Effective Spatial Planning of Watchtowers for the Detection of Wildfire Hotspots in Thasos Island, Greece

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Abstract: Forest fires, beyond the obvious ecological role that plays in forest ecosystems, can be a detrimental factor to natural and human ecosystems downgrading the quality of life of local population. The paper aims to enhance forest fire prevention through the prompt detection of fire events, a fact that would immediately alarm the firefighting forces to contain and mitigate the severity of this phenomenon. To this end, viewshed analysis has been implemented taking into consideration multiple factors: the overlapping effect minimization; the visibility maximization with a certain number of observatories; the sufficient visibility of certain land cover types. The results indicate the selection of four groups of observatories (each group covered a sufficient percentage of visibility) covering almost 70% of the entire island which is considered a satisfying figure given the rough topography of the study area. After these first 20 positions, the incorporation of extra locations would provide marginal profit in visibility terms. Therefore, the selection of the number of groups of observatories is mainly a political decision weighting the interaction of environmental protection and financial restrictions.

Keywords: fire hotspots; visibility analysis; GIS; Thasos island; Greece.

1 Introduction

Forest fires, beyond the obvious ecological role that plays in forest ecosystems, can be a detrimental factor to natural and human ecosystems downgrading the quality of life of local population. Due to specific peculiarities of some geographic regions, many countries in the Mediterranean Sea are at high risk for high severity forest fires as statistics indicates (Sakellariou et al. 2017). These peculiarities are related to specific climatic conditions, topography, and the high degree of interaction of forest with urban areas. Thus, fire prevention constitutes the most significant strategy to tackle high severity forest fires with unpredictable consequences in natural environment and social web. In addition, the restoration cost could reach massive amount of funding. To this end, several models have been developed aiming to detect any forest fire event as quickly as possible. Many researchers have focused on different aspects of fire prevention. In this project, we concentrate our attention to the detection of fire hotspots through a certain number of locations that maximize both the visibility and financial effectiveness. To this end, aim of the project is to find the best positions for the establishment of observatories based on visibility efficacy (both in absolute and relative terms: positions that guarantee large areas of visibility, covering the most susceptible and critical land covers simultaneously). Even though numerous applications on viewshed analysis for certain socioeconomic activities have been implemented (Mouflis et al. 2008, Zhou et al. 2011) there is a shortage of research focusing on forest fires phenomenon (Temiz and Tecim 2009, Pompa-García et al. 2010, Pompa-García et al. 2012, Kang et al. 2013, Sivrikaya et al. 2013). Hence, here we would like to emphasize the added value of visibility analysis on forest fires events. The results indicated that not only the highest locations were effective, but other positions with lower altitudes proved to be very efficient in terms of visibility.

2 Materials and methods

Thasos constitutes a small island which is located in the north-eastern region of Greece. Figure 1 depicts the geographical characteristics of the study area, namely, the exact geographic position of the island in a national and global perspective; the elevation variation across the study domain as well as some cartographic characteristics (projection system, coordinates, scale of map). Thasos island is characterized by significant parts of mountainous areas. The elevation levels fluctuate from 0 (coastal areas) to 1,204 meters. The higher altitudes can be found in the interior of the island, especially in the central and north-eastern region. The dominant land cover type consists of forested areas (63%), followed by agricultural fields (21%), shrubs (13%) and 1% of livestock area, arid land and residential area respectively (Sakellariou 2016).

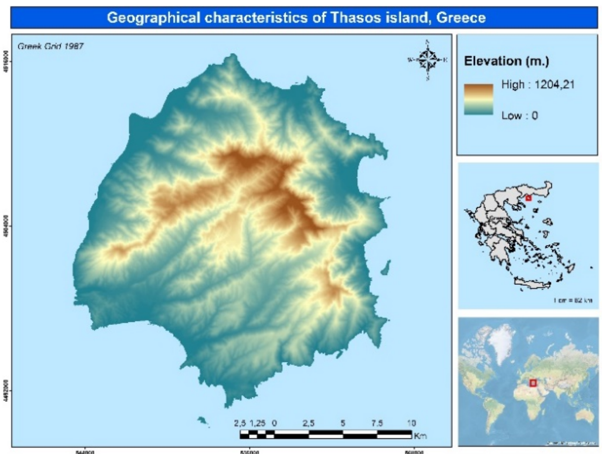

Figure 1. Geographical position and elevation levels of the study area.

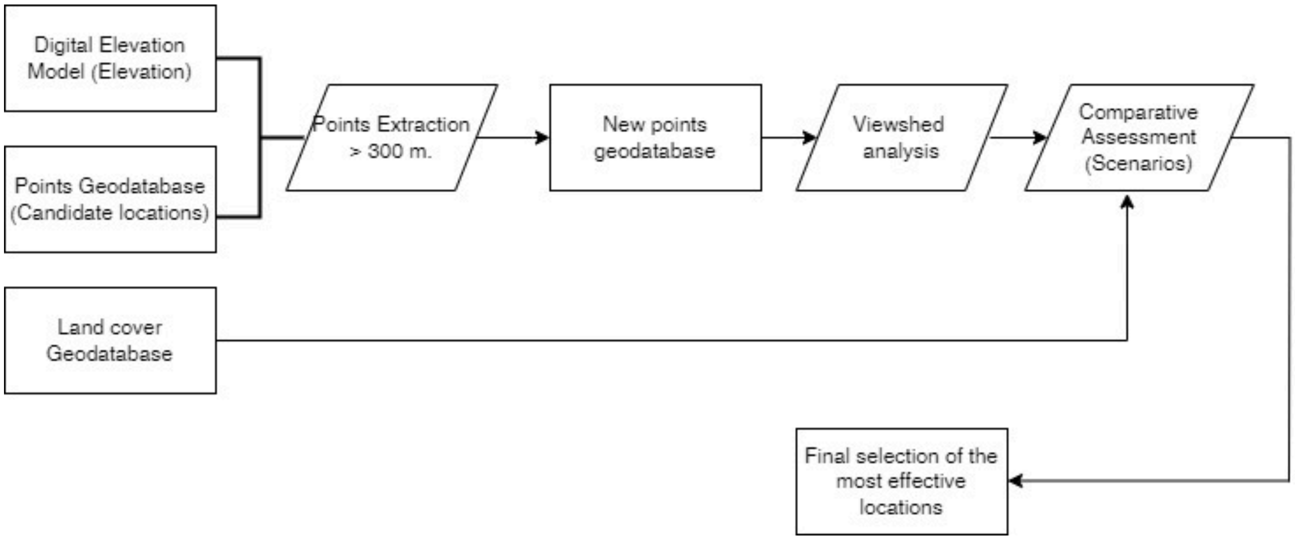

Figure 2. Flowchart of viewshed analysis.

The primary data that was used for this project was the digital elevation model (DEM) of Thasos island and a point geodatabase that reflected the points features across the ridge of mountains (HMGS 2012). In addition, a layer of land cover was used so that we can determine the overlay of visible area and the corresponding land cover type. The cornerstone of this project is relied on viewshed analysis which is integrated in the Geographical Information Systems. We removed all potential locations that lied below 300 meters due to the fact that and fire event could be relatively easily detected by the moving vehicles as well as by the boats approaching the island. However, it should be highlighted the fact that many potential locations above 300 meters are characterized by visibility which approaches the coastline. This happens due to the size and topography of the island. After we have extracted the final potential locations for the observatories, we conducted a viewshed analysis for each location recording the individual capacity of visibility. Next, we proceeded to a comparative assessment of all positions with the corresponding visibility potential and the spatial configuration of the visible area. Locations with high degree of overlapping visibility were removed. Finally, the most efficient locations which met specific criteria (low degree of overlapping visibility; type and significance of land cover type) were chosen trying to minimize the number of potential observatories with the maximum visible area. In the same context, the interrelation of visible area and the corresponding land cover type was calculated, so that we are able to protect the most vulnerable regions.

One more parameter which was defined is related with the suggested elevation of potential watchtower. This factor plays a crucial role, since the higher the observatory the higher visibility is expected. So, taking into account the normal circumstances in Greece, the suggested elevation was defined to 3 meters above the ground. The following chart (Figure 2) summarizes the inputs, methods and the corresponding outputs of this project.

3 Results and discussion

Initially, the geodatabase consisted of 100 candidate locations which are located on the top of ridges. We consequently removed all positions that lied under the elevation level of 300 meters. After this procedure, we implemented the viewshed analysis for each point and calculated the final visibility potential in terms of visible hectares. Figure 3 shows the visibility potential of all 55 remaining locations.

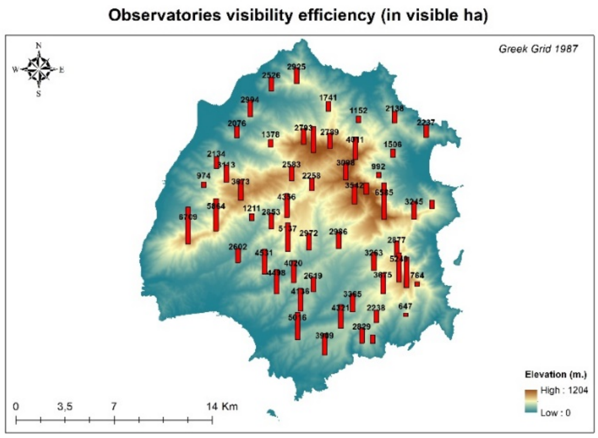

Figure 3. Visibility potential for each candidate location.

As we may see from Figure 3, there is a great variability in visibility capability of each position which is based both on altitude level and the underlying topography of the island. Thus, we had to proceed to a comparative analysis of all these locations, taking into account the overlapping effect as well as the extent and the visibility magnitude of each land cover type.

To this end, we decided to recommend 20 potential locations for the establishment of observatories for two main reasons. Firstly, the suggested 20 positions reduce the overlapping effect (covering adjacent regions) and cover a significant area of critical land cover types. Secondly, we adopted a theoretical scenario of employing all the 55 locations and the gained area (in terms of visibility) was quite marginal. Hence, after the finally selected 20 best positions, the visible added value can be characterized quite marginal. Figure 4 presents the final selected locations and the respective visible area per group of observatories (each group consists of 5 potential observatories meeting a crucial threshold of visibility effect). As we may notice from Figure 4, the majority of the study area is adequately covered by selecting 20 potential locations. After this number, the added value of extra observatories offer quite limited value. From statistical point of view, the first 5 selected locations (First Group) covered 40.4% of the whole study area; the second group covered 15.8%; the third group covered 8.8%, while the last one covered 4.2%. In total, almost 70% (69.2%) of the entire island is covered by the establishment of the suggested 20 observers. If we adopted the unrealistic scenario (establishment of another 35 observers), the total visibility percentage would approach 80%. So, the proposal of establishment of another 35 observers would just add 10% of visibility in total, which is not feasible in financial terms.

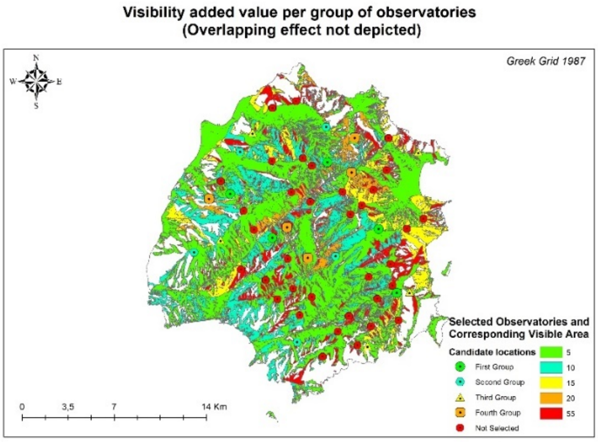

Figure 4. Final selected locations and their respective visible area.

Figure 5 summarizes the viewshed analysis with land cover types. First of all, it should be highlighted that 82% of total forests in the island is now visible from the proposed scenario (20 observers). 73% of agricultural and residential areas respectively are covered by this scheme. 83% of livestock is visible, but this was expected, due to the small area of this specific land cover type. Finally, 53% of shrubs is only visible from this scenario.

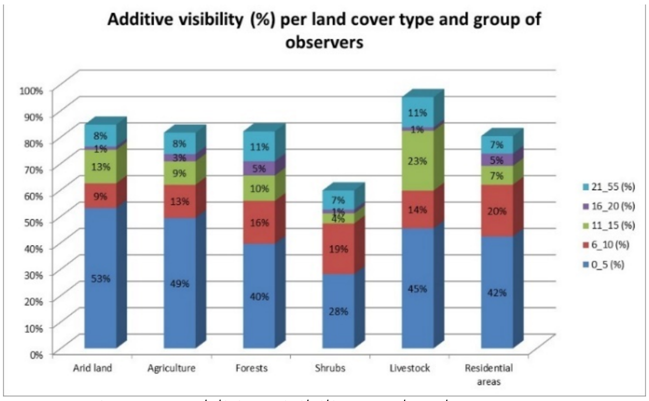

Figure 5. Additive visibility per land cover type.

Here, it should be mentioned that, except the first group of observatories, the visibility potential for the other groups only refer to the additive visibility (having removed any overlapping effect). That is why, the first group seem to have the greatest visibility potential. Another reason is that we sought to find the best locations for the other groups which met the criteria of overlapping minimization, taking into account the types of land cover. As we may notice from the Figure 6, almost all the groups offered substantial additive visibility. The last group was included because it covers added regions of forests, agriculture and residential areas which are all considered very important aspects. The inclusion of extra groups of watchtowers would almost fall in the same curve as the last one (fourth group). Hence, the selection of maximum 20 locations is considered the best solution given the specific characteristics of the island.

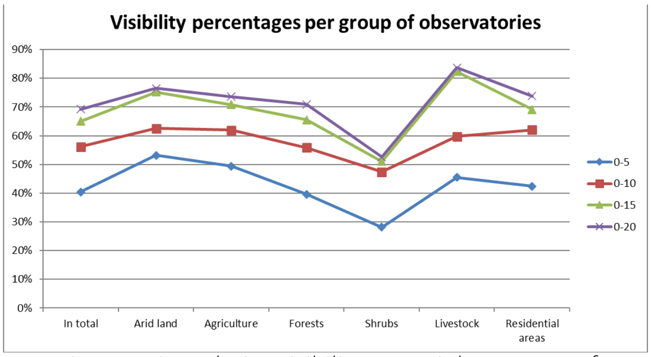

Figure 6. Cumulative visibility potential per group of observatories and land cover types.

4 Conclusions

The paper aims to enhance forest fire prevention through the prompt detection of fire events, a fact that would immediately alarm the firefighting forces to contain and mitigate the severity of this phenomenon. To this end, viewshed analysis has been implemented taking into consideration multiple factors.

First, we needed to choose only candidate locations that are above 300 meters and secondly, a thorough comparative assessment and analysis was followed in order to select the best locations for the establishment of observatories. The primary factors that were involved in the analysis were: the overlapping effect minimization; the visibility maximization with a certain number of observatories; the sufficient visibility of certain land cover types.

The results indicate the selection of four groups of observatories (each group covered a sufficient percentage of visibility) covering almost 70% of the entire island which is considered a satisfying number given the rough topography of the study area. After these first 20 positions, the incorporation of extra locations would provide marginal profit in visibility terms. Therefore, the selection of the number of groups of observatories is mainly a political decision weighting the interaction of environmental protection and financial restrictions. The nature of land cover types may contribute to this final selection given the priorities of any society.

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