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Determination of Economic and Financial Rotation Lengths of Hybrid Poplar Plantations: the Case of Turkey

Sait Engindeniz
Department of Agricultural Economics, Faculty of Agriculture,
The University of Ege, 35100 Bornova/Izmir/Turkey

Abstract: The purpose of this study was to determine the economic and financial rotation lengths for hybrid poplar plantations (Populus x Euramericana Guiner cv.I-214) in a selected area from Turkey. It was determined the year providing maximum mean annual increment to economic rotation length should be measured. However, it was determined the year providing maximum financial return to financial rotation length should be measured. According to results, the economic and financial rotation lengths have been determined as 9 years and 11 years, respectively. The rotation lengths could be determined according to various factors. For example; many previous studies indicate that economic and financial rotation lengths in hybrid poplars depend on the site characteristics and planting spaces. Therefore, the most appropriate rotation length for hybrid poplar plantations should be determined by local studies.

Key words: Poplar, hybrid poplar, wood, planting, rotation length, agro-forestry

Introduction

It is estimated that hybrid poplar cultivation is currently done in 160000 hectares area in Turkey (Saribas, 1993). For producer, the aim of hybrid poplar cultivation is to get maximum financial return. Therefore as it has been discussed in many studies before (Banoun, 1982; Birler, 1984; Chaturvedi, 1992; Fang *et al.*, 1997; Streed, 1999; Nuss, 1999; Yukun and Dingguo, 2000), poplars should be cut at the end of most appropriate rotation length.

In poplar cultivation, the cutting time after ripening of trees is called as rotation length. Many factors could influence rotation length, but selection of planting area, planting space, inputs used and market conditions are the most important factors (Birler, 1984). Selection of the planting area includes matching the site characteristics with the most appropriate clone.

If rotation length is determined according to maximum mean annual increment, it is referred to as economic rotation length. But, if rotation length is determined according to maximum annual economic or financial return, it is referred to as financial rotation length. Producers want to obtain maximum financial return. Therefore, the most appropriate rotation length for producers is the financial rotation length.

Hybrid poplars reach the cutting age between 10 and 12 years at the normal conditions (Nuss, 1999; Streed, 1999). But, according to rearing up and market conditions, cutting age could be taken to an earlier time or may be delayed for 3 or 4 years. Earlier or later cutting of poplars can create the negative effect on wood quality. Therefore, the most appropriate rotation length for poplars should be determined taking the local conditions into account. Generally, the most appropriate length should maximize the economic or financial return.

In this study, the economic and financial rotation lengths of hybrid poplar plantations in a selected area from Izmir province in Turkey have been determined.

Materials and Methods

The data used in this study are collected from the producers by a survey study and obtained by biological measurements on the trees. As a secondary data resource, previous studies have been widely used.

According to the year 2000 data of the Agriculture Directorate of Izmir province; 89.1% of the total poplar areas (2498 ha) in Izmir province are located in Bayindir, Beydag, Kiraz, Odemis, Selcuk, Tire and Torbali counties that form Kücük Menderes River Basin. Therefore, Kücük Menderes River Basin had been selected as the survey area.

Kücük Menderes River Basin is situated in the western part of Turkey between 38° 15' N and 27° and 28° 30' E. The river basin is about 4000 km^2 in area and it is located in the mountainous catchment area in the southern part of Izmir province. The river basin is separated from the Gediz River Basin in the north and Büyük Menderes River Basin in the south by two mountain chains, which form its natural boundaries.

Kücük Menderes River Basin has a Mediterranean climatic tendency towards continental climate. According to the bioclimatic map, the climate is thermomediterranean (attenuated) in the inland part of the river basin and mesomediterranean (accentuated) near the coast (Boxem and Wielemaker, 1972). The average annual temperatures, those of the warmest (July) and the coldest month (January) are rather similar for the entire river basin. The annual precipitation is about 700 mm and the average relative humidity is 60%.

In the river basin, 65% of the total area is used for agriculture. However, 15% of the river basin is used for forestry being mainly pinus species on the mountainous part of the river basin and poplars on the lower parts of the river basin. The remaining 20 % of the river basin is wasteland and includes rocks, riverbeds, sanddunes and strongly salt-affected, mainly marshy areas.

According to pre-research in the river basin, 71 hybrid poplar plantations were determined to be between 1 and 12 years-old and these plantations are included in the scope of current study. The range of plantation size changes between 0.2 and 15 ha. The total plantation area is 119.9 ha and the average size was calculated as 1.7 ha. All the poplar-trees are from the clone of Populus x Euramericana Guiner cv. I-214. This clone grows very fast and is widely cultivated in Turkey. Therefore, this clone was selected for this study. Distribution of poplar plantations according to ages of trees is given in Table 1.

The technical and economical data collected from producers were derived by the survey in February 2001. The cultivation treatments and the cost of these were asked in the year 2000 and this is the latest year before the survey. By this way, the quantity of using inputs and the current price of them were also determined. And, it is asked when the cutting-time is and who the buyers of poplar are. In addition, the market of poplar-wood was examined and the purchase price of poplar-wood was determined by diameter. For this purpose, it was interviewed with the authorities of the purchaser companies.

Some data were derived by the biological measurements on the trees, too. For this purpose, randomly two poplar plantations in every age have been selected (all the plantation which is 1 and 2 years old was selected). After that, in every poplar plantation, tree in proportion 5% of total tree number have been determined with systematic random sampling and the measurements of diameter in heights of 1.30 m from place of these trees have been determined one by one by a measure. The measurements of diameter of total 647 trees had been made in this way. Measurements on trees have been verified on February, 2001.

Total costs have been subtracted from the total gross income for the calculation of net income by years in surveyed poplar plantations. Wood quantity to be obtained from trees by ages and current wood prices in wood purchase market have been multiplied for getting the gross income by years.

Establishment and production costs were found by survey in the view of data from producers. Laborer and machine costs, material costs (sapling, fertilizer, pesticide etc.), interest of total costs and administrative costs have been considered as cost elements. Examined poplar plantations are tax-free and were not insured. For calculation of interest of total costs had been taken half of interest rate (55%), which was valid on working capital loan for a year of the Turkish Agricultural Bank. Administrative costs were estimated to be 3% of total costs.

The inflation level of Turkey was 70% at that time. It is needed to know current and real value of money and it is needed to know making analysis in which criteria. The

Table 1: Distribution of poplar plantations according to age of trees

Age of trees	Number of plantations	% of plantations	Total area of plantations (ha)	% of plantation areas	Total number of trees	% of trees
1	2	2.82	3.0	2.50	1150	2.17
2	2	2.82	2.5	2.09	1100	2.08
3	3	4.23	2.8	2.34	1250	2.36
4	5	7.04	3.3	2.75	1120	2.11
5	4	5.63	1.2	1.00	500	0.94
6	8	11.27	36.2	30.19	13954	26.34
7	13	18.31	25.7	21.44	11310	21.35
8	10	14.08	15.7	13.09	7650	14.44
9	8	11.27	8.3	6.92	5335	10.07
10	8	11.27	12.0	10.01	5860	11.06
11	4	5.63	5.6	4.67	2480	4.68
12	4	5.63	3.6	3.00	1270	2.40
Total	71	100.00	1 19.9	100.00	52979	100.00

more practical way in forestry investment during the project preparation, it is advised that real prices accept and use in the project (Kengen, 1997; Türker, 2000). In the economic analysis of this study, average total costs in year 2000 of poplar plantations have been calculated by age of trees. By this way, an average value was found for each years old of poplar plantations. So, the possible negative effects of inflation were removed in the analysis. All the poplar producers perform same cultivation treatments in the river basin. So, there is no big difference using inputs between the producers. Performed cultivation treatments by producers were ploughing (two times in a year), hoeing (for space and bottom), fertilization (generally farm-yard manure and ammonium nitrate), irrigation (between May and September), calcification (for stem of trees against insects), insecticide application and pruning.

In this study, the econometric analysis was performed for determination of economic and financial rotation lengths of hybrid poplar plantations and exponential and curvilinear functions were also developed.

Results and Discussion

Planting space of trees in poplar plantations: Biomass wood production from fast growing tree plantations is becoming more wide spread in the world. In order to increase mass production in unit area, experiments are conducted to reduce planting space, to innovate growing techniques and to improve the genetic gain (Birler *et al.*, 1996).

Planting space can impact yields in poplar plantations. That impact also varies over time. For example; while there is little impact of a 6 x 6 m^2 spacing on a young plantations, that impact is much greater than the same age plantation if the spacing is 3 x 3 m^2. Many previous studies have indicated that planting rotation length decreased against increasing wood quantity when planting spaces become closer in hybrid poplar plantations (Anderson and Zsuffa, 1980; Usta, 1985; Szendrödi, 1996).

The planting spaces of hybrid poplar plantations are varied in the river basin. However, it is difficult to find similar planting space for different ages of trees in hybrid poplar plantations. In this study, it had been determined that planting space mostly (66% of total plantation area) applied as 5 x 5 m^2 (Table 2). The number of trees per hectare changes between 280 and 1110 in examined poplar plantations. The average number of tree per hectare was determined to be 442. This average value is taken into consideration for economic analysis in this study.

Measurement of diameter, height and volume of the trees at different ages: The stem of the trees included in the sample are measured at 1.30 m of height (Table 3). The measurement of heights for the poplar plantations hasn't been carried out in this study. Instead, the following regression equation which shows the relation between diameter and height for the poplar plantations is used in order to measure the hights for different diameters (R^2= 0.954683).

$$Y = 0.241750 + 0.248178\,x \quad \text{----------------------------------} (1)$$

This equation has been taken from a study, done previously in the river basin to estimate the heights of the hybrid poplar plantation (Populus x Euramericana Guiner cv. I-214) corresponding to the diameter sizes (Gökce, 1978). In this equation, (Y) is expressed as the height of trees (m) and (x) is diameter of the trees (cm). The average height measurements have been estimated substituting the diameter sizes, which had been determined by ages, in equation (1).

In determination of the volume measurements at different ages in poplars, 1.30 m height diameter measurements and the total heights of the trees are used. For this purpose, usually, case specific yield tables are prepared. However, as the real heights hasn't been measured in this study, it hasn't been possible to establish the specific table of yield. For this reason, when determining the volumes by ages of the trees the diameters already measured and the corresponding heights were used and the required yield tables were taken from the same study which way carried out in the river basin before (Gökce, 1978). As the trees under tree year old fall bellow the size elligible for usage, the volumes for these ages hasn't been estimated. The estimated mean volume measurements are given in Table 3.

Investigations show that diameter growth is affected by the planting spaces thus wider spaces produced larger diameters. No significant effect was observed between space and height growth. Stand. volume is also affected by the planting space thus closer spaces produced greater amount of volume in unit area however wider spaces produced stems with larger diameter. Plantations with closer spaces produced greater amount of maximum mean annual increment per unit area.

Determination of economic rotation length: Relation between age and volume of trees in poplar plantations must be examined for determination of economic rotation length. Generally, there is a relation between age and volume of trees. But this relation can show changes with the effect of various factors. In this study, relation between age and volume of trees in poplar plantations was examined as econometric. For this purpose, many models such as linear (logarithmical and semi-logarithmical) and non-linear (cubic, quadratic and exponential) have been tried, but it had been determined

Table 2: Distribution of poplar plantations according to the planting spaces

Age of trees	No. of plantations	% of plantations	Total area of plantations (ha)	% of plantation areas	Total No. of trees	% of trees	No. of trees ha^{-1}
3 x 3	8	11.27	8.7	7.25	7850	14.82	902
4 x 4	14	19.72	12.9	10.76	7869	14.85	610
4 x 5	9	12.67	9.0	7.51	4635	8.75	515
5 x 5	26	36.62	66.3	55.30	26485	49.99	399
6 x 6	14	19.72	23.0	19.18	6140	11.59	267
Total	71	100.00	1 19.9	100.00	52979	100.00	442

Table 3: Measures of diameter, height and volume of poplars

Age of trees	Diameter per tree (cm)	Height per tree (m)	Volume per tree (m^3)
1	14.12	3.75	-
2	29.67	7.61	-
3	41.81	10.62	0.053
4	52.31	13.22	0.113
5	61.95	15.62	0.201
6	72.43	18.22	0.329
7	81.47	20.46	0.394
8	88.69	22.25	0.615
9	98.11	24.59	0.836
10	104.74	26.24	0.983
11	108.55	27.18	1.088
12	114.59	28.68	1.196

Table 4: Estimated volume measurements of poplars

Age of trees (1)	Volume per tree (m^3) (2)	Average volume increase (m^3) (2/1)
3	0.001	0.0003
4	0.039	0.0097
5	0.161	0.0322
6	0.332	0.0553
7	0.500	0.0714
8	0.641	0.0801
9	0.750	0.0833
10	0.831	0.0831
11	0.892	0.0811
12	0.935	0.0779

Table 5: Obtained net income from poplar plantations according to years

Year	Gross income (million TL ha^{-1})	Total costs (million TL ha^{-1})	Net income or loss (million TL ha^{-1})	Average annual net income or loss (million TL ha^{-1})
1	-	389	- 389	-389
2	-	370	-370	-185
3	466	402	64	22
4	994	476	518	130
5	2211	484	1727	345
6	3619	439	3180	530
7	5548	423	5125	732
8	8659	402	8257	1032
9	11771	325	11446	1272
10	13841	266	13575	1358
11	15312	275	15037	1367
12	16840	267	16573	1381

TL= Turkish Lira

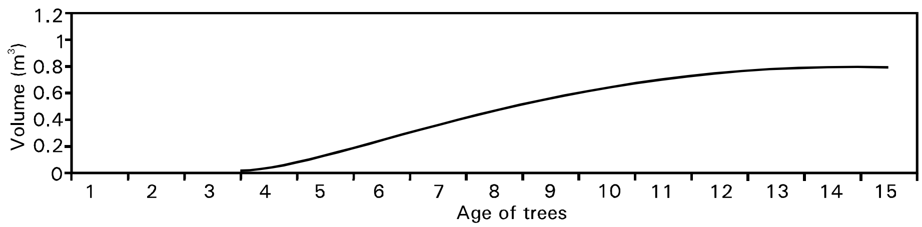

Fig. 1: Relationships between age and volume of trees in examined poplar plantations

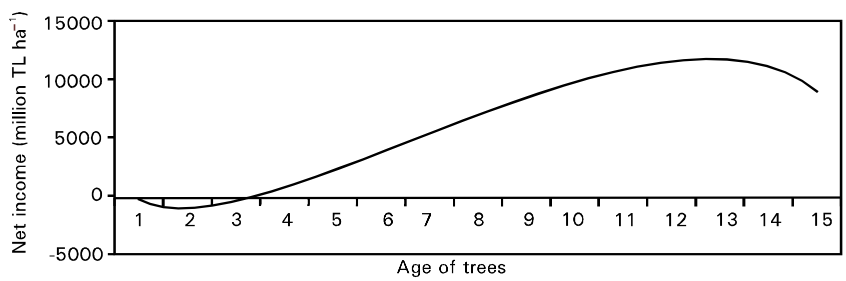

Fig. 2: Relationships between age of trees and obtained net income in examined poplar plantations

Table 6: Estimated net income of poplar plantations according to years

Year (1)	Net income or loss (million TL ha^{-1}) (2)	Average annual net income or loss (million TL ha^{-1}) (2/1)
1	- 240	-240
2	- 618	-309
3	- 306	-102
4	564	141
5	1859	372
6	3448	575
7	5197	742
8	6974	872
9	8647	961
10	10082	1008
11	11148	1013
12	11711	976

that this relation can be expressed with an exponential function such as below. In this function, (Y) is expressed as volume (m^3 per tree) and (x) is expressed as age of trees. The curve of this function can be drawn (Fig. 1).

$$Y = e\left(-0.145268 + \frac{7.623960}{x} - \frac{80.210978}{x^2}\right) \text{------- (2)}$$

The summary of statistics concerned with this function had been deter mined as follow:

Coefficient	S.E	t	R^2
A -0.145268	0.152509	-0.952521	0.87988
B 7.623960	2.611694	2.919163*	
C-80.210978	10.841241	-7.398690**	

* significant at the level of 0.05 , ** significant at the level of 0.01

When estimated values have been calculated using the above equation (2), the maximum mean annual increment that shows the economic rotation length has been found as being 9 years (Table 4). On the other hand, many previous studies indicate that economic rotation lengths in hybrid poplars can be vary between 7 to 12 years according to the planting spaces (Gökce, 1978; Chaturvedi, 1992; Birler *et al.*, 1996; Nuss, 1999).

Annual net income obtained from poplar plantations by years: As a result of the pre-researches, it is stated that poplar trees are sold at the farmland as planted. During the sale buyer takes on the whole expenses such as cutting, transportation, etc. The price of the poplar-wood is stated in kilograms in the river basin. For this reason, the volume (m^3) are converted into mass (kg) values to predict the wood quantity will be obtained by age of trees. In this stage the equation $1m^3$=1000 kg of poplar-wood is used (Saribas, 1993). There are three different prices by the diameter of the trees in the poplar buyers market in the river basin. These prices are; trees have diameter less then 30 cm, sold at the price 20,000 TL kg^{-1}, trees have diameter between 30-40 cm, sold 25,000 TL kg^{-1}, trees have diameter more then 40 cm and sold at the price 32,000 TL kg^{-1}.

When predicted wood quantity by the age of trees and poplar-wood prices in the river basin are taken into consideration, it is obvious that the gross income increases 36 times between the ages 3 and 12 (Table 5). According to the results of the research, important part of the establishment cost consists of labor and machinery costs (51.8%). On the other hand, the production costs of the poplar plantation decreases as the harvest age comes closer.

The costs of mentioned years were subtracted from the gross incomes of the poplar trees and net income according to the tree ages were calculated. According to the results, the annual and total net income also increases as the poplar age increases. Similar results were fixed in previous studies (Birler *et al.*, 1989; Diner and Kocer, 1989; Chaturvedi, 1992; Nuss, 1999).

Determination of financial rotation length: For determining financial rotation length that is year given maximum average annual net income; firstly, relation between age of trees and obtained net income from poplar plantations must be examined. In this study, it had been determined that this relation can be expressed with a curvilinear function such as below. In this function, (Y) is expressed to as obtained net income from poplar plantation (000 TL ha^{-1}) and (x) is expressed to as age of trees. The curve of this function can be drawn (Fig. 2).

$$Y = 961603.65953 - 1657259.606x + 477808.57184x^2 - 22087.88678x^3 \quad \text{------} (3)$$

The summary of statistics concerned with this function had been determined as follow:

Coefficient	S.E.	t	R^2
A 961603.65953	93119.020305	1.032661	0.94631
B -1657259.60600	51504.088762	-3.217724*	
C 477808.57184	8425.487213	5.670990*	
D -22087.88678	412.870563	-5.349833*	

* significant at P<0.01

When estimated values have been calculated using the above equation (3), the maximum average net income that shows the financial rotation length has been found as being 11 years (Table 6). However, many previous studies indicate that financial rotation lengths in hybrid poplars can vary between 8 and 13 years according to the planting spaces (Gökce, 1978; Chaturvedi, 1992; Birler *et al.*, 1996; Nuss, 1999).

In poplar cultivation, economic and financial rotation lengths are determined according to the purposes. If purpose is to determine the year providing maximum mean annual increment, economic rotation length should be measured. But, if purpose is to determine the year providing maximum financial return, financial rotation length should be measured. Rotation lengths could be determined according to various factors. Economic and financial rotation lengths in hybrid poplars can be changed according to site characteristics and planting spaces. Therefore, the most appropriate rotation length for hybrid poplar plantations should be determined by local studies.

Many studies indicated that economic and financial rotation lengths in hybrid poplars can vary between 7 and 13 years according to site characteristics and planting spaces (Gökce, 1978; Birler *et al.*, 1989; Diner and Kocer, 1989; Chaturvedi, 1992, Nuss, 1999). In poplar plantations, economic and financial rotation lengths do not generally overlap. In the researched poplar plantations, the economic and financial rotation lengths had been found as 9 and 11 years, respectively. Although financial rotation length can change depending on poplar-wood prices and the rate of interest, economic rotation length doesn't change unless there is a change in soil productivity and production conditions. Besides, economic rotation length is closely related with the planting space of poplar.

In recent years, due to stagnation in poplar-wood prices, poplar cultivation has lost its attractiveness. In the river basin, the majority of producers have told that the most convenient cutting age for hybrid poplar is 10 years. But, the majority has told that they cut their trees at the age of 7 or 8. The main reason for early cutting is low prices.

When the researched results were calculated, the cutting of hybrid poplar in the year of 4, 5, 6, 7, 8, 9 and 10 instead of the 11th year have caused an income loss of 94, 83, 69, 53, 37, 22 and 9%, respectively.

As a conclusion, it could be stated that hybrid poplar cultivation should be developed to meet poplar-wood demand in Turkey. However, the low poplar-wood prices are causing a decrease in the number of poplar-wood producers. Currently, poplar cultivation areas are irrigated land. In these areas, producers can produce two or three products in a year, instead of poplar. So, they can shift to the other product because of low prices. For this reason, poplar producers should be supported by subsidy policies. This is the only way, the poplar production will be increased and qualified.

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