Tree farming guidelines

4th Edition (2022)

Part 3 - Forest engineering

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PART 3 - FOREST ENGINEERING

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CHAPTER 1 – PLANNING

Forest engineering includes all the activities necessary to transfer the standing tree into a product that is suitable for further processing or woodworking[1]. These activities are associated with timber harvesting, timber transport and road construction.

Because forest engineering constitutes between 60% and 80% of the operational budget it requires that operations are performed cost-effectively and efficiently.

Proper harvest planning ensures that:

- operations utilize the most effective systems in terms of cost, productivity, safety, and environmental impacts.
- goals and targets are set, against which performance can be checked and corrective action taken if required.

The harvesting plan defines the operation in terms of compartment boundaries, felling direction, direction of extraction, management of special zones, production levels, task requirements, safety precautions and time frames.

The plan should include the following detail:

1. A map of an appropriate scale (1:5000 should be fine) showing:
   - compartment boundaries.
   - compartment roads.
   - streams and stream crossings.
   - power and telephone lines
   - other physical attributes that could affect the harvesting operation.
   - special management zones including safety areas.
   - a terrain classification matching the harvesting system to the terrain.
   - felling direction.
   - special felling conditions and/or precautions.
   - extraction routes.
   - cable yarding corridors, landings, anchors, etc. (where applicable).
   - main haulage routes.
   - direction of timber flow and timber haulage.
2. A harvesting and transport schedule showing:
   - required harvesting equipment per terrain class.
   - detailed task requirements for each harvesting activity to ensure that bottlenecks are identified and eliminated.
   - planned production and stock levels.
   - manpower requirements based on planned productivities.
3. A harvesting schedule indicating planned start and end dates.
4. A detailed compartment costing exercise.
5. Quality, quantity, and safety control mechanisms.

Reference

[1] Warkotsch, PW (1987) The Relevance of Harvesting in Forestry. South African Forestry Handbook. Southern African Institute of Forestry.

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CHAPTER 2 – FELLING **Page**

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The preparation of timber includes felling, debranching, topping, debarking, cross-cutting and stacking. These activities can be done motor-manually or mechanically.

1. Motor-manual felling

Equipment for motor-manual felling includes a chainsaw and a felling lever. Chainsaw operators must be suitably trained for the task. The size and characteristics of an appropriate chainsaw is a function of the following[6]:

- Tree diameter: The cutter bar length is primarily determined by the tree diameter to be cut.
- Tree species: The species determine the hardness of the timber, which has a bearing on the required power output of the saw.

A chainsaw should be specified for about 80% of the most difficult tasks it is required to do. Typical professional forestry saws range between the 60 to 80 cc class[6].

For more information regarding chainsaw operations, refer to the South African Chainsaw Safety & Operating Handbook[1].

1.1 Personal protective equipment

- Chainsaw helmet with visor & earmuffs.
- Orange/yellow T-shirt, or high visibility vest, or chainsaw jacket.
- Chainsaw/cow hide gloves.
- Chainsaw trousers.
- Steel toe capped safety boots.
- Rain suit when required.
- Other:
    - o tool pouch with required tools (round file, flat file, combination spanner, depth gauge tool).
    - o fuel and oil container.
    - o cloth or brush for cleaning purposes.
    - o fire extinguisher (at the workstation).
    - o first aid kit (at the workstation).

1.2 Felling technique

- Ensure that no other person is within the felling danger zone of at least two tree lengths radius from the tree to be felled. The danger zone is 360° around the tree to be felled.
- Determine an appropriate escape route, preferably two. Usually, 45° away from the felling direction.
- Ensure the escape route is open and clear of obstacles.

Figure 1 shows the danger zone and the escape routes:

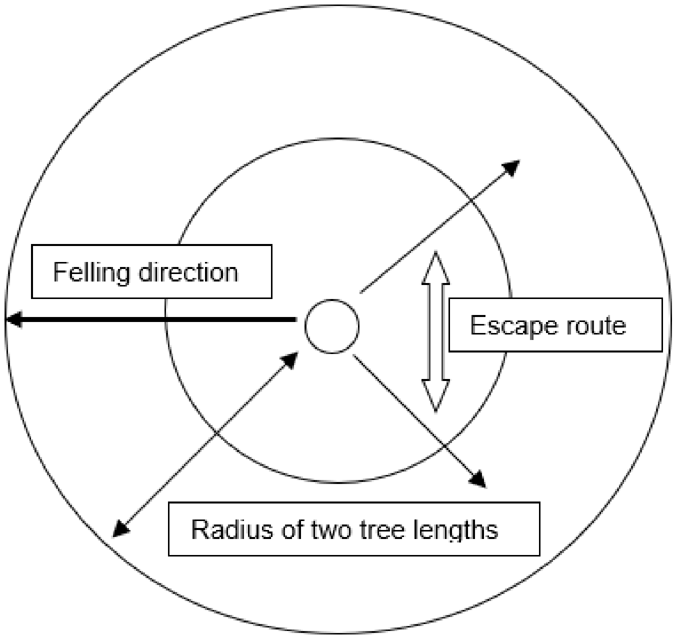

Figure 1: Danger zone and escape routes

- Check the possible felling direction by considering the following:
    - the angle at which the tree is leaning.
    - crown size and overhang.
    - dead material in crown.
    - neighbouring trees.
    - wind direction.
    - planned extraction direction.
    - slope on which the tree is growing.
    - environmental considerations.
    - silvicultural requirements.

- Fell the tree using the following three cuts: (in the case of manual felling, the felling height should be 100mm or less)
    - directional notch/front cut
    - bottom cut.
    - felling/back cut, 25-35mm higher than bottom cut. This step serves as a felling hinge, steering the tree in the desired direction.

Figures 2a, b & c show the three felling cuts.

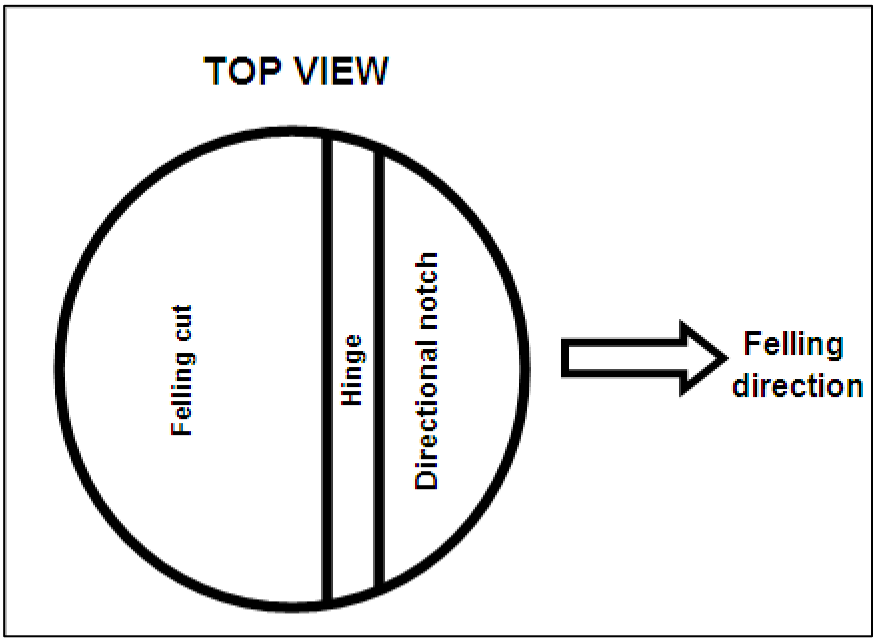

Figure 2a

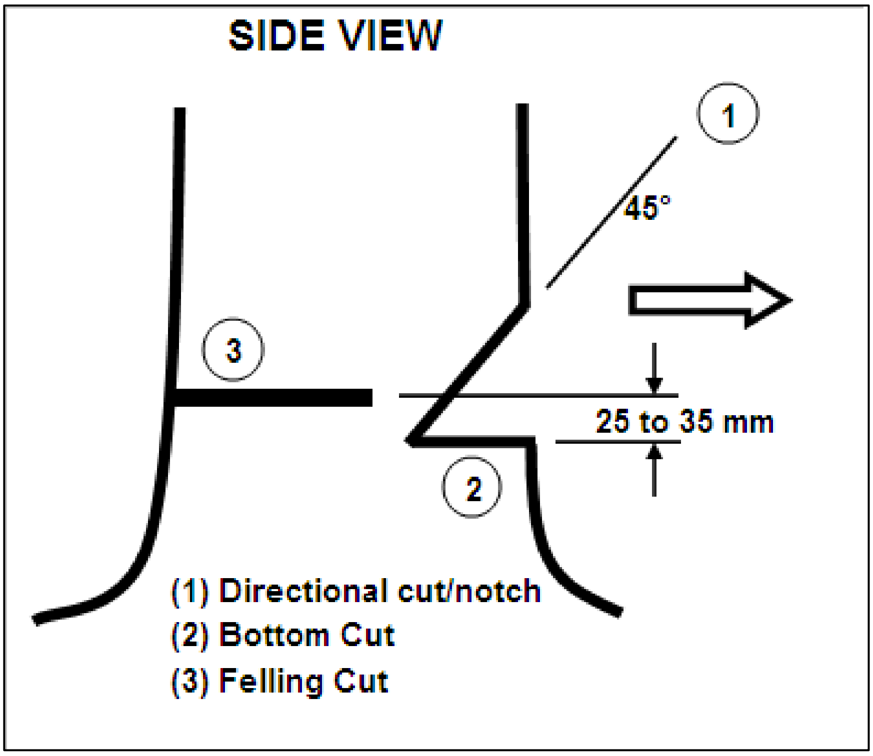

Figure 2b

Figure 2c[9]

1.3 Felling production

The following factors could influence felling productivity[6]: (refer to Annexures 8 and 12)

- Tree size.
- Species.
- Branching intensity and size.
- Terrain.
- Understory vegetation.
- Climatic conditions, especially wind.

2. Manual debarking

Debarking is the process of removing the bark from *Eucalyptus* and *Acacia* species after felling. Manual debarking of logs (or tree lengths) is usually performed with a sharpened hatchet. Debarking spuds (hoe-type equipment) and shaped spades can also be used.

The bark is detached either as long or short strips or small plates. As far as possible, effort should be made to ensure that logs are free of cambium once debarked.

2.1 Protective clothing for manual debarkers

- overalls.
- high visibility vest or if not, highly visible overall.
- hard hat.
- steel toe cap safety boots.
- leg protectors.
- rubber gloves.
- rain suit when required.

Manual debarking is a strenuous job with an awkward posture. Debarkers must be trained in the correct technique.

Debarkers must take note of the following:

- Always debark on the far side of the log, away from feet and legs.
- Always use a properly maintained debarking tool.
- Always chip away from yourself.
- Do not walk or stand on wet logs.

2.2 Debarking percentage

Debarking percentage is the percentage of cleanly debarked logs in a total number of debarked logs. Debarking % = (number of cleanly debarked logs ÷ total number of logs sampled) x 100.

Clean debarked logs are logs where no cambium, or less than 30% cambium remain on the log. Chiselled or shaved logs are where more than 30% cambium remain, and the bark must be chiselled off in small pieces. See photos below:

Photo 1 (left) Clean debarked log and **Photo 2** (right) chiselled log[3]

The debarking percentage is expressed in classes as shown in the following table. Refer to Annexure 9 for the tables on a debarking task percentage.

Debarking class	Debarking %	Task %
1	0 - 40	40
2	41 – 55	50
3	56 – 75	60 - 70
4	76 – 85	80
5	86 - 100	90

Table 1: Debarking classes

The debarking percentage is influenced by:

- species.
- growing site.
- season of debarking.
- time of day.
- temperature.
- time after felling.
- whether the trees are stressed by e.g., drought or disease.

Rip-stripping is a term used where the bark is ripped off in long strips from standing trees. This practice is only viable when trees are easily debarked. Debarkers should beware of falling branches and premature breaking of the bark when rip-stripping.

Photo 3: Rip-stripping[9]

2.3 Preparing wattle bark

Wattle bark is usually stacked in bundles and tied using a thin strip of bark. Bark thickness is an important factor as mills pay a premium for thicker bark.

Bundle size is determined by the specifications of the receiving bark mill. Bark bundles vary in mass from 25kg to 40kg per bundle. Photo 4 below is an example of a bark bundle.

Photo 4: A bark bundle[9]

3. Manual debranching

Debranching is the process of removing the branches from felled trees. Refer to Annexure 10.

When debranching by axe the following should be noted:

- Work from the butt-end of the tree towards the top.
- Always debranch from the far side of the log.
- Axe strokes should be with the angle of the branch and not against it.
- Only debranch merchandisable timber. Do not waste effort to debranch above the minimum diameter mark.
- Debranchers should be outside the danger zone of two tree lengths from felling operations.[4]

Debranching by chainsaw is the preferred method to remove branches. There are mainly two different methods, namely the six-point lever method and the sweep method. See Figure 3.

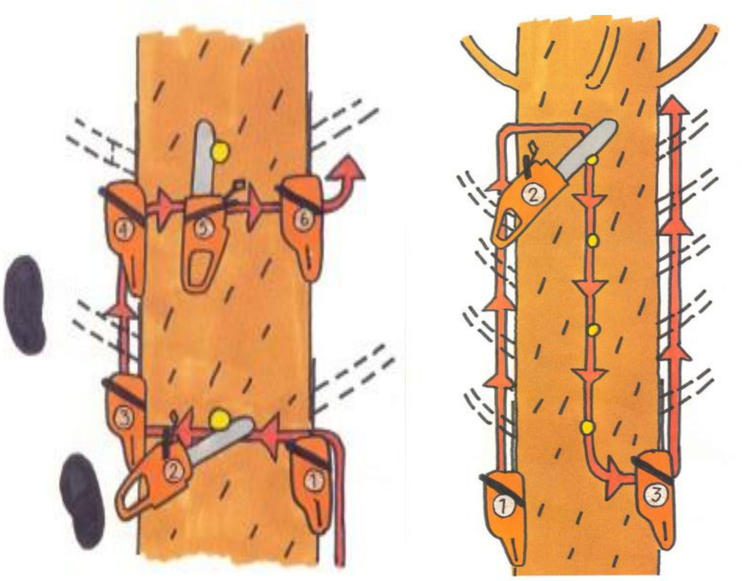

Figure 3: (left) six-point lever method and (right) sweep method[5]

Irrespective of which method is used, the following basic rules should be observed:

- Work at a comfortable height and try to avoid bending over. This can be achieved by planning ahead and by correct felling. Use already felled trees, rocks, or the terrain to create a comfortable working height.
- Get a firm foothold and work with the chainsaw close to your body.
- Flex your knees and not your back.
- Do not move your feet when you are cutting on the same side of the tree as you are standing.
- The weight of the saw should be against the tree and not your leg.
- Lead with your left leg when starting to debranch.

4. Manual cross-cutting

Cross-cutting is the process whereby felled trees are cut into marketable lengths infield or at landings. It is important to use the correct technique when cross-cutting, as the incorrect technique can cause accidents, pinching of the saw or splitting of the log.

Observe the following when cross-cutting:

- Determine the stresses the log is under, for example upward, downward, or sideways.
- Observe carefully how the timber reacts to being cut.
- Be aware of where you are standing when you cross-cut.
- Stand off to one side instead of right in front of the cut.
- When cross-cutting logs with sideways tension, one must always stand on the inside of the curve when cutting.

Figures 4, 5 and 6 demonstrate the cutting technique for the most common tensions a log can be subjected to.[5]

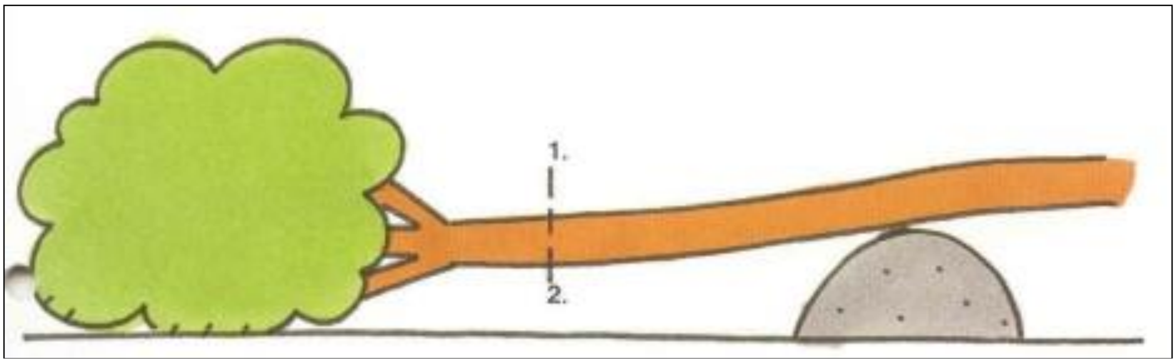

Figure 4: Stem with downward tension

Method: start by making a cut from the top downwards until the cut begins to pinch the guide bar. Continue the cut from the bottom upwards. Try to make the two cuts meet.

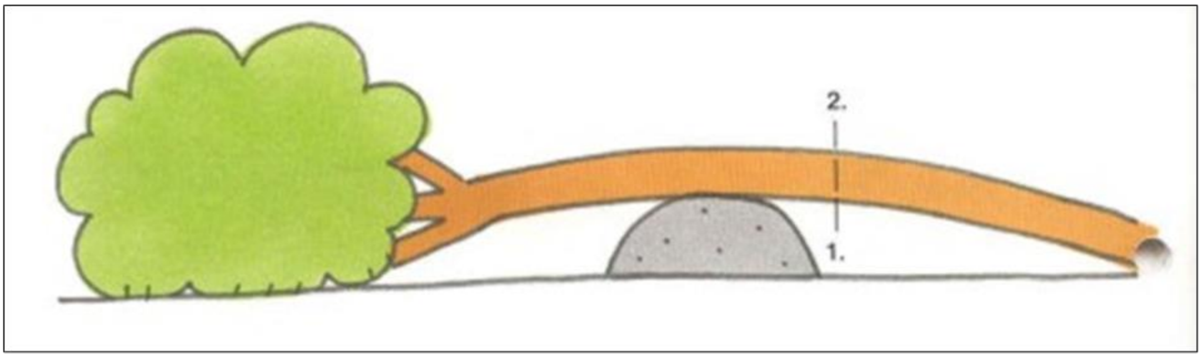

Figure 5: Stem with upward tension

Method: start by making a cut upwards until the cut begins to pinch the guide bar. Continue the cut from the top side downwards. Try to make the two cuts meet.

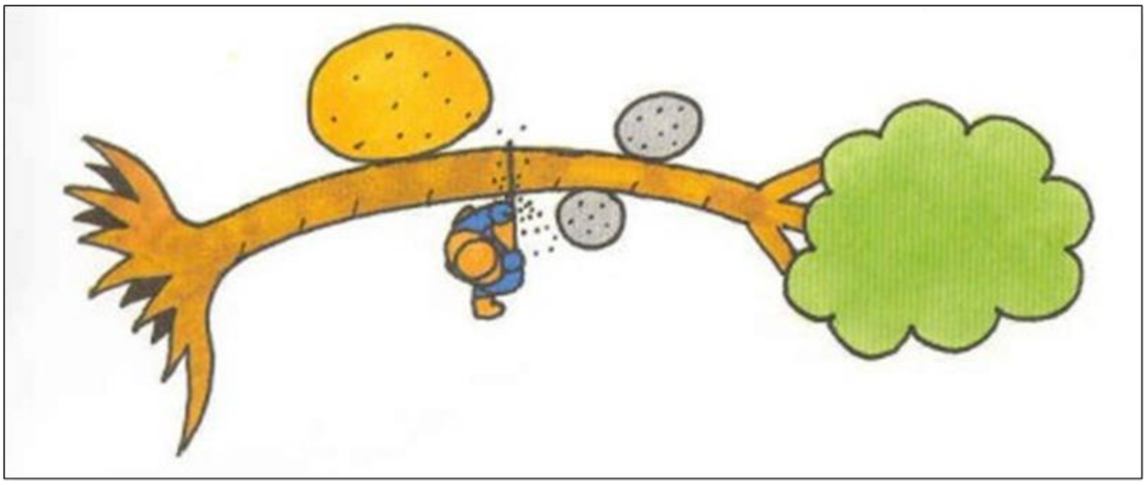

Figure 6: Stem under sideways tension

Method: Cut an open directional wedge on the inside or non-stressed side of the stem. Start at the top and cut in stages until the stem breaks. Remember to always stand on the inside or non-stressed side of the stem.

Guidelines for cross-cutting can be found in Annexure 11.

5. Infield stacking

Infield stacking is the process to group logs for loading. The size of the stack is determined by the available volume, the log size and the loading method that will be used.

Stacking can be done by hand or mechanically. As excessive infield disturbance of the soil is not good practice, mechanical stacking by 3-wheeler should be minimised where possible. It also poses a safety risk as the machine can overturn when traversing over stumps.

Stackers should always ensure that the stacking area is free of bark, branches, or other debris. Building the stack on bearers will ensure that minimum debris is picked up at loading.

Stacking productivity and quality may be influenced by:

- safety considerations.
- log length.

- piece size and mass.
- available volume per hectare.
- terrain conditions.
- stacking area.
- stacking method.
- machinery employed.

Positioning of the stack is important. If the stack is positioned in between stumps or standing trees, it could negatively affect the loading of the timber. The stack must be created in such a position that the point where the grab of the loading machine secures the logs, is free of all obstacles.

All stackers should be issued with logging tongs and should be trained in its the proper use.

Photo 5: Logging tongs

5.1 **Stack types**

Depending on the terrain, stacking method, piece size, and loading method, different types of stacks can be constructed.

5.1.1 **Rough-lining of timber**

In this method the timber is just turned so that it all faces the same direction. The timber is not stacked but lies on long roughly aligned rows. See photo 6.

Photo 6: Rough-lined timber[3]

5.1.2 **Classic stack**

This type of stack is constructed by laying down two bearer logs approximately 2m apart. Uprights are hit into the ground to support the stacked timber. Depending on the loading and/or extraction method, stack size may vary anything from 2 to 5 tons per stack. See photo 7.

Photo 7: Classic stack[3]

5.1.3 **Diamond stack**

This type of stack does not require any uprights to be driven into the ground for support. The stack is built to supply its own support. This type of stack works well in flat areas. See photo 8.

Photo 8: Diamond stack[3]

5.2 **Stacking production**

Stacking production is a function of the log size (length and volume), available volume, terrain, and the type of stack to be built. Task tables for stacking of *Eucalyptus* are given in Annexure 13. These tasks are based on building a classic stack.

6. Mechanised felling

Mechanised timber preparation is gaining acceptance throughout the industry. The mechanised timber preparation system can be classified into semi-mechanised and fully-mechanised systems. See figure 7.

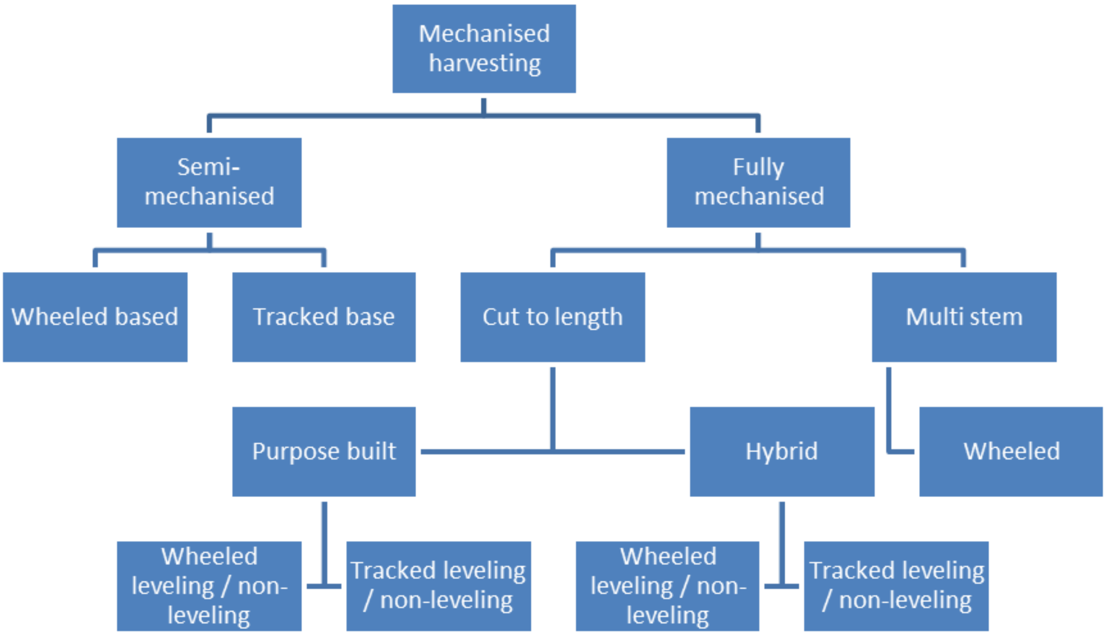

Figure 7: Classification of mechanised harvesting systems

Semi-mechanised systems are defined as a combination of motor-manual felling and mechanical debarking or further processing. The debarking, for example, can be done by a debarking head or other mechanical means like flail debarkers. Photo 9 shows a locally developed debarking head and photo 10 a small flail debarker.

Photo 9: Locally designed debarking head[3]

Photo 10: Locally manufactured small flail debarker

Fully mechanised systems are systems where the felling and further conversion of the tree is done by fully mechanical means. The fully mechanical system can further be categorised as Cut to Length (CTL) or multi-stem systems.

CTL systems use equipment that can process one tree at a time. The tree is felled, debranched, debarked (where applicable) and cross-cut into lengths and deposited ready for loading, by one machine. See photos 11a & b.

CTL systems can be classified into so-called hybrid systems or purpose-built systems. The hybrid systems are set up utilising an excavator or other suitable carriers, together with a harvesting head. Purpose-built systems are specifically designed to perform a harvesting function.

Photo 11a: Tracked single stem harvester (CTL system)

Photo 11b: Wheeled harvester.[8]

Multi-stem systems can process more than one stem at a time. See photo 12. The multi-stem system uses a felling and bunching piece of equipment, an extraction piece of equipment, a cross-cut or debarking system or even a chipping system.

Photo 12: Equipment used in a multi-stem harvesting system (feller-buncher, grapple skidder, slasher deck).

Mechanised felling has the following advantages over motor-manual felling:

- Increased safety of the felling operation.
- Increased felling production and productivity.
- Improved downstream extraction activities due to improved directional felling and bunching.
- Multi-shift felling allows for better equipment utilization.

Factors influencing mechanised felling productivity:

- safety considerations.
- tree species.
- tree size.
- tree diameter.
- espacement.
- terrain.
- underfoot conditions.
- debarking percentage (where applicable).
- stem form.
- crown shape and size.
- number and size of branches.

- equipment type.
- operator competence.

Mechanical felling heads use either a shear or a non-shear function to cut through a tree. Shears cut through a tree like scissors – photo 13. Non-shear disks cut through the tree using either a rotating disk or a bar and chain – photo 14.

Photo 13 (left): Shear type felling head[7]

Photo 14 (right): Felling head utilizing bar and chain[3]

Photo 15: This felling grapple weighs just 225 kg and can be mounted on a truck-mounted crane, a three-wheeler, or a small excavator. It can cut standing trees up to 350 mm diameter.[8]

There are various types of mechanical debarking heads on the market. They all work on the principle of grooved rollers rotating the stem under pressure, which cause the bark to be stripped off as the log passes through the rollers. Cutting knives shear off the branches in front of the rollers – photo 15.

Photo 16: Felling/debarking head³

Factors influencing debarking production and quality:
- species.
- roller feed speed.
- roller pressure.
- tree form.
- number and size of branches.
- operator competence.
- terrain.
- season.

Photo 17 (left): Mechanically debarked timber³

Photo 18 (right): Timber presentation from mechanical felling, debarking and cross-cutting³

7. References

[1] Forest Engineering Southern Africa and Institute for Commercial Forestry Research (2015) South African Chainsaw Safety & Operating Handbook.
[2] De La Borde (1992) Timber Harvesting Manual. Institute for Commercial Forestry Research, Pietermaritzburg, South Africa.
[3] Photos by A Immelman.
[4] Zaremba W (1976) Logging Reference Manual Vol. 1, 2 and 3.
[5] Husqvarna. Work Technique for Felling and Limbing.
[6] Forest Engineering Southern Africa and Institute for Commercial Forestry Research (2010) South African Ground Based Harvesting Handbook.
[7] Photo by G van Huyssteen.
[8] Photo from SA Forestry. https://saforestryonline.co.za/
[9] Photos by A Jooste.

Take note that references 1 and 6 can be downloaded from the website of the Institute for Commercial Forestry Research (ICFR); https://www.icfr.ukzn.ac.za/publications/

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1. Terminology

To identify and cost the different phases of timber transport, the following terminology was developed:

- Primary transport (PT) is the transport of timber from the stump area to a roadside landing which could be either centralised or continuous.
- Extended primary transport (EPT) or short haul is terrain transport past the roadside landing to an intermediate storage site or directly to the processing site.
- Secondary intermediate transport (SIT) is timber transport from a roadside landing to an intermediate storage site (timber does not reach the processing site in this phase of transport).
- Secondary terminal transport (STT) is timber transport from an intermediate storage site to the processing site (the final stage of transport).

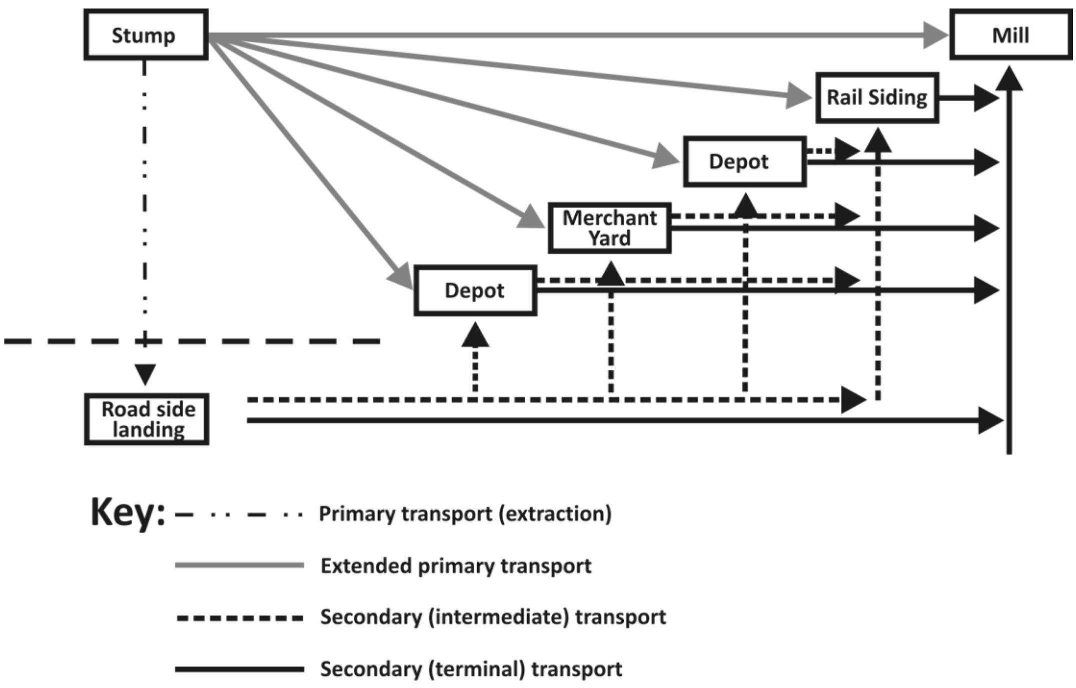

Figure 1: Transport terminology[3]

2. Harvesting systems

To plan, implement, and operate cost-effective and safe harvesting operations, a systems approach must be followed. This approach will ensure the success of harvesting operations in terms of economics, social aspects, the environment, and technical feasibility. In striving for sustainability and sustainable forest management, choosing an appropriate and suitable harvesting system is not simple and is subject to a variety of variables[3].

The condition of the terrain has a direct influence on the type of equipment used in a harvesting operation and on the planning of such an operation. Important terrain features are the carrying capacity of the ground (ground conditions), the surface structure or obstacles (ground roughness) and the slope[3].

Table 1 lists examples of appropriate harvesting systems based on slope:

Flat area (0% - 20% slope)	Semi-steep area (20% - 35% slope)	Steep area (35% + slope)
Drive-in systems Tractor and trailer Tractor with winch Forwarders Bundle trailers Manual systems Skidders High lead Skyline Wheeled felling/processing Tracked felling/processing	Ground cable systems Skidder Forwarders Chutes Manual systems High lead Skyline Wheeled felling/processing Tracked felling/processing	High lead Skyline Chutes Manual systems Aerial systems

Table 1: Harvesting systems based on slope

The following terrain limitations apply when using wheeled extraction systems:

Criteria	Agricultural tractor (winch & A-frame)	Wheeled skidders		Forwarding machines		Clam bunk skidder
		Normal tyres	High flotation	Tractor & trailer	Wheeled forwarder	
Slope % up Slope % down	0-10 0-3	0-20 0-35	0-20 0-40	0-10 0-20	0-30 0-40	0-25 0-40
Ground roughness (Table 3)	1-2	1-3	1-2	1-2	1-3	1-3
Ground conditions (Table 3)	1-2	1-3	1-2	1-2	1-4	1-3
Skidding distance	50-300m	50-500m	50-500m	50-500m	50-1000m	50-1000m

Table 2: Terrain limitations for wheeled extraction systems[2]

The National Terrain Classification System for Forestry[4] provides an indication of the physical characteristics and accessibility of an area:

Ground conditions (mobility within the stand)	Ground roughness	Slope* (in %)
1. Very good	1. Smooth	1. Level (0%-11%)
2. Good	2. Slightly uneven	2. Gentle (12%-20%)
3. Moderate	3. Uneven	3. Moderate (21-30%)
4. Poor	4. Rough	4. Steep 1 (31%-35%)
5. Very poor	5. Very rough	5. Steep 2 (36%-40%)
		6. Steep 3 (41%-50%)
		7. Very steep (>50%)

Table 3: Terrain classification

The consequences of improper equipment selection may range from unsafe working conditions, unacceptable cost, and excessive environmental damage with possible legal implications.

The following factors affect equipment selection:

- Slope, ground profile, streams, wetlands, and ground roughness.
- Soil characteristics such as soil type, texture and moisture content affect the bearing strength of the soil.
- Tree size, species, volume per hectare and timber quality. The physical ability of the equipment to handle the timber and the harvesting economics of piece size are the primary concerns.
- Mill specifications, availability of labour, equipment availability and operating costs.
- Severe weather conditions can affect the degree of soil disturbance by different equipment types.
- Espacement and coppice can limit machine movements.
- Legislation, regulation, and certification requirements. Environmental guidelines, training of operators and limitations on access can limit the range of candidate equipment.

Essentially, it is a matter of matching machine and site to risk.

Risk factors applicable to all harvesting equipment and systems:

- Operator/contractor experience, attitude, and history. Risk is decreased by an experienced operator/contractor who has worked successfully under similar conditions.
- The risk of causing soil disturbance increases with higher soil moisture content.
- Working in the vicinity of riparian zones or other sensitive sites increases risk.
- Risk decreases when tree size is matched to machine size.
- Risk increases with poor timber quality due to reduced values.

Forest engineering is the most expensive component of the forest value chain. Accurate cost calculation, quotation and management are thus key ingredients for successful business within this environment[5].

The calculation of a machine cost includes the following categories:

- ownership cost.
- operating cost.
- labour cost.
- overhead cost.
- profit.
- productivity analysis.

3. Extraction methods

Ground-based extraction systems are the most common in South Africa and include manual, wheeled and cable systems. The timber can be extracted as complete trees or as cut to length.

3.1 Manual extraction

Manual extraction is the carrying or rolling of timber from infield to a point where it can be transported by other means. This method of extraction is seldom used but is suited for timber in sensitive or steep areas, and when no other means for extraction are available.

Small growers have utilised three-wheel motorbikes “trikes”, not only for extraction, but also for chemical spraying and other applications.[15]

Photo1a: Trike example[14]

3.2 Animals[3]

In South Africa, horses, mules, and oxen are still used for the primary transport of round wood. Despite their relatively low production, they continue to play an important role where volumes and terrain prevent the use of expensive mechanical equipment. Animals are also used for skidding, but their use is mostly limited to rural and small-scale operations. Refer to Zaremba's Logging Reference manuals[11] for more detailed information regarding the use of animals for skidding.

The use of draught animals is synonymous with low soil disturbance, soil compaction and damage to residual trees. Animal extraction operations are normally limited to pulpwood and light sawtimber logs. When planning for these operations, cognisance must be taken of the animals' physical capacities, and their care and maintenance.

3.3 Chutes

Chutes consist of round or half pipes joined end-to-end to form a continuous channel guiding the timber down a slope. These pipes are usually manufactured from high density polyethylene (HDPE). Chute extraction is recommended for slopes between 20% and 60%.

3.4 Tractors

Tractor and trailer combinations are widely used South Africa. Trailers are loaded either mechanically or by hand. Self-loading bundle trailers is a popular method of extracting timber. Timber is stacked infield in loads of four to five tons. The trailer reverses into the stack, pulling it onto the trailer via chains.

Photo 1b: Self-loading bundle trailer.[6]

Agricultural tractors are less robust, balanced or protected than tractors purpose-built for forestry. Hazards to agricultural tractors include over-turning, falling and penetrating objects, fire, whole-body vibration, and noise.

Only all-wheel drive agricultural tractors should be used and a minimum of 20% of the machine weight should be maintained as load on the steered axle during operation. This may require attaching additional weight to the front of the machine. The engine and transmission may need additional mechanical protection. Minimum engine power should be 35kw for small-dimension timber, while 50kw is usually adequate for normal-size timber.

Agricultural tractors fitted with an A-frame or drum winches (single or double) can be used to skid timber (see Photo 2a).

Photo 2a: Tractor with winch (www.logloader.com)

Timber growers are often innovative. As the saying goes "*'n boer maak 'n plan*", refer to photo 2b for an example of a tractor adapted for extraction.

Photo 2b: Tractor adapted for extraction by Normandien Farms, Newcastle.[13]

Safety precautions for tractors:

- Tractor seats should be shock-absorbent, fully adjustable, and fitted with safety belts. The safety belt must remain fastened whilst driving.
- All pulleys, shafts, belts, and fan blades must be securely guarded.
- Tractors must be equipped with an approved roll-over protection structure (ROPS) - a four-post structure should preferably be used.
    - ROPS are designed to absorb energy and deform permanently in the case of a roll-over. Where visible damage has been sustained, the structure must be assessed by the original designer or a suitably qualified, registered mechanical/structural engineer experienced in this type of work. Under no circumstances is a damaged structure to be straightened.
    - No alterations are to be made to the ROPS and nothing may be welded against it. Holes may not be drilled to secure items.
- Cabins should be protected against falling objects.
- Engines should be equipped with a stopping device which is not self-turning, clearly marked and easily reachable from the drivers' working position.

- The engine starter should be interlocked with the transmission or clutch to prevent the engine from starting if left in gear.
- Parking brakes must be capable of holding the machine and its load stationary on all slopes.
- Exhaust pipes should be equipped with spark arresters (engines equipped with turbo chargers are excluded).
- Fire extinguishers should be available on every machine, and the driver should be trained in its use.
- Tractors should be equipped with all-wheel drive for safe performance.
- Terrain (refer Table 1):
  - Where possible, avoid operating near ditches, embankments, and holes. Equipment needs to remain behind the shear line of the soil and embankment. The minimum distance recommended is a 1:1 ratio to the depth of the embankment. This distance should increase with adverse soil conditions, e.g., sandy, or wet soil.
  - Slopes:
    - Use low gear whenever moving heavy loads up or down - tractor brakes have limited holding power.
    - When travelling across a steep slope which is unavoidable, travel slowly and always turn uphill rather than downhill. Never turn sharply - make wide turns - it is better to edge gradually uphill. Tight turns can result in slipping, loss of control or roll over.
    - When travelling at speed across a mild slope, always turn downhill.
    - Backing up or driving down slopes can prevent rear overturn.
    - Use the widest possible wheel adjustment, and very slow speed while watching for obstacles.
- Speed:
  - Avoid high speed.
  - Reduce speed when turning and crossing slopes, rough terrain, slippery or muddy surfaces.
- Watch for obstacles and other hazards in the tractor path.
- Operate the tractor smoothly, avoiding jerky turns, starts, and stops.
- Eliminate sharp corners or curves, and rough or slippery surfaces.
- When the tractor gets stuck, always try to back out. Trying to drive forward is dangerous and can result in rear overturn. If backing out is not possible, get towed out forward by hitching to the tractor frame. If the tractor must be towed out backwards, hitch only to the drawbar.
- When towing use only a chain or steel cable and tighten slowly.
- Never take shortcuts.

3.5 Forwarders

Forwarding is the extraction of timber by wheeled equipment, carrying the timber on load decks or trailers. Equipment includes tractor and trailer units as well as specialised machines.

Specialised forwarders (see Photos 3a & b) may be equipped with a grapple crane for loading and unloading. The length of timber transported is dictated by the length of the load deck. Specialised forwarders are less suitable for timber with a diameter of more than 50cm.

Photo 3a: Forwarder

Photo 3b: An all-terrain forwarder.[12]

3.6 Skidders

Skidding is the extraction of trees by dragging or trailing, partially suspended, by specialised equipment. Crawler tractors can be used but are more suited for road building activities.

Wheeled or articulated skidders are specifically designed to winch and skid timber from stump to landing. The three main skidder configurations are:

- cable skidders.
- grapple skidders.
- clam bunk skidders.

Clam bunk skidders are equipped with a grapple loader and transport full trees by supporting the butt-end of the stem on a log bunk. These machines are suited for large size timber skidded over longer distances.

The use of articulated skidders is a capital-intensive operation and proper planning of the operations is essential.

Photo 4 (left): Cable skidder

(middle): Grapple skidder

(right): Clam bunk skidder

Skidder productivity is influenced by:

- skidding distance.
- load size.
- terrain.
- travel speed.
- machine capacity.
- operator decisions.

For all skidding operations, planning of the felling pattern and the skid trails is very important. Skid trails must be planned appropriately to minimize random driving in a compartment. Chokers and de-chokers must be trained and supplied with the appropriate protective equipment. These include overalls, steel capped boots, hard hats, and steel studded gloves.

Refer below for examples of skid trail layouts.[7] Factors like terrain, slope and the availability of haulage roads will determine the skidding pattern.

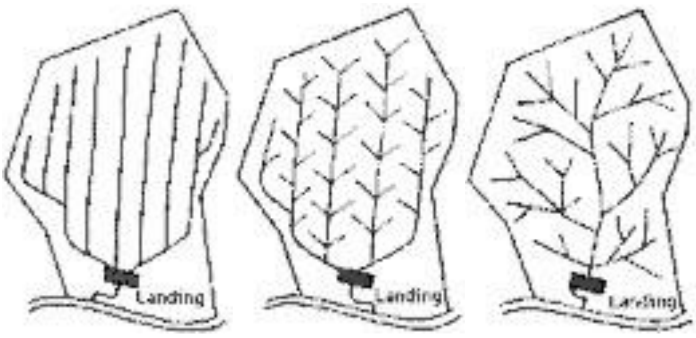

Figure 2: Skid trail layouts, left to right: parallel, herringbone, and dendritic design.

General notes on skidding operations and terrain limitations:

- Proper skid trail planning will minimise ground disturbance and compaction.
- When extracting with cable skidders, taglines should be used with smaller dimension timber to optimise load size.
- Grapple skidders usually work in conjunction with feller-bunchers. The feller-buncher fells the trees and bunches them into load sizes for the grapple skidder.

3.7 Cable yarding systems

Cable yarders are used when terrain conditions prevent the use of vehicles or other extraction methods, e.g., steep terrain (normally > 35% slope), excessive ground roughness, environmentally sensitive areas, and areas with soft underfoot conditions.

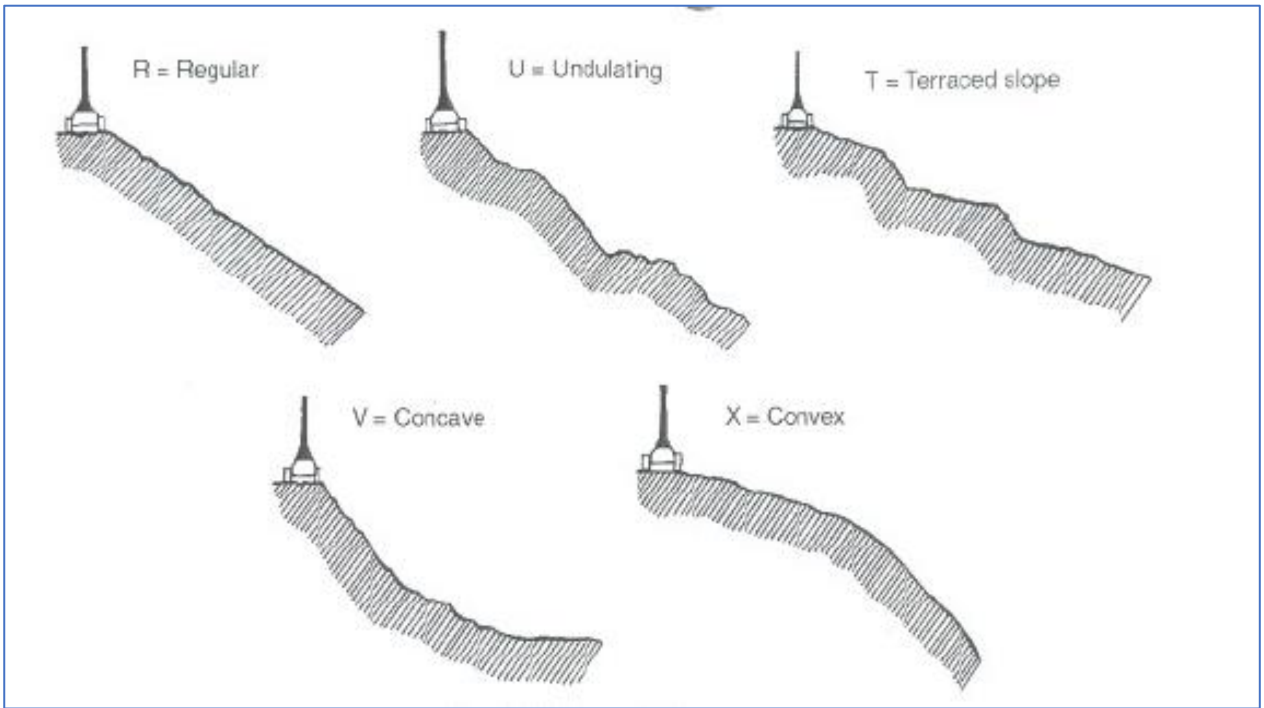

Figure 3: Types of slopes.[8]

Cable yarders are classified into three categories:
- high-leads.
- skylines.
- monocables.

3.7.1 High-leads

There are basically three types of high-leads:
- high-leads with butt-rigging.
- high-leads with a high-lead carriage (as used in South Africa – see Figure 4).
- shovel yarder high-leads (see Photo 5).

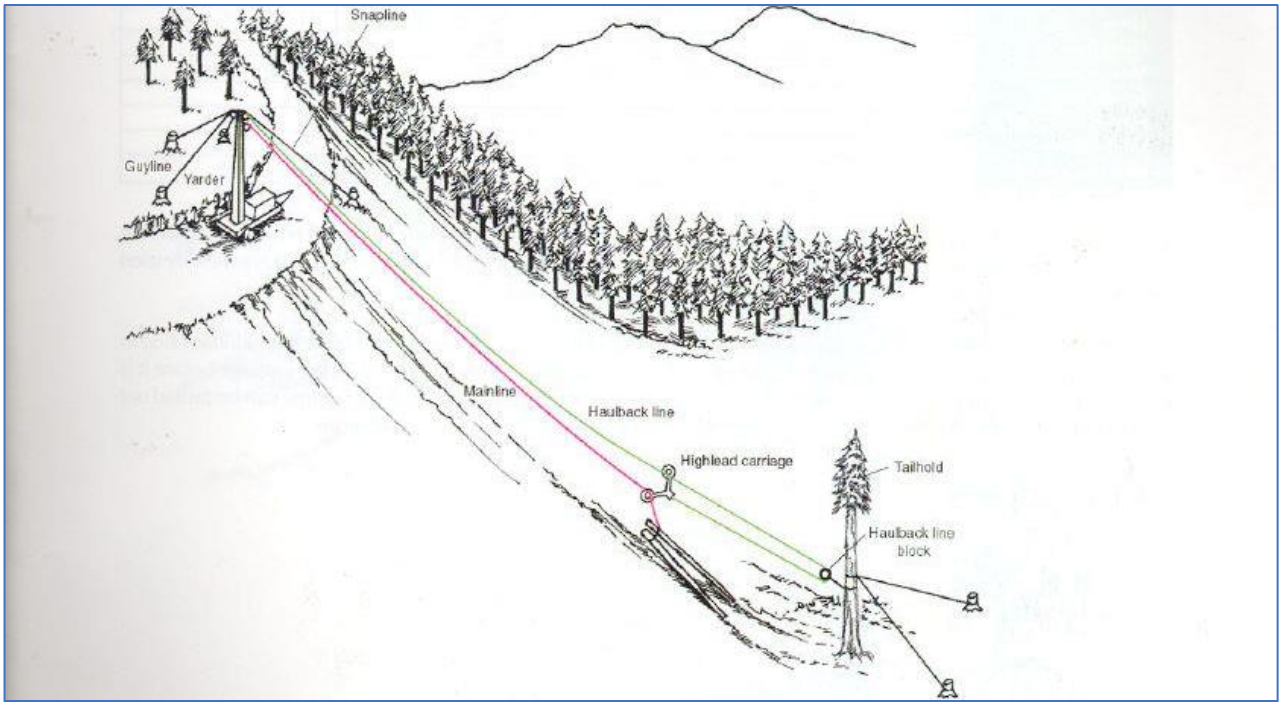

Figure 4: High-lead system with a carriage as used in South Africa. [8]

High-lead systems use two operating lines, i.e., the mainline and the haul-back line. During haul-back the logs are dragged on the ground. In some systems lift can be obtained by braking on the haul-back line. Some lateral yarding is possible. See Figure 4.

Photo 5: High power double drum shovel yarder with extended tower.[9]

The shovel yarder hi-lead is much safer than the conventional yarders because the yarder is operating without guy ropes and cannot be pulled over easily. It can also operate as a swing yarder, by leaving the timber next to the machine and not in front, as in a conventional yarder (see Photo 5).

The use of shovel yarders is increasing as opposed to traditional high-leads and skylines. Apart from being safer, it's quick to set up and therefore increases productivity.

Terrain limitations when using high-lead systems:

High-lead	Butt-rigging		High-lead carriage	
	Downhill yarding	Uphill yarding	Downhill yarding	Uphill yarding
Slope (%)	20 - 40		20 - 50	
Ground conditions (Table 3)	1 - 3		1 - 5	
Ground roughness (Table 3)	1 - 2	1 - 3	1 - 3	1 - 4
Yarding distance	50 – 200m		50 – 200m	

Table 4: Terrain limitations for high-lead extraction systems[2].

Types of slopes conducive to high-leading are regular and concave slopes (Figure 3).

3.7.2 Skylines

Skyline systems can either be standing or running skylines, single-span or multi-span. Although the high-lead described above is an example of a simple running skyline, standing skyline configurations are commonly used in South Africa.

Standing skylines have the skyline cable fixed at both ends and it remains fixed throughout the operation. The carriage runs on the skyline while the haul-back line, used in downhill yarding, runs through the corner and tail-block back to the carriage. The mainline runs through the carriage and the choked logs are attached to the mainline. The carriage is hauled out either by gravity (shotgun) in an uphill operation or with the haul-back line in a downhill operation. See Figure 5.

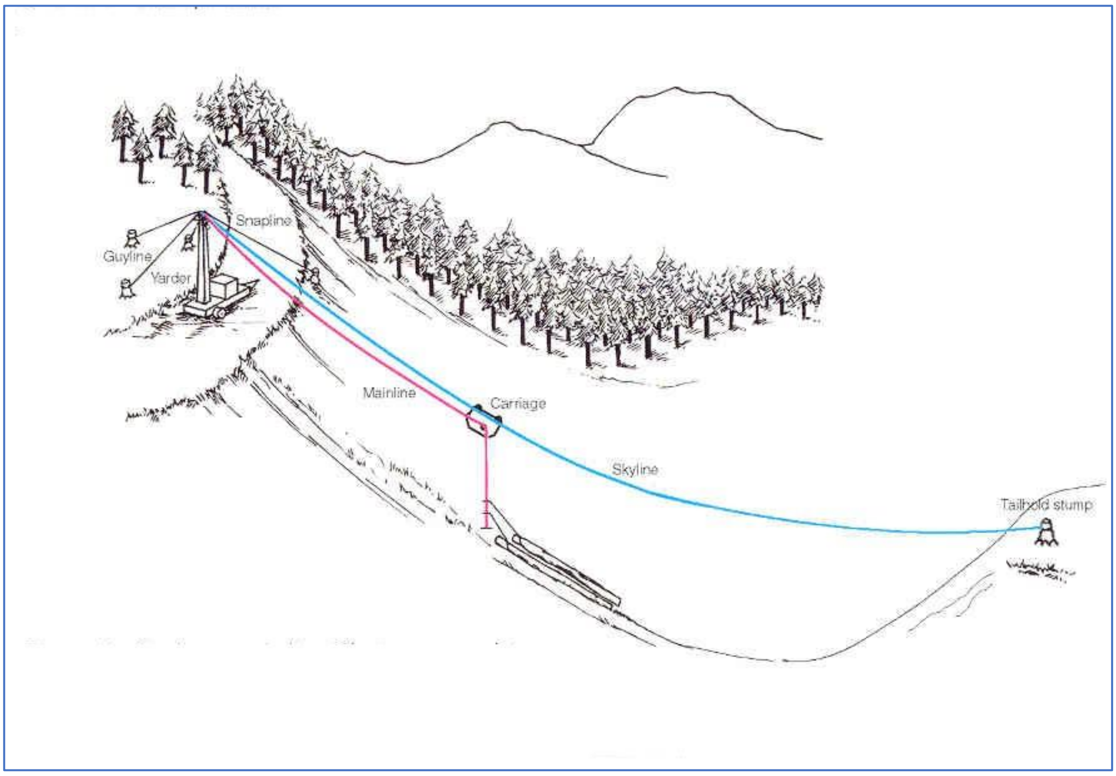

Figure 5: Standing skyline system.[8]

A long-distance gravity skyline can be used where access to the compartment is limited. This configuration is a low productive unit, but an effective method to harvest difficult terrain with timber of high value.

Photo 6: Long-distance gravity system.

Photo 6 shows the operational area for a long-distance gravity skyline over 800m, with the depot in the foreground and the harvesting area in the background.

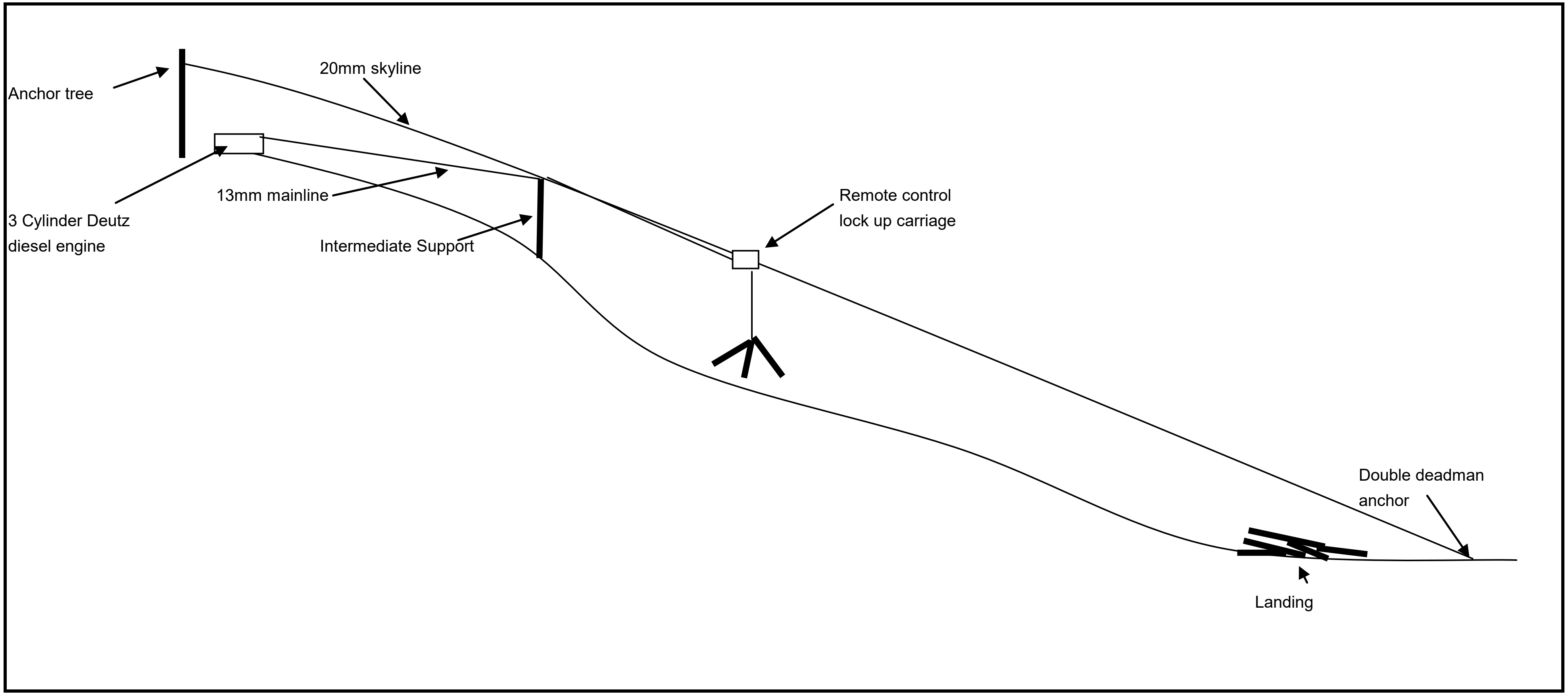

Figure 6: Concept design of a long-distance gravity skyline configuration.

Advantages of a gravity skyline vs. a conventional skyline:

- Capital layout much cheaper.
- With a gravity skyline an 800m haul-back line is needed, compared with a line of 1600m for conventional skylines.
- Range of conventional skylines rarely exceed 600m.

Terrain limitations when using skyline extraction systems:

Skyline	Downhill yarding	Uphill yarding	
		Full suspension	Partial suspension
Slope (%)	0+	0+	
Ground conditions (Table 3)	1 – 5	1 - 5	
Ground roughness (Table 3)	1 – 3	1 - 5	1 - 4
Yarding distance	100 – 600m	100 – 600m	

Table 5: Terrain limitations for skyline systems.[8]

3.7.2.1 Single-span skylines

A single-span system is used where there is adequate deflection to provide the required lift off the ground. Deflection refers to the amount of sag in the skyline and is influenced by the shape of the terrain.

Advantages of a single-span vs a multi-span skyline:

- set-up time is quicker.
- cycle time is faster.
- not as complex as multi-spanning.

Disadvantages of a single-span vs a multi-span skyline:

- the length of a rack is restricted to the distance where the required deflection occurs.
- restricted to concave and regular slopes (Figure 3).

3.7.2.2 Multi-span skylines

Compartments often have areas with little or no deflection, such as convex, undulating and long regular slopes. In such conditions deflection can be provided by installing intermediate supports. The carriage must be able to operate over the support jack. The supports are chosen along the length of the rack to provide skyline lift where deflection is inadequate. Supports are therefore positioned at a change in topography.

Advantages of a multi-span vs a single-span skyline:

- better deflection and clearance on unfavourable terrain.
- higher payload.
- higher lift.
- less wear and tear on the yarder.
- extended yarding distances.
- less environmental damage.
- reduced lateral deflection of skyline in thinnings.

Disadvantages of a multi-span vs a single-span skyline:

- slower operation.
- planning is more complex.

- rigging is more difficult and time-consuming.
- multi-span systems can be more expensive than a single-span (e.g., additional rigging, longer yarding distance).

3.7.3 Monocables

A monocable system consists of a continuous cable that runs through a series of open side blocks that are hung in support trees. The cable is powered by a capstan winch. Logs are choked to the moving line. Monocables are used in thinnings or other small-scale operations and can be up to 1,000m of continuous loop. See Figure 7.

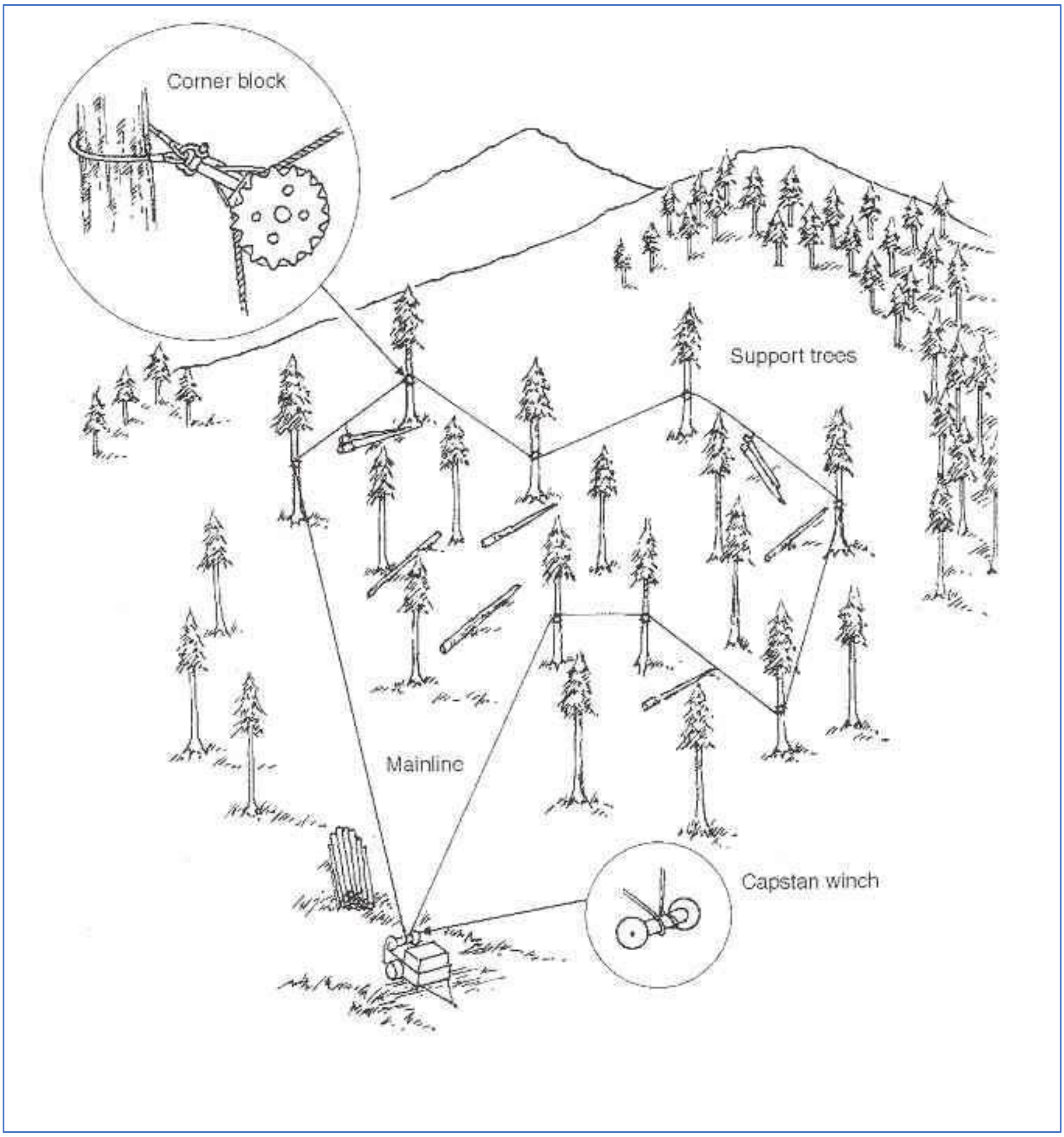

Figure 7: Monocable system.[8]

3.7.4 Wire rope

It is recommended that wire rope of the IWRC (independent wire rope core) type be used in cable yarding operations because of its strength and crush resistance. Wire ropes in a cable yarding operations experience both static and dynamic loading. Experience has shown that if tensions due to static loading are kept below one-third of the braking strength of the cable, there is adequate provision for the combined loading of static and dynamic loads. Therefore, a safety factor of three is typically applied to all wire ropes in cable yarding. Safe working load (SWL) = breaking strength / 3.

3.7.5 Planning a cable yarding operation

The following should be noted when planning for cable yarding operations:

- A paper plan detailing the operation should be compiled.
- The paper plan should indicate landings, felling direction, transport direction and areas that would incur special management.
- Guy line anchor availability and suitability must be checked.
- Landings:
    - should be as level as possible to ensure equipment stability.
    - should be big enough to accommodate all subsequent operations.
    - should be away from sensitive areas.
- The infield cable profile needs to be checked as it will have an influence on payload.
- Intermediate support trees must be marked clearly.

Cable yarding operations are one of the most dangerous forestry operations. The yarder crew must therefore be properly trained, experienced, and equipped. Only experienced crew members must be used if possible. Special attention must be given to the communication between the yarder operator and the choker men in the field.

Common hazards caused by incorrect rigging:

- Guy line failure caused by:
    - insufficient number of guy lines.
    - incorrect guy line angles.
    - insufficient guy line strength.
    - incorrect guy line tensions.
    - small sheaves.
    - fatigued guy lines.
    - guy lines are not in the lead at the point of attachment to the anchor.
- Anchor failure caused by:
    - using the wrong type of anchor system for the situation.
    - poor selection and notching of stumps.
    - incorrect guy line tension.
    - overloading of the yarding system.
- When yarding on convex slopes, cables will rub heavily on the ground causing wear and tear, which could lead to wire rope failure. Wire rope running over rock will also be damaged and could cause fires.
- Poor selection of intermediate supports and tail trees could injure workers.
- Intermediate supports, towers and tail trees can be pulled over if rigged incorrectly.
- Failure of rigging accessories due to mismatching the accessories and cables within the system.

4. Loading

4.1 Infield loading

Infield loading can either be manually or mechanically. Manual loading is a labour intensive and dangerous operation and should be minimised where possible. The type of loading equipment that is most popular is the three-wheel loader, the flexi loader, and the truck/self-mounted knuckle boom loaders.

4.2 Three-wheel loaders

These machines are very popular due to their high mobility and manoeuvrability. They are used extensively for infield stack building and loading. Visibility of the driver can be restricted, and the relatively short reach does not allow high stacks to be built or the loading of trailers from behind. They are well suited for short wood handling.

The three-wheel loader requires a reasonable flat working terrain and can cause extensive damage to the ground due to the churning up of the soil. For this reason, they are not environmentally friendly machines, and their infield use should be minimised and limited to depots and sidings where possible.

4.3 Knuckle boom loaders

This type of loader consists of a boom with a hydraulic operated joint at the midpoint on the boom. Knuckle boom loaders can be mounted on a trailer or on an independent carrier. These loaders have good reach and loading trailers from the back is possible. See Photo 7.

Knuckle-boom loaders seldom move in the compartment during the loading operation since the swinging boom moves the timber from where it is stacked. Timber presentation however does affect loading times and should therefore be carefully managed. A knuckle boom loader works best when the maximum distance that timber must be moved is a maximum of 180° swing of the boom, without the carrier moving.

Photo 7: Truck-mounted knuckle boom loader.[6]

4.4 Flexi loaders

The flexi loader is a four wheeled, all-wheel drive articulated vehicle with a mounted crane. It can secure and index a grab load and position it on a trailer at a rate equal or faster than attained with a three-wheel loader. This is due to its ability as a slewing crane as opposed to a fixed type of crane.

The flexi loader is a productive machine that has improved operational comfort in terms of ergonomic design, visibility, and mobility. The improved reach also allows the loading of the trailer from the back. As a rule of thumb, infield loading takes from 1 minute to 2.5 minutes per ton. This depends on the piece size, timber availability, timber presentation, grab size and type of loading equipment employed.

4.5 Self-loading trailer

The trailer shown in Photo 8 has a load capacity of 12 tons and can complete 12 loads in an 8-hour shift in pine thinnings. The crane has a 7-metre reach.

Photo 8: Self-loading forestry trailer.[12]

5. Roads

Forest roads provide required access for management of forest resources. Timber harvesting, fire protection, recreation, and administrative activities are highly dependent on access through a good forest road network.[10]

A comprehensive South African Forest Road Handbook (2005)[10] can be accessed free of charge from the ICFR website and should be used as the source manual for road design, construction, and maintenance. It has been designed specifically for South African conditions.

While roads are viewed as an asset to the forester, they can be a source of erosion and sedimentation of water resources which have a negative effect on the aquatic biodiversity and water quality. Further, forest roads use valuable forest land which could be used for timber production. Therefore, a well-planned road network contributes towards optimising road construction and spacing, reducing construction and maintenance costs and minimising negative impacts on both water quality and biodiversity.

In short, the surfaces of roads are the main source of sedimentation of water courses in the forest plantation environment. The impact of sedimentation on rivers can be reduced through proper design, construction, and regular road maintenance.

Forest roads disrupt the hydrological cycle and alter the natural water movement processes. The following are effects associated with forest road construction:

- Soil is loosened and exposed.
- Infiltration is reduced.
- Subsurface flow is interrupted and converted to overland flow.
- Overland flow is concentrated and accelerated.

These effects become more pronounced as the terrain becomes steeper.

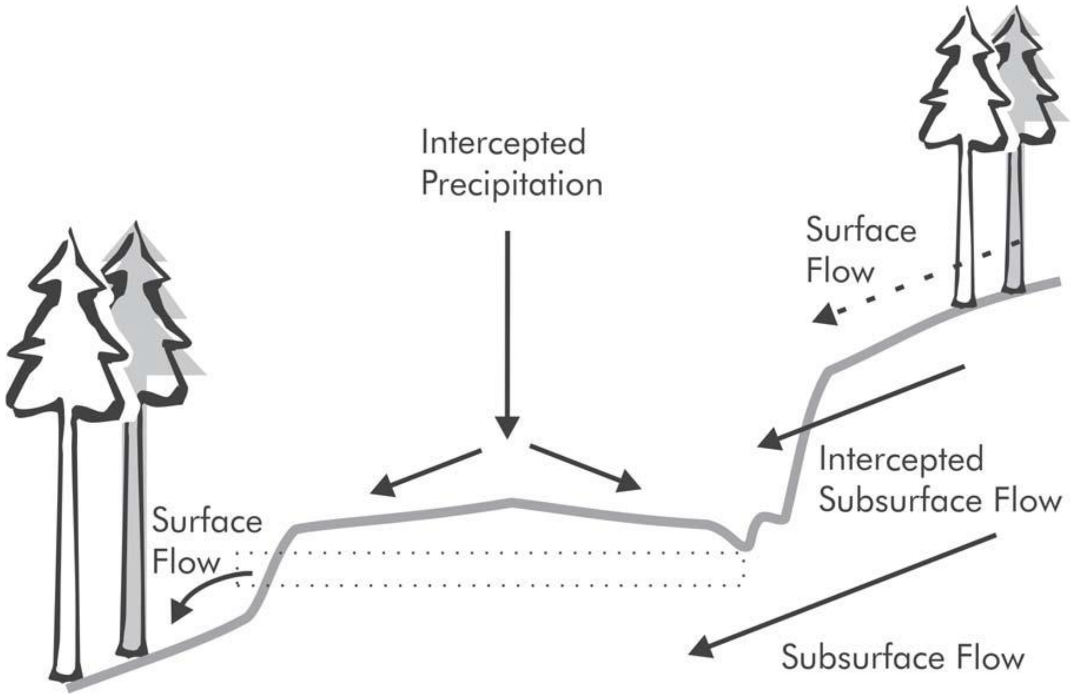

Figure 8: The effect of forest roads on surface and subsurface flow.[10]

A properly engineered, constructed, and managed road system is an essential component of a sustainably managed forest. A common challenge for the forest manager is determining the appropriate level of roading – how much, when, and where.

Planning an optimised road network and harvest system can produce a lower road density when compared with harvesting operations without a comprehensive road plan. The appropriate road density for a particular area will depend upon the type of forest, cost of road construction and maintenance, extraction methods and other factors.

A plantation with a high road density requires a large investment. Such a network is typically associated with close road spacing and reduced primary transport costs. Conversely, a plantation with a low road density requires less investment, but typically requires longer primary transport distances and associated higher harvesting costs.[10]

Generally, roads should be accessible and in good condition. For safety and quick response times during fires, dead end plantation roads should, as far as possible, be avoided. All dead ends should be marked as such. Gradients should not exceed 8°. If they do, possible erosion should be prevented by correct road contours, drainage systems and road camber. Water from a road should not drain directly into a stream as siltation will result but should go through at least 10m of natural vegetation. The construction and upgrade of crossings should ensure stream flow as well as preventing prevent bank scouring. Delineation as specified for wetlands, water bodies and watercourses apply to roads as well. All roads should be monitored regularly.

An environmental impact assessment (EIA) may be required prior to the construction of a new road, the major upgrading of existing roads, and for gravel pits.

Quarries and gravel pits could have the following environmental and safety risks:

- Erosion in and around the gravel pit.
- Safety risk in that people and animals could fall into the gravel pit. High quarry faces must either be fenced off or terraced.

Gravel pits should not be situated in water courses, wetlands, or flood plains.

Depots and loading points should be managed as follows:

- Maintained for easy access.
- Timber should be stacked safely – not higher than 3m.
- Depots should be free of debris and litter.
- Old, disused depots should be maintained and be free of weeds and other invasive plants.

6. References

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Take note that references 1, 2, 3, 5, 8 and 10 can be downloaded from the website of the Institute for Commercial Forestry Research (ICFR); https://www.icfr.ukzn.ac.za/publications/