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REVIEW OF SUSTAINABLE PRODUCTIVITY OF DRYLAND FARMING SYSTEMS THROUGH FURROW DIKING

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Abstract

In areas where crop production is limited by low and variable rainfall, the search continues for cultural practices that conserve soil and water while maintaining or improving crop yield and quality. One of such practices is furrow diking (also known as tied-ridging, furrow damming, basin tillage or micro basin tillage). The practice involves constructing small earthen dams or dikes at certain intervals in furrowed fields to capture potential runoff water, thus increasing the ponding period for infiltration. This paper attempts to highlight the potentials of this land configuration practice for improving crop yields in areas where crop production is limited by low and variable rainfall. The constraints associated with its use have been identified and prospects for improving its effectiveness under various climatic conditions are discussed. Cost implications of the practice, as well as suggestions for scaling down costs are considered. Maximum benefits from furrow diking are generally obtained in dryland areas characterized by high intensity, short duration rainfall events which produce significant runoff.

1. Introduction

It is widely acknowledged that low productivity of crops grown in many parts of arid and semi-arid tropics is largely due to the harsh environment, with rainfall and soil being the major environmental constraints (Chiroma *et al*., 2006a., ICRISAT, 1987). In these areas, low and variable rainfall coupled with high evaporative demand occasioned by supra-optimal temperatures often expose plants to varying degrees of stress even during normal rainfall years. Furthermore, majority of the soils that occur in these regions have poor structural stability which contributes significantly to loss of water and soil during intense rainstorms. During rainfall events, runoff losses exceeding 50% is not uncommon in these zones (Parr *et al*., 1990) thus, efforts in improving crop production in these water deficit areas should consider cultural practices with potential for preventing runoff and increasing infiltration. Furrow diking also known as tied ridging is one of such practices. Furrow diking as the name implies, is the practice of putting earthen dikes periodically in a furrowed field to obstruct the flow of water, reduce runoff, and increase moisture storage for crop production (Jones and Stewart, 1990). The potential of furrow diking for conserving rain or irrigation water for crop use has been demonstrated in many dryland cropping systems (Jones and Nyamudeza, 1991; Selvaraju *et al*., 1999; Sow *et al*., 1997). This paper highlights the major research findings on furrow diking for improving dryland crop yields.

2. Description of furrow dikes

Furrow diking or tied ridging involves mechanically constructing small earthen dams periodically through a furrowed field to increase surface detention storage, thus preventing runoff and increasing infiltration (Jones and Stewart, 1990). Series of small basins created by these dikes hold the precipitation until it can be infiltrated into the soil. Depending on site and soil characteristics, furrows are blocked at 1 to 3 m intervals.

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3. Role of furrow diking in rainwater harvesting

The surface roughness created by the ridge and dikes obstruct the free flow of potential runoff water, thus providing enough time for increased water infiltration. According to Baumhardt *et al.* (1992), the contribution of furrow diking to increase in infiltration can be explained by three factors; (i) increased hydraulic head due to ponding of water in the diked furrow, (ii) reduced seal formation in the furrow, and (iii) tillage of the furrow before forming dikes. The potential of furrow diking in increasing infiltration and soil water storage have been demonstrated in several dryland cropping systems. Field experiments conducted in drought prone areas of southern India have demonstrated the advantages of tied and open ridge systems for soil water conservation (Selvaraju *et al*., 1999). Their study showed that the tied ridge treatment stored 15% more water at 0-15 m depth and 8% more water at 15-30 cm depth on 30 days after sowing than the flat bed on the alfisol during the first year of the experiment. During the second year of the experiment, the tied ridge treatment also stored 20% and 18% higher soil water than did the flat bed at 0-15 cm and 15-30 cm soil depths respectively on 90 days after sowing (Table 1). They attributed the increased soil water storage with the tied ridge treatment to reduced runoff and greater soil water retention in the furrows of the tied-ridge plots. In a similar research conducted on clay loam soil at Bushland, Texas, Sow *et al.* (1997) reported that furrow diking effectively captured rainfall and reduced the amount of runoff in both the experimental years. Average runoff from the flat bed plots was about 56% lower than from the no-tillage plus residue plots. Early in the season, when little canopy was available to completely cover the plots, runoff from the bare soil surface resulted in much lower soil water content in the conventionally tilled and no-tillage plots when compared with the furrow-diked and no-tillage plus residue plots.

Table 1: Soil water content (m^3m^{-3}) at different depths as affected by land configuration in the Alfisol

Treatments	**1991-1992 (30 days after sowing)**		**1992-1993 (90 days after sowing)**	
	0-15 cm	***15-30 cm***	***0-15 cm***	***15-30 cm***
Flat bed	0.199	0.204	0.093	0.137
Tied ridge	0.229	0.219	0.112	0.162
Open ridge	0.209	0.216	0.107	0.157
LSD (0.05)	0.012	0.005	0.014	0.018

Source: Selvaraju *et al*. (1999).

Experiments carried out in semi-arid region of Zimbabwe showed that tying a furrowed field at 1.5 and 2.0 m intervals resulted in greater soil water storage compared with the traditionally prepared sites with 1.0 m row spacing on the flat (Nyamudeza, 1991). Land configuration practice such as tied ridging has also been shown to trap runoff water when rainfall exceeds infiltration in drought prone shallow soils of the West African Sahel (Hulugalle, 1990). Studies have shown that, for furrow diking to significantly reduce runoff, rainstorms must be of sufficient intensity and duration to exceed the infiltration capacity of the soil (Gerard *et al*., 1984; Baumhardt *et al*., 1992; 1993). These reports demonstrate the potentials of furrow diking for trapping runoff water in dryland cropping systems where rains often occur in intense storms. For example, rainfall intensities in many parts of West Africa usually range from 20-60 mm/h with high values sometimes reaching between 120 and 160 mm/h (ICRISAT, 1987). Because majority of the soils that occur in arid and semi-arid regions of West Africa are characteristically sandy and have poor structural stability, much of such intense rains could be lost to runoff leading to low effective rainfall and heavy soil loss. For example, Kowal (1973) noted that only a little less than a quarter of the total rainfall in the Savannah Zones of Nigeria enters into the soil during such intense rains.

Recent field experiments conducted on coarse textured soil of semi-arid northeast Nigeria by Chiroma *et al*. (2006a) showed that the practice of tied ridging alone or in combination with mulching increased the profile moisture storage relative to the flat bed during most of the sampling dates of all the three experimental years (Table 2).

Table 2: Soil profile (0-2.2 m) water storage under different treatments measured at different growth stages during 2000, 2001, and 2002 growing seasons

	Moisture storage (mm)								
	2000			**2001**			**2003**		
Treatments§	Vegetative	Booting	Maturity	Vegetative	Booting	Maturity	Vegetative	Booting	Maturity
FB	187	164	143	91	183	100	78	178	185
OR	204	166	158	108	197	107	90	185	189
TR	195	172	151	107	202	104	98	186	188
FBM	202	168	155	112	205	100	105	183	187
ORM	201	186	173	119	218	106	115	187	185
TRM	194	175	162	122	228	108	123	190	191
s.e.	7.5	11.7	13.9	1.3	8.6	2.8	3.0	1.7	2.8

§ FB = flat bed, TR = tied ridge, OR = open ridge, FBM = flat bed + mulch, TRM = tied ridge + mulch, ORM = open ridge + mulch
Source: Chiroma *et al*. (2006a).

The improvement in soil profile water storage with the tied ridge were partly attributed to the surface modifying effects of ridging and ties which tended to prevent runoff and increased the time of ponding for infiltration and partly to the reduction of evaporation losses due to the presence of a surface mulch. Previous studies (Folorunso *et al*., 1994) conducted in this same region revealed that tied ridging significantly enhanced profile water storage at Karasuwa where the slope of the land was much higher (3.6 to 8.2%), but not at Gwio Kura and Amaduri with fairly gentle slopes of 0.6 to 2.5% and 0.1 to 2.6%, respectively (Table 3). Contrary to these results, Kronen (1994) while appraising the water conservation techniques used by smallholder crop production systems in semi-arid areas of South African sub-region noted that the advantages of tied-ridge system in concentrating runoff water is evident only on soils with a relatively high clay content (vertisols, paragneiss and alluvium soils) and not on lighter soils characterized by poor water retention. However, significant crop yield responses were obtained on these coarse textured soils when tied ridging was combined with proper fertilization indicating that the lack of yield response by crops grown on the tied-ridged field was largely due to the low inherent fertility level of these soils than to the inefficiency of the tied-ridge system to harvest and store rain water for use by crop plants. Others have attributed the poor performance of the tied-ridge system on light textured soils to increased soil temperature and dryness on the ridges (Vogel, 1994) and compaction of the furrow due to human traffic and ponding following heavy rainstorms (Materechera and Mloza-Banda, 1997; Chiroma *et al.*, 2006b; Radke, 1982). According to Vogel (1994), temperatures on the ridges could be reduced by aligning the ridges north-south so as to provide maximum shading by the standing crop of the between row spaces. Another possibility would be to use ridges in the form of letter M to collect as much direct rainfall as possible and to provide for maximum shading of the ridge top centre during the day time and to impound warm air in the centre of the ridge top, thus preventing influx of cold air at night. Burrows (1963) found that afternoon soil temperatures beneath ridges of east-west rows during summer were higher than those beneath ridges of north-south rows.

Table 3: Mean soil profile water storage (mm) over all sampling dates

Location	Ridging	Flat	Tied-ridge	LSD (P,0.05)
Amaduri	234.0	242.8	253.8	21.2
Gwio Kura	176.3	211.0	204.6	15.4
Karasuwa	167.4	123.8	152.2	21.0

Source: Folorunso *et al*. (1994).

Soil water and temperatures within the ridge-tillage system were simulated with a heat and moisture model (Benjamin *et al*., 1990). It was demonstrated that taller ridges differed from shorter ridges in their patterns of soil temperatures and water content. Ridges 20 cm high had higher temperatures than ridges less than 20 cm high, and all ridges had warmer temperatures than flat soil surface except for the furrow position. Shaw and Buchele (1957) measured higher soil temperatures and lower water contents beneath ridges and slopes than beneath furrows. These general conclusions suggest that on lighter soils, planting in the furrow between the ridges could promote better crop performance since the furrow remain cooler and wetter compared with the slope or the ridge top. Compaction of the furrow positions can be alleviated through occasional light tillage performed in raising collapsed ridges and dikes or moving loose soil from the furrow into dikes, thus reducing the amount of soil available in the furrow to form depositional seals as described by Baumhardt *et al.* (1990) and Krishna & Arkin, (1985).

4. Effects of furrow diking on crop yield

The potential of furrow diking for improving dryland crop yields have been demonstrated in many areas where crop production is limited by rainfall. In the Rolling Plains of Texas characterized by low and variable rainfall, Gerard *et al*. (1984) reported yield increases of up to 108% in sorghum and 32% in cotton due to furrow diking. Under the same Texas condition, Jones and Clark (1987) reported an average sorghum grain yield increase of 176% during a two-year study period. Others also reported grain yield increase of up to 72% in sorghum and 23% in wheat due to furrow diking (Tewolde *et al*., 1993). However, the practice of furrow diking in the Rolling Plains of Texas as in other dryland areas, does not always result in higher crop yields. For example, McFarland *et al*. (1991) did not find any effect of furrow diking on the grain yield of corn on nearly level (1% slope) fields in south central Texas where annual rainfall was below average and a tendency toward lower yields when annual rainfall was above average. Nelsol *et al*. (1988) attributed the lack of yield response of soybean to furrow diking in northeastern Texas to soil cracking and lack of slope, which result in low potential runoff. In contrast, Gerard *et al*. (1984) reported significant increase in lint yield of diked cotton grown on soil with a 0.5% slope over the un-diked cotton. Several others have equally observed significant yield responses due to furrow diking on fields with less than 1% slope (Tewolde *et a*l., 1993; Sow *et al*., 1997).

Luebs (1962) summarized his long term (1937-1953) research to assess the suitability of different tillage methods for dryland farming in Kansas State, USA by stating that holding rain with dikes on nearly level land appeared to have merit for increasing dryland crop yields. Most controversies in literature could be attributed to differences in soil and climatic conditions of the study area. It is important to note that the potential benefit to be derived from furrow diking depends largely on site and soil characteristics such as texture, slope and landscape position (Gerard *et al.,* 1984). Other factors include rainfall (amount, intensity and distribution) and crop species (Tewolde *et al*., 1993; McFarland *et al*., 1991). However, the benefits from furrow diking are generally most substantial in semi-arid regions that are subject to high intensity, short duration rainfall events which produce significant runoff (Lyle and Dixon, 1977; Jones and Clark, 1987). Field investigations by Gerard *et al*. (1984) to assess the effects of furrow diking and sub-soiling on runoff and crop yields on gently sloping land of Texas show that average sorghum yields for 1981 and 1982 of sub-soiled, half-diked, diked and diked-sub-soiled treatments were 27, 57, 108 and 111% higher than yield of the check treatment respectively (Table 4). Lint yield from the half-diked, diked and diked-sub-soiled averaged 24, 33 and 26% higher than the control treatment respectively. They found significant linear relationship between percent yield and distance down the slope for the check, half-diked and diked treatments. These results also demonstrate the effectiveness of furrow diking in capturing rainwater for crop production on gently sloping fields. Also in Texas, Clark (1983) compared diked, alternate row-diked and non-diked treatments for cotton production and found that diking alternate or every furrow resulted in yield increases of 16 and 36% respectively when compared to non-diked treatments on a clay loam soil. Jones and Nyamudeza (1991) reported the results of a 7-year tied-ridge study in south east Zimbabwe and showed that planting in the tied-furrows resulted in higher yields of cotton, sorghum and maize compared with that from planting on the flat in each of the seven crop growing seasons (Table 5).

Table 4: Grain sorghum yields (kg) under different treatments and location on the slope in 1981 and 1982

	1981				1982				1981/1982 Average
Treatments	Upper	Middle	Lower	Average	Upper	Middle	Lower	Average	
Check	536[a§]	1065[a]	1887[a]	1164[a]	735[a]	1694[a]	3162[a]	1864[a]	1513[a]
Sub-soiled	350[a]	591[a]	2805[a]	1249[a]	1439[b]	2558[a]	3799[a]	2598[b]	1924[b]
Half-diked	1615[b]	1995[b]	2644[a]	2084[b]	2285[c]	2410[a]	3273[a]	2656[b]	2370[c]
Diked	2027[b]	2579[bc]	2872[a]	2493[b]	3083[d]	4036[b]	4324[a]	3815[c]	3154[d]
Diked and sub-soiled	2175[b]	2872[c]	2507[a]	2518[b]	3827[e]	4169[b]	3633[a]	3876[c]	3197[d]

§Values within each location on slope or averages followed by same letter are not significantly different at 5% level according to Duncan's Multiple Range Test

Source: Gerard *et al*. (1984).

Table 5: Sorghum grain yield ($Kgha^{-1}$) as affected by land configuration, manure and fertilizer in the Alfisol§

Treatments	Land configuration practice			Mean
	FB	TR	OR	
1989-90				
FYM + $N_{40}P_9$	1389	1571	1523	1494
FYM + $N_{20}P_{45}$	1052	1324	1180	1185
CD + $N_{40}P_9$	1468	1710	1633	1604
CD + $N_{20}P_{45}$	1351	1969	1385	1568
Mean	1315	1644	1430	
LSD (0.05)		L, 50; MF, 113; L x MF, 165		
1990-1991				
FYM + $N_{40}P_9$	836	1090	963	963
FYM + $N_{20}P_{45}$	627	992	820	813
CD + $N_{40}P_9$	1082	1335	1149	1189
CD + $N_{20}P_{45}$	854	1220	1061	1045
Mean	850	1159	998	
LSD (0.05)		L, 81; MF, 110; L x MF, 192		
1991-1992				
FYM + $N_{40}P_9$	3760	3934	3891	3862
FYM + $N_{20}P_{45}$	3558	3731	3688	3659
CD + $N_{40}P_9$	3683	3860	3824	3789
CD + $N_{20}P_{45}$	3481	3652	3620	3584
Mean	3621	3794	3756	
LSD (0.05)		L, NS; MF, 179; L x MF, NS		

§FB = flat bed, TR = tied ridging, OR = open ridging, FYM = farm yard manure at 5 $Mgha^{-1}$, CD = coir dust at 12.5 $Mgha^{-1}$, $N_{40}P_9$ = 40 kgN and 9 kgP ha^{-1}, $N_{20}P_{45}$ = 20 kgN and 45 kgP ha^{-1}, L = land configuration, MF = manures and fertilizers and NS = not significant

Source: Selvaraju *et al*. (1999).

5. Combined effects of furrow diking and manure on dryland crop yields

Benefits from furrow diking have generally been obtained when diking was combined with cultural practices such as organic or inorganic fertilizers. Nyamudeza *et al.* (1991) evaluated various water and soil fertility management options for increasing crop production on light textured soils of south eastern lowland of Zimbabwe. It was found that the use of 1.0 m tied furrows combined with 150 $kgha^{-1}$ fertilizer (8:14:7 NPK) as basal application and additional 25-50 $kgha^{-1}$ top dressing are the best combination for sorghum and maize production on these light textured soils. The maximum use of 50 kg ha^{-1} top dressing was recommended for wet years, especially for crops like maize, which are highly sensitive to low fertility. They also noted that on these light textured soils, yield improvement with tied ridging were generally small and insignificant even at high fertility levels indicating that factors other than fertility could be responsible for the low performance of the tied-ridged system on these light textured soils. In contrast, substantial yield increases have been reported when tied ridging was combined with organic manures and mineral fertilizers on light textured soils of south Indian peninsular (Selvaraju *et al*., 1999). The study shows that utilization of tied ridging and organic manures such as coir dust (a bi-product from coconut industries) and farm yard manure in combination with inorganic fertilizers offer prospect for alleviating climatic and soil constraints such as low soil water retention and low soil fertility. The study on alfisol indicated that tied ridging in conjunction with coir dust at 12.5 Mg ha^{-1} + 40 kgN and 9 kgPha^{-1} produced higher sorghum yield in low and medium rainfall years compared to tied ridging in combination with farm yard manure at 40 kgN and 9 kgPha^{-1}. This observation was attributed to greater water availability resulting from the mulching effect of the added coir dust. However, in a high rainfall year, tied ridging in combination with farm yard manure at 5 Mg ha^{-1} + 40 kgN and 9 kgPha^{-1} produced more grain yield than did tied ridging in combination with coir dust and 40 kgN and 9 kgPha^{-1} owing to greater availability of nutrient from the farm yard manure than coir dust (Table 5). These results demonstrate that the practice of tied ridging in conjunction with manures (Coir dust and farm yard manure) and mineral fertilizers (N and P) can increase the soil water storage and yield of crop when compared to the traditional practice of planting on flat seed bed in soils of semi-arid tropics.

Field experiment conducted by Sow *et al*. (1997) at the southern Great Plains of Texas also showed that the practice of furrow diking in combination with residue incorporation produced more sorghum yield than did conventional tillage with residue incorporation or no-tillage with or without residue mulch (Table 6). For the conventional tillage and furrow-diked treatments, wheat residues were incorporated by disking twice and sweep ploughing once just prior to planting. Averaged across the two experimental years, the furrow-diked treatment produced 19, 3 and 20% more yield of sorghum than did the conventional tillage, no-tillage plus residue mulch and no-tillage without residue mulch, respectively. The spectacular sorghum yield response to furrow diking and no-tillage plus residue mulch systems were attributed to decreased penetration resistance and increased depth of rooting which allowed for more efficient utilization of water and nutrients by plants growing under these two treatments.

Table 6: Sorghum grain yield (kgha^{-1}) as affected by different soil management systems in 1991 and 1992 at Bushland, TX

Management systems	1991	1992	Average
Furrow diking	4680^{a§}	4990^{a}	4840^{a}
Conventional tillage	3900^{b}	4240^{c}	4070^{c}
No-till + residue	4620^{a}	4760^{b}	4690^{b}
No-till – residue	3880^{b}	4160^{d}	4020^{c}

[§]Means within each column followed by different letters are significantly different at the 0.05 level according to the Duncan's Multiple Range Test

Source: Sow *et al.* (1997).

Recently, Chiroma *et al*. (2006a) compared the relative efficiencies of a number of land configuration practices for improving rainwater harvesting and yield of grain sorghum on a sandy loam soil of semi-arid northeast Nigeria. The study indicate that maintaining wood-shavings mulch at the rate of 10 tones/ha on the surface of flat bed, open or tied ridged systems tended to significantly increase the yield of sorghum when the annual rainfall was above average in 1999, 2000 and 2001, and when it was near average in 2002 (Table 7). Averaged over the four experimental years, the flat bed + mulch, open ridge + mulch, and tied ridge + mulch treatments produced more yield than the flat bed without mulch treatment by 577 $kgha^{-1}$ (71%), 505 $kgha^{-1}$ (50%) and 509 $kgha^{-1}$ (63%) respectively. The corresponding mean increases in water use efficiencies due to these treatments relative to the flat bed without mulch were 41, 21 and 27%.

Table 7: Effects of land configuration and wood-shavings mulch on grain yield and grain water use efficiency of sorghum

Treatments[§]	1999	2000	2001	2002	Mean
		Grain yield ($kgha^{-1}$)			
FB	599	1007	782	858	812
OR	758	920	1186	904	942
TR	997	980	1212	884	1018
FBM	1183	1558	1598	1402	1389
ORM	1015	1338	1383	1134	1217
TRM	1000	1448	1456	1199	1321
Mean[Þ]	925	1208	1269	1063	
s.e.	69.4	81.0	108.2	75.9	42.2
		WUE-ET ($kgha^{-1}mm^{-1}$)			
FB	-[ß]	2.12	1.58	2.15	1.95
OR	-	1.85	2.37	2.14	2.12
TR	-	1.92	2.36	2.12	2.13
FBM	-	2.70	2.69	2.82	2.74
ORM	-	2.36	2.40	2.31	2.36
TRM	-	2.54	2.48	2.42	2.48
Mean	-	2.25	2.31	2.33	
s.e.	-	0.059	0.089	0.040	0.080
		WUE-R ($kgha^{-1}mm^{-1}$)			
FB	0.75	1.55	1.28	1.46	1.26
OR	0.95	1.42	1.94	1.54	1.46
TR	1.24	1.51	1.98	1.51	1.56
FBM	1.48	2.40	2.61	2.39	2.22
ORM	1.27	2.06	2.26	1.93	1.88
TRM	1.25	2.23	2.38	2.04	1.97
Mean	1.16	1.86	2.07	1.81	
s.e.	0.090	0.120	0.180	0.130	0.070

[§]FB = flat bed, TR = tied ridge, OR = open ridge, FBM = flat bed + mulch, TRM = tied ridge + mulch, ORM = open ridge + mulch, WUE-ET = evapotranspirational water use efficiency, WUE-R = rainfall water use efficiency

[Þ]Standard error of difference between means of treatments across years (34.45 for grain yield; 0.027 for WUE-ET and 0.050 for WUE-R

[ß]Not determined

Source: Chiroma *et al*. (2006a).

The results of the cost benefit analysis indicate that even though ridging (open or tied) in combination with mulching was found to be effective in increasing soil water storage, yield and water use efficiency of sorghum in all the four experimental years, higher production cost limited the profitable application of the ridge tillage systems under the edapho-climatic conditions of Maiduguri, northeast Nigeria. A possible option for increasing the profitability of the ridge tillage systems is by exploiting the possibility of utilizing ridges left over from the previous seasons cropping. Studies in Malawi by Materechera and Mloza-Banda, (1997) indicate that existing ridges can be used without affecting yield at least in the first two years after they were constructed. Planting using the previous year's ridges will drastically reduce cost on labour and energy requirement, which in most environments are beyond the reach of the smallholder farmers.

6. Conclusion

The present review has indicated that crop yields in many areas where crop production is limited by low and variable rainfall can be substantially improved with furrow diking. Many field experiments carried out in the arid and semi-arid tropics highlighted the advantages of furrow diking in reducing runoff and increasing water storage and subsequent crop yield. However, it is evident from this review that whether furrow diking will increase water storage and subsequent crop yield depends on several factors with site, soil characteristics and environmental conditions being the most important considerations. Generally, benefits from furrow diking are most substantial in dryland areas subject to high intensity, short duration rainfall events which produce significant runoff. Compared to heavy textured soils, benefits from light textured soils are relatively low owing to problems with low fertility, development of surface seals or crust and increased soil temperature and dryness on the ridges. It was suggested that temperatures could be reduced by aligning ridges north-south or using ridges in the form of letter 'M' so as to collect as much rainfall as possible and to allow for optimum shading of the ridge top during the day time. In addressing the problems associated with low fertility and development of surface crust with high intensity rains (which is characteristics of most dryland areas), the combination of furrow diking with organic manuring or mulching will not only enhance the soil fertility, but the surface mulch will also act to dissipate raindrop impact energy thus increasing infiltration. Occasional light tillage in raising collapsed ridges and dikes will help in breaking surface crust and improve permeability in light textured soils. For heavy textured soils, provision of adequate drainage should be given proper attention especially in a high rainfall year. Such soils may also require deeper dikes to hold rainfall for longer periods, thus providing more time for infiltration. Since ridging requires a lot of time and energy which most farmers cannot provide in a limited time, planting using the previous years ridges will, beside reducing the cost of labour and energy requirement, help farmers to avoid the risk of reduced yields associated with late planting.

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