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Observatories Establishment for the Prevention of Forest Fires. The case of Thasos Island, Greece

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Abstract- Forests are primary providers of fundamental tangible and intangible goods to our planet, from vital chemical substances (O_2) to more economic issues (wood for economic activity etc.). Hence, for the comprehensive protection of these priceless ecosystems, immediate detection of forest fires is of vital importance, so that the firefighting forces may react in the least possible time before forest fires take large dimensions with unpredictable consequences. Primary aim of the paper is the immediate fire detection through establishing observatories across the entire area of a Greek island, Thasos. Vital objective is the selection of the most efficient observatories in terms of maximizing the visible area as well as their optimal location for avoiding significant degree of overlapping. According to the visibility analysis, the five most efficient observatories in terms of visible area and least degree of overlapping have been selected. In addition, establishing only 5 observatories, we will be able to monitor approximately 42% of the entire study area and its corresponding land cover types. Certainly, the visibility potential could be increased if the firefighting authority decides to establish more than 5 observatories, which means demand of additional financial resources.

Keywords: Forest fires, Fire detection, Visibility analysis, Observatories, GIS, Thasos, Greece

I. INTRODUCTION

Forests are primary providers of fundamental tangible and intangible goods to our planet, from vital chemical substances (O_2) to more economic issues (wood for economic activity etc.). Therefore, besides the ecological role of forest fires at our ecosystems, effective prevention measures for confronting recurrent and destructive fires should be taken by the involved authorities. Hence, the effective forest fires prevention aims to the conservation of the ecological richness of any national territory (endemic flora and fauna; retention of carbon dioxide and oxygen release; anticorrosive properties and protection of adjacent urban areas from flooding; special places for leisure purposes etc.) and saves the already limited fiscal resources (for the restoration of damages etc.), while, at the same time, it enhances the socioeconomic cohesion and development of the local and regional population (Sakellariou et al., 2015).

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Thus, immediate detection of forest fires is of vital importance, so that the firefighting forces may react in the least possible time before forest fires take large dimensions with unpredictable consequences. A highly effective measure for forest fires prevention is the optimal establishment of observatories based on the maximum size of area which is visible from any candidate observatory. Pompa-García et al. (2010, 2012) proposed an effective network of observatories exploring the current as well as the optimal location of observatories based on their effectiveness in terms of visible area. In addition, they combined the effectiveness of this network in conjunction with the land cover significance from ecological and financial point of view (Pompa-García et al. 2010, 2012). Primary aim of the paper constitutes the selection and establishment of the most effective observatories developing a productive network of observatories for the immediate detection of forest fires. This analysis is combined with the corresponding land cover which is overlapped by the visible area. This occurs because the firefighting authority may have the opportunity to develop its priority plan.

II. STUDY AREA

The island of Thasos is situated in the northeastern part of Greece and administratively belongs to the region of Eastern Macedonia and Thrace. The length of the shoreline amounts to 115 km, while the area of the island is 380 km^2 (Wikipedia, 2015). Thasos constitutes an island of the Northern Aegean. The geomorphology of the study area is abnormal, as it seems from the huge mountainous areas. Despite the mountainous nature of the island, accessibility is considered quite satisfying due to the high density of forest roads (Sakellariou et al., 2015). Figure 1 depicts the geographical position of the Thasos island in the context of the country as well as the administrative division of the island. Finally, Thasos island is characterized by rich vegetation, as it is reflected from the great variety of trees, such as olives, plane, fir, linden, cedar etc (Wikipedia, 2015).

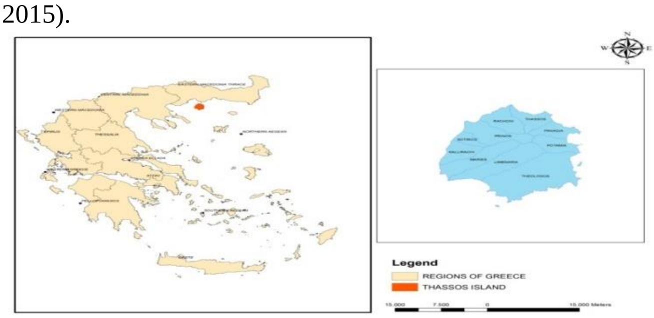

Figure 1. Geographical position and administrative division of the island of Thasos

Source: Tampekis et al., 2015

III. MATERIALS AND METHODS

Principal objective of the study is the optimal location of observatories based on their visibility effectiveness (conjunction of maximum visible area and land cover type). It is obvious, that, under these financial circumstances, any firefighting authority has to make its choice, concerning the maximum number of observatories to be established which will be proportional to the degree of visible area, and consequently, to the forest fires prevention effectiveness. That is why, the fewest locations with the maximum visible area should be selected. In the same context, despite the fact that the observatories which are located in positions with the higher altitudes may be selected, however, our analysis presents different results. This is happening because the relief of the study area is characterized by great fluctuations in slope and aspect dimensions. Therefore, it should be emphasized the fact that there are additional criteria (like topography) which should be taken into consideration, beyond the altitude dimension, for the final and optimal selection of candidate positions. These fluctuations are depicted in detail in Thasos profile and the respective charts (Charts 1 to 4). These charts present the great altitude fluctuation along the island. In addition, Map 1 depicts the elevation evolution measured by the corresponding 300 meters contours.

Chart 1. Elevation fluctuation from North to South (Elevation vs Distance in meters)

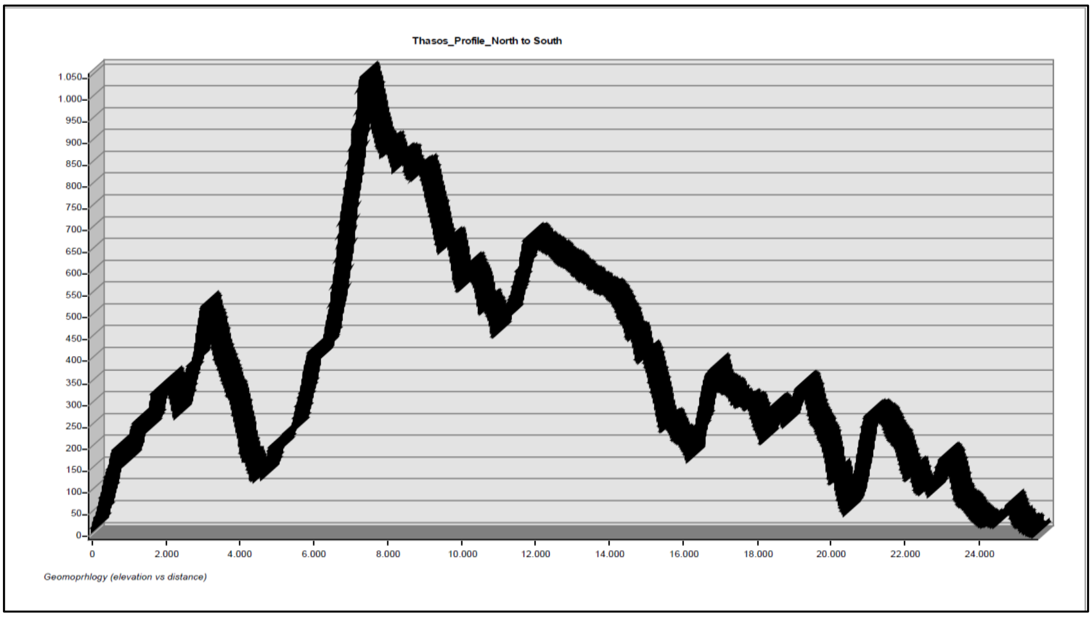

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Chart 2. Elevation fluctuation from West to East (Elevation vs Distance in meters)

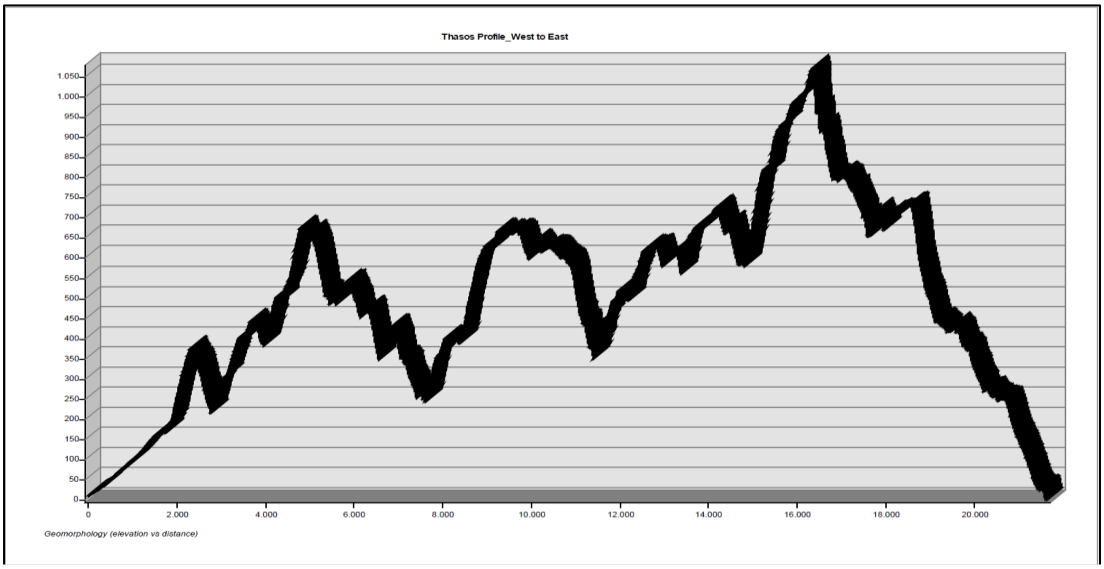

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Chart 3. Elevation fluctuation from Northwest to Southeast (Elevation vs Distance in meters)

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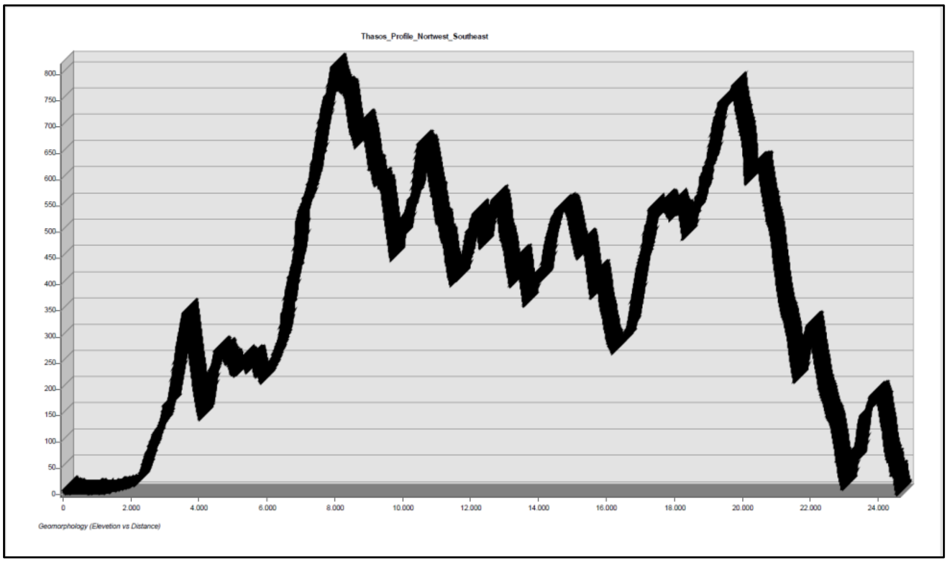

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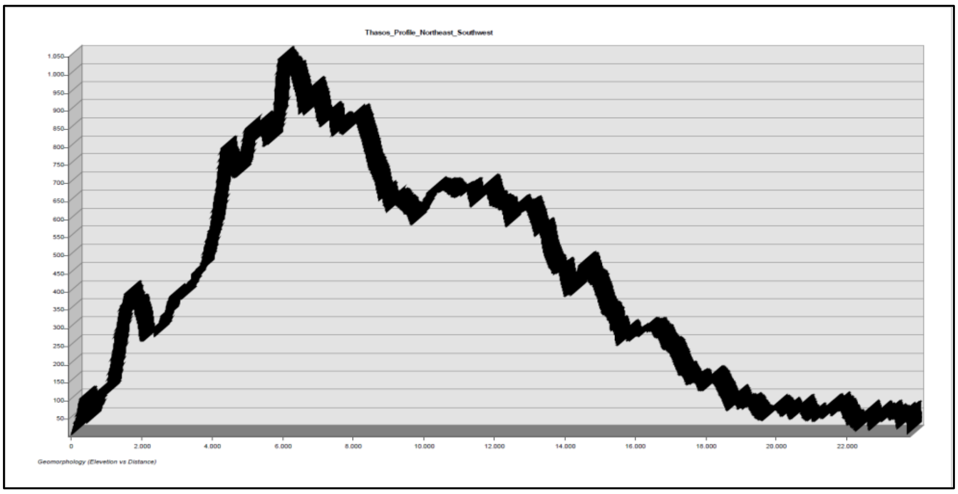
Chart 4. Elevation fluctuation from Northeast to Southwest (Elevation vs Distance in meters)



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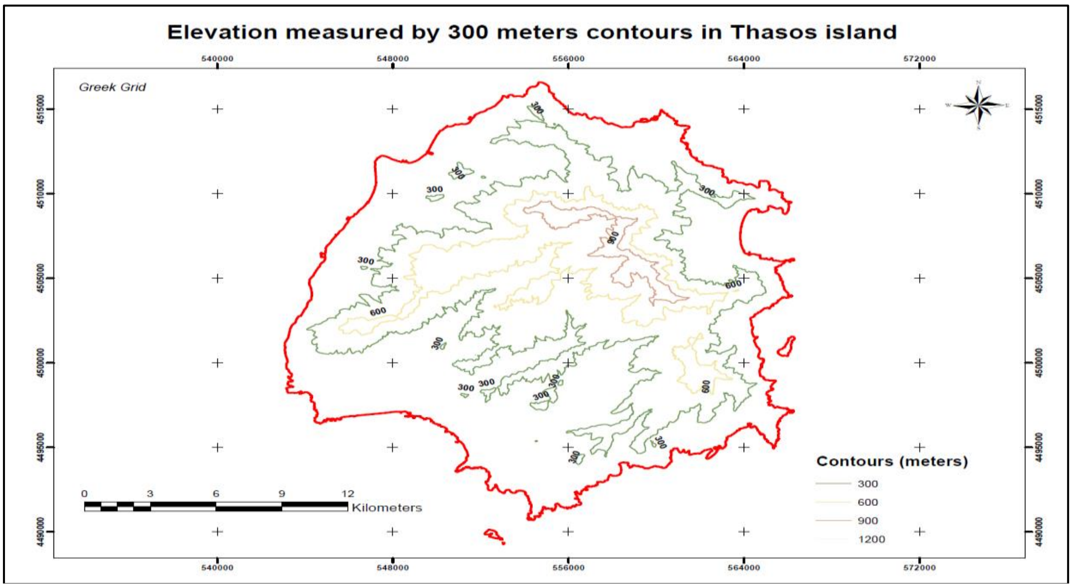
Map 1. Elevation evolution of Thasos island (300 meters contours)



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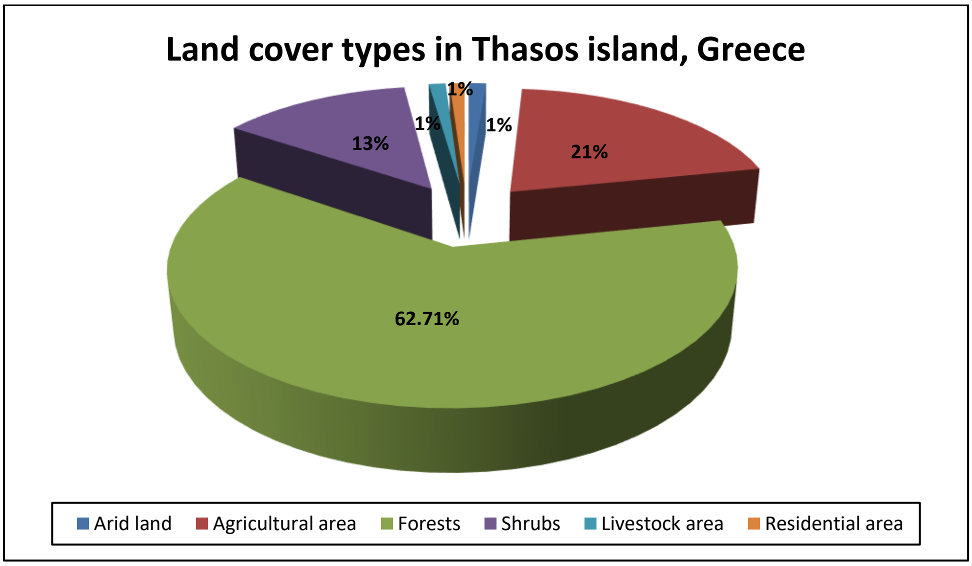
The necessary materials that were used for the analysis are the digital elevation model (DEM) of the island; the candidate points for locating the observatories which stem from the Hellenic Military Geographic Service. These points are mainly located at the ridge of the mountainous area of the island, but not only; and the land cover types of the island. The visibility analysis was conducted with the aid of Geographical Information Systems and the software ArcGIS 10.2.1. Primary input of the analysis is the land cover layer. Concerning the land cover characteristics of the study area, we observe that the major land cover type is forests (62.7%), followed by the agricultural land (20.5%), shrubs (13.3%), while, the remaining land cover types (arid land; livestock and residential area) amount to 1%. Table 1 and Chart 2 present the area occupied by each land cover type as well as their percentage participation to the total area.

Table 2. Land cover type area

Land cover	Area (Ha)	Percentage (%)
Arid land	472	1.22
Agricultural area	7,951	20.55
Forests	24,256	62.71
Shrubs	5,140	13.29
Livestock area	455	1.18
Residential area	408	1.05
Sum	**38,682**	**100**

Source: Forest Service of Thasos island 2012, Own processing

Chart 2. Land cover type allocation in Thasos island



Source: Forest Service of Thasos island 2012, Own processing

Initially, there is a database of 100 candidate points from which we should select the most efficient locations in terms of visibility. It should be emphasized the fact that we have excluded all candidate location below 300 meters on the grounds that in this geographic zone, any fire incident could become perceptible by the numerous people and/or tourists which reside or commute in these places. So, there are 55 candidate points left (after the exclusion of 0-300 meters geographic zone). The analysis is based on the analytic tool of *visibility*, which is located in the Spatial Analyst (Surface) toolbox. Following, we computed the visible and not visible area for each candidate point in relation to the relief of the island. In addition, we gave an extra parameter to our analysis, raising the observatory by 3 meters from the ground (*Observer offset*). The coordinate system used is the Greek Grid.

IV. RESULTS AND DISCUSSION

After implementing the above analytical procedures, we computed the visible area per candidate observatory. Table 3 (descending order of the variable "area") depicts the visibility potential for each observatory as well as their corresponding height. As we observe from the following table, the 7 most efficient observatories cover visible area more than 5,000 ha. The next 8 candidate observatories cover area from 4,000 to 5,000 ha, while the following 9 observatories cover area from 3,000 to 4,000 ha. The remaining 31 candidate positions are considered of lower effectiveness in terms of visibility, since they only cover area less than 3,000 ha.

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Table 3. Visibility potential and altitude of the observatories

Serial number	No. of observatory	Area (Ha)	Altitude (m)	Serial number	No. of observatory	Area (Ha)	Altitude (m)
1	7	**6708.8**	808	31	33	2828.8	370
2	1	**6584.9**	1075	32	42	2793.5	1079
3	15	**5863.8**	736	33	2	2789.4	1031
4	5	**5530.4**	857	34	40	2618.9	309
5	24	**5248.6**	811	35	55	2601.7	318
6	47	**5137.4**	595	36	46	2583	811
7	9	**5016.4**	303	37	49	2526	366
8	39	**4740**	1135	38	41	2258.5	726
9	51	**4531.2**	451	39	30	2237.9	445
10	48	4498.1	377	40	12	2236.6	437
11	19	4355.9	713	41	26	2137.9	462
12	37	4320.9	396	42	54	2134.1	448
13	43	4136.1	343	43	10	2075.6	359
14	45	4020.1	401	44	32	2059.8	1206
15	17	4011.2	1109	45	8	1741.2	564
16	38	3909.3	329	46	21	1552.9	581
17	28	3674.8	590	47	11	1545.6	336
18	53	3672.7	874	48	27	1505.7	398
19	34	3542.2	1029	49	50	1377.9	588
20	35	3365.4	374	50	52	1211.1	430
21	31	3263.5	568	51	16	1151.5	435
22	22	3245	744	52	29	992	394
23	3	3112.8	739	53	20	974.2	420
24	36	3097.5	1048	54	14	764.4	725
25	13	2994.4	417	55	23	647.1	453
26	6	2986.3	513				
27	18	2972	494				
28	44	2925	572				
29	25	2876.7	704				
30	4	2853.4	605				

Source: Hellenic Military Geographic Service 2012, Own processing

Map 2 presents the visibility potential of each observatory as they are located along the study area.

Map 2. Visibility potential of each observatory in Thasos island, Greece

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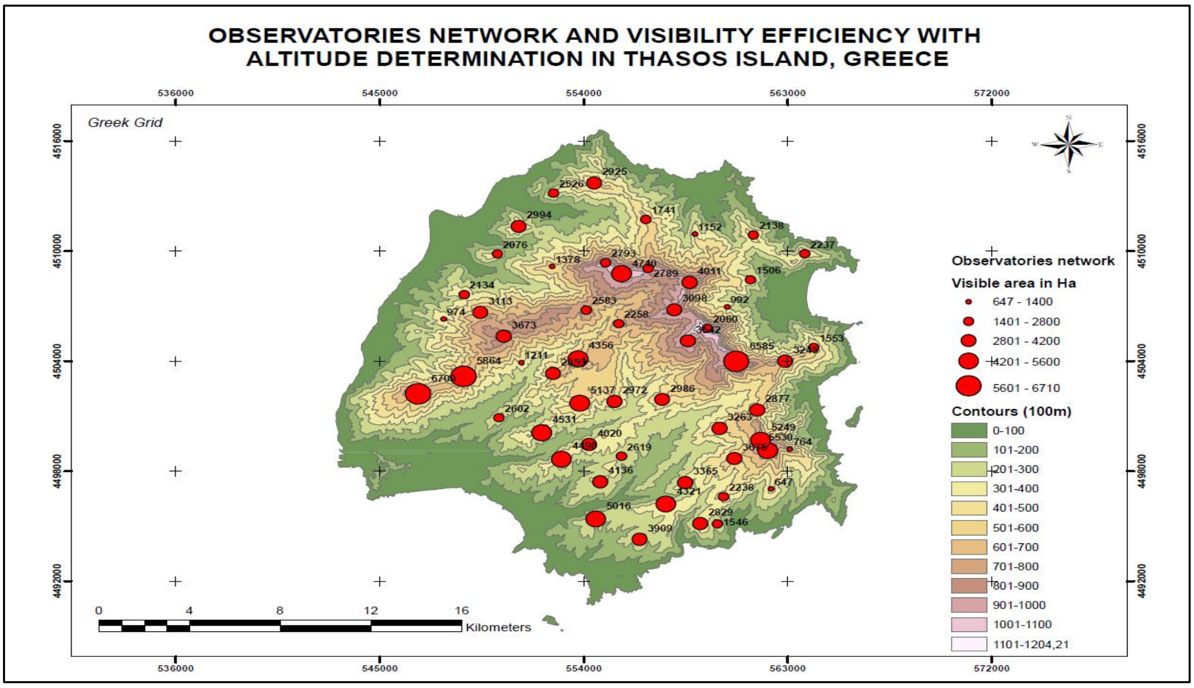

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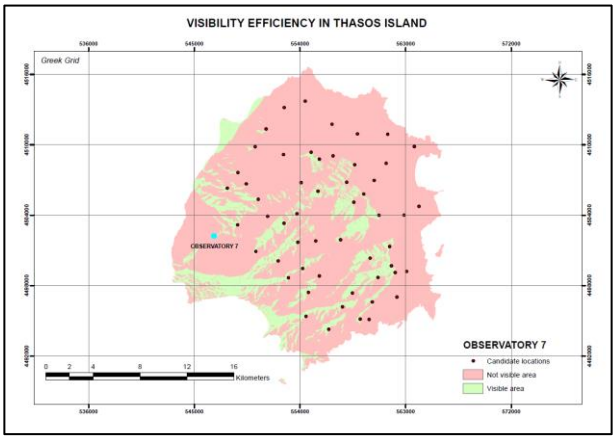
Table 2 and Map 2 present the general picture of visibility efficiency of all observatories in the island. Primary criteria for selecting the best positions for locating the permanent observatories is the functional efficiency in terms of visible area as well as the spatial optimization, so that we may avoid large degree of overlapping among the candidate observatories. We assume that the firefighting authority aims to locate the most efficient observatories, which means positions with total visible area more than 4,500 ha. Secondly, under these narrow financial circumstances, the involved authority targets to avoid overlapping among the candidate points. So, there are 9 candidate points which meet the first criterion, namely, they cover visible area more than 4,500 ha. Maps 3 to 11 show the visible and not visible area of the most efficient candidate points for establishing the required observatories. As previously mentioned, our target is to find the optimal locations for the establishment of observatories, taking into account the visibility efficiency in terms of visible area as well as the overlapping issues. The latter has its own value, since we will be able to exploit only the most efficient points with the least cost. Maps 3 to 11 present the visibility analysis for the locations at which the observatories cover visible area more than 4,500 ha. This amount of visibility is considered satisfying given the total area and the relief fluctuations of the island.

Map 3. Visibility efficiency for observatory no. 7



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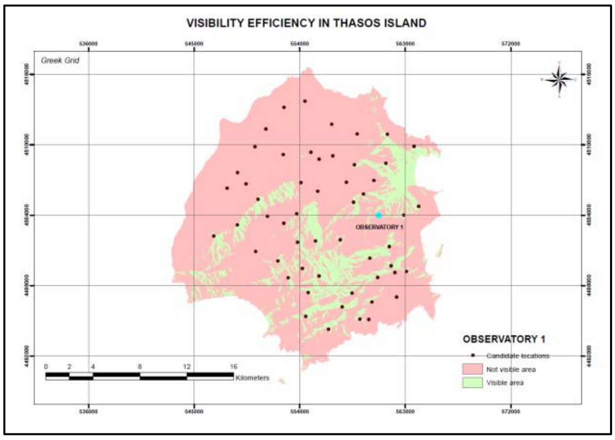
Map 4. Visibility efficiency for observatory no. 1



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Map 5. Visibility efficiency for observatory no. 15

Map 6. Visibility efficiency for observatory no. 5

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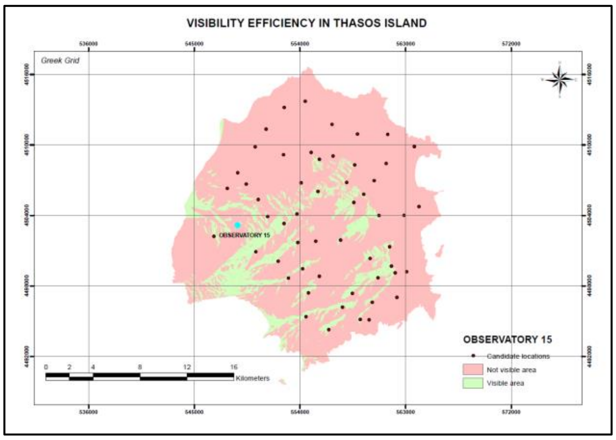

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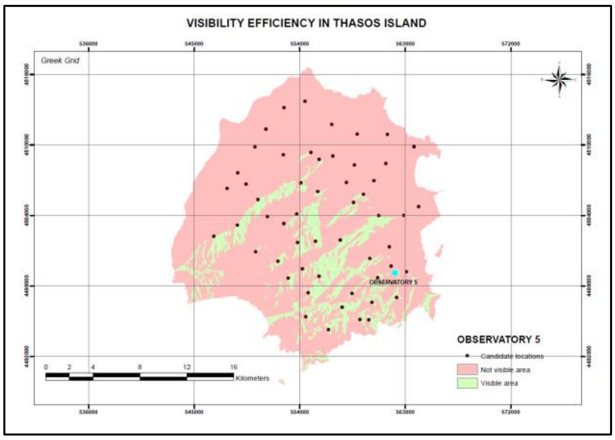

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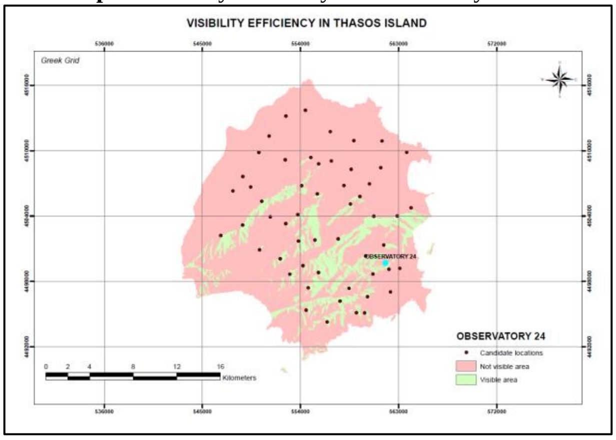
Map 7. Visibility efficiency for observatory no. 24



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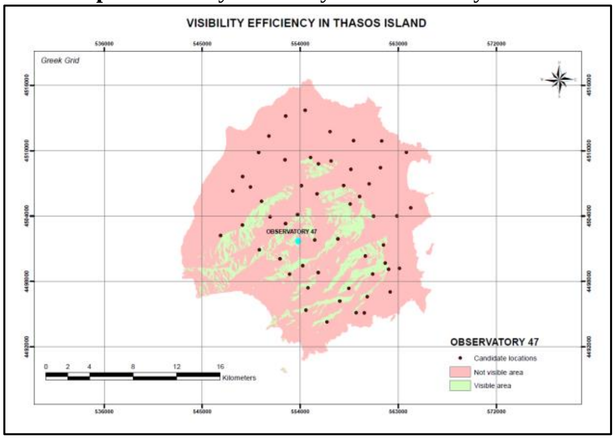
Map 8. Visibility efficiency for observatory no. 47



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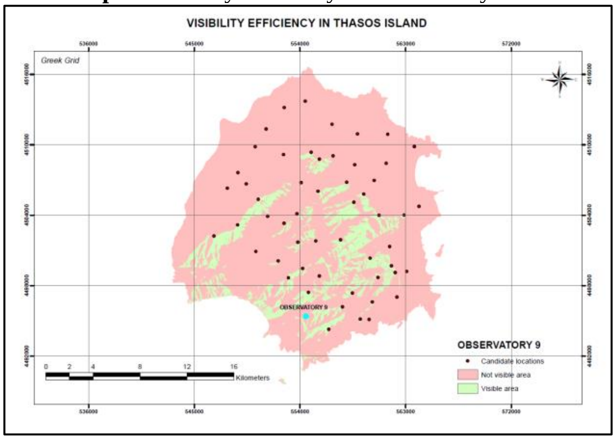
Map 9. Visibility efficiency for observatory no. 9



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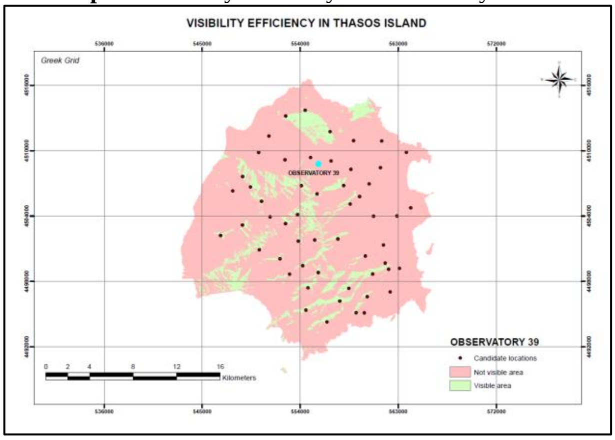
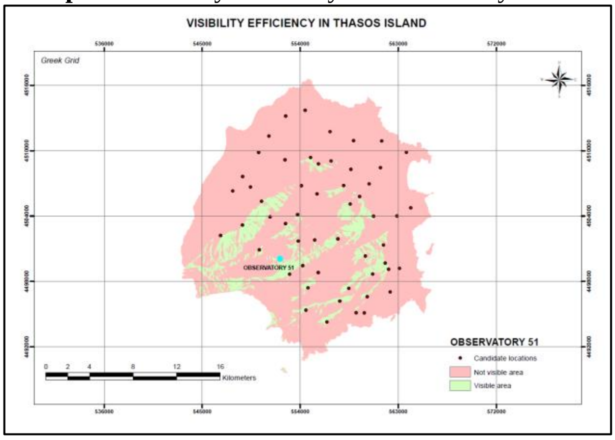
Map 10. Visibility efficiency for observatory no. 39



Source: Own processing

Map 11. Visibility efficiency for observatory no. 51



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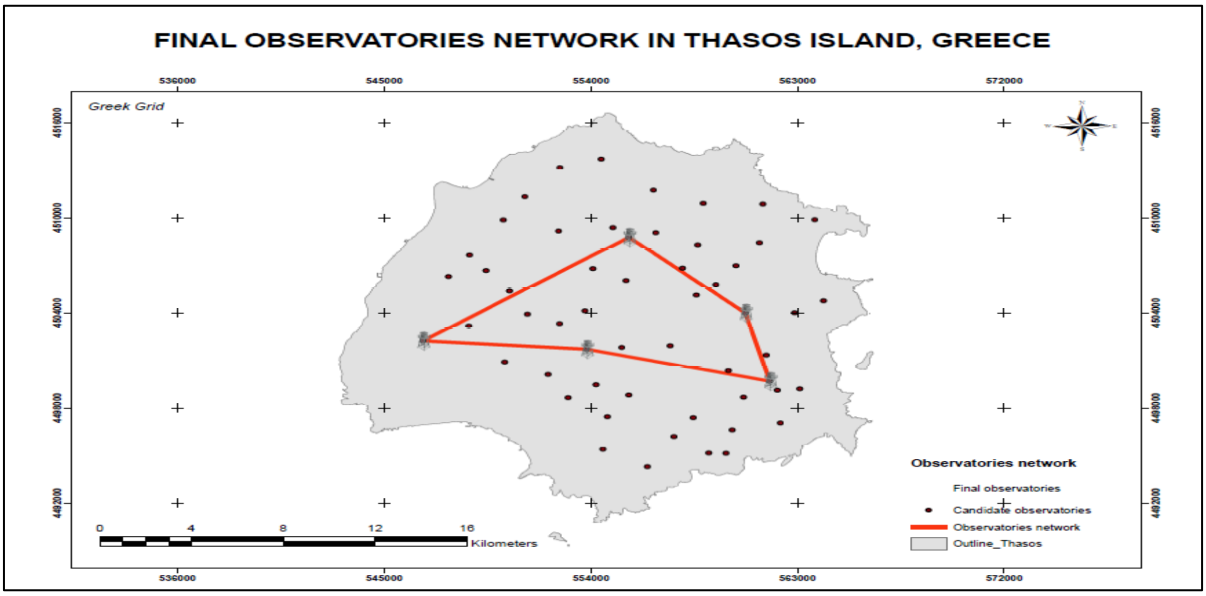
Source: Own processing

Through the comparative assessment of the above thematic maps, we observe that there is a significant degree of overlapping among several maps. Specifically, Map 15 is primary overlapped by Map7; Map 5 is basically overlapped by 24; Maps 9 and 51 are primary overlapped by Map 47. Hence, we decided to choose the most efficient locations in terms of visible area and less overlapping, namely, the observatories 7; 1; 24; 47; 39. In this stage, this selection meets the criteria of maximum visibility efficiency with the fewest candidate observatories in the study area. Map 12 shows the final selected observatories as well as the established observatories network. As it seems, there is a rational establishment of the observatories, meeting both the functional and spatial criteria at the same time, since the proposed network covers all the sides of the island. It should be outlined the fact that the final selected observatories do not have the highest altitude as someone would expect. This situation is due to intense relief fluctuations (topography) as previously emphasized.

Map 12. Final selected observatories and proposed observatories network



Source: Own processing

Finally, we should examine the relationship of final observatories network with the land cover types. Table 4 depicts the total land cover types area of the island as well as the land cover type covered by the proposed observatories network. As we may conclude from the figures of Table 4, establishing only 5 (the most efficient) observatories, we will be able to monitor approximately 42% of the entire study area and its corresponding land cover types.

Table 4. Land cover types covered by the proposed observatories network

Land cover type	Total land cover type		Land cover type covered by the proposed observatories network	
	Area [Ha]	Percentage [%]	Area [Ha]	Percentage [%]
Arid land	472	1.2	271.7	57.55
Agricultural area	7951	20.6	3,511.6	44.17
Forests	24,256	62.7	10,345.3	42.65
Shrubs	5,140	13.3	1,913.9	37.23
Livestock area	455	1.2	249.8	54.90
Residential area	408	1.1	175.1	42.92

Source: Forest Service of Thasos island 2012, Own processing

On the other hand, table 5 shows the individual visibility efficiency of each selected observatory in absolute and relative terms. Based on the Table 5, we observe that each and every observatory has a visibility potential which ranges from 10-20% for each land cover type. This range definitely relies on the location as well as the proximity and visual perspective of each observatory to the respective land cover type.

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Table 5. Individual visibility efficiency of each selected observatory

Land cover type	No. 7		No. 1		No. 24		No. 47		No. 39	
	Area [Ha]	Percentage [%]	Area [Ha]	Percentage [%]	Area [Ha]	Percentage [%]	Area [Ha]	Percentage [%]	Area [Ha]	Percentage [%]
Arid land	59.6	12.6	110.7	23.5	163.1	34.6	88.3	18.7	15.1	3.2
Agricultural area	1699.4	21.4	1317.4	16.6	576.1	7.2	621.7	7.8	895.6	11.3
Forests	3588.4	14.8	4226.9	17.4	3465.7	14.3	3596.8	14.8	3142.5	13.0
Shrubs	1044.3	20.3	690.9	13.4	742.2	14.4	660.8	12.9	450.6	8.8
Livestock area	66.7	14.7	61.2	13.4	170.4	37.5	61.3	13.5	26.2	5.8
Residential area	92.9	22.8	42.9	10.5	11.9	2.9	13.3	3.3	86.7	21.3

Source: Forest Service of Thasos island 2012, Own processing

Finally, according to the above analysis, the five most efficient observatories in terms of visibility and spatial terms have been selected. Certainly, the visibility potential could be increased if the firefighting authority decides to establish more than 5 observatories, which means demand of more financial resources. If so, similar analysis may be conducted, so that we may explore the remaining most efficient locations. Hence, fire detection may be strengthened and as result the valuable natural as well as cultural resources to be protected in a more comprehensive manner.

V. CONCLUSIONS

Primary aim of the paper is the immediate fire detection through establishing observatories across the entire area of a Greek island, Thasos. Vital objective is the selection of the most efficient observatories in terms of maximizing the visible area as well as the optimal location for avoiding significant degree of overlapping. According to the visibility analysis, the five most efficient observatories in terms of visible area and least degree of overlapping have been selected. In addition, establishing only 5 observatories, we will be able to monitor approximately 42% of the entire study area and its corresponding land cover types. Certainly, the visibility potential could be increased if the firefighting authority decides to establish more than 5 observatories, which means demand of more financial resources. This practice is quite applicable to any territory, adjusted to the local differences and peculiarities. The importance of such a project is prominent, while constitutes a project with great added value and the least cost. This project could be the first preventative measure which may be combined with other supporting activities such as the rational planning of forest road network and firebreaks (Majlingova 2012, Narayanaraj and Wimberly 2012, Oguz Coban and Eker 2010); projects regarding fuels treatment where necessary (Demir et al. 2009, Stergiadou et al. 2007); the optimal allocation of the firefighting forces and limitations of accessibility in critical and sensitive areas in the peak of summer season.

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