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To cite this article: M Lobovikov and Tran Thi Thanh Nga 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **226** 012033

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Economic criteria of forest management

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Abstract. Forest managers face two competing paradigms: traditional multiple use sustainable management and ecosystem management. Traditional management maximizes sustainable yield with certain preservation limitations. Maximization of the yield without discounting is called the "forestry" decision and implies maximization of average wood increment. Maximization with discounted cash flow is often referred to as the "economic" decision and is based on the concept of financial maturity employing criteria of I.Fisher, M.Faustman, R.Hartman and their numerous latest modifications. Economic criterion results in harvesting of rather young forests. Preservation or conservation tends to stop forest management of any type and leave forest intact. Traditional forestry employs logging criteria with preservation limitations. Ecosystem management is a new paradigm. It needs new forestry approaches and economic criteria. It imitates forest structures in pursuing simultaneously ecological and economic targets. It employs criteria based on targeted sustainable forest structures, which is different from targeting sustainable forest products yield.

1. Introduction

Determination of rotation period is a basic issue for the current models of forestry scenarios and risk analysis. In this respect, forests were always treated as a regular agricultural crop with longer rotation period. Specific forest conditions have traditionally been ignored. There are three methods to establish the rotation age: (1) maximization of discounted or undiscounted sustainable yield, (2) forest preservation (with infinite rotation age) and (3) ecosystem management as an alternative to the previous two approaches. These methods constitute background for the use of criteria and indicators (C&I) for data collection, monitoring, assessing and reporting results on sustainable forest management (SFM). This process was established and has been growing since the Earth Summit in 1992. It was actively supported by eleven intergovernmental, regional and international C&I forest processes [1-2]. The Earth Summit triggered a new paradigm of forest ecosystem management in mid 1990s. It marked a new ecological era of forest management. The aim of this paper is to briefly summarise previous methods and findings for the forest scenarios modelling [3]. Based on this analysis it will then suggest new approaches of forest planning in the new ecological era of forest ecosystem management, when the previous logging criteria become counterproductive [4-5].



2. Experimental part

2.1 Criteria and optimization methods of multiple use of sustainable forest management

Natural dynamics of forests provide the basis for forestry scenario modeling and risk analysis (figure 1). Forests grow unevenly. Annual increment (i.e. marginal increment as first derivative of growing stock - V'), mean increment (or average increment - V/T) and growing stock (V) consequently culminate at different points of time. Similar curves are typical in biology: for instance in vineyards, fisheries, and agriculture. Old forest growth appears if the stands are left unmanaged for long periods of time.

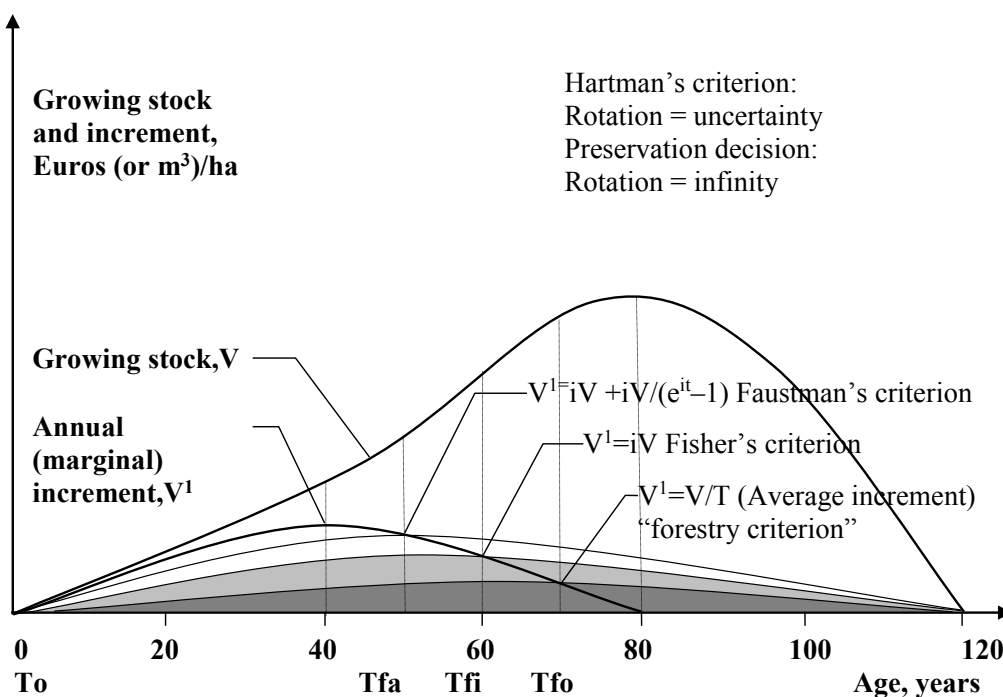


Figure 1. Traditional criteria for forest scenario modeling.

Maximization of undiscounted sustainable yield means maximization of mean (average) increment:

$$\text{MAX } V/T$$

where V - function of growing stock over time T , T - time.

Mathematical maximum of mean increment occurs when its derivative is equal to zero:

$$d(V/T)dT = (TV' - V)/T^2 = 1/T(V' - V/T) = 0; V'/V = 1/T \text{ or } V' = V/T$$

The decision is graphically illustrated in fig.1 by point T_{fo} on axis T (time), when mean increment (V/T) arrives at its maximum and intersects annual (marginal) increment (V'). Rotation T_{fo} provides maximum sustainable yield of wood. Foresters consider this decision to be quite reasonable. For this reason it is often called "forestry" decision.

Meanwhile economists noticed long time ago that economic aging of forests is faster than natural aging. Economists view the forests as "growing capital", which has to produce interest as money in a bank. Economic theory criticizes forestry science for ignoring interest rate. Economic problem is resolved by maximizing present value of discounted growing capital:

$$\text{MAX } Ve^{-it}$$

where e^{-it} - discounting coefficient, i - compound interest, e - basis of natural logarithm, $e = 2.71828...$ The function culminates when its derivative is equal to zero:

$$d(V)/dT = e^{-iT}V' - iVe^{-iT} = 0 \quad \text{or} \quad V' = iV$$

The decision is geometrically interpreted by point in which a curve of interest (iV) cuts the curve of annual (marginal) increment (V'). Implication of the interest rate considerably reduces the rotation period ($T_{fi} < T_{fo}$). American economist Irving Fisher described this solution for the situation, which was typical for United States in the beginning of the century, when forests were cut for agricultural or other use without subsequent regeneration [6-8]. Today this situation is very unusual.

Preceding to I. Fisher, a young German landlord and economist M. Faustmann, discovered, in the middle of the XIX century, an excellent result for continuously reproduced forests [9]. These forests were typical for Germany at that time. Faustman has maximized infinite series of sequential rotations:

$$\text{MAX } V(e^{-iT} + e^{-i2T} + \dots + e^{-inT}) = V(e^{iT} - 1)$$

Maximum is determined by differentiating the function and equating the result to zero:

$$V' = iV/(1 - e^{-iT}) = iV + iV/(e^{iT} - 1)$$

The conclusive part of the formula ($iV/(e^{iT} - 1)$) is interpreted as so called Soil Expectation Value (SEV or Le). It lifts upward the curve of growing stock interest by the value of bare land and thus shortens the rotation age compared to Fisher's and "forestry" criteria ($T_{fa} < T_{fi} < T_{fo}$). The higher the interest rate (i), the lower the rotation of forest, and vice versa. Consequently, forests grow older during recessions and are cut early during economic booms. When interest rate equals to zero, the Faustman and "forestry" decisions coincide. When the interest rate is high, then increment of growing capital may never reach it. In this case forest stand is considered to be submarginal. It has to be cut according to the economic theory and never regenerated. Forest land, in this case, would be transferred to the other more profitable types of land use: agricultural, housing etc. Normal interest rates usually fluctuate between 5 and 10%. Application of these rates to forests often demands logging of very young forests - usually at 30-40 years. At this age forest stands are not able to produce quality sawn wood and may yield only pulpwood. For this reason, the interest rate is normally artificially decreased to 1-4%. In addition, to allow for more flexibility in forest management, the lower interest rates are applied to the areas, that otherwise would be submarginal.

The concept of financial maturity is considered to be a theoretical cornerstone of the modern economic theory of forest management [10-15]. In practice, however, it doesn't find broad application due to many doubtful suggestions and allowances regarding level of interest rate, soil fertility, prices, inflation, forest policy, management schemes, technical progress etc. But the major drawback of the Faustmann result (along with the "forestry" solution) is that forest non market products, services and amenities are ignored. Attempts to introduce these amenities into the Faustmann formula make the problem practically irresolvable.

R. Hartman has undertaken an attempt to generalize Faustmann problem by introducing into it all the forest values [16]. Hartman maximized the combined present value of all possible forest goods and services:

$$U(t) = (G(t) e^{-it} + \int_0^t e^{-ix} F(x) dx) / (1 - e^{-it}),$$

where $U(t)$ - price of all the forest values per acre of forest area, $G(t)$ - price of wood, $F(x)$ - value of all other than wood forest products and services in conditional "market" prices, i - interest rate.

Optimal rotation (like in the Faustman decision) satisfies condition of first derivative:

$$G^1(t) + F(t) = i[G(t) + \int_0^t e^{-ix} F(x) dx] / (1 - e^{-it}).$$

The most vulnerable point in Hartman model is qualitative, quantitative and monetary measure of forest products and services, such as biodiversity, water transpiration and evaporation, carbon sequestration, oxygen emission etc. Attempts to put "fair market prices" on non-marketed products and amenities might likely never be successful [17-20].

In practice, the Hartman model produces unpredictable results. Depending on included forest services and their pricing the model may generate rotation age, which is shorter or longer than in

Faustman decision. It may produce few optimal solutions, or may recommend infinite rotation. Uncertainty, vagueness and ambiguity of Hartman model allows to "scientifically" justify almost any socio-political wish of any interest group by means of simple manipulation of input data, including structure and makeup of products, prices, interest rates, inflation etc. Theoretically, there are reasons to suggest, that if it were possible to accurately evaluate all the ecosystem forest values, which have vital significance for the mankind, Hartman model would lead to an infinite rotation, termination of management and total forest preservation.

2.2 Preservation method

The preservation movement has emerged and developed as a vigor protest against conventional logging practices. Preservationists consider that human production activity is adversary to the natural ecosystem processes and advocate large set asides to protect remains of and create new old growth. Static preservation theory does not take into account that natural forest aging is not possible in close proximity to contemporary human beings and consequent economic activity. Preservation causes both ecological and economic problems: (1) Increasing swamping and greenhouse effect due to low biological activity of old growth. (2) Increasing losses from fires, pests and diseases due to overcrowding of forests. (3) Accelerated logging of potential old growth caused by fear of new environmental legislation. (4) Surge of production of harmful substitutes for wood. (5) Shift of logging to young, less productive and ecologically frangible forests. (6) Import of wood and export of environmental problems to the third world countries. (7) Poor quality of recreation. (8) Decline of wood production and a subsequent loss of revenues. (9) Increased cost and price of wood products. (10) Fall of level of life, rise of social problems. (11) Shrinking employment. (12) Tax loss. (13) Disintegration of forest communities. (14) Reduction of means to fight forest fires, pests and diseases. Thus, preservation along with employing existing criteria to determine forest rotation threatens society with serious ecological and economic losses.

3. Results and discussion

Ecology recognizes at least five quality stages of forest reproduction: stand re-initiation (SR), stem exclusion (SE), understory re-initiation (UR), old growth (OG) and open structures (OS) [21]. Quality of a forest's productive capacity is not a determinant of the relative value of various forest structures. All the stages are equally valuable and needed for ecology and biodiversity. Quality of forest is a question of presence, relative abundance and distribution of various forest structures at landscape level.

Natural old growth forests dominated the Planet during many thousands and millions of years before human productive capacity became significant. During very short time period, human being has drastically changed the historical Planetary landscape, initially, through the use of fire to open up wild lands and then by suppressing fire in order to maximize forest production. The dominant portion of inhabited regions is represented now by young structures with relatively low biodiversity. Modern society does not accept predominance of monocultural young growth, nor can it afford to return back to restore old growth forests in vast set asides.

Ecological science proposes an alternative decision - to imitate, simulate, emulate old growth forests from younger stands by employing traditional and nontraditional forestry techniques. The major instrument of imitation is the use of traditional thinning. These silvicultural techniques may lead to understory re-initiation and multistory forests 10 or 20 years faster compared to natural forest aging. Thinning is able to artificially age forests. Another instrument of imitation is leaving apart so called "biological legacy" after logging [5] - copies of old growth inside younger forests, green, dead, dry, diseased, rotting, hollow trees, decomposed wood, snags and debris. By means of imitation, certain essential features of old growth (large trunks, big diameters, thick crowns, ample re-initiation, many stories, dry, hollow, rotting, and dead wood) may be produced twice as faster compared to the natural forest aging. If these areas are scattered in the forest, then increased risk of wild fire is tremendously diminished.

4. Conclusion

Forestry theory and techniques for producing old growth structures using younger stands are just emerging. This theory cannot develop further without field practice. Field forest managers can feed the new theory by facts and experience. Initial, prime targets for ecosystem preservation management can be easily defined unlike rather vague principles of multiple purpose sustained yield forest use. These targets are intended to put on order forest structures, institutional structures and economic structures of forest management.

Field managers can start to eliminate misbalance in their forests by transforming existing structures of forests to desired targeted structures. Target structures may be defined by employing two methodologies: (1) determination of historical structures and (2) determination of soil and biological forest potential. Restoration of the long term sustainable balance of forest structures is to be the major target of modern forest management. A series of structures may meet the target. Methods to achieve the targets may differ on time length and transformation cost. Multiple scenarios, holistic and systematic approaches are to be the major vehicles for forestry planning.

Forest field managers are to be granted wider freedom for experiments, including economic experiments. Field managers better than anyone know where forest investments produce maximum yield. Forest policy should rely more on qualification, responsibility and professional intuition of foresters. Forest scenarios should be developed to provide continuous and active feedback from foresters actively engaged in forestry practice.

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