CHAPTER 7

DISCUSSION

The aim of this chapter is to endure step by step through the landslide assessment procedures while evaluating the possible errors and their reasons. Furthermore, a comprehensive flowchart will be produced while discussing and evaluating these stages.

7.1. Data Production

In harmony with the purpose and scope of the project three data domains were used to generate the needed data. These domains are remote sensing, topographical maps and existing geological maps.

The working size of the pixels for all of the products are selected as 25 by 25 meters. By rule of thumb, 1 map millimeter equivalent of the base map is adequate. Finer resolution would yield in larger errors as the locations of the pixels would be suspicious, moreover, the products other than topographic map should have to be resampled rigorously.

The first step through any hazard assessment scheme is the evaluation of current situation and preferably having information about the past states of the hazard. In order to achieve this goal, remote sensing technology is used, unless there are no archive information and no monitoring stations.

The spatial resolution of the satellite images is becoming as good as comparable to the aerial photographs, however, the prices of the same resolution satellite products are incomparable to conventional aerial photographs. The aerial photographs are still the cheapest solution, in addition the military bloom of the cold war resulted in presence of at least one full coverage of the country almost in all nations across the world, which are hosting the true and non speculative information about the past situation of the hazards. On the other hand, the presence of distortions in the aerial photographs makes the information extraction stage quite painful, as the interpretation should have to be transformed into plain cartographic coordinates. Recent developments in the computer based photogrammetry reduce the time required for these transformations but requires another investment item through the institute's budget. Nevertheless, with the aid of these systems the horizon of the researchers would be quite broadened as they will be able to derive the topographical and morphological decision rules of the period at which the aerial photographs are taken.

In this research, the spatial positions of the landslides in 4 different periods were extracted from the aerial photographs and cordially transformed into base maps manually (Figure 7.1). The interpretation is acquainted with a photo checklist regarding the observable characteristics of the landslides. This checklist in the further stages would be converted to a database attached to every single landslide.

This base map transformation, when done by experienced interpreters, is quite comparable with the results obtained from digital products. Yet, the manual transformation is always remaining as a large debate over one of the principal inputs of the hazard assessment procedures. This transformation inherits a minor subjectivity to the system depending on the experience of the interpreter.

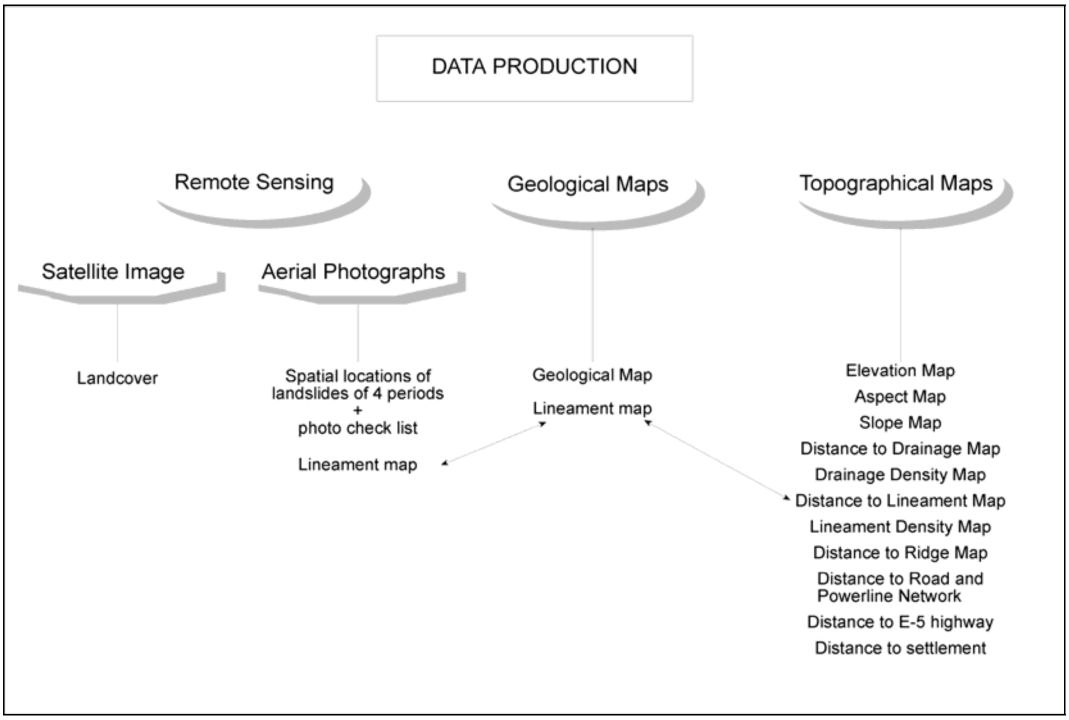

Figure 7.1. The elements of data production stage.

Though the aerial photographs are considered as the most capable and cheapest item within the remote sensing products, the great spectral resolution of satellite products still have superiority over the panchromatic aerial photographs.

However, their restricted superiority also restricts their usages as they could now only be used for land cover extraction or for gathering regional geological information. The new trends of researches point out that probably within a decade the prices of the satellite and historical aerial photographs would equalize. Furthermore, the researches in active sensors (radar systems) and laser-dominated systems (Lidar) are flourishing, which are promising activities for the next decade beyond the hazard assessment point of view. Landsat TM 5, due to its spectral superiority and price advantage, is used to extract the land cover information in Asarsuyu catchment, which would be treated as a parameter map in further stages (Figure 7.1).

The second and the most speculative domain is the geological map domain, as the maps have been prepared for general geological needs without considering the special needs of the hazard assessment procedures. Further groupings regarding the material are made rather than its stratigraphic content and age. These maps were compiled from existing literature, so coordinate mismatches and information inadequacies are frequent in the published maps. These geological unit mismatches also inherits a speculative perspective to the map prepared which is also dependent on the experience of the geologist. The lack of coordinate system in the compilation map creates a positional error, which should be eliminated by further resampling of the geological maps. Consequently the lineament information has same deficiencies, as though it was both compiled from existing maps and refined after aerial photographical interpretation (Figure 7.1)

The third and relatively the least speculative domain is the topographical map domain, assuming that there are not any errors present in the elevation information. In this thesis 11 variables out of 13 variables are derived from topographical maps (Table 5.16). The morphology, and infrastructure information are all derivatives from these topographical maps (Figure 7.1). The topographical maps have minimal processing errors as they have been digitized from the hardcopy templates by the Mapping Headquarters. The nature of the information present in the topographical maps generally consisted of vector coverages, as the representations of contour lines in point, line or polygon form. This form is not the most suitable form to be used in a GIS, yet it has to be converted into continuous maps. When the vector data has z attributes (topographical contours), this conversion is achieved through gridding operations. On the other hand if the vector object has no z attributes (infrastructure information), either the density of the feature or the nearest distance of the pixels to that feature is calculated to form a continuous map. A new approach is taken in this thesis, as taking the true distances to the objects rather than taking the map distances, which inturn duplicates the importance of the accuracy of the elevation model, as true distance is the function of DEM (Figure 4.5).

In order to achieve standardization, through the three domains, all of the maps were resampled by using a reference raster as the DEM. This resampling is vital to fix the extents and the centers of the pixels.

The products of aerial photograph and geological map domains have quite large subjectivities, when created by novice users, which should then have to be treated very carefully. The topographic map domain remains more objective than the others, as the errors might rise only from mechanical procedures, which could be validated more easily without thematic information about the maps.

Although the sequences presented here is quite objective the data domain and data type selection is still dependent on the available data and also dependent on the experience of the user, in which the assumption is that the selected maps will represent adequately the sliding conditions. Extreme caution should be applied in data set selection in order not produce redundant information. Although the distance to drainage and drainage density pair and distance to fault and fault density pairs seems to create duplicate information, they do possess different information. Distance to drainage maps are controlling the chance of any stream to erode the toe part of the landslide, while the drainage density yields in hydrological properties of the lithologies. Similarly the distance to fault map has information about the seismic activity and if not sealed would yield in increase in surface water with springs, while the fault density is a direct representation of how crushed the rock units are in the area. As noted above maps like distance to n^{th} Strahler order, or distance to epicenters are not used in order not to create redundant data sets and they are still not dependable as the errors in the epicenter locations are far beyond the resolution of such studies.

7.2. Data evaluation

The maps produced include the information of a particular parameter considering whole of the study area. The whole area is needed to be subdivided as the decision rules should have to be created from the landslide related pixels. In order to quantitatively discriminate the regions, a point mesh structure is laid over the region. The landslide polygons are cropped out and the nodes are stored in “slided mass” database with parameter map information.

A new approach is followed in the generation of decision rules of landsliding mechanism, as it is believed that the best undisturbed morphological conditions (conditions before landslide occurs) would be achieved by adding a buffer zone to the crown and side areas. These buffer areas are then extracted from the point mesh and the parameter map information is transformed. The resulted spreadsheet is converted into a database, which is named as “seed cells”. The information in this database is used to create the decision rules (Figure 7.2).

The databases depending on “slided mass” are evaluated in Chapter 5. They are used to characterize the landslides and to figure out the after-slide morphology. Furthermore, the investigation of size and shape changes through 4 periods resulted in quite large contributions for the reasons of failure. On the other hand the “seed cell” database is used to create decision rules about sliding, as it reflects the most likely pre-sliding conditions.

The data mining results of both the “slided mass” database and the “seed cells” database are presented in detail in Chapter 5, hence only important issues will be raised here.

After the examination of 4 periods of polystats, fuzzystats and photo-characteristics (photo checklist) database (Figure 7.3), it is found that by using these three databases only very broad conclusions could have been achieved. Such as, the removal or change of land cover and construction of significant engineering structures. Among these databases the photo-characteristics database is found to be the most useful one, unless there are different types of landslides in the project area. Unlike to the literature (Carrara and Merenda, 1974; van Westen, 1993; Soeters and van Westen, 1996), it should have to be stressed that the single use of any of these databases would neither result in any factual conclusion about the events going on in the geomorphological history of the area nor would characterize the landslides.

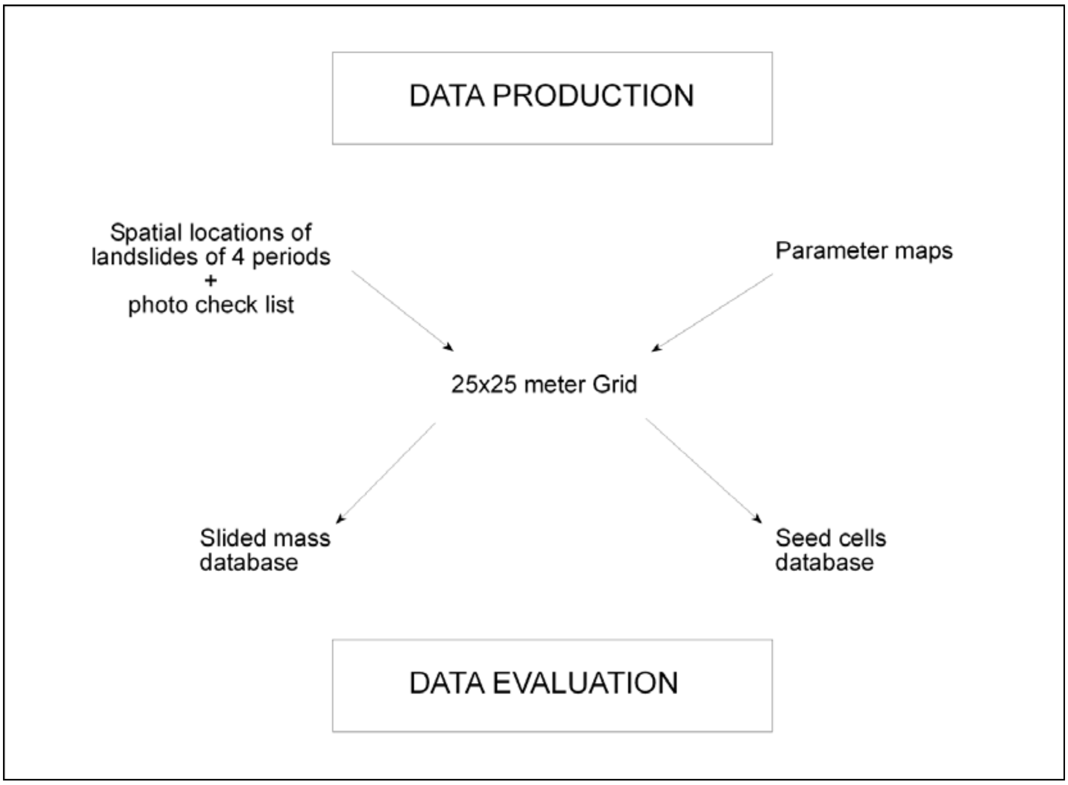

Figure 7.2. Snapshot methodology for information transformation.

The examination of the parameter distributions of “seed cell” database resulted in some conclusions about the contributions of every single parameter to the landsliding phenomena and /or the preferences of landslides on parameters. Other contributors in literature such as Lessing et al. (1983); Turrini and Visintainer (1998); Gupta and Joshi (1990), Carrara et.al (1991), Pachauri and Pant (1992); van Westen (1993), Chung et al. (1995), Soeters and van Westen (1996), Gupta and Anbalagan, (1997) and Guzzetti et al. (1999) tried to solve this parameter contributons by generalizing the whole event such as, getting averages parameters in slope facets or creating unique condition areas or creating dummy variables. However, none of these proposed methodologies are applicable to individual pixel analyses; furthermore, no factual reason is valid to generalize and to degrade the resolution of adequately detailed data. Although seed cells let the user to upgrade the analyses to individual pixels, the interactions of parameter maps could not still be explored efficiently.

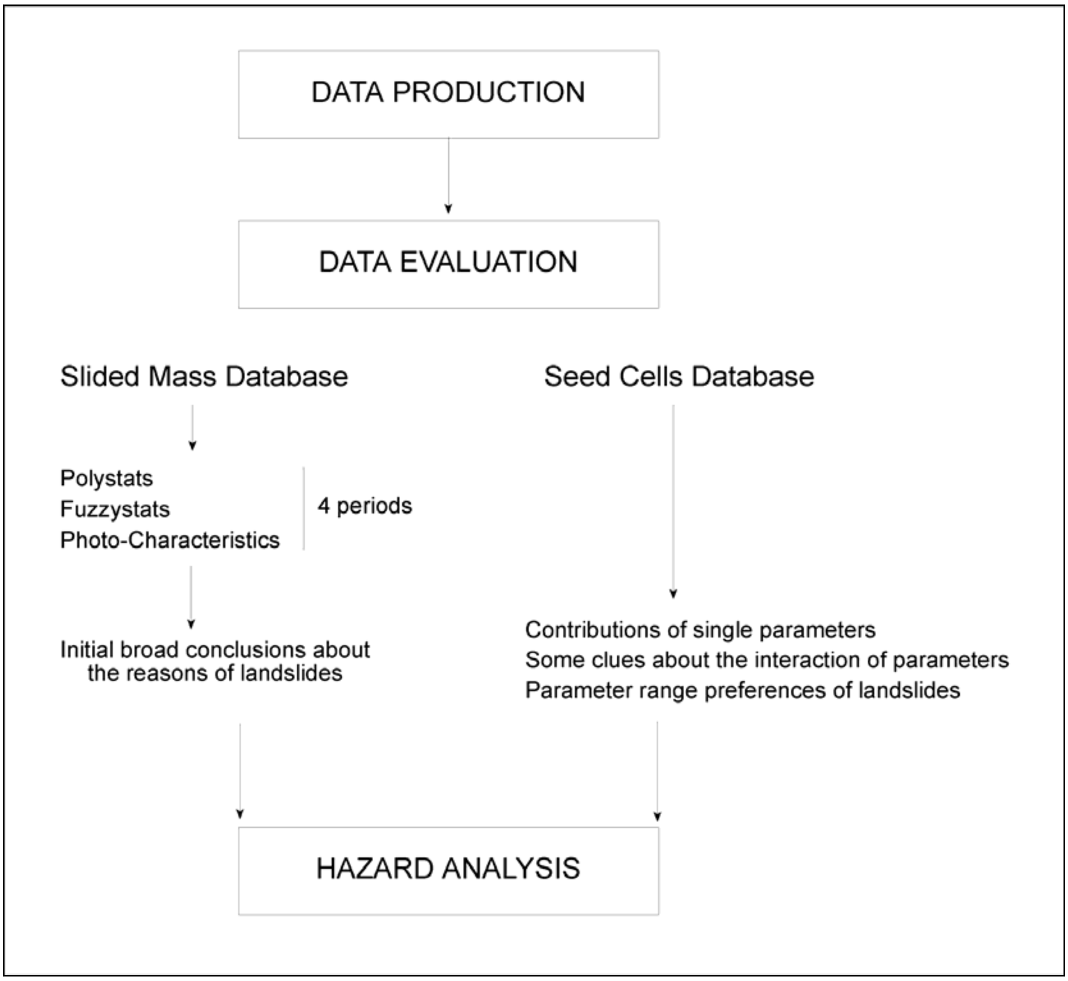

Figure 7.3 Components of data evaluation stage

7.3. Hazard Analysis

The aggregation of information through the steps of data production and evaluation yielded in a tailor-made hazard analysis. The analyses scheme started from the very primitive one, ending with the complex statistical models in order to show the limits of the proposed methodologies through the literature (Figure 7.4).

The most primitive analysis, Thematic Landslide Attribute Spatial Distribution Analysis (TLASDA), is explained in Section 6.1., which is extensively used by van westen and his colleaques (Wieczorek, 1984; van Westen, 1993; Soeters and van Westen, 1996). However, it is found that this methodology could only be useful in regional scale with very large number of landslides.

The second analysis, Landslide Activity Analysis (LACTA) is detailed in Section 6.2., which is found to be valuable, when used with polystats and fuzzystats databases, as this methods validates the conclusions about the land cover and landuse change in the study area. Single use of this analysis is of no use. However, the use of this methodology is encouraged as being the only method to evaluate the hazard with a historical perspective. Yet, it is still not advisable to base any hazard maps only on this analysis. Further examples could be seen in works of Canuti et al. (1979) and van Westen (1993).

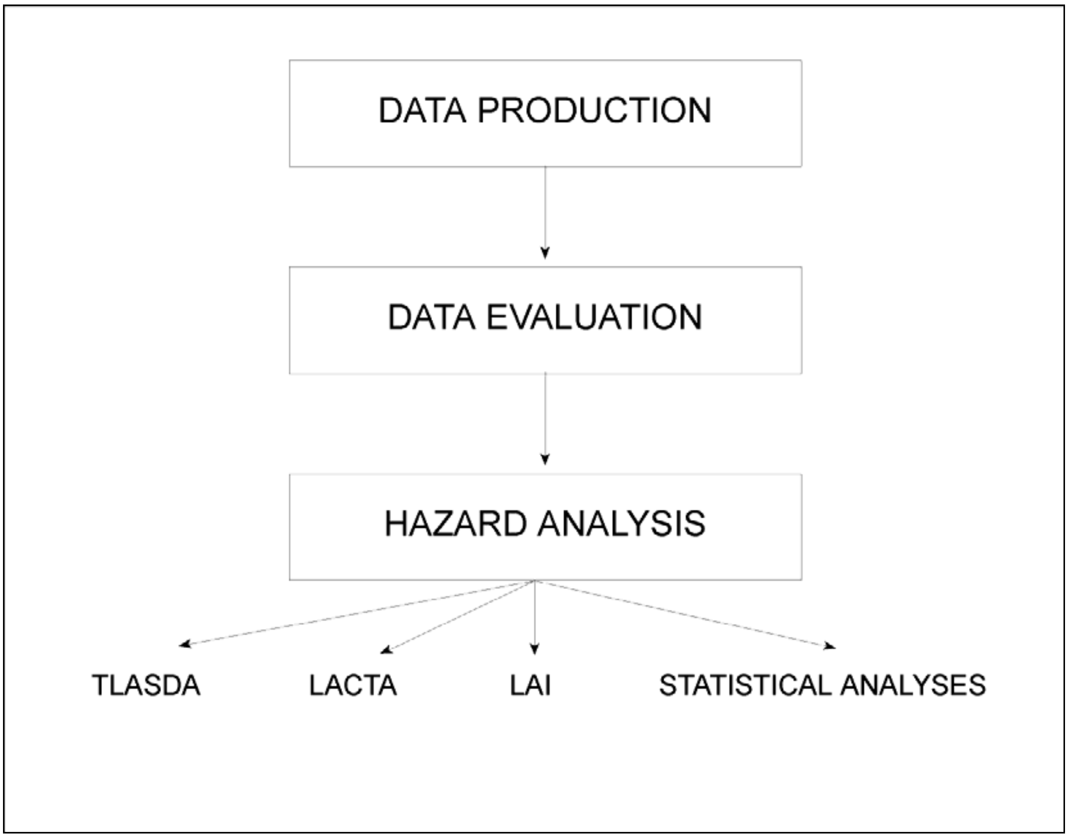

Figure 7.4. Components of Hazard Analysis.

The third analysis is Landslide Isopleth Analysis, which is explained in Section 6.3. This analysis reflects the current situation of the state, and to some extent shows preferences of parameters that is responsible of landsliding. Parameter map crossing could be exploited in order to show the relative preferences of landslides over parameter maps. Although the analysis seems to be robust and free of subjective results, it can turn into a very speculative map production method, as an experienced user can easily manipulate the size of the counting grid and the threshold of landslide density in order to show what he/she intends to emphasize. This analysis is also encouraged to use as an entry for initiation of statistical analyses in regional scales.

By the fourth analysis the hazard analysis scheme enters to a new realm, the statistical domain. Two main trends are observed in this realm as explained in Chapter 2, the bi-variate and multi-variate (Figure 7.5).

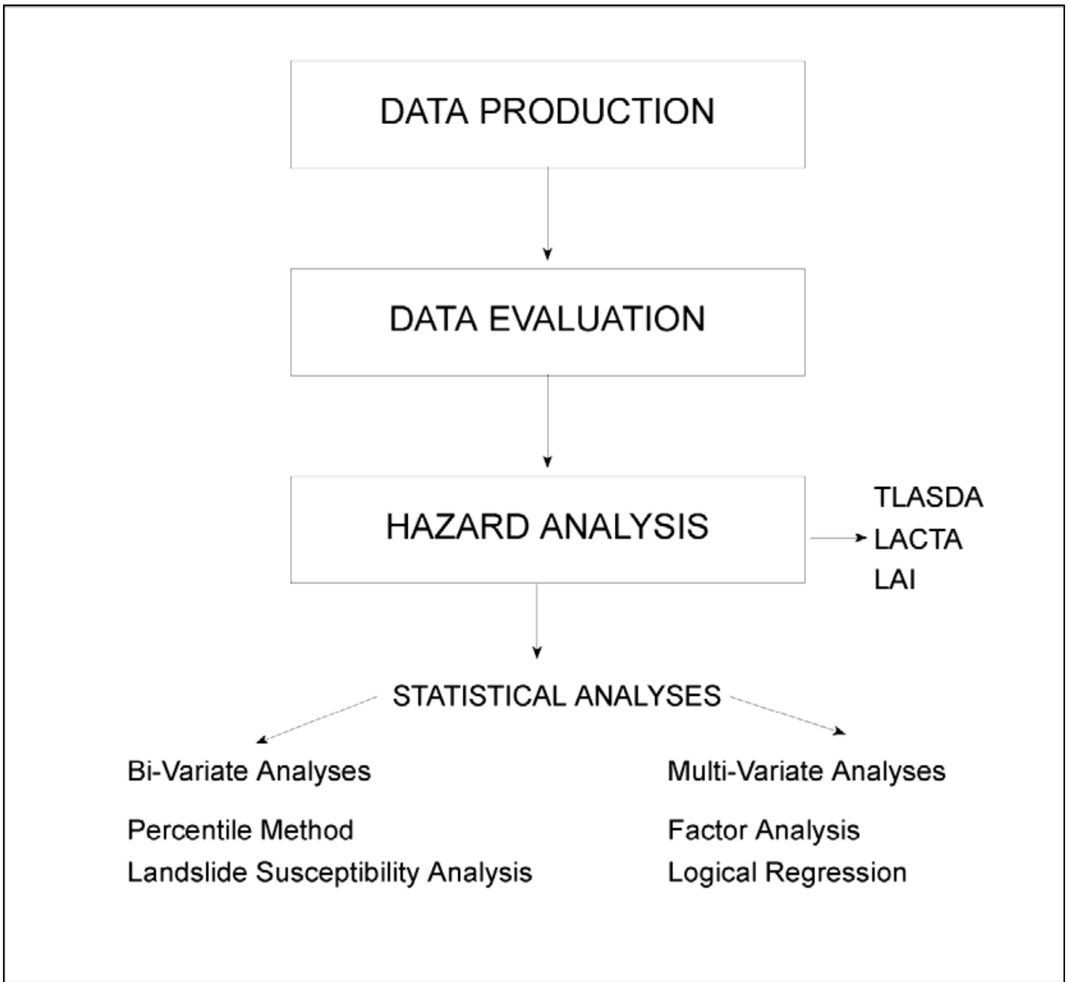

Figure 7.5. Components of Statistical analyses.

In order to proceed with bi-variate analysis, the continuous parameter maps should have to be converted into discrete maps, as the landslide densities in each class of the parameter maps constitute the core of this analysis. However, this conversion issue remains always unclear in literature as most of the authors use their expert opinion for the boundaries of the classes (Carrara and Merenda, 1974; Meneraud and Calvino, 1976; Kienholz, 1977, 1978; Stevenson, 1977; Malgot and Mahr, 1979; Kienholz et al., 1983, 1988; Ives and Messerli, 1981; Rupke et al., 1988; Gupta and Joshi, 1990; Pachauri and Pant,1992; van Westen, 1993, Soeters and van Westen, 1996; Gupta and Anbalagan, 1997). The use of expert opinion results in subjectivity and removes the reproducibility of the proposed methods for different area in the globe. Based on this issue, a data driven methodology is proposed, as the classes should be selected according to the percentile divisions of seed cells. The data outside the seed cell range is discarded as it is also been discarded by the nature by not having a single landslide at these regions. In order to reduce complexity in the calculations stage, 10 classes are proposed to use, as even in 10 classes with 13 parameters, 130 different classes should have to be maintained. The magic number of 10 as the class number, is selected arbitrarily considering the complexity. However, it is believed that lower class numbers would result in large generalizations in the final hazard map, where higher class numbers would result in isolated pixels, that should have to be filtered out, where filtering would alter the objectivity of the hazard map.

Furthermore, this data dependent division reduces the problem, in bi-variate analyses, of what weight should be given to each parameter map, as each class acts like a map and the ratio of the landslide density over the class area gives its natural weight.

In bi-variate analysis, explained in Section 6.4.1., all continuous parameter maps are converted to categorical variables, and corresponding weight values of each class is calculated and added up to create the final hazard map. The complexity of this analysis is moderate and it could easily be implemented to any scales. However, the evaluation of parameter maps should be done in caution, as some parameters gets quite large weights. Further divisions of parameter maps might be needed, as discussed in Section 6.4.1, the distance to E-5 highway gets the maximum natural weight but it has two distinct divisions. The mountain pass gets its desired weight, on contrary the Kaynaşlı valley pass of this highway gets also the same weight without having a single landslide nearby. Moreover, it should also be checked in detail that duplicate information should not be present in the parameter weights, such as the distance to E-5 highway and the road class of land cover in Table 6.7.

Further in the analysis, factor analysis is carried out. Although factor analysis does not yield in a hazard map, the new factors could easily be used to validate the natural weights of bi-variate analysis and could easily create a base for logical regression analyses. Such that the largest component of factor analysis points out that human activity is the most important factor, which is in concordance with the natural weight scheme as the percentiles of distance to E-5 highway, land cover and distance to settlement get quite large natural weights.

The last analysis performed in Asarsuyu Catchment is Logical Regression, which is presented in section 6.4.2.2. Although this analysis is fairly new in Landslide Hazard Assessment realm, a new approach is followed. The previous researches (Atkinson and Massari, 1998; Dai et al. 2001; Lee and Min, 2001) use categorical variables in the analysis, which creates doubts in the selection of classes of variables, which was discussed in the former paragraphs. The new approach is to use the continuous data as it is, in order not to alter the state and information present in the parameter maps.

Although the understanding of this analysis requires a good statistical background, the application is quite simple. It is encouraged to be used in medium and large scale applications, if fed with adequate parameter maps. It is believed that the analysis would end in more accurate results when the number of parameter maps increases.

In both hazard maps 4 classes are used to define the degree of the hazard. They are very low, low, high and very high. The moderate hazard class is not implemented here, as the definition of moderate is obscure and the question of “being moderate relative to what?” is still a great debate over hazard analysis. More willingly than using 3 classed hazard scheme (low, moderate, high), a four class scheme is used as dividing the moderate class into two (low and high), and stretching the end members to very low and to very high.

7.4. Hazard Map Comparison

Upon the completion of the hazard maps, a quantitative comparison scheme should have to be implemented. In order to do this, a two fold methodology is followed (Figure 7.6). First one is to compare the areas of hazard classes and the corresponding densities of landslides. This analysis is important because the idea in optimum zonation refers to allocating minimum areas for high hazard zones, while covering most of the landslides present in the area. Based on this optimum zonation concept, an index is defined as Seed Cell Area Index (SCAI) and the two hazard maps are compared. The logical regression hazard map is found to be more accurate and possesses acceptable results relative to that of bivariate analyses.

The second method is to compare the hazard classes of the two produced maps via their spatial locations. In order to achieve this a re-coded matrix is prepared and presented in Table 6.19. It is found that 80 % of the two maps are converging into acceptable results. The remaining mismatched 20% of the area is reflected by the deficiencies of bivariate analyses as discussed in previous sections. The overweight of percentiles of distance to E-5 highway, distance to fault, fault density and the geological map are the major sources of this mismatch.

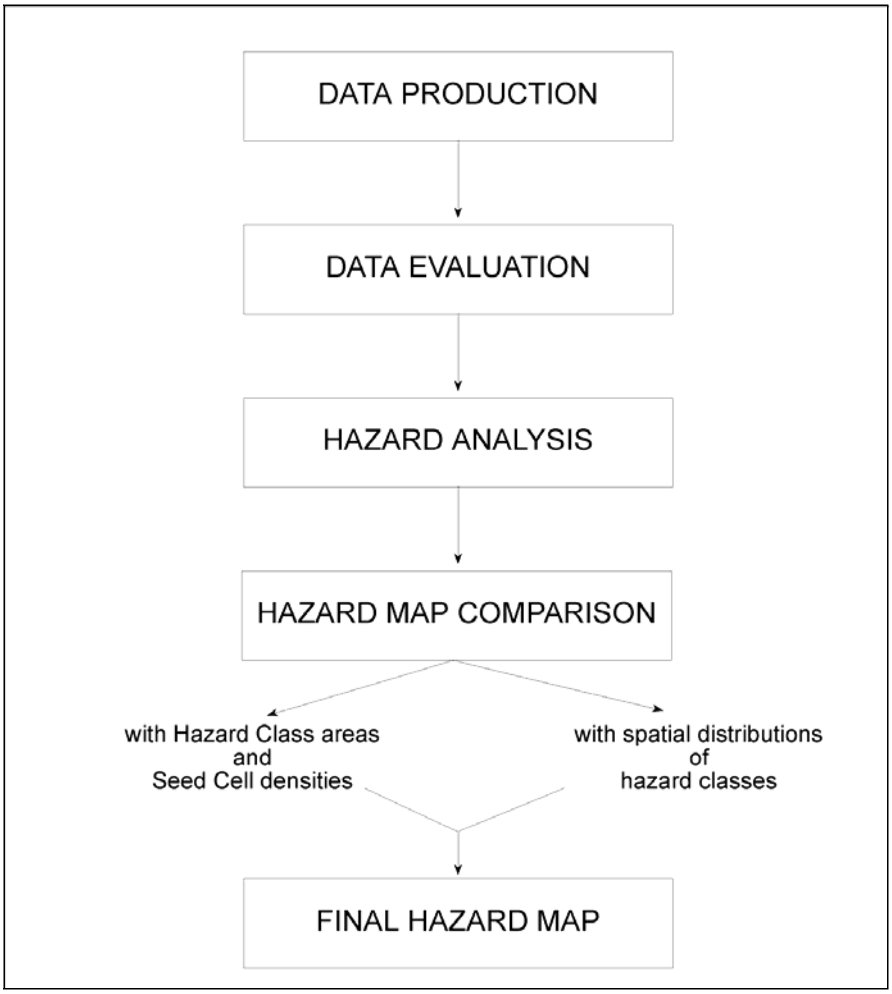

Figure 7.6. Components of Hazard Map Comparison

After it has been decided to use the logical regression hazard map as the final output, it is seen that, the northern slope of Asarsuyu catchment is definitely classified as very low hazard. The attributes responsible for this classification is quite reasonable as these areas are the least populated, the land cover is not disturbed and the cover is dense forest, very distant to E-5 highway and the major active fault, the lithology is resistant enough, although the drainage density and slope values are higher than the rest of the area.

On the other hand the southeastern slopes are definitely on very high hazard class. The reasons could be listed as: the removal of lateral supports by E-5 highway cut slopes, fill areas of E-5 highway result in readily unstable unconsolidated material, close location to active faults, high disturbance to land cover, high activity of highway resulting in extra vibration and the presence of flyschoidal units.