ISGSR2007 First International Symposium on Geotechnical Safety & Risk
Oct. 18~19, 2007 Shanghai
Tongji University, China

The Changes of Ecological Conditions Induced by Rock Tunnelling in LaoShan Mountainous Area

X.Z. Li, X.B. Zhao, Z.S. Wang
Department of Earth Sciences, Nanjing University, Jiangsu Province, P. R. China, 210093.
(Email address of corresponding author: xzli@nju.edu.cn)

ABSTRACT: Through a field investigation, this paper studies the changes of ecological conditions induced by tunnelling construction in Laoshan mountainous area, Nanjing, P. R. China. The effects of habitat fragmentation and edge effect are examined and discussed. It is found that the environmental factors and vegetation situation have been influenced by the tunnelling activity, and the disturbed area is approaching the sampling patch centre. The changed ecological conditions are beneficial for the settlement and growth of some herb and shrub species, and are unfavorable for the existence and growth of the saplings, especial for the predominant species (e.g., robur) in this area. If the time of habitat fragmentation is long enough and there is no supplement from external areas, some vegetation species in Laoshan mountainous area will deteriorate, or even distinguish in the future. In addition, the present investigation results can be used as a reference for the long-term ecological study in this area.

1 INTRODUCTION

Tunnel construction often causes negative effects on ecological conditions around its neighboring area (e.g., Tian, 2004). Once the ecosystem is changed or destroyed, it may arouse serious ecological consequences, and the habitat restoration will be difficult, costly and time-consuming. Therefore, great care and special methods should be taken to reduce the engineering disturbance, during the planning and construction of tunnel projects, especially in urban and ecologically sensitive areas (e.g., Li et al., 2001; Karlsrud et al., 2001). Laoshan tunnel is a 3.5 km long road tunnel. It passes through a karst mountainous area (Laoshan mountains, Nanjing, Jiangsu, P. R. China), where a national forest park is located. Due to its ecological sensitivity, it is important to study the effects of tunnel construction on neighboring ecosystem.

During the tunnel construction, civil works (e.g., soil or rock excavation and temporary road construction etc.) break large habitat into small patches. Habitat fragmentation causes changes of environmental factors (e.g., air solar radiation, soil surface temperature and soil humidity etc.) in these patches, and subsequently deteriorates functions of the ecosystem, such as water circulation, nutrition circulation and species diversity (e.g., Hall, 1996; Gigord et al., 1999). At the edge of a patch, the effects of air solar radiation and desiccation become strong and the temperature changeability increases. These induce a large decrease of inadaptable local species at a range of several hundreds meters to the edge (Murcia, 1995; Zhang and Chen, 2000). Meanwhile, foreign species, which are adaptive to the new environment, increase rapidly, and compete with original species for nutrition and habitat. In addition, habitat fragmentation reduces the connection between different patches, especially when the population of local species at the edge decreases largely. If the time of habitat fragmentation is long enough and there is no supplement from external areas, some vegetation species in the patches will deteriorate, or even distinguish finally.

In order to study the effects of Laoshan tunnel on neighboring vegetation, a field near the tunnel entrance is selected as a sampling patch to investigate the situation of air solar radiation, soil temperature, soil humidity and vegetation distribution. Subsequently, ecological changes caused by habitat fragmentation and edge effect are analyzed and appraised based on the collected data.

2 FILED INVESTIGATION

In the present study, the vegetation in the sampling patch is categorized into three groups: arbor, shrub and herb. Because the species numbers of fern, liana and epiphyte are small, these numbers are counted into herb in the current investigation.

The details of filed investigation are described as following (the schematic diagram of sampling strips for different vegetation groups is shown in Fig.1):

(1) First, four sampling strips with a width of 10 m are determined to investigate the richness and density of arbor. These strips are located along patch edges and orientated at the north, south, east and west positions, individually. Subsequently, sampling blocks within these strips are further divided with the sizes of 10*50m for arbor and 10*5m for arbor sapling. In these blocks, the species name, height, diameter at breast height and crown width of arbor and arbor sapling are recorded;

(2) Within the sampling strips for arbor, four strips with a width of 2 m are set up to investigate the situation of shrub. Then, sampling blocks with the sizes of 2*2.5m are divided, and the species name, height, diameter at breast height and crown width of shrub are recorded;

(3) In a similar way, strips with a width of 1 m are determined within the sampling strips for shrub to investigate the richness and coverage of herb. After that, sampling blocks with the sizes of 1*1m are divided, and the species name, height and coverage of herb are recorded;

(4) Meanwhile, air solar radiation, soil surface temperature and soil humidity are monitored within the 1*1m sampling blocks.

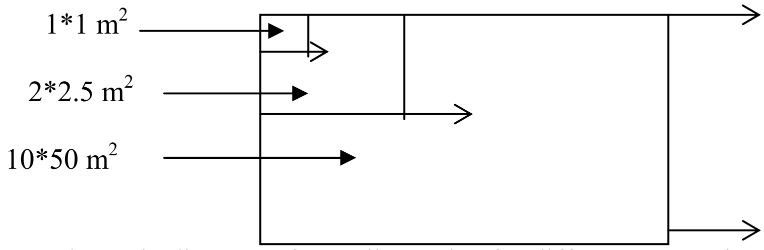

Fig.1 Schematic diagram of sampling strips for different vegetation groups

3 DATA ANALYSIS

Based on the investigation data, the composition and distribution of the vegetation and environmental factors are analyzed.

3.1 The Changes of Vegetation Species

Totally, there are 87 vegetation species found in the sampling patch, which include 39 species for arbor, 24 species for shrub and 24 species for herb. From patch sides to the centre, the richness of herb does not have obvious change, and the species number is at a range of 2-2.5 species in a sampling block (as shown in Fig.2). However, the herb coverage has distinct change along the sampling strip. At a distance of 10 m to edge, the herb coverage is around 50-60%. The coverage decreases rapidly to 30-35% at the distance of 15-25 m. The value increases to 28-55% at the distance of 30-80 m and largely drops to 20-35% at the field near the patch centre (as shown in Fig.3). The investigation results indicate that the disturbed area in the sampling patch is relatively large, and the influencing intensity has strong diversity.

The shrub richness and density have obvious changes with the distance to edge. From Fig.4 and 5, it is found that the shrub richness and density are small at the edge of the sampling patch. Then, these values gradually increase with the distance and reach the maximum values at the patch centre. These results demonstrate that the new environment influenced by habitat fragmentation is beneficial for the entry of foreign annual herb and shrub, and the patch centre has been disturbed to a certain extent, where some foreign shrub species have settled down.

Compared with grown trees, the sapling is more sensitive to the changes of environmental factors in a given period. Therefore, in the following analysis, only the richness and density of the sapling are discussed. Based on the classification method proposed by Lutz (1930), the arbor sapling is further divided into three groups. The first level sapling refers to the seedling whose height does not exceed 33 cm. For the second level sapling, its height is larger than 33 cm, but its diameter at the breast level is smaller than 2.5 cm. When a sapling's breast diameter is at a range of 2.5-7.5 cm, it is classified into the third level sapling. Fig.6 shows that the sapling richness does not have distinct diversity along the sampling strips. However, the densities of different level saplings obviously vary with the distance to edge as shown in Fig.7:

(1) The densities of sapling in total and the first level sapling are closely related to the distance. Within the distance of 20 m, the densities increase slowly with the distance. When the distance exceeds 20 m， the sapling number in a sampling block increases rapidly with the distance;

(2) The density of the second level sapling obviously changes with the distance. The value increases from 6.08 at patch edges to 11.4 at the patch centre;

(3) The third level sapling is not sensitive to the distance and its density almost keeps constant with the distance.

From these plots, it can be concluded that the first level sapling is most sensitive to the environmental changes, and its trend indicates that the disturbed area is approaching the patch centre.

In addition, it is observed that the densities and richness (or coverage) of herb, shrub and sapling have distinct diversity in sampling strips at different orientations (Table 1). In the west strip, the herb has the largest coverage and richness. Meanwhile, the shrub and sapling have the largest richness in the sampling strip. In the south strip, shrub density has the largest value, but the sapling density in this strip is much smaller than that in other strips. These results demonstrate that the environmental conditions in the west and south parts have been seriously disturbed, and they are favorable for the existence and growth of herb and shrub, but are unfavorable for those of sapling.

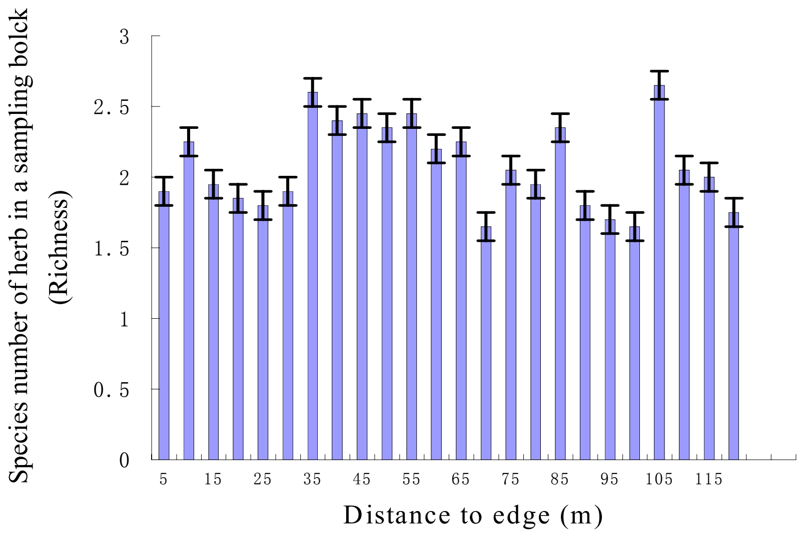

Fig.2 The variation of herb richness with the distance

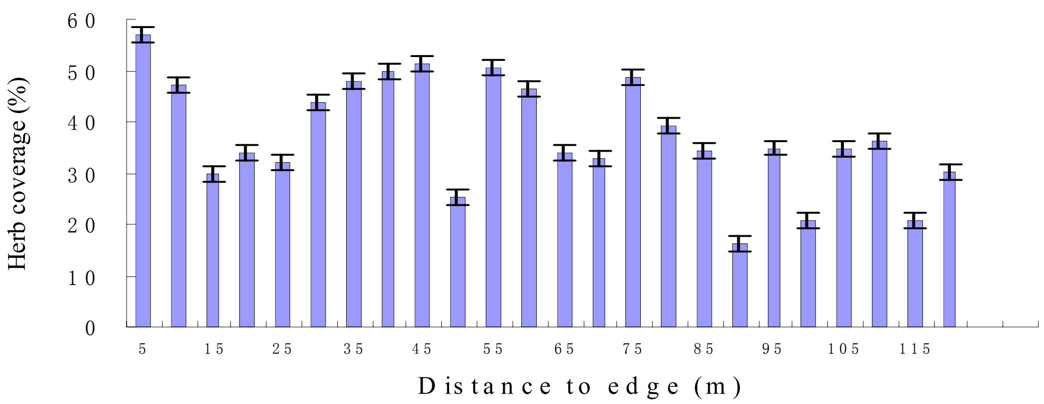

Fig.3 The variation of herb coverage with distance

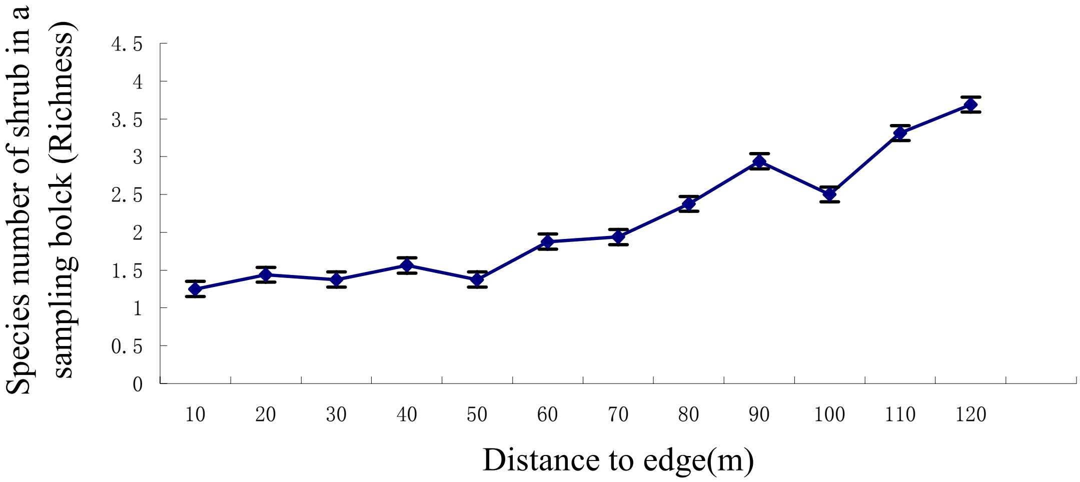

Fig.4 The variation of shrub richness with the distance

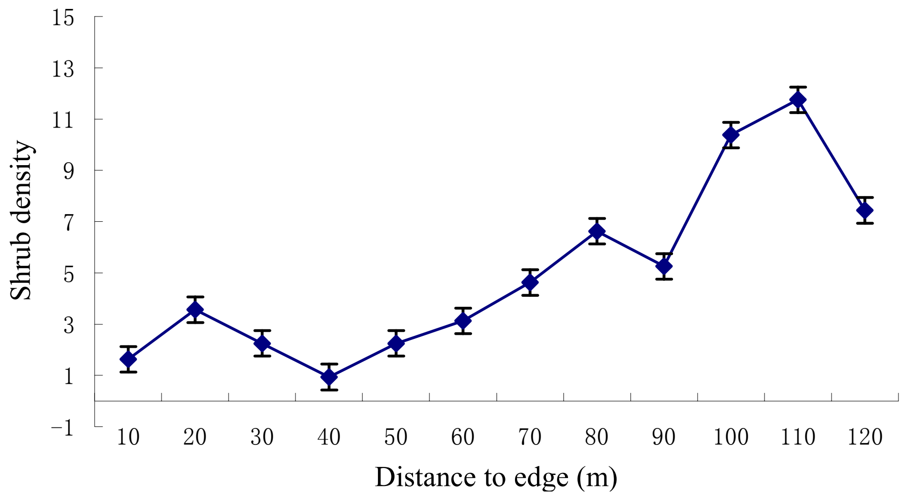

Fig.5 The variation of shrub density with distance

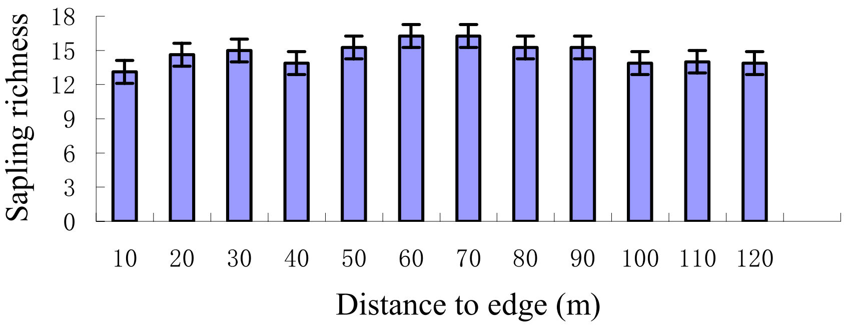

Fig.6 The variation of sapling richness with the distance

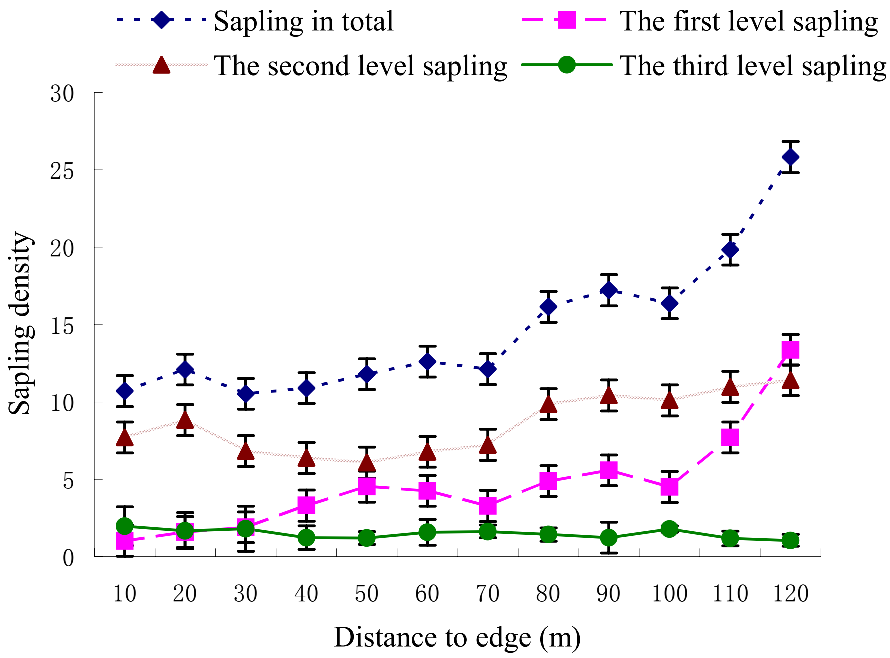

Fig.7 The variation of sapling density with distance

Table 1 The changes of herb, shrub and sapling in sampling strips at different orientations

Orientation	Grass coverage（%）	Grass richness	Shrub density	Shrub richness	Sapling density	Sapling richness
East	39.28	2.09	4.24	1.94	17.59	14.21
West	49.19	2.34	10.16	2.98	14.08	17.17
South	27.49	1.59	10.52	2.21	9.13	13.08
North	25.83	2.25	5.12	2.17	17.93	14.42

3.2 The Changes of Environmental Factors

The intensity of air solar radiation in the sampling patch can be divided into three parts. Within the distance of 5-25 m to edge, the air solar radiation is 0.49-1.02 Klux. When the distance is at the range of 45-120 m, the air solar radiation is 1.33-7.42 Klux. For the distance between 25 and 45 m, the solar radiation is 0.78-3.58 Klux, and its fluctuation range is between those of the other two parts. These results show that at the patch edge, the air solar radiation is low and steady. After a transition area, the air solar radiation becomes high and has large fluctuation. The changes of air solar radiation are quite important to the distribution of herb and shrub in the patch.

From the edge to the patch centre, the distribution of soil surface temperature can also be divided into three parts. When the distance to edge is at 5-30 m, the soil surface temperature varies from 20.65 to 21.95℃. When the distance ranges from 35 to 120 m, the soil surface temperature is 21.7-22.98℃. These data indicate that the temperature fluctuation in the sampling patch is large, and the temperature at the inner part is larger than that at the patch edge. The trend of soil surface temperature with the distance is correspondent to that of air solar radiation. Because the air solar radiation and soil surface temperature are relatively high at the patch centre, these are favorable for the entry and growth of external shrub and herb species.

The trend of soil humidity with the distance to edge is presented in Fig.8. From the plot, it can be found that from the edge to the centre, the soil humidity does not have significant variation (its fluctuation is around 15% of the average value), except for the soil humidity at the distance of 35-55m. This demonstrates that the edge effect has small influence on the soil humidity. This may be due to the high canopy density and thick subsoil layer in the sampling patch.

Comparing environmental factors between sampling strips at different orientations (as shown in Table 2), it is found that the solar radiation in the south strip is much lower than those in other strips. In addition, the soil surface temperature in these strips has following sequence: temperature in west strip（22.84℃）> temperature in east strip（22.33℃）> temperature in north strip（21.50℃）> temperature in south strip（21.13℃）. For the soil humidity, the east and north strips have relatively high values. These results demonstrate that the environmental factors are related to sampling strip's orientation and surrounding media. The low value of solar radiation in the south strip is due to canopy effect caused by a nearby hardwood patch.

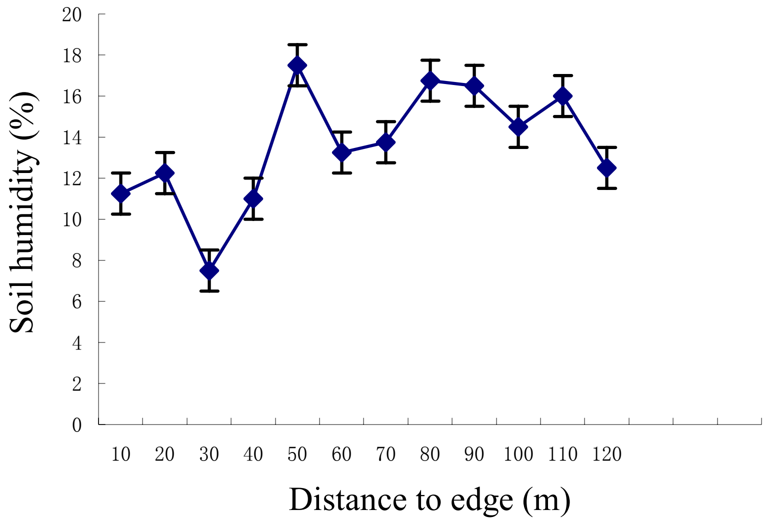

Fig.8 The variation of soil humidity with distance

Table 2 The changes of solar radiation, soil surface temperature and soil humidity in sampling strips at different orientations

Orientation	Solar radiation (Klux)	Soil surface temperature (℃)	Soil humidity (%)
East	2.68	22.33	16.21
West	2.18	22.84	10.17
South	0.73	21.13	8.08
North	3.83	21.50	17.75

4 DISCUSSIONS

Based on above analyses, it can be concluded that the tunnel construction has influenced the environmental factors, including air solar radiation, soil surface temperature and soil humidity, to a certain extend: the air solar radiation and soil surface temperature obviously increase with the distance to edge. Subsequently, the changes of environmental factors induce the changes of the composition and distribution of the vegetation. Although the herb richness almost keeps constant with the distance to edge, its coverage has distinct change along the sampling strip. For shrub, its richness and density obviously increase with the distance. The sapling richness does not have distinct change with the distance, but its density decreases a lot at the patch edge. Present studies show that influencing area of habitat fragmentation and edge effect is approaching the patch centre. The changed environmental factors are favorable for the settlement and growth of some herb and shrub species, and are unfavorable for the existence and growth of some saplings. Meanwhile, the Habitat fragmentation reduces the connection between different patches and will influence the propagation path of some predominant species (e.g., robur) in Laoshan mountainous area. In addition, the increasing traffic after the completion of the tunnel will further affect the vegetation's propagation and distribution. If there is no supplement from external areas, the predominant species are just restricted within the patches, and will be replaced by herb and external species in the future.

It is noted that this study starts after the beginning of Laoshan tunnel construction and therefore, the original ecological data has not been obtained and could not be used to compare with the present results. However, current research can be used as a reference for the future long-term ecological study in this area. In addition, the factor analysis of ecological changes is very complicated. Obviously, the tunnel construction is the main factor causing the ecological changes near the tunnel entrance. The future long-term study will be much helpful for the factor analysis, especially when the tunnel is open for traffic.

ACKNOWLEDGEMENTS

The authors are grateful to the Nanjing Highway Construction Headquarter, the Fourth Railway Survey and Design Institute of China, the Second Highway Survey and Design Institute of China, the First Bureau and the Nineteenth Bureau of China Railway Construction for their cooperation in the study. This work is supported by the Program for New Century Excellent Talents in University of China (NCET-04-0454).

REFERENCES

Gigord, L. et al. (1999) Effects of habitat fragmentation on Dombeya acutangula (Sterculiaceae), a native tree on La Reunion (Indian Ocean). Biological Conservation, 88, p43-51.

Hall, P. et a1. (1996) Effect of forest fragmentation on genetic diversity an d mating system in a tropical tree, Pithellabium elegans. Biological Conservation, 10, p757-768.

Karlsrud, K. (2001) Control of water leakage when tunneling under urban areas in the Oslo region. Norwegian Tunneling Society, Water control in Norwegian tunneling.

Li, X.Z. et al. (2001) Urban geoenvironmental variation issues caused by geotechnical engineering disturbances. Proc. of Int. Symp. High Altitude and Sensitive Ecological Environmental Geotechnology, Nanjing University Press, p23-29.

Lutz, H.J. (1930) The vegetation of hearts content, a virgin forest in Northwestern Pennsylvania. Ecology, XI, 1-29.

Murcia, C. (1995) Edge effects in fragmented forests: implications for conversation. Trends in Ecology and Evolution, 10(2), p58-62.

Tian, J.J. (2004) Study on the impact of long railway tunnel on ecological environment. Transportation and Environment Protection, 25(5), p21-23.

Zheng, D. and Chen, J. (2000) Edge effects in fragmented landscapes: a genetic model for delineating area of edge influences (D-AEI). Ecological Modelling, 132, p175-190.