



Forestry's golden rule and the development of the optimal forest rotation literature

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Abstract

In this paper, a discussion of the development of the optimal forest rotation literature and an extensive bibliography is presented. The body of literature has grown at an almost constant rate for the past two decades, with no apparent let-up likely. A total of 313 published works have appeared in books and over sixty journals, with individuals contributing to this body of work. Developed from the relatively simple question of the determination of the value of timberland, the optimal rotation literature has grown into a mature discussion that embodies a full range of issues and topics.

Key words: Faustmann, timber harvest, forest management

Introduction

Martin Faustmann, in his seminal work, "*On the determination of the value which forest land and immature stands pose for forestry (1849)*" had a profound impact on our view of forestry, forest management, and forestry investment. From asking the seemingly simple question, How much is a piece of land worth if it is devoted to the growing of trees, a substantial body of literature has developed. The 150th anniversary of the publication of Martin Faustmann's landmark treatise provided an impetus for renewed interest in the development of the optimal rotation literature. A major international conference, held in Darmstadt, Germany with 68 authors from 16 countries, confirms the interest and broad appeal that Faustmann's work and the questions it raises maintains.¹ At the time of this anniversary, it seemed a reasonable time to step back and evaluate the optimal rotation question and the body research that has developed from it.

¹ 150 Years of the Faustmann Formula: The Consequences for Forestry and Economics in the Past, Present, and Future, October 3–6, 1999, Darmstadt, Germany, see: <http://www.lsu.edu/guests/sjchang/Faustmann.html>.

The purpose of this report is two-fold. Most important is the presentation of an extensive and reasonably complete bibliography of works touching on aspects of the optimal rotation decision. This compilation will hopefully provide a good resource for researchers interested in this fundamental problem of forest management. The second objective is to review and document the development of the body of literature that Faustmann spawned. The bibliography and the discussion build on a number of previous reviews and assessments (e.g. Gaffney 1957; Samuelson 1976; Hyde 1980; Newman 1985; Reed 1986). Most of these have focused on the development of the optimal rotation decision problem and while thorough, have not necessarily been exhaustive. This paper updates this work and provides a thorough bibliography and an assessment of the optimal rotation literature, its development, and the manner in which it has been published.

The paper is structured as follows. The next section details the manner in which the bibliography was put together. This is followed by the presentation of a statistical analysis of the bibliography including timing and development, the journals that have been active in publication, and an analysis of those authors who have published and the impact of their work. The paper concludes with a discussion of the literature and its likely further development.

Data and methods

In performing an assessment such as this and in compiling a bibliography of the literature, a number of choices were necessarily made and a few caveats and concerns must be mentioned. The works cited in the bibliography have been obtained through a variety of means. For some of the more recent literature, computer-assisted searches of databases were utilized. However, the majority of the cited works were found through the rather painstaking method of searching through literature-cited sections of papers and then determining their applicability. Also, tables of contents of leading forestry and natural resource journals were scanned for likely articles. The data was compiled into a database using the bibliographic software EndNote ver. 5.0.²

During this process, it was necessary to make a determination of whether or not to include a work in the bibliography. This decision hinged on several factors including content, importance, and interest. While trying to be expansive in the listing of optimal rotation works, several areas, most notably harvest scheduling/operations research approaches, were less intensively searched and listed. As much as anything, this was due to the personal interest of the author and a need to put limits on the bibliography and not as a result of some evaluation of importance.

² <http://www.endnote.com>

A sincere *mea culpa* is extended to any and all authors whose work is not included in the bibliography and who feel that it should have.³

An important decision was also made to limit the number citations derived from the gray literature. This was primarily due to the fact that many of the results of these works have found their way into peer-reviewed journals so that it would have led to double counting. Also, many of these citations are very difficult for individuals to find and thus limit their usefulness. Only in cases that I knew that no further publication of the work occurred, that the work has been cited frequently, or that I found the work particularly interesting or useful were dissertations, working papers, or conference proceedings included. As a result, many of the fine and interesting dissertations and theses that have dealt with the question of optimal forest management are not present.

Several outcomes result from this somewhat idiosyncratic method of putting together a bibliography. An obvious limitation is that non-cited works or those from unchecked journals are less likely to be listed. While this is true, the high number of works with no cites in the list indicates that this may not be too heavy a bias. I delved quite deeply into the literature and I believe that there are very few relevant titles that are not included in this listing. Another is that works from the past 10–20 years are more likely to be listed in online databases and thus included. This bias cannot be ignored but it appears that the literature has become much more robust over the past 25 years and is not a result solely of any obvious bias in the search. Finally, English language works received much more acknowledgement due, as much as anything, to the limitations stated above.

Analysis of the bibliographic database

As shown in Figure 1, the body literature assessing the optimal forest rotation has increased dramatically over the past twenty years. A total of 313 works have been published since Faustmann, but over two-thirds of these (211) have come since 1985. If we examine just the years since 1979, fully 87 % of the literature has been published. The production of literature has been fairly consistent over this 22-year period, averaging 22.8 works per year with a standard deviation of 6.4 (Figure 2)

The vast majority of works dealing with the optimal rotation have been in the form of journal articles. Only 41 works are cited as books or chapters in books. A total of 272 articles have been published in 61 journals, but over 72 % of the total are found in only 11 journals (Table 1). Clearly, *Forest Science* has been the dominant journal involved in the publication of optimal rotation articles, publishing more than the next four journals combined. More importantly, it has shown a con-

³ As a follow-up to this work, I would be very happy to receive citations of works that should have been included in this bibliography. Given the pace of the literature, I am sure that an update of this listing will be needed long before Faustmann's 175th birthday.

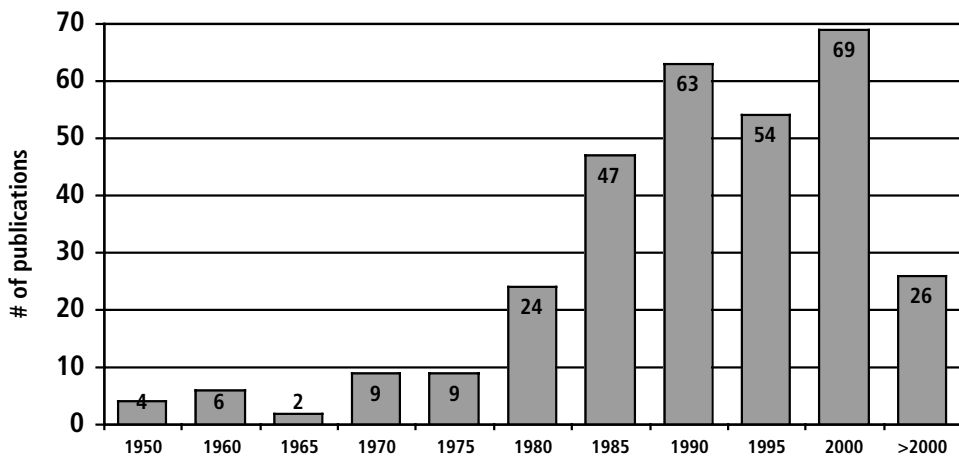


Fig. 1. Optimal rotation literature by year of publication, $n = 313$.

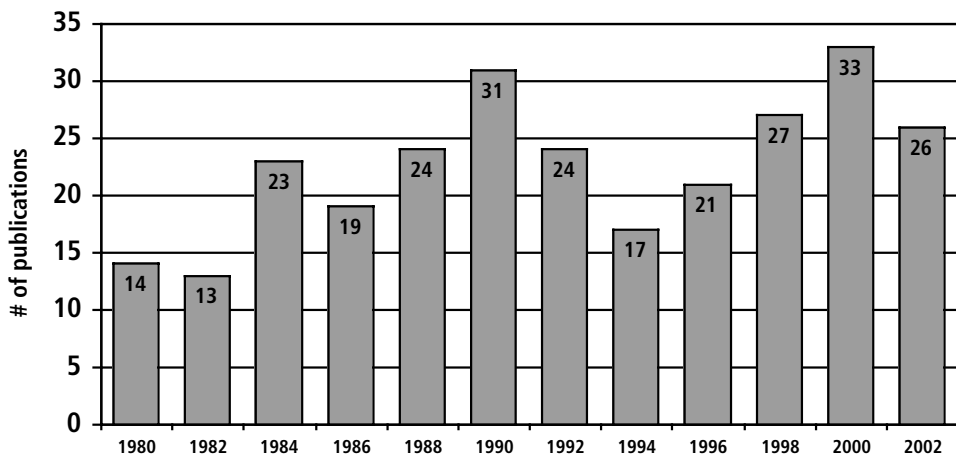


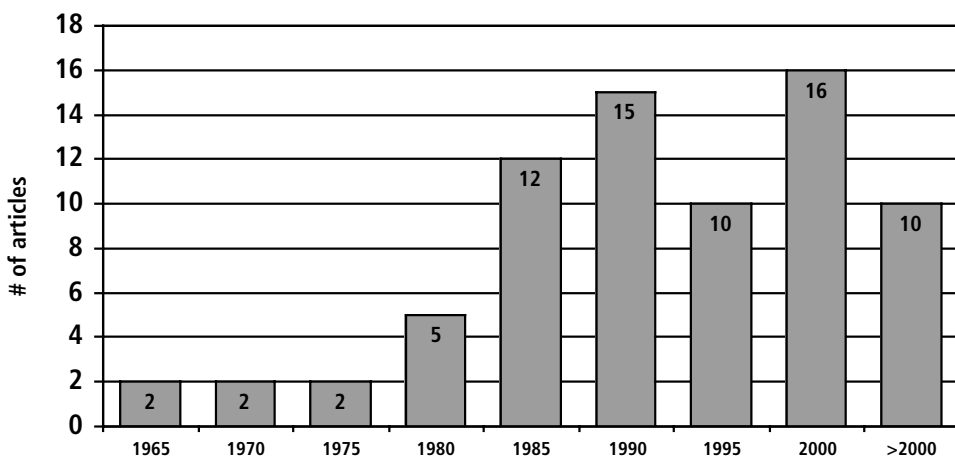
Fig. 2. Optimal rotation literature by year of publication since 1979, $n = 272$.

tinuing, increasing commitment to the publication of these articles. It has maintained an increasing flow of output since its first article was published in 1964 (Figure 3).

Table 1 also illustrates the ebb and flow of literature dealing with fundamental forest economics issues such as the optimal rotation. The *Journal of Forestry* was at one time a major outlet for the publication of technical articles regarding economics research. However, no articles have been published that deal with the

Table 1. The 9 leading journals publishing optimal rotation literature, n = 272.

Journal	Count	% of total	1st article published	Most recent
Forest Science	74	27.2 %	1964	2000
Journal of Environmental Economics and Management	20	7.4 %	1979	2001
Canadian Journal of Forest Research	19	7.0 %	1980	2001
Journal of Forest Economics	18	6.6 %	1995	2000
Natural Resource Modeling	12	4.4 %	1986	1997
Land Economics	12	4.4 %	1949	1992
Forest Policy and Economics	10	3.7 %	2001	2001
Journal of Environmental Management	7	2.6 %	1979	1994
Journal of Forestry	7	2.6 %	1953	1979
American Journal of Agricultural Economics	7	2.6 %	1977	2001
Journal of Economic Dynamics and Control	6	2.2 %	1983	2002
Environmental and Resource Economics	5	1.8 %	1997	1999
Other	75	27.6 %		

**Fig. 3.** Distribution by year of *Forest Science* optimal rotation articles, n = 74.

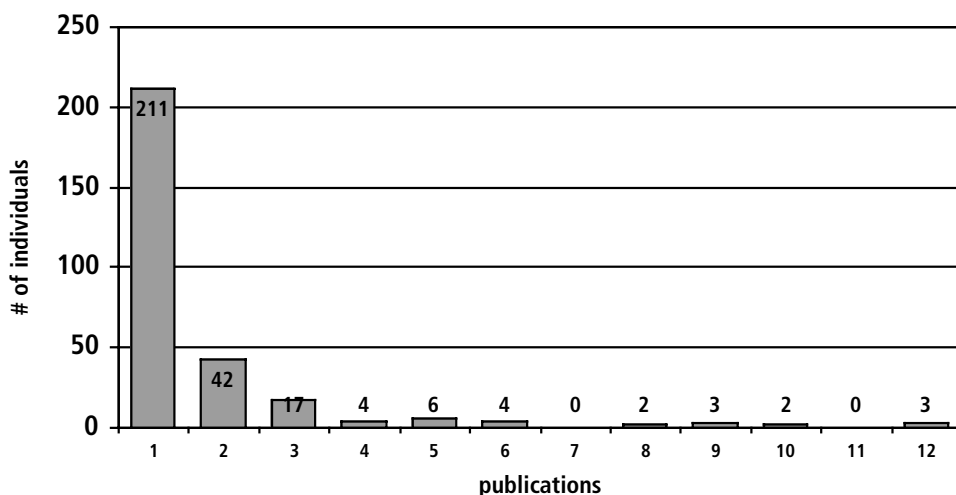


Fig. 4. Publications by an individual as either author or co-author, $n = 294$.

optimal rotation question since 1979, a period prior to the major build-up in the literature. This indicates a substantial shift in editorial policy at a time when this literature was only beginning to expand. The very rapid rise of journals such as the *Journal of Forest Economics* and *Natural Resource Modeling* as a major publisher of optimal rotation articles indicates that it is possible for new journals to quickly establish prominence in specialized topic areas such as this.

A total of 294 individuals have authored or co-authored works dealing with questions related to the optimal rotation (Figure 4). The great majority of the authors, nearly 72 %, have only a single work listed in the bibliography. There is no clear indication as to why such a high percentage would have only a passing interest in the topic. A slight variant of a quote from the acknowledgement to Clark Binkley's (1981) seminal monograph on nonindustrial private forest owners may explain this phenomenon.

*"The study of the optimal forest rotation is prerequisite to the appellation 'forest economist,' or so it has been said. That being the case, I thought it prudent to complete mine early on."*⁴

If this argument is valid, then it is likely that many authors may have touched on issues of the optimal rotation as part of their initial introduction into the forest economics profession and then have moved on to other topics and interests.

The majority of the publications (52 % of the publications or 164) are single authored and only 14 % (45) have 3 or more authors. As shown in Figure 5, there has

⁴ Binkley's statement has been modified to replace "forest ownership" with "the optimal forest rotation."

been a substantial decline in the percentage of single-authored papers over the years. Over 80 % of the works published before 1976 were single-authored, while only 37 % of them were after 1995. This reflects the changes that have occurred in academia regarding shared authorship and reflect the development of team approaches to research that have developed in solving some of the more difficult problems that the literature now deals with.

Table 2 presents data on the 14 individuals who have authored or co-authored six or more works. The list shows a wide diversity of longevity and country of origin for the authors. Many have been involved with the literature for a long time, with an average number of years between first and most recent publications being 12.2 years. The longest duration of publication is by Jagdish Nautiyal, who published articles over a 24 year span. The shortest duration is by Olli Tahvonen who has only been publishing in the literature for only the past 3 years. The list also shows the impact of multiple authorships on citation counts. Many of the authors worked primarily alone or with a variety of others. However, Koskela and Ollikainen, Brazee and Amacher, and Yin and Newman are primarily on the list as a result of their joint works.

A final set of issues deals with the impact that any work may have on the literature as a whole. The number of citations is the best measure that we have for evaluating the influence that a work generates. For this analysis, citation counts were developed from the literature cited sections of only the works contained in the bibliography. Thus, while a work may have numerous citations outside of this bibliography, those cites do not relate to its impact on the optimal rotation literature.

Figure 6 shows the distribution of the number of citations for the bibliography. Over 52 % of the works are cited 2 or fewer times and nearly 30 % are not cited at all. Only 16 % of the works have been cited more than 10 times. The fact that

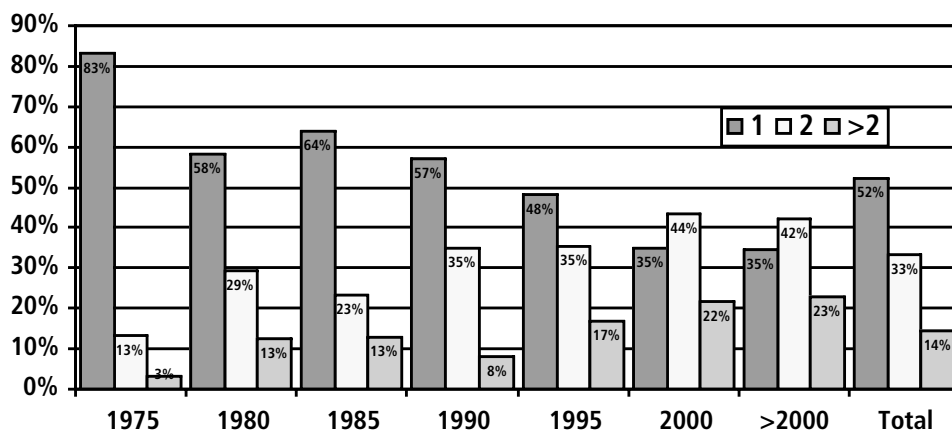


Fig. 5. Percentage of publications by number of authors, $n = 313$.

Table 2. Authors with 6 or more published works.

Author	Work	1st public.	Most recent	Longevity	Country of origin
J. C. Nautiyal	6	1966	1990	24	Canada
O. Tahvonen	6	1998	2001	3	Finland
P. Gong	6	1991	2001	10	Sweden
P. Lohmander	6	1983	1991	8	Sweden
R. G. Haight	9	1990	2000	10	USA
R. Yin	8	1995	2001	6	USA
S. J. Chang	8	1981	2001	20	USA
D. H. Newman	9	1985	1999	14	USA
G. S. Amacher	9	1991	2001	10	USA
E. Koskela	10	1989	2001	12	Finland
W. J. Reed	10	1984	1996	12	Canada
K. G. Löfgren	12	1983	2001	18	Sweden
M. Ollikainen	12	1990	2001	11	Finland
R. J. Brazee	12	1988	2001	13	USA

so many works have been cited so few times is not entirely surprising given the high percentage of works published in the last 10 years.

As shown in Figure 7, only 15 works have received more than 25 citations. Interestingly, no author has more than one work on this list of seminal pieces, and no work was published in the 1990s. In addition, only 4 of the authors on the most prolific list are also found on the most highly cited list.

It would come as little surprise to researchers in the field that the dominant works in the literature are by Faustmann (1849) and Samuelson (1976). Of the 12 articles listed, the majority deal either entirely or heavily with issues of the comparative statics of the optimal rotation decision (Jackson 1980; Hyde 1980; Chang 1983; Pearse 1967; Bentley and Teeguarden 1965; Gaffney 1959; Clark 1976; Hyde 1980; Jackson 1980; Johansson and Löfgren 1985; Samuelson 1976). The other topics of the works included in this list are nonmarket goods (Hartman 1976; Calish et al. 1978), risk and uncertainty (Clarke and Reed 1989; Norstrom 1975) and sto-

chastic prices (Brazee and Mendelsohn 1988). These last three topics have formed the basis for much of the literature that has been published in the last decade.

Discussion of the optimal rotation literature

A logical separation point for the optimal rotation literature is 1976. Four major works came out that year which profoundly influenced the development of the literature. Samuelson's, "Economics of forestry in an evolving society," marked a major departure in the literature and opened new areas of research and thinking about the optimal rotation problem. The fact that it was presented in a conference that contained two other seminal papers, Hartman (1976) and Ledyard and Moses (1976) only makes clearer the reasonableness of this demarcation point. Finally, Colin Clark's "Mathematical Bioeconomics: the Optimal Management of Renewable Resources," provided a solid grounding for the use of analytical techniques that have been heavily used since then. These four works pointed to the legitimacy of the economic analysis of the question as well as positing new tools and questions that could be answered.

Prior to 1976, the literature was still wrestling with more fundamental questions in the optimal rotation debate. Such issues as economic versus physical optimal criteria (Gaffney 1957; Goundry 1960; Bentley and Teeguarden 1965; Pearse 1967; Hirschleifer 1974), the role of the interest rate (Boulding 1955; Bierman 1968; Hirschleifer 1970; Fortson 1972), and basic land valuation questions (Worrell 1953; Duerr et al. 1956). Only scattered alternative concerns were examined.

Following 1976, the range of questions being evaluated increased dramatically. First, the fundamental question of the comparative statics of the management

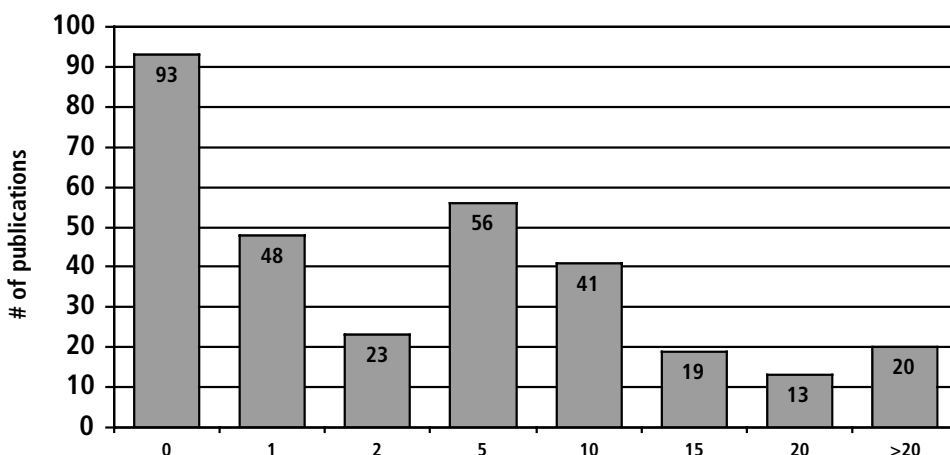


Fig. 6. Citation count for the optimal rotation literature, $n = 313$.

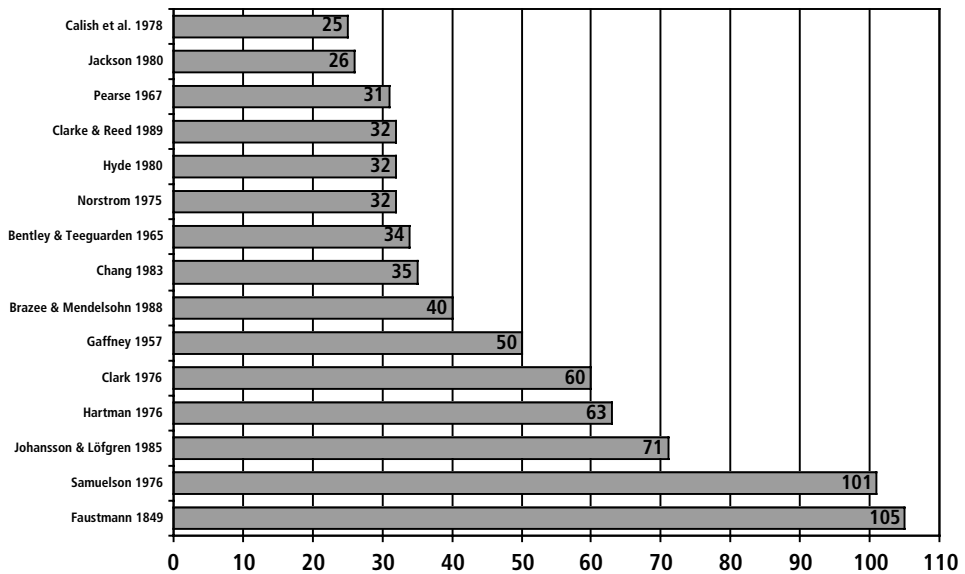


Fig. 7. Works which have received 25 or more citations.

decision was fully delineated (Morgan 1974; Hyde 1980; Jackson 1980; Chang 1983; Graham-Tomasi 1983). Then, new issues arose, such as the role of nonmarket goods and other market failures (Calish et al. 1978; Nautiyal and Fowler 1980; Berck 1981; Bowes 1983), catastrophic uncertainty (Routledge 1980; Reed 1984; Reed and Errico 1986), stochastic markets (Norstrom 1975; Miller and Voltaire 1980 and 1983), and other changing factors (McConnell et al. 1983; Newman et al. 1985; Löfgren 1988).

Finally in the late 1980s and into the 1990s, there has been an increased focus on risk and uncertainty analysis and the influence of stochastic markets (Lohmander 1987; Brazee and Mendelsohn 1988; Haight and Holmes 1991), the role of nonmarket factors on management (Englin and Klan 1990; Koskela and Ollikainen 1999) and taxation (Koskela 1989; Amacher et al. 1991; Amacher 1997).

As we move into the new millennium, these and other questions will continue to drive research. Thus, the literature continues to develop. The list of topics has changed over the years as analytical techniques and research questions have evolved. The Faustmann conference contained over 50 presentations on a wide range of topics, many of which have already entered into the literature.⁵ Thus, the assessment presented here is only a brief respite from an ongoing process.

⁵ Three journals, *Journal of Forest Economics*, *Forest Science* and *Forest Policy and Economics* published special issues containing articles from the conference.

In my 1988 review of the literature, I commented that, "One would think that a topic with such a long written history had been completely described and understood by, but the theory of the optimal forest rotation continues to attract new ideas and research." I believe that this comment still holds. The issue of the long-term management of forest resources will not go away and the belief that we can explain positive behavior as well as provide normative guidelines will continue to push researchers into areas that Faustmann never considered.

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(Values in bold represent the number of times the work was cited)

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