

The background of the cover is a photograph of a forest. The upper portion shows tall, thin tree trunks against a bright sky, while the lower portion shows a dense forest floor with green undergrowth and sunlight filtering through the trees.

Tenth Edition

MARK S. ASHTON

MATTHEW J. KELTY

THE PRACTICE OF
SILVICULTURE
APPLIED FOREST ECOLOGY

WILEY

The Practice of Silviculture

Dedication

DAVID MARTYN SMITH
March 10, 1921–March 7, 2009



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David M. Smith, longtime Professor of Silviculture at Yale University, was our mentor and our friend. We dedicate this 10th edition of *The Practice of Silviculture* to his memory, in thanks for all he gave to us.

Dave was born in Texas and raised in Rhode Island. After graduation from the University of Rhode Island, he served as a meteorologist for the US Army Air Force during World War II. He earned his masters and doctorate degrees from Yale University under the guidance of Professor Harold Lutz. Dave quickly became a faculty member in the School of Forestry and Environmental Studies at Yale. One of his most notable contributions involved helping to found the sub-discipline of silviculture known as *forest stand dynamics*, which uses stand reconstruction to evaluate the past and to project the future of forest growth. During his years at Yale, Dave served as the Director of School Forests and as the Morris K. Jesup Professor of Silviculture. His wit and

wisdom are fondly remembered, as are the many lessons taught in the classroom and in the field. Dave educated a legion of professionals who have had a lasting impact on forests throughout the world.

David Smith worked with Ralph C. Hawley as co-author of the 6th edition of this book, and then went on to author the 7th and 8th editions alone. He was lead author on the 9th edition, working with three of his former students. In his field trips and teaching, Dave showed his students how a practical knowledge of botany, ecology, and geology could allow a forester to look at a stand of trees, pick out clues, and make deductions about the forces shaping the forest. His skills in this area led some students to dub him “Sherlock Holmes of the forest.” We are ever grateful for his wisdom and guidance.

Mark S. Ashton
Matthew J. Kelty

The Practice of Silviculture

Applied Forest Ecology

Tenth Edition

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WILEY

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Preface

The late Ralph C. Hawley, one of the pioneers of American forestry, wrote the first edition of this book in 1921. He based it on knowledge imported from Europe and on what he, and a few hundred foresters, had learned by managing the limited tracts of forest on which true long-term forestry was being practiced. At the time, American society regarded forests only as a source of timber, and the book focused on timber production silviculture that would be financially sound in the long run. Professor Hawley went on to revise the book four times. David M. Smith became a co-author on the 6th edition, published in 1956. Emphasis was placed on presenting the scientific basis for silvicultural practice. Professor Smith wrote and edited two more editions as sole author. In the 9th edition, Professor Smith brought on three colleagues, all of whom were his past students: Bruce C. Larson, Matthew J. Kelty, and Mark S. Ashton. His intent was to carry on the tradition of the text in the same manner in which Professor Hawley had worked with him. In the 9th edition, published in 1997, the phrase *Applied Forest Ecology* was added to the title. The basic purpose was to call attention to the fact that foresters should design forests based on sound ecological theory. This applied ecology is concerned with managing the interactions among organisms and their environment, regardless of the degree to which the forests are managed or devoid of human influence.

This 10th edition is a significant revision of the 1997 text. The contents have been completely restructured to further emphasize the ecological basis for silviculture, as well as to expand the relevance of silviculture to a range of forest and tree-related resource management issues. In this edition there are six parts: (1) an introduction and history of silviculture, (2) a summary of the ecological foundations for silvicultural practice, (3) methods of regeneration, both natural and artificial, (4) post-establishment (intermediate) treatments, (5) silvicultural considerations for forest management, and (6) examples of applications for different land ownerships and uses. The previous edition began with intermediate treatments;

this book starts with concepts and treatments for regeneration, then progresses to intermediate treatments. The text ends with a new and more elaborate section on applications of silviculture to different resource issues: industry and industrial management, public lands and ecosystem management, restoration and forest health, watershed management, wildlife habitat, agroforestry, urban environments, and climate mitigation.

The 10th edition has been expanded and largely rewritten with clearer language and explanations, updated references, and new photographs, tables, and figures. Boxed inserts have been added to provide greater detail on particular silvicultural treatments or examples of their use. Each chapter strives to provide regional examples for the southern, northeastern and western United States. The glossary contains words and phrases which are highlighted in the text using bold color font. Words in black bold font are for emphasis only.

The book still has a strong North American focus, but contains more examples from across the world to provide a more global perspective of silvicultural use for the North American forester or student. This may be the most expansive book on silviculture yet, and covers a wide range of topics and resource issues that are currently faced by the forester or resource professional. It does not lose its strength in explaining the principles for silvicultural treatments.

Work on this 10th edition began over 10 years ago. The long process has involved many people acknowledged elsewhere in these initial pages. It is hoped that this effort will be well received and appreciated by the forestry community. We thank our families for their patience and the time we have been allowed in preparing this book.

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Part 1

Introduction to Silviculture

A history of silviculture and the philosophical approach taken in this book.

1

The History and Philosophy of Silviculture

Introduction

There are three parts to this chapter that describe silviculture as an evolving sub-discipline of applied ecology and its contribution to the well-being of society. The three parts include: (1) history, (2) philosophy, and (3) the literature and sub-disciplines of research relevant to current resource issues. The first part summarizes the origins and evolution of silviculture as a part of an ancient indigenous agricultural practice used by many peoples for production of food and shelter in combination. Silviculture was originally the forest part of swidden systems where forest patches were cleared for agricultural use for a period of years to provide food, before being left fallow and allowed to grow back to trees, and secondary forest that was harvested for timber, fiber, fruits, and medicinals. With the development of permanent agricultural and pastoral fields, silvicultural systems followed suit and forests and woodlands were managed separately from agriculture. There is then a discussion of silviculture's systematic evolution as a science in response to the degeneration and degradation of forest lands associated with the industrialization of economies in central Europe, then in North America, and subsequently elsewhere. A synopsis of silviculture's roots to reforestation and restoration in Germany, British India, and the United States follows. Finally there is a discussion of silviculture as it is practiced at present.

The second part comprises a discussion of the different philosophical approaches of silviculture. It first describes silviculture as an ecological technology. It shows that silviculture has a relationship with the social sciences and contributes to the management discipline of forests and woodlands. It describes how silviculture should be used as part of a long-term economic view for the betterment and sustainability of social values obtained from trees. It then discusses the variations in the intensity of practice in relation to circumstance. This part of the chapter concludes with a philosophical perspective of how silviculture should be applied to forests.

The third part comprises a synthesis of the silvicultural literature as a body of scientific knowledge. It uses

the literature to discuss modern day developments in silvicultural research as a sub-discipline of ecology, and then relates this body of research to today's resource issues.

Silviculture, its Origin and Development as an Applied Ecology

Silviculture is the oldest application of the science of ecology and is a field that was recognized before the term *ecology* was coined (Toumey, 1928). Many of the ways of developing forest stands rest heavily on cuttings that alter or modify the stand environment in order to regulate the growth of remaining vegetation. The reliance on ecological knowledge in silviculture is therefore all the better for not simply resting on philosophical principle. The economic returns from forestry are usually not great enough to protect forests from all the shifts and changes of nature. Therefore, silviculture is usually far more the imitation of the natural processes of forest growth and development, than of completely substituting a new stand for them.

Silviculture as a Preindustrial Construct

Silviculture, as a practice of cultivating and growing vegetation within forests and woodlands, has a much longer history of development and learning over thousands of years than its more recent transformation into a science. The most ancient form of silviculture was, and still is in the more remote forests of the world, a part of what is called **swidden agriculture**. It is a temporary intensive cultivation of a patch of cleared forest for food crops, which is then either abruptly or more slowly relinquished back to forest through succession. It is widely practiced in the more remote forest regions of the world and can be a very sustainable form of agri-silviculture.

Such systems have different lengths of successional development before returning back for cultivation. They are largely dependent upon the soil's inherent capacity to become fertile again. After cultivation of arable crops is stopped, many swidden systems incorporate tree

plantings and intentional natural regeneration methods that are then followed up with the tending and harvesting of tree crops. Trees that provide fruits, medicinals, and building materials can be harvested with the growth of the new forest into the future until the next cycle of forest clearance and cultivation (Box 1.1). People who practiced swidden agriculture knew exactly where, when, and what tree species to cultivate within a swidden. Many swidden systems can be regarded as very sophisticated, much more so than the credit given them by western science and the modern day practice of agriculture and forestry.

In particular regions of the world, agriculture developed into a permanent practice of cultivation allowing

people to settle. These regions can be considered the birth places of modern agriculture and of the origins of civilization (Fig. 1.1). In addition to permanent agriculture came silvicultural practice to produce the goods and services desired from these agricultural systems. Such systems resulted in complex land-use practices with a mixture of intensive to non-intensive treatments reflecting the inherent productivity gradient across a landscape (Box 1.2).

Across most of Europe and the British Isles up to the 18th century, the monarchy, the church, or the nobility held the land rights to hunt and to extract large timbers for shipbuilding and construction. Peasant and tenant

Box 1.1 Examples of preindustrial silviculture.

Swidden Cultivation System of the Yanomami in Brazil

The Yanomami Native Americans are one of the largest tribes in Latin America, straddling the borderlands of northern Brazil and southern Venezuela. The combined Yanomami territories of Brazil, comprising 23.7 million acres (9.6 million ha), and Venezuela, comprising 20.3 million acres (8.2 million ha), form the largest indigenous lands in the world (Chagnon and Gross, 1973). The lands are under threat from goldminers, cattle ranchers, and poor national government enforcement. The Yanomami live in relatively large communal houses called yanos. Men hunt and fish for game, providing about 10% of the food; women farm, providing about 80%. Only about 4 hours of work per day is necessary to maintain their way of life. Villages

periodically move within the territory about every 30 years to accommodate the shifting agricultural systems. Large gardens are cleared by the men from primary forest (old-growth) and crops (cassava, sweet potatoes, plantains, beans, corn, squash) are cultivated by the women for only 2–3 years because the soils are so infertile (Fig. 1). New gardens are then created in another patch of primary forest. Old gardens are used for hunting animals that like early successional habitat, harvesting insect grubs feeding upon young growth, and harvesting fruit, medicinals, and vines for cordage and basketry (Nilsson and Fearnside, 2011). It usually takes no longer than 2 hours walk to get to a garden from the village. Several gardens are worked at the same time. In other areas, the Yanomami have old groves of fruit



Box 1.1 Figure 1 An aerial view of swidden cultivation in the Amazon comprising a patchwork of current and abandoned fields. Source: R. Butler, 2008. Reproduced with permission from Rhett Butler/mongabay.com.

Box 1.1 (Continued)

trees planted and then protected from years ago. The total number of plant species used by the Yanomami is well over 500 and cater to every necessity of life ranging from tooth-picks, to foods, to medicines, to fish poisons. Hunting for different purposes is carefully zoned across the forest for different kinds of game and for hunting at different seasons and even times of day. Other zones are restricted as game preserves. All of this means there is an extensive trail network for the different hunting and gardening practices.

Cultivation Systems of Native Americans in Eastern North American Oak Forests

Indigenous peoples of North America strongly influenced the landscape vegetation of the eastern oak forests of the United States. They did this by cultivating crops. However they also manipulated tree density and species composition to increase mast and game populations, to encourage easy woodland travel, and to reduce pests and diseases. Eastern tribes cultivated maize, beans, squash, and tobacco, often on a large scale, and sited these clearings on fertile soils most suitable for agriculture, usually in large river flood plains. Early explorers reported extensive areas of cultivation. In 1616, Smith remarked that the Massachusetts coast “shewes you all along large cornfields” and “many lles all planted with corne” (Day, 1953). In New England, cultivation shifted after soil exhaustion and more forest had to be cleared for new fields. This kind of cultivation created a patchwork of successional ages and structures (Cronon, 1983). In addition to intensively managing agricultural fields, Native Americans managed forests to create open savannah woodlands with

grassy understories and widely spaced trees. These woodlands were primarily composed of fire-adapted, masting species such as oaks, chestnuts, and hickories. In 1525, Giovanni da Verrazzano traveled 15–18 miles inland from Narragansett Bay, Rhode Island and observed open plains, completely free of trees, extending miles, as well as woodlands that “might well be traversed by an army ever so numerous.” (Verrazzano, 1825 in Day, 1953 p. 334). Other early explorers echoed such reports and also noted the large and numerous fires, which were ignited annually or twice a year in the spring and fall. These fire-maintained savannahs had several purposes, chief among them being the provision of food. Frequent fires favored nut-producing hardwoods, such as oaks, particularly the sweet acorn-bearing white oaks, chestnuts, hickories, walnuts, and butternuts, and maintained them in open conditions, maximizing sun exposure and thus mast volumes. Nut collection was also facilitated by the open understory. The growth of fruit-bearing understory plants such as blueberries, raspberries, strawberries, and hazels was also encouraged. Not only did these savannahs feed humans directly but they also supported abundant game populations (Abrams and Nowacki, 2008). Denton (1670) reported “stately Oaks” with “broad-branched-tops” and “grass as high as a man’s middle, that serves for no other end except to maintain the Elk and Deer, ... then to be burnt every spring to make way for new” forage (Day, 1953). Just as frequent fires increased game populations, they reduced populations of pests such as rodents, ticks, and fleas (Williams, 2005). In fact, the Narragansetts listed the “destroying of vermin” as a reason for burning in their discussions with Roger Williams in 1643 (Day, 1953).

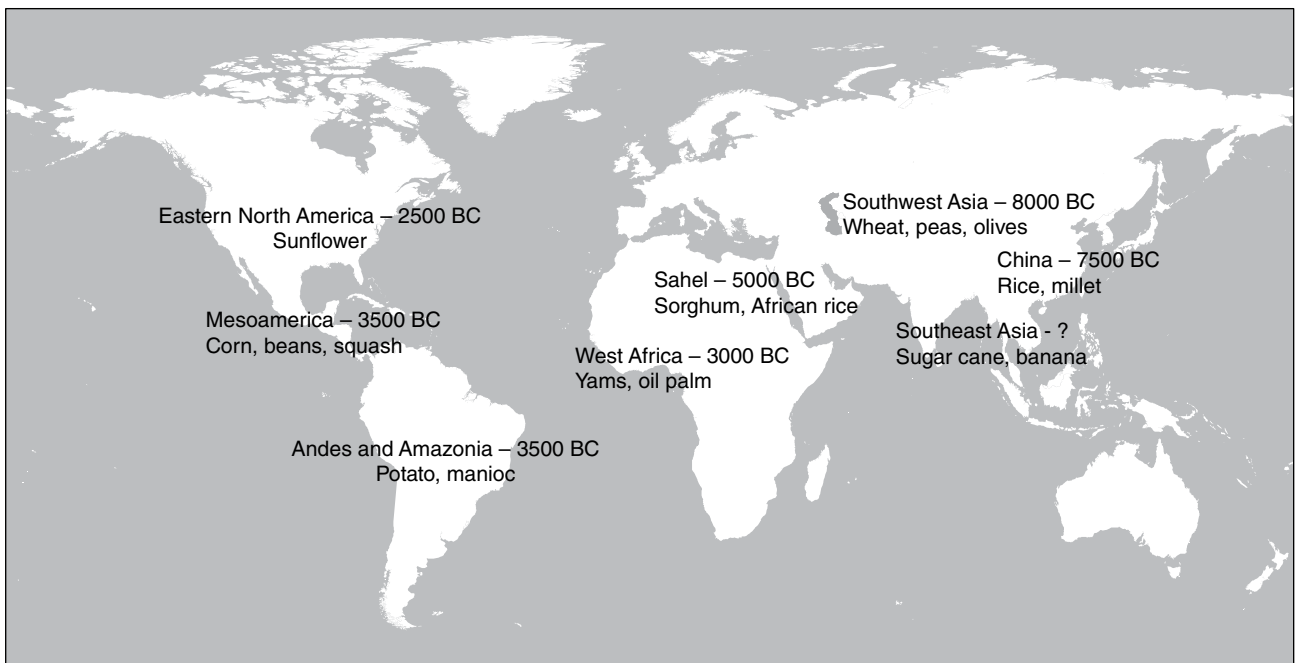


Figure 1.1 Early agricultural civilizations of the world and their main crops. *Source:* Adapted from mapsopensource.com under the terms of the Creative Commons Attribution Licence, CC-BY 3.

Box 1.2 Indigenous silvicultural systems of ancient civilizations.**Maya of the Yucatan, Mexico**

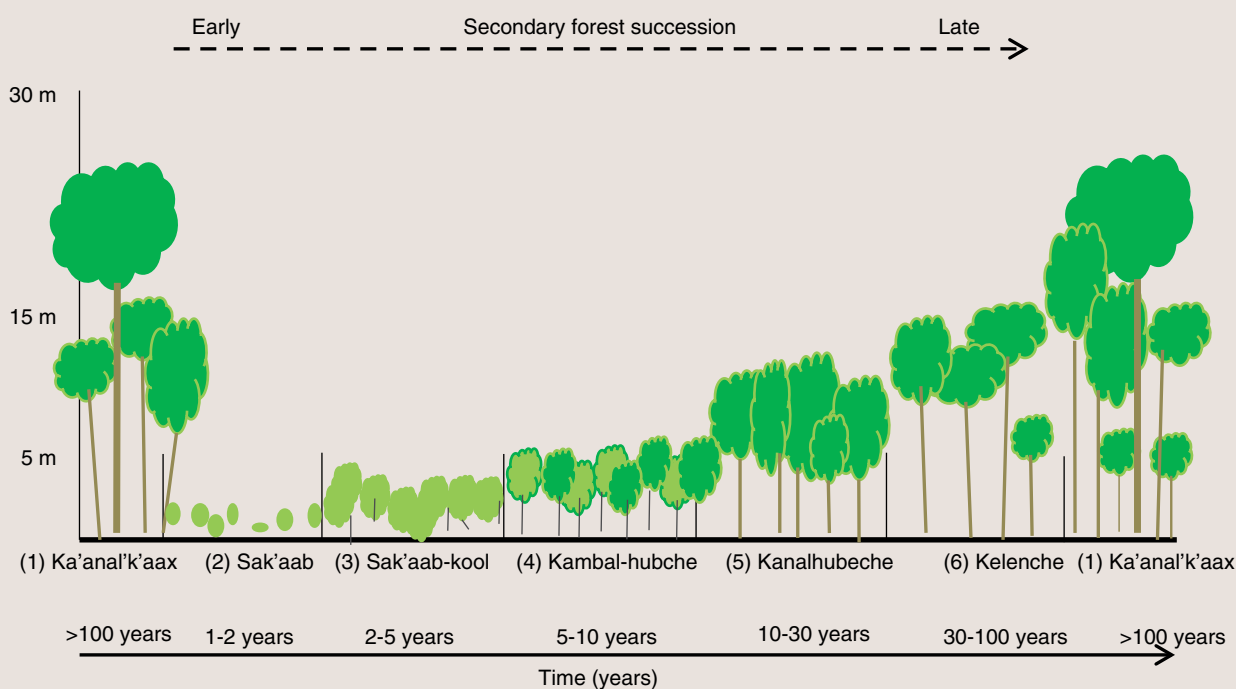
The Maya civilization of Mesoamerica can be defined by two periods: the pre-classic period (2000 BC – 250 AD) established the first complex cities and the cultivation of staple crops (maize, beans, squash, and chili peppers); and the classic period (250 AD – 1000 AD) which saw the rise of a large number of city states interconnected by trade highways. This period was the zenith of complex agricultural and silvicultural systems. Trees were incorporated into almost all components of an intensively managed landscape. Hydraulic systems were used to both drain and irrigate the staple crops of beans and maize. Swamps were drained and fields raised with trees planted along the bunds and the channels used for aquaculture. Upland slopes were terraced and irrigated for cultivation and shade trees used for stabilization and protection. Further away on poorer upland soils, the milpa swidden system (see Fig. 1) that is still used by the descendants of the Maya was widely practiced to cultivate crops (corn, beans, squash) for a short period of time. In preparation, second-growth pioneer species were slashed at about a meter high to open up the ground to sunlight. Annual crops were dibble planted for several years while the pioneers re-sprouted and were used as shade and fuelwood. Enrichment planting of cacao often follows annual crop cultivation using the shade of the second growth for

establishment. Most milpas had an arboreal shelterbelt that was protected around the margin as a conservation strip. Around the households forest gardens cultivated a wide variety of fruit trees (e.g., *Brosimum alicastrum*, *Chrysophyllum cainito*, *Manilkara zapota*, *Spondias* spp.) and medicinal herbs and spices. These tree gardens were called Pet Kot. In addition, the Maya had sacred forests and groves around temples that were protected and where Maya harvested a variety of medical plants. Over one third of the flora have known medicinal value. The Maya civilization collapsed about 12,000 AD from unknown causes – possibly warfare, disease, or from land degradation and soil erosion or some combination. The second growth that has come back within the region is reflective of this historic land use dramatically enriched in species from purposeful Mayan silviculture.

For more information read: Gomez-Pompa, A. 1987. On Maya silviculture. *Mexican Studies*, 3(1): 1–17.

Sinhala of Northeastern Sri Lanka

Southern India has a very sophisticated history of forest and crop cultivation dating back to 2000 BC. The start of civilization in northeastern Sri Lanka dates back to about 500 BC with the arrival of the Sinhala people and the Prince of Vijaya from North India. Northeastern Sri Lanka has a monsoonal climate that comprises a long dry season and a



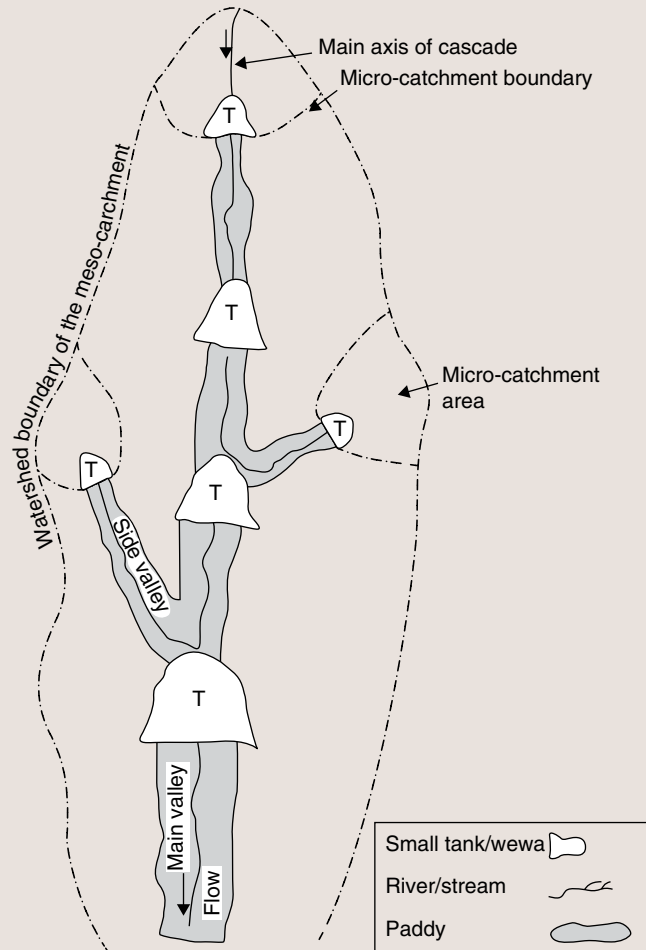
Box 1.2 Figure 1 A diagram depicting Maya swidden succession. Maya succession nomenclature are (1) Ka'an'al'k'aax: old tropical forest (30 or more years old); (2) Sak'aab (or Sak'ab): second year milpa; (3) Sak'aab-kool: Recently abandoned milpa; early succession; (4) Kambal-hubche': 5–10 years old succession; (5) Kanalhubche': 10–30 years old succession; (6) Kelenche': 30–100 years old succession; (3-6) Hubche': secondary vegetation. *Source:* Adapted from Gomez-Pompa, 1987.

Box 1.2 (Continued)

shorter wet season. The people learned to manage water by a complex system of reservoirs (called tanks) that were arranged as a cascade that comprised an interconnected series of tanks that reused water for irrigation within a single watershed and that gradually increased in size progressing from the upper to the lower parts of the watershed (Figs. 2, 3). These systems developed over a 2000-year period culminating in about 30,000 tanks in a dry zone area of 15,500 mi² (40,000 km²). The undulating topography with its ancient impermeable metamorphic geology and relatively thin to bedrock soils that were weathered *in situ* make this landscape perfect for water capture and irrigation. The Tank Cascade System allowed two to three crops of rice to be cultivated per year in the lower lying land beneath each tank by a system of irrigation channels and fields. Some of the lower lying fields were purposely left for the birds to draw them away from those that were cultivated. The tanks themselves were lined with riparian forests and vegetation that served to protect the sides of the tank and to serve as a wind barrier. Potable drinking water was purified through a system of channels drawn from the tank separate from the irrigation

systems. These channels flowed into small wetlands in which the water was cleansed of sediments and pollutants. The villages and houses were organized immediately outside but adjacent to the floodplain. Individual households had kitchen gardens and patios surrounding the house where many of the perennial light-loving shrubs (banana, plantains, citrus) and herbs (curry plant, cumin, cardamom) could be cultivated. Surrounding the kitchen garden, tree gardens of a variety of shade-loving long-lived species (mango, coconut, jak fruit, tamarind, areca palm) were grown for fruit and timber. Upstream and at higher elevations of the catchment areas beyond the tree gardens, second-growth forests were managed through swidden cultivation (called Chena) for upland dry crops, firewood, and medicinals. Beyond these second-growth forests, in the most remote and highest parts of each watershed catchment, existed relatively undisturbed forests whose main purpose was to yield subsurface water flow into the dry season through deep infiltration. These areas were carefully controlled by the community and by the temple monks. Many of these forests were regarded as sacred and completely protected from use.

Box 1.2 Figure 2 An example of a tank cascade for a single watershed in northeast Sri Lanka. *Source:* Geekiyanage, 2013. Reproduced with permission of Elsevier.



(Continued)

Box 1.2 (Continued)

Box 1.2 Figure 3 The ancient managed landscape of northeastern Sri Lanka. The tank cascade systems can be seen in the distance. Adjacent and downstream areas to the tanks are the cleared lands for paddy cultivation. The settlements with complex tree gardens are adjacent to the tanks on the upper ends along the margin in the middle of the picture. On higher ground is sacred forest associated with the temple that serves as watershed protection. *Source:* Mark S. Ashton.

farmers had grazing rights for livestock, rights to gather fuelwood and litter, and rights to some timber for building, but they were obliged to pay a fee for these rights. Similar land right arrangements between nobility and the peasants were present in northeast Asia (China, Korea, and Japan) during this time. Particularly innovative and forward-thinking nobles started the systematic and purposeful management of forests for timber on such lands as early as the 14th century in Germany (Nurenburg) and by the 16th century in Japan. Forests were divided into sections, with the ideas of sequentially harvesting for timber over time and purposeful regeneration. In the 17th century, the ideas of John Evelyn and Jean-Baptiste Colbert led to the first plantations in the British Isles and France respectively. Each of these men were sent by their respective governments to assess the depleted state of the forests in their countries.

Prior to the industrial revolution, one predominant form of silviculture and forest type was associated with permanent agriculture. These were coppice or sprout origin forests. Still throughout much of Africa, Asia, and

Central America, forests and woodlands are all managed based on sprout growth to produce fuelwood for cooking and heating, litter and mulch for agricultural fields, timbers for buildings, artisanal wickerwork and poles and posts for farm infrastructure (Box 1.3). It is amazing that in this modern age of technology, the majority of the world's population still relies on fuelwood for energy and forest leaf litter as a source of soil fertilizer.

Silviculture as a Western Construct

It was with the birth of the industrial revolution, particularly in central Europe, that forest lands were decimated for timbers to support underground mining for coal, iron ore, and salt, and for fuelwood. This was to create charcoal to power the furnaces for the smelting of iron ore, evaporating water to extract salt, and to provide heat and cooking fuel for a burgeoning and urbanizing populace that had come for work in the cities. Whole areas of central Europe were converted from subsistence agricultural and coppice woodland systems to waste-

Box 1.3 A coppice and wood pasture system in medieval Europe.

Ancient wood pastures, often identified today by the presence of old pollarded “veteran” trees or land records, were common throughout Europe since at least the Neolithic Age. In England, documentation dates back 1200 years (Rackham, 1996). While the practice was largely abandoned several centuries ago, wood pastures do persist. While most were converted to other land uses, some have “infilled” with younger cohorts of trees and are now barely discernible, while others are preserved as living museums, and fewer still are actively managed as wood pasture.

A rich literature has accumulated, particularly in the British Isles, on the social and ecological history of these wood pastures (Fig. 1) and their role in a complex landscape of commons, forests, parks, and woodlands. The grazing of animals and growing of trees on the same land has been sustainably practiced for centuries (Rackham, 1998). The nuances of these pasture systems vary by region and make use of different species and techniques to meet location specific needs. Two broad categories of wood pastures can be distinguished: (1) coppice meadows and (2) pollard meadows (Hæggström, 1998). Coppice meadows are comprised of multi-stemmed trees that are cut at intervals of some decades to produce stakes, poles, firewood, and wood for carpentry. Hay is produced between the coppice trees. Livestock are often excluded from these meadows at least for a period of several years to give recently cut trees time to grow above the browse line. Pollard meadows are used to produce fodder

from tree cuttings while livestock are allowed to graze between the trees. These trees are cut at 3–5 ft (1–1.5 m) to keep them safe from browse. Cuttings are often dried and stored as winter fodder or used directly. Shredding is an alternative pollarding technique where only the lateral branches are cut and the top of the tree left intact. Differences in pollarding technique arise from variations in species autecology and climate.

A case study by Bargioni and Sulli (1998) on the Valdagno farm on the eastern slopes of the Lessini Mountains, Italy provides an illustrative example of pollard meadow management. The local climate exhibits long, cold winters with short, hot summers and an annual precipitation of 58 in (1489 mm). The farm breeds cows and at any given time has 4–5 milking cows, 2–3 sheep, 25–30 chickens, and one pig. The 10–12 acres (4–5 ha) is 47% grassland, 29% wooded pasture, and 10% coppice woods with the remaining 14% split between high forest and farm infrastructure. The Valdagno farm faces constraints on its productivity. The 4–5-ha farm encompasses only 2 tillable hectares, which significantly constrains total productivity. To help overcome this limitation, vertical space is cunningly utilized to expand animal husbandry.

Between May and October, cows are grazed in the wooded pastures and excluded from the winter hay-producing meadows except for the time following the second mowing. The animals are sustained through the long winters with a mixture of meadow hay and tree fodder. Two kinds of fodder



Box 1.3 Figure 1 An ancient sweet chestnut (*Catanea sativa*) wood pasture in Monmouthshire, Wales. Source: A. Miles, 2012. Reproduced with permission from A. Miles.

(Continued)

Box 1.3 (Continued)

are produced on the farm. *Broco* is produced by shredding leaves directly from the tree for immediate use, while *frascari*, faggots of branches and leaves, are collected and preserved for winter nourishment. Ash (*Fraxinus* sp.) is the most important species for fodder production, while alder (*Alnus* sp.), poplar (*Populus* sp.), and hazel (*Corylus* sp.) are commonly used to produce *broco*. Beech (*Fagus* sp.) is a common spring fodder as its shoots appear before grass emerges from under the forest cover.

Pollarding commences when trees are between 7 and 12 in (18–30 cm) in diameter and are 7–8 years old. At this time, the leader is cut causing the stem to bifurcate and

all branches along the stem are cut at 6–8 in (15–20 cm) from the main stem leaving stubs. These stumps will produce the *frascari* and can be used as ladder rungs for the farmer to climb the tree in the future. Each year, *broco* is produced from the top crown while every third year the stems, which are 1.5 m long at this point, are cut to produce *frascari* bundles in late August. Trees are cut and replaced when their tops stop producing leaves, usually at a diameter of 10–12 in (25–30 cm). These pollarding techniques have enabled the Valdagno farm to take advantage of vertical space and sustain itself despite a shortage of tillable land.

lands in order to supply the wood necessary for this development. As a result in the state of Hesse, Germany, George Ludwig Hartig envisioned the first school of forestry for reforestation in 1787. Later, Heinrich Cotta, who has been attributed the name “pioneer of forestry”, started a forestry school in 1811, in the town of Tharandt, near Dresden, Saxony. His school and his teaching became the foundation for German forestry and its later

influence around the world. The notion of teaching forestry and the idea of forestry schools spread in the late 18th century to Russia, Austria, Sweden and France. Spain opened its first Forest Engineering School in 1844 in Madrid, and the British government commissioned Sir Dietrich Brandis, a student of Cotta, to start the Indian Forest Service and a School of Forestry at Dehra Dun (Box 1.4).

Box 1.4 The development of the Indian Forest Service and Sir Dietrich Brandis.

Sir Dietrich Brandis was born in Germany where he studied botany at Copenhagen, Göttingen, Nancy, and Bonn (Fig. 1). At the behest of Lord Dalhousie, Governor of British India, he was asked to take on supervision of the famous native teak forests of Burma in 1856 (Milward, 1947, Underwood, 2013). He developed the “taungya system” whereby villagers were allowed to cultivate vegetables in between planted trees and in return they weeded and protected the new plantings (Fisher, 1910). This has now been repeated worldwide and is an agroforestry practice that can involve communities in tree planting. In 1864 he became the first Inspector General of the Indian Forest Service. He founded the Imperial Forest School at Dehra Dun in 1878 to formally educate the local peoples in scientific forestry (Fisher, 1904). He wrote a treatise on Forestry in British India and the book “Indian Trees” and documented and described sacred groves throughout India. He was among the first to acknowledge the relationship between forest protection and involving local peoples. For his service to the British Empire he was knighted and retired back to Germany where he met future German foresters as well as Gifford Pinchot and Henry Graves. Pinchot relied on Brandis for advice in setting up the nascent US Forest Service. He died at the age of 83 in 1907. The model for modern forest management in the United

States, Britain, and Australia lies in the practices of the Indian Forest Service (IFS) that Brandis started (Pyne, 1997; Oosthoek, 2007).



Box 1.4 Figure 1 Sir Dietrich Brandis. Source: Forest Research Institute, Dehra Dun, India.