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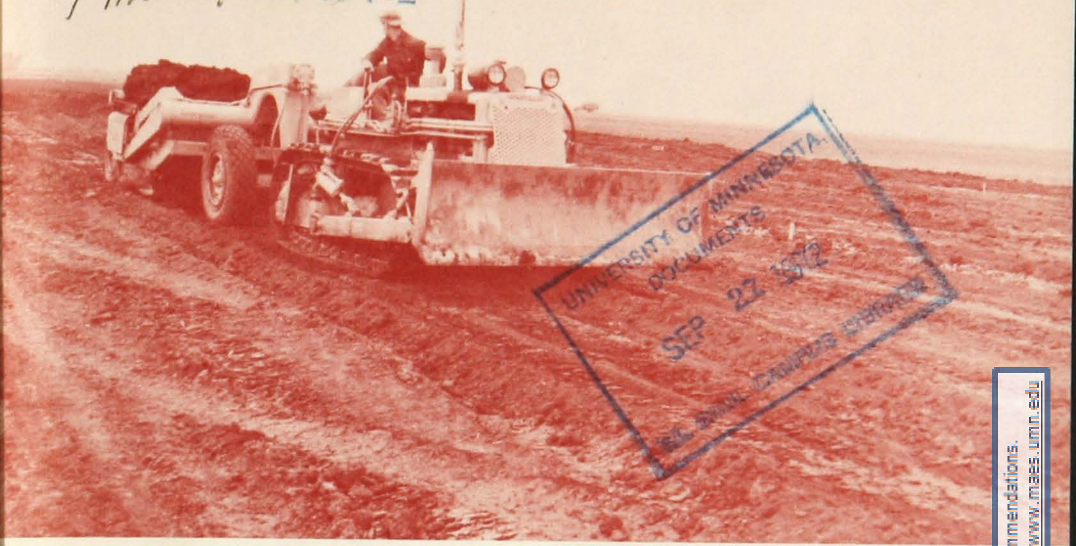

land forming in the red river valley

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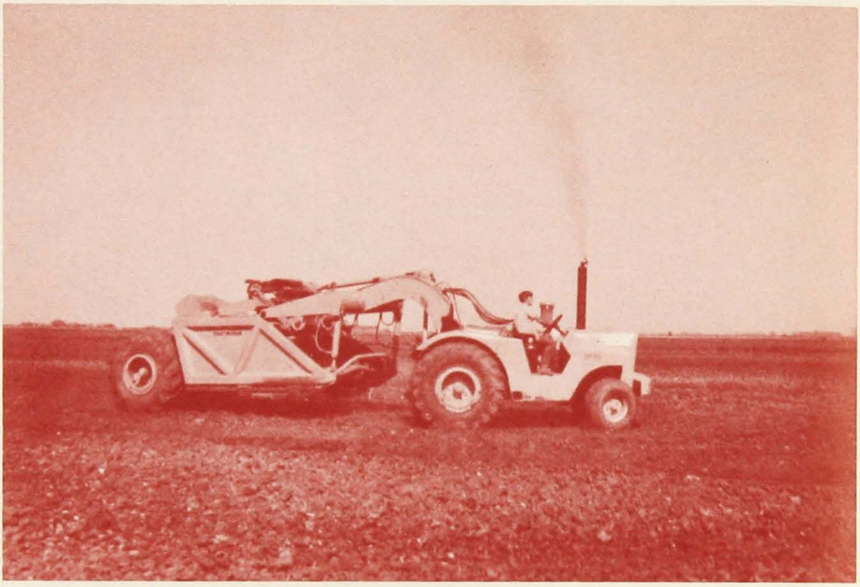

Custom operators are available for land forming.

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Land Forming in the Red River Valley

Olaf C. Soine

"Land forming" (1)* means reshaping the surface of the land to insure orderly movement of water over a field or section of a field, and to provide better distribution of water in the soil. It includes ditching, filling low spots, building grades if no natural slope exists, and smoothing.

The flat land of the Red River Valley, pitted with shallow depressions and potholes, is in need of some land forming to help improve the distribution of water over the land surface for normal crop needs and to allow for the removel of excess water. There are approximately 2 million acres of this type of land in the Valley, composed mainly of the Fargo and Bearden soil series. On land where these small depressions and potholes occur, water runs off the high land and collects in the low areas. In the spring they are too wet to be tilled and must be seeded at a later date. Often during the growing season excessive rain from thunderstorms drowns out the crops in these depressions, resulting in an economic loss to the farmer. Also, with the limited precipitation in this Valley, better moisture utilization is needed.

Land forming can cause soil compaction, especially if the land is very wet during land forming operations. There may be some loss of soil fertility if too much topsoil is removed and large areas of subsoil are exposed. However, with good engineering plans and management these losses can be kept to a minimum.

A land forming experiment was planned and developed in 1965 on a Bearden silt loam soil at the Northwest Experiment Station with help from the personnel at the Agricultural Research Service at Morris, Minnesota. Field construction took place in the fall of 1965 with the cropping system initiated in the spring of 1966. This experiment was concluded in 1970.

The objectives of this research were:

1. to determine the effect of five different methods of land forming on crop yields.
2. to determine machine requirements and cost.

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* Numbers in parentheses refer to literature cited.

Review of literature

There is limited information in the literature about methods of land forming, effect on crop yields, and construction costs. A 5-year study of land forming was conducted on two 60-acre experimental plots in Wilkin County, Minnesota, which dealt specifically with excess surface water problems of cultivated fields (2).

Variations in slope, soil type, and type of design affect costs (3). Hermsmeier and Larson, working with land forming experiments near Moorhead, Minnesota, concluded that cost of construction, depth of topsoil removal, and depth of available outlets are significant factors affecting the selection of the optimum grade and row length when land forming in the Red River Valley (4). Crop yields, average soil moisture, or soil temperature are not significantly affected by grade or length. Land forming tends to increase average yields by both increasing yields on formerly depressed wet areas in the field and permitting more timely farming of the remaining parts of the field.

Methods and procedures

The five different methods of land forming used were as follows:

1. Check—no land treatment.
2. Level grade—entire plot area formed to level grade.
3. Land smoothing—pulling soil from higher areas to fill low depressions without any instrument survey work.
4. 0.1 percent grade—land formed to 0.1 percent grade in one direction.
5. 0.2 percent grade—land formed to 0.2 percent grade in one direction.

Four different crops with four fertility levels were placed on each land forming plot.

Construction—The engineering staff from the Soil Conservation Service of Thief River Falls and at Crookston helped to design the field layout and staked out the plot areas. The experimental area, which covered 13.5 acres of land, was 320 feet wide and 1,840 feet long. The check plot, which contained several small depressions and potholes, was not disturbed during the construction.

In preparing the level grade plot, soil material from the high spots was pulled into the low areas by a tractor and land plane. A minimum amount of topsoil, 2 to 3 inches, was removed from a given area and no subsoil was exposed. This required a minimum of equipment and resulted in low cost construction per acre.

The land smoothing also was done with a tractor and land plane, moving soil from the high spots to low areas. No survey work was necessary in this method because the operator moved back and forth until the land appeared reasonably level. The least amount of soil was moved in preparing this plot.

To achieve the 0.1 percent and the 0.2 percent grades, the contractor moved soil from one end of each plot to the other end to build up the grade. No attempt was made to save the topsoil, and as a result subsoil was showing on one-fourth of the lower end of this area, but most of it was mixed with small amounts of topsoil. Approximately 5,000 yards of soil were moved in the construction of the two plots.

Cropping and fertilizer plan—The five main land forming plots were 368 feet long and 320 feet wide and were arranged side by side, extending 1,840 feet in length. A 4-year rotation of corn, wheat, barley, and alfalfa hay was laid out across each land forming plot. These plots were 80 feet wide and 1,840 feet long.

A randomized split plot design was used. The seeding rate for wheat (Chris) and barley (Larker) was 5 and 8 pecks per acre. Corn (85-day maturity) was planted in 22-inch rows at approximately 20,000 kernels per acre. Alfalfa was established with the barley crop and two cuttings were taken in the following year for hay. The alfalfa stubble was then plowed under approximately on September 1 of each year.

Three different fertilizer treatments were broadcast before planting and each plot received the same fertilizer treatment each year of the trial. Each of the fertilized plots and unfertilized check plot were 23 feet wide by 80 feet long. Soil samples were taken prior to forming and tested medium in nitrogen, low in extractable phosphorus, and very high in exchangeable potassium. Land treatments will be referred to as whole plots and fertilizer treatments as subplots.

Results and discussion

Crop yields varied from year to year depending on growing conditions such as weather, disease, and insect problems. Because of the late spring in 1966, wheat and barley were planted on May 24, approximately 1 month later than normal. Corn was planted on May 25. Disease and a midsummer drought lowered barley yields. Alfalfa was sown in the spring of 1967 and the first yields were taken in 1968.

The month of July 1967 was the driest on record at the Northwest Experiment Station. Both wheat and barley yields were the highest in 1967 for the 4-year period. The small grain plots were free from disease, which contributed to higher yields. However, alfalfa yields were average and corn suffered from drought with yields being lowest for the 4-year period.

An all-time record at the Northwest Experiment Station was set in June 1968 when a total of 8.86 inches of rain was recorded compared to 3.36 inches for the 65-year average. Small grain and alfalfa yields were good and corn yields were the highest for the period.

Growing conditions during 1969 were favorable and crop yields were near average. Above normal rainfall during the summer helped produce the highest alfalfa yields for the 4-year period. Above normal rainfall during the spring of 1970 provided moisture for two good cuttings of alfalfa hay in this fourth and last year.

Corn—Yields are given in table 1 for the different fertility treatments on the land formed areas. These varied on the different land formed areas, but no consistent trend was noticeable. In general, the highest yields occurred on the level and land smoothing areas and lowest on the 0.1 percent slope. Yields differed with the various fertility treatments, but no definite trend or pattern appeared. For example, corn yields from fertilizer 40-40-20 were significantly higher than from fertilizer 0-40-20 on land treatments 0.1 percent and 0.2 percent whole plots. This pattern did not appear in the remaining 3 years or in the 4-year averages. Average yields over the 4 years showed that fertilizer rate 0-40-20 produced the lowest corn yields, but this difference was not significant. Fertilizer rate 40-40-20 gave higher yields on three of the four land treatment areas than on the unfertilized check area.

Table 1. Ear corn yields on five land forming treatments with annual fertilization (1966-69)

1965 land treatment	Nutrients applied annually			Yield per acre				
	N	P_2O_5	K_2O	1966	1967	1968	1969	1966-69
	Pounds per acre			Bushels				
	0	0	0	82	68	105	85	85
Check	0	40	0	83	67	100	80	83
	0	40	20	73	61	105	74	78
	40	40	20	87	65	112	75	85
	0	0	0	88	62	104	88	86
Level	0	40	0	91	69	104	95	90
	0	40	20	75	77	94	91	84
	40	40	20	95	69	104	98	92
	0	0	0	96	67	100	87	88
Land	0	40	0	91	69	104	80	86
smoothing	0	40	20	92	71	93	80	84
	40	40	20	89	81	97	88	89
	0	0	0	81	47	100	84	78
0.1%	0	40	0	89	43	96	84	78
grade	0	40	20	89	55	91	80	79
	40	40	20	94	56	96	85	83
	0	0	0	81	65	112	88	87
0.2%	0	40	0	86	60	96	86	82
grade	0	40	20	72	57	98	89	79
	40	40	20	94	67	98	82	85

Table 2 summarizes corn yields on the five land forming whole plots from the four fertilizer treatments. Yields from all fertilizer plots on each land forming treatment were averaged and each value in table 2 represents 16 plots for each year and 64 plots for the 4-year averages. (All remaining crops are summarized in the same manner.) Although the corn yields on the five land treatments varied, the differences for any individual year or the 4-year averages were not significant. The level and land smoothing treatments had the highest yields. This may have been due in part to the fact that less soil material was moved or disturbed on these two treatments. Even though the check treatments had numerous potholes where some corn drowned out, corn yields were not significantly lower than those from the other land forming treatments.

All corn yields on the fertilized subplots for each land forming whole plot were averaged and each value in table 2 represents 20 plot annual averages and 80 plot 4-year averages. In 1966, corn yields on 40-40-20 were highly significantly different from 0-40-20, but not from the other two treatments. In the 4-year average, yields on treatment 40-40-20 were significantly different only from 0-40-20.

The fertility x land forming interaction was significant only on 1966 corn yields, which means that the combination of fertilizer and land forming was significant.

Table 2. Summary of average corn yields from land forming and fertilizer treatments (1966-69)

		1966	1967	1968	1969	1966-69
	Check	82	65	106	79	83
Land	Level	87	69	101	93	88
treatments	Land smoothing	92	72	98	84	87
	0.1% grade	88	50	96	83	79
	0.2% grade	83	62	101	86	83
Significance		NS	NS	NS	NS	NS
	0 0 0	85ab*	62	104	86	85ab
Fertilizer	0 40 0	88ab	61	100	85	84ab
rates	0 40 20	80a	64	96	83	81a
	40 40 20	92 b	67	102	86	87 b
Significance		‡	NS	NS	NS	†
Fertilizer x land forming interaction		†	NS	NS	NS	NS

* Any two averages followed by the same letter do not differ at the 5% level according to Duncan's New Multiple Range Test.
† Significance at 5% level.
‡ Significance at 1% level.
NS Not significantly different at 5% level.

Wheat—Wheat yields are given in table 3. Yields were highest on the check and land smoothing plots with the least soil movement, and lowest on the 0.1 percent, 0.2 percent, and level grade whole plots where the greatest soil disturbance and movement took place.

Table 3. Wheat yields on five land forming treatments with annual fertilization (1966-69)

1965 land treatment	Nutrients applied annually			Yield per acre				
	N	P_2O_5	K_2O	1966	1967	1968	1969	1966-69
	Pounds per acre			. . . . Bushels				
	0	0	0	17	56	41	47	40
Check	0	40	0	20	50	41	47	40
	0	40	20	15	52	40	47	39
	40	40	20	19	51	48	49	42
	0	0	0	23	48	33	43	37
Level	0	40	0	23	46	35	46	38
	0	40	20	25	40	36	42	36
	40	40	20	25	47	46	43	40
	0	0	0	23	52	41	43	40
Land smoothing	0	40	0	22	47	47	40	39
	0	40	20	20	57	41	41	40
	40	40	20	23	49	45	48	41
	0	0	0	20	44	32	39	34
0.1% grade	0	40	0	19	45	30	43	34
	0	40	20	20	45	36	48	37
	40	40	20	27	44	48	50	42
	0	0	0	27	43	36	40	37
0.2% grade	0	40	0	25	46	33	42	37
	0	40	20	29	42	30	40	35
	40	40	20	25	52	43	44	41

Fertilizer treatments on the 0.1 percent, 0.2 percent, and level plots produced the greatest variations in wheat yields. The 40-40-20 produced the most consistent yield increase when compared to the unfertilized plot, especially in 1968 and 1969. In 1968, 40-40-20 on the 0.1 percent grade produced a 16 bushel increase over the unfertilized plot.

Yields for the land forming whole plots are summarized in table 4. In 1967, those from the check treatment were significantly different from those on the 0.1 percent grade, but not from the other land treatments. In the 4-year averages, there were no significant differences in wheat yields on the land forming plots.

Table 4 shows that in 1968 the average fertilizer treatment yields and the 4-year average were highly significant. Fertilizer treatment 40-40-20 showed increases of 9 bushels in 1968 and 5 bushels in 1969 over the unfertilized plots.

Table 4. Summary of average wheat yields from land forming and fertilizer treatments (1966-69)

		1966	1967	1968	1969	1966-69
	Check	18	52 b*	43	48	40
Land	Level	24	45ab	38	44	38
treatment	Land smoothing	22	51ab	43	43	40
	0.1% grade	21	44a	37	45	37
	0.2% grade	26	46ab	35	41	37
Significance		NS	†	NS	NS	NS
	0 0 0	22	49	37a	42a	37a
Fertilizer	0 40 0	22	47	37a	43ab	37a
rates	0 40 20	22	47	36a	44ab	37a
	40 40 20	24	49	46 b	47 b	41 b
Significance		NS	NS	‡	†	‡
Fertilizer x land forming interaction		†	NS	NS	NS	NS

* Any two averages followed by the same letter do not differ at the 5% level according to Duncan's New Multiple Range Test.
† Significance at 5% level.
‡ Significance at 1% level.
NS Not significantly different at 5% level.

The fertilizer x land forming interaction was significant on wheat yield only in 1966.

Many farmers have equipment for land forming.

Barley—Yields are given in table 5. Highest yields were on the level, land-smoothing, and check plots. The lowest yields were on the more disturbed 0.2 percent slope treatments except in 1966 when the 0.1 percent plots were least productive.

Barley showed much more response to fertilizer than either corn or wheat. Yields were variably affected by the different fertility treatments depending on weather conditions and amounts of soil transferred. Treatment 40-40-20 was most consistently effective, with varying increases from a low of 2 bushels in 1966 on the land smoothing to a high of 32 bushels in 1967 on the 0.2 percent slope treatment.

Table 5. Barley yields on five land forming treatments with annual fertilization (1966-69)

1965 land treatments	Nutrients applied annually			Yield per acre				
	N	P_2O_5	K_2O	1966	1967	1968	1969	1966-69
	Pounds per acre			. . . . Bushels				
	0	0	0	35	60	57	53	51
Check	0	40	0	40	61	63	50	54
	0	40	20	32	55	58	53	50
	40	40	20	39	65	67	67	60
	0	0	0	37	67	56	45	51
Level	0	40	0	36	75	56	47	54
	0	40	20	36	82	62	46	57
	40	40	20	40	74	68	57	60
	0	0	0	34	77	57	49	54
Land	0	40	0	32	68	60	47	52
smoothing	0	40	20	37	84	61	46	57
	40	40	20	36	76	74	60	62
	0	0	0	24	46	61	38	42
0.1%	0	40	0	22	45	60	26	38
grade	0	40	20	27	53	62	38	45
	40	40	20	39	69	73	68	62
	0	0	0	28	44	52	26	38
0.2%	0	40	0	34	44	56	25	40
grade	0	40	20	34	52	62	24	43
	40	40	20	39	76	69	39	56

The 4-year summary in table 6 shows that the barley yields on land forming treatments were highly significantly different in 1967 and in 1969. The lowest 4-year average yield was on the 0.2 percent treatment, being 12 bushels less than barley yields on the land smoothing treatment.

Summary table 6 shows fertilizer treatments to be highly significantly different both annually and for the 4-year average. The 40-40-20 produced a 4-year average increase of 13 bushels over the unfertilized and the 0-40-0, and a 10 bushel increase over the 0-40-20.

Fertilizer x land forming interaction for barley yields was significantly different in 1967 and for the 4-year average.

Table 6. Summary of average barley yields from land forming and fertilizer treatments (1966-69)

		1966	1967	1968	1969	66-69
	Check	36	60ab*	61	56 b	53
Land	Level	37	75ab	61	49ab	55
treatment	Land smoothing	35	76 b	63	51ab	56
	0.1% grade	28	53a	64	42ab	47
	0.2% grade	34	54ab	60	29a	44
Significance		NS	‡	NS	‡	NS
	0 0 0	31a*	59a	57a	42ab	47a
Fertilizer	0 40 0	33ab	58a	59a	39a	47a
rates	0 40 20	33ab	65ab	61a	41ab	50a
	40 40 20	39 b	72 b	70 b	58 b	60 b
Significance		‡	‡	‡	‡	‡
Fertilizer x land forming interaction		NS	†	NS	NS	†

* Any two averages followed by the same letter do not differ at the 5% level according to Duncan's New Multiple Range Test.

† Significance at 5% level.

‡ Significance at 1% level.

NS Not significantly different at 5% level.

Alfalfa—Yields are given in table 7. This crop was sown each year with barley and the first yields were taken in 1967 on all but the land smoothing treatment.

Only one cutting was made in 1968 on the level and the land smoothing treatments because of summer drought. Highest alfalfa yields occurred in 1969, partly because of ample rainfall and generally good growing conditions. The lowest yields occurred in 1968. Alfalfa is more responsive to ample soil moisture conditions than are small grain crops, especially in midsummer for the second cutting.

There was no definite pattern in alfalfa yields from the different fertilizers applied. The 0-40-0 gave the most consistent increase when compared with the other three, but yield increases were not significant. Table 8 summarizes alfalfa yields on the land treatment whole plots and fertilized subplots. Yield differences on the land forming plots were highly significant in 1968 and in 1969, but not significant in 1967, 1970, and for the 4-year averages. The 4-year average yields on the 0.1 percent and 0.2 percent treatments were the highest, but the results were not significantly different from the other land forming treatments with less soil disturbance. This indicates no significant effect of the different methods of land forming on alfalfa production in the following 4 years.

Table 7. Alfalfa yields on five land forming treatments with annual fertilization (1967-70) (alfalfa hay at 15.5% moisture)

1965 land treatment	Nutrients applied annually			Yield per acre				
	N	P_2O_5	K_2O	1967	1968	1969	1970	1967-70
	Pounds per acre			. . . . Pounds				
	0	0	0	5885	4670	6799	5243	5649
Check	0	40	0	5566	4927	6504	6067	5766
	0	40	20	5566	4402	5771	4944	5170
	40	40	20	5485	4015	6312	5835	5412
	0	0	0	7757	2689*	6834	4337	5404
Level	0	40	0	6792	2784	6514	5802	5473
	0	40	20	7004	2025	6239	5425	5173
	40	40	20	6096	2899	6293	5841	5282
	0	0	0	No yield	2623*	6443	4726	4597
Land	0	40	0	"	2071	7065	5384	4840
smoothing	0	40	20	"	2033	6777	5114	4641
	40	40	20	"	2044	6380	4229	4218
	0	0	0	5953	4242	7119	3427	5185
0.1%	0	40	0	5536	5255	7163	4428	5596
grade	0	40	20	5644	5903	7056	4623	5807
	40	40	20	7304	4599	7379	4218	5875
	0	0	0	6832	4435	6233	4263	5441
0.2%	0	40	0	7309	5116	6479	4447	5838
grade	0	40	20	6931	5353	6088	4493	5716
	40	40	20	7403	4474	5871	4692	5610

* Only one cutting for level and land smoothing treatments.

Fertilizer treatments (summary in table 8) were significant only in 1970. In that year, 0-40-0 was significantly different from check, but not from 0-40-20 and 40-40-20. During 1968-70 and for the 4-year average, the 0-40-0 appeared to produce more alfalfa when compared with the other treatment yields, but the differences were not significant.

The only significant fertilizer x land forming interaction was in 1967.

Table 8. Summary of average alfalfa yields from land forming and fertilizer treatments (1967-70)

		1967	1968	1969	1970	67-70
	Check	5626	4504ab*	6347ab	5522	5500
Land forming treatment	Level	6912	2599ab	6470ab	5351	5333
	Land smoothing	No yield	2193a	6666ab	4863	4574
	0.1% grade	6109	5000 b	7179 b	4174	5616
	0.2% grade	7119	4845 b	6168a	4474	5652
Significance		NS	‡	‡	NS	NS
	0 0 0	6607	3732	6686	4399a	5356
Fertilizer rates	0 40 0	6301	4031	6745	5226 b	5576
	0 40 20	6288	3943	6386	4920ab	5384
	40 40 20	6572	3606	6447	4963ab	5397
Significance		NS	NS	NS	†	NS
Fertilizer x land forming interaction		†	NS	NS	NS	NS

* Any two averages followed by the same letter do not differ at the 5% level according to Duncan's New Multiple Range Test.

† Significance at 5% level.

‡ Significance at 1% level.

NS Not significantly different at 5% level.

Land forming costs—Table 9 gives the cost per acre for each land forming treatment. These figures of 1965 do not apply today, but may be used as a comparison in discussing the different land forming treatments. The land smoothing and level plots were constructed by the experiment station farm staff using the station's tractor, land plane, and carryall. A local contractor constructed the 0.1 percent and 0.2 percent grade treatments. No staking or survey costs are included as the Soil

Table 9. Construction costs in dollars per acre for five land forming treatments, 1965

Land treatment	Labor	Machine	Total
		...... dollars per acre	
Check	0	0	0
Level	10.62	45.55	56.17
Land smoothing	10.50	51.83	62.33
0.1% grade	17.50	99.50	117.00
0.2% grade	35.00	199.00	234.00

Conservation Service provides this service at no cost to cooperating farm members.

Soil conditions and the microtopography vary from farm to farm and will influence the cost of land forming. No one method will apply to all farms, and often a combination of land smoothing and installing shallow surface ditches is commonly used. Land smoothing is the method most commonly used by farmers. Many farmers own or can rent a land plane and carryall at a very nominal cost and do their own work. The field work is done in late summer and early fall and may take two to three seasons to complete a given field.

The 0.1 percent and 0.2 percent grade treatments had the highest construction costs. They are not practical methods of land forming for this area because of the large volume of soil to be moved and the time required.

Checking the grade on a land forming project.

Summary

This experiment was initiated in the fall of 1965 to determine the effect of different methods of land forming treatments on crop yields and per acre cost of each method. A crop rotation of corn, wheat, barley, and alfalfa was used and four different fertilizer treatments were applied annually.

There were some year-to-year differences in crop yields, but these were partly due to weather and other growing conditions. In general, yields were depressed on the 0.1 percent and 0.2 percent land forming plots, but not significantly lower. The 4-year average summary shows no significant changes in yields on the different land forming treatments.

The fertilizer treatments produced more yield variance than the land forming treatments. Barley was most responsive to the fertilizers. The fertilizer 40-40-20 gave the most consistent yield increases.

Construction costs were lowest on level and land smoothing treatments with no cost on the check areas. They were highest on the 0.1 percent and 0.2 percent grade treatments.

The most practical method of land forming in the Red River area shown by this study is the land smoothing method. Many farmers own equipment or can rent it at a nominal cost and do their own land forming with farm tractors.

There was no runoff or water standing on the four land formed treatments during the four growing seasons of this experiment. Some runoff occurred from the check areas and some water collected in the depressions on this natural surface.

Acknowledgement

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Literature cited

(1) Hermsmeier, L. F. and Olaf C. Soine. April 1967. Land Forming—A Means of Controlling Surface Water on Level Fields. Minnesota Science, Vol. 23, No. 3.

(2) Hermsmeier, L. F. February 1967. Land Forming—A Means of Controlling Surface Water on Level Fields. U.S. Department of Agriculture, Leaflet No. 539.

(3) Hermsmeier, L. F. and Curtis L. Larson. October 1959. Land Forming—A New Water Management Practice. Minnesota Farm and Home Science, Vol. XVII, No. 1.

(4) Hermsmeier, L. F. and Curtis L. Larson. 1962. Land Forming: Grade and Row-Length Studies in the Red River Valley. Reprint from Transactions of American Society of Agricultural Engineers. Vol. 5, No. 2.