Possible silvicultural systems for use in the rehabilitation of poorly performing pole-stage broadleaf stands – Coppice-with-standards

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Abstract

This paper is a review of the coppice-with-standards system, a system that may have potential for the rehabilitation of some poorly performing pole-stage broadleaf stands. The system was once a very common system throughout Europe, producing much needed fuelwood and sawlog. Its decline in Ireland, the UK and elsewhere was primarily due to market forces. This review was conducted because the system may have potential once again due to the recent increased demand for firewood. Coppice-with-standards can provide material of various sizes to supply local demand for fuelwood, pulpwood, fencing material and sawlog. The system also has non-market benefits such as amenity and biodiversity values. One disadvantage of the system is that it requires greater silvicultural skill to manage to a high standard. The coppice-with-standards system is being trialled as a means to rehabilitate a poorly performing 19-year-old stand of ash:oak mixture.

Keywords: *Broadleaf silviculture, management, coppice-with-standards, rehabilitation*.

Introduction

As part of a Teagasc 5-year COFORD-funded research programme on the silviculture of broadleaf plantations (the B-SilvRD project) with UCD, silvicultural systems for the rehabilitation of poorly performing pole-stage (10 to 20-year-old) stands are being investigated. One such system being considered is coppice-with-standards. The history of coppice-with-standards, its management, species suitability, products and yield from the system, and its advantages and disadvantages are reviewed in this paper.

Coppice-with-standards

Coppice-with-standards is a silvicultural system that produces a multi-storied stand consisting of a lower storey of an even-aged coppice underwood and an uneven-aged partial upper storey of standard trees grown at wide spacing which is treated as high forest (Matthews 1989, Nyland 2002, Harmer 2004). The lower storey is cut regularly to produce small material while the objective of the upper storey is to produce large timber. The system is also sometimes called "compound coppice" or "stored coppice". In French it is "taillis sous futaie" and "taillis compose"; in German "mittelwald" and Spanish "cortas en monte bajo con resolves" or "monte medio".

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History

Oak (*Quercus* spp.) coppices were probably not uncommon in Ireland before modern forestry (Rackham 2010). Hayes (1794) refers to oak being managed as coppice-with-standards in Ireland. It was at one time the principal system applied to the growing of hardwoods in Great Britain (Forbes 1904, Guillebaud 1927, Begley 1955). The system has a long history of use in Europe and has only fallen out of favour during the last century. A form of coppice-with-standards appears to have been practiced in Germany from about 600 A.D. (Troup 1928). The standards consisted of forage-yielding species such as beech (*Fagus sylvatica* L.), oak and fruit trees which provided some sustenance to the cattle and pigs that were allowed to graze in the stand. Forest grazing within coppice-with-standards was still in evidence in the 19th century in Germany (Groß and Konold 2010). There are records of the system being used since the 12th century in Melton Constable Park, Norfolk, U.K. (Troup 1928) and it was the principal broadleaf silvicultural system in Great Britain up to approximately the end of the 19th century. Evelyn (1670) refers extensively to coppice management in Britain. In Ireland industrial development, particularly glass making and iron smelting, later began to reduce forest cover significantly. Many industries, from salt-making to iron-smelting, from pottery to dyeing, resulted in a great demand for charcoal for use in their furnaces (Neeson, 1991). In England, coppicing was practised by ironmasters to ensure a continuous supply of the best charcoal, derived from twenty-five-year-old oak coppice. All the known ironmasters in Ireland were Englishmen and were likely familiar with coppicing. McCracken (1971) argues that, except in Wicklow, no such management was carried out in Ireland and that, if it had, the woods could have been preserved. However, Rackham (2010) posits that coppice-woods could have been present in a large scale at one time because Viking buildings in Dublin were made extensively of wattle. House walls, wooden pathways and property fences would all have been made of woven hurdle panels and would have required vast quantities of long, straight hazel (*Corylus avellana* L.), willow (*Salix* spp.) and ash (*Fraxinus excelsior* L.) rods or underwood (O'Sullivan 1994). The Civil Survey (1654-6) records "underwood" and "copps" (Tomlinson 1997), indicating that some form of coppice management was being carried out. The earliest record of coppice management (i.e. rotational felling of underwood in fenced woods) from the Watson-Wentworth estate in Co. Wicklow was 1698 (Jones 1986). Young (1780) also mentions coppicing in the logs of his travels around Ireland in the 18th century, some with forty-year rotations. The coppice-with-standards system was also being employed on some Kilkenny estates early in the 19th century (Tighe 1802), though this appeared to have decreased in popularity, with some former coppices having been abandoned or neglected by this stage. A survey of Co. Wicklow woodlands in 1903 demonstrated that the system was still popular there, with almost 60% still being managed as coppice-with-standards (Nisbet 1904). Attentive landlords would fence copses to protect the regrowth from grazing animals. One of the first laws enacted on forest management was in the 16th century, which required enclosure for four years following coppicing (Bosbeer et al. 2008). Many scrub woods of the Watson-Wentworth estate were managed as coppice woods, but they were not fenced and it was this that distinguished them from the coppices (Jones 1986). A survey of the

Watson-Wentworth-Fitzwilliam estate coppices, carried out in 1724, often remarked on the presence of fencing (Carey 2009). A similar survey of 1728 described four coppices as having been destroyed by cattle (Carey 2009).

The demand for coppice produce rapidly declined in much of Europe from about 1870 until, by the early 20th century, it almost ceased to exist (Savill et al. 1997). The introduction of new inventions and technologies during the industrial revolution made available cheaper and better alternatives to the traditional forest produce. Efficient transport provided by railways also enabled coal to be taken to the countryside, largely replacing fuelwood. In Britain, the demand for large timbers for ship building declined and the use of coal and coke increased in industry, all adding to the demise of coppice-with-standards. While the data in Table 1 are not directly comparable, they do indicate a trend of decrease in the area managed using coppice-with-standards in Britain during the last century.

It was also fairly widely practiced until the middle of the 19th century in Switzerland (Troup 1928). In the early 20th century, almost all of the private and communal broadleaved forests in France, about 35% of the total forested area, were managed as coppice-with-standards (Troup 1928). Demorlaine (1907) provided statistics for the area of forest in France managed under coppice-with-standards. The total of over 5 million ha was slightly more than half of the total forested area, 4.9 million ha of which were privately or communally owned. Even in the 1980's, there was still a substantial area (3.9 million ha) managed in France using this system, of which over 2 million ha were privately or communally owned (Auclair 1982). The system is still widely used in France (Garfitt, 1995), where it is the most common silvicultural system (Du Bus de Warnaffe et al. 2006). It is also quite common in Belgium. Rondeux (1991) stated that the major stand types in private woodlands in the Wallonian region were conifer (55%), coppice-with-standards (20%), coppice (11%) and hardwood high forest (14%). In Austria, half of the ca. 150,000 ha of oak stands are managed as coppice or coppice-with standards (Hochbichler 1993). Over 3.5 million ha of Italian forest, 43% of the total forest area, are currently managed as coppice-with-standards, where the standards are left to produce seed for stump reproduction (Piussi 2006). It is surprising that a silvicultural system that is still in extensive use in parts of continental Europe was once relatively common in Ireland and the UK, but has so fallen out of favour during the last two centuries.

Management

The management of coppice-with-standards requires greater silvicultural skill than the majority of other silviculture systems. Generally, the forest is arranged into a number of coupes, also known as cants, corresponding to the rotation length of the coppice, such that one coppice coupe can be harvested annually. The coppice rotation length is dependent on the species, site productivity and product size required, but is normally from 10-30 years. The overstorey rotation is a multiple of the coppice rotation such that, if the coppice rotation is r years, the overstorey rotation could be $2r$, $3r$, $4r$, $5r$ years etc. As each annual coupe in turn becomes due for felling, the following operations are carried out in it (Troup 1928, Matthews 1989):

Table 1: *Estimated areas (000s ha) of simple coppice and coppice with standards recorded in surveys carried out in Britain during the 20th century (after Harmer and Howe 2003).*

Survey Year	England		Wales		Scotland		Britain			
	C	S	C	S	C	S	C	S	Total	Comments
1905[a]	215		6		9				230	Data from Board of Agriculture returns.
1913[a]	208		8		11				227	
1924[b]	31	163	7	8	2	2	40	173	213	Based on questionnaires, minimum area of each woodland = 0.8 ha.
1947	41	91	7	1	<1	<1	48	92	140	Very detailed field survey, minimum area of each woodland = 2 ha, needed minimum of 15 standards ha^{-1} to classify as **S**.
1965	18	10	<1	n/a	n/a	n/a	18	10	29	Field survey, minimum woodland area 0.4 ha, minimum of 15 standards ha-1 for **S**, maximum coppice stem diameter 19.4 cm at breast height (≡ 6" quarter girth). Areas of different types of coppice do not include Forestry Commission's 840 ha, but this is included in the total.
1980	26	11	2	<1	<1	<1	28	12	40	Field survey, minimum area of each woodland = 0.25 ha, minimum of 25 standards ha^{-1} for **S**, maximum coppice stem diameter 15 cm DBH.
1997[c]	11	10	<1	n/a	<1	<1	12	11	23	As 1980, except minimum woodland area = 2 ha.

C = Simple coppice.
S = Coppice with standards.
[a] In 1905 and 1913 coppice types were not separated.
[b] Figures estimated from county data. Prior to 1924 data for Monmouth was included in totals for England.
[c] Data from National inventory of Woodland and Trees carried out between 1995 and 2000.
n/a None recorded in this survey.

Figure 1: *Coppice-with-standards. Underwood rotation = 20 years; Overwood rotation = 100 years. Numbers denote age of standards (Schlich 1910).*

1. the coppice is clear cut;
2. some existing standards are reserved for at least one more coppice rotation, whilst the remainder are felled;
3. a number of new standards of similar age as the coppice are selected from natural regeneration, preferably from seed origin, and reserved. If there is insufficient natural regeneration, then transplants can be used. Standards that have derived from seed origin are called maidens;
4. vacancies caused by the removal of standards or the death of coppice stools are filled up using seedling natural regeneration or transplanted seedlings to ensure a future supply of both coppice and standards.

The result of the above operations, after numerous coppice rotations, is a multi-aged stand that consists of an even-aged coppice understorey with a multi-aged overstorey, as illustrated by Figure 1. The age of each class of standard is a multiple of the coppice rotation age. The terms used to denote these classes are given in Table 2.

Table 2: *English, French and German terms used to denote the several classes of standards in coppice-with-standards (Demorlaine 1907, Troup 1928, Matthews 1989).*

Age class	English	French	German
1r	Teller	Baliveau, Baliveau de l'âge	Lassbaum, Lassreis, Lassreitel
2r	2nd class standard	Moderne	Oberständer
3r	1st class standard	Ancien (de 2^{e} classe)	Hauptbaum
4r	Veteran	Bisancien, Ancien (de 1ère classe)	Alter Baum, Altholz
5r	—	Vielle écorce (de 2^{e} ou 1ère classe)	—

Note: r = one coppice rotation

The key to successful coppice-with-standards management is getting the right balance of standards per ha and the right distribution of ages (Law 2001). The number of standards to be reserved will depend on (Cheyney 1942):

1. the target rotation age of the standards;
2. the target diameter at felling of the standards;
3. the shade cast by the standards and the shade-tolerance of the coppice species.

The percentage of the total area allotted to standards should be decided upon before any cutting is carried out (Hawley 1921). According to Mutch (1998) the crowns of the standards should not occupy more than one-third of the area, although Hart (1991) suggested that they should occupy 30 – 50% of the ground area. Obviously, this should vary depending on the density of shade cast by the overstorey and the shade tolerance of the coppice species. The area occupied by the standards should be apportioned equally amongst each of the age classes (Brown and Nisbet 1894, Crowther and Evans 1986, Harmer and Howe 2003). This requires that the number of stems of each age class is reduced with increasing age and canopy size (see Table 3). Harmer and Howe (2003) take this one stage further to illustrate how these numbers can be derived, when the proportion of the area is divided equally between the different age-classes of standard (Table 4). This assumes that the standards comprise 40% of the canopy cover.

Table 3: *Proportion of standards reserved by age-class.*

Age class of standard	1*r*	2*r*	3*r*	4*r*	5*r*
Brown and Nisbet (1894)	16	8	4	2	1
Schlich (1910)	20	12	3	2	1
Adapted from Troup (1928)	50	30	20	10	
Matthews (1989)	50	30	20	10	
Crowther and Evans (1986)	50	30	13	7	
Demorlaine (1907)[a]	80	50	6		
Decocq et al (2004)	*80*	*40*	15	5	

[a] Assumes oak on 50-year coppice rotation, 150-year sawlog rotation.

Table 4: *Number of standards of different age classes in coppice cut on a rotation of 20 years using data adapted from Crowther and Evans (1986) by Harmer and Howe (2003).*

Age class	Number of stems to remain (ha^{-1})	Approximate canopy cover (m^2)	
		Average Tree	Total
Teller	50	20	1,000
2nd Class	30	33	1,000
1st Class	13	77	1,000
Veteran	7	143	1,000
Total	100	30	4,000

According to Matthews (1989), a higher than normal number of tellers is sometimes reserved to protect young coppice shoots from frost. Once the risk of damage has passed, the tellers are thinned to their required number. In 1749, the stocking of standards in existing coppices of the Watson-Wentworth/Fitzwilliam estates in Co. Wicklow ranged from 9 – 129 acre^{-1} (14 - 195 ha^{-1}) (Jones 1986). This illustrated that there was great variability in the stocking standards.

Species selection

The underwood must consist of species that can tolerate some shade, produce satisfactory stool shoots and also be marketable in small dimensions (Köstler 1956). There is very little information on species choice for coppice-with-standards in Ireland. Rackham (2010) makes mention of remnants of sessile oak (*Quercus petraea* (Mattuschka) Liebl.) coppice in Co. Wicklow. Sessile oak is listed again by Jones (1986) as a constituent of coppice in Wicklow. Other species also used were birch (*Betula* spp.), hazel, ash, willow, alder (*Alnus* spp.) and holly (*Ilex aquifolium* L.). In addition to pure oakwoods, valley floors and lower slopes would have birch-hazel-oakwoods; higher elevations and steep slopes: birch-oakwoods without hazel; steep slopes with freely draining soils: ash-hazel-oakwoods; wet ground: alder and willow. In England, the understorey of coppice-with-standards usually consisted of a mixture of species including alder, ash, beech, birch, cherry (*Avium* spp.), elm (*Ulmus* spp.), field maple (*Acer campestre* L.), hazel, hornbeam (*Carpinus betulus* L.), lime (*Tilia × europaea* L.), oak, sweet chestnut (*Castanea sativa* Mill.), sycamore (*Acer pseudoplatanus* L.), sallow (*Salix* spp.) and aspen (*Populus tremula* L.), the last two regenerated from suckers (Matthews 1989). These species may also be suitable for use in Ireland. The underwood can also occur as a monoculture, particularly of ash, hazel, oak or sweet chestnut (Matthews 1989). The most common understorey species in England is sweet chestnut. Oak is the most common overstorey species (see Table 5).

Table 5: *Area (ha) of coppice-with-standards in England by principal species of both coppice and standards (Forestry Commission Census of Woodlands and Trees, 1979-82 (Evans 1984)).*

Principal species of standard	Principal species of coppice						Total	% of total
	Sycamore	Ash	Sweet chestnut	Hornbeam	Hazel	Other species		
Conifers	0	0	16	4	0	0	20	<1
Oak	97	173	4,897	1,594	1,444	2,728	10,933	95
Ash	8	20	0	88	21	0	137	1
Sweet chestnut	0	0	353	0	0	0	353	3
Other broadleaves	10	0	9	11	0	0	30	<1
Total	115	193	5,275	1,697	1,465	2,728	11,473	100
% of total	1	2	45	15	13	24	100	

The overstorey is suited to light-demanding species with rapid growth and sufficiently good, valuable timber that can compensate for the loss of increment in the underwood (Troup 1928, Köstler 1956) and may be the same as, or different from, the understorey species (Crowther and Evans 1986). The standards should ideally have strong apical dominance, thick bark, a deep root system and cast only light shade (Crowther and Evans 1986). In the Watson-Wentworth estate, the standards were mostly oak (Jones 1986), a species that casts a light shade which doesn't inhibit the underwood to a great degree (Bagneris 1882). It has also been suggested that oak was possibly grown as a standard in coppice in the Tullynally estate in county Westmeath in the 19th century (Lefort et al. 1998). Other species that Bagneris (1882) recommended for the overstorey are ash, the common elm (*Ulmus procera* Salisb.), sycamore and Norway maple (*Acer platanoide*s L.). Troup (1928) recommended ash, poplar, cherry, robinia (*Robinia pseudoacacia* L.) and birch as the most suitable species as standards due to their light crowns. However, it is believed in Britain that some open-crowned trees, such as ash and birch, make unsatisfactory standards because coppice grows poorly beneath them, despite their thin crowns; this may be due to their dense rooting near to the soil surface (Matthews 1989). However, Harmer and Howe (2003) postulated that ash and birch may be more suitable as standards than species such as beech, lime and, to a lesser extent, oak because they have lighter crowns and cast less shade on the understorey. Economically, ash may be particularly suitable in Ireland due to the market for fast-grown ash for hurley sticks and its inherent suitability for fuel wood. Light-foliaged conifers, particularly larch (*Larix* spp.), can also make suitable standards (Troup 1928, Köstler 1956). Species identified in the literature as not being suitable are beech, lime and hornbeam due to their heavy crowns (Bagneris 1882, Troup 1928, Crowther and Evans 1986, Harmer and Howe 2003) and hazel because it only grows to a maximum height of 12 m (Crowther and Evans 1986).

Yield and products

The coppice-with-standards system produces timber of various sizes from small diameter to large, which is suitable for various markets. Lanier (1986) provides an indication of the assortments possible in France from various silvicultural systems (see Table 6 below). The greatest proportion of product is fuel wood. Other coppice products include thatching spars, turnery products, pulpwood, round, cleft or sawn fencing, fence posts and charcoal, dependent on species (Evans 1992).

Table 6: *Summary of different assortments derived from forests in France (% of total production) from Lanier 1986).*

Silvicultural regime or system	Waste and small wood	Fuel wood	Pulp and board wood	Sawlogs and veneer logs
Broad-leaved high forest	18	34	17	31
Coniferous high forest	13	14	25	48
Simple coppice	15	65	20	0
Coppice with standards	16	58	20	6

Table 7: *Estimated diameter at breast height of different age-classes of standards of various broadleaf species.*

Age class		Teller	2nd Class	1st Class	Veteran
Number of stems to remain (ha^{-1})		50.0	30.0	13.0	7.0
Approximate average tree canopy cover (m^2)		20.0	33.0	77.0	143.0
DBH of standard (cm)	Ash	21.1	28.1	44.9	62.6
	Birch	25.2	34.1	55.3	77.5
	Cherry	21.3	30.7	52.9	76.2
	Chestnut	21.1	34.6	66.6	100.3
	Oak	21.3	30.5	52.4	75.4
	Sycamore	23.3	31.0	49.3	68.5

Using the data from Table 4 and the regression equations of Hemery et al. (2005) relating individual tree canopy area to DBH, the DBH of the standards of various species can be estimated (Table 7). This illustrates the different sizes of material that can be produced by the coppice-with-standards system and their associated quantities. Using oak as an example, after the second coppice rotation, 20 standards with approximately 21 cm DBH can be harvested, together with 17 standards with approximately 31 cm DBH, 6 with 52 cm DBH and 7 with 75 cm DBH. This is in addition to the coppice wood.

Insley (1988) made estimates of the likely yields of coppice wood in a coppice-with-standards system. Oak grown on a 20- to 35-year rotation would be expected to produce 3-7 m^3 ha^{-1} yr^{-1}, and for ash, sycamore and other hardwoods or mixed coppice on 20- to 25-year rotations, 6 – 10 m^3 ha^{-1} yr^{-1}. The preliminary yield tables for oak coppice, published by Crockford and Savill (1991), estimated that the mean annual increment to range between 2.3 and 11.1 m^3 ha^{-1} yr^{-1}, depending on site index and whether a 20-year or 35-year rotation was employed. Furthermore, Crockford and Savill (1991) concluded that mean annual increments of oak coppice would be similar to those expected from high forest plantation, but that they would occur at much earlier ages. The annual increments illustrated by Brown and Nisbit (1894) also largely concur with this assessment (see Table 8). Blythe et al. (1987) state that native broadleaves yield about 40 – 60 tonnes of air-dry wood per ha on a 20- to 25-year rotation. They calculate that 4 to 5 ha of coppice would be sufficient to supply the fuelwood needs (about 8 dry tonnes per year) in perpetuity to heat a typical house with cants 0.25 ha in size.

Decocq et al. (2004) describe the commercial management of hornbeam coppice with oak standards in France. The coppice was cut on a 30-year rotation and three quarters of the standards were also felled. The total volume extracted was approximately 200 m^3 (≈ 6.7 m^3 ha^{-1} yr^{-1}), retaining at least 80, 40, 15 and 5 standards ha^{-1} of 30, 60, 90 and 120-year-old trees, respectively.

Table 8: *Average annual increment in timber crops m³ ha⁻¹ yr⁻¹ (converted from Brown and Nisbet 1894).*

Kind of tree and method of treatment	Increment per category[a] (m³)					Age at maturity[b] (years)	
	I	II	III	IV	V	I & II	IV & V
HIGH-FOREST							
Oak	4.6 - 5.2	4.0 - 4.6	3.5 - 4.0	3.1- 3.5	2.6 - 3.3	160	120
Beech	5.2 - 5.8	4.4 - 5.0	3.8 - 4.3	3.1 - 3.8	2.6 - 3.3	(140) 120	90
Beech with spruce, etc.				4.2 - 4.6	3.8 - 4.2	…	100
Spruce	7.6 - 8.4	6.5 - 7.3	5.6 - 6.3	4.4 - 5.0	3.4 - 3.9	120	70
Scots pine	5.5 - 6.5	4.2 - 5.2	3.5 - 4.2	2.7 - 3.4	1.9 - 2.3	(120) 100	60
Birch	6.0 - 6.8	4.7 - 5.5	3.3 - 3.9	1.7 - 2.3	1.2 - 1.2	60	40
Alder	5.2 - 5.8	4.2 - 4.7	3.1 - 3.7	…	…	70	50
COPSE							
With many beech etc. in the overwood, and hardwoods as underwood	6.3 - 6.8	5.2	4.4	3.6	2.1 - 2.7	30	35
With oaks etc., as standards, and a mixture of hardwoods and softwoods as coppice	4.7	4.2	3.7	3.1	2.5	18	25
COPPICE							
Oak and hornbeam, mixed with other hardwoods and with hazel, etc.	4.8 - 5.2	4.2	3.6	2.8	1.9 - 2.1	15	20
Alders (marshy land)	6.5 - 6.9	5.5 - 5.9	4.2 - 4.7	2.7 - 3.4	1.6 - 2.1	25	35
Birches, pure or predominating	5.2 - 5.8	4.4 - 5.0	3.6 - 4.2	2.9 - 3.4	2.1 - 2.5	20	30

[a] Quality of the soil and situation relates to the suitability of the growing environment for the crop being considered, ranging from I (very good) to V (poor), and covers the productivity of the soil as well as an assessment of the existing stand on the site.

[b] Age at maturity relates to the age of economic maturity. On better classes of soil (I & II) the capital, represented by the land plus the growing stock of timber, in a high-forest will continue to show good profits for a longer time than can be yielded by poorer classes of land (IV & V). In the case of coppice, poorer classes of land require a longer rotation than more favourable classes of land to maintain the continuous productive capacity of the soil.

Advantages of coppice-with-standards

Coppice-with-standards can supply local demand for fencing material, pulpwood, fuelwood poles, charcoal, turnery wood and timber, all from one silvicultural system, because it can provide material of various sizes (Matthews 1989). The inclusion of coppicing within the system provides early returns (Troup, 1928) and since the standards are grown with their crowns entirely open, they grow very rapidly, resulting in the production of a few trees of exceptional size and value in a comparatively short time (Cheyney 1942). If ash is grown as the standard, thinnings of tellers and 2nd class standards could be used for hurleys if the butts have the required form. The cash-flow resulting from a well-managed coppice-with-standards system will be more stable than that from high forest because, in theory, identical volumes of timber of the various sizes will be harvested at the end of each coppice rotation, i.e. the same volume of tellers, 2nd class standards, 1st class standards and veterans will be harvested from one coppice rotation to the next.

Harmer et al. (2010) (see Figure 2 below) rate coppice-with-standards highly because it can provide timber, biodiversity and visual amenity benefits. From the viewpoint of nature conservation on lowland sites, coppice-with-standards is now regarded as being among the most desirable silvicultural treatments of broadleaves (Hart 1995). The standards provide a continuity of woodland conditions and a deep canopy, better protecting the soil than in the case of simple coppice (Troup 1928). Buckley and Howell (2004) reviewed the literature for sweet chestnut in England and concluded that to increase biodiversity in sweet chestnut stands, the age structure and species structure should be diversified. One method would be to introduce/maintain some standards within the stand. Some county councils in southern England (e.g. Kent and Surrey) consider traditional coppice-with-standards as the preferred management system for biodiversity in sweet chestnut (Buckley and Howell 2004). Coppice-with-standards was advocated by Towler and Barnes (1982) as the ideal management system for private woods in East Anglia. Their reasoning was that the system could fulfil the multiple objectives of woodland owners, providing a wide range of additional financial and other options, such as shooting game, farm shelter, small roundwood production for fuelwood or fencing, production of more valuable timber, landscape enhancement and wildlife conservation. Gascoigne (1980) wrote: *The growing of coppice-with-standards would in all probability be applauded by the public and planners on visual amenity grounds, would be welcomed by sporting landowners, be interesting to investors, and should silence the most telling criticism, that of the environmentalists and ecologists*. One would hope that this might be the case in Ireland. However, the coppice-with-standards system also has disadvantages compared to other more conventional silvicultural systems currently employed here.

Table 9: *Yields from some species of coppice (adapted from Begley and Coates (1961) by Harmer and Howe (2003)).*[a]

Species	Soil type	Number of stems ha^{-1}		Stools ha^{-1}	Maidens ha^{-1}	Age (yr)	Top height (m)	Yield (fresh weight t ha^{-1})		MAI (m^3 $ha^{-1}yr^{-1}$)
		≤ 5 cm	> 5 cm					≥ 8.75 cm	≥ 5 cm	
Site 1										
Sycamore	Sandy loam	1,275	2,500	475	50	16	12.3	47	67	
English elm				75	50					
Birch				50	100					
Site 2										
Ash	Gleyed calcareous clay	200	2,125	600	100	32	15	75	94	2.8
Birch				-	225					
Ash	Gleyed calcareous clay	500	2,300	600	450	32	13.5	102	126	3.8
Birch				-	50					
Site 3										
Oak	Sandy loam	350	1,575	425	50	37	12.6	190	216	5.1
Sweet chestnut				-	50					
Birch				-	50					
Oak	Sandy loam	200	1,425	400	25	37	13.8	155	158	3.6
Wild cherry				-	25					
Site 4										
Alder	Alkaline peat	1,425	3825	625	-	20	9.9	66	88	4.0
Birch				50	-					
Willow				25	-					
Alder	Alkaline peat	1,450	3,850	450	-	20	11.4	96	138	5.8
Birch				-	25					
Willow				25	25					

[a] Only oak was previously managed as coppice, for other coppice stools the stems were first growth from maiden stems. Yield includes maiden trees. Data for each species were from different plots on the same site. Species in bold type are the predominant species of coppice. MAI: mean annual increment.

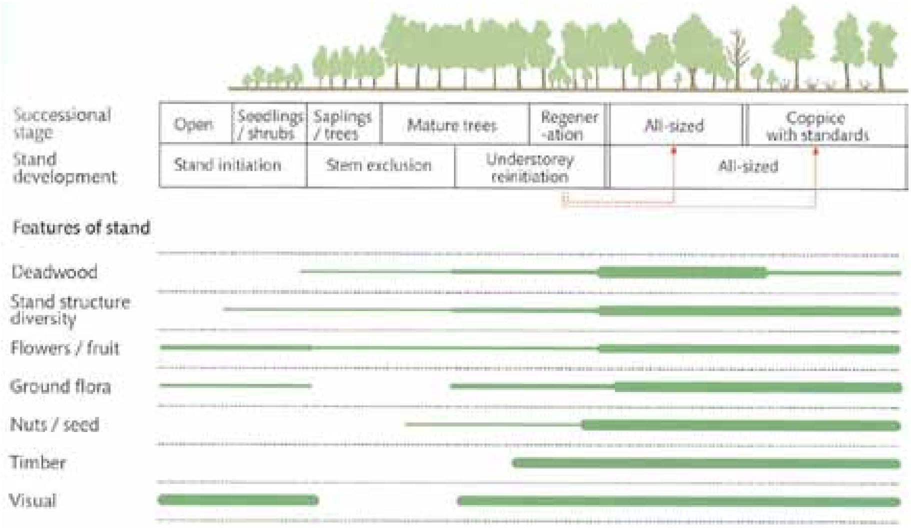

Figure 2: *Indicative relationships between stages of woodland development and relative value for a range of social, environmental and economic factors; wider bars indicate higher value. This shows general trends and does not apply to all woodland types. Adapted from Smith et al. (1997) by Harmer et al. (2010).*

Disadvantages of coppice-with-standards

Troup (1928) and Matthews (1989) both highlight the following disadvantages associated with the coppice-with-standards system:

1. The system is difficult to apply correctly. Maintaining the balance between standards and coppice and the correct distribution of standards of the different age classes is difficult. The selection of standards requires skill to implement in practice. A thick growth of coppice, which can reduce visibility, may make it more difficult to efficiently select the best quality stems in the higher canopies.
2. The standards are often more short-stemmed and branchy than trees grown in high forest, yielding a smaller proportion of clear timber. The amount of small material, including branchwood, can be approximately 75% of the total volume. Much of it will only be suitable for fuel.
3. Coppice grown under standards is generally not as vigorous as simple coppice.
4. Harvesting is more labour intensive than in high forest or simple coppice.
5. The coppice can be damaged by browsing deer. While older standards are windfirm, young standards suddenly freed from the intervening coppice are liable to be bent or uprooted by wind and snow. Smooth-barked standards may suffer from sun-scorch when exposed.

Cheyney (1942) agrees with Troup (1928) and Matthews (1989) that greater skill is required to manage coppice-with-standards correctly. However, the only other disadvantage that he provides, in comparison with simple coppice, is that a small proportion of the coppice may be suppressed by the standards. None of the above highlighted disadvantages is insurmountable, and may be of little consequence to private owners who want to manage their broadleaf stands for fuelwood and sawlog for home/farm consumption. The deleterious impact on stem form of the reserves may be improved by the use of careful selection of reserves and judicious pruning.

The potential for coppice-with-standards

The predominant product from coppice-with-standards, in terms of volume, may be firewood. The Irish market for firewood has grown by 35% over the period 2006 – 2010 with nearly 200,000 m^3 of firewood (roundwood equivalent) sold in 2010 (O'Driscoll 2011). With the current and expected future high demand for firewood, coppice-with-standards has increasingly greater potential as a multi-functional silvicultural management system in Ireland. Managed on a rotational basis, such that an area is harvested each year, the system will provide a constant cash-flow and product assortment. This will be looked upon favourably by owners.

Integrating a coppice-with-standards system within a broadleaf plantation will involve heavy thinning(s). Considering the numbers of standards presented in Table 4, achieving these numbers from a plantation planted at 1.5 – 2 m spacing may involve stumping back over 90% of the initial stems. Such an intervention may be most appropriate where the plantation quality is particularly poor. Plantation quality may be based on the number of potential crop trees (PCTs) per hectare (see Short and Radford 2008). PCTs are well-formed, vigorous, disease free stems. The application of coppice-with-standards may be best suited to plantations with fewer than 100 PCTs/ha.

The coppice-with-standards system is being trialled as a method of bringing a poorly performing pole-stage ash/oak mixture into a productive state by the B-SilvRD (Broadleaf Silviculture Research and Development) project, a 5-year COFORD-funded project. Two plots (B-SilvRD CWS1 and CWS2) have been established within a stand that was planted in 1992 in Co. Mayo and had been largely neglected since then. The original planting was 1:3 lines of ash: oak, respectively, with lines 2 m apart. Prior to intervention, the ash was in a situation resembling free-growth because the oak growth rate was poor, most likely due to suppression from the adjacent ash, and therefore there was little side competition. This may have increased the windfirmness of the ash stems relative to those growing in a monocultural situation. The stem form of the oak in the stand was also very poor (Figure 3). The best ash stems (93 stems ha^{-1} per plot) have been selected for retention as standards and the remainder felled. All the oak, except those very few stems that exhibited some potential as standards (33 and 120 stems ha^{-1} for CWS1 and CWS2 plots respectively), has been stumped back (Figure 4). It is hoped that the resultant oak coppice will exhibit greater vigour than the original planting due to the release from overhead competition, deeper and more extensive root systems and a better-developed forest soil. The conversion of the stand to coppice-with-standards may provide some flexibility for future management. If the coppice growth rate is acceptable, a decision can then be made to either single the coppice regrowth (remove all coppice regrowth except the best shoot per stool), resulting in a two-tiered high forest, or to maintain it as coppice-with-standards.

If the growth rate is unacceptable, then the coppiced area can be reconstituted via natural regeneration or it can be replanted with a suitable species to create a two-tiered high forest. Whichever choice is finally made, the end result will hopefully be an aesthetically pleasing productive mixed broadleaf stand that will become financially beneficial to the owner in later years. The stand will be managed and monitored and its potential to deliver some of these benefits will be examined in the B-SilvRD project.

Figure 3: *B-SilvRD CWS1 plot, a poorly performing stand of oak / ash mixture in Co. Mayo, prior to being converted to a coppice-with-standards system.*

Figure 4: *B-SilvRD CWS1 plot, a poorly performing stand of oak / ash mixture in Co. Mayo that has been recently converted to a coppice-with-standards system.*

Conclusions and recommendations

Coppice-with-standards was once a very common silvicultural system, but has fallen out of favour during the last two centuries, mainly due to the decreased demand for fuelwood and small dimensioned timber. However, with the recent increase in fuelwood demand, it is a system that may have greater potential once again. A considerable number of young broadleaf plantations in Ireland are currently underperforming, producing little quality sawlog timber. These forests may be suitable for conversion to this system. If the presence of 300 PCTs/ha^{-1} represents the lower limit for conventional thinning (Short and Radford 2008), then alternative silvicultural systems, which have the potential to increase crop value, need to be explored. Coppice-with-standards has the potential to:

- provide a sustainable supply of firewood and other merchantable small dimension timber; and
- vary stand structure and integrate over time a proportion of sawlog quality trees through the development of new PCTs, either by singling of coppice regrowth, natural regeneration seedlings or supplementary planting.

The B-SilvRD project is trialling the coppice-with-standards system as a means of bringing a poorly performing pole-stage broadleaf stand into productive use. The system provides some flexibility during the conversion process, so management practices can be modified depending on the success or otherwise of the coppicing. It is envisaged that the resultant stand will either be: oak and ash coppice-with-standards; two-tiered high forest with oak/ash stools singled; and/or two-tiered high forest with an underplanted/ naturally regenerated understorey. Whichever combination turns out to be the case, the future stand will hopefully be productive, sustainable, biodiverse and aesthetically pleasing. Further investigations of alternative broadleaf silvicultural systems are required, with a view to maximising the potential of poorly performing pole-stage broadleaf stands.

The main practical implications of this study are that:

- a reappraisal of the coppice-with-standards silvicultural system is warranted as it may have some potential due to the increased demand for fuelwood;
- it may also have the potential to improve poorly performing pole-stage broadleaf stands and supply a variety of products, including sawlog; and
- it will result in aesthetically pleasing, biodiverse, sustainable and productive stands.

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References

Auclair, D. 1982. Present and future management of coppice in France. In *Broad*leaves *in Britain*. Proceedings of a Symposium, Loughborough, Leicestershire, 7 – 9th July 1982. Eds. Malcolm, D.C., Evans, J. and Edwards, P.N., The Institute of Chartered Foresters, pp. 40-46.

Bagneris, G. 1882. *Elements of Sylviculture: A Short Treatise on the Scientific Cultivation of the Oak and Other Hardwood Trees*. Translated from the French (2nd ed.) by Fernandez, E.E. and Smythies, B.A. William Rider and Son, London.

Begley, C.D. 1955. *Growth and yield of sweet chestnut coppice*. Forest Record Number 30. Forestry Commission, Edinburgh.

Begley, C.D. and Coates, A.E. 1961. Estimating yield of hardwood coppice for pulpwood growing. In *Forestry Commission Report on Forest Research for the Year Ended March, 1960*. HMSO, London, 189-196. Cited in Harmer, R. and Howe, J. 2003. *The Silviculture and Management of Coppice Woodlands*. Forestry Commission, Edinburgh. HMSO, London. p. 49.

Blythe, J., Evans, J., Mutch, W.E.S. and Sidwell, C. 1987. *Farm Woodland Management*. Farming Press Limited, Ipswich.

Bosbeer, S., Denman, H., Hawe, J., Hickie, D., Purser, P. and Walsh, P. 2008. *Review of Forest Policy for the Heritage Council*. May 2008. http://www.heritagecouncil.ie/fileadmin/user_upload/Publications/Landscape/Forest_Policy_Review_05-08.pdf [Accessed September 2012].

Brown, J. and Nisbet, J. 1894. *The Forester. Vol. II*. William Blackwood and Sons, Edinburgh and London.

Buckley, P. and Howell, R. 2004. *The Ecological Impact of Sweet Chestnut Coppice Silviculture on Former Ancient, Broadleaved Woodland Sites in South-east England*. English Nature Research Report 627. English Nature, Peterborough.

Carey, M. 2009. *If Trees Could Talk*. COFORD, Dublin.

Cheyney, E.G. 1942. *American Silvics and Silviculture*. The University of Minnesota Press, Minneapolis.

Crockford, K.J. and Savill, P.S. 1991. Preliminary yield tables for oak coppice. *Forestry* 64(1): 29-49.

Crowther, R.E. and Evans, J. 1986. *Coppice*. Forestry Commission Leaflet 83. HMSO, London.

Decocq, G., Aubert, M., Dupont, F., Alard, D., Saguez, R., Wattez-Franger, A., De Foucault, B., Delelis-Dusollier, A. and Bardat, J. 2004. Plant diversity in a managed temperate deciduous forest: understorey response to two silvicultural systems. *Journal of Applied Ecology* 41: 1065-1079.

Demorlaine, J. 1907. *Sylviculture – Aide Mémoire du Forestier.* Société Forestière de Franche-Comté et Belfort, Besançon.

Du Bus de Warnaffe, G., Deconchat, M., Ladet, S. and Balent, G. 2006. Variability of cutting regimes in small private woodlots of south-western France. *Annals of Forest Science* 63: 915-927.

Evans, J. 1984. *Silviculture of Broadleaved Woodland*. Forestry Commission Bulletin 62. HMSO, London.

Evans, J. 1992. Coppice forestry – an overview. In *Ecology and Management of Coppice Woodlands*. Ed. Buckley, G.P., Chapman and Hall, London.

Evelyn, J. 1670. *Sylva, or a Discourse of Forest Trees, and the Propagation of Timber in His Majesties Dominions*. John Martyn and James Alleſtry, Printers to the Royal Society, London.

Forbes, A.C. 1904. *English Estate Forestry.* Edward Arnold, London.

Garfitt, J.E. 1995. *Natural Management of Woods – Continuous Cover Forestry.* John Wiley and Sons Inc., Chichester.

Gascoigne, P.E. 1980. A case for coppice-with-standards – for profit and pleasure. *Quarterly Journal of Forestry* 74(1): 47-56.

Groß, P. and Konold, W. 2010. Mittelwald als Agroforstsystem zwischen geordneter Nachhaltigkeit und Gestaltungsvielfalt - Eine historische Studie [The "Mittelwald" - an agroforestry system between rigid sustainability and creative options. An historical study]. *Allgemeine Forst- und Jagdzeitung* Vol. 181(3/4): 64-71

Guillebaud, W.H. 1927. Silviculture of hardwoods in Great Britain. *Forestry* 1: 24-34.

Harmer, R. 2004. Coppice silviculture practiced in temperate regions. In *Encyclopedia of Forest Sciences. Volume III*. Eds. Burley, J., Evans, J. and Youngquist, J.A., Elsevier Academic Press, Oxford, pp 1045-1052.

Harmer, R. and Howe, J. 2003. *The Silviculture and Management of Coppice Woodlands*. Forestry Commission, Edinburgh. HMSO, London.

Harmer, R., Kerr, G. and Thompson, R. 2010. *Managing Native Broadleaved Woodland*. The Stationery Office, Edinburgh.

Hart, C. 1991. *Practical Forestry For the Agent and Surveyor.* 3rd ed. Sutton Publishing, Stroud.

Hart, C. 1995. *Alternative Silvicultural Systems to Clear Cutting in Britain: A review.* Forestry Commission Bulletin 115. HMSO, London.

Hawley, R.C. 1921. *The Practice of Silviculture, With Particular Reference to Its Application in the United States*. John Wiley and Sons, Inc., New York.

Hayes, S. 1794. *A Practical Treatise on Planting and Management of Woods and Coppices*. The Dublin Society, Dublin.

Hemery, G.E., Savill, P.S. and Pryor, S.N. 2005. Applications of the crown diameter-stem diameter relationship for different species of broadleaved trees. *Forest Ecology and Managemen*t 215: 285-294.

Hochbichler, E. 1993. Methods of oak silviculture in Austria. *Annals of Forest Science* Vol. 50(6): 583-591.

Insley, H. 1988. *Farm Woodland Planning*. Forestry Commission Bulletin 80. HMSO, London. Cited in *Harmer, R. and Howe, J. 2003*. The Silviculture and Management of Coppice Woodlands. Forestry Commission, Edinburgh. HMSO, London. p. 48.

Jones, M. 1986. Coppice wood management in the eighteenth century: an example from County Wicklow. *Irish Forestr*y 43(1): 15-31.

Köstler, J. 1956. *Silviculture*. [Waldbau]. Translated by Mark L. Anderson. Oliver and Boyd, Edinburgh.

Lanier, L. 1986 *Précis de Silviculture*. École Nationale du Genie Rural, des Eaux et des Forêts, Nancy. Cited in: Matthews, J.D. 1989. Silvicultural Systems. Clarendon Press, Oxford.

Law, B. 2001. *The Woodland Way. A Permaculture Approach to Sustainable Woodland Management*. Permanent Publications, Hampshire.

Lefort, F., Lally, M., Thompson, D. and Douglas, G.C. 1998. Morphological traits, microsatellite fingerprinting and genetic relatedness of a stand of elite oaks (*Q. robu*r L.) at Tullynally, Ireland. *Silvae Genetic*a 47(5-6): 257 – 262.

Matthews, J.D. 1989. *Silvicultural Systems*. Clarendon Press, Oxford.

McCracken, E. 1971. *The Irish Woods Since Tudor Times: Their Distribution and Exploitation*. David and Charles (Publishers) Ltd., Newton Abbot.

Mutch, W. 1998. *Tall Trees and Small Woods. How to Grow and Tend Them*. Mainstream Publishing Company, Edinburgh.

Neeson, E. 1991. *A History of Irish Forestry.* The Lilliput Press: Dublin.

Nisbet, J. 1904. *Interim Report Regarding Inspection of Woods and Plantations in County Wicklow. Dublin*. Cited in Carey 2009 *If Trees Could Talk. Wicklow's Trees and Woodlands Over Four Centuries*. COFORD, Dublin. p. 58.

Nyland, R.D. 2002. *Silviculture – Concepts and Applications*. 2nd ed. Waveland Press Inc.

O'Driscoll, E. 2011. *UNECE Timber Committee Market Report for Ireland 2011*. http://www.unece.org/fileadmin/DAM/timber/country-info/Ireland.pdf [Accessed September 2012].

O'Sullivan, A. 1994. Trees, woodland and woodmanship in early Mediaeval Ireland. *Botanical Journal of Scotland* 46(4): 674-681.

Piussi, P. 2006. Close to nature forestry criteria and coppice management. In *Nature-based Forestry in Central Europe: Alternatives to Industrial Forestry and Strict Preservation*. Ed. Diaci, J., Department of Forestry and Renewable Forest Resources – Biotechnical Faculty, University of Ljubljana, Slovenia, pp. 27-37.

Rackham, O. 2010. *Woodlands*. Collins, London

Rondeux, J. 1991. Management of small woods in Belgium. *Quarterly Journal of Forestry* 85(1): 37-42.

Savill, P., Evans, J., Auclair, D. and Falck, J. 1997. *Plantation Silviculture in Europ*e. Oxford University Press, Oxford.

Schlich, W. 1910 Schlich's *Manual of Forestry. Volume II. Silviculture*. 4th ed. revised. Bradbury, Agnew and Co. Ltd., London.

Short, I. and Radford, T. 2008. *Silvicultural Guidelines for the Tending and Thinning of Broadleaves*. Teagasc, Dublin.

Smith, D.M., Larson, B.C., Kelty, M.J. and Ashton, P.M.S. 1997. *The Practice of Silviculture: Applied Forest Ecology*. 9th ed. John Wiley and Sons, Inc., New York.

Tighe, W. 1802. *Statistical Observations Relative to the County of Kilkenny Made in the Years 1800 and 1801*.

Tomlinson, R. 1997. Forests and woodland. In *Atlas of the Irish Rural Landscape*, Eds. Aalen, F.H.A., Whelan, K. and Stout, M., Cork University Press, pp. 122-133

Towler, R.W. and Barnes, G.C. 1982. What future for broadleaved farm woodlands in East Anglia? Abstract. In *Broadleaves in Britain*, Eds. Malcolm, D.C., Evans, J. and Edwards, P.N., Proceedings of a symposium, Loughborough, Leicestershire, 7 – 9th July 1982. The Institute of Chartered Foresters, pp. 250.

Troup, R.S. 1928. *Silvicultural Systems*. Clarendon Press, Oxford.

Young, A. 1780. *A Tour in Ireland: With General Observations of That Kingdom: Made in the Years 1776, 1777, and 1778. And Brought Down to the End of 1779*. Vol. II. 2nd ed. Printed by H. Goldney for T. Cadell, the Strand, London.