Dr. Bruce Worcester and Dr. Lynn Brun use a portable refraction seismograph to detect and measure the depth to subsurface layers important in measuring saline seep development.

The Role of Alfalfa in Saline Seep Prevention

Lynn J. Brun and Bruce K. Worcester

Use of alfalfa in conjunction with continuous cropping or crop fallow will prevent seep formation on coarse-textured soils in southwestern North Dakota. A relatively high percentage of land must be maintained in alfalfa and this may not fit well with a primarily small grain operation; however, this system can provide guidance to those who already use alfalfa in their farming operations.

Movement of water beyond the root zone of annual crops, which is aggravated by fallowing, is a major factor leading to seep formation. Once below the root zone, water may move laterally until it surfaces at some lower landscape position where soluble salts are deposited and further concentrated by evaporation. Farmers can use a variety of cultural practices to contain and reclaim saline-seep areas. These include reducing fallow acreage, continuous cropping and use of grasses or deep-rooted perennials in recharge areas and the cropping sequence.

While the increasing demand for agricultural products should reduce summer-fallowed acreage in North Dakota, a high percentage of crop land will likely still be fallowed in the foreseeable future. This report discusses the periodic use of alfalfa to extract "excess" soil moisture that has accumulated under crop-fallow or continuous cropping management.

Water Extraction by Alfalfa

Ability of alfalfa to extract soil moisture has been determined by field samples taken within a 12-mile radius of Dickinson, North Dakota. Cores

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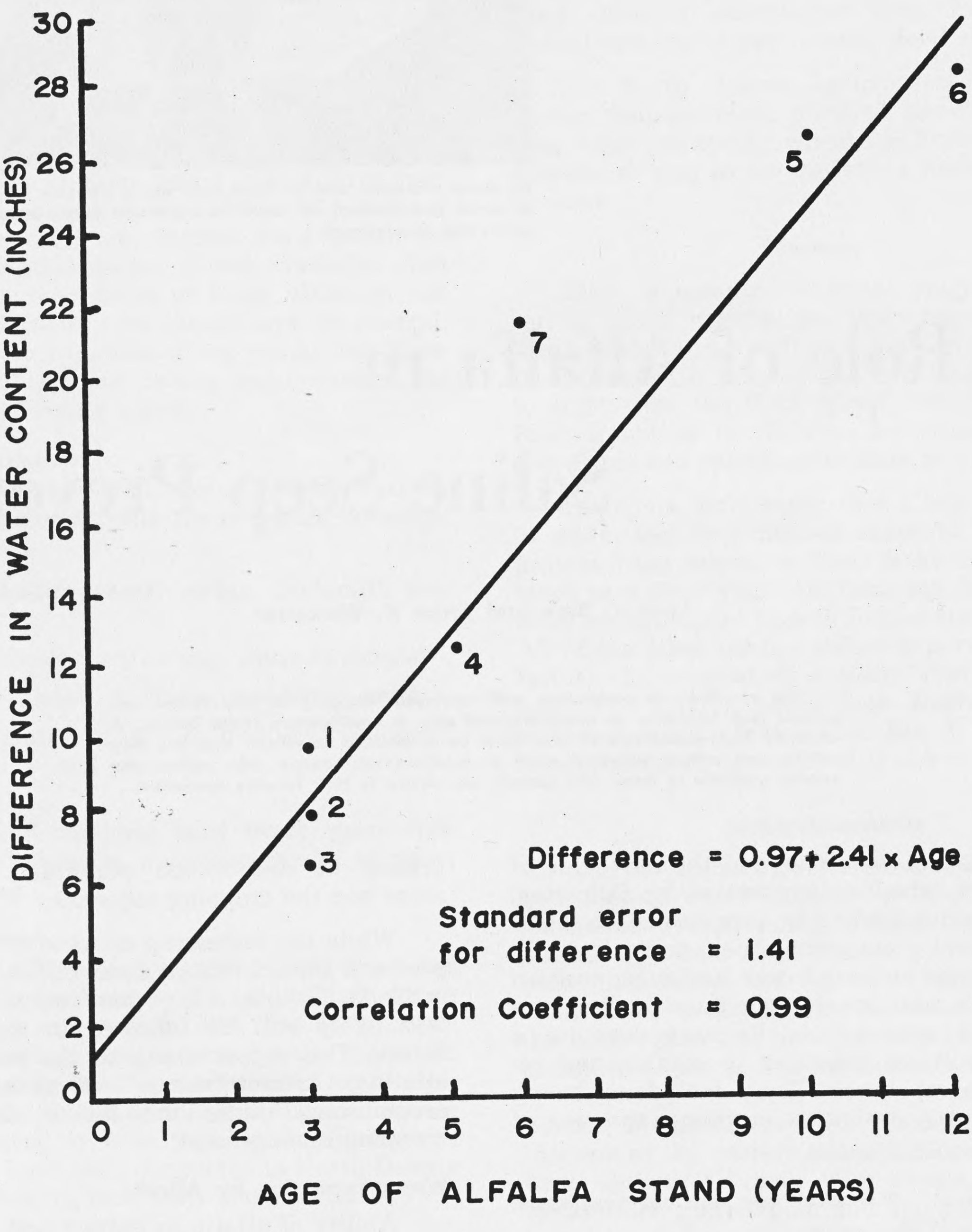

Figure 1. Difference in Water Content (Total Soil Water in Crop Fallow Minus Total Soil Water in Adjacent Alfalfa Stand) as a Function of Age of Alfalfa Stand. Sample 7 is Data of Brown (1) Not Included in Curve Fitting.

Table 1. Physical Description of Sample Data Points on Figure 1. Sample 7 is data of Brown (1).

Sample	Location	Soil Mapping Unit	Sample Depth (ft.)
1	4.5 mi. NW Dickinson, N. D.	Vebar-Parshall fine sandy loam, undulating	9
2	4.5 mi. NW Dickinson, N. D.	Vebar-Parshall fine sandy loam, undulating	11.5
3	4.5 mi. NW Dickinson, N. D.	Vebar-Parshall fine sandy loam, undulating	10
4	12 mi. S Dickinson, N. D.	Belfield-Rhoades loams, level	12
5	6 mi. N Dickinson, N. D.	Morton and Farland silt loams, gently sloping	13.5
6	5 mi. NW Dickinson, N. D.	Vebar-Parshall fine sandy loam, sloping	13
7	12 mi. N Geraldine, Mont.	Gerber	23

were taken in alfalfa fields of various ages and adjacent fields in crop-fallow culture. The difference in soil moisture between the alfalfa and crop-fallow management as a function of age of the alfalfa field is shown by Figure 1.

Though we were not able, in all cases, to reach the depth at which the soil moisture converged to a common value for the two cropping systems, we did reach a depth where the two moisture levels appeared to be converging or actually had converged. The cases where convergence had not been reached were extrapolated to a point of convergence which was not more than two feet additional in any case. It can be seen from Figure 1 that water extraction is highly correlated with age of alfalfa stand and did not seem to be influenced by soil type. These data indicate there is about 2.41 inches less water in the soil per year under alfalfa than under crop-fallow management.

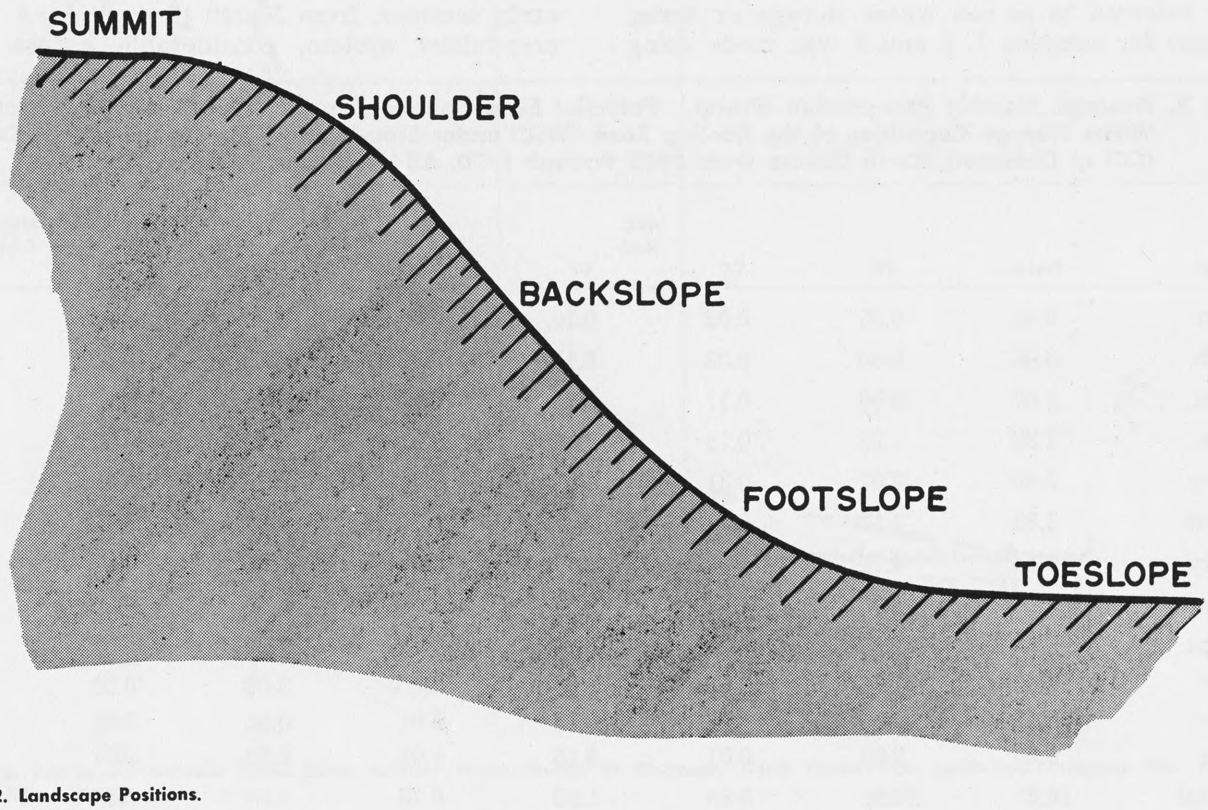

Figure 2. Landscape Positions.

Field Site Descriptions

Samples 1, 2 and 3 were taken in the same field at different landscape positions, shoulder, backslope and toeslope, respectively (Figure 2). Sample 4 was on a stream terrace, sample 5 was on a relatively flat upland position, and sample 6 was in a toeslope position. Table 1 gives further physical information for each sample location.

Seventeen cores were taken in the NW¼ Section 25, T 140N, R 97W (includes samples 1, 2 and 3). Most of these 160 acres are mapped as Vebar-Parshall fine sandy loam and are continuously cropped. There is one active saline seep about ½-acre in size in a footslope-toeslope position. A second small seep area in a footslope-toeslope position has been reclaimed in three years by planting the surrounding area to alfalfa. The farm operator stated seep areas occasionally occur on backslope positions and that he does not fallow because it aggravates the seep problem.

Coring indicated the surficial sands are underlain by a dense clay layer which was encountered at depths varying from 3.5 to 18 feet. The average depth to clay for all holes is about nine feet. There was little relationship between landscape position and depth to the clay layer which, in this case, confounds the problem of determining recharge areas and flow patterns related to seep formation.

Moisture Budget Model

An estimate of plant available water (hereafter referred to as soil water storage or water storage) for samples 1, 2 and 3 was made using pressure plate data. These data are shown in Table 2. The lower landscape positions have a considerably higher soil water storage capacity in the top 42 inches, which we are considering as the rooting zone for annual crops. The Cassel-Ramirez (2) moisture budget was utilized for two management systems, continuous cropping and alternate crop-fallow, and the soil water storage determined for samples 1, 2 and 3.

Table 2. Soil Water Storage for Three Landscape Positions for Vebar Fine Sandy Loam.

Depth (inches)	Soil Water Storage (inches) Sample 1 Shoulder	Sample 2 Backslope	Sample 3 Toeslope
0-6	0.88	0.80	1.22
6-12	0.67	0.91	1.04
12-18	0.52	0.87	0.86
18-30	1.36	1.40	1.66
30-42	1.22	1.24	1.56
Total	4.65	5.22	6.34

Climatic data for Dickinson from 1903 through 1970 was used to estimate potential evapotranspiration by the Thornthwaite method. The model then separates water use into storage, recharge, actual evapotranspiration and excess water. The term "excess water" describes water in excess of the soil water storage of the rooting zone and would either be lost as surface runoff or percolate beyond the root zone. The data in Table 3 show most excess water occurs in spring and early summer, from March through June. In the crop-fallow system, considerable excess water

Table 3. Average Monthly Precipitation (Precip.), Potential Evapotranspiration (PE) and Excess Water for Three Water Storage Capacities of the Rooting Zone (WSC) under Crop-Fallow (CF) and Continuous Cropping (CC) at Dickinson, North Dakota from 1903 through 1970. All Values are Inches of Water.

			Excess Water					
			WSC 4.65		WSC 5.22		WSC 6.34	
Month	Precip.	PE	CC	CF	CC	CF	CC	CF
Jan.	0.44	0.00	0.02	0.10	0.02	0.09	0.01	0.05
Feb.	0.41	0.00	0.03	0.12	0.02	0.11	0.02	0.05
Mar.	0.68	0.06	0.11	0.26	0.09	0.24	0.07	0.17
Apr.	1.38	1.22	0.19	0.36	0.12	0.32	0.07	0.24
May	2.40	2.87	0.31	0.38	0.27	0.35	0.19	0.30
June	3.82	4.13	0.23	0.29	0.20	0.27	0.17	0.22
July	2.24	4.71	0.02	0.02	0.02	0.02	0.01	0.02
Aug.	1.80	3.99	0.00	0.01	0.00	0.00	0.00	0.00
Sept.	1.28	2.41	0.02	0.02	0.02	0.02	0.02	0.02
Oct.	0.88	1.06	0.00	0.01	0.00	0.02	0.00	0.01
Nov.	0.51	0.06	0.01	0.06	0.01	0.05	0.00	0.03
Dec.	0.39	0.00	0.01	0.06	0.01	0.05	0.01	0.03
Total	16.23	20.51	0.95	1.69	0.78	1.54	0.57	1.14

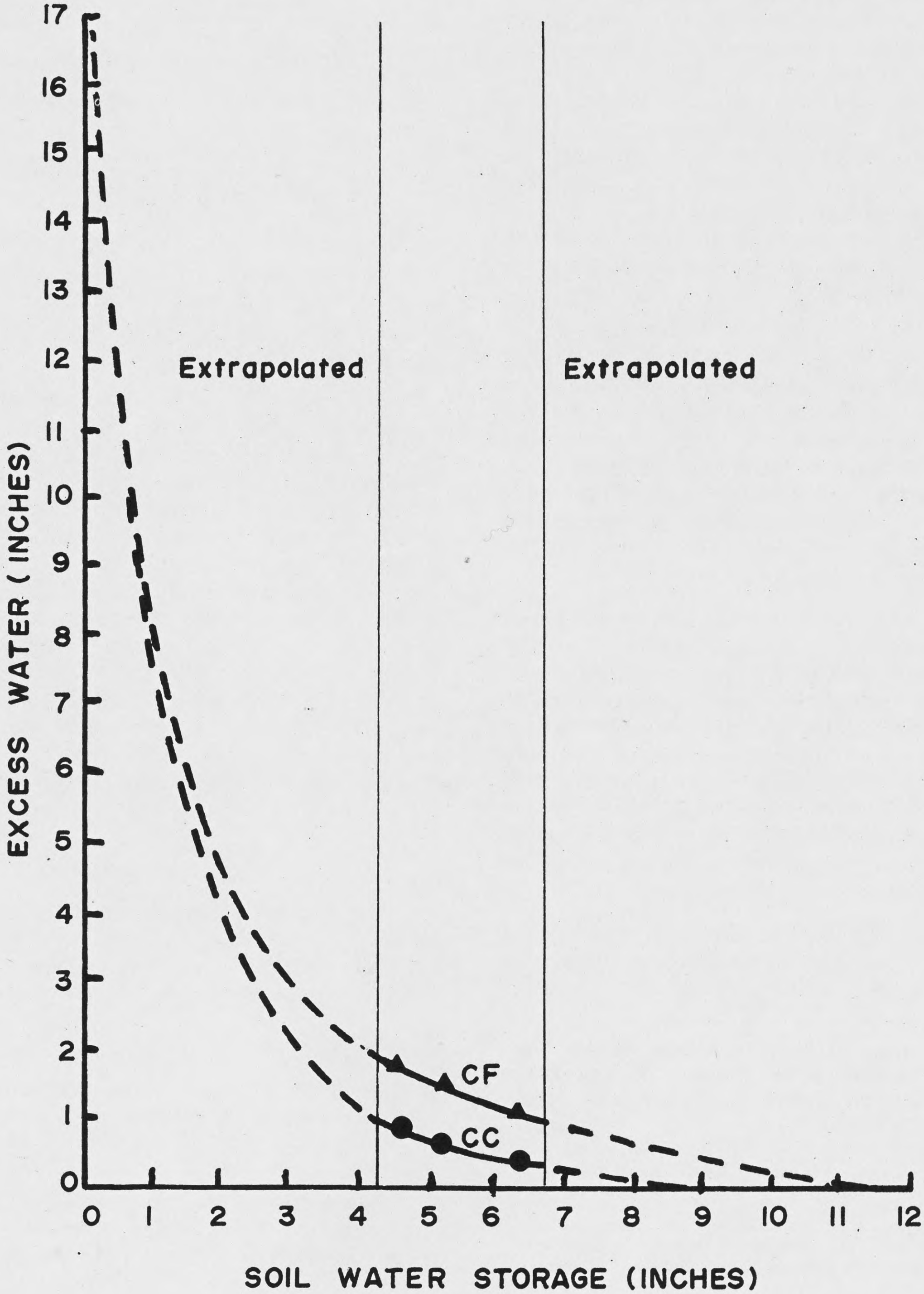

Figure 3. Relationship Between Excess Water and Soil Water Storage at Dickinson, North Dakota for Continuous Cropping (CC) and Crop Fallow (CF).

also occurs during the winter months. Excess water under crop-fallow is almost twice that under continuous cropping.

Figure 3 shows the relationship of excess water to soil water storage. While our data is for a limited soil water storage range, it is obvious that as soil water storage approaches zero excess water will rapidly approach the annual precipitation on the average. This helps illustrate why seeps in rangeland are not unusual phenomena near scoria or gravel capped hills. If we had a soil water storage of 16.23 inches, our excess water is obviously zero, on the average. However, since the average annual precipitation is not likely to occur in one day, the zero point should be considerably lower. When extrapolated, our curves intercept zero excess water near nine and eleven inches storage for continuous cropping and crop-fallow, respectively.

Use of Alfalfa

This information indicates seep formation may be alleviated by including alfalfa in the cropping sequence. Soil water storage can be measured or estimated from the textural class. The depth to the transmitting layer (clay layer or coal vein) is largely unknown, however. This can be estimated or determined by coring or seismic and geophysical techniques.

If a soil has a water storage of five inches in the rooting zone, the excess water will be 0.80 inches per year under continuous cropping and 1.55 inches per year under crop-fallow (Figure 3). Thus, one year of alfalfa will compensate for three years excess water under continuous cropping (2.41 divided by 0.80). One year of alfalfa will compensate for 1.55 years of excess water under crop-fallow (2.41 divided by 1.55). This is assuming all excess water contributes to seep formation through percolation beyond the root zone.

Table 4 shows the required percentage of land in alfalfa so that the extraction by alfalfa matches the excess water contributed by crop-fallow or continuous cropping. The alfalfa should be grown 0.6 years for each foot of soil above the transmitting layer. For example, if a soil had an average of 10 feet of sand overlying a clay layer, alfalfa should be grown for six years (0.6 times 10). The length of the crop-fallow or continuous cropping period is found by:

$$\frac{\text{(100-percent of land in alfalfa)}}{\text{(percent of land in alfalfa)}}$$

x years alfalfa should be grown

Assuming soil water storage of five inches, continuous cropping and six years of alfalfa:

$$\frac{(100 - 25) \times 6}{25} = 18 \text{ years}$$

In the above example, six years of alfalfa would be required to remove "excess" water accumulated during 18 years of continuous cropping.

Table 4. Percentage of Land in Alfalfa in the Cropping Sequence to Balance Excess Water Contribution under Crop-Fallow and Continuous Cropping.

Soil Water Storage (inches)	Average Annual Excess Water (Inches)		% of Land in Alfalfa	
	Crop Fallow	Continuous Cropping	Crop Fallow	Continuous Cropping
4	2.10	1.20	47	33
5	1.55	0.80	39	25
6	1.20	0.60	33	20
7	0.90	0.25	27	9

Conclusion

The accuracy of the results depends upon the validity of the data shown in Figures 1 and 3. The relationship between age of alfalfa stand and water extracted is based on actual field data and should vary only slightly for other southwestern North Dakota locations. As the difference between potential evapotranspiration and precipitation increases, we would expect a greater rate of soil water extraction. Figure 3 is certainly correct in principle. The Cassel—Ramirez moisture budget is similar to Palmer's (3) method with an improved approach for extraction of soil water. Based on field experience in the Dickinson area, the results seem reasonable since the area in which most of the work was done had seep problems similar in degree to that described by the model.

Acknowledgement

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