SNOW TRAPPING AND MOISTURE INFILTRATION ENHANCEMENT

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ABSTRACT

Generally, snow constitutes over 25 percent of the amount of precipitation on the Canadian prairies. Water equivalent of the snow varies between 70 - 140 millimeters per year. Various techniques to trap snow have been studied by Agriculture Canada and the University of Saskatchewan since 1973. Snow trapping efficiencies as high as 99 percent have been observed. The depth of snow trapped was closely related to the height of vegetation when snowfall, fetch, vegetative cover and other conditions favour the transport and deposition of wind blown snow.

The amount of water from trapped snow that can be stored in the soil profile was found to be highly variable. Snowmelt infiltration studies indicate that a direct association between snow cover depth and snowmelt infiltration should not be expected because of differences in the physical properties of the snow cover, seasonal ablation process, soil moisture and soil temperature regimes at the time of melt.

Preliminary studies also suggest that to maximize water recharge from snow management practices, it is necessary to combine them with tillage practices such as subsoiling that increases the macropore content of the soil at the time of melt. Data are presented to demonstrate that "ripping" to a depth of 600 mm increases the water intake on the average of six times the amount compared to undisturbed stubble depending on the available snow water equivalent. The increases are in the same order of magnitude found in heavy clay soils that naturally fracture when dry.

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INTRODUCTION

The prairie farmer plays a vital role in the management of soil and water. Some of the more pressing problems facing the producer are soil erosion by wind and water, soil degradation due to salinity, and the loss of organic matter. Research has shown that extending the cropping system can increase organic matter, control salinity, and reduce soil erosion. However, continuous cropping increases the risks of poor yields in dry years and so it may not be a practical alternative for farmers facing high annual production costs. This is particularly true in the brown and dark brown soil zones of the prairies. Retaining the snow where it falls improves the potential of water conservation and thereby soil conservation.

"Manipulation of snow cover offers the greatest potential for increasing available water for dryland crops on the Canadian prairies" (Rennie 1979). Snow management to increase soil water conservation requires that snow be trapped, distributed and held on the field until the crop has grown. This also means that on melting, the water should have a good opportunity to enter the soil rather than be lost by runoff.

This paper will review the advances made in the trapping of snow and examine the potential for meltwater enhancement.

SNOW MANAGEMENT PRACTICES

Snow management implies the use of a physical barrier to trap snow uniformly on a field where it is held until a crop is grown. Barriers for snow management can be grouped into competitive and noncompetitive types, depending upon whether the barrier competes with the crop for the stored soil water supply.
Noncompetitive Barriers

Stubble management is the most viable snow management practice for the prairies because of the type of crops grown and nature of cultural operations. The most popular methods include tall stubble, alternate height stubble, trap strips and leave strips.

Tall stubble. The term "tall" stubble is used in a "relative" sense to infer that the crop is cut at the highest possible height during the harvesting operation thus leaving a field of "high" stubble. Normally this practice is used when the crop is straight-combined. The actual height of a "tall" stubble is a function of the crop variety, plant density and crop height but usually will fall in the range from 30 to 60 cm.

Studies on the use of tall stubble for trapping snow were conducted by the Division of Hydrology at Saskatoon and Port Reeve (Nicholaichuk et al. 1985). Based on average stubble height differential of 6 cm between conventional stubble height and tall stubble height suitable for straight combining, the net increase in snow water equivalent available for soil recharge was 1.6 cm. Consequently the amount of moisture that can be gained by utilizing "tall" stubble is limited by the height of stubble.

Alternate-height stubble. Swathing at alternate heights is a form of snow management that has been investigated for a period of 13 years at the Swift Current Research Station (Nicholaichuk et al. 1985). Treatments consisted of alternately swathing the wheat crop at two different heights using a self-propelled swather. The heights are dependent on the crop stand condition. The control consisted of wheat that was swathed at a uniform height.

The average depth of snow trapped by non-uniform stubble was 4 cm, or 22% more than on the uniform stubble. Additional soil water increase from trapped snow was 1.4 cm or 23% greater indicating an approximate linear relationship between snow depth and moisture equivalent.

Trap-strips. A concept developed in 1979 consists of leaving a strip of tall standing stubble that acts as a barrier to trap snow on stubbled fields. Development of the concept was continued during 1979 and 1980 with two Agriculture Canada AERD contracts with the Department of Agricultural Engineering of the University of Saskatchewan (Steppuhn, 1980). At Swift Current two types of strips spaced at 6.4 m are being evaluated. The first type consists of leaving a strip of tall standing stubble that is created by using a deflector-type attachment mounted on a conventional swather. The second type of leave-strip is created by using a clipper type of attachment mounted on a conventional swather which leaves a narrow strip of standing stubble with the heads clipped off (Dyck et al. 1982).
Only 3 years of study have been devoted to this trap system of snow management. The clipper system tended to trap more snow than the deflector attachment. The clipper system left more erect standing stubble that tended to provide additional turbulence for compacting snow within the tall strips of tall standing stubble. On the average, the clipper system trapped 15 percent more snow than the deflector system. In addition, the clipper system trapped 39 percent more snow compared to the uniform stubble check.

Trap strips, either the deflector or clipper type, were on average 20 and 36 percent more effective in trapping snow over the same three year period compared to the alternate height stubble method. In comparing the two systems, the trap strip offers a greater potential capacity because of the physical configuration.

In terms of soil water storage, at Swift Current, the three year study showed the trap system by either the deflector or clipper method increased the stored water by as much as 2.2 and 3.6 cm respectively. This increase in water storage represents an intake efficiency of 62 percent for the deflector and 74 percent for the clipper compared to 38 percent for the check. In other words, the intake efficiency for the clipper is near double the control. In comparison to the alternate stubble heights the intake efficiency was found to be considerably higher than either control or the alternate height system. This suggests that a barrier created by the clipper system may act as a heat sink during the thaw period resulting in increased moisture trap.

In contrast, similar studies conducted by Chanasyk (1985) in central Alberta showed snow trapping using trap strips did not enhance moisture gain significantly at any of the sites in any of the three years of study from 1982 to 1985. No trend of higher or lower moisture gain was evident for the stripped treatment, in spite of a wide range of fall moisture contents.

Leave strips. In this practice, 30 to 40 cm wide strips of crop, spaced 1, 2 or 3 swather-combine widths apart are left unharvested to act as barriers to trap snow (Nicholaichuk et al 1985). The width of a swather usually is in the range from 4.6 to 7.6 m. With a 30 cm wide strip placed on a 15 m. spacing, approximately 2% of the area of a field is left unharvested.

A particular advantage in cutting a field to leave stubble at different heights is that the vegetative surface formed is aerodynamically rougher than that of a uniform stubble; consequently, its snow trapping efficiency is higher. The practice would be favoured where crop conditions, principally density and height, are insufficient to provide a "tall" dense stubble and on highly-exposed topographic facets, e.g. the tops of ridges and knolls.
Based on four years of data from Saskatoon and Port RIne approximately twice as much water was trapped by this technique compared to the control. The maximum differential of additional water trapped observed in the four years of study was 8.9 cm which is somewhat higher than the clipper system.

Competitive Barriers

The Tall Wheat Grass barriers concept developed in northern Montana (Black & Siddoway 1976) and later studies at Swift Current has been found to be effective for trapping snow (Nicholalchuk et al 1985). Barriers consist of tall wheat grass planted in single or double rows spaced 9 m to 15 m apart. The grass barrier offers a greater potential for trapping more snow than the non-competitive types. This is mainly attributed to the fact that the tall wheatgrass provides a barrier that is a meter in height or more. Five years of data suggest that the barrier system traps approximately twice as much snow compared to the uniform stubble.

Not only did the barrier system trap offer an opportunity to trap more snow, the net increase in water stored was 73% greater than the control. Results to date are similar to those reported by Black and Siddoway (1976).

SNOWMELT INFILTRATION

Infiltration to frozen soils involves the complex phenomenon of coupled heat and mass transfer through porous media. The process is affected by many factors including: the hydrophysical and thermal properties of soil; the soil moisture temperature regimes; the rate of release of water from the snowcover and the energy content of the infiltrating water. However it is recognized the most important hydrophysical property of a frozen soil that governs its ability to absorb and transmit water is its moisture content.

Granger et al. (1984) undertook an extensive field study of snowmelt infiltration to frozen, medium to fine-textured soils in central Saskatchewan. The study resulted in the development of a simple physically-based model describing snowmelt infiltration into frozen soils (Gray et al. 1985). Three categories with regard to infiltration potential were identified. Namely:

Restricted - infiltration is impeded by an impermeable layer, such as an ice lens at the soil surface or within the soil near the surface

Limited - infiltration is governed by the snowcover water equivalent and the frozen water content of a shallow layer of soil, 0 - 300 mm

Unlimited - a soil in this condition contains a high percentage of large air-filled, non capillary pores or macropores or macropores at the time of melt and most or all
the snow water will infiltrate. Examples of such soils are dry heavily-cracked clays and coarse, dry sands. The latter category lends itself to snow management practices.

**Infiltration Into Cracked Soils**

Gray et al. (1985) showed that cracked soils have the capacity to infiltrate most or all the water equivalent of an average snowcover and depending on the number, density and physical dimensions of the cracks even heavy snowcovers encountered on the prairies. These soils then offer a high potential for increased infiltration from increased snowcover and as such represent an ideal situation for the implementation of snow management practices.

Granger et al. (1986) observed that texture of soils susceptible to cracking affects the amounts of infiltration. Data (Table 1) suggests that the ability of a cracked soil to infiltrate meltwater is directly related to its susceptibility to cracking: i.e. heavy clay soils produce wide and deep cracks and thus can take in a greater quantity of water.

Table 1. Average infiltration into cracked soils. (Taken from Granger et al. 1986)

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Crack depth</th>
<th>Infiltration depth</th>
<th>Average Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Clay</td>
<td>0.90</td>
<td>0.95</td>
<td>106</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0.81</td>
<td>0.87</td>
<td>93</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>0.73</td>
<td>0.76</td>
<td>78</td>
</tr>
<tr>
<td>Silty Loam</td>
<td>0.72</td>
<td>0.75</td>
<td>74</td>
</tr>
</tbody>
</table>

**Enhancement of Snowmelt Infiltration**

Data collected to date suggest that snow trapping techniques are successful in trapping snow. However, 13 years of data by swathing at alternate heights also suggests the benefits that can be attributed to snow management are highly variable due to reasons given earlier in this paper. To this end, exploratory studies have been initiated to determine whether snowmelt infiltration can be enhanced. (Nicholaichuk et al. 1984, Gray et al. 1985).

Utilizing a conventional subsoiler, a Killefer plow and a Paraplow (registered trademark) (Pidgeon 1983), trial experiments were initiated to determine whether such tillage practices would enhance meltwater infiltration from trapped snow (Nicholaichuk et al. 1984, Gray et al. 1985).
From the one year study at Swift Current, Saskatchewan (Nicholaichuk et al. 1984) subsoiling or paraploughing between the strips of tall standing stubble did not appear to reduce the depth of snow trapped. The practice of 'Paraplowing' did have a beneficial effect of enhancing snowmelt infiltration when compared to the control. The benefits attributed to these types of tillage practices are related to the amount of snow entrapped. On uniform stubble, when a smaller amount of potential stored moisture was trapped, tillage had a detrimental effect on the amount of water that was stored.

Preliminary data (Table 2) suggests that "naturally-cracked" heavy clays and "ripped" subsoiled soils offer high potential for soil water augmentation by snow management practices (Gray et al. 1985). On average, depending on the available snowcover water equivalent, water intake in fractured soils was in the order of 6 times the amount of infiltration to undisturbed stubble.

Table 2. Mean ratio of the amount of snowmelt infiltration in a cracked or subsoiled soil to the amount in the same soil in an uncracked or undisturbed condition for different ranges of snowcover water equivalent. (From Gray et al. 1985)

<table>
<thead>
<tr>
<th>SWE (mm)</th>
<th>Cracked</th>
<th>300 mm</th>
<th>600 mm</th>
<th>Paraplowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30</td>
<td>4.5</td>
<td>1.1</td>
<td>---</td>
<td>1.5</td>
</tr>
<tr>
<td>30-50</td>
<td>2.9</td>
<td>0.7</td>
<td>---</td>
<td>0.7</td>
</tr>
<tr>
<td>50-70</td>
<td>4.1</td>
<td>---</td>
<td>6.9</td>
<td>1.5</td>
</tr>
<tr>
<td>70-100</td>
<td>4.7</td>
<td>1.8</td>
<td>6.8</td>
<td>1.2</td>
</tr>
<tr>
<td>100-150</td>
<td>7.5</td>
<td>0.8</td>
<td>6.7</td>
<td>1.5</td>
</tr>
<tr>
<td>&gt;150</td>
<td>---</td>
<td>6.7</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

- SWE = snowcover water equivalent
- Measurements of soil moisture changes made with the crack located between source and detector.
- Ripped to depth of 300 mm on 1-m spacings; loam soil at Swift Current. Measurements of soil moisture changes taken at 300 mm intervals to a depth of 1.2 m.
- Ripped to a depth of 600 mm on 1.85-m spacing with a Killefer plow; clay loam and clay soils at Kerrobert. Measurements of soil moisture changes made with the rip located between the source and the detector.

Studies to date suggest water augmentation practices by deep ripping or paraploughing appear to be beneficial provided sufficient snow is trapped by standing stubble.
FUTURE OF SNOW MANAGEMENT AND MELTWATER ENHANCEMENT

Snow management studies to date have identified a number of deficiencies that need to be addressed such as equipment requirements, area extent of applicability of the practice, probability of moisture storage from snowtrapping without meltwater enhancement, benefits and economics of meltwater enhancement, impact of snow management practices on surface runoff and groundwater recharge etc. Some of these concerns are being addressed in current studies that are presently underway.

Although considerable effort has been made to develop equipment to create trap strips in standing stubble (Dyck et al. 1982), suitable equipment has not been perfected that could be used to create a trap strip in drought years when grain height is limited. Use of simple, low cost deflectors have not become popular because of some of the inherent operational difficulties when grain height is limited. Excellent progress has been made by entrepreneurs such as Merv Lloyd from Darcy, Saskatchewan in the development of a clipper attachment that can be universally mounted on any make of swather. As new equipment ideas are developed, there is a need for equipment evaluation so that appropriate recommendations can be made by extension personnel. Availability of appropriate equipment is vital to the adoption of snow management practices by producers.

The question of areas of applicability of snow management practices especially in the Chinnok belt of the southern prairies needs to be addressed. Studies at Swift Current (Nicholaichuk et al. 1985a) over a thirteen year period suggest that the amount of water stored as a result of snow management can be highly variable. However, other studies at Swift Current have shown that benefits in added crop yields can be attributed to microclimate effects of trap strips even though moisture gains were minimal (Campbell et al. 1986). Effects of barriers on the micro-climate have been examined by Black and Siddoway (1976) at Culbertson Montana and were shown to have an effect on the reduction on evapotranspiration. Preliminary studies at Swift studies by Nicholaichuk (1981) confirmed the studies at Culbertson. Observations by Markle (1986), a producer at Claresholm Alberta suggests that tall uniform stubble not only traps snow for added soil moisture but does lower the wind velocity at the ground surface resulting in reduced evaporation. Drawing on these results, the use of trap strips in the Chinnok zones of the prairies should have a positive effect even though snow cover may be intermittent for the area.

An unpublished report by Heywood (1986) suggests that snow management practices would have a larger potential impact during wet years than dry years for southern Alberta. In addition, snow management practices may result in sufficient moisture to make annual cropping economically viable.
In the black and grey soil zones of the prairies, snow management practices may not be beneficial. With a shorter growing season in these regions, tall stubble for snow trapping may result in a longer period of time for soil temperatures to rise. In addition, added soil moisture may simply delay normal seeding operations. Consequently, further studies are required to determine optimum stubble management practices that would result in added soil moisture storage without hampering cultural operations.

The rate of adoption of snow management practices without meltwater enhancement has been reduced when producers realized results of the practice were highly variable. As shown by Gray et al. (1985), the amount of infiltration can be minimal in situations where infiltration is impeded by an impermeable layer such as an ice lens or in situations where the infiltration capacity is limited. Granger et al. (1984) found heavy clay soils that naturally fracture are receptive to meltwater infiltration. Such soils lend themselves to snow management practices that can prove to be beneficial.

In order to assess the areal extent of snow management practices on the prairie an analysis of textures of soils in the brown and dark brown soil zones of the prairies indicates approximately 20,739,000 hectares out of 43,082,000 or 48% of the cultivated area is either classified as clay or clay loam (Table 3). On these type of soils that naturally crack, studies to date suggest that snow management without snowmelt enhancement can be very beneficial. Additional studies are required to fully assess the benefits of snowmelt augmentation practices on the loam and sandy loam soils.

Table 3. Cultivated area (thousands of hectares) of soil classes in the Brown and Dark Brown Soil Zones on the Prairies. (Unpublished data. Personal Communication, J.A. Shields, Western Correlator, Land Resource Research Institute, Ottawa, Ont.)

<table>
<thead>
<tr>
<th>ZONE</th>
<th>SAND</th>
<th>SANDY-LOAM</th>
<th>LOAM</th>
<th>LOAMY-CLAY</th>
<th>CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>241</td>
<td>306</td>
<td>8646</td>
<td>10390</td>
<td>1559</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>---</td>
<td>2320</td>
<td>10830</td>
<td>5251</td>
<td>3539</td>
</tr>
<tr>
<td>Total</td>
<td>241</td>
<td>2626</td>
<td>19476</td>
<td>15641</td>
<td>5099</td>
</tr>
</tbody>
</table>
The impact of snow management practices on surface runoff and groundwater recharge have not been fully examined. Nicholaichuk et al. (1983) showed that runoff was inversely related to infiltration. This study showed that trapping snow by swathing at alternate heights did not adversely affect the amount of runoff. Depending on topography, soils type and climatic conditions snow trapping may result in added runoff that may result in added erosion.

**SUMMARY**

Extending the cropping system has been said to be the answer to overcome the problem of land degradation faced by many producers in Western Canada. However, the yield variability has to be reduced if this system is to become acceptable. The answer appears to be in the more efficient moisture management systems that includes snow management.

Recent research suggests that snow management practices can substantially augment soil water reserves. The potential impact of these practices is variable due to a number of factors such as soil type and climatic conditions.

Preliminary snowmelt infiltration studies indicate that naturally cracked soils are ideal for snow management for obvious reasons. Although preliminary studies suggest that mechanically fracturing of soils (ie. subsoiling) can be beneficial, the limitations and economics of these tillage practices have not been fully assessed.

Although all the research information is not available at this time, there are a few statements that can be made with respect to the impact of snow management and meltwater enhancement on crop production. These are:

1. On the average, half of the annual snowfall can be trapped by the use of stubble or permanent grass barriers. Grass barriers offer the greatest potential to trap the most snow.

2. Depending on climate and soil conditions, sufficient water can be stored to eliminate the need for summerfalling.

3. Stubble or grass barriers alters the microclimate next to the soil surface by reducing windspeeds and evaporation which has a positive impact on crop yields.

4. Snow management on soils that naturally fracture should be a recommended practice. Approximately 48% of the cultivated soils are classified as clay or clay-loam.

5. Tillage practices to enhance meltwater infiltration show promise but require further study.
REFERENCES


