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An Alternative Method for Long-Term Land Cover Change Detection: A Case Study of Hasanlar Dam

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Abstract

Dams which needed to drinking and irrigation water supply, flood control etc. at first have undertaken an another task with hydroelectric power which emerged from the increasing energy demand due to population growth, technological developments and changes in consumption habits in recent years. This process has accelerated from the 1980s which was the beginning of the increasing trends in renewable energy sources due to the environmental impacts of fossil fuels. However, even though dam type hydroelectric power plant project is a renewable energy, it has some adverse effects on ecosystems. The changing flow regime with the intervention to the river generally results in destruction and fragmentation in the riparian ecosystem. This change in the land cover can lead to modification on the microclimate, thus it can change the hydrological cycle of the basin. For this reason, the monitoring of the change in the land cover at the dam and its surroundings is important for revealing the effects of the project. In this context the Hasanlar Dam in Düzce province was examined in the scope of this study. The land cover change has been determined in two temporal periods through 1:25000 scale topographic maps date on 1960, 1982 and 2013. The land cover which is consist of 4 classes was obtained by visual classification method. The amount of change was determined as the unit by grid method. It was observed that forest areas showed a decreasing tendency after the dam construction during the first temporal period but an increase was shown later. On the other hand it has been determined that non-vegetated areas are transformed into orchard predominantly. As a result, it has been seen that the proposed method can provide an effective analysis for the land cover change detection when old dated aerial photos or satellite images can not be reached.

Key words

Land cover change, Dam, Hydroelectric power plant, Hasanlar Dam

1. INTRODUCTION

In our day, the development and conservation of water resources have become one of the most important parameters of their modernity beside influencing the development of countries [1]. In this context, the concept of sustainability comes to the forefront in the projects that countries implement for the utilization of water resources. Among these projects, dam projects have an important share.

It is seen that the first samples of dams were constructed for agricultural irrigation, drinking water supply and flood control. However, when it came out that the controlled water can be an energy source when released, the dams gained another function [2]. Although there are different methods that do not require a dam crest to obtain energy from the river, this discovery of humans has played a role in the increase of dam projects. This method, called hydroelectric, which works by the principle of converting the potential energy of water flowing from the highs through the turbines and generators to electric energy, is preferable as it is a cleaner and renewable resource compared to fossil fuels [3], [4]. Such that; the report by The World Commission on Dams, published in 2000, shows the extent of intervention in streams in a rational sense. In the report, it is stated that in European Union countries and United States, 60-65% of rivers were controlled, although it differs by the basin, whereas in Asia, the number of rivers taken under control by more than one large-scale dam was well below half the total number of rivers [5].

Although the dam projects have an important place in development, they have some adverse effects on ecosystems. The results of studies in developed countries in the northern hemisphere show that river regulation is the most powerful and common anthropogenic impact on the riverine ecosystem [6]. These adverse effects can be seen in the short or long term and can be grouped as effects on aquatic ecosystems, fauna, and flora. Depending on the changing regime of flow; the changing habitat areas in the river due to the blocking of sediment transport [4], blocking of the transport of nutrients required for aquatic life [4], defects in some vital activities (determination of migration time etc.) of living beings due to the regime of flow [7], declining water quality resulting from eutrophication starting with transition to stagnant water [7] and changing bottom structure [8] are examples of the effects on aquatic ecosystems. In other words, the changing flow regime generally results in the destruction and fragmentation of the riverine ecosystem [9]. In terms of fauna, prevention of the passage of fish species moving between the lower and upper parts of the river seems to be an important impact value [8]. The adverse effects on the flora becomes visible in a much shorter period in the construction phase. For example; the dust created by the construction work sticks on leaves and decreases the light transmittance, thus, affects the photosynthesis and slows the growth rate of the plant [10]. In the long term, the evaporation increases together with the dam reservoir formed and therefore some climatic effects occur. The humidity in the air increases, the air movement change, and the temperature, wind, and precipitation become different. This creates a sudden change in the natural vegetation in the region, and only species that can adapt to this change can survive [7]. In the light of this information, it understood that the change in land cover is inevitable as a result of the intervention to nature through the dam projects. In fact, in the change of microclimate and land cover, there is a bi-directional setup that affects both. In other words, the change in land cover can lead to modification of the microclimate, thus, change the hydrological cycle of the basin [11]. As a result, changing land cover also affects other landscape functions. For example; the infiltration capacity of the area varies due to changing land cover, and it changes surface flow dynamics [12]. In this context, land cover change analysis can be an effective method in order to interpret long-term environmental effects of dam projects.

Nowadays, satellite images are mostly preferred as a data set in land cover change analysis. The most important reason for this preference is that the reflection values processed on the raster data can be classified by different methods in line with their closeness to each other. Since the archival images are free of charge and easy to reach, the images by Landsat satellites are frequently preferred, however, these records also do not cover the data of pre-1970s. This is the greatest constraint on the use of satellite images in long-term analyzes. For this reason, it is aimed to develop an alternative method that can be used in the analysis of land cover change, especially when there is no effective data such as the satellite image for past. In addition, the effects of the dam project and the findings obtained with this alternative method applied in Hasanlar Dam in Düzce province were interpreted.

2. MATERIAL AND METHOD

Hasanlar Dam and HEPP (Hydroelectric Power Plant) located in Düzce province were determined as study area (Figure 1). The construction of the dam on the Küçük Melen stream, located between the Düzce and Yığılca districts, was started in 1965 [13]. The maximum water level of the dam is 271.30 m. and the crest elevation is 70.80 m. [14].

Materials used within the scope of this study are:

- Topographic maps numbered G26b1 of 1960, 1982 and 2013, provided in raster format by General Command of Mapping,
- ArcGIS 10.2, a GIS (Geographical Information System) based software used for digitizing topographic maps, storing and mapping all data, and analyzing,
- Literature review regarding the field of study and the subject,
- Interviews with officials and local people made during the area survey.

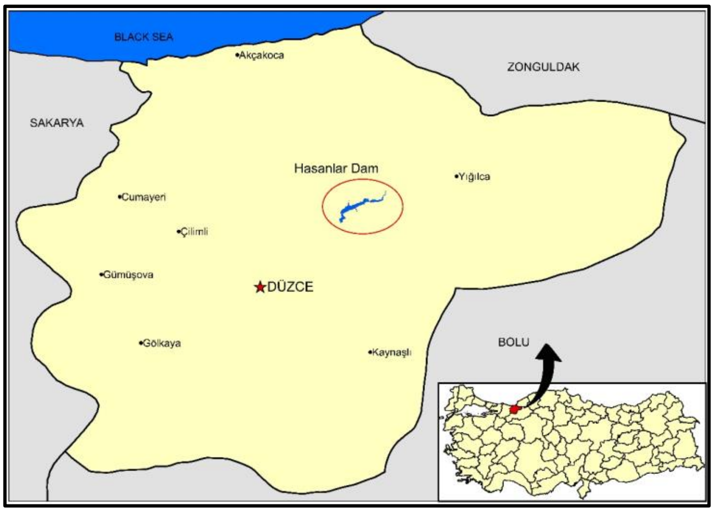


Figure 1. The location of study area

During the literature review, the largest damages and land cover changes by the dam projects were found out to be in the riverine ecosystem. For this reason, when determining the boundaries of the study area, it was meant to determine the ecological border closest to the shore line. In this context, the "direct drainage area" defined by Zielenski (2002) [15] was accepted as the boundary. The direct drainage area defines areas that are wedge-shaped on both sides of the main stream following the determination of the basin boundaries of the side streams, which has more than two branches, connected to the main stream, and which do not belong to any sub-basin boundary. These areas are not included in the sub-basin boundaries as they consist of the aspects which directly faced to the main stream. In other words, the surface flow in these areas is directed to the main stream. Zielenski argues that these areas have a sub-basin character when evaluated together. The boundaries of the study area are shown in Figure 2 starting from this point of view.

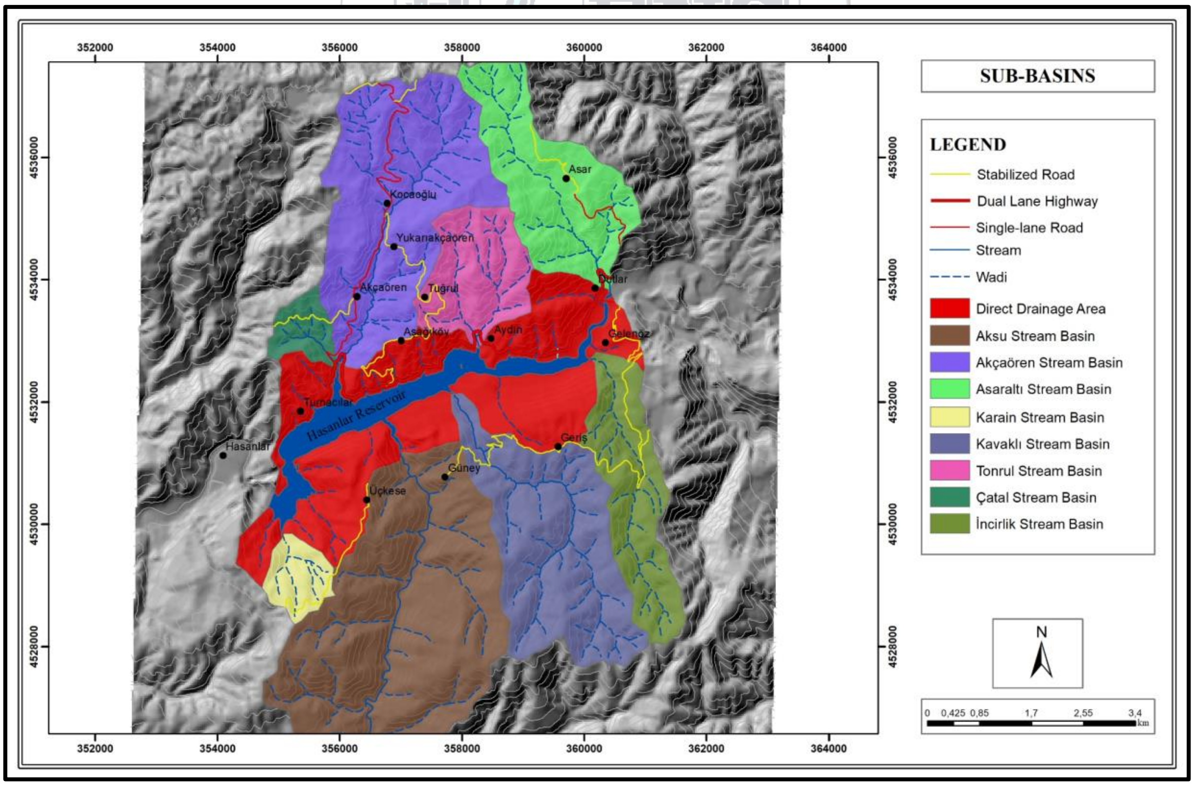


Figure 2. Direct drainage area for Hasanlar reservoir

In the mapping of the land cover for the relevant years, four classes were used in the study due to the limited information contained in the 1:25000 scale topographic maps. These are; forest, orchard, water surface, and non-vegetated area. In order to be able to perform the change analysis, the vector data required were obtained by manual on-screen digitization of the topographical maps. However, in this method, the digitization is followed by a grid method in order to eliminate the user-related differences. In this context, the area was divided into 250x250 m. flags (each square= 6.25 ha) and a land cover class was assigned for each square (Figure 3). Thus, the size of the change was not area-based but unit-based. The determination of the land cover is considered as a process consisting of two stages. In the first stage; it is aimed to determine whether the relevant square belongs only to aquatic or terrestrial ecosystems. For this purpose, the class which was bigger was assigned. Thus, the grids forming the surface of the water were identified and the only thing left was the reclassification of the terrestrial ecosystem, which contains the forests, orchards, and non-vegetated areas classes. In the second stage, this process was carried out by applying the same method. Since there were two classes in the first stage, the area that holds 50% of the overall size was looked for to make the assignment, whereas, in the second stage there were three classes, therefore the area with the largest size was assigned directly.

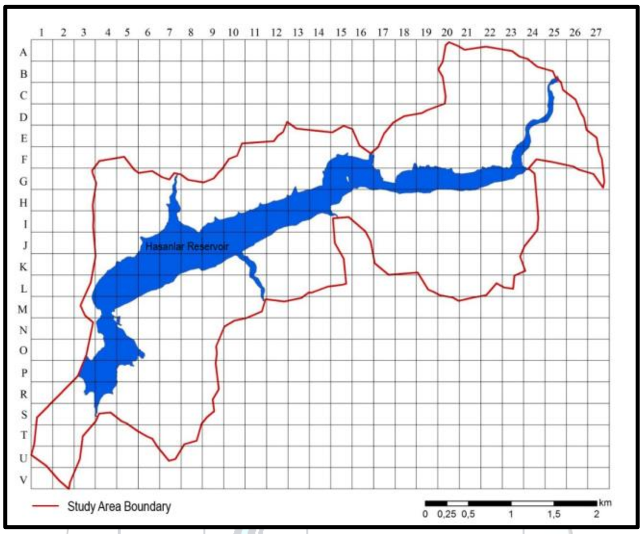


Figure 3. Applying grid method to the study area

An analysis of change in land cover was periodically examined as a 53-year process between 1960-1982 and 1982-2013, then between 1960 and 2013, which would most commonly reflect the change.

3. RESULTS

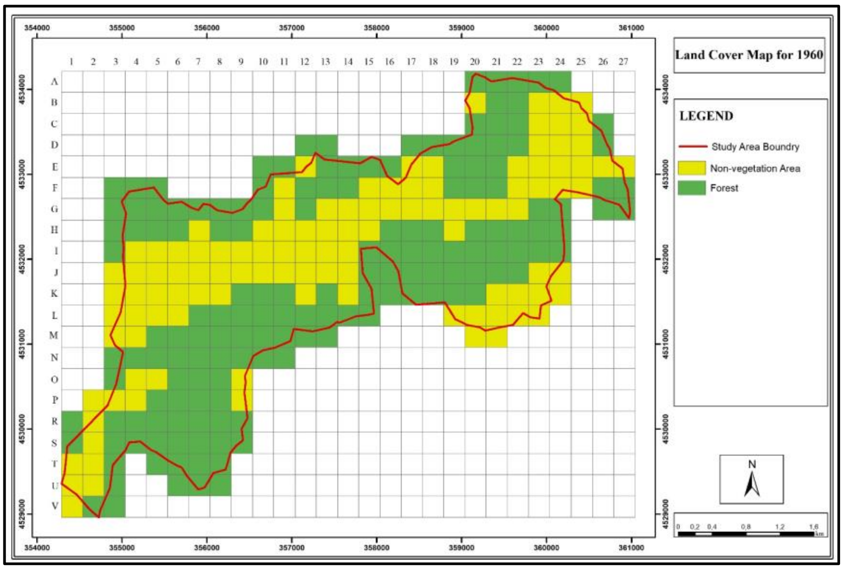
The area size distributions of the land cover structure for the related years, which were formed by applying the method, are shown in Table 1. There are only two classes that consist of forest and non-vegetated area in the 1960 land cover, which is a date before the start of the dam construction. In the 1982 land cover, even though it has a very small percentage with 2% the orchards have been seen and so four classes have presence at the area. It appears that four classes retain their existence in 2013 which is the latest land cover. On the other hand, the spatial distributions of the land cover classes are shown in Figure 4 which contains the maps by the years.

Table 1. The area size distributions of the land cover classes by the years

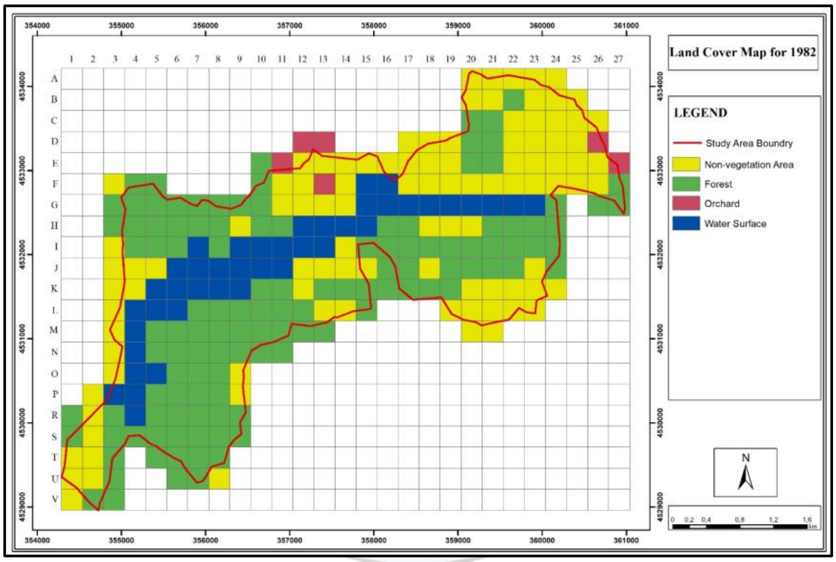
Land Cover Based On the Years (Unit/Percentage)	**Forest**	**Orchard**	**Non-vegetated Area**	**Water Surface**
1960	159 / 59%	-	111 / 41%	-
1982	122 / 45%	6 / 2%	101 / 38%	41 / 15%
2013	140 / 52%	67 /25%	22 / 8%	41 / 15%

3.1. Land Cover Change Analysis in 1960-1982 Period

It can be seen from the matrix in the Table 2 that the reservoir observed with 41 units was formed in the year 1982 by transforming 37 units from the non-vegetated area and 4 units from the forest. Forest areas lost 37 units, despite gaining 9 units from the non-vegetated area. The losing of 28 units on the forest class is remarkable. In addition, the orchards started to be seen at the area with a small area size like 6 units by transforming 5 units from the forest and 1 unit from the non-vegetated area at the end of this temporal period. The spatial distributions of the changes in the period are shown in Figure 5.



(a)



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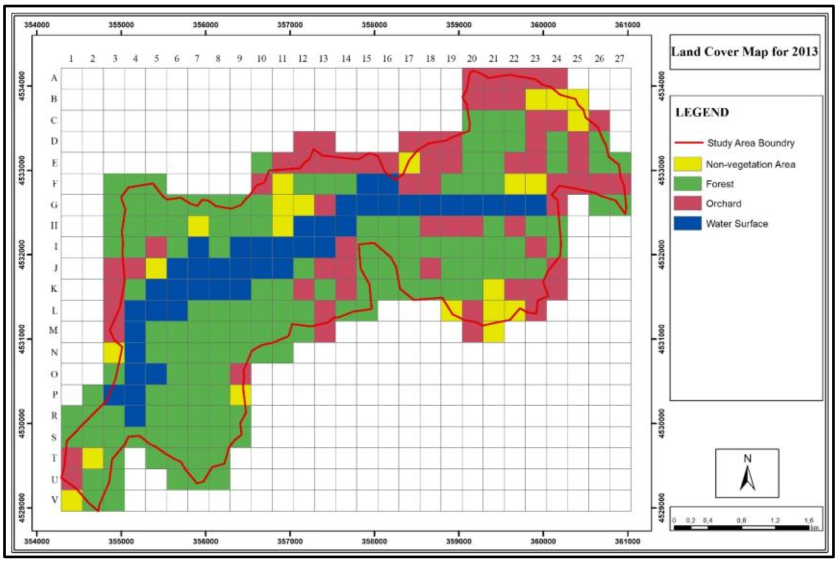

(c)

Figure 4. Land cover maps by the years a)1960, b)1982, c)2013

Table 2. The area size change of the land cover classes in 1960-1982 period

Changes in 1960-1982 (by Units)	**Forest**	**Orchard**	**Non-vegetated Area**	**Water Surface**	**The situation of 1960**
Forest	113	5	37	4	159
Orchard	-	-	-	-	-
Non-vegetated Area	9	1	64	37	111
Water Surface	-	-	-	-	-
The situation of 1982	122	6	101	41	**Total**:270

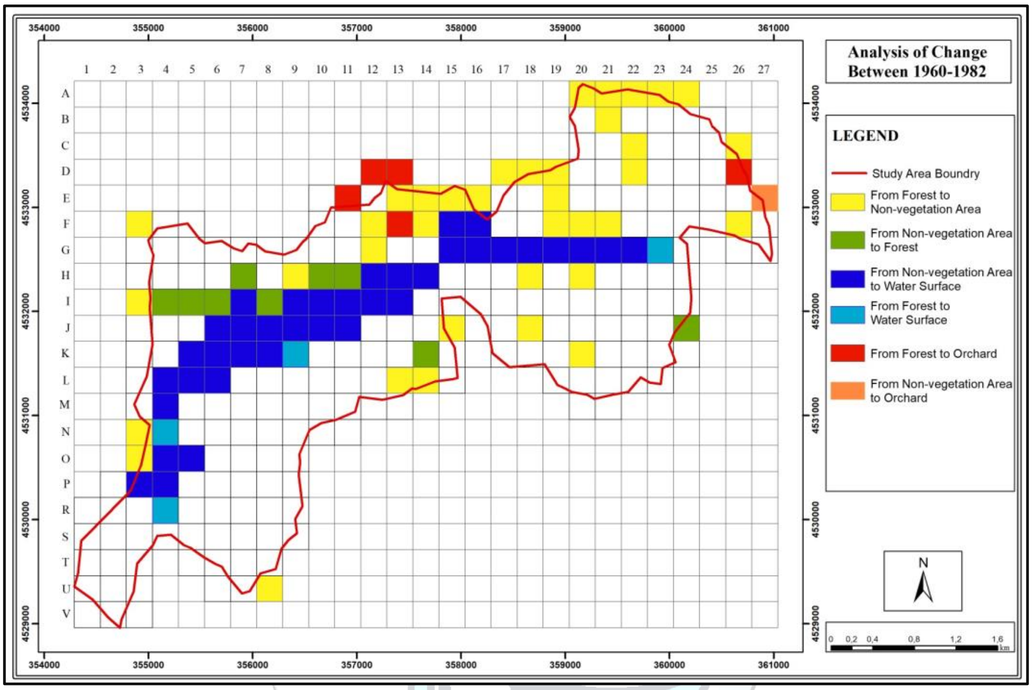

Figure 5. The units which show a change in 1960-1982 period

3.2. Land Cover Change Analysis in 1982-2013 Period

It has been determined that the non-vegetated areas rapidly transformed into forest and orchard areas in this temporal period. Only 22 units of non-vegetated area has been left by 2013. Besides the orchards reached 67 units by gaining 54 units from non-vegetated areas (Table 3). The spatial distributions of the changes in the period are shown in Figure 6.

Table 3. The area size change of the land cover classes in 1982-2013 period

Changes in 1982-2013 (by Units)	**Forest**	**Orchard**	**Non-vegetated Area**	**Water Surface**	**The situation of 1982**
Forest	110	10	2	-	122
Orchard	3	3	-	-	6
Non-vegetated Area	27	54	20	-	101
Water Surface	-	-	-	41	41
The situation of 2013	140	67	22	41	**Total**:270

3.3. Land Cover Change Analysis in 1960-2013 Period

This is the longest period analyzed in the frame of data at the study. Therefore, analyzing the period demonstrates the most general change between the land cover classes. It is almost impossible not to focus on non-vegetated areas in this analysis. 37 units of this class have been submerged, 37 units have turned into orchard and 17 units have gained forestry qualities (Table 4). The spatial distributions of the changes in the period are shown in Figure 7.

Table 4. The area size change of the land cover classes in 1960-2013 period

Changes in 1960-2013 (by Units)	**Forest**	**Orchard**	**Non-vegetated Area**	**Water Surface**	**The situation of 1960**
Forest	123	30	2	4	159
Orchard	-	-	-	-	-
Non-vegetated Area	17	37	20	37	111
Water Surface	-	-	-	-	-
The situation of 2013	140	67	22	41	**Total**:270

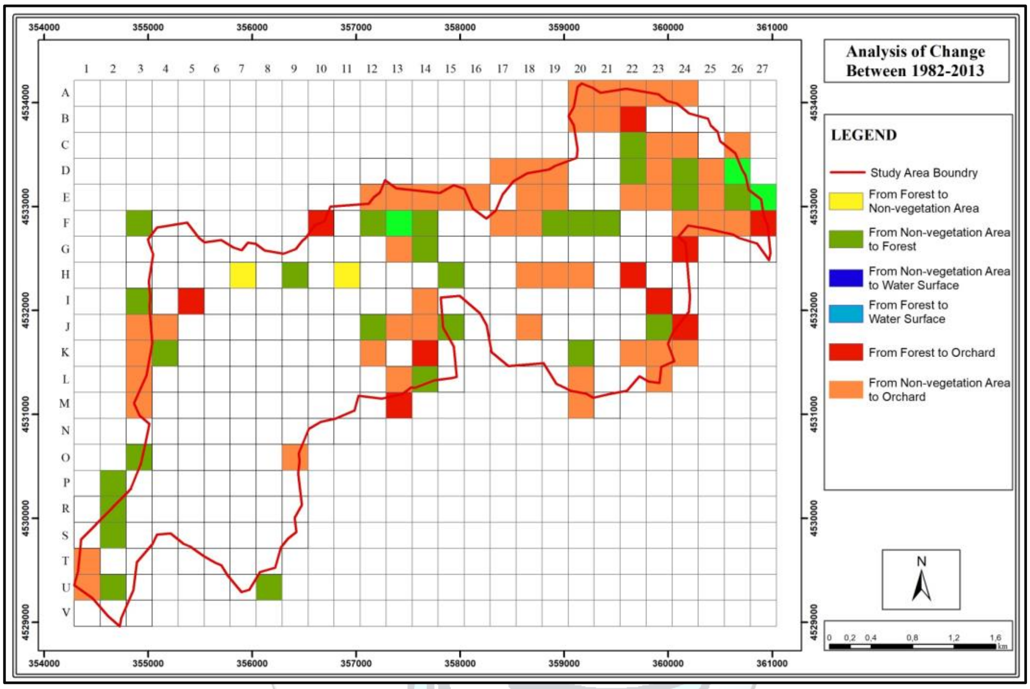

Figure 6. The units which show a change in 1982-2013 period

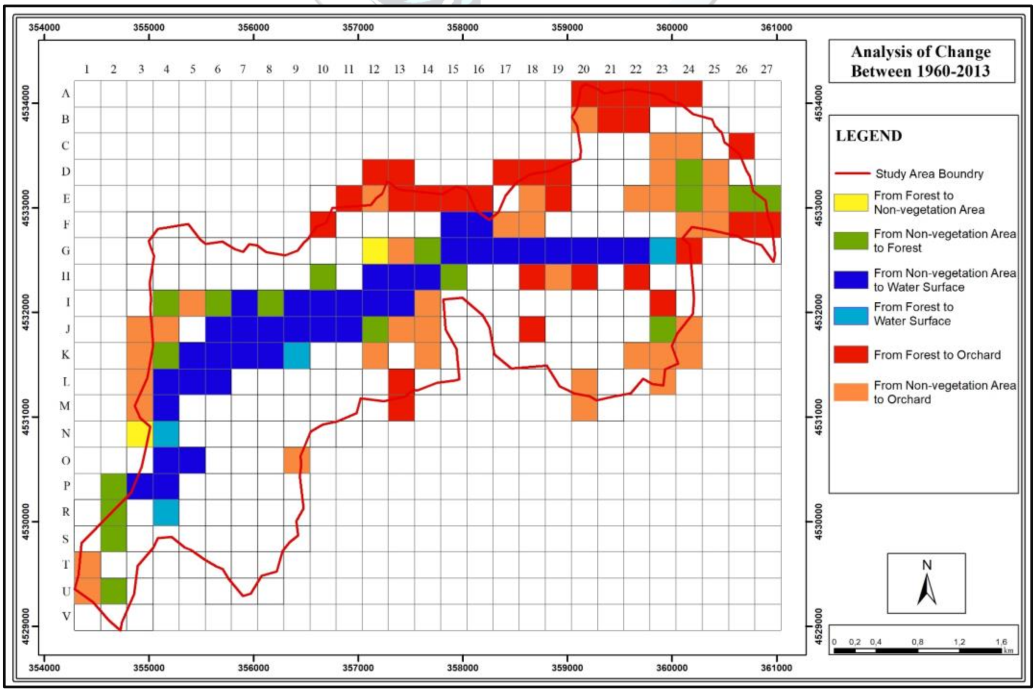

Figure 7. The units which show a change in 1960-2013 period

4. DISCUSSION AND CONCLUSION

Although it has some weaknesses, the method that been proposed in this study has an efficient use in order to monitor the temporal land cover change in general terms. As the study area expands, this efficiency increases. The method is likely to provide a good alternative when old dated aerial photos or satellite images can not be reached. The weaknesses of the method can be summarized as follows:

- Enable to create a limited number of classes
- Having low sensivity with regards to the size of changing areas

On the other hand, assessment of the environmental impacts of the Hasanlar Dam by interpreting the results is another output of the study. Interpretations in this context are as follows:

- The changes in the forest and non-vegetated area indicate the modification of microclimate in the study area with the reservoir.
- Increasing rapidly orchard areas which were not found before the dam construction, is an indirect anthropogenic effect of the dam project. Because, the changing climate conditions have become suitable for orchards and transportation to irrigation water has become easier.

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