



CLUB OF BOLOGNA

*strategies for the development of agricultural
mechanisation*



27th Members' Meeting of the Club of Bologna

Agricultural mechanization: present meets future!

12-13 November 2017

Hannover, Germany

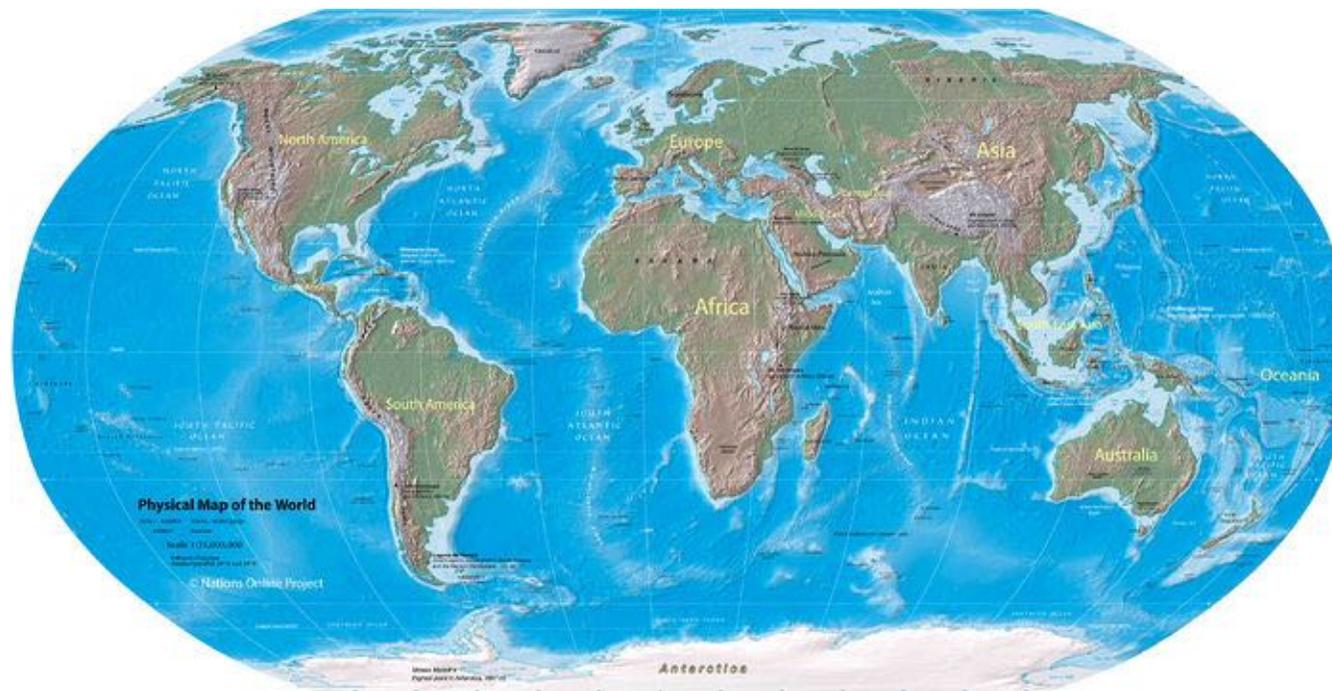
A case study: ground yarding operations in mountainous
terrain

Raffaele Cavalli – raffaele.cavalli@unipd.it

Dzhamal Amishev - dzhamal.amishev@fpinnovations.ca

Mountain forests

- The world's mountain areas cover 24% of the Earth's surface
- Mountain forests cover over 9 Mkm² of the Earth's surface
- Mountain forests represent a remarkable 23% of the Earth's forest cover



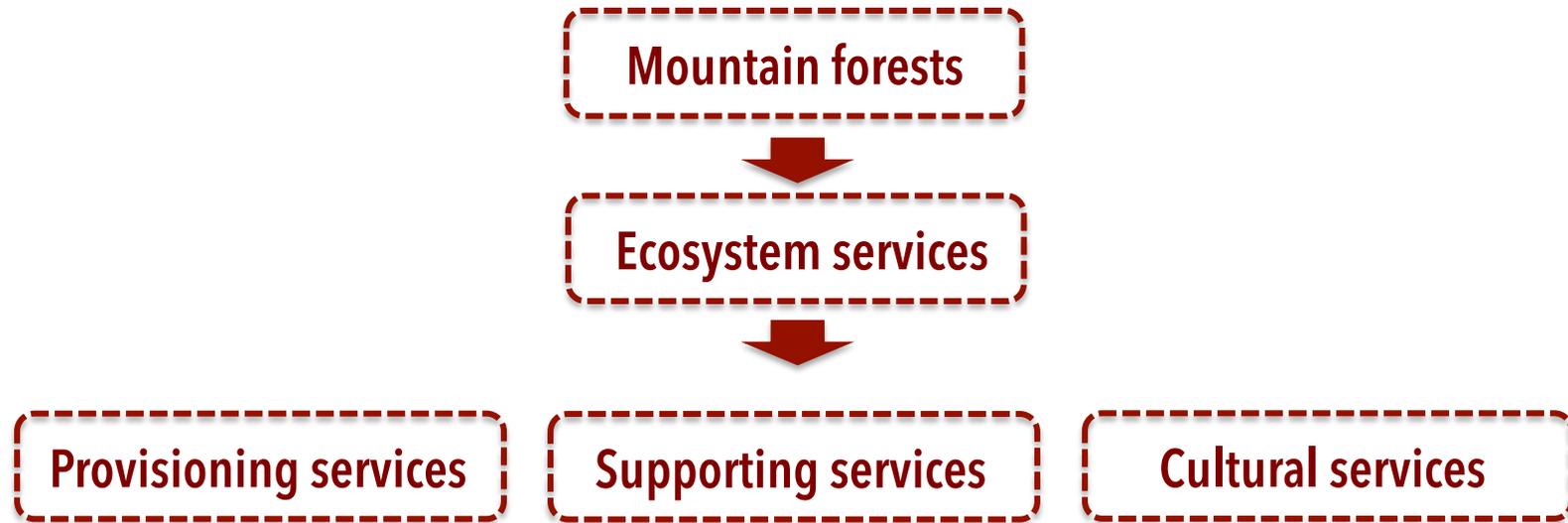
Mountain forests

Mountain forests

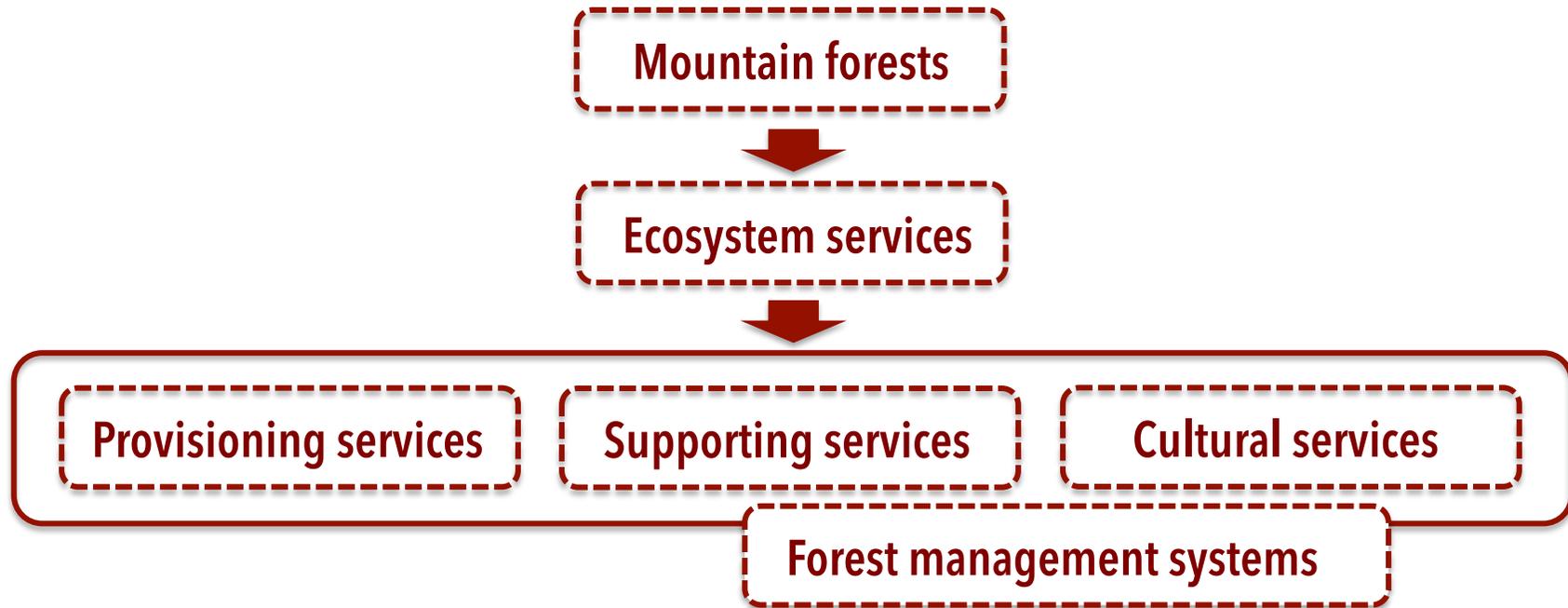
Mountain forests



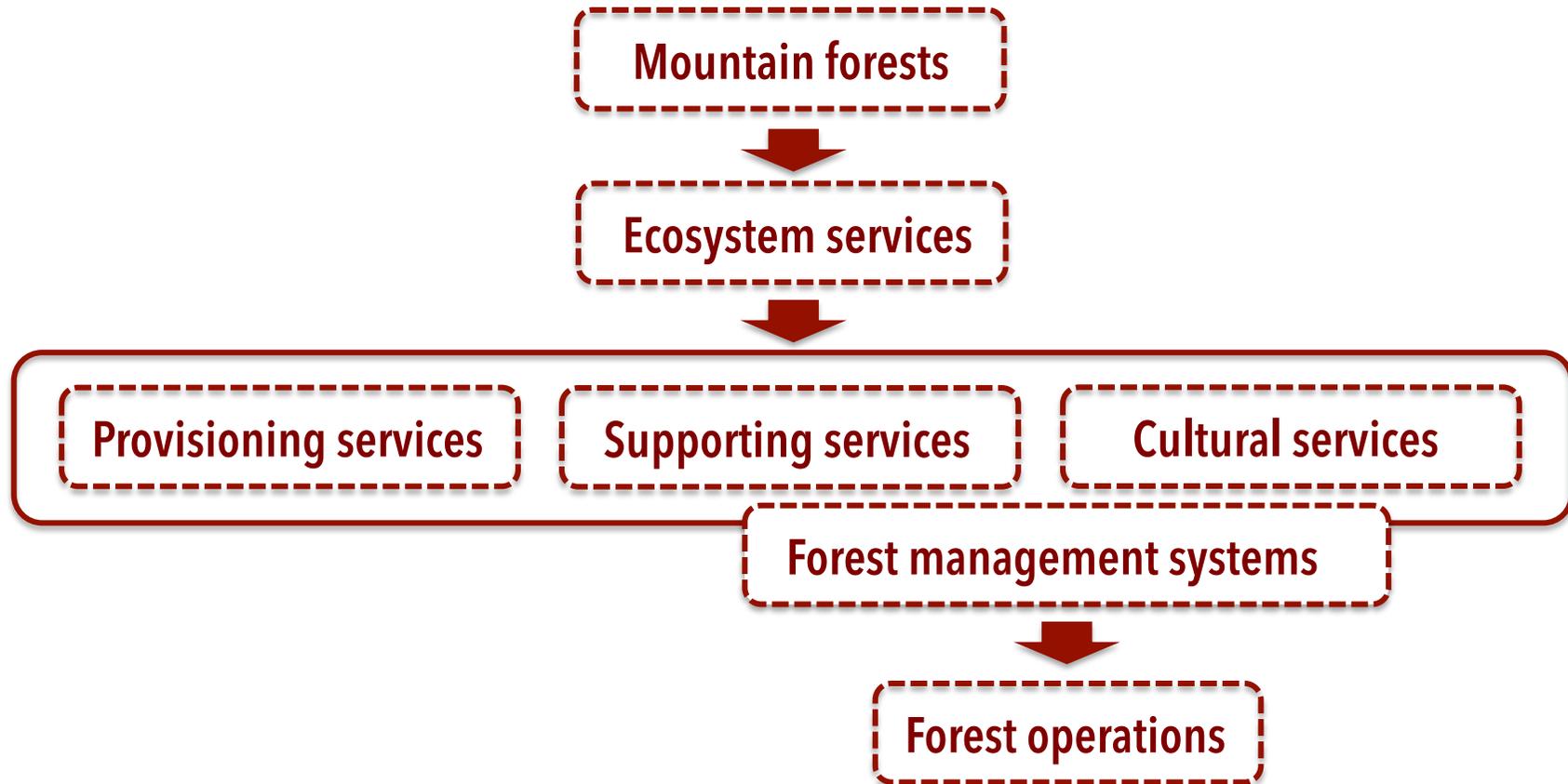
Mountain forests



Mountain forests



Mountain forests



Steep-slope harvesting operations in mountain forests

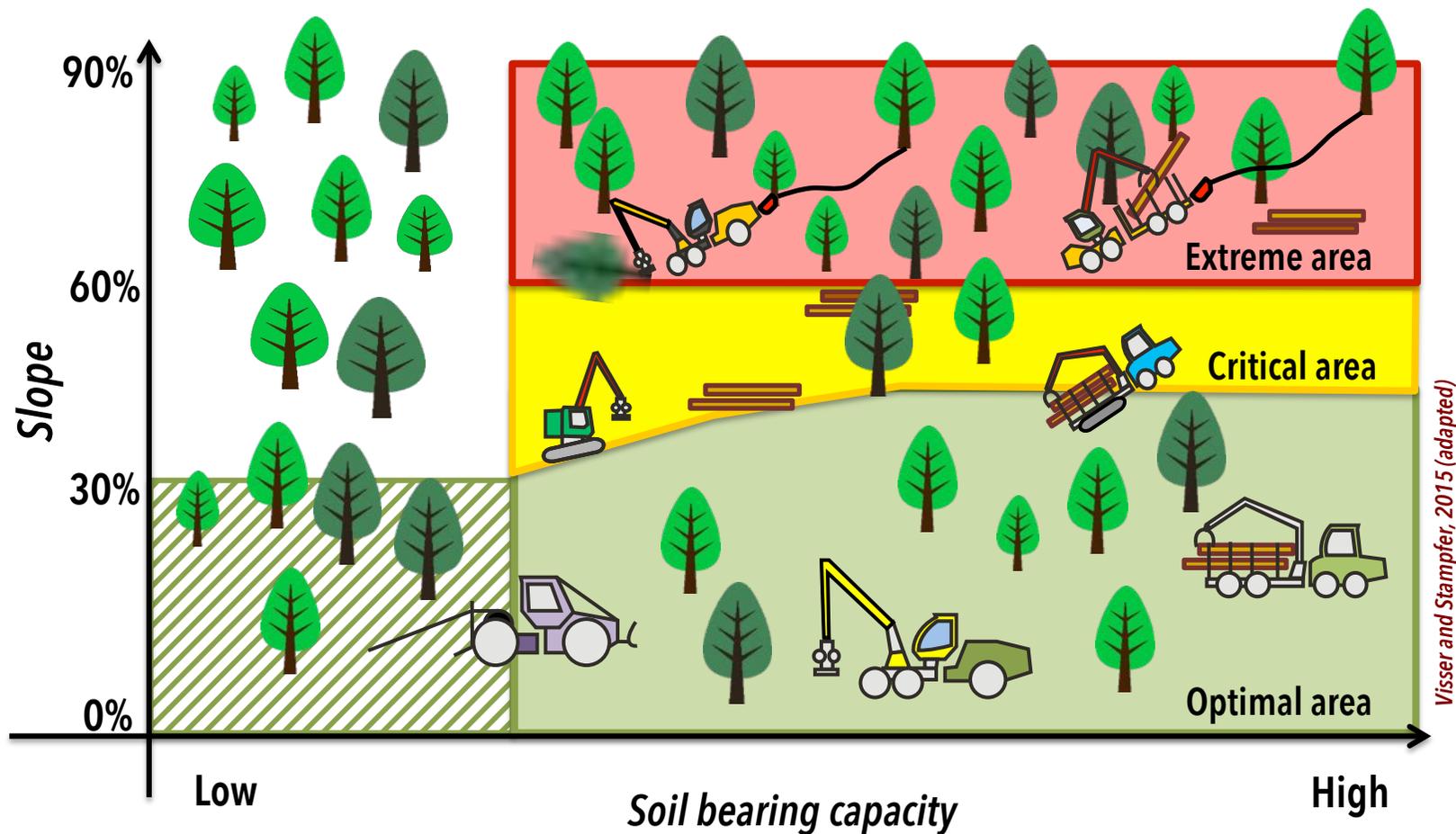
- **World forest industry is facing challenges in accessing wood fibre on steep terrain**
- **Up to now harvesting systems such as hand felling, cable yarding, and helicopter have been used but these options in some cases are expensive and much hazardous**
- **New steep-slope harvesting machines with specialized undercarriages and carriers have been shown to safely access and operate on terrain up to 70% slope**

Steep-slope harvesting operations in mountain forests

Traction devices and undercarriage		Ground steepness (%)		
		<i>Harvesting</i>	<i>Skidding</i>	<i>Forwarding</i>
<i>Wheel with chains and band tracks</i>		35-45	35-45	30-35
<i>Triangular tracks</i>		50-70	n.c.	n.c.
<i>Integral tracks</i>		45-60	45-55	35-45
<i>"Walking" carriers (e.g. Menzi Muck)</i>		60-80	n.c.	n.c.
<i>Ground carriage (e.g. Konrad Pully)</i>		n.c.	80-100	n.c.

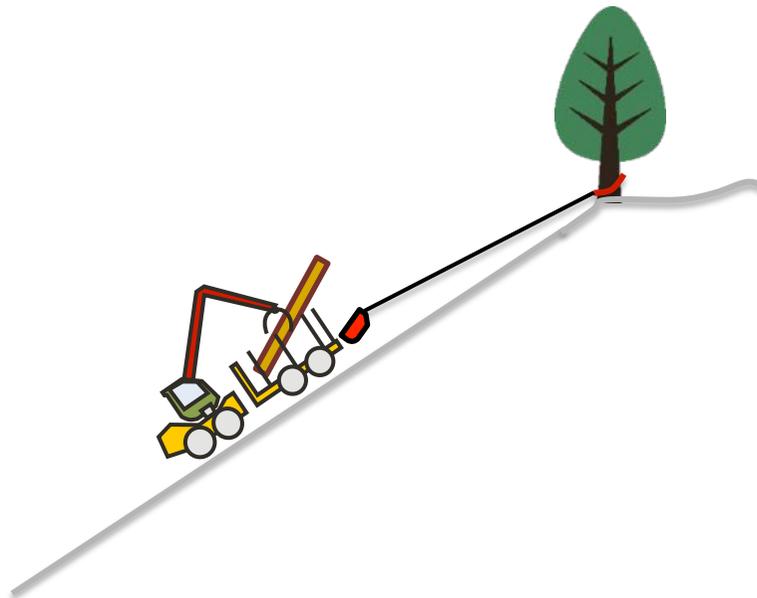
Steep-slope harvesting operations in mountain forests

- Slope is not the only limiting factor, modern fully mechanised ground-based systems have always been limited by other terrain factors as well such as soil strength and/or roughness



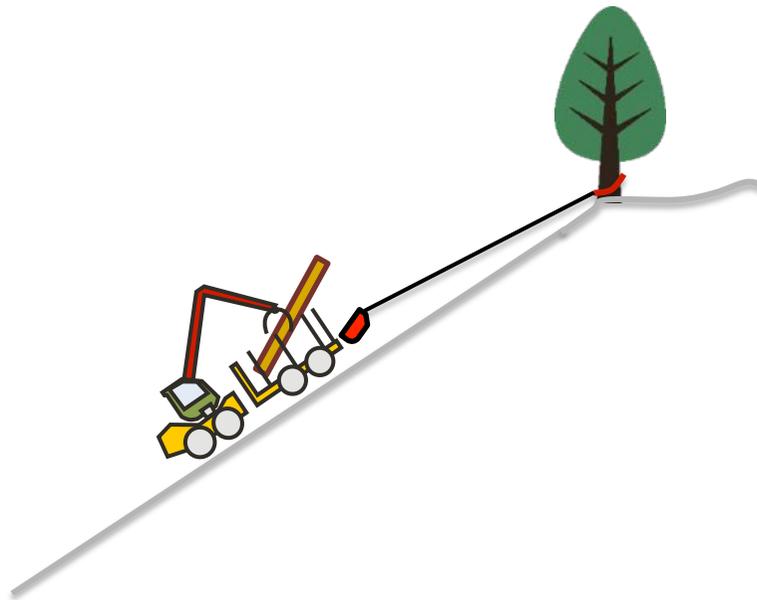
Winch-assist systems - Principles

- One way to improve traction and stability on steep slopes is through assisting harvesting machines by winch and cable to anchor locations such as tree stumps or stationary equipment



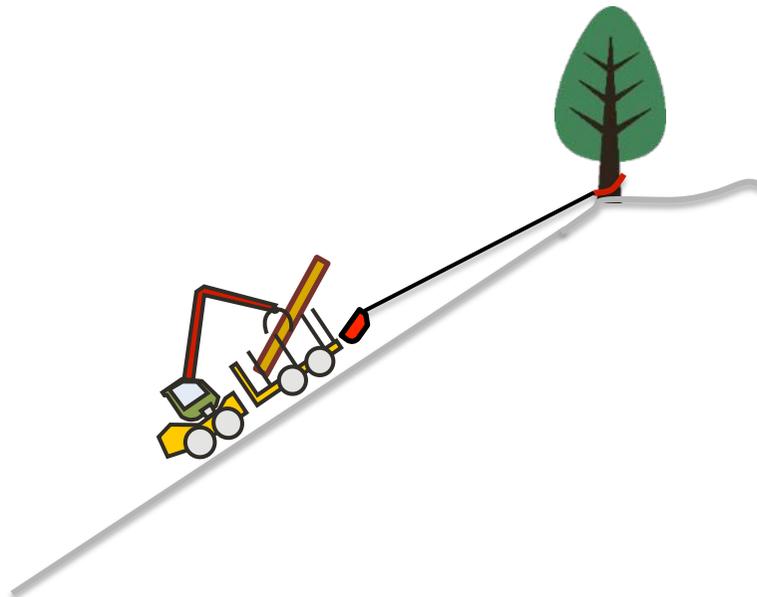
Winch-assist systems - Principles

- One way to improve traction and stability on steep slopes is through assisting harvesting machines by winch and cable to anchor locations such as tree stumps or stationary equipment
- Terms such as *winch-assist*, *traction-assist*, *cable-assist* and *tethering* all refer to technology that helps a harvesting machine climb a steep slope



Winch-assist systems - Principles

- One way to improve traction and stability on steep slopes is through assisting harvesting machines by winch and cable to anchor locations such as tree stumps or stationary equipment
- Terms such as *winch-assist*, *traction-assist*, *cable-assist* and *tethering* all refer to technology that helps a harvesting machine climb a steep slope
- Machines are not suspended from the cables and primary (assisted) machines should be able to stop in full control at all times without reliance on the cable



Winch-assist systems - Design options

- *Integrated winch systems*

Winches are built into or bolted onto the primary (assisted) machines

The category includes most European-type traction-assist systems and the New Zealand-made ClimbMAX



Winch-assist systems - Design options

- *Anchor machine winch systems*

Dedicated anchor machines are used to house and power winches that are tethered to primary (assisted) machines

The category includes the Remote Operated Bulldozer (ROB), EMS Tractionline, T-Mar Rhino, EcoForst T-Winch and HAAS "Three Point Winch"



Winch-assist systems – Design options

- *Anchor machine winch systems*

Bulldozers

Have a sturdy base with low center of gravity and great stability for anchoring once positioned with the blade buried into the ground or against a stump

The cable is positioned close to the ground which reduces the risk of tipping and potentially allows a wider operating angle for the primary (assisted) machine



Winch-assist systems – Design options

- *Anchor machine winch systems*

Excavators

Are agile and can pull themselves up slopes using their buckets improving access to anchor positions

They can turn and position on narrow roads

Are versatile regarding tasks they can be used for (hoe-chucking, loading, road-building)

Excavator buckets could penetrate frozen ground easier than a bulldozer blade



Winch-assist systems – Design options

- *Anchor machine winch systems*

Purpose-Built Systems

They are unmanned so workers are not exposed to danger when operating on hazardous terrain

Smaller size and weight allows for easier transportation and repositioning. Can be secured additionally using guyline winch ropes or synthetic belts

Operator of the primary (assisted) machine can reposition and set up the anchor machine without leaving the cab



Winch-assist systems – Design options

- *Anchor machine winch systems*

Tractor Based Systems

They are unmanned so workers are not exposed to danger when operating on hazardous terrain

Mobility of the tractor allows for easier transportation and repositioning. Tractor can be secured additionally using guyline winch ropes or synthetic belts



Winch-assist systems - Factory solutions

- *Factory solutions to accommodate winch-assist systems*

Winch-assist systems - Factory solutions

- *Factory solutions to accommodate winch-assist systems*

Operator station enhancements in the primary (assisted) machine

front escape hatch for improved steep slope safety

four-point seat belt operator comfort and support while operating on steep slopes

Winch-assist systems - Factory solutions

- *Factory solutions to accommodate winch-assist systems*

Operator station enhancements in the primary (assisted) machine

front escape hatch for improved steep slope safety

four-point seat belt operator comfort and support while operating on steep slopes

Enhanced engine and hydraulics system (reservoirs, oil tanks, sumps) grade capabilities designed for continuous 100% grade operation and intermittent 125% grade operation

Winch-assist systems - Factory solutions

- *Factory solutions to accommodate winch-assist systems*

Operator station enhancements in the primary (assisted) machine

front escape hatch for improved steep slope safety

four-point seat belt operator comfort and support while operating on steep slopes

Enhanced engine and hydraulics system (reservoirs, oil tanks, sumps) grade capabilities designed for continuous 100% grade operation and intermittent 125% grade operation

Engineered attachment points (hitches) that are rated at 150% of total machine mass

Winch-assist systems - Factory solutions

- *Factory solutions to accommodate winch-assist systems*

Operator station enhancements in the primary (assisted) machine

front escape hatch for improved steep slope safety

four-point seat belt operator comfort and support while operating on steep slopes

Enhanced engine and hydraulics system (reservoirs, oil tanks, sumps) grade capabilities designed for continuous 100% grade operation and intermittent 125% grade operation

Engineered attachment points (hitches) that are rated at 150% of total machine mass

Extended roller frames for enhance stability of the rigid track machines on steep slopes

Winch-assist systems - Benefit

- *Safety*

Exposure to hazards is greatly reduced and the number of workers required for the same amount of harvested volume is substantially lowered

- *Productivity*

Productivity gains are usually achieved when properly planned and laid out for winch-assist implementation

In addition previously non-economical stands could be viable for harvesting



Winch-assist systems - Benefit

- *Adaptivity*

- Quality

- Delivered product quality

- Environmental performance quality

- Mechanized felling and bunching provides for better directional felling and reduced tangling and breakage

- Track spinning and soil disturbance (even on moderate terrain) is reduced to a minimum

- Yarding from bunched piles results in less breakage and operator effort



Winch-assist systems - Benefit

- *Adaptivity*

- Worker attraction and retention

- Improved working methods, comfortable and protected ergonomic working places would require less effort and result in less fatigue and stress

- As result attracting younger workers to consider a career in forestry harvesting and retaining such workers would be enhanced



Winch-assist systems - Benefit

- *Adaptivity*

- Versatility**

- Winch-assist technology can be used in a variety of equipment configurations that fit a contractor's suite of equipment, terrain type, piece size, labour availability



Winch-assist systems - Benefit

- *Adaptivity*

Versatility

Winch-assist technology can be used in a variety of equipment configurations that fit a contractor's suite of equipment, terrain type, piece size, labour availability

Sustainability

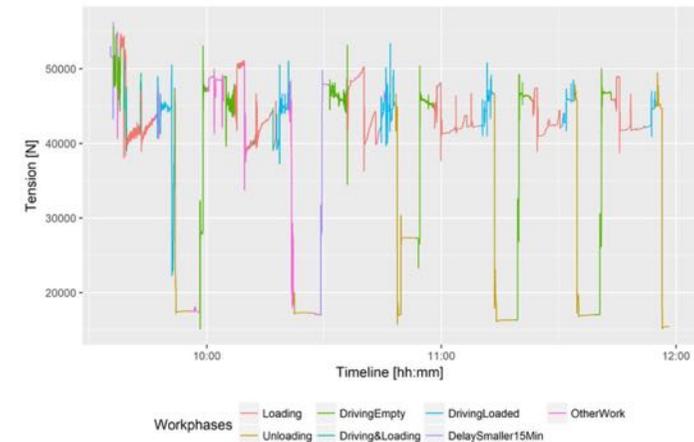
Reduced breakage during mechanized directional felling and better tree and log positioning for yarder extraction will contribute to higher stand utilization and value recovery

The possibility of on-site delimiting and processing will result in less road side debris disposal and minimizing the need to remove piles



Winch-assist systems – Safety measures

- *International developments in safety measures for winch-assist technology*
 - Rules, approved codes of practice, best practice guidelines
 - Equipment manufacturers' designs
 - Research focus



Holzleitner et al., 2017

Remote control and teleoperation

- **An integrated approach must be developed for conducting productive and injury-free mechanical harvesting operations on steep slopes that draws on the skills and accountabilities of the working team**

Remote control and teleoperation

- An integrated approach must be developed for conducting productive and injury-free mechanical harvesting operations on steep slopes that draws on the skills and accountabilities of the working team
- Shifting the paradigm

No foot on the ground
No hand on the timber



No man in the machine
No hand on the handles



Remote control

- Remote control

Advantages

- removing the operator from hazards

- providing options for getting the primary (assisted) machine out of a difficult situation

Disadvantages

- reduced productivity and operator ergonomic comfort level in order to maintain line of site



Teleoperation

- **Teleoperation**

Extends the concept of remote control even further where a primary (assisted) machine is controlled by an operator at a remote location (no line of sight) with the use of cameras, sensors, and possibly additional positioning software



Teleoperation

- **Teleoperation**

Is a difficult problem, primarily due to the unstructured and uncontrolled environment in which forestry harvesting takes place



Teleoperation

- Primary (assisted) machine

Teleoperation

- **Primary (assisted) machine**
 - in the forest it moves slowly enough that the operator could work out of the machine dynamics in real time

Teleoperation

- **Primary (assisted) machine**

in the forest it moves slowly enough that the operator could work out of the machine dynamics in real time

manoeuvring the machine's crane or boom can be controlled manually or in semi-autonomous way

Teleoperation

- **Primary (assisted) machine**

in the forest it moves slowly enough that the operator could work out of the machine dynamics in real time

manoeuvring the machine's crane or boom can be controlled manually or in semi-autonomous way

the repetitiveness of the hydraulic rams movements of the machine's crane or boom can be easily modelled and then automatized

Teleoperation

- **Primary (assisted) machine**

in the forest it moves slowly enough that the operator could work out of the machine dynamics in real time

manoeuvring the machine's crane or boom can be controlled manually or in semi-autonomous way

the repetitiveness of the hydraulic rams movements of the machine's crane or boom can be easily modelled and then automatized

devices capable of identifying the position, size and orientation of trees and other obstacles in the forest are under development

Billingslay, 2008; Westenberg and Shiriaev, 2013

Teleoperation

- **Teleoperation**

 - Benefits**

 - improved safety and comfort of the operator

 - improved operator's productivity

 - enhancement of operator's skills through the implementation of interfaces and algorithms

 - redesign of the primary (assisted) machine for maximal productivity and minimal building*



Teleoperation

- The implementation of teleoperated, semi-autonomous and fully autonomous forestry equipment, in conjunction with constantly improving winch-assist technology, will provide a platform for safely extending the range of ground-based equipment to previously infeasible terrain conditions



*Intelligent Off-Road Vehicles
Umeå University, Umeå Sweden*

Thank you for your attention

TESAF Dipartimento Territorio
e Sistemi Agro-Forestali
Università di Padova

raffaele.cavalli@unipd.it

FPInnovations 

dzhamal.amishev@fpinnovations.ca

