Harvesting systems: contents

- Objectives and choice of harvesting systems (HS) under CFF
- HS for target diameter harvesting
- HS for thinnings
- Examples for harvesting systems
  - Motor-manual systems
  - Fully mechanised systems
- Directional felling
- Marking of trees
Objectives of harvesting systems under CCF 1

- Maintainance of soil fertility
- Sustainable production of timber (in large amounts and of high quality)
- Maintenance of structure, biological diversity and stability of stands
- Maintenance of other forest functions
Objectives of harvesting systems under CCF

- Soil damages must be limited to the extraction racks (distance between them?).
- Stand damages should avoid future crop (or frame) trees.
- Damage to the regeneration must be seen with differentiation due to:
  - age of the stand,
  - role of the regeneration (depends on the silvicultural concept).
Objectives of harvesting systems under CCF 3

• Similar to objectives related to other types of forestry
• But with CCF more complex stand structures -> higher demands on choice, adaptation and execution of harvesting systems
• Target diameter harvesting involves large-size trees and necessity of directional felling
• Thinnings aim at structural diversity and high quality trees
Objectives of harvesting systems under CCF 4

- Certain prerequisites must be fulfilled if these objectives are to be realised:
  - Knowledge by workers and contractors
  - Availability of proper machines and equipment
  - Careful execution of harvesting operations based on clear objectives and complete work orders (+ fair contracts)
  - Timely control and feedback
Choice of harvesting system 1

• Criteria:
  – **Terrain**
  – **Soil** (site type)
  – **Stand** type
  – Type of intervention
  – **Products** (as demanded by timber markets)
  – **Economics**
  – (Risks)
  – (Human factor: occupational safety and health …)
  – (Availability of the harvesting system)
Choice of harvesting system 2

- **Terrain**: trafficable – non-trafficable
- **Soil** (site type): risk classes of deformation
- **Stand** type: species or mixture of species, dimension of timber, density of stands, undergrowth or regeneration …
- **Type of intervention** depends on the silvicultural concept: larger dimensions reduce costs; as many interventions as possible should “pay” …
Choice of harvesting system 3

- **Products** = assortments to be produced: determined by the market (demand, price, volume, time of delivery). Short assortments reduce harvesting damages at remaining trees.

- Human factor: ergonomics, occupational safety and health
Target diameter harvesting: harvesting systems (1)

- Large tree dimensions!
- What to do in the case of regeneration as additional storey in the stand?
- Motor-manual harvesting systems (power saws; tractors or skidders [forwarders] for preskidding and skidding)
Target diameter harvesting: harvesting systems (2)

• Fully mechanised systems if tree dimensions are not too large and terrain allows
• But fully mechanised systems might reach their limit.
• Wheeled or track type harvesters might be used.
Target diameter harvesting requires

- Well trained people (foresters, forest workers)
- Road system
- Prescribed and marked extraction racks
- Marking of trees (including felling direction)
- Directional felling
- „Careful“ skidding operation
- Monitoring of harvesting operations
- Mitigation (elimination of damaged trees, possibly some supplementary planting)
Thinning: Harvesting systems

Fully mechanised systems:
• Dense network of extraction racks required
• High productivity – low costs
• Limited damage (in particular in case of short-wood)

Motor-manual systems:
• Low productivity – high costs
• Greater distance between extraction racks possible
• Extensive damage when skidding tree-lengths
Harvesting in thinnings requires

- Optimal planning (e.g. prescribed and marked extraction racks)
- Well trained workers (chain saw and other machine operators)
- Clear working orders (or “agreement on objectives”)
- Optimal time of harvesting during the year
- Continuous control
- Post-harvesting assessment and feedback
Potential harvesting systems: overview

• Full tree
• Tree length
• Short-wood (assortments)

• Partly mechanised
• Fully mechanised (harvester + forwarder)

• Differences between flat and steep terrain
• (and small- and large-sized timber)
Motor-manual systems

• How well is directional felling – which is a must - known and used?
• Tree length has the advantage of greater volume per piece, but it results in larger skidding damages
• Short wood with less volume per piece but fewer damages (and high productivity if forwarders are used for skidding)
• Short wood might be a problem on (steep) slopes
Motor-manual systems: flat terrain 1

• Short-wood:
  – Felling, delimbing, bucking
  – Preskidding manually and skidding with forwarder or
  – Preskid and skid all the timber by forwarder (requires special felling direction and bucking technique)
## Harvesting systems as matrix

<table>
<thead>
<tr>
<th>Place of operation</th>
<th>Stand</th>
<th>Extraction rack</th>
<th>Forest road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
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<tr>
<td>Felling</td>
<td>Factors</td>
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<tr>
<td>Limbing</td>
<td>of</td>
<td>...</td>
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<tr>
<td>Measuring</td>
<td>production</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Bucking</td>
<td>...</td>
<td>...</td>
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</tr>
<tr>
<td>Preskidding</td>
<td>...</td>
<td>...</td>
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</tr>
<tr>
<td>Skidding</td>
<td>...</td>
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</tr>
</tbody>
</table>
Preskid

Transportlinie

Skid trail (extraction rack)
Rückegasse
Maschinenweg
Seillinie
layon de débardage
piste de débardage
ligne de cable grue

skid trail (strip road)
skid road (strip road)
cable road (cable line)
sentiera di esbosco
pista
linea di gru a cavo

stapeln
empiler
to pile
accatastare

rücken
débusquer, débarrer
to extract (to skid, to forward, to yard)
esboscare

Source: Heinimann
## Harvesting Systems under CCF

<table>
<thead>
<tr>
<th>Ablaufabschnitt/Arbeitsort</th>
<th>Stand</th>
<th>Extraction rack</th>
<th>Forest road</th>
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<td>Rücken Lagern</td>
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</tr>
</tbody>
</table>

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Motor-manual systems: flat terrain 2

• Variations:
  – Skid sawlogs with skidder, preskid “fuelwood” by skidder and skid by forwarder – (crowns?)
  – Preskid all assortments by tractor, skid by forwarder or by skidder with grapple
  – Integrate felling and skidding – bucking at roadside (“Modifiziertes Goldberger Verfahren”)
Trees to be cut  Tree-length  Short-wood
<table>
<thead>
<tr>
<th>Ablaufabschnitt/Arbeitsort</th>
<th>Bestand</th>
<th>Rückegasse</th>
<th>Waldweg</th>
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<td>![Diagram of logging trailer]</td>
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<td>Aufarbeiten</td>
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<td>![Diagram of logging trailer]</td>
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<tr>
<td>Vorrücken</td>
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<td>![Diagram of logging trailer]</td>
<td></td>
</tr>
<tr>
<td>Rücken</td>
<td>![Diagram of felling]</td>
<td>![Diagram of logging trailer]</td>
<td>![Diagram of debris]</td>
</tr>
<tr>
<td>Lagern</td>
<td>![Diagram of felling]</td>
<td>![Diagram of logging trailer]</td>
<td>![Diagram of debris]</td>
</tr>
</tbody>
</table>
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(Short-wood)
Motor-manual systems: flat terrain 3

• Variations continued:
  – Large-size timber/stands with complex structure: fell towards the extraction racks, skid with skidder with strong crane with wide reach (if necessary preskid multiple length and skid after bucking)
<table>
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<th>Rückegasse</th>
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<tr>
<td>Storing</td>
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<td><img src="image13.png" alt="image" /></td>
<td></td>
</tr>
</tbody>
</table>
Motor-manual systems: flat terrain 4

• Tree-length:
  – Felling – Limbing – Topping
  – Preskidding and skidding with tractor or skidder
  – Storing at roadside

• Variation:
  – Integration of felling, preskidding and skidding (“Modifiziertes Goldberger Verfahren”)
<table>
<thead>
<tr>
<th>Ablaufabschnitt/Arbeitsort</th>
<th>Bestand</th>
<th>Rückegasse</th>
<th>Waldweg</th>
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<td>Entasten/Einschneiden</td>
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<td><img src="image" alt="Waldweg" /></td>
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<tr>
<td>Rücken/Lagern</td>
<td><img src="image" alt="Rücken" /></td>
<td><img src="image" alt="Rückegasse" /></td>
<td><img src="image" alt="Waldweg" /></td>
</tr>
</tbody>
</table>
Integration of felling, processing, preskidding and skidding (tree-length) ("Modifiziertes Goldberger Verfahren")

Two workers (feller + tractor driver) who ideally should take turns (job rotation)

The system can be used in steep as well as in flat terrain.
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Systems under CCF, 12./13.05.2010
Motor-manual systems: flat terrain 5

- Full-tree:
  - Felling (and topping)
  - Preskidding and skidding
  - Limbing and bucking at roadside (manually or with processor)

- Problems:
  - Loss of nutrients
  - Risk of extensive damages in stands with regeneration (or in dense stands)
Steep terrain and harvesting systems

- Beyond about 30 to about 50 % gradient: use of extraction roads
- Beyond about 50 % gradient use of cable systems (which will not be covered for motor-manual systems)

- Due to new developments (track-type harvesters and forwarders with “traction winch”) extraction racks perpendicular to contour lines up to about 40 (50) % gradient
<table>
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<th>ground based</th>
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<th>airship-based</th>
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<td><strong>Skid trails</strong></td>
<td><strong>Skid roads</strong></td>
<td><strong>cable roads</strong></td>
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<td>10-35% slope</td>
<td>35-50% slope</td>
<td>economical ecological</td>
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<tr>
<td>economical ecological</td>
<td>economical ecological</td>
<td>economical ecological</td>
</tr>
</tbody>
</table>

Source: Heinimann

Prof. Dr. H. H. Höfle, Harvesting Systems under CCF, 12./13.05.2010
Motor-manual systems: steep terrain 1

• **Extraction roads:**
  - **Short-wood** with problem of reduced dimension/volume per piece: felling, limbing, bucking – preskidding and skidding with tractor or skidder (with winch)
  - Special systems for large-size coniferous trees (developed in the Black Forest: “System Triberg”, “Todtmoos”, “System Excavator”)
<table>
<thead>
<tr>
<th>Arbeitsschritt</th>
<th>Bestand</th>
<th>Maschinenweg</th>
<th>Waldstraße</th>
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<tbody>
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<td><img src="image1" alt="Diagram" /></td>
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<tr>
<td>Produkt</td>
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<tr>
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<td>integrierte Restauarbeiten</td>
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<td><img src="image12" alt="Diagram" /></td>
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<tr>
<td>KH ablegen mit Forst(Spezial)-Schlepper</td>
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<td><img src="image14" alt="Diagram" /></td>
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<tr>
<td>Rücken mit Poltern</td>
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<td><img src="image20" alt="Diagram" /></td>
<td><img src="image21" alt="Diagram" /></td>
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<td>Produkt</td>
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<td><img src="image23" alt="Diagram" /></td>
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</tbody>
</table>

Abb. 4: "Triberger Zweiseilverfahren"
Abb. 2: "Todtmooser Verfahren"
Potential felling direction
Harvesting system "Excavator"

<table>
<thead>
<tr>
<th>Arbeitsort</th>
<th>Bestand</th>
<th>Maschinenweg</th>
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<td>Produkt</td>
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<tr>
<td>Vorrücken integrierte Restauffaerbeitung</td>
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<td></td>
</tr>
<tr>
<td>KH stapeln mit Bagger</td>
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</tr>
<tr>
<td>Produkt</td>
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<tr>
<td>Rücken mit Poltern / Direktverladung</td>
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<tr>
<td>Produkt</td>
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</tbody>
</table>

Abb. 5: "Seilbaggerverfahren"
Motor-manual systems: steep terrain 2

- Tree-length:
  - Felling, limbing – preskidding and skidding with tractor or skidder – sold as tree-length or bucking and storing at roadside
  - Variation: integration of all phases ("Modifiziertes Goldberger Verfahren")
Motor-manual systems: steep terrain 3

• Full tree:
  – Felling, (topping) – preskidding and skidding with tractor or skidder – limbing, bucking and storing at roadside
  – Variation: integration of felling, preskidding and skidding if the further operations at roadside are performed by rocessor
Motor-manual systems: advantages

Very flexible with respect to:

- Stands (dimension of timber, density)
- Terrain (flat vs. steep terrain)
- Assortments (short-wood, tree-length, full-tree; sawlogs vs. pulpwood/fuelwood; stems vs. crowns)
- Machines (tractors, skidders; tractors with trailers, forwarders; cable systems)
Motor-manual systems: disadvantages

- Limited productivity due to manual labour and use of skidders -> high(er) costs
- Problems in reaching the desired felling direction
- Larger damages to remaining trees and to regeneration (compared to felling with harvester and skidding with forwarder)
- Ergonomics!
Fully mechanised systems 1

• How far are the extraction racks apart?
• What to do if crane reach is smaller than 10 m; generally: if there are trees to be cut beyond the crane reach?
  – Combination of manual work (felling into the crane zone) and use of harvester
  – Possibly preskidding by tractor or skidder in addition
Fully mechanised systems 2

• Problems if:
  – stands are very young: visibility, economics
  – timber is large-sized
  – stands are dense: visibility, felling
  – there is regeneration: potential damages
  – terrain is not trafficable
Fully mechanised systems 3

Flat terrain – short-wood:
• Extraction racks 20 m apart: felling … with harvester, skidding with forwarder
• Special system for small-sized hardwood trees: forwarder with power saw in the grapple (“Fällgreifer”)
Fully mechanised harvesting system (short-wood)

<table>
<thead>
<tr>
<th>Ablaufabschnitt/Arbeitsort</th>
<th>Stand</th>
<th>Extraction rack</th>
<th>Forest road</th>
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</thead>
<tbody>
<tr>
<td>Fällen</td>
<td>Felling</td>
<td>Rückegasse</td>
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<td>Aufarbeiten</td>
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<td>Vorrücken</td>
<td>Preskidding</td>
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<td>Rücken</td>
<td>Skidding</td>
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<tr>
<td>Lagern</td>
<td>Storing</td>
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</tbody>
</table>
Holzernte mit Vollerntern

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Source: Heinimann
<table>
<thead>
<tr>
<th>Ablaufabschnitt</th>
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<td>Rücken Poltern</td>
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</tbody>
</table>
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Fully mechanised systems

- Extraction racks 30 m apart:
  - 1. step: work in the crane reach (possibly also skid)
  - 2. step: fell trees manually into the crane reach or fell manually and preskid trees into the crane reach (via tractor or skidder), work in the crane reach and skid (with forwarder)

- Stands with regeneration: large track-type harvesters that lift trees into the ER
Fully mechanised systems  

- Extraction racks 40 m (or more) apart:
  - 1. step: harvester works in the crane reach, skid with forwarder
  - 2. step: fell trees manually into the crane reach or fell manually and preskid trees into the crane reach (via tractor or skidder), harvester reaches trees in the crane reach, skid with forwarder

- Large size timber: system “Königsbronn”
<table>
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<tr>
<td>Lagern</td>
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</tbody>
</table>
Average harvesting costs (€/m³; felling, processing, skidding) depending on distance between extraction racks and DBH (spruce stands with regeneration)
Fully mechanised systems 6

• Steep terrain – extraction racks perpendicular (rectangular) to contour lines - short-wood:
  – Harvester and forwarder work up to about 40 % gradient
  – Between 40 and 60 (50) % track type harvester, forwarder with “Traktionshilfswinde” or cable system for skidding
  – Beyond 60 (50) %: motor-manual felling in the stand, skidding with cable system to forest road, limbing … with processor (“Gebirgsharvester”)
Process mapping - example
Process mapping - example
Fully mechanised systems 7

Use of extraction roads – short-wood:

• Motor-manual felling in the stand, preskidding and skidding as full tree, processing at roadside with processor

• Variation: integration of felling, preskidding and skidding (“Modifiziertes Goldberger Verfahren”)
Fully mechanised systems

Tree-length:

- Generally possible in both types of terrain.
- But it has to be considered that the one-grip harvester has been developed for short-wood ("cut-to-length").
- Skidding of tree-lengths either with clambunk-forwarder or grapple skidder.
Fully mechanised systems

- Harvesters have been developed for conifers (dominant species in Scandinavia).
- Harvesting of **broad-leaved trees** is possible:
  - Limit is reached with smaller tree dimensions due to higher weight of timber
  - Problems with fork trees and “steep branches” -> require special working methods or support by worker with power saw
  - Generally larger categories of harvesters are required (medium to large harvesters)
Fully mechanised systems: advantages

• Hight productivity -> low(er) costs
• Possibility to realise the desired felling direction
• Reduced damages to remaining trees and to regeneration
• Optimal ergonomics
Fully mechanised systems: disadvantages

- Certain limits with respect to:
  - Stands (dimension of timber, stem form, density)
  - Steep terrain
  - Distance of ER (ideal for 20 m)
  - Assortments (short-wood better than tree-length)
- Require special machines (harvesters, forwarders …)
- Heavy machines with large dimensions and high ground pressure
What to do with underplanting or advance planting?

• Advance planting: ideally, there is space into which trees can be felled (see picture from Harz)

• Underplanting: if the whole area is planted, problems with fully mechanised harvesting operations (at least as long as the trees are still relatively young and dense)
Directional felling

• Directional felling is a must:
  – Relatively easy to attain in fully mechanised harvesting operations
  – Also to attain in motor-manual harvesting operations if workers are (well) trained
Fig. 6.6. Felling pattern and skid trail spacing

Source: Sessions 2007

Prof. Dr. H. H. Höfle, Harvesting Systems under CCF, 12./13.05.2010
Choice of felling direction

buffer zone
fell trees away from buffer zone
fell trees to protect future crop trees
skid direction
skid track
fell trees into track openings
fell trees to assist skidding
fell tree into gap created by previous felled tree
Marking of trees 1

• By machine operators in Sweden
• A recent study in third thinnings in homogeneous pine stands in Germany showed that there was no difference between experienced machine operators (with a forest background) and foresters – either in quality of marking nor in machine productivity
• Studies from Austria in more complex stands showed that marking pays through higher machine productivity and better stand quality
Marking of trees 2

• Consequence:
  – Ideally, stands should be marked before a harvesting operation takes place (positively = frame trees/future crop trees + negatively = trees to be cut; at least positively).
  – The question, then, is: who should mark the trees?
Marking of trees by supervisors or operators (1)?

The quality of the silvicultural intervention should live up to expectations (formulated objectives)!

Clear guidelines are mandatory:
- What trees to favour: vitality and quality of trees
- How many trees to favour
- Which and how many trees to take out
Marking of trees by supervisors or operators (2)?

How can a satisfactory standard be reached?
• Clear and quantitative guidelines
• Sample plots as model stands
• Demonstration of stands before and after felling
• Training in stands
• Control of marking
• „Marking specialists“