Understanding the Impacts of Illegal Logging in Turkey: a Case Study on Junipers in Eskişehir

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Abstract

Juniper forests in Turkey are one of the most valuable ecosystems for the country due to their ecological, socio-economic and cultural importance. Because of its wide usage for wood, non-wood products and feedstock, people have historically benefited from these forests. Juniper forest area has been eroded by anthropogenic as well as natural forces leading to critical environmental problems. Illegal logging is one of the most important anthropogenic threats. In this study, in order to assess the impacts of illegal logging on juniper forests, we determined cutting dates and seasons of foetid junipers and calculated financial losses using an interdisciplinary approach. The cutting dates of the trees in a small area were dispersed over a period of time between 1949 and 2001. That refers rather to illegal logging for livelihood of villagers than to commercial logging. Although we calculated monetary cost of the illegal logging, we conclude that losses were more appropriately considered using a total economic value approach.

Keywords: Forensic dendrochronology, tree rings, *Juniperus foetidissima*, sustainability.

Introduction

Juniper forests in Turkey are characterized by unproductive stands located in skeletal soils (Eler and Çetin 2006). According to the forest inventory assessment results of Turkey in 2015; there is a total of 958,423 ha of juniper forests, which corresponds to 4.29% of the total forest area. It has mainly spread in Mediterranean and Central Anatolia regions (GDF 2015). Of juniper species, *Juniperus oxycedrus* L., *J. communis* L., *J. macrocarpa* Sibth. & Sm., *J. sabina* L., *J. excelsa* M. Bieb., *J. foetidissima* Willd., *J. phoenicea* L. and *J. drupacea* Labill. naturally grow in Turkey (Coode and Cullen 1965, Yaltırık 1993, Farjon 2010, Yılmaz et al. 2011).

Juniper forests are one of the most outstanding ecosystems of Turkey due to their ecological, socio-economic and cultural importance. These valuable ecosystems produce different goods, values and services. Juniper woods have been used for fuelwood (GDF 2006), fence posts (Akkemik et al. 2008), musical instrument and natural paint (Güzel and Kocaman 2015), furniture, pencil, wood carving and wood veneer, and especially for ceiling and ground cover of the village houses (Yaltırık 1993) in Anatolia since the earliest times. Apart from the benefits obtained from wood, juniper cones have been used as flavour for distilled spirits such as gin. Furthermore, juniper tar has historically been attained by using its wood and leaves (Yaltırık 1993). A juniper stand also provides perching and nesting sites for animals and is important for livestock and wildlife as a source of food and habitat. For example, goats consume foliage and bark of juniper in some parts of Turkey (Keskin 1991, Eler 2000). Finally, juniper trees are also used in landscaping parks and gardens, making wind and snow fences and preventing erosion (Ürgenç 1998).

Juniper forest area has been decreased by natural and anthropogenic threats, such as natural regeneration problem, hunting, overgrazing and illegal logging (Keskin 1991, Eler 2000, Eler and Çetin 2006, Gültekin 2005, Akkemik et al. 2008). Of these threats, illegal harvesting of juniper and other species is the most common forest offence (Güneş and Elvan 2005, Yaman and Akkemik 2009). According to statistics from 1937 to 2011, illegal logging comprised 39% of forest offences, illegal transporting 30%, forest encroachment 19%, illegal grazing 8% and others 4% (GDF 2012).

Illegal logging causes serious environmental problems such as global deforestation leading to reductions in carbon stocks; degradation of biodiversity including rare and endangered species (Moiseyev et al. 2010, Bueno and Cashore 2013); discouraging sustainable logging practices and forest management (Moiseyev et al. 2010); increasing soil erosion and landslides (Ananda and Herath 2003); raising CO_2 release and climatic changes;

damaging local water supplies (Bosello et al. 2013). Besides its environmental effects, illegal logging also leads to various social, economic and cultural problems. Illegal logging causes human rights abuses and disrespect of the basic needs of local communities and their culture (Reboredo 2013, Rahmonov et al. 2017), often supports corruption (Lee et al. 2015), and reduces government revenues such as royalties and taxes (Bosello et al. 2013, Guritno and Murao 1999). It is generally agreed that illegal logging endangers sustainable forest management (Özden and Ayan 2016).

Besides these problems, one of the most important questions is how to determine the financial losses caused by illegal logging as well as identifying who is responsible for its compensation. The first step to determine culpability is to know cutting dates and/or seasons. Dendrochronology, dating of tree rings, has been used as a very effective tool to determine the date of cutting trees in forest offences. For instance, Jozsa (1985) presented case examples of forensic dendrochronology resulting as dating a crime year and/or season. Wolodarsky-Franke and Lara (2005) listed the dates and seasons illegally cutting *Fitzroya cupressoides* (Molina), Johnston trees, in Chile, which are determined by the Dendrochronology Laboratory, the Universidad Austral de Chile. Läänelaid (2009) used tree-ring analysis to find out the felling dates of *Betula pendula* Roth. in southern Estonia. As an example, from Turkey, Yaman and Akkemik (2009) dated totally 13 *Pinus nigra* Arnold and *Pinus sylvestris* L. stumps in Samsun, to answer the question by the judge in 2007.

Today juniper forests cannot generate optimal environmental, cultural and socio-economic benefits due to the anthropological impacts over the last few centuries. Accordingly, the Turkish National General Directorate of Forestry (GDF) implemented the Juniper Rehabilitation Action Plan between 2006 and 2015. This action plan aimed to ensure that 300,000 hectares juniper forests were rehabilitated to regain environmental and socio-economic values produced by juniper forests (GDF 2006). To date a considerable amount of activity in this programme has taken place, but final results have not been reported yet.

Of the native species of juniper, foetid juniper (*Juniperus foetidissima* Willd.) is the most degraded because of having more valuable wood and importance for livestock (Eler 1988, Eler and Çetin 2006). Because of this management regime, today *J. foetidissima* which covers 15% of juniper forest in Turkey is seen individually or in small groups in the forests (Eler and Çetin 2006). In this study, we discuss various dimensions of disadvantages caused by illegal cutting of *J. foetidissima* trees based on tree-ring dating and lost economic value.

Materials and Methods

Study area

The sampling area is in Forest Enterprise Directorate (FED) of Mihalıççık in the province of Eskisehir, Turkey (Figure 1). The FED of Mihalıççık has an area of 11,496.3 ha of juniper forest. About half of this juniper forest area (5,748.15 ha) is composed of foetid juniper. Location of the sampled site is 39º 44' N in latitude and 30º 40' E in longitude and its altitude is 1,600 m a.s.l. The surface of the soil is stony. The forest type is a conifer forest composed of old foetid juniper and black pine trees (Figure 2a, b). In the area we observed some juniper trees cut over about 1-1.5 m above the ground level (Figure 2c). This cutting way was not appropriate for forestry technique. Our observation and forester officers' testimony indicated that these were illegal logging.

Figure 1. Location of study area. Image source: d-maps.com

Figure 2. a) and b) View from the sampling site, c) Sampling by chainsaw

Sampling and Dendrochronological dating

We cut nine stem discs from these foetid juniper stumps using a chainsaw (Figure 2c). Samples were fine-sanded to make tree rings visible. Two measurements were performed for each cross-section. Tree-ring widths were measured to the nearest 0.01 mm using LINTAB-TSAP-Win measurement system (RINNTech, Germany). Each individual undated series of the samples compared visually and statistically against each other. Relatively dated measurement series were tested using COFECHA program (Holmes 1983, Grissino-Mayer 2001). Each measurement series was standardized by means of a negative exponential or linear regression to remove trends related to age, size and the effects of stand dynamics (Fritts 1976, Cook et al. 1990). Then a floating standard chronology were built using ARSTAN program (Cook 1985, Grissino-Mayer et al. 1996). We used four different black pine chronologies from Eskişehir (Köse et al. 2005, 2011, 2013) and one juniper chronology (Touchan et al. 2005) from Antalya as reference chronologies. Dating of the floating standard chronology against the reference chronologies gave statistically significant coefficient of agreement (*Gleichläufigkeit, GLK*) value, which is percentage of year-to-year agreement of two chronologies (Eckstein and Bauch 1969), and T_{BP} (the *t*-value adapted to time series by Baillie and Pilcher (1973)) values, which employs trend removed data.

Calculation of financial losses

Our approach for calculating financial losses of forest service is to find out how much forest service would earn when timbers were sold. We calculated financial losses applying the following steps: first we estimated volumes of each illegally cut tree. For volume estimation, we converted a double entry volume table to a single-entry volume table because we only have diameter information of the stumps. There is no volume table for *J. foetidissima* in Turkey. Therefore, we could involve double entry volume table of *J. excelsa* built by Eler (1988). To convert the double entry volume table to a single-entry volume table, an exponential regression curve was fitted on diameter-volume data of double entry volume table. Because the relation of diameter and volume makes an interval, we gave the volumes of each illegal cut trees as intervals, which are the minimum and maximum volume values of related diameter. Accordingly, market values of each tree were given into these intervals.

Eler (1988) mentioned that they could not find enough number of foetid juniper trees because of overgrazing. However, in order to be able to obtain data for the taxa, they sampled trees from the similar age class in the same site and compared to *J. excelsa* results. Second, we obtained market price of foetid junipers from GDF sales. There was a problem in that juniper forest has not had a determined production function for the last decade. Therefore, we could establish the price only for Elmalı, Antalya, for the year of 2011. It is a limitation of our research to not reach the sales price on the cutting dates of each tree, which range from 1949 to 2011. Third, we reached the present value of foetid junipers price using Domestic Producer Price Index (Yİ-ÜFE) produced by Turkish Statistics Institute (TÜİK).

Results

Tree-ring dating

We calculated statistically significant *GLK* values between almost all relatively dated individual series of samples (Table 1). MIH08 does not have a common period with three samples (MIH01, 03 and 07). Then, we obtained a 519 years long undated mean standard chronology from the samples. Comparison of the floating mean chronology with reference chronologies showed a strong agreement with the reference chronologies for the period of 1483-2001 (Table 2). The highest *GLK* and T_{BP} values were calculated with a *Juniperus excelsa* chronology from Antalya (Touchan et al. 2005). Figure 3 shows the agreement between our mean chronology and the *Juniperus excelsa* chronology from Antalya.

Of nine samples, only MIH08 have neither bark nor sapwood. Therefore, we could only date outer ring and

Table 1. *Gleichläufigkeit (GLK)* values between individual curves and their mean chronology

	MIH01	MIH02	MIH03	MIH04	MIH05	MIH06	MIH07	MIH08	MIH09	MEAN	OVERLAP (n)
MIH01	.	158	161	158	165	165	153	-	165	165	
MIH02	70***	.	154	182	182	182	146	21	182	182	
MIH03	63***	60**	.	154	172	202	194	-	202	202	
MIH04	66***	70***	62**	.	252	252	146	91	252	252	
MIH05	66***	77***	63***	67***	.	271	164	92	271	271	
MIH06	69***	64***	62***	66***	65***	.	194	180	389	389	
MIH07	61**	65***	72***	61**	66***	63***	.	-	194	195	
MIH08	-	73*	-	55NS	77***	64***	-	.	210	309	
MIH09	63***	63***	61**	62***	62***	69***	57*	59**	.	419	
MEAN	77***	78***	71***	74***	77***	73***	68***	81***	76***	.	

GLK VALUE

"*", "**", "***" indicate statistically significant values, $p<0.05$, $p<0.01$ and $p<0.001$ respectively. "NS" indicates insignificant values. "-" indicates no common interval between two time series.

Table 2. *Gleichläufigkeit (GLK)* and T_{BP} values between the mean chronology of the samples and reference chronologies

Reference chronology	*GLK*	T_{BP}
TAN	61***	7.1
CAT	62***	6.3
EKS	62***	4.8
TUR	61***	5.1
SUB	64***	11.7

"***" indicates statistically significant values ($p<0.001$). CAT (Köse et al. 2005); EKS, TAN (Köse et al. 2013); TUR (Köse et al. 2011) are previously published *Pinus nigra* chronologies from Eskişehir, and SUB (Touchan et al. 2005) is a *Juniperus excelsa* chronology from Antalya.

Table 3. Cutting dates and seasons of the samples

Sample code	Time span	Length, year	Cutting date	Cutting season	Comments
MIH01	1795-1959	165	1959	end of EW formation	Rotten inside, older than 165 years
MIH02	1771-1952	182	1952	end of EW formation	Bark and pith exist
MIH03	1799-2000	202	2000	end of EW formation	Bark and pith exist
MIH04	1701-1952	252	1952	end of EW formation	Rotten inside, older than 252 years
MIH05	1700-1970	271	1949	end of EW formation	Rotten inside but very close to pith, older than 271 years
MIH06	1612-2000	389	2000	end of EW formation	Rotten inside, older than 389 years
MIH07	1807-2001	195	2001	end of EW formation	Bark and pith exist
MIH08	1483-1791	309	1791+	undetermined	Sapwood does not exist, older than 309 years
MIH09	1582-2000	419	2000	end of EW formation	Rotten inside, older than 419 years
MEAN	1483-2001	519	-	-	-

"EW" indicates earlywood.

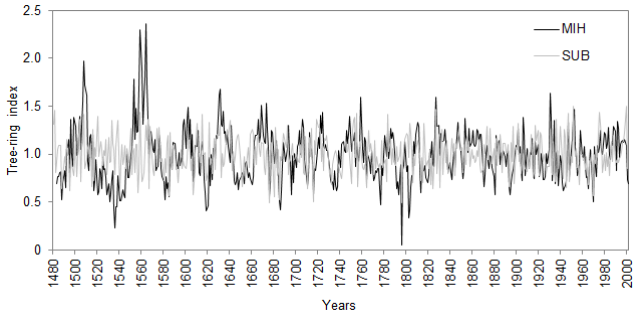

Figure 3. Comparison of the floating mean standard chronology of illegally cut trees (MIH, in black) with Juniperus excelsa chronology (SUB by Touchan et al. 2005, in grey) from Antalya

not give an exact cutting date for this sample. Existing bark or outermost rings provided to establish cutting dates of the remaining eight samples (Table 3). Determined cutting dates of the trees in a small area were very dispersed over the time, ranging from 1949 to 2001. We could also determine the cutting season of eight samples as the end of earlywood formation (Figure 4).

Our results showed that all the sampled trees were old. The counted ring number of the sampled trees range from 165 to 419. But, six of them were older than counted ring number, as they had rotten inside (MIH01, 04, 05, 06, 05) and removed outer part (MIH08) (Table 3).

Figure 4. The outermost ring of the sample MIH03 demonstrate that the cut season is at the end of earlywood formation

Financial losses due to illegally cut juniper trees

We converted the double entry volume table by Eler (1988) to a single-entry volume table and obtained the formula $y=7E\text{-}05x^{2.4841}$ to calculate the volume of each tree (Figure 5) where *y* is the volume (m^3) and x is the diameter at breast height (cm). Table 4 shows the calculated volume of each illegally cut tree.

Then, the market price of foetid junipers was taken from GDF sales for April 2011 as 457 TRY/ m^3. The present value of 457 TRY/m^3 was calculated to 709.18 TRY/m^3 in April 2017 based on Domestic Producer Price Index (Yİ-ÜFE) using online TÜİK monetary values update tool (TÜİK 2017). Finally, we obtained the market value of each illegally cut tree (Table 4).

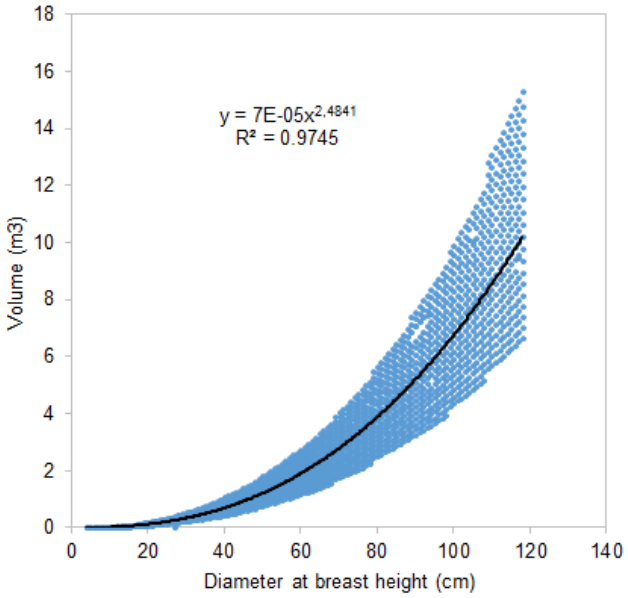

Figure 5. Regression curve of foetid juniper for single entry. Diameter – volume data obtained from double entry volume table by Eler (1988). Blue dots indicate individual trees

Table 4. Diameter, volume and market value of each sampled tree

Sample code	Diameter, cm	Volume (Min-Max), m^3	Unit Price, TRY	Market Value (Min-Max) TRY	Market Value (Min-Max), EURO*
MIH01	39	0.63 (0.47 - 0.96)	709.18	446.78 (333.31 – 680.81)	112.52 (85.75 – 175.14)
MIH02	35	0.48 (0.33 – 0.75)	709.18	340.41 (234.03 – 531.89)	85.73 (60.21 – 136.83)
MIH03	32	0.38 (0.29 – 0.61)	709.18	269.49 (205.66 – 432.60)	67.87 (52.91 -111.29)
MIH04	36	0.51 (0.35 – 0.80)	709.18	361.68 (248.21 – 567.34)	91.09 (63.85 – 145.95)
MIH05	48	1.50 (0.67 – 1.60)	709.18	1063.77 (475.15 – 1134.69)	267.90 (122.23 – 291.90)
MIH06	57	1.62 (1.05 - 2.45)	709.18	1148.87 (744.64 – 1737.49)	289.33 (191.56 – 446.98)
MIH07	38	0.59 (0.40 – 0.91)	709.18	418.42 (283.67 – 645.35)	105.37 (72.98 – 166.02)
MIH09	66	2.32 (1.46 – 3.41)	709.18	1645.30 (1035.40 – 2418.30)	414.35 (266.36 – 622.12)
		Total financial losses (Min-Max)		5694.72 (3560.08 – 8148.48)	1464.99 (915.85 – 2096.23)

*It is accepted that 1 EURO = 3.8872 TRY according to Central Bank of the Republic of Turkey

Discussion and conclusions

Determined cutting dates of the trees in a small area were very dispersed over the time, ranging from 1949 to 2001. This finding indicates that illegal logging is for livelihood of villagers rather than commercial purposes. Illegal commercial removal of timber is generally associated with a number of trees felled at the same time as the perpetrators maximize efficiency. Moreover, our results showed that all stumps were cut at the end of earlywood formation of the outermost ring that is nearly from the second half of May to the end of June. Some researches on intra-annual ring formation have shown that earlywood formation occurs after the second half of May up to the end of June (Bozkurt 1966, Akkemik et al. 2006) in Turkey. Moreover, dendroclimatological studies have revealed that the highest correlation between tree-ring widths of juniper trees and precipitation occurred during May-June (Touchan et al. 2005, 2007). This season overlaps with the period when villagers moved to the highlands close to our stand.

The total economic value of any goods or services consists of both direct use values and indirect use values (Bekiroğlu 2002, Rudd et al. 2016). Although financial losses caused by our studied instances of illegal logging were calculated as 1464.99 (915.85 – 2096.23) Euro for eight trees, in fact all losses should be viewed in the context of total economic value approach (Pearce 2001). This is because losses occur not only in timber products but also in other important goods and services. The total economic value approach takes into account the following: 1) direct uses, including timber products, non-timber products, medicine, plant genetics, recreation, education, and research; 2) indirect uses including nutrient cycling, watershed protection, carbon store, and soil protection; 3) option uses including future uses, biodiversity and conserved habitats; and 4) non-uses including existence, or passive use values, such as endangered species, cultural heritage, and traditional ecological knowledge. On the other hand, benefits from illegally cut trees can increase opportunity cost (Türker et al. 2002).

The other important values of junipers are their educational and research values. Dendrochronological data obtained from juniper trees, which are long-lived and very sensitive to climate variability, have been used to understand the nature of past climate. For example, Touchan et al. (2007) used juniper tree-ring chronologies as proxy records to get the longest precipitation reconstruction from Turkey, which covers the last 900 years. Esper et al. (2007) found out uniform growth trends of the juniper trees growing in low and high elevations of central Asia, which were considered to be a result of solar radiation variations. Opała et al. (2017) provided

juniper tree-ring chronologies from Central Asia, which are potentially useful for millennial hydroclimatic reconstructions.

Junipers have strong existence value related to cultural heritage. Because of rot resistant wood (Köse and Taylor 2012), juniper trees were used widely in ancient settlements and historical buildings. For example, the wooden structure of Gordion King Cemetery was built from foetid juniper (Aytuğ and Görcelioğlu 1987, Kuniholm 2000). The woods from Çayırhan Necropolis were also identified as foetid juniper (Akkemik and Metin 2011). Juniper woods are also found in the structure of historical buildings from Ottoman period and their tree rings used to determine construction and/or restoration dates (Kuniholm 2000).

Our dendrochronological results showed that all the illegally cut trees are rather old; the youngest one was older than 165 and the oldest one more than 419 years. According to General Directorate of Nature Conservation and National Parks of Turkey (GDNCNP 2015), there are three very old *J. foetidissima* trees as a nature monument in Mihalıççık. Juniper forests in Turkey have been protected by Juniper Action Plan of GDF mostly because of natural regeneration problem. The region is also pretty rich in terms of old *J. foetidissima* trees. These points testify to the high conservation and biodiversity values (optional use) in the region.

In this study we present the negative effect of illegal logging on juniper forest in a small area in Turkey. It appears that similar cases have been encountered in the countries, where the junipers grow naturally. For example, excessive or illegal logging, overgrazing and climate change are the leading factors that influence the juniper forests in Tajikistan (Rahmonov et al. 2017) and Pakistan (Achakzai et al. 2016). As a result, it is necessary to develop conservation measures and related programmes to ensure the sustainability of juniper forests, which are the ecosystems of high ecological and socio-economic value on local and global scale.

Our results support the notion that dendrochronology is a very effective tool to determine the exact time of illegal logging events over time as well as the type of illegal logging such as commercial use or private cutting. Due to the lack of forensic dendrochronology studies in Turkey, this study will serve as a step to increase the visibility on this approach. The methods demonstrated here can be used as key criteria in the prosecution of perpetrators by finding exact cutting date and calculating economic losses. The other values of junipers, such as research, education, biodiversity and conserved habitats, cultural heritage, traditional ecological knowledge, should not be ignored. This study presents an example of a comprehensive perspective on ecosystem values of junipers, threatened by illegal logging, based on total economic value. These values have been protected by Juniper Action Plan of GDF since 2005, but it is still unclear how the protection strategy has improved juniper forests. Future research efforts are needed to focus on determination of total economic value in light of ongoing protection strategies.

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