Increased Soil Water Storage and Herbage Production from Snow Catch in North Dakota

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Abstract

This study documents the effect of three grass stubble heights (15, 30, and 60 cm) on overwinter storage of soil water and the subsequent effect on forage production the following growing season. Soil water was increased over the winter by 0.24 cm for each centimeter of grass stubble left between 15 and 60 cm in height. Each centimeter increase in soil water stored over the winter increased forage production by 115 and 62 kg/ha for introduced and native species, respectively. Results indicate the importance of stubble height in increasing forage production from grasslands of the Northern Great Plains by trapping snow and storing soil water for use by the plant community the following growing season.

Snow catch and the resulting meltwater can be an important source of soil water for dryland agriculture. Matthews (1940) discussed the importance of using snow meltwater in Canadian prairie agriculture in Saskatchewan and described some of the methods used for trapping snow. Willis and Haas (1969) discussed the importance of snow as a source of water in the Northern Plains.

Various techniques have been used over the years to increase snow catch and subsequent storage of meltwater for use in agricultural production. Haas and Willis (1968, 1971) reported that conservation bench terraces and level bench terraces increased the snow catch and reduced snow melt runoff when compared with nonterraced areas. The additional soil water stored on the benched areas significantly increased crop and forage production. Rauzi (1973) reported similar findings from the use of level bench terraces in northeastern Wyoming.

Perennial grass barriers of tall wheatgrass (*Agropyron elongatum* Host.) provided effective snow catch and erosion control in northeastern Montana (Black and Siddoway 1971). Greb and Black (1971) evaluated vegetation barriers and artificial fences for managing snow in the Central and Northern Plains. Both techniques enhanced snow catch, resulting in more soil water available for use by desired vegetation. Pitting and interseeded crested wheatgrass (*Agropyron* spp.) increased trapped snow resulting in increased soil water storage, forage and annual carrying capacity of native shortgrass rangeland in southeastern Wyoming (Rauzi 1968). Wight et al. (1975), discussing snow management in relation to eastern Montana rangeland, pointed out that snow management on the semiarid rangelands of the Northern Great Plains could provide a hedge against drought. They believe new ideas and research can lead to more effective use of snow as a resource for rangeland. Nicholaichuk and Norum (1975) addressed snow management on the Canadian prairies. They described snow distribution, the history of snow management, the influence of shelterbelts on snow accumulation, and the effect on snow trapping by swathing grain at alternate stubble heights. Data collected for 1973-75 showed that wheat stubble (*Triticum aestivum* L.) swathed at alternate stubble heights of 12 to 5 inches (30 to 13 cm) consistently trapped more snow and retained more potentially available water than uniformly swathed stubble.

The objectives of this study were: (1) to document any change in soil water storage from trapped snow as affected by three grass stubble heights, (2) to document the response of forage production the following growing season to the increased stored soil water.

Study Area and Methods

This study was conducted at the Northern Great Plains Research Center, Mandan, North Dakota, during the winter of 1976–77 and the summer of 1977. The soil was a Parshall fine sandy loam (a member of the fine-loamy, mixed family of *Pachic Haploborolls*). This soil holds about 4.72 cm of water at field capacity and 1.83 cm of water at the wilting point per 30 cm of soil depth.

Data of precipitation, snowfall, temperature and windspeed during the study period (August, 1976–August, 1977) are given in Table 1. Weather data were collected approximately 0.4 km from the study area using U.S. Weather Bureau procedures. Precipitation during the period (26 cm) was substantially below average (44 cm). Snowfall during the winter of 1976–77 was 79 cm, 7 cm less than average. Average wind speed during the study period was 5

Table 1. Weather data during study period (Aug. 1976–Aug. 1977) and long-term average (1915-1977) from the weather station at Northern Great Plains Research Center, Mandan, N.D.

	Precipitation (cm)		Snowfall (cm)		Average windspeed (km/hr.)		Average temperature (°C)	
Month	Actual	Avg.[1]	Actual	Avg.	Actual	Avg.	Actual	Avg.
Aug. '76	1.24	4.14	—	—	5.0	6.6	22	20
Sept. '76	1.22	3.76	—	0.4	4.2	7.1	14	14
Oct. '76	0.20	2.26	7.6	3.0	5.1	7.4	4	7
Nov. '76	0.43	1.30	10.2	10.7	4.7	7.7	- 4	- 2
Dec. '76	0.94	0.99	22.9	15.0	6.0	7.2	-10	- 9
Jan. '77	1.35	0.96	25.4	15.0	5.3	7.7	-17	-13
Feb. '77	0.64	0.96	10.2	14.0	5.3	8.0	- 5	-10
Mar. '77	1.14	1.75	2.5	17.0	7.7	9.2	2	- 3
Apr. '77	0.28	4.04	—	9.1	5.5	10.3	10	6
May '77	3.66	5.43	—	1.3	5.8	9.5	18	13
June '77	5.74	8.74	—	T	5.1	7.7	19	18
July '77	4.22	5.84	—	—	6.1	6.4	22	22
Aug. '77	4.67	4.14	—	—	5.5	6.6	17	20
Total	25.73	44.31	78.8	85.5				

[1]Long-term average

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km/hr, slightly less than long-term average. The air temperature averaged 7° C with 6° C the long-term average.

A mixture of introduced forage species and native forage species, both established in 1975, were used for this study. This experimental area was plowed to a depth of 75 cm before seeding in the spring of 1975. The introduced mixture was seeded on level 6 × 6-m plots at a rate of 18.5 kg/ha pure live seed composed of 27% smooth bromegrass (*Bromus inermis* Leyss.), 37% Russian wildrye (*Elymus junceus* Fisch.), 27% pubescent wheatgrass (*Agropyron trichophorum* (Link) Richt.), and 9% alfalfa (*Medicago sativa* L.). The native mixture was seeded on level 6 × 6-m plots at a rate of 18.0 kg/ha pure live seed composed of 20% slender wheatgrass (*Agropyron trachycaulum* Link Malte), 20% western wheatgrass (*Agropyron smithii* Rydb.), 30% sideoats grama (*Bouteloua curtipendula* Michx. Torr.), and 30% blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.). The established stand of introduced forage species was better than the stand of native forage species. Plot areas were fertilized with 100 kg N/ha and 45 kg P/ha in the spring of 1975. In the spring of 1976 and 1977, 55 and 80 kg N/ha, respectively, were applied.

Three stubble height treatments were randomly assigned at harvest in 1976 (Fig. 1). One area was clipped to a grass stubble height of 30 cm, a second area was clipped to 15 cm height, and a third area was unclipped (60 cm height). Clipped plant material was removed. Since the prevailing winter winds are from the northwest, a 10-m buffer strip was left on the west and a 14-m buffer strip on the north of each area. Buffer strips were composed of the same introduced and native forage species and were in the same stubble height as the associated plot areas. Of the plots available outside the buffer zones, five for each species mixture were randomly selected in each of the three stubble height areas.

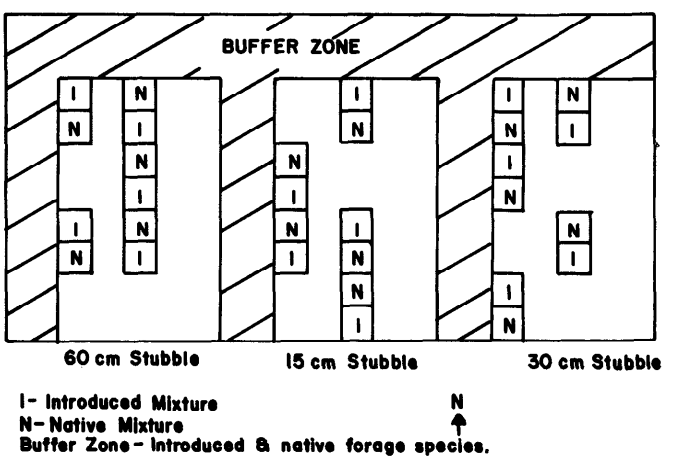

Fig. 1. *Diagram of experimental area.*

Each plot contained a neutron access tube in the center, and soil water content was determined in 30-cm increments to a depth of 1.8 m in mid-October 1976. Soil water content was measured again in mid-April 1977. The difference between the fall and spring was designated as amount of soil water stored over the winter of 1976–77 under the three stubble height treatments.

In late April 1977, all plots were clipped to a 5-cm height and all clipped material was removed to enhance subsequent herbage production measurements.

Production from the two mixtures was measured at near peak biomass accumulation during the 1977 growing season. Vegetation was clipped by species on ten 30 × 30-cm plots within each 6 × 6-m plot. The clipped plant material was oven dried (70° C for 24 hr) and weighed. Production data for each mixture were grouped into forage species, weedy species, and total for further analysis.

Data were analyzed using a split plot analysis of variance, with stubble height as whole plots and species mixtures (introduced or native) as sub-plots.

Analysis showed no significant effect of type of species mixture (introduced or native) on overwinter storage of soil water. Consequently, soil water data for the two species mixtures were combined for further analysis. The relationship between increased soil water content and stubble height was established with linear correlation-regression analysis.

Analysis of forage species, weedy species, and total dry matter production showed that the response to stubble height was significantly different for the two species mixtures. Therefore, further production analyses treated the two types of mixtures independently. The yield response of each mixture was analyzed by linear correlation and regression analysis techniques to establish relationships between production, overwinter stubble height, and increased stored soil water.

Results

Soil Water Storage

The depth to which stored water was increased from meltwater of snow catch over the winter of 1976-77 increased with stubble height. Stored soil water accumulated to a depth of 61, 94, and 162 cm for stubble heights of 15, 30 and, 60 cm, respectively. Soil water below these depths did not change. Overwinter increases in stored water content to a depth of 1.8 m ranged from 1.83 cm under the 15-cm stubble to 12.67 cm under the unclipped 60-cm stubble (Table 2).

Table 2. Change in soil water content from October 1976—April 1977 to a depth of 1.8 m under three heights of grass stubble left over the winter.

Overwinter stubble height stubble height cm	Stored soil water soil water cm
60	12.67 a[1]
30	5.54 b
15	1.83 b

[1]Average values followed by a different letter differ significantly at the 5% level of probability according to Duncan's multiple range test.

Correlation and regression analysis showed that stored water was highly correlated with height of the grass stubble that remained over the winter (see Fig. 2). Based on the equation shown in Figure 2, which was derived from data collected during the winter of 1976–77, an increase of 0.24 cm of stored soil water can be expected for each centimeter increase in stubble height (between 15

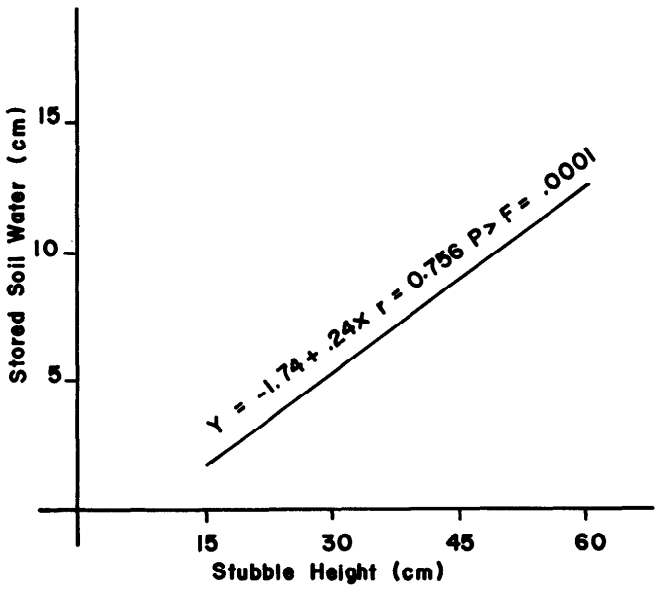

Fig. 2. *Correlation coefficient and regression equation for the relationship of stored soil water to height of overwinter grass stubble.*

to 60 cm of height) that remains over winter. Therefore, each 15 cm of stubble that could be left over winter would increase stored soil water by 3.6 cm.

Herbage Production 1977

Analyses conducted for the forage species, weedy species, and total dry matter components of the vegetation show that forage species production increased with increased stubble height ($P = .001$) and that the native mixture produced less forage than the introduced species mixture ($P = .003$). The production of weedy species was not affected by stubble height, but weed dry matter production was greater in the native ($P = .018$) than in the introduced mixture. Total dry matter was greater in the 60-cm plots than in the other stubble plots ($P = .003$), but there was no measurable difference between the native and introduced species mixtures. Table 3 presents species composition of the vegetation harvested in 1977 from the introduced and native mixtures. These data show that more weeds were present in the native mixture than in the introduced mixture. We believe that the difference was related to the difficulty to establishing native species.

Table 3. Total species composition (percentage on weight basis) of dry matter harvested from introduced and native mixtures in 1977.

Introduced mix		Native mix	
Smooth bromegrass	11%	Western wheatgrass	33%
Russian wildrye	15	Slender wheatgrass	36
Alfalfa	11	Sideoats grama	T
Pubescent wheatgrass	55	Blue grama	1
	92		70
Weeds	8	Weeds	30
	100		100

Herbage production of the introduced mixture ranged from 1,702 kg/ha where 15-cm stubble remained over winter to 3,706 kg/ha where stubble had been unclipped (60 cm) (Table 4). Weedy species production was greatest where the 15-cm stubble remained over the winter (Table 4).

Table 4. Production of introduced and native mixtures as related to height of the stubble left over the previous winter (1976-77).

Overwinter stubble height cm	Herbage production (kg/ha)			
	Introduced mix		Native mix	
	Seeded species	Weedy species	Seeded species	Weedy species
60	3706 a[1]	79 b	2208 a	806 a
30	1835 b	61 b	1654 ab	537 a
15	1702 b	338 a	1189 b	1237 a

[1]Average values in columns followed by a different letter differ significantly at the 5% level of probability according to Duncan's multiple range test.

Forage species yield in the native mixture peaked at 2,208 kg/ha where 60-cm of stubble remained over winter (Table 4). Weedy species in the native stand were not significantly affected by stubble height over the winter (Table 4).

Results of correlation and regression analyses show significant relationships between forage production, overwinter stubble height, and stored soil water for both the introduced and the native mixtures (Fig. 3 and 4). Weedy species production was not related to overwinter stubble height or to increased stored water for either mixture.

Based on the relationship developed from the data collected in this study, a 1-cm increase in stubble height (between 15-60 cm of stubble) left over the winter would increase forage production by the introduced species 47 kg/ha and native species 22 kg/ha. Forage production would be increased 115 and 62 kg/ha, respectively, for each 1-cm increase in overwinter stored soil water.

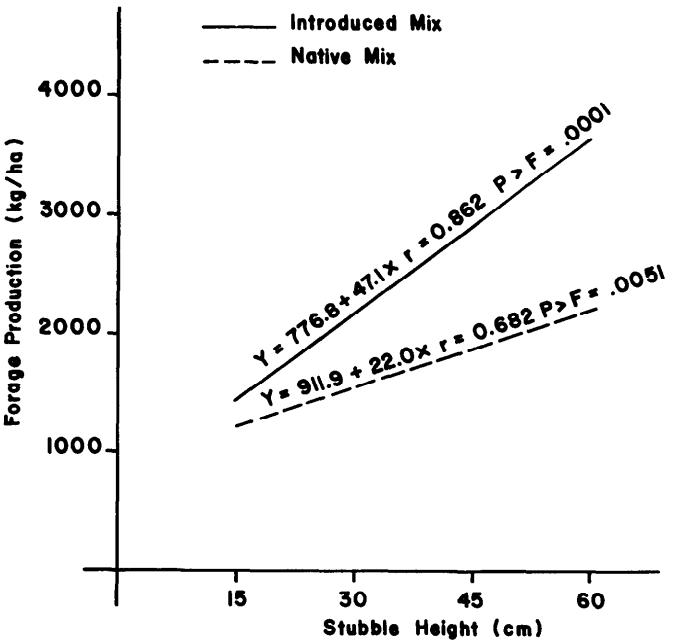

Fig. 3. Correlation coefficients and regression equations for the relationship of forage production to height of grass stubble left over the previous winter for introduced and native mixtures.

Discussion

Many environmental factors affect the conversion of snowpack into soil water available for use by vegetation. Snowfall variability between winters and the water content of snow are of prime importance. If snowfall or snow water are below normal, little change in stored soil water content can be expected. Also important are the size and location of the contributing area from which snow can be transported. Other important factors such as winter temperatures, humidity, and wind affect the amount of water lost from the snowpack. Soil permeability, soil water storage capacity, antecedent soil water content, topography of the land area, and the rate at which the snowpack melts also affect soil water storage.

The results from this study show the net gains in soil water storage over the winter of 1976-77 on a Parshall fine sandy loam

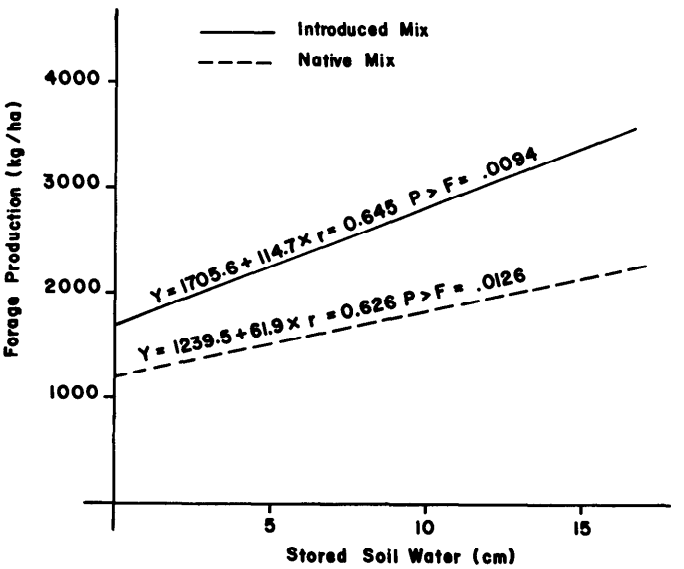

Fig. 4. Correlation coefficients and regression equations for the relationship of forage production to stored soil water for introduced and native mixtures.

soil. All factors mentioned above and possibly others affected the net change in soil water observed. These can be expected to vary from year to year and with soil type, and this must be considered in use and interpretations of the data presented.

An evaluation of the conditions during the winter of 1976–77 and of site characteristics where this study was conducted showed a situation favorable for maximum conversion of snow catch to stored soil water. The snowfall was near normal; the soil was dry at the start of the snowfall season; the soil had been deeply tilled to increase infiltration; the area was level to minimize runoff; and the windspeed was somewhat less than normal.

The response of the vegetation to increased stored soil water was also accentuated by low precipitation received during the 1977 growing season, thus increasing the dependence of plant growth on stored soil water. Our study illustrated the protection against drought that can be obtained in the Northern Great Plains by increasing soil water stored from snowmelt, suggested by Wight et al. (1975).

Although these results are not directly applicable to rangeland, they were a quantitative estimate of the effect of stubble height on snow catch and subsequent soil water recharge and herbage production. Grass stubble heights can be controlled by grazing management.

Herbage production response of introduced forage species in this study (115 kg/ha per cm of soil water) was comparable to that of *Elymus junceus* Fisch. (93 kg/ha per cm of soil water) reported by Greb and Black (1971). Smika et al. (1965) measured increases in yields of native mixed prairie forage of about 50 to 100 kg/ha per cm additional water after applying 20 to 40 kg N/ha as compared to 62 kg/ha per cm of soil water for native forage species in this study.

The lower response of the native forage species in this study does not necessarily indicate a lower productivity because there were fewer native forage species established in the native stands. Since weedy species did not respond favorably to increased overwinter stubble height or soil water, stands fully stocked with desirable forage species benefit more from conversion of snow catch to stored soil water than would weedy stands. The significant increase in production of weedy species in the introduced mixture under the 15-cm stubble height (less stored water) seemed to indicate that weeds are strong competitors when soil water becomes limiting.

The significant increase in stored soil water and forage production in response to relatively small increases in the height of grass stubble left over the winter is encouraging. Research on techniques that can put this principle into practice on Northern Great Plains rangeland merits further attention.

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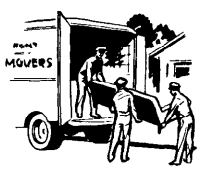

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