the continent/island, while the shoreline is the boundary of the land [13]. The *coastline* term was used following these two reasons (1) this manuscript studies the Iž-Rava island group and (2) the term "coastline" is used within a large number of papers about automatic extraction of that demarcation line, published in the last couple of years [14,15,16,17]. The instantaneous coastline can be most easily defined as the physical interface of land and water (LWI) [18] at one instant in time [10] which are very hard to extract due to constant water level changes [19]. An alternative definition of coastline can be a *particular elevation contour of the land (or water) surface* [20]. Coastline changes are regarded as one of the most dynamic processes (a time-dependent phenomenon) in coastal zones [21,22] and critical information in the *Coastal Geographic Information System* (CGIS) [19]. The combination of these factors made a study of changing coastlines *more than a topic of scientific curiosity* [23]. Therefore, they are considered *as one of the most important linear dynamic features on the Earth's surface* [12].

Coastline mapping is crucial for detection and monitoring of various coastal spatiotemporal changes [24,25,26], the study of specific coast-related processes and pressures such as coastal erosion [27,28], urbanization [29,30], management and protection of endangered coastal areas [31,32,33], maritime affairs and safe navigation, sustainable coastal development and planning, and monitoring and protection of endangered coastal ecosystems [15,34,35,36]. Therefore, accurate coastline mapping is crucial not only from a scientific perspective but for its importance for society, as it can provide valuable information that can be essential in mitigating the above-mentioned problems and pressures [37,38]. However, accurate coastline mapping is not a simple task, especially over large,

Automated Coastline Extraction Using the Very High Resolution WorldView (WV) Satellite Imagery and Developed Coastline Extraction Tool (CET) https://doi.org/10.3390/app11209482 Applied Scieces


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Development of the new methodological framework for multiscale modelling of urban pluvial flooding

Ante Šiljeg[1]; Vlatko Roland[2]; Lovre Panđa[1]; Ivan Marić[1]; Fran Domazetović[1]; Silvija Šiljeg[1]; Rina Milošević[1]

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In recent years pluvial (rain-related) floods are causing more and more damage to urban areas. In the future, an increase in ongoing urbanization and in extreme precipitation events are expected, which imposes the need to develop a comprehensive (multiscale) methodological framework that could prevent and mitigate adverse consequences of pluvial floods. In this paper, we present a new methodological framework for multiscale modeling of urban pluvial flooding developed in the STREAM (Strategic development of flood management) project, funded by the Italy-Croatia cross-border cooperation program 2014-2020. This newly developed framework includes three levels of research (macro - meso - micro). The macro-level encompasses the catchment area of the Zadar settlement, meso-level the administrative border of the city and, the micro-level encompasses a small pilot area (<5 ha) within the Zadar. Spatial data with a resolution of several millimeters up to 60 cm will be collected and processed using a wide range of geospatial technologies. This developed multiscale framework can be considered as an important decision-support tool that can further improve existing decision practices in relation to urban drainage.

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Izvorni znanstveni članak

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Usporedba GEOBIA klasifikacijskih algoritama na temelju Worldview-3 snimaka u izdvajanju šuma primorskih četinjača

Lovre Panđa orcid.org/0000-0003-4549-4481 ; Sveučilište u Zadru, Odjel za geografiju
Ante Šiljeg orcid.org/0000-0001-6332-174X ; Sveučilište u Zadru, Odjel za geografiju
Ivan Marić orcid.org/0000-0002-9723-6778 ; Sveučilište u Zadru, Odjel za geografiju
Fran Domazetović ; Sveučilište u Zadru, Odjel za geografiju
Silvija Šiljeg orcid.org/0000-0002-5473-2579 ; Sveučilište u Zadru, Odjel za geografiju
Rina Milošević orcid.org/0000-0002-2302-7738 ; Sveučilište u Zadru, Ured za znanost, projekte i transfer tehnologija

Sažetak

Šume primorskih četinjača, sa svojom ekološkom, ekonomskom, estetskom i društvenom funkcijom, predstavljaju važan dio europskih šumskih zajednica. Osnovni cilj ovoga rada je usporediti najkorištenije GEOBIA (engl. *Geographic Object-Based Image Analysis*) klasifikacijske algoritme (engl. *Random Trees – RT, Maximum Likelihood – ML, Support Vector Machine – SVM*) s ciljem izdvajanja šuma primorskih četinjača na visoko-rezolucijskom *WorldView-3* snimku unutar topografskog slijevnog područja naselja Split. Metodološki okvir istraživanja uključuje (1) izvođenje izoštrenog multispektralnog snimka (*WV-3*$_{MS}$-a); (2)testiranje segmentacijskih korisničko-definiranih parametara; (3) dodavanje testnih uzoraka; (4) klasifikaciju segmentiranog modela; (5) procjenu točnosti klasifikacijskih algoritama, te (6) procjenu točnosti završnog modela. RT se prema korištenim pokazateljima (*correctness – COR, completeness – COM* i *overall quality – OQ*) pokazao kao najbolji algoritam. Iterativno postavljanje segmentacijskih parametara omogućilo je detekciju najprikladnijih vrijednosti za generiranje segmentacijskog modela. Utvrđeno je da sjene mogu uzrokovati značajne probleme ako se klasificiranje vrši na visoko-rezolucijskim snimkama. Modificiranim *Cohen's kappa coefficient* (K) pokazateljem izračunata je točnost konačnog modela od 87,38%. *WV-3*$_{MS}$ se može smatrati kvalitetnim podatkom za detekciju šuma primorskih četinjača primjenom GEOBIA metode.

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GEOBIA and Vegetation Indices in Extracting Olive Tree Canopies Based on Very High-Resolution UAV Multispectral Imagery

by Ante Šiljeg 1,*, Rajko Marinović 1, Fran Domazetović 1, Mladen Jurišić 2, ...jan Radočaj 2 and Rina Milošević 1

1 ... Trg Kneza Višeslava 9, 23000 Zadar, Croatia

2 ...aj Strossmayer University of Osijek, 31000 Osijek, Croatia

* ...dressed.

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Abstract

In recent decades, precision agriculture and geospatial technologies have made it possible to ensure sustainability in an olive-growing sector. The main goal of this study is the extraction of olive tree canopies by comparing two approaches, the first of which is related to geographic object-based analysis (GEOBIA), while the second one is based on the use of vegetation indices (VIs). The research area is a micro-location within the Lun olives garden, on the island of Pag. The unmanned aerial vehicle (UAV) with a multispectral (MS) sensor was used for generating a very high-resolution (VHR) UAV_{MS} model, while another mission was performed to create a VHR digital orthophoto (DOP). When implementing the GEOBIA approach in the extraction of the olive canopy, user-defined parameters and classification algorithms support vector machine (SVM), maximum likelihood classifier (MLC), and random trees classifier (RTC) were evaluated. The RTC algorithm achieved the highest overall accuracy (OA) of 0.7565 and kappa coefficient (KC) of 0.4615. The second approach included five different VIs models (NDVI, NDRE, GNDVI, MCARI2, and RDVI2) which are optimized using the proposed VITO (VI Threshold Optimizer) tool. The NDRE index model was selected as the most accurate one, according to the ROC accuracy measure with a result of 0.888 for the area under curve (AUC).

Keywords: geospatial technologies; Lun olive groves; object-based image analysis; classification algorithms; machine learning; accuracy assessment

Graphical Abstract

1. Introduction

The olive tree is one of the oldest species in the Mediterranean area [1,2,3] which has been spreading throughout history and shaped the recognizable Mediterranean landscape [4,5]. Resistance to extreme climatic conditions and adaptability to different types of poorly fertile soils ensure the olive's social, ecological, and economic benefits [6,7]. Sustainability and preservation of olive trees are especially important [8] due to the frequent impacts of various economic activities such as industry, wildfires [9], and tourism sector activities [10,11]. Preservation mostly depends on sustainable environmental management and precision agriculture (PA) methodologies [12,13,14,15]. Geospatial technologies and their products have become easily available and widely accessible in everyday life, which has advanced and accelerated their use in various research [16,17,18,19]. The development of advanced geospatial technologies has enabled PA in the olive management sector, especially in the context of precise canopy extraction for management [20,21,22], monitoring [23,24,25], assessment of crop quality [26], disease detection [27], and preventive actions [28]. Therefore, geospatial technologies have a meaningful role in the observation and

GEOBIA and Vegetation Indices in Extracting Olive Tree Canopies Based on Very High-Resolution UAV Multispectral Imagery https://doi.org/10.3390/app13020739 Applied Sciences

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Pluvial Flash Flood Hazard and Risk Mapping in Croatia: Case Study in the Gospić Catchment

by Nino Krvavica [1,2,*], Ante Šiljeg [3], Bojana Horvat [1] and Lovre Panda [3]

[1] Faculty of Civil Engineering, University of Rijeka, 51000 Rijeka, Croatia
[2] Center for Artificial Intelligence and Cybersecurity, University of Rijeka, 51000 Rijeka, Croatia
[3] Department of Geography, University of Zadar, 23000 Zadar, Croatia
* Author to whom correspondence should be addressed.

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Abstract

Since the beginning of the 21st Century, Europe has been affected by destructive floods. European Union Member States have an obligation to develop flood hazard and flood risk maps as support to the Flood Risk Management Plan (FRMP). The main objective of this study is to propose a methodological framework for hazard and risk assessment of pluvial flash floods in Croatia at the catchment level, which can be integrated into the FRMP. Therefore, a methodology based on the source–pathway–consequence approach for flood risk assessment is presented, which complies with the EU Floods Directive. This integrated and comprehensive methodology is based on high-resolution open data available for EU Member States. Three scenarios are defined for a low, medium, and high probability, defined by design storms of different durations. The proposed methodology consists of flood hazard analysis, vulnerability assessment, and risk analysis. Pluvial flash flood hazards are analyzed using a 2D hydrologic–hydraulic model. The flood vulnerability assessment consists of a GIS analysis to identify receptors potentially at risk of flooding and an assessment of susceptibility to potential flood damage using depth–damage curves. Flood risk is assessed both qualitatively in terms of risk levels and quantitatively in terms of direct damages expressed in monetary terms. The developed methodology was applied and tested in a case study in the Gospić catchment in Croatia, which surrounds a small rural town frequently affected by pluvial flash floods.

Keywords: flash floods; flood risk; flood modelling; flood mapping; Floods Directive

1. Introduction

Between 1995 and 2015, floods accounted for 43% of all documented natural disasters, affecting 2.3 billion people worldwide and causing USD billions in damage [1]. Total economic damages caused by weather- and climate-related extremes in the European Economic Area (EEA) amounted to more than EUR 433 billion in the period 1980–2015, with the largest share of economic impacts (38%) caused by floods [2,3]. Furthermore, extreme flooding in Europe between 1998 and 2009 caused more than 1100 deaths and the displacement of about one million people [4].

The most catastrophic flood events are caused by extreme rainfall, but the consequences of flooding are also exacerbated by inefficient river regulation measures, deforestation, and (unplanned) urbanization in floodplain areas [5]. Over the years, many communities in the EU have been affected by some form of flooding. Recognizing that flood impacts and damages are likely to increase in the near future due to climate variability and change, increased urbanization, and migration trends [6,7,8,9], awareness of the importance of flood risk management plans (FRMP) to mitigate the consequences of flooding has increased [10,11,12].

The best-known example of an international document that refers to flood risk management plans is the EU Floods Directive (FD) (2007/60/EC, 2007) [13,14]. The main objective of the FD is to assess, reduce, and manage the risks that floods pose to human health and life, the environment, cultural heritage, and economic activities in the European Union (EU). The FD requires all EU Member States to undertake a preliminary flood risk assessment (PFRA) of their river basins and coastal areas to identify areas where there is a potentially significant flood risk [13,14]. They must also prepare and develop flood hazard maps, flood risk maps, and flood risk management plans

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ELSEVIER — Coastal Engineering, Volume 173, April 2022, 104081

Ensemble technique application to an XBeach-based coastal Early Warning System for the Northwest Adriatic Sea (Emilia-Romagna region, Italy)

Luis Germano Biolchi [a b c d], Silvia Unguendoli [d], Lidia Bressan [d], Beatrice Maria Sole Giambastiani [a], Andrea Valentini [a d]

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Highlights

- A (semi-)probabilistic XBeach-based EWS is tested with multi-model ensemble outputs.
- XBeach calibration is fundamental to avoid modeled erosion overestimation.
- A GLUE-like calibration procedure yields an optimized parameter set.
- The new EWS approach provides additional information to the forecaster/decision maker.

Abstract

During the last three decades, ensemble modelling has switched the focus from deterministic to probabilistic outcomes after its successful application in meteorological forecasting. This work involves the application of Ensemble Prediction System (EPS)-based results as forcing for a coastal EWS employing the morphodynamic model XBeach in a so-called (semi-)probabilistic way. First, calibration following the GLUE approach is performed for a profile in Cesenatico (Emilia-Romagna coast, Italy), while the (semi-)probabilistic system is implemented subsequently for two nearby locations. Ensemble mean and standard deviation from the Transnational Multi-Model Ensemble (TMES) forecasting system are combined in varied ways and used to force XBeach. A testing period of two months is analyzed (March and April 2020) together with the already operational deterministic implementation with one specific day of high sea conditions being used to assess the performance of the system. The deterministic results present higher outcome variability compared to the usage of the TMES mean and mean plus/minus one standard deviation (SD). Adding two SDs to the TMES mean results in higher variability than the deterministic approach. The (semi-)probabilistic system

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Local and large-scale controls of the exceptional Venice floods of November 2019

Christian Ferrarin [a,*], Marco Bajo [a], Alvise Benetazzo [a], Luigi Cavaleri [a], Jacopo Chiggiato [a], Silvio Davison [a], Silvio Davolio [b], Piero Lionello [c], Mirko Orlić [d], Georg Umgiesser [a,e]

[a] CNR - National Research Council of Italy, ISMAR - Marine Sciences Institute, Venice, Italy
[b] CNR - National Research Council of Italy, ISAC - Institute of Atmospheric Sciences and Climate, Bologna, Italy
[c] Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy
[d] Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia
[e] Marine Research Institute, Klaipėda University, H. Manto 84, 92294 Klaipėda, Lithuania

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Venice

ABSTRACT

On 12 November 2019, an exceptional flood event took place in Venice, second only to the one that occurred on 4 November 1966. Moreover, with four extremely high tides since 11 November 2019, this was the worst week for flooding in Venice since the beginning of sea level records (1872). The event that struck Venice and the northern Adriatic Sea on 12 November 2019, although having certain conditions seemingly typical of the events causing exceptional high waters, had some peculiar characteristics not observed before, which deserved an in-depth analysis. Several factors made this event exceptional: the in-phase timing between the peak of the storm surge and the astronomical tide; a deep low-pressure cyclone over the central-southern Tyrrhenian Sea that generated strong Sirocco (south-easterly) winds along the main axis of the Adriatic Sea, pushing waters to the north; a fast-moving local depression – and the associated wind perturbation – travelling in the north-westward direction over the Adriatic Sea along the Italian coast, generating a meteotsunami; very strong winds (28 m s^{-1} on average with 31 m s^{-1} gusts) over the Lagoon of Venice, which led to a rise in water levels and damages to the historic city; and an anomalously high monthly mean sea level in the Adriatic Sea, induced by a standing low-pressure and wind systems over the Mediterranean Sea, that was associated with large-scale low-frequency atmospheric dynamics. In this study, the large set of available observations and high-resolution numerical simulations have been used to quantify the contribution of the mentioned drivers to the peak of the flood event and to investigate the peculiar weather and sea conditions over the Mediterranean Sea during the Venice floods of November 2019.

1. Introduction

The sea level at a given coastal location is the sum of several contributions, such as mean sea level variability, astronomical tide, changes in sea temperature and the salinity, meteorological surge, seiche, river runoff, and wave setup and run-up, acting on different temporal and spatial scales (Woodworth et al., 2019). Different atmospheric controls on the sea level are characterized by different dynamics, with synoptic and planetary-scale (planetary atmospheric wave, hereinafter PAW) disturbances dominating over periods of a day to a few weeks (storm surge and PAW surge, respectively), while mesoscale forcing are affecting changes occurring at periods lower than the inertial period (Vilibić et al., 2020). If the response of the sea to the air-pressure and wind driven by a mesoscale atmospheric phenomenon surpasses the equilibrium response, a meteotsunami wave is generated. In bays or harbours, such tsunami-like waves can be amplified through the harbour resonance with consequent destructive effects (Vilibić and Šepić, 2009). In semi-enclosed sea, the sea level could also be strongly influenced by sub-daily oscillations (seiche) triggered by storm surges (Cerovečki et al., 1997).

As discussed by Vilibić et al. (2017), all the mentioned components play a role in controlling the sea level variability in the Adriatic Sea, an 800 km long and 150 km wide elongated semi-closed basin separating the Italian Peninsula from the Balkans and communicating with the Mediterranean Sea only through the Otranto Strait. Storm induced

* Corresponding author.
E-mail addresses: c.ferrarin@ismar.cnr.it (C. Ferrarin), marco.bajo@ismar.cnr.it (M. Bajo), alvise.benetazzo@ismar.cnr.it (A. Benetazzo), luigi.cavaleri@ismar.cnr.it (L. Cavaleri), jacopo.chiggiato@ismar.cnr.it (J. Chiggiato), silvio.davison@ve.ismar.cnr.it (S. Davison), s.davolio@isac.cnr.it (S. Davolio), piero.lionello@unisalento.it (P. Lionello), orlic@irb.hr (M. Orlić), georg.umgiesser@ismar.cnr.it (G. Umgiesser).

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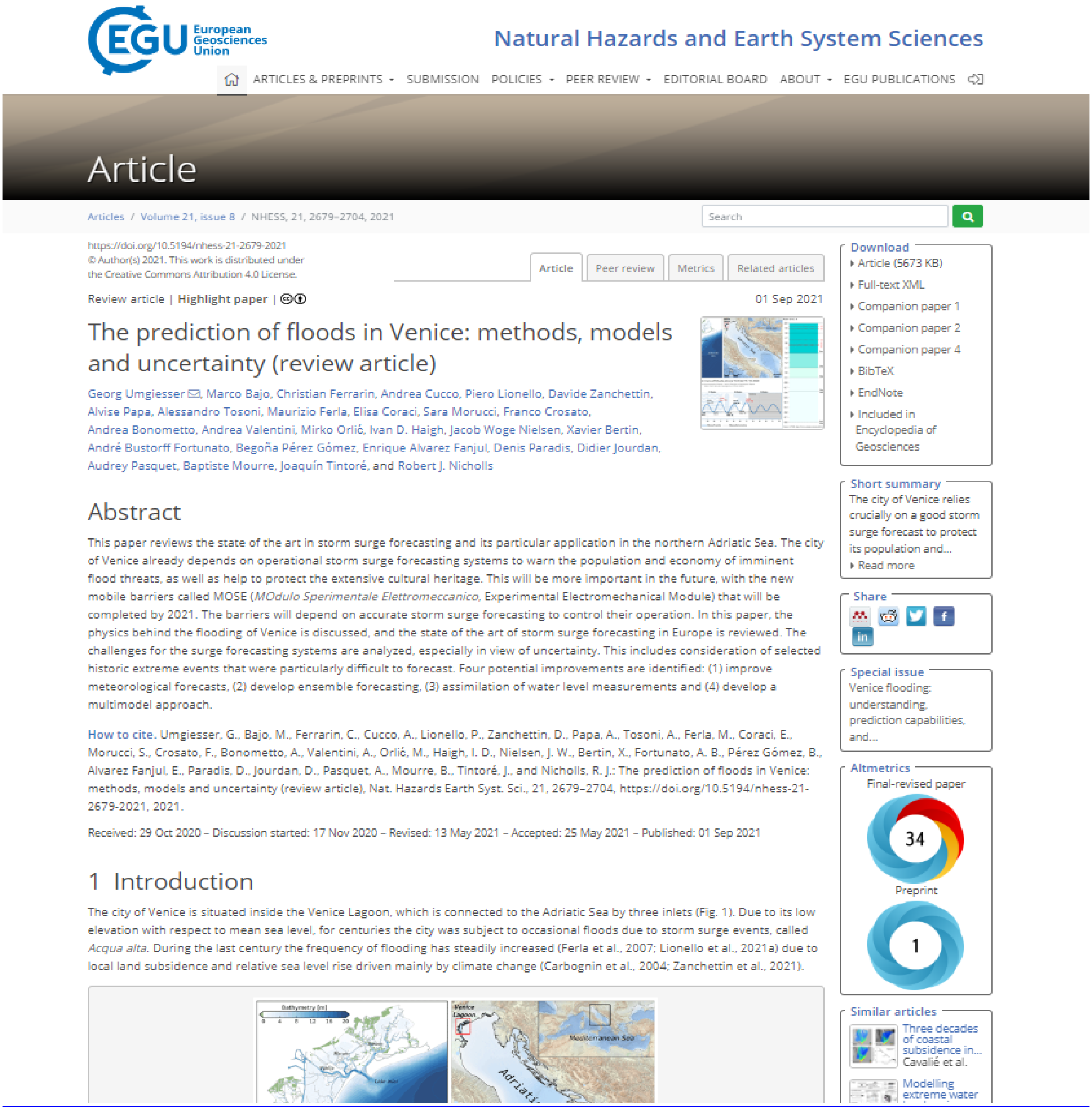
Local and large-scale controls of the exceptional Venice floods of November 2019 Available on : https://doi.org/10.1016/j.pocean.2021.102628, Progress in Oceanography.



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01 Sep 2021

The prediction of floods in Venice: methods, models and uncertainty (review article)

Georg Umgiesser, Marco Bajo, Christian Ferrarin, Andrea Cucco, Piero Lionello, Davide Zanchettin, Alvise Papa, Alessandro Tosoni, Maurizio Ferla, Elisa Coraci, Sara Morucci, Franco Crosato, Andrea Bonometto, Andrea Valentini, Mirko Orlić, Ivan D. Haigh, Jacob Woge Nielsen, Xavier Bertin, André Bustorff Fortunato, Begoña Pérez Gómez, Enrique Alvarez Fanjul, Denis Paradis, Didier Jourdan, Audrey Pasquet, Baptiste Mourre, Joaquín Tintoré, and Robert J. Nicholls

Abstract

This paper reviews the state of the art in storm surge forecasting and its particular application in the northern Adriatic Sea. The city of Venice already depends on operational storm surge forecasting systems to warn the population and economy of imminent flood threats, as well as help to protect the extensive cultural heritage. This will be more important in the future, with the new mobile barriers called MOSE (*MOdulo Sperimentale Elettromeccanico*, Experimental Electromechanical Module) that will be completed by 2021. The barriers will depend on accurate storm surge forecasting to control their operation. In this paper, the physics behind the flooding of Venice is discussed, and the state of the art of storm surge forecasting in Europe is reviewed. The challenges for the surge forecasting systems are analyzed, especially in view of uncertainty. This includes consideration of selected historic extreme events that were particularly difficult to forecast. Four potential improvements are identified: (1) improve meteorological forecasts, (2) develop ensemble forecasting, (3) assimilation of water level measurements and (4) develop a multimodel approach.

How to cite. Umgiesser, G., Bajo, M., Ferrarin, C., Cucco, A., Lionello, P., Zanchettin, D., Papa, A., Tosoni, A., Ferla, M., Coraci, E., Morucci, S., Crosato, F., Bonometto, A., Valentini, A., Orlić, M., Haigh, I. D., Nielsen, J. W., Bertin, X., Fortunato, A. B., Pérez Gómez, B., Alvarez Fanjul, E., Paradis, D., Jourdan, D., Pasquet, A., Mourre, B., Tintoré, J., and Nicholls, R. J.: The prediction of floods in Venice: methods, models and uncertainty (review article), Nat. Hazards Earth Syst. Sci., 21, 2679–2704, https://doi.org/10.5194/nhess-21-2679-2021, 2021.

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1 Introduction

The city of Venice is situated inside the Venice Lagoon, which is connected to the Adriatic Sea by three inlets (Fig. 1). Due to its low elevation with respect to mean sea level, for centuries the city was subject to occasional floods due to storm surge events, called *Acqua alta*. During the last century the frequency of flooding has steadily increased (Ferla et al., 2007; Lionello et al., 2021a) due to local land subsidence and relative sea level rise driven mainly by climate change (Carbognin et al., 2004; Zanchettin et al., 2021).

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Venice as a paradigm of coastal flooding under multiple compound drivers

Christian Ferrarin[1✉], Piero Lionello[2], Mirko Orlić[3], Fabio Raicich[4] & Gianfausto Salvadori[5]

Full comprehension of the dynamics of hazardous sea levels is indispensable for assessing and managing coastal flood risk, especially under a changing climate. The 12 November 2019 devastating flood in the historical city of Venice (Italy) stimulated new investigations of the coastal flooding problem from different perspectives and timescales. Here Venice is used as a paradigm for coastal flood risk, due to the complexity of its flood dynamics facing those of many other locations worldwide. Spectral decomposition was applied to the long-term 1872–2019 sea-level time series in order to investigate the relative importance of different drivers of coastal flooding and their temporal changes. Moreover, a multivariate analysis via copulas provided statistical models indispensable for correctly understanding and reproducing the interactions between the variables at play. While storm surges are the main drivers of the most extreme events, tides and long-term forcings associated with planetary atmospheric waves and seasonal to inter-annual oscillations are predominant in determining recurrent nuisance flooding. The non-stationary analysis revealed a positive trend in the intensity of the non-tidal contribution to extreme sea levels in the last three decades, which, along with relative sea-level rise, contributed to an increase in the frequency of floods in Venice.

Coastal flood events are among the most disastrous natural phenomena of major risk to the safety and sustainability of coastal communities worldwide. Coastal flood risk has increased world-wide in the last decades, mostly due to mean-sea-level rise[1–4]. Coastal flooding is determined by anomalously high sea levels which are the sum of several tidal and non-tidal processes acting at different temporal and spatial scales[5]. Meso-scale atmospheric disturbances, synoptic-scale phenomena, seasonal oscillations and planetary atmospheric waves generate sea-level disturbances at different frequencies. Seiches, river floods, ocean waves, inter-annual and inter-decadal dynamics and relative sea-level rise can also contribute to the total sea level.

In this study, we analyze the long term sea-level time series recorded in the low-lying historical city of Venice (Italy), located in the northern end of the Adriatic Sea, a semi-enclosed regional basin with one of the largest tidal range (the height difference between high tide and low tide) and extreme sea levels (ESLs) in the Mediterranean Sea[6]. As a result of the devastating series of floods occurring in November 2019[7], Venice has been defined as the "canary in a coal mine" for coastal flooding worldwide[8], also because with 15 flood events in a month it experienced something similar to what the flooding frequency will be in the future with 30 cm of sea level rise[9]. The city of Venice represents a key study site for coastal flooding for several reasons: (i) it has a long-lasting record of sea-level observations (since 1872), (ii) Venice is frequently exposed to floods, locally called *Aqua Alta* (literally, high water), (iii) the frequency of flood events has increased over time and is likely to continue increasing in the future mainly due to sea-level rise and subsidence, (iv) it has a worldwide recognized relevance as the site is present in the UNESCO world heritage list (https://whc.unesco.org/en/list/394/), (v) an experimental and extensive flood protection plan based on the MoSE mobile barrier system has been designed (https://www.mosevenezia.eu/).

The unexpected and peculiar characteristics of November 2019 floods[7,8] reveal the need to further explore the processes determining coastal flooding. Interestingly enough, such a phenomenon belongs to the class of so-called compound events, of utmost interest in recent geophysical research[10]. The specific objectives of the present research are to (i) investigate the relative importance of the different contributions to extreme sea levels, (ii) study their temporal change, (iii) examine their non-linear interactions and (iv) estimate the probability of

[1]CNR - National Research Council of Italy, ISMAR - Institute of Marine Sciences, Venice, Italy. [2]DiSTeBA - Department of Biological and Environmental Sciences and Technologies, University of Salento, Lecce, Italy. [3]Department of Geophysics, Faculty of Science, University of Zagreb, Zagreb, Croatia. [4]CNR - National Research Council of Italy, ISMAR - Institute of Marine Sciences, Trieste, Italy. [5]Department of Mathematics and Physics, University of Salento, Lecce, Italy. ✉email: c.ferrarin@ismar.cnr.it

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Developing a framework for the assessment of current and future flood risk in Venice, Italy

Julius Schlumberger, Christian Ferrarin, Sebastiaan N. Jonkman, Manuel Andres Diaz Loaiza, Alessandro Antonini, and Sandra Fatorić

Abstract

Flooding causes serious impacts on the old town of Venice, its residents, and its cultural heritage. Despite this existence-defining condition, limited scientific knowledge on flood risk of the old town of Venice is available to support decisions to mitigate existing and future flood impacts. Therefore, this study proposes a risk assessment framework to provide a methodical and flexible instrument for decision-making for flood risk management in Venice. We first use a state-of-the-art hydrodynamic urban model to identify the hazard characteristics inside the city of Venice. Exposure, vulnerability, and corresponding damage are then modeled by a multi-parametric, micro-scale damage model which is adapted to the specific context of Venice with its dense urban structure and high risk awareness. Furthermore, a set of individual protection scenarios are implemented to account for possible variability in flood preparedness of the residents. This developed risk assessment framework was tested for the flood event of 12 November 2019 and proved able to reproduce flood characteristics and resulting damage well. A scenario analysis based on a meteorological event like 12 November 2019 was conducted to derive flood damage estimates for the year 2060 for a set of sea level rise scenarios in combination with a (partially) functioning storm surge barrier, the Modulo Sperimentale Elettromeccanico (MOSE). The analysis suggests that a functioning MOSE barrier could prevent flood damage for the considered storm event and sea level scenarios almost entirely. A partially closed MOSE barrier (open Lido inlet) could reduce the damage by up to 34 % for optimistic sea level rise prognoses. However, damage could be 10 % to 600 % higher in 2060 compared to 2019 for a partial closure of the storm surge barrier, depending on different levels of individual protection.

How to cite. Schlumberger, J., Ferrarin, C., Jonkman, S. N., Diaz Loaiza, M. A., Antonini, A., and Fatorić, S.: Developing a framework for the assessment of current and future flood risk in Venice, Italy, Nat. Hazards Earth Syst. Sci., 22, 2381–2400, https://doi.org/10.5194/nhess-22-2381-2022, 2022.

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1 Introduction

Flood events are among the most disastrous natural catastrophes, causing significant damage and fatalities all around the world. In Europe, coastal flood events are estimated to affect more than 100 000 citizens, causing losses of about EUR 1.4 billion annually (Vousdoukas et al., 2020). Under consideration of climate change scenarios, future flood damage is expected to increase due to rising sea level (Hinkel et al., 2014).

In this context, hazard and flood risk assessment has been broadly implemented according to the 2007/60/EC directive in the European Union (EU; European Commission, 2007). According to the Intergovernmental Panel on Climate Change (IPCC), flood risk is defined as the combination of a specific hazardous flood event; elements (i.e., infrastructure; people; livelihoods; environment; and cultural, social, and economic assets) which might be exposed to a hazard in a certain area; and the vulnerability of these elements, meaning predisposition to be adversely affected (IPCC, 2021; Cardona et al., 2012). As such, outcomes of a flood risk assessment framework can support systemic and individual decisions to mitigate flood damage or adapt accordingly.

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Review

Hydrodynamic modelling in marginal and coastal seas — The case of the Adriatic Sea as a permanent laboratory for numerical approach

Georg Umgiesser [a], Christian Ferrarin [a], Marco Bajo [a], Debora Bellafiore [a], Andrea Cucco [b], Francesca De Pascalis [a], Michol Ghezzo [a], William McKiver [a], Luca Arpaia [a]

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Highlights
- An overview of the present state of the art in coastal and marginal seas hydrodynamic modelling.
- The semi-enclosed Adriatic Sea represents a natural long-standing laboratory for model development.
- A set of examples that can be used as guidelines for different model applications.
- A look and a prospect for the corresponding possible future developments.

Abstract
Understanding the water circulation in oceans and coastal seas is among the key topics of oceanographic and climate research. Hydrodynamic studies form the basis for many oceanographic subjects, whether sediment transport, morphology, water quality, ecological and climate changes are being investigated. Hydrodynamic modelling of oceans and coastal seas has become a fundamental tool for describing the dynamics of marine environments, revealing the human impact on the sea and promoting sustainable development of marine resources. By complementing – through data assimilation – more and more diffuse and integrated global and regional observing systems (composed of coastal gauges, moorings, buoys, satellites, drifters), hydrodynamic models provide a deterministic 4D view of the ocean state. In this context, the semi-enclosed Adriatic Sea represents a natural long-standing laboratory for hydrodynamic modelling. The peculiar historical, morphological and oceanographic characteristics of this basin and its complex coastline stimulated over decades the development and application of several ocean and coastal models. In this work, we review different aspects of hydrodynamic modelling

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11 Jan 2023

Assessing the coastal hazard of medicane Ianos through ensemble modelling

Christian Ferrarin, Florian Pantillon, Silvio Davolio, Marco Bajo, Mario Marcello Miglietta, Elenio Avolio, Diego S. Carrió, Ioannis Pytharoulis, Claudio Sanchez, Platon Patlakas, Juan Jesús González-Alemán, and Emmanouil Flaounas

Abstract. On 18 September 2020, medicane Ianos hit the western coast of Greece resulting in flooding and severe damage at several coastal locations. In this work, we aim at evaluating its impact on sea conditions and the associated uncertainty through the use of an ensemble of numerical simulations. We applied a coupled wave-current model to an unstructured mesh representing the whole Mediterranean Sea, with a grid resolution increasing in the Ionian Sea along the cyclone path and the landfall area. To investigate the uncertainty of modelling sea levels and waves for such an intense event, we performed a multimodel ensemble of ocean simulations using several coarse (10 km) and high-resolution (2 km) meteorological forcings from different mesoscale models. The performance of the ocean and wave models was evaluated against observations retrieved from fixed monitoring stations and satellites. All model runs emphasized the occurrence of severe sea conditions along the cyclone path and at the coast. Due to the rugged and complex coastline, extreme sea levels are localised at specific coastal sites. However, numerical results show a large spread of the simulated sea conditions for both the sea level and waves highlighting the large uncertainty in simulating this kind of extreme event. The multi-model / multi-physics approach allows us to assess how the uncertainty propagates from meteorological to ocean variables and the subsequent coastal impact. The ensemble mean and standard deviation were combined to prove the hazard scenarios of the potential impact of such an extreme event to be used in a flood risk management plan.

How to cite. Ferrarin, C., Pantillon, F., Davolio, S., Bajo, M., Miglietta, M. M., Avolio, E., Carrió, D. S., Pytharoulis, I., Sanchez, C., Patlakas, P., González-Alemán, J. J., and Flaounas, E.: Assessing the coastal hazard of medicane Ianos through ensemble modelling, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-990, 2023.

Received: 26 Sep 2022 – Discussion started: 11 Jan 2023

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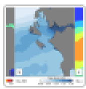
Assessing the coastal hazard of Medicane Ianos through ensemble modelling
Christian Ferrarin, Florian Pantillon, Silvio Davolio, Marco Bajo, Mario Marcello Miglietta, Elenio Avolio, Diego S. Carrió, Ioannis Pytharoulis, Claudio Sanchez, Platon Patlakas, Juan Jesús González-Alemán, and Emmanouil Flaounas
Nat. Hazards Earth Syst. Sci., 23, 2273–2287, https://doi.org/10.5194/nhess-23-2273-2023, 2023



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The contribution of hurricane remote ocean forcing to storm surge along the Southeastern U.S. coast

Kyungmin Park [a], Ivan Federico [b], Emanuele Di Lorenzo [a], Tal Ezer [c], Kim M. Cobb [d], Nadia Pinardi [e], Giovanni Coppini [b]

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Highlights

- Newly developed high-resolution observation and model reveal the hidden role of extreme water level drivers.
- The timing and structure of the remote ocean forcing exerts a dominant control on the regional distribution of storm surge.
- The alignment in the peak timing of the local and remote forcing can increase the peak surge level by ~50%.

Abstract

The dynamics controlling the spatial and temporal expressions of storm surges over the coastal wetlands and communities of the South Atlantic Bight (SAB) is complex and not well understood. Leveraging a newly developed high-density hyper-local network of water level sensors in the North Georgia coast, we implement and test an unstructured numerical coastal ocean model (up to 10-m horizontal resolution) that can resolve and diagnose the storm-induced sea-level rise during the two Hurricanes Matthew (2016) and Dorian (2019) that have shore-parallel tracks. Using a set of model sensitivity analyses we decompose the drivers of the storm surge into a component that is associated with direct surface forcing by the hurricanes over the targeted area (e.g., local atmospheric wind and pressure condition in the nested model domain) and remote ocean forcing that is connected to hurricane-induced sea level anomalies and baroclinic effect through the open boundary of the model. For both hurricanes, we find that local surface atmospheric forcing leads to a uniform alongshore response in water level along the entire North Georgia coast with amplitudes that are proportional to how close to shore are the hurricane tracks (e.g., stronger in Matthew and weaker in Dorian). However, the alongshore structure and location of maximum storm surge are determined entirely by the arrival timing of ocean remote forcing. In the case of Matthew, the remote forcing arrives within 2h of the direct passage of the hurricane over North Georgia and drives peak surges in the northern region of the domain (e.g., the City of Savannah and Tybee Island). In contrast, during Dorian, there is a 14-h difference between the remote and local forcing, and maximum storm surges are found in the southern region around Sapelo Island. We estimate that if local and remote forcing were to be simultaneous, the peak storm surge and the water level would be amplified by up to 30% for Matthew and 50% for Dorian. While this sensitivity analysis only includes two hurricanes and is focused on a case study around North Georgia, it is clear that predicting and

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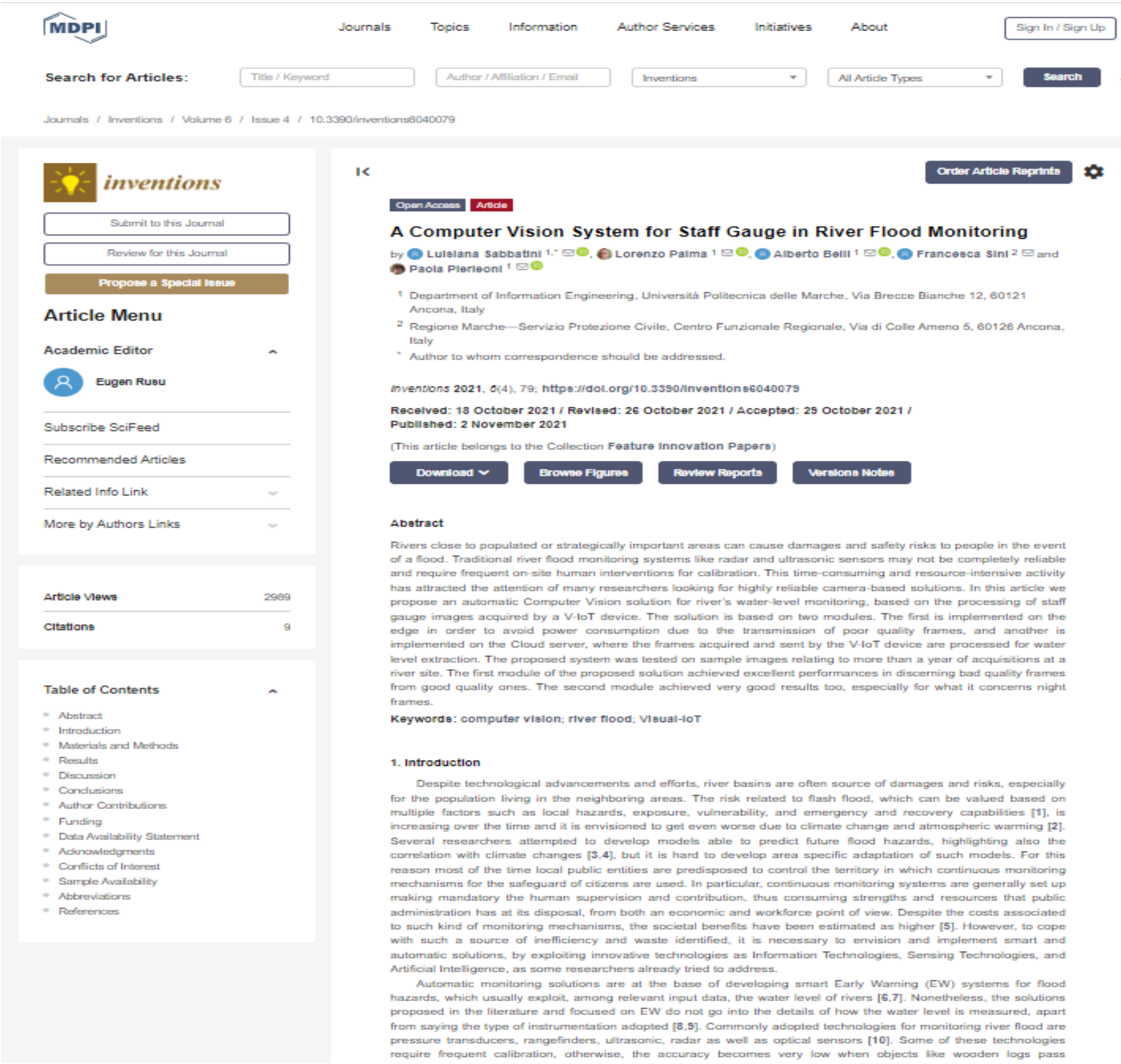
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A Computer Vision System for Staff Gauge in River Flood Monitoring

by Luisiana Sabbatini [1,*], Lorenzo Palma [1], Alberto Belli [1], Francesca Sini [2] and Paola Pierleoni [1]

[1] Department of Information Engineering, Università Politecnica delle Marche, Via Brecce Bianche 12, 60121 Ancona, Italy
[2] Regione Marche—Servizio Protezione Civile, Centro Funzionale Regionale, Via di Colle Ameno 5, 60126 Ancona, Italy
[*] Author to whom correspondence should be addressed.

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Abstract

Rivers close to populated or strategically important areas can cause damages and safety risks to people in the event of a flood. Traditional river flood monitoring systems like radar and ultrasonic sensors may not be completely reliable and require frequent on-site human interventions for calibration. This time-consuming and resource-intensive activity has attracted the attention of many researchers looking for highly reliable camera-based solutions. In this article we propose an automatic Computer Vision solution for river's water-level monitoring, based on the processing of staff gauge images acquired by a V-IoT device. The solution is based on two modules. The first is implemented on the edge in order to avoid power consumption due to the transmission of poor quality frames, and another is implemented on the Cloud server, where the frames acquired and sent by the V-IoT device are processed for water level extraction. The proposed system was tested on sample images relating to more than a year of acquisitions at a river site. The first module of the proposed solution achieved excellent performances in discerning bad quality frames from good quality ones. The second module achieved very good results too, especially for what it concerns night frames.

Keywords: computer vision; river flood; Visual-IoT

1. Introduction

Despite technological advancements and efforts, river basins are often source of damages and risks, especially for the population living in the neighboring areas. The risk related to flash flood, which can be valued based on multiple factors such as local hazards, exposure, vulnerability, and emergency and recovery capabilities [1], is increasing over the time and it is envisioned to get even worse due to climate change and atmospheric warming [2]. Several researchers attempted to develop models able to predict future flood hazards, highlighting also the correlation with climate changes [3,4], but it is hard to develop area specific adaptation of such models. For this reason most of the time local public entities are predisposed to control the territory in which continuous monitoring mechanisms for the safeguard of citizens are used. In particular, continuous monitoring systems are generally set up making mandatory the human supervision and contribution, thus consuming strengths and resources that public administration has at its disposal, from both an economic and workforce point of view. Despite the costs associated to such kind of monitoring mechanisms, the societal benefits have been estimated as higher [5]. However, to cope with such a source of inefficiency and waste identified, it is necessary to envision and implement smart and automatic solutions, by exploiting innovative technologies as Information Technologies, Sensing Technologies, and Artificial Intelligence, as some researchers already tried to address.

Automatic monitoring solutions are at the base of developing smart Early Warning (EW) systems for flood hazards, which usually exploit, among relevant input data, the water level of rivers [6,7]. Nonetheless, the solutions proposed in the literature and focused on EW do not go into the details of how the water level is measured, apart from saying the type of instrumentation adopted [8,9]. Commonly adopted technologies for monitoring river flood are pressure transducers, rangefinders, ultrasonic, radar as well as optical sensors [10]. Some of these technologies require frequent calibration, otherwise, the accuracy becomes very low when objects like wooden logs pass

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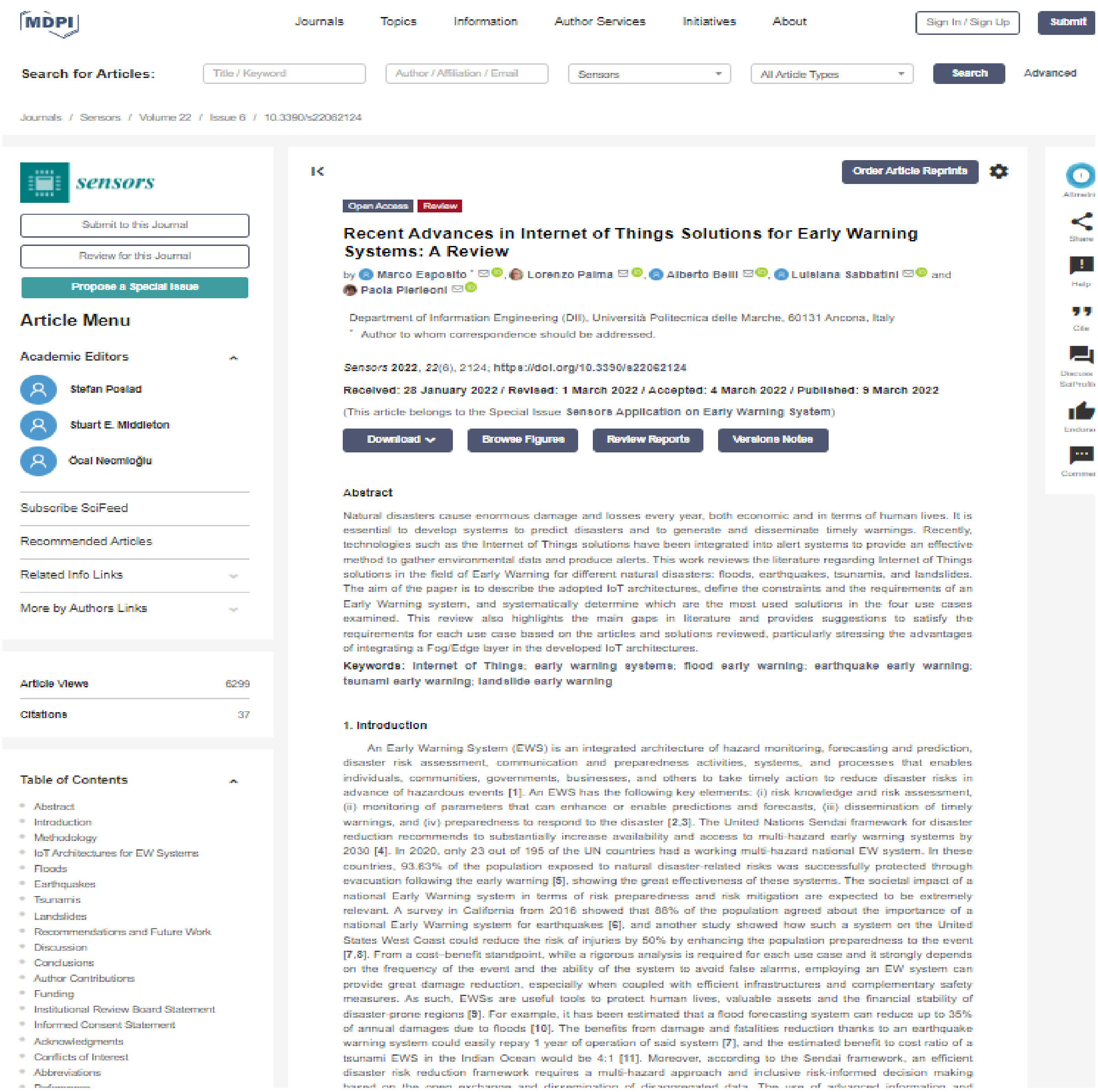
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Recent Advances in Internet of Things Solutions for Early Warning Systems: A Review

by Marco Esposito *, Lorenzo Palma, Alberto Belli, Luisiana Sabbatini and Paola Pierleoni

Department of Information Engineering (DII), Università Politecnica delle Marche, 60131 Ancona, Italy

* Author to whom correspondence should be addressed.

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Abstract

Natural disasters cause enormous damage and losses every year, both economic and in terms of human lives. It is essential to develop systems to predict disasters and to generate and disseminate timely warnings. Recently, technologies such as the Internet of Things solutions have been integrated into alert systems to provide an effective method to gather environmental data and produce alerts. This work reviews the literature regarding Internet of Things solutions in the field of Early Warning for different natural disasters: floods, earthquakes, tsunamis, and landslides. The aim of the paper is to describe the adopted IoT architectures, define the constraints and the requirements of an Early Warning system, and systematically determine which are the most used solutions in the four use cases examined. This review also highlights the main gaps in literature and provides suggestions to satisfy the requirements for each use case based on the articles and solutions reviewed, particularly stressing the advantages of integrating a Fog/Edge layer in the developed IoT architectures.

Keywords: Internet of Things; early warning systems; flood early warning; earthquake early warning; tsunami early warning; landslide early warning

1. Introduction

An Early Warning System (EWS) is an integrated architecture of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities, systems, and processes that enables individuals, communities, governments, businesses, and others to take timely action to reduce disaster risks in advance of hazardous events [1]. An EWS has the following key elements: (i) risk knowledge and risk assessment, (ii) monitoring of parameters that can enhance or enable predictions and forecasts, (iii) dissemination of timely warnings, and (iv) preparedness to respond to the disaster [2,3]. The United Nations Sendai framework for disaster reduction recommends to substantially increase availability and access to multi-hazard early warning systems by 2030 [4]. In 2020, only 23 out of 195 of the UN countries had a working multi-hazard national EW system. In these countries, 93.63% of the population exposed to natural disaster-related risks was successfully protected through evacuation following the early warning [5], showing the great effectiveness of these systems. The societal impact of a national Early Warning system in terms of risk preparedness and risk mitigation are expected to be extremely relevant. A survey in California from 2016 showed that 88% of the population agreed about the importance of a national Early Warning system for earthquakes [6], and another study showed how such a system on the United States West Coast could reduce the risk of injuries by 50% by enhancing the population preparedness to the event [7,8]. From a cost–benefit standpoint, while a rigorous analysis is required for each use case and it strongly depends on the frequency of the event and the ability of the system to avoid false alarms, employing an EW system can provide great damage reduction, especially when coupled with efficient infrastructures and complementary safety measures. As such, EWSs are useful tools to protect human lives, valuable assets and the financial stability of disaster-prone regions [9]. For example, it has been estimated that a flood forecasting system can reduce up to 35% of annual damages due to floods [10]. The benefits from damage and fatalities reduction thanks to an earthquake warning system could easily repay 1 year of operation of said system [7], and the estimated benefit to cost ratio of a tsunami EWS in the Indian Ocean would be 4:1 [11]. Moreover, according to the Sendai framework, an efficient disaster risk reduction framework requires a multi-hazard approach and inclusive risk-informed decision making

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Open-Source Data Processing Chain for Marche Region X-band Weather Radar

Francesco Iocca

Functional Centre, Marche Region Civil Protection Service, 60126 Ancona, Italy
https://orcid.org/0009-0000-3197-2038

Marco Lazzeri

Functional Centre, Marche Region Civil Protection Service, 60126 Ancona, Italy
https://orcid.org/0009-0009-6427-0230

Marco Pellegrini

1. LIF Srl, 50018 Scandicci (Firenze), Italy; 2. Department of Life and Environmental Sciences (DISVA), Università Politecnica delle Marche, 60131 Ancona, Italy
https://orcid.org/0000-0003-0959-8937

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Keywords: X-band weather radar, data processing, open-source software

Abstract

In the framework of three projects co-funded by the European Union (EU), an X-band (8-12 GHz frequency range) polarimetric radar was installed in the Marche Region territory (East-Central Italy) at Cingoli municipality, province of Macerata. The radar site is located at about 750 m above sea level and about 30 km away from the Adriatic Sea. The radar, managed by the Marche Region Civil Protection Service, is employed for weather monitoring purposes and is in pre-operational stage. It is known that radar measurements are affected by various sources of error, to be addressed in order to improve the accuracy of final products. Among these, the most important are radar calibration, ground and sea clutter, beam blockage, rain attenuation, wet-radome attenuation, beam-broadening, non-uniform beam filling, vertical variability of precipitation and wireless local-area-network (WLAN) interferences. Nowadays quantitative rainfall estimation using X-band weather radar are essential to meet requirements for flood forecasting, water management and many hydro-meteorological applications. Besides higher resolution, X-band radars are cost-effective compared to S- or C-band radars because of smaller antenna size. On the other hand, main disadvantages of such systems are the large influence

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A Computer Vision System for Staff Gauge in River Flood Monitoring

by Luisiana Sabbatini [1,*], Lorenzo Palma [1], Alberto Belli [1], Francesca Sini [2] and Paola Pierleoni [1]

[1] Department of Information Engineering, Università Politecnica delle Marche, Via Brecce Bianche 12, 60121 Ancona, Italy

[2] Regione Marche—Servizio Protezione Civile, Centro Funzionale Regionale, Via di Colle Ameno 5, 60126 Ancona, Italy

* Author to whom correspondence should be addressed.

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Abstract

Rivers close to populated or strategically important areas can cause damages and safety risks to people in the event of a flood. Traditional river flood monitoring systems like radar and ultrasonic sensors may not be completely reliable and require frequent on-site human interventions for calibration. This time-consuming and resource-intensive activity has attracted the attention of many researchers looking for highly reliable camera-based solutions. In this article we propose an automatic Computer Vision solution for river's water-level monitoring, based on the processing of staff gauge images acquired by a V-IoT device. The solution is based on two modules. The first is implemented on the edge in order to avoid power consumption due to the transmission of poor quality frames, and another is implemented on the Cloud server, where the frames acquired and sent by the V-IoT device are processed for water level extraction. The proposed system was tested on sample images relating to more than a year of acquisitions at a river site. The first module of the proposed solution achieved excellent performances in discerning bad quality frames from good quality ones. The second module achieved very good results too, especially for what it concerns night frames.

Keywords: computer vision; river flood; Visual-IoT

1. Introduction

Despite technological advancements and efforts, river basins are often source of damages and risks, especially for the population living in the neighboring areas. The risk related to flash flood, which can be valued based on multiple factors such as local hazards, exposure, vulnerability, and emergency and recovery capabilities [1], is increasing over the time and it is envisioned to get even worse due to climate change and atmospheric warming [2]. Several researchers attempted to develop models able to predict future flood hazards, highlighting also the correlation with climate changes [3,4], but it is hard to develop area specific adaptation of such models. For this reason most of the time local public entities are predisposed to control the territory in which continuous monitoring mechanisms for the safeguard of citizens are used. In particular, continuous monitoring systems are generally set up making mandatory the human supervision and contribution, thus consuming strengths and resources that public administration has at its disposal, from both an economic and workforce point of view. Despite the costs associated to such kind of monitoring mechanisms, the societal benefits have been estimated as higher [5]. However, to cope with such a source of inefficiency and waste identified, it is necessary to envision and implement smart and automatic solutions, by exploiting innovative technologies as Information Technologies, Sensing Technologies, and Artificial Intelligence, as some researchers already tried to address.

Automatic monitoring solutions are at the base of developing smart Early Warning (EW) systems for flood hazards, which usually exploit, among relevant input data, the water level of rivers [6,7]. Nonetheless, the solutions proposed in the literature and focused on EW do not go into the details of how the water level is measured, apart from saying the type of instrumentation adopted [8,9]. Commonly adopted technologies for monitoring river flood are pressure transducers, rangefinders, ultrasonic, radar as well as optical sensors [10]. Some of these technologies require frequent calibration, otherwise, the accuracy becomes very low when objects like wooden logs pass underneath, or when the wind causes waves. Moreover, these technologies are prone to measurement errors which could happen especially during dry riverbed and during extreme weather conditions like heavy rainfall, which are those conditions to be controlled more strictly for flood monitoring purposes. This has led many public entities to set up low-cost cameras for remote monitoring and visual inspection of river sites. In such sites the cameras can also frame the staff gauge which is generally installed to indicate the water level of the river. Using such cameras able to provide images related to the water level, it is possible to develop a Computer Vision (CV) system for flood hazards. Therefore, many researchers in recent years focused on using optical sensors like cameras to monitor the water level [10]. A camera equipped with remote transmission capability and eventually processing capability can be used as Visual-IoT device (V-IoT) for estimating the water level. Developing such V-IoT systems require less effort for calibration respect to using sonic and radar sensors, is economically viable, and allows the creation of a reliable

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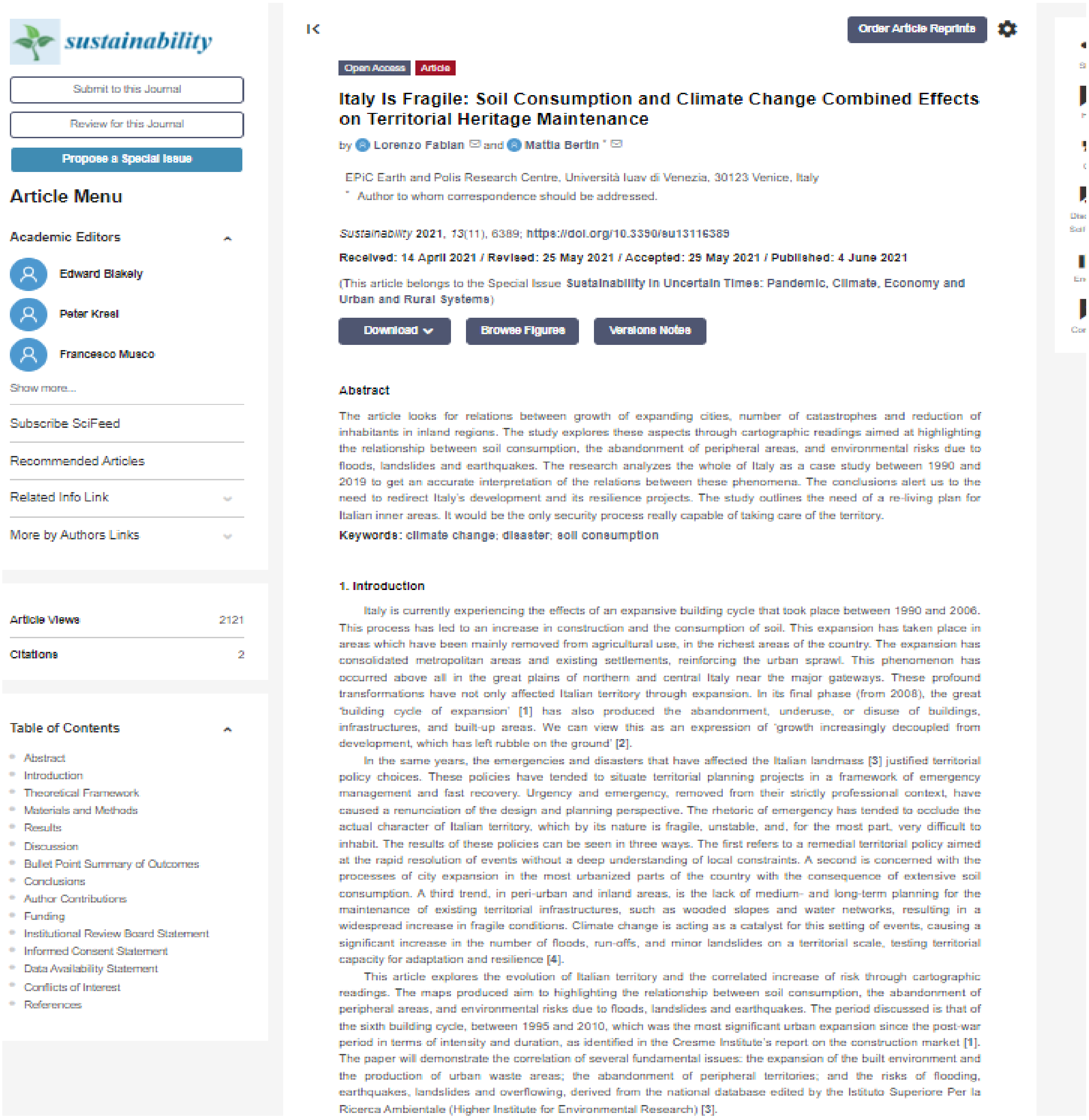

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Italy Is Fragile: Soil Consumption and Climate Change Combined Effects on Territorial Heritage Maintenance

by Lorenzo Fabian and Mattia Bertin *

EPiC Earth and Polis Research Centre, Università Iuav di Venezia, 30123 Venice, Italy

* Author to whom correspondence should be addressed.

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Abstract

The article looks for relations between growth of expanding cities, number of catastrophes and reduction of inhabitants in inland regions. The study explores these aspects through cartographic readings aimed at highlighting the relationship between soil consumption, the abandonment of peripheral areas, and environmental risks due to floods, landslides and earthquakes. The research analyzes the whole of Italy as a case study between 1990 and 2019 to get an accurate interpretation of the relations between these phenomena. The conclusions alert us to the need to redirect Italy's development and its resilience projects. The study outlines the need of a re-living plan for Italian inner areas. It would be the only security process really capable of taking care of the territory.

Keywords: climate change; disaster; soil consumption

1. Introduction

Italy is currently experiencing the effects of an expansive building cycle that took place between 1990 and 2006. This process has led to an increase in construction and the consumption of soil. This expansion has taken place in areas which have been mainly removed from agricultural use, in the richest areas of the country. The expansion has consolidated metropolitan areas and existing settlements, reinforcing the urban sprawl. This phenomenon has occurred above all in the great plains of northern and central Italy near the major gateways. These profound transformations have not only affected Italian territory through expansion. In its final phase (from 2008), the great 'building cycle of expansion' [1] has also produced the abandonment, underuse, or disuse of buildings, infrastructures, and built-up areas. We can view this as an expression of 'growth increasingly decoupled from development, which has left rubble on the ground' [2].

In the same years, the emergencies and disasters that have affected the Italian landmass [3] justified territorial policy choices. These policies have tended to situate territorial planning projects in a framework of emergency management and fast recovery. Urgency and emergency, removed from their strictly professional context, have caused a renunciation of the design and planning perspective. The rhetoric of emergency has tended to occlude the actual character of Italian territory, which by its nature is fragile, unstable, and, for the most part, very difficult to inhabit. The results of these policies can be seen in three ways. The first refers to a remedial territorial policy aimed at the rapid resolution of events without a deep understanding of local constraints. A second is concerned with the processes of city expansion in the most urbanized parts of the country with the consequence of extensive soil consumption. A third trend, in peri-urban and inland areas, is the lack of medium- and long-term planning for the maintenance of existing territorial infrastructures, such as wooded slopes and water networks, resulting in a widespread increase in fragile conditions. Climate change is acting as a catalyst for this setting of events, causing a significant increase in the number of floods, run-offs, and minor landslides on a territorial scale, testing territorial capacity for adaptation and resilience [4].

This article explores the evolution of Italian territory and the correlated increase of risk through cartographic readings. The maps produced aim to highlighting the relationship between soil consumption, the abandonment of peripheral areas, and environmental risks due to floods, landslides and earthquakes. The period discussed is that of the sixth building cycle, between 1995 and 2010, which was the most significant urban expansion since the post-war period in terms of intensity and duration, as identified in the Cresme Institute's report on the construction market [1]. The paper will demonstrate the correlation of several fundamental issues: the expansion of the built environment and the production of urban waste areas; the abandonment of peripheral territories; and the risks of flooding, earthquakes, landslides and overflowing, derived from the national database edited by the Istituto Superiore Per la Ricerca Ambientale (Higher Institute for Environmental Research) [3].

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Conclusion

Total of 19 scientific publications describing the most innovative aspects of methodological approach used related to developing forecasting systems.