Potential distribution of the tiger mosquito *Aedes albopictus* in Northern Italy derived from reconstructed MODIS Land Surface Temperature maps

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Abstract

We developed an innovative methodology for the reconstruction of MODIS Land Surface Temperature (LST) time series, and derived temperature indicator maps to describe the potential distribution areas for the invasive tiger mosquito Aedes albopictus*, a vector of several human diseases. The distributional limit of this species in temperate areas is determined by a minimum January mean temperature (*$JanT^{mean}$*, winter egg survival), a minimum annual mean temperature (*$AnnT^{mean}$*, adult survival) and a number of minimum growing degree days (life developmental cycle). As input we used more than 11,000 daily MODIS LST maps from 2000 to 2009 which we reconstructed in an Open Source GIS framework (GRASS GIS) on a Linux cluster in order to fill gaps originating from clouds in the LST maps. The average maps were subjected to thresholding in order to obtain binary maps indicating habitat suitability. All maps were superimposed, achieving a final integrated map showing the risk of potential distribution of* Ae. albopictus*. This map was validated with entomological field records of known invasion. The maps indicates new areas that may be colonized in the near future:* Ae. albopictus *could expand its distribution towards northern latitudes and higher altitudes, increasing the area at risk of mosquito-borne diseases.*

1. Introduction

In the last decades, the Asian tiger mosquitoes *Aedes albopictus* (Diptera: Culicidae) has become an increasing health problem in several areas of the world. Native of the tropical rain-forests of Asia, it has extended its range worldwide principally through taking advantage of the international used tire trade. *Ae. albopictus* is a competent vector of at least 22 arboviruses, and it is involved in the epidemic transmission of Dengue and Chikungunya diseases (Gratz 2004). The spreading of this invasive vector in Europe increases the risk of the introduction of tropical infectious diseases: in 2007, the first European outbreak of Chikungunya occurred in Emilia Romagna region with more than 200 affected humans (Angelini 2007). In Italy, the presence of establish populations of *Ae. albopictus* was reported the first time 1991 in Padua city and from there it has gradually spread to all the regions of the peninsula (Romi et al. 2008).

The distribution of *Ae. albopictus* is controlled by photoperiod (duration of direct sunlight per day), rainfall, humidity and temperature with the latter being one the most limiting factor for the spread in temperate areas. According to literature data, the 0°C $JanT^{mean}$ isotherm indicates where *Ae. albopictus* eggs can survive the winter in temperate climates. Additionally, the threshold of 11°C $AnnT^{mean}$ limits adult survival (Alto & Juliano 2001; Kobayashi et al. 2002). Since annual rainfall of ≥ 500 mm is sufficient to provide *Ae. albopictus* with a variety of breeding habitats, we did not consider it as a limiting factor in north-east Italy. We added growing degree days (GDD) as another limiting factor as life cycle completion indicator.

2. Methods

In order to overcome the limited availability and scarce distribution of meteorological station data, we used satellite based temperature threshold maps to identify the potential distribution areas of *Ae. albopictus*. On more than 11,000 daily MODIS LST maps (2000-2009) obtained from NASA, we performed outlier detection and gap filling in GRASS GIS in order to produce a sound basis for the temperature and GDD threshold map series (Neteler 2010a). Thanks to the high temporal resolution of four LST maps per day, the diurnal temperature cycle is sufficiently described. The MODIS LST map reconstruction involved an automated data download, the reprojection to a commonly used map projection system, and a complex procedure to eliminate temperature outliers. In order to estimate the LST values in cloud contaminated areas, a temperature gradient based model was developed and used as an input to volumetric splines interpolation in GRASS, leading to 11,000 complete LST maps (Neteler 2010b). For this purpose, we implemented convenient batch job handling and a new time series thresholding method in GRASS GIS 6.4. The processing was done on a 128 nodes Linux cluster.

To obtain the suitability maps, we integrated the beforehand created individual $JanT^{mean}$ maps (2001-2009) into a final average map. Likewise, we calculated the $AnnT^{mean}$ maps (2001-2009) and averaged them, too. Both resulting maps were thresholded according to the values mentioned above. For the life cycle indicator, we calculated a GDD map series with baseline temperature of 11°C and cut-off temperature of 30°C (Hawley 1988). The final, all-years averaged GDD series was thresholded for 1350 GDD (Kobayashi et al. 2002) and filtered for pixels with average autumnal temperature > 11°C in order to avoid that the GDD threshold was reached in early winter. All maps were superimposed, achieving the final integrated map showing the risk of potential distribution of *Ae. albopictus*.

3. Results and conclusions

We determined the potential distribution areas of *Ae. albopictus* in North-eastern Italy at regional scale using mean January temperatures, mean annual temperatures and accumulated growing degree days derived from reconstructed MODIS LST data time series (Fig. 1). All municipalities except for one (n=594) where *Ae. albopictus* is present are covered in the final map. It shows that in the near future *Ae. albopictus* could expand its distribution furthermore towards north and also to higher altitude ranges, leading to an increased risk for mosquito-borne diseases. We propose the use reconstructed time series of daily MODIS Land Surface Temperature (LST) data as alternative to traditional meteo-station data approaches since they reflect better microclimatic conditions, especially in complex terrain as found in the European Alps. This methodology, hereby applied to an emerging vector of human diseases, may be used in future to identify the distribution of other invasive or endangered species.

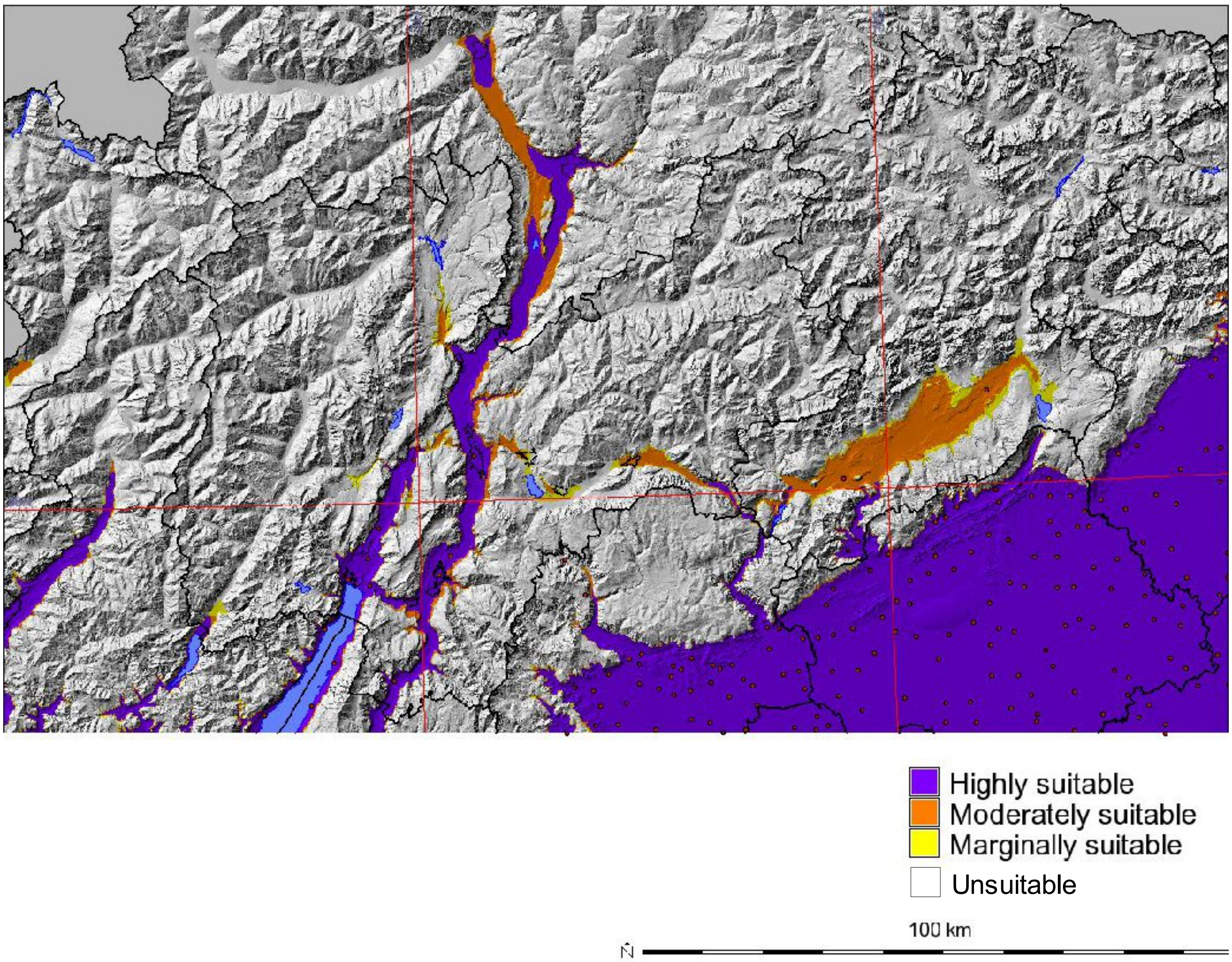

Figure 1: Habitat suitability map of *Ae. albopictus* in North-eastern Italy, based on the classified summary of the egg winter survival, adult annual survival, and the areas of successful life cycle completion. Uncoloured are unsuitable areas; in yellow marginally suitable areas (one threshold reached), in orange moderately suitable (two thresholds reached), in violet highly suitability (three thresholds reached). The currently known distribution of *Ae. albopictus* in the area is represented with red spots.

References

Angelini, R. et al., 2007. 'Chikungunya in north-eastern Italy: a summing up of the outbreak'. *Euro Surveillance: Bulletin Européen Sur Les Maladies Transmissibles = European Communicable Disease Bulletin*, vol. 12, no. 11, E071122.2.

Alto, B.W. & Juliano, S.A., 2001. 'Precipitation and temperature effects on populations of Aedes albopictus (Diptera: Culicidae): implications for range expansion'. *Journal of Medical Entomology*, vol. 38, no. 5, pp. 646–656.

Gratz, N., 2004. 'Critical review of the vector status of Aedes albopictus'. *Medical and Veterinary Entomology*, vol. 18, no. 3, pp. 215-227.

Hawley, W., 1988. 'The biology of Aedes albopictus'. *Journal of the American Mosquito Control Association. Supplement*, vol. 1, pp. 1-39.

Kobayashi, M., Nihei, N. & Kurihara, T., 2002. 'Analysis of northern distribution of Aedes albopictus (Diptera: Culicidae) in Japan by geographical information system'. *Journal of Medical Entomology*, vol. 39, no. 1, pp. 4–11.

Neteler, M., 2010a. 'Estimating daily Land Surface Temperatures in mountainous environments by reconstructed MODIS LST data'. *Remote Sensing*, vol. 2, no. 1, pp. 333–351.

Neteler, M., 2010b. '*Spatio-temporal reconstruction of satellite-based temperature maps and their application to the prediction of tick and mosquito disease vector distribution in Northern Italy'*. PhD thesis. University of Hannover, Germany.

Romi, R. et al., 2008. 'Twenty years of the presence of Aedes albopictus in Italy – From the annoying pest mosquito to the real disease vector'. *European Infectious Diseases*, vol. 2, no. 2, pp. 98-101.