A HISTORY OF PLOUGH DEVELOPMENT IN BRITISH FORESTRY

I. INTRODUCTION AND EARLY DEVELOPMENTS

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Reprinted from
SCOTTISH FORESTRY, Vol. 30, No. 1, January 1976

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I. INTRODUCTION AND EARLY DEVELOPMENTS

Introduction

The last fifty years have seen major and continuing changes in technology as applied to land use. At the beginning of this era, British afforestation involved virtually no site improvement other than at the planting spot except for a few hand-cut drains on wet land. At the end of this period, practically all afforestation was on ploughed ground. The intervening period saw a succession of developments from light agricultural equipment to the current purpose-built tools atttaining depths of up to six times that achieved with the earliest equipment. The course was not a smooth one; foresters have never been unanimous in specifying the soil changes to be obtained by ploughing; hence various development lines were followed; plough development had frequently to await progress in the standard of available tractors. As ploughs were strengthened for deeper penetration, more power was needed and as more power was applied so they had to be made stronger. Plantations established on the earliest types of ploughing are now reaching the productive stage and their yield, root form, stability and ease of extraction are of current interest. A new generation of foresters to whom the names of the early ploughs, their capabilities, and their scale of use are only vaguely known is having to deal with these crops—and from this experience to forecast the likely condition of crops established with modern equipment.

The large British afforestation programme is internationally well-known and professional visitors from abroad have frequently sought a record of ploughing development. Not least, this record may well illuminate an aspect of research and development which one might claim has provided the basis of the current Forestry Commission estate. Useful generalised lessons may be learned in the course of recognising the pioneering efforts of enthusiasts during this fruitful era.

One intentional omission from this record is the succession of tractors. Heavier, more robust ploughs demanded more powerful tractors and varying terrain necessitated a constant re-appraisal of existing equipment in terms of optimising capacity, reliability, costs and availability. This story must remain for another author. Also, neither costs nor productivity details have been given. They would add greatly to the length of this record and without very careful interpretation in respect of inflation and scale effects would add little towards its objectives.

HISTORICAL SOURCES

The information presented has been obtained from a wide variety of sources. Firstly, experimental records were a mine of information, because Silvicultural Research staff were closely involved as initiators of ideas, observers and project team participants; utilising equipment as soon as, or even before it became practicable. Departmental papers including reports of machinery demonstrations were sifted and user experience published in the Forestry Commission Journal and Conservancy reports etc. have been abstracted. In addition the personal recollections of surviving participants, Forestry Commission staff from all levels and plough manufacturers, have been sought and in some cases tape recorded. Several key participants, now retired, have had the opportunity to comment on preliminary drafts. It is noteworthy that records of new introductions are more explicit than records of the extent of usage and dates when a particular tool became obsolete.

It is also inevitable that a retrospective view must be coloured by personal bias. Even yesterday's machinery demonstration is regarded in a different light by its organiser and its spectators. Also in some instances more than one participant may claim the credit for a particular idea. Hence it is unavoidable that some readers may query the accuracy of a particular source and its interpretation. The author therefore makes no claim to absolute truth but hopes that he has, with no special reputation in this field to vindicate, been reasonably fair to all parties. Nevertheless it must be stated that the result is not necessarily an "official" history and that where uncited opinions are given, these are the author's own.

At several stages in the narrative crucial decisions appear to have been made on somewhat subjective grounds as there was frequently little firm evidence allowing an objective decision.

ORGANISATION OF RESEARCH AND DEVELOPMENT IN PLOUGHING

Responsibility for innovation, development and appraisal has not been confined. Any user of a tool, especially in an expansionist era when new conditions were constantly being encountered, might offer suggestions towards its improvement. From below suggestions might come from the operator, the supervising Forester, or other field staff looking ahead to new site types. Alternatively, a silviculturist with specific objectives in cultivation may ask for an appropriate tool, or an engineer or manufacturer may for ease of production or improvement of a mechanical design, offer a new modification. Innovative ideas may have come from various sources and their promotion was to a great extent dependent on the availability of local resources of finance and expertise and the manufacturers' goodwill in persevering through the proving stages. In theory, and quite late in the history, a central co-ordinating committee (the Machinery Development Committee, whose functions were later passed to the Work Study Section) had the responsibility of authorising expenditure as well as taking appropriate initiative. However it is apparent from a cursory glance at the history of ploughing development that the crucial

steps have almost invariably originated from a team consisting of a Forester (of various ranks in the field or in the Research Division), a mechanical engineer at conservancy or directorate level, and a strategically placed enterprising rural blacksmith or agricultural engineer. Development costs at least in the early years, were more commonly borne by the manufacturer or "lumped" in normal maintenance and repair costs rather than specifically allocated. There are, especially to orthodox administrators, obvious disadvantages associated with such a loose system, but bearing in mind the relatively few staff involved and their close effective and informal liaison, the system did maintain a high level of local enthusiasm and initiative and produced the great majority of the commonly used forest ploughs.

Although an individual path of progress could be drawn for every machine, a common though rather idealised sequence of development was as follows:

1. A trial of commercially available tools from an agricultural or civil engineering background.
2. Complete rejection or modification into a usable form.
3. Extensive use for a prescribed site type.
4. Trial under new conditions leading to local amendment, often in the course of repair.
5. Amendment of the basic design to encompass proved local modifications. Failing this, a completely new design might be evolved.

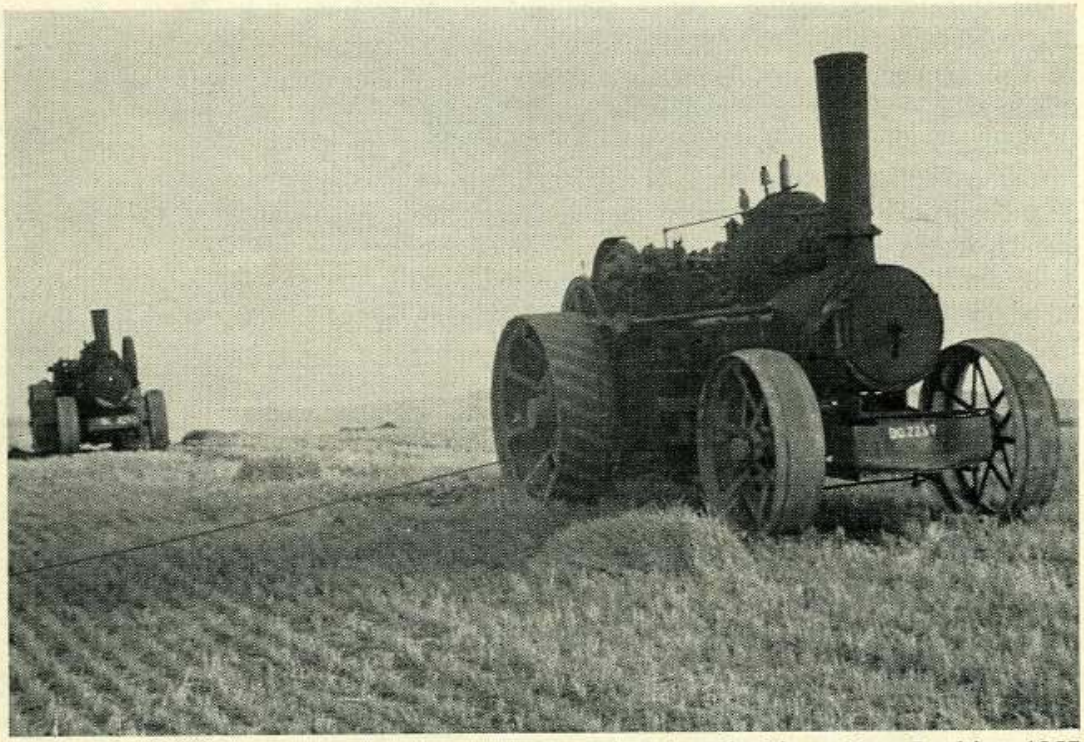
Administrative difficulties arise when local modifications are designed for very restricted site conditions which may render the tool less satisfactory in other parts of the region. (Ploughs and their operators have always been mobile, generally working a co-ordinated conservancy programme which involved several weeks at each of a succession of forests). It was to avoid costly duplication of effort, that attempts have been made to maintain centralised control of development.

Early cultivation of hill land

EARLY AGRICULTURAL PLOUGHING AND FIRST PLOUGHING FOR FORESTRY

It is commonly thought, quite erroneously, that ploughing of hill ground began in the 1920s; but in the 19th century much thought was given to site improvement by mechanical means. In 1803 Nicol prescribed ploughing (presumably horse-drawn) as the cheapest and most effective method of preparation on tillable sites (Pl. 1). Depth was sometimes achieved by using another plough following in the same furrow. Symon (1959) described the major reclamation projects of the previous century in which ploughs, both trailed and winched by steam engines, were used (Pl. 2). The scale and optimism of the work was such that, for example, on Dalchork, Sutherland, an observer recorded "14 engines puffing away at one time" and 1829 acres were ploughed there in four years. An

Pl. 1 The Grants "Craigellachie" Standfast pulled by three horses ploughing Findlays Seat Teindland area 1931. (Photograph: Forestry Commission B 2068).



Pl. 2 Two traction engines engaged in ploughing by winching. East Lothian 1957. (Photograph: Forestry Commission A 1126).

English plough maker was induced in 1837 to take his plough to Lochar Moss, Dumfries-shire. The engine remained stationary and the plough was drawn by means of a long rope wound on a drum and passing through a large pulley anchored at the other end of the moss. Fowler of Leeds produced the most effective steam plough, at least one of which was exported to Germany, where a party of Scottish foresters on an excursion in 1895 saw its work for an afforestation project (Anderson, 1967).

Not only were intensive cultivations in vogue, but the longevity of their effects were the subject of much professional discussion. Anderson (1967) quotes an extract from the Quarterly Review of 1827 when a writer, generally accepted to have been Sir Walter Scott, wrote:

> "It may be some comfort to know that, as far as we have observed, the difference betwixt the growth of plantations, where the ground has been prepared or otherwise, supposing the soil alike, and plants put in with equal care, seems to disappear with 10 or 12 years. It is only in its earliest days that the plant enjoys the benefit of having its roots placed among earth which has been rendered loose and penetrable; at a certain period the fibres reach the subsoil which the spade or plough has not disturbed and thus the final growth of the tree which has enjoyed this advantage, is not often greater than that of its neighbour, upon which no such indulgencies were ever bestowed."

This view was subsequently challenged by an English forest owner, a Mr Withers, a strong advocate of very intensive cultivation, who also practised inter-row cultivation until canopy closure.

In 1872 a description by J. Bradley of ploughing for afforestation of some 70 acres on the Yorkshire Moors was published in the Transactions of the Highland and Agricultural Society of Scotland, and incidentally earned the writer a "medium gold medal." The operation included burning, spaced furrow ploughing, sub-soiling at 10-18 inches (using six-horse equipment) and final cultivation and consolidation (Bradley, 1872). The resultant crop was felled in the Great War and replanted by Forestry Commission in 1922.

It should not be thought that only shallow ploughing was achieved. A special committee of the (Scottish) Highland and Agricultural Society in 1871 defined shallow furrows as not exceeding eight inches in ordinary soil and deep cultivation as not less than 12-14 inches (Ramsay, 1879). This may be compared with Zehetmayr (1960) whose definitions in Bulletin No. 32 were:

Shallow ploughing up to 7 inches.

Moderate deep ploughing 8-12 inches.

Deep ploughing 12-16 inches.

On the peculiar edaphic condition of chalk downland Pontey (1808) recommended complete shallow ploughing followed by a wheat crop or a year's fallow consolidation period as a prelude to afforestation.

It is therefore impossible not to concur with Anderson (*ibid*) in describing the early part of the 20th century as one of "inaction and laissez-faire"

and to recognise some truth in his view that up to the mid 1950s the main cultivation research had been concerned with re-learning in the context of the internal combustion engine what had been forgotten in that period which preceded it. A similar conclusion was reached by Wood and Nimmo (1962) in their historical review of chalk downland afforestation. "On reading Pontey (1808) one feels (in the parlance of the cinemagoer) that this is where we came in." Admittedly the use of new species and fertilisers added new factors to the systems of afforestation.

SITE PREPARATION IN THE FIRST DECADES OF THE 20TH CENTURY

The first edition of the Forestry Commission's handbook of "Forestry Practice" (Bulletin No. 14) published in 1933 describes ploughing in three sentences, and only dry grassy areas were considered ploughable. Several pages were devoted to a variety of planting methods involving a range of intensities of soil disturbance around the planting spot, but although there was some attempt to associate these with soil and vegetation types it was concluded that only trial and error would determine the best method in a particular case.

The most intensive method was pit planting by which trees are placed with the roots carefully spread in a hole often dug considerably in advance of planting. This very localised complete hand cultivation was prohibitively expensive and efforts were made to cheapen it with semi-circular spades (unsuitable in heavy soils) and with mattocks (especially on steep slopes). On the site types being afforested at that time there was no suggestion that such pit planting yielded benefits commensurate with the cost of the method and it was prescribed, as it is today, only for planting very large plants.

On all soil types other than peat, various types of notch planting were preferred. These included dibbling (with a steel wedge fitted to the end of a shaft, or the Schlich Vertical Notching Spade), but L-, T-, or H-shaped notches using an ordinary garden spade were the commonest methods (Fig. 1). Mattocks were also used on stony soils and elsewhere in order to quicken this operation but it was generally recognised that this tool required greater skill and closer supervision to obtain a well planted tree. Tool lists of that time bear witness to a wide variety of preferred tools in different regions. Zehetmayr (1954) summarises in greater detail than is given below the development of hand methods of site preparation and planting of peat. An interesting pioneer attempt to afforest a bog was on the estate of Lord Mountjoy in County Tyrone (McEvoy, 1802). The form of turf planting invented there was apparently not followed elsewhere as it was not until the early 20th century that turf planting originating from Prussia was introduced via the Ardennes in Belgium to Great Britain by Sir John Stirling Maxwell. By 1910, after several years' experience, he was convinced of the advantages of this method, but Zehetmayr (1954) suggests that the evidence in favour of turf planting was not conclusive even in 1920, and this is supported by the relatively large areas of direct notch planting on peat clad ground in 1921-1922 at Inverliever, Argyll and Inchnacardoch, Inverness-shire.

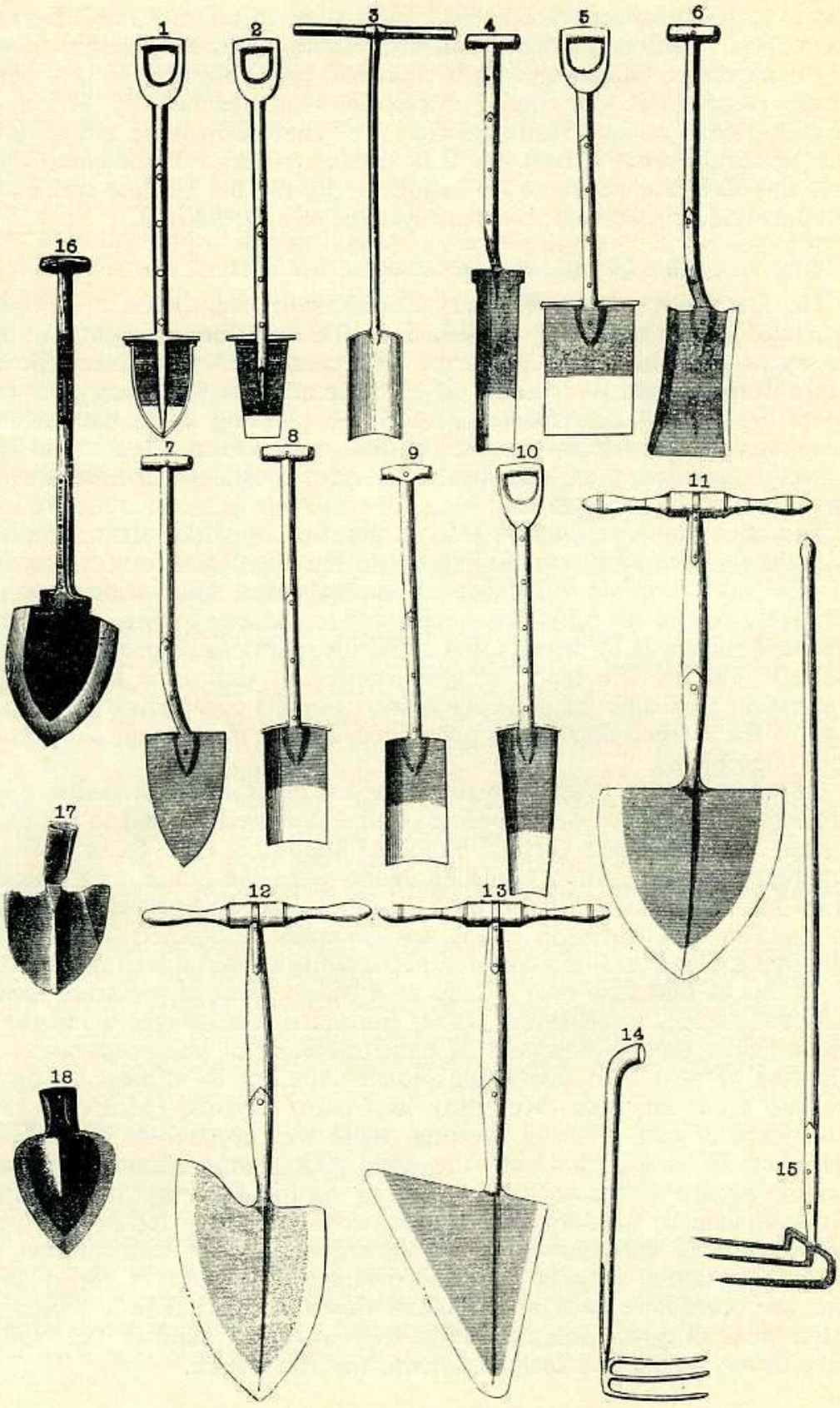


Fig. 1 Planting and Draining tools illustrated in the Forestry Commission tool Sheet 1950. See opposite.

In 1923 H. M. Steven, the Scottish Research Officer, followed his report "Root form on peat" with experimental turf planting from drains about six inches deep; a method which, after a few years of trial and modification, became extensively used on peaty sites in the latter half of the decade (Fig. 2). The heavy so-called Belgian turf which was common between 1928-1935 then gave place to a thinner vertical slice taken from drains, partly for reasons of cost, partly because of easier combination with prevalent drainage practice, and partly because this lighter turf was less inclined to sink into the peat. "Sliced turfs" remained the standard method until superseded by ploughing, although a variant was widely used when after the Second World War there was insufficient mechanical equipment to complete the large afforestation programmes of that time. The spacing of ploughing was widened to 17 or 21 feet and ridges were cut into turves which were spread by hand to fill the intervening area (MacDonald, 1953). In 1928-29, M. L. Anderson, who had become Steven's successor as Research Officer (Scotland) established several hand dug experiments in peatland at Inchnacardoch (Experiment 44) and Achnashellach (Experiment 8) including complete digging and lazy beds. The latter, illustrated in Plate 3, is of interest in view of the much later return to similar principles with mechanically produced riggs and furrs.

Although the first attempts to plough peatland in 1927 were unsuccessful, Anderson assumed that this would eventually become feasible and he laid down several experiments in which the expected configuration of both complete and spaced furrow ploughing was simulated by hand work. In at least one "mock ploughed" plot phosphate fertiliser was placed under the ridge in the vegetation sandwich thus simulating the action of and effect produced by the fertiliser spreading plough, which was developed in the early 1960s (Pl. 4)—and incidentally providing crops whose root form could be examined to determine the effect of such fertiliser placement. This has remained one of the most farsighted research trials ever carried out. Anderson also introduced hand-cultivation of patches at final crop spacing in order to economise on cultivation costs. But this motive for "Anderson groups" was superseded by ploughing.

An attempt to supersede the horse with a machine, very like modern horticultural tillage equipment, called an "auto-culto" machine (Pl. 5) failed to produce a large enough turf on Calluna sites in the South of England. Results were better than those obtained from direct notching into the natural surface but did not justify extensive use of the machine.

1. Schlick vertical notching spade treaded; 2. Mansfield planting spade treaded; 3. Semicircular Transplanting spade; 4. Claycutter or Drain tool; 5. Planting spade; 6. Square Drain shovels; 7. Diamond pointed Drain shovels (Dumfries); 8. Circled Grafting tool; 10. Circled Drain spade; 11. Sheep or Hill Drain spade; 12. Rutter spade LF or RF; 13. Rutter spade (Kirriemuir) LF or RF; 14. Hill Drain Drag; 15. Drainers' Drag; 16. Hodding spade; 17. Flauchter spade; 18. Hay spade.

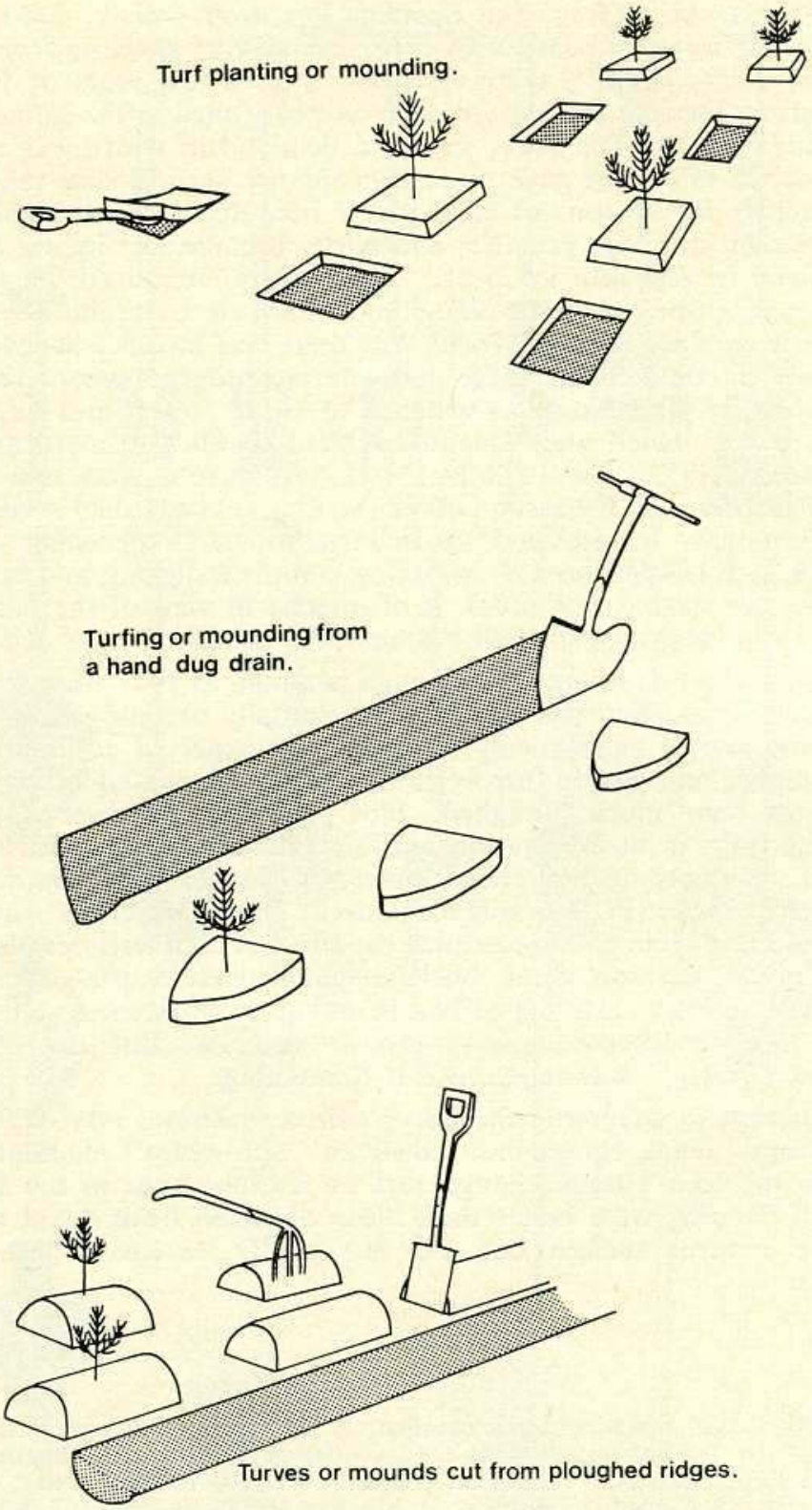
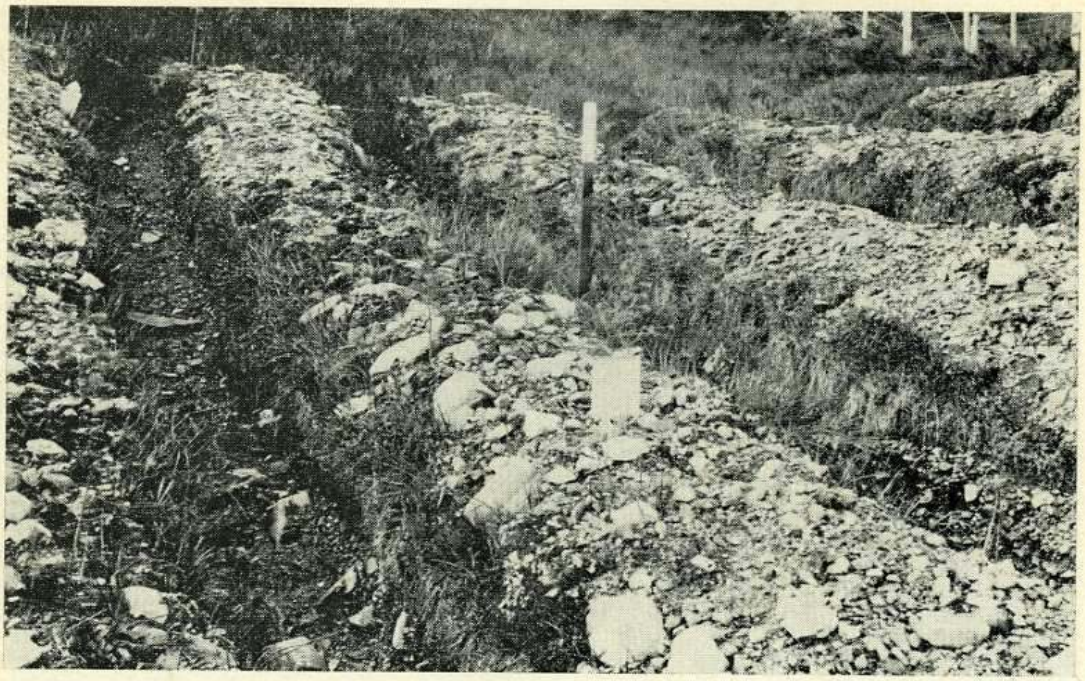
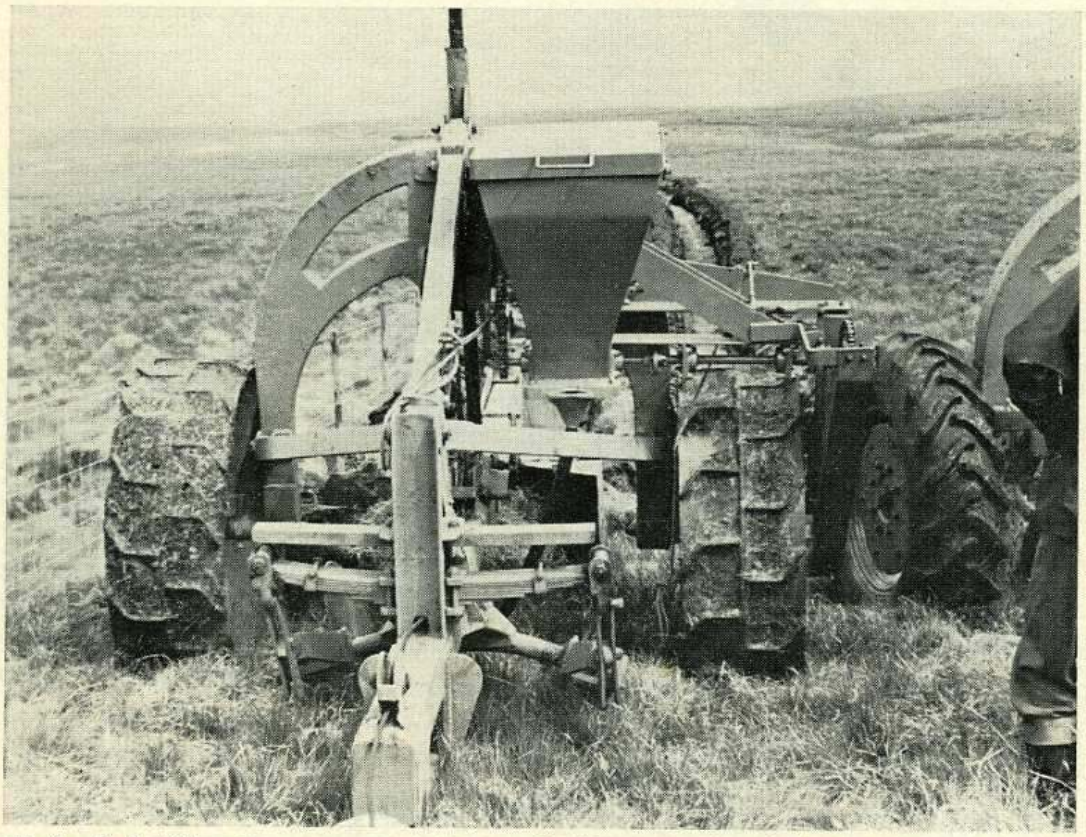


Fig. 2 Progression of development from single turf to spaced turves to turves from spaced ploughing.



Pl. 3 Hand dug lazy beds. Achnashellach 1929. (Photograph: Forestry Commission).



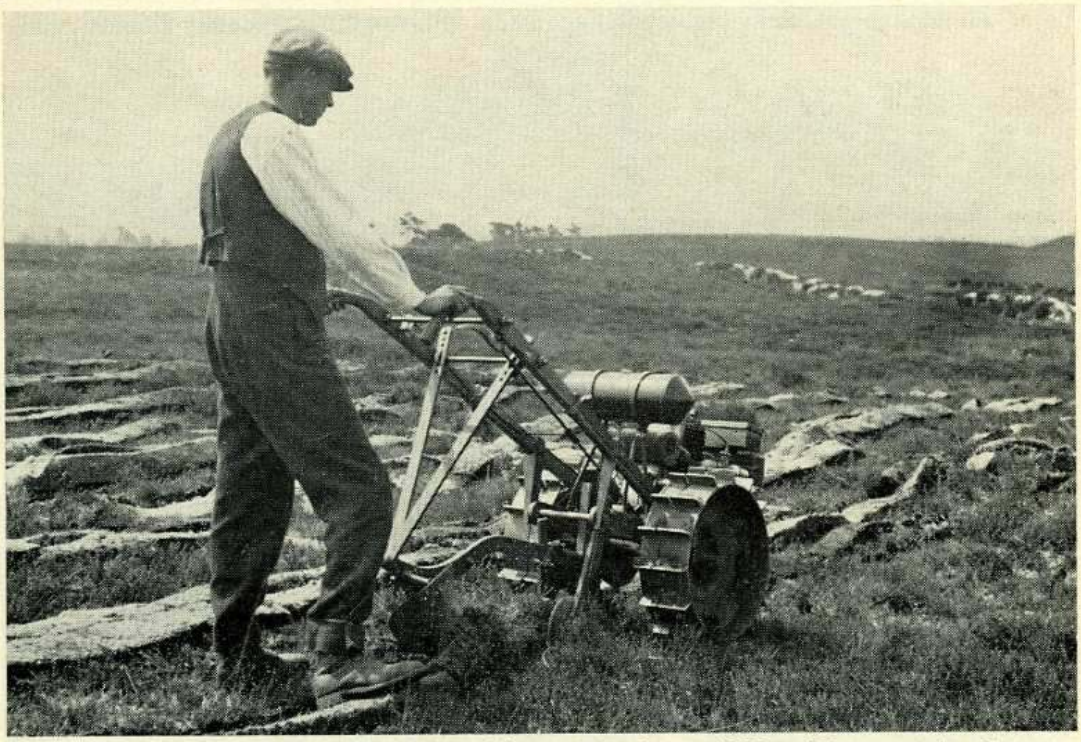
Pl. 4 A fertiliser hopper mounted on a Cuthbertson plough by Wm. Clark & Son, Parkgate 1961. (Photograph: M. Clark).

Aims and effects of ploughing

Ploughing, which for the last 20 years has been an almost universal first step in afforestation, may alter a site in a variety of interlocking ways. Taylor (1970), provided a very useful analysis which is briefly summarised below.

1. REGULATION OF WATER MOVEMENT

Water movement is influenced first by breaking the superficial peaty seal of some soils; by rupturing impervious layers, or by loosening compact or indurated deeper horizons. In addition, on slopes, strategically sited deep plough furrows may be used to intercept water before reaching lower lying ground. The effectiveness of a plough depends largely on the depth it is capable of reaching and the spacing at which it is employed. The distinction between the drainage and cultivation functions of ploughing, which was usefully drawn by Henman (1963) in the research context is less appropriate in the context of this paper because, as will be seen, several of the ploughs described have been used for both functions. Short term benefits are concentrated in the ridge and longer term effects are produced by the furrow.



Pl. 5 The Auto-culto-machine ploughing. Wareham 1933. (Photograph: Forestry Commission D 39).

2. IMPROVEMENT OF SOIL AERATION

If the water movement is improved by ploughing aeration is also improved, the degree of improvement being dependent upon the depth and spacing of the plough furrows.

Pl. 6 The Finn planter which was tried but failed to work on ploughing. (Photograph: Forestry Commission).

3. MOBILISATION OF NUTRIENTS

In brief, improved aeration, more rapid water movement and increased soil temperatures combined with the mixing of previously discrete soil horizons (especially organic with inorganic ones) lead to chemical changes and to the increased availability of nutrients to plants.

Spaced-furrow ploughing confines the bulk of these effects to the ridge and hence turf size is of significance. In complete cultivation these effects are more widely distributed in the rooting zone. The depth, intensity and quality of the disturbance is crucial to the degree and longevity of effect. Indeed some effects are very short-lived as instanced by the poor tree growth which results when there is an interval of a few years between ploughing and planting.

4. SUPPRESSION OF WEEDS

Growth of trees can generally be correlated with the degree to which vegetation has been suppressed. In addition to the mobilisation of nutrients, the adverse physical effects of competing vegetation are delayed or avoided and this aim alone may be the motive for ploughing some sites. Reduction of competition for available moisture or nutrients or the removal of an antagonist (most of all *Calluna*) are also of importance. Henman (1963) draws attention to the difficulties of separating the (strict) effects of cultivation from those of suppressing the vegetation. Trees

may gain advantage from their elevated position on the ridge. In addition because the trees are on straight rows where planted on spaced furrow ploughing any later weeding is made easier.

5. PROVISION OF A FAVOURABLE PLANTING POSITION

In addition to the complex benefits described above, the planting operation is significantly cheapened by reducing the area and time of search and choice of a suitable microsite for planting. Furthermore radiation frost hazard is reduced, and by ensuring optimum early growth the period of time during which the tree is susceptible to a variety of birds and animals is reduced.

6. LIMITATION OF LATERAL ROOT EXTENSION

Spaced furrow ploughing of wet soils has been shown to influence root development in that main structural roots are encouraged firstly to develop along the plough ridge and secondly to explore the land between the furrows. Very few main roots traverse the furrow and this is disadvantageous to the tree's longer term resistance to strong winds.

It should be noted that deep furrows and high ridges are difficult for vehicles to traverse in subsequent forest operations, for example mechanised planting has not been found practicable (Pl. 6) and some timber extraction difficulties are created.

SITE AND SILVICULTURAL CONSIDERATIONS

The extent to which a site can be improved depends on a number of features. These include:

(a) The inherent qualities of the soil and site in question. The choices are more difficult in mosaics of site types where usually the dominant components set the pattern.

(b) The availability of ploughs, tractors and skilled operators.

(c) The existing state of knowledge about the effects that the treatment is likely to have on the yield and stability of the planted crop. This consideration has played the most significant role in the direction and the rate of ploughing development. A change in ploughing specification, to be readily acceptable to the field manager, must appear clearly worthwhile and consequently attention has tended to be concentrated on early benefits such as improved survival and early growth. Later benefits, or the longevity of effect, are of necessity somewhat speculative and hence make a lesser contribution to a change in practice. Cultivation research has been essentially empirical; *i.e.* new and practicable techniques were applied to a given set of soil conditions, and, in well designed experimental layouts, were compared to the current standard method. The benefits of the new system were appraised in terms of tree growth and root pattern as assessed by excavation. This strategy has at its best led to a rapid response to changing technology and a rapid

application of research findings into large scale practice. Its main disadvantages have been occasional diversions down unprofitable avenues and an over-emphasis of short term responses at the expense of longer term benefits; *e.g.* tine ploughing of indurated heathland soils, and the choice of the tine channel as the planting spot for pines gave promising initial survival, but later resulted in wind loosening, butt sweep of pine and a sudden fall-off in growth when the roots had fully exploited the loosened tine channel and the trees were again limited by the unaltered parts of the soil.

Only in more recent years has a more fundamental approach been initiated, involving attempts to characterise the environmental needs of tree roots and matching these to the physical and biochemical effects obtainable from a range of amelioration treatments. This phase, with its more systematic classification of soil variation (*e.g.* Pyatt, 1970) and more careful assessment of physical factors should allow greater precision in extrapolating experimental results. As well as giving greater confidence in the estimation of future tree responses, it may also suggest technological changes more basic than those constrained by current practicalities.

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