CUTTING PRINCIPLES

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CONTENTS:

1. Review of the physical basis of the forces involved in cutting and bucking

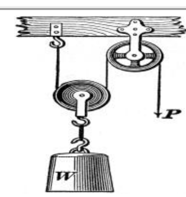
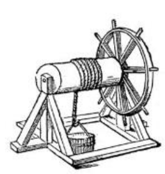
Here with the experience of teaching lesson and observing different kinds of students, I found it necessary that before dealing with the correct method of cutting trees, first of all, the readers should regain familiarity with the physical basis of the forces. Here in this part, while describing and drawing the proper shapes for these forces in the trees, the possibility of understanding and analyzing forces and understanding how trees are cut, especially when using wedges and winches and choosing the depth of undercut in different situations.

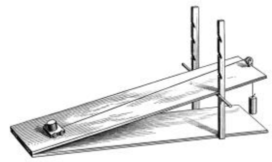
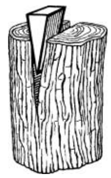
In general, mechanics can be defined as a science that predicts and describes the conditions of immovability or motion of the things affected by forces. This science is divided in to three parts: solid mechanics (rigid bodies), deformable body mechanics and fluid mechanics.

In this topic, we assume that objects like tree, wedge, winch and cables are absolutely rigid, but the reality is that these objects are not completely rigid in their physical sense and they are actually deformed by the pressures applied on them, but these deformations are usually so small that they do not have a remarkable effect on equilibrium conditions or motion of these objects. So, with a little bit of neglect, all the topics discussed in this book will be about solid mechanics.

The mechanics of rigid bodies are divided in to two parts: Statics and Dynamics. The first one dealing with motionless objects, and the latter one deals with moving objects and the most discussed in this topic is Static.

There are six types of simple machines and most complex of machines are made up with the combination of these six which are: lever, pulley, wheels and axes inclined planes, wedge and screw.

	**lever:** A lever is made up of effort and resistance arms and can change the size and direction of the force.
pulley: The pulley along with the rope or cable can change the direction of the force.	
	**Wheels and axles:** A wheel and axles can help in changing the size of the force.

Inclined planes: The Inclined planes help in lifting heavy objects.	
	**Wedge:** A wedge can transform small forces into larger forces and thereby facilitate physical work.
Screw: A screw can penetrate an object or connect two objects together by changing the direction of the force	

1.1. Vector and scalar quantities

The basic concepts used in mechanics are: space, time, mass and force. The concept of space is related to the notion of a point like (P). The location of (P) can be defined by three lengths that are measured from a references point or source in three distinct directions. These lengths are called point coordinates (P).

The concept of mass is used to identify and compare objects based on fundamental mechanical experiments. For example, two objects with equal masses are attracted in to the earth and resist to a change in movement in a same way. Force represents the effect that an object places on another object. Force can be applied through direct contact or like gravitational and magnetic forces by remote action. All the topics of this discussion in cutting and cross cutting of trees are related to direct contact forces.

With the help of the point of effect, the magnitude and direction of the forces are indicated and they are shown by a vector.

In physics, concepts with magnitude but without direction and point of application are called scalar quantities and concepts with magnitude, direction and point of application are called vector quantities. Scalar concepts such as mass, time and vector concepts are such as force and weight. Space, time and mass are three concepts in Newtonian mechanics that are absolute and independent, but the concept of force is not independent of the other three concepts.

1.2. Weight

The gravity force affected to a rigid body from the earth is called weight of the object and is represented by a single force W.

$W = mg$ equation [1]

Where W is the object weight (N), m is the mass of the object (kg) and g is the gravitational acceleration of the earth. This force is also known as gravity force ($g=9.8\ m/s^2$)

$F = ma$ equation [2]

According to equation [2], force is equal to mass multiplied by acceleration. Therefore, when calculating the weight of an object, gravity acceleration can be used so the gravitational force on a mass of one kilogram is 9.8 N

1.3. Center of gravity

A force is known by the point of effect. In the mechanics of solids, each object is known to be a until of its total particle, and it can be assumed that any force applying any particle of an object is such the set of force is applied to a particle representing the object. When these force are considered as the force of weight, the center of the representative of an object which may not even be a real particle and only be a place in space around the object, is called center of gravity. In other words, the center of gravity of an object is the point of mass balance in the object and to determine its location, different methods can be used, and perhaps the simplest of them is the following:

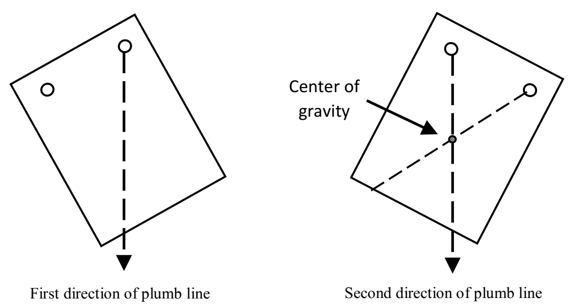
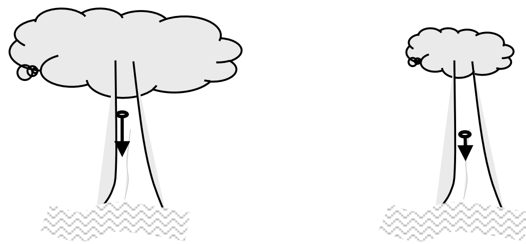


Fig1. Recognizing the center of gravity in a 2 dimensional body

If a flat object such as a paper or book is intended, it is possible to use two corners and if a 3D object such as box or chair is intended, it is possible to use three corners to hang them in turn and specify the direction of plumb line. The intersection of the direction of plumb line shows the center of gravity. Sometimes the center of gravity of objects that do not have a geometric and symmetrical shape are not in the body itself and maybe outside of it. The geometric objects center of gravity is within the body itself. For calculations of vectors, arms and forces, the center of gravity is the criterion of action. The center of gravity of an object that weighs on one side, is closer to the heavier part.

In the case of trees and the method of calculating their center of gravity it must be said that, first, it is impossible to accurately calculate it, and secondly, in many cases, this center of gravity locates outside of trees body. In estimating the trees center of gravity we should have a good guess about the weight of its parts, then, according to the weight and distance of each of the sections, their determinants contribution is determined at the center of gravity.

In case of weight share, for example, the greater the weight of the crown of a tree, the center of gravity is naturally higher and is closer to the crown.

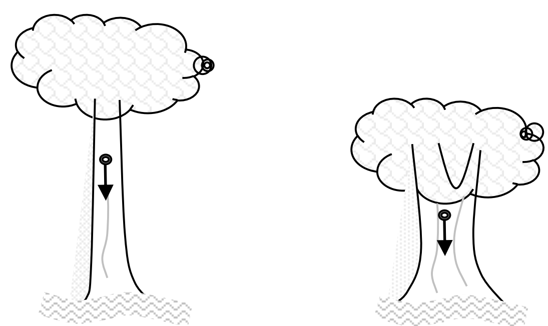


A **B**

Fig2. The center of gravity in two trees with the same trunks and different crowns in terms of weight, has a different height; A) Heavy crown and high center of gravity, B) Light crown and low center of gravity

In case of distance, as the crown of a tree is at a higher height, the center of gravity will be higher from the ground.

In the cutoff operation, having a good guess at the center of gravity of the tree is necessary to calculate and estimate the forces applying from the tree.



A B

Fig3. The center of gravity in two trees with different heights and same weight for trunk and crown; A) High crown and high center of gravity, B) Low crown and lower center of gravity

1.4. Fulcrum

The loads loaded onto a structure, such as a column, tower, or tree, are distributed to its components and then transmitted by the fulcrum (or its fulcrums) to the ground, Therefore, the main task of the fulcrums is to withstand load loaded from the structure. Fulcrums also maintain the stability of structure and secure its free movements in the area. Thus, knowing the function of a fulcrum is of great value for maintaining balance and stability of structures. It should be noted that before the operation of cutting, the place of fulcrum in cutting section is the whole tree trunk with healthy fiber without any rottenness. Therefore, the surfaces of the trunk section, which have rotten fibers, although they appear to be the trunk, are not, in principle, the fulcrum of the tree and its standing factor. After the start of cutting, with every cutting fiber, the amount of support area is reduced and at last as the undercut and back cut ends, the remainder of the fiber at its hinge wood will be consider as the tree fulcrum. Never will this area be cut off by chainsaw operator, because it will release the body (tree) and disrupt all forces. In other words, the tree will fall out of our hands.

The fulcrum in the tree, though is a fiber set with a width of about 0.1 of tree diameter and stepping elevation (hinge wood) but it is assumed to be in the form of a hinged support as a line in the calculation. It should be noted that fulcrums have different types such as: spherical, corrugated, pins and hinges.

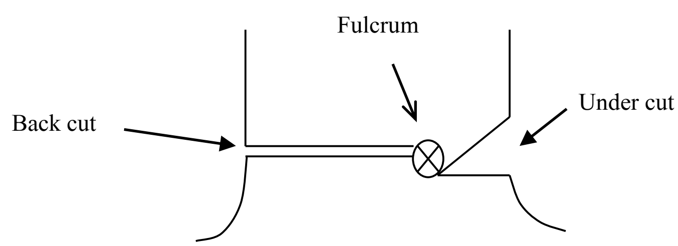


Fig4. Display the tree support after the necessary cuttings in the cut operation

Balance: balance is a situation in which an object does not move from its place if it is not applied with a force from outside. A balanced body is a body that stays in place without a maintainer and without any force input from the outside.

The condition of the balance of an object is the placement of its center of gravity in the place of the fulcrum or its fulcrums. Assume a seat, if this seat has three or four pillars (fulcrum) and is located alongside its center of gravity, this chair is balanced and will remain in its place. Now assume that this chair has lost two of its legs, and one or two more remains for it; what happens then? Obviously its extension of center of gravity is not in the fulcrum, and as a result the chair moves out of balance and fell.

This is a bit different for trees, because there are holder factors in trees. The fibers that are attached to each other in the body and the roots of the trees are a factor in keeping the tree intact and preventing it from falling out of its center of gravity from the stump, Now, if the tree cutting operation is continued, the retaining fibers are cut off; if the tree's line of direction of center of gravity extends beyond the stump, the tree will fall and if the tree's line of direction of center of gravity is located at the stump area, then after the cutting of all trunk fibers the tree is still in balance and will stand (Fig 5).

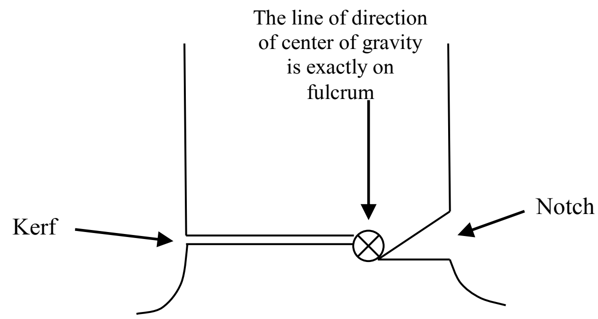


Fig5. The balance of a cut tree (the line of direction of center of gravity is exactly along the hinges)

Of course, this state of balance will not last long, because the brief flow of air will force the outer forces into the tree and move it. The fall of this tree occurs when the line of direction of center of gravity moves from the fulcrum to undercut.

In the operation of cutting trees, which is carried out by undercut and back cut, its hinge wood area remains as the attaching hinge. This means the tree is not that much free that it can move in any direction, and not so much taken by the retainer as before, which it cannot move.

In this case, a back cut and undercut tree can be rotated around its hinge support. Here, as long as the line of direction of center of gravity is located before the fulcrum and on the side of the back cut, the tree is balanced and will stand in its place. This situation may be with the natural balance of the tree (Fig 5), or the tree may stand on two fulcrums, hinge wood and wedge (Fig 6).

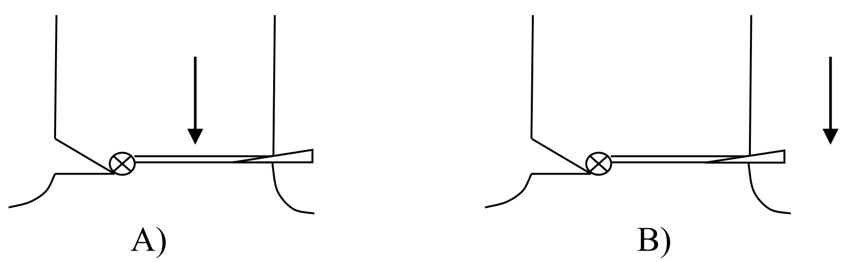


Fig6. The balance of the cut tree on the hinge wood and wedge; A) The line of direction of the center of gravity in the stump, B) The line of direction of the center of gravity outside the stump

In Figure 6, the hinge wood is an attached support and as seen in section (B), although the center of gravity is beyond the wedge support, the hinge wood support prevents falling as it is still attached. Now for the tree to fall to the desired position, the direction in which the notch is located, it is enough to cross the wedge and open the kerf, increasing the treeی sleaning while line of direction of the center of gravity passes through the hinge wood support.
A remarkable point in this issue is the height of the center of gravity. The higher the center of gravity of the object and the taller the height of the tree for a wedge entry and a certain degree of opening of the back cut kerf, the shift of the center of gravity will take place more quickly. As it can be seen in Fig 7:

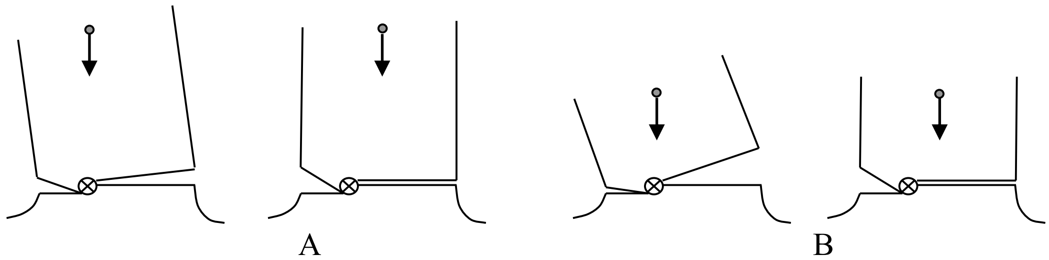


Fig7. Taller tree falls faster; A) A tall tree with a high center of gravity, B) a short tree with a low center of gravity

As it can be seen in Figure 7; A, which has a higher center of gravity than section B, a less leaning is required to reach the line of direction of center of gravity to the hinge wood support and falling of tree. In other words, in Fig. A, which is taller and therefor a higher center of gravity, by opening the kerf, the line of direction of center of gravity passes the support more quickly, and the tree will fall faster.

1.5. Forces and torque

In order to fully identify a force, we should know the magnitude, the point of effect, line of direction and direction. The contact type force (discussed in this book), which affects the mutual area between two objects, actually spreads on that area. In cases where the dimensions of the contact surface can be neglected in comparison with other dimensions of the body, this force can be considered as a concentrated force. For example, the force from the wedge to the floor and the ceiling of the back cut kerf, although not exactly at one point, is at the whole area of the wedge, but in this section, the bodies are rigid and the point of effect is also concentrated and assumed to be a point. In fact, there is no concentrated force in the exact sense, but for the ease of computation, concentrated force is considered where this transformation does not cause a significant change in the body's stability conditions. The magnitude of the force is determined by comparing it with another known force; for example, to measure a force, changing the length of a scaled linear spring can be used. The line of direction of a force is a straight line that passes through the point of effect and the force wants to move the body along that line. The direction of a force is the hypothetical movement of an object in which the force is applied. Each force is characterized by its magnitude and line of direction. The unit of measurement of magnitude of a force or force magnitude is Newton and the line of direction of the force is determined by the direction of force and its extension line.

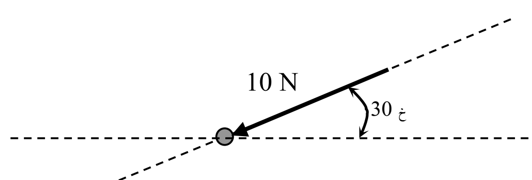


Fig8. Point of effect, line of direction, magnitude and direction of the force

A Newton is, by definition, the force that, if it affects a kilogram, it will accelerate one meter per second squared. The magnitude of the force is represented by a segment and with a suitable scale on the line of action, and the length of this segment can be chosen to represent the magnitude of force. The force direction can also be displayed with the tip of the arrow.

In classical mechanics, the property of a force should be taken into account in the manner described by Newton's Third Law. The action of a force is always accompanied by a reaction that is equal to it and acts in the opposite direction. The issue of which of these two forces should be taken into consideration is vital. In order to avoid any mistakes, it is better to assume that the object is separated from the surrounding environment. In this case, the effect of the environment on the body is easily detected by the reaction forces. That is, it is necessary to calculate and estimate the forces in the tree, the remainder of the trunk at the hinge wood, Wedge friction with back cut kerf, Influence of minor winds, minor contact of the tree crown with the crown of other trees, etc., are entirely ineffective. Although they have a minor impact, and they need to be considered in cases where the impact is no little.

The torque of a force relative to a point is the amount of force multiplied by the vertical distance of the point along the force. In other words, the factor affecting the movement of an object around a single axis is called the torque of force, and it is equal to the multiplication of force at its distance from the axis of which an object rotates around. This distance is called the force arm or effort arm.

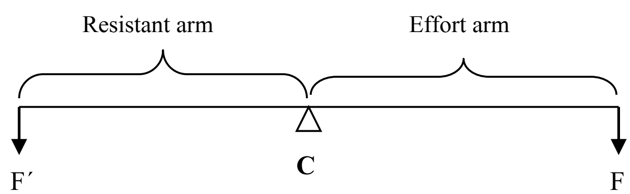


Fig9. Display of the effort arm in the torque

In Figure 9, if C is a support, the length of the effort and resistance arm is equal and the two forces F and F' are acting as effort and resistant force, the torque of these two forces is equal and the lever remains in equilibrium. Now, if one of these forces is not perpendicular to the axis of its lever, the effective arm of this force is the length of the vertical line that comes from the support on the direction of the force. This arm is shown in Figure 10.

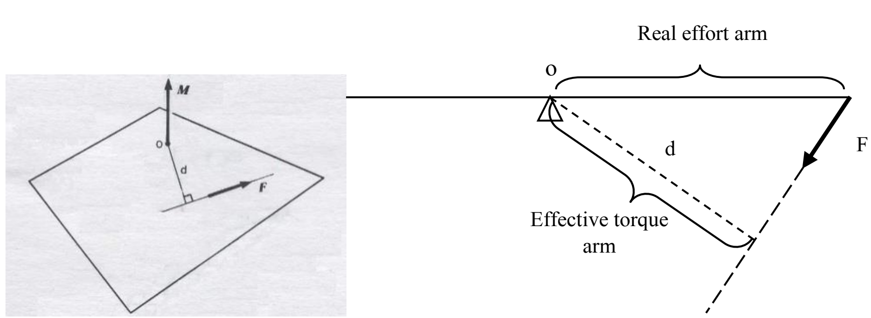


Fig10. The display of the effective torque arm when the direction of force is not perpendicular to the real effort arm

If the direction of force is perpendicular to the effort arm, the length of the effort arm is from the point of effect of the force to the support, and that force and arm are the same force and arm of the effort.

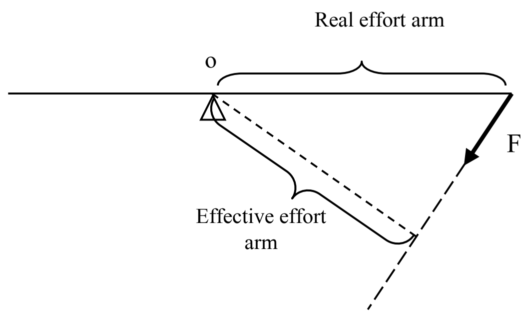


Fig11. The length of the effective effort arm when the direction of force is not perpendicular to the real effort arm

If the direction of force is not perpendicular to the real effort arm, the length of the effective effort arm is equal to the vertical line applied from the support to the line of direction of the force. Therefore, the length of the effective effort arm is shorter than the real effort arm. So the first use of this is that all the pressure on the lever arm should be perpendicular to the lever, otherwise, the value of the effective effort arm (d) will be less than the effort arm of the lever and the efficiency of the device decreases. This torque calculation method, known as algebraic method, is often useful for two-dimensional problems, but for trees that are three-dimensional objects, it's also possible with a little neglect. To do this, we will consider a surface that matches the direction of leaning of the tree, and we consider all other forces in it. An effective factor in moving a body around a support is the torque associated with that support.

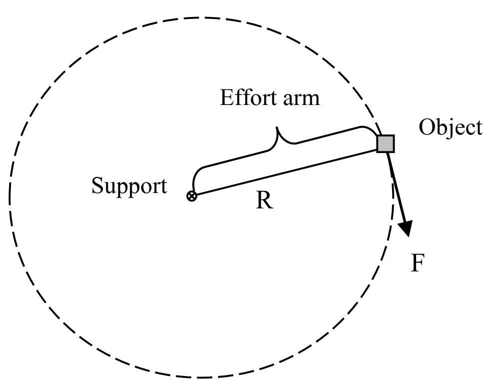


Fig12. The object rotates around the support, and in fact the radius of this circle is the effort arm

For example, if there are two arm (2m) on both sides of a see saw and its forces on both sides are 20 kg, then this see saw is in equilibrium condition. If the forces are not equal on two sides, it will naturally overcome and move on to the side of the larger force. Here, we have to change the place of the support in order to stay in balance. By doing this, we have changed the length of the arms, in this way one of the arms is the effort arm and the other arm is the resistant arm. The effort arm is an arm with move factor on it, and the resistant arm is an arm that provides resistance to movement. For example, in a plier or pincer, the part where the force applies (from the hand to the support) is the effort arm and from the support to the tip is the resistant arm.

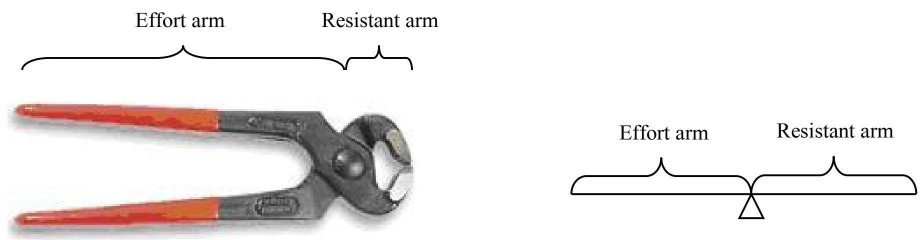
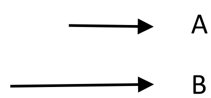


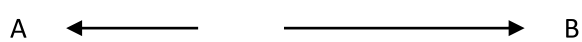
Fig13. Display of the effort and resistant arms in a see saw and a pincer

1.6. Relations between vectors

The vector A and B are same direction and not in the same line of direction, and the vector B is larger than the vector A.



In the latter case, the vector A and B are in the same line of direction and not in the same direction.



In statics we always deal with force systems. A force system is a number of forces that are applied to a target object or set. Given the fact that the forces of a system are all located on one plane or not, they are called a flat (two-dimensional) force system or (three-dimensional) spatial force system. Although the force system in trees is three dimensional, however, to simplify the calculations, the tree tends to fit into a plane and all the forces are examined on this plane and so our calculations will be based on a two-dimensional force system. In previous discussions, it was pointed out that force is a vector quantity. The rules of combining forces are the same rules as of combining vectors, and in this section, various operations, such as addition, subtraction and resolving on vectors are examined. The resultant forces are, by definition, the force that results from the performance of different forces of a system and alone has the overall effect of that system.

Empirical evidences show that the two forces P and Q affecting a particle can be converted into a single force (R), which has the same effect on it, and is called the resultant of forces P, Q (Fig 14).

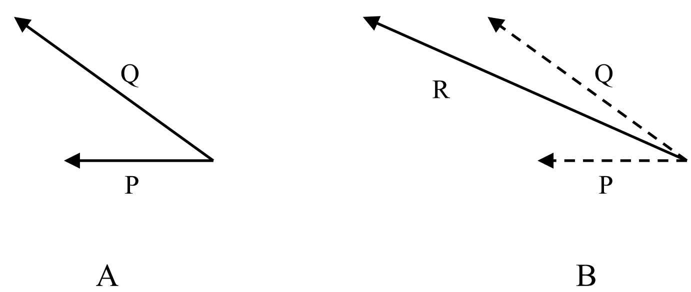


Fig14. A) Showing P and Q forces; B) Showing the resultant of these two forces, which is equivalent to their effect, and replaces them

There are several methods to determine the resultant of the forces but here we only show in a parallelogram method:

If vectors P and Q are assumed to be two adjacent sides of a parallelogram, the resultant of these two vectors is equal to the diagonal of the parallelogram, which passes through the intersection of the vectors.

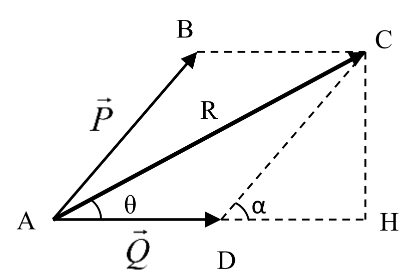


Fig15. Displays the sum of two vectors in a parallelogram

In figure 15 assume that two vectors P and Q passing from one point, are determinate, meaning the magnitude and direction of each of the two vectors and the angles between them (α) are given. We want to define the resultant vector R (magnitude) and θ (direction) of it. To calculate the value R (AC length) and angle θ, extend the AD side to intercept the perpendicular from C. Now you can write the following equations:

$AB = DC = P$ $\quad$ $BC = AD = Q$

$DH = DC\cos(\alpha) = P\cos(\alpha)$ $\quad$ $CH = DC\sin(\alpha) = P\sin(\alpha)$

$AH = AD + DH = Q + P\cos(\alpha)$ $\quad$ $AC^2 = AH^2 + CH^2$

$R^2 = [Q + P\cos(\alpha)]^2 + [P\sin(\alpha)]^2 = P^2 + Q^2 + 2PQ\cos(\alpha)$

$R = [P^2 + Q^2 + 2PQ\cos(\alpha)]^{1/2}$ [3]

$\tan(\theta) = CH / AH = P\sin(\alpha) / Q + P\cos(\alpha)$ [4]

Equation [3] yields the resultant vector (addition) and from equation [4] the direction of the resultant vector is obtained. Of course, instead of solving the above equations, the problem can be solved graphically. For this purpose, first we plot the parallelogram with the appropriate scale, then measure the diameter of the AC with the ruler and measure the angle of the AC diameter with the AD side, ie, θ with the protractor.

The vectors are also subtracted by reversing their direction (That is, multiplied by -1) and then the addition of the new vectors is calculated. Addition of different vectors can also be calculated by repeatedly forming a parallelogram method and obtaining intermediate vectors.

Vectors can also be resolved. There are three modes for resolving a vector into its components, in the case of cutting trees, only resolving of a vector into its components in two orthogonal axes will be investigated and used. Here, resolving action can be taken as the opposite of resultant action. That is, each single force F that acts on an object can be converted into two or more forces that (together) put the same effect on that object. These forces are called components of the main force F, and the process of replacing these components instead of F is called resolving. In other words, the resultant can be sum of two or more vectors (components) if they pass from one point. Consider the two orthogonal axes x and y of the force vector F, as shown in Figure 16.

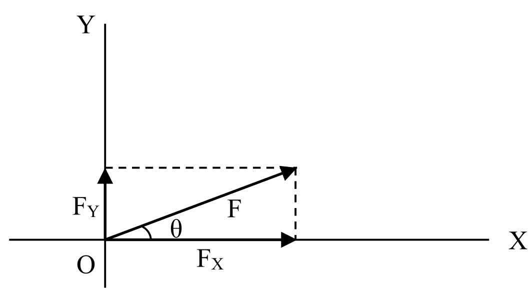


Fig16. The components of x and y in the vector F

If a parallelogram (in this case a rectangle) is considered with its diagonal as the force F, then the adjacent sides of the diameter (along x and y), respectively, are called force components in the x and y directions and they are shown with $\vec{F}_x$ and $\vec{F}_y$. Thus, the size of the x component of force F, is the size of the image of that force on the x-axis and the size of the y component of force F, is the size of it on the y-axis; meaning:

$F_x = F\cos(\theta)$, $F_y = F\sin(\theta)$

Obviously, in this case, the sum of the two vectors of the component x and y will be equal to the primary force:

$$\vec{F}_x + \vec{F}_y = \vec{F}$$

To understand the resolving of forces, consider the example below in which the ball, due to their weight, gains an active force on an inclined plane. In Figure 17, if a body with mass (m) and weight (W = mg) on an inclined plane that forms an angle of α with horizon, slips downward due to its weight; the force of the (mg) can be resolved into two components.

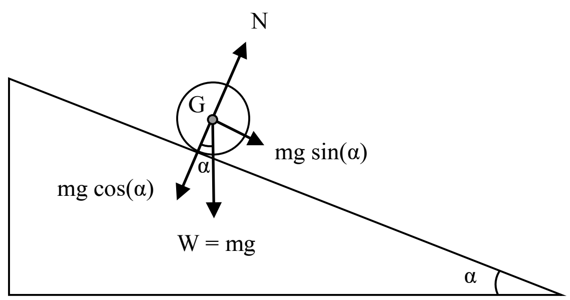


Fig17. Displays the resolve of forces and determine the magnitude and direction of the ball's active force

In Fig 17, the component mg cos(α), which is perpendicular to the slope, is neutralized by the third law of Newton with the surface response force (N) applied to the object and equivalent to the force of mg cos(α). Mg sin(α) causes the ball to move on the inclined plane, and if friction is negligible, it is the only force that accelerates the object and is the basis for calculating the ball's momentum. It is obvious that each force F can be resolved in to infinite category of components, and for this purpose there are different methods depending on whether the magnitudes and direction of the components are known or not, thus, in the topic of this book, in the operation of cutting trees, resolving the forces only in to two components is in use with the parallelogram law and the line of direction of one of the components is always known and is the direction of the fulcrum. Figure 18 illustrates the force of the tree's gravity and the line of direction of the fulcrum as one of the components needed to resolve the force.

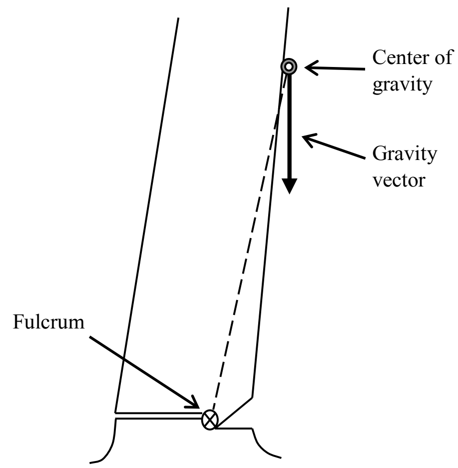


Fig18. The vector of gravity of the tree and its direction along with the line of direction of gravity (arrow direction) and the fulcrum

It was pointed out that in the topic of cutting trees, we will use the resolve of a vector into its components in two orthogonal axes, so it is natural that the second direction for the resolving is to be oriented in a vertical direction to the line of direction of fulcrum. Now the magnitude and direction of the components are obtained using the parallelogram law and drawing of lines from the center of gravity along with the line of forces. In order to fully understand this, a practical example of the weight force of a leaned tree and the way of resolving to obtain the momentum force is brought:

Consider a tree with a height of 30 meters and a total weight of 4 tons that has a leaning of 5 degrees and a gravity elevation of 16 meters. We want to get the tree's leaning force to fall.

Note: In order to calculate the forces in a tree, considering that the exact magnitude of the forces is not considered, it is their general calculation, and then judgment about the depth of the undercut or the calculation of using winch is considered, therefore, in many cases, issues are followed by neglect. For example, when we say that the tree's leaning is 5 degrees, that the leaning is from the center of the tree trunk, or that it differs slightly from the support, or when forces are spoken, usually in physics forces are calculated to Newton, but here are mass units such as Kilograms, Tones and so on.

Here we can calculate this force using two methods (computed by means of formulas or by graph solution). For the graphical method, it can be used to plot the general state of the tree, showing its 5-degree leaning and the center of gravity. Then, we plot the weight force vector from the center of gravity to the appropriate scale. For example, a 4 cm length segment, representing a force of 4 tons, can be drawn along the direction of plumb line. The two orthogonal line of directions in the force resolve are the line of center of gravity to the support and its perpendicular along the tree's leaning direction (Fig 19).

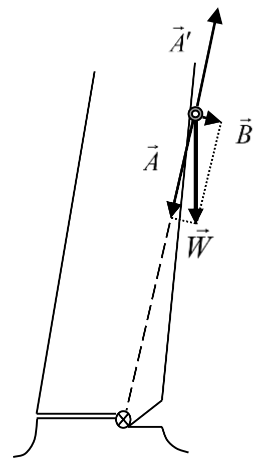


Fig19. Resolving the tree's gravity force

Subsequently, with the parallelogram method, the tree weight vector (W) can be resolved into two components perpendicular to each other. The size of the component A is the weight force that is applied into the fulcrum and, in accordance with Newton's third law, the force is equivalent to and in the reverse direction ($\vec{A}'$) to neutralize it. The next component that is displayed with the vector (B) shows the size and direction of the force that created the tree's leaning. The length of this vector can be measured by a ruler, and given the scale of 4 cm to 4 tons weight vector, the force vector (B) also can be calculated.

1.7. Levers

The levers are divided into three sets of type I, II and III, depending on the position of the fulcrum in them. Lever is the simplest machine. The levers are able to change the size and direction of the force while transferring it. In the application of levers, recognizing their types and paying attention to the importance of the fulcrum point and the length of the effort and resistant arms are the basic principles. Each lever has a resistant arm, a fulcrum and an effort arm and depending on the combination of these components, many types of levers are formed.

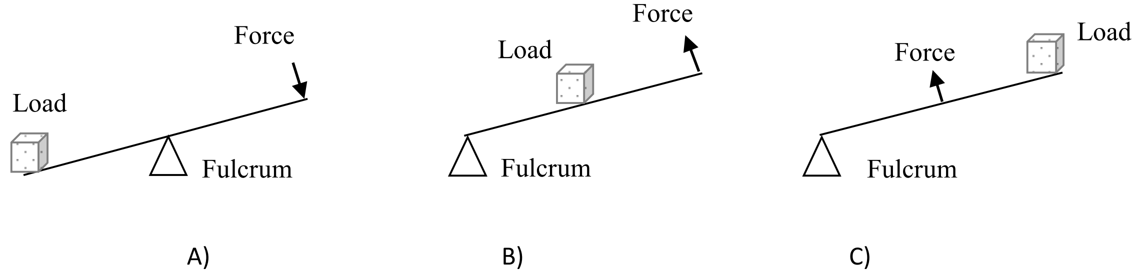


Fig20. Types of levers; (A) Type I; (B) Type II; (C) Type III

In all levers, the distance from the effort force to the fulcrum, is called the effort arm and the distance between the loads to fulcrum is called the resistant arm. In the levers, the result of the multiplication of the effort force with the effort arm is the effort force torque and the result of the multiplication of the resistant force over the resistant arm's length is the torque of the resistant force relative to the support. And if the lever is in equilibrium, the torque of the resistant force is equal to the torque of the effort force.

Choosing the location of the fulcrum in the levers will cause changes in the length of the arms and determining the mechanical advantage of the machine, In simple terms, it determines the amount of output of a machine; As the support is closer to the resistant force, the ratio of the length of the resistant arm to the effort arm is smaller and the output force of the device is larger with a smaller displacement size. Therefore, if it is necessary to apply more force into an object, we need to reduce the distance between the fulcrum to the target object.

Fig21. The lever A applies more force than B

In the forest utilization, knowing the levers is very helpful so that:

- In the operation of cutting trees, knowing the levers helps to calculate the pressure on the tree. It is also impossible to detect the proper depth of undercut without knowing the principles of the levers.

- In the process of cross cutting, detecting forces in the logs, compression zone, tension area and detecting movements after cutting, is almost impossible without recognizing the levers.

- In wood transportation operations, knowing the principles of the levers help to do more work and save time and reduce costs and possible accidents.

- While the logs are stick in the forest, whether the tree is involved or for the skidding logs, knowing the principles of the levers and applying them correctly is very helpful.

The following describes the types of levers and how to use them in the forest.

1.7.1. Single and double levers of the first class

In the first-class levers, the fulcrum is located between the effort and the resistant forces. Figure 22 shows the single and double leverage of the first class.

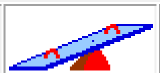
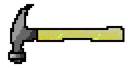
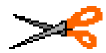
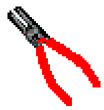
a single class 1 lever		Seesaw
a single class 1 lever		Hammer's claws
double class 1 levers		Scissors
double class 1 levers		Pliers

Fig22. Single and double levers of the first class

The purpose of using first-class levers depending on the location of support can be to increase the force or increase the momentum. A seesaw is a single class 1 lever. If two levers are connected to each other (in fulcrum location), a double lever is created. Pliers, scissors, pincers and ... are examples of double levers of the first class. As you can see in the scissors, if the device requires a big output force, the ratio of the effort arm to the resistant arm should increases. For example, iron-cutting scissors have a taller lever and a shorter blade than tailoring scissors. A single lever of the first class is effective in translocating the logs in the forest. Especially when the logs need to be raised before moving (Fig 21), such as when the log is stuck in place.

1.7.2. Single and double levers of the second class

On levers of the second class, the support is located on one side and the resistant force is located between the effort force and fulcrum. Figure 23 shows the single and double levers of the second class. The purpose of using second class levers is only to increase the force.

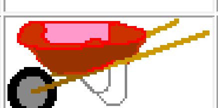
a single class 2 lever		Stapler
a single class 2 lever		Bottle opener
a single class 2 lever		Wheelbarrow
double class 2 levers		Nut cracker

Fig23. Single and double levers of the second class

In the single lever of the second class, because it is not necessary to provide a place for the fulcrum, in comparison with the first class levers that requires a high ground, it is easy to leverage the lever on the ground and use it as a fulcrum and so this type of leverage is most used among people. And it's also used in the forest. The peavey is a single lever of the second class and the nutcracker is a double lever of the second class.

1.7.3. Single and double levers of the third class

On levers of the third class, fulcrum, as in the levers of the second class, is on one side, but here the effort force is between the resistant force and the fulcrum. Figure 24 shows the single and double levers of the third class. The purpose of using levers of the third class is not to increase the force, but in these levers the force is reduced and instead the displacement increases. The ice tongs on the dining table and the charcoal tong are double-levers of the third class and the sappie and the billhook are a single lever of the third class.

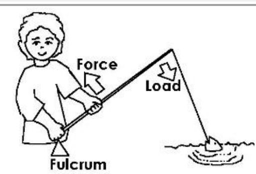
a single class 3 lever		Fishing rod
double class 3 levers		Tweezers
double class 3 levers		Tongs
double class 3 levers		Nail clippers

Fig24. Single and double levers of the third class

Of course, in a nail clipper, there is a combination of two levers of the second and third class, in the form that the handle is a single lever of the second class and the nail clipper is the double lever of the third class.

1.8. Efficiency and mechanical advantage

A machine in which friction does not exist and its output is equal to its input, is called an ideal machine. In a real machine, friction forces always do some work, and the output of the work is smaller than the input. The mechanical efficiency of each machine is defined by the following ratio:

$\eta = output / Input$

It is obvious that the mechanical efficiency of an ideal machine is equal to $\eta=1$, because in this case the output and input work are equal, while the mechanical efficiency of the real machine is always smaller. In case of cutting and cross cutting of trees, the machine is assumed to be an ideal and we will ignore frictions.

Mechanical Advantage: If the force applied on a machine is called the effort force and the force that machine applies to overcome resistance or move a body is called the resistant force, then we have:

Mechanical Advantage= Resistant Force / Effort Force

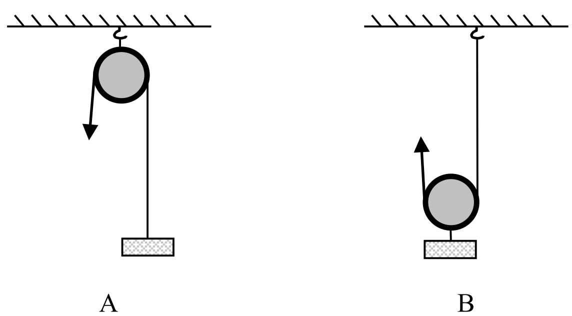


Fig25. A) Machine with mechanical advantage 1, B) Machine with mechanical advantage 2

If, with the assumption of negligible friction, the weight of 2,500 N, with a force of 500 N, rises from an inclined plane (Fig 26), the mechanical advantage of this machine will be 5.

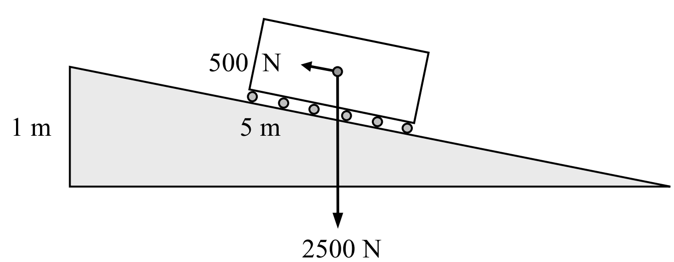


Fig26. Showing the mechanical advantage of the inclined plane

The mechanical advantage of each inclined plane is the result of dividing the length of the inclined plane along its height. This relationship can be explained in a right triangle, as in Figure 26:

Mechanical advantage of an inclined plane = hypotenuse Length / front leg

The mechanical advantage of each lever is equal to the ratio of the length of the effort arm to the length of its resistant arm. In a pliers if the handle is 20 cm and the opening is 5 cm, its mechanical advantage is 4, that is, 4 times the force we apply. Gardening scissors have taller handles and smaller openings than tailoring scissors, so they have a greater mechanical advantage and more cutting power and less cutting distance. By choosing the short or long arm for the levers, their mechanical advantage varies. The mechanical advantage of the pulley (Fig 25 A) is 1, because it moves as much as it stretches out.

The mechanical advantage of the double pulley is 2. In this device, the displacement is half the pulling, meaning the resistance distance is half the moving distance.

1.9. Work

Consider a rigid body on a horizontal surface. If the horizontal force $\vec{F}$ is applied to the object so that the body is displaced as amount of $\vec{d}$, then, by definition, the work done by this force is:

$$W = f \times d$$

It should be noted that in the above example force and displacement are in the same direction and according to the principle, the work is done positively. On the other hand, the work done is a numerical or scalar quantity, the unit of which is the unit of force multiplied by the unit of distance, which is, a torque force. In other words, the work is equal to the result of the force multiplied to the amount of displacement of the point of force effect in the direction in which the force affects.

In the SI, the units display the work are Newton meter (Nm), Kilo Newton meters (KN.m) or Joules (J). A joule is, by definition, the work of the force of a Newton when its point of effect is displaced by a meter along with the direction of the force. A joule is a Newton-meter and the practical unit is kg-m (Kgm). One kilogram meter is equal to the work of a kilogram of force at a distance of one meter, since one kilogram of force is about 8.9 Newton so:

$$1\ Kgm = 9.8\ J$$

In the work done by the weight force, it should be noted that the amount of work done is independent of the direction of motion of the body, and only depends on the height of the points at the beginning and the end of the movement. In other words, the body weight does not work when the bodyیِ center of gravity is moved horizontally and we can say that the weight W is equal to the result of W multiplied by the vertical displacement of the center of gravity of the body. Therefore, it should be noted that the amount of work that is done when a tree falls is equal to the displacement of the vertical axis of the center of gravity of tree, multiplied to its weight, not the length that the center of gravity moves. Also, the amount of the work done by winch or Wedge is as much as center of gravity vertical displacement when we want to turn an inclined leaning tree to its right position.

Work is a scalar quantity, meaning, it has a magnitude and a signal, but not direction.

1.10. Wedge

Wedge is a simple tool for transferring large forces and is often used to convert a relatively small force into a much larger force, approximately perpendicular to the initial force. A wedge is used for small displacements of very heavy objects, which is done in the operation of cutting and cross cutting and tilting them in a direction other than the tree's leaning, by moving and opening the back cut kerf.

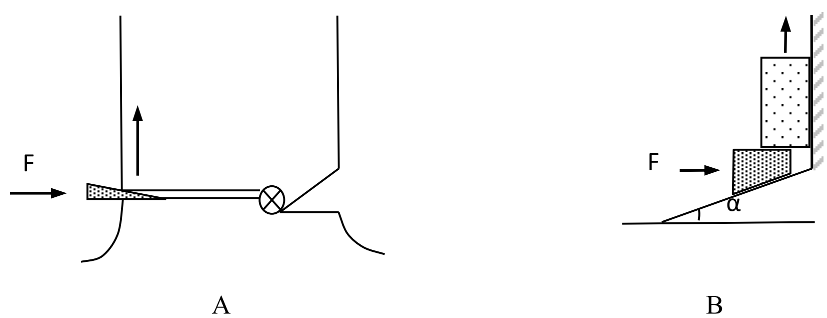


Fig27. Wedge display; A) Opening the tree cutting kerf, B) Raising a heavy weight

In the calculation of force applied by the wedge, the wedge weight is assumed to be negligible, but its friction cannot be ignored. The friction coefficient of the known surface with the wedge must be specified and entered into the calculation.

The wedges will remain in place and keep the heavy body in the same place, if they have a sufficient friction after moving the heavy body. But if they have a slight friction coefficient, they will lift the heavy object more easily, but they will again come out of their place due to the weight of the object and cause the body to return to its place.

In the case of wedges used in the forest, furrows are inserted on the wedges to ensure that the wedges have sufficient friction, not so much that they are difficult to sink, and not to the extent that they come out of place. The presence of a furrow in the wedges is especially important when the trees are absorbing the water in spring, because at this time the kerf is slippery and the wedge is swallowed. The use of wedge in cross cutting is mainly to prevent the kerf closure and the sticking of the blade and the chain of chainsaw, which in this case no work is done by the wedge and itِsnot under compression. The use of a wedge in the operation of cutting is along with a lot of work and with the strike of sledgehammer, the kerf will be open. In this operation, the wedge should not come out again. The wedge turns the strikes of sledgehammer into a very large force of about 30 tons and opens the cutting kerf.

In forest utilization, sometimes wedges are used to split wood, in which case the wedges are beaten along the length of the fiber (longitudinal stroke) and with the help of the sledgehammer and split bolts of short length (max 1m).

2. Correct methods in felling trees

In this topic, with regard to the successive tasks mentioned for felling the trees, such as finding, determining the falling direction, etc., and using the physical principles of the forces involved in the cutting operation, the details of how the cutting steps are performed for each of the states are given. It is reiterated that the cutting of each tree involves all the steps mentioned above, and, as stated below, deleting some of the steps is not meant to eliminate that stage, it means not having a new and different point to discuss about. For example, cutting the inactive buttresses is one of the common stages in all cases that could be eliminated.

2.1. Balanced trees

A balanced tree has a symmetry crown with its stretching line along the vertical direction. So that the tree's line of center of gravity is located in the stump. In these trees there is no tension in any direction. When we cut such trees, after the undercut and back cut, they will sit back on the back cut area because of disinclination. Therefore, in such trees, the use of wedge is necessary. Sometimes the blow of wind is used to fell a tree which is not acceptable.

The steps of cutting the balanced trees are as followed:

- First we make a normal undercut (1:4 tree diameter). Note that in these trees, low deep undercut (1:5 tree diameter) increases the wedging and deep undercut (1:3 tree diameter) increases the waste wood.

- In the next step, the operation of back cut and wedging are operated and the tree will fall in the desired direction (perpendicular to the hinge axis). Here, back cut and wedging will vary slightly depending on the diameter of the tree in such a way that:

- In small diameter trees (less than 40 centimeters) wedging and back cut interferes in a way that the wedge will collide with the chainsaw blade. Therefore, it is necessary to use the following technique:

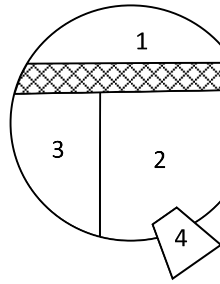


Fig28. Back cut and wedging in small diameter trees

In Figure 28 it can be seen that after undercut (1), a part of the back cut (2) is cut off. At this stage, due to the remnant of the back cut region (4), the tree cannot sit back and catch the chainsaw blade. Afterwards, we place the wedge (3) and proceed to cut the remainder of the back cut area (4). With this method, while cutting off the entire area of the back cut and doing the wedging, neither tree will sit back on the chainsaw blade nor wedge will collide with blade and chain. In the last step, the same wedge and, if necessary, auxiliary wedges, are hammered to fall the tree to the desired position.

- If the tree is thick, the back cut area will be so large that it will be possible to place the wedge without colliding with the chain before completing the back cut operation and subsiding of tree on the chainsaw blade.

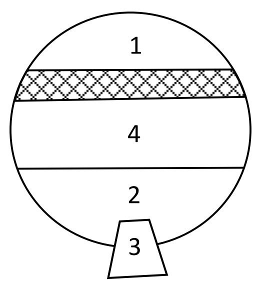


Fig29. Back cut and wedging in thick trees

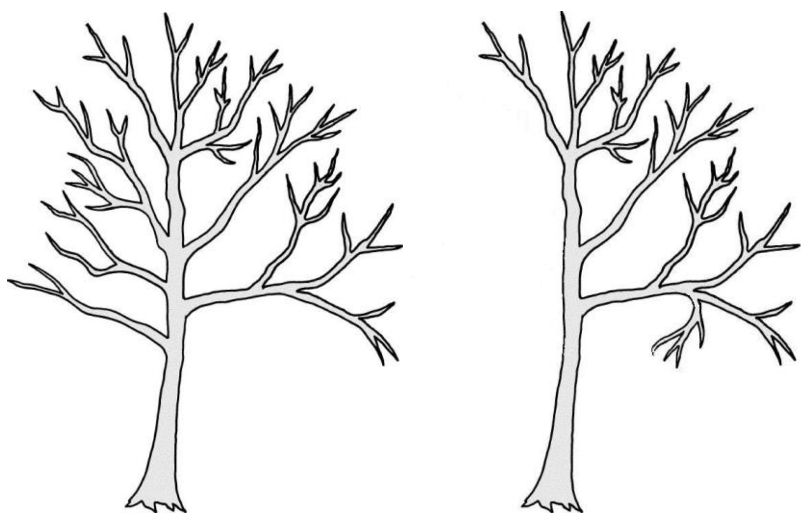
As can be seen in Fig 29, in thick balanced trees back cut operation and wedge placing can be done together. In this way, after making some back cut (2) and creating space for wedging without collision with the chainsaw blade, the wedging takes place (3), and then the back cut operation continues to the end (4). Eventually, after pulling the chainsaw out of the back cut kerf, same wedge or auxiliary wedges are hammered so that the tree falls to the desired position.

2.2. Low leaning trees

If the tree appears to be symmetric, but the branches and are unilateral, the tree has a hidden tendency and the line of center of gravity lies outside the stump (but not too much).

If the wind is mild, the tree tends to be on the side, but here's a problem; if a mild wind is drawn and the tree is pulled to that side, because the forces on which it applied are not equal, the tree will vacillate. Uniformity of forces makes work dangerous.

The trees with low leaning are the trees that, due to the tendency of the trunk or the crown asymmetry, have a slight tendency to one side, so that if no direction is taken into account and their entire cross-sectional area is cut, they slowly fall in their leaning. Low leaning means the center of gravity is out of the stump to a small amount (up to 1 meter). Sometimes the leaning angle of two trees is the same, but the extension of the crown causes a low or high tendency in the particular trees (Fig 30).



(A (B

Fig30. Two trees with same leaning angles; A) Low leaning, B) High leaning because of the crown

Low leaning trees can be fell down with the help of wedges in any desired direction. Depending on the other conditions considered to fell the trees such as sound logs, the stand, etc., we first decide to choose the direction and then to fall it in desired direction, using the special way as follows.

2.2.1. Felling the low leaning trees in the leaning direction

The simplest and fastest operation in cutting down the trees is to cut down the trees with low leaning in their leaning direction. In this operation there is no need for wedge or any other pulling tools and we just need to cut the buttresses. (Except the back buttresses that are holding the tree). In other words, we cut the neutral buttress and the buttress that are under tension and compression are not cut. Then a normal under cut and then a quick back cut will be done. At this time, the tree will slowly fall in the leaning direction.

A normal back cut is done because the line of center of gravity of this tree is located outside the stump and with the deepening of the undercut, the distance from the line of center of gravity to the fulcrum (the hinge axis) increases. This increase strengthens the tree's falling effort arm and exerts further compression on the treeِ sholding strap (back cut area). So, in back cut operation when the tensional and tree holding straps are cutting down, it is unlikely that the fibers give up and the trunk splits. Specially when the back cut operation is done slowly.

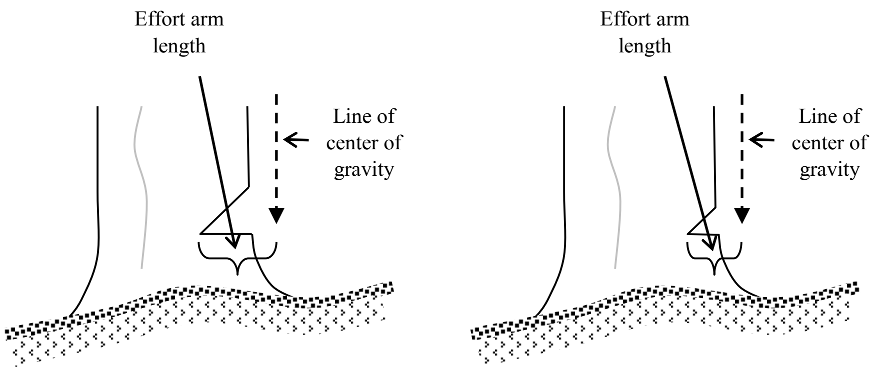


Fig31. Selecting a deep undercut increases the length of the tree effort arm

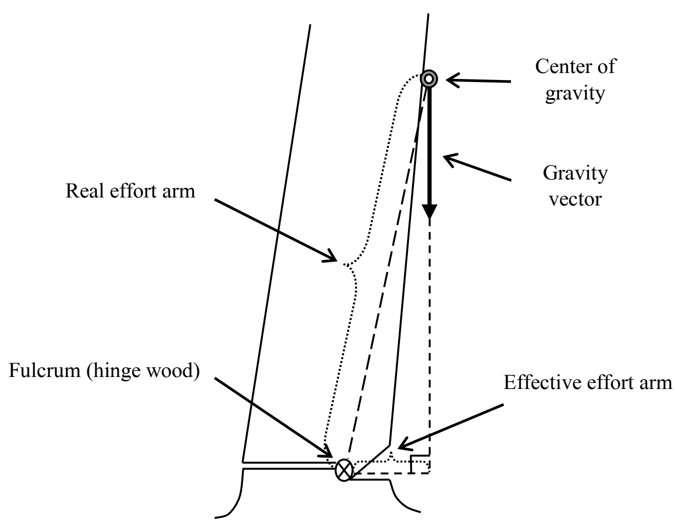


Fig32. Effective effort arm in leaning trees

Reminder: The real effort arm in these trees is from the center of gravity to the fulcrum; however, as already mentioned, when the direction of the force is not perpendicular to the real effort arm, the effective effort arm is the vertical distance from the fulcrum to the line of direction of the force (Fig 32).

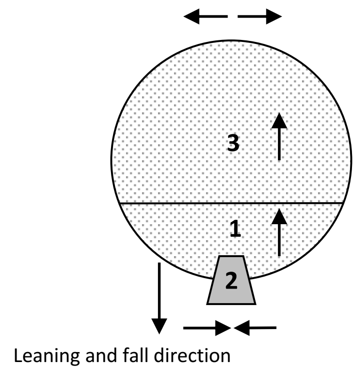


Fig33. Falling a tree with a low leaning to leaning direction without under cut

In another way for cutting these trees, under cut can be ignored and this is the only exception that the tree felling operation is done without undercut; in such a way that it is cut from the back cut area, and before sticking the blade, we put the wedge in the kerf and then cut it to the end. In this way the tree falls to its leaning direction. It is not necessary to keep the hinge axis in this way, because the treeِبs leaning and fall direction are the same.

2.2.2. Felling trees with a low leaning in the side direction of leaning

Trees can be fall down with or without a wedge in the side direction of leaning. If we want to fall the tree without using a wedge, we can do this with up to 30 degrees with the help of the hinge wood. The cutting of buttress in this case will include all the buttresses those in the hinge wood are. Then we have to have a deep under cut and a non-parallel hinge wood. Here, as noted above, falling direction of tree is perpendicular to bisector of two sides of the hinge wood.

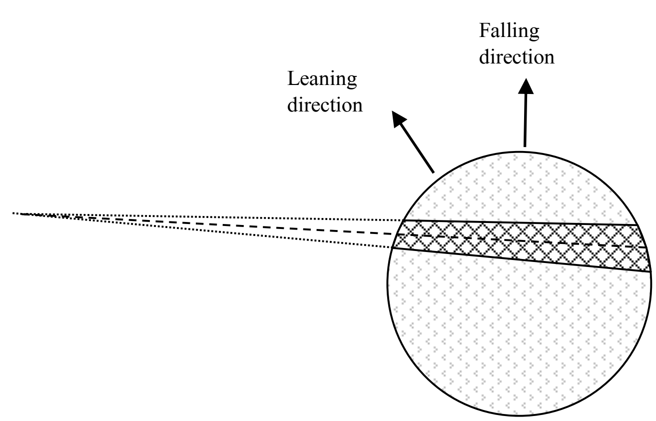


Fig34. Falling the tree in the side direction of leaning with the help hinge wood

When we do a deep undercut, the length of the hinge wood increases, and eventually we will have a stronger hinge. This hinge will have enough power to pull the tree in the side direction, but when we use a wedge, this will be possible mainly by the wedge.

In this case, first do a deep under cut, and then we make a clockwise or counterclockwise back cut using bumper spike to a limit so that the hinge wood remains as shown in Figure 34. At that time, the tree slowly begins to move and fall with its leaning force, and its created hinge wood, causing the tree to be pulled and guided towards the fall direction (desired direction).

In such trees, using a wedge of up to 50 degrees, a tree can be pushed in the lateral felling direction, so that, while doing a undercut and regarding the hinge wood like before, wedges are also used to direct the tree to the desired direction.

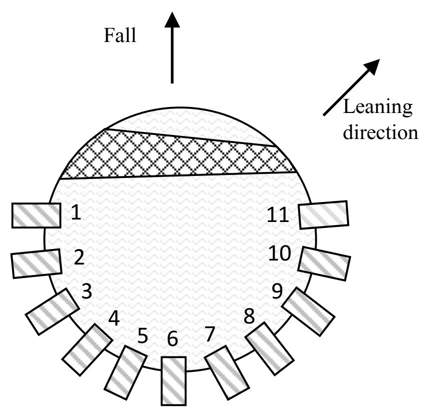


Fig35. Using wedge for Felling trees with light leaning in side of leaning direction

Wedges No. 1 and 11 are in the worst possible position, because they are very close to the hinge wood, and the operation of these wedges and the opening of the kerf means pulling out the hinge wood fibers; So, first, they cannot fall into the kerf due to the resistant of the hinge wood fibers, and secondly, their function is not to help the desired goal. Wedges 2, 3, and 4 are also not in suitable locations because their performance is in the leaning direction and intensifying the leaning of the tree and our attempts for felling the tree in side of leaning direction will be neutralized.

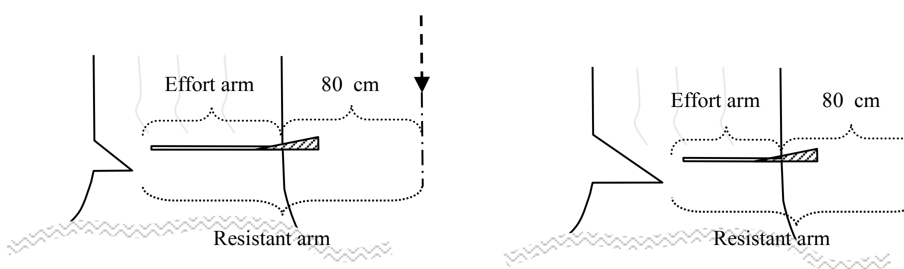
Choosing the best place for wedging is that, after determining the direction of leaning and felling of the tree, the wedge should be placed in a position where the resultant of the force of the wedge and the leaning force of the tree are in direction of fall. In this case, the wedges of No 8 and 9 will have such a place and therefore they will be our main wedges. Remember the vectorﯼ resultant methods and figures 14 and 15 to determine the location of the wedges. Here, the force of the wedge must be applied in a direction where the resultant of the force of the wedge and the leaning force of the tree are in direction of felling.

Sometimes we need auxiliary wedges to strengthen the main wedge, so first we have to identify the position of the best wedge and then place the wedges on the sides. In the example, wedges No. 7 and 10 can be used as auxiliary wedges.

In this example, after doing the undercut and back cut, due to the large angle of the hinge wood and the hinge axis according to the leaning, the tree will not move from its place. Here we begin to wedging. If the wedges number 8 and 9 are enough, we continue to use the two of them and if they are not enough, then wedges 7 and 10 can also help and we continue wedging until the tree fell in the desired direction. It is absolutely wrong to cut off some of the hinge wood to ease the falling of a tree. In this case, the leaning force of the tree will overcome its weakened hinge wood, it will be taken off from its place and fell in its leaning. Of course, if the width of the hinge wood is more than 0.1 of the diameter of the tree, itبsobviously high and will prevent that work from happening.

2.2.3. Felling trees with light leaning in opposite of leaning direction

There are two ways in which the trunk is suitable for wedging or not. If the trunk is suitable to be wedged, by using a wedge we can fall a tree with low leaning to the opposite direction. Here, as the depth of the undercut is increases, the ratio of the effort arm to the resistant arm becomes smaller and the wedging work becomes more difficult. As shown in Fig 4-5-9, the increase in the depth of the undercut shortens both the effort and resistant arms. But this shortening is more likely to happen for the effort arm and it will make wedging worse.



A B

Fig36. Deep under cut for felling the trees in their opposite leaning direction, make wedging harder; A) low deep undercut B) deep undercut

In Figure 36 assume that in a tree with a diameter of one meter in a cut section that has a low leaning, the line of direction of the center of gravity is in its distance of 80 cm. if the felling direction is opposite of the leaning, then the notch will be chosen according to the figure. Now, suppose in a) we select a deep undercut (1/3 of the diameter of the stump) with a depth of 33 centimeters. The hinge wood width here is 0.1 of the tree diameter, 10 cm, and therefore the back cut depth will be 100 ت33 ت10 = 57 cm. The length of the effort arm is from the wedging place at the beginning of the back cut to the middle of the hinge wood, and the length of the resistant arm extends along the line of direction of the treeبscenter of gravity to the middle of the hinge wood. In this case we will have:

Length of the effort arm: 57 + 5 − 62 cm

Length of the resistant arm: 80 + 62 − 142 cm

Now assume that the weight of the tree is 10 tons and we want to overcome this force with the wedging and open the kerf. To do this, it is necessary to achieve the equality point of the effort torque according to the resistant torque which is:

Resistant force × resistant arm = effort force × effort arm

We will have:

10000 kg × 1.42 m − effort force × 0.62

Effort force − 22903 kg

That is, if 22903 kg of force is applied from the wedge, the effort force is equal to the resistant force and if the effort force exceeds this, the tree will move.

Now, look at Section A) this issue (Figure 37). In this case, we select a low deep undercut (1:5 stump diameter) with a depth of 20 centimeters. If other assumptions are like the previous one, we will have:

Length of the effort arm − 75 cm

Length of the resistant arm − 155 cm

Therefore, we will have:

10000 kg × 1.55 m − effort force × 0.75

Effort force − 20667 kg

In this case, if 20667 kg of force is applied from the wedge, the effort and resistant forces will be equal and if the effort force exceeds, the tree will move.

As you can see, in this example, the selection of a small undercut depth causes less force from the wedge, and in other words, wedging will be simpler.

At the end of this discussion, it should be noted that the resistant arm is not always from the line of direction of center of gravity to the fulcrum. Occasionally, this distance may be the effort arm, and this depends on the fact that the tree's weight in the discussed issue is a moving factor or a resistant factor. In the case that a tree falls in the opposite of its leaning direction, the line of direction of the center of gravity to the fulcrum is the resistant arm and in the cases in which the tree falls in its leaning direction the distance of line of direction of the center of gravity to the fulcrum is the effort arm.

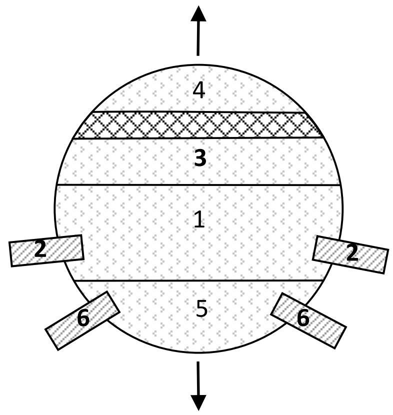


Fig37. Using bore cut to fell trees with a low leaning in the opposite of leaning direction

Another method for cutting these trees when wedging is not possible at the end of back cut is using bore cut (Figure 37). In this case, first a bore cut (1), then wedging from the sides (2), a back cut for setting the hinge wood (3), then a low deep undercut (4) and finally finishing the back cut (5) and extra wedging (6) until the tree falls. The setting of hinge wood (3) is due to the fact that during bore cut, we did not cut as it is required along the hinge wood side. When we place number 2 wedges, the tree cannot sit back by cutting off part 3, and this way the hinge wood width can be adjusted.

The second mode in low leaning trees is that their trunks are not suitable for wedging. This condition may be due to the small diameter of the trunk or the rotten fibers in the wedging position. In this case, pulling devices such as winches, motor winches, or machines such as tractors and skidders are used. Cutting a tree in this state is described in the description of the use of winch.

2.3. Trees with heavy leaning

A tree with a heavy leaning is a tree in which the tree's leaning is clearly seen in its appearance. In these trees, the line of direction of center of gravity is located more than one meter outside the treeِsstump (Fig. 38). These trees can also be felled with the help of techniques and equipment in any direction. Below is an outline of these issues.

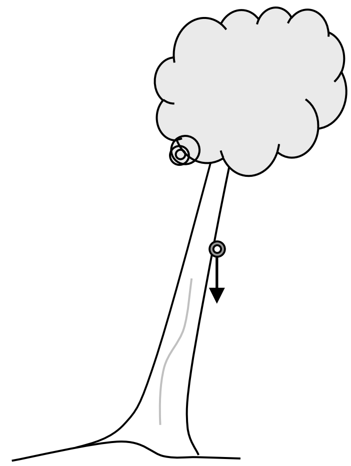


Fig38. Tree with heavy leaning

2.3.1. Felling trees with heavy leaning in leaning direction

In this case, the center of gravity is far from the tree and itـِsthe most sensitive type in the felling of trees. Mostly trees with heavy leaning are fell in their direction of leaning because changing it requires a lot of time and money, and it needs economic rationalization.

In this case, the treeـِsfiber is under heavy tension and compression. When the center of gravity is close to the tree, the effort arm is short and the tension wood fibers are under less tension. But when the center of gravity is far from the tree, the effort arm is taller and the fibers will be under heavy tensions. In this case, if we begin to back cut in the usual way, in the middle of the work the remaining fibers will not resist, and the tree will split, and it will kick back dangerously. This is named as barber chair (Fig 39). With this mistake, there is also the risk of the death of chainsaw operator.

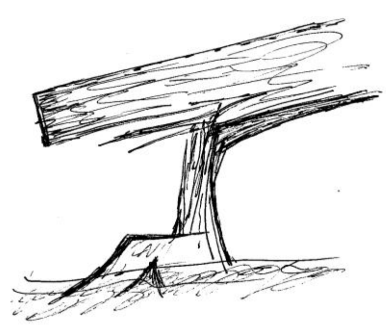


Fig39. False cutting in a tree with a heavy leaning and trunk splitting

So for such trees, cuts must be done with caution and using bore cut.

The method of cutting trees with a heavy leaning in their leaning direction is as follows:

At first, the side buttresses will be cut (of course if they exist), and the tension and compression buttresses will remain in the area. A bore cut will be used in the neutral part of the tree trunk fiber. Note that in leaning trees, the fibers of one side of the trunk are under the pressure and heavy weight of the tree, and the fibers of the opposite side are under tension and prevent the tree from falling (Fig 40).

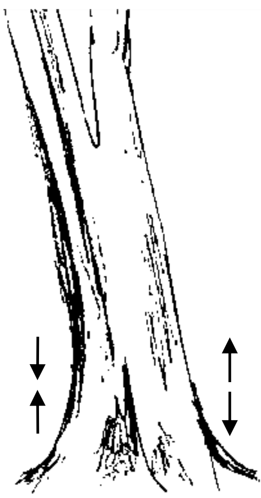


Fig40. The fibers in the leaning direction are under compression, and the fibers in the opposite of the leaning direction are under tension

The area between compression and tension fibers is known as the neutral fiber. Of course, the neutral fibers are neutral and do not have an effect in maintaining the tree, only when the fibers under compression and tension are exist, but as soon as any tension or compression fibers are removed, the neutral zone fibers will have its effect.

However, at the beginning of the work, a bore cut (1) is placed in the neutral area, until the final cut is done, no fibers remain in this neutral area causing resistant and trunk splitting (Fig 41).

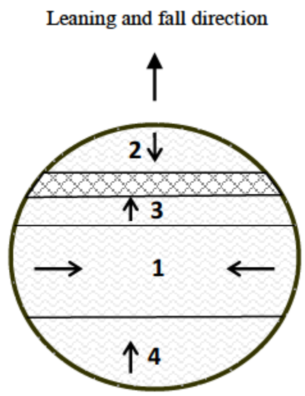


Fig41. Performing the necessary cuts for felling in trees with a heavy leaning in their leaning direction (arrows show cutting direction)

Then a low deep undercut is performed (1: 5 diameter tree) (2), and then hinge wood is set by the bore cut (3). At the last step, a quick back cut will be made (4) and the tree suddenly begins to move from its place and falls. With this method, the trunk is cut off and the tree starts to fall without any damage to the cutting group and the tree itself. What is the reason for choosing a low deep under cut at this stage? Note figure 42.

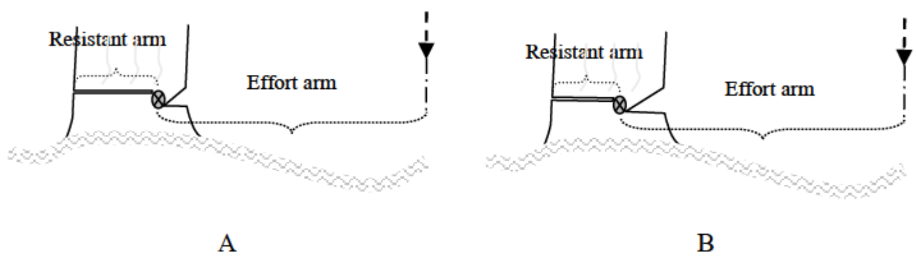


Fig42. Selecting a low deep under cut for felling trees with a heavy leaning in their leaning direction will reduce the compression, tension, risks and consequences.

Suppose we have a tree with a diameter of one meter in the cutting section, with a heavy leaning that places the tree's line of direction of center of gravity outside the buttress at a distance of 2 m. In the case of A), a low deep under cut will be made and, according to its hinge wood width equal to 0.1 stumpبs diameter, the distance and length of the effort and resistant arms will be:

Length of the effort arm: 200 + 20 + 5 – 225 cm

Length of the resistant arm: 100 ت20 ت5 – 75 cm

If the weight of this tree is 10 tons, in order to obtain the minimum necessary resistance in the treeبs holding straps (back cut area fibers) for the tree to stand still, we will have:

Resistant force × resistant arm – effort force × effort arm

Resistant force × 75 – 10000 × 225

Resisting force – 30000 kg

That means that for the tree to stand still, it is necessary to withstand, at least, 30,000 kilograms of force. In the same example, in the "B" status with a deep undercut we will have:

Length of the effort arm: 200 + 33 + 5 – 238 cm

Length of the resisting arm: 100 ت33 ت5 – 62 cm

Resisting force × 62 – 10000 × 238

Resisting force – 38387 kg

As can be seen, in the "B" state, which increased the depth of the undercut, a greater tension will occur on the back cut area, making it harder and more dangerous to back cut. In addition, as the back cut advances and more of the back cut area fiber (resistant) is cut off, the remainder of this area forms the length of the resistant arm and all the forces are cumulatively applied to the remaining fiber. This tension in the advance of back cut is so much that it usually in the middle of back cut operation, the resistant of the fibers end and the trunk will split. Bore cut done at the beginning of work is to prevent such a problem.

In this case, cleaning around the tree and creating an escape route is very serious. In particular, chainsaw operator should never be in the back of the tree, cutting the back cut area, but should always be beside the tree and continue to cut it.

2.3.2. Felling trees with heavy leaning in side of leaning direction

These trees can be fell about 10 degrees without wedging and between 30 to 35 degrees with wedging in side of their leaning direction. The method for these trees is a combination of the method of felling trees with light leaning in opposite of leaning direction and felling trees with heavy leaning in leaning direction. The cutting steps are summarized in Figure 43. The trees can also be fell by pulling tools up to 50 degrees in the side of their leaning direction. This example is described when describing how to use a winch.

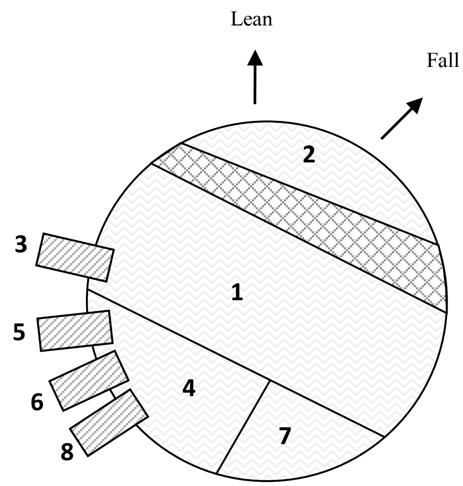


Fig43. Felling a tree with heavy leaning in the opposite of leaning direction with wedging

2.3.3. Felling trees with heavy leaning in opposite of leaning direction

It is not possible to fell these trees without the use of pulling tools.

The most commonly used puller in the forest is winch. The steps involved in cutting and felling these trees have been described when describing the methods of using winch.

2.4. Felling of special trees

Some trees have a different situation with ordinary trees because of their special conditions and it is necessary to consider their circumstances during the cutting operation. For example, rotten, dead, and wind thrown trees are among the things where the cutting operations are somewhat different.

To cut rotten trees, it must be tried that the tree falls to its leaning direction, and if it is necessary to fall it in any other direction but its leaning direction, only the use of pulling tools is effective. In these trees, we do not know the depth, amount and intensity of rottenness, and this is one of the biggest problems. If the size of the rotting or hollow of the trunk is specific and up to a meter high, then we cut off the operation in the normal routine of one meter high, and this is very rare. It should be noted that on height higher than one meter, this work is not allowed.

To cut rotten trees, first we do a low deep under cut, and then do a quick back cut to fell the tree in its leaning direction. Low deep depth under cut is chosen because there is no certain hinge wood, and it is only a place for tree rotation. Deepening of the undercut, due to the lack of knowledge of the rotting spread, may cause the saw to be stuck in the kerf. It is possible that the only healthy and holding straps of the tree are being cut. However, it should be known that felling the rotting trees is very sensitive and usually causes the most difficulty.

Dead trees also have conditions that are often like a rotten tree. The problem of dead trees is the presence of different branches in diameter in the crown of the tree, which is dry and very brittle. So, when cutting these trees, it is very important to observe the safety measures and prevent the shaking and sudden movement of the tree. If a dry tree suddenly moves, the upper part of the tree will be broken and its moving direction will be opposite of its felling direction. This problem appears to be very dangerous in the case of dry, young trees, or kicking it out by untrained workers.

Cutting operations are also of great sensitivity in wind thrown trees, which is discusses in cross cutting section.

2.5. Felling of trees in steep slopes

There is always a general leaning in the trees down the slope, so we are trying to fall them in their leaning direction.

Escaping the cutting team in steep slopes is very important, because on these slopes, the escape route is simply not provided, and it is necessary to prepare this route in place. The worker also needs to have a good base for himself when he wants to begin the cutting operation, sometimes it may be necessary to create a standing place on the ground first.

The choice of falling direction in the slopes is also more limited. The notable issue in felling trees on the slopes is the possibility of their felling and slipping down the slope. If the steep of slope is more than 40%, this is very likely, and the tree can be restrained to prevent it. To cut the trees on steep slopes, inverted undercut can be use (Fig. 44).

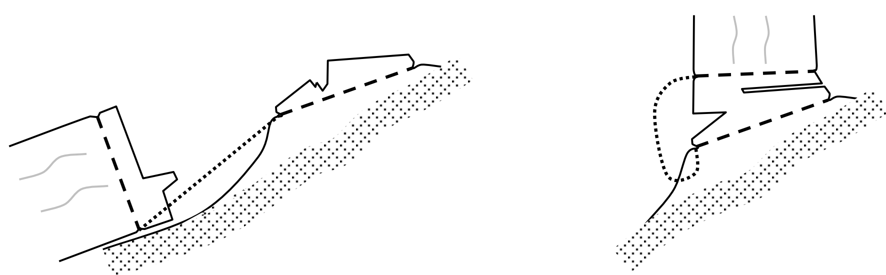


Fig44. Performing the inverted under cut and restraining the trees on the steep slopes

The reason behind the inverted under cut is that in these slopes, there is enough space for the inverted under cut and with this, it is possible to eliminate the effect of back cut cutting at the beginning of the trunk. In other words, we will have less wastage at the beginning of the log.

Also, in order to control the trees in the steep slopes, it is possible to bind the tree trunk to the stump (Fig. 44). By doing this, after felling, the tree will remain in its place by cable or chain restrainers and it won꞉t slip down the steep.

2.6. Release of hang up trees

The hang up tree is said to be a tree that is stuck to other trees after being cut off and it will not lie to the ground. The thicker and heavier the tree is, the less hang up, and the young, same aged, dense stand and longer trees will hang up more. Also the possibility of hanging up in broadleaves with a wide crown is more than conifers. The hang up tree should never be leaved in its situation, and it is absolutely necessary to free the hang up tree and lay it on the ground before leaving the area. Remaining a hang up tree will have a lot of potential dangers for anyone crossing the area.

Procedures that should be avoided when trees are hanged up:

- Cutting down a third tree and felling it on hang up tree.

- Climbing the tree and cutting off the stuck branches.

- Cutting the support tree is to be a very dangerous operation.

- Back cut from the beginning of a cut off and hang up tree.

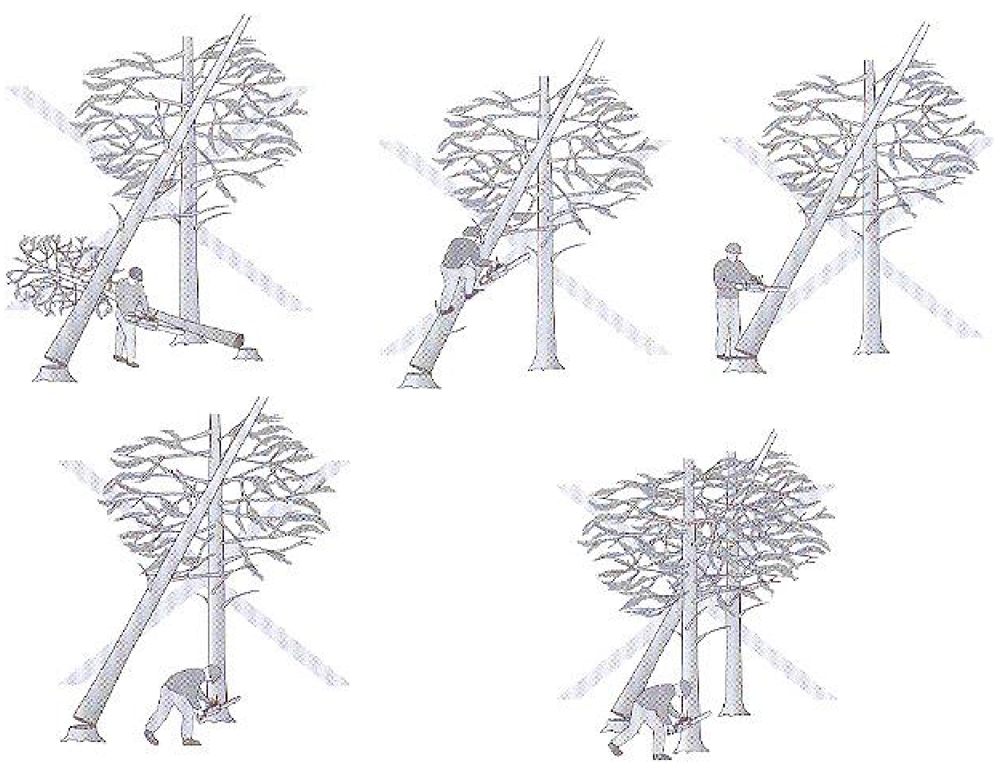


Fig45. Forbidden operations in releasing hang up trees (ILO, 1998)

From the beginning of the hang up tree's trunk, back cut is the most common and fastest operations performed by the chainsaw operators, but it must be avoided for the following reasons:

- The risk of working as the chainsaw places higher than the operatorِs chest.

- Chainsaw catches during cutting.

- The degree of quality of the log decreases due to the fact that the cutting location is often not suitable for grading.

- Increase of wastage because of oblique crosscutting in this situation.

- Risk of falling trunk on chainsaw operator.

- The probability of seesaw and upward moving of the tree, in which case the continuation of releasing work will be extremely dangerous.

Appropriate methods for releasing hang up trees:

First, it is necessary to carefully cut the remaining fibers of the hinge wood so that the trunk is separated from the stump. Note that the fibers of the hinge wood of the tree are pull out (take out) when the tree falls and the notch is closed, but there is still no opportunity here and the fibers of the hinge wood are connected. After the release of the trunk, the following methods can be followed:

- Drag the end of the tree trunk with pulling tools. This method is the best and most reliable way for releasing trees. To do this, we can use the help of motorized or manually winches, or tractors and the skidder, to tie end of the hang up tree and pull it in the opposite of leaning direction. With this method, without exception, all hang up trees are released without any danger (of course the connected hingwood should be cut off at first).

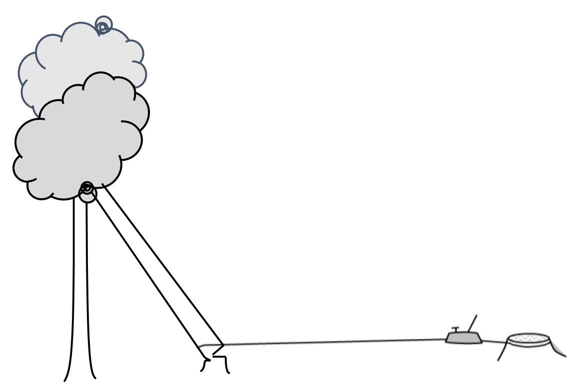


Fig46. Dragging end of the trunk to release the hang up trees

Another way to release the hang up trees is to use the turning hook and to create rotating movements in the hang up tree trunk. This method is suitable for conifers with a diameter of less than 40 centimeters.

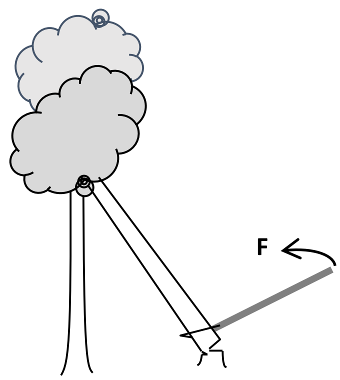


Fig47. Using turning hook in releasing the hang up tree

- Another method for releasing hang up trees is to use first and second class levers, and in particular the first class for the displacement of the trunk. With this method, we can move the end of the trunk in several steps, and move away from the stump in the opposite of the tree's leaning direction. This method is suitable for trees with a diameter of less than 50 cm and can be used for conifers and broadleaves.

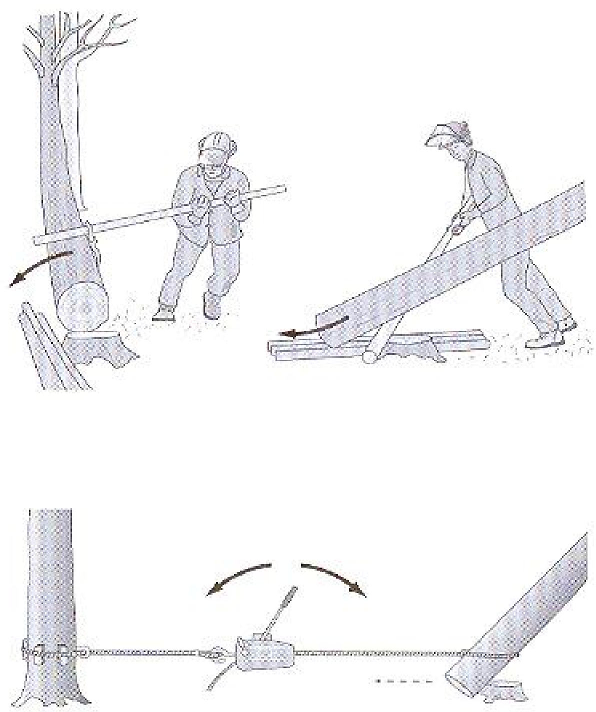


Fig48. Use a lever or winch to release the involved trees (ILO, 1998)

- Finally, as the last method, in the absence of any of the dangers and harms of the cross cut from the beginning of the trunk, this method can be done.

2.7. Using winch

From the experience of the author, about 1 to 2 percent of the operations of cutting the trees require the use of winch. The winch and related accessories are heavy and cannot be and should not be carried during the cutting operations with the cutting team. It is necessary for chainsaw operator to make a note of any of the items required during the cut off operation and, with a special program, carry the winch and its attachments by machines or mule to the areas needed for the cutting operation.

The use of winch is expensive because of the longtime of transportation, setting up and using, and it is only recommended for trees that paying this cost would be beneficial. In order to use the winch, it is necessary first to find a suitable place for setting up. Usually because of the heavy weight of the cable, only 25 meters of it would be enough to carry. It is necessary to use a pulley to choose the location of the winch in order to be safe from felling of a tree. In order to tie the winch, its belt can be restrained to a healthy and strong tree.

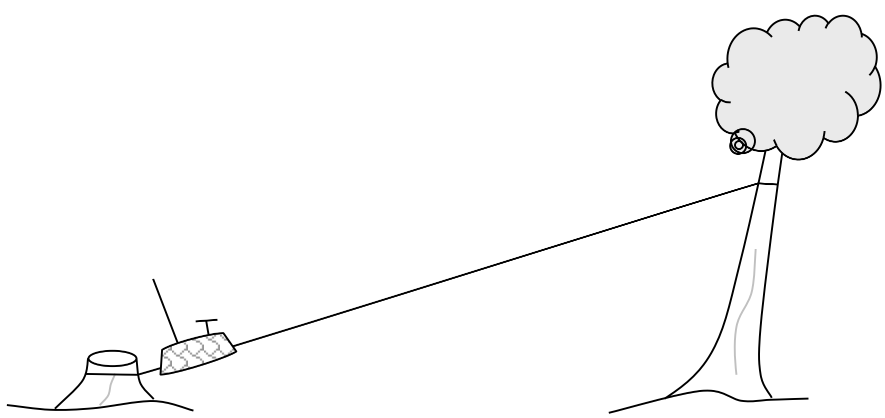


Fig49. Tightening the cable at a higher height makes it easy to pull through the winch.

Similarly, the pulley is tightened to a stump almost in the treeِsleaning direction. Note that if the length of the cable is short and the height of the tree is tall, if the pulley is tightened in the leaning direction of tree, then after the tree is cut and fall, the pulleys and cables will be caught under the tree, Therefore, it is that the pulleyِs tightening position to be different with the falling direction. After preparing the pulley and the winch, cable is attached to the target tree. To do this, it is better to attach the cable to a higher elevation (Fig. 49). Here, according to the rules of the levers, remember that the length of the effort arm will be from the point of effect of the force to the fulcrum, so obviously the higher this point, which is the same as the height of the cable connection to the tree, increases the length of the effort arm and it's easier to overcome the tree's resistance and leaning.

For example, suppose a 5-ton tree has a gravity center that extends 2 meters beyond the tree's stump. If the diameter of this tree is 50 cm, suppose that the cable is attached in two cases: a) 3 meters high; and b) 6 meters high. Calculate in any of the situations, what force is required by the winch to move the tree from its place?

Look at the answer to this in Figure 55:

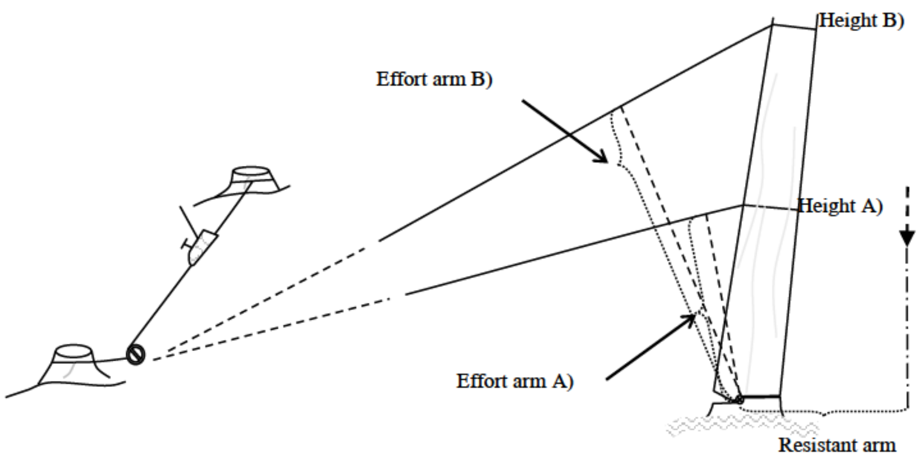


Fig50. The difference in the tension force at the cable attaching height

In this example, the length of the resistant arm is the distance perpendicular from fulcrum to the line of direction of tree's center of gravity. Therefore, if the distance between the fulcrum (the hinge wood) and the beginning of the back cut is 30 cm, the resistant armي s length will be 230 cm. Also, the actual length of the effort arm is from the cableي s attach point to the fulcrum place and the length of the effective effort arm for each of the modes, is the vertical distance from the fulcrum to the line of direction of the tension force. Here, with a little bit of neglect, the length of the effective and real effort arm is considered to be the same. Now, the least required force for each of the situations A and B is:

A) Effort arm = 300 cm
Effort arm × force = Resistant arm × load

Then we will have:

Force = 5000 × 230 / 300 =3833 kg

In this case, it is necessary for the winch to apply a force equal to 3,833 kg, so the forces will be balanced, and then the tree will move through more force from the winch.

B) Force = 5000 × 230 / 600 = 1917 kg

Here, as you can see, doubling the length of the effort arm (the height of the cable tight), the required force is reduced by half; that is, the pulling operation by the winch will be much easier and more reliable.

The problem here is that it is possible to attach the winch cable to higher places in the tree, which is very difficult and sometimes impossible. The cable wire shouldnبtbe shorter than 5 meters height and, if it is not possible, the winch will not work effectively. In order to attach the cable to the tree, it is necessary for one of the experienced workers, using tree climbing equipment, to do this, and it is necessary to have a thin nylon rope with it; when it comes to the desired height, with the help of this rope, he pulls the cable from the ground and then attach it to the tree trunk. The use of a nylon rope is due to the heavy weight of the cable and its disturbance when climbing a tree that may even pose risks to the climber. The following describes each of the modes of using the winch.

2.7.1. Felling of trees in leaning direction using winch

This is absolutely impossible and very dangerous. Occasionally some uninformed people are saying that valuable trees that fell and damaged, can be lay in their leaning direction slowly on the ground using the winch. This method is not only unattainable, it is also very dangerous and will break the cable and the dangers that would follow.

To understand this, suppose we have a tree with a diameter of 60 cm and a height of 30 m and a weight of 4 tones with a center of gravity at a height of 16 meters (Figure 51). If this tree has a leaning that the line of direction of the center of gravity is 2 m out of the stump, and the cable is attached at a height of 6 meters, the condition of forces to lay the tree on the ground is as follows:

In this example, the factor of moving is treeبsgravity and, therefore, the effort arm is the perpendicular direction of the fulcrum to the direction of the gravity. This amount is 2 meters outside the stump, assuming a distance of 20 cm from the undercut to the hinge wood, it will be 220 cm.

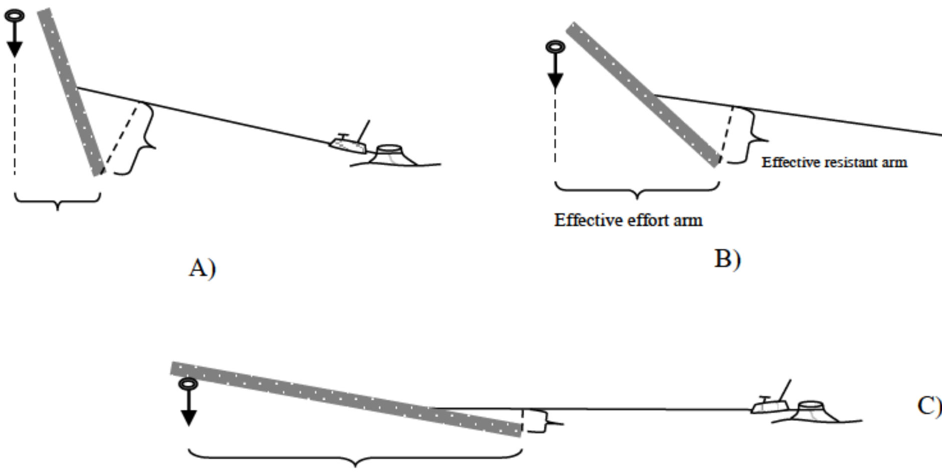


Fig51. The difference in the tension force of the tree on the winch at various angles

Now the resistance force of winch for holding the tree in its current position, after back cut and undercut is the vertical distance from the fulcrum to the winch cable and it will be different depending on the horizontal and vertical distance of winch location against fulcrum and the height of attachment on the trunk. Assuming the height of two points is equal and the distance of 20 m between the winch and fulcrum, the length of the effective arm of the winch is equal to 5.8 meters and we will have:

Resistant force × resistant arm = force × effort arm

Resistant force = 4000 × 220 / 580 = 1517 kg

As can be seen, in this situation, 1517 kg of force is applied into the winch, and if the winch can withstand this, the tree is stable and the releasing operation can be slowly carried out. Now suppose a tree is released to its leaning direction and the angle of leaning increases, so that the line of tree's center of gravity would be in a distance of 4 meters (Fig. 51-A). In this case, the length of the resistant arm is 5.2 meters and the force applied to the winch is:

Resistant force = 4000 × 420 / 520 = 3231 kg

It can be seen that the force applied to the winch has almost been doubled. Now assume that the releasing operation is continued by the winch and according to the condition of Fig. 51-B) the distance from the line of center of gravity to the fulcrum is 8 meters, in this case, the length of the resistant arm is 3.7 m and the applied force on the winch is:

Resistant force = 4000 × 820 / 370 = 8865 kg

As you can see, the force is much increased and a suitable winch with a tonnage of 3 to 5 tons cannot withstand nearly 9 tons. At this stage, there is the probability of breaking the gears or tearing of the cable. Note that this tree still does not lie on the ground and until that stage it is necessary to become so leaned that the center of gravity of the tree reaches the ground. In the form of Figure 51-C) the length of the effort arm reaches 15 meters and the length of the resistant arm is 2 meters, in this case the force on the cables and the winch will be 30400 kg.

A force that neither the cables nor the winch can resist. Meaning it is impossible to lay a 4-ton tree with a height of 30 meters with the help of a winch to its leaning direction on the ground.

Therefore, it is necessary to avoid the felling of trees in their leaning direction with the help of the winch.

2.7.2. Felling of trees in side of leaning direction using winch

By using the winch, trees with a heavy leaning can be fell at any angle in the side of their leaning direction. For this purpose, it is necessary to set up the winch in a direction where the resultant of the forces on the tree (lean and winch) are intended to be in the felling direction; however, it should be noted that the forces that are applied to the tree, should act simultaneously and to the end, because If one of the forces is removed, the tree is drawn to the other force.

It should be noted that the tree's leaning force is applied to it until the end of felling, but the winch force can only be operative at the beginning of pulling, and immediately after the tree starts to move, due to the shortening of the cable's attached distance from the tree to the winch, the cable is loosened and no other tensile force from the winch is on the tree. Therefore, the tree is drawn to the leaning force and its hinge wood may not be able to maintain the tree's guidance in the desired direction.

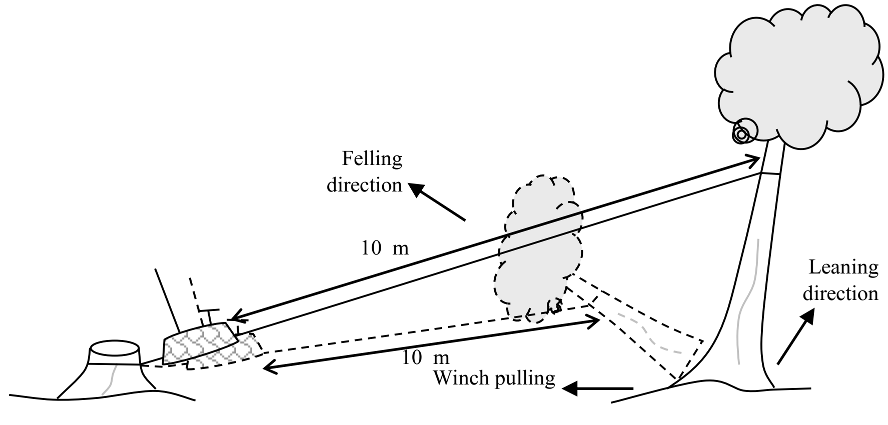


Fig52. Choosing winch location for felling the tree with heavy leaning in side of leaning direction

To prevent this problem, the winch should be attached in a place where the tree couldnبtlose the cable during its movement, and remain under tension until it falls to the end. This location is chosen in such a way that the distance from the cable attached location to the fallen tree trunk on the desired path is the same as the distance from the winch to the location of the cable attached on the standing tree trunk (Fig. 52).

By this method, while pulling the tree at the beginning of the work by the winch, in the direction in which the resultant of forces will be the felling direction, the felling tree will never have the opportunity to move away from the winch and move toward its leaning direction and falls exactly in the desired path.

2.7.3. Felling of trees in opposite of leaning direction using winch

The most common use of winch is in felling of trees with a heavy leaning in their opposite of leaning direction. To do this, we need a good guess at the strength and power of the winch to pull the desired tree. According to calculations and experience, it can be said that if a tree has a diameter of 80 cm and its line of direction of center of gravity is about 2 m outside the stump, it can easily be pulled in the opposite of leaning direction by using a 4 tons winch and a fasten cable on 6 meters height. To calculate, it is enough to have a good guess of the location of the treebscenter of gravity, its line of direction, and the vertical distance of this line to the fulcrum (resistant arm). Then the attaching distance of cable to the fulcrum will be the effort arm and the strength of the winch will also be the effort force. Felling of trees in opposite of their leaning direction using winch is described as followed:

- At first, a suitable location for the winch and the pulley is selected and the cable is to be attached to the appropriate height.

-We winch a bit so that the cable is completely tight and somewhat shakes the tree.

The tree is to be shaked about one centimeters, and it makes us sure of the power of the winch to overcome the tree.

- First a deep under cut and then a half back cut.

- Once again, we winch to make another shake to the tree and ensure that the winch has overcome the tree.

- A full back cut until the hinge wood remains.

- Turn off the chainsaw and put away from the work area.

- Winch is used until the tree stands still and then fell in the desired direction.

At the end of this discussion, the cause of deep under cut is examined in this regard, and so it is hoped that readers will find the ability to calculate other similar items by explaining the physical bases of forces and expressing several examples.

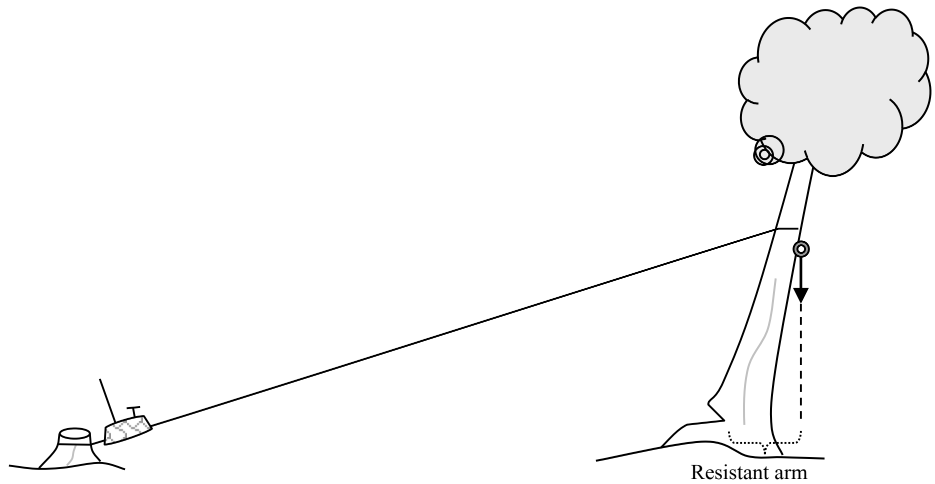


Fig53. A deep undercut facilitates winching in felling trees with heavy leaning in the opposite of leaning direction.

Look at Figure 53; in this figure it is seen that as the depth of the undercut increases, the distance between the fulcrum area and treeِsline of center of gravity will be shortened. Here, the tree's weight prevents the tree from moving in the desired direction by the winch, therefore, the tree's weight is as the resistant force and the perpendicular distance from the fulcrum to the line of direction of the center of gravity is the length of the resistant arm. Therefore, the shorter the resistant arm, pulling the winch will be easier and hence the deep undercut will be considered. This example can be proved by numbering.

2.7.4. Safety measures in use of winch

It is important to measure safety precautions in use of winches. For example, if the fingers remain below the cables, where the steel cables of pulley are, they will get serious damages. We must also take safety measures when climbing the tree for attaching the cable.

- Winch and its equipment include cables and pulleys weighing up to 50 kilograms and a tractor or a mule is need for their transporting. Winchِ transport by hand is limited to a distance of 50 meters from the road. Nevertheless, handy transportation, while causing serious joint problems for workers, sometimes causes felling and injuries in the slopes.

- When collecting and unpacking equipment and wrapping and unplugging cables from around the pulley, while wearing safety gloves, it is necessary that the body is not in the direction of cableِ escape and strikes (something that caused the accident in the presence of the author).

- When tightening the winch, the tightness of the location, such as rock, trees trunks, etc. must be ensured, that during operation and under compression, the winch would not be thrown out of place.

- If the length of the cable is shorter than 1.5 times the tree height (which is usually the case), use the pulley to protect the winch and worker from the fall of the tree.

-To attach the cable to the desired tree height, the worker must have the full tree climbing equipment. This equipment, other than clothing, helmet and gloves, includes shoes and special belt for climbing a tree.

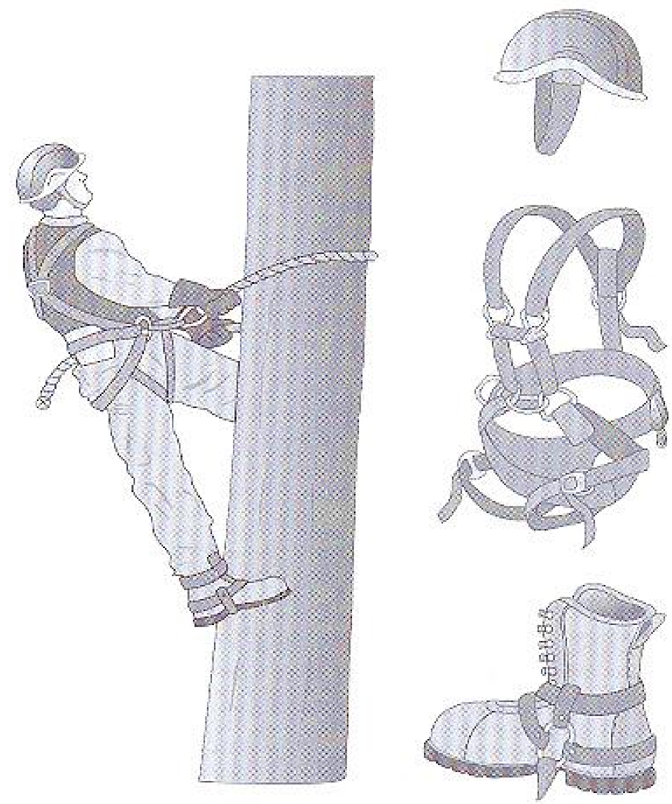


Fig54. Use of shoes and special belts to climb a tree (ILO, 1998)

- Before cutting the tree, it must be ensured that the winch is required with sufficient power. To do this, you can pull it by the winch (winching) after the undercut. If the winch has the power to pull and move the vertical axis of the tree at the attached point of the cable, even to a centimeter, it is enough and we can make sure that it has enough power to pull the tree.

Performing the necessary cut is extremely hazardous before assuring the power of the winch. Because if the winch does not have enough power and is tensile, it cannot pull the tree in the opposite of leaning direction to the desired direction and this case will be like felling the tree in leaning direction with the winch which is extremely dangerous.

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