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Understanding the Effects of Historic Land Use Pattern on an Urbanized Stream Corridor

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Abstract: This case study aims to understand the characteristics of the historic land use pattern in the surrounding areas of a streambed in Aydin, Turkey. Aerial photographs from 1960 and Ikonos images from 2002 are utilized in GIS environment. Two analytical approaches exist: (1) detecting the magnitude of growth in the urban area and (2) detecting the land use transformation along the streambed. Matrix Utility index is employed to relate the amount of imperviousness to each land use type. Overall, the City has expanded 80.14% and the matrix utility value dropped 25.30%, which mean that less compatible land uses surrounded the stream each coming year. The typical outcome of this trend is increasing high density with very high percentages of impervious surfaces. A new land use scenarios should be generated to bring the index value to its initial levels. In this aspect, the matrix utility index could be an effective tool in land use decisions and in developing common language between urban planners and landscape architects.

Key words: Stream corridors, urban, land use change, matrix utility, GIS

INTRODUCTION

Stream and riverbeds make landscapes valuable a number of ways. They are a fundamental part of ecological networks by working as conduits for organisms and energy (Forman, 1997). Dispersal is a particularly critical function of these corridors in fragmented landscapes (Noss, 1993). Vegetation in these areas differs from their surrounding hence offering habitats for wildlife (Shaw *et al*., 1998). In economic sense, they work as transportation routes and attract industrial uses; while navigable rivers and large lakes attract the development of major urban centers (Cronon, 1983; Walsh *et al*., 2003). Moreover, riverbeds present many recreational opportunities. In an urban context, their contribution is even more significant in maintaining the quality of life. However, urban land use can severely degrade stream ecosystems in a variety of ways that are not easy to separate (Wang *et al*., 2001; Hatt *et al*., 2004). Stream hydrology, geomorphology, water chemistry and biota are largely determined by a combination of regional factors, such as geology and climate and local land cover and land use (Richards *et al*., 1996; Bunnell *et al*., 2003).

A growing body of literature documents substantial alterations in flow patterns, channel morphology, water quality and biotic communities associated with urbanization: increased precipitation runoff volume and rate rising the magnitude and frequency of floods, excessive bank erosion, loss of pool habitat and in-stream cover, increased loads of pollutants and excessive streambed scour and deposition are few examples of the consequences. The alteration of flow regimes is often claimed to be the most serious and continuing threat to ecological sustainability of rivers (Ward *et al*., 1999; Bunn and Arthington, 2002) by influencing the structure and function of vegetation communities (Paul and Meyer, 2001). In addition, urban runoff contains a variety of pollutants hence declining water quality. All of these physical and chemical alterations restructure biotic communities and affect the diversity and productivity. Relatively small amounts of urban land use in the surrounding areas of streambeds can lead to major changes in biota and there appear to be threshold values of urbanization beyond which degradation of biotic communities is rapid and dramatic (May *et al*., 1997; Wang *et al*., 2001). Due to the relationship between the structure of the surrounding land use types and the habitat quality of streambeds, quantifying the spatial and temporal characteristics of a landscape is an important step for understanding the link between landscape patterns and ecological processes (Turner, 1990). According to Allan and Johnson (1997), these ecosystems are strongly linked to the surrounding landscape and should not be studied exclusive of their

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environment. Subsequently, the evaluation of the surrounding land uses over time is beneficial to develop sound land use policies to protect the ecological viability of these valuable corridors. Thus, the objective of this study is to understand the characteristics of the historic land use pattern in the surrounding areas of a streambed in the City of Aydin, Turkey.

In previous studies, several different measures have been used to characterize the degree of urbanization and its relation to stream habitats. Biological diversity and integrity have been negatively correlated with percentage urban land cover (Klauda *et al.*, 1998), human population density (Schueler, 1994) and house density. Recently, the amount of impervious surface (the proportion of a landscape covered by surfaces impermeable to water, such as roofs and roads) has been proposed as a key environmental indicator of urban land-use effects (Schueler, 1994; Arnold and Gibbons, 1996). The extent of imperviousness has an obvious direct effect on stream hydrology and water quality and an indirect but strong effect on stream habitat and biota (Booth and Jackson, 1997). Increased imperviousness results in increased frequency and intensity of flood flows, decreased groundwater levels, increased stream channel and bank erosion and increased loads and concentrations of pollutants (Novotny and Olem, 1994). Increases in impervious surface cover from urbanization as little as 10-20% have been shown to be associated with physical, chemical and biological degradation of their associated watersheds (Paul and Meyer, 2001). Because of this relationship between the impervious surfaces and the health of stream ecosystems, in this study, the amount of impervious surface in each land use is taken into consideration during the analysis in GIS.

MATERIALS AND METHODS

Study area: This case study focuses on the Tabakhane stream in the City of Aydin Turkey (Fig. 1). Aydin is located in the western part of Turkey with a current population of approximately 143000.

Tabakhane stream runs through north-south direction from 250 m to 50 m elevation. It starts from the mountainous natural landscape on the north of the town, traverses through a highly developed urban matrix and then passes through an agricultural landscape on the south before it reaches to one of the prominent river basins of Turkey, the Big Meander River. During its journey the vegetation characteristics of the surrounding landscape changes (Fig. 2); indigenous plants of olive, poplar, chastee, oleander and sycamore prevail in the natural landscape on the north, while the part of stream corridor in the Aydin urban area possesses mostly the exotic species (typical of urban landscapes in Turkey) and the agricultural landscape on the south shelters mainly eucalyptus and giant reed. The stream runs between December and May and is dry for the rest of the year.

Tabakhane stream holds a great potential for improving the ecological, social and recreational qualities of the City of Aydin. Currently, none of these important aspects are recognized in the planning and land use practices. A considerable part of the stream in the urban matrix is channeled hence reducing its various benefits. Different types of land uses take place along the stream ranging from a large urban park, residential and commercial lots to industrial uses. This study specifically deals with the part in the urban boundaries where all of these land uses compete with each other. The selection of this portion is deliberate, because the habitat values of the stream has changed the most in this part and also because the greatest threat to the ecological qualities of the stream is generated by the excessive impervious surfaces of the surrounding land uses.

Material: This case study utilized 1/5000 scale black and white aerial photographs from 1960 and already rectified Ikonos image of the City from 2002. The resolution of the satellite images was 4 m. In addition, previously created GIS covers of Aydin streets, city plan and soil map were used. Sets of ancillary data such as population information, historic documents were also employed. The analyses were done in a GIS environment by using ArcGIS 8.3 software.

Method: A time series approach was pursued in the research. First, the aerials were rectified by using the Ikonos images and were geographically registered to the UTM Zone 35. A histogram equalization technique was applied for the better interpretation of the study material. Two analytical approaches pursued in the study: (1) to detect the magnitude of the growth in the urban area and (2) to detect the land use transformation along the Tabakhane stream within a 42 year period.

As for the first part of the study, the urban boundary in 1960 was delineated from the aerials by on screen digitization. The border of the already developed lots defined the boundary. Those areas that are undeveloped or showing the signs of development in the near future was not included. This approach was pursued to be consistent with the population census information. The urban boundary of the 2002 was extracted from the 2002 satellite image by supervised and unsupervised classification techniques. The city plan was used as a guide in this step. Those areas not corresponding to the

Fig. 1: Study area- the City of Aydin, Turkey

Fig. 2: Tabakhane stream corridor vegetation, (Right: Natural landscape on the north, Center: Streamed in the urban landscape, Left: Agricultural landscape on the south

map was adjusted by on screen digitization. The magnitude of the growth in the urban area was detected by extracting the urban area of 1960 from the 2002's. A simple correlation (Spearman) analysis was conducted to see the relationship of population increase and the spatial expansion of the city.

Those areas, which are in the 100 m distance from the streambed in 2002, were investigated to identify the characteristics of the land use change in the Tabakhane stream corridor. The same area was used for the analysis for 1960. In order to detect the land use transformation along the stream corridor the land use categories were defined by studying the images: 1- low density development (5.6-23.8%), 2- medium density development (23.9-42.0%), 3- high density development (42.1-60.3%), 4-open space (vacant lots with signs of imminent development), 5- park, 6- natural, 7- agricultural (fruit grow and crop land) and 8- streambed. The density categories refer to the percentage of developed area in an urban lot (Deniz, 2005). The polygons for each land use type were created by on screen digitization and their related features were entered manually to the attribute table. This procedure was applied to each period of the study. The findings were used in one of the landscape structure indices- a matrix utility index.

Matrix utility analysis focuses on the conditions along the boundary of a natural landscape elements-in this case the streambed. If the structural and functional differences between these corridors and their surrounding habitats are high, the integrity of the environments will decline (Meffe and Carroll, 1994). In other words, matrix utility refers to the compatibility of the land uses immediately surrounding the streambeds. Because of this direct relationship between the condition of surrounding environments and streambeds, matrix utility analysis would be an effective method in estimating the impacts on these corridors and the changes in the ecological integrity of these habitats. The matrix utility index is higher in an ideal condition where the whole corridor is buffered with compatible land use types such as natural open spaces or low-density developments. If this buffer is dominated by incompatible land uses, edge effects increase. This reduces the habitat value of the stream. Each land use has different levels of impact on the stream corridor. For example, environmentally sensitive, low-density land uses provide opportunities for material and energy flow. Whereas, less compatible land uses such as high-density residential or heavy industrial uses comprise excessive amount of impervious surfaces and damage surrounding environments even more by diminishing native productivity, species richness and the recovery rate of the system.

Since each of these land uses generates different amount of impacts on the Tabakhane environment, assigning intensity values to each type is essential for further analyses. In this research, the amount of permeable soil cover was used to develop the intensity values, because Forman and Godron (1986) list pervious soils as an indicator of ecological integrity. Moreover, the significant effects of impervious surfaces on the stream systems were elaborated in the introduction of this study. Deniz (2005) has already generated the numbers for the amount of impervious surfaces in different land uses in the City of Aydin. This study employed his numbers. Findings were determined by the formula below:

$$M = \Sigma\ (ai \times ri)$$

Where,
M = Matrix utility index,
ai = Percentage of land use type i along the perimeter,
ri = Intensity value for the land use i.
Σ = Sum of

The ratio would vary from 0.0 in the hypothetical case where the entire perimeter of the streambed was covered with incompatible land uses, up to 1.0 for a solely compatible land use along the entire perimeter- an ideal case.

RESULTS

Change in the urban area: Population wise, the City of Aydin has grown progressively since 1940s (Fig. 3). After 1960, the steady increase continued with an accelerated rate until 1990 and then the magnitude of population rise slowed down between 1990 and 2000 period. The city experienced 29.74% population increase between 1960 and 1970 period, the percentage went up to 31.69% in the following decade. The city's population rose from 74021 to 107011 in the 1980-1990 period corresponding to a 30.83% increase. The proliferation of the population was only 25.30% until 2000. These numbers indicate that most of the population increase occurred between 1970 and 1990. The speed of urban population increase is slowing down because more and more people prefer to live in the peri-urban areas. This could be one example of changing social and cultural structure due to globalization; more people is exposed to life style in the developed countries and inclined to live like those examples. In spite of the slowing down, the urban population increased, overall, 75.20% between 1960 and 2000.

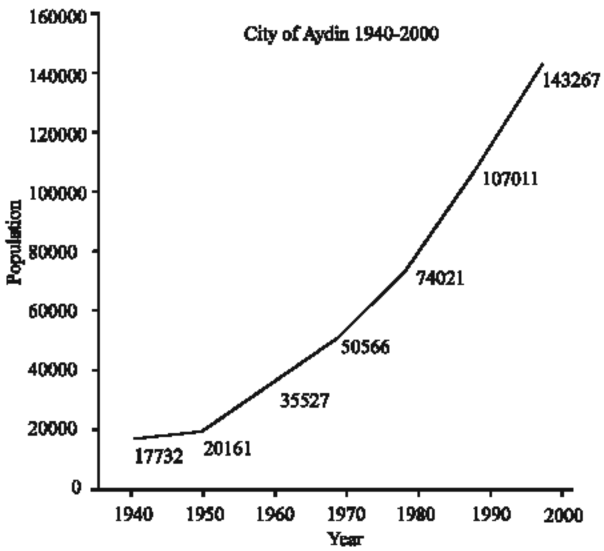

Fig. 3: Population of the city of Aydin

As a consequence of the population increase, which was contributed mostly by the migration from the Eastern part of Turkey and the other towns in the Aydin Province, the City of Aydin spatially expanded in the 42 year period. The correlation between the population and the spatial growth of the city was very significant ($p<0.001$). Overall, an 80.14% spatial growth occurred between 1960 and 2002 in the developed area of the City of Aydin (Table 1).

In 1960, the city form was rather compact and the core urban area constituted the 90.14% of the total area. Although, the core urban area expanded 4.92 times, a more fragmented and patchier development style prevailed in 2002. The percentage of the core urban area decreased to 88.06% in the total developed area and the peri-urban areas increased 6.1 times. Similarly, the number of peri-urban patches went up from 6 in 1960 to 39 in 2002. The boundary of the City became more convoluted, thus the boundary between the core urban area and the surrounding agricultural and natural areas increased 4.70 times - from 17.73 km. to 83.32 km.

The development did not occur in a concentric form rather it was stretched along the major highway connecting two neighboring highly industrialized cities of Izmir and Denizli (Fig. 4). Most of the residential development took place in the west and south directions. Relatively limited growth on the east was contributed by the industrial land uses. Industrialization has become a national policy to trigger the nation's economy since 1980s and these organized industrial zones are the outcome of the policies. Aydin has always been an agricultural community; the industrialization effort means not only economic change but also change in the social structure of the City. Moreover, increase in the magnitude of urbanization directly affects the surrounding agricultural landscape hence not only a change in the spatial structure but also a change in the ecological functioning of the landscape.

As Figure 4 depicts, our study area the Tabakhane stream corridor separates these mainly residential uses on

Table 1 Aydın urban area 1960-2002

Year	2002	1960
Core urban (ha)	1049 003	213 286
Peri-urban (ha)	142 263	23 334
Total Area ha)	1191 267	236 619

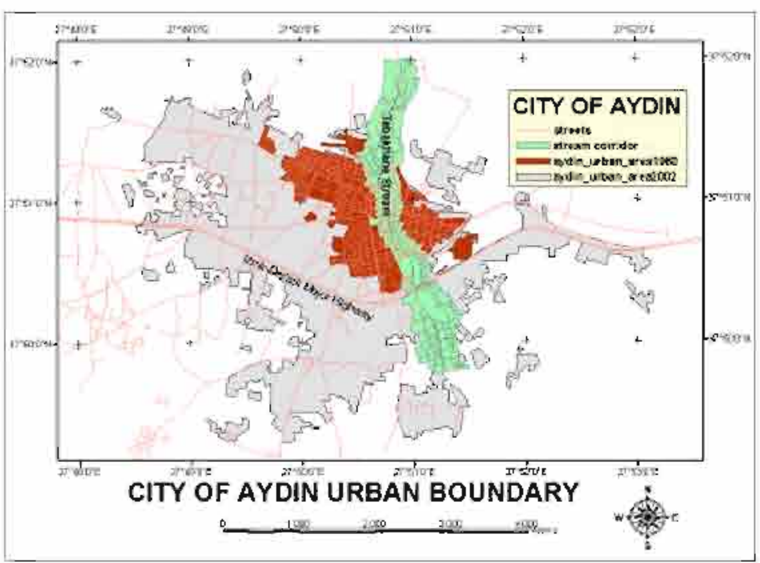

Fig. 4: Growth of urban area in Aydin (1960- 2002)

the west from the industrial uses on the east. In a way, it generates a transitional zone and shelters various land use types. The corridor was socially, economically and ecologically affected by the general transformation of the urban matrix.

Land use change in the stream corridor: The results (Fig. 5) show that, in 1960, natural lands occupied most of the corridor; while in 2002 the high-density land uses were dominating the corridor. As the second major land use in 1960, the agricultural areas (cropland and fruit grows) occupied almost 18% of the study area followed by high and medium density land uses. In 2002, the second prevailing land use type was medium density followed by natural lands. This means that in the 42 year period, the natural areas around the stream decreased almost 55%.

As urban development encroached upon the streambed, a larger portion of the perimeter was occupied with less compatible land use types. During this time, the empty lots in the urban matrix were developed. The increase in the amount of open space patches apparently suggests that the development is going to continue after 2002. The open space category refers to the vacant lots with the signs of imminent construction. A significant increase in this category indicates the magnitude of upcoming urban development. Similarly, the increase in the percentage of parks implies that the Municipality of Aydin establishes parks to ease the daily pressures of urban life. This also is a sign of changing social structure in the city.

In the 42 year period, an eye opening change occurred both in the area and the structure of the Tabakhane stream. The area of the streambed decreased from 2.00 ha in 1960 to 0.65 ha. in 2002. The streambed narrowed down, because it was canalized in areas corresponding to the urban matrix. In a sense, it was transformed from being a natural corridor to a synthetic corridor. Synthetic corridors, such as utility right of ways, canals, scenic roads are linear patches with lesser values as habitats. Synthetic corridors are typically cultural elements that may be adapted in establishing ecological networks. Even though they are not as valuable as natural corridors, synthetic corridors provide reasonable opportunities for restoring some of the natural functions (Cook, 2000). They offer cultural and economic benefits even though they have very little inherent ecological value. Therefore, their redesign should be considered to increase urban ecological integrity.

In Fig. 6, the shrinkage of the streambed is apparent especially for the south sections of the Tabakhane stream. The change in the structure of the stream ecosystem certainly changed the habitat values of the corridor. In addition, the aesthetic qualities of this natural corridor diminished because of the excessive amount of concrete involving in the construction. Nowadays, the stream corridor has an unappealing look due to the garbage and other urban disposal dumped. Ecological restoration of the whole streambed is necessary to capture back the ecological, aesthetic and social qualities.

Matrix utility analysis: The initial steps of the analysis involved the assignment of intensity values to each land use type by utilizing the amount of permeable surfaces. The findings showed that natural, agricultural, low density and open spaces deserved the highest value, while high density and park type of uses were possessing less habitat qualities due to the excessive use of impervious surfaces (Esbah, 2006). This means that the latter land uses are less compatible with the stream ecosystem and may pressure these habitats more.

The investigation of the percentage of land uses directly nearby the streambed showed that, in 1960, most of the stream was neighboring with the natural areas and medium density land uses (Table 2). Whereas natural areas, urban parks and high density land uses primarily occupied the perimeter of the Tabakhane stream in 2002. Decline in the magnitude of the natural areas are substantial. Also the increase in the percentage of open spaces reveals the signs of future urban development. The drop in the low-density uses and croplands is the corollary of the increasing density in the urban matrix. The scrutiny of the aerials and the satellite images displayed a transformation from agricultural lands to low-density and then to the higher densities of urbanization; this complies with the general trend in the whole urban matrix (Deniz, 2005).

Because relatively more compatible land use types surrounded most of the perimeter, the matrix utility index yielded higher value in 1960. The index is close to the ideal situation where the whole perimeter is neighbored by compatible land uses and least threat is generated to the habitat qualities of the stream. However, a 25.30% decline occurred in the matrix utility value by 2002 indicating a decline in the habitat qualities of the stream due to the historic land use development in the city. As mentioned before increased share of the high-density and urban park type of uses contributed this decline the most. These types of areas hold the lowest intensity values hence the least compatible with the ecologically valuable stream corridor. The significant increase in the index value is possible if their re design and planning involves increased infiltration and permeable surfaces.

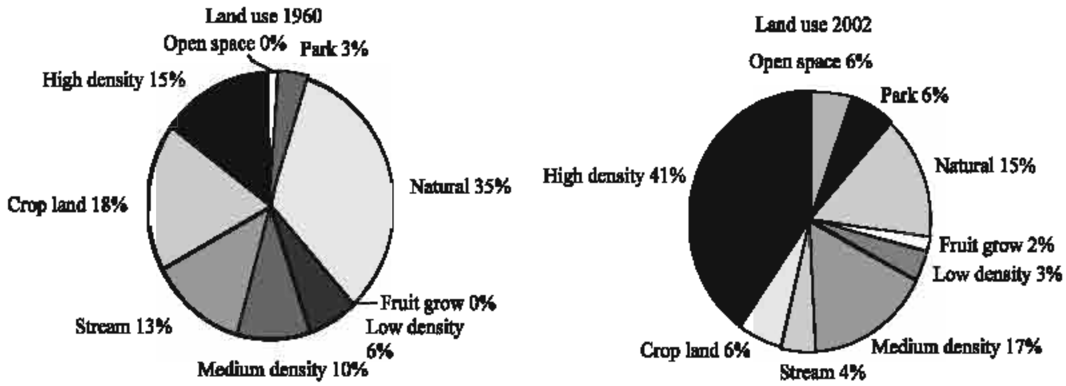

Fig. 5: Percentage of land uses in the stream corridor

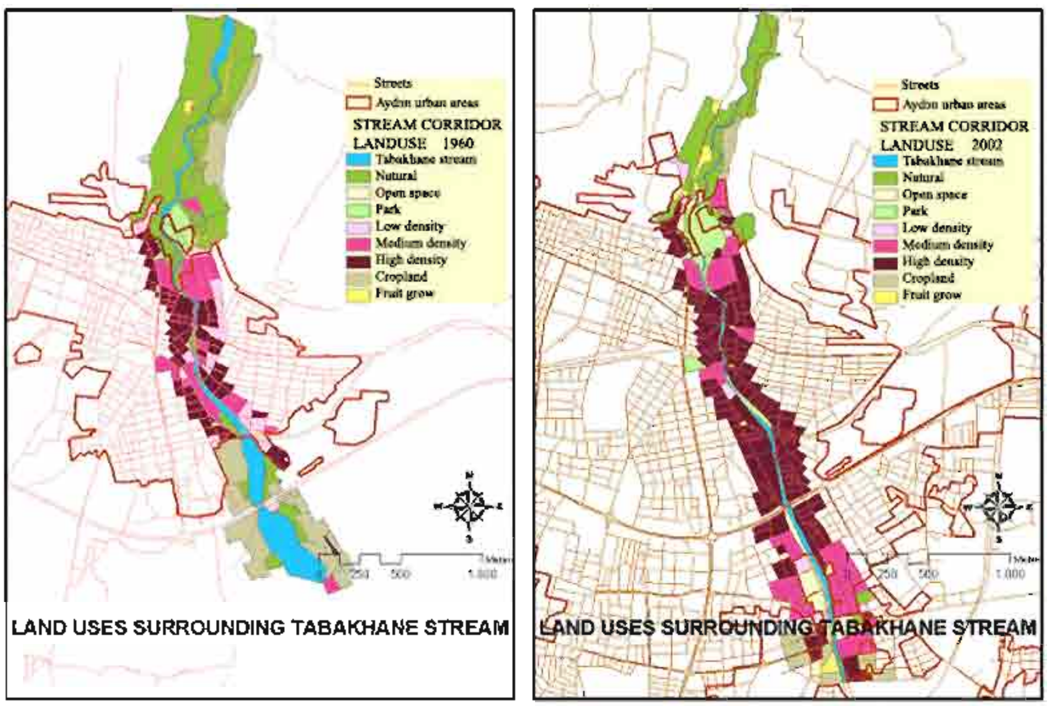

Fig. 6: Land use change in the Tabakhane corridor

Table 2 Intensity and matrix utility values

Land use	Intensity value**	% on perimeter 1960	% on perimeter 2002	M value 1960	M value 2002
Open space	0 62	0 00	0 11	0 000	0 068
Park	0 43	0 05	0 20	0 022	0 090
Natural	0 96	0 65	0 30	0 620	0 290
Low density	0 68	0 05	0 02	0 030	0 014
Medium density	0 59	0 08	0 07	0 047	0 041
High density	0 36	0 06	0 28	0 022	0 101
Fruit grow	0 74	0 00	0 02	0 000	0 015
Crop land	0 74	0 11	0 01	0 081	0 007
Toplam	-	1 00	1 00	0 830	0 620

**Intensity values indicate the % of pervious surfaces in each land use Adopted from Deniz (2005)

DISCUSSION

The overall goal of this research was to understand the characteristics of the historic land use pattern in the surrounding areas of a streambed in the City of Aydin, Turkey. The research methods involved the measurement of spatial changes in the urban area and the spatial changes in the Tabakhane stream corridor. While this study utilized only matrix utility analysis, development and application of other indicators can provide a useful measure of the effects of different planning decisions on ecologically important stream corridor.

The assessment of the land use types around the streambed indicate that Tabakhane stream is surrounded by less environmentally sensitive land uses with each coming year. The transformation of the landscape works as the detriment of natural and agricultural areas. This trend will continue in the near future if some zoning and protection measures are not taken. This emphasizes the importance of creating buffer areas around the streambed. The buffer concept is used for planning for some nature reserves, large regional parks and national park systems (Shafer, 1999; Noss and Harris, 1986). Its application to the stream environment is scarce in urban areas. The problem of adapting this concept for the currently developed stream corridor is that most of the perimeter is already covered by incompatible land uses. To acquire these lands is impossible and the ecological structure of these areas is not easy to rehabilitate. The most appropriate response may be to provide incentives and/or subsidies to facilitate transformation of existing urban areas incrementally. For those undeveloped areas, the land ownership and zoning strategies should be developed before the urbanization impinge upon these areas. Creating buffer areas along the streambed and encouraging designs with low percentages of impervious surfaces should be priority. Hatt *et al.* (2004) suggest that urban development that minimizes amount of connected impervious surface and establishes undeveloped buffer areas along streams should have less impact than conventional types of development. Moreover, priority should be given to low-impact urban design, which primarily involves reducing drainage connection, to minimize urbanization-related pollutant impacts on streams.

In addition to buffer concept, the connection of the streambed to other natural patches and corridors is essential to improve the habitat qualities of the Tabakhane stream. In a sense developing an urban ecological network is imperative to maintain the viability of the stream ecosystem. However, the concept of ecological networks is not easy to adapt in the highly developed urban matrix. Most of the time finding a natural patch or corridor is a challenge. Cook (2002) demonstrates that reconnection of ecological network elements via synthetic corridors provides opportunities within the urban matrix. Therefore, all types of opportunities should be embraced to tie Tabakhane stream with the rest of the urban open spaces. A previous study elaborates that the public open spaces, the campuses of public offices and the medians of major streets and highway right of ways contribute substantially to the green network of the City of Aydin (Deniz, 2005).

CONCLUSIONS

The findings of this study demonstrate that the urban area of the City of Aydin experienced an eye opening spatial expansion within a 42 year period. The transformation in the urban matrix changes not only the ecological but also the social structure of the city. The ecological integrity of the Tabakhane stream has changed as a result of the historic land use development pattern in the City of Aydin. The surrounding areas of the stream were occupied by less compatible land uses between 1960 and 2002. The typical consequence of this trend is increasing high-density land uses with very high percentages of imperviousness. The decline in the matrix utility values indicates a potential decrease in the habitat values of the stream. A new land use scenarios should be generated to bring the index value to its level in the past. From this point of view matrix utility index may guide the land use decisions and help develop a common language between the urban planners and landscape architects. The utilization of additional landscape indices could improve the communication between these professions. Further research employing these indices to detect the urban land use and ecological change in natural corridors are needed. The importance of this research comes in the form of integrating matrix utility and its related concepts to a stream landscape.

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