Terrace formation in cropping strips protected by tall wheatgrass barriers

by J.K. Aase and J.L. Pikul, Jr.

ABSTRACT: Tall wheatgrass barriers have been successfully tested in the northern Great Plains for wind erosion control and plant protection. Our objective was to document the passive formation of hillside terraces occasioned by grass barriers on a variable 2 to 4% west to east slope. Eleven double-row tall wheatgrass [Elytrigia elongata (Host) Nevski] barriers with 10 15-m-wide cropping intervals 530 m long were established in 1967 on a Williams loam (fine-loamy mixed, Typic Argiboroll) 11 km north of Culbertson, Montana. The barriers were oriented north and south in traditional field orientation. In 1991 we established four transects 15 m apart across the barrier system and designated five sampling points along the transects in each cropping interval for a total of 200 sampling points. To avoid confounding by slopes parallel to the barriers, we selected a segment of the barrier system on a near 0% north to south slope for the measurements. Elevation was determined at each point, and soil cores were taken to a depth of about 90 cm to determine depth to $CaCO_3$ layer, and to determine total and organic carbon by 5 cm increments. A stair-step pattern, with a maximum drop of 30 cm from one grass barrier to an adjacent cropping interval, was documented. Depth to $CaCO_3$ and organic carbon concentration increased downslope between barriers, showing soil movement. Grass barriers may serve as a substitute for mechanically built terraces.

Soil terraces are commonly constructed on sloping soils to control erosion. Construction of terraces requires heavy equipment and is costly. An alternative to terraces may be to plant vegetative strips on the contour at appropriate intervals. Various types of wind barriers and shelter belts have been tried over the years (Marshall; Skidmore and Hagen; van Eimern et al.). Trees and shrubs are popular field barriers in the more subhumid and humid parts of the Great Plains. Short-growth barriers such as strips of corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], sunflowers (*Helianthus annuus* L.) and flax (*Linum usitatissimum* L.) have also been used for wind erosion control and snow trapping. However, low precipitation in the semiarid Great Plains seriously limits the choice of vegetative barriers.

One type of vegetative barrier that has been successfully tested in the semiarid northern Great Plains for wind erosion control and plant protection is formed by perennial tall wheatgrass [*Elytrigia elongata* (Host) Nevski]. The grass was seeded in rows to create 15-m (50 ft) cropping intervals, resulting in excellent crop protection, wind erosion control, and snow trapping (Aase and Siddoway; Aase, Siddoway, and Black; Black and Aase 1986; Black and Aase 1988; Siddoway). In the first studies involving tall wheatgrass barriers, grass seedings were done in double rows spaced 0.9 m (3 ft) apart. However, the grass can effectively be seeded in single rows, or in narrow double rows [about 0.15m (0.5 ft) apart] to guard against any skips that may occur during establishment.

J.K. Aase and J.L. Pikul, Jr., are soil scientists with U.S. Department of Agriculture—Agricultural Research Service, Northern Plains Soil and Water Research Center, Sidney, Montana 59270. *Published in cooperation with Montana State University Agricultural Experiment Station Journal Series No. J-2870. We thank L.L. Reitz and D.C. Harris for help with the field and laboratory work and C.D. Bighorn of the Soil Conservation Service for the elevation measurements.*

Vegetative strips must be dense enough to stop or reduce water flow and to trap soil and residues carried by water, and tall enough to reduce wind erosion and provide a protected environment for plants. Snow catch and subsequent snowmelt are important components of the water budget on the semiarid northern Great Plains. Grass barriers can accumulate snow for subsequent snowmelt and water accumulation in the soil profile.

Grass barriers create a favorable environment for plant growth by reducing wind speed, suppressing soil water evaporation, and increasing early season soil temperatures (Aase and Siddoway). Increased crop production in the barrier system is large enough to offset any yield loss that may occur due to land occupied by the barriers (Aase and Reitz).

Tall wheatgrass barriers are approved as an interim conservation practice in Montana (U.S. Department of Agriculture—Soil Conservation Service). On land that will be brought back to production after Conservation Reserve Program contracts expire, we suggest that grass strips be left as temporary buffer strips until permanent grass barriers can establish in about 1 year.

Aside from benefits of grass barriers already documented, an additional benefit of the barriers has become evident on hillsides during 25 years of barrier farming. Stair-step patterns have developed downslope next to each grass row. Slope length and steepness are important factors in the erosion process. The grass barriers interrupt slope length and the steps reduce steepness suggesting that grass barriers may substitute for mechanically formed terraces. Our objective was to document formation of hillside terraces incident to the establishment of grass barriers.

Materials and methods

Eleven double-row [0.90 m (3 ft)] tall wheatgrass barriers, 530 m (1,740 ft) long, with 15 m (50 ft) cropping intervals were seeded in 1967 11 km (7 mi) north of Culbertson, Montana, on a Williams loam (fine-loamy mixed, Typic Argiboroll) and became established in 1968. The barriers were oriented in a north–south direction, according to field orientation, which resulted in a 45° angle to the prevailing erosive winds from the northwest. The barriers reach a height of about 1.2 m (4 ft) and the stems remain erect throughout the winter. The study was originally designed as a "farm-size" study, aligned with conventional farming directions with no consideration of contours, and made large enough for conventional farm equipment to be used.

Numbered from the west, the first, fifth, and tenth crop strips were cropped annually in a rotation of either spring or winter wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.) and safflower (*Carthamus tinctorius* L.). The second, third, and fourth crop strips were in a 3-year fallow–spring wheat–winter wheat rotation. The sixth and seventh strips were in a fallow–spring wheat rotation, and the eight and ninth strips in a fallow–winter wheat rotation. The fallow period before spring wheat seeding is 21 months. Before winter wheat seeding the fallow period is 14 months. The crop strips were cultivated on the average four times during fallow periods with "V"-blades to a depth of about 10 cm (4 in). Seedbeds were prepared with a tandem disk and "V"-blades.

Reprinted from the *Journal of Soil and Water Conservation*
January-February 1995, Volume 50, Number 1
Copyright © 1995, Soil and Water Conservation Society

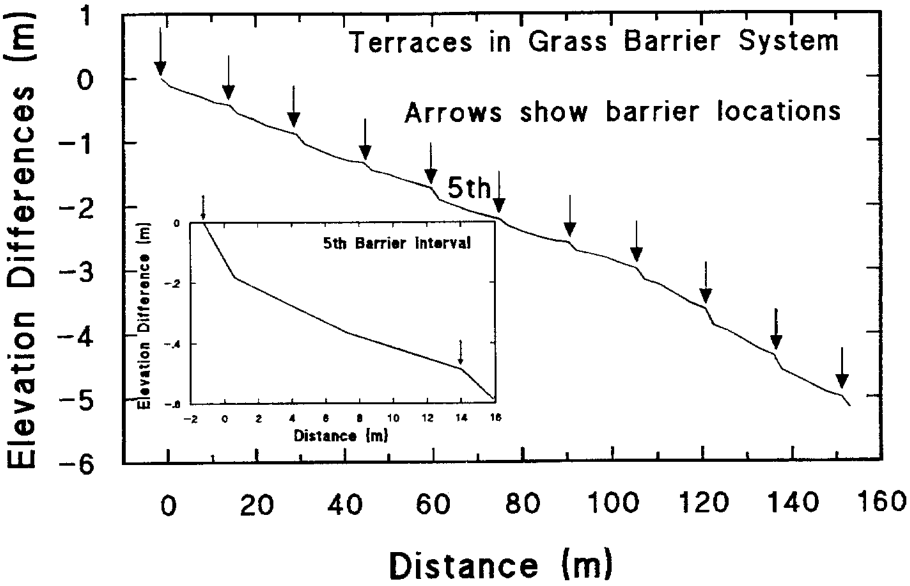

Figure 1. Elevation differences across 11 grass barriers with 15-m cropping strips between each grass barrier. The curve represents the average of four transects measured down slope from west to east

We established four west–to–east transects 15 m (50 ft) apart in the fall of 1991 on a selected segment of the barrier system with a near 0% slope from north to south. This was done to avoid any confounding by slopes parallel to the barriers. Within each cropping interval five sample point locations, as measured from west to east, were established along each transect at 0.6, 4.0, 7.3, 10.7, and 14 m (2, 13, 24, 35, and 46 ft) from the downslope edge of each grass barrier, resulting in 50 sampling points along each transect. Elevation at each sample point was referenced to a point about 12 m (40 ft) west of the barrier system.

To document soil physical and chemical evidence of soil deposition towards the east end (downslope) of each cropping interval we used a hydraulic soil sampling machine to extract soil cores to about a depth of 0.9 m (3 ft) at each sample point. Two hundred soil cores were extracted within the barrier system. We stored the cores on sample trays manufactured from corrugated fiberglass and plywood. Depth to calcium-carbonate layer was determined by detecting effervescence from application of weak hydrochloric acid dropped on the cores. The depth was used as a reference from which soil loss/gain was measured. We cut the cores into 50 mm (2 in) segments that were air dried in preparation for total and organic carbon determinations. The mineral portion ($CaCO_3$) of carbon was reacted with weak hydrochloric acid before analysis for organic carbon. Carbon was determined using a commercially available carbon–nitrogen analyzer. Regression methods were used where applicable to analyze the data.

Results and discussion

Passive terrace formation in the barrier system is illustrated in Figure 1. Each transect showed a typical stair-step shape. The curve in the figure is an average of four transects, each of which showed the same pattern. Individual measurements showed maximum drops from one interval to the next of about 30 cm (12 in). Drops between barrier intervals generally increased with increasing distance downslope and as the original slope of the land increased. The insert shows a detailed transect of the fifth cropping interval, including the easternmost point in the fourth interval and the westernmost point in the sixth interval, and reveals an average drop from the fourth to the fifth crop interval of about 20 cm (8 in), and a minimal drop from the fifth to the sixth interval of about 10 cm (4 in). Estimated average original slope from a grass area west of the westernmost grass barrier to a grass area east of the easternmost grass barrier is about 3.2%. Current average slope between grass rows in each interval is about 2.2%. Average slope, or "drop," from the fifth measurement point in one interval to the first measurement point in the next interval is about 7.9%.

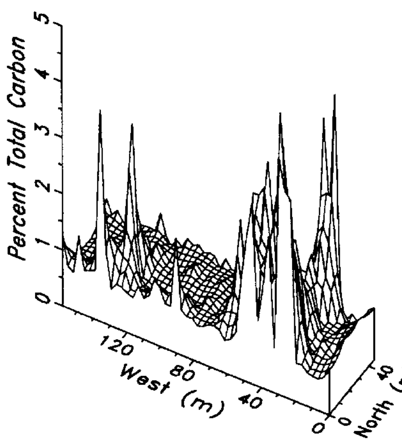

Figure 2. Total carbon concentration in the 25– to 30–cm depth interval across four transects of barrier system

Profile characteristics of the Williams glacial till loam vary considerably across short distances. To visualize spatial patterns of calcium carbonate within our 45 × 160–m (150 × 525 ft) sampling area, total carbon for selected depths was plotted three–dimensionally using kriging interpolation methods ("SURFER" v.4; Golden Software; Golden, Colorado). Total carbon includes organic carbon and mineral carbon in form of $CaCO_3$. Beginning at the 25 cm to 30 cm (10-12 in) depth (Figure 2), we detected significant amounts of $CaCO_3$. Organic carbon accounts for about 0.6% of total carbon at this depth. Slope positions with high levels of total carbon indirectly identify locations that have had overlying soil stripped away. The position at 60 m (200 ft) west (Figure 2) corresponds to the location of the seventh and eighth barrier interval (Figure 1). This is also a convex slope position where soil cutting would be expected to be more severe than on other slope positions.

Depth to carbonate layer (B3ca horizon) was measured to determine hillside locations for soil gain or loss. Even though there was considerable variation in the measurements, a trend in soil depth as related to position within a cropping interval was evident. Depth to the $CaCO_3$ layer by position within cropped intervals showed a significant (P = 0.01, r^2 = 0.91, degrees of freedom = 198) increase proceeding from west to east (downslope) (Figure 3). Each point on Figure 3 represents an average of 40 determinations.

The movement of soil downslope within barrier intervals is further illustrated

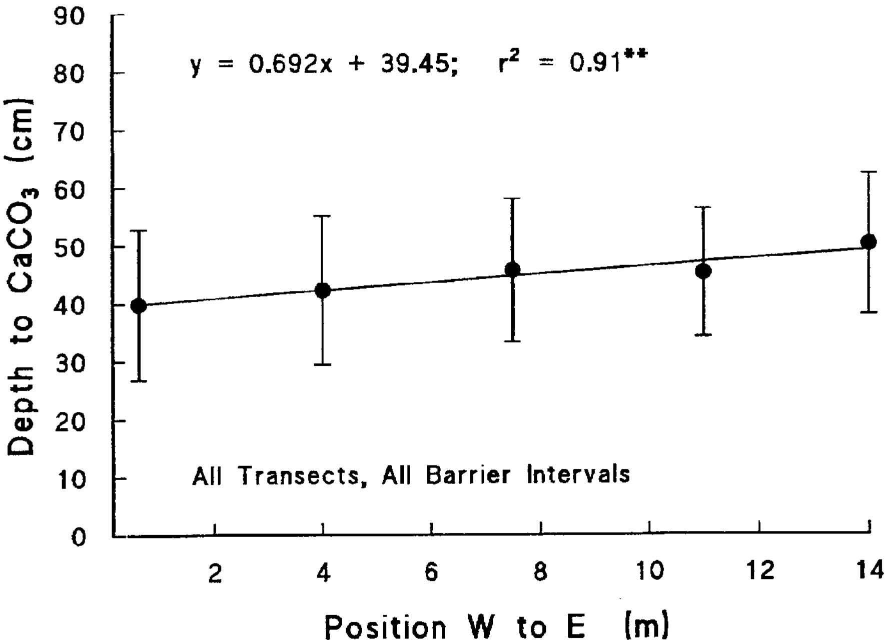

Figure 3. Depth to $CaCO_3$ layer. The plot represents all barrier intervals in all transects. Each point is an average of 40 determinations

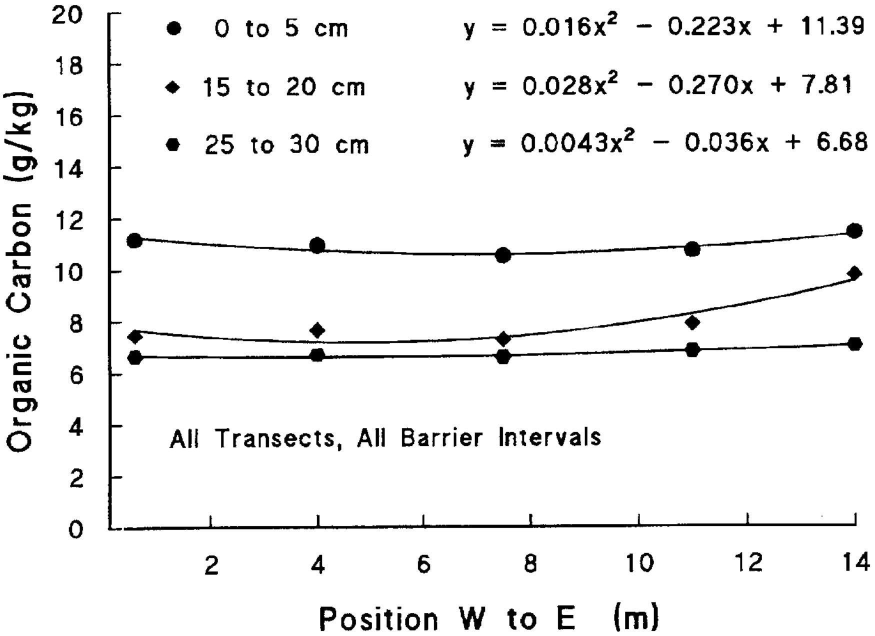

Figure 4. Organic carbon concentration in four depth intervals. The plot represents all barrier intervals in all transects. Each point is an average of 40 determinations

with organic carbon contents as shown in Figure 4. For clarity of presentation, only the results from three depth increments are shown. Each point on the figure represents an average of 40 determinations. There was a gradual increase in organic carbon from upslope to downslope at all depth increments, the greatest being in the 15 to 20 cm (6-8 in) depth increment, until we reached the 25 to 30 cm (10-12 in) increment, where organic carbon was the same at all positions.

Factors contributing to downslope soil movement include wind, rainfall, and tillage. Wind movement of soil was probably the least significant of the three because, as Aase, Siddoway, and Black have shown, the barriers are very effective in preventing wind erosion. Only when the wind is parallel, or nearly so, to the barriers is there a tendency for some significant soil movement to occur. Soil will move in response to heavy rainfalls. Since tillage operations are always done parallel to the barriers, soil tends to move downslope. Tillage probably plays a major role, in combination with soil movement during heavy rains, in downslope deposition of soil, eventually forming the characteristic stair-step pattern.

Grass barriers effectively control wind erosion, provide a protective environment for plant growth, store additional soil water from snow catch, and reduce soil water evaporation. They can also create a system of hillside terraces and thereby reduce soil erosion by water. As the slope between barrier intervals is reduced over time, there should be a positive influence on rainfall retention and water infiltration. A disadvantage of the narrowly spaced grass barriers is the breakup of large field strips into narrow strips. Consequently farming around the barriers is more time consuming and needs to be done more carefully than on regular field-size strips. Another disadvantage is that modern-day large farm equipment needs to be matched to narrow 12 to 18 m (40-60 ft) wide barrier intervals. Therefore, to be widely adopted, a need exists for education of the long-term benefits that grass barriers can provide.

REFERENCES CITED

Aase, J.K., and F.H. Siddoway. 1974. Tall wheatgrass barriers and winter wheat response. Agric. Meteorol. 13:321–338.

Aase, J.K., and L.L. Reitz. 1989. Conservation production systems with and without grass barriers in the northern Great Plains. Journal of Soil and Water Conservation 44:320–323.

Aase, J.K., F.H. Siddoway, and A.L. Black. 1985. Effectiveness of grass barriers for reducing wind erosiveness. Journal of Soil and Water Conservation 40:354–357.

Black, A.L., and J.K. Aase. 1986. Cropping systems' dependence on snow management. In: Proceedings of symposium: Snow management for agriculture, pp. 461–475. Swift Current, Saskatchewan. Great Plains Agric. Council Pub. No. 120.

Black, A.L., and J.K. Aase. 1988. The use of perennial herbaceous barriers for water conservation and the protection of soils and crops. Agricultural Ecosystems Environ. 22/23:135–148.

van Eimern, J., R. Karschon, L.A. Razumova, and G.W. Robertson. 1964. Windbreaks and shelterbelts. Tech. Note No. 59. World Meteorologocal Organization, Paris, France. 188 pp.

Marshall, J.K. 1967. The effect of shelter on the productivity of grasslands and field crops. Field Crop Abstr. 20(1):1–14.

Siddoway, F.H. 1970. Barriers for wind erosion control and water conservation. Journal of Soil and Water Conservation 25:18–184.

Skidmore, E.L., and L.J. Hagen. 1977. Reducing wind erosion with barriers. Trans. American Society of Agricultural Engineers 20:911–915.

U.S. Department of Agriculture—Soil Conservation Service. 1977. Tall wheatgrass barriers. Technical Guide, Section IV. Soil Cons. Serv., Bozeman, Montana.