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## ECONOMICS OF DRYLAND CROP ROTATIONS FOR EFFICIENT WATER AND NITROGEN USE

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### ABSTRACT

Conventionally tilled wheat-fallow systems may not be sustainable in the long term. Reducing tillage and maintaining a residue cover on the soil increases water storage, but to attain the maximum increase in water use efficiency (WUE), rotations must be intensified. Switching from wheat-fallow to wheat-corn-fallow and wheat-corn-millet-fallow systems has increased WUE by 60 to 100%. Although these new systems increase input costs by 65%, they result in net income increases of 30%. Compliance with the 1990 farm bill residue requirements can be attained with reduced tillage and extended rotation systems.

### INTRODUCTION

The modern Great Plains has a productivity far beyond the dreams of the most optimistic settlers and early scientists that contended with its eccentricities. Populations have boomed and retrenched several times since the late 19th century. Problems in the Plains have been closely linked with its unpredictable climatic conditions. Records show that since 1908 the probability of receiving 75% or less of average annual precipitation at Akron and Burlington CO occurred 20 and 28% of the time, respectively (Greb, 1979). Obviously successful management must be able to deal with these extremes.

These erratic precipitation patterns led to the development of summer fallow to stabilize crop yields. Historically, fallowing has meant bare soils with a large erosion potential and very low water use efficiency (WUE). A wheat-fallow system using moldboard plow tillage lost 28 t/A per 24 month period over an eight year period at Alliance NE (Fenster, et al., 1977). Fallow precipitation storage efficiencies generally have been 25% or less since the 1930's and WUE less than 50 to 60 lbs/A/in (Greb, 1979).

Soil organic matter losses from cultivated soils in wheat-fallow systems average over 50% in most Great Plains soils. Fallowing compared to continuous cropping hastened organic matter loss (Haas and Evans, 1957).

Economic instability associated with the irregular weather patterns has been a problem in the Great Plains since the 19th century. Declining farm prices accompanied by rising production costs have complicated the situation in recent years. More than one-half of the land enrolled in the Conservation Reserve Program is found in 396 Great Plains counties (Skold, 1991). Obviously producers are opting for programs that improve economic stability when present practices are not highly profitable.

Water is the primary driver of production in the Great Plains. However, tillage choice can greatly modify the water driver because effective water capture and efficient use are greatly affected by it (Peterson, 1991). For example, fallow precipitation storage efficiencies can vary from less than 15% to as high as 50% depending on tillage system.

Efficient use of stored water and precipitation cannot occur if plants are deficient in N. Past management has caused most soils in the Plains to be N deficient. Nitrogen fertilization is necessary to achieve optimum yields.

Our objective is to discuss current research that addresses the problems enumerated above. Increasing soil cover, decreasing soil stirring, and judicious N fertilization are critical to their solution. The approach involves substitution of herbicides for some or all of the tillage operations usually associated with farming in the Great Plains. The goal of each step is maximizing residue cover during non-crop periods and seedling growth stages. Smika and Wicks (1968) showed 20 years ago that reduced and no-till systems simultaneously improved water storage and reduced potential erosion by increasing cover. Fenster and Peterson (1979) reported significant improvements in water storage efficiency with no-till wheat-fallow, but little overall improvement in grain yield compared to conventional bare fallow farming. Success of a wheat crop in the central Plains is more highly correlated with April through June rainfall than with stored water at seeding. Thus the improved water storage with reduced tillage can only be expected to contribute to wheat grain yield when precipitation in these months is below normal.

Exploitation of the water savings associated with reduced tillage is being attempted by insertion of more crops into the systems. Summer fallow time is reduced and the additional water is provided to spring planted crops such as corn, grain sorghum and millets. Rotations with two years of crop out of three, three years out of four and even continuous cropping are being researched. New systems are being studied over a range of climates and soils (Peterson, et al., 1991; Halvorson, 1990).

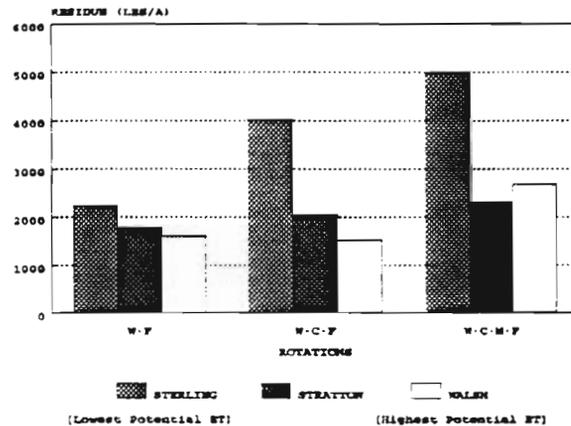
## RESULTS

### Erosion Potential

Crop residue covers are an effective erosion control device in the Plains (Fenster, et al. 1977). Installation of no-till cropping systems at three eastern Colorado locations greatly reduced erosion potential by increasing residue cover (Fig. 1). The minimum residue present in the most stressful environment, Walsh, with high ET, was about 1500 lb/A. This amount of wheat residue provides about 40-50% cover, which in turn should reduce erosion during fallow by 70% compared to bare conditions (Dickey, et al., 1983). A rotation such as wheat-corn-millet-fallow with more crop periods and fewer fallows increased residue weight by 60%, compared to

wheat-fallow, resulting in even better potential erosion control.

Figure 1. Crop residue on summit soils at winter wheat seeding in fall 1990 as affected by location (ET regime) and rotation.



Water Use Efficiency

Total production and WUE are dependent on total precipitation and on the effectiveness of that precipitation. Increases in evaporative demand increase potential ET and decrease precipitation effectiveness. Locations at Sterling, Stratton and Walsh CO each have about 16-17 inches of annual precipitation, but range widely in potential ET. Open pan evaporation at Sterling is 42 in/crop season but is 75 in/crop season at Walsh, which indicates the large potential ET gradient between these sites. Increasing rotation intensity has increased grain WUE markedly in all environments (Fig. 2). The wheat-corn-millet-fallow rotation has increased WUE by 100, 60, and 100% compared to wheat-fallow at the Sterling, Stratton and Walsh sites, respectively. Halvorson (1990) found similar relationships at Akron CO plus additional increases in WUE using annual cropping (Fig. 3). Intensifying rotations has increased WUE because it efficiently uses the extra water stored under no-till management.

Figure 2. Annualized grain water use efficiency (WUE) as affected by climatic area and crop rotation.

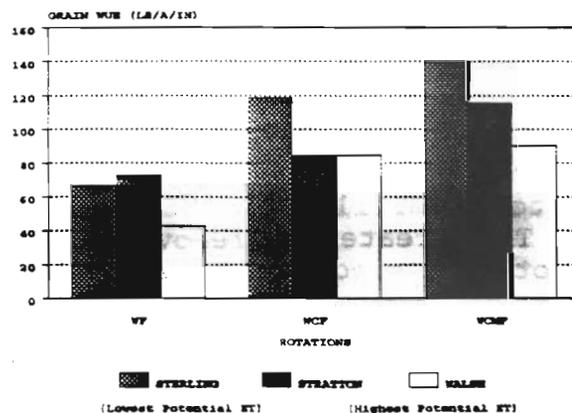
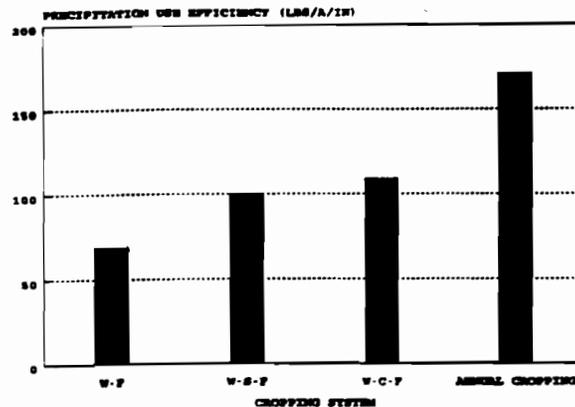


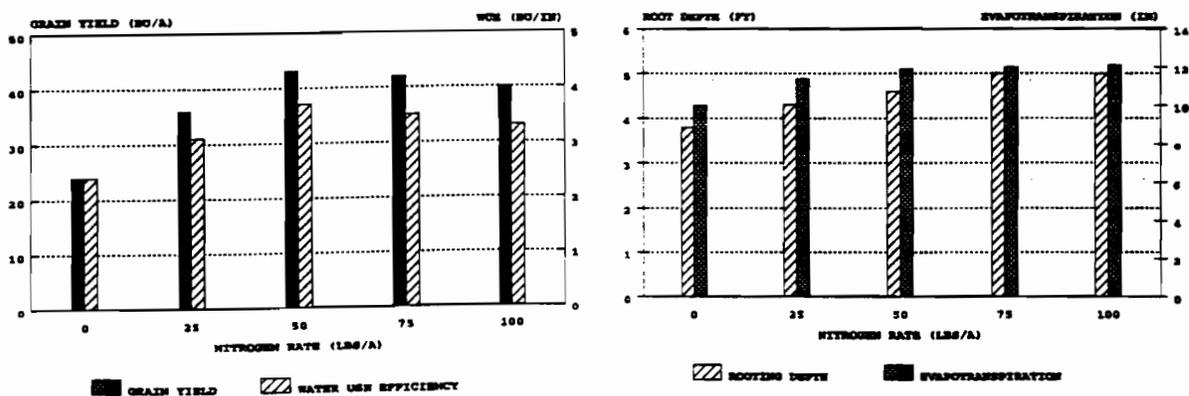
Figure 3. Precipitation use efficiency as affected by cropping system at Akron CO. (Adapted from Halvorson, 1990).



### Nitrogen Management

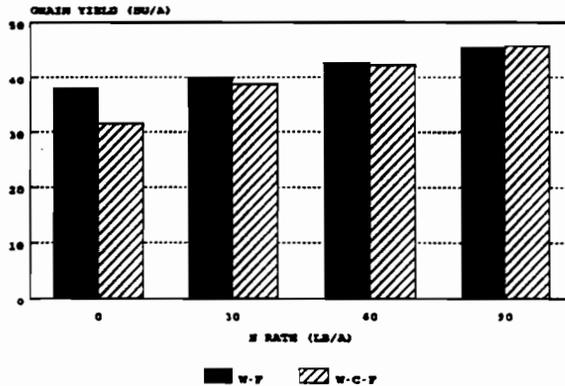
Grain yield and water use efficiency are improved when N deficient soils are fertilized. Nielsen and Halvorson (1991) showed that N fertilization maximized transpiration, but also enhanced root development (Fig. 4). They concluded that, although N fertilization increased transpired water, the exploration of more stored soil water by deeper rooting allowed increases in total production and WUE even in moderately stressed environments.

Figure 4. Grain yield, water use efficiency, root depth and evapotranspiration as affected by N fertilization. Adapted from Nielsen and Halvorson (1991).



Nitrogen response data from Sterling and Stratton CO indicate that more intense rotations like wheat-corn-fallow result in soils that respond more to N fertilization than soils in wheat-fallow systems (Fig.5). The greater N removal in grain in the more intensely cropped rotations increases the need for N fertilization.

Figure 5. Wheat yield response to N fertilization as affected by rotation and N rate at Sterling and Stratton, CO from 1989-91.



### Economics of Systems

Wheat yields have either remained stable or increased as rotation intensity increased, in spite of shorter summer fallow periods preceding wheat seeding (Table 1). Corn yields have been equal in the two rotations.

Table 1. Crop yields for 1988-1991 for the Sterling and Stratton sites as affected by crop rotation.

Crops						
Wheat			Corn		Millet	
W-F	W-C-F	W-C-M-F	W-C-F	W-C-M-F	W-C-M-F	
-----Bu/A-----						
41	41	45	78	78	37	
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Intensifying rotations increased gross income by 45% using a reasonable price scenario (Table 2). These incomes were annualized to account for varying rotation length and the unproductivity of the fallow year.

Costs of the more intensive rotations, compared to conventionally tilled wheat-fallow, increased by 65% because of added herbicides, more sophisticated planting equipment and increased harvesting cost etc. These costs do not include land cost and overhead. Net income has increased by extending rotation length and decreasing summer fallow. Wheat-corn-fallow, compared to tilled wheat-fallow, increased net income per acre per year by 30%. No-till wheat-fallow decreased net income by 35% compared to tilled wheat-fallow. The wheat-corn-millet-fallow rotation increased net income with millet prices at the long term average. However, proso millet markets are historically volatile compared to wheat, corn and grain sorghum, and the 1991-92 price is now \$1.50/Bu compared to the average of \$2.80/Bu. Using the lower price wheat-corn-fallow is superior to wheat-corn-millet-fallow by about \$9.00/A/Year. Benefits of the longer rotation, such as

improvements in weed control and residue cover, may still make it the best choice even when millet prices are low.

Table 2. Annualized gross income, system costs, and net income as affected by crop rotation and tillage system.

Rotation	Gross*	System Costs		Net	
		Tilled	No-till	Tilled	No-till
-----\$/A/Year-----					
W-F	80.22	32.11	49.57	48.11	30.66
W-C-F	117.96	-	54.60	-	63.36
W-C-M-F	117.50	-	51.32	-	66.18

\* Wheat @ \$4.20/Bu for first 30 bu and \$3.13/Bu for balance, Corn @ \$2.48/Bu, and Millet @ \$2.80/Bu. [Historic average target and farmgate prices for wheat, corn and millet in Colorado since 1980 (Hudson and Fretwell, 1991)]

#### DISCUSSION

Maintaining residue on the soil surface and decreasing soil stirring improves WUE, decreases erosion potential, and increases total productivity when rotation intensity is increased. The improved productivity leads to increased economic returns to the producer. Proper residue management with reduced tillage permits the addition of spring crops to the rotations and decreases the use of wasteful summer fallow. The combination of reduced soil stirring and greater stover production with increased cropping intensity has allowed soil organic matter levels, both C and N to be increased (Wood, et al. 1991). These changes were evident just four years after establishment of the intensive rotation.

Wheat-fallow, a monoculture system, also has resulted in increased grassy weed problems such as jointed goat grass, downy brome, and volunteer rye. Westra (1990) estimated that these three weeds cost Colorado wheat growers in excess of \$20,000,000 annually. Changing to more intensive rotations with more time between wheat crops is probably the only feasible way to eliminate these weed problems, especially jointed goatgrass.

Compliance with the U.S. farm bill also will require a change in present practices. It appears that one way of being in compliance and remaining economically viable is to switch to more intensive crop rotations managed as a no-till or reduced till system.

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