Economic Evaluation of Water Supplying Function of a Mountain-forest Area of Turkey: Forest Rotation Impacts

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Abstract

Background: Mountain-Forest ecosystems provide essential services within the economic system of the region and perhaps the country. These natural resources, which have many apparent or not apparent functions, are facing economic development pressures in recent years. The benefits of water provided by mountain-forest ecosystems to the downstream basin and the benefits of eliminating the adverse conditions created by rainwater are economically valuable. However, they are benefits that decision-makers often do not consider. With quality and rational forest management, these benefits can be gained much more publicly. Forest rotation, silviculture studies, economic value determination, and rational forest management taking all these into account can provide this.

Methods: The Faustmann approach made essential contributions to natural resource management and especially to the economic analysis of mountain-forest ecosystems in the middle of the 19th century. Highlighting the importance of the forest area's regeneration process, Faustman gave important opinions to decision-makers about when the timber value will be suitable for rotation. Hartman developed the Faustman approach by stating that the forest area has not only timber value but also non-timber values. In this study, the function of providing water resources from the Uludag National Park (UNP) resource values examined both approaches; and three models were created.

Results: The basic model where only the timber value is taken into account is the model in which the impact of the rain flow regulation service on the UNP rotation is analyzed, and all forest water services are taken into account. Here, it was taken into account that the increased water quality value due to the forest will increase by 10%. According to the first model results, the UNP must be subjected to rotation at intervals of 44 years. UNP reaches its current net value of 956 USD/Ha in 44 years. In the second model, in which the service of eliminating problems such as floods, landslides, and landslides may occur in settlements below the basin due to the retention of rainwater in forest soil, there was no effect on the rotation period. However, the stand value increased to 976 USD/year per hectare. The third model assumed that the water quality value increased by 10%; It was concluded that the rotation increased to 107 years, and the stand value per hectare this year is 147 006 USD/Year.

Conclusions: The study has made important contributions to the literature. It integrates the natural resource value determination studies with the forest rotation system. Also, essential implications are made for regional decision-makers and UNP forest management. It was concluded that the necessity of increasing the business investments made to the UNP is how important the allocation, use, and development decisions of the UNP are.

Keywords: Faustmann rotation modeling, Hartman rotation modeling, Uludag National park, Economic evaluation

Background

Introduction

In addition to the many benefits they provide, mountain-forest ecosystems are among the natural resources that economic decision-making units do not care about but produce valuable services. The community settled down on the downstream benefits significantly from these services provided by forest resources. The most known benefit of forest areas is the value of timber. Yet, other benefits are also important for people who live in downstream.

The support provided by the forest resource with water resources is primarily related to the "protection of the existing soil." The support process, which started with siltation and sedimentation prevention, continues with the water flow regulation. Meanwhile, services such as protection from floods, provision of water supply, and quality are closely related to forest existence. Siltation and sedimentation are important economic costs that occur when valuable surface parts of the soil flow downward and accumulate in the basin in sloping lands of mountain ecosystems (Kara 2018). The degradation of forest existence and trees cut before the rotation period can cause problems such as an increase in soil temperature, an increase in ground and surface water temperature, and adversely affect biological activity related to water. The lack of these services, which may occur due to the loss of forest assets or the formation of degraded forest areas, brings about certain costs. Certain costs will have to be incurred, for example, to clean up sediment in the basin. The deterioration in water quality may necessitate certain treatment costs. Besides, the repair of damage caused by floods can incur high costs. Another problem is related to forest roads, construction, and maintenance services. Unplanned or poorly planned forest rotations or conversion of forest assets to other areas (agriculture) rapidly increase sedimentation (Webb et al. 2012). Studies pointed out that long-term and violent intervention on forest soil may cause soil

compaction of the soil's fertile top layer (Munoz-Rojas et al. 2017). In this case, natural hydrological activities such as the surface flow of water and supporting groundwater cannot occur. It was highlighted that infrastructure works in the forest area, heavy vehicle use, overgrazing, and other anthropogenic factors might cause the soil's upper layer to tighten. The effect of the mountain-forest ecosystem on water quality is also due to the rich minerals and ions it releases into the water. Less organic matter and microbial activity content increase the quality of the water. Keeping the water cooled thanks to altitude and shading ensures that many biological problems that may occur due to water temperature do not occur (Koralay et al. 2015; Wang et al. 2015). Indeed, if the forest ecosystem is not destroyed and healthy, the flow rate of the water flowing down, through inner soil and surface water, from the upper parts of the basin will be less than in the forestless state, but the flow time will be longer. Besides, water quality is higher for all living things in the forest ecosystem and downstream. If the forest ecosystem deteriorates and the forest covered areas decreases too much, the amount and speed of the surface water flow increase and cause soil erosion. Then, forest water causes soil losses due to erosion, disasters such as floods. In addition, freshwater resources have a short life and water quality becomes poor. Due to the waters flowing rapidly to the downstream and the sea before the dry seasons, the streams dry up in the dry season, the water flowing in the rivers decreases, and the drought process begins early.

In basins that get integrated with the mountain-forest ecosystem, the importance of integrated basin management is frequently emphasized (EPA 2015). Especially the flow of water starting from the springs in mountainous lands can cross the settlements by combining with many large and small scale basins, and this journey ends by flowing into the sea. This flow of water provides many services to human beings and the economic and social living areas on the routes it passes through. Besides, different allocation decisions may be made in areas under the responsibility of political decision-makers. Therefore, the contributions of the mountain-forest ecosystem to the economy of water resources should be determined well.

Apart from the problems related to ignoring the economic values of the mountain-forest ecosystem relationship, the correct management of the forest area can also play an important role in alleviating the problems mentioned above. Effective timber management, good determination of rotation periods, rational selection of tree species, regeneration studies, and other silvicultural activities are directly related to the quality of sloping forest soil because of their different water holding capacities (Keles 2019).

While numerous empirical studies have investigated household WTP for water ecosystem services in forest land, any attention has been given to examining the proxy values of water and soil ecosystem values. In a study, 143 participants from 23 European countries investigated which party concerns the cost of services provided by forest-water relations or the problems that may arise with a survey study; The effects of forest and water services on each other have been investigated. 48.4% of the participants questioned whether the state authority or individuals should pay for these ecosystem services (or the costs that may arise in their absence). It was revealed that these services should be regulated by the state. The 6.5% respondent emphasized that the cost of these services should be covered by the stakeholders (Balikova et al. 2020). A survey study was distributed within the state of Oklahoma/US to evaluate changes to water ecosystem service willingness to pay and valuation. It was found that prior exposure to environmental disasters had no effect on peoples' preferences (Burch et al. 2020). A study examined the probability of catastrophic wildfire and watershed relationship in Phoenix Salt Verde River watershed in central Arizona, USA. The highest willingness to pay was \$41.92 for restoration projects that protect critical habitats for endangered and threatened species in this region. It is claim that the results are one of the first estimates for groundwater recharge as an attribute of watershed restoration (Mueller et al., 2019). In a study carried out in China, respondents are asked if they contribute to promotion of urban green space's ecosystem benefits. Participants with higher socio-economic studies typically had greater perceptions of ecosystem services and WTP (Tian et al. 2020). Water services' improvements and benefits were investigated in upper basin, middle basin and lower basin of a region in China. The households were willing to pay more for the water quality attribute compared to other water services benefits. Household income level, residential location, education level, and sex were the main factors influencing WTP (Khan and Zhao 2019). A paper explores the impact of the determinants of risk perception on willingness to pay for flood risk prevention in Dunkerque (France) using a contingent valuation survey. It is found that actual distance of a respondent's home to the flood source, knowledge of flood risk, prior experience and trust in local authorities have a limited influence on WTP (Verlynde et al. 2019). Some behavioral studies are existed in the literature. In a study, behavioral motives were investigated for flood damage mitigation. It is found that households' choices are highly sensitive to information that provokes people's feelings of fear (Koning et al. 2019). A research article describes the perceptions of residents to flood risks to their property and factors that can influence this perception in the Hawkesbury-Nepean Catchment in

NSW, Australia. The data was collected through on-line, face-to-face and postal surveys. Findings of this research show that the communities have a low perception of flood risks in the region and that factors such as proximity to the rivers, gender, age and duration of living in the area can influence perceptions of flood risks to property (Masud et al. 2019). In a study, a survey method was used to estimate the value for improving water quality in China. About 70.1% residents wanted to support government to take active measures to improve water quality. Some demographic variables such as gender, age, income, education and occupation of residents were tested (Lei et al., 2018). In a study carried out in Sweden, it is examined trade-offs among the multiple ecosystem services generated by forests, and stressed that timber production conflicts with the provisioning of public-good ecosystem services such as the storage of carbon, nutrient retention and conservation of biodiversity. It is stated that intensifying biomass production are not maximizing societal welfare, because of conflicts in the management decision at forests (Zanchi and Brady 2019). Current study aims to economically analyze the ecosystem services related to the mixing of surface runoff caused by rainfall into groundwater with the presence of forest ecosystem and regulation of surface flow in a forest land. Although such specific services were technically expressed in previous studies, evaluations were made based on willingness to pay (WTP) in economic studies. Yet, specific ecosystem services and trade-offs among them cannot be easily envisioned and appreciated a WTP value. In this study, the proxy values of such services are used; how the found values should be evaluated was analyzed with the "Hartman Forest Rotation System." The study results will shed light on decision-makers and those who directly benefit from this natural resource (riparian community) to better understand the issue.

Material

The research was carried out in the Uludag National Park (UNP) of Bursa-Turkey. The data used in the study are also used in the UNP management plan. Moreover, previous studies based on UNP were taken into consideration.

Many studies have been conducted regarding the UNP mountain-forest ecosystem's resource values, which is the study's material. On an area of 12,762 hectares, 71% of UNP is forest, 28% are meadow and rocky areas, 0.4% are open areas, 0.1% are areas covered with water, and 0.8% are residential areas. Uludag has a wide variety of habitats such as forested lands, macquis groves, peatlands, subalpine heaths, alpine rock faces, and open areas. In Uludag, a plant diversity center,

1320 plant species are located, and it hosts 171 endemic species consisting of 33 Uludag endemics and 138 Turkey endemics. Also, Uludag constitutes the habitat of 3 endangered species on a global scale and 54 endangered species on the European scale (Eltan et al. 2016; Ozhatay et al. 2003; Daskin 2008).

The annual number of visitors to UNP is approximately 1,697,000 people, and about 75% of the visitors reach the national park through freeway and 25% by cable car. 50% of these visitors visit the national park in the summer season, 35% in the winter season, and 15% in the spring. Winter sports can be done in Uludag for an average of 4 months. Uludag is open to camping, mountaineering, hiking, picnic recreation activities in summer. UNP has two development zones. 1. There are 18 private sector tourism facilities and 12 public facilities in the Development Zone. In the 2nd Development Zone, four tourism facilities belonging to the private sector provide service. Also, there are two public facilities in Kirazliyayla locality. There are 22 mechanical facilities (teleski-chair lifts) serving ski tourism in the Hotels Region. The tourism and public facilities in the National Park mostly serve for winter tourism. During the Summer Season, the guests can accommodate in Sarialan and Cobankaya Camping and Day-trip Areas. Twelve country houses are serving in the summer season in the Sarialan Camping and Day-trip Areas, and there are 300 tent camping areas (BOBM 2020).

Figure 1: Uludag National Park

Method

Functions related to the regulation of flow in UNP lead to various benefits. Some of these benefits include the prevention of soil erosion in the UNP downstream basin, the protection of settlements and cultivated farmland from possible flooding, and groundwater support. One of the most important benefits provided by forest ecosystems is that the water flowing from the slope accumulates the upper layer of the soil layer downwards, and the fertile soil layer appears. Erosion is observed in many parts of the world. Considering that the UMP is within the mountain-forest ecosystem's scope, the amount of soil it accumulates in the lower basin is noteworthy. It is stated that erosion is mostly due to water flow (Gorcelioglu 2003). The destruction of the vegetation cover of the soil, excessive rainfall, extreme winds, and slope are the concepts that trigger erosion. The functions of soil protection and water flow regulation are among the regulatory functions of forests as an ecosystem. Therefore, "forests are considered the most effective tool in water production and soil protection (Deniz 2016). This activity of forests in terms of soil protection contributes directly to erosion control. It is important to keep the soil and improve the soil properties with the activities carried out within the scope of erosion control activities. Conservation of the soil is associated with

proper management of the water flow. Especially in mountainous ecosystems such as UNP, while ensuring the retention of rainfall water; supports groundwater. All these improve soil quality.

Roots of trees in the forestland have an important ecological function. In the studies, it was found that 90 tons of roots in a forest full of spruce trees and 40 tons of roots in a beech forest were found in an area of 1 hectare. It was also stated that 200-250 tons of soil humus and 10 000 tons of mineral soil were kept in the 1-hectare area (Trash 1995). With a good rotation and management, the slope flow of rainwater in mountain-forest ecosystems is mechanically prevented. In the UNP water resources management plan, values regarding water infiltration have been neglected. Apart from the trees' roots and trunks, the branches and leaves also reduce the evaporation of water by shading.

Wastes of forest trees are dried leaves, branches, and trunk parts, or the tree itself. It is accepted that they give three to four tons of organic matter mass to one hectare of forest land each year. Since rainwater does not directly hit the soil, these tree wastes prevent the soil from being transported by allowing water to leak into the soil. All of these affect groundwater. Besides, it is stated that many rivers, large and small, have a positive effect on water quality.

The UNP is closely related to the estimated risk factor of the economic value of downstream settlements and cultivated agricultural lands in preventing potential flooding. It is pointed out that this risk is higher, especially in mountainous areas in tropical climates. UNP, which is not under the influence of excessive rainfall, gradually saturates the soil with water by melting the snow water. In the economic value estimation related to flood prevention, it was stated that 18% of the total forest value in a national park in Sumatra Region of Indonesia could be allocated to flood prevention service (van Beukering et al. 2003). It can be said that this value, which is quite high for tropical regions, maybe lower in forests in temperate climates. The yield losses of downstream agricultural lands due to floods can be used to assess the environmental damage. However, the fact that no previous scientific study has been conducted for UMP may bring the use of option prices to the agenda. Flooding is an important risk, and people can be willing to pay to avoid this risk (Boardman et al. 2001). This preliminary calculation (ex-ante) to measure the welfare effects under risk and uncertainty in the environmental economy is called the "option price" of a policy. The main difference between the option price of a policy and the ex-post estimate of the policy's expected net benefits is that the option price explains the risk and uncertainty preferences. In other words, while option prices explain the costs incurred for risk aversion, the net benefit calculations

expected after the expected policy are applied assume that the society is neutral on risk. If there is no need to contract with an insurance company to reset the risk, then the society would benefit from a public policy that reduces risk. These services provided by natural resources are essential, as insurance companies do not insure against risks in large-scale natural disasters. In this study, the public policy that reduces the risk can be regarded as the UMP benefits, which provides a flood prevention service. Rainwater containment (interception) provides an important flood prevention service (Biao et al. 2010). Tuncer and Kaya (2010) talk about this process as "interception water"; and highlight the importance of original forest soil architecture. Seepage water prevents surface flow and transports them to sources and rivers as seepage water. Biao et al. (2010) stated that the amount of seepage (S_w) that comes with precipitation depends on three factors:

- i. Trees shading to prevent water evaporation (canopy interception, C_i)
- ii. The amount of wood and plant waste (litter containment, L_c)
- iii. Water retention of forest soil (soil retention, S_r)

So S_w can be expressed as the sum of these three factors:

$$S_w = C_i + L_c + S_r \quad (1)$$

The rainiest days of the year are taken into account in the formulation regarding the prevention of flood risk by seepage water. The reason for this is that the amount of rainfall per square meter is important in preventing the risk of flooding. Shading interception of trees (C_i) is a factor that depends on climatic conditions and an index designated as the "shading interception rate." Shading interception rate (α) depends on the type of forest, shade density, and leaf surface width (Wang et al., 2012). In studies, the shading interception rate was found between 18.33% and 26.38% (McDowell et al., 2020; Duval, 2019; Biao et al., 2010). It was stated that this ratio is between 23.50% and 26.38% in pine species and forest areas with mixed trees. Interception of Trees using this ratio (C_i) was calculated as follows:

$$C_i = \alpha \times R \times A \quad (2)$$

α = Shading interception rate

R = The highest amount of precipitation per square meter (mm)

A = Wooded area (Hectares)

In the calculation made for UMP, the interception rate was accepted as 24.94%. It is known that the forest area is 9061 ha (Eltan et al. 2016; Ozhatay et al. 2003; Daskin 2008). The highest amount of

precipitation by years was measured in 2014 with 2596.4 mm (UMP 2019). Tree interception for UMP was calculated as follows.

$$C_i = 0,2494 \times 2596,4 \times 9061 \text{ ha} = 5.867.379 \text{ m}^3$$

Water retention service of forests, especially on sloping terrain, can be compared with structures such as dams and ponds. In sloping forest areas, this service can be called a "green reservoir." Thus, since there is also a cost of holding water in the reservoir, the cost here can be compensated with the obtained water retention function. According to the cost determination study for water retention in an artificially manufactured reservoir (dam), the cost of holding 1 m³ of water was taken as 0.00111 TL (Keskin and Demir 2018). The value per hectare of this service provided by UMP is also calculated as **0,718TL / Year**. However, this value is for the current forest asset. Since the tree's biomass value will also be low at the beginning of the rotation, it is obvious that this value will typically be lower.

Shading interception (C_i), (canopy interception) approaches obtained from the literature determine the effect of UNP on forest rotation. The effect of shading on the water cycle of UNP, the growth areas approach was used. The 'effective growth area' and 'potential growth area' of each tree was demonstrated with approaches. The sum of the crown projection area of a tree in the stand and its share of the unclosed spaces around it was defined as the potential growth area (Assmann 1970; Usta 1990). The effective growth area that a tree benefit from is accepted as the crown area (Sun 1983). The crown area grows to full shade and reaches an effective growth zone. The effective growth area reaches the potential growth area after a certain year, and full shadowing occurs. In this study, it was assumed that if a tree reaches a crown width of 24 m², it would create full shading (Usta 1990; Sun 1983). Accordingly, the relationship between tree chest diameter and age was primarily investigated; The size of the chest diameter was obtained over a period of 150 years from the beginning. (Giray 1984; Yavuz 1995). It was revealed that the UMP will reach a growth area of 24 m², that is, full coverage in the 25th year. The following formulation was used in the relationship between the varying bust diameter and crown width over the years (Assmann 1970; Usta 1990):

$$m = 1,3702 + 0,20062d \tag{3}$$

d: Chest diameter (cm)

m: Crown width (m)

In the next stage, using the crown width, the circular closure to be created by each tree was calculated. If full coverage occurs in 24 m², the water produced due to shading in 1 ha area will be $C_i = 0.2494 \times 2596.4 = 647.54 \text{ m}^3$ using Equation 1. Since a unit value of 1 m² is needed instead of this value during the rotation years, this value is divided by the area value (24 m²) that creates a fully closed condition, and the equivalent water production amount of 1 square meter of shading is obtained. By multiplying the shading area column by age and the value of 26.98 m³ (647.54 / 24), the amount of water generated by shading was calculated every year. The cost advantage provided by the value found was calculated by using the green reservoir value (0.00111 TL). Therefore, the increased value in the annual shading interception water was revealed.

Table 1 Canopy interception value

Years	Quadratic Stem Diameter (cm)	Crown Width (m)	Canopy Area (m ²)	Canopy Interception Amount (m ³)	Canopy Interception Value (TL/m ³)
1	1,022	1,5752336	1,9478684	52,55	0,06
5	4,95	2,363269	4,3842567	118,29	0,13
10	9,5	3,27609	8,4252211	227,31	0,25
20	17,4	4,860988	18,548925	500,45	0,56
30	23,7	6,124894	29,448746	794,53	0,88
40	28,4	7,067808	39,213819	1057,99	1,17
..	..	..	..	..	..

Wood and plant wastes (litter containment, L_c) is another factor that allows water to be retained and turned into spillage water. The water retention ability of forest soil due to wood waste depends on the water holding capacity and waste layer thickness parameters, and it was formulated as in Equation 2 (Biao et al. 2010). In studies conducted in various forest areas and different tree species, it is stated that the water holding capacity of 1 cm thick waste in the 1-hectare area varies between 4.59 and 16.08 tons (Li et al. 2004). In this study, the evaluation was made according to the mixed forest type of UNP, and the mean value of 10.33 tons cm⁻¹ ha⁻¹ per year was taken into consideration.

$$L_c = \beta \times t \times A \quad (4)$$

β = water holding capacity of 1 cm thick waste in 1-hectare area (ton)

t = Thickness of forest waste (cm)

A = Wooded area (Hectares)

As a result of the calculations, when the forest waste of UMP is considered as 1 cm thick, it was determined that its contribution to the seepage water is 93600 tons/year. In the reservoir, the cost of water retention was taken into account as 0.00111 TL / m³, similar to the above calculation. Accordingly, it can be said that the value of this service is 103.89 TL per year. This value is **0,0114 TL / year** per hectare.

In calculating the effect of the obtained result on the optimal rotation time, $y = 1 / 177,81x$ function was utilized (Gunel 1981; Senyurt 2011). In the equation, the x parameter indicates the stand age, while the y variable shows the amount of wood waste as a percentage of the annual tree biomass. Accordingly, the percentage of annual biomass in the UNP and the amount of forest waste were calculated. Accordingly, it was calculated that 0.031 tons of forest waste accumulated in the first year. If it is assumed that 100 cm thick forest waste will correspond to 1 m³, this will correspond to approximately 10000 gr waste. With a proportion, the forest waste height in 1-hectare area will reach 3.1 cm in the first year. Forest waste heights can be determined by years. It was calculated that this amount would correspond to 10.33 tons of cm⁻¹ ha⁻¹ water per year, according to Equation 2. Thus, it is clear that the amount of water that this amount of forest waste will hold in the first year will be 32.1 tons. With this value obtained, annual monetary values were obtained by using the green reservoir value (0.00111 TL / m³) (Table 2)

Table 2 Forest litter value

Years	Biological Mass Amount (Ton)	Tree Litter as a percentage of Bio.Mass. Amount	Forest Litter Amount (Ton)	Forest Litter Height (cm)	Interception Water of Forest Litter (m ³)	Value of Int.Water of Forest Litter (TL)
1	5520	0,0056	0,031	3,10	32,1	0,04
5	8190	0,0281	0,230	23,03	237,9	0,26
10	13362	0,0562	0,751	75,15	776,3	0,86
20	34727	0,0844	3,906	390,60	4034,9	4,48
30	84332	0,1125	14,229	1422,85	14698,1	16,31
40	155535	0,1687	39,982	3998,21	41301,5	45,84
..	..	..	..	..	..	..

Water retention of forest soil is closely related to soil porosity in forest soil. The variability in pores allows water to remain in the soil or not. If the pores are small, the water's movement in the soil will slow down (Isler 2020). Soil porosity, which can be formulated as follows, is also related to the topsoil depth:

$$S_r = \varphi \times h \times A \quad (5)$$

φ = Soil porosity (porosity)

h = Soil layer depth cm

to = Wooded area (Hectares)

Studies on soil porosity observed that the porosity values of areas with various woodlands vary between 30.70-60.25% (Biao et al. 2010). For UMP, this parameter was accepted as the average value of 45.47%. The depth of the soil layer was accepted as 20 cm, according to the study of Cepel and Karaveli (1990). Accordingly, the amount related to the UMP forest soil's water retention has been calculated to be 82400 m³ per year. If an assessment is made with the cost of holding water in the reservoir, the value will be 91.47 TL / year. This value is **0.010 TL / year** per hectare.

The growth function was used to calculate the effect of the obtained result on the optimal rotation time. It is assumed that trees' annual biomass increase is not directly related to the permeability level of the soil. In general, high or low soil porosity is related to the fact that the volumetric ratios of macropores in the soil are close to each other (Oguz 2008). $B_0 * e^{\beta t}$ was used as a growth function. While the B_0 value indicates the initial size (0.010TL / Year), the β coefficient indicates the annual growth rate (taken as 0.01) and indicates the number of years.

Table 3 Forest soil porosity value and its annual growth

Years	Forest Soil Porosity (%)	Forest Soil Porosity Value (TL/Ha)	Forest Soil Porosity Growth Value (TL/Year)
1	45,47	0,010	0,0101
5	45,47	0,010	0,0105
10	45,47	0,010	0,0111
20	45,47	0,010	0,0122
30	45,47	0,010	0,0135
40	45,47	0,010	0,0149
..	..	..	..

The annual sum of these three values will give the monetary value of keeping the rainwater in the green reservoir, that is, in the UNP forest area. The effect of this on forest rotation was analyzed with the Faustmann and Hartman approaches, which are accepted as fundamental in forest management.

In addition to the benefits of the retention of rainwater mentioned above in the UNP, another benefit is the lowering of the water by gravity. The water accumulating in the underground galleries performs an important hydrological regulatory function. In the studies conducted in the soils of forest areas with various tree species, it was stated that the porosity coefficients of the gallery gaps under the soil vary between 6.9-16.6% (Lu et al. 2005). This water (W_s) collected in the galleries in the depths of the soil, the porosity coefficient (ε) depends on the size of the area, and the soil depth and is formulated as follows:

$$W_s = \varepsilon \times h \times A \quad (6)$$

ε = Soil porosity (porosity)

h = Soil layer depth cm

A = Wooded area (Hectares)

In the calculation of this value for the UNP, it was concluded that the porosity coefficient of the underground gallery spaces is 11.75% and the amount of water seeping down from the upper layers of the forest soil is 2.35 m³ per hectare, considering the depth of the soil layer and the amount of woodland as above. However (Biao et al. 2010) identified four types of terrain (plain, hilly, mountain slope, and mountain slope); and stated that only 19.2% of the total groundwater is found in the mountain slope and above forestland. According to this calculation, the amount of water accumulated in the galleries for UNP is calculated as 0.45 m³ per hectare annually. This water, which can be considered as the gravity water of the soil, supports surface water resources (Liu et al. 2003). It helps water to stay on the upper surface of the soil due to its filtration function. The fact that the water seeps down to the galleries has a positive effect on the total water budget. In this study, it can be accepted that 0.45 m³ of water per hectare remains above the ground, and this amount has a positive effect on the water budget. In other words, in the water budget calculations for Bursa Province, it has been accepted that the value of this water collected in the galleries at a depth of the soil will be equivalent to the price of 1 m³ water in Bursa. Since the price per m³ of water in Bursa is 7.13 TL (BUSKI 2020), the ha⁻¹ value of approximately 3.20 TL has been

accepted as the filtration function value of the soil water in the region where the UNP is located. With the assumption that this value has an annual growth tendency of 1% today, where global warming has shown its effects, similar operations above were carried out for the rotation process. Table 5 shows the annual changes regarding the filtration benefit of water.

It can be said that the water (W_f) remaining above the ground and flowing towards the lower basins of the UNP is an important economic value. In other words, it can be considered as a positive externality for the people of Bursa. However, since evaporation due to the presence of trees will reduce the amount of water in the basin, this situation can be considered as a kind of negative externality. In other words, forest existence has a negative effect on the water budget in increasing evaporation on the amount of water (Tuncer and Kaya 2010). Thus, when calculating forest areas' economic value on providing potable water, losses due to evaporation become important due to trees' presence. In the calculations made for the UNP, the effect of the water accumulated under the ground is not taken into account. Losses due to evaporation are calculated as the loss of economic value. The studies conducted stated that the water lost by evaporation was 900 mm in forest areas, 775 mm in grass and shrubs, and 625 mm in bare soil (Keles 2019; Ozhan 1998). If the area of the UNP is not forested, but bare soil, a 900-625 mm water yield difference will occur, and as a result of this amount of water transformed into a forest of 9061 hectares, it will be concluded that 2,491,775 m³ of water is lost annually. It can be said that the cost of this amount of water to the region should no longer be evaluated by holding water in the reservoir, but by the market price of the water. Because it would be possible to process and use this amount of water. The average price per cubic meter of water in Bursa is determined as 7.13 TL (BUSKI 2020). UNP's annual water loss value due to evaporation is calculated as 1960.75 TL.

The negative externality created by the forest presence in the UNP towards the decrease in the amount of water can be compensated with positive externality towards the increase of water quality. Therefore, both values must be known. Since there is no water quality assessment study applied to the region, a value can be determined for higher quality water by adding a certain percentage to the price of 7.13 TL / m³ of tap water. For example, the increase in water quality can be calculated as 7.13 * 10% or 7.13 * 20%, and valuations can be done. UNP management allows commercial companies processing (bottling) water to supply 5 650 000 m³ / year of water per year (UMP, 2019). The price per cubic meter of this water was determined as 7.84 or 8.55, and the quality change was determined in two different values. Commercial firms set a higher price for

bottled water. However, the quality of the water is not fully reflected in the prices, as they add a profit share as well as investment, operating, and rental costs when determining the liter price. Accordingly, the share of water quality per hectare will vary between 4888.64 TL and 5331.36 TL. The table below lists the UNP's water budget benefits. When Table 4 is examined, the amount of water lost by the forest-covered area due to evaporation is compensated by the increase in water quality.

Table 4 Impacts of UNP on Bursa province's water resources

Benefits and Costs	Amount m³ ha⁻¹	Value TL ha⁻¹
Water filtration	0,45	3,20
Forest evaporation	-275	-1960,75
Water quality improvement %10	623,5	4888,64
Water quality improvement %20	623,5	5331,36
<i>Total Impacts with water quality improvement %10</i>	<i>348,95</i>	<i>2931,09</i>
<i>Total Impacts with water quality improvement %20</i>	<i>348,95</i>	<i>3373,81</i>

The water supply and groundwater filtration service benefits of the UNP and their annual increment values suitable for forest rotation are given in table 5. While using the logarithmic function that takes 1% growth into account for the Forest Water Filtration value, the UNP's water supply function has been increased in parallel with the increase in the shading area of the forest by considering the 10% and 20% quality increase values (Table 5).

Table 5 Water supplying and filtration benefits of UNP and its annual growth

Years	Forest Water Filtration Benefits (TL/Year)	Water Supply Benefits (TL/Year) 10% Water Quality Improvement	Water Supply Benefits (TL/Year) 20% Water Quality Improvement
1	3,23	5703,14	6565,50
5	3,36	12836,62	14777,62
10	3,53	24668,12	28398,13

20	3,91	54309,21	62521,19
30	4,32	86222,69	99260,24
40	4,77	114813,75	132174,49
..	..	..	..

Faustmann and Hartman's approaches were examined to examine the effects of forest water's economic value on rotation management. The Faustmann approach made important contributions to natural resource management and especially to the economic analysis of mountain-forest ecosystems in the middle of the 19th century. Faustmann-based Hartman solution algorithm was used in forest land management in order to use the value of water resources related benefits in UNP management and make it more meaningful. Faustmann's model mainly has a single rotation and a specific tree growth function. It is predicted that the amount of lumber to be harvested will change over time as the tree grows. The beginning of the Faustmann analysis indicates the amount of lumber in the rotational age T with $q(T)$ in m^3 form. If it is assumed that there is a homogeneous tree group in the whole tree (stand) (such an assumption will be used for UNP) $Q(T)$ shows the whole timber amount of the stand. The $nq(T) = Q(T)$ equation is mentioned here, where n represents the number of trees in the stand. If the initial stock amount is shown with Q_0 , it can be said that this value is the $Q(T)$ value at $T = 0$. The stand's timber amount is related to the growth rate of biomass α and the bearing capacity of stand K . The growth rate varies depending on whether the tree structure is thin or thick. It is known that the growth rate of thick textured trees will be lower. The carrying capacity is the maximum timber volume that the stand can support. It relies on a temperate climate, rainy season, and soil quality. Based on these data, the model was developed through the following biomass lumber volume:

$$Q(T) = \frac{K}{1 + \left[\frac{K - Q_0}{Q_0} \right] e^{-\alpha T}} \quad K > Q_0 > 0 \quad (7)$$

Equation 7 indicates an "S" curve that remains at low levels initially for timber biological mass and increases up to the bearing capacity level in line with the rotation age. In the model, it is assumed that price, cost and interest rate (discount rate) to be used in the analysis are fixed under a fully competitive market. In the setup of the stand, a fixed price (S) is incurred at the beginning of the rotation. However, it is then assumed that the stand grows under a natural environment without

incurring any costs. Harvest costs (C) and stamping price (p) are market prices. Here, two important costs have to be included in the analysis. The first one is the interest incomes that the expenses incurred for the stand during the growth period will be lost until the product is harvested. This cost will increase as the rotation interval becomes longer. This opportunity cost is reflected in the model with an interest rate (r). Naturally, the present value of the T-aged stand can be brought up to date with a reduction factor (e^{-rT}). The initial planting cost, S, is not subjected to reduction. At this point, the equation giving the net present value of harvested stand in T rotation length will be as follows:

$$N(T) = (p-C)Q(T)e^{-rT} - S \quad (8)$$

Another cost is related to the land value and it is an important cause of environmental management problems. Since the places near forest zones are valued excessively, it may cause such areas to be converted into money and used in further zones. In other words, alternative income that can be obtained by renting or selling the land is the second type of cost in this model. Assuming that all ecological and economic parameters are constant, the problem that forest management will face in the next period is the same. In other words, the problem in each rotation will remain the same.

Therefore, V(T) will give the sum of the net current rate of the timber value obtained by cutting trees at the end of the rotation period and the present rate of bare land value at the end of the rotation period:

$$V(T) = [(p-C)Q(T)e^{-rT} - S] + V(T)e^{-rT} \quad (9)$$

The following equation can be written here:

$$V(T) = \frac{(p-C)Q(T)e^{-rT} - S}{1 - e^{-rT}} \quad (10)$$

In line with community interests, Equation 7 needs to be maximized. Thus, an economically inefficient natural resource management will be against society. The equality that maximizes V(T):

$$MAX_T : V(T) = \frac{(p-C)Q(T)e^{-rT} - S}{1 - e^{-rT}} \quad (11)$$

For the maximization problem, the first derivative bound to V(T) should be equalized to zero.

$$V(T^*) = \frac{(1 - e^{-rT^*})[(p - C)Q_{T^*}e^{-rT^*} - re^{-rT^*}(p - C)Q(T^*)]}{(1 - e^{-rT^*})^2} - \frac{re^{-rT^*}[(p - C)Q(T^*)e^{-rT^*} - S]}{(1 - e^{-rT^*})^2} = 0 \quad (12)$$

The expression of QT in the equation indicates that the first derivative based on the T rotation period is considered. The expression T* indicates the optimal rotation year. An easier form of Equation 12 can be written as follows:

$$\frac{(p - C)Q_T}{(p - C)Q(T) - S} = \frac{r}{1 - e^{-rT}} \quad (13)$$

Equation 13 is called the Faustmann formula, which shows the optimal rotation length (Amacher et al. 2009). The easier representation of Equation 12 as a calculation tool can be given as follows:

$$(p - C)Q_T = r[(p - C)Q(T) + V(T)] \quad (14)$$

Equation 14 explains that the effective rotation period of stand will occur if the rate of change in forest value is equal to the rate of return to be earned by converting trees and forest land into capital. In an economic sense, the left side of equation is the marginal product value of timber that is allocated for the stand growth. The right side of the equation is the sum of the capital (opportunity cost of this choice) due to the capital used by growing timber if the land is not used for further purposes. Reflecting the water resources and relevant values on the model is a solution for the following maximization problem:

$$MAX_{T^*} : V(T) = \frac{\int_0^T B(t)e^{-rt} dt + (p - C)Q(T)e^{-rT} - S}{1 - e^{-rT}} \quad (15)$$

The first row of differential required for the solution of T-related maximization problem is as follows:

$$(P - C)Q_T + B(T) = r[(P - C)Q(T) + V(T)] \quad (16)$$

Equation 16 refers to the Hartman solution as an extended approach of Faustmann optimal forestland management. For the Hartman solution, there is a need for a function that describes the entire flow of biodiversity benefits. Because the optimal rotation conditions change with the benefit of biodiversity. In the Hartman approach, environmental benefit values B(t) occurring during

infinite rotation are included in the model by Boman et al. (2010) for the effective rotation period T:

$$B(T) = \frac{\int_0^T B(t)e^{-rt} dt}{1 - e^{-rT}} \quad (17)$$

It is more appropriate to use the expression VV(T) as the sum of Equation 17, the timber value of the forest area, the value of the area and the water resources. Therefore,

$$VV(T) = V(T) + B(T) \quad (18)$$

The statement shows that the benefit of water resources will also be taken into account when considering the new optimization condition. In this case, it becomes the first-order differential of:

$$VV'(T) = 0 \Rightarrow (P - C)Q'(T) + B(t) = r[(P - C)Q(T) + VV(T)] \quad (19)$$

equation 18. Exponential growth function is the most used function type in terms of showing values other than timber value (Burgess, 2000). Therefore, the function $B(t) = B_0 e^{bt}$ is the function that will represent biodiversity values in this study. $B(t)$ is the composite index value (USD / Ha) of water resources at t rotation time; it can be observed that this value will be equal to the water resources initial value (B_0) at $t = 0$. Because biological diversity has values that will increase with forest biological mass; some value do not depend on it. Therefore, B_0 value can be $B_0 > 0$, $B_0 < 0$ or $B_0 = 0$. In the calculation of interception water, canopy interception value and forest litter water-holding value are calculated directly through related data. Yet, amount of static water stored due to soil porosity is calculated by growth function. Here S_r was found 0,01 TL/Ha (B_0) and growth rate was considered as 1 % annually. Similarly, the soil water storage water was calculated with a 3,20 TL/Ha of constant value and 1 % growth rate. Water provision benefit is also calculated directly through related data.

Exponential growth function is the most used function type in showing values other than timber value (Burgess 2000; Swallow and Sedjo 2000). Therefore $B(t) = B_0 e^{bt}$ function is the function that will represent the benefits of forest water resources in this study. $B(t)$ is the composite *index value of forest water resources* (USD Ha⁻¹) at the time t of rotation; it can be observed that this value will be equal to the initial value (B_0) of forest water resources during $t = 0$. Because forest water resources have values that will increase with forest biological mass, there are also values that do not depend on it. Thus, B_0 value can be $B_0 > 0$, $B_0 < 0$, or $B_0 = 0$.

All parameters used in Faustmann and Hartman's approaches, which form the study's mathematical model, are given separately in Tables 6 and 7.

Table 6 Faustmann's main model parameters

Parameter	Value
α (Annual tree growth rate)	0,1
K (Stand bearing capacity)	500 m ³ Ha ⁻¹
PC (Planting cost)	100 USD Ha ⁻¹
p (Stamping price)	63 USD/m ³
C (Harvest/cut cost)	25 USD/m ³
r (reduction rate)	%5
Q ₀ (Initial Biological Mass Value)	5m ³ Ha ⁻¹

Table 7 Hartman's forest water benefit model parameters

Parameter	Value
Interception Water	
Canopy Interception rate(α)	%24,94
Maximum Rainfall (R)	2596,4 mm
Forest cover(A)	9061 ha
Crown area(m)	24 m ²
Thickness of forest litter layer(t)	1 cm
Water-holding capacity of forest litter(β)	10,33 ton ha ⁻¹
Capillary porosity of soil(ϕ)	%45,47
Depth of soil layer(h)	%45,47
Water Filtration	
Non-capillary porosity coefficient	%11,75
Mountain-forest impact of groundwater	%19,2
Water supplying	
Water productivity difference by evaporation	275 mm
Water quality increases (10%)	7,84 TL/m ³
Mains water price	7,13 TL/m ³
Green reservoir benefit	0,00111 TL/m ³

Results and Discussion

The study was written with the help of the "Microsoft Excel Spreadsheet." The mathematical differential was solved with the help of Matlab. Three different models are established in this study. The first of these is the model in which the effect of water resources on forest rotation management is not taken into account. The second model is the one in which the benefits arising from the retention of rainwater are taken into account in addition to the stand value. In this model, the Hartman approach has been constructed as an add-on to the first model. In the third model, the effects on the water budget caused by the existence of the UNP were investigated; The effects of contributions to water quality on stand value and rotation periods were revealed. In other words, all forest water services were taken into account in the third model. Here, it was taken into account that the increased water quality value due to the forest will increase by 10%. The numerical values in Table 8 were taken into account at the beginning of all models used in the study. When Table 8, which shows the results of the basic model, is examined, the UNP should be renewed at 44-year intervals. In the 44th year, a net present value of 956 USD / Ha is reached. The left side of Equation 13, which shows the optimal rotation length of the UMP, is shown in Figure 2 with a red line and the right side of the equation with a blue line. It was concluded that this value reached depends on the changes in the bare land value in accordance with Equation 13. If this value ($V(T)$) is taken as zero, the rotation interval becomes 43 years. It is clear that if the bare land value becomes positive and begins to appreciate, the rotation range will be lower so that the 0.05 reduction ratio (r) remains the same. In the UNP model, while the rotation interval was 43 years in the first condition ($V(T) = 0$), it was observed that when the value of $V(T)$ increased by 20%, the rotation interval decreased to 41 years (Figure 1). The stand value this year is 948 USD / Ha. The declining direct use value of UNP (timber biomass) may bring up the economic savings of forest assets in other ways. In other words, the elimination of forest quality would theoretically be more meaningful. The policy required to avoid this situation is to determine the non-timber values of UMP exactly and make it usable in UNP management. Another point is about the prevention of excessive, untimely, and unplanned valuation of land value. Unplanned urbanization, the need for industrial areas, the effects of large infrastructure projects on land value pose a problem for forest land management. There appears to be competitiveness in natural resource areas close to such places due to the land gaining value. Many studies, especially investigating the disadvantages related to the misuse of agricultural lands and the unplanned urban development, support the results obtained from this study (Dirim et

al. 2009; Karakayaci 2010). It is a fact that the rules regulating land use affect the housing supply and housing prices. In this context, the fact that housebuilders have more freedom of choice in land development supports the creation of fast and flexible solutions in the face of changing market conditions. In this context, local and regional planning for land use should be designed to support the increase in housing supply (Coskun 2016).

Table 8 Basic Model of UNP and maximization case

Rotation Years	Biological Mass(Ton)	$dQ(T)/dt^1$	Discount Rate(r)	Faustmann Maximization Condition			Timber NVP ³ N(T)	Stand NPV V(T)
				$[(p-C)*[dQ(T)/dT]]$	$[(p-C)Q(T)]+V(T)$	Maks ²		
0	5,00	0,50	0,05	18,81	NA	NA	90,00	NA
5	8,19	0,81	0,05	30,61	954,97	0,032	142,39	643,73
10	13,36	1,30	0,05	49,42	1036,29	0,048	207,97	528,54
15	21,65	2,07	0,05	78,72	1370,03	0,057	288,70	547,15
20	34,73	3,23	0,05	122,80	1929,39	0,064	385,46	609,78
25	54,79	4,88	0,05	185,38	2777,69	0,067	496,47	695,82
30	84,33	7,01	0,05	266,41	3996,33	0,067	615,05	791,70
35	125,33	9,39	0,05	356,87	5643,07	0,063	727,59	880,62
40	177,73	11,46	0,05	435,31	7695,19	0,057	814,02	941,43
41	189,34	11,76	0,05	447,04	8143,42	0,055	826,26	948,34
42	201,24	12,02	0,05	456,93	8600,40	0,053	836,45	953,17
43	213,38	12,23	0,05	464,81	9064,09	0,051	844,48	955,82
44	225,69	12,38	0,05	470,51	9532,32	0,049	850,26	956,21
45	238,12	12,47	0,05	473,93	10002,81	0,047	853,71	954,29
46	250,61	12,50	0,05	475,00	10473,21	0,045	854,78	950,03
47	263,10	12,47	0,05	473,70	10941,18	0,043	853,47	943,45
48	275,52	12,37	0,05	470,05	11404,37	0,041	849,80	934,58
49	287,82	12,21	0,05	464,13	11860,56	0,039	843,80	923,49
50	299,93	12,00	0,05	456,05	12307,60	0,037	835,55	910,27
100	497,76	0,22	0,05	8,46	18942,62	0,000	27,45	27,63
200	500,00	0,00	0,05	0,00	18900,85	0,000	-99,14	-99,14

¹Timber Biological Mass Change ² $(p-C)*[dQ(T)/dT] / (p-C)Q(T)+V(T)$

³Net Present Value NA: Not available

Figure 2. UNP Optimal Rotation Length (Basic Model)

In the second model, the effect of the monetary value of rainwater retention by means of forestry on the rotation process was examined. Total rainwater interception benefit is treated alone as non-timber benefits of Hartman methodology. Annual values derived by the methodology described above were subjected to the Hartman rotation process. The benefits associated with stormwater retention were weak compared to the stand value of the UNP. Providing natural reservoir and water filtration increased the stand value to 956 USD / Ha (Table 9). The rotation period has been extended by one year. However, the calculations made are naturally for the rainwater retention function (green reservoir). Values such as the effects of the captured water on the underground biological diversity, the contribution to the urban settlers living with the risk of flood in the lower basin, and the sustainability of the stand are excluded from the calculation. When these values are taken into account, the value of rainfall interception will also increase. Concerning the retention of rainwater in the UNP, focusing on silvicultural studies, making tree simulations to increase shading, and allocating funds for regular soil maintenance will increase the benefit of the rainfall interception provided by the UNP. Particularly, the areas with high slopes should be focused more, and the chances of success should be increased by cultivating strategic tree species. Another political action is for residential areas at risk. If zoning permission is not given here, restoration should be provided for the degraded or treeless areas of the UNP with a certain tax burden.

Table 9 Hartman Solution of UNP Rainfall Interception Benefits

Rotation Period	Biological Mass(Ton)	$dQ(T)/dt^1$	Rainwater Interception Value(USD/Ha)	Hartman Maximization Condiiton			Stand Value VV(T) (USD/Ha)
				$[(p-C)*[dQ(T)/dT]] + B(t)$	$[(p-C)Q(T)] + VV(T)$	Max ²	
0	5,00	0,495	0,00790	18,82	190,00	0,099	-
10	13,36	1,300	0,16424	49,58	1037,67	0,048	592,92
20	34,73	3,231	0,73671	123,53	1933,19	0,064	613,58
30	84,33	7,011	2,51245	268,92	4004,82	0,067	800,19
40	177,73	11,455	6,86627	442,17	7711,64	0,057	957,88
41	189,34	11,764	7,48561	454,52	8160,85	0,056	965,77
42	201,24	12,025	8,13796	465,07	8618,84	0,054	971,62
43	213,38	12,232	8,82207	473,63	9083,57	0,052	975,31
44	225,69	12,382	9,53630	480,04	9552,87	0,050	976,76
45	238,12	12,472	10,27800	484,21	10024,44	0,048	975,92
50	299,93	12,001	14,32312	470,38	12334,92	0,038	937,59
60	401,48	7,9111	22,89903	323,51	15989,10	0,020	732,91
70	458,60	3,797	30,44192	174,74	17914,88	0,010	488,11
80	483,93	1,556	36,64883	107,83	18686,47	0,006	297,19
90	493,96	0,596	42,02210	69,55	18941,57	0,004	170,90
100	497,76	0,223	46,98652	57,30	19007,33	0,003	92,35

In the third model, all forest water and stand values were taken into consideration. It was assumed that the UNP forest area's impact on water quality would be a 10% increase. In this model, where the full effect of forest water is reflected, the optimal rotation period has increased to 107 years; The stand value was calculated as 147046 USD / Ha (Table 10). It can be said that the timber value provided by the forests remains at a very low level, among other benefits. Considering the effects on the water budget, although the water production of the bare land area is high, the value of the increase in water quality exceeds the benefits of bare soil when it comes to cost/benefit calculation. Thus, forests are becoming increasingly important as the main source of high-quality, usable water. In rational forest management, conservation of forest water and water quality should be included in silvicultural planning criteria. Obviously, water resources management should be taken into account within the scope of forest management.

Although the amount and quality of forest water are known, its economic value was revealed in this study. In rational forest management, where the above-mentioned benefits of water resources are also taken into account, natural vegetation should be preserved, or areas other than wooded

areas should be supported with species with low water consumption. In the selection of species to be made within the scope of afforestation studies, interception and leaf evaporation rates of tree species should be considered. This strategy becomes more important in regions close to residential areas. The construction and excessive visitor density in the UNP necessitate the establishment of highways, accommodation facilities, etc. Hence, the adverse conditions and risks that the urban expansion to be realized in the UNP may create in the downstream basin should be taken into consideration in the feasibility studies.

Table 10 Hartman Solution of UNP Total Water Benefits with 10% Water Quality Improvement Condition

Rotation Period	Biological Mass(Ton)	$dQ(T)/dt^1$	Total Water Benefit Value %10 Quality Imp.(USD/Ha)	Hartman Maximization Condition		Max ²	Stand Value VV(T) (USD/Ha)
				$[(p-C)*[dQ(T)/dT]] + B(t)$	$[(p-C)Q(T)] + VV(T)$		
0	5,00	0,495	630,42	649,23	190,00	3,42	-
10	13,36	1,300	3601,87	3651,28	41236,13	0,09	40728,38
20	34,73	3,231	7929,66	8052,46	68188,13	0,12	67868,52
30	84,33	7,011	12590,40	12856,81	96192,71	0,13	92988,07
40	177,73	11,455	16768,69	17204,00	119811,93	0,14	113058,17
50	299,93	12,001	19855,75	20311,80	138797,80	0,15	127400,46
60	401,41	7,911	21447,68	21748,29	151932,58	0,14	136676,40
70	458,59	3,797	21347,87	21492,17	159588,87	0,13	142162,09
80	483,92	1,556	19568,98	19628,09	163495,55	0,12	145106,28
90	493,96	0,596	16331,91	16354,57	165252,47	0,10	146481,81
100	497,76	0,223	12064,92	12073,38	165891,41	0,07	146976,43
105	499,81	0,018	1572,08	9740,84	165989,62	0,06	147041,28
106	499,83	0,017	1306,01	9270,76	165998,34	0,06	147045,09
107	499,84	0,015	1062,06	8801,41	166004,17	0,05	147046,48
108	499,86	0,014	841,51	8333,68	166007,38	0,05	147045,67
110	499,88	0,011	475,86	7406,61	166007,00	0,04	147038,37

Conclusions

While urbanization and industrialization efforts in the world put pressure on forest areas, it may also cause the services provided from forest areas to be cut. High quality and amount of water can be produced naturally in mountain-forest ecosystems. Upper basin interventions create negative

externalities in downstream and settlements. Hence, the opportunity cost of every economic activity undertaken in forest areas should be analyzed well.

In this study, the importance of the forest water source of Uludag National Park (UNP) was investigated. Some hydrological functions that occur due to the forest area were subjected to economic analysis. The methodology followed in the study can be a reference for Turkey Forest Management. Although there are many sources emphasizing forest resources' value, there is no study examining the effect on forest rotation within the scope of ecological factors.

This study aims to economically analyze the ecosystem services related to the mixing of surface runoff caused by rainfall into groundwater with the presence of forest ecosystem and regulation of surface flow. Although such specific services were technically expressed in previous studies, evaluations were made based on willingness to pay in economic studies. However, it is a significant problem that people answering the questionnaire do not have much technical knowledge of payment request studies. In this study, the proxy values of such services are used; how the found values should be used was analyzed with the "Hartman Rotation System." The economic benefits of the UNP for stormwater retention will be increased by considering various risk factors (landslides, erosion, floods, etc.). In the study, ecosystem benefits arising from the effect of water resources benefits arising from forest areas were lacking. Faustman and Hartmann's solutions have been used in forest management for many years. However, it is crucial to include the values of forest functions determined at shadow prices in the analysis. In particular, if the economic value of the benefits of water to UNP biodiversity can also be included in the calculations, the rotation range can become limitless. The economic benefits of forest hydrology in research can contribute to forestry science, examining the Faustmann and Hartman approaches.

The study results will shed light on decision-makers and those who directly benefit from this natural resource for a better understanding of the issue.

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Figures

Figure 2

UNP Optimal Rotation Length (Basic Model)