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## Ground Preparation

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### Introduction

Ground preparation is defined as the set of preliminary operations on soil that are required for effective establishment of tree seedlings. The main objective of ground preparation is to assure access to nutrients, air, and water for the seedlings to be planted.

Ground preparation is associated with site preparation. Ground preparation is more focused in soil treatment for plant establishment, considering the simple meaning of ground as 'solid surface of the earth' or 'the upper soil.' Site preparation may be understood as a wider concept referring to a modification of the surrounding environment for plant establishment. In this sense, site preparation may include operations prior to ground preparation.

Thus, site preparation includes clearing, soil cultivation, and also protection operations, such as management of pre-existing vegetation especially weeds, fencing and other animal control systems, protection of plants against frost and wind, etc. Conversely, ground preparation as a normal step leading to plant establishment is concerned with soil cultivation, including either drainage or water storage according to site conditions.

As a major operation for ground preparation in planting sites, soil cultivation frees ground and it facilitates a deeper penetration of water and air into the root zone and therefore, it allows root systems better access to soil nutrients and assists their correct placement, anchorage, and development. Also, draining facilitates aeration for roots in extremely wet and waterlogged fields. Furthermore, water harvesting increases soil water availability in dry zones.

Intensity of the operations for ground preparation may be defined in terms of work or power per unit area, which varies from site to site, depending on

constraints of cost, plantation objectives, and site conditions. Ground preparation work may be classified as low intensity operations or high intensity operations. Low intensity operations include basically manual support and simple soil cultivation. High intensity ground preparation includes the use of agricultural machinery and mechanical support for soil cultivation.

Operations for ground preparation may be further classified according to their use of labor or machinery. Thus ground preparation may be implemented through a manual support system, a mechanical or machinery support system, or a combination of both systems. Ground preparation with manual support is normally preferred in low intensity ground preparation and small-scale operations such as the construction of furrows, mounds, bunds, ditches or trenches.

In general terms, field conditions such as slope, deepness, and stoniness are not limiting factors for manual ground preparation, which is performed by using hand tools such as shovels or spades, *azadas*, or a plow drawn by animals. Also, ground preparation with manual support may be used for smoothing and compaction of mounds and bunds, when combined with machinery or mechanical support operations.

Ground preparation with machinery or mechanical support is used for large-scale operations and it cannot be used on steep slopes because its application requires gentle to moderate slopes. Operations of ground preparation with mechanical support involves plowing, disking, or bedding, mounding, also scratch or spoil drain mounding, ditching, ripping, subsoiling or scarifying operations. However, disking and ripping are the most widely used operations of this type.

Machinery used for mechanical support operations consists of tractors or dozers with special attachments, especially blades, disks, rippers, rutters, or excavators, among other devices. Agricultural equipment may be used in most operations for soil cultivation in planting sites, where field conditions are not too rugged or stony. Heavy machinery should be used if there are relatively adverse conditions such as heavy clay soils, moderately steep slopes, or stoniness in the field.

Thus mechanical support to ground preparation can be classified into three categories of equipment: (1) machines for vegetation cutting and stump removal; (2) machines for vegetation cutting plus breaking up the ground up to certain depth; and (3) machinery that breaks ground structure to a deep level (Table 1).

For example, bulldozers may be used to remove remaining trees and stumps. A rotovator works over ground vegetation and it turns over the upper soil

**Table 1** Equipment required for ground preparation, according to field conditions

<i>Fields conditions</i>	<i>Operation</i>	<i>Machinery recommended</i>
Deep soil; light soil density; flat to gentle slope	Cultivation without restriction	Low intensity work: agricultural disks on tractor
Deep soil; light soil density; flat to gentle slope	Ripping and mounding without restriction	Low intensity work: winged ripper on tractor; disk moulder on tractor
Deep soil; heavy soil density; moderate slope	Cultivation with restriction	Moderately high intensity work: heavy disks on tractor
Moderately deep soil; very heavy soil density; moderately steep slope	Ripping and mounding with restriction	Very high intensity work: ripper on bulldozer; 'Savannah' type mound plow; excavator on hauler
Shallow soil; steep slope	Machinery operation restricted	Manual support system recommended

layer. Rippers are typical devices for breaking up soil in depth. A mechanical excavator may be used for ground preparation in areas with heavy slash where stump and debris removal should be done prior to any plant establishment operation.

Appropriate operations for ground preparation depend on soil physic features, relief, water regime, and previous management. Field conditions requiring ground preparation are related to dense grass cover, detrimental field disturbance, compaction, heavy bulky soils, waterlogging, or dryness. Analysis of these conditions allows definition of needs for clearing, land reclamation, soil cultivation, drainage, or water harvesting.

## Clearing

Clearing is an important preliminary matter in ground preparation and it is carried out to remove cover, specially shrubs and trees. Clearing allows effective soil cultivation, improving access for establishment operations. Clearing for plantation development may include the removal of posts from old fencing, stump and timber removal, and filling of holes.

Areas carrying a dense cover of grass require special attention because they put up competition with tree seedlings. First, grass needs to be eliminated with herbicides and allowed to decompose prior to working for complete breakdown of the sod. Then, soil cultivation may be required and appropriate cultivation might be considered, such as line cultivation with a heavy disk, mound plow, or ripper if necessary.

Soil cultivation is strongly recommended in sites carrying bracken (*Pteridium aquilinum*) or light scrub. Soil cultivation should be done twice in dense bracken or scrub cover: once in autumn; then again in the following summer. Over winter the sod and rhizomes break down and any new spring germination is removed in the second cultivation. In this case, the rhizomes mat of bracken has to be completely broken before plant establishment and seedlings planted into mineral soil.

## Land Reclamation

Management conditions leading to soil cultivation for plant establishment are related to disturbance during harvesting. Site disturbance may be considered desirable for forest regeneration. However, site disturbance may occur under inappropriate conditions, e.g., a high risk of compaction, erosion, or soil mass movement, especially when soil is water saturated. Thus, land reclamation may be performed if disturbance becomes detrimental.

For example, compaction may occur due to machinery travel during harvesting operations, e.g., where conditions in soil water content are not appropriate for machinery operation such as skidders or feller buncher harvesters. Land reclamation is intended to return the site as closely as possible to its initial level of productivity in such a manner that the site will maintain that level of productivity without further management.

Land reclamation is often very expensive and does not guarantee that an area can be returned to its former level of productivity. Therefore, prevention is always the best way to deal with detrimental site disturbance. The first step in undertaking reclamation work is the development of the reclamation plan. The reclamation plan should include specific instructions and procedures for different treatments.

A reclamation plan must be based on specific site conditions, such as: moisture regime; soil texture; nutrient status; range and wildlife interests; possible negative consequences of the reclamation; locally available resources; and special concerns for the given site. Some of the options currently being explored i.e. the process of land reclamation are: recontouring of steep cuts; loosening the soil; revegetation; restoration of organic matter; fertilization; and, finally, monitoring.

As an example, soil can be loosened by a variety of methods, including a ripper, winged ripper, winged subsoiler, excavator with bucket, or excavator with fork. The winged subsoiler and ripper are usually

more applicable to large areas of continuous disturbance, such as roads and landings.

Revegetation is an important measure for land reclamation because vegetation plays an important role in maintaining soil structure, and when it is removed, exposed mineral soils are more susceptible to compaction damage. High root activity helps restore and maintain soil structure. Traditional approaches for revegetation have been to plant grass plus legume mixtures, which are useful in extreme situations where erosion control is necessary. However, there are circumstances where these types of mixtures may compete for moisture with seedlings or may increase the risk of frost damage.

Organic matter may be restored by moving forest floor or logging debris from slash piles or roads. The layer of organic material on the forest floor surface serves many important functions: it is often an important nutrient reservoir; it prevents soil erosion; and it protects soil from compaction after the removal of vegetation. Straw is a suitable mulch, because of its relative unpalatability and low carbon/nitrogen ratio. Hydroseeding mulches may be used in certain cases, or plants such as rye grain, which generally do not survive in extreme conditions and die after 1 year, leaving a layer of organic matter on the ground.

Fertilization replaces nutrients lost from the site, stimulates biological activity to speed up the process of soil structure restoration, and accelerates ground-cover development. Nutrient application may also help to offset an anticipated decline in productivity when other means are not practical.

## Compaction

The physical effect of compaction on soils is an increase in soil bulk density. Other effects of soil compaction are: reduction of porosity and thus aeration and useful water retention; loss of soil structure; reduced hydraulic, thermal, and gas conductivity; and increased dry strength or shear stress. Thus, soil compaction may affect root growth, limiting the roots' ability to explore the soil volume for nutrients and water moisture.

Other side effects of soil compaction include: increased risk of ponding of water; greater depth of soil freezing; and reduced growth of soil organisms. Any of these changes can contribute to short-term reductions in tree growth or long-term reductions in site productivity.

## Cultivation

Cultivation is carried out to improve soil physical conditions, to allow improved root growth and

therefore tree anchorage, to improve root access to soil nutrients and moisture, and to improve the quality of planting. Also, cultivation removes competing weeds, thereby improving moisture and nutrient availability to planted seedlings; and it provides a surface to which herbicides can be effectively applied.

It is important to determine the optimum technique for ground preparation in any particular field condition. A balance of cost to effectiveness must be achieved; on some sites, e.g. sites with heavy weed infestation such as blackberry (*Rubus fruticosus*) or gorse (*Ulex europaeus*), it will not be economically possible to establish plantations due to high costs of controlling this type of weeds. In addition, poor cultivation may increase erosion. Farmers should be aware that preparation equipment can be very specific where heavy work is required; in such a case special care must be taken to minimize erosion.

Soil cultivation should be contoured on all soils of high or very high erosion class such as silty or granitic soils, and on slopes greater than 15% for the moderate to high erosion class. All cultivation must avoid disturbing flowlines. In areas of very high rainfall cultivation may be undesirable for some moderate and moderate to high erosion class soils above 15% slope.

Soil cultivation lines oriented at right angles to the contour will facilitate machine access for subsequent establishment and harvesting operations on other than high and very high soil erosion classes and on slopes over 15% on moderate to high soil erosion class.

Soil cultivation must be done when the soil is friable, dry enough to crumble from cultivation but not so dry that it pulverizes. The soil should only be lifted enough to cause fracturing and then dropped back without any inversion of the soil profile. Soil cultivation is normally performed through disking.

## Disking

Disking is an operation for ground preparation using disks as attachment devices on a tractor. Disking may be used to improve soil structure; to break down compacted surface horizons; to break up sods or bracken rhizomes; or to prepare a cultivated weed-free surface for herbicide application. Disking may be carried out on soils not requiring subsoil ripping.

Disk type will depend on the field conditions. Soil should be cultivated as deep as rocks and roots permit and to a minimum depth of 0.20 m. Heavy disks should be used, because smaller disks do not cultivate to sufficient depth. Mounding disks are used for drainage and water harvesting systems.

Disking is effective in soils with compacted surface and it promotes infiltration. Nevertheless, disking may reduce medium pore soil volume in dry areas and therefore it may affect water availability for plants. Also, disking may affect soil organic matter.

## Ripping

Trees form shallow root systems where there is any impediment to root penetration. Shallow root systems make trees susceptible to windthrow, and to summer drought stress. Thus, ripping is required on compacted and heavy clay soils. Ripping breaks up subsoil, promoting root penetration to a reasonable depth. Grassland soils should benefit from ripping. In general, light density soils such as sandy soils do not require ripping.

Normally, ripping is carried out with a winged ripper. Ground preparation of planting sites by cultivation with a winged ripper will break up hard soil pans, increasing infiltration, and enhance early root development and subsequent tree growth. The wing on the ripper spreads the shattering effect of the ripper by lifting the soil as the ripper is pulled through and then dropping and shattering it behind the ripper.

Ripping should ideally be carried out to a depth of 1 m, or a minimum of 0.7 m for satisfactory results. Subsoil shattering occurs over most of the planting site when soils are relatively dry. Under this condition, subsoil shattering is obtained at a reasonable speed. Speed of ripping is important for shattering soil and large machines capable of reasonable speed should be used where possible.

Rippers shatter compact soils and provide easy access to the ripped profile for roots when fitted with a wing at least 0.40 m wide, mounted at the toe, and angled rear-upwards. Narrow boot rippers without wings produce very narrow shattering and can cause trenching in moist soils. Suitable rippers are commercially or locally made.

Subsoil plows are designed to provide full ground preparation treatment in hilly areas worldwide. Subsoil plows are designed for areas where the dozers available are lower in horsepower. More maneuverable than a heavy trailing unit, subsoil plows are very rugged machines designed for use with 225–350 HP dozers. The design may include a heavy-duty coulter and swept-back tine, and a choice of two or four disks. Subsoil plows may have the ripper shank and the disk body both in the swiveling frame, for high maneuverability on sloping ground. Also, some equipment includes a disk coulter ahead of the ripper shank.

High-performance plows may be used for bedding and soil structure improvement at higher speeds. They

can use a four-point linkage lift kit, a 48-inch coulter, ripper shank and either two or four 36-inch cultivating discs. High-performance plows have a new design of hubs and spindles, which are massively stronger than previously. Bodies have been completely redesigned to allow up to 34-inch high-lift jump height. It is now very unlikely that a jump-arm would ever hit against the mechanical stop and it will be rare for the weight of the plow to be placed on the disk spindles, even in extremely high stump conditions. As an example, the action of the ‘Savannah’ jump arm raises the disk higher with a minor angle of cut and a greater rolling effect over a stump, eliminating stresses on the disk and spindle in straight-line plowing.

Effective depth of subsoiling has been a matter for debate around the world. Effectiveness is one criterion, but economy is a better approach for foresters to use. Generally, it may be much better to have a slightly shallower depth using a winged ripper tip, than to deep rip using only a standard ripper tip. The standard ripper tip will not create any fracture zone in plastic or wet soil condition. On the other hand, using a wide-winged tip and with plenty of longitudinal surface area, it is possible to break out plastic soils right to the surface. Thus, a subsoiling operation may be effective if it can produce additional growth in trees to justify expenses.

## Mound Plowing

Mound plowing is an operation that raises the level of ground surface on planting spots. Mound plowing is often carried out on low-lying, flat areas, wet and poorly drained sites, and shallow infertile soils. It enables low, wet parts of generally better sites to be developed and planted. Mound plowing may be applied if 20% maximum of the field area is affected by waterlogging. Mounds can increase runoff on poorly drained sites and large mounds may provide a better rooting medium on wet or shallow soils. Mounds can be used in dry areas to retain runoff and therefore increase moisture content in soil.

Mounding is more effective on fine-textured soils. Soil is well aerated by mounding but it may need consolidation before planting. This can be achieved by rolling or by allowing the soil some time to settle, about 1–2 months before planting. Mounding delineates rows and it leaves an obvious planting line thereby reducing planting cost. Planting holes may be dug easily in loose soil. Seedling roots may be arranged neatly, minimizing shock or damage. These conditions allow seedlings to begin to grow earlier, increasing the length of the first growing season.

Mound plowing is often done in conjunction with ripping. Mound plowing allows planting directly

over the ripped line. Mound plowing is best carried out when soils are moist but not wet. Plowing should be complete by early autumn to allow time for the mound to pack down before planting.

Various mound plows are available for use. Normally a set of tandem offset 600–800 mm diameter disks is attached to a tractor or dozer, which works well in easy conditions. Much heavier disks are available, and the recommended big disk for special operations is the ‘Savannah’ plow, which is mounted directly onto a large bulldozer.

## Operational Impacts

Ground preparation has both positive and negative effects on soil properties. Use of proper equipment and correct timing of preparation will reduce any detrimental impact. **Table 2** describes the potential impact of ground preparation operations on soil properties.

## Drainage

Draining is a special operation in waterlogged fields, and its objective is to promote aeration for root systems. Normally, draining is carried out by ditching, bedding, or mounding. Ditching allows water to be discharged towards lower areas. Bedding and mounding raises ground allowing a water-free zone on upper soil.

Spine drainage is a typical example for ditching drainage systems. In this system, a central trench is excavated in the slope direction. Lateral trenches regularly spaced on both sides are connected to the central trench that receives their discharge. Spine drainage is a very efficient system for depleting local water table in planting sites; however, it has significant impacts on sediment yield and is therefore falling out of use.

Bedding and mounding are the preferred systems to address drainage in planting sites. These opera-

tions raise the ground to a position free of water, increasing available root depth and protecting seedling stems from low temperatures occurring during frost over the ground surface. Most of the better results in tree growth are obtained by placing seedlings over the top of the mound.

Bedding is an operation more appropriate for clear areas, because it is difficult to get a continuous line of plowing for bedding under conditions such as heavy slash or high stumps. Therefore, mounding should cope better with irregularities on the ground surface.

## Water Harvesting

In dry areas, water harvesting must be considered in order to supply water if it is deficient during establishment and early growth of plantation. Water harvesting should gain massive adoption in the near future because of the excellent results obtained in the afforestation of areas with rainfall as low as 80 mm year<sup>-1</sup>. Most harvesting systems are designed for flat areas. Nevertheless, higher steep slopes also may be treated with the systems for water collection. There are many water harvesting systems that can be applied for improving forest plantations. For example, microcatchments or ‘negarims,’ contour bunds, contour stone bunds, semicircular bunds, individual terraces, ‘limans,’ ‘kasukas,’ permeable rock dams, subsurface dams, and others.

Water harvesting systems are ground preparation systems with a high cost and a considerable amount of ground disturbance. Nevertheless, water harvesting systems can make feasible afforestation in dry zones, achieving good success in tree growth. As an example, **Table 3** shows the earthworks required for three of the most popular water harvesting systems.

Water harvesting systems should be considered as soil and water conservation systems, because besides harvesting water for the trees, they simultaneously conserve soil. Dimensions of water harvesting systems are based on the catchment area size required to provide an additional supply of rainfall. Under extreme conditions of drought there must be a minimal runoff in the area. The design of water harvesting systems must also consider maximum discharge in order to avoid destruction of the structure. Larger structures may take more labor per unit volume of earthworks than smaller structures such as negarim microcatchments, because of the increased earthmoving required.

Negarim microcatchments are diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner. Runoff is collected from within the basin and stored in the infiltration pit. Microcatchments are mainly used for

**Table 2** Potential impact of ground preparation operations on soil properties

Soil factor	Operation		
	Disking	Ripping	Mounding
Compaction	+ SI (r-2-LT)	+ HI (r-1-LT)	+ SI (r-1-LT)
Soil moisture	+ SI (r-2-LT)	+ HI (r-1-LT)	+ HI (r-2-LT)
Soil organic matter	- LI (r-2-LT)	O	- LI (r-1-LT)

Impact sign: +, positive; -, negative.

Impact magnitude: O, no effect; LI, light effect; I, significant effect; HI, very significant effect.

Importance: 1, point; 2, local.

Reversibility; r, reversible effect; p, irreversible effect.

Duration: SD, short-term effect; LD, long-term effect.

**Table 3** Minimum earthworks required by typical water harvesting systems

Additional rainfall supplied by water harvesting system (mm)	Runoff (mm)	Crop area to catchment ratio	Trees per hectare	Earthworks with a minimum cross section of 0.08 m <sup>2</sup> and a forest crop area of 4 m <sup>2</sup> (m <sup>3</sup> ha <sup>-1</sup> )		
				Microcatchments	Contour bunds	Semicircular bunds
200	10	1:20	125	208	48	80
150	20	1:7.5	330	288	128	211
100	30	1:3	850	464	200	326

growing trees or bushes. This technique is relatively easy to construct and appropriate for small-scale tree planting in areas with moisture deficit. A modified system is used in Latin America by a double plowing at right angles to get the diamond shape over the ground. Also, the soil in the pit is removed and placed in the top of the bund at the lowest corner of the diamond and one to three seedlings spaced at 0.4–0.6 m are planted at that point. This planting method is named the ‘taba-ue’ system from its original name in Japanese. The cluster of plants creates its own environment and the synergy effect can improve their survival and growth.

Contour bunds are a simplified form of microcatchments. Bunds follow the contour at regular spacing. Small earth ties perpendicular to contour prevent collapse of the system under high intensity rain events. Construction of bunds can be mechanized and the technique is therefore suitable for implementation on a larger scale. Bund construction is relatively economical particularly for large-scale implementation on even land. Contour bunds are suitable for trees and also for the cultivation of crops or fodder between the bunds.

Semicircular bunds are earth embankments in the shape of a semicircle with the tips of the bunds on the contour. Semicircular bunds are used mainly for rangeland rehabilitation or fodder production, with varying dimensions. This technique is also useful for growing trees and shrubs and, in some cases, has been used for growing crops. They may be placed as an *in situ* short slope catchment or an external long slope catchment, depending on the location and the chosen catchment to cultivated area ratio. Semicircular bunds, ‘half moon’ or ‘demi-lune’ in francophone Africa, are recommended as a quick and easy method of improving rangelands in semi-arid areas, and may be used in afforestation projects. Semicircular bunds are more efficient in terms of impounded area to bund volume than other equivalent structures such as trapezoidal bunds, for example.

Contour ridges, sometimes called contour furrows or microwatersheds, are used for crop production, and the technique may also be applied for afforestation

purposes. This is a microcatchment technique where ridges follow the contour at a spacing of usually 1–2 m. Runoff is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges. Crops are planted on both sides of the furrow. Contour ridges are simple to construct with manual or machinery support, and this can be even less labor intensive than the conventional tilling of a plot. The yield of runoff from microcatchment lengths in contour ridging is extremely efficient and when designed and constructed correctly there should be no discharge out of the system. Contour ridges provides even growth because each plant has a similar contributing catchment area. Contour ridges is a technique being tested for crop production in Africa.

Trapezoidal bunds have a layout with shape of a trapezoid, a base bund connected to two side bunds or lateral walls, which extend upslope at an angle of usually 135° or higher. Trapezoidal bunds are used to enclose larger areas up to 1 ha or more. In this system, runoff is harvested from an external catchment area. Crops such as trees are planted within the enclosed area. Overflow may discharge throughout a spillway constructed over the central bund or as a channel at the end of the lateral walls. The main advantages for this technique are simplicity of design and construction, and the minimum maintenance required.

Contour stone bunds are used to reduce runoff speed, thereby promoting infiltration and collecting sediment. The water and sediment harvested improve crop growth. Bunds construction is a traditional practice in many parts of the world and villagers may be trained effectively in its application. Stone bunds are well suited to small farmers because of their low cost and simplicity. Improved construction and alignment along the contour makes the technique considerably more effective. Stone bunding techniques are used for hillside terracing around the world, specially in the Andean zone. The supply of stones may be a constraint for application of this technique. The filtering effect of the semipermeable barrier along its full length spreads the runoff, avoiding

concentration and resultant damage. Systems based on stone do not need spillways and they require much less maintenance.

Permeable rock dams are a floodwater farming technique where runoff waters are spread in valley bottoms for improved crop production. The structures are typically long and low dam walls across valleys. Rock dams have been developed mostly in West Africa, and the technique had grown substantially by the end of the 1980s. The technique is labor intensive and needs a group approach, as well as some assistance with transport of stone.

Water spreading bunds are often applied in situations where trapezoidal bunds are not suitable, usually where sudden runoff discharges may be extremely high and would damage trapezoidal bunds or where the crops to be grown are susceptible to the temporary waterlogging, which is a characteristic of trapezoidal bunds. Water spreading bunds are usually used to spread floodwater which has either been diverted from a watercourse or has naturally spilled onto the floodplain. The bunds, which are usually made of earth, slow down the flow of floodwater and spread it over the land to be cultivated, thus allowing it to infiltrate. Water spreading bunds may be combined with the construction of a ground dam, which is a long structure that retains subsurface flow.

## Final Remarks

Several ground preparation operations and their uses have been described. Tree growth following different treatments for ground preparation should be monitored and integrated on information systems. Further progress in forestry may be supported by information systems about the results of different treatments for ground preparation under specific field conditions.

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## Stand Establishment, Treatment and Promotion – European Experience

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## Introduction and Definitions

There are many aspects to the establishment of forest stands, which are reflected in a number of definitions:

- Reestablishment of existing forests is possible by means of generative or vegetative renewal. Strictly speaking, stands are regenerated only when grown from seed. This may occur through natural or artificial regeneration:
  - Natural regeneration takes place when seed is dispersed without human interference.