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EFFECTS OF DIFFERENT TILLAGE AND FALLOW METHODS ON WHEAT YIELD AND SOIL QUALITY

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ABSTRACT

The study was conducted to determine the effects of different tillage strip and fallow methods on wheat yield, and yield components, and loam soil quality in semiarid Central Anatolia region in 2010 and 2011. Three plowing and fallow methods, the minimum tillage/stubble fallow, plowing/stubble fallow and plowing/non-stubble fallow methods were implemented, and bread wheat (*Triticum aestivum* cv. Ekiz) was planted. The plowing/stubble fallow method was more effective than the other methods in terms of high grain yield and yield components. This method led to a yield increase of ~50% in both years when compared to the minimum tillage/stubble fallow method. Although both wheat yield and soil quality were positively affected by stubble fallow method, the several farming problems, such as, ignorance of strip farming, difficulty of cultivating in a strip, and leaving a strip blank, and decreased annual net income due to the fallowed strips, may prevent the use of this conservation practice.

Key words: wheat, strip farming, minimum tillage, fallow, wind erosion, Central Anatolia.

INTRODUCTION

Drought effects have gradually increased in the Central Anatolia Region due to a classic continental climate in recent years. Studies have suggested that the level of underground water will decrease faster due to global warming and that some areas will be abandoned because agriculture will not be continued and wind erosion will occur again, as it did in the 1960s (Zengin et al., 2012). Desertification is the lack of water, and the presence of wind erosion related to the excessive consumption of underground waters, and this problem is common in the Konya Province (Zengin et al., 2012). Even if some administrative and technical measures have been taken, the underground water decrease so quickly that it will not be able to sustain agriculture. In addition, winds during some periods of the year erode the upper fertile soil. Drought, combined with soil lacking plant cover, increases wind erosion. Strip farming is not yet performed for cereal cultivation in the district, to help combat wind erosion and maintain soil fertility (Zengin et al., 2012). Natural factors, such as climate factors, a lack of precipitation, abnormal precipitation, topography and plant cover, in addition to human factors, such as the misuse of land and insufficient agricultural management trigger soil erosion (Akalan, 1974). Throughout Turkey, which is approximately 67,000,000 ha, soil fertility has gradually reduced, and erosion generally occurs in agriculture areas (TEMA, 2011). In Turkey soil erosion is classified as follows: 63% extremely severe or severe; 20% moderately severe; and 7% slightly severe. In the Konya Province, agricultural land covers 2,600,000 ha, with 1,600,000 ha of this land being sown every year. The remaining 1,000,000 ha is fallowed. Wheat is mainly sown in field crops among the cereals in the Konya Province. In 2009, wheat was sown on 627.485,4 ha, and 1.696.165 t of products was harvested in the Konya Province. The average yield was 2.700 kg ha^{-1} (TUİK, 2009), and the share of wheat in the field crop sowing area was approximately 52% (DİE, 2011).

In developed countries, fallowed cereal cultivation usually is carried out as strip

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farming perpendicular to the dominant wind direction in regions where there is severe wind erosion. Although agricultural strip farming began 625 years ago, its applications to control soil erosion started 75 years ago. Strip farming is more easily applied in governmental areas than in farm lands (Çanga, 2002). Strip farming is an agricultural system, and it consists of growing certain crops, such as wheat and barley, which are grown densely, thus maintaining the soil fertility, on relatively narrow land strips. In the region of cereal/fallow farming systems, cereal is sown in a strip, and the strip is then fallowed. Therefore, strips can be arranged as cereal-fallow-cereal-fallow (Doğan, 1989).

Strip farming is more effective on 2-12% slopes on strips of land with widths less than 400 m (Okur, 2007). According to Sayın (1980), strip farming supplies 40% more yield in comparison with tillage and sowing with slope direction in Central Anatolia. In addition, strip farming is about 100% beneficial with respect to reducing soil and water loss. Çelebi (1968) reported that strip farming is effective when applied in combination with other soil remediation methods. Strip widths depend on slope grade, total precipitation, soil hydraulic conductivity, erosion potential and equipment facilities. Steeper slopes require narrower strips (Çelebi, 1968; Okur, 2007). According to an experiment performed in the USA, soil loss decreases at a rate of 15% when the land is divided into 4 strips with widths of 400 m (Anonymous 2011a). An experiment conducted between 1974 and 1976 in the Karapınar District of Konya demonstrated that a strip width of 40 m resulted in minimal soil loss with a maximum yield (Topçu, 1979). In the same district, crop yield was maintained and wind erosion was prevented in an area of 2.000 ha by planting cereal and implementing the fallow strip farming agricultural production method (Anonymous, 2011b).

The objective of this study was to investigate the effects of different tillage methods and fallow systems used in strips arranged perpendicular to the dominant wind direction on the yield and yield components of bread wheat (*Triticum aestivum* cv. Ekiz), and soil properties affected by the wind erosion in a farmer field in the Apak Plato (Karapınar District, Konya Province) over a two-year period (2010 and 2011).

MATERIAL AND METHODS

The experiment area, Karapınar vicinity, was located in the southwest part of Central Anatolia on the ancient sea base lands. The area has alluvial soil, and is 1.050 m above sea level. The area has a climate type characterized as 'hot semiarid', which means that it is hot and arid in the summer and cold with little rain in the winter. According to the long term average, the sum of the total rain is 290 mm. The total precipitation during the period from October to June, which is the season when wheat is grown, was 304.8 mm in the first year and 408.7 mm in the second year (Table 1) (Anonymous 2011c).

Table 1. Meteorological data of the Karapınar District

Parameters	2009			2010					
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Mean
Air temp. (^oC)	14.4	5.1	5.0	3.7	6.1	8.2	10.8	17.0	20.7	10.1
Air humidity (%)	55.5	73.9	74.7	72.0	64.5	59.9	64.1	52.6	54.6	63.5
Precipitation (mm)	14.7	44.8	52.3	37.4	18.9	7.5	39.8	12.3	77.1	304.8*

Table l (continued)

Parameters	2010			2011						
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Total
Air temp. (^oC)	11.0	7.3	5.1	1.1	1.5	5.2	9.5	13.0	18.8	8.1
Air humidity (%)	68.7	64.5	74.4	84.4	79.8	72.9	68.3	69.4	58.2	71.2
Precipitation (mm)	56.8	6.5	93.4	34.9	53.3	35.3	28.8	73.3	26.4	408.7*

*Represents the total.

Ekiz bread wheat (*Triticum aestivum* cv. Ekiz), which is commonly grown in the district, was sown in the field experiments with different tillage and fallow methods for strip farming in the Karapınar District of Konya Province in the Central Anatolia Region in 2009 and 2010.

In the first and second year, the plots were set, plowed and the wheat sowed on October 10, 2009 and December 11, 2010 accordingly. In the spring, the crops were fertilized, and an herbicide was applied for weeds (Table 2). During sowing, 27 kg N ha^{-1} and 70 kg P_2O_5 ha^{-1} (DAP) were added to the base. Moreover, 80 kg N ha^{-1} (urea; 46% N) was added for the first top fertilization, and 40 kg N ha^{-1} (AN; 33% N) was added for the second top fertilization (Gökmen et al., 2008). For sowing, 450 seeds m^{-2} were sown by a seed drill with 16 cm row spacing. Details of the experimental timetable are given in the Table 2.

Table 2. Experimental timetable

Experiment operations	First year	Second year
Plot setting, base fertilizing (27 kg N ha^{-1}, 70 kg P_2O_5 ha^{-1}, DAP) and wheat sowing	10.10.2009	12.11.2010
Determination of emerged plants	14.11.2009	22.01.2011
Top fertilizing 1 (80 kg N ha^{-1}, urea, by machine)	06.03.2010	05.03.2011
Tiller number determination	21.03.2010	31.03.2011
Herbicide use	02.04.2010	08.04.2011
Top fertilizing 2 (40 kg N ha^{-1}, AN-33, by spring water, and spring irrigation 1; 6 hours)	10.04.2010	20.04.2011
Spring irrigation 2 (6 hours)	30.04.2010	No irrigation
Spring irrigation 3 (6 hours)	10.05.2010	No irrigation
Harvest	08.07.2010	12.07.2011

For each year three different soil tillage and fallow methods in strip farming were tested. The treatments were: 1) the minimum tillage/stubble fallow: minimum tillage + wheat sowing and stubble fallow (non-hoed), 2) plowing/stubble fallow: plowing + wheat sowing and stubble fallow (non-plowed), and 3) plowing/non-stubble fallow: plowing + wheat sowing and non-stubble fallow (plowed). For each treatment 4 strips (total 12 strips) with 50 m length, 40 m width were used (Figure 1).

Treatments		North
Plowing/non-stubble fallow	Plowing, wheat sowing in 2011 Non-stubble fallow (plowed) in 2010	12 x 40 m = 480 m; Wind direction (↑)
	Non-stubble fallow (plowed) in 2011 Plowing, wheat sowing in 2010	
Plowing/stubble fallow	Plowing, wheat sowing in 2011 Stubble fallow (non-plowed) in 2010	
	Stubble fallow (non-plowed) in 2011 Plowing, wheat sowing in 2010	
Minimum tillage/stubble fallow	Minimum tillage, wheat sowing in 2011 Stubble fallow (non-hoed) in 2010	
	Stubble fallow (non-hoed) in 2011 Minimum tillage, wheat sowing in 2010	
	50 m	South

Figure 1. Design of the field experiment

In each year and for each method two strips were created, and three independent and random measurements were carried out on each strip. The strips were set with east-west direction, perpendicular to the dominant wind direction which is from south to north. Wheat was sown on 6 strips which were spaced, one was sowed and the second strip was left blank, third strip was sown, and this pattern was continued for all strips (Figure 1). In the second year, the strips sown in the previous year were not planted, and the unplanted strips from the first year were planted.

The soils of the experimental strips, according to Kacar (1997), had a slightly alkaline pH, no salt problem, low organic matter, very rich lime and loamy texture (Tables 3 and 4). Both year the plant height, number of ears per m^2, number of grains per ear were determined in July before harvest, and thousand grain weight, harvest index and grain yield were determined after the wheat was harvested by a combine harvester.

Determination of the yield and its components were done by the following methods. Plant height: after the plants reached final height, the height (cm) from the soil surface to the tip of the upper spike (excluding awns) was measured on the main stems of five randomly selected plants from each plot (Yürür et al., 1981). Number of ears per m^2: during the period of early maturity, in two lines in the middle of each plot, the ear number was counted at a 1 m horizontal distance and the number of spikes per square meter was counted (Tosun and Yurtman, 1973). Number of grains per ear: the spikes on the main stem of 10 plants in each plot were harvested by hand, and the grains were counted and averaged (Yürür et al., 1981). Thousand grain weight: from each plot, 4 groups of 100 grains were counted, weighed using a balance with 0.001 g sensitivity, averaged and expressed in grams multiplied by 10 (Genç, 1974).

Harvest index (expressed as a percentage): the rate of grain yield obtained from each plot was calculated from the stubble and grain yields from the same area (Çölkesen et al., 1993). Grain yield: the plants grown long enough to be harvested in a certain field trial were harvested and threshed. The grains were then weighed using a sensitive balance, and the grain yield was expressed as kg ha^{-1}. The residual stubble amount was determined as estimated as 2000 kg ha^{-1} after the stubble was removed by a baler following harvest.

The Minitab statistical analysis package was used for the statistical analysis of the data obtained from this study, and a Duncan's multiple range test was performed in the comparison of applications that were significant (Düzgüneş et al., 1983).

Table 3. Soil properties before the first sowing (October 2009)

Properties	Minimum tillage/ stubble fallow		Plowing/ stubble fallow		Plowing/ non-stubble fallow		Mean
	Min. tillage, wheat sowing	Stubble fallow (non-hoed)	Plowing, wheat sowing	Stubble fallow (non-plowed)	Plowing, wheat sowing	Stubble fallow (plowed)	
pH (1:2.5 s:w)	7.55	7.50	7.65	7.60	7.60	7.60	7.58
EC (1:5 s:w; µS cm^{-1})	324.75	305.25	307.75	356.00	297.50	294.00	314.20
Org. matter (%)	1.84	1.76	1.84	2.04	1.64	1.50	1.77
Lime ($CaCO_3$; %)	47.15	44.10	38.95	40.15	44.90	40.20	42.57
NH_4+NO_3-N (mg kg^{-1})	19.28	38.10	27.78	32.70	18.80	25.98	27.10
P (mg kg^{-1})	25.68	19.95	15.18	17.10	16.50	21.08	19.24
K (mg kg^{-1})	303.75	265.75	364.00	477.00	331.25	309.00	341.79
Ca (mg kg^{-1})	4422.75	4510.00	4778.75	4735.25	4560.50	4627.75	4605.83
Mg (mg kg^{-1})	266.00	281.25	301.00	314.00	282.00	285.00	288.21
Na (mg kg^{-1})	29.75	45.25	70.25	56.25	39.00	39.25	46.63
Fe (mg kg^{-1})	5.29	4.61	4.54	4.83	4.83	5.44	4.92
Zn (mg kg^{-1})	1.24	1.16	1.36	1.84	0.77	0.88	1.21
Mn (mg kg^{-1})	26.11	21.48	18.27	11.93	20.97	21.24	20.00
Cu (mg kg^{-1})	0.81	0.82	0.75	0.87	0.97	0.96	0.86
B (mg kg^{-1})	0.78	0.82	0.86	1.10	0.80	0.81	0.86

Table 4. Soil properties after the final harvest (July 2011)

Properties	Minimum tillage/ stubble fallow		Plowing/ stubble fallow		Plowing/ non-stubble fallow		Mean
	Stubble fallow (non-hoed)	Min. tillage, wheat sowing	Stubble fallow (non-plowed)	Plowing, wheat sowing	Stubble fallow (plowed)	Plowing, wheat sowing	
pH (1:2.5 s:w)	7.15	7.27	7.32	7.42	7.15	7.27	7.26
EC (1:5 s:w; μS cm^{-1})	193.00	175.50	164.00	149.00	193.00	175.50	175
Org. matter (%)	1.38	1.16	2.10	2.39	1.38	1.52	1.66
Lime ($CaCO_3$; %)	46.60	45.65	36.30	44.75	46.60	22.28	40.36
NH_4+NO_3-N(mg kg^{-1})	2.34	4.34	8.53	8.80	2.34	4.34	5.11
P (mg kg^{-1})	11.08	8.22	11.17	10.48	11.08	8.22	10.04
K (mg kg^{-1})	284.50	345.50	485.00	400.00	372.00	287.00	362.33
Ca (mg kg^{-1})	4236.00	4214.50	4350.50	4440.00	4190.00	4178.50	4268.25
Mg (mg kg^{-1})	264.00	262.50	287.50	280.50	274.00	258.00	271.08
Na (mg kg^{-1})	32.00	30.50	52.50	35.00	32.50	51.00	38.92
Fe (mg kg^{-1})	3.52	4.54	2.59	3.24	3.32	3.57	3.46
Zn (mg kg^{-1})	0.58	0.76	0.68	0.79	0.84	0.59	0.70
Mn (mg kg^{-1})	3.52	5.16	5.43	4.89	6.55	5.77	5.22
Cu (mg kg^{-1})	0.65	0.74	0.79	0.74	0.70	0.54	0.69
B (mg kg^{-1})	0.78	0.88	0.90	1.00	0.87	0.85	0.88

RESULTS AND DISCUSSION

The effects of tillage and fallow methods on soil properties, within each treatments and for each treatment before sowing (October 2009) and after the final harvesting (July 2011) are presented in the Tables 3-5. As it appears from the Tables 3 and 4, generally, for all applications the means of the studied properties generally decreased after final harvest (July 2011) in comparison with the mean of same soil characteristics before the first sowing (October 2009). However, plowing/stubble fallow treatment increased soil organic matter, available potassium and also boron content, but differences were mostly not significantly (Tables 3 and 4).

With regard to important soil physico-chemical and chemical properties, the pH, organic matter, nitrogen, phosphorus and potassium content in the soils of the unplowed/uncultivated plot were lower than that of the soils in the cultivated plots. However, the lime content of the unplowed/uncultivated soil was higher than that of the cultivated soils (Tables 3-5). The organic matter in the plowing soil was higher than that of minimum tillage, because, organic materials could not be completely decomposed in the minimum tillage method. It may have resulted from the oxidation caused by plowing in semiarid conditions. Therefore, organic materials might be changed into soil organic matter. But, usually excess tillage decreases organic matter in the soil. If manure or compost is added into soil before sowing, the organic matter content decreases due to oxidation resulting from turning the soil upside down. Thus, to prevent the loss of organic matter and moisture in the soils of arid and semiarid areas, plowing must be conducted as little as possible, i.e. one time in one growing season, rather than 2 or 3 times.

The plowing/stubble fallow system increased the loamy soil N, which was involved in increasing soil organic matter content. But this treatment decreased available P in the soil root zone in comparison to the minimum tillage/stubble fallow method (Table 5).

Table 5. Mean values of the soil properties for each treatment before sowing (October 2009) and after the final harvesting (July 2011)

Properties	Minimum tillage/ stubble fallow		Plowing/ stubble fallow		Plowing/ non-stubble fallow	
	Before sowing	After final harvest	Before sowing	After final harvest	Before sowing	After final harvest
pH (1:2.5 s:w)	7.21	7.53	7.37	7.63	7.21	7.60
EC (1:5 s:w; μS cm^{-1})	184.25	315.00	156.50	331.88	184.25	295.75
Org. matter (%)	1.27	1.80	2.25	1.94	1.45	1.57
Lime ($CaCO_3$; %)	46.13	45.63	40.53	39.55	34.44	42.55
NH_4+NO_3-N (mg kg^{-1})	3.34	28.69	8.66	30.24	3.34	22.39
P (mg kg^{-1})	9.65	22.81	10.82	16.14	9.65	18.79
K (mg kg^{-1})	315.00	284.75	442.50	420.50	329.50	320.13
Ca (mg kg^{-1})	4225.25	4466.38	4395.25	4757.00	4184.25	4594.13
Mg (mg kg^{-1})	263.25	273.63	284.00	307.50	266.00	283.50
Na (mg kg^{-1})	31.25	37.50	43.75	63.25	41.75	39.13
Fe (mg kg^{-1})	4.03	4.95	2.91	4.69	3.44	5.14
Zn (mg kg^{-1})	0.67	1.20	0.73	7.90	0.71	0.83
Mn (mg kg^{-1})	4.34	23.79	5.16	15.10	6.16	21.10
Cu (mg kg^{-1})	0.69	0.82	0.77	0.81	0.62	0.96
B (mg kg^{-1})	0.83	0.80	0.95	0.98	0.86	0.81

On the other hand the P also remained in the soil because the fertilizer residue remained in the uncultivated strips from the previous year, resulting in decreased P uptake by the plants in the planted strips (Table 4). Generally in the arid or semiarid regions minimum tillage method positively affect on some soil properties, and is recommended for protection of soil moisture and less fuel consumption. However, in the current study, higher wheat yield and soil properties were obtained by the plowing/stubble fallow system. Probably, a clearer picture on the effect of treatments on soil organic matter and other soil properties could be obtained from longer term tillage/fallow experiments in strip farming.

The results of the analysis of variance and Duncan groups test related to the effects of different tillage and fallow methods on the wheat yield and yield components in strip farming in both years are shown in tables 6. Effect of treatments, with exception of the tiller number in the first year, and the number of grains per ear and the harvest the index in the second year, were statistically significant at $P < 0.01$ (Table 6).

The minimum tillage/stubble fallow method had the highest effect on the number of emerged plants per m^2 in the first year of the experiment, but the plowing/stubble fallow method had the greatest effect on this parameter in the second year. This situation may be due to the differences in the microclimate and soil pre-plant conditions each year. While the effects of the methods on the tiller number were not statistically significant in the first year, they were significant in the second year, and the highest tiller number (2.62) was obtained by the plowing/non-stubble fallow method, followed by the plowing/stubble fallow and minimum tillage/stubble fallow methods (Table 7). The slightly lower soil organic matter content at the minimum tillage/stubble fallow method in the first year was probably affected by this situation (Table 3). Moreover, the precipitation was greater in the second year and no irrigation needed in April and May in 2011 (Tables 1 and 2). Thus, rainwater was able to infiltrate into the loamy soil in a greater amount in the plowed strips. Çelebi (1968) stated that rain or irrigation waters are stored in higher amounts in plowed soil.

The highest tiller number was obtained by the plowing/non-stubble fallow method, which may have been due to the better-prepared seed bed. Similarly, Yürür et al. (1981) reported that wheat tiller number depends on plant variety, soil conditions and cultivation conditions.

In addition, better grain yield, plant height and some yield components (number of ears per m^2, number of grains per ear, thousand grain weight and harvest index) were also obtained in the plowing/stubble fallow method in both years (Table 7). This may have been due to the lack of optimal seed bed preparation by the minimum tillage method with respect to plant growth (Çelebi, 1968). Using the hoe machine for the minimum tillage method resulted in shallow tilled soil, so the plant roots could not grow downward due to harder soil layer. Low organic matter and drought increase soil hardness. Seed bed preparation by the hoe machine in the minimum tillage method is not optimal in arid environments. Tosun and Yurtman (1973) and Doğan (1989) reported that an homogeneous root-zone soil better supports plant root growth and that soil organic matter content, moisture content, time of plowing and soil depth are important factors affecting resulting crop yields.

Table 6. Results of the analysis of variance on effects of different tillage and fallow methods on wheat yield and yield components in strip farming

Years	Variance source	DF	Mean of Squares							
			Sprouting plant m^{-2}	Tiller number	Plant height	Number of ears per m^2	Number of grains per ear	1000 grain weight	Harvest index	Grain yield
2009-2010	Treatments	2	3305.0**	0.7800	119.46**	845341**	12.875**	6.0648**	20.566**	59809**
	Error	15	10.9	0.5413	1.95	8	0.249	0.0027	0.142	137
2010-2011	Treatments	2	888.0**	1.1438**	20.580**	6233.9**	10.516	35.745**	3.734	56550**
	Error	15	0.13	0.0114	1.439	3.5	4.201	1.512	2.168	6

**$P < 0.01$

Table 7. The effects of treatments on wheat yield and yield components

Years	Applications	Emerged plant m^{-2}	Tiller number	Plant height (cm)	Number of ears per m^2	Number of grains per ear	1000 grain weight (g)	Harvest index (%)	Grain yield (kg ha^{-1})
First year (2009-2010 season)	Plowing/non-stubble fallow	280.0 b	3.1	75.1 b	483.3 b	23.0 a	44.88 b	33.03 b	5290 a
	Plowing/stubble fallow	268.0 c	2.9	80.1 a	681.2 a	23.5 a	46.40 a	36.00 a	5400 a
	Min. tillage/stubble fallow	313.3 a	2.4	71.2 c	468.7 c	20.7 b	44.50 c	32.60 b	3619 b
	LSD (P < 0.05)	*4.06*	-	*1.72*	*3.48*	*0.61*	*0.06*	*0.46*	*144.0*
Second year (2010-2011 season)	Plowing/non-stubble fallow	413.5 b	2.62 a	72.8 a	328.0 b	28.8	32.80 a	34.63	4218 b
	Plowing/stubble fallow	433.5 a	2.25 b	73.5 a	382.0 a	29.2	34.05 a	34.11	5624 a
	Min. tillage/ stubble fallow	411.5 c	1.75 c	70.0 b	323.9 c	26.8	29.45 b	33.02	3762 c
	LSD (P < 0.05)	*0.44*	*0.13*	*1.48*	*2.30*	-	*1.51*	-	*30.1*

CONCLUSIONS

In conclusion, the plowing/stubble fallow method resulted in an increased yield of 49.2% in the first year and of 49.5% in the second year compared to the minimum tillage/stubble fallow method. In addition to the yield, yield components had high values with the plowing/stubble fallow method. As soil fertility parameters, the pH, organic matter, nitrogen, phosphorus and potassium content of the minimum tillage method were lower than that of plowing one, while the lime content was higher in the minimum tillage plot soils. The main obstacles in utilizing the fallow stubble method, which gave positive results on soil quality, are the difficulty of strip planting, the presence of unplanted strips in fields, an ignorance of strip farming, and a decreased net income due to fallow strips left every year. To implement this method in semiarid regions, farmers should be reasonably subsidized by the government for areas left to fallow. In addition, systematic training should be given to farmers by public institutions and universities to inform the farmers of the positive effects of strip farming and tillage methods on the yield and soil quality. In semiarid regions, strip farming in agriculture and terracing on sloped areas should be utilized, and strips suitable to grading curves should be prepared. For more accurate results, field experiments with more strips and longer studies should be conducted.

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