Analysis of Urbanization Change According to NEHRP Soil Classification Map

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SUMMARY

Geological and geotechnical researches and studies must be done before the preparation of construction plans of urban area for the proper and safe construction. The perfect urbanization should be carried out on the pre-determined favorable soil.
In this scope, 32 different Seismic Cone Penetration Test (SCPT) was applied into new alluvial deposit in the study area. The studied area is approximately 25 km^2. The soil classification map of the studied area was prepared based on the regional changes of the average shear wave velocity (Vs_{av}) value of the unconsolidated layer recommended by the standards of National Earthquake Hazards Reduction Program (NEHRP). Supervised classification method was applied on Landsat satellite images of 1987 and 1999 of the area to determine the development of urbanization. Development of the urbanization was examined according to NEHRP soil classification. The distribution of the urban development on different soil conditions was sought using Geographic Information System (GIS). It is determined that, the increase of urbanization on the D type soil and E type soil were 63 % and 7 % respectively. On the other hand 30 % increase was determined on old alluvial deposit and rock formations. As a result, it is understood that the development of urbanization was increasing on unavailable soil conditions.

KEYWORDS: *Change Detection, GIS, NEHRP, Remote Sensing, SCPT.*

INTRODUCTION

Damages by earthquakes and the results which were obtained from the researches of the earthquakes showed the importance of the interaction of earthquake and the local soil conditions (Ansal 1999, Bozdağ 2002, Dikmen 2004). Earthquake waves affect the properties of soil layers and the local conditions of the earthquake. This effect could cause a softening and loosing strength of soil layers. Thickness, consistency, elasticity and plasticity of soil layers are the factors that cause an increase in earthquake properties on the soil (Ansal 1999). Values of shear wave velocity of the soil layers are important variables to determine the earthquake effects on the soil (Ercan 2000).

Microzonation maps are used to determine the earthquake risk potential at urban and industry areas. Earthquake hazard scenario and microzonation studies are made based on GIS technology (Erdik 1996). Seismic Cone Penetration Test (SCPT) were applied on the alluvial deposits for microzonation studies. Totally 32 different SCPT were applied in the studied area. Average shear wave velocity (Vs_{av}) of the unconsolidated layer of upper parts of the stratigraphy was mapped by use of SCPT seismic trace records. The soil classification map of the study area was prepared according to the Vs_{av} value. The amplification of the upper parts of the soil layer was determined according to the National Earthquake Hazards Reduction Program (NEHRP) procedure and then soil classification map was prepared.

Development of the urbanization was determined by using supervised classification method of remote sensing technique. Landsat satellite images of 1987 and 1999 were used for this purpose. Nearest neighborhood which is one of the mostly used supervised classification method is used in the study. Residential areas were tried to be separated from the other features such as industry area, farm, rock, forest and road by this classification. Development of the urbanization belonging to 1987 and 1999 was examined according to NEHRP soil classification and the distribution of urban development on different soil condition was sought using GIS.

CHARACTERISTICS OF THE STUDY AREA

Study area involves a part of Eskisehir settlement area and the topography of the area changes between 779 m and 800 m. Porsuk River which is the main river of the region, divides the study area into two parts in the east-west direction (Figure 1).

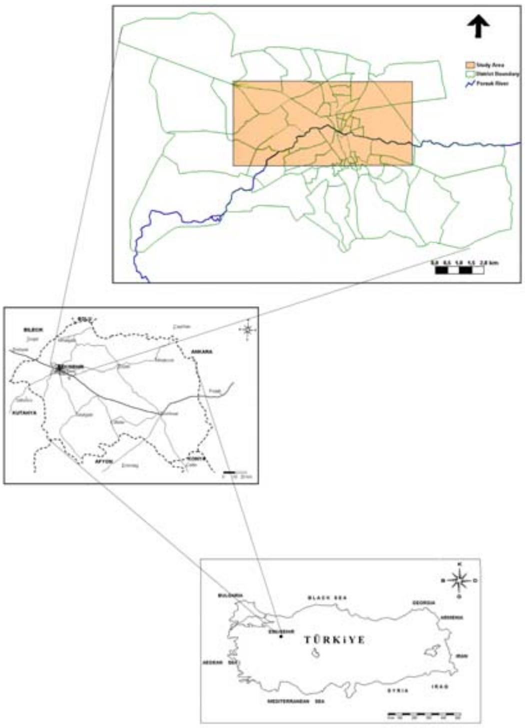


Figure1: Location of Study Area.

Study area is mostly composed of alluvial and rock units. Previous studies demonstrated the presence of two different major alluvial units which can be defined as the old and the new alluvial deposits. The studies of earthquake risk pointed out that the new alluvial has high liquefaction potential on that region (Ayday et al., 2001).

The new alluvial deposit, into which SCPT applied, consists of loose sediments. The thickness of the organic soil at the upper level of this unit varies from place to place (Ayday et al., 2001). Below this level a silt-sand unit and a thick clay layer can be observed at some regions. Sandy and a pebble-sand level occupy, respectively below this level (Ayday et al., 2001). The north-west part of the study area is composed of old alluvial deposits and the south part of the study area covered by rock units.

DETERMINATION OF NEHRP CLASSIFICATION USING SCPT RECORDS

Local soil conditions affect seismic characteristics of the soil. Generally it is known that, during a possible earthquake, if the soil has low shear wave velocity, and a low consolidation and in addition to these factors if locate very close to the surface (≤50 m) the deformation of the soil will be high. This is due to the deformation of S waves in the soil.

When NEHRP conditions utilized, average shear wave velocity, a characteristic variable for the amplification of the soil, is calculated for the unconsolidated layer of the upper parts of the stratigraphy (Street et al., 1997).

A lot of techniques according to shear wave velocity changes are improved for earthquake risk determination studies and GIS based microzonation applications were made in relation with these studies (Huntera et al., 2002). Standards recommended by NEHRP were improved by using regional changes of average shear wave velocity of alluvial unit to determine the amplification of soil movement (Table 1) (Romero & Rix 2001, Schneider et al., 2001, Bauer et al., 2001). In this study it indicated that the amplification property of the soil increases from A to F soil type.

Table 1: NEHRP soil classification (NEHRP, 1997) (Romero & Rix 2001).

Soil Type	**General Description**	**Vs (m/s)**
A	Hard Rock	Vs > 1500
B	Rock	760 < Vs ≤1500
C	Hard and/or stiff/very stiff soils; most gravels	360 < Vs ≤ 760
D	Sand, silts and/or stiff/very stiff clays, some gravels. Having average blow counts of 15 ≤ N ≤ 50 or average shear strength of 50 kPa ≤ S ≤ 100 kPa	180 < Vs ≤ 360
E	Having thickness lower than 3 meters and PI > 20, w ≥ 40% and s_u < 25 kPa soft clay	Vs < 180
F	Needs specific calculations	

32 seismic cone penetration tests were done on different locations into the new alluvial deposit to classify the soil according to NEHRP classification in the study area.

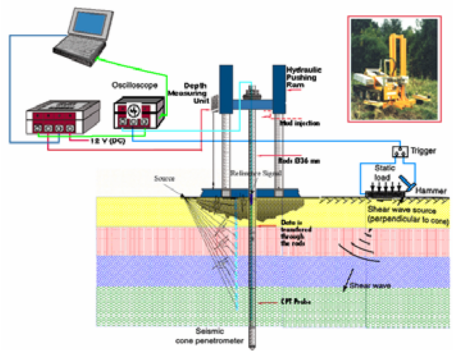


Figure 2: Schematic diagram of SCPT.

SCPT cone which has a built in seismic sensor is used. Seismic energy is created by knocking on a horizontal metal slap with a sledgehammer to horizontal direction (Figure 2). A shear wave is generated at the soil surface and the time required for the shear wave to reach the seismometer in the cone penetrometer is recorded (Schneider et al., 2001).

Seismic trace data that obtained from the repetition of above process at 1 m intervals is filtered by 30-100 Hz band pass filter. Digital filtering on SCPT seismic data analysis is an ideal approach for this process (Campanella and Stewart 1991, Campanella et al., 1989). Vs_{av} was determined by using the first and the last level reference signals.

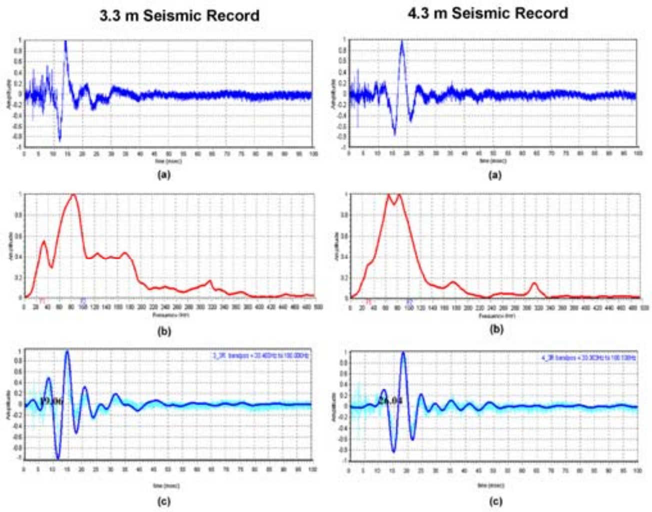


Figure 3: Seismic records obtained from two different levels. (a) Unfiltered seismic record. (b) Frequency spectrum of seismic signal. (c) Filtered seismic signal.

NEHRP soil classification map was prepared by using the SCPT data. The prepared map indicates the average shear wave velocity values (Vs_{av}) obtained from SCPT applications (Figure 4).

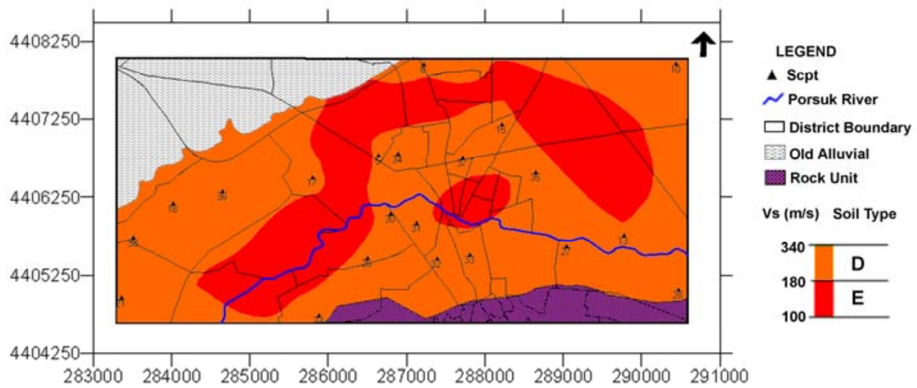


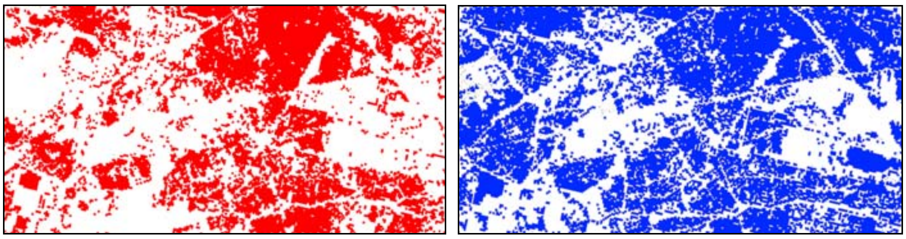
Figure 4: NEHRP classification map of the study area.

When NEHRP soil classification was evaluated to the study area, it is found that the dominant soil type is D but in E type soil which indicates very poor condition according to earthquake is located along Porsuk River and parallel to its drainage path (Figure 4).

URBAN CHANGE DETECTION BY SUPERVISED CLASSIFICATION

In this study, supervised classification method was selected as a classification algorithm. Supervised classification is an automatic classification method; however, user must constitute the training set as a pre-stage of supervised classification. Supervised classification constitutes the statistical basis for given pre-information about land cover and land usage, and assembles the classification to that basis. Before automatic classification, sample pixels are collected for all land classes on the image. The set of these pixel groups is called training set.

The purpose of this classification is to classify urban area of Eskisehir by using remote-sensing technique. For this reason, only two classes, residential areas and non-residential areas, are selected. Supervised classification was applied to the TM 7, TM 5 and TM 2 bands of Landsat satellite images (30x30 m resolution) of the years 1987 and 1989. Residential areas are separated from the other units such as industry, farm, rock, forest (Figure 5 a-b).



(a) (b)

Figure 5: Supervised classification of satellite image. (a) 1987 September dated satellite image, (b) 1999 September dated satellite image.

Accuracy assessment is a control method that based on a statistical comparison of pixel values of the test area, with the pixel values of accurate information about map or land (Ayhan et al., 2003). The error matrix obtained from the classification of images of 1987 and 1999 of the study area was shown on Table 2. The change in residential area between year 1987 and 1999 were correlated after the classification. It is found that the overall accuracy values of the image classification are 93.18% and 80.43% for years 1987 and 1999, respectively.

Table 2: Error matrix of image classification.

Error Matrix (Landsat 1987)	Residential	Other	Total	Average Accuracy	Overall Accuracy
Residential	92,77%	7,23%	100,00%	93,30%	93,18%
	4133	322	4455		
Other	6,14%	93,86%	100,00%		
	170	2599	2769		
Error Matrix (Landsat 1999)	Residential	Other	Total	Average Accuracy	Overall Accuracy

Residential	86,19%	13,81%	100,00%	80,79%	80,43%
	1323	212	1535		
Other	23,76%	76,24%	100,00%		
	417	1338	1755		

Then the classified maps of the classification are superimposed with NEHRP soil classification variables (D and E), old alluvial deposit and rock unit (Figure 6, 7). The areal distributions of residential areas on different soil conditions for two different years are shown on Table 3 and 4.

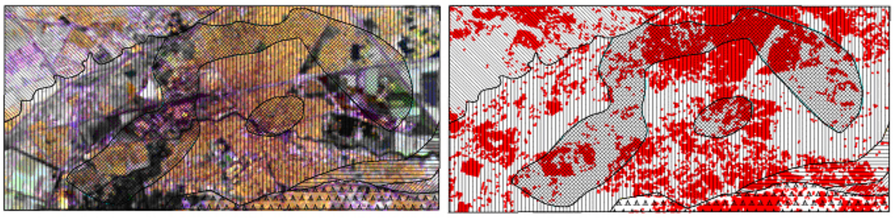


Figure 6: Supervised classification of 1987 September dated satellite image.

Table 3: 1987 dated distribution of residential area on different soil conditions (m^2).

	D	E	Old Alluvial	Rock Unit	Total
Residential	4824690.1	2320983.7	740635.8	574967.2	8461276.8
Other	8779620.1	3723481.5	2329292.5	694346.0	15620319.8
Total	13604310.2	6044465.2	3069928.3	1269313.2	24081596.6

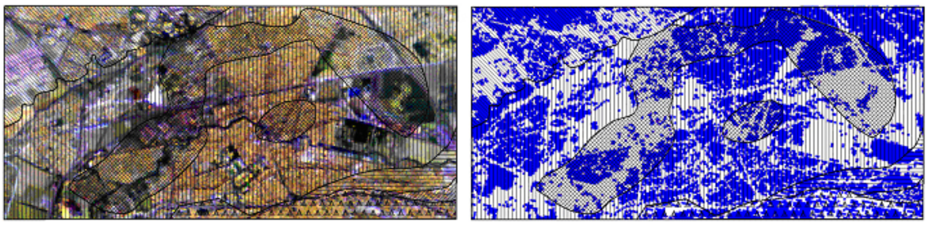


Figure 7: Supervised classification of 1999 September dated satellite image.

Table 4: 1999 dated distribution of residential area on different soil conditions (m^2).

	D	E	Old Alluvial	Rock Unit	Total
Residential	6569229.9	2514382.9	1483809.6	663667.6	11231090.1
Other	7035955.5	3499992.1	1612406.4	587228.9	13101589.4
Total	13605185.4	6014375.0	3096216.0	1250896.5	24332679.5

The percentage distribution of residential area in 1987 and 1999 are investigated (Figure 8 a, b). It was determined that the urbanization was increased 2769813.3 m^2 between two periods on the studied area.

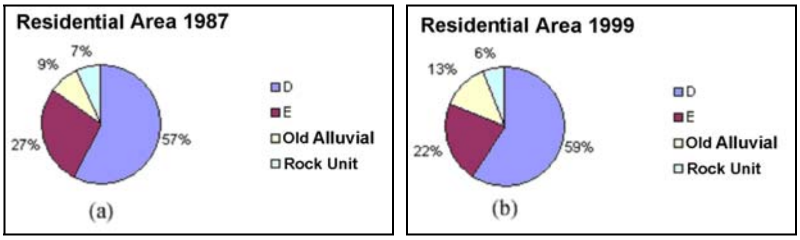


Figure 8: Urbanization ratio on different soil types for 1987 and 1999.

The areal and the percentage change in residential area between two periods were calculated for different soil types and lithologies (Table 5).

Table 5: Total and normalized values of satellite images.

Region	Landsat87		Landsat99		Change in Residential Area (m^2)	% Change in residential
	Total Area (m^2)	%	Total Area (m^2)	%		
D	4824690.1	57.02	6569229.9	58.49	1744539.9	62.98
E	2320983.7	27.43	2514382.9	22.39	193399.2	6.98
Old Alluvial	740635.8	8.75	1483809.6	13.21	743173.8	26.83
Rock Unit	574967.2	6.80	663667.6	5.91	88700.3	3.20
Total	8461276.8	100.00	11231090.1	100.00	2769813.3	100.00

It was found that urbanization increase on D type soil is 63% and on E type soil is 7%. On the other hand, on old alluvial and rock units 30% urbanization increase was determined from the table above (Figure 9).

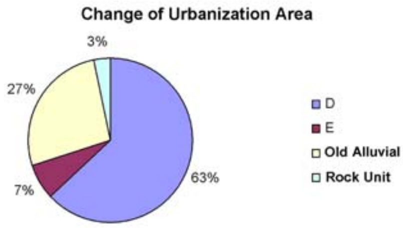


Figure 9: Change of urbanization development according to different soil condition.

The previous studies of the liquefaction analysis of the study area showed that, the areas having high liquefaction risk correspond to E type soil and the areas having low liquefaction risk correspond to D type soil (Figure 10) (Ayday et al., 2001). According to the zonation based on liquefaction potential, urbanization intensifies on low liquefaction zone, examining the urban development between 1987 and 1999, (Figure 11). According to NERHP classification it intensified on D type soil class (Figure 9).

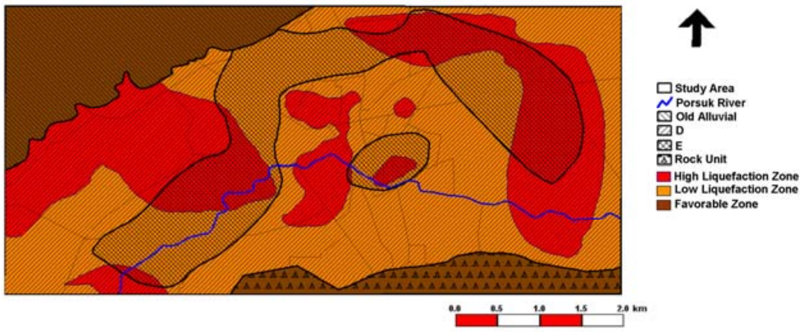


Figure 10: NEHRP classification and soil liquefaction map.

The urbanization between two periods was utilized according to NEHRP conditions and liquefaction potential. It concluded that the urban development of Eskisehir settlement area between 1987 and 1999 periods was increased on unsuitable soil.

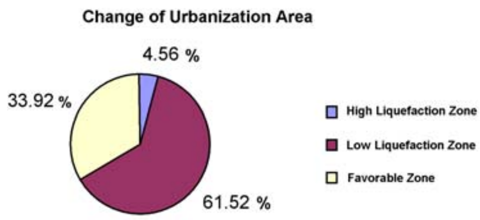


Figure 11: Change of urbanization according to liquefaction potential

CONCLUSION

The soil type of the study area was defined as D type soil, but the west part of the study area, along Porsuk River and the north part of the study area, parallel to Porsuk River, was defined as E type soil according to NEHRP soil classification. It was understood that the channel of Porsuk River passes along the E type soil from the examination of the aerial photographs. It is suggested that it will be valuable information for further soil applications for the study area.

Supervised classification method was applied on Landsat satellite images of 1987 and 1999 of the area to determine the development of urbanization. Development of the urbanization was examined according to NEHRP soil classification and liquefaction potential. The distribution of the urban development on different soil conditions was utilized using GIS. It was determined that the areal urbanization increase on D type soil is 63% and on E type soil is 7%. On the other hand, on old alluvial and rock units 30% increase were determined in urbanization. According to the zonation based on liquefaction potential, 4.56% and 61.52% increases were determined on high liquefaction zone and low liquefaction zone respectively but 33.92% increases was determined on the area favorable zone. As a result of this study, it was realized that the urbanization showed an increase on unsuitable soil according to both NEHRP soil classification and the liquefaction potential for the period between 1987 and 1999.

It is advanced that, the governmental planners and authorities of the municipality should take the arrived results into consideration, and conduct further similar studies in the future for a better city planning.

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