DEVELOPMENT OF A PROTOCOL FOR ECOEFFICIENT WOOD HARVESTING ON SENSITIVE SITES (ECOWOOD)


PROJECT DELIVERABLE D2 (Work Package No. 1) on

SELECTION AND OPERATION OF CABLE SYSTEMS ON SENSITIVE FOREST SITES

D. Tiernan†, P.M.O. Owende*, C.L. Kanali*, R. Spinelli‡, J. Lyons†, and S.M. Ward*

*Forest Engineering Unit, Agricultural and Food Engineering Department, University College Dublin, Earlsfort Terrace, Dublin 2, IRELAND
Tel: (+353) 1 716 7351; Fax: (+353) 1 475 2119; email: forest.eng@ucd.ie
ECOWOOD Project URL: www.ucd.ie/~foresteng

†Irish Forestry Board (Coillte Teoranta), Sullivan’s Quay, Cork, IRELAND
Tel: (+353) 021 4964 366; Fax: (+353) 021 496 4072; email: john.lyons@coillte.ie

‡Consiglio Nazionale Delle Ricerche (CNR), Instituto Per la Ricerca Sul Legno, Via Barazzuoli 23, I-50136, Florence, ITALY
Tel: (+39 055) 661 886; Fax: (+39 055) 670 624; email: spinelli@mailbox.irl.cnr.it

February 2002
TABLE OF CONTENTS

LIST OF ABBREVIATIONS .................................................................................................................. ii
LIST OF TABLES .................................................................................................................................... iii
LIST OF FIGURES .................................................................................................................................... iv
EXECUTIVE SUMMARY .......................................................................................................................... 1

1. INTRODUCTION .................................................................................................................................. 2
   1.1. Background on the ECOWOOD Project ...................................................................................... 2
   1.2. Terrain Classification for Ecoefficient Wood Extraction ............................................................. 2
   1.3. Challenges to wood harvesting and extraction under alpine conditions and other steep terrain ................................................................. 4
   1.4. Challenges to wood harvesting and extraction on soft soil conditions ........................................ 5
   1.5. Role of Cable Systems in Sustainable Forest Management (SFM) on Sensitive Sites ............. 5
   1.6. Current trends in the utilisation of cable systems for wood extraction in Europe ...................... 7

2. DESCRIPTION OF CABLE EXTRACTION SYSTEMS ........................................................................ 9
   2.1. Cable yarder ................................................................................................................................. 9
   2.2. Rope configurations for Cable Systems ...................................................................................... 10
      2.2.1. High lead system .................................................................................................................. 10
      2.2.2. Skyline systems .................................................................................................................. 10
      2.2.3. Motorised carriages ............................................................................................................. 12
      2.2.4. Yarding patterns ................................................................................................................... 12
   2.3. Anchorage Systems ................................................................................................................... 12

3. OPERATIONS IN CABLE EXTRACTION SYSTEMS .......................................................................... 14
   3.1. Operations Planning .................................................................................................................. 14
      3.1.1. Spatial location ..................................................................................................................... 14
      3.1.2. Layout design ....................................................................................................................... 14
   3.2. Road Construction .................................................................................................................... 19
   3.3. Selection of appropriate cable system ...................................................................................... 20
      3.3.1. Yarding specifications .......................................................................................................... 20
      3.3.2. Cable configuration ............................................................................................................. 20
      3.3.3. System power requirements ................................................................................................ 20
      3.3.4. Cable tension during load transport .................................................................................... 21
      3.3.5. Economic considerations ................................................................................................... 22
   3.4. Wood harvesting ....................................................................................................................... 22
      3.5. Yarders ...................................................................................................................................... 22
         3.5.1. Tower yarding .................................................................................................................... 22
         3.5.2. Sledge yarding .................................................................................................................... 23
         3.5.3. Motorised yarding .............................................................................................................. 23
      3.6. Tree processing ....................................................................................................................... 23

4. PRODUCTIVITY AND COST OF WOOD EXTRACTION WITH CABLE SYSTEMS .................................. 27
   4.1. Factors affecting the productivity of cable systems ...................................................................... 27
   4.2. Cable systems and small-dimensioned timber ............................................................................. 28
   4.3. Maintenance costs for cable systems ........................................................................................ 29
   4.4. Cost of wood extraction using cable systems ............................................................................ 30

5. ADAPTATION OF CABLE SYSTEMS FOR COST-EFFECTIVE WOOD HARVESTING ON SENSITIVE SITES ...32
   5.1. Trends in the Use of Cable Systems .......................................................................................... 32
      5.1.1. Increased use of contract labour .......................................................................................... 32
      5.1.2. Increased productivity of cable yarders ............................................................................... 32
      5.1.3. Integrated machine processes ............................................................................................ 33
      5.1.4. Use of steep terrain harvesters ........................................................................................... 34
      5.1.5. Use of excavator based cable yarders ................................................................................... 36
   5.2. Management of human resources ............................................................................................. 37
      5.2.1. Ergonomic concerns ........................................................................................................... 40
      5.2.2. Safety considerations ........................................................................................................... 40
      5.2.3. Effective training .................................................................................................................. 40
      5.2.4. Motivation ............................................................................................................................. 40
      5.2.5. Future development of cable extraction systems ............................................................... 41

6. RECOMMENDED PRACTICE FOR USE OF CABLE SYSTEMS ON SENSITIVE FOREST SITES ........... 43

REFERENCES ........................................................................................................................................... 44

ANNEXES .............................................................................................................................................. 49
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS</td>
<td>Austrian Schilling</td>
</tr>
<tr>
<td>AYD</td>
<td>Average Yarding Distance</td>
</tr>
<tr>
<td>CTL</td>
<td>Cut-to-Length harvesting system</td>
</tr>
<tr>
<td>DBH</td>
<td>Tree Diameter at Breast Height</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>DTM</td>
<td>Digital Terrain Model</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agricultural Organisation of the United Nations</td>
</tr>
<tr>
<td>FOPS</td>
<td>Falling Object Protective Structures</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organisation</td>
</tr>
<tr>
<td>OP</td>
<td>Operations Protocol</td>
</tr>
<tr>
<td>PH</td>
<td>Productive Hours</td>
</tr>
<tr>
<td>PMH</td>
<td>Productive Machine Hour</td>
</tr>
<tr>
<td>pmh</td>
<td>Productive Man Hour</td>
</tr>
<tr>
<td>PTO</td>
<td>Power-take-off</td>
</tr>
<tr>
<td>PSH₀</td>
<td>Productivity per standard hour with delays greater than 0 minutes excluded</td>
</tr>
<tr>
<td>PSH₁₅</td>
<td>Productivity per standard hour with delays greater than 15 minutes excluded</td>
</tr>
<tr>
<td>SFM</td>
<td>Sustainable Forest Management</td>
</tr>
<tr>
<td>SDSS</td>
<td>Spatial Decision Support System</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. General terrain classification scoring for Ireland (Forest Service, 2000) ....................... 3
Table 2. Machines operations most suited to respective terrain classes (Adapted from Forest Service, 2000) ........................................................................................................... 3
Table 3. Examples of steep terrain harvesters ...................................................................................... 4
Table 4. Comparison of the intensity of soil erosion resulting from skidding operations between tractor, horse and cable systems (Lukáè, 2001) ...................................................................................... 6
Table 5. Estimated number of cable systems in operation and the percentage annual cut that is extracted by cable systems in Europe in the period 1999-2000 .................................................... 7
Table 6. Proportion of wood extracted by cable and wheeled skidder systems in the Ukraine region for the period 1950-1995 ........................................................................................................ 8
Table 7. Sample of commercially available cable yarders ................................................................... 10
Table 8. Road densities as a function of yarding distances for various harvest plans in western Washington (Schiess, 2001) .................................................................................................. 16
Table 9. Summary of results from a scheduling and network analysis for two (5-year) management plans for a 36 square mile planning area in Eastern Washington, USA. (Schiess, 2001) ........................................................................................................ 16
Table 10. Optimal line lengths for a Syncrofalke cable crane in Slovenian conditions (Košir, 2001). ................................................................................................................................. 18
Table 11. Purchase prices for a range of cable systems in the market (FBVA, 1999) ....................... 22
Table 12. Examples of the working combinations available for the operation of cable systems .... 26
Table 13. Estimated productivity of cable systems ........................................................................... 28
Table 14. A 12-year productivity (1986-1998) and cost breakdown for a Koller K300-yarder operating in Austria .................................................................................................................. 30
Table 15. Examples of production costs for cable systems in France and Italy ............................... 31
Table 16. Productivity and tree damage results between conventional and mechanised harvesting on steep slopes (Oswald and Frutig, 2001) ........................................................................... 36
LIST OF FIGURES

Figure 1. Valmet™ 911 steep terrain harvester, and the Shift/Tilt mechanism of Timberjack 608L/762C harvester that is designed for operation on slopes of up to 27° (51%). ........ 4
Figure 2. Challenges to forwarding operations on sensitive forest sites ........................................ 5
Figure 3. Site disturbance and increased potential erodibility due to wood harvesting and extraction on soft soil sites. ................................................................. 6
Figure 4. Example of skyline with fully suspended log (adapted from Sist et al., 1998) ............... 9
Figure 5. Illustration of a highlead layout (Conway, 1986) ...................................................... 11
Figure 6. Illustration of common cable rope configurations (Owren, 1997) ......................... 11
Figure 7. Illustration of fan shaped and parallel yarding pattern, the latter showing extraction lines from areas lateral to roadlines. ......................................................... 12
Figure 8. Types of cable anchors in use (Samset, 1985) .......................................................... 13
Figure 9. Planning map with terrain classification codes (Mellgren, 1980) ......................... 14
Figure 10. Variation of setup and skidding costs with line length for a Syncrofalke™ cable crane in Slovenian conditions (Košir, 2001) .......................................................... 17
Figure 11. Situations that may cause shock loading of a cable system (Visser, 1999) .............. 21
Figure 12. Tension in the skyline caused by concentrated load (Q) and the weight of skyline (q). 21
Figure 13. A sledge yarder and set-up for extraction. Set-up courtesy of Greifenberg snc, Trento, Italy. .......................................................... .......................................................... 23
Figure 14. Woodliner™ motorised carriage and setup (Konrad Forsttechnik, 2001) ............ 24
Figure 15. A continuous roadside-processing rig composed of the cable yarder and processing unit with combined processing head and grapple (inset right) and an independently rotating cab (inset left). .......................................................... 24
Figure 16. Mode of uphill operation with a continuous processing system (Konrad Forsttechnik, 2001) .......................................................... .......................................................... 25
Figure 17. The relationship between tree size and harvesting and transportation costs for a cable system (Sirols, 1981) .......................................................... .......................................................... 29
Figure 18. The effect of average load size on productivity for a Koller K 300 cable yarder extracting uphill over a 200m extraction distance (Tunay, 2001) .......................................................... 29
Figure 19. A 12-year maintenance cost breakdown for a Koller 300-yarder operating in Austria. 30
Figure 20. Effect of pmh on the costs of operating a Koller 300-yarder in Austria for period of 12 years (Rieger, 2001) .......................................................... .......................................................... 30
Figure 21. Trend of cable extraction costs in Austria (Loschek, 2001) ........................................ 32
Figure 22. Trends in contract labour in the forestry sector in Austria. Source (Fladl et. al, 2001). 33
Figure 23. Trend in mechanisation and contract labour as experienced by MM Forestry Enterprises, Austria (Loschek, 2001) .......................................................... .......................................................... 34
Figure 24. Variation of productivity with DBH for mechanised and conventional (chainsaw) harvesting on steep slopes (Oswald and Frutig, 2001). .......................................................... 34
Figure 25. Valmet™ steep terrain harvester and Timberjack walking harvester .................... 35
Figure 26. Typical variation of productivity (PSH15) of a tracked harvester with tree volume (without bark) at 25 and 50% terrain slope (Stampfer, 1999) .......................................................... 35
Figure 27. End and side views of an excavator based cable extraction system in working position. .......................................................................................................................... 37
Figure 28. Excavator based yarder that allows for slew of base-machine for simultaneous yarding and processing. Inset is detail of the processor-head .......................................................... 38
Figure 29. Illustration of a cable systems mounted on light wheeled carriage (Unimog). Details show the winch drums and the guyline spools .......................................................... .......................................................... 39
Figure 30. Details of a combined yarder/processor (Konrad Forsttechnik, 2001) ................. 41
EXECUTIVE SUMMARY

A sensitive forest site is where alterations to the normal mechanised harvesting practices are required in order to avoid adverse effects on ecological, economic and social functions of the forest and its surroundings. Harvesting of such sites presents considerable limitations to the use of ground-based forest harvesting machines, as significant damage to forest ecosystems may be incurred from:

- **soil disturbance and compaction** — may impede the growth of residual trees in thinning operations, and also increase the potential for soil erosion and windthrow;

- **physical damage to residual trees and other vegetation** — may lead to timber value and volume loss in subsequent harvests, and;

- **direct and indirect damage to streams** (including the damage to drainage and soil stabilisation features) — for example, skidding/forwarding of timber across streams and steep road embankments without proper temporary bridging structures, and; introduction of spilled fuel and lubricants into streams.

In order to minimise the potential damage to the forest ecosystem (e.g. soil compaction, damage to residual stand, accelerated soil erosion, and siltation of watercourses adjacent to harvesting sites), there is increasing demand for envirotgentle harvesting and extraction of wood on sensitive forest sites. **Cable extraction or cable logging systems involve the transportation of material within the forest by means of steel cables, the load being partially or wholly lifted off the ground. It is different from the ground-based wood extraction systems (forwarders and skidders) in that soil-machine interaction is minimal or eliminated altogether, hence, it offers possible means of minimising the site disturbance and damage that may result from wood harvesting and extraction.** For example, soil losses of between 0.16–0.51 m$^3$ per m$^3$ of extracted material have been recorded for skidding operations with a crawler-tractor under the unfavourable condition of low soil bearing capacity. In contrast, the expected soil erosion resulting from the use of cable system and by skidding with horses are both less that 0.14 m$^3$ per m$^3$ of extracted material.

Although wood extraction with cable systems is environmentally friendly, hence may contribute to Sustainable Forest Management (SFM) on sensitive sites, it is also recognised that it is more complex and expensive than current alternative option such as ground skidding. **Generally, there has been a decline in the use of cable systems in Europe due mainly to the cheaper cost (less that 50% of the production costs for cable extraction), and increased capability of harvester and forwarder combinations to operate on steep terrain. Currently, less than 3% of the annual timber harvested in the European Union (EU) countries is by cable systems. The relatively lower productivity of cable systems (1–10 m$^3$ per Productive Machine Hour), when compared to ground-based systems (5–25 m$^3$ per Productive Machine Hour) significantly reduce profit margins.** In addition, the high manual workload and skill demands for operating the systems, and comparatively low wages, impede the recruitment and retention of personnel.

While wood extraction with cable systems may be more complex and expensive than ground-based systems, it is a viable complement to the adaptation of ground-based machines for SFM on sensitive sites. **New trends in wood harvesting with cable systems are therefore geared to the development of: integrated machine processes (to maximise on productive time) and enhancement of mobility of harvesters used with cable extraction systems on difficult terrain (bearing capacity < 40 kPa, and gradient > 20% or 12$^\circ$); improvement of related operational planning/logistics, and; ergonomic consideration (viz. minimisation of workload, and improvement of tools and accessories), in order to enhance the cost-effectiveness. Advances in these areas, and the need for ecoefficient wood harvesting and extraction suggest that cable systems will continue to play a significant role in Sustainable Forest Management on sensitive forest sites.**