II

THE CLEAR-CUTTING SYSTEM


1. GENERAL DESCRIPTION

Under this system successive areas are clear felled and regenerated, most frequently by artificial means but sometimes naturally. As a general rule the clearing of a coupe should be complete, although pre-existing poles and saplings may be left if they occur in promising groups large enough to form self-contained crops. Under ordinary conditions, however, isolated poles and saplings should be removed, as these are likely to develop into branchy trees as well as to interfere with the new crop.

On the other hand it may be necessary in special cases to introduce nurses to assist in the establishment of the new crop: in some of the high moors of Bohemia, for instance, spruce regenerated artificially on clear-cut areas cannot withstand the severe frosts without the aid of temporary nurses, such as birch and mountain-ash, which appear naturally or are introduced artificially. It is sometimes customary, especially in the tropics, to kill unmarketable trees by ‘ringing’ or ‘girdling’ and to leave them standing in order to save the cost of felling them.

All timber and other marketable material should be removed at once, and if the debris remaining is likely to interfere seriously with sowing or planting, or with the establishment of the new crop, it should be burnt.

2. SIZE, FORM, AND ARRANGEMENT OF COUPES

General Considerations. In its ideal form the clear-cutting system involves felling and regenerating each year equal areas (coupes) on which the stands have reached the predetermined age of maturity (rotation). If this process is repeated each year for the whole rotation and no accidents have happened to interrupt the continuity, a normal series of age gradations, aged 1, 2, 3 ... r years (r being the number of years in the rotation), will have been established. Where the quality of the soil varies appreciably from place to place, coupes not equal in area but equiproductive are formed, those on the poorer soils being larger than those on the more fertile soils.
In point of fact the ideal form of clear-cutting system, involving the felling and regeneration of equal annual coupes and the formation of an uninterrupted series of age gradations, has been found impracticable in high forest except under very favourable conditions. Modelled on the coppice system, it was introduced in the coniferous forests of Germany at the end of the eighteenth century, but proved a complete failure owing to the impossibility of maintaining the ideal regularity aimed at; the longer the rotation the more difficult it became to fulfil the aim. For this reason the modification of periodic instead of annual coupes was adopted in Germany at the beginning of the nineteenth century. Under this modification it may be arranged, for instance, to fell and regenerate an area ten times that of the theoretical annual coupe in a period of ten years, the actual area felled annually varying from year to year within this period. Such a procedure is indicated where considerable latitude is desired for economic reasons, or where natural regeneration from adjoining woods is relied on, or where artificial regeneration is carried out but supplies of seed or plants are obtainable only at irregular intervals.

The size, form, and arrangement of the coupes vary greatly according to local conditions and requirements. Where damage from wind, frost, insects, erosion of hill-sides or other dangers is not to be feared, the coupes may be of any size or shape compatible with local topography, means of extraction and transport, and other considerations; but in certain cases special measures may be necessary.

**Protective Measures.** A protective measure sometimes adopted against frost, snow, drought, cold winds, and other dangers, is to make within a mature crop small scattered coupes which are usually regenerated artificially. Further coupes are made from time to time in the remaining portions of the mature crop until the whole area has been felled and regenerated. As a means of introducing sensitive species or of producing somewhat uneven-aged crops, this procedure has its merits, but it is somewhat difficult to control and is expensive to operate, owing to the scattered nature of the fellings; it also increases danger from wind, while on steep hill-sides damage is liable to be caused to groups of young growth by the sliding of timber during extraction. Hence where protective measures are required, it is preferable to adopt the procedure followed in countries like Saxony, where clear cutting has been systematized in the manner described below with the view of preventing damage by storms, cold winds, frost, drought, insects, and timber extraction.

Where damage by storms is to be feared, care is necessary to
avoid cuttings which will suddenly expose the interior of a wood to the prevailing storm direction, which in northern and central Europe is from the west or south-west. Trees grown from youth upwards in a crowded state develop long boles, small high crowns, and feeble root-systems; if such trees are exposed to the force of a strong wind, the lateral pressure of the wind on the crown, acting at a considerable distance from the ground, exercises a leverage which the feeble root-system cannot always withstand, and the tree is uprooted, or, failing this, the bole may snap across at some point of weakness. For this reason, in regions subject to storms the coupes should be so arranged that fellings in successive adjacent areas proceed against the prevailing storm direction, that is, in Europe from E. to W., or from NE. to SW., with local diversions in hilly country. By this arrangement there is always a sheltering wood, or failing this there should be a good shelter-belt, to windward of the coupe felled. The usual procedure, therefore, is to select areas containing woods which will come under the axe for a limited period ahead, say 20 years, and arrange the coupes in those areas in such a way that fellings proceed against the storm direction. A further precaution is to form narrow coupes approximating to cleared strips running at right angles to the storm direction, and to avoid anything in the nature of large clearings. In the spruce forests of Saxony these coupes vary from about 20 to 100 yards or more in breadth. Such strip-like fellings have been practised for centuries in Central Europe, and are the most suitable form of clear fellings in mountainous country.

Risk of damage by insects may further complicate the arrangement of fellings. For example, a special arrangement of fellings is adopted in many pine and spruce forests in Europe as a protective measure against the pine weevil, *Hylobius abietis*, Fabr. This insect lays its eggs in the stumps and roots of felled trees, where the larvae feed innocuously. The perfect beetle inflicts great damage on young coniferous plants, chiefly Scots pine and spruce up to 6 years of age, by gnawing the bark of the stem and frequently killing the plant outright. Among measures adopted to check the multiplication of these insects are (1) the formation of small coupes, and (2) the avoidance of fellings in contiguous areas except after the lapse of some years; in the spruce forests of Saxony the interval varies from 5 to 10 years. This formation of small segregated coupes was based on the supposition that the insect was almost incapable of flying, and could only crawl slowly, its radius of activity being very restricted in consequence. The investigations of Munro in Great Britain, however, have shown that the beetle is capable of travelling
to much greater distances than was at one time supposed, and that although the formation of small segregated coupes is a good precautionary measure, it is effective only if accompanied by the constant trapping of beetles before, during, and after the fellings.

**Cutting Sections.** In order to facilitate the formation of small or narrow coupes and their arrangement in some regular order, it is usual to divide each main unit of the forest into a number of cutting sections. These may be defined as units, usually of limited size, formed for some special purpose (not necessarily the purpose with which we are concerned here). Within each cutting section the coupes are arranged in such manner as will meet the necessities of the case. Figs. 1 and 2 show how coupes may be arranged in cutting sections so that the general direction of felling is from NE. to SW. against the prevailing storm direction, while at the same time intervals of 5 years are allowed for between successive fellings in adjacent coupes. Narrow coupes arranged in this way also serve as a protection against frost and cold NE. winds. In Saxony the tendency in recent years has been to alter the felling direction to one of N.–S. in places where frost damage is severe, and in fact to adopt

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1 These are sometimes termed 'cutting series' but it is preferable to use the term 'series' (Fr. *série*) to denote a unit comprising, ideally, a complete series of age-gradations from 1 to 7 years: a cutting section will then be a subdivision of a series.
the clear strip system (see p. 103). Wherever possible, cutting sections should be bounded on the windward side by shelter belts of low-branching trees. Where permanent cutting sections are laid out, roads and rides bordered by such trees make the best boundaries.

In the formation of cutting sections it may be necessary to divide existing woods into two or more parts. If this can be foreseen long enough ahead, wind-belts of low-branching trees may be produced by making 'severance cuttings'. These are cleared lines of varying breadth, usually 30–50 feet, cut through the wood while it is still comparatively young in order to induce low branching by the border trees (see Fig. 2). Severance cuttings, which run more or less at right angles to the prevailing wind direction, may be used as roads or rides, or may be planted up.

![Diagram](image)

Fig. 2. Clear-cutting system. Longitudinal elevation of a single cutting section. Numbers denote ages of crops. $s, s$; severance cuttings; $a, a$, adjoining cutting sections; $c$, coupe of the year; $f$, felling direction; $w$, wind direction.

In order to facilitate extraction of timber, where the nature of the ground allows of it the cutting sections should be bounded by roads running along the narrow ends of the coupes as shown in Fig. 1; in Saxony this is a common arrangement on more or less level ground, where the main extraction roads run parallel to each other in a general NE. to SW. direction.

The length of a cutting section may vary considerably. In the Tharandt School Forest in Saxony cutting sections generally extend over two compartments, and have an average length of about 600 metres, with a maximum of over 1,000 metres. The modern tendency, however, is to decrease the size of cutting sections in order to provide mobility in the working.

**Form and Arrangement of Coupes in Hilly Country.** In hilly country considerations of protection against storms and insects should be combined with measures of protection against damage to young crops through the sliding of timber down the slopes. In such country the prevailing winds tend to become diverted according to the trend of the valleys, and the local wind direction has to be studied. The coupes themselves are generally long and narrow, and are
arranged in one of two ways, (1) with the long axis running up and down the slope and the fellings proceeding against the local storm direction, and with a road running along the lower edge of the cutting section (see Figs. 3 and 5), and (2) with the long axis running more or less contourwise, but slightly inclined to the hori-

![Diagram](https://via.placeholder.com/150)

**Fig. 3.** Diagrammatic representation of clear-cutting system in hilly country, showing a cutting section with vertical coupes with successive cuttings at 10-year intervals arranged against the prevailing wind direction. Numbers denote ages of crops. Rotation 80 years. c, coupe of the year; f, felling direction; t, direction of timber extraction; w, wind direction.

![Diagram](https://via.placeholder.com/150)

**Fig. 4.** Diagrammatic representation of clear-cutting system in hilly country, showing horizontal coupes with successive cuttings at 10-year intervals arranged in a downhill direction in a short cutting section to prevent damage to young crops by the sliding of large timber. Numbers denote ages of crops. Rotation 80 years. c, coupe of the year; f, felling direction; t, direction of timber extraction; w, wind direction.

horizontal if this is necessary in order to avoid exposing unprotected woods to the prevailing winds; the cutting direction is downhill (see Fig. 4). Under the latter arrangement short cutting sections are necessary, bounded by graded roads at fairly frequent intervals, in order that large timber may not have to be slid down through young woods.
3. CLEAR-CUTTING WITH ARTIFICIAL REGENERATION

**General Procedure.** Under the clear-cutting system artificial regeneration is far more commonly practised than natural regeneration, planting being more general than direct sowing in temperate countries; patch sowing of Scots pine, however, is not unusual in France, while oak is regenerated by direct sowing of acorns in various parts of Europe. As a rule it is important that sowing or planting should be carried out as soon after the felling as possible: cleared areas left for a year or more tend to become covered with weeds and regrowth, and the soil deteriorates, dry soils becoming drier on the surface, and wet soils becoming more swampy.

**Artificial Regeneration with the Aid of Field Crops.** (Fr. *Cultures intercalaires, culture sylvicole et agricole combinée*. Ger. *Waldfeldbau, Baumfeldwirtschaft, Brandwirtschaft.*) Under this special form of artificial regeneration, field crops are cultivated temporarily on the cleared coupes for one or more years, the sowing or planting of the tree species being carried out before, along with, or after the sowing of the agricultural crop. This practice, which varies greatly in detail, has long been in force in parts of Germany, and was much in vogue in Finland until last century. In the Spessart and in Hesse-Darmstadt there are some excellent stands of oak, the oldest dating from 1813, raised by sowing acorns along with cereal crops (see Fig. 64). In Hesse-Darmstadt the regeneration of Scots pine is carried out to the present day along with the cultivation of potatoes. This may be seen typically on the sandy tracts in the neighbourhood of Darmstadt, where the stumps are dug up, the soil is worked, pine seedlings one year old are planted in lines in April, and potatoes are put in between the lines of pine seedlings in May (see Fig. 68). The importance of potatoes in the food-supply of Germany is so great, that even where their cultivation in this manner is scarcely remunerative the practice is continued.

In Switzerland the custom of clearing forest for the temporary cultivation of field crops, which dates back for a long time, was put to systematic use after 1840, at the time of the great potato disease. The method employed was to grow potatoes, or potatoes alternating with cereals, for 2 or 3 years, or sometimes up to 10 years, and then to plant spruce. This method of forming plantations was subsequently abandoned when it was found that the spruce, which generally developed well at first, subsequently became unhealthy and was attacked by red rot.

In the tropics the practice of clearing forest for temporary cultiva-
Fig. 5. Clear-cutting system with replanting of spruce, Postelwitz State Forest, Saxony. Part of a cutting section with narrow vertical coupes in hilly country. Felling direction from left to right (NE. to SW.), with 5-year intervals between fellings in adjacent coupes. Ages of coupes from left to right: (1) 15 years (trees in immediate foreground), (2) 10 years, (3) 5 years, (4) old wood about to be felled.

Fig. 6. Natural regeneration of Douglas fir, *Thuja plicata*, *Abies grandis*, and *Tsuga heterophylla*, sprung from seed stored in the ground, on an area devastated by fire; Vancouver Island.
tion is common among many primitive tribes, and under ordinary conditions it results in the destruction of extensive tracts of forest. If controlled and utilized for the formation of plantations of valuable trees, this otherwise harmful practice can be turned to very good account. The so-called *taungya* plantations of Burma, begun in 1869 and now covering a large area, have been created with the aid of temporary cultivation, usually of hill rice, on forest clearings in which all unmarketable timber is felled and burnt, the soil being enriched by the ashes. The plantations are chiefly of teak (*Tectona grandis*), which is introduced along with the field crop. These plantations have been formed efficiently and cheaply, while the cultivators provide local forest labour and grow their own food supply, a matter of great importance in tracts where communications are not good.

This method of regenerating clear-felled areas has since been applied not only in other parts of India but also in other countries where this primitive form of agriculture is practised. In East Africa it has proved to be a useful method of regenerating forests of pencil cedar (*Juniperus procera*) and other valuable trees.

4. CLEAR-CUTTING WITH NATURAL REGENERATION

Under certain conditions clear-cutting may be followed by successful natural regeneration. This may be obtained either (1) from seed already on the area, or (2) from seed disseminated from trees outside and usually adjoining it.

**Regeneration from Seed already on the Area.** In this case the seed either falls from the trees at the time of or shortly after felling, or is already lying on the ground or stored in it; sometimes the seed may be provided from both sources.

**Examples.** The best-known case of natural regeneration following clear-cutting is to be seen in the maritime pine (*Pinus Pinaster*) forests of the coastal regions of the Landes in south-western France. Clear-cutting is here carried out over large coupes, and natural regeneration springs up in abundance from seed, some of which is already on the ground, but much of which escapes from the cones of the felled trees in the months of April or May (see Figs. 7 and 8). Natural regeneration is specially favoured by the abundant annual seeding of the pine, the loose sandy soil, and the complete exposure to light of a species which demands it. After the felling and removal of the timber, the brushwood is spread evenly over the coupe in order to distribute the seed; this tends to produce an even stocking of the area with young plants.
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The system of clear-cutting with natural regeneration is applied to the pedunculate oak in the valley of the Adour in SW. France. Here, owing to the mildness of the climate, the oak seeds abundantly every year. The areas are low-lying and subject to inundations, and there is a heavy undergrowth. After a coupe is cleared, the undergrowth is cut down, and any pre-existing oak seedlings are cut flush with the ground; these shoot up again, and large numbers of new seedlings appear from the seed lying on the ground, with the result that complete restocking is generally assured without artificial aid.

The lodgepole pine (Pinus contorta, var. Murrayana) and jack pine (P. Banksiana) of North America afford good examples of natural regeneration following on the destruction of the old crop by fire. The cones are borne in large numbers on the branches, and may remain there unopened for some years; the heat of a fire which may be sufficient to kill the trees will cause the cones to open and shed the seed, abundant natural regeneration resulting.

Natural regeneration from seed stored some time in the ground is well exemplified in the case of the Douglas fir and its associates in the Pacific coastal region of North America. Areas which are clear-felled often regenerate with great profusion, particularly if the debris is consumed by fire immediately after the felling and before the seed stored in the ground has time to germinate. Similar abundant regeneration may also follow the destruction of the old forest by fire (see Fig. 6).

These examples from North America indicate the applicability of the clear-cutting system, followed by the burning of debris, to the types in question. This treatment, however, could not be systematized unless the protection of the new crop from fire is assured, since there is no further store of seed in the ground to effect regeneration should the young crop be destroyed by fire.

One of the most remarkable instances of natural regeneration on clear-cut areas from seed stored in the ground is to be seen in the case of the teak (Tectona grandis) in Burma and Southern India. The seed is enclosed in a hard-shelled nut, and retains its vitality for many years. Where seed-bearers are plentiful the nuts accumulate in the ground, but germination does not take place until they are alternately heated by the sun and moistened by rain, when dehiscence takes place. This condition is secured by clear-cutting, which is followed by the appearance of large numbers of seedlings springing from seed which may have lain dormant in the ground for many years. The survival of these seedlings can be secured only
Fig. 7. Clear-cutting system with natural regeneration in the maritime pine forests of the Landes. A recently felled coupe, with temporary sawmill.
Fig. 8. Clear-cutting system with natural regeneration in the maritime pine forests of the Landes. On right, naturally regenerated crop 6 years old; on left, mature crop being tapped for resin; fire-line in centre.
by repeated and costly weeding, for which reason it is generally found less expensive to ignore the natural regeneration and to plant up the area in regular lines, so that weeding may be facilitated.

**Regeneration from Seed disseminated from Outside.** This form of regeneration applies chiefly to species with light or winged seeds which are disseminated by wind, as in the case of many pines and other conifers as well as certain broad-leaved trees like birch and various invasive tropical species which habitually spring up in quantity on recent clearings. Less commonly, water or animal agencies may operate, as in the case of the irrigated plantations of the Punjab in India, where the mulberry (*Morus alba*) springs up extensively on cleared areas from seed spread by irrigation water and by starlings.

In Europe clear-cutting with natural regeneration from adjoining woods or belts has been systematized chiefly in the case of the Scots pine, although it has been applied to other conifers, including the Austrian pine (*Pinus Laricio*, var. *austriaca*). The coupes are in the form of strip-like clearings\(^1\) made in one of two different ways, either (1) by progressive fellings, or (2) by fellings in alternate strips.

These methods of regeneration should not be employed unless seed-years occur regularly and at frequent intervals, otherwise there is a risk of the soil being left exposed for too long a period.

**Progressive fellings.** Under this method, which is a very old one, the fellings proceed successively in a definite direction in the manner already described for the clear-cutting system with artificial regeneration. If the wind direction at the time the seed ripens is at all constant, it is a great advantage to arrange the fellings so as to proceed against this direction; by such an arrangement the seed is blown on to the adjoining cleared strip, the breadth of which should be such that seed in abundance will reach every part of it. The actual breadth of the strip must be determined by local

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\(^1\) It is a question whether a strip-like clear-cutting should be classed as a form of the clear-cutting system or as a form of strip system. The distinction is not always easy to draw. It is proposed to adopt as the most logical distinction that which is now generally recognized in Europe, namely, to reckon as a (clear) strip felling one which is so narrow that the adjoining old wood exercises a powerful influence on the strip in regard to soil moisture and other physical factors which affect seed germination and the growth of the seedling; the breadth of such a strip would be about half the height of the adjoining wood, or not much more. A strip-like clear-cutting, on the other hand, is not so influenced except possibly along the immediate edge of the adjoining wood. It follows, therefore, that clear-strip fellings apply generally to species like spruce, which are sensitive to drought in early youth and may benefit by lateral protection from the sun, rather than to hardy species like Scots pine, the seedlings of which demand much light and may be adversely affected by close proximity to an adjoining wood.
observations, since even in the case of one and the same species the distance to which the seed is disseminated in sufficient quantity must depend largely on the velocity and direction of the wind under average conditions.

The interval between successive adjacent fellings will depend on the frequency of seed-years and the readiness with which regeneration appears and establishes itself. If one strip is cleared, the one adjoining it should not be cleared until the original one is fully regenerated, for which purpose a liberal margin of time should be allowed. Assuming, for instance, that under the prevailing seeding conditions a period of 3 or 4 years is found to be sufficient to ensure the establishment of natural regeneration over a cleared strip of

![Diagram](image)

**Fig. 9.** Clear-cutting by progressive fellings with natural regeneration by seed from adjoining woods. Diagrammatic representation of an area divided into 6 cutting sections with 3 coupes in each; interval between successive adjacent fellings 6 years. Numbers denote year of felling; \( f \), felling direction; \( w \), wind direction.

a certain width, then it should be safe to allow a period of, say, 6 years between the cutting of one strip and the cutting of the next one adjoining it. The arrangement of cuttings in such a case is shown in Fig. 9. In this example the area to be regenerated is divided into 6 cutting sections with 3 coupes of the required breadth in each, so that it will take a period of 18 years to fell and regenerate the whole. In the last coupe of each cutting section a belt of seed-bearers should be left along the windward side in order to regenerate the coupe, after which the belt should be felled and the blank strip regenerated artificially. In the diagram one self-contained area is shown; the 6 cutting sections might equally well be distributed over two or more areas if necessary.

More elasticity can be introduced into the working by allotting a number of areas for regeneration during a given period, and not rigidly fixing the interval between successive fellings; this allows for the distribution of fellings over several areas, which will tend to equalize the area felled each year without too close an adherence to
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a fixed scheme, to which the vagaries of natural regeneration may not always lend themselves.

Fig. 10 illustrates clear-cutting with natural regeneration from an adjoining wood in the case of the Austrian pine.

FELLINGS IN ALTERNATE STRIPS (Ger. Kulissenhieb). A method which has been tried from time to time is that of felling parallel clear strips, usually about 40–60 yards wide, through the wood to be regenerated, leaving intervening strips of similar width untouched; the cleared strips regenerate naturally, and the young crop is allowed to grow to an age when it is capable of producing seed in quantity, when the intervening old strips are clear-felled, and the process is repeated. This method has not proved satisfactory; apart from the difficulty of controlling it owing to the presence of two widely different age-classes distributed over the area, there is considerable waste of space, particularly in the case of pines, owing to the failure of regeneration along the edge of the strips left uncut.

A more workable and successful adaptation of this method is that begun experimentally about the year 1918 in the forest of Rouvray in Normandy, the species being Scots pine. Clear-cuttings were made in parallel strips 40 to 50 metres (averaging roughly 150 feet) wide, belts of untouched forest 15 to 20 metres (roughly 50 feet) wide being left between them to furnish seed (see Fig. 11). Natural regeneration established itself well on the cleared strips, the young plants growing vigorously in the enjoyment of full overhead light. When the young crop was sufficiently advanced, that is, about 6 years after the first felling, the intervening belts of seed-bearers were felled and the blank strips were sown up in patches. No account was taken of wind direction in cutting the strips, which were aligned in any direction more or less at right angles to roads, so that when the seed-bearers were felled the timber did not require to be dragged through the young crop.

The chief advantages of this system over the uniform system, which is employed in the forest in question and in which seed-bearers are left scattered singly over the area, are (1) greater security against wind, experience in this locality having shown that scattered trees are more subject to windfall than trees left in belts (see p. 53), and (2) avoidance of damage to the young crops during the felling and extraction of the seed-bearers. Its chief advantage over progressive fellings is that seed is scattered in two directions instead of one, a fact which would be of importance where the constancy of the wind direction could not be relied on.

Its chief defect is the necessity for regenerating artificially at
least one-third of the area, that is, not only the space actually occupied by the belts of seed-bearers but also a narrow strip on either side of them where regeneration fails, on which account this method of regeneration was abandoned after a few years’ trial.¹ It owed its origin to the fact that strip-like clearings for artillery camps in the outskirts of the forests during the war were found to result in promising natural regeneration where this was not actually impeded by the camps; further strips were therefore cleared experimentally and kept under observation, with the results already noted.

5. ADVANTAGES AND DISADVANTAGES OF THE CLEAR-CUTTING SYSTEM

ADVANTAGES. The chief advantages of the clear-cutting system are as follows:

1. It is the simplest of all high forest systems, since it dispenses with marking operations requiring skill, occupying the time of the staff, and therefore costing money.

2. It represents the utmost concentration of work, every tree on the coupe being felled; this means a larger outturn per unit of area, and therefore greater economy in felling and extraction, than in systems where only a portion of the trees are felled at a time.

3. It affords complete overhead light, an important consideration in the case of strong light-demanders.

4. There is no damage done to the young crop through the felling and extraction of timber, since this is all completed before the young crop originates.

5. Owing to the even-aged condition of the stands it produces cleaner and more cylindrical timber than that produced by the more uneven-aged systems.

6. As a rule the new crop is established more rapidly under the clear-cutting system than under systems in which regeneration is established by degrees; this saving of time may be of considerable financial advantage.

DISADVANTAGES. The chief disadvantages of the system are as follows:

1. The complete clearance of the forest cover may produce conditions adverse to the growth of young plants of many tree species; such conditions are the following:

   (a) Desiccation and general deterioration of the soil through exposure to sun and air currents;

¹ An attempt has been made recently to obtain natural regeneration along the strips occupied by the belts of seed-bearers by opening out the latter in the form of a seeding felling (see p. 32); the results of this experiment are awaited.
Fig. 10. Clear-cutting with natural regeneration from adjoining woods. Forest of Austrian pine (*Pinus Laricio*, var. *austriaca*); Steinfeld plains, Austria.

Fig. 11. Clear-cutting of Scots pine in alternate strips, with natural regeneration. Forest of Rouvray, France.
(b) Increase of swampiness in areas which tend to be swampy;
(c) A rank growth of grass and weeds, which may interfere with regeneration and add to the cost of establishing it;
(d) Exposure to frost and cold winds;
(e) Multiplication of injurious insects, particularly weevils, which tend to breed in clearings where stumps are present in abundance, and cockchafers, which are more prevalent in clearings than under a shelter-wood.

2. On hill-sides it exposes the area to erosion and, where the ground is unstable, to landslips, while it affords no safeguard against the rapid run-off of rain-water.

3. It results in the accumulation on the ground of large quantities of debris (slash) after the fellings; where utilization is not intensive, and tops and branches of some size are left lying on the ground, this debris forms the breeding ground of bark beetles, which are destructive more particularly to coniferous forests; this risk can be avoided by collecting and burning the debris.

4. It possesses the disadvantage of even-aged systems in general in producing a type of forest less resistant to damage by snow and wind than the more uneven-aged systems.

5. From the aesthetic point of view the clear-cutting system is the least desirable of high forest systems.

The disadvantages just mentioned are intensified if the coupes are large, or if the ground remains exposed for some time before the young crop closes up; they are reduced to a minimum where small or narrow coupes are adopted, or where the area is rapidly reclothed.

In connexion with insect damage, it may be noted that in the Scots pine forest of Isenburg in Hesse-Darmstadt clear-cutting followed by artificial regeneration with the aid of field crops was abandoned in 1885 in favour of natural regeneration under a shelter-wood, since the former system was found to encourage the multiplication of cockchafers, the working of the soil for temporary cultivation probably being a contributing factor.

6. EXPERIENCE OF THE CLEAR-CUTTING SYSTEM IN SAXONY AND SWITZERLAND

No account of the clear-cutting system would be complete without some reference to the abuse of silvicultural principles which has accompanied it in certain parts of Europe; this has led, in certain cases, to adverse results which have been cited, on occasion, in support of a condemnation of the clear-cutting system in general. The cases of Saxony and Switzerland may be specially considered,
although similar results might be quoted in the case of other parts of Europe.

**Saxony.** For more than a century Saxony has been one of the chief strongholds of the clear-cutting system in Europe. It was introduced by Cotta¹ at the beginning of the nineteenth century as the only means of regenerating forests which had suffered to such an extent from unregulated selection fellings and excessive grazing and removal of litter, that natural regeneration was out of the question. The forests of Saxony may be considered as occupying three different zones of altitude: (1) the upper zone, about 600 metres (1,950 feet) and over, where spruce thrives under the influence of an ample rainfall; (2) the middle zone, 800–1,950 feet; (3) the lower zone, below 800 feet, with a rainfall of only 20 to 25 inches, which is too low for the healthy growth of spruce. In the mountainous parts of the country the original forest probably consisted of spruce mixed with silver fir, Scots pine, and beech. In the lower zone spruce is everywhere an introduced species.

One important result of the clear-cutting system was that the tender beech and silver fir largely disappeared, their place being taken by spruce, a species better adapted for this form of treatment. In this way large areas of mixed forest were converted into pure spruce, a condition which was viewed with alarm by Cotta himself, as is shown by his warnings, as early as 1820, against the indiscriminate planting of this species. Later on, under Pressler’s influence, the policy of planting pure spruce was still more vigorously prosecuted for financial reasons, since it was found that spruce, worked on a comparatively short rotation for paper-pulp and mining timber, gave the best financial results.

The adverse effects of this policy began to be noticed as far back as 1869, when a reduction of growth was observed in young spruce woods, as compared with that of the previous rotation. About this time Gayer in particular issued warnings against a continuance of the policy of planting pure spruce under the clear-cutting system, and advocated a return to mixed crops and shelter-wood systems; but in Saxony, at all events, these warnings passed unheeded. By 1920 the increment had fallen to such an extent that in certain cases woods had to be placed two quality classes (out of five) below the assessment of 30 years previously. During recent years the unhealthy state of many of the coniferous woods in which spruce predominates has become more and more evident. The outward

¹ Heinrich von Cotta, 1763–1844, Director of the Forest Academy of Tharandt, Saxony, 1816–44; one of the foremost authorities of his day.
signs are stunted growth, short yellow needles, a growth of lichens on the trees, and the appearance of *Chermes* in quantity on the shoots. The ground vegetation has also changed, heather replacing grass, *Epilobium*, blackberry, raspberry, and other plants indicative of active nitrification; a peaty formation with a covering of lichens is frequently present, and in some cases a hard pan has formed some little distance below the surface.

In 1921 Dr. E. Wiedemann undertook a series of investigations with the object of determining the causes of these unsatisfactory conditions, and after two years of steady work he published his results in 1923 and 1924.¹ In the course of these investigations he examined and analysed a large number of soil samples, made numerous stem analyses, and also utilized the excellent records of operations in the forests of Saxony dating from 1817. He found that the production of crops raised on clear-cut areas had diminished considerably as compared with that of crops raised under shelterwoods, the worst results occurring where the mixture of beech had disappeared. The mean annual loss of increment during the past 100 years was estimated at 0.65 cubic metres per hectare, or 9.29 cubic feet per acre, representing an annual loss of over 3½ million cubic feet over the whole of the Saxon State forests. Further, judging by the decrease of increment in woods already twice clear-cut, there were indications that this decrease would be intensified if clear-cutting and planting were persisted in.

Dr. Wiedemann’s investigations brought out the important fact, revealed from a study of height curves, that a definite period of stagnation of growth occurred more or less in the same year in different widely separated localities; this was most noticeable in the case of pure spruce, without beech. Similar stagnation of growth was observable in woods raised under a shelter-wood, but it was less well-marked and of shorter duration. It was worst in the lowest, prevalent in the middle, and only slight in the highest zone. Where it was not excessive, and where the spruce formed a canopy, the woods were found after a time to grow on fairly satisfactorily unless a second period of stagnation intervened. These periods of stagnation of growth were found to be correlated with diminished rainfall during the growing season, and occurred after drought years which reduced the amount of moisture below the minimum required for healthy growth. The evil effects of the drought were intensified by

¹ (a) *Zuwachsrückgang und Wuchsstockung der Fichte* (W. Laux, Tharandt, 1923).
(b) ‘Fichtenwachstum und Humuszustand’ (*Arbeiten aus der Biologischen Reichsanstalt für Land- und Forstwirtschaft*, XIII. 1, 1924).
the disappearance of the beech. A concomitant factor was the unfavourable decomposition of humus as a result of long exposure which inhibited the production of nitrates, except in soils of greater fertility than those commonly devoted to forests, or under the influence of favourable climatic conditions. Former mixed woods regenerated under a shelter-wood were found to be free from these adverse conditions.

Dr. Wiedemann's investigations have indicated the steps to be taken to remedy matters, namely, (1) a return to shelter-wood methods and a mixture of beech and silver fir with the spruce, and (2) the raising of the rotation with the view of obtaining natural regeneration. These measures have already been initiated, and this will mean a departure from purely financial considerations where these are antagonistic to good silviculture.

Switzerland. The experience of Switzerland is somewhat similar to that of Saxony. During the eighteenth century the forests of that country were much depleted by wasteful methods of working, and by the beginning of last century drastic action was necessary in order to remedy matters. In the early part of the century, great progress was made in Germany with clear-cutting followed by artificial regeneration by planting, a system which promised good results. From about 1820 onwards for a time almost all the Swiss foresters had had their training in Germany, and were influenced by the new German system, which was consequently introduced into Switzerland.

The original forests of Switzerland consisted largely of a mixture of spruce, silver fir, and beech, but since the two last-named species are very sensitive to frost during youth, the introduction of the clear-cutting system led to their extinction over considerable areas, and a great extension of pure spruce woods resulted. The spruce succeeded well for 30 or 40 years, and proved economically valuable, and hence its cultivation was rapidly extended to regions below its natural habitat, where it replaced the indigenous hardwoods and silver fir. Natural regeneration was abandoned by degrees, and continued only in the forests of the mountains; even in the latter clear-cutting with artificial regeneration was largely extended during the second half of the nineteenth century.

The effects of this policy in time became evident through decreased increment, accompanied by heart-rot, in the pure spruce stands, particularly in localities below the natural region of this species, and through damage by storms and snow in the even-aged spruce woods of the mountains. Hence when Gayer declaimed against the wholesale growing of pure spruce woods, and advocated
the adoption of more natural methods, he found willing listeners in Switzerland. The clear-cutting system with artificial regeneration of pure spruce, therefore, has fallen into disrepute in that country, where it is being replaced by more natural methods, and the law now prohibits large clear-cut coupes in the mountains.

**Conclusions.** The evidence afforded by the investigations in Saxony appears to warrant the following conclusions and comments:

1. The adverse results described are due in part only to the adoption of the clear-cutting system; this is evident from the fact that they are also observable to some extent in woods raised under a shelter-wood.

2. These adverse results are intensified by, and are probably due in no small measure to *(a)* the substitution of pure spruce for the original mixed crops, *(b)* the introduction of spruce into regions outside its natural habitat, where the rainfall is insufficient to promote its healthy growth.

3. No evidence has been produced to show the effect of growing mixed crops of spruce, silver fir, and beech both inside and outside the natural habitat of these species in Saxony, in order to compare the results with those obtained by growing pure spruce in the same localities. Without such evidence it is impossible to say to what extent the adverse results are due respectively to *(a)* the adoption of the clear-cutting system, *(b)* the cultivation of pure spruce, *(c)* the wrong choice of locality.

Although the causes of the adverse results do not appear to have been investigated in so much detail in Switzerland as in Saxony, the evidence available from the former country also leaves us somewhat uncertain as to the extent to which the clear-cutting system as such, rather than the cultivation of pure spruce, often outside its natural habitat, is responsible for the bad results. Nevertheless the object lessons afforded by Saxony, Switzerland, and other countries where the clear-cutting system has been wrongly applied, have led at times to the unjustifiable condemnation of this system in general. It is true that in localities subject to severe frosts a mixture of beech and silver fir would be difficult, if not impossible, to secure under the clear-cutting system, and hence if such a mixture is desired this system is not suitable. But the financial policy of Saxony deliberately aimed at pure spruce, and while this policy was followed no serious efforts were made to secure a sufficient mixture of the other species. Switzerland also appears to have been carried away for a time by the glamour of the financial returns yielded by pure spruce crops.
We are hardly justified, therefore, in condemning the clear-cutting system out of hand on the evidence afforded by its application to pure spruce woods. The system has its drawbacks, and may be inapplicable under certain conditions, but on the other hand it is in many cases the only possible system to adopt with success. Its application under different conditions will therefore be considered in the next section.

7. APPLICATION OF THE CLEAR-CUTTING SYSTEM

Conditions of Application. The examples of Saxony and Switzerland show that while the clear-cutting system is simple in execution, it is on this very account a powerful instrument in the hands of man owing to the fact that it lends itself readily to artificial measures. It is therefore the more necessary to guard against its abuse. Before considering the conditions under which the clear-cutting system should be applied, it is necessary to emphasize the fact that although typically an even-aged system, it does not necessarily involve the growing of pure crops, as is sometimes alleged against it. It is true that in some of the best-known examples of clear-cutting with natural regeneration (cf. pp. 11–13) pure crops are produced, but in the case of the Scots, Austrian, and maritime pines, to quote three instances only, a shelter-wood system in the same localities would also produce pure crops. Where artificial regeneration is practised, any mixture of species can be adopted that the locality will permit and the circumstances of the case may demand; the chief difficulties to be faced in this connexion are the correct choice of species and the best method of forming the mixture.

Before deciding on the adoption of the clear-cutting system in any locality it is necessary to consider various points in relation to each other and to the local conditions; among the more important of these are the following:

1. Species. The clear-cutting system is specially indicated for strong light-demanders which will not tolerate a shelter-wood; but in areas subject to frost, drought, or other risks it is unsuitable for sensitive shade-bearers which will not stand exposure in youth, although these may be introduced on clear-cut areas with the aid of nurses. Wessely, however, writing in 1853, stated that in the Austrian mountains some of the finest young beech woods had been produced on clear-cut areas.

2. Locality. The clear-cutting system is unsuitable, at all events with large coupes, (a) for unstable hill-sides or where serious erosion, snowslides or avalanches are to be feared, (b) in catchment areas
where the water-supply is likely to be endangered, (c) for 'protection forests', i.e. forests maintained primarily for protective purposes.

3. Soil and soil-covering. The clear-cutting system is unsuitable where the soil is liable to serious deterioration through temporary exposure, or where clear-cutting is followed by a heavy growth of weeds which prevent regeneration except at prohibitive cost; the latter difficulty may be counteracted by the temporary cultivation of field-crops, and by artificial regeneration with regularly spaced plants, which facilitates weeding. It is sometimes maintained that the clear-cutting system is suitable only for fertile soils, and should be avoided on poor soils; this is not borne out in practice, since some of the most light-demanding species, such as birch and certain pines, which do not tolerate cover during youth, frequently occur on poor soils and can best be regenerated under the clear-cutting system. Where natural regeneration is relied on, fertile soils may be a positive disadvantage owing to the competition of weeds.

4. Conditions for regeneration. The clear-cutting system should not be introduced unless regeneration each year or period of years can be absolutely assured. With natural regeneration this involves conditions favourable to the rapid seeding of the coupe and the successful establishment of the young crop. With artificial regeneration it involves a sufficiency not only of seed or plants but also of suitable labour during the season of sowing or planting; in the tropics planting is usually done in the rainy season, when forest labour is sometimes difficult to obtain.

5. Type of forest produced. The clear-cutting system, in common with other systems producing more or less even-aged crops, is well adapted for the production of large quantities of material of special dimensions, for instance mine-props or pulpwood. Even-aged crops, however, are more susceptible to damage by wind and snow than uneven-aged crops, though the risk can be lessened by attention to thinnings, by an admixture of species resistant to wind or snow, and by a suitable arrangement of coups and cutting sections. In many mountainous regions of Europe uneven-aged crops are deliberately aimed at owing to the risk of damage by snow and storms.

6. Change of species or composition of forest. The clear-cutting system is the one most commonly adopted for replacing an existing forest by one consisting largely or entirely of new species; in the case of the more sensitive shade-bearers, however, new species are often introduced under the protection of the old wood. Where an existing wood has become derelict through mismanagement or
neglect, the clear-cutting system with artificial regeneration is usually the only one by which it can be brought into a satisfactory state.

A type of forest more commonly represented in the tropics than elsewhere is that in which many different species of trees are mixed together, only one or a few of which are marketable. The clear-cutting system may be adopted to replace such forest by plantations of valuable species. The circumstances of each case must determine (a) whether the clear-cutting system is permissible on silvicultural grounds, (b) whether the felling of undersized trees of valuable species, at present unmarketable but with a high potential value, is justified, (c) whether the felling of large numbers of trees of different species, at present unmarketable, is justified in view of the possibility of a future demand, (d) whether the cost of felling and burning a large number of unmarketable trees is justified by the results likely to be obtained by replacing the old crop by a more valuable new one. So far as the last point is concerned, the cost can be reduced considerably by utilizing the practice of shifting cultivation, by which coupes are cleared without cost by cultivators who raise field crops on the area for one or more years and form plantations of trees on the clearings.

7. Economic Considerations. The economic advantage of felling and extracting the largest quantity of timber from the smallest area in the shortest time is so great, that the clear-cutting system has been frequently adopted on the ground that under no other system could remunerative exploitation have been undertaken. This applies particularly to places in which ordinary means of transport are deficient, and in which the construction of special export works, such as tramways, ropeways, and the like is necessary. For this reason the clear-cutting system has sometimes been practised in regions where physical conditions have been against its adoption, as in the Austrian mountains, where it has been in operation for many years, with large coupes and artificial regeneration, on terrain naturally unsuitable for it. It must be admitted, however, that there have been some serious failures in restocking, resulting in loss of time and money. In these mountains it is only within recent years that steps have been taken, partly as a result of improved communications, to replace these large clear-cuttings by shelterwood systems or clear-cutting in narrow strips.

Application in Practice. The progressive clear-cutting system with natural regeneration from adjoining woods appears to have been in operation in Germany for some hundreds of years, the
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coupes being long and narrow for seeding purposes. In Europe the clear-cutting system with artificial regeneration began to receive serious attention about the middle of the eighteenth century; its effectiveness and the sureness of its results brought it more and more into favour, so that by the end of the century it was in full swing. In France considerable areas of poor gravelly sand, originally supporting a scrubby growth of oak and other hardwoods, were clear-felled and regenerated artificially with Scots or maritime pine; in inland regions the former is now preferred to the latter, and has replaced it on all but the poorest soils.

It was in Germany, however, and in countries influenced by German ideas, that clear-cutting came to be most widely practised, although it was not until 1811 that Cotta systematized it by the formation of cutting sections with the object of affording protection against the wind. In the Austrian Forest Ordinance of 1786 the clear-cutting system with artificial regeneration is recognized as the general system in force. In Germany oak was among the first species employed for reafforesting clear-felled areas, and there are many fine examples of oak woods raised by dibbling acorns, often in conjunction with the raising of field crops. During the latter half of the eighteenth century and subsequently, much reafforestation of poor sandy areas was carried out by means of sowings of Scots pine. Spruce, however, is the species with which the clear-cutting system has been most widely associated. As we have seen, its economic value and its adaptability to this system, owing to its comparative hardiness, led to its extensive cultivation, often in localities outside its natural habitat; hence one of the most important effects of the clear-cutting system in Central European countries has been the supersession of the original forest types by crops of pure or nearly pure spruce. Thus economic considerations prevailed against good silviculture, with the result that the adverse effects of growing pure spruce in unsuitable situations began to make themselves apparent, and a conflict arose in the early part of the nineteenth century as to the suitability of the clear-cutting system as compared with shelter-wood systems (see p. 29). The Baden Forest Law of 1833 actually prohibited the clear-cutting system, and this prohibition is still on the statutes, although it is ignored in practice. The conflict in regard to the clear-cutting system has been renewed from time to time with great bitterness, and has been revived in recent years owing largely to the experience of Saxony, with the result that opinion generally has veered round in favour of more natural methods of treating and regenerating
woods. This applies not only to Germany but also to Austria, Czechoslovakia, and other countries where the clear-cutting system has been widely practised in the past. Although this system is being superseded by systems involving more natural methods of regeneration, it is still practised in Europe to a considerable extent, and in certain cases the great economic advantage of concentrated fellings has led to its retention for a time even where its application on other grounds might seem undesirable, as in the case of the Austrian mountain forests.

In Great Britain clear-cutting with artificial regeneration is much more widely practised than any other form of treatment in high forest, but frequently there is little or no attempt at systematic method. This system is likely to play a leading part in British forestry for many years to come, owing mainly to the following causes:

1. The existence of woodlands rendered derelict by past mismanagement, which could not be regenerated satisfactorily in any other manner.

2. The prevailing policy of introducing exotic conifers to replace the existing types of forest, for economic reasons.

3. The necessity for fencing against rabbits, requiring the utmost concentration of regenerative work in order to justify the cost of fencing.

The large schemes of afforestation begun after the war and now in progress necessitate the creation of artificial woods on a large scale on bare land or on cleared derelict woodland areas; nevertheless it is not improbable that when these woods come to maturity, systems other than the clear-cutting system will in many cases be found applicable to them.

The lumbering operations of Canada and the United States, by which extensive areas of forest have been cleared, are examples of clear-cutting on a large scale; this method of working was adopted primarily on economic grounds, in order to reduce the cost of working to a minimum by felling and removing the largest possible quantity of timber from a given area in the shortest possible time, often by specialized methods of extraction. For the most part these operations have been purely destructive and have no claim to be classed as the clear-cutting system, since no attempt has been made at regeneration.

In certain parts of the tropics the clear-cutting system has played an important part, and it is likely to play a still greater rôle in future. Most tropical forests consist of a large number of different species,
of which only a few are marketable, and in order to increase the proportion of valuable species artificial methods frequently have to be adopted. The method which has been found most economical and successful is that of forming plantations of the desired species on areas cleared of forest for temporary cultivation with field crops. The future of tropical forestry is likely to be influenced in no small measure by the extension of this form of the clear-cutting system.

The increasing attention given to the formation of plantations of exotic species in South Africa, Australia, New Zealand, and other countries outside the tropics, indicates that in these regions also the clear-cutting system is likely to play a very important part in the future. And in general, the predicted world shortage of timber, particularly of soft woods, is a factor which is likely to raise the importance of this system to a level never attained before, since measures necessary to meet this shortage must include the formation of extensive plantations of conifers on areas where they have not existed previously or where they have been depleted by wasteful methods of working. Everything therefore points to the increasing importance of the clear-cutting system in spite of any disadvantages it may possess.