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Chapter 1

Technological Transformation in the Global Pulp and Paper Industry: Introduction

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Abstract

At a high level of abstraction, the evolution of any industry is a function of changes in product market demand, availability and supply of capital, knowledge and technology, the surrounding institutional framework and organisational solutions. New technological innovations emerge because of changes in product market demand or institutional framework that encourage entrepreneurs and firms to take advantage of new business opportunities. This

contributed volume provides illustrative, well documented case studies of technological transformation in the global pulp and paper industry from the inception of mechanical papermaking in early nineteenth century Europe until its recent developments in today's business environment with rapidly changing market dynamics and consumer behaviour. The study focuses on the roles of various factors that affected this process, including the availability and supply of inputs on the one hand, and demand characteristics on the other hand, within regional, national and transnational organisational frameworks. It deals with the relationships between technology transfer, technology leadership, raw material dependence, and product variety on a global scale. The introductory chapter outlines the research setting, and briefly summarises the research questions posed, methods used and the case studies analysed.

Keywords

Technology transfer; Papermaking: Pulp and paper industry

1.1 Research Setting

This contributed volume endeavours to analyse the past 200 years of technological transformation in the global pulp and paper industry from a comparative perspective. The study is motivated by the realisation that using comparative methods is a highly revealing way of exposing the complexities the modern pulp and paper technologies have undergone in the past and of analysing today's business environment with changing market dynamics and consumer behaviour. Methodologically, the study combines transnational, national and regional level analyses with the micro level case studies by focusing on the development of a

single industry – pulp and paper. The research concentrates on the various historical trajectories of the manufacture of pulp and paper and the technologies related to them. It covers the entire history of technology transfer in the global pulp and paper industry from raw materials to mill management, and from transportation to environmental issues. As a result, the book is arguably the most comprehensive historical analysis of papermaking technology available.

The investigation is directly linked to *The Evolution of the Global Paper Industry 1800–2050: A Comparative Analysis* by Lamberg, Ojala, Peltoniemi and Särkkä, eds, in 2012, which revealed several impetuses for an in-depth study of technological transformation in the global pulp and paper industry. The present volume is primarily intended as a basic introduction to the history of papermaking technology and it is aimed at the same category of readers as *The Evolution of the Global Paper Industry*; it is also geared toward students and teachers as course material at the secondary and tertiary levels and as a handbook for professionals working either in industry or research centres. The content could be best utilised for raising important questions among the more advanced graduate audiences by thoroughly familiarising them with the characteristics of the technological transformation of the global pulp and paper industry. It caters to graduate audiences in four intersected but conventionally separate fields of study, each having its distinct but interlinked interest and relationship within the pulp and paper industry: forestry, business, technical sciences, and history.

The primary idea behind the present volume was to write a comprehensive volume that covers all the important areas related to the history of papermaking technology. Furthermore, it was believed that the need for a volume of this type is very real and continuing, and that

updated research on changes that have been taken place in some of the key areas during recent years are useful for purposes of teaching and research. However, it is also obvious that this book pays less attention to certain topics and regions, which have already been covered in *The Evolution of the Global Paper Industry*. For this reason, in these cases a complementary use of both volumes is recommended. The world's pulp and paper industry is becoming increasingly global and with a speed unforeseen in the past. Thus covering what is termed here the global pulp and paper industry runs the risk of becoming outdated as the geographical orientation of the industry is constantly shifting. For instance, from the present point of view the emerging pulp and paper industry regions in Latin America could arguably be considered worthy of investigation. The present study is not intended to deny their importance. Instead, it outlines the development processes of the technological transformation of the industry from a historical perspective, and concentrates on phenomena and regions that are considered to be revealing for the topic as a whole.

1.2 The History of Papermaking Technology

The research starts with a comprehensive historical analysis of the evolution of cellulose chemistry. Paper can be defined as being an aqueous deposit of any plant fibres and other materials in the form of a web or sheet. It is manufactured from a filament product, which has been obtained by mechanically or chemically separating plant fibres from each other. In papermaking the liberated fibres are brought together again on the paper machine, where they interact with each other in the presence of chemicals charged to the liquid stock. As paper consists of plant fibres, paper partakes not only of the chemical nature of the fibre, but its physical nature as well. For instance, cotton rags formed an excellent papermaking material for the reason that a single cotton fibre is immensely strong: it is capable of supporting

enormous weight in comparison with its thickness. Therefore, the characteristics of finished products can always be traced to the form, size, and chemical behaviour of the ultimate fibre itself. For this reason, any investigation into the history of papermaking technology inevitably encompasses the history of cellulose chemistry as well. (Chap. 2; see also Alén 2007, pp. 18, 20; Beadle 1908)

By the judicious choice of raw material, and also by modifying both the mechanical and chemical treatments to which it is subjected, divergence in the qualities of paper can be achieved. The processes that are used to convert fibrous feedstocks into a mass of liberated fibres by dissolving the components (mainly lignin) that binds the cellulosic fibres together are collectively called “pulping”. The purpose of pulping is to separate the fibres from the plant and render them suitable for papermaking. These conversions can be accomplished either mechanically (i.e., by means of mechanical beating) (Sundholm 1999, p. 17) or chemically (i.e., by means of chemicals) (Gullichsen 2000, p 14) or by combining these two types of treatment. In fibres with low yields of cellulose that consume a large volume of chemicals, the cost of chemical treatment per ton of finished pulp is often so high as to prohibit the material from industrial use, regardless of whether the resulting pulp is of excellent quality. These factors need to be carefully considered in estimating the value of any raw material for the purpose of manufacture as several case studies (Chaps. 9, 10, 11) in this volume vividly demonstrate.

Until very recently, paper offered the most convenient, cheapest and democratic medium for communication in the form of newsprint, and printing and writing papers. In the 2000s, the rise of electronic media and information technology has slowly but what appears to be rather irreversibly eroded the role paper once played as the main medium for communication.

During roughly the same period, a significant increase in the demand for packaging (e.g. liner, fluting, boxboard), hygienic, health care and other specialised end uses of paper have taken place. The expanded diversity of output can be determined from total global production. In 2016, wrapping and packaging paper grades accounted for more than half (57%) of total global production (409 million tonnes). Newsprint, printing and writing paper grades constituted approximately a third (31%) of the total, followed by household and sanitary paper grades (8%). (FAO 2016) Significantly, however, for most of the research period investigated in this study, by far the dominant use of paper was for newsprint, printing or writing. Naturally, then, the fundamentals that have defined technology transfer until very recently have mainly been connected to communication in one way or another.

One of the fundamentals that has defined technology transfer in the global pulp and paper industry is connected to the technical development of the paper machine itself. (Chaps. 2, 8) The Fourdrinier machine represented a straightforward mechanisation of what was formerly done by hand. In principle, it performs the same sequence of actions as in handmade papermaking, but does so at a much faster rate. Since its introduction more than 200 years ago, the maximum speed (m/min) and width (m) of the machines have increased dramatically, thus contributing – arguably more than any other factor – to the increase in production capacity. During the period from 1900 to 2005, for instance, the maximum speed of the machine rose ten folded (from 200 to 2000 m/min), and the maximum width of the machine grew from circa three metres to eleven. During roughly the same period, global production of paper grew from less than 10 million tons (in 1900) to 409 million tons (in 2016). (Diesen 2007, p. 11; FAO 2016) Without improvements in technology – whether related to papermaking engineering, cellulose chemistry, energy efficiency or transport – such a dramatic increase in production capacity would not have been possible.

Besides paper production capacity, global production of fibre furnish (i.e. wood-based pulp, non-wood-based pulp and recycled fibres) is an important measure of technology transfer. Paper is manufactured from plants containing cellulose fibres, and they can be planted or grow naturally under favourable conditions of climate and soil. Today, the typical plants used for paper manufacture are coniferous trees, such as pine (*Pinus* spp.), spruce (*Picea* spp.), fir (*Abies* spp.) and hemlock (*Tsuga* spp.), and deciduous trees, especially eucalypts. In 2016, global production of fibre furnish amounted to 415 million tonnes. From this total refuse materials (e.g. recycled paper) represented 54% (217 million tonnes) of global fibre furnish, with the rest (46%) coming from virgin forest resources and various fibrous, non-wood feedstocks together with industrial forest plantations for the production of pulpwood. (FAO 2016)

Prior to the mid-nineteenth century paper was manufactured almost exclusively from non-wood feedstocks. Grasses and straws were among the oldest raw materials used by the papermakers in East Asia. Paper was first introduced in China as a writing material to replace the use of the wooden tablets (i.e. flat pieces of wood on which records have been written in *sumi*, the traditional medium for writing in East Asia using an ink composed principally of soot and binders). Wood-block printing technology emerged during the Tang Dynasty (618-907). The expansion of the imperial dynasty to Korea brought the Chinese in contact with Japan, where some papermakers still use the paper mulberry as raw material to make *washi*, the traditional Japanese paper. (Chap. 2)

The domestication of important papermaking plants such as cotton and flax and their use for fabrics were important milestones in the history of papermaking. Gradually both the Arabs

and the Greco-Roman world became familiar with the secrets of the cotton fibre and printing technology. The use of the Arabic and Latin alphabet gave the technological advantage to the Arabs and the Europeans over the Chinese, the Koreans and the Japanese, who used Classical Chinese characters (i.e. the relatively simple character sets facilitated the introduction of printing technologies that used types casted from metal as opposed to blocks of wood engravings). The immensely strong cotton and flaxen fibres in the form of rags from fabrics and technological innovations connected with printing ensured since the late fifteenth century the establishment of paper mills and printing presses first in the Old World, and then following European colonisation in the New World. (Chap. 2)

The use of rags as the primary papermaking material started to show symptoms of saturation in early-Victorian Britain – the first "journalising" society in the world (i.e. the mass media can be interpreted as the ideological environment of early-Victorian society). The extension of education and literature, and the increased literacy and heightened social consciousness directly increased demand for paper. Furthermore, the mechanisation of the industry indirectly gave people and institutions more reason to need paper. The rise of the popular press and technological improvements in lithographic printing allowed for the mass production of penny and halfpenny newspapers, journals, magazines, reviews and cheap editions of books; they thus came within the reach of the very poorest members of society. The more economical methods of manufacturing and exponentially greater output to meet larger demand led to the quest for new raw materials. Two separate developments took place: the introduction of new processing treatments to some of the old papermaking materials (e.g. esparto and bamboo) (Chap. 11) and the introduction of a range of new technologies connected with the utilisation of coniferous wood-fibres, the use of which prevailed.

The utilisation of wood-fibres for making paper created the foundation for an industrial sector – the pulp and paper industry – in countries endowed with abundant coniferous forests, which served as its raw material, and hydro-electric power for energy; two prime examples are Finland (Chap. 3) and Canada (Chap. 7). From a historical perspective, wood-based fibres entered paper manufacture relatively late, circa 150 years ago, but the impact of their utilisation has been an important economic determinant for the geographical orientation of the industry. Previously, the availability of rags influenced the location of paper mills since rags from fabrics were not typically available in abundance. Hence, the early paper mills tended to spring up at a fairly short distance from large urban centres, which were both the biggest markets for paper and the centres of rag supplies, or cotton and flax mills, which were other major sources of these refuse materials. From the mid-nineteenth century onwards, mills began to spring up in regions remote from economic centres – on the shores of lakes and rivers, where it was possible to obtain the raw material needed from the forests. Where to locate production remained the crucial question until the latter part of the twentieth century. Thereafter the technological developments in seaborne transportation, and the subsequent dramatic reduction in the cost of shipping goods, started to erode the importance of distance *vis-à-vis* fibre sources and markets. The expansion of overseas trade highlighted the importance of proximity to good harbours so that the raw materials and finished goods did not have to be transhipped far from ocean-going vessels. (Chap. 12)

The practically unlimited access to wood-based fibre resources some of the major producers had enjoyed since the mid-nineteenth century became an even greater advantage during and immediately after the First World War, which caused a violent disruption in the global paper trade. During the conflict, a shortage of shipping caused trade between the pulp producing countries and the rest of the world to collapse. The British Empire and Commonwealth

countries, with the single exception of Canada, (Chap. 7) relied heavily on softwood imports. In the UK, paper makers imported practically their entire softwood supply. (Chap. 11) Apart from Canada, only in New Zealand were there extensive stands of coniferous woods and this was the case only because the country had embarked on a vigorous afforestation programme of species that had been transplanted from California. (Chap. 9) In Australia, coniferous species were limited to certain areas of the vast continent, rendering the exploitation of softwood resources economically unviable. In their absence, Australian papermakers adopted technologies that were aimed at pulping hardwoods, especially the indigenous eucalypt species. (Chap. 11) In Europe, Portugal (Chap. 6) was among the first countries in which eucalypts were established in plantations for the production of pulpwood.

With little doubt, environmental regulation has occupied one of the main impetuses for technology transfer over the past fifty years. It was during the 1970s that effluent loadings and sulphur emissions from the pulp and paper industry were for the first time subjected to considerable scrutiny. Thereafter, emissions have fallen significantly in many technologically advanced pulp and paper producing countries. The reasons for the decrease can be found in changes in production technology and in the finished products themselves. For example, in many countries the calcium-based sulphite mills, which cause high emissions, have been closed down. In the case of pulp and paper products, major global upheavals such as the oil shocks of the 1970s have had a major impact on environmental protection. The crisis led to the introduction of numerous measures that resulted in improvements in energy efficiency and reductions in mill water consumption and emissions into the environment. Regulatory bodies also played a role in precipitating this progress by stepping up their work towards greening the pulp and paper industry. They introduced new and tightened existing legislation, particularly in relation to effluents. The main economic instruments available for the

authorities were compensation procedures for defraying the cost of environmental protection and measures related to taxation. Lifting the turnover tax on environmental protection investments can be mentioned as an example. Furthermore, nongovernmental organisations have put pressure on producers for lower emissions and a more sustainable use of forest resources. (Chap. 4; see also Hynninen 1998) From the mid-1980s onwards, the rise of green consumerism in some major paper consuming countries such as Germany and the UK functioned as an additional incentive for the transfer of environmentally driven technology. More recently, environmentally sustainable products using wood and forestry residues as well as other forms of biomass have gained considerable attention. (Chaps. 2, 4)

As a final point, it can be said that an appreciation of the surrounding institutional environment is of paramount importance in analysing the evolution of the global pulp and paper industry. As the case studies highlight the institutional environment differs considerably from one country to another. (Chap. 5) Modern papermaking technologies would not have been realised without dedicated individuals, educational institutes, research laboratories, mills and workshops, (Chaps. 3, 7, 8, 9, 10, 11) and even political bodies that have created incentives – and in some illustrative cases even fetters – on adopting technological innovations. (Chap. 7) Sometimes institutional instability *per se* has hindered the technology transfer. (Chap. 8) Thus, while papermaking technology encompass the research work done in the field of cellulose chemistry, it also involves a function of changes in the market demand, availability and supply of capital, knowledge and technology, the surrounding institutional framework and organisational solutions. Together these variables create what can be termed the main drivers in technology transfer in the global pulp and paper industry.

1.3 The Case Studies

In compiling the volume, it was deemed best to employ a simple organisational framework that grouped the 11 case studies (Chaps. 2-12) in three parts (Parts I-III) that were followed by a conclusion (Chap. 13). It is hoped that this straightforward approach will help the reader trace connections between the different case studies and better understand the research setting as a whole. Part I, “Research and Development”, focuses on the evolution of cellulose chemistry, research and development of papermaking engineering and environmentally driven technology transfer. In Chap. 2, “Manufacturing Cellulosic Fibres for Making Paper: A Historical Perspective,” Raimo Alén traces the long evolution of the development of pulp and paper technology from the inception of paper manufacture in China about 2000 years ago up to its recent developments. The analysis focuses on the last two centuries, during which period the manufacture of cellulosic fibre has been closely integrated with the growth of our fundamental knowledge of chemistry in general and the enhancement of our knowledge of the possibilities of chemical processing of cellulosic fibre in particular. The more recent developments deal mainly with the quest for new cellulose-based products and their possible applications as well as environmental concerns. The chapter represents arguably the most comprehensive and detailed, and yet relatively condensed, account of the history of how cellulosic fibres have been manufactured into a plethora of paper products over the last two millennia.

The tradition of research and development in the paper industry has historically been divided into two separate branches of research and development. One consists of chemistry, namely studying the possibilities of chemical processing of fibre. The other part of the history of research and development is mechanical engineering, and its roots can be traced back to the

construction and use of paper machines. In Chap. 3, “Development in the Finnish Wood Processing and Paper Industry, c. 1850-1990,” Panu Nykänen investigates the tradition of research and development in the context of the Finnish wood processing and papermaking industries. In addressing its subject, the chapter is mainly concerned with the operation of Finnish paper mills from the 1850s onwards when the utilisation of coniferous wood as the new raw material for making paper revolutionised the entire industry. The chapter also addresses the related subjects of technical research, formal higher education and work-related, practical learning in Finland.

Environmental concerns are the focus in Chap. 4 “The Greening of the Pulp and Paper Industry: Sweden in Comparative Perspective,” by Ann-Kristin Bergquist and Kristina Söderholm. It analyses the environmentally driven technology transfer in the pulp and paper industry by focusing on Sweden, which has pioneered parts of this transition. The chapter illustrates that the overall transition towards cleaner and more energy efficient production technologies in Sweden was the result of long-term incremental development, which gained momentum with the environmental awakening in the 1960s and was followed by the rise of green consumerism in the 1980s. More recently, the burning issue of climate change has been a major impetus to environmentally driven technology transfer, for instance in the development of cellulose-based products such as biofuels.

Part II “Regulations and Institutions” assesses the role of regulatory institutions in technology driven transfer in the global pulp and paper industry, within regional, national and transnational organisational frameworks. In Chap. 5 “Varieties of State Aid and Technological Development: Government Support to the Pulp and Paper Industry, the 1970s to the 1990s,” Jari Ojala, Niklas Jensen-Eriksen and Juha-Antti Lamberg analyse government

support for the pulp and paper industry in the Organisation for Economic Co-operation and Development (OECD) countries. The chapter reports that the favourable regulatory environment tended to exist in such major pulp and paper producing countries as Finland and Sweden, in which pulp and paper companies had very strong bargaining power over the government. On the contrary, in those OECD countries in which the pulp and paper industry's share of total manufacturing was marginal, bargaining power and consequently direct government support tended to remain rather limited.

Interestingly, in Chap. 6 "From Backward to Modern: The Adoption of Technology by the Pulp Industry in Portugal, 1891-2015," Amélia Branco and Pedro Neves find that in Portugal, where the pulp and paper industry remained technologically backward prior to the 1950s, government support was the main boost to the pulp industry. The main explanation can be found in the development of eucalyptus for plantation purposes and pulping hardwoods, which emerged as a major field of manufacturing in Portugal after the Second World War. The analysis highlights the roles played by the availability of knowledge, capital, and raw materials on the one hand and demand characteristics on the other in technologically driven transfer in the Portuguese pulp industry. Taking a longitudinal perspective on the Portuguese pulp industry, the chapter sheds light on the international economic integration of a peripheral country that suffered from a poor endowment of capital and natural resources.

In Chap. 7 "Natural Potential, Artificial Restraint: The Dryden Paper Company and the Fetters on Adopting Technological Innovation in a Canadian Pulp and Paper Sector, 1900-1950," Mark Kuhlberg analyses the issue of government support on national, provincial and organisational levels in Canada, one of the world's foremost pulpwood suppliers. The analysis focuses on the case of a pulp and paper mill in Dryden, northern Ontario, and

highlights that the presence of abundant natural resources does not alone guarantee a technologically driven transfer in pulp and paper industry. The case of the Dryden Paper Company, which left finding economies of scale in the industry to others, is a reminder that the first mover in an industry does not always dominate it in the long run. Another significant conclusion of the chapter is that institutional support mechanisms and demand characteristics remain as important as abundant natural backings in analysing the main drivers in technology transfer.

The industrialisation process in the nineteenth century was based on the transfer of technology from pioneering countries to countries that had not yet participated in the process. Southern Europe in general and Spain in particular were very late in experiencing this modernisation wave. In Chap. 8 "The Endless Sheet: Technology Transfer and the Papermaking Industry in Spain, 1800-1936," Miquel Gutiérrez-Poch explores the technology transfer in Spain, whereby foreign technology was the main driver in achieving the transfer in the papermaking sector. The chapter maintains that the institutional framework and its stability – into which the new technology is adapted – can accelerate or restrain the impact of the new technology. Therefore, the setting into which the new technology is received is a crucial consideration that affects the technology transfer. It is also influenced by numerous other factors, including the geographical concentration of the activity (i.e. industrial district) and simply the existence of an industrial base. In regard to papermaking in Spain, it was fundamental to have an active mechanical engineering sector that was able to adapt the new technology to local conditions.

Part III "Local Innovations and Global Markets" pays attention to the role of global upheavals and demand characteristics in analysing the birth of the pulp and paper industry in three peripheral regions of the global economy, namely New Zealand, Australia and India.

In Chap. 9 “Technology Transfer and Local Innovation: Pulp and Paper Manufacturing in New Zealand, c.1860 to c.1960,” Michael Roche traces the birth of a wood-based pulp and paper industry in New Zealand from its modest beginnings until the 1960s, by which time there were pulp and paper mills in operation serving local and export markets. In New Zealand the birth of a viable pulp and paper industry was fostered through a vigorous afforestation programme of *Pinus radiate* – a Californian coniferous species previously untried for papermaking, technical assistance from North American and Scandinavian countries, and a group of dedicated researchers working for both the Forest Service and private companies in New Zealand.

In place of conifers, pulping indigenous hardwoods, specifically the eucalypts, formed the basis for the emergence of a national pulp and paper industry in Australia. In Chap. 10 “Making Paper in Australia: Developing the Technology to Create a National Industry, 1818-1928,” Gordon Dadswell traces the evolution of the pulp and paper industry in Australia, in which the comparative inaccessibility and the tyranny of distance had rendered the exploitation of the country’s wood resources economically unviable until 1914. The need for establishing an Australian pulp and paper industry became imperative following the end of the First World War. The armistice resulted in a serious shortage of imported wood pulp, with the outcome that manufacturers in Australia were forced to switch to indigenous raw materials instead. The initial investigations for pulping indigenous hardwoods were undertaken in Perth, Western Australia after the war. The final stage of paper making in Australia shifted from the laboratory to commercial production in 1924, when the first Australian mill using indigenous hardwoods went into production in Tasmania.

Another remarkable story of pulping indigenous raw materials in place of conifers is told in Chap. 11 “The Quest for Raw Materials in the British Paper Trade: The Development of Bamboo Pulp and Paper Industry in India up to 1939,” by Timo Särkkä. Bamboo – the fastest growing plant on earth – was introduced as the raw material for papermaking in India at the beginning of twentieth century. The impetus for this development was the global nature of the First World War, which led to the collapse of shipping between Britain and some of its colonies. The increased dependence on wood pulp, the likelihood of a pulp famine, and the consequent increase in the price for imported wood pulp were the means for drawing attention to the possibility of making commercial volumes of pulp by utilising Indian grasses in general and bamboo in particular. The technology was developed under British auspices, but was later adopted by Indian paper producers in response to the rising cost of imported wood pulp.

The final case study, Chap. 12 “Creating Global Markets: Seaborne Trade in Pulp and Paper Products over the Last 400 Years,” by Jari Ojala and Stig Tenold, brings the very issue – where to locate production – to the fore of analysis by adopting a longitudinal perspective on the global seaborne trade in pulp and paper products. In contrast to the situation prevailing today, globally operating multinational companies were rarities in the world’s pulp and paper industry prior to about the 1950s. Nationally and regionally conditioned technological and organisational solutions survived into the post-1945 era, although they soon went into a rapid decline. The development of technological solutions for dramatically improving the efficiency of ocean-going transportation were crucial for the high-volume, bulk products – both in terms of the raw material and end product – that define the pulp and paper industry. The chapter concludes that the declining cost of sea transport has been a necessary condition for the growth of the global pulp and paper industry into new regions of the world, ranging

from South-East Asia to Latin America, which have traditionally been remote from the world's established economic heartlands.

Chap. 13 "Technological Transformation in the Global Pulp and Paper Industry: Concluding Remarks," by Mark Kuhlberg, Timo Särkkä, and Jussi Uusivuori summarises the theoretical framework presented in the introductory chapter and the key empirical findings of the case studies.

References

Alén R (2007) Introduction to Papermaking. In: Alén R (ed) Papermaking Chemistry, 2nd edn. Finnish Paper Engineers' Association, Helsinki, pp 16–26

Beadle C (1908) Chapters on Papermaking. Vol. I. Comprising a series of Lectures Delivered on Behalf of the Battersea Polytechnic Institute in 1902. Crosby Lockwood and Son, London

Diesen M (ed) (2007) Economics of the Pulp and Paper Industry. Papermaking Science and Technology. Book 1. Finnish Paper Engineers' Association/ Paperi ja Puu Oy, Helsinki

Food and Agriculture Organization of the United Nations (FAO) (2016). Global Forest Products Facts and Figures 2016. Available at http://www.fao.org/3/I7034EN/i7034en.pdf. Accessed 21 March 2018

Gullichsen J (2000) Introduction. In: Chemical Pulping. Gullichsen J and Fogelholm C-J (eds) Papermaking Science and Technology. Book 6A. Finnish Paper Engineers' Association/TAPPI, Helsinki, pp 14–16

Hynninen P (ed) (1998) Environmental Control. Papermaking Science and Technology. Book 19. Finnish Paper Engineers' Association/TAPPI, Helsinki

Sundholm J (1999) What is mechanical pulping? In: Sundholm J (ed) Mechanical Pulping. Papermaking Science and Technology. Book 5. Finnish Paper Engineers' Association/TAPPI, Helsinki, pp 17–21