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# Temporal Changes in Forest Landscape Patterns in Artvin Forest Planning Unit, Turkey

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**Abstract** Understanding the historical dynamics, composition, and environmental disturbances of forest landscapes provides a context for monitoring changes, describing trends, and establishing reference conditions. This study analyses the temporal changes in forest ecosystem structure in Artvin Forest Planning Unit (AFPU), Turkey, during 1972–2002 period based on digitized forest stand type maps using geographic information system (GIS) and interpretation of satellite data. The results showed that there was a net decrease of 450 ha in total forested areas between 1972 and 2002. Forest ecosystem structure changed over time depending on a few factors such as demographic movements, insect outbreaks, dam and road construction, unregulated management actions, and social pressure. In conclusion, temporal changes and the factors affecting these changes should be determined for sustainable management of natural resources.

**Keywords** Forest landscape change · Forest management · Geographical information system · Historical dynamics · Remote sensing

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## 1 Introduction

The progressive decrease of forest resources in terms of both area and quality is a major concern on several fronts. It is significant to global climate warming and regional climate change, global losses in biotic diversity and net primary productivity, local-to-regional land degradation, and threats to ecosystem services and other valuable functions. These impacts, in turn, affect the vulnerability of places and people to perturbations of all kinds.

In addition, it is generally agreed that sustainable development and management of natural resources for the welfare of local populations should be the key objective of watershed management, which includes sustainable utilization and conservation of forest resources at community or watershed level as one of its important components (Sharma & Krosschell, 1996). To provide foundations for effective management of forest and other natural resources, an understanding of the variability in time and space of the resources and the factors affecting these changes are some of the fundamental requirements (Naiman, Bisson, & Turner, 1997).

There are various methods that can be used in the collection, analysis and presentation of resource data but the use of remote sensing and geographic information system (RS/GIS) technologies can greatly facilitate the process. Repeated satellite images and aerial photographs are useful for both visual assessments of natural resources dynamics occurring at a particular time and space as well as quantitative evaluation of land use/land cover changes overtime (Peterson & Running, 1989; Tekle & Hedlund, 2000). The advantages in applying RS and GIS methods are evident in the evaluation and management of forest resources. Data from these technologies can be useful in delineating structural and functional characteristics of forest at a variety of geographical scales (Iverson, Graham, & Cook, 1989). Applications of these data to illustrate changes in forest over time have been reported by many investigators (Fearnside, Turdin, & Meira, 1990; Gren & Sussman, 1990; Hall, Strebel, & Sellers, 1988; Iverson et al., 1989; Kennedy & Spies, 2004; Luque, 2000; Sader & Joyce, 1988; Wakeel, Rao, Maikhuri, & Saxena, 2005).

This study analyses the temporal changes in forest ecosystem structure in AFPU, Turkey, during 1972–2002 period based on digitized forest stand type maps. Thus, we have the opportunity to investigate how the forests developed over time. High resolution satellite images, aerial photos and the GIS are used accordingly to help analyze both composition and some aspect of configuration of forest ecosystem.

## 2 Methods

### 2.1 The study area

The study area is the AFPU surrounding the city of Artvin and characterized by a dominantly steep and rough terrain with an average slope of 62% and an altitude from 400 to 2,220 m above sea level (Figure 1). It extends along UTM ED 50 datum 37. zone 731000–743000 E and 4556000–4570000 N on the Northeastern Black Sea Region of Turkey. The total area is 5,221 ha. The vegetation type is forest vegetation and the dominant tree species of the vegetation are *Picea orientalis* (L.) Link, *Pinus sylvestris* L., *Abies nordmanniana* (Stev.) Spach

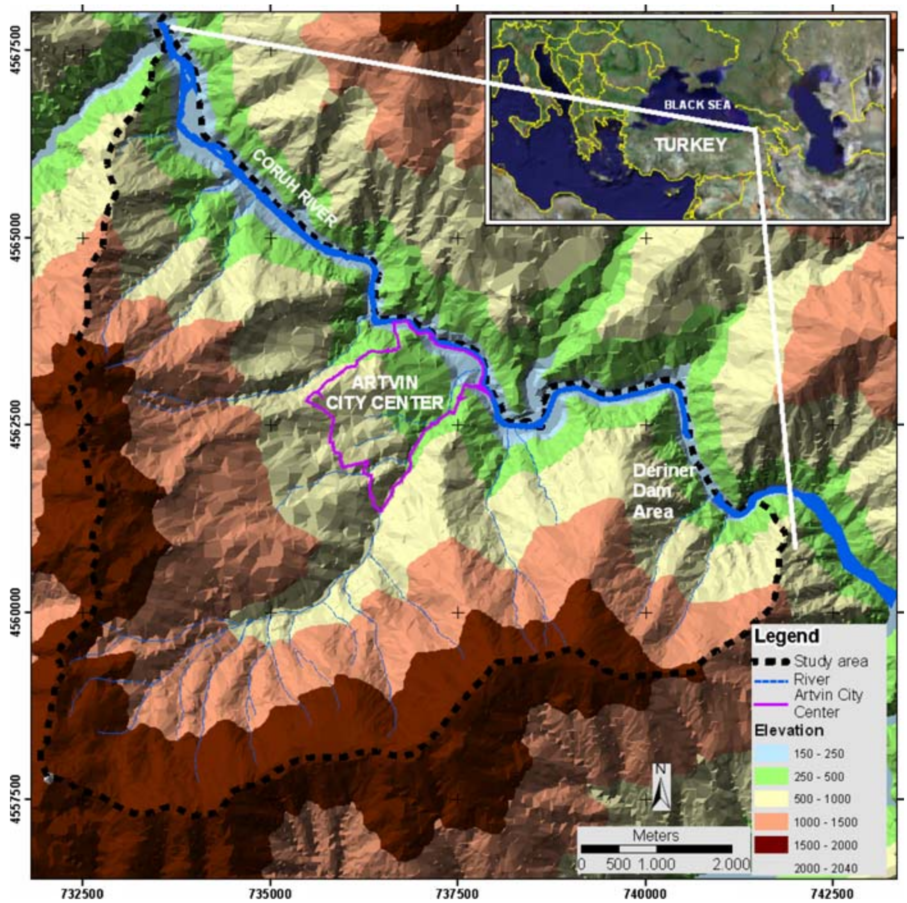


**Figure 1** Map of the study area indicated with *dotted line* and Coruh river.

**Table I** Classification of crown closures and development stages

| Crown closure types | Criteria (% cover) | Development stages | Criteria (average dbh) |
|---|---|---|---|
| 0 | Regenerated areas | a (regenerated) | <8 cm |
| Degraded forest | 0–10% | b (young) | 8–19.9 cm |
| 1 (low coverage) | 11%–40% | c (mature) | 20–35.9 cm |
| 2 (medium coverage) | 41%–70% | d (over mature) | >36 cm |
| 3 (full coverage) | >71% | | |

subsp. *nordmanniana*, *Fagus orientalis* Lipsky, *Quercus petraea* (Maattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln., *Carpinus betulus* L., *Ostrya carpinifolia* Scop., and *Pinus pinea* L. *Pinus pinea* community is locally distributed in the study area as a Mediterranean enclave (Varol, Karaer, Terzioğlu, & Kutbay, 2003). Mean annual temperature of the study area is 11.9°C, and mean annual precipitation is 719.7 mm. Main soil types are sandy clay loam, clay loam and sandy loam.

Demographic dynamics of Artvin have been considerably varied to the wave of immigration between 1970 and 2000 (Republic of Turkey, State Institute of Statistics). The population of Artvin has increased from 13,109 in 1970 to 23,157 in 2000, providing pressure to the fragile forest ecosystems. Also, recent building of series of dams for hydro-electrical power generation along Çoruh river adjacent to the edges of the study area provides further interest on the vegetation of the areas. Employed people in city of Artvin have studied in agriculture, industry and the other service sectors; 72%, 9% and 19%, respectively.

## 2.2 Database development

The spatial database developed consisted of forest stand maps derived from remote sensing (RS) data (aerial photographs and satellite images) and field survey. Aerial photographs of the study area were obtained from the General Directorate of Forestry, for the years 1972 (scale 1:22,000 and panchromatic aerial photographs), 1985 (1:15,000 panchromatic aerial photographs) and 2004 (1:15,000 color infra-red aerial photographs and high resolution satellite images (IKONOS). In 1972 and 1985, interpreting these aerial photographs and field survey data, forest stand maps were produced in raster format by Forest Management Team (FMT). The 2002 forest stand map was derived from interpreting aerial photographs, high resolution satellite images and field survey. These maps data were digitized and processed using a Geographic Information System (GIS, ArcInfo version 8.3) with a maximum root mean square (RMS) error of 15 m. Spatial database consists of stand types, which is characterizing crown closure, stand age and development stages. Classification of

**Table II** Evolution of selected landscape variables in the study area from 1972 to 2002

| Year | 1972 | | 1985 | | 2002 | |
|---|---|---|---|---|---|---|
| Total area | ha | % | ha | % | ha | % |
| Degraded forest | 1,607.8 | 30.8 | 1,583.3 | 30.3 | 1,385.7 | 26.5 |
| Mixed forest | 1,558.9 | 29.9 | 1,556.4 | 29.8 | 1,664.7 | 31.9 |
| Forest openings | 414.7 | 7.9 | 98.7 | 1.9 | 114.4 | 2.2 |
| Broadleaf forest | 240.9 | 4.6 | 424.5 | 8.1 | 351.4 | 6.7 |
| Conifer forest | 794.3 | 15.2 | 640.1 | 12.3 | 650.3 | 12.5 |
| Water | 126.5 | 2.4 | 95.5 | 1.8 | 59.5 | 1.1 |
| Settlement and agriculture | 478.1 | 9.2 | 822.6 | 15.8 | 887.3 | 17.0 |
| Dam | – | – | – | – | 107.8 | 2.1 |
| Total | 5,221.2 | 100 | 5,221.2 | 100 | 5,221.2 | 100 |
| Number of patches | 108 | | 103 | | 202 | |

**Table III** The change in crown closures of forest between 1972 and 2002

| Year | 1972 | | 1985 | | 2002 | |
|---|---|---|---|---|---|---|
| Crown closure | ha | % | ha | % | ha | % |
| 0 | 0 | 0 | 41.1 | 0.8 | 104.9 | 2.0 |
| 1 | 0 | 0 | 184.4 | 3.5 | 307.1 | 5.9 |
| 2 | 12.8 | 0.2 | 764.5 | 14.6 | 657.7 | 12.6 |
| 3 | 2,573.3 | 49.3 | 1,631.1 | 31.2 | 1,596.7 | 30.6 |
| Degraded forest | 1,615.9 | 30.9 | 1,583.3 | 30.3 | 1,385.7 | 26.5 |
| Forest openings | 414.6 | 7.9 | 98.8 | 1.9 | 114.4 | 2.2 |
| Agriculture and settlements | 478.1 | 9.2 | 822.5 | 15.8 | 887.4 | 17.0 |
| Dam and water | 126.5 | 2.4 | 95.5 | 1.8 | 167.3 | 3.2 |
| Total | 5,221.2 | 100 | 5,221.2 | 100 | 5,221.2 | 100 |

crown closures and development stages in Turkey is given Table I. However, it is possible to see mixed development stages in a forest, being different from the samples given in Table I. For example, development stage “bc” means that the stand has both “b” and “c” development stages but the volume belonging to “b” is larger.

## 3 Results

### 3.1 Changes in land use cover

The land use/cover changes among 1972, 1985 and 2002 are given in Table II. According to the table from forest planning area between 1972 and 2002 years, there was a net decline of 300 ha in forest openings as opposed to a net increase of 409 ha in settlement and agricultural areas (Table II). Broadleaf forest increased 110 ha, conifer forest decreased 144 ha, degraded forest decreased 222 ha, and mixed forest increased 105 ha. As an overall change, there was a net decrease of 450 ha in total forested areas.

On the other hand, the number of patches within the forest planning unit in 1972 and 1985 are nearly the same as 108 and 103, respectively (Table II). However, the number of patches in 2002 increased by 202 because of harvesting, insects, road construction, urbanization. While total road length in FPU was 67 km in 1972, it was 130 km in 2002 with a net increase of 63 km. A series of dams have been built since the year 2000 along Çoruh River, passing just near the study area. One of them is the Deriner Dam adjacent to the AFPU. Approximately 107 ha of forest areas were lost to the building of the dam.

### 3.2 Changes in crown closures of forest

Crown closure is another important stand parameter to see and analyze changes in forest structure. The change of crown closure of forest is given in Table III. In terms of crown closure change between 1972 and 2002 years, stands with the crown closure 1 (11%–40%) increased 307 ha, crown closure of 2 (41%–70%) increased 645 ha, and crown closure of 0 increased 104 ha. However, stands with the crown closure of 3 decreased 976 ha. Because of the deterioration of forest ecosystem structure, fully covered areas were changed in favor of less covered areas. Breakdown of crown closure in forest ecosystem structure has especially resulted from unplanned exploitation, settlement, dam and road construction, insect outbreaks on spruce stands, and conversion and over utilization.

Furthermore, the temporal transitions among the crown closures of forest ecosystem are also documented and evaluated to see the intertemporal dynamics of this parameter. The transitions of crown closures among 1972, 1985 and 2002 are given in Table IV. Some apparent forest crown closure transitions between 1972 and 2002 could be illustrated as; from full closure to regenerated area 24 ha, from full closure to low coverage 170 ha, from full closure to medium closure 562 ha. However, some degraded forest areas changed to covered areas with forest. For example, 376 ha degraded forest areas

**Table IV** Transitions among crown closures between 1972 and 2002

| CLASS | | 1985 year stand closure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | DF[1] | FO[2] | AS[3] | DW[4] |
| 1972 year stand closure | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 2.0 | 2.0 | 0 | 8.2 | 0 | 0.5 | 0 |
| | 3 | 41.1 | 124.2 | 628.5 | 1493.5 | 227.3 | 25.1 | 33.5 | 0 |
| | DF | 0 | 47.2 | 91.5 | 80.6 | 1,234.2 | 12.9 | 140.7 | 7.9 |
| | FO | 0 | 11.0 | 30.8 | 52.9 | 61.1 | 60.8 | 198.1 | 0 |
| | AS | 0 | 0 | 11.7 | 4.0 | 39.9 | 0 | 421.9 | 1.6 |
| | DW | 0 | 0 | 0 | 0 | 13.6 | 0 | 26.8 | 86.1 |
| | | 2002 year stand closure | | | | | | | |
| 1985 year stand closure | 0 | 0.5 | 0 | 1.9 | 38.2 | 0.6 | 0 | 3.9 | 0 |
| | 1 | 6.3 | 32.1 | 40.3 | 61.3 | 39.0 | 1.5 | 19.3 | 0 |
| | 2 | 27.8 | 64.8 | 200.2 | 331.3 | 113.6 | 7.2 | 11.2 | 0 |
| | 3 | 5.8 | 112.5 | 322.0 | 960.6 | 188.5 | 30.5 | 5.5 | 0 |
| | DF | 64.5 | 85.4 | 79.2 | 148.3 | 924.1 | 13.9 | 624.0 | 109.9 |
| | FO | 0 | 3.3 | 6.7 | 20.2 | 10.1 | 52.8 | 43.7 | 0 |
| | AS | 0 | 8.9 | 7.5 | 36.8 | 109.8 | 8.6 | 21.5 | 5.6 |
| | DW | 0 | 0 | 0 | 0 | 0 | 0 | 158.2 | 51.8 |
| | | 2002 year stand closure | | | | | | | |
| 1972 year stand closure | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 2.0 | 10.6 | 0 | 0 | 0 | 0 | 0.2 | 0 |
| | 3 | 23.6 | 170.8 | 562.2 | 1424.5 | 340.4 | 38.7 | 13.1 | 0 |
| | DF | 79.1 | 112.5 | 77.9 | 106.8 | 940.9 | 6.5 | 184.3 | 105.8 |
| | FO | 0.1 | 9.3 | 13.0 | 58.1 | 71.8 | 69.2 | 193.4 | 0 |
| | AS | 0 | 3.8 | 4.6 | 7.4 | 30.6 | | 428.8 | 2.7 |
| | DW | 0 | 0 | 0 | 0 | 0 | 0 | 69.8 | 58.7 |

[1] Degraded forest, [2] Forest openings, [3] Agriculture and settlements, [4] Dam and water.

**Table V** The change in development stages of forest between 1972 and 2002

| Year | 1972 | | 1985 | | 2002 | |
|---|---|---|---|---|---|---|
| Development stages | ha | % | ha | % | ha | % |
| a | 0 | 0 | 41.1 | 0.8 | 204.9 | 3.9 |
| ab | 0 | 0 | 0 | 0 | 67.3 | 1.3 |
| b | 897.8 | 17.2 | 242.2 | 4.6 | 121.2 | 2.3 |
| bc | 0 | 0 | 1,426.6 | 27.3 | 774.5 | 14.8 |
| bd | 1,148.2 | 22.0 | 0 | 0 | 0 | 0 |
| c | 0 | 0 | 0 | 0 | 785.4 | 15.0 |
| cb | 0 | 0 | 58.6 | 1.1 | 0 | 0 |
| cd | 0 | 0 | 791.0 | 15.1 | 564.6 | 10.8 |
| d | 0 | 0 | 61.4 | 1.2 | 148.6 | 2.8 |
| db | 540.0 | 10.3 | 0 | 0 | 0 | 0 |
| Degraded forest | 1,615.9 | 30.9 | 1,583.5 | 30.3 | 1,385.7 | 26.5 |
| Forest openings | 414.7 | 7.9 | 98.7 | 1.9 | 114.4 | 2.2 |
| Agriculture and settlements | 478.1 | 9.2 | 822.6 | 15.8 | 887.3 | 17.0 |
| Dam and water | 126.5 | 2.4 | 95.5 | 1.8 | 167.3 | 3.2 |
| Total | 5,221.2 | 100 | 5,221.2 | 100 | 5,221.2 | 100 |

**Table VI** Transitions among development stages between 1972 and 2002

| CLASS | | 1985 year development stages | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | bc | cb | cd | d | DF | FO | AS | DW |
| 1972 year development stages | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | 0 | 218.0 | 467.8 | 32.1 | 79.9 | 0 | 66.2 | 16.2 | 17.7 | 0 |
| | bd | 7.6 | 13.6 | 570.9 | 7.8 | 427.8 | 10.7 | 93.2 | 2.9 | 13.7 | 0 |
| | db | 33.6 | 0 | 181.2 | 10.0 | 210.6 | 19.8 | 76.1 | 6.1 | 2.8 | 0 |
| | DF | 0 | 6.9 | 154.3 | 0.1 | 30.4 | 27.5 | 1234.2 | 12.8 | 141.7 | 7.9 |
| | FO | 0 | 1.6 | 43.9 | 6.7 | 39.0 | 3.4 | 61.1 | 60.8 | 198.1 | 0 |
| | AS | 0 | 2.1 | 8.4 | 1.9 | 3.3 | 0 | 38.9 | 0 | 421.9 | 1.5 |
| | DW | 0 | 0 | 0 | 0 | 0 | 0 | 13.6 | 0 | 26.8 | 86.1 |

| CLASS | | 2002 year development stages | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | ab | b | bc | c | cd | d | DF | FO | AS | DW |
| 1985 year development stages | a | 36.9 | 0 | 0 | 0.6 | 0 | 2.9 | 0 | 0.6 | 0 | 0 | 0 |
| | b | 0 | 0 | 8.4 | 110.6 | 12.8 | 0.6 | 3.6 | 105.0 | 0.6 | 0.7 | 0 |
| | bc | 50.0 | 0 | 43.3 | 435.8 | 433.4 | 240.6 | 22.3 | 163.6 | 20.6 | 17.1 | 0 |
| | cb | 0 | 0 | 0 | 13.1 | 9.5 | 14.4 | 0 | 17.3 | 1.3 | 3.1 | 0 |
| | cd | 10.2 | 0 | 26.0 | 148.5 | 213.3 | 234.4 | 95.6 | 35.7 | 16.4 | 11.0 | 0 |
| | d | 9.4 | 0 | 0 | 2.6 | 7.4 | 14.8 | 4.7 | 19.5 | 0.4 | 2.5 | 0 |
| | DF | 98.4 | 58.2 | 28.3 | 42.3 | 86.2 | 45.4 | 18.7 | 924.1 | 13.7 | 158.2 | 109.9 |
| | FO | 0 | 0 | 2.4 | 5.2 | 14.0 | 8.6 | 0 | 10.1 | 52.9 | 5.5 | 0 |
| | AS | 0 | 9.1 | 12.9 | 15.6 | 8.7 | 3.0 | 3.8 | 109.7 | 8.6 | 645.5 | 5.6 |
| | DW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43.7 | 51.8 |

| CLASS | | 2002 year development stages | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | ab | b | bc | c | cd | d | DF | FO | AS | DW |
| 1972 Year Development Stages | a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | b | 1.5 | 21.4 | 65.4 | 343.8 | 191.3 | 30.0 | 14.7 | 210.7 | 12.4 | 6.8 | 0 |
| | bd | 24.4 | 0 | 1.8 | 243.3 | 390.6 | 293.3 | 82.5 | 88.3 | 18.8 | 5.2 | 0 |
| | db | 60.7 | 0 | 0 | 120.5 | 82.9 | 202.4 | 23.4 | 41.3 | 7.5 | 1.2 | 0 |
| | DF | 118.2 | 39.2 | 41.5 | 41.8 | 93.8 | 20.3 | 21.6 | 942.9 | 6.5 | 184.2 | 105.8 |
| | FO | 0.1 | 6.6 | 9.2 | 21.8 | 22.1 | 18.6 | 2.1 | 71.8 | 69.2 | 193.3 | 0 |
| | AS | 0 | 0 | 3.4 | 3.3 | 4.8 | 0.1 | 4.3 | 30.6 | 0 | 428.8 | 2.7 |
| | DW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67.8 | 58.7 |

developed into regenerated areas, low, medium and fully covered areas as 79, 112, 78 and 107 ha respectively.

### 3.3 Changes in development stages

Development stages of forests are important parameter to analyze the change in the quality of forest ecosystem structure. The change of development stages of forest ecosystem are given in Table V. The change of development stages between 1972 and 2002, regenerated areas (a) increased 205 ha, ab increased 67 ha, b decreased 777 ha, bc increased 774 ha, bd decreased 1148 ha, c increased 785 ha, cd increased 565 ha, and d increased 149 ha.

The transition among development stages between 1972 and 2002 were also analyzed. The transitions among 1972, 1985 and 2002 are given in Table VI. Some apparent development stage transitions between 1972 and 2002 could be illustrated as; from b to bc 343 ha, from b to c 191 ha, from b to cd 30 ha, from b to d 15 ha, from bd to c 391 ha, from bd to cd 293 ha, from bd to d 82 ha, from db to a 61 ha, from db to bc 120 ha, from db to c 83 ha, from db to cd 202 ha, and from db to d 23 ha. This change shows that about 60 ha of overmature forests were regenerated into a development stages. 118 ha of degraded forest were also regenerated. Some other development stages was left to grow older development stages while some of the them changed to lower development stages as a result of either erroneous determination of developmental stages or possible harvesting of larger trees in precommercial thinning.

## 4 Discussion

Land-use and land cover change can play a pivotal role in environmental changes and contribute to global change (Dale, 1997; Imbernon, 1999; Meyer & Turner, 1991). Changes in land-use and land cover have important consequences for natural resources through their impacts on soil and water quality, biodiversity, and global climatic systems (Houghton, 1994; Houghton, Lefkowitz, & Skole, 1991; Turner et al., 1995). Land-use and land cover change are particularly related to increase of population and intensive agriculture (Verburg, Veldkamp, & Bouma, 1999). Land cover modification and conversion are driven by the interaction in space and time between biophysical and human dimensions (Turner et al., 1995). With the awareness of the importance of land-use change on global change, the study of regional or global land-use and land cover change has become the focus of much scientific endeavor and international organizations (Chen, Wang, & Qui, 2001; Turner, Wear, & Flamm, 1996).

This study has provided important insights into the dynamics of forest ecosystems that occurred in forested area and other major land uses of AFPU between 1972 and 2002. In examining three periods in planning unit, some important changes in land use and forest cover type structure occurred. The most important change between 1972 and 1985 is to extend the city boundary in north direction. That enlargement has continued up to 2004. The most important reason in this city expansion is rural migration to Artvin city from 1970 to 2000. The population of Artvin has increased two times over 30 years. In conversion of forested areas to non forest areas, human intervention has been effective.

As an overall change, there was a net decrease of 450 ha in total forested areas because of especially expansion of settlement and agricultural area from 478 ha in 1972 to 887 ha in 2002. While mixed and broadleaf forest area was increasing during the study period, conifer forest area decreased by 144 ha because of insect outbreaks. A lot of dams have been built up since 2000 on the Çoruh River. One of them is the Deriner Dam near AFPU. Forest area of 108 ha has lost owing to the building of dam. While the total road length in AFPU was 67 km in 1972, it was 130 km in 2002 with an increase of 63 km.

One of the key reasons of land use and forest cover type changes in AFPU is insect attacks on spruce (*Picea orientalis*) stands. 55% of whole forest area in planning unit is spruce stands. First insect attacks started in 1966, and came from Georgia. The most destructive insects are *Ips typographus*, *Ips sexdentatus ve Dendroctonus micans* (Güner, Tüfekçioğlu, & Öztürk, 2004). Mechanical control against these insects was made up to 1985. Diseased trees were generally harvested from the area. However, these struggles had not stopped the insect outbreaks, and therefore, biological control has started since 1985. For these reasons, some activities relating insect outbreaks as well as forest harvesting were made in the planning area. In AFPU, forest harvesting activities with maximum wood production aim were made up to the year of 1980. After that year, they have been interrupted in these forests near city. However, some harvesting studies have been made because of insect outbreaks since 1990.

Furthermore, in examining the changes in crown closure between 1972 and 2002 in planning unit, the results showed that fully covered areas were changed in favor of less covered areas. Some development stages was left to grow older development stages while some of the them changed to lower development stages as a result of either unusual harvesting activities or possible harvesting of larger trees in precommercial thinning.

In conclusion, forest ecosystems have important functions from an ecological perspective and provide services that are essential to maintain the life-support system on a local and global scale. Greenhouse gas regulation, water supplies and regulation, nutrient cycling, genetic and species diversity as well as recreation are only some examples of the services that forest ecosystems provide. Recognition and understanding of landscape dynamics as a historical legacy of disturbances are necessary for sustainable management of forest ecosystems.

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