Chronology of Some Developments in Forest Engineering Research in Japan

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ABSTRACT

The forests and forestry industries within Japan are in a period of uncertainty and change. It must be the responsibility of not only government and industry but also research to identify problems and set the priorities solving these problems.

This paper presents the role of forest engineering research in forestry-oriented technology, and how our approach to research is changing with societal needs through a brief history of plantation forestry in Japan. This review of the research "movement" is based on the assumption that the quantity of published papers would be directly a function of their contributions to related technological development, but indirectly would be influenced by public understanding of research effort with the result of the performance of technology transfer.

Six different journals dealing with forestry-related research papers were surveyed. Almost thirty-eight thousand pertinent papers issued in the period from 1955 to 1995 were captured through bibliographical information services available in university libraries and government research institutes. A considerable difference in structure and trend of changes in the number of papers issued has been observed among them. Particularly, forest engineering research within about 10 years between 1970s and 1980s has fairly altered in structure, function and orientation. The increased social concerns for various environmental issues propelled researchers toward making major changes in research-oriented activities. One of the notable trends in this research movement was the growing diversification in research areas and related subjects through active introduction of associated disciplines. The tendency has more steadily continued with increasing competition through the entry of associated and/or cross disciplines, organizational and educational reform, and priorities for research objectives.

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Keywords: *Forest engineering, chronology, diversification in research objectives, interdisciplinary research, task force and team approaches.*

INTRODUCTION

In the Pacific-rim, Japan has been prominent as a big importer of timber, reflecting the fact that it has had to heavily rely on imported logs to meet the vast demand in the domestic market. Seventy eight percent of the total consumption was supplied from foreign countries in 1994 [3]. The large proportion of imported timber is a result of easing of Government regulations affecting log trades for the purpose of easing the extraordinary rise in the timber price in the late 1950s (Figure 1, Figure 2).

The price rise in the timber market in the late 1950s and 1960s has not only expanded timber imports but also encouraged forest owners to invest in plantation of commercially valuable species such as sugi (*Cryptomeria japonica*) and hinoki (*Chamaecyparis obtusa*). Moreover, it was a national priority to increase domestic timber supply concomitant with increasing timber demand brought on by growth in the Japanese economy as a whole. The Government promoted the conversion from natural forests to more productive plantation forests not only on private forests but also on national forests (Figure 3).

At present, the goal of the conversion has been almost achieved: 41% of the forest land in Japan is plantation forests in 1991, while the final goal is 45%. However, most of those plantation forests are 35 years old or less and yet to be matured as commercial timber. With more than 10 million ha of plantation forests going to be available in the following two or three decades, Japanese foresters are expecting "the era of domestic timber", the time when domestic timber will lead the market in terms of both price and quantity, and domestic forestry and forest product industries will correspondingly benefit. Forestry will compete with the import which has the advantage in production costs including plantation costs (Figure 4).

Forest engineering technology and related scientific research, past and present, will give witness to a need for a global perspective in problem solving. Despite successful past research contributions to develop various forestry-oriented technology, including forest engineering, none of us would be correct if we did not recognize the urgency of the problems, and some of the limits of existing tech-

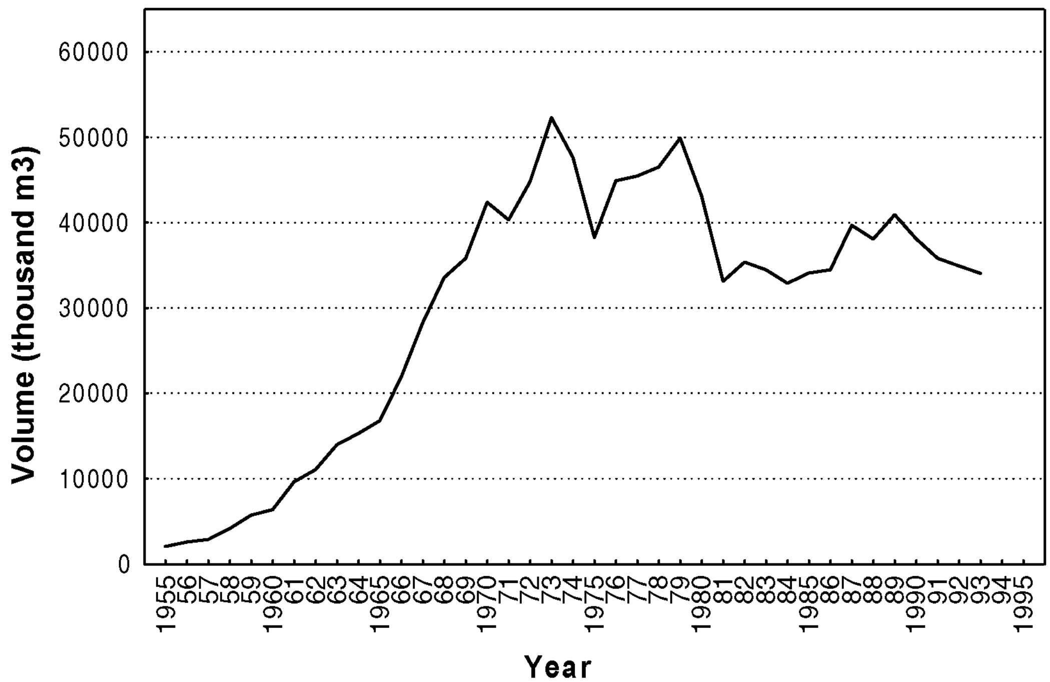


Figure 1. Change in volume of logs imported.

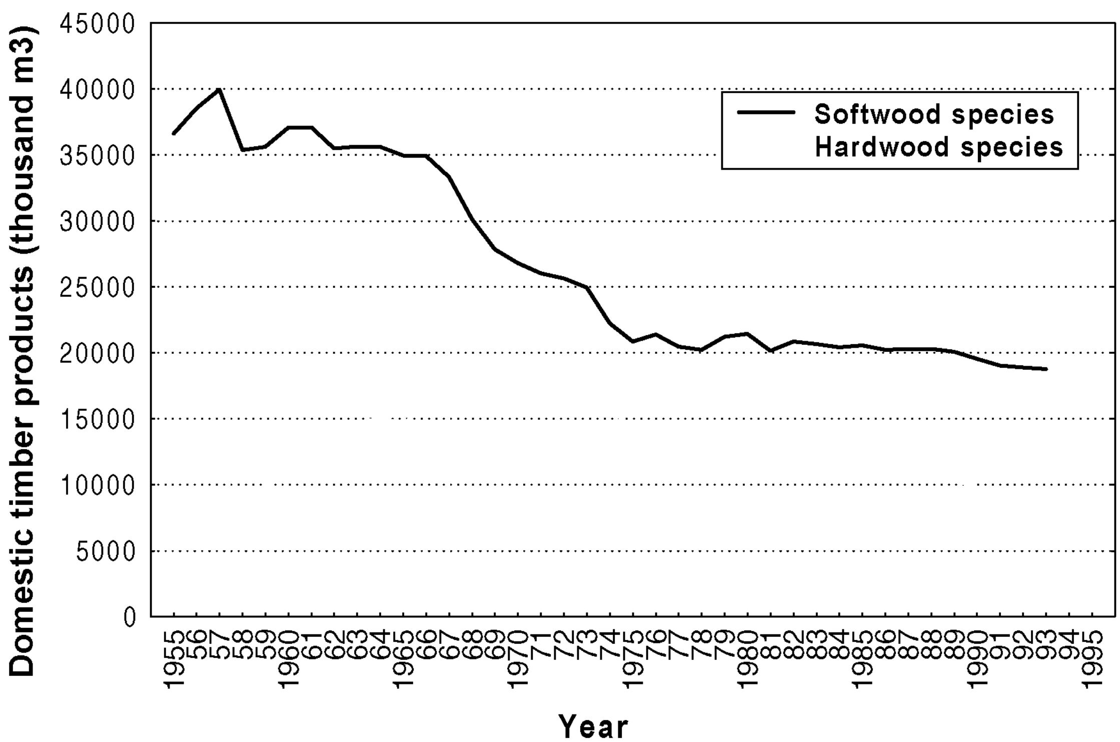


Figure 2. Domestic timber products by species.

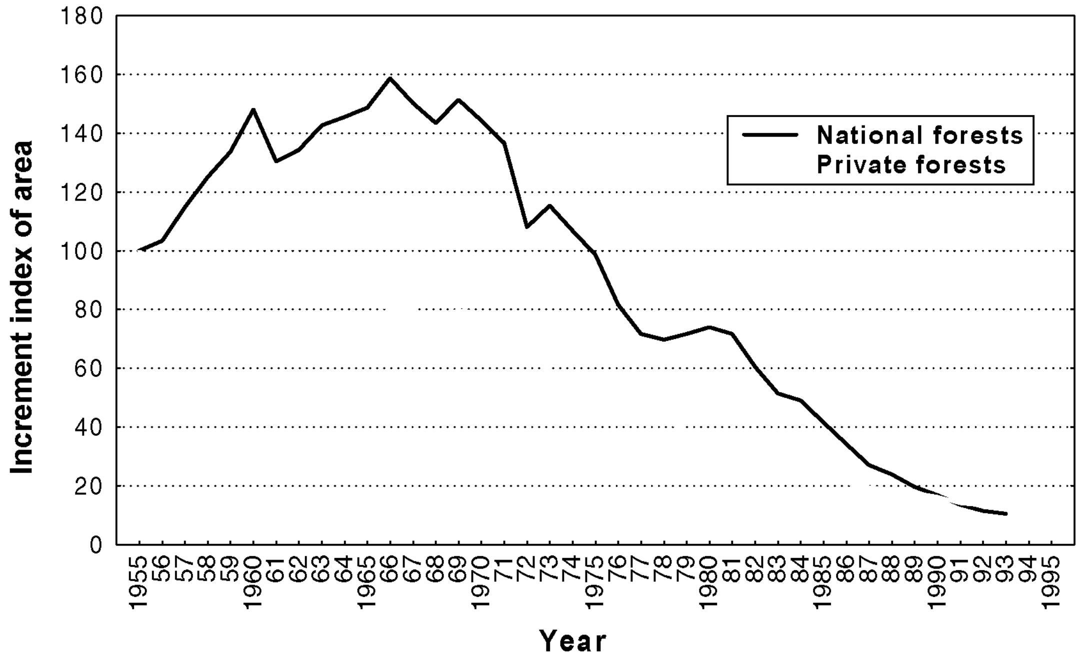


Figure 3. Increment index of plantation forest area by ownership: set 100 in 1955.

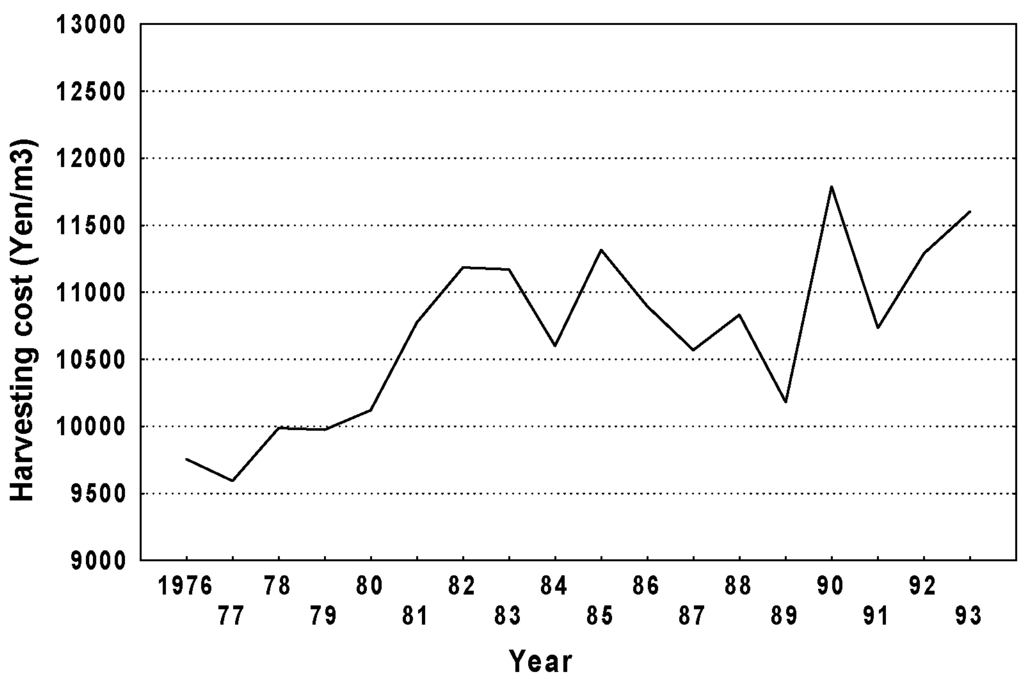


Figure 4. Change in average harvesting cost by cable yarding system.

nology and knowledge on future demands, that seem to be multiplying faster than solutions. During the almost 40 years following the postwar, the vast majority of forest engineering research was done, and the results generally answered the questions that set studies in motion. In addition, past research results are the primary bases for current knowledge. They are how we know we are facing forest engineering problems.

This paper represents a cross section of research on how forest engineering technology in forestry-oriented practices developed, and how our approach to research is changing with changing societal needs. Research findings fuel our awareness of current and pending problems, and our science questions are not asked or solved within strict disciplinary limits. The diversity of research areas and related subjects on forest engineering indicated in this paper stand as a testimony to this important effort.

FOREST RESOURCES OF JAPAN: OVERVIEW

Japan consists of many islands spreading from the subtropical region to the sub-frigid zone. The four largest ones are usually recognized as the main islands (the total land area is 377812Km^2). They (over 95% of the land area) are, from northeast to southwest, Hokkaido, Honsyu, Shikoku, and Kyusyu. A large part of the land (approximately 71%) is covered with mountains and hills with steep slopes, where human activities are restricted. Thus the population is concentrated in the scattered non-mountainous areas. Thanks to the high annual precipitation (generally between 1000 and 2500 mm) brought by the monsoons travelling over the ocean, forests easily grow naturally all over the country. Although almost all the potential area on the plains have been converted to farm lands, towns, etc., 68% of the total land area is still classified as forest land. This is, roughly speaking, equivalent to the mountainous area.

In 1990, the total forest land area in Japan was 25.21 million ha. This figure has been fairly stable in the past few decades. 10.33 million ha, 41% of the forest land, is plantation forest. Natural forests account for 13.52 million ha, 54% of total forest land. The rest, 1.36 million ha, is classified as unstocked land. The forest land is classified into three broad ownership groups; national, public (mostly prefectural and municipal) and private forests. National forests, most of which are administered by Forest Agency of Japan, occupy 7.9 million ha, 31% of the forest land. This represents the largest single ownership. A large area, 14.7 million ha, 58% of the forest land, is owned by various kinds of private owners, while small portion, 2.7 million ha, 11% of the forest land is owned by local public bodies and categorized as public forests. Though the total area of forest land and the basic ownership structure have remained unchanged during the last few decades, a drastic change of the resource structure has been achieved - conversion of natural forests to plantation forests in the postwar period; plantation forests, accounting for only 31.5% of the forest land in 1966, the year in which the inventory of plantation forest first appeared, has increased to 10.2 million ha, 40.5% of the forest land in 1986. Due to the high growth of plantation forests, the total growing stock has rapidly increased. It more than doubled between 1966 and 1986 for the plantation forest. Even though the area of natural forests decreased, overall volume showed a steady increase in growing stock [4, 5, 13].

TECHNOLOGICAL CONVERSION: LOGGING AND TRANSPORT TECHNOLOGY AFTER POSTWAR

The massive structural changes the industry underwent during the twenty-five years following the war coincided with equally significant changes in logging and transport technology. The use of internal combustion powered machinery, particularly trucks, was just becoming widespread in the early postwar period. Two of the most significant areas of technological advance were in engine design, particularly diesel engines, and tire manufacturing. The impact of these changes was most evident in trucks that became available during the late 1950s. The increased demand for trucks came from several directions. Small independent logging and contracting operations were springing all over the rural area. The rapid increase in pulp mill construction led to the opening of large areas to logging. In addition, most operations had worked back into areas too steep for rail transport and were looking at trucks to replace the rail systems. Throughout the 1950s and 1960s, numerous improvements and modifications were made on logging trucks, many of them devised in the dozens of local garages and machine shops. In the mid-1960s, self-loading trucks equipped with log-loading machinery were introduced. The availability of self-loading trucks had some far-reaching effects. Separate, expensive machines were no longer needed to load logs. A small operator had only to get his logs to roadside, where they were picked up.

The development of road building techniques and equipment made possible the rapid growth of truck logging. For example, the introduction of functional bulldozers for use on crawler tractors in the late 1950s made it possible to built roads economically and quickly. Another critical development was the air drill, which enormously speeded up the drilling of holes to blast rock. Before the air drill, blasting holes were hand drilled, a slow and laborious process. The first air drills were mounted on tractors, trucks and sleds. When combined with improved blasting techniques and materials, this equipment was capable not only of clearing rock from a right-of-way, but also of pulverizing it into small pieces suitable for surfacing roads in locations where gravel was scarce. In the mid-1960s, self-propelled air track drills appeared, simplifying the process even further (Figure 5).

The abandonment of the rail lines had a significant effect on other phases of logging. With the move out of the valley bottoms and into higher, rougher terrain, a demand arose for more mobile, powerful yarding machines. Various cable systems consisted of a drum yarder, a set of wire ropes, and a carriage developed since the 1950s. In spite of limited mobility, cable yarding systems were used extensively on hard-to-reach sites such as the steep mid-slope of mountains that have been logged from valleys below and the ridges above. Cable yarding systems have been the dominant yarding technique used on the mountainous areas until the present time (Figure 6). During the same period, one other major piece of logging equipment was developed. The skidders with diesel engines and good tires available, had evolved as the most efficient means of skidding logs over limited distances on rough, rocky ground at a faster speed than a crawler tractor. They were not really suited to skidding big logs, but this did not stop loggers from using them. They made it possible to move logs quickly from a landing to the dump, and to return for another turn even more quickly, with little or no road building. And the skidder was a reasonably priced machine that could handle forty percent slopes [10, 11].

After the mid-1970s, the pace of change in the forestry industry slowed. With a few exceptions, there were no major technical alterations in the machinery used for logging. Instead, there was a steady refinement and improvement of the equipment introduced during the twenty-five years of rapid technical change following the war. In the falling and bucking phase, few changes in procedures were introduced in the late 1970s. One of the bottlenecks in the early development of a feller-buncher was the lack of a suitable machine on which to mount the cutting head. The evolution of feller-bunchers par-

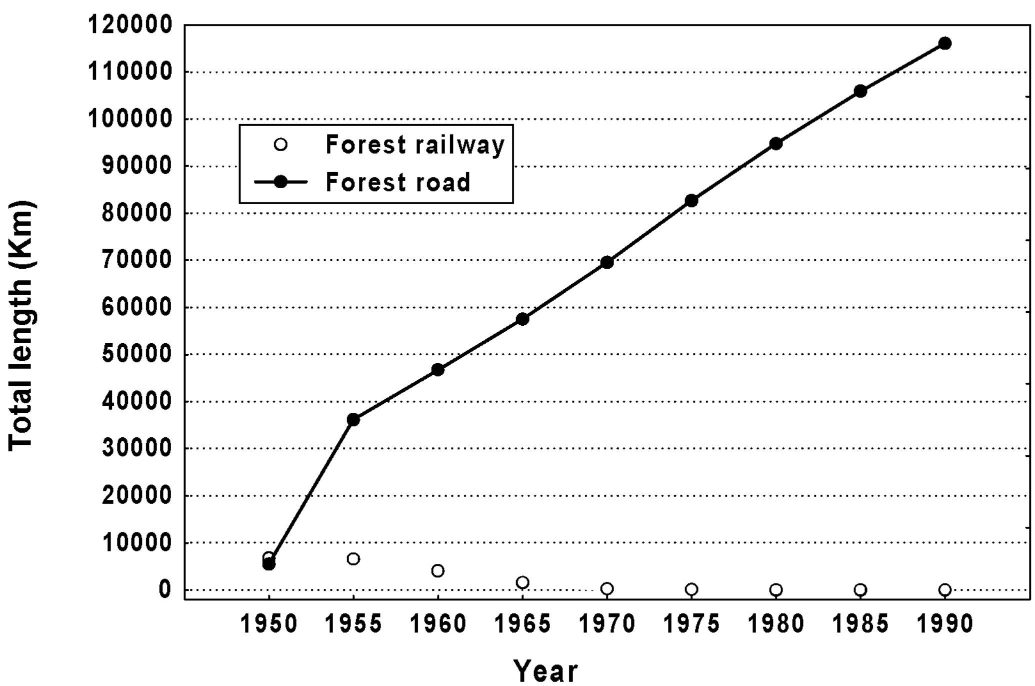


Figure 5. Extension of forest road network after postwar.

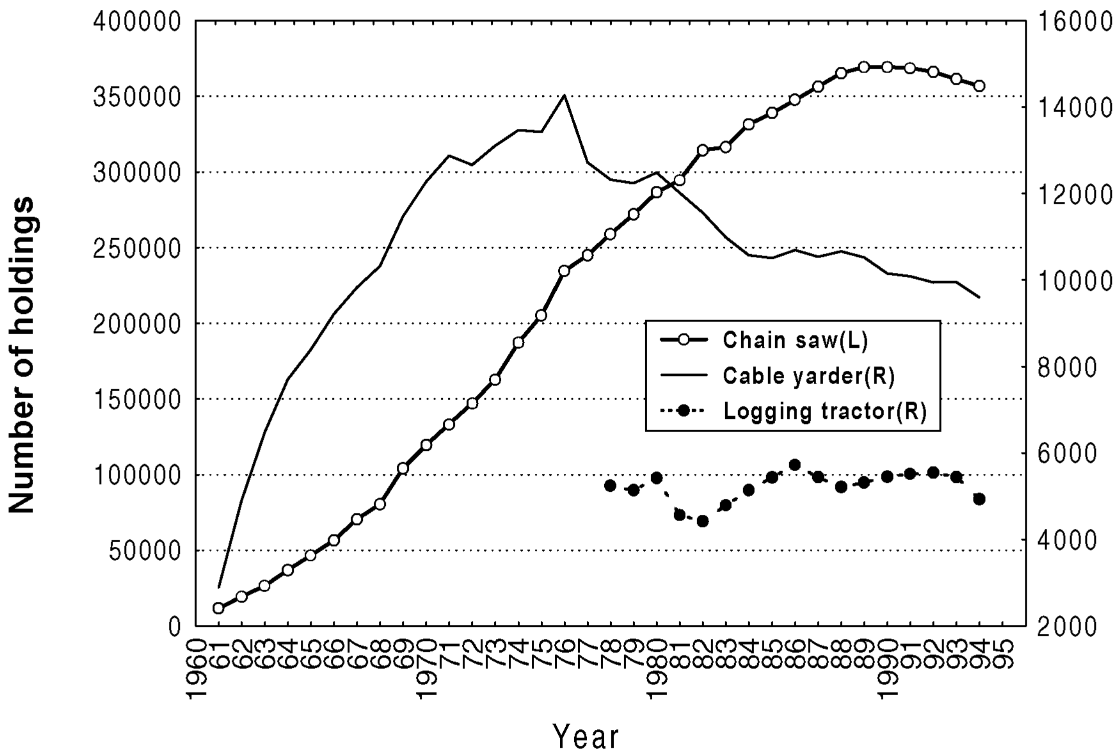


Figure 6. Change in holdings of traditional forestry machineries: chain saw, cable yarder and logging tractor.

alleled the development of tracked excavators, but those machines were generally too light and could not work on a steep slope site. One other versatile piece of ground-based equipment applied to logging was the swing machine, originally developed as an excavator. The basic swing machine consists of an engine, cab and turntable, which can be mounted on tracks, wheels, the back of a truck and various other bases. It was developed primarily to be part of the excavator built to replace track shovels, a machine that found instant popularity among loggers because of its utility in building roads. Soon a variety of other applications evolved, one of the first being to use it as a heel-boom loader. As log sizes decreased and utilization standards got tighter, cable loading machines became less practical and hydraulic machines gained popularity. On the other hand, the search for equipment to log inaccessible stands of high-value timber focused attention on unconventional aerial logging systems during the 1980s. While helicopter logging is undergoing an increasing level of testing on a commercial scale, indications appear that the use of helicopters is close to being economic today and in the near future they are bound to play an important role in mountain logging (Figure 7).

Since the late 1980s, a relatively new type of logging operations with the introduction of mobile tower yarders, forwarders, harvester and timber processors began on the private woodlots, to harvest immature plantation forests, usually referred to as commercial thinning (Figure 8). Two general methods are used to harvest this timber. One employs a capital-intensive, mechanized system using feller-bunchers, grapple yarders, grapple skidders, forwarders and other sophisticated, high-production machines such as timber processors and harvesters. This approach involves small clear-cut logging and plantation forestry on low rotations designed to produce high volumes of wood fiber. The second approach entails more labour-intensive methods, tending toward selective cutting, and the creation of intensively managed, uneven-aged stands that are harvested with the kind of small-scale, relatively low-cost harvesting machinery now used in central European mountain forests [1, 2, 6, 7].

TREND ANALYSIS IN FOREST ENGINEERING RESEARCH

Attempts to evaluate research movement through the relatively short-term history are very difficult, but my review is based on the assumption that the quantity of published papers would be directly a function of their contributions to related technologi-

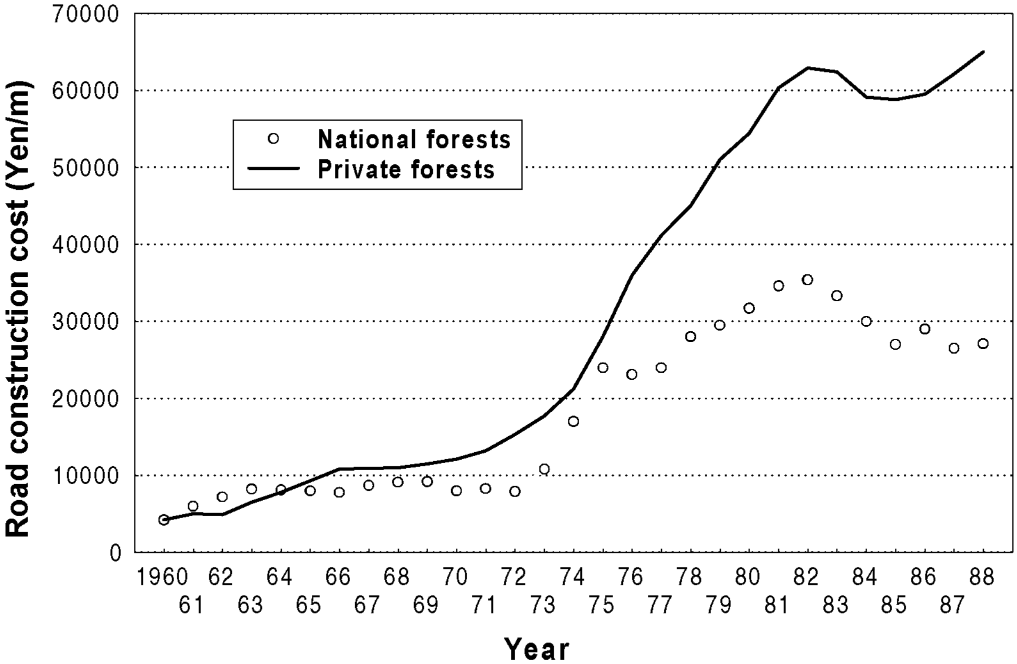


Figure 7. Change in road construction cost by ownership.

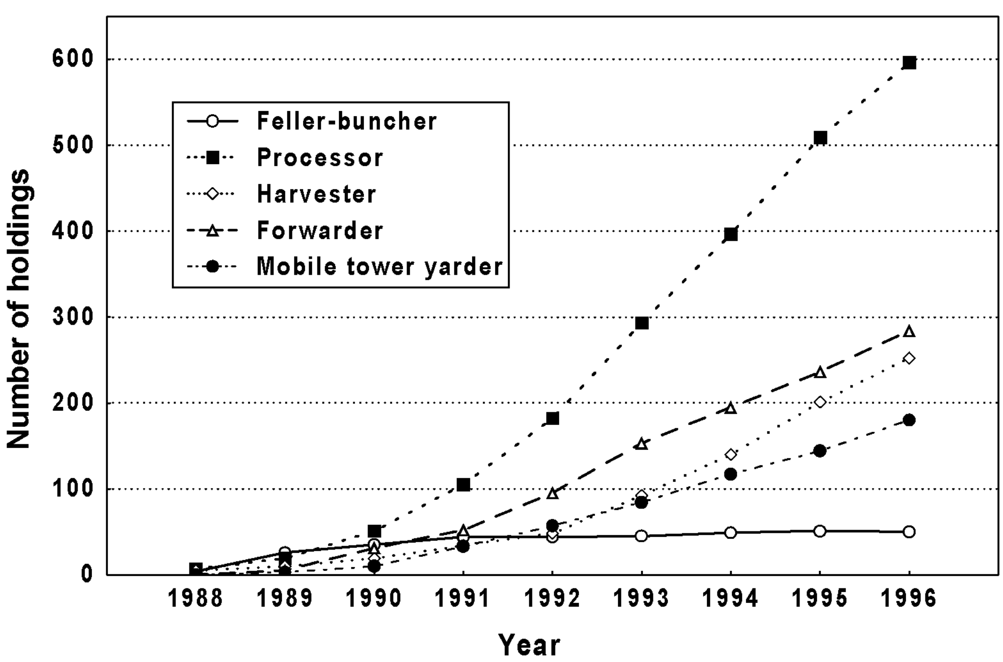


Figure 8. Change in holdings of multi-process, high production forestry machineries.

cal development but indirectly would be influenced by public understanding of research effort with the result of the performance of technology transfer. A change in the number of papers issued, therefore may be a useful measure of the cumulative effect of research movement, when provided with some solid statistical evidence for purposes of this count [15].

Six different journals dealing with forestry-related research papers that would potentially indicate the extent to which these issues reached the public were surveyed – Journal of Japanese Forestry Society (JJFS), Transactions of the Annual Meeting of Japanese Forestry Society (TAMJFS), Transactions of the Annual Branch Meeting of Japanese Forestry Society (TABMJFS), Bulletin of the University Forests (BUF); Hokkaido Univ., Tokyo Univ., Kyoto Univ., and Kyusyu Univ., Bulletin of the Forestry and Forest Products Research Institute (BFFPRI), and Technical Report of the Forest Agency (TRFA) respectively. Thirty-seven thousand, nine hundred and sixty-three pertinent papers issued in the period from 1955 to 1995 were captured through various bibliographical information services (data base researches, retrospective researches, reference services and photocopying) available in university libraries, government research institutes, and the related societies and associations. Searches were made by subject and key word, including forestry-related research as a whole and those associated with forest engineering, which coincide with most of the topics dealt with by IUFRO Division 3: Forest Operations and Techniques. As a verification of the sampled papers, the front page of each issue was roughly read. Confidence in this research was heightened by the substantial number of the reference papers (Table 1). In addition to descriptive comments on change in number, auto-correlation function defined as the linear correlation between a time series and the same series at later interval of time, was calculated to identify the pattern of periodic change. Results are plotted as a correlogram which is a diagram of the auto-correlation coefficient versus the lag year [14].

Table 1. Summary of resource data gathered through bibliographical information services.

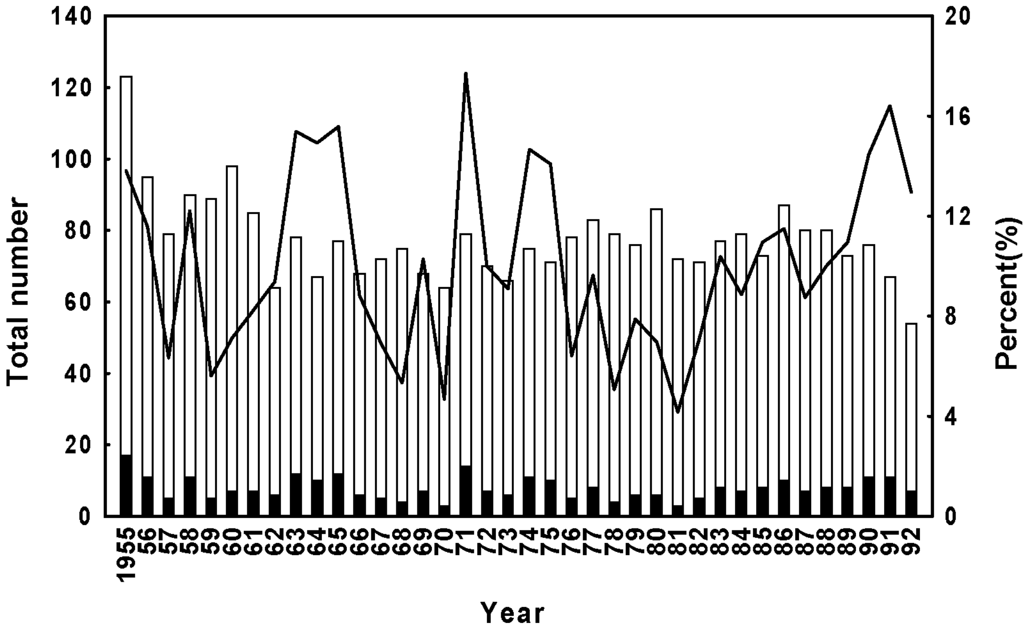
Name	Period	TNP[1]	FER[2]	Proportion(%)
JJFS	1955-1992	3006	306	10.2
TAMJFS	1955-1993	11424	1142	10.0
TABMJFS				
Hokkaido	1955-1994	2125	101	4.8
Tohoku	1955-1993	2546	91	3.8
Kanto	1959-1995	2454	207	8.1
Cyubu	1955-1994	1886	111	5.9
Kansai	1955-1993	3243	170	5.2
Kyusyu	1955-1994	4951	171	3.5
BUF				
Hokkaido	1955-1992	568	19	3.3
Tokyo	1955-1992	342	29	8.5
Kyoto	1955-1992	756	112	14.8
Kyusyu	1955-1992	226	8	3.5
BFFPRI	1955-1995	1397	55	3.9
TRFA	1988-1994	3039	713	23.5
Total		37963	3235	8.5

Remarks:
[1] Total number of papers issued in journals.
[2] Papers related to forest engineering research.

Name:
JJFS: Journal of Japanese Forestry Society.
TAMJFS: Transactions of the Annual Meeting of Japanese Forestry Society.
TABMJFS: Transactions of the Annual Branch Meeting of Japanese Forestry Society.
BUF: Bulletin of the University Forests.
BFFPRI: Bulletin of the Forestry and Forest Products Research Institute.
TRFA: Technical Report of the Forest Agency.

Journal of Japanese Forestry Society (JJFS)

There was no significant increase in the total number of papers issued in JJFS and the figures remained fairly constant around 80 papers from 1955 to 1992. However, three cyclic peaks in the number of papers related to forest engineering research appeared in the mid-1960s, the early 1970s and the late 1980s respectively. The apparent upsurge at these times may almost correspond to the period of rapid economic growth with the increasing demand for industrial timber since the late 1950s, to that of restructuring in timber industries caused by the oil crisis in 1973, and to the mechanization in timber harvesting operation began in the late 1980s, with the introduction of mobile tower yarders, forwarders, harvesters and timber processors. The correlogram shows steadily decreasing correlation but several periodic components of the time series appear at lag of 6, 8 and 11 respectively (Figure 9).



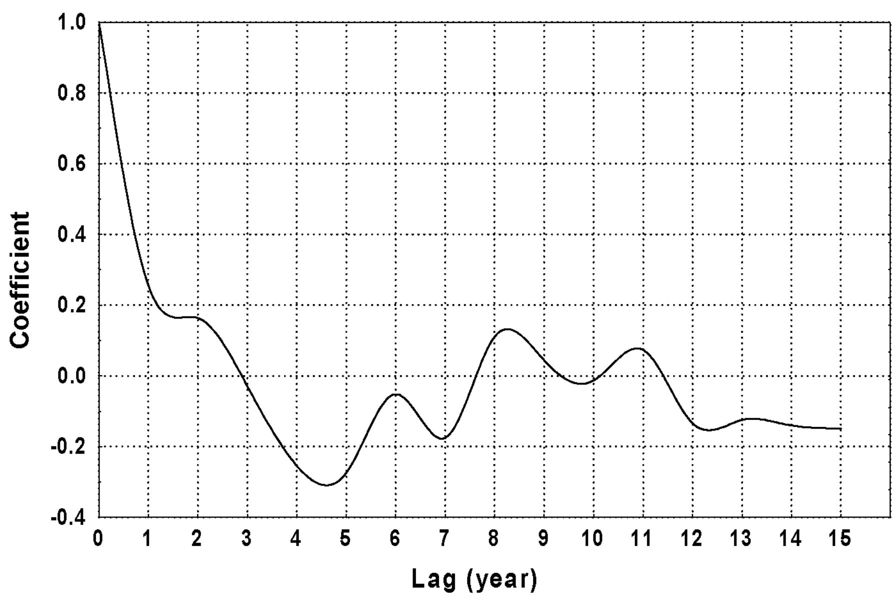


Figure 9. Change in number of papers issued in JJFS (upper) and auto-correlation structures of time series (lower).

Transactions of the Annual Meeting of Japanese Forestry Society (TAMJFS)

Overall, the number of papers issued in TAMJES indicated steady growth and the increase since the late 1970s was remarkable. The figures increased about 3 times in the forty years between 1955 and 1993. The number of papers dealing with forest engineering was closely coupled with total one in TAMJFS, except for the period between 1955 and 1967. The correlogram shows rapidly decreasing correlation and indicates a general pattern of time series expressed as linear trend plus random noise (Figure 10).

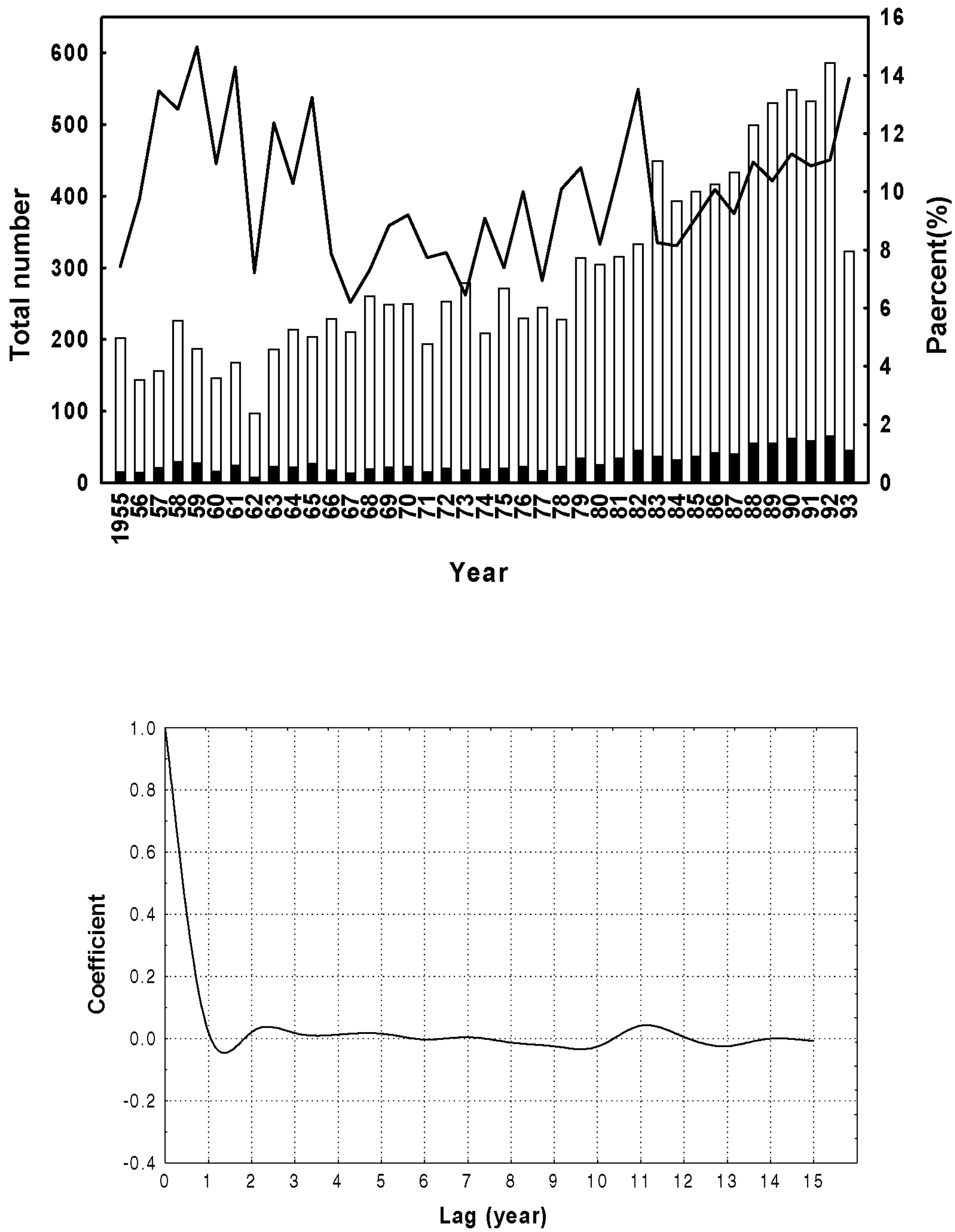


Figure 10. Change in number of papers issued in TAMJFS (upper) and auto-correlation structures of time series (lower).

Bulletin of the University Forests (BUF)

Depressed hovering around 40 papers in BUF in the period from 1960s to 1970s is no surprise, since it corresponds to the times of student movement occuring at these universities. There is a peak at the lag of 2, 5 and 7 suggesting an annual dependency. It may be assumed that there is a general pattern of annual changes related to the academic duration of graduate program (Figure 11).

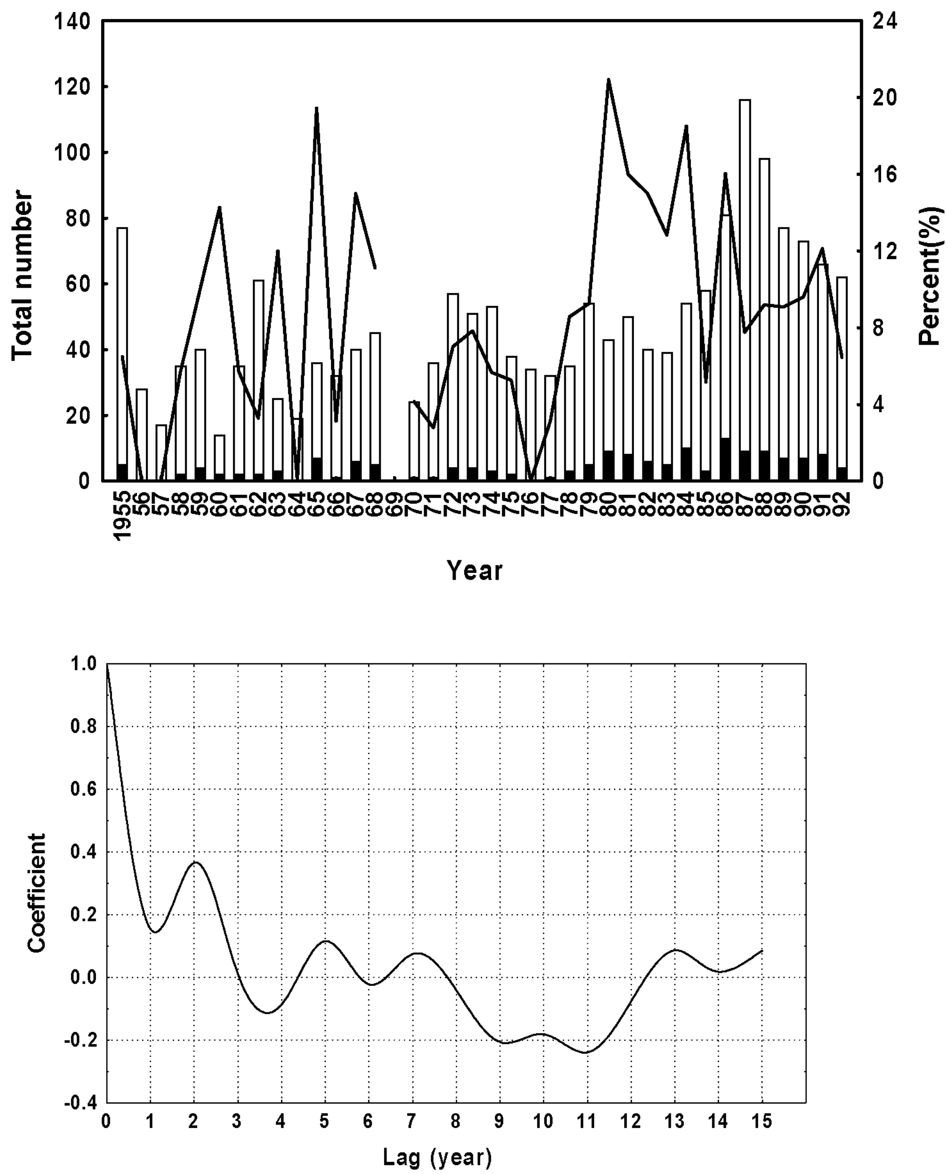
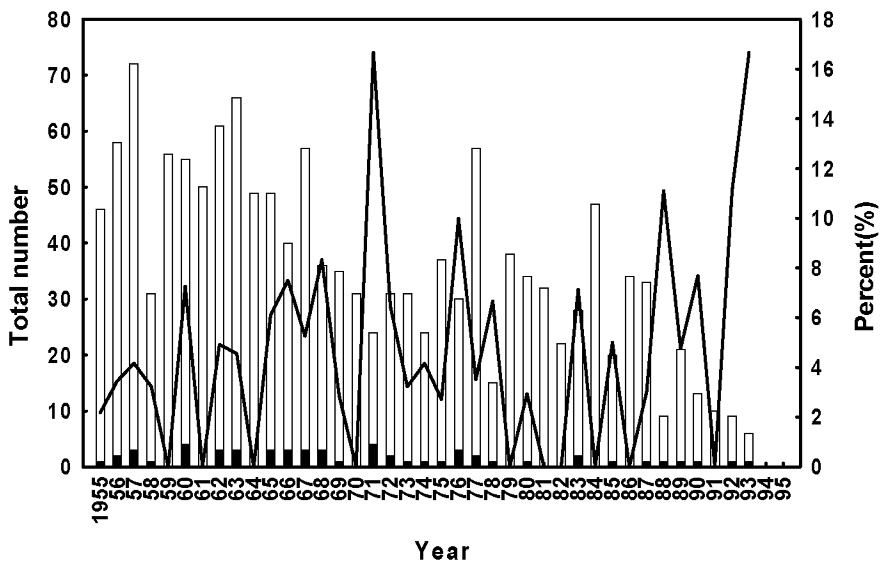


Figure 11. Change in number of papers issued in BUF (upper) and auto-correlation structures of time series (lower).

Bulletin of the Forestry and Forest Products Research Institute (BFFPRI)

There was a steady decline in the number of papers issued in BFFPRI over the entire period. This is in contrast to TAMJFS. It is difficult to explain why the number trended consistently downward. In all likelihood, the various organizational reform, particularly since the late 1960s, was reflected in movement of research activities. The correlogram shows a very salient peak at lag of 5 (Figure 12).



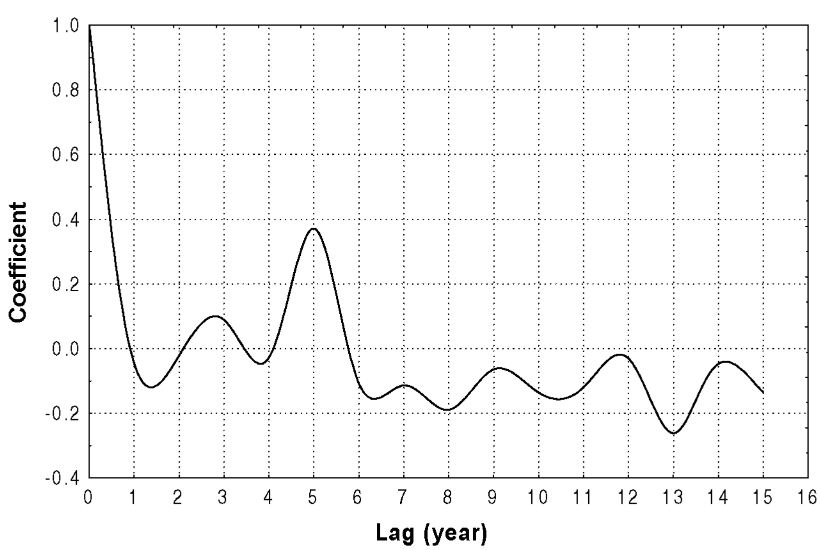


Figure 12. Change in number of papers issued in BFFPRI (upper) and auto-correlation structures of time series (lower).