UTULITY OF GIS IN SEARCH AND RESCUE OPERATIONS

(CASE STUDY: KÜTAHYA-TAVŞANLI)

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ABSTRACT

The main purpose of search and rescue operations is making effective and efficient searches with the ultimate goal of saving lives in the determined area. Two key factors are important in these operations. The first is to determine and specify the incident area by shrinking it; since determining a smaller search area decreases the search time. Secondly, reaching this area in an optimal way, so that the search team will not loose time during the operations.

Use of Geographic Information Systems (GIS) assists search and rescue teams in favour of these two key factors. By using GIS techniques; firstly, probability maps, which show most probable locations containing the target, can be generated. Secondly, optimal routes to the search and rescue teams can be suggested. The case study is about a plane crash near Kütahya, Turkey which occurred in 2003.

Key words: Search and rescue, Geographic information systems (GIS), Plane crash, Kütahya, Turkey

1. Introduction

In any type of disaster, search and rescue (SAR) operations are vital but also time and source consuming operations. Thus, it is important to decrease the searching time to find the target while the survivor is still alive. This is especially important for plane crashes. A search operation is generally implemented in the following steps: determining the searching area, scanning the area by applying suitable search patterns and performing a quick search. In these operations, search team is obliged to know where the search should be started in the area and how to scan this area with their limited resources (Stone, 1979).

The first step in a methodological approach to search strategy in SAR operations is to establish an appropriate search area, or the total area to be investigated. The periphery of the search area is defined using confinement tactics based on the behaviour of the lost subject and good initial information. Search area may be redefined if the existing area has been searched to satisfaction with no success or as new information or clues become available (Frost, 1998).

On the 16th of January in 2003 a Turkish Air Force F-16 plane crashed near Tavşanlı, twenty kilometers south of Kütahya in Turkey. After the incident, Turkish authorities, both military and civilian, started a search and rescue operation immediately. However, wreckage of the plane could only be found on January 18, three days after the incident. When they reached the wreckage they found out that the pilot unfortunately was not alive. This crash is used as the case study for this research.

Finding target as early as possible is the most important part of search and rescue operations, therefore in this study, there are two main goals for searching the lost object to be found as soon as possible. The first one is to prepare a probability map, which shows the most probable locations of the target according to clues obtained from the area, people and also from historic data. The second one is to suggest an optimal search path (or paths) to the search team (or teams) to reach the lost object as soon as possible.

Last known coordinates (LKC) of the plane were the main clue for this study. There are some spatial clues such as primary and secondary roads, residential areas that are in the search area and also other clues regarding the airplane such as its speed, route and falling angle. According to these inputs, some interpretable graphical presentations like probability maps are generated by using GIS techniques to be used by the search teams so that they will waste less time and search efforts.

2. Study Area

The crash occurred near Tavşanlı, twenty kilometers south of Kütahya city in Turkey (Figure 1). After making a thorough study of the region some parts of the cities Kütahya, Bursa and Bilecik are included in the search area. According to last known position, speed and height of the plane, study area was determined as a region with a size of 20 * 20 km. The determined area was bounded by one primary road, a number of secondary roads, and contains a few small settlements. The region is mountaneous with a number of high hills. Most of the area has dense forest, and was covered by snow at the time. As it would be obvious, SAR operations are more diffucult to conduct in areas with changing topography, especially with steep slopes. Thus, such natural obstacles together with dense forest increase search time. For the present case, there was also a dense fog in the area at the crash time, which could be the reason for the crash.

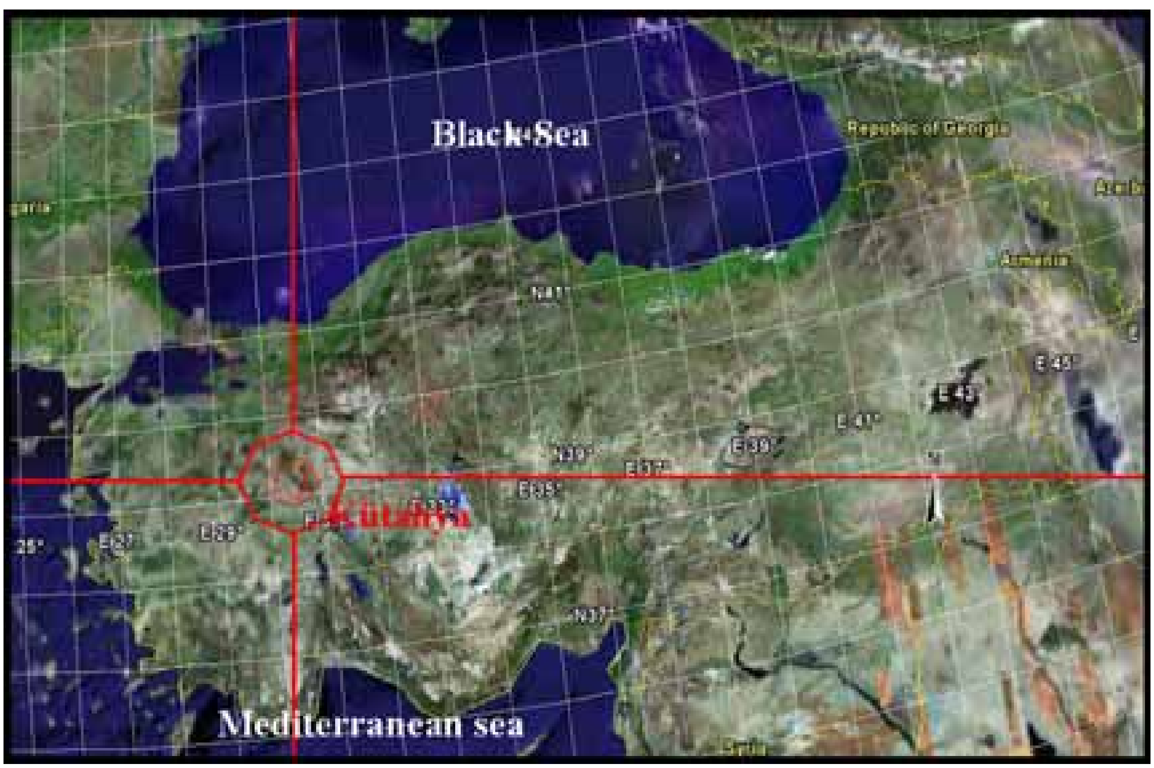

***Figure 1**: Location of project area in Turkey.*

3. Methodology

The methodology consists of three steps as shown in Figure 2.

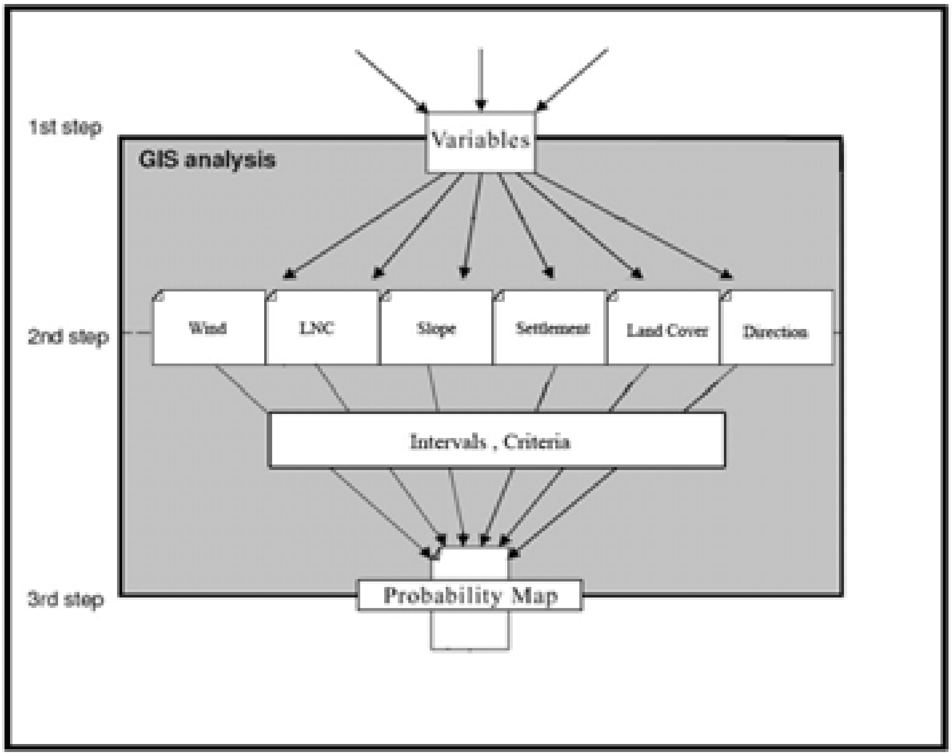

Figure 2: *Methodology steps*

First comes the identification of the main variables for probability map generation within the considered region, and the collection of their related data. This step is a function of available data, which would also affect the following steps and the result. For each variable, intervals that indicate the areas with small or large probability of containing the lost object are determined.

Second step is the preparation of GIS layers for the variables. The collected information were:

1. About the plane, its speed, route, height, and last known coordinates,
2. About the wind, its speed, and direction,
3. About the area, its roads, settlements, contour lines, and digital elevation map,
4. Description of the area, which is scaned by the search and rescue teams after the crash and location of this area on the map.

All the information are processed and put into GIS layers in such a way that they would help to indicate probable areas for the crash site.

Finally, prepared layers are overlayed into a resultant map. The sites not indicated as less probable in any of the layers are considered more probable areas for SAR operation in the resulting layer.

4. Analyses

4.1. Preparation of data layers

The collected data are entered into the GIS software in digital form to obtain necessary layers for the study. They are: contours lines of the region, settlements in the area, primary and secondary roads, flight direction and last known coordinates of the plane. Figures 1 and 2 show the topgraphic map and the digital elevation model of the area

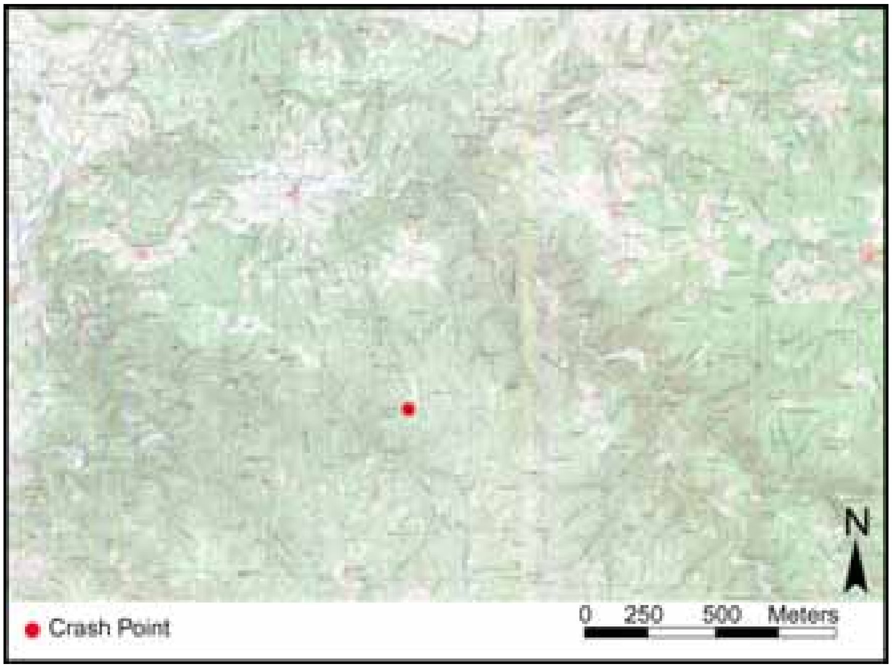

Figure 3*: Topographic map of the region*

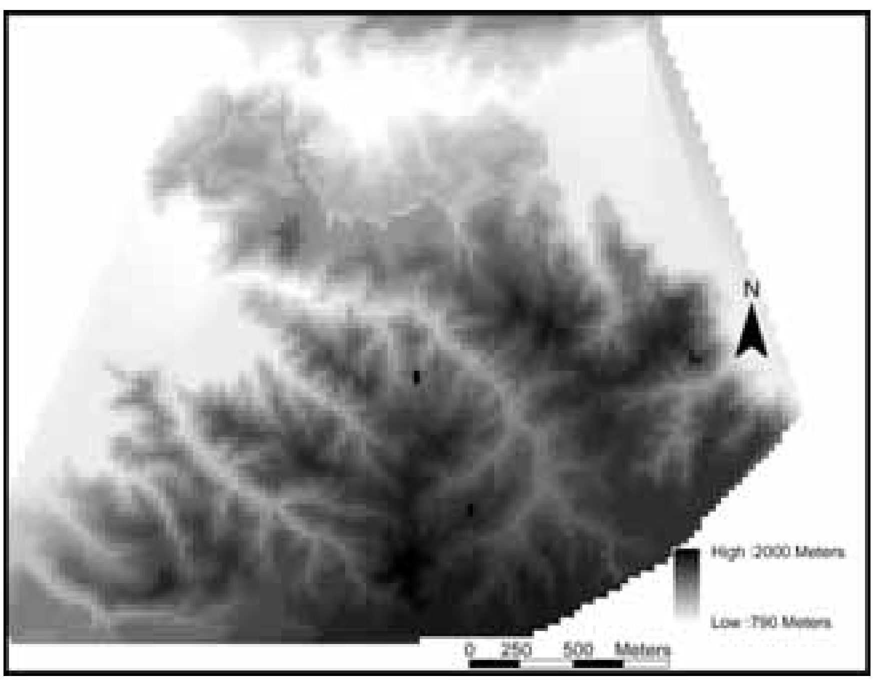

Figure 4*: Digital elevation model of the region*

4.2. Preparation of buffer layers

As explained before, in search and rescue operations the main issue is to prepare quick and reliable probability map. To optain this map a number of new GIS layers are determined using the previously prepared layers.

The last contact with the pilot of the plane indicated that, the height of the plane was 3600 km with a speed of 1000-1100 km/hr, and the coordinates were 39 39 652 N and 29 35 376 E. Around that point, circular areas are determined by taking continuing 10 degree angles with the vertical as shown in Figure 5, imitating the falling angle of the plane, and indicating the area it would be in.

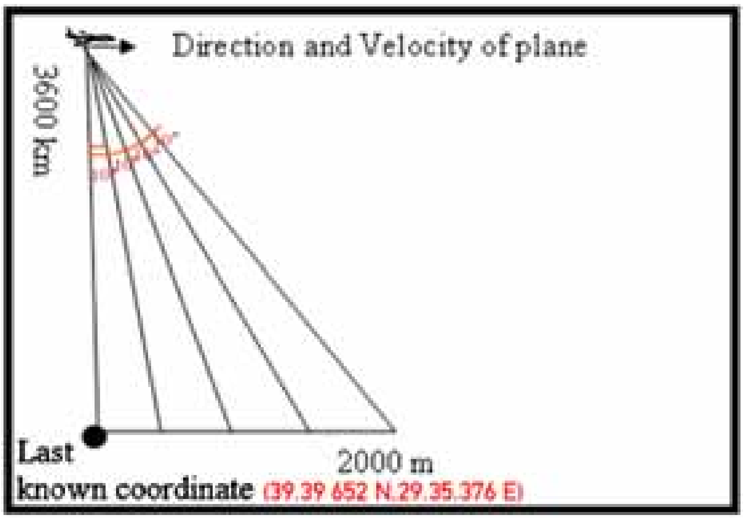

Figure 5: *Falling angle of plane*

As given in Figure 6 as draped on the topographic map of the region, these areas would indicate time buffer areas. The possible flight direction of the plane is also marked on the same figure. Using the result of the surveying analysis of the Turkish Air Force search and rescue teams in the crash site, and discussions with them, five circular areas (buffers, up to 50 degrees) are considered. It is assumed that, the probability of finding the wreckage decreases as the inclination angle increases.

According to the possible flight direction of the plane, another buffer map is generated. There are again 10 degrees between each buffer area around the flight direction. The most probable area, which is just around the flight direction, is shown as blue and least probable area is shown as purple as given in Figure 7.

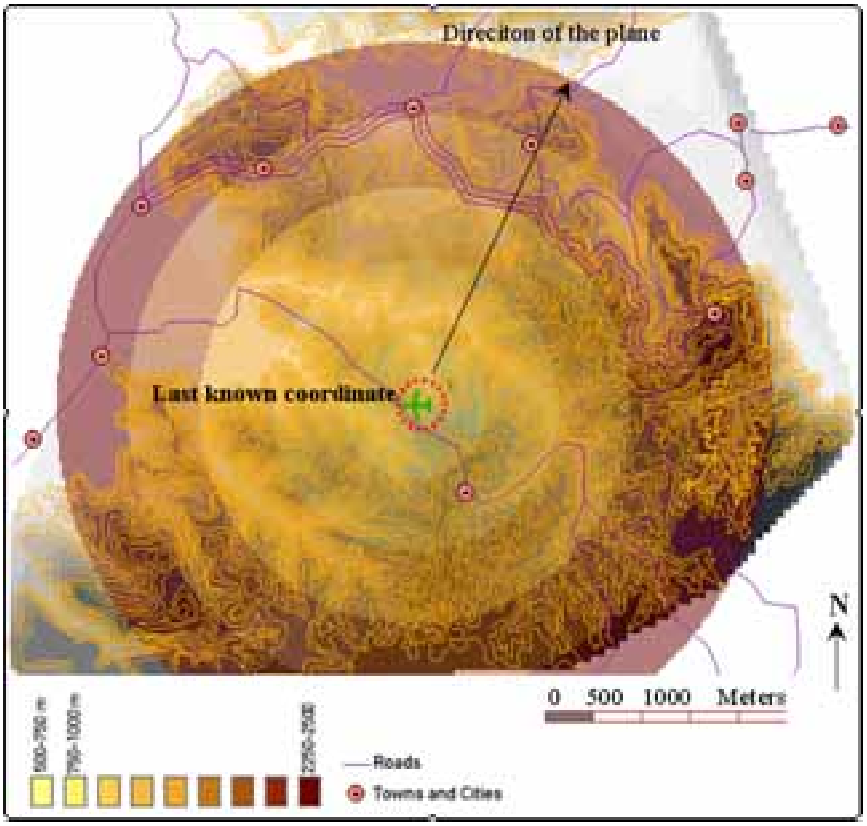

__Figure 6__: Buffers about last known position of the plane

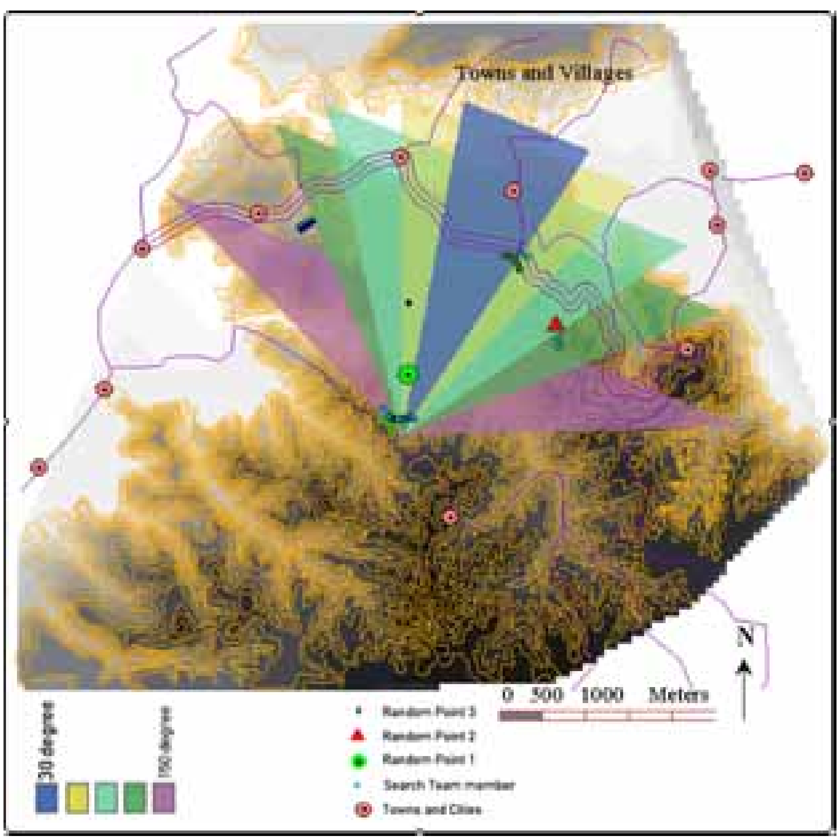

__Figure 7__: Buffer areas around the flight direction

The buffers around the roads and residential areas provide information about the probability of finding the wreckage of the plane. After the crash, it would have been seen immediately if it occurred in or near the city centers or on the roads. Since it was not the case it is accepted that the probability of finding the target increases as moving away from the city centers and the roads. Buffer widths are accepted as 250 meters for residential areas and as 50 meters for primary and secondary roads, as shown in Figure 8.

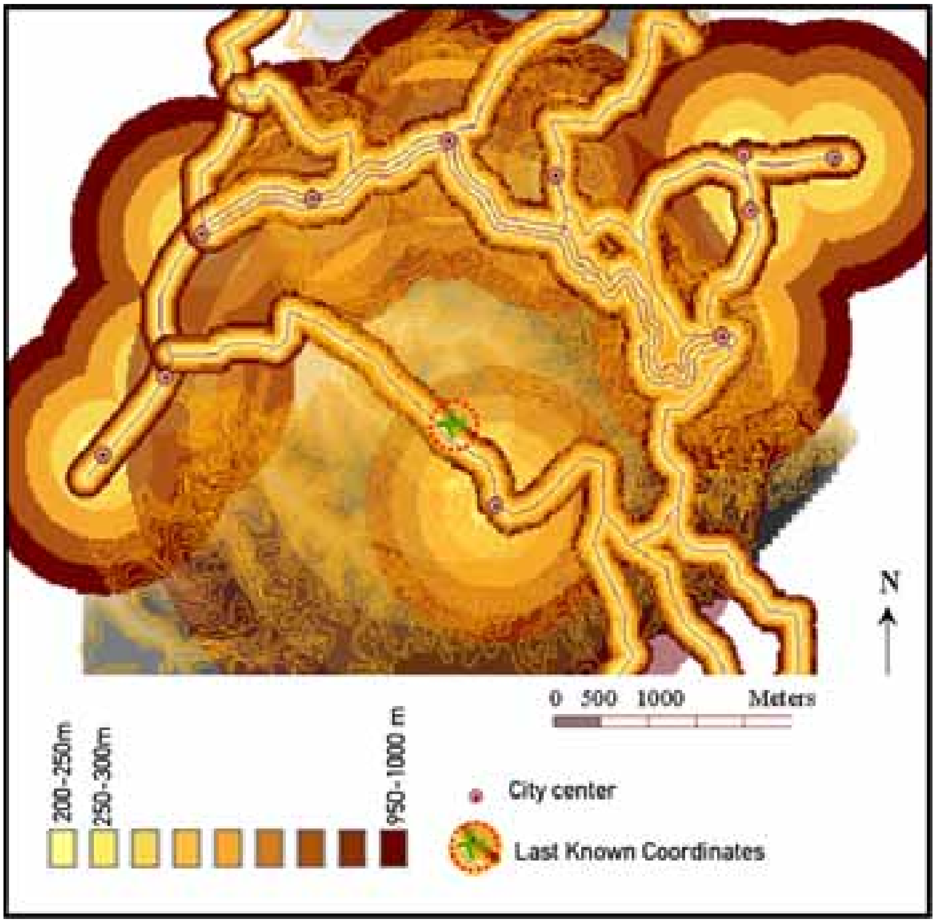

Figure 8: *Buffers around the roads, and towns*

4.3 Reclassification of buffer layers

After buffer analyses, the prepared layers are reclassified by giving class values to each buffer area according to the determined criteria, and rasterized layers are obtained. For example, the probability of target being in the related area increases gradually in every 250 meter while moving away from the city center up to 1000 m. These buffer areas are given class values as 1, 2, 3 and 4 respectively. If there is no data, it is shown with zero.

As mentioned above, similar buffer areas are determined around the roads with 50 m widths. This layer is also reclassified and rasterized with class values of 1, 2, 3 and 4 respectively.

The probability of target being in an area decreases gradually in every 500 meter while moving away from the last known position coordinates up to 2500 m. Those areas are given class values as 1, 2, 3, 4 and 5 respectively. Figure 9 shows last known position of plane and buffers around it.

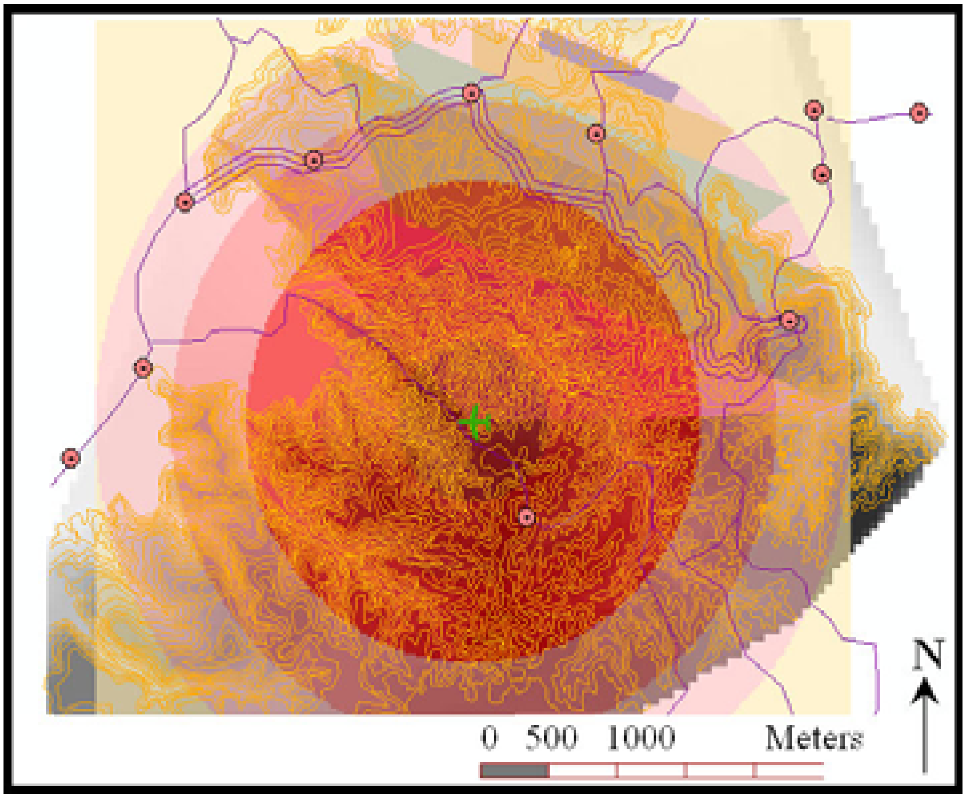

***Figure 9**: Buffers around last known position*

4.4. Obtaining probability map

As shown in Figure 10, a probability map is generated by using four GIS layers with the buffers around cities, roads, last known position, and direction of plane. While generating this map the probabilities are summed in the positive way to determine the most likely areas containing the wreckage. The area with the highest probability is contained within the very small light area in the center of the map, but the surrounding area still has considerable probability to have the plane, due to intersection of some layers as a result of raster calculation.

To clarify strengths and weaknesses of the different layers, Multi Criteria Decision Analysis (MCDA) was used. Not only the different buffer areas in the layers, but also the layers themselves have different weights according to their importance. In this study, the importance of layers is determined by subjective judgment. Five classes are considered, namely; most important, medium important, important, less important and least important.

4.5 Determination of optimal routes

According to probability map (Figure 10), the most probable area is seen as the white region at the center of the area. However this area is still a very large area, about 9 km^2, for search and rescue teams. To have probable routes for the search teams, three random points are attained in the area with the help of random number generator software. Hence the probabilities of these points are the same. These hypothetical points were thought as crash points. After locating those points in the area, the three search teams are placed in the area close to the roads that bound the most probable area found in the previous step.

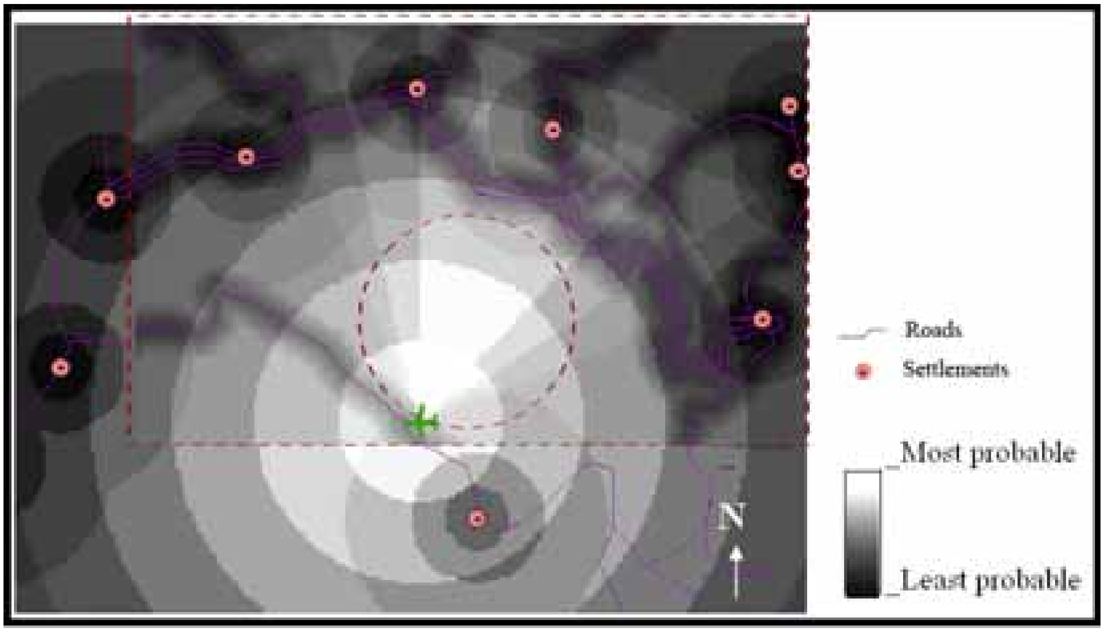

Figure 10: *Resulting probability map*

According to consequent probability map and locations of the search teams, paths are defined with the help of cost weighted spatial analysis tool of software. These paths, shown as green lines in Figure 11, are the proposed optimal routes for search teams. Density (width) of these green lines is related to the number of search team members. If a search team is crowded, then the density of its green path is larger than that of the small search teams.

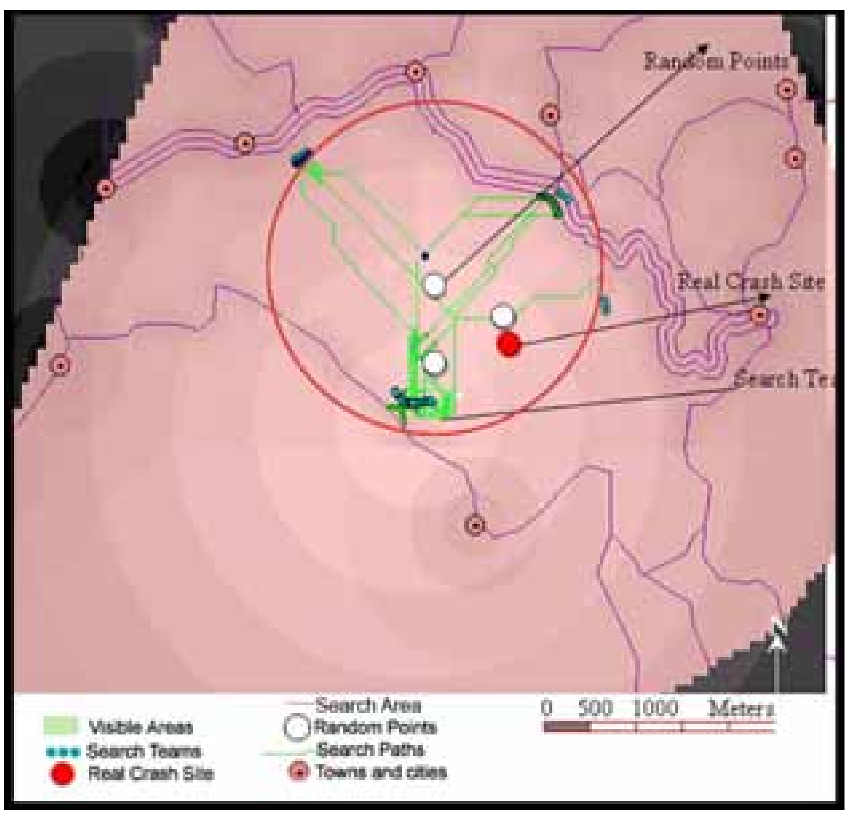

Figure 11*: Routes suggested to search teams.*

4.6. Visibility analysis

The next step is visibility of the random points from the view of search team members. A separate visibility layer is prepared for each search team. After determining visibility of each random point, they are combined with the help of raster calculator to obtain the visibility of all three points. This resulting map (Figure 12) shows visibility of random points from the green paths. Result of the present visibility analysis does not include poor weather conditions because of lack of proper information at the crash time.

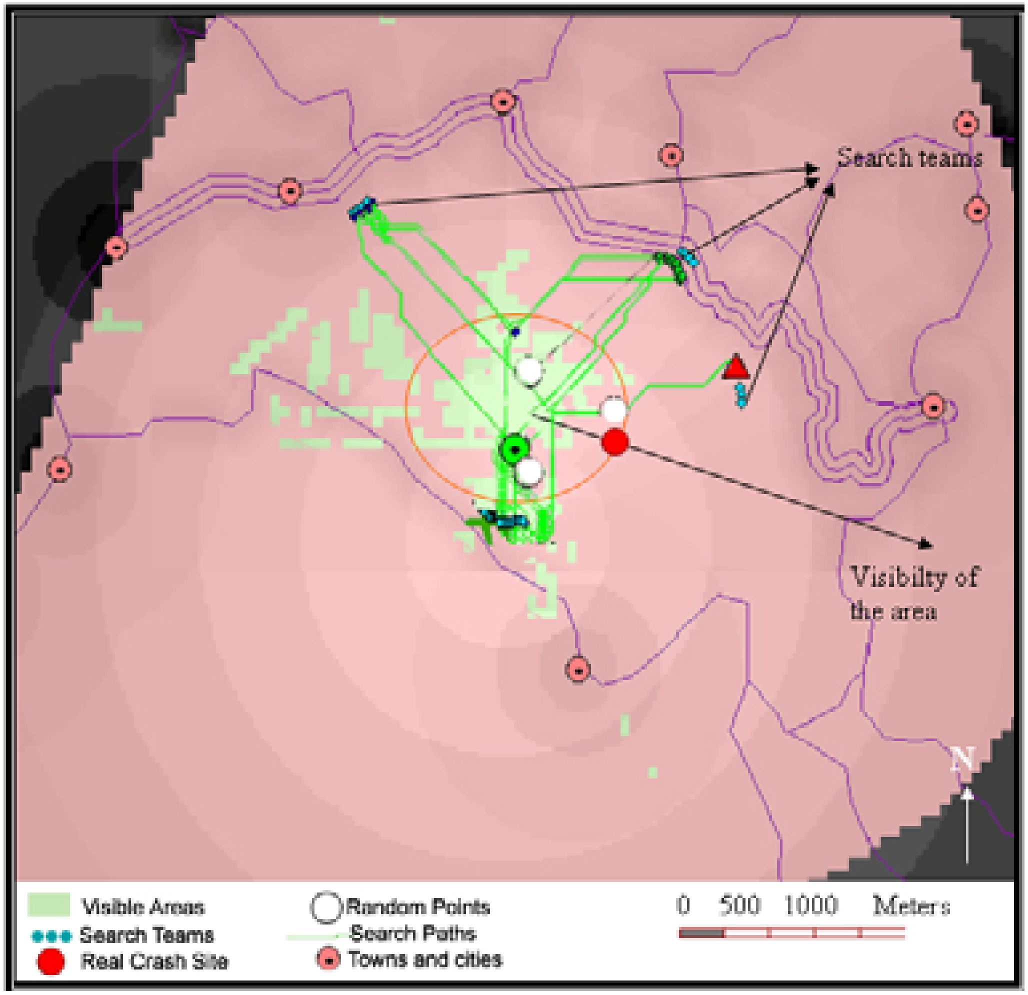

***Figure 12**: Resulting visibility map and location of search teams*

5. Results and Conclusion

In this study, the location of crash site of an F-16 plane near Kütahya is tried to be found. After determining the probability map containing the most probable position of the target in the first step, optimal sweep paths are also obtained and suggested to the search teams. Lastly, visibility maps of the probable area were generated from the locations of search team members.

At the beginning of this study it was assumed that the exact crash coordinates were not known. There were only some clues about last known coordinates of the plane. However according to the result of the analyses; the obtained search area is found to be very near to actual crash site. That is; wreckage of the plane was within the boundary of defined scanning area, and one of the suggested routes was passing near that location.

While working on this study it is realised that GIS techniques are very helpful in this type of work, and the results are obtained very quickly, which is vital for SAR operations. It can then be concluded that, results of such analyses can help to decrease search time and reduce search efforts.

References

Stone, L. D. 1979, Search Theory and Applications, NATO Scientific affairs division pp (79-80).

Frost, J. 1998, The Theory of Search A Simplified Explanation, Report by Soza & Company Ltd.and Office of Search and Rescue US Coast Guard.

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