LIFE +
Environment Policy & Governance

Annex A.2

<u>Deliverables A2:</u> Methodology Report for the Analysis of the climatic data influencing the IMS introduction and establishment in Greece and Italy and for the development of suitability maps

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LIFE CONOPS (LIFE12 ENV / GR / 000466)

Development & demonstration of management plans against - the climate change enhanced - Invasive Mosquitoes in S. Europe

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Table of Contents

The current report presents the methodology followed for the implementation of Action A.2: Analysis of the climatic data influencing the IMS introduction and establishment, of the LIFE CONOPS project.

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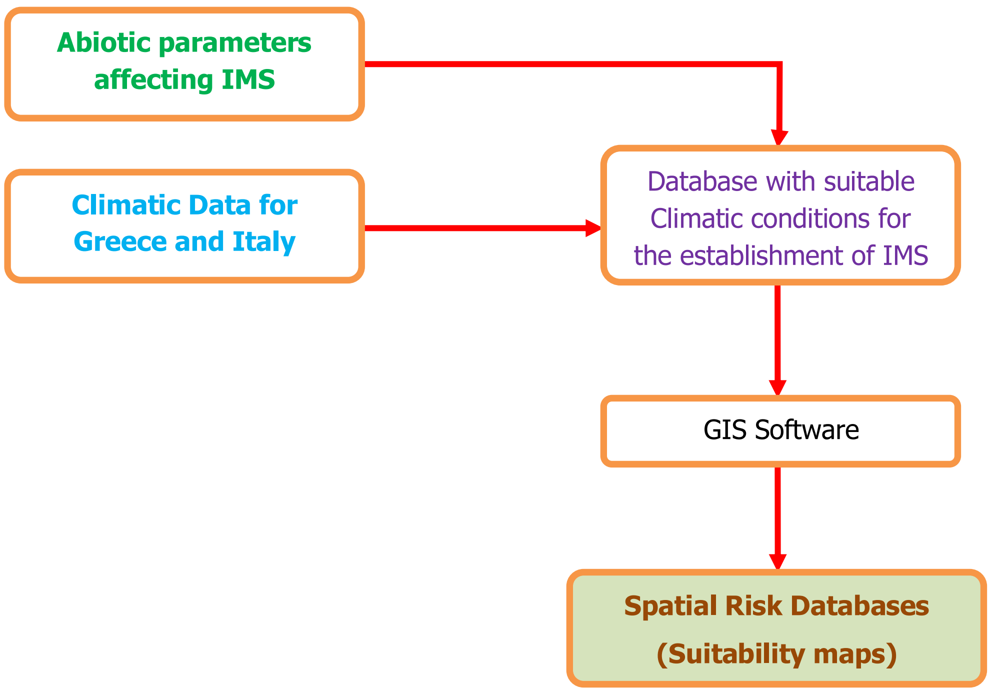
1. Introduction

Scope of this Report is to provide the methodological approach used for the development of the Spatial Risk Databases for the establishment of IMS in Greece and Italy (Action A.2 Deliverables).

The report consists of 3 chapters presenting the necessary research and data mining performed in order to develop the IMS Spatial Risk Databases (Suitability Maps) for Greece and Italy, according to the following diagram:



2. Abiotic parameters affecting mosquitoes

Mosquitoes, like all organisms, can be affected by biotic and abiotic parameters. Regarding their response to environmental changes, mosquitoes show significant capacity to adapt to various climatic factors.

For instance, the ability of *Aedes albopictus* and *Ochlerotatus j. japonicus* to adapt to moderate climatic conditions and the fact that they lay eggs which are resistant to desiccation and survive more than a year in combination with their ability to adapt to artificial breeding sites, such as flower pots and tyres, make them successful species (Becker 2010).

Mosquitoes, as members of the order Diptera, have complete metamorphosis. The several stages they go through are affected by abiotic factors. It is known that the duration of embryonic development of mosquitoes is dependent almost entirely on temperature, which also regulates egg hatching (Becker 2010). Even the flight behavior of mosquitoes is affected by abiotic factors, such as temperature, humidity and wind velocity (Becker 2010).

In this chapter, the abiotic parameters that could affect the development and dispersal of invasive mosquito species which are considered important to Europe according to ECDC (2012) are presented.

These mosquito species are:

- ***Aedes albopictus***
- ***Aedes aegypti***
- ***Aedes atropalpus***
- ***Ochlerotatus japonicus* (also known as *Aedes japonicus*)**
- ***Aedes koreicus***
- ***Aedes triseriatus***

Aedes albopictus (commonly known as the Asian tiger mosquito) is a mosquito species that has invaded many countries globally; its spread has been directly linked to the increase of international trade and is considered one of the world's 100 most invasive species (Caminade et al. 2012).

According to ECDC (2009) and Caminade et al. (2012) populations of *Ae. albopictus* are affected by:

- **annual precipitation**

the suitability of an area for the establishment of this mosquito species is zero when rainfall is lower than 450 mm and maximum when precipitation is higher than 800 mm),

- **the coldest month temperature**
  is critical for egg survival during winter. The suitability is zero when temperatures are lower than -1°C and maximum when temperatures are higher than 3°C
- **summer temperature**
  the suitability is zero when temperatures are lower than 15°C and higher than 30°C, and maximum between 20°C and 25°C

The average flight capacity of *Aedes Albopictus* is considered weak (about 676 meters) (Verdonschot and Besse-Lototskaya 2014).

Ae. aegypti has been reported to be limited by an isotherm curve of 10°C in low-latitude regions during winter (Eisen and Moore 2013). The maximum temperature threshold for its egg viability is 42°C (Christophers 1960), whereas the minimum temperature for its survival is below -5°C for 2 days (Mogi 2011). It exhibits limited adaptation to egg stage survival in unfavorable periods (Brady et al. 2013).

Generally speaking, it is doubtful if *Ae. aegypti* undergoes true hibernation as larva or adult (Christophers 1960); some other authors insist that *Aedes aegypti* has neither diapause nor cold hardiness (Sota and Mogi 1992). Finally, its dispersal capacity is considered very weak (333 meters, mean maximum distance) (Verdonschot and Besse-Lototskaya 2014).

Ae. atropalpus is a North American mosquito species. There is little information about its development and dispersal and how abiotic parameters affect it. It has been reported that this species can be found within a 500-meter radius away from its breeding sites (Scholte et al. 2012). It undergoes diapause in the egg stage (Juliano and Lounibos 2005). There is also a scientific study dealing with the suitability of *Oc. atropalpus* for dispersal in the Netherlands based on the CLIMEX model (Scholte et al. 2009) and taking into account parameters such as temperature, moisture, heat stress, dry stress, wet stress and degree-days.

Unfortunately, although the project team tried to contact the authors requesting more information about the parameters used, in order to create a relevant map for Greece and Italy, this was not achieved up till now.

Oc japonicus is native to Eastern Asia (Japan, Korea, China and Taiwan) (Sevins 2007) and has spread in many areas of the world including the U.S.A. and Eastern

Canada (Morris et al. 2007; Andreadis and Wolfe 2010). It overwinters in the egg stage in Northeastern Japan and in the larval stage in Southwestern Japan (New Zealand Biosecure 2007).

This mosquito species seems not to emerge from instars when temperature exceeds 34°C and its range expansion is presumably limited in the southern latitudes of the Northern Hemisphere by temperatures regularly exceeding 30–35°C (Kaufman and Fonseca 2014).

However, both larvae and adults exhibit tolerance to low temperatures (Kaufman and Fonseca 2014), which can justify the presence of *Oc. japonicus* as north as Canada or in mountainous regions of the world, such as Switzerland (Schaffner et al. 2009). Its mean maximum flight range is about 1600 meters and this feature classifies it as having moderate dispersal capacity (Verdonschot and Besse-Lototskaya 2014).

In comparison to the aforementioned mosquito species, little is known about ***Ae. koreicus*** regarding its biology and activity (Capelli et al. 2011). It overwinters in the egg stage and hatches in spring (Capelli et al. 2011). This species originated in Eastern Asia (South Korea, Japan, parts of China and the former USSR) (Versteirt et al. 2012). It has been also recorded from Belgium (Versteirt el al. 2012) and Italy (Montarsi et al. 2013).

Finally, as regards ***Ae. triseriatus*** it must be pointed out that it is a North American mosquito species that overwinters as diapausing egg (Medlock et al. 2012) and its dispersal capacity is very weak in terms of flight range (about 362 meters) (Verdonschot and Besse-Lototskaya 2014).

For ***Ae. albopictus*** and ***Ae. triseriatus*** the CLIMEX model was used to generate suitability maps for Greece and Italy based on published models. Authors of both models used distribution data as well as biology data to construct the parameters of the model.

CLIMEX is software that has been developed to create Bioclimatic models for species distribution. Basically, Climex, enables the development of models that describe the potential distribution and relative abundance of a species based on climate. CLIMEX uses several indices to estimate the potential growth and survival of a population at a given location. These indices are grouped into growth-related indices and stress-related indices. Major parameters included in the model are temperature, moisture, light, diapause and depending on the species, cold-stress, heat-stress and wet-stress. The final outcome of the model is the Ecoclimatic Index that integrates all indices to indicate long-term survival of a species in a specific region.

3. Climatic data for Greece and Italy

In the framework of the project, in order to identify the current state of the IMS problem, it was necessary to depict the current state of the main climatic parameters influencing the establishment and seasonal abundance of IMS. The main climatic parameters which are related to the suitability of a region are the precipitation and the temperature.

The aforementioned meteorological parameters were collected for both Greece and Italy using daily data from the European Climate Assessment and Dataset (ECA&D) project (http://eca.knmi.nl/)

ECA&D has attained the status of Regional Climate Centre for high–resolution observation data in World Meteorological Organization Region VI (Europe and the Middle East). ECA&D is receiving data from 63 countries and the dataset contains series of observations for 12 elements, i.e.:

- Cloud cover
- Humidity
- Maximum temperature
- Mean temperature
- Minimum temperature
- Precipitation amount
- Sea level pressure
- Snow depth
- Sunshine
- Wind direction
- Wind gust
- Wind speed,

at 7855 meteorological stations throughout Europe and the Mediterranean.

The participants contribute daily, quality controlled data from (a subset) of their national meteorological station networks. In order to ensure that each station's time series are as complete as possible, the database contains an automated update procedure that relies on daily data from SYNOP (surface synoptic observations) messages that are distributed in near real-time over the Global Telecommunication System (GTS). Any gaps in data are filled with observations from nearby stations, provided they are within a 25 kilometers distance radius and within a height range of less than 50 meters. In order to achieve the most correct interpretation of observations, metadata are collected for each station in the ECA&D database. Apart from the standard longitude, latitude and elevation, ECA&D collects other metadata as well. This includes the World Meteorological Organization station identifiers and whether or not the station is part of the Global Climate Observing System. Other examples of metadata are the land use around the observing area, soil type, surface coverage, station relocations and/or instrument changes. A photograph of the observing site may be included as well.

All series in ECA&D are quality controlled, and all blended temperature and precipitation series are checked for inhomogeneities. The quality control procedures lead to each data being flagged as either "OK", "suspect" or "missing" and homogeneity testing results in the classification of series as "useful", "doubtful" or "suspect". Here, only the "OK" and "useful" data have been used. This daily gridded dataset is a European land–only, high–resolution gridded observational dataset produced using the ECA&D blended daily station data.

The dataset covers the area 25–75N x 40W–75E and comes in two grid flavors with two resolutions: a 0.22° and 0.44° rotated grid (North Pole at 39.25N, 162W) and a 0.25° and 0.50° regular grid.

For the purpose of Action A.2 of LIFE CONOPS project, the 0.25° regular grid was used. The dataset is freely available for non–commercial research and non–commercial education projects only and can was freely downloaded from the ECA&D website.

In order the data collected to be representative of the current state, the 10 years data (for the period 2003 – 2012) were averaged as below:

For the annual precipitation, the daily rates for the 10 year period were averaged.

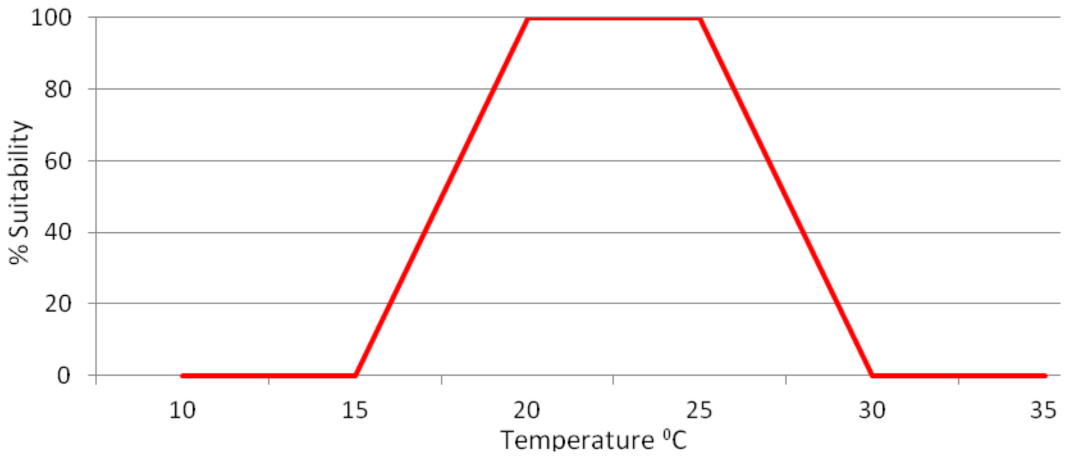
For cold period's temperature, the temperatures of November-February were averaged for the 10 year period. For the warm period's temperature, given that in the Mediterranean high temperatures are faced for a longer period, the monthly average for the months March – October was examined for the 10 year period. The 10 year period was selected as it is considered representative of the climatic conditions currently faced.

4. Spatial Risk Database (Suitability maps)

For the development of the Spatial Risk Database for the entry, spread and establishment of IMS in Greece and Italy, the following methodology was applied.

Based on the abiotic factors that affect each IMS species, at the climatic parameters' databases a new column of data was added, presenting the % suitability. This % suitability was calculated for each one of the abiotic factors described in Chapter 1 of the Report.

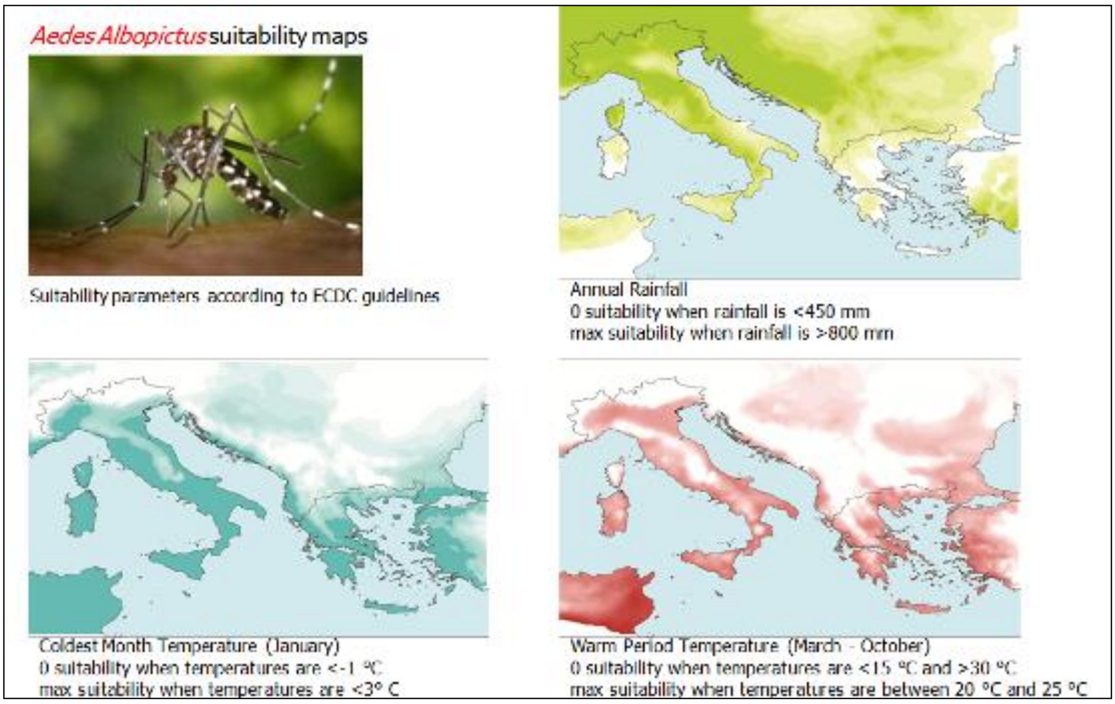
For example, for *Ae. albopictus*, regarding warm period's temperature the % suitability is presented in the following diagram:

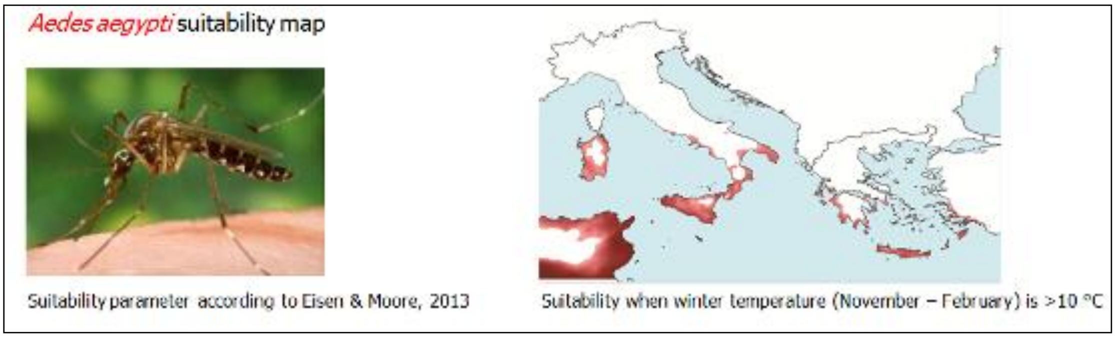


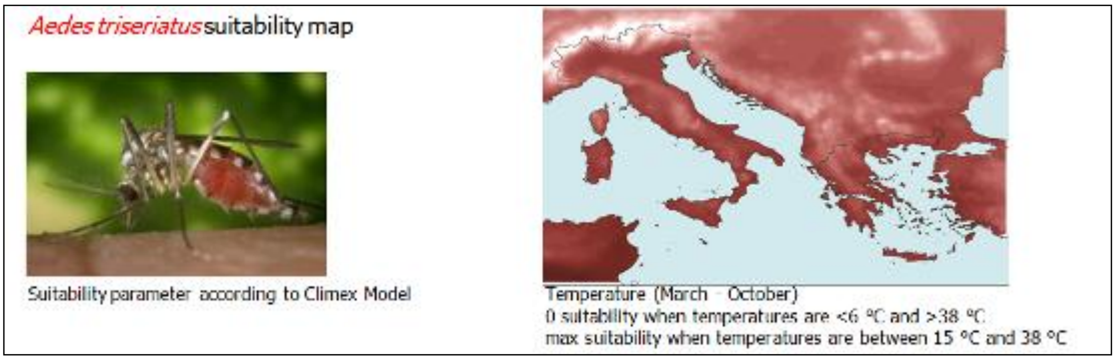
As a result, for this parameter (warm period's temperature) the %suitability was calculated based on the following logical assumptions:

- For T<15 ^{o}C, %suitability is zero
- For T between 15 and 20 ^{o}C, %suitability is increasing from 0 to 100
- For T between 20 and 25 ^{o}C, %suitability is 100
- For T between 25 and 30 ^{o}C, %suitability is decreasing from 100 to 0
- For >30 ^{o}C, %suitability is zero.

The climatic parameters' databases were then imported into GIS software in order to develop the spatial risk databases.

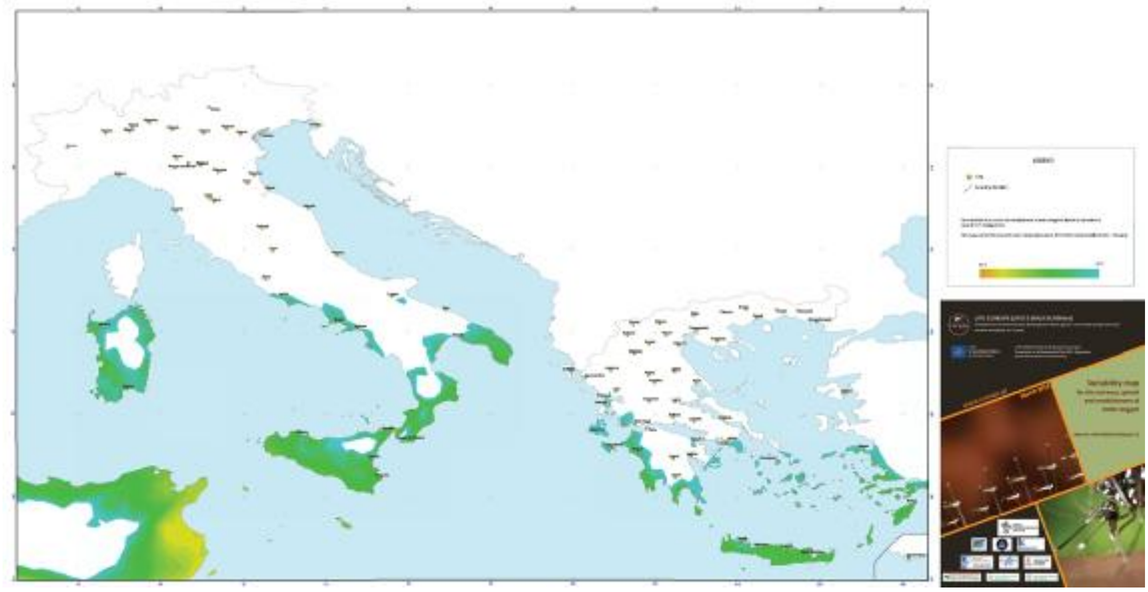




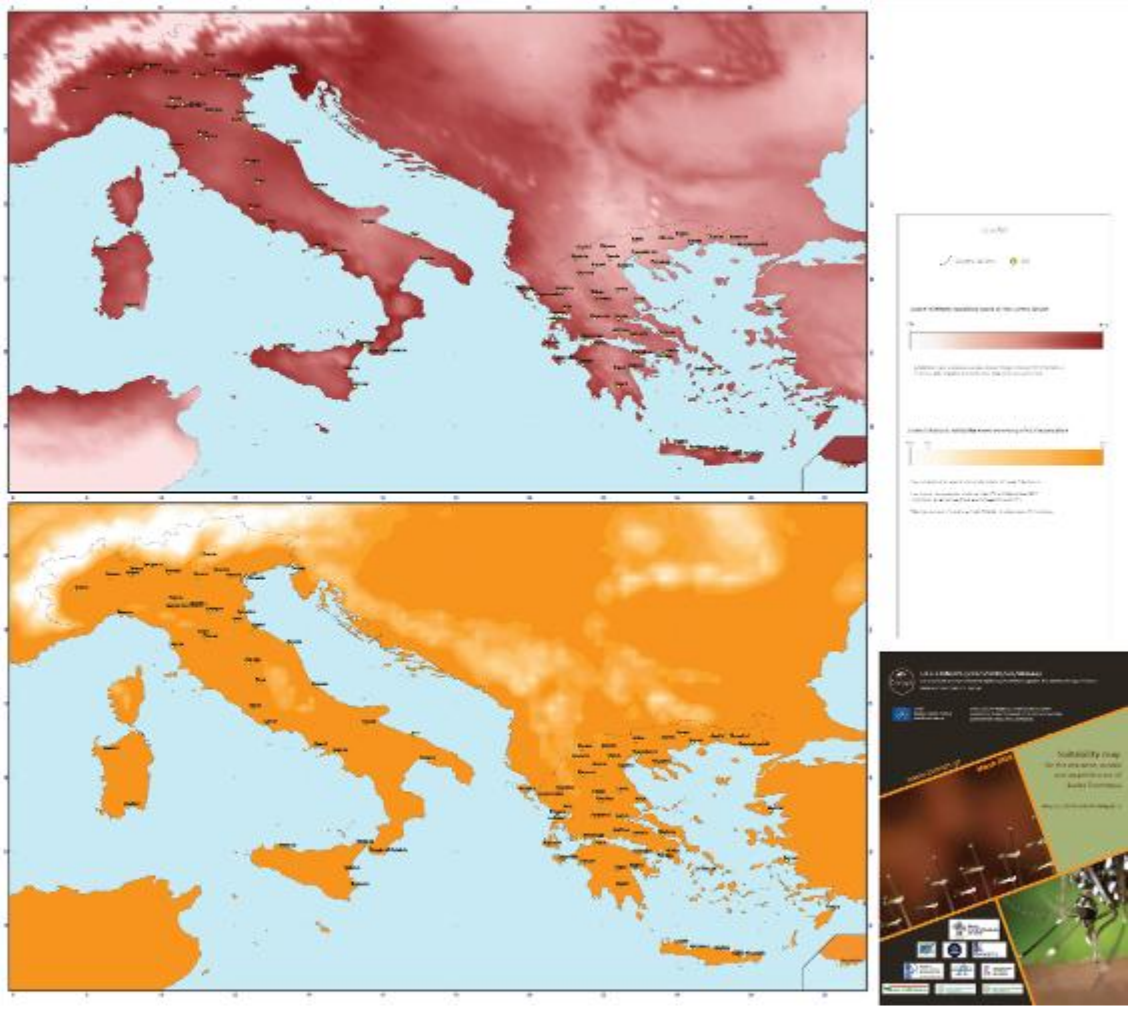


The above presented maps as well as their attached databases were combined based on the % suitability factor for each IMS species in order to develop the %suitability index of Greece and Italy for all abiotic factors affecting IMS.

For *Ae. aegypti* and *Ae. triseriatus* the abovementioned procedure was easy because only one climatic parameter is affecting the risk for their entry, spread and establishment in an area (winter temperature and warm period's temperature, respectively). It must be mentioned that for *Ae. triseriatus* the suitability index was also compared and verified with the outcome of the CLIMEX model. The developed suitability maps are presented below:



Suitability map *for Ae. aegypti*



Suitability maps *for Ae. triseriatus*

For *Ae. albopictus*, the case was more complex because three different factors (climatic parameters) affect the suitability of an area for its entry, spread and establishment.

The formula used for the calculation of the suitability of an area is:

$$\textbf{\% Suitability} = (a * S_{T(warm\ period)}) + (b * S_{Rainfall}) + (c * S_{T(January)})$$

where,

a,b,c	= Weighting factors of the three different climatic parameters' suitability
$S_{T(warm\ period)}$	= % Suitability based on the warm (March - October) period's Temperature
$S_{Rainfall}$	= % Suitability based on the annual rainfall
$S_{T(January)}$	= % Suitability based on the coldest month's (January) Temperature

In order to develop more accurate suitability results for the project areas (Greece and Italy), several different scenarios were tested and evaluated.

For the evaluation of these scenarios and the verification of the most accurate, the CLIMEX model was used for *Ae. albopictus* (similar to the *Ae. triseriatus*), based on previously published models. In addition, verification was also performed with the comparison with existing risk maps already developed for *Ae. albopictus* by other organizations and projects (i.e. ECDC, VBORNET).

The different scenarios used are described below:

1st scenario

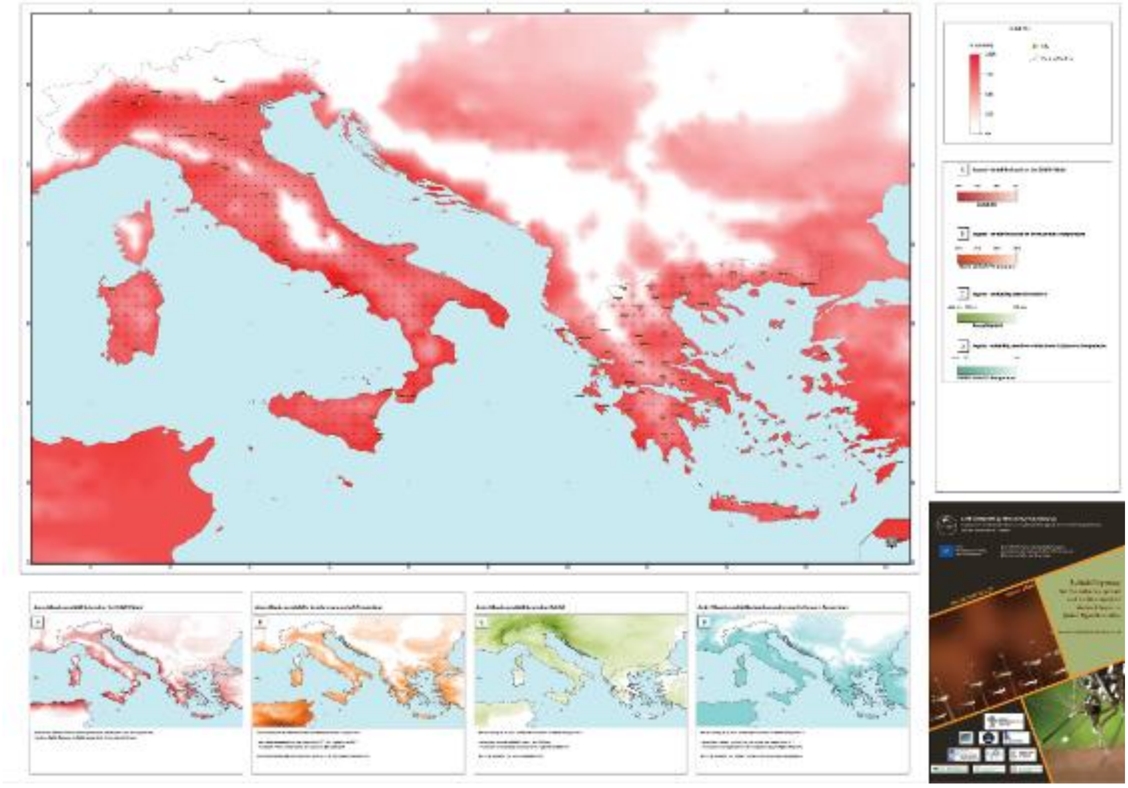
The 1st scenario was taking into account that all three parameters had the same weighting factor (0.33) for the calculation of the suitability. According to the results of the CLIMEX model as well as according to the risk maps of ECDC, the map (suitability index map) developed using this scenario was not presenting the real status of the risk.

2nd scenario

In the 2nd scenario the three parameters had the different weighting factor for the calculation of the suitability. Within this scenario different weighting factors were applied always keeping in mind that the warm period's temperature is the main and most important parameter affecting IMS. These sub-scenarios are presented in the following table:

Sub-scenario	**a** Weighting factor for warm (March - October) period's Temperature	**b** Weighting factor for annual rainfall	**c** Weighting factor for coldest month's (January) Temperature
2.1	0.5	0.25	0.25
2.2	0.6	0.2	0.2
2.3	0.8	0.1	0.1
2.4	0.8	0	0.2
2.5	0.8	0.2	0

The application of these different sub-scenarios revealed that the 2.2 sub-scenario (weighting factors a = 0.6, b = 0.2 and c = 0.2) was verified to be the most accurate. As a result, using this scenario the suitability map of *Ae. albopictus* was also developed.



Suitability map *for Ae. Albopictus*

Finally, it has to be mentioned that for *Ae. atropalpus*, *Oc. japonicus* and *Ae. koreicus*, the required abiotic parameters for the development of the relevant suitability maps for Greece and Italy were not found in the bibliography.

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