Tilling Compacted Soils with RipPlows: Best Management Practices

(October 2012)

by

David H. McNabb, PhD, RPF

ForestSoil Science Ltd.
Edmonton, Alberta

Table of Contents

Introduction

The trafficking of boreal forest soils by the energy and forest industries and the construction of facilities to access these resources have a wide range of impacts on forest soils. The severity of the impact on soil depends on the equipment involved, the work being done, soil properties – particularly soil wetness, and terrain. For example, a wide-tired skidder will significantly compact soil to a depth of more than 0.2 m when the soil is wet. Loaded log trucks will compact soil to soil densities similar to the maximum density obtained with compaction tests, impact soil to depths of over 60 cm, and destroy most of the ecologically important soil porosity in the process. Medium sized dozers working close to their full potential can compact soils to maximum densities as well if the soil moisture content is near optimal. Although soil moisture contents are often higher than that needed for maximum compaction of forest soils in Alberta, the trafficking of wetter soils destroys soil structure, which has significantly impacts the ecological function of the soil.

Hence, the trafficking of forest soils by most industrial equipment generally causes a complex combination of an increase in soil density and destruction of soil structure. While soil structure and porosity are impacted regardless, the destruction of soil structure creates a massive, structureless soil. In destroying soil structure, the natural fracture planes in soil through which water flows and roots penetrate the soil are essentially destroyed forever. The dominant ecological consequence of compacting soil, creating massive soil, or a combination of both is that the hydrologic function of the soil is impaired. The impairment includes reducing water infiltration (entry of water into the soil), and soil permeability (horizontal and vertical movement of water within soil) that can increase the probability of overland flow and the risk of surface erosion. The impairment also reduces the ability of the soil to store water for plants and to rewet in summer, which can create drought in plants. At other times, the impaired hydrologic function increases the probability of creating a temporary water table just below the surface which can create anaerobic soil environments. All of these changes in hydrologic function have the greatest impact on perennial forest species because of the impacts that changing soil aeration and water supply can have on their ability to maintain their perennial root systems.

The effects of moderate to severe compaction and destruction of soil structure on the hydrological and ecological function of forest soils are not expected to recover naturally, particularly at depths below about 0.15 m, for a very long time. For example, the subsoil in early wagon roads that crossed Alberta have remained impacted at depths below 0.15 m after a century. Thus, the persistence of the impaired hydrologic function in trafficked forest soils not only has the potential to impact the establishment of forest species on industrial sites but affect the sustainability of maturing forest vegetation that does become established. The issue for maturing forest vegetation is that its robustness and resiliency depends on a larger volume of soil than commonly assumed. While a majority of the roots of forests are found near the surface (80 or more percent are generally found within the top 20 cm of the soil), deep soils with minimal physical restrictions allow forest to maintain a minimal but efficient and effective deep root system to sustain them during annual drought cycles. In this regard, the most productive ecotypes in Alberta occur on forest soils that 1- to 2 m deep without restrictive horizons. Even in poor quality black and white spruce forests on Gleysols in northwestern Alberta, the soil by the end of summer has been observed to be dry to a depth greater than 0.5 m. Hence, restoration of the soil physical environment as deep as reasonably possible to reduce the impaired hydrologic function of industrial sites is of upmost importance in restoring sustainable forest and ecological function to these sites.

Deep tillage practices have been developed in Alberta over the past 20 years that alleviate the severe and often deep impacts of industrial trafficking of forest soils. During this time a set of criterion were developed to define effective deep tillage practices that are primarily based on the early testing of a non-conventional, but highly effective tillage practice. This criterion has since been used to assess the effectiveness of common practices and design a new deep tillage implement that could be used on dozers and excavators. The tillage implement designed is a RipPlow, which can plow soil to a depth up to 0.90 m using a Caterpillar® D7R sized dozer while retaining most of the topsoil on or near the surface. Since 2006, RipPlows have been used to till hundreds of new and previously certified wellsites in Alberta forests and over a thousand kilometers of access roads that no longer being used by the energy and forest industries.

This paper will provide a brief overview of the results of the work that has led to the development of RipPlows and practices for the deep tillage of forest soils, including the criterion for effective deep tillage. However, the overall objective of this paper is to describe and illustrate best management practices for the use of RipPlows for deep soil tillage, the conditions that limit their use and effectiveness, practices that fail to optimize their effectiveness, and practices to improve operational productivity.

Restoring Soil Physical Quality

The primary goal of restoring the soil physical environment is to allow the hydrologic function of a damaged soil to return to normal. While 'normal' depends on the ecosite, the basic process is to increase infiltration and permeability of the soil profile, lower the watertable, increase water retention of the soil profile during dry summers, and minimize runoff. If the restoration of hydrologic function is effective, the hydrologic function of the soil is likely to initially be better than that of the original soil. Over time, which may be several decades in the absence of machine trafficking, a wider range of natural soil processes will continue to normalize the soil physical environment, which will become more similar to that of the surrounding soil.

The process of restoring hydrologic function requires the fracturing of the soil profile to increase soil porosity. This fracturing of soil will also improve soil aeration and allow the permanent root systems of perennial plants to occupy the soil and establish more sustainable root systems, which are necessary for maintaining a resilient forest cover as it matures. Improving the resiliency of forest cover will also allow disturbed land to respond to future environmental disturbances, and help insure the site can naturally regenerate similar to the surrounding forests.

The general failure of natural processes to restore soil structure and hydrologic function of impacted soil requires a tillage intervention to restore the soil physical environment. . Deep tillage, defined here as depths in excess of 70 cm, will improve the hydrologic function better than shallow tillage. In fact, effective shallow tillage or spreading loose topsoil over severely impacted subsoil can acerbate the impairment of hydrologic function by encouraging the repeated formation of temporary water tables, anaerobic soil environments, and cyclic drought. Such practices have been observed to cause high mortality and reduce the growth of planted seedlings that do survive.

Criterion for the Effective Restoration of the Soil Physical Environment

Tilling forest soil with a reforestation plow and spreading topsoil without subsequent trafficking of the soil provided valuable insight as the kind of practices and processes that were needed for effective tillage of forest soils. The insight is grouped into four core principles: 1) till soil as deep as possible; 2) create large voids in the tilled soil that are not trafficked until after the soil as frozen; 3) maximize the effectiveness of the freeze/thaw process to fracture clods the first winter; and 4) retain as much of the topsoil on or near the surface as possible. In essence, tillage is a two-step process where the mechanical tillage creates an initial soil environment that maximizes the opportunity for the freeze/thaw process to mechanically restructure the entire plowed layer and in places, a little deeper. With cold winters, the two-step process allows the mechanical tillage to effective across a much wider range of soil wetness and severity of soil damage than conventional tillage.

Tillage that creates large clods and void spaces and rough surfaces will freeze faster and deeper in the fall. The freezing process fractures the soil in the large clods by allowing the soil to expand into the voids during freezing, and not just vertically as occurs near the surface of untilled soil. When the clods thaw in the spring, most of the clods will become small aggregate sized peds that fill most of the voids. Hence, the fracturing of clods in this manner is similar to what the freeze/thaw process does to soil at the surface but can occur throughout the plowed layer. Therefore, the effectiveness of the freeze/thaw process is enhanced if the soils are relatively wet at the time that the soil freezes. Soil wetness at the time of initial tillage is less important because of the two-step process. Most of the criteria are intended to maximize the post-tillage effectiveness of the freeze/thaw process.

Retention of topsoil is important, and can be critical, to the establishment of a diverse mix of forest perennials. However, the topsoil does not have to evenly cover the tilled site after tillage, but the homogenization of topsoil with underlying soil has been found to be detrimental to the growth of conifers in BC. In fact, mixing of soil layers nearly negated the benefit of tillage. Furthermore, the rough surface remaining the first year after tillage and the variability of exposed soil create a wide range of microsite that can benefit the initial establishment of either natural or planted species. Effective deep tillage of severely impacted soil is far more important to establishment of sustainable forest cover than is retention of large amounts of woody debris; and the roughness of the soil surface after deep tillage will generally create a wider range of microsites for establishment of vegetation than will woody debris.

Hence, a set of criterion based on these principles were first proposed in 2006 to guide the development of alternative implements and practices. The sustained growth of lodgepole pine on the original research trial, the subsequent operational testing of new implements and practices, and research conducted elsewhere have continued to validate the principles and the resultant criteria. The criteria defining effective tillage practices are as follows:

1. Tillage should be as deep as possible to restore hydrologic function of the soil profile.
2. Leave the soil rough and containing large voids to maximize the effectiveness of the freeze/thaw process to fracture and restructure severely impacted soil the first winter.

3. A high soil water content prior to freeze enhances soil fracturing by the freeze/thaw process.
4. Retain topsoil during tillage and minimize admixing of topsoil with subsoil.
5. Till soil with only one or two passes to minimize mixing of soil layers and loss of topsoil down the furrows.
6. Till soil as the last practice in the physical restoration of soil on a site.
7. Do not traffic tilled soil until the soil has frozen.
8. Retention of short pieces of woody debris on the site prior to tillage is acceptable but the quantity must not compromise the effectiveness of the tillage operation.

The criteria serve as the platform on which to develop a set of Best Management Practices for effective deep tillage of forest soils and the operational practices to achieve the best results.

Development of RipPlows

Unfortunately, there are few implements available for deep tillage of forest soils and none that are consistently effect for the deep tillage of medium and fine textured soils. For example, dozer ripper shanks and shanks with small wings are sometimes effective in coarser-textured and other nonplastic soils but are generally ineffective in finer-textured soils because rippers and other implements with tinges have a critical depth of effectiveness (Raper et al. ___). The volume of soil that is effectively tilled is limited to a relatively narrow 'V-shaped' furrow, and the bottom of the 'V' in the furrow defines the critical depth of their effectiveness. The critical depth decreases as clay content and wetness of the soil increases. The critical depth is also reduced in massive soil and as soil wetness changes with depth. In wetter soils, it is not uncommon for ripping to only create a small bulging of the surface adjacent to the slit created by the shank. In fact, ripper shanks operating below the critical depth will compact and/or create massive soil as the soil flows around the shank. Hence, to produce deep fracturing of these soils, the shear forces have to be much greater deep in the soil than current implements can produce. Furthermore, the tillage of forest subsoils during reclamation of many industrial sites is likely to be recompacted by the trafficking of the soil by dozers when the topsoil is spread. Hence, the net benefit of any tillage forest soils will be ineffective, or of marginal effectiveness, unless done as the last treatment of a site by machines.

The reforestation plow on a large dozer that was used in the early tillage of forest roads in Alberta was used like an agronomic plow, but it created deep furrows and inverted the subsoil. The inversion of soil was not an issue because the topsoil and debris was spread over the clods in a second operation. Spreading topsoil with an excavator was an expensive operation and is only possible on narrow disturbances accessible from the edge. Plowing soil after the topsoil was spread was not considered an option, and subsequent research and observations validated that decision. How to achieve the high level of strain, which a plow can achieve, and retain most of the topsoil was a challenge and the focus of developing a new tillage implement.

Prototype RipPlows were designed in 2005 and tested during the following winter season. RipPlows were designed to create large amounts of and upward and lateral strain, which could also be increased with the use of the adjustable, parallelogram toolbar on many dozers. The prototype plows were designed to be used in pairs in the outside shank-pockets of a multi-shank toolbar so that each plow was directly behind each track. Hence, dozers would not be driving on soil which had not been plowed. The amount of lateral soil displacement allowed was limited to prevent the creation of a continuous, deep furrow as well as limit the amount of topsoil that was likely to fall into the furrow from the edges. Scale model testing of different angles of soil engaging surfaces, which were then made to the original unit, were made and validated during testing on a wide range of soils in the fall of 2006. The RipPlow design is now covered by Canada and US Patents for use on a variety of prime movers.

When RipPlows are used on a Caterpillar® D7R sized dozers, RipPlows can plow soil to depths of 70-90 cm (measured from the original soil surface elevation), and have consistently produced and average gain in soil elevation of 15 cm. The gain in soil elevation is a measure of the increase in soil porosity produced. Follow up measurements have found that about 30 percent of the gain in soil elevation remained after four years. This increase in pore space improves the hydrologic function, improves soil aeration, and increases the water holding capacity of the soil. The improved hydrologic function has also been observed to lower the temporary water table forming in depressions on wellsites when they do occur.

RipPlows were designed and tested in cooperation with contractors using Caterpillar® D7R dozers, but have also been used on D7G, D7H, and D7E machines as well. A bigger shank version of RipPlows is also being used on D8 dozers. The D7G had neither the power nor weight to pull RipPlows as deep as the other machines. ***The mention of the brand and models is done only for reader clarity as to the size of dozers for which RipPlows been found to work effectively.*** RipPlows are built on a custom shank, which improves their plow function and allows the dozer to work more efficiently. Hence, RipPlows can be made to fit the toolbar pocket of most medium and larger sized dozers.

Much discussion and other methods of tilling soil with smaller dozers has been done over the past few years, but the tillage benefit was much less effective in both depth and areal coverage of the soil. Hence, the total volume of soil loosened in these attempts was only a small fraction of the volume produced by the original machines. Smaller dozers lack the clearance under the toolbar to plow the soil deep, and plowing soil at depths less than about 50 cm greatly increases the amount of mixing of soil layers and deep furrowing that occurs.

Best Management Practices

The Best Management Practices (BMP) for using RipPlows for soil restoration of severely impacted soil on industrial sites focus on improving their overall effectiveness as a tillage implement and the operational efficiency of the dozer and operator. Hence, the focus is on medium- to finer-textured soils that are often moist to wet in part of the soil when plowed, massive in structure from previous trafficking, and undergo a freeze/thaw cycle soon after plowing. The BMPs are for plowing non-frozen soil, when or the frozen soil does not impede the plow entering or remaining below the frozen soil; a separate set of BMPs will be given for frozen soil. The list will also include practices to avoid. The BMPs are divided into five categories: machine/RipPlow interaction; maximizing the tillage benefit; operational practices; environmental risks; and tilling frozen soil. A brief rationale for each BMP or practice to avoid will also be provided.

Machine/RipPlow Interaction

1. RipPlows are a purpose built implement for soil tillage.

- RipPlows are built for the sole purpose of tilling soil and not for ripping or prying. Ripper shanks are better designed for the latter tasks.
- Speed for plowing is generally between 1 and 3 km/hr. A larger dozer may have the power to go faster.
- If plowing at speeds less than 1 km/hr, the plowing should be assessed in using practices identified in the section on operational practices.
- A single RipPlow in the middle pocket has been tested in frozen ground that was difficult to plow with two. The dozer became extremely difficult to control as one track would lose traction and the dozer would change direction

2. RipPlows are designed to be used in pairs in the outside pockets of a multi-shank toolbar:

- In this position, dozers will not be trafficking plowed soil, which will maximize the effectiveness of the freeze/thaw process and the rougher surface will provide a wider range of microsite on which vegetation may become established.

- More than half the elevation gain from plowing can be lost in just driving a machine across plowed soil, and one third is lost in the area between the tracks.

3. RipPlows should not be in the ground when turning.
   - Because of their large size at depth, steering of the dozer while they are in the ground become nearly impossible and increases the risk of breaking a shank.

4. The tilt of the toolbar of adjustable parallelogram toolbars needs to be monitored.
   - RipPlows are designed with a 5 degree downward tilt that allows them to plow their way to maximum depth in about 5m or so, but they can not be forced into the soil like a ripper shank.
   - Tilting the tooth down will allow the RipPlow penetrate the soil faster but is not recommended.
   - Tilting the tooth down will increase the shear stain in soil more and increase the fracturing of wetter soils.
   - Too much forward tilth of the tooth will increase soil mixing, create a larger furrow, and require more power. In the extreme the RipPlows will become anchors.

5. RipPlows should be operated at depths greater than 60 cm
   - Plowing less deep has been observed to increase the mixing of soil layers. Hence, more subsoil comes to the surface and mixed with the topsoil.
   - The furrow left by the shank and plow bottom is wider and more consistently deeper. It can also increase the closure of adjacent furrows.

6. Maximum control of RipPlows is achieved when both are in similar soils.
   - Plowing similar soil will improve the operational efficiency of RipPlows.
   - Control of the dozer is always easier when both RipPlows are operating in similar soil
   - If one RipPlow is allowed to interact with an adjacent furrow, the dozer is likely to be forced into that furrow by the better traction of the other track.

7. Blade on the dozer will add extra weight on the front of the dozer.
   - Although the blade is not used during plowing, it does provide some extra weight to help hold the front of the machine down.

Maximizing the Tillage Benefit

1. Plow soil as deep as possible:

- Increases the volume of soil available to sustain maturing forests and serves as a buffer to climatic stresses.
- Plowing <60 cm increases mixing of soil layers, which reduces ecological value of topsoil.
- Deep plowing will lower any temporary watertable where a high watertable is likely to affect forest establishment.

2. Plow sites in straight lines whenever possible, and is most important when starting to plow.

- Straight furrows improve operator control of the dozer direction.
- Both tracks have more equal traction.
- Maximizes the volume of soil tilled in the least number of passes.
- Reduces the number of times the dozer slides into a previous furrow, which also causes excessive mixing of soil.
- The straighter furrows also improves control of the dozer in poor light where the differences between plowed and non-plowed soil become more difficult to see.

3. Plow soil in lapping passes

- The first pass of a pair of RipPlows will result in about 30-35 percent of an area being tilled at the bottom of the plowshares but the D7 sized RipPlows are not large enough to fracture the soil between the furrows of trafficked soil.
- Lapping the first pass will result in furrows being about 1 m apart, and cover a minimum of about 65 percent of the area; however, the second pass generally fractures all of the soil between the first pass furrows.
- The tillage benefit of the first pass is generally greater than that achieved in the first pass.
- The effectiveness of the second pass plowing is improved if the furrows are straight.
- The second pass plowing requires less power and the dozer can more easily go deeper and faster than during the first pass, but the depth of plowing needs to be referenced against the elevation of the original soil and not the top of the plowed soil from the first past.
- When soil is plowed in parallel passes the RipPlows are always operating in unplowed soil. Plowing the second pass perpendicular to the first pass is inefficient for two reasons:
    - A third of the time the RipPlows will be operating in the previously plowed soil.

- Cross-lapping produces much larger blocks of soil, which can reduce the effectiveness of the freeze/thaw process.

4. Minimize shallow plowing at the ends of furrows

- RipPlows cause less mixing of soil layers when entering the soil than when lifted at the end of the furrow.
- Slowing raising the plows when approaching the end of the site generally brings up more subsoil; some of which cannot be avoided.
- Raising the plows at the end of a furrow while stopped or slowly backing up to turn around lessens the amount of subsoil exposed.
- The added benefit is that the ends of a site can generally be plowed in two passes perpendicularly to the primary direction which also minimizes soil mixing.

5. The optimal soil moisture for plowing is operationally wide but moist soils are preferred.

- Dry and wet soils require more power to pull RipPlows, which can limit the depth at which they can operate.
- Wet soils also require more strain the fracture them; hence, the front tooth will need to be tilted down and/or the soils plowed less deep.
- Unlike conventional tillage, plowing with RipPlows can be done as long as the dozer has traction because the plowing increases the effectiveness of the freeze/thaw process.
- Plowing wet soil does tend to expose larger clods of subsoil in the furrow.
- Whenever, possible schedule plowing or control existing vegetation prior to plowing so that soils will be moist at the time of soil freezing so that the maximum benefit of the freeze/thaw cycle is achieved. Freezing does not fracture large, dry clods.

6. RipPlows have a critical depth beyond which they become less effective.

- Regardless of the length of shank and clearance under the toolbar, RipPlows designed for D7 sized dozers have a critical depth of 0.9 m, and less in massive and wet soil that requires more stain to fracture the soil.
- A larger plow, and dozer, are needed to plow deeper, but will improve both their effectiveness and productivity.

Operational Practices

1. Tilling soil with RipPlows differs from ripping ground with ripper shanks in several ways and some changes in operating technique and practices are required.

- Plowing can require more power, hence, the performance of the dozer needs to be monitored accordingly.
- Dozers should be able to maintain a minimum speed or changes in practices should be considered.
- Plowed soil can roll up in front of the toolbar, which is mostly topsoil, so the toolbar needs to be checked frequently to avoid exposing subsoil.
- Monitoring of the plow performance needs to increase when plowing through woody debris, because of the risk of logs coming up through the frame of the toolbar and damaging hoses.
- Maintaining directional control and position of the dozer at all times, is critical to maximizing the effectiveness of the tillage operations in the least number of passes.

2. When plowing gentle slopes, make the first pass downslope.

- The first pass always requires the most power so the plowing will be deeper and more efficient if the first pass is downhill
- The lapping second pass will be easier going uphill after the first pass has been completed and can be deeper as well.

3. Small cyclic changes in the depth of plowing (3-5 cm) can reduce the power required for plowing and increase speed.

- When plowing requires a maximum amount of power, the requirement can be reduced by temporarily raising the plow. Because RipPlows are designed to apply both upward and lateral forces to soil, raising the plow temporarily will cause the soil to fracture further in front of the plow, which will temporarily reduce the power required and increase forward speed.
- Within in a meter or so, the depth can be decreased to the original depth of plowing.
- A few operators have perfected this technique and use it all the time regardless of the soil condition because it reduces the same steady pull on the dozer.

4. Dozers should not attempt to turn while RipPlows are in the ground

- Some steering in wide curves is possible with RipPlows in the ground but the radius of the curve is generally greater than 100 m.

- If a dozer is unable to track a curve easily, the radius is too short to plow with RipPlows in the ground. The alternative is to plow short curves in short straight segments.

5. Except for short distances, turning the dozer around will generally provide better control than backing between the furrows of the first pass to make the second pass.

- Backing between furrows requires the dozer remain on the inter-furrow soil, which requires more control if backing at higher speeds. Otherwise, the dozer will drift into the plowed furrow, which can make it difficult to make a second pass in non-plowed soil.
- There is also more trafficking of plowed soil as the machine starts to back across a site.

6. Exposure of subsoil should be minimized by avoiding plowing too shallow.

- More subsoil is exposed when RipPlows operate at a depth less than about 60 cm, which also increases the mixing and loss of topsoil.
- Some exposure of subsoil will be exposed when the plow enters or exits the soil, but some exposure is inevitable on existing.
  - The least exposure of subsoil occurs at the end of the furrow if the dozers stops, or stops and starts to back up, before raising the plows.
  - This process also allows the dozer to turn on looser soil.
  - The unplowed soil at the end of a site can generally be plowed in two passes perpendicular to the main direction of plowing. If more area is used to turn around, more passes are needed to plow the ends of a site, which results in more soil mixing and may produce larger clods in areas that were not plowed deep at the start.

7. Tilling strong dry soils.

Severely impacted surface soils that are dry, such as in old roads, can have penetration resistances many times greater than when the soil is moist. This can become an obstacle to plowing these roads with RipPlows, because a D7 sized dozer probably does not have the necessary power.

- Dozers will have the best opportunity to plow strong soils, if the lower body of the plow is kept below the strong surface soil.
- If RipPlows rise up in strong soil, it is better to back up and re-enter the soil where they were operating deeper in the soil than trying to force them down in hard, dry soil.
- The best alternative for tilling hard surface soil where RipPlows become inefficient is to rip the hard soil with ripper shanks to a depth of about 30 cm. This practice should improve the

fracturing of the surface than ripping deeper, and allow the RipPlows to access the deeper soil that is likely wetter and for which RipPlows are better suited.

- Plowing these soils with a larger dozers and RipPlows will also work, but shallow ripping of the surface may still improve the overall effectiveness of the tillage.

Environmental Risk

1. On steeper slopes where downslope flow of water is an issue, plowing across the slope is recommended.

- The high porosity of plowed soil will seldom erode from the surface but the water can flow downslope in the bottom of the furrow and exit the soil at the lowest point.
- Surface erosion will be more likely after the soil has had a season to freeze/thaw and settle.
- Slopes should be plowed in ways that water from multiple furrows do not accumulate at one location, and plowing perpendicular to the contour treat the ends of a site should be avoided.
- Periodically starting the plowing on the contour from openings in the edge of adjacent forests will help divert water into the forest that may accumulate in furrows.

2. When plowing narrow, linear disturbances on steeper slopes, Extra effort is required to minimize the flow of water in furrows.

- Water bars and other methods of diverting on these slopes should be installed as required prior to plowing. These structures should insure that water is diverted off the site.
- Plowing cannot reduce the integrity of the water diversion structures.
- Logs that are sometimes placed across roads to divert water are not effective on plowed soil because the soil will settle in the furrows and the water can flow under them unimpeded.
- Periodically starting a downslope end of a furrow off the edge of a linear disturbance may help divert water as well.
- A RipPlow on an excavator is probably a better machine for treating linear disturbances on steeper slopes than is a dozer.

3. Protocols for buried pipe and other services must be followed.

4. Workers on foot should be warned not to walk in furrows but to always step across them.

- The largest voids are often in the bottom of the furrow, which can sometimes be covered with unstable clods. Stepping on or near these clods could result in their collapse and falling with a leg caught in the furrow.
- Soil around furrows will remain unstable until a freeze/thaw cycle and effectively fractured the large clods and filled the voids.

Frozen Soil

Background: Frozen soils are the most difficult soils to till and many cannot be plowed with RipPlows or require some specific practices to increase the probability of success. As a point of reference, the wide bottom of RipPlows cannot penetrate frozen soil nearly as easily as ripper shanks. The depth of frozen soil that limits plowing depends on the depth that the soil is frozen, soil texture, and amount of water in the soil when it freezes; interaction of how these variables affect plowing is complex. Deeper frozen layers of coarse- and medium-textured soils that are not wet can be plowed easier than can finer-textured and wetter soils. Therefore, knowing the depth and hardness of the frozen soil and limiting the trafficking of soil in winter in advance of plowing are important to improving reliability of scheduling winter plowing operations. Most of the early testing of RipPlows was done in winter; unfortunately, the conditions that limit their use are difficult to assess beforehand and can vary across a site. Some observations suggest that if a 1.2 cm diameter piece of reinforcing rod cannot be driven into the soil with a 2 kg hand sledge, the frozen soil mostly like cannot be plowed. In general, soils in the Boreal Ecoregions are more likely to limit the use of RipPlows on a D7 size dozer later in the winter than in the Foothills Ecoregion, where deep snow and less cold can insulate the soil unless it has been disturbed.

- Winter sites should not be trafficked until just prior to plowing because the soil can freeze quickly once the snow cover is removed.
- Snow that has changed to a more granular ice crystal may have to be cleared from a site to be plowed so that the dozer will have traction.
- Plow winter sites as early in the winter as possible.
- If RipPlows are to work in partly frozen soil, most of the wide bottom of the RipPlows needs to remain below the frozen layer.
- Entering the soil where snow is deeper may allow the plows to get through the frozen layer easier.
- If the depth of plowing cannot be maintained in frozen soil, it is better to back up and to the point where the RipPlows were deeper in the soil rather than continue to try and push them down.

- Going over a frozen soil in more than two cycles to get deeper is not recommended because of the excessive soil mixing and the plows and dozer.
- The most successful three pass tillage of a drier frozen soil was to plow the first pass furrows a second time. The tracks of the dozer remained in the furrow, which improved control and traction, and the RipPlows were able to go deeper. The third pass was a parallel lapping pass between the original furrows and effectively broke the soil to the full depth. Although severe soil mixing occurred in the original furrows, the mixing was avoided on about half the area.
- Plowing soil before it has frozen during the contouring of a reclamation project in winter is a viable option. Once the soil has frozen, it can be handled and trafficked by dozers and other equipment without compromising the outcome of the tillage. Once a plowed soil has frozen, it should not be plowed because it will bring the largest clods to the top and the smallest clods and topsoil will most likely be buried.

Conclusions

RipPlows are a highly effective implement for the deep tillage of forest soils that is necessary for restoring the hydrologic function of the soil and its accessibility by the roots of perennial forest vegetation. The primary advantage of RipPlows in northern climates is that the large voids created between clods by plowing enhance the ability of the freeze/thaw process to fracture the soil. RipPlows are designed to plow soils to depths of 70 to 90 cm using a D7 sized dozer with minimal loss of topsoil unless operated at depths less than about 60 cm. The roughness of the plowed soil also creates a wide range of microsite on which to establish native forest vegetation.