Short Rotation Forestry Establishment

Summary

Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) are methods of growing high yielding energy forestry crops. This series of studies aims to establish output and cost information for operational scale establishment of SRC and SRF, gather experience of mechanised planting methods used, and collect information on fuel usage. The efficacy of SRC planting machines has long been established, however, these studies show that mechanised planting machines are also capable of establishing SRF on ex-agricultural sites with a range of broadleaf and conifer species.

Five establishment studies were carried out over a range of former land uses and with different tree species. Outputs for these planting studies in SRF ranged from 0.13ha/shr for Scots pine/birch mixture on ex-pasture ground (target density 2700 trees/ha) to 0.34 ha/shr for pure Scots pine on ex-arable ground (target stocking 2700 trees/ha; the range of outputs achieved includes crops established at different densities). Planting two mixed species had the greatest impact on reducing output than any other variable in the study owing to the increased handling when the operator alternated between different species.

Fuel usage figures of 16.7 l/ha for SRF and 5.4 l/ha for SRC will allow comparisons with future studies and increase understanding of the energy balance of energy forestry crops.

Introduction

Short Rotation Forestry involves growing high yielding tree species over short rotations (between 10 and 20 years) using single stem management and conventional forest establishment and harvesting techniques. Trees grown under SRF are primarily managed for biomass but offer flexibility to be grown on to maturity in response to changing management objectives and market conditions, therefore offering greater flexibility over alternative woody biomass crops such as short rotation coppice (SRC).

In September 2007, Forestry Commission Scotland (FCS) identified an information gap in the knowledge of growth and development of Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) in Scotland. Consequently, a series of exemplar Energy Forestry (EF) trials, throughout Scotland was proposed by FR and FCS.

Technical Development have carried out time study as part of the FCS Short Rotation Forestry and SRC establishment trials to determine output and cost information, as well as recording information on operational practice and fuel use to inform future best practice guidance and energy balance calculations.

Objectives

1. To carry out formal time study for Short Rotation Forestry establishment at FCS EF site East Grange.

2. To comment on operational efficiency and stocking density of establishment systems studied and, where appropriate suggest method improvements in the interests of efficiency, efficacy and health and safety.

3. To collect figures of fuel use for SRF establishment; fuel use to be measured against outputs during time study and area established.

Work Method

Site description and location

The location of this study was at East Grange, Blairhall, Dunfermline, Scottish Lowlands FD (grid reference at main entrance: NS 000018 89140).

Site conditions

Site conditions were assessed and recorded at the start of each study as shown in Table 1. Study sites were located to include uniform conditions in terms of slope, ground conditions and access with no specific obstacles, hazards or constraints that would affect the study. Due to the division of former land use at East Grange of previously cultivated agricultural land (sown with Barley) and land previously established as pasture, separate studies were carried out on these different areas to contrast the effects of former land use on SRF establishment.

Two distinct site strata were present across East Grange: i.) Former grazing pasture and ii.) Former agriculturally cultivated land, cropped with Barley prior to SRF establishment. Separate studies were carried out on these two strata in order to assess the effects of former land use on SRF establishment outputs.

The range of studies carried out assessed outputs with a range of different species established. Study sites were chosen to be homogenous in terms of ground conditions and slope study area was determined by the homogeneity of the site. Study site descriptions are shown in Table 1.

Table 1 Study site descriptions

Study Number	Study Type	Species	Previous land use	Study area ha	Terrain	Soil type	Weather Conditions	Grid reference
1	Mechanised SRF Planting	Scots Pine	Arable	1.12	2,1,1	Indurated brown earth	Bright, overcast, occasional rain	NS 98866 89434 (SE corner)
2	Mechanised SRF Planting	Scots Pine	Pasture	0.598	2,1,3	Indurated brown earth	Overcast, cool, dry	NS 99101 90330 (NW corner)
3	Mechanised SRF Planting	Scots Pine /birch	Pasture	0.295	2,1,3	Cultivated brown earth	Overcast, cool, dry	NS 99117 90388 (NW corner)
4	Mechanised SRF Planting	birch	Arable	0.854	2,1,2	Indurated brown earth	Overcast, cold, rain	NT 00093 89417 (NW corner)
5	Mechanised SRF Planting	aspen	Arable	0.333	2,1,2	Indurated brown earth	Overcast	NS 99842 89325 (NW corner)
6	Mechanised SRC Planting	willow, mixed spp.	Arable	1.216	2,1,1	Surface water gley	Bright, sun, warm	NS 99159 88974 (NW corner)

Table 2 Planting specification

Study Number	Date of study	Operation and Species	Planting Stock	Planting machine	Number of operators	Target Stocking Density trees/ha
1	27th November 2008	SRF establishment, Scots Pine	Bare root stock	Keen Planter	1 (plus driver)	2700
2	27th February 2009	SRF establishment, Scots Pine	Bare root stock	Keen Planter	1 (plus driver)	2700
3	27th February 2009	SRF establishment, Scots Pine /birch	Bare root stock	Keen Planter	1 (plus driver)	2700
4	20th February 2009	SRF establishment, birch	Bare root stock	Keen Planter	1 (plus driver)	4400
5	20th February 2009	SRF establishment, aspen	Bare root stock	Keen Planter	1 plus driver	4400
6	13th May 2009	SRC establishment, Willow, mixed spp.	Cuttings from willow rods	Salix Maskiner Step Planter	2 (plus driver)	15000

Machinery description and specification

Mechanised Planters

Mechanised planters are typically tractor pulled machines that create a narrow trench in the soil into which a tree is placed, packing wheels or skids on the planter then close the trench and firm the soil around the plant. In addition, recent machine designs have spray attachments for applying herbicides for weed control.

Tree-planting machines are of three general types:

- Floating - attached to a tractor by a three-point linkage allowing the entire machine to be raised from the ground by hydraulic lift from the tractor.
- Semi-floating – the front end is carried by the tractor and its back end supported on wheels; semi-floating machines cannot be lifted by the tractor.
- Trailer - all or nearly all the machine's weight is carried on its own wheels.

Common machine components of mechanised planters are shown in Figure 1.

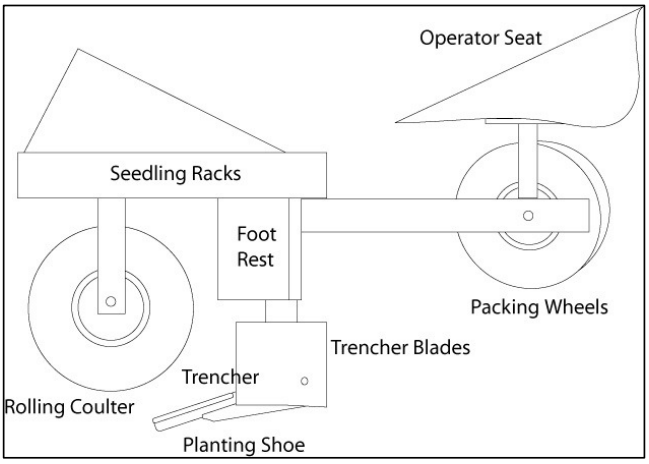

Figure 1 Common features of a forestry planting machine

During use the planting speed varies with the ground conditions, species and size of trees, and operator experience.

SRF planting at East Grange was carried out by the 'Keen Planter', a mechanised planting machine (Figure 2). The Keen Planter was towed by a McCormick MTX175 tractor for study numbers 1, 2 and 3 and with a New Holland (TK90M) crawler for studies 4 and 5 (a low ground pressure machine was used to improve traction over wet ground, following heavy rain).

The Salix Maskiner Step Planter studied for SRC planting was towed by Fendt tractor (model Vario Fendt 716).

Keen Planter

The Keen planter is a continuous, single row planting machine, capable of planting a single row of conifer or broadleaved bare rooted trees within a height range of 15–90 cm. The planting machine is mounted on the prime mover 3 point linkage. The machine design is *floating* and can therefore be raised from the ground by hydraulic lift from the tractor.

Figure 2. New Holland TK90M tracked crawler with trailed Keen planter.

Figure 3. Operator's seat inside the Keen planter.

During operation a planting trench is created by a hydraulically operated ploughshare (Figure 4). The ploughshare is mounted on a vertical ram controlled by the planter by means of a foot pedal. The ploughshare can be lowered to a depth of 40 cm into the soil, to adapt the resulting depth of the planting trench to the planting stock. The entire planting machine, mounted on the tractor's three-point-linkage can be lifted off the ground, in order to clear obstructions.

A land measuring wheel attached to the planter's frame indicates required plant spacing by tripping a tine which sounds a horn at the required spacing, indicating to the operator when the plant should be inserted into the planting trench. The trench is closed by 2 solid packing wheels after planting (Figure 4). The planting station seats the planter parallel to the planting

furrow, facing the direction of travel, reducing excessive bending effort and therefore improving ergonomics. Machine specifications are shown in Table 3.

Figure 4. Keen planter ploughshare and packing wheels

Figure 5. New Holland TK90M tracked crawler with trailed Keen planter.

Salix Maskiner Step Planter

This complex planting machine consists of four linked planting units, driven from a central shaft powered by the PTO of the prime mover. 'In row' spacing can be adjusted by changing the pressure on the friction gear driving the individual planting units, thereby changing the speed of planting.

Figure 6. Salix Maskiner step planter and Fendt Vario 716 tractor.

Figure 7. Willow cuttings in situ following planting.

The Salix Maskiner uses willow rods for planting rather than prepared cuttings (Figure 6). Each rod (c. 2 m long) is fed between a pair of feed belts, these guide the rod down to the 'planting shoe'. The rod is automatically cut and the severed cutting is pushed down into the soil (Figure 7). The length of the cutting can be varied between 10 cm and 20 cm in 2 cm increments. The maximum rod diameter is 20 mm.

Figure 8. Salix Maskiner planter planting willow cuttings, fed by operators on the rear of the machine

Planting proceeds semi-automatically; each operator places single rods into the top of the feed belts where they are drawn into the cutting mechanism. Two operators are required to keep the feed mechanism charged with rods, each feeding two planting units (Figure 8). Machine specifications are shown in Table 4 detailed machine costings are shown in Table 10 in the appendices.

Table 3 Machinery specification – Keen Planter

Planting machine	Keen Planter	
Prime mover	McCormick MTX175 Tractor	New Holland tracked crawler (TK90M)
Rows planted per pass	1	1
Operators	2 (1 prime mover driver 1 planter)	2 (1 prime mover driver 1 planter)
Capital cost (£): Planting machine	4000	4000
Capital cost (£): Prime mover	64000	24000
Operator/s cost (£):	1 tractor operator at £10/hr. 1 planter operator at £10/hr = total £20/hr	1 tractor operator at £10/hr. 1 planter operator at £10/hr = total £20/hr

Table 4 Machinery specification – Salix Maskiner Step Planter

Planting machine	Salix Maskiner Step Planter
Prime mover	Fendt, Vario Fendt 716 tractor
Rows planted per pass	4 (two pairs of double rows per pass, one pair planted by each operator)
Capital cost: Planting machine	£ 30 000
Capital cost: Prime mover	£ 105 000
Operator/s Cost	1 tractor operator at £10/hr. 2 planter operators at £8/hr = total £26/hr

Method

Operational time studies

All planting was carried out using mechanised planting machines. Mechanised planting outputs were measured using standard time study methodology, as described in Technical Development time study instructions for tree planting.

Fuel use assessment

Fuel used during establishment was assessed for a sample of operations by first dipping the fuel tank before the study to determine the level of fuel in the tank. Following the study the fuel level was refilled to the starting level to determine fuel use during the study, over the specific area measured.

Plant stocking density and efficacy

Following planting, measurements were taken of plant spacing within and between rows and of stocking density by using 0.01 ha sample plots as described in the Forestry Commission stocking density assessment procedure (Operational Guidance Book 4).

Results

Operational observations from Short Rotation Forestry planting:

- Trees were planted to an acceptable standard using the Keen planter for the variety of species studied. In wet weather the Keen planting machine's packing wheels occasionally lost traction and slid over the ground surface causing the wet soil to be deposited in front of them.

Whenever the packing wheels lost traction the machine's effectiveness at firming the trees into their planting positions was reduced. Subsequent survival assessments did not however, show this to significantly impact on tree mortality.

- Using the Keen planter, spacing is determined by the operator feeding trees into the planting mechanism at an audible signal; plant spacing accuracy therefore is highly dependant on operator concentration. Over long time periods and in poor weather conditions if concentration is not maintained then there is potential for plant spacing accuracy and planting quality to suffer. The post planting stocking density assessments recorded overall stocking and potential for variable stocking density with time was not recorded.

- Unearthing of a small sample of trees at the time of planting indicated that most trees had rooted securely. Due to the linear planting method and placement of the trees into the furrow however, tree roots were typically swept into a 'J' shape (Figure 9). Although potentially undesirable for timber quality and tree stability this may not represent a significant issue for energy forestry crops grown on shorter rotations. Implications for stability and tree form would be important for crops intended to be grown on as high forest however.

Figure 9. J-shaped rooting of excavated pine following mechanised planting

- Mechanised planting was restricted due to cold (frozen ground) then wet weather hampering the operation and setting back planting timescale.

- Wet weather led to rutting of the ground surface when planting was carried out using a conventional wheeled agricultural tractor and traction was reduced. Implications of ground compaction were not assessed as part of this study however, ground compaction due to regular machine movements during short rotation lengths of SRF and SRC has potential to negatively impact on site fertility and soil sustainability.

  Previous research by Technical Development has shown ground pressure to be higher for wheeled machines than for machines fitted with tracks (Deboys, 1997).

- Following a period of very wet weather an alternative low ground pressure, high traction New Holland crawler was brought onto site to provide improved grip in wet conditions. The crawler (Figure 5) was fitted with extra high floatation tracks and enabled planting with lower ground impact and improved traction compared with the conventional agricultural tractor prime mover.

- Operator ergonomics inside the Keen planter were good, protection from the elements was provided by the enclosure of the machine and a comfortable reclining seat was provided.

Operational observations from Short Rotation Coppice planting:

- Operators in this case came from an agricultural labour ring and had not planted SRF before, however despite this the simple work activity was quickly understood and the work was undertaken in a conscientious way.

- Fresh willow rods had to be transported to site everyday (boxed on a trailer, Figures 10 and 11) towed to site with a pick up. Off site storage of willow rods was in a refrigerated cold store.

Figure 10. Boxed willow stems transported to site by pickup and trailer.

Figure 11. Boxed willow stems following transport to site.

- Operator ergonomics could be improved with the addition of a seat or support at the rear of the machine for the planters to rest on, rather than having to stand (Figure 8).

Outputs and Costs

The outputs achieved during the trials are summarised in Table 5 showing output per standard hour and cost per hectare. Cost calculations for the planting machines studied are shown in Table 10 in the appendices.

Table 5 Summary of Outputs and Cost

Study Number	Machine	Total area established during study	Total cyclic time (Shr)	Cost per hour			Output (ha/Shr*)	Cost (£/ha)
				Planting machine (£/Shr)	Prime mover (£/Shr)	Total system (£/Shr)		
1 SRF Scots pine establishment on ex-arable	Keen planter + tractor	1.12	3.29	11.50	20.57	32.08	**0.34**	**94.34**
2 SRF Scots pine establishment on ex-pasture	Keen planter + tractor	0.598	2.49	11.50	20.57	32.08	**0.24**	**133.65**
3 SRF Scots pine +birch establishment on ex-pasture	Keen planter + tractor	0.295	2.27	11.50	20.57	32.08	**0.13**	**246.73**
4 SRF birch establishment on ex-arable	Keen planter + crawler	0.854	3.88	11.50	15.40	26.90	**0.22**	**122.28**
5 SRF aspen establishment on ex-arable	Keen planter + crawler	0.333	1.665	11.50	15.40	26.90	**0.2**	**134.51**
6 SRC Willow establishment on ex-arable	Salix Maskiner Step Planter	1.216	1.59	27.43	23.80	51.24	**0.77**	**66.54**

* Shr: Standard hour: standard time includes allowances for rest and other work.

See Table 10 in the Appendices for detailed machine costing.

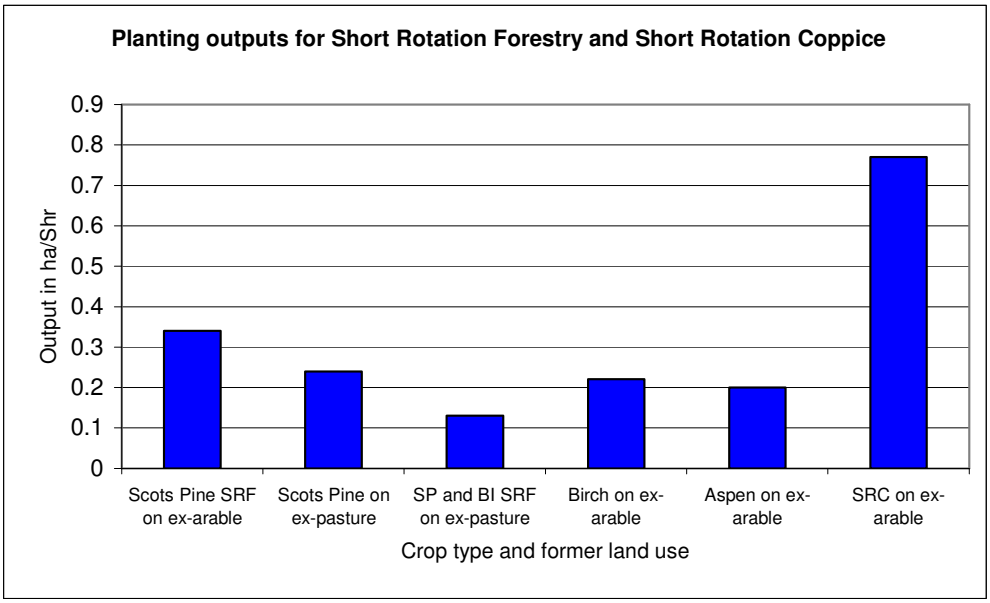

Figure 13 Planting outputs for Short Rotation Forestry and Short Rotation Coppice

An elemental breakdown by percentage of the cyclic time studied for each aspect of the work is shown in Table 6.

Table 6 Breakdown of cyclic time by planting study

Study Number	Machine	Percentage of cyclic time studied					
		Move to plant	Move to reload	Load Trees	Plant	Turn on Headland	Adjust load
1 SRF Scots pine establishment on ex-arable	Keen planter	0.2	0	10.1	77.1	12.6	0
2 SRF Scots pine establishment on ex-pasture	Keen planter	0	0	17.3	68.8	13.9	0
3 SRF Scots pine +birch establishment on ex-pasture	Keen planter	0	0	10.1	73.6	16.3	0
4 SRF birch establishment on ex-arable	Keen planter	0	0	4.8	81.0	14.2	0
5 SRF aspen establishment on ex-arable	Keen planter	0	0	2.2	77.7	20.1	0
6 SRC Willow establishment on ex-arable	Salix Maskiner Step Planter	1.7	0.6	16.9	72.6	7.1	1.1

A measurement of fuel use for each crop type (SRF and SRC) was taken to provide an assessment of fuel consumption during planting operations. The results of these measurements are shown in Table 7.

Table 7 Fuel use assessment for SRF and SRC establishment

Study Number	Operation	Area studied for fuel use assessment	Machine combination	Fuel used litres	Fuel use per hectare
1	SRF establishment	0.45* ha	Keen planter + McCormick MTX175 Tractor	7.5 litres	16.7 l/ha
6	SRC establishment	1.216 ha	Salix Maskiner Step Planter + Fendt, Vario Fendt 716 tractor	6.5 litres	5.4 l/ha

*Fuel use was assessed over a proportion of the total 1.12 ha study area.

This assessment includes fuel consumption during establishment but does not include additional fuel inputs for ancillary activities such as transport of machinery and operators to site and therefore should be considered in the context of fuel use for establishment alone.

Table 8 Planting spacing

Study Number	Operation	Mean in row spacing (m)	Mean between row spacing (m)	Mean Stocking per 0.01 ha sample plots	Stocking per hectare*	Target Stocking per hectare
1	SRF Scots pine establishment	1.74	1.94	29	2880	2700
2	SRF Scots pine establishment	1.56	1.85	34	3400	2700
3	SRF Scots pine/birch establishment	1.60	1.85	31	3100	2700
4	SRF birch establishment	1.24	1.79	45	4490	4400
5	SRF aspen establishment	1.23	1.77	47	4650	4400
6	SRC Willow establishment	0.62	1.13	142	14060	15000

*Based on stocking density plot figures

Results from survival assessments carried out c. 3 months after planting are shown in Table 9. Plant survival has been calculated per hectare based on 0.01 hectare plot data, gathered using FC OGB4 stocking density methodology.

Table 9 Survival Assessments

Study Number	Operation	Target Stocking per hectare	Number of possible planting positions/ha	Number Live/ha *	Dead Plants/ha *	Missing Plants/ha *
1	SRF Scots pine establishment	2700	2880	2790	80	10
2	SRF Scots pine establishment	2700	3400	3280	120	0
3	SRF Scots pine/birch establishment	2700	3100	2960	100	40
4	SRF birch establishment	4400	4490	4380	100	10
5	SRF aspen establishment	4400	4650	4500	150	0
6	SRC willow establishment	15000	14160	14060	0	100

* Based on stocking density plot figures

Post Planting Observations

- After planting spiral guards were placed around each tree. Where trees have subsequently emerged from the top of the guard they have often developed a lean in the direction of the prevailing wind. Throughout the SRF planting, particularly the fast growing broadleaf species, some trees have developed a distinct bend in the stem (Figure 12) as a result and a small number (currently insufficient to feature in the survival assessment) on exposed areas of the site have snapped at the point of the top of the spiral guard (Figure 13). On very exposed sites this could be an issue for fast growing species.

Figure 12. Leaning tree emerging from the top of spiral guard in the direction of the prevailing wind

Figure 13. Recently snapped birch at the point of emergence from the top of spiral guard

- In some areas existing field drains were broken by the planter's ploughshare, where this occurred on sloping ground water has diverted from the drain and (following the path of the planting furrow) eroded the soil, uprooting and displacing planted trees along the planting line (Figure 14).

Figure 14. Broken drain leading to water runoff and channelling along a planting furrow uprooting trees in the process

Discussion

Operational Observations

Both the Keen planter and Salix Maskiner Step Planter showed they could plant satisfactorily on formerly agricultural new planting sites. The single row Keen planter provided an advantage of greater flexibility of between row plant spacing compared to alternative double row planting machines.

During SRF planting, due to poor weather the tractor prime mover was replaced with a tracked crawler for two of the planting sites which improved traction and reduced ground impact and risk of soil degrade on the sites where birch and aspen were planted. The crawler was able to deliver a high standard of planting for comparable cost with the tractor and while planting at higher stocking density per hectare.

During planting of both SRF using the Keen planter and SRC with the Salix Maskiner Step planter the prime mover operator and planter/s were able to communicate with each other. During SRC planting the tractor driver and planters were able to communicate with each other through the rear window of the tractor, and in the closed environment of the Keen planter

radios were used to communicate between the planter and tractor driver. Communication between the planter and prime mover was essential to maintain the planting machines at the appropriate speed for the operation, as well as raising the need for stopping without compromising the quality of planting.

Following plant excavation a small number of trees showed swept roots (Figure 6). This 'J-shaped' root development is characteristic of mechanically planted trees established in a linear furrow and has implications for future tree stability. The short rotation length of SRF crops compared to conventional high forest may make root development in the interests of tree stability a lower priority for managers. This is an aspect where future research would be beneficial to establish the implications of plant rooting for SRF growth and yield.

Outputs and Costs

The output recorded for study number 1 (shown in Table 5) was higher than for the other SRF establishment studies. This higher output may be due to the good ground conditions on the ex-arable site compared to the ex-pasture sites.

SRF planting output dropped from 0.24 ha/shr to 0.13 ha/shr when planting a mixture of two species, a reduction in output of almost 46% and an increased cost of 85%. The reason for this reduction was the additional time taken to change species and the resulting disturbance to the working method.

In previous studies by Technical Development (Drake-Brockman, 1998) outputs for the Keen planter on new planting sites ranged from 0.21 ha/shr with an average row length of 100 m to 0.26 ha/shr with an average row length of 200 m and 0.28 ha/shr with an average row length of 300 m (with a target stocking of 2500 trees/ha and single species planting). Outputs from East Grange (shown in Table 5) are comparable with these figures indicating that outputs were consistent with previous experience on similar sites.

The crawler and Keen planter combination was able to achieve higher planting densities with comparable outputs to the tractor. The forward speed of the prime mover could be maintained over the wet ground, aided by the increased traction of the crawler and a higher stocking per hectare was achieved.

In previous evaluations of SRC planting machines by Technical Development (Forestry Commission 1996) the Salix Maskiner Step Planter achieved similar outputs as observed at East Grange. During previous evaluation of the Step Planter outputs of 0.89 ha/shr were achieved planting 12422 plants/ha (target stocking 10000 trees/ha), compared to the East Grange output at 0.77 ha/shr establishing 14160 plants/ha (target stocking 15000 trees/ha).

Manual planting outputs on farm woodlands recorded by Technical Development[1] were lower and more expensive than mechanised planting at East Grange in all cases other than when mixed species were planted. Typical output figures for bare root transplants at spacing of 2 m x 2 m on ploughed ground were recorded as c. 0.056 ha/shr at a cost of £143/ha. On weedy stubble requiring screefing an output of 0.041 ha/shr was recorded at a cost of £195/ha.

Although costs of mechanised planting were generally only marginally cheaper than previously recorded manual planting figures, the outputs were considerably higher. Higher planting outputs were an advantage at East Grange where the available time for planting was restricted due to poor weather conditions.

Table 6 shows the proportion of time taken by each aspect of the work cycle, proportion of planting time for SRF is consistent across the different studies. Time taken to turn on the headland for the aspen planting was higher than on other areas, this was possibly due to additional care required to negotiate the moderate side slope on the planting site. Time taken to load trees varies quite considerably between the different studies from 2.2 percent in aspen to 17.3 percent in the Scots pine on ex-pasture. Differences in loading times were due to distance and accessibility of plant storage on site. This difference in loading time shows potential for method improvement to increase outputs by improving on-site plant handling logistics.

There are not currently many mechanised planting machines and contractors in Britain with the necessary expertise to carry out mechanised planting on large scale areas of SRF. This is likely due to limited demand for mechanised planting and a lack of 'off the shelf' machinery. If SRF establishment increases in Britain then the mechanised planting resources will also need to increase to cope with the demand in order to establish SRF crops economically. Limited availability of mechanised planting machines reduces the potential for method development because there are so few machine configurations to trial.

Fuel Use Assessment

Fuel usage shown in Table 7. Fuel use figures will inform energy balance calculations for SRF and SRC.

Gathering information on fuel use for forestry operations is a new discipline for Technical Development and comparison data for the measurements taken at East Grange is not therefore available. As management operations at East Grange and other FC SRF sites continues experience will increase and an understanding of fuel use for a variety of forest operations will be accumulated.

[1] Drake-Brockman, G.R. (1998) 2. New Planting of Farm Woodlands: Output Guidance.

Fuel use for SRF planting was greater per hectare than SRC. Likely reasons for the higher fuel use for SRF planting include differences in machines used and site conditions, traction and the physical effort of the trailed SRC planter compared with the resistance of the ploughshare on the Keen planter and the single row establishment of the Keen planter compared with the four row establishment of the Salix Maskiner Step Planter.

In addition to the fuel use assessment made during the SRF and SRC studies additional fuel use was incurred by other elements of the operations. During SRC planting vehicle movements took place every day to transport Willow whips to site from an offsite coldstore. Containerised whips were transported to site in palletised cardboard boxes. The boxes observed during the study contained lengths of willow between 5300m – 7500m in c. 1.5 – 2.0 m lengths.

During planting the Fendt tractor and Salix Maskiner planter were kept on site and machine operators drove to site on a daily basis with a trailer, towing fresh willow to site from the cold store.

The planters loading the planting machine with willow rods were supplied by an agricultural machinery ring, as subcontracted labour, they were transported to and from site on a daily basis in a minibus.

Future assessment of energy balance for energy forestry crops will require additional inputs such as transportation to be defined as a precursor to the assessment.

Plant Stocking and Survival

The quality of SRF planting was generally high, quality was however observed to drop where ground conditions were very wet and consequently the packing wheels slipped over the ground surface, rather than rotating effectively.

The survival assessment was based on the criteria in the Forestry Commission's Operational Guidance Booklet 4 stocking density assessment. The SRC planting showed a high, post planting survival rate, compared to the original number of possible planting positions. Within the SRC crop no dead trees were found, only missing plants in plant locations, indicating that plant locations had likely been missed at time of planting, rather than subsequently predated.

Conclusions

Mechanised planting of short rotation forestry and short rotation coppice has been successfully achieved at East Grange. During this study mechanised planting machines demonstrated their ability to operate effectively on ex-arable and pasture sites. The site conditions, terrain and previous land use suited mechanised planting well due to the lack of obstacles to impede the operation of the planting machine.

Establishment of SRC is a well developed operation and the mechanised planting process is highly automated, owing to the uniformity of the willow planting stock. By contrast there is less experience of establishment and management of SRF in Britain, these trials show that there is potential to mechanise SRF planting, increasing outputs compared to manual planting.

Mechanised planting is beneficial where large areas are to be established and the planting window is restricted due to adverse weather conditions. At East Grange the site was frequently wet or frozen during the planting season during SRF establishment which impeded planting and the high output of the Keen planter allowed planting to be done in the restricted time available.

Where ex-agricultural land is planted care is required during establishment to avoid damage to drains across the site when mechanised ground preparation is carried out. Use of spiral tree guards may have implications for future tree growth which may limit the future suitability of the crops to being grown on extended rotations as high forest.

Outputs achieved for SRC and SRF establishment at East Grange were similar to previous studies by Technical Development. Outputs dropped by 46% and cost per hectare increased by 85% when planting mixed species, this has important considerations for species mixtures in SRF. Likely reduction in outputs for mixed species planting should be carefully considered at the planning stage and included in operational costing.

Replacing the tractor prime mover with the tracked crawler increased traction, and appeared to reduce ground impact and achieved comparable outputs to the tractor. The use of the crawler was beneficial in terms of output although operator ergonomics were not as good as the tractor, particularly in adverse weather due to the lack of an operator cab (see Figure 5).

Good communications between the driver of the prime movers and the planter/s was essential; particularly for SRF mixed species planting where the planter needed to reduce forward speed to allow greater time to alternate between species. Communication by radio allowed contact to be maintained between the operators with benefits for quality of planting and operational safety.

Recommendations

Mechanised planting machines are suitable for establishing short rotation forestry and short rotation coppice on ex-agricultural sites and where available their use is recommended. Selection of an appropriate prime mover for the ground conditions can greatly improve the efficacy of planting in wet conditions and help minimise soil disturbance to the site. For mechanised planting a prime mover with a hydrostatic clutch offers a high degree of control over the speed of the machine which is an advantage for achieving uniformity of plant spacing. In energy forestry crops maximising site productivity is linked to plant spacing. Where this is the case machine features that improve accuracy of stocking density are recommended.

Spiral tree guards have potential to protect trees from damage however, due to the cost involved and the potential negative consequences on stem development further research into the need for guards and the most effective design would be beneficial in the interests of minimising cost and maximising tree survival and form.

Little information exists on fuel use in forestry operations, and gathering more fuel usage figures for a variety of forest operations will allow effective modelling of the carbon balance of energy crops such as SRF. Future time studies should include fuel use assessment to increase our understanding of fuel consumption for a range of work activities and site types. Where fuel usage is measured it is important to collect as much supporting information as possible to identify variables that influence fuel use in order to strengthen predictions of energy balance in the future.

Opportunities exist to gather further information on SRF establishment and management operations and further time study work should be carried out to gather information on outputs over a wide range of site conditions and crop types. The large-scale establishment of energy crops such as SRF is a new practice and the techniques used to achieve SRF establishment are also new in this context. As with any new operation, there is potential for further method development to improve efficiencies, ergonomics and economics. Currently mechanised planting machines show considerable potential for improved efficiency for short rotation forestry crops over manual planting.

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Appendices

Table 10 Machine Costing

		Case Study 1		Case Study 2		Case Study 3		Case Study 4		Case Study 5		Case Study 6	
COST ELEMENT	**UNIT**	Keen Planter	McCormick MTX 175	Keen Planter	McCormick MTX 175	Keen Planter	McCormick MTX 175	Keen Planter	New Holland	Keen Planter	New Holland	Fendt Vario Fendt 716 tractor	Salix Maskiner Planter
Capital Cost	£	4,000	64,000	4,000	64,000	4,000	64,000	4,000	24,000	4,000	24,000	105,000	30,000
Residual Value	£	2,000	12,800	2,000	12,800	2,000	12,800	2,000	6,000	2,000	6,000	21,000	6,000
Life in Years	Years	5	5	5	5	5	5	5	5	5	5	5	5
Hours/Year	Hours	560	2,000	560	2,000	560	2,000	560	2,000	560	2,000	2,000	560
Interest Rate	%	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Discount Factor	D	0.7835	0.7835	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.7835	0.7835	0.7835
Equivalent Annual Cost	AN	0.2310	0.2310	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.2310	0.2310	0.2310
Capital Cost / Hour	£/hour	**1.00**	**6.23**	**1.00**	**6.23**	**1.00**	**6.23**	**1.00**	**2.23**	**1.00**	**2.23**	**10.23**	**10.43**
Repair & maintenance	£/hour	0.50	1.00	0.50	1.00	0.50	1.00	0.50	1.00	0.50	1.00	1.00	1.00
Fuel (@ £0.50 per litre)	£/hour	0.00	2.84	0.00	2.00	0.00	1.09	0.00	1.84	0.00	1.67	2.08	0.00
Fuel use calculation		(16.7/ha * 0.34 ha/shr) = 5.68 litres/shr		(16.7/ha * 0.24 ha/shr) = 4.00 litres/shr		(16.7/ha * 0.13 ha/shr) = 2.17 litres/shr		(16.7/ha * 0.22 ha/shr) = 3.67 litres/shr		(16.7/ha * 0.20 ha/shr) = 3.34 litres/shr		(5.4 l/ha * 0.77 ha/shr) = 4.16 litres/shr	
Insurance	£/hour	0.00	0.50	0.00	0.50	0.00	0.50	0.00	0.50	0.00	0.50	0.50	0.00
Operator (inc. on-costs)	£/hour	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	16.00
Total Operating Cost	£/hour	**10.50**	**14.34**	**10.50**	**14.34**	**10.50**	**14.34**	**10.50**	**13.17**	**10.50**	**13.17**	**13.58**	**17.00**
Total Hourly Cost	£/hour	**11.50**	**20.57**	**11.50**	**20.57**	**11.50**	**20.57**	**11.50**	**15.40**	**11.50**	**15.40**	**23.80**	**27.43**
Total Hourly Cost system	£/hour	**32.08**		**32.08**		**32.08**		**26.90**		**26.90**		**51.24**	
System output	ha/shr	0.34		0.24		0.13		0.22		0.20		0.77	
Total cost system	£/ha	**94.34**		**133.65**		**246.73**		**122.28**		**134.51**		**66.54**	

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