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State of stone pine (*Pinus pinea*) forests in Turkey and their economic importance for rural development

D.M. Küçüker and E.Z. Başkent

Karadeniz Technical University, Faculty of Forestry, 61080 Trabzon (Turkey)

Abstract. Stone pine is one of the most characteristic tree species in Mediterranean landscape, due to the ancient use of its edible seeds. In Turkey, specifically, stone pine (*Pinus pinea*) is the most valued pine species because of its multiple use. Multi-objective management of stone pine forest focuses on timber and pine nut, as the main products, as well as other beneficial services such as soil protection, recreational use and biodiversity. Among these ecosystem services and products, nut production is currently the most profitable one for the owners of stone pine forests and villagers. Pine nut production in stone pine areas promotes rural development by providing employment and supplementary income for forest villagers. It can play an economic role by increasing income level of forest villagers based on its primary and secondary products. In Turkey, the incomes from pine nut production are around three times greater than the revenues from timber production. In this study, changes in size and structure of stone pine forests in Turkey during 10 years were analyzed in terms of age class, development stage, crown closure, tree mixture, functions and productivity. In addition, the amount of cones in number and weight, in-shell pine nut and kernel production were estimated based on age classes within some regional directorates of forestry (OBM) by using traditional estimation equations of constant per tree cone yields by age classes. Turkey would have a potential to produce about 600,000 tons cones and 15.600 tons pine nut kernels, which with current market prices would be worth US\$ 320 million and 550 million, respectively. These figures show that stone pine forests in Turkey can make an important contribution to the rural development and global pine nut market. However, this gross estimation of pine cone or nut was based only on age class distributions and has not taken into account several factors such as climate-driven yield variation or losses due to insect damages. For a better integration of cone or kernel production into forest management plans and the development of a sustainable management oriented to these products will require more realistic empirical yield models. Such models must integrate climate factors and stand variables for allowing more accurate predictions of the actual annual cone and nut production.

Keywords. NWFP-cone production – Rural development – Pine nut export.

I – Introduction

1. Stone pine (*Pinus pinea*) as a NWFP

Stone pine, *Pinus pinea*, is one of the most characteristic tree species in the Mediterranean ecosystems, specially due to the ancient use of its edible seeds, the pine nut kernel. In Turkey, stone pine is considered as the most valued pine species because of the emergence of multiple use forest management. Multi-objective management of stone pine forest focuses on timber and pine nut as the main products, as well as other beneficial services such as soil protection, recreational use and biodiversity.

Edible kernels extracted from the cones of stone pine are among the most important non-wood forest products (NWFPs). The woody rest of the cone is a renewable resource used as wood based panel (Ayrilmiş *et al.*, 2009). Edible seeds are highly valued for health and gourmet product, with rich flavour and excellent dietetic values. Stone pine nut has about 50% lipids, mainly unsaturated fat acids, and 35% proteins, doubling the protein content of the two other main commercial pine nuts species, Chinese and Pakistani pine (Mutke *et al.*, 2012).

Turkey is one of the largest producers and exporters of pine nuts in the world. Based on official production data for 2000-2010, total annual production in Turkey increased from 1,500 to 6,000 metric tons of cones only in state forest, hence not taking into account private forests and plantations (OGM, 2015). Stone pine forests play an essential economic role for forest villagers with nut and timber products in Turkey. Forest villagers can have an employment opportunity and supplementary income. Many rural inhabitants worldwide depend on harvest of pine nuts as they collect and sell them in market, a major economic source for these people (Mutke *et al.*, 2012). Thus this product nicknamed “ingenious pine” by rural inhabitants is considered one of the most profitable NWFPs. Furthermore, due to important additional income by picking and selling of this product many landowners do not think of earning their income from timber. Even, in some region of Turkey, like Kozak near Bergama, incomes from pine nut production (about 7 million US\$) are about three times greater than incomes from timber (Geray *et al.*, 1993). The local forest administration allows local people to collect pine cones for household consumption. But, for commercial purposes, they have to pay a stumpage prices. In fact, the price in effect is not a real stumpage price and is deliberately determined by General Directorate of Forestry (OGM) as quite low to support rural development. However, increasing revenue from pine nut trade causes intense collection of this product. Thus, sustainable management of the product within the framework of ecosystem based multiple use planning is paramount.

Since the initiation of forest management planning in Turkey (1960s), timber has been considered the major forest product, while NWFPs, such as pine nuts, have been considered as “minor” products. Because of complexity of inventory, planning and harvesting of these products, they have not been well integrated into forest management plans up to now. In cases where these products have wide distribution and economic value, “harvesting plans” were mandated to be prepared by the forest management department. In the plans average yield was estimated by information taken just from a few sample points. With the adoption of new ecosystem-based multiple use planning approach, the interest to those products increased over the last decade. New forest management planning guidelines include and consider stone pine forests for cone production, too. However, management plans to integrate NWFP such as cone production have not been well prepared because the lack of field data and the other necessary information, such as optimal rotation ages for cone production, relationships between yield variation and environmental variables, summarized as yield models.

Even though some empirical models analyzing the relationship between cone or nut yield and environmental parameters were developed in other countries (Calama *et al.*, 2008; 2011), in Turkey we don't have any yield models for pine cone yet. Some regional studies have discovered empirical relationships between pine cone production and stand age (Sülüoğlu, 2004; Fırat, 1943; Çukur, 1994; OGM, 1995, 2013).

In this study, changes in size and structure of stone pine forests in Turkey during 10 years were analyzed in terms of age class, development stage, crown closure, tree mix, function and productivity. In addition, the amount of cones in number and weight, the resulting hypothetic production of pine nuts in shell and finally of shelled pine nut kernels were estimated based on age classes within regional directorates of forestry (OBM) by using traditional per- tree or per-hectare estimations. Applying current market prices, figures for value of estimated cone and nut production were calculated separately, and they were also referred per-inhabitant for each OBM. In this way, the potential of pine nut on rural development was analyzed.

II – Materials and methods

The data from digitized database of Turkish forests (including state and private areas), demographic information and statistical data of international trade for pine nut were used. Digital database built with Arc/Info GIS for 2015 year was provided by OGM. The names of villages in or adjacent to the stone pine forests were gathered from each OBM. Demographic information about each village for

2015 was supplied from address based registration system by Turkish Statistical Institute (TUIK, 2015b). To estimate of total amount of cone (in number and weight), and corresponding amount of nut and shelled kernel, the following assumptions were used:

- Stone pine stands in the first age class (0-10 years) don't produce cone (Genç, 2004).
- In the second age class (11-20 years): 50 cones/tree (Sülüüşoğlu, 2004).
- 30-80 years: 300 cones/tree, corresponding 100-120 kg and 6-8 kg kernel (OGM, 1995, 2013).
- Above 80 years: 200 cones/tree (Çukur, 1994).
- For degraded areas, 1 ha includes 30 trees, 1 tree produces 50 cones and 1 cone produces 10 g kernel.
- For the rest of classes, 70 productive trees per hectare were assumed (OGM, 2006).
- 1 cone produces about 15 g kernel, (Çukur, 1994).
- 4 kg nut in-shell produces about 1 kg shelled kernel (OGM, 2013a).

For the economic value estimation, current market prices for pine cone (0.53 US\$/kg) and kernel (35.5 US\$/kg) were used. In addition, the international market price for pine nut kernel was provided by TUIK (2015a) as 51 US\$/kg.

III – Results and discussions

1. Stone pine forest areas and structure in Turkey

The total area of stone pine forests in Turkey was about 70,000 ha ten years ago (OGM, 2004), but today it approaches 200,000 ha (Table 1). Some OBM hadn't had any stone pine forests in 2004, but they have included the species in 2015 forest plans due to new pine nut plantations. The huge increase in area allocated for stone pine plantations is thanks to various utilization opportunities of stone pine from bark, wood, cones and resin, and also use for aesthetic and soil conservation purposes (Anşin, 1994), though the present interest for pine nuts a business opportunity is overwhelming. According to spatial forest database in 2015, 140,863 ha of stone pine forests are pure stands (71%), more than two times the area occupied by mixed stands with stone pine (56,686 ha, 29%).

Although an ecosystem-based multiple-use planning approach has been adapted in Turkish forestry for almost a decade, analysis of forest plan data indicates that most stone pine forests (58%) are still oriented toward maximum timber production. In only 9% (18,315 ha) of stone pine forests, planning is oriented to maximal pine nut production. Another 12% are devoted in the first place to ecological purpose such as nature conservation, erosion control and climate protection, while in the resting 12%, priority is given to social and cultural ecosystem services, including drinking water provision, community health by preventing air pollution and noise, landscape and recreation, as well as scientific research. Some areas have nature conservation status such as national park, nature protection areas, genetic reserves or for wildlife conservation, and others are mapped for the elevated social pressure they are suffering for not authorized or illegal uses.

Given the threefold expansion of stone pine forests from 70,000 to nearly 200,000 ha only in the last 10 years, it can be easily seen that in terms of development stages, approximately 63% (123,934.8 ha) are still considered regenerated, including those new plantations, whereas 9%, 8% and 6% are quite balanced between young, mature and old-growth, respectively (Table 2). Due to this recent expansion, also in terms of crown closure, most area (54%) still corresponds to low coverage, less than 50%. If crown cover were maintained so low in a future, it would be a positive development for pine nut production, due to positive effect of low coverage on crown diameter and cone formation (Mutke *et al.*, 2012).

Table 1. Total stone pine areas in 2004 and 2015 years according to Regional Directorates of Forestry (OBM)

Regional Directorates of Forestry	Stone pine areas (ha)		Regional Directorates of Forestry	Stone pine areas (ha)	
	2004	2015		2004	2015
Izmir	18,639	59,329	Zonguldak	41	1,041
Muğla	25,517	50,312	Amasya	100	891
Balikesir	6,821	25,523	Ankara	–	721
Istanbul	790	12,121	Kütahya	–	617
Çanakkale	8,560	9,427	Kastamonu	–	366
Bursa	3,145	8,968	Isparta	65	341
Kahramanmaraş	–	8,903	Eskişehir	10	216
Adana	422	7,500	Artvin	100	125
Antalya	–	4,790	Trabzon	–	123
Sakarya	12	3,168	şanlıurfa	–	15
Denizli	100	1,665	Bolu	–	11
Mersin	913	1,355	TOTAL	69,294	197,550

Table 2. Turkish stone pine forests according to development stages

Development stages (dbh)	Total areas (ha)
Degraded areas	12,686
a (regenerated, < 8 cm)	123,926
b (young, 8 - 19.9 cm)	17,450
c (mature, 20 - 35.9 cm)	15,820
d (old growth, > 36 cm)	12,404
Unknown	15,265

Some studies about pine nut production indicated that stone pine trees begin to bear cones at the age of 10 years, the ability to seed will continue until the age of 100 and cone production is maximum between 40-50 ages (Genç, 2004). In this study, all stone pine stands in Turkey were evaluated according to the age class distribution obtained from the digital database. In the mixed stone pine stands where long rotation forestry dominates, age classes are ranged according to 20 years. 46% of stone pine forests in Turkey are still in the first, immature age class (under 10 years) without cone production, and only 4.5% exceed 50 years (Table 3).

Table 3. Dominant age class distribution of Turkish stone pine forests

Age classes	Total Areas (ha)		
	Short rotation	Long rotation	Total
I (0-10 year)	90,440	1,294	91,734
II (10-20 year)	35,594	61	35,654
III (20-30 year)	13,875	41	13,916
IV (30-40 year)	6,687	–	6,687
V (40-50 year)	12,605	–	12,605
VI (50-60 year)	7,665	40	7,705
VII (60-70 year)	405	–	405
VIII (70-80 year)	152	–	152
IX (80-90 year)	11	–	11
X+ (90-100 year)	692	–	692
Unknown	26,157	1,794	27,951

Regarding site quality, estimated from dominant height-age relation, stone pine forests in Turkey were classified predominantly (83%) in the medium II. and III. quality y classes, whereas both higher and poorer qualities are quite rare (1.5% and 0.5%). This homogeneity will facilitate future studies on growth and come yield modeling, both known to depend strongly on site quality (Calama *et al.* 2008, 2011).

2. Estimation of potential cone and nut production in Turkish stone pine forest

The potential production of stone pine in Turkey, estimated in the present study roughly by assuming aforementioned theoretical fixed per-tree average productivities for different age classes, would hypothetically mean as much as 600,000 t cones and 15,600 tons pine nut kernels from stone pine areas in Turkey (Table 4).

Table 4. Predicted cone yield in number and weight, corresponding amount of pine nuts in shell and shelled kernel (t) for each regional directorates of forestry (OBM)

OBM	Stone pine Area (ha)	Potential cone production		Pine nuts in shell (t)	Pine nut kernels (t)
		(Units)	(t)		
Adana	7,500	51,612,745	36,431	3,095	774
Amasya	891	3,120,100	2,872	179	45
Ankara	721	1,429,750	2,860	86	21
Antalya	4,790	46,133,550	25,002	2,744	686
Artvin	125	436,800	146	26	7
Balikesir	25,523	54,423,700	53,736	3,238	809
Bolu	11	16,350	20	0.7	0.16
Bursa	8,968	11,331,750	12,701	675	169
Çanakkale	9,427	20,542,215	18,194	1,232	308
Denizli	1,665	4,018,485	6,552	241	60
Eskişehir	216	771,050	380	46	12
Isparta	341	2,088,100	1,933	125	31
Istanbul	12,121	44,807,300	23,216	2,685	671
Izmir	59,329	234,324,500	178,320	13,584	3,396
Kahramanmaraş	8,903	12,735,100	7,608	762	191
Kastamonu	366	625,450	246	38	9
Kütahya	617	836,150	1,025	50	13
Mersin	1,355	3,883,800	2,693	233	58
Muğla	50,312	555,440,400	225,772	33,040	8,260
Sakarya	3,168	1,612,000	2,356	96	24
Şanlıurfa	15	52,850	106	3	0.8
Trabzon	123	619,800	411	35	9
Zonguldak	1,041	2,548,700	1,757	153	38
Turkey	197,550	1,053,410,645	604,335	62,366	15,592

These estimations for potential production are extremely high when compared with official Turkish forestry statistics, which report only about 2,000-6,000 t of cones each year between 2006 and 2015 (OGM, 2015). However, these official statistics refer only to the legal production from state forests, that is, 89,000 ha (OGM, 2013b), only 45% of total stone pine area in Turkey, giving a mean productivity of less than 60 kg cones per hectare, though computing herein also non-harvested regeneration stands, protection forests etc. As a matter of fact, Turkish export statistics report about

1,500 t pine nut kernel exports annually (TUIK, 2015a), and only 90% of Turkish kernel output are exported (Bilgin, 2012). Applying a kernel-cone weight ratio of 4%, plausible annual cone production exceeds 40,000 t, that is about 200 kg/ha of total stone pine area, but more than 600 kg/ha when referred to areas in 2004, excluding hence immature newer plantations (Table 1). These averages values are in the same order of magnitude as references in other countries (Calama *et al.*, 2008, 2011; Mutke *et al.*, 2012). Nevertheless, the hypothetical productive potential of Turkish pine forests given here exceeds more than tenfold this value, and more than twofold the actual production of Mediterranean pine nut kernel in the world (Mutke *et al.*, 2012). Possible causes are their calculation depending just on age classes, assuming per-hectare average cone yields up to 7,000 kg/ha, while other important factors that limit yields, such as climate or insect damages, could not be reflected in the gross prediction at regional OBM scale.

Anyway, Muğla is, and was predicted correctly as, the most productive OBM among all because of the extension of its mature stone pine stands. Though Izmir has today a wider stone pine area, for the moment it would produce less cones and pine nuts than Muğla, due mainly to its age classes centred in the first and second one (less than 20 years). Indeed, OBM Izmir has more than tripled its stone pine area only since 2004 (Table 1). On the other hand, in OBM Muğla many stone pine forests are between 30-80 years old, the most productive age classes for cones.

According to the information from the address-based registration system in 2015, the total rural population in the villages or neighborhood located in or adjacent to stone pine forests is about 881,000. This is about 1% of total population of Turkey. Regionalized yield estimations (Table 4) imply a total market value of those potential cone and kernel yields from Turkish forests exceeding US\$ 320 million and 550 million, respectively, even US\$ 790 million if all kernel were exported – assuming no world market price decay. Referring the market values of hypothetical annual average cones and kernels yield estimations to regional rural population in each OBM, per-inhabitant figures are about US\$ 360 and 630, respectively. But even assigning only the reverse-estimated mean annual cone production considered plausible, 40,000 t, market value of cones exceeds US\$ 20 million, kernels US\$ 55 million, this is US\$ 24 and 62 per rural inhabitant, respectively. In fact, official exportation statistics have computed annual pine nut export for US\$ 25-68 million between 2007 and 2013 (TUIK, 2015a). More interesting, if in cone harvesting an average man-day yield of 400 kg cones is estimated, cone harvest season will require about 5,000 man-month of local, rural employment each year.

IV – Conclusions

This study has evaluated the potential of cone or pine nut kernel production in Turkey, supposing that postulated per-tree and per-hectare can be matched. The exportation incomes from pine nuts are higher than the other important NWFPs such as bay laurel or lime tree when they are compared. Therefore, stone pine forests might be allocated primarily for production though always based on compatible multiple use forest management planning approach. Stone pine forest areas are drastically increasing over the last decade. Though it is a good progress, the quality of the expanded stone pine areas to produce high rate of cones and nuts need to be improved too.

In addition, traditional prediction methods for cone or nut production from fixed per-tree yields per age-class are not effective estimations, because this coarse calculation does not take into account yield variation due to soil or climate factors, silviculture (stand density) or insect damages and could not reflect real production. Integration of cone or nut production into forest management plans and the development of a sustainable management of these products will require therefore sound empirical yield models which are still to be developed. Such models built by climatic and stand variable would allow us to accurately predict the cone or nut production. Thus, the first step in integration of the products into forest management is to focus on modelling the production of pine cone or nut. The integration of these models to decision support systems will help forest managers and

planner to specify management activities for optimal co-productions of various forest values. Empirical models and decision support systems will have a great potential to support the nut industry. Such approach would provide good opportunities for developing countries' economy and rural development. Besides, management treatments such as reforestation and rehabilitation of degraded areas should keep going. Because more added value can be obtained from kernel sale than cone sale based on this study results, the last suggestion would insist for the establishment of processing plants working on pine nut in the rural areas.

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