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Geological and hydrometeorological hazards and related disasters amid COVID-19 pandemic in Greece: Post-disaster trends and factors affecting the COVID-19 evolution in affected areas

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ABSTRACT

Since the first confirmed COVID-19 case in December 2019 the pandemic has severely affected humanity in various ways on all sectors of the everyday life. Natural hazards and related disasters did not stop for the novel virus. The parallel evolution of disasters and the pandemic have high potential for producing compound emergencies characterized by new unprecedented challenges. Greece was no exception. It was struck by disasters induced by geological and hydrometeorological hazards amid the pandemic. The most destructive events in terms of human and economic losses were the Mw = 5.7 Epirus and Mw = 6.9 Samos earthquakes on March 21 and October 30 respectively, the Evia flood on August 9 and the Ianos medicane in mid-September 2020. We studied the daily recorded laboratory confirmed COVID-19 cases in the disaster-affected areas in selected pre- and post- disaster periods. Increase of the reported COVID-19 cases in the post-disaster period has been detected only after the Ianos medicane in affected areas. No change in cases was observed after the studied earthquakes and flood. We examined various factors related to the evolving pandemic, the studied disasters and their management plan that may have contributed to the post-disaster evolution of cases. It is shown that the pre-existing viral load and the infection rate in the affected areas, the intensity of the disaster effects and the measures adopted for the effective disaster management of the compound emergencies have the potential to affect the post-disaster evolution of the pandemic in the disaster affected areas.

1. Introduction

Over the past 2 decades, two highly pathogenic coronaviruses with zoonotic origin, severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) emerged in humans and were associated with outbreaks of severe or fatal respiratory infection in East Asia (2002) and the Middle East (2012), respectively (Dhama et al., 2020; Sharma et al., 2020; Hu et al., 2020). In late December 2019, a novel coronavirus named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) emerged in the city of Wuhan, the capital of Hubei province in China (Li et al., 2020a). Similarly to patients with SARS and MERS, patients infected with SARS-CoV-2 showed symptoms of viral pneumonia, such as fever, cough and shortness of breath (Gralinski and Menachery, 2020; Huang et al., 2020; Ding et al., 2020). Less common signs at the disease onset and the time of hospital admission include diarrhea, nausea/vomiting, headache and new loss of smell or taste (Klopfenstein et al., 2020; Luethgen et al., 2020; Walker et al., 2020). Being highly transmissible, this novel disease, also known as coronavirus disease 2019 (COVID-19) (Gorbalenya et al., 2020), has rapidly spread throughout China and, subsequently, to all over the world (Wu et al., 2020), making the declaration of a pandemic by the World Health Organization necessary on March 11, 2020 (WHO, 2020a).

The incubation period for the COVID-19 is between 2 and 14 days after exposure to SARS-CoV-2 (Lauer et al., 2020). Most SARS-CoV-2 infections, in particular in children and young adults, are asymptomatic or mildly symptomatic, whereas elderly people (over 60 years old) and/or individuals with underlying medical conditions, such as hypertension, diabetes, and/or cardiovascular and chronic respiratory diseases are at higher risk of severe pneumonia, respiratory failure and

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death (WHO, 2020a).

SARS-CoV-2 is most commonly transmitted from person-to-person through virus-containing respiratory droplets produced not only during sneezing or coughing, but also during breathing, talking, laughing and singing (Anastassopoulou et al., 2020). SARS-CoV-2 transmission can also occur through direct contact when shaking contaminated hands or indirect contact with contaminated surfaces (Li et al., 2020b). SARS-CoV-2 is transmitted before the onset of symptoms by symptomatic persons and even by asymptomatic individuals, which further contributes to the complexity of transmission dynamics in COVID-19 infections (He et al., 2020; Long et al., 2020).

In the absence of vaccines or medications, personal protective measures including social distancing, mask-wearing and hand washing are the most important drastic measures for the mitigation of the spread of COVID-19. Consistent mask-wearing, regular and thorough hand washing with soap and water or an alcohol-based hand sanitizer, and adhering to social distancing recommendations (at least 1 m from each other) are significantly associated with lower risk of COVID-19 infection and SARS-CoV-2 transmission in public settings (Doung-Ngern et al., 2020).

The emerging, rapidly evolving COVID-19 pandemic and its impacts on the everyday life gave rise to difficulties for people worldwide. Unfortunately, natural hazards and related disasters do not stop for a virus. Only a few months after the initiation of the COVID-19 pandemic, several natural hazards including earthquakes and their primary and secondary effects (Čivljak et al., 2020; Markušić et al., 2020), hydrometeorological events comprising floods (Guo et al., 2020; Frausto-Martínez et al., 2020), hurricanes (Shultz et al., 2020; Pei et al., 2020) and droughts (Mishra et al., 2021) crossed its path. They adversely affected the pandemic evolution in various direct and indirect ways comprising impact on various sectors of the daily life (Čivljak et al., 2020; Silva et al., 2020; Han and He, 2021; Mishra et al., 2021; Shen et al., 2021). The synergy of the evolving pandemic and natural hazards has high potential for causing compound disasters, complex emergencies and multiple crises, which threaten human life and well-being and involve various effects and challenges for authorities at all administration and governance levels (global, regional, national and local level) not only in developing but also in developed countries (Phillips et al., 2020; Lau et al., 2020; Kavanagh et al., 2020). The introduction of health as a significant element and major focus for disaster risk reduction and disaster risk management as well as the inclusion of public health emergencies and the protection of health facilities in the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNDRR, 2015) makes perfect sense nowadays, amid the COVID-19 pandemic. The implementation of COVID-19 mitigation measures is now a major priority for many national disaster management agencies.

Greece was no exception to this crisis. The pandemic was initiated in late February 2020 [Hellenic National Public Health Organization (HNPHO, 2020)]. The first confirmed case of the novel COVID-19 infection has been reported on February 26. One month later, the first destructive event struck the northwestern part of the country. The March 21, 2020, Mw = 5.7, Epirus earthquake (Lekkas et al., 2020a) was one of the earliest wake-up calls for agencies involved in civil protection and disaster and crisis management and for population that natural hazards are still present amid the pandemic. More geological, hydrological and meteorological hazards were generated with effects on the local population and the built environment, including buildings and infrastructure. The most destructive events in terms of human and economic losses were the Evia (Central Greece) flood (Lekkas et al., 2020b), the Ianos medicane (Lekkas et al., 2020c) and the Samos (Eastern Aegean Sea) earthquake (Lekkas et al., 2020d, 2020e), which occurred on August 9, September 17 and October 30, 2020 respectively.

Taking into account the conditions newly introduced by the pandemic and the aforementioned disasters, we examined the trend that prevailed after the disasters in the evolution of the laboratory-confirmed daily recorded COVID-19 cases, in order to identify possible changes (increase, decrease) and to investigate the possible causes and factors of these changes and the potential impact of the disasters. For achieving this, we studied the laboratory-confirmed daily reported COVID-19 cases in the regional units affected by the disasters for selected pre- and post- disaster periods. These periods were selected taking into account published data reporting the incubation period of the novel virus. From this study, several trends were detected in the post-disaster evolution of the COVID-19 cases including increase, decrease and stability.

For the identification of the causes of these observed post-catastrophic trends in the evolution of the pandemic, various factors related to the characteristics of the pandemic in the affected areas, the properties of the disasters and the characteristics of the affected areas were taken into account. The main ones are the pre-existing viral load, the distribution and the type of the disaster-induced damage and the post-disaster accessibility of the affected areas, among others, which will be mentioned below. Emphasis is given to the actions conducted by the governmental authorities to prevent spreading of the novel virus during the immediate response phase and to their potential impact to the evolution of the pandemic in the affected areas.

Thus, we briefly present the main characteristics of the aforementioned disasters and their impact on the local population as well as on the natural and built environment. Based on the spatial distribution of the induced damage, the affected areas and in particular the affected regional units were identified. Moreover, a detailed presentation of the evolution of the pandemic in Greece is made since its initiation on February 26, 2020 up to 21 days after the Samos earthquake. Emphasis is given on the measures taken by the governmental authorities to deal with the adverse effects of the pandemic. From the combination of all these, important data emerge not only for the post-disaster evolution of the pandemic in the affected areas but also for the potential impact of the studied factors to the evolving pandemic.

2. Evolution of the COVID-19 pandemic in Greece

2.1. First phase of the COVID-19 pandemic

The first documented case of the novel COVID-19 infection in Greece was on February 26, 2020 (Fig. 1) and it has been attributed to a business trip to the northern part of Italy. However, from the subsequent evolution of the pandemic, it is considered very likely that the SARS-CoV2 had been introduced to Greece in the form of isolated cases, as a consequence of international movements, earlier than the first confirmed cases. Since the first cases, various aspects of life in Greece have been seriously or partially disrupted.

After the confirmation of the first cases, the Greek government imposed new emergency measures in order to prevent the spread of the virus. On February 27, 2020, all cultural events during the carnival period were cancelled (Fig. 1). The health and state authorities issued recommendations and guidelines for protection against SARS-CoV-2 respiratory infection.

However, due to the SARS-CoV-2 outbreak in several parts of Greece during March and due to non-compliance with social distancing measures, a Joint Ministerial Decision was issued by the Ministries of Health and of Education and Religious Affairs on the suspension of all educational activities in all educational public and private institutions in all levels (elementary, middle and high schools, colleges, universities) on March 11 and for the next 14 days (Fig. 1). These institutions have suspended the on-site (in-person) education activities as well as gatherings in their facilities including restaurants, libraries, reading rooms, gyms and sport facilities among others, but not the distance learning and remote courses.

On March 13, the suspension of services was extended to restaurants, museums, shopping malls and sports facilities (Fig. 1). On March 16, all commercial stores and places of worship for all religions also suspended their services (Fig. 1). Bakeries, supermarkets, pharmacies, private health services and some other businesses remained open. In the

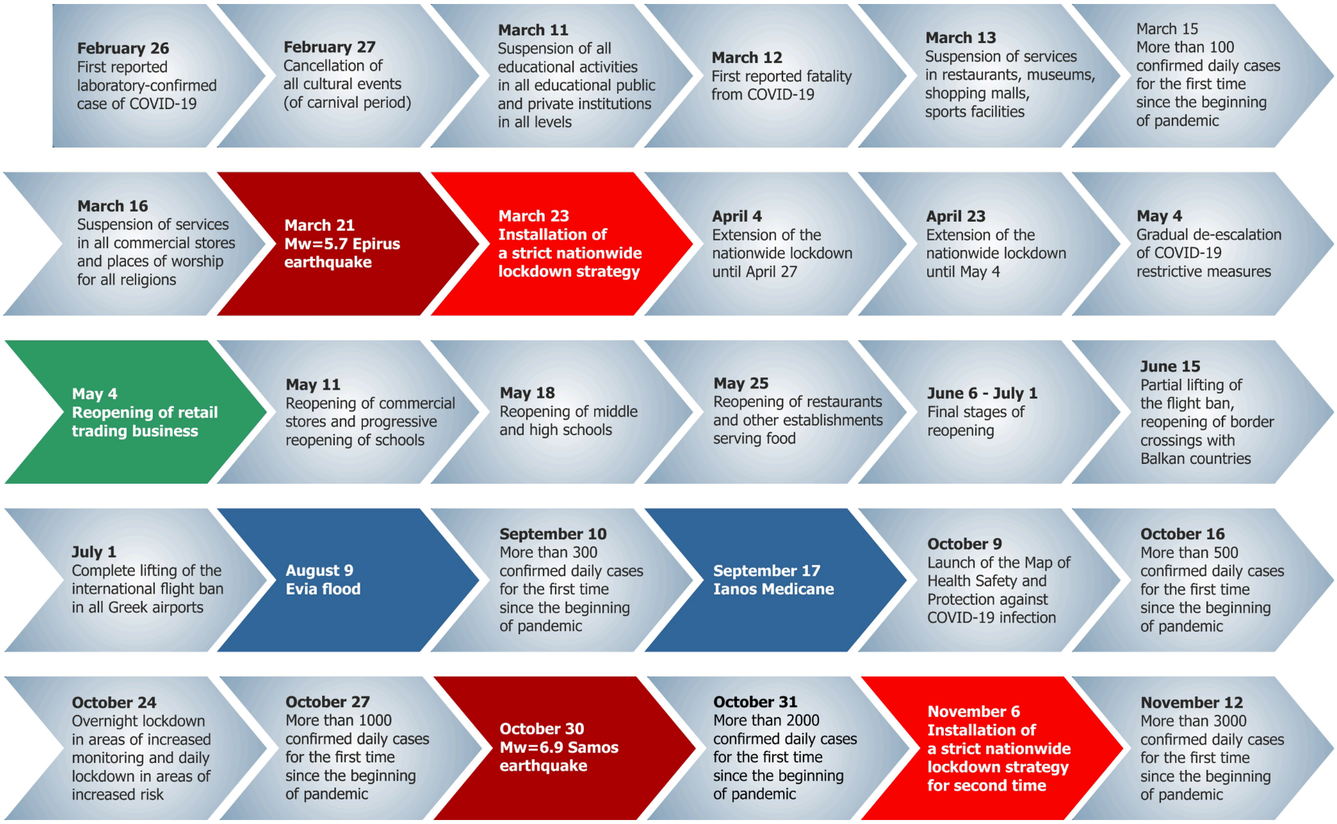

Fig. 1. Timeline showing the major COVID-19 events taking place in Greece from the first reported case on February 26, 2020 to the beginning of the second nationwide lockdown in the early November 2020. The beginning of the lockdowns are highlighted with red color, the reopening with green, the generated disasters induced by earthquakes amid the pandemic are highlighted with dark red and the disasters induced by hydrometeorological hazards with dark blue. Four disasters occurred in Greece amid the pandemic. They were induced by the March 21, Mw = 5.7, Epirus earthquake, the August 9 Evia flood, the September 17 Ianos medicane and the October 30, Mw = 6.9, Samos earthquake.

meantime, the first fatality was confirmed on March 12, while on March 15 more than 100 daily cases were reported for the first time since the beginning of the pandemic in Greece (Fig. 1). On March 21, the first destructive earthquake amid the pandemic struck the Region of Epirus (Fig. 1).

Due to the further increase in daily cases, on March 23, 14 days after the suspension of all educational activities in Greece, Greece commenced a strict nationwide lockdown with a total ban on all non-essential movements and travelling throughout the country in order to more effectively deal with SARS-CoV-2 spread (Fig. 1). Moving outdoors was permitted for goint to or returning from: (i) work, (ii) a pharmacy or a doctor, (iii) a food store, (iv) a bank for services not available online, (v) people in need, (vi) a major ritual and (vii) personal exercise individually or in pairs as well a pet walk. The implementation of lockdown measures was undertaken by the Hellenic Police, the Municipal Police, the Hellenic Coast Guard and the National Transparency Authority. Moreover, a series of measures of around € 24 billion was announced by the government for supporting the economy and the affected businesses and workers. On April 4, the lockdown restrictions were extended until April 27, and on April 23 they were extended again until May 4 (Fig. 1).

As of May 4, the government's plan for the gradual de-escalation of emergency COVID-19 restrictive measures was implemented, with the reopening of retail trading business (Fig. 1). The restart at this phase involved a total of 26,167 companies (about 10% of the total suspended) and 68,528 employees (also about 10% of the total suspended).

On May 11, commercial stores were reopened, accompanied by an obligation to observe personal protection measures by employees and customers, restrictions regarding the maximum number of customers within the stores and the occasional mandatory use of disposable masks and gloves (Fig. 1). On May 11, 155,962 employees returned to work (22.5% of the total suspended) and 66,010 companies reopened (25% of the total suspended). As of May 11, a total of 93,000 companies had reopened (about 35% of the total suspended) and 225,000 employees had returned to work (about 33% of the total suspended). On the same day, high schools and student tutoring centers reopened, but only for the students of the last class of the secondary educational levels preparing for the nationwide exams for entrance into Greek public universities, which had to follow hygiene and social distancing measures. On May 18, the courses for students in all classes of the secondary educational level (middle and high school) started again.

From June 6 to July 1, the last stages of lifting the suspension of services followed (Fig. 1). During this period, 63,000 companies reopened (about 24% of the total suspended), and 89,000 employees returned to work (about 13% of the total suspended). In total, by July 1, 97% (670,000) of suspended employees had returned to work and 95% (249,000) of all closed businesses had reopened.

Since June 15, ban on flights from Italy, Spain and the Netherlands was lifted at the Athens International Airport Eleftherios Venizelos (ATH), but the restrictions for flights from Albania, Northern Macedonia, Great Britain and Turkey remained, while all international flights at the Thessaloniki Macedonia Airport (SKG) were allowed except for those from Italy, Spain, Holland, Great Britain, Turkey, Albania and Northern Macedonia (Fig. 1). As regards the land borders crossings, the crossing between Greece and Bulgaria reopened, while the rest with Turkey, Albania and Northern Macedonia remained closed.

Since July 1st, all international flights were allowed at all airports of the country with mandatory completion of passenger locator form (Fig. 1). All travelers had to complete their Passenger Locator Form until the day before entering the country, providing detailed information on their point of departure, the duration of previous stays in other countries, and the address of their stay while in Greece, among others. Moreover, the sea arrivals from abroad in Greek ports was also allowed.

2.2. Second phase of the COVID-19 pandemic

The second wave of the pandemic in Greece started in early August with a more aggressive evolution than the first one according to the daily reported confirmed cases, ICU patients and fatalities reported (HNPHO, 2020) (Fig. 1). Since the beginning of August (August 4), the number of daily confirmed cases in Greece is steadily three-digit and constantly growing based on the daily reports of the Hellenic National Public Health Organization (HNPHO, 2020). Greece exceeded 200 daily confirmed cases on August 9 (HNPHO, 2020), the day that the second destructive event induced by floods occurred. The third disaster induced by medicane started on September 17 and completed two days later on September 19. Greece exceeded 500 daily confirmed cases almost one month after Ianos medicane, more specifically on October 16, 1000 cases on October 27, 2000 on October 31, a day after Samos earthquake and 3000 on November 12 (HNPHO, 2020). The maximum number of confirmed daily cases in Greece was 3316 reported on November 12 (HNPHO, 2020). During the second wave of the pandemic, the highest numbers of cases are observed in Athens, which is the capital and largest urban center of the country, in Thessaloniki, which is the co-capital of the country, and in towns of Central and Northern Greece, including Larissa and Kozani respectively, among others (HNPHO, 2020).

Due to this rapid increase in daily cases in the country, it was imperative to take additional measures for preventing the spread of COVID-19. Based on the experience gained from the first phase of the pandemic as well as on the available scientific and technological tools that have been developed, the Greek government gradually implemented targeted local measures for the safe and smooth continuation of economic and social life during the second phase. Since September 21 and until October 4, the implemented measures comprised ban on gatherings in open and closed spaces, suspension of cultural events, small numbers of people attending religious ceremonies, compulsory teleworking in public and private sector, mandatory use of a mask and increased controls and tests of HNPHO in workplaces and gatherings in busy neighborhoods of affected areas, as well as in several important public and non-public services comprising schools, hospitals, public means of transport among others.

On October 9, the Map of Health Safety and Protection against COVID-19 infection was launched (Figs. 1 and 2). It was an interactive, virtual map that assessed the epidemiological burden of each Greek region in order to control the spread of the COVID-19 throughout the country. It presented four levels of epidemiological state for each regional unit of the country, which helped determine if local COVID-19 restrictive measures were required to be taken. These levels were: (1) preparedness, (2): surveillance, (3): increased surveillance, (4) increased risk (Fig. 2). The determination of the risk level in each area depended on the increasing or decreasing trend of epidemiological parameters including the number of cases per 100 thousand inhabitants, the completeness of health facilities comprising simple beds used and beds of Intensive Care Units (ICU) and epidemiological situation, as reflected by the trace data.

The map was updated every 14 days based on the recommendations of a special committee of infectious diseases of the Ministry of Health or more often when this was required by the health and epidemiological indicators (Fig. 2). The definition of measures and rules was subject to modification on the basis of recent scientific and research data.

Following the rapid increase in daily confirmed cases after mid-October, an overnight lockdown and mandatory use of mask in all open and close spaces were imposed on October 24 at areas in level 3 of increased surveillance and daily local lockdown in level 4 of increased risk. Unfortunately, the daily confirmed cases continued to increase after all these measures and Greece commenced a second strict nationwide lockdown from November 6 until November 30 with a total ban on all non-essential movements and travelling throughout the country in order to limit the spread of SARS-CoV-2 (Figs. 1 and 2).

In Greece, as of November 21, the total confirmed cases of COVID-19 were 90,185 and the total fatalities from COVID-19 1527 (HNPHO, 2020). As of December 31, the total confirmed cases of COVID-19 were 138,850 and the total fatalities 4838 (HNPHO, 2020) (Fig. 3).

3. Geological, hydrological and meteorological hazards and related disasters in Greece amid the COVID-19 pandemic

Earthquakes were generated in several areas of Greece amid the pandemic. Most of them were only felt by the inhabitants without further impact on other sectors of daily life and activities. However, two strong earthquakes were not only felt, but also destructive with significant effects on the local population, the natural environment, the buildings and the infrastructure of the affected areas. The first earthquake hit the northwestern part of Greece and especially Epirus on March 21, 2020 during the first lockdown for dealing with the first wave of the pandemic in Greece, while the second event hit the Eastern Aegean Sea and especially the Samos Island, on October 30, 2020, during the second wave of the pandemic and 6 days before the second lockdown in the country.

Hydrometeorological extreme events also occurred in Greece amid the COVID-19 pandemic. The Evia flood occurred on August 8 in the beginning of the second wave of the pandemic and the Ianos medicane struck in mid-September, when the second wave evolved gradually. Emphasis is given on their damage induced on the built environment of the affected areas comprising buildings and infrastructures, which largely affected the daily life of the local population amid the COVID-19 pandemic.

3.1. The March 21, 2020, Mw 5.7 Epirus (Greece) earthquake

On March 21, 2020 (00:49:52 UTC) an earthquake struck Epirus, located in northwestern Greece. Its magnitude has been assessed as Mw = 5.7, its epicenter has been located at a distance of 15 km east of Parga city and its focal depth ranged from 5 to 16 km (Lekkas et al., 2020a; Valkaniotis et al., 2020).

The main shock was felt in Epirus, the Ionian Islands, the western part of the mainland Greece and the Northwestern Peloponnese. It was also felt in the southern part of the neighboring Albania. Fortunately, the earthquake resulted in only injuries. Three people were slightly injured in Kanallaki village due to falling items and debris, while about 20 residents stayed in hotels due to heavy structural damage in their homes.

The earthquake affected area is extended in Parga, Souli and Dodoni municipalities belonging to the Regional Units of Preveza, Thesprotia and Ioannina respectively (Fig. 4). All affected regional units belong to the Epirus Prefecture. More specifically, 21 villages and towns founded mainly on recent deposits suffered damage by the 2020 Epirus earthquake (Lekkas et al., 2020a).

As regards the earthquake impact on the building stock of the affected area, low-rise buildings with masonry load-bearing walls composed of bricks, stones and concrete blocks suffered the most by this earthquake (Fig. 5a-5d). Structural damage included extensive cracking and partial collapse of the masonry walls (Fig. 5a-5d). Non-structural damage included detachment of plasters from the walls and small cracks in the masonry. The reinforced concrete buildings suffered not only non-structural but also structural damage, but in small extent (Fig. 5e-5f). The structural damage included mainly failure of columns of the ground floor, while non-structural damage included detachment of plasters from and small cracks in the brick infill walls (Fig. 5e-5f).

As regards the earthquake impact on infrastructure and lifelines, slope failures were generated along the road network resulting in temporary traffic disruption (Lekkas et al., 2020a) (Fig. 5g). Moreover, the earthquake caused temporary electric power shutdowns in the affected area. In addition to the aforementioned slope failures, the 2020

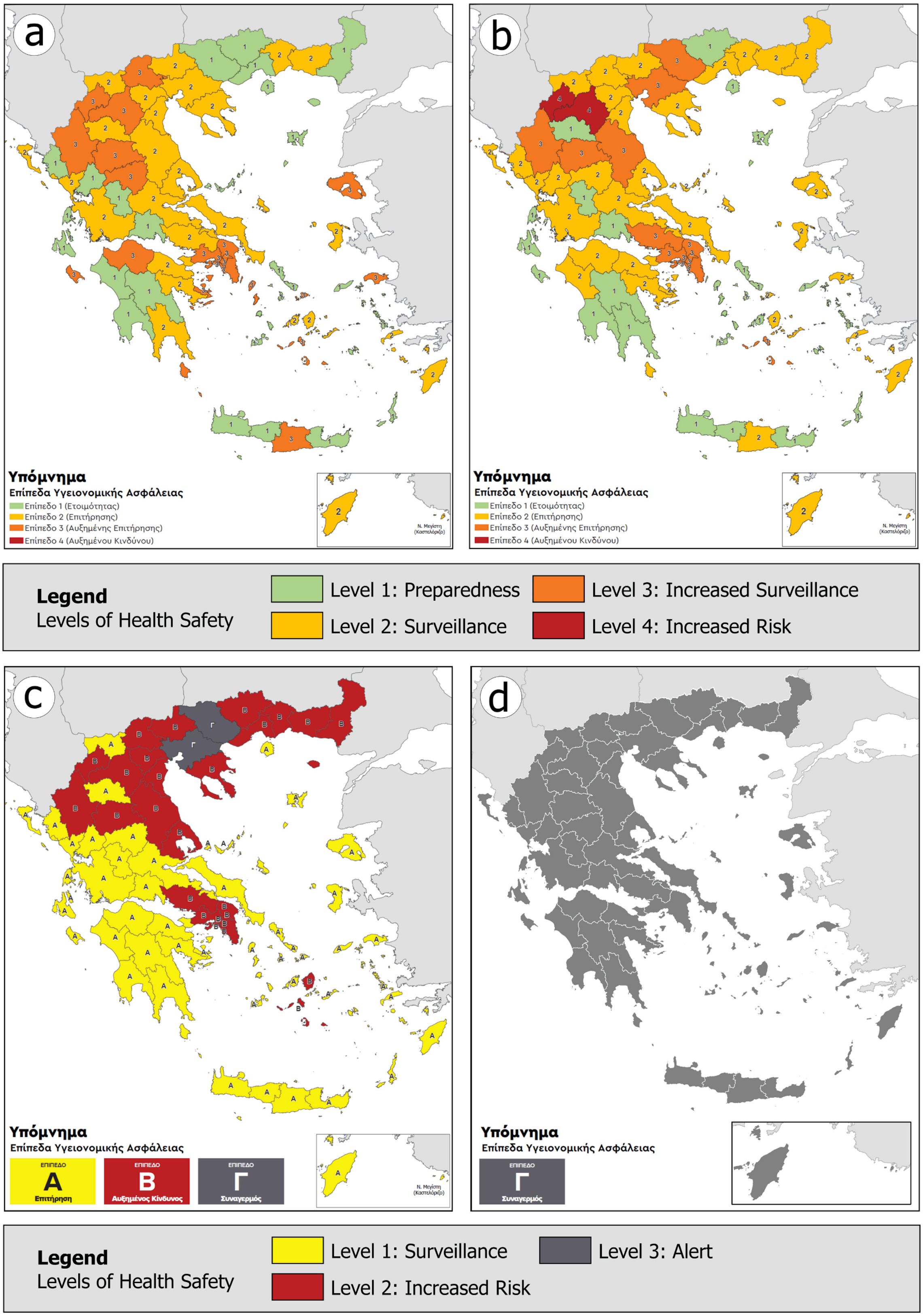

Fig. 2. (a) The Map of Health Safety and Protection against COVID-19 infection on (a) October 9, 2020, (b) on October 23, 14 days after the compilation of the first map, (c) on November 2, 14 days after the compilation of the previous map. There is a large epidemiological load in Northern Greece, where regional units are located at levels 3 and 4, where overnight or total lockdowns have been imposed respectively. The spread of the virus was not restricted, with the result that a second national lockdown was imposed on November 6. The viral load in the regional units of Northern Greece was heavy corresponding to level 3 of Increased Surveillance and level 4 of Increased Risk on maps (a) and (b) as well as to level 2 of Increased Risk and level 3 of Alert on maps (c) and (d). Overnight or total lockdowns have been imposed in these regional units. Due to the fact that the spread of the virus was not limited, a second strict nationwide lockdown started on November 6 (d, alert level).

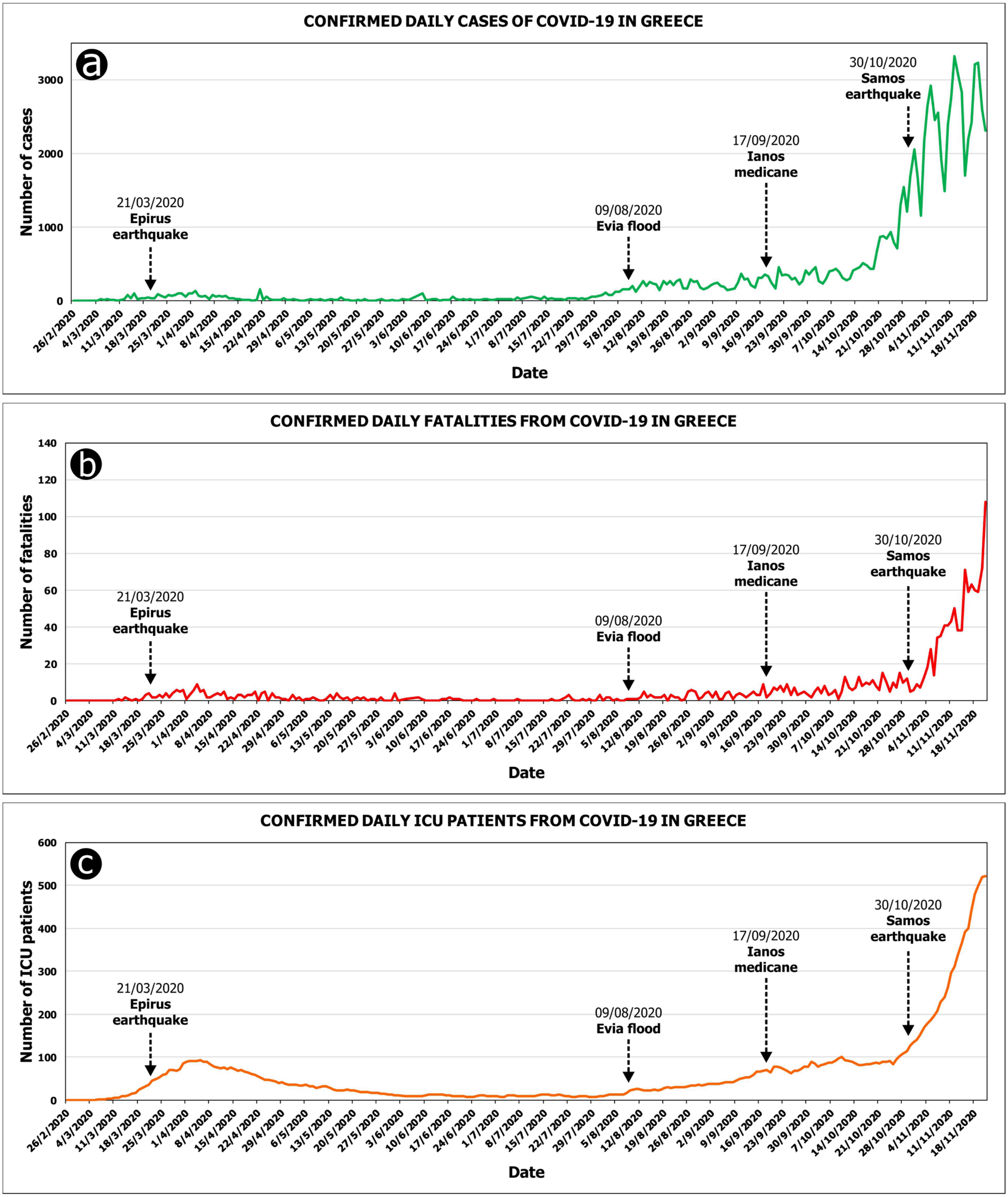

Fig. 3. (a) Laboratory-confirmed COVID-19 cases in Greece has been tracked since February 26, 2020 and is updated daily up to November 11, 2020 as new cases are identified. The occurrence dates of the Epirus earthquake, the Evia flood, the Ianos medicane and the Samos earthquake are depicted in the diagram. The Epirus earthquake was generated during the first wave of the pandemic, while the other three destructive events occurred within the second wave of the pandemic, which has started in the early August 2020. (b) ICU patients with laboratory-confirmed COVID-19 in Greece and (c) fatalities from COVID-19 in Greece since February 26 up to November 11, 2020. These numbers are reported and updated daily by the National Public Health Organization (HNPHO, 2020).

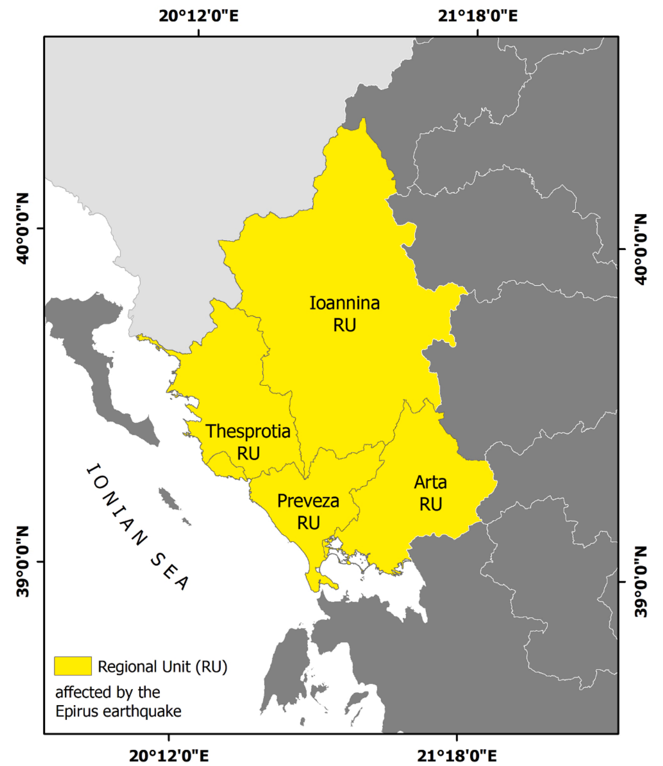

Fig. 4. The Preveza, Arta, Ioannina and Thesprotia Regional Units of the Epirus Region affected by the March 21, 2020, Mw = 5.7, Epirus earthquake based on the distribution of earthquake-induced damage presented by Lekkas et al. (2020a).

earthquake induced hydrological anomalies including water turbidity in Acheron River water (Lekkas et al., 2020a) (Fig. 5h, 5i).

3.2. The August 9, 2020 Evia (Central Greece) flood

In the beginning of August 2020, an almost stationary mid/upper-tropospheric cut-off low-pressure system in the area of South Adriatic Sea approached Greece from the northwest. It was called "Thalia" by the National Observatory of Athens. On the early hours of August 8, 2020, the cut-off center was located in the area of the Ionian Sea. The center moved southeastwards, more specifically over the mainland Greece and eventually over the Aegean in the early morning hours of August 9.

In the evening of August 8, high levels of rain and intense lightning activity were recorded and reported in Evia Island (Fig. 6), especially between Nea Artaki, Psachna and Steni areas. The intensively bad weather formed high clouds and maintained its strength for five hours producing large amounts of rainfall. Based on recordings of accumulated rainfall at the meteorological stations of the National Observatory of Athens, 300 mm within 8 h were recorded in Steni station, 226 mm in Psachna station and 183 mm in Setta station, all of them located in Evia Island.

As a result of the storm in Evia Island, Lilas and Messapios Rivers and Politika stream overflowed their banks. Based on water stage recordings conducted by Lekkas et al. (2020b) in the affected areas, flood waters reached 1.5 m in several sites. The induced floods resulted in 8 fatalities, increased intense erosion and slope failures, extensive damage to buildings, infrastructure, businesses, facilities and agriculture in the Chalkida and Dirfia-Messapia municipalities (Lekkas et al., 2020b). The floods caused damaged to 2500 buildings (Fig. 7a-7f), as well as extensive damage to businesses and crop fields (Fig. 7g-7i). Road infrastructure including roads in several sites of the affected area and three bridges across Lilas River suffered partial or total destruction (Lekkas et al., 2020b) (Fig. 7j-7l). Thus, traffic and communication with the mainland Greece was temporarily disrupted. Moreover, the water supply and the electricity networks were extensively damage resulting in water and electricity shut-offs in several affected villages.

3.3. The mid-September 2020 medicane Ianos

Medicane Ianos has formed offshore the Africa coasts on September 12, 2020. It rapidly intensified while moving northeast and crossing the Ionian Sea. It carried unstable air masses and caused the first weather change characterized by occurrence of extreme weather phenomena. It reached the southern Ionian Islands (Lefkada, Cephalonia, Ithaki, and Zakynthos from north to south) and the northwestern coast of Peloponnese (Elis and Achaia regional units) on September 17. This storm swept across Greece through central Thessaly, affecting large cities comprising Karditsa, Trikala, Larissa and Farsala until September 19. Then, Ianos headed towards southern Greece and Crete losing its intensity until its dissipation on September 21.

During its destructive crossing from Greece, Ianos was accompanied by strong winds, heavy precipitation and thunderstorms that have affected the western, the central and the southern part of Greece (Fig. 8). Based on recordings of the meteorological stations of the National Observatory of Greece on October 18, 188 mm of rainfall were recorded in Karditsa station (Thessaly), 158 mm in Mouzaki station (Thessaly), 138 mm in Karpenissi station (Mainland Greece), 133 mm in Lamia station (Mainland Greece) and 104 mm in Trikala station (Thessaly). The maximum rainfall in Western Greece was 186 mm in the Ionian Sea and 123 mm in Gavalou of Aetoloakarnania within 32 h (from the early hours of September 17 to morning of September 18).

Except for its tropical characteristics and its intensity, Ianos affected an extended geographical area, which received high rainfall resulting in increased probability of flooding. The induced floods resulted damage to the natural and built environment of several areas. Impact was recorded in the Region of the Ionian Islands (Lefkada, Cephalonia, Ithaki and Zakynthos regional units), the Region of Western Greece (Elis and Achaia regional units in Peloponnese area and Aetoloakarnania regional unit in mainland Greece), the Region of Peloponnese (Corinthia regional unit), the Region of Thessaly (Karditsa, Trikala, Magnesia and Larissa regional units), the Region of mainland Greece (Phthiotis regional unit) as well as the Region of Crete (Herakleion, Rethymnon and Chania regional units) (Lekkas et al., 2020c) (Fig. 8).

The destructive effect of Ianos was reported on coastal and inland rural and urban areas (Lekkas et al., 2020c) (Fig. 9). Damage was recorded on vegetation (Fig. 9a), private properties including buildings (Fig. 9b-9e), vessels and vehicles, agriculture as well as infrastructures comprising health facilities including health centers and hospitals (Fig. 9f-9g), road network (Fig. 9h, 9i), railway lines, electricity (Fig. 9j), water supply and telecommunications networks and coastal infrastructures including port facilities and coastal roads (Fig. 9k, 9l) (Lekkas et al., 2020c).

As regards the impact of Ianos to the built environment, flood debris filled roads, public and private spaces in the affected areas causing temporary traffic disruption, stuck and destroyed cars in flood debris, and caused slight non-structural damage to recent constructed buildings comprising detachment of plaster and cracks in brick walls and heavy structural damage in old buildings with load-bearing walls comprising partial or total collapse (Lekkas et al., 2020c).

As a result, 4 fatalities and many injured people were reported, hundreds became homeless after losing their properties, while others remained stuck in their flooded houses for hours without access to basic supplies and health, water and sanitation services.

3.4. The October 30, 2020, Mw 6.9 Samos (Greece) earthquake

On October 30, 2020 (11:51:26 UTC time) an earthquake struck the eastern part of Greece and the western part of Turkey. Its epicentre was located offshore northern Samos Island (Eastern Aegean Sea, Greece), its

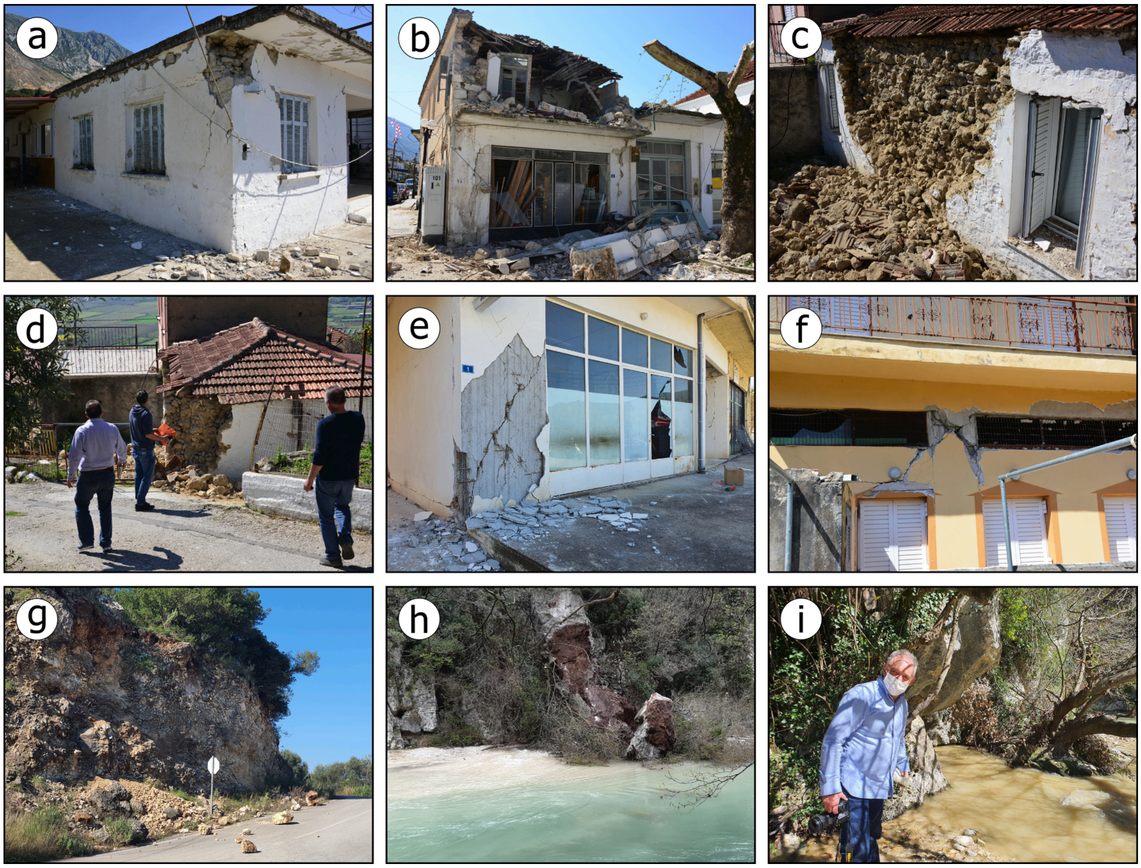

Fig. 5. Impact of the March 21, 2020, Mw = 5.7, Epirus earthquake on the natural and built environment. (a-f) Characteristic views from damage induced by the March 21, 2020, Mw = 5.7, Epirus earthquake. The old buildings with masonry load-bearing walls suffered the most by this earthquake (a-d). The recorded damage varied from cracks in the masonry (a) to partial collapse of the structure (b, c, d). The recent building suffered mainly non-structural damage, but there were exceptions with reinforced-concrete buildings severely affected by the earthquake (e, f). They suffered heavy damage to the columns of their ground floor (g-i). The earthquake environmental effects comprised hydrological anomalies including temporary turbidity in the Acheron River springs and rockfalls along the road network and along the Acheron River bed.

magnitude has been assessed as Mw = 6.9 and its focal depth was determined at 13 km (Papadimitriou et al., 2020).

The mainshock was felt in several areas of Greece and Turkey, extending from the North Aegean Islands to Peloponnese in Greece and from the Minor Asia to Istanbul in Turkey. The most affected areas were the Samos Island in the administrative region of North Aegean (Greece) (Fig. 10) and Izmir city along the Turkey's Aegean coast. Unfortunately, it claimed 119 lives, in particular 117 in Izmir city and 2 in Vathy town of Samos Island based on official announcements of authorities in Turkey and Greece respectively involved in the disaster management followed the earthquake. As regards the injured, 1034 were reported in Turkey and 19 in Samos. The fatalities and injuries were attributed mainly to partial or total collapse of buildings and debris falling and secondarily to the subsequent tsunami.

The earthquake had considerable impact on the natural and built environment of Samos (Figs. 11 and 12). As regards damage on buildings, the old structures with load-bearing masonry walls built on the beginning of the 20th century suffered the most by the earthquake (Lekkas et al., 2020d, 2020e; Vadaloukas et al., 2020) (Fig. 11a-11d). Structural damage on these buildings varied from heavy cracking of the masonry walls (Fig. 11a, 11b) to partial or total collapse of the structures (Fig. 11c, 11d). Non-structural damage included small cracks and detachment of plasters from the masonry walls. The recent buildings with reinforced concrete frame and infill walls were slightly affected by the earthquake. However, limited cases of severe structural damage to reinforced concrete buildings including detachment and collapse of the infill walls from the surrounding frame and failure of columns, were also observed (Fig. 11e-11f). Most damage was observed within basins of the affected area filled with Neogene formations and loose Quaternary deposits (Lekkas et al., 2020d, 2020e), lying over the alpine basement of the island comprising mainly metamorphic formations (Roche et al., 2019).

As regards the impact on infrastructures, the road network has suffered damage attributed to surface ruptures and ground cracks as well as to slope failures resulting in temporary traffic disruption (Fig. 12a-12c). The water supply network and the electricity network suffered from damage and power outages respectively. As regards the tsunami, it caused impact on mobile objects (vehicles, vessels, equipment of shops along the coastal area were drifted away), to infrastructures (makeshift facilities were washed away), to the natural environment (debris was accumulated along the coastline) and to buildings (slight damage were observed on non-structural elements of structures along the coastal zone) (Fig. 12d-12f). The damage along the coastal zones were manly observed in Vathy and Karlovassi towns, both situated in the northern coastal part of Samos facing the earthquake epicenter and the causative fault (Lekkas et al., 2020d; Triantafyllou et al., 2021).

As regards the environmental effects, the 2020 Samos earthquake generated primary and secondary effects (Lekkas et al., 2020d; Triantafyllou et al., 2021) (Fig. 12). The primary effects included permanent coseismic surface deformation comprising uplift and coseismic surface ruptures in the northwestern Samos, uplift in the southeastern Samos and subsidence in the north-central part of the affected island (Lekkas et al., 2020d). The secondary effects included tsunami with considerable impact on the northern coast of Samos (Triantafyllou et al.,

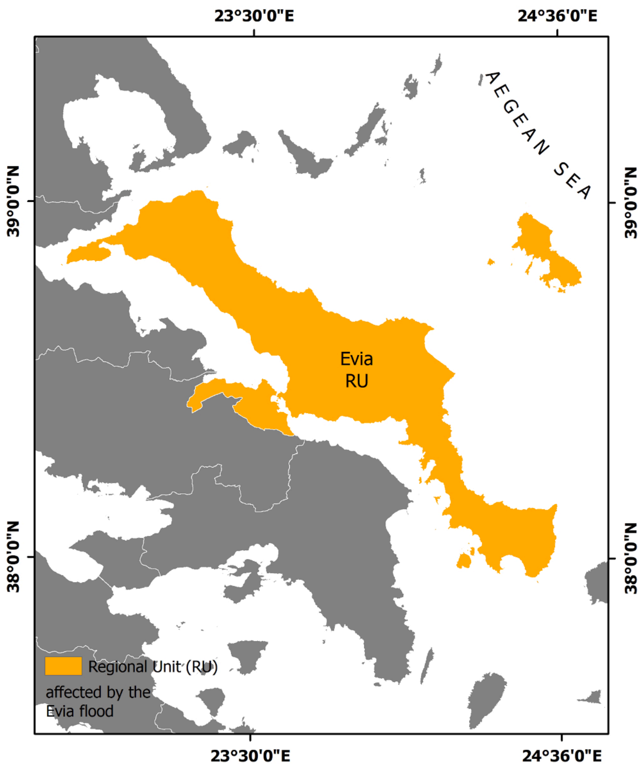

Fig. 6. The Evia Regional Unit of the Region of Central Greece was most affected by the August 9, 2020, Evia flood based on the distribution of flood-induced damage presented by Lekkas et al. (2020b).

2021), slope failures in several sites along the road network mainly in the northern coastal part of the island and liquefaction phenomena in its northeastern coastal part (Lekkas et al., 2020d) (Fig. 12).

In Samos Island, 2000 buildings were checked for structural damage during the initial post-earthquake building inspection and 1200 suffered severe damage and were characterized as temporarily unusable until repaired until November 19, 2020. Almost 250 residents were staying in hotels in the eastern and 150 in western Samos, while others were hosted by friends and relatives. Moreover, severe damage was also observed in schools and monumental structures including churches and archaeological sites (Lekkas et al., 2020d). 11 out 44 schools were characterized as temporarily unusable until repaired, 64 churches were heavily damaged and archaeological museums and sites were moderately affected.

4. Study of the possible effect of natural hazards and related disasters in the evolution of the pandemic in the affected areas

4.1. Methodology

Daily reported laboratory-confirmed COVID-19 cases from the affected areas were used in order to study the possible effect of the above geological and hydrometeorological hazards and related disasters on the post-disaster evolution of the pandemic. The daily reported COVID-19 cases, which were used in this study, were obtained from the following official sources (Table 1):

- The daily reports of COVID-19 epidemiological surveillance of the Hellenic National Public Health Organization (HNPHO), which are available on the HNPHO website (https://eody.gov.gr/epidimiologika-statistika-dedomena/ektheseis-covid-19/). These reports include the daily reported number of laboratory-confirmed COVID-19 cases, fatalities and intubated patients treated in intensive care units, their geographic and age distribution and the total number of cases, fatalities and intubations since the initiation of the COVID-19 pandemic in Greece. The number of samples, which have been tested by laboratories and Health Units of HNPHO performing tests for the detection of SARS-CoV-2, are also presented.
- The HNPHO press releases (https://eody.gov.gr/category/deltia-typoy/) that mainly include updates from the authors of the Hellenic Ministry of Health accredited by the representatives of authorities involved in the management of the pandemic as well as by infectious disease specialists, participating in the Government Committee for Coordination and monitoring of Government Policy to deal with the COVID-19 pandemic.
- The HNPHO announcements (https://eody.gov.gr/category/anakoinoseis/).
- The progress reports of the Observatory of the Government Committee for Coordination and Monitoring of Government Policy to deal with the COVID-19 pandemic and its effects on the health situation of the country as well as the economic and social life, which are available on the respective website (https://covid19.gov.gr/category/paratiritirio/). These reports present the evaluation of new data on the evolution of the pandemic in Greece aiming to determine whether the trends in the main observational axes, which were already apparent from previous reports, are being verified or reversed by the addition of more and more up-to-date data. The data are collected and processed by the COVID 19 Observatory, headed by the Chairman of the Economic Experts Council.

All data are freely accessible to public on the respective websites mentioned above.

The estimated incubation period of SARS-CoV-2, the time between exposure to the virus and emergence of symptoms ranges from 2 to 14 days (Lauer et al., 2020; WHO, 2020b). Thus, the time period selected for the study of the pandemic evolution in the affected areas is the first 21 days (first 3 weeks) after the disasters' occurrence not only because it covers the aforementioned incubation period but also because it is observed that SARS-CoV-2 is detected up to 21 days after onset of symptoms by PCR in infected patients (La Scola et al., 2020; García et al., 2020). However, the median incubation time is 5 days (Lauer et al., 2020; WHO, 2020b). This means that the cases recorded 5 days from disasters' occurrence could be also attributed to the disaster-induced adverse effects. In order to study the viral load and the infection rate in each affected area before the disaster occurrence, it was considered appropriate to monitor the number of daily confirmed cases in the 7 days (1 week) that preceded the disaster. In this way, any pre-existing outbreak of the novel virus in the affected areas will be perceived and the evolution of this outbreak will be possible to correlate or not with the disaster generated amid this outbreak.

Taking into account all the aforementioned data, the number of daily cases in the present study has been tracked:

- from March 14 to April 11, 2020 for the Epirus earthquake generated on March 21, 2020,
- from August 2 to August 30, 2020 for the Evia flood occurred on August 9, 2020,
- from September 10 to October 8, 2020 for the Ianos medicane that started on September 17, 2020 and
- from October 23 to November 21, 2020 for the Samos earthquake generated on October 30, 2020.

Based on the above data and the available sources of the daily COVID-19 cases, the smallest local government organization for which daily case numbers are announced and which includes the affected areas is the regional unit. Therefore, data from the above sources were used in our study for the following regional units (Fig. 13):

Fig. 7. Characteristic views of the flood effects in the Chalkida and Dirfia-Messapia municipalities in the Evia regional unit generated by the storm system Thalia. The induced floods resulted in damage to buildings including inundation of yards, basements and ground floors (a-d), damage to non-structural building elements (e) and damage to structural elements resulting partial collapse of the structure (f). Moreover, field crops were also affected by flood inundation (g-i). Damage to the road network included partial destruction of roads (j, k) and bridges (i).

- the regional units of Arta, Thesprotia, Ioannina, and Preveza of the Epirus Region, which were affected by the earthquake on March 21, 2020,
- the regional unit of Evia of the Region of Central Greece, which was affected by the flood on August 9, 2020,
- the regional units, which were affected by the Ianos medicane in mid-September 2020:
  - o the regional units of Lefkada, Cephalonia, Ithaca and Zakynthos of the Region of the Ionian Islands,
  - o the regional units of Elis, Achaia and Aetoloakarnania of the Region of Western Greece,
  - o the regional unit of Corinthia of the Peloponnese Region,
  - o the regional unit of Phthiotida of the Central Greece Region,
  - o the regional unit of Herakleion, Rethymno and Chania of the Crete Region,
  - o the regional units of Karditsa, Magnesia, Larissa and Trikala of the Thessaly Region and
- the regional unit of Samos, which was affected by the earthquake on October 30, 2020.

4.2. Results for the regional units of Epirus region affected by the March 2020 Epirus earthquake

In the comparative graph for the affected Region of Epirus, the daily confirmed COVID-19 cases for the regional units of Arta, Thesprotia, Ioannina and Preveza are presented for the week before the earthquake and for the following 3 weeks (Fig. 14). More specifically:

- For the Arta regional unit, no confirmed COVID-19 cases were reported during the week before the earthquake, while 3 cases were recorded in the following three weeks. In particular, 1 case was recorded during the first week after the event, 2 cases during the second and no cases during the third.
- For the Thesprotia regional unit, COVID-19 cases were not recorded during the pre- and post- earthquake periods.
- For the Ioannina regional unit, 2 confirmed COVID-19 cases were recorded during the week before the earthquake and 1 case during the first week after the earthquake.

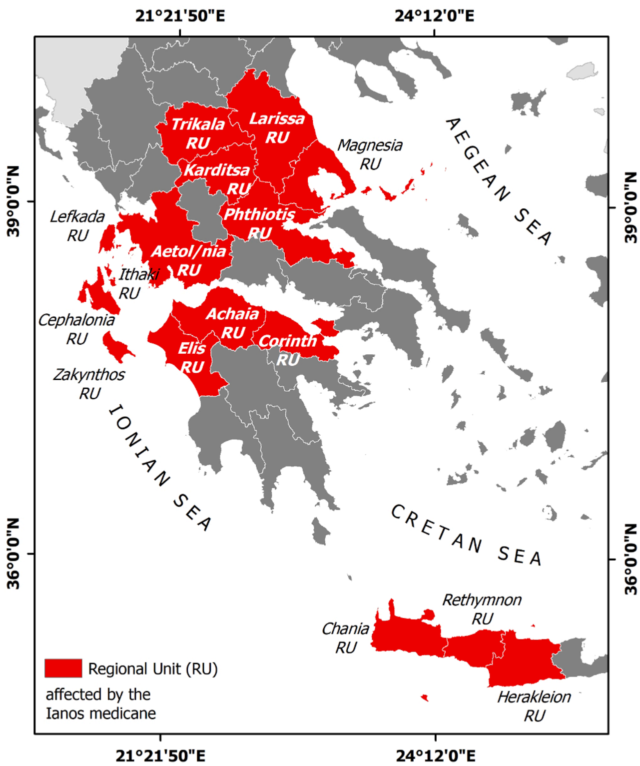

Fig. 8. The Regional Units affected by the September 17–19, 2020, Ianos medicane based on the distribution of its effects on the local population, the natural and built environment presented by Lekkas et al. (2020c).

- For the Preveza regional unit, no confirmed COVID-19 cases were recorded the week before the earthquake, while 1 case was recorded during the first week after the earthquake.

4.3. *Results for the regional unit of Central Greece Region affected by the August 2020 Evia flood*

In the graph for the affected regional unit of Evia in the Central Greece Region, the daily confirmed COVID-19 cases are presented for the week before the flood and for the following 3 weeks (Fig. 15). More specifically, 3 confirmed COVID-19 cases were reported during the pre-flood period, while 10 cases during the studied post-flood period. In particular, 5 cases were recorded during the first week after the flood, 1 case during the second and 4 cases during the third. The most cases were recorded during the first week after the flood. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 6 cases recorded during the post-flood period could be attributed to the flood-induced adverse effects.

4.4. *Results for the areas affected by the Ianos medicane in September 2020*

4.4.1. *Results for the affected regional units of the Ionian Islands Region*

In the comparative graph for the affected region of the Ionian Islands, the daily confirmed COVID-19 cases for the regional units of Lefkada, Cephalonia, Ithaki and Zakynthos are presented for the week before the Ianos medicane and for the following 3 weeks (Fig. 16a). More specifically:

- For the Lefkada regional unit, no confirmed COVID-19 cases were recorded during the pre-medicane period, while 2 cases in the post-medicane period. In particular, 1 case during the first week and 1 case during the third.
- For the Cephalonia regional unit, 8 confirmed COVID-19 cases were recorded during the pre-medicane and 2 cases in the post-medicane period. In particular, 1 case during the first week and 1 case during the third.
- For the Ithaki regional unit, no confirmed COVID-19 cases were recorded during both pre- and post- medicane periods.
- For the Zakynthos regional unit, 7 confirmed COVID-19 cases were recorded during the pre-medicane period and 6 cases in the post-medicane period. In particular, 1 case was recorded during the first week after the flood, 4 cases during the second and 1 case during the third.

4.4.2. *Results for the affected regional units of the Western Greece Region*

In the comparative graph for the affected region of Western Greece, the daily confirmed COVID-19 cases for the regional units of Elis, Achaia and Aetoloakarnania are presented for the week before the Ianos medicane and for the following 3 weeks (Fig. 16b). More specifically:

- For the Elis regional unit, 2 confirmed COVID-19 cases were recorded during the pre-medicane period and 8 cases in the post-medicane period. In particular, 2 cases were recorded during the first week after the medicane, 1 case during the second and 5 cases during the third. Taking into account the median incubation period, only 6 cases could be attributed to the adverse effects generated by the Ianos medicane.
- For the Achaia regional unit, 10 confirmed COVID-19 cases were recorded during the pre-medicane period and 111 cases in the post-medicane period. In particular, 16 cases were recorded during the first week after the medicane, 35 cases during the second and 60 cases during the third. Only 100 cases could be attributed to the medicane-induced adverse effects, taking into account the median incubation period. It should be noted that a considerable increase in the number of confirmed COVID-19 cases is observed during the three weeks following the disaster. Particularly, there is an almost 2-fold increase in the number of confirmed COVID-19 cases from the first week to the second and from the second to the third.
- For the Aetoloakarnania regional unit, 5 confirmed COVID-19 cases were recorded during the pre-medicane period and 33 cases during the post-medicane period. In particular 3 cases during the first week, 7 cases during the second and 23 cases during the third. Taking into account the median incubation period, 33 cases could be attributed to the Ianos medicane effects. There is an almost 3-fold increase in the number of confirmed COVID-19 cases from the second week to the third.

4.4.3. *Results for the affected regional unit of the Peloponnese Region*

In the graph for the affected Corinthia regional unit of the Peloponnese Region, the confirmed COVID-19 cases are presented for the week before the medicane and for the following 3 weeks (Fig. 16c). More specifically, 4 confirmed COVID-19 cases were reported during the pre-medicane period. During the post-medicane period, 49 COVID-19 cases were recorded. In particular, 9 cases were recorded during the first week after the medicane, 6 cases during the second and 34 cases during the third. The number of confirmed COVID-19 cases during the third week is almost 6-fold increased in comparison with the number of cases reported during the second week after the medicane. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 41 cases recorded during the post-medicane period could be attributed to the adverse effects of medicane and the related disaster.

4.4.4. *Results for the affected regional units of the Central Greece Region*

In the graph for the affected Phthiotis regional unit of the Central Greece Region, the confirmed COVID-19 cases are presented for the week before the medicane and for the following 3 weeks (Fig. 16d). More specifically, 10 confirmed COVID-19 cases were reported during the pre-medicane period. During the post-medicane period, 23 COVID-

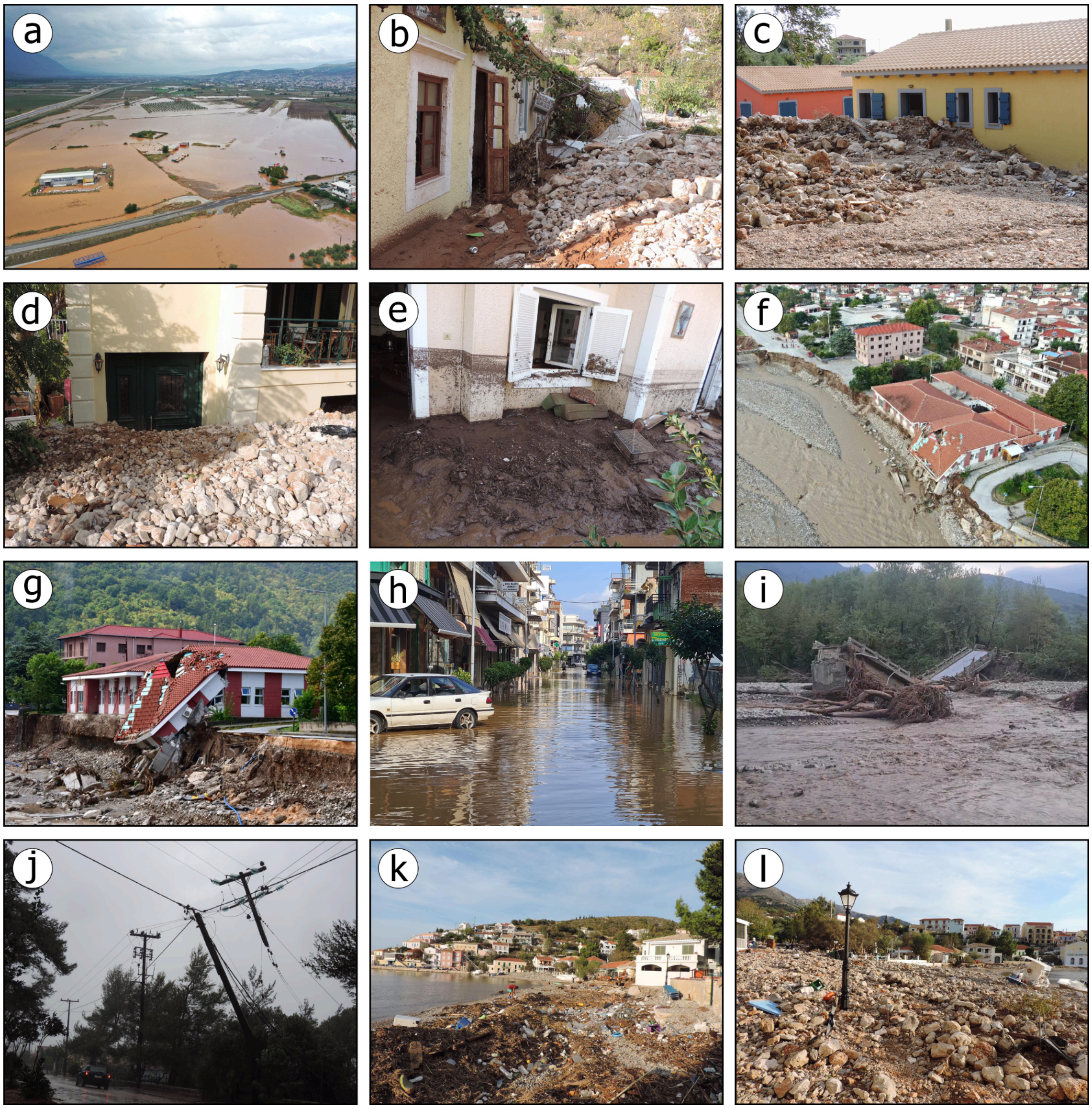

Fig. 9. Characteristic views of the effects of Ianos medicane in various areas of Greece. (a) Flooded rural areas and impact on infrastructure in the Spercheios River valley around Lamia city [Phthiotis Regional Unit (RU), Region of Central Greece]. (b, c, d) Debris filled roads in Assos town (Cephalonia RU, Ionian Islands Region) resulting in non-structural damage to buildings. (e) Impact on buildings comprised flooding of yards, basements and ground floors resulting in damage to the home furnishing. (f, g) Partial collapse of the health facilities in Mouzaki town (Karditsa regional unit, Region of Thessaly) attributed to the water level rise of the adjacent Pamisos River and to the surging waters. The impact on the road network comprised inundation of roads and total destruction of bridges [h in Karditsa City, Karditsa RU, Region of Thessaly and i in Mouzaki area in the same RU). The infrastructures including the electricity network (j) and port facilities (k, l, in Assos port, Cephalonia RU in the Region of Ionian Islands) suffered the most by the Ianos medicane.

19 cases were recorded. In particular, 10 cases were recorded during the first week after the medicane, 7 cases during the second and 6 cases during the third. Taking into account the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 19 cases recorded during the post-medicane period could be attributed to the Ianos adverse effects.

4.4.5. Results for the affected regional units of the Crete Region

In the comparative graph for the affected administrative region of Crete, the daily confirmed COVID-19 cases for the regional units of Herakleion, Chania and Rethymnon are presented for the week before the Ianos medicane and for the following 3 weeks (Fig. 16e). More specifically:

- For the Herakleion regional unit, 38 confirmed COVID-19 cases were recorded during the pre-medicane period and 36 cases in the post-medicane period. In particular, 15 cases were recorded during the first week after the medicane, 11 cases during the second and 10 cases during the third. It should be noted that the number of confirmed COVID-19 cases decreased from 38 to 15 during the first week after the medicane and remained at the same level for the following 2 weeks. Only 25 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.
- For the Chania regional unit, 3 confirmed COVID-19 cases were recorded during the pre-medicane period and 6 cases in the post-medicane period, particularly during the third week. All 6 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.
- For the Rethymnon regional unit, 13 confirmed COVID-19 cases were recorded during the pre-medicane period and 7 cases during the post-medicane period. In particular 5 cases during the first week after the medicane and 2 cases during the third. Only 3 cases could be

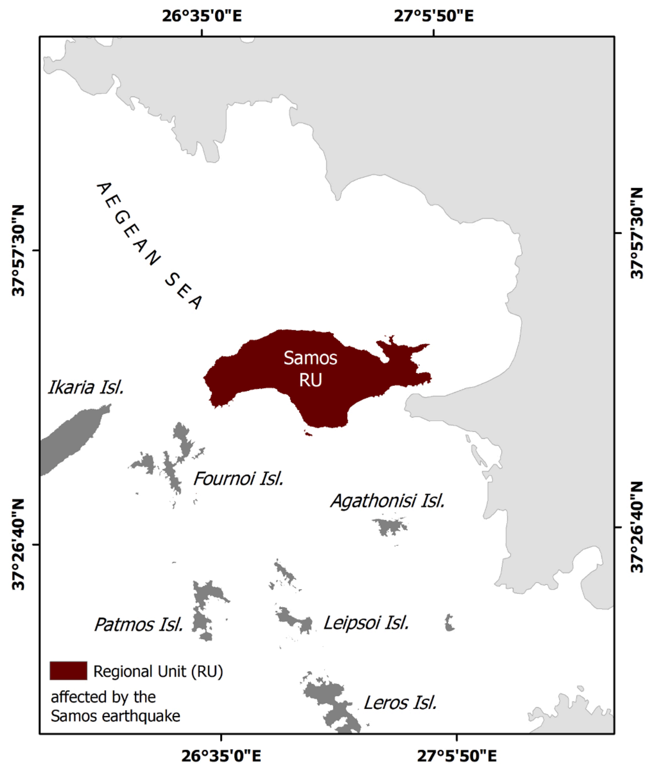

Fig. 10. The Samos Regional Unit of the North Aegean Region was most affected by the October 30, 2020, Mw = 6.9, Samos earthquake based on the distribution of earthquake-induced damage presented by Lekkas et al. (2020d).

attributed to the Ianos adverse effects taking into account the median incubation period.

4.4.6. Results for the affected regional units of the Thessaly Region

In the comparative graph for the affected administrative region of Thessaly, the daily confirmed COVID-19 cases for the regional units of Karditsa, Larissa, Magnesia and Trikala are presented for the week before the Ianos medicane and for the following 3 weeks (Fig. 16f). More specifically:

- For the Karditsa regional unit, 6 confirmed COVID-19 cases were recorded during the pre-medicane period and 60 cases in the post-medicane period. In particular, 7 cases were recorded during the first week after the medicane, 24 cases during the second and 29 cases during the third. Only 56 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.
- For the Larissa regional unit, 19 confirmed COVID-19 cases were recorded during the pre-medicane period and 99 cases in the post-medicane period. In particular, 41 cases were recorded during the first week after the medicane, 26 cases during the second and 32 cases during the third. Only 69 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.
- For the Magnesia regional unit, 2 confirmed COVID-19 cases were recorded during the pre-medicane and 23 cases during the post-medicane period. In particular, 5 cases during the first week after the medicane, 4 cases during the second week and 14 cases during the third. Only 19 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.
- For the Trikala regional unit of, 23 confirmed COVID-19 cases were recorded during the pre-medicane period and 167 cases during the post-medicane period. In particular 59 cases during the first week after the flood, 57 cases during the second week and 51 cases during the third. Only 124 cases could be attributed to the Ianos adverse effects taking into account the median incubation period.

4.5. Results for the regional unit of Samos affected by the October 2020 earthquake

In the graph for the affected Samos regional unit of the North Aegean Region, the confirmed COVID-19 cases are presented for the week before the earthquake and for the following 3 weeks (Fig. 17). More specifically, 7 confirmed COVID-19 cases were reported during the pre-earthquake period. During the post-earthquake period, 12 COVID-19 cases were recorded and could all be attributed to the adverse effects

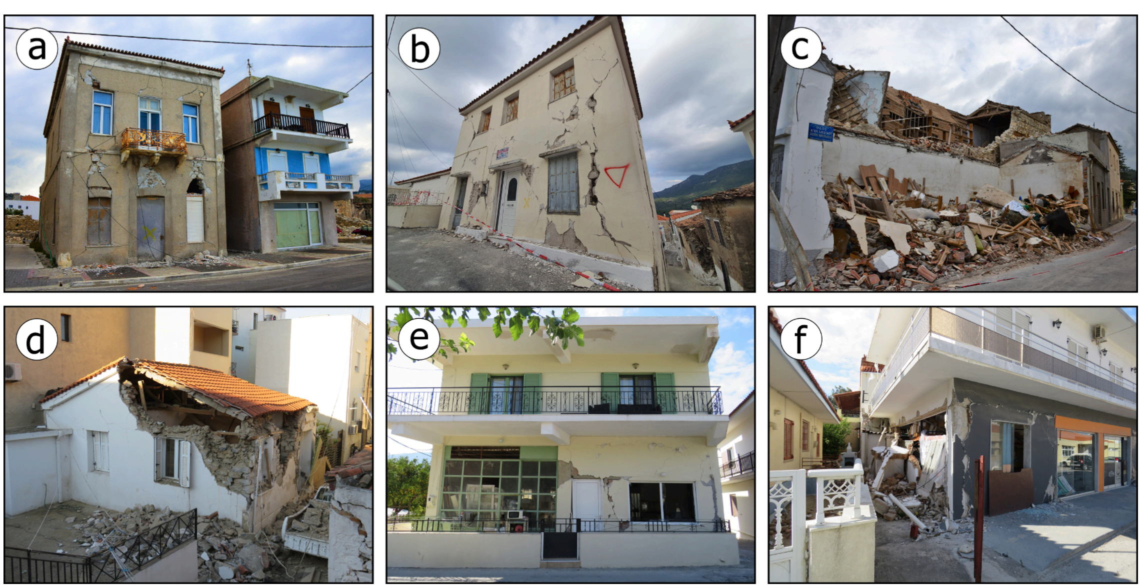

Fig. 11. Damage induced by the October 30, 2020, Mw = 6.9, Samos earthquake to the building stock of Samos island. The old buildings with load-bearing masonry walls (a-d) suffered the most by the earthquake. The observed damage varied from extensive cracks of the masonry walls (a) to partial or total collapse of the structures (b, c, d). The recent buildings with reinforced-concrete frame and infill walls, constructed according to seismic building codes applied after 1985, remained almost intact. (e, f) Exceptions to this rule, these reinforced-concrete buildings suffered extensive damage to their non-structural elements, in particular detachment of the infill walls from the surrounding reinforced-concrete frame and partial collapse of the brick infill walls.

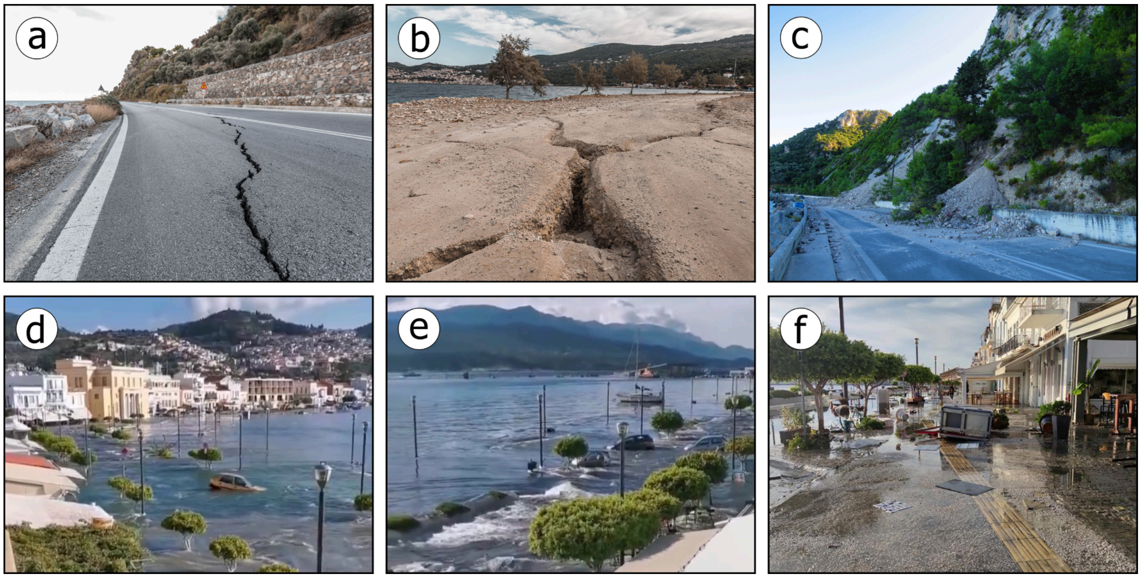

Fig. 12. Environmental effects triggered by the October 30, 2020, Mw = 6.9, Samos earthquake in the homonymous island. They comprised ground cracks resulted from gravitational movements (a) and liquefaction phenomena (b) as well as slope failures (c) and tsunami (d-f). These effects resulted in damage to the road network (a-c) and to infrastructures and properties along the northern coastal area (d-f).

Table 1
Official sources, authorities and availability period for the daily reported laboratory-confirmed COVID-19 cases in Greece.

Source	Authorities	Period on the source availability
Daily reports of COVID-19 epidemiological surveillance	HNPHO	From March 20, 2020 (with data from February 26, 2020) to present
Press releases	HNPHO	From February 28, 2020 to present
Announcements	HNPHO	From March 23, 2020 to present
Progress reports of the COVID-19 Observatory	Greek Government	From May 29, 2020 to present

generated by this earthquake. In particular, 2 cases were recorded during the first week after the earthquake, 6 cases during the second and 4 cases during the third.

4.6. Comparison of the evolution of confirmed COVID-19 cases per week for the studied natural hazards and the related disasters

In the comparative graph of the evolution of confirmed COVID-19 cases recorded for all natural hazards and the related disasters (Fig. 18a), the daily confirmed COVID-19 cases per week recorded in all affected regions of Greece are presented for the week before the respective disaster and for the following 3 weeks. More specifically, as regards:

- the Epirus earthquake, 2 confirmed COVID-19 cases were reported during the week before the earthquake, 3 cases were recorded during the first week after the event, 2 cases during the second and no cases during the third. This data refers to the Arta, Thesprotia, Ioannina and Preveza regional units of Epirus Region.
- the Evia flood, 3 confirmed COVID-19 cases were reported during the week before the flood, 5 cases were recorded during the first week after the event, 1 case during the second and 4 cases during the third. This data refers to Evia regional unit of Central Greece Region.
- the Ianos medicane, 150 confirmed COVID-19 cases were reported during the week before the medicane, 175 cases were recorded during the first week after the event, 182 cases during the second and 275 cases during the third. This data refers to 16 regional units of Greece affected by the Ianos medicane.
- the Samos earthquake, 7 confirmed COVID-19 cases were reported during the week before the earthquake, 2 cases were recorded during the first week after the event, 6 cases during the second and 4 cases during the third. This data refers to the Samos regional unit of the North Aegean Region.

The evolution of SARS-CoV 2 spread is characterized by an increase in the daily confirmed COVID-19 cases following the Ianos medicane, especially from the second to the third week after the medicane occurrence (Fig. 18b). On the contrary no considerable increase in the number of COVID-19 cases was detected in the respective evolution after the Epirus earthquake, the Evia flood and the Samos earthquake (Fig. 18b).

As regards the Ionian Islands Region, 15 cases were observed in the pre-medicane period and 10 cases during the post-medicane period. In particular, 3 cases during the first week after the medicane, 4 cases during the second and 3 cases during the third. Most cases were recorded during the pre-medicane period at least in the Cephalonia and Zakynthos regional units. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 8 cases (2 cases in the Lefkada regional unit, 1 in the Cephalonia regional unit and 5 in the Zakynthos regional unit) recorded during the post-medicane period could be attributed to the adverse effects of the Ianos medicane.

In the affected regional units of the Western Greece Region, 17 cases were observed in the pre-medicane period and 152 cases during the post-medicane period. In particular, 21 cases were reported during the first week after the medicane, 43 cases during the second and 88 cases during the third. Most cases were recorded during the post-medicane period especially during the second and third week after the medicane occurrence. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 139 cases recorded during the post-medicane period could be attributed to Ianos medicane.

In the affected Corinthia regional unit of the Peloponnese Region, 4 confirmed COVID-19 cases were reported during the pre-medicane period. During the post-medicane period, 9 cases were recorded during the first week after the medicane, 6 cases during the second and 34 cases during the third. Due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 41 cases recorded during the post-medicane period could be attributed to the adverse effects of

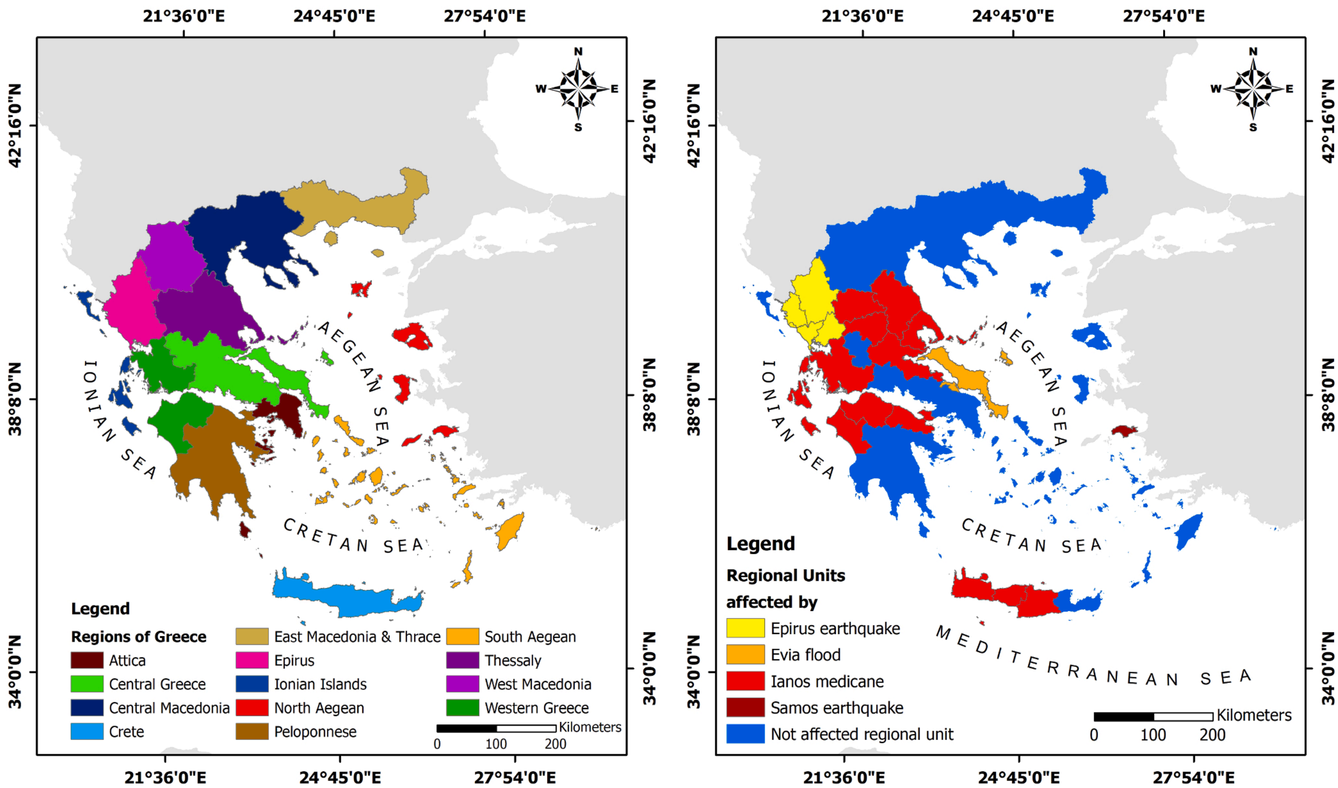

Fig. 13. (Left) The 13 regions of Greece. (Right) The Regional Units affected by the studied 2020 disasters induced by the geological and hydrometeorological hazards in Greece. The March 21 Epirus earthquake affected the entire Region of Epirus (yellow units). The August 9 Evia flood affected the eastern part of the Central Greece Region (orange units). The Ianos medicane impacted several regional units of the central, central-western and southern part of Greece (red units) from 17 to 19 September. The October 30 Samos earthquake affected the southern part of the North Aegean Region and especially the Samos Regional Unit (dark red unit). Green units are the regional units unaffected by the aforementioned disasters.

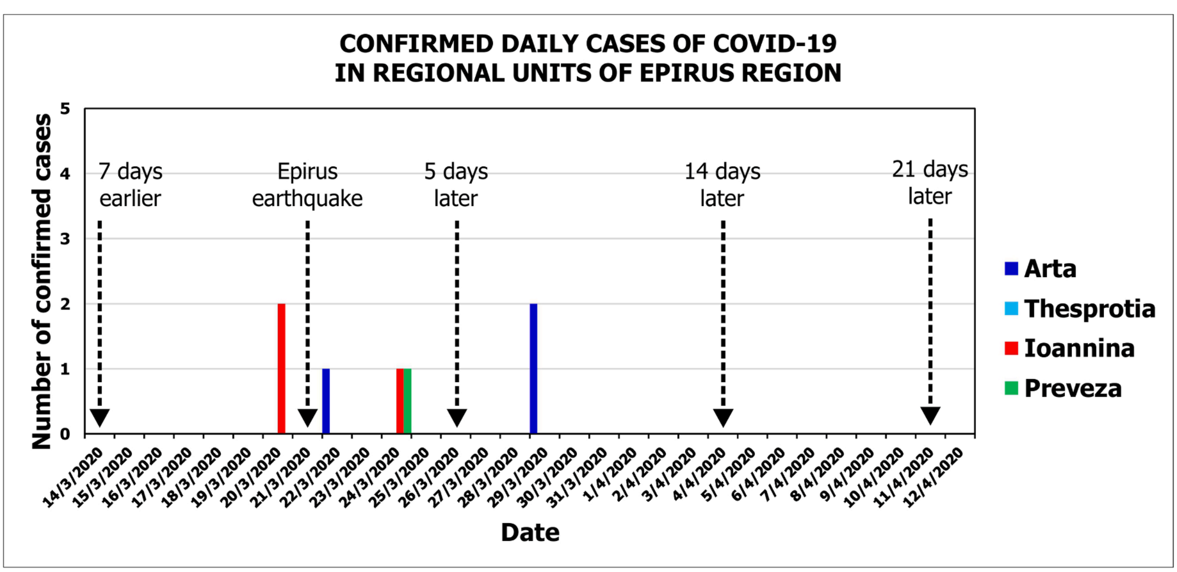

Fig. 14. Comparative graph of the daily confirmed COVID-19 cases recorded in Arta, Thesprotia, Ioannina and Preveza regional units of Epirus Region, which were affected by the earthquake that occurred on March 21, 2020. Recording of daily confirmed COVID-19 cases was performed for the week (7 days) before the earthquake and for the following three weeks (21 days) after the earthquake occurrence. The vertical axis illustrates the number of confirmed COVID-19 cases, represented by the colored bars (blue for Arta, light blue for Thesprotia, red for Ioannina and green for Preveza regional units). The horizontal axis represents the days in the period from March 14 to April 12, 2020.

the medicane.

In the affected Phthiotis regional unit of the Central Greece Region, 10 confirmed COVID-19 cases were reported during the pre-medicane period. During the post-medicane period, 10 cases were recorded during the first week after the medicane, 7 cases during the second and 6 cases during the third. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 19 cases recorded during the post-medicane period could be attributed to the

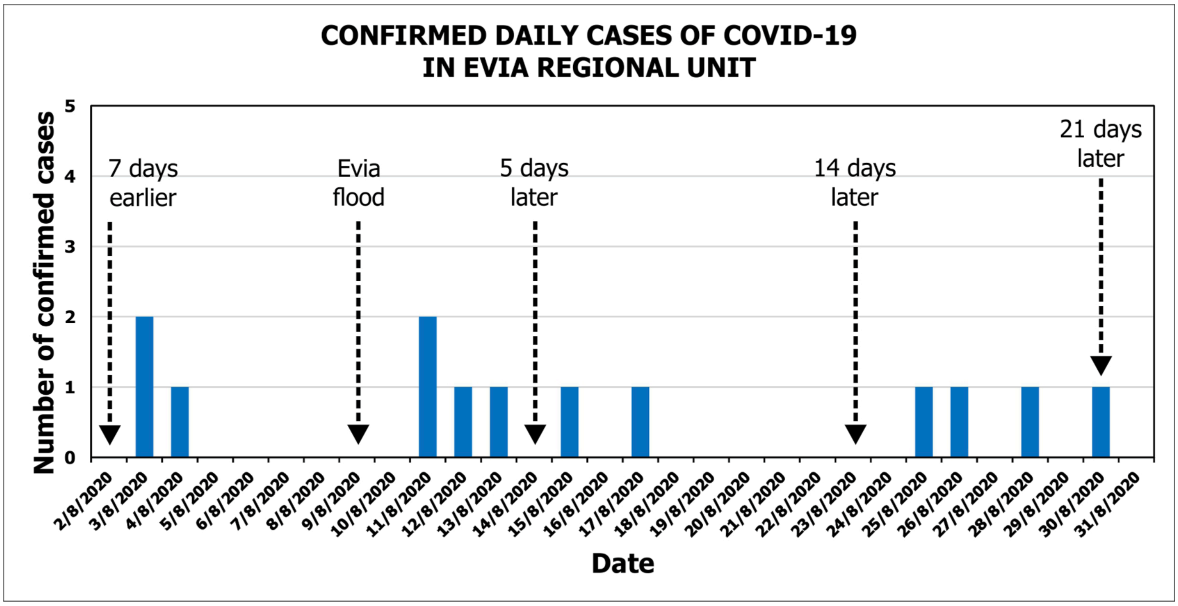

Fig. 15. Comparative graph of the daily confirmed COVID-19 cases in Evia regional unit of Central Greece Region, which was affected by floods that occurred on August 9, 2020. Recording of daily confirmed COVID-19 cases was performed for the week (7 days) before the flood and for the following three weeks (21 days) after the flood occurrence. The vertical axes show the number of daily confirmed COVID-19 cases, represented by the blue bars, while the horizontal axis represents the days from August 2 to August 31, 2020.

Ianos adverse effects.

As regards the affected regional units of the Crete Region, 54 cases were observed in the pre-medicane period and 49 cases during the post-medicane period. In particular, 20 cases were reported during the first week after the medicane, 11 cases during the second and 18 cases during the third. Most cases were recorded during the pre-medicane period especially in Herakleion and Rethymnon regional units. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 34 cases recorded during the post-medicane period could be attributed to the Ianos adverse effects.

In the affected regional units of the Thessaly Region, 50 cases were observed in the pre-medicane period and 349 cases during the post-medicane period. In particular, 112 cases were reported during the first week after the medicane, 111 cases during the second and 126 cases during the third. However, due to the aforementioned median incubation period (Lauer et al., 2020; WHO, 2020b), only 268 cases recorded during the post-medicane period could be attributed to the adverse effects generated by this medicane.

5. Factors with potential impact and control on the pandemic evolution in the disaster affected areas

Earthquakes are among the most impressive geological processes with destructive effects on humans, nature and infrastructures. Within a few seconds and without warning, they set off a chain of effects, which lead to destruction of buildings and facilities that significantly affects public health resulting in casualties and injuries, effects on mental health as well as non-infectious and infectious diseases emerging during the post-earthquake period (Mavroulis et al., 2017a; Mavrouli et al., 2017a).

The risk factors leading not only to disease emergence but also to disease incidence increase after earthquakes and their effects comprise (Mavroulis et al., 2017a; Mavrouli et al., 2017a): (a) damage to infrastructures and health care systems that remained unfixed for a long time in the critical post-earthquake period, (b) aggravating weather conditions comprising immense and dramatic temperature changes, (c) prolonged physical exposure to large dust clouds generated by landslides and aspiration of contaminated tsunami water, (d) unfavorable conditions in overcrowded emergency shelters, (e) increased exposure to disease vectors population, (f) the weak immune system of elders, chronically ill individuals and young children, (g) large percentage of illiteracy and population living below the national poverty line (insufficient personal hygiene), (h) poor education and training on disease prevention, (i) sanitary deficiencies, (j) lack of screening for blood-borne diseases before emergency surgeries, blood transfusions and intravascular drug use, (k) use of unsterilized medical equipment, (l) insufficient or low vaccination coverage and (m) close contact with the affected local population.

During the evolving COVID-19 pandemic that requires social distancing and personal hygiene practices and measures for preventing transmission, homes act like fortresses against the spread of the virus. However, after the generation of a destructive earthquake, the practices of social distancing are difficult to apply during the first hours and days of the emergency response phase and even during the recovery phase, as everybody physically comes together and converges on a group, in a community. In Epirus and Samos, even anxiety forced residents to rush outside, to leave temporarily their homes, and to seek for safety outdoors, away from the adverse effects of an earthquake. Across the affected urban and rural residential areas all residents did the same. Moreover, many buildings were severely affected by the earthquake and characterized as temporarily unusable until repaired or permanently unusable. Thus, the majority of residents has no other option but to leave their houses and gather initially in open air spaces and then in emergency shelters, where overcrowding and unhygienic conditions may occur, while the practices of social distancing are either difficult to be applied or not applied at all.

Moreover, many earthquake-affected residents involved in search and rescue operations along with rescue teams from different areas with different COVID-19 prevalence and incidence rates. Many responders involved in various immediate actions during the emergency response phase including post-earthquake building and infrastructure inspections, damage assessment and hazard mitigation among others (Lekkas et al., 2020e), actions requiring close contact with the local population (Fig. 19a-19f).

Many volunteers participated in several important activities comprising distribution of humanitarian aid including protective

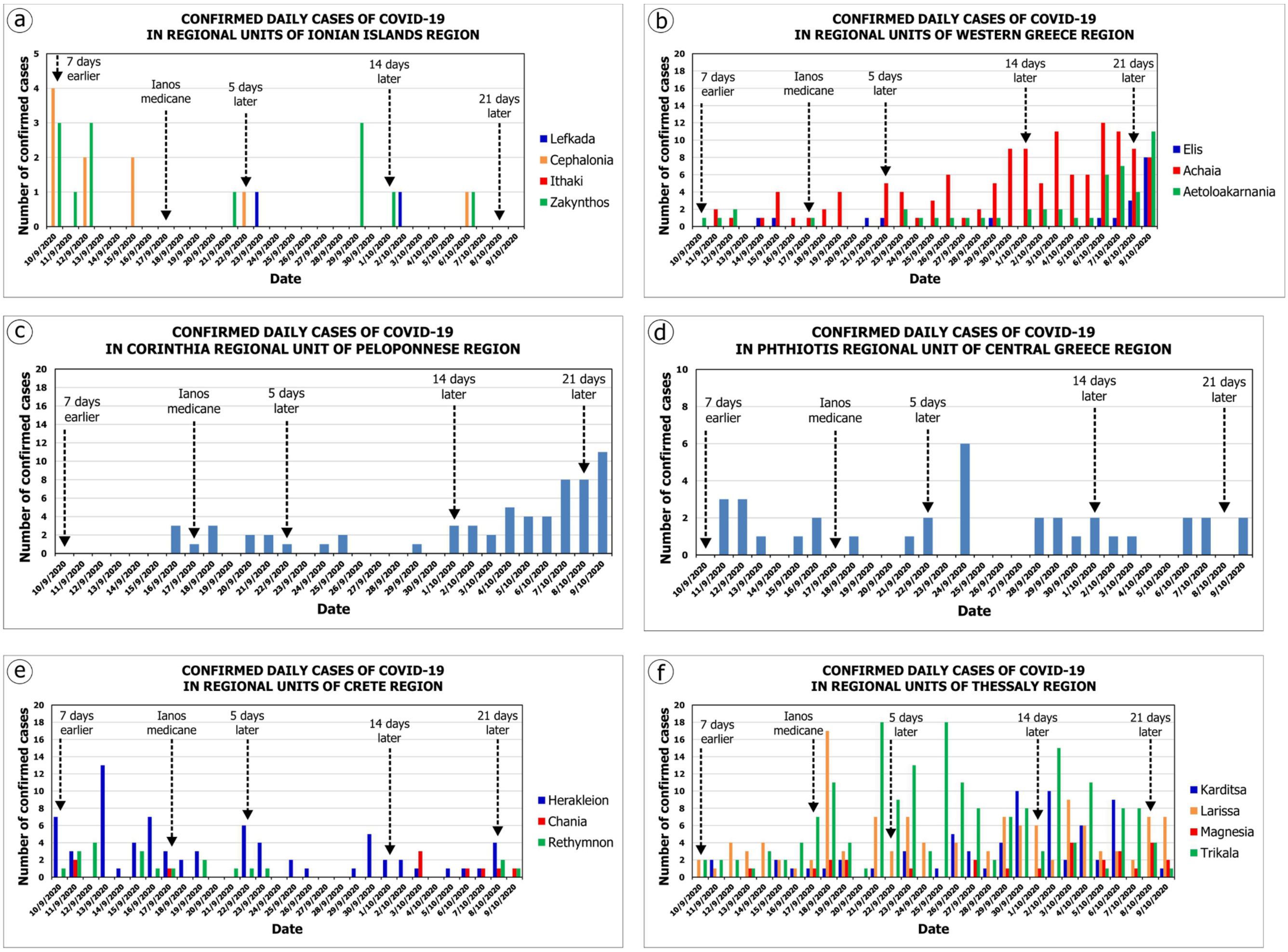

Fig. 16. Comparative graphs of the daily confirmed COVID-19 cases in the regional units affected by the Ianos medicane and its adverse effects in mid-September 2020. Recording of daily confirmed COVID-19 cases was performed for the week (7 days) before the first impact of the Ianos medicane and for the following three weeks (21 days) after the medicane occurrence. The vertical axis shows the number of daily confirmed COVID-19 cases, represented by different colored bars where necessary, while the horizontal axes represent the days from September 10 to October 9, 2020. Graphs for: (a) Lefkada, Cephalonia, Ithaki and Zakynthos regional units of the Ionian Islands Region, (b) Elis, Achaia and Aetoloakarnania regional units of the Western Greece Region, (c) Corinthia regional unit of Peloponnese Region, (d) Phthiotis regional unit of Central Greece Region, (e) Heraklion, Chania and Rethymnon regional units of Crete Region and (f) Karditsa, Larissa, Magnesia and Trikala regional units of Thessaly Region.

equipment for the homeless, long-term food and personal hygiene items, participation in setting up temporary emergency shelters for the affected population as well as provision of psychological support and counseling to residents with significant psychological stress attributed to the earthquake (Lekkas et al., 2020e) (Fig. 19g-19i). Moreover, they daily visited hotels and tourist facilities for homeless and affected people in order to assess health needs, to provide pharmaceutical / medical supplies and to train staff and guests on measures for the prevention of the spread of the novel SARS-CoV-2 virus (Lekkas et al., 2020e).

Amid the pandemic, these life-saving and relief activities pose extra risk for public health. All these actions require physical contact and communication with the affected local population (Fig. 19**a-19f**). Moreover, they create overcrowding conditions and give rise to difficulties in compliance with physical distancing measures. Failure to take the necessary measures against the spread of the virus in these emergencies can create clusters of the virus in the affected areas resulting in increase of the daily confirmed COVID-19 cases and fatalities and making the road to recovery longer and more stressful.

However, as the above study on the post-earthquake evolution of the daily reported COVID-19 cases in the affected areas showed, no increasing trend was observed and therefore no change in the evolution of the pandemic in the earthquake-affected areas during the emergency phase. The measures taken during the immediate response phase, which helped to limit the transmission of the novel virus, comprised the following:

- The Operations Coordination Centers were set up outdoors and the coordination meetings of the involved authorities took place outdoors. This action provided not only protection during the aftershock period from subsequent large aftershocks, but also ease of maintaining social distancing between meeting participants. In these centers, all personal protection measures were available to the earthquake-affected residents as well as to the staff of the involved services and authorities, including masks, hand sanitizers and disposable gloves. As for the basic emergency supplies, bottled water, packaged food and disposable gloves were available when needed.
- The implementation of measures of personal protection and protection of the local population was mandatory for the emergency staff, which participated in the management of the disaster induced by the earthquake in the affected areas. The majority of the involved staff came from other areas with different infection rates, degrees of public health emergency and relative risks for the impact of COVID-19. The main measures included mandatory use of masks indoors and

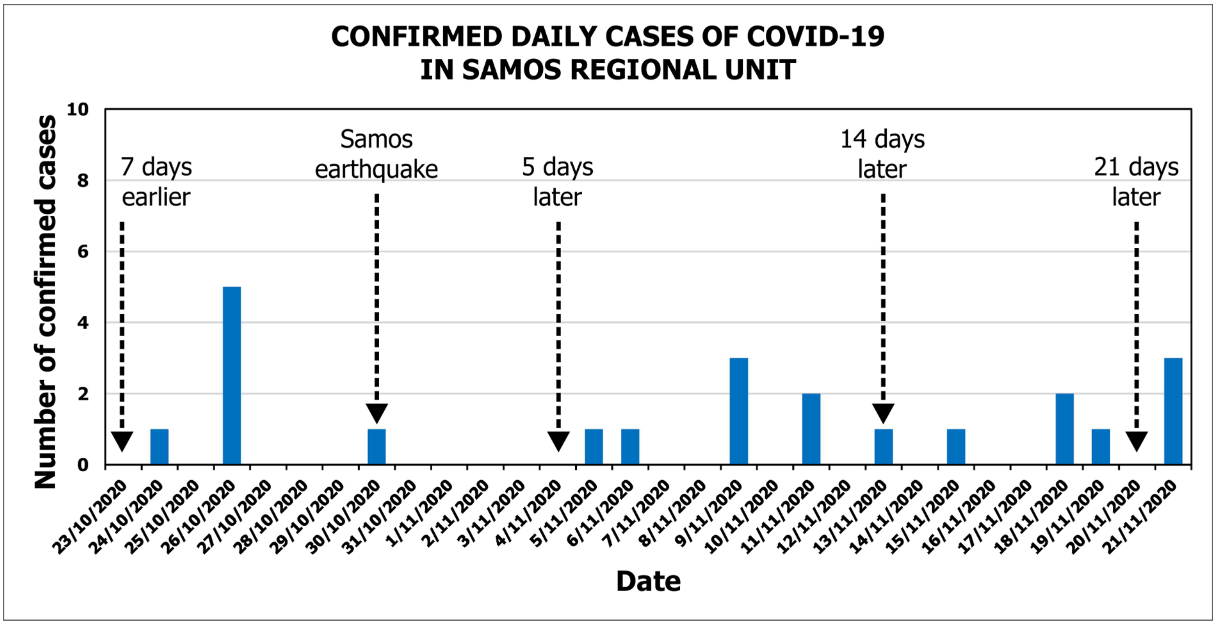

Fig. 17. Comparative graph of the daily confirmed COVID-19 cases in Samos regional unit of North Aegean Region, which was affected by a destructive earthquake generated on October 30, 2020. Recording of daily confirmed COVID-19 cases was performed for the week (7 days) before the earthquake and for the following three weeks (21 days) after the earthquake occurrence. The vertical axis shows the number of the daily confirmed COVID-19 cases, represented by the blue bars, while the horizontal axis represents the days from October 23 to November 21, 2020.

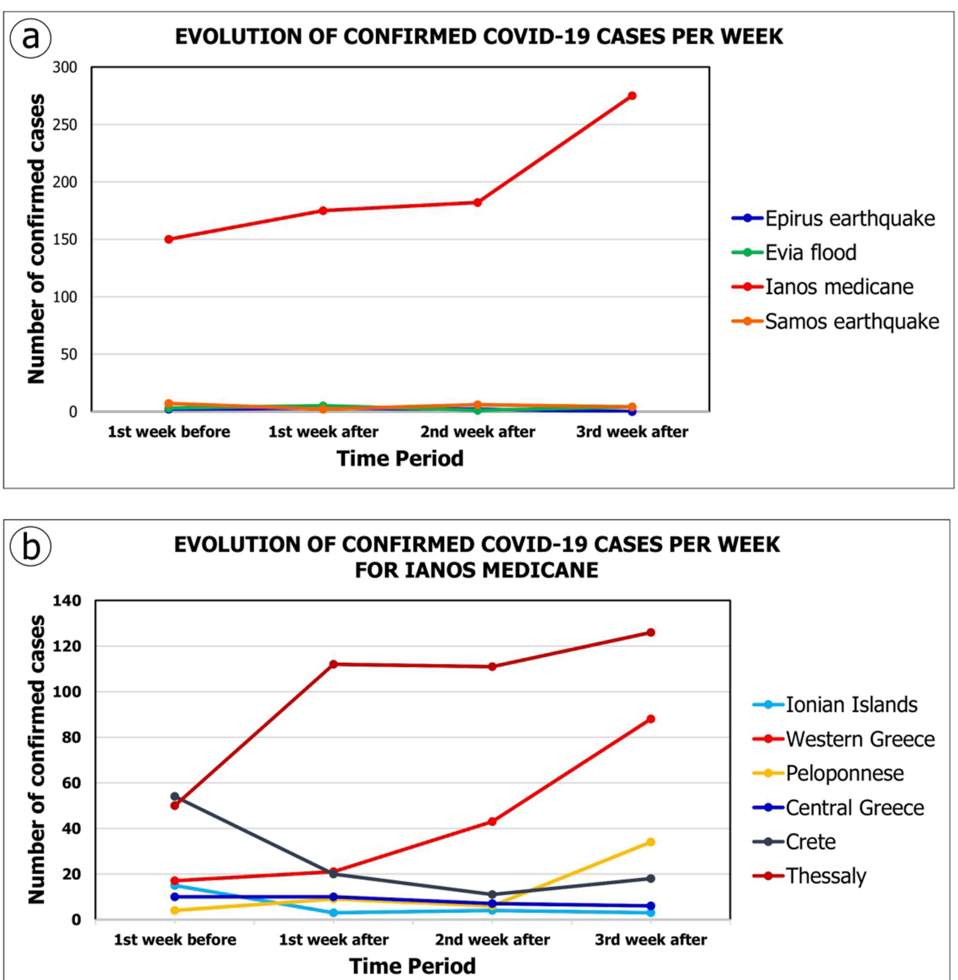

Fig. 18. (a) Comparative graph of the evolution of daily confirmed COVID-19 cases per week recorded for the first week before the disaster and for the following three weeks after the disasters' occurrence. The vertical axis illustrates the number of confirmed COVID-19 cases and the horizontal one represents the time period of four studied weeks. The evolution of confirmed COVID-19 cases per week for the different disasters is represented by the colored lines (blue for the Epirus earthquake, green for the Evia flood, red for the Ianos medicane and orange for the Samos earthquake). (b) Comparative graph of the evolution of daily confirmed COVID-19 cases per week recorded for the first week before and for the following three weeks after the Ianos medicane. The vertical axis illustrates the number of confirmed COVID-19 cases and the horizontal one represents the time period of four studied weeks. The evolution of confirmed COVID-19 cases per week for the different affected regions is represented by the colored lines (light blue for the Ionian Islands Region, red for the Western Greece Region, yellow for the Peloponnese Region, blue for the Central Greece Region, gray for the Crete Region, dark red for the Thessaly Region).

Fig. 19. Activities during the emergency response phase after the October 30, 2020, Mw = 6.9, Samos (Eastern Aegean Sea, Greece) earthquake. During this phase, practices and measures of physical distancing are either difficult to be applied or not applied at all due to the overcrowding conditions in several sites. Thus, wearing masks is mandatory for all involved in the immediate actions of the emergency response. Overcrowding conditions (a-f) in open air spaces for recording earthquake- and tsunami- induced damage to properties and during disaster management meetings. (c, d, e) Many responders participate in buildings inspection of damage requiring direct physical contact and communication with the affected local population. (f, g, h, i) The vast majority of responders from public authorities, services, agencies and volunteer teams involved must apply all necessary measures against the spread of the virus in these emergencies. These measures mainly comprise (f, g) wearing masks and (h, i) keep the necessary distance from the others during post-earthquake evacuation and during educational activities on earthquake prevention measures.

outdoors and frequent use of hand sanitizers, keeping distance from the local population and disinfection of equipment and tools used by many people. These measures were strictly used especially in actions that required closer contact with the local population, such as search and rescue operations, assessment of building damage as well as distribution of basic emergency supplies.

- The immediate housing of homeless residents in unaffected hotels and tourist facilities as well as in undamaged houses of close relatives or friends was the best practice for maintaining social distancing and avoiding overcrowding conditions. This measure helped to decongest the emergency shelters that had been set up outdoors in order to host affected residents.
- Psychosocial support actions especially in Samos were undertaken by the psychological services of the affected municipalities and by voluntary organizations. The psychological support and counseling took place after making an appointment in specially designed spaces in compliance with measures for the virus transmission prevention. In each meeting, wearing mask and keeping the appropriate distance was mandatory both indoors and outdoors. Moreover, remote telecommunication was also available via teleconference or videoconference in order to apply social distancing practices and to avoid overcrowding conditions.
- Personal protective equipment was distributed to staff involved in emergency response actions, more specifically in outdoor offices set up for recording the earthquake-induced damage to properties. In these centers, maintaining social distancing was difficult, especially during the first hours and days of the emergency, when affected residents gathered to report damage to properties.
- Personal protective equipment comprising masks, disposable gloves, hand sanitizers and disinfectants were available for distribution to the affected residents in the emergency shelters.
- Educational and training activities for teachers were also conducted outdoors. Space was well organized and distances were easily maintained between trainers and trainees. The training included preventive measures both against possible large aftershocks and virus transmission.

Moreover, both earthquake-affected areas of Epirus and Samos were characterized by low viral load during the studied pre-disaster period as it is concluded for the above analysis. Thus, there was no emerging or evolving outbreak of SARS-CoV-2 transmission in the earthquake-affected areas and sufficient cases to trigger an outbreak during the post-disaster period. In the case of the October earthquake, this reason is further solidified by the fact that the second strict nationwide lockdown was not installed in the affected regional unit of Samos. There was no ban on all non-essential movements and travelling throughout the affected island and the activities of the retail sector were continued.

Furthermore, both earthquakes did not resulted in large numbers of displaced people. Large evacuations were not ordered shortly after the earthquake without prior organization adapted to the newly formed conditions of the pandemic.

Taking into account the results from the study of the daily reported COVID-19 cases, it is concluded that the pre-disaster low viral load in the earthquake-affected areas along with applied measures during the emergency response phase contribute to keeping the viral load and transmission rate at low levels during the selected post-earthquake observation period.

As regards the hydrological and meteorological hazards, the detected risk factors for disease emergence and disease incidence increase from floods and related disasters comprise: (a) poor economic status and living in flood prone areas, (b) destruction of infrastructures, disruption of public utilities and interruption of basic public health services, (c) direct physical exposure to sewage-polluted flood water, (d) lack of adequate potable water and water-supply from contaminated ponds and tube wells, (e) aggravation of environmental conditions comprising rapid cooling of the environment and heightened humidity, (f) population displacement resulting in densely populated and overcrowded regions, (g) unfavorable living conditions in emergency shelters (h) improper and inadequate sanitation or no access to clean water and sanitation, (i) proliferation and abrupt increase of vector and rodent populations after flooding, (j) contamination of water, damp soil, mud or vegetation caused by rodent urine, dead animals and overflow of latrines (Mavroulis et al., 2017b; Mavrouli et al., 2017b).

During or after the occurrence of the above disasters related to hydrometeorological hazards (flood and medicane), various activities took place, which could adversely affect the evolution of the pandemic in the affected areas and contribute to the increase of the daily COVID-19 cases and therefore the related ICU patients and fatalities (Fig. 20).

Even curiosity about the type and the extent of the impact of these hydrometeorological hazards and anxiety about the evolution and effects of the phenomena could lead the affected residents away from their homes, which, as mentioned before, act as a safe fortress against the virus transmission. These actions caused overcrowding conditions in severely affected areas, where residents, impressed by the intensity of the phenomena, gathered ignoring the protection measures and especially social distancing (Fig. 20a-20c). Taking into account the fact that during the occurrence of the Evia flood in early August and the Ianos medicane in mid-September 2020, wearing masks outdoors was recommended and not mandatory, these actions are characterized by high potential for virus transmission.

Typical examples of actions during the immediate response phase shortly after the floods and the medicane, which could contribute to the increase of the daily COVID-19 cases, are the search and rescue operations in remote and isolated areas, neighborhoods and buildings. Many rescuers and volunteers rush to help during the first hours of the emergency response from different areas with different viral loads and infection rates and they were inevitably in close contact with the affected residents (Fig. 20d, 20e). In addition, many locals with the contribution of volunteers from other areas participated in removing debris, cleaning the affected areas and restoring the affected networks and infrastructure (Fig. 20f). These actions could adversely affect measures and practices applied for preventing virus transmission and create clusters attributed to close contact with someone infected but also to contact with contaminated surfaces or flood waters that have a high viral load, especially in urban areas, which have been flooded along with heavily overflowed sewage (Fig. 20). The exposure to overflowed sewage and non-dispersed human excreta during a local urban flooding event have high potential for posing renewed risks comprising sewage-associated transmission in affected areas and communities (Han and He, 2021).

Moreover, the destruction of health facilities and disruption of basic public health services, improper and inadequate sanitation or no access to clean water from the above disasters induced by hydrometeorological hazards could contribute negatively to the evolution of the pandemic in the affected areas. Characteristic example of such destruction and disruption occurred in Mouzaki area located in the Regional Unit of Karditsa (Region of Thessaly) after the Ianos medicane. The Mouzaki Health Center partially collapsed after water level rise of the adjacent Pamisos River and the surging waters that washed away part of its walls. Additionally, the General Hospital of Karditsa City (Regional Unit of Karditsa, Region of Thessaly), which was extensively flooded after the extreme rainfall, was unable to provide effective medical assistance. Moreover, the health services provided by the National Center for Emergency Assistance in the affected Region of Thessaly were disrupted due to damage induced along the road network. In evolving conditions of rapid spread of the pandemic and the aggravated living conditions of

Fig. 20. Activities during the emergency response phase after the Evia flood on August 9, 2020. During this phase, practices and measures of physical distancing are either difficult to be applied or not applied at all. (a, b, c) Harsh conditions were developed in several sites severely affected by the disaster induced by the flood. In these sites, overcrowding was observed and attributed to stress and curiosity resulted from the severity of the generated hydrometeorological phenomena. (d) Evacuation of flood-affected areas with the assistance of rescuers. (e) Self-evacuation without applying protective measures. (f) Immediate actions after the flood occurrence included removing accumulated debris from roads and buildings. Residents, responders and volunteers involved should to avoid overcrowding conditions and apply protective measures including wearing masks, hand sanitizing and social distancing.

the affected population, the heavily affected health care facilities are not able to cope adequately and safely in identifying and responding to actual or suspected incidents of COVID-19. Moreover, the aforementioned effects constitute ideal factors for new clusters and extended spreading of this novel virus.

In the case of the Evia flood, no increase in COVID-19 cases was observed during the post-flood period, a fact that can be attributed to the following factors:

- The flood occurred at the beginning of the second wave of the pandemic in Greece. At that time, the viral load and the infection rate in the flood-affected area was low.
- The flood occurred during the summer season, when the temperature and humidity are high. High temperature and high humidity reduce the virus transmission (Wang et al., 2020; Haque and Rahman, 2020).
- The synergy of the high temperature, the high humidity and the low viral load in the flood-affected area resulted in no emerging or evolving outbreak of SARS-CoV-2 infection occurred during the pre- and the post- flood periods.
- The flood did not result in large evacuation of flood-affected areas and hosting many displaced people in emergency shelters. During cleaning flood debris from their houses, the residents cleaned their homes and applied social distancing.

As regards the Ianos medicane, its impact to the evolution of the pandemic in the affected regional units and regions was considerable. The numbers of COVID-19 cases were increased during the post-medicane period in the affected Regions of Thessaly, Western Greece and Peloponnese, while in the affected Regions of the Ionian Islands and Crete the respective numbers were decreased. The only region characterized by stability of the reported cases during the pre- and the post-medicane period is the affected Region of Central Greece.

The impact of the Ianos medicane and its effects on the evolution of the pandemic in the affected regional units is strongly related to the preexisting viral load and the intensity of the effects. More specifically, in areas with high preexisting viral load and high intensity of the medicane-induced effects (Region of Thessaly), the daily confirmed COVID-19 cases presented increasing trend during the post-medicane period. Lower but existing viral load was recorded in the Regions of Western Greece and Peloponnese during the pre-medicane period. This viral load along with the high intensity of the medicane-induced effects resulted in increasing trend during the post-medicane period in the Western Greece and Peloponnese Regions.

Decreasing trend during the post-medicane period was reported in the island Regions of the Ionian Islands and Crete. This trend could be attributed to the weakened action of the medicane over Crete and the subsequent lower intensity in this island region. Moreover, in the case of the Region of the Ionian Islands, the decreasing trend could be attributed to the different type of the induced effects comprising mainly scree and debris flows and slope failures and secondarily of extensive flooding of large urban and rural areas. The population density and the spatial distribution of the residential urban and rural areas in the islands along with the difficulties in visiting the island areas due to state restrictions for virus transmission prevention during the pre- and post- medicane period had also a positive effect in the aforementioned decreasing trend.

In addition to this increasing and decreasing trend, there was stability in the evolution of the pandemic in the region of Central Greece during the pre- and the post- medicane period. This effect could be attributed to the low viral load during the pre-disaster phase related to an effective management of the pandemic in this affected region.

6. Conclusions

This paper comprises the study on the laboratory-confirmed daily recorded COVID-19 cases in areas affected by disasters induced by natural hazards, in order to identify possible changes in their evolution and to investigate the possible causes of these changes and the potential impact of disasters.

Two geological and two hydrometeorological events were included as the most important in terms of human losses and damage to the built environment and as the most destructive with high potential to impact COVID-19 pandemic in the affected areas. Their timing gave the opportunity to study their effects in virus transmission in different phases of the pandemic. More specifically, the Epirus earthquake was generated during the first wave of the pandemic in Greece, on March 21, 2020, that is one month after the first laboratory-confirmed COVID-19 case and 2 days before the installation of the first strict nationwide lockdown in the country. The total confirmed COVID-19 cases in Greece on the occurrence day of the Epirus earthquake were only 530 and the total fatalities were 13 (HNPHO, 2020). The Evia flood was generated at the beginning of the second phase of the pandemic in Greece, on early August. The total confirmed COVID-19 cases in Greece on August 9 was 5692 and the related fatalities were 213 (HNPHO, 2020). The areas affected by the strike of Ianos medicane were distributed mainly in the western, central and southern parts of Greece. This event was generated almost two months after the initiation of the second wave of the pandemic. At this time, the total confirmed COVID-19 cases in Greece were 14,636 and the related fatalities were 326. The Samos earthquake struck the Eastern Aegean on October 30, 2020, during the second wave and a week before the installation of the second strict nationwide lockdown in the country on November 6.

The fact that the Epirus earthquake had magnitude $Mw = 5.7$ and maximum intensity $I = VI$, while the Samos earthquake had magnitude $Mw = 6.9$ and maximum intensity $I = VII$, gave the opportunity to study if the possible effects on the study on the pandemic evolution is related to the magnitude and the intensity of the seismic events. The same was possible for the studied hydrometeorological events. The disaster in Evia was caused by a flood resulted from extreme rainfall, which affected only one regional unit in the eastern part of Central Greece, while Ianos medicane affected several regional units in the western, central and southern part of the country.

Based on the aforementioned, the impact of the Epirus earthquake and its primary and secondary effects on the pandemic evolution in the affected northwestern part of Greece was negligible (Fig. 21). Only 5 COVID-19 cases were recorded during the post-earthquake period and only 2 of them could be attributed to the adverse effects of the earthquake and the harsh conditions formed after its occurrence. The impact of the Samos earthquake on the pandemic evolution in the eastern part of Greece was also low (Fig. 21). Only 12 COVID-19 cases were recorded during the studied post-earthquake period and all of them could be attributed to the adverse earthquake effects. In the case of the Evia flood, no increase in COVID-19 cases was observed during the post-flood period, while the impact of the Ianos medicane to the evolution of the pandemic in the affected regional units and regions was considerable comprising increasing trends in the affected Regions of Thessaly, Western Greece and Peloponnese, and decreasing trends in the affected Regions of the Ionian Islands and Crete (Fig. 21).

As the above examples showed, the impact of the studied disasters caused by natural hazards in the evolution of the pandemic in disaster-affected areas comprises local increasing, decreasing or stability of the COVID-19 cases during the post-disaster period. These trends are strongly related to:

- the viral load in the disaster affected area during the pre-disaster period,
- the number of people involved in disaster management, especially during the immediate response phase, in the affected areas,
- the measures adopted by the responders to protect themselves and the disaster-affected population during the first hours and days of the emergency response phase,

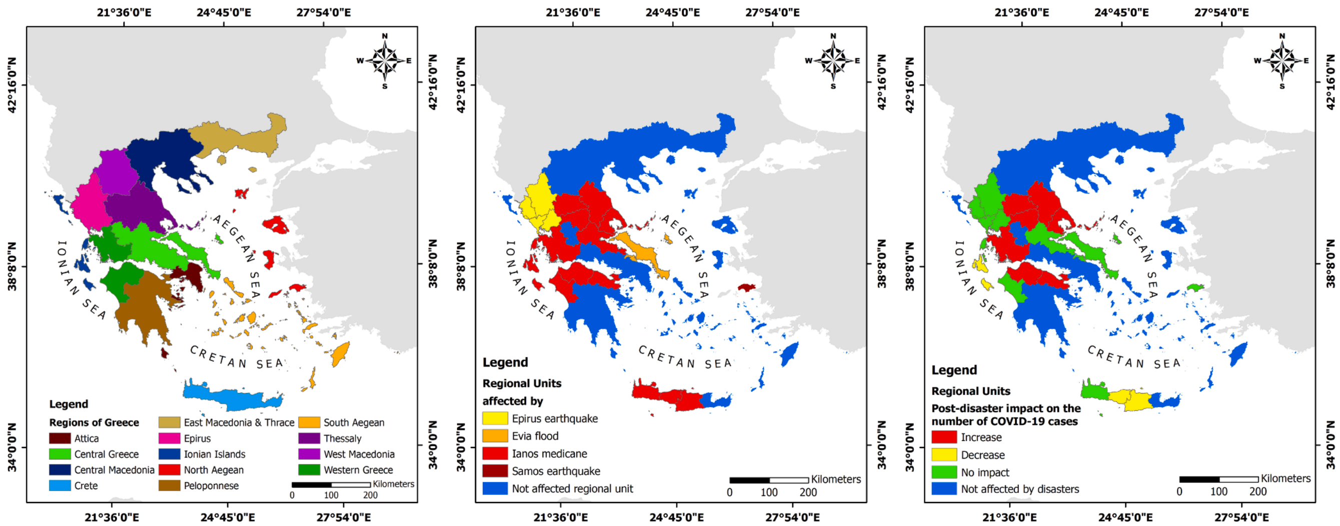

Fig. 21. (left) The Regions of Greece. (middle) The Regional units affected by the studied disasters induced by geological and hydrometeorological hazards. (right) Impact of the disasters on the number of the laboratory-confirmed COVID-19 cases during the post-disaster period in the disaster-affected regional units of Greece.

- the measures adopted by the authorities involved in the disaster management for the immediate housing of the disaster-affected population and more specifically of homeless people,
- the intensity of the studied events and their effects on the local population (fatalities and injuries), on the natural environment (primary and secondary environmental effects) and on the built environment (structural damage to buildings, infrastructures and lifelines),
- the need for immediate evacuation without assistance of the emergency responders,
- the ease of access before the disaster and the accessibility to the affected area after the disaster,
- the demographic features of the disaster affected areas including the population density and the spatial distribution of affected urban and rural residential areas,
- the level of education, organization and preparedness of the involved authorities, agencies and services for the management of the simultaneous impacts of natural hazards and related disasters and biological hazards including pandemic.

Taking into account the above points, it is concluded that it is crucial for the effective disaster risk management amid the pandemic to review national legislation, strategies and policies and to incorporate public health-related emergencies and pandemic. This could comprise integration of alerts for public health emergencies including pandemic in existing early warning systems for natural hazards, update of impact-based scenarios of all natural and technological hazards amid the pandemic and adaptation of emergency management systems to incorporate public health emergencies including pandemic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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