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The effect of crop type, crop rotation, and tillage practice on runoff and soil loss on a Vertisol in central Queensland

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Abstract

In 1982, a long-term project was established in central Queensland to study the effect of crop type, crop rotation, and tillage practice on runoff and soil loss. Runoff and soil loss were measured at the outlet of 9 large contour bay catchments (approximately 13 ha) where wheat, sorghum, and sunflower were grown in 3 crop sequences. Each crop sequence consisted of zero, reduced, and conventional tillage fallow practices. Monoculture cropping was practised from 1983 to 1985, then opportunity cropping from 1986 to 1993.

During the study, wheat cropping had lower average annual runoff and soil loss ($P < 0{\cdot}01$) than sorghum and sunflower. Zero and reduced tillage retained more crop stubble (median >50%) and had less soil loss ($P < 0{\cdot}05$) than conventional tillage. Zero tillage wheat had the lowest average annual runoff and soil loss, and conventional sunflowers had the highest. The erosion risk associated with sunflowers was reduced by a wheat–sunflower crop rotation, particularly when zero-tilled. Monoculture sunflower must be avoided.

The region is susceptible to large episodic erosion when crops are not sown, there are long fallows, and soil cover falls below levels critical to control erosion (<30%). Opportunity cropping is the most appropriate system to maximise the regions variable rainfall and reduce runoff and soil loss.

Introduction

Soil erosion by water is of particular concern in central Queensland, where shallow soils have been developed for cropping. Between 1982 and 1986, the area of grain production on the central highlands of central Queensland expanded from 250 000 to 512 000 ha. Since 1986, the area of crop grown has varied from 222 000 to 518 000 ha, depending on seasonal rainfall.

The region's variable rainfall is the major limitation to cropping, with periods of insufficient rainfall to grow a crop (1 in 10 years), and times of very high rainfall causing severe soil erosion (5% of rainfall >100 mm/day). When crops are not sown, fallows are longer than intended, and when conventionally tilled, inadequate stubble cover is retained to control soil erosion.

Farm management practices that retain crop stubble (such as zero and reduced tillage) reduce raindrop impact, sediment detachment, sediment transport, runoff,

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and soil loss (Unger and McCalla 1980; Freebairn and Wockner 1986; Glanville and Smith 1988; Loch and Donnollan 1988).

In the central highlands, the 3 predominant crops grown are wheat in winter, and sorghum and sunflower in summer. Soil erosion rates from these 3 crops have not been reported in central Queensland. However, in southern Queensland, Freebairn and Wockner (1984, 1986) found zero-tillage wheat produced the least erosion, and sorghum crops reduced soil movement by 50% compared with sunflower crops. Approximately half of the Australian sunflower crop is grown in central Queensland. Consequently, appropriate management practices are required to reduce the erosion risk associated with the crop.

During 1982–93, a large-scale catchment study measured runoff and soil loss from various crop and residue management practices. Previous reports on the study showed crop stubble retained during a fallow depended on the crop type (wheat > sorghum > sunflower), crop yield, and the number and type of tillage operations undertaken; and increasing soil water deficit and soil cover reduced both total runoff and peak runoff rate (Sallaway *et al.* 1988*a*, 1988*b*, 1990). This paper presents results from the 12-year study and evaluates the effect on runoff and soil loss of (*i*) wheat, sorghum, and sunflower cropping; (*ii*) zero, reduced, and conventional tillage; (*iii*) long fallow, particularly on episodic erosion; and (*iv*) a wheat–sunflower crop rotation. Opportunity cropping and its impact on runoff and soil loss are also discussed.

Table 1. Soil properties of a Vertisol at the Capella experimental site

Depth (cm)	pH	CEC (cmol/kg)	Particle size distribution (% of total) Coarse sand	Fine sand	Silt	Clay
0–10	8·0	84	2	11	9	76
10–20	7·8	n.a.	n.a.	n.a.	n.a.	n.a.
20–30	7·9	85	1	11	11	78
50–60	8·4	85	2	11	11	78
80–90	8·8	54	60	22	7	8

n.a., not available

Materials and methods

Location and soils

The experimental site was near Capella, in the Peak Downs Shire of the central highlands of Queensland (23·06′ S, 148·02′ E, elevation 250 m). The soil is a black cracking clay derived from basalt, Vertisol, mollic torrert, 76% clay, pH 8·0 (Table 1); Ug5·12 (Northcote 1979), and is representative of about 70% of the cropping area in the central highlands. The topography of the area is gently undulating; land slope in the experimental area ranged from 1·6 to 2·5%.

Vegetation prior to cropping was predominantly grassland, with the dominant species Queensland blue grass (*Dichanthium sericeum*) and desert blue grass (*Bothriochloa erwartiana*) (Gunn *et al.* 1967).

Rainfall

Average annual rainfall for the 1982–1993 experimental period was 535 mm, lower than the long-term average of 588 mm for the Capella area (Table 2). Long-term annual rainfall (1899–1994) has varied between 200 and 1400 mm.

Table 2. Average rainfall and climatic data for Capella area

Month	Rainfall (mm) Site (1983–93)	Rainfall (mm) Capella (1899–1994)	Temp. (°C) (1964–94) Max.	Temp. (°C) (1964–94) Min.	Evap. (mm/day) (1967–84)
January	76	97	34·0	21·6	8·9
February	62	95	32·9	21·2	7·5
March	46	65	31·7	19·7	6·3
April	52	33	29·2	16·2	5·3
May	54	31	25·7	12·3	4·1
June	21	30	22·8	8·1	3·8
July	32	25	22·6	6·9	4·1
August	17	16	24·9	8·7	5·2
September	12	19	28·3	12·3	6·9
October	36	36	31·4	16·4	8·4
November	70	57	33·5	19·1	9·8
December	57	84	34·3	20·9	9·9
Tot./av.	535	588	29·3	15·3	6·7

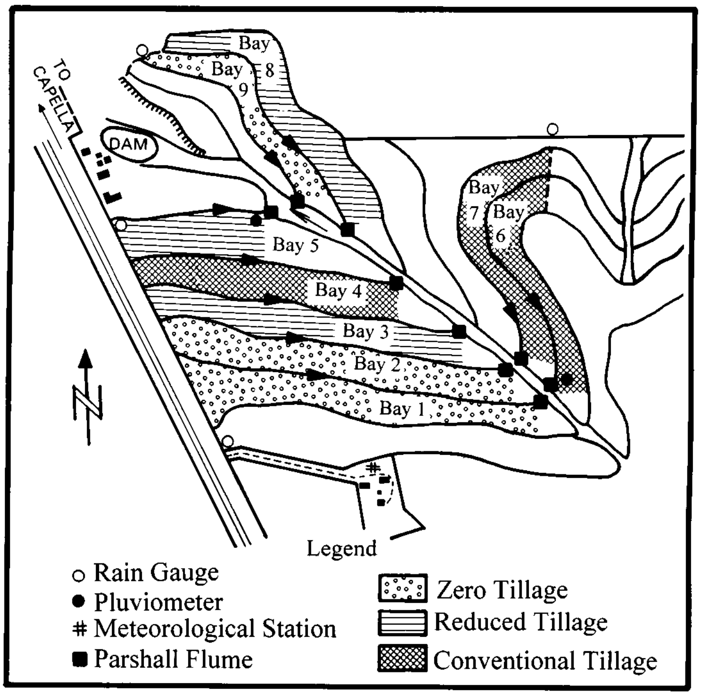

Fig. 1. Experimental layout at Capella site.

Over the experiment, rainfall was lower in summer (October–March) and higher in winter (April–September) than the long-term seasonal averages. The highest annual rainfall was 982 mm in 1983, with 550 mm between April and September. Half of the long-term average rainfall fell in 1982, 1992, and 1993. During the study, 3 cyclonic influences produced low intensity depressional rainfall: Cyclones Charlie (150 mm), Arviu (116 mm), and Joy (250 mm) in 1988, 1989, and 1990–91.

The average maximum temperature in midsummer (January) is 34°C, and the average minimum temperature in midwinter (July) is 7°C. The mean annual potential evaporation (Class A pan) is 2438 mm and monthly evaporation exceeds mean monthly rainfall throughout the year.

Experimental design

Runoff and soil loss were monitored from 9 catchment areas (contour bays). Catchments were separated by broad-based contour banks (Fig. 1). Contour bank spacing ranged between 96 and 161 m, depending on the slope of the land. Contour bank length varied from 725 to 1370 m, with bank gradients between 0·12 and 0·3%. Catchments were 8–17 ha.

The catchment size of the bays was chosen so that runoff and soil loss data were representative of, and applicable to, the agricultural land management in the region (Sallaway *et al.* 1988*b*; Table 3).

Table 3. Contour bay number, catchment area, slope, and tillage practice for crop sequences S1, S2, and S3

ZT, zero tillage; RT, reduced tillage; CT, conventional tillage

	S1			S2			S3		
	ZT	RT	CT	ZT	RT	CT	ZT	RT	CT
Bay no.	1	8	6	2	5	7	9	3	4
Area (ha)	16·1	14·4	9·1	15·2	10·3	10·1	7·0	14·2	12·4
Slope (%)	1·7	1·9	2·4	2·0	1·6	2·5	1·7	1·9	1·8

Crop sequence and tillage practice

The experiment had 9 treatments. Sorghum, sunflower, and wheat were grown at the experimental site in 3 crop sequences, S1, S2, and S3 (Fig. 2). Each crop sequence consisted of zero, reduced, and conventional tillage practices, grouped together in bays 1, 8, 6; 2, 5, 7; and 9, 3, 4, respectively (Table 3). The tillage treatments were randomly allocated to the contour bays and maintained in each catchment throughout the study.

In the conventional tillage, a disc plough was used for primary tillage, followed by tine cultivation (chisel plough and scarifier).

A 0·9-m blade plough was used for primary tillage in reduced tillage, followed by secondary cultivation using a rodweeder and tine cultivation. Strategic herbicide applications were also used to control weeds and retain crop stubble.

Zero tillage consisted of herbicide weed control to retain the maximum amount of crop stubble over a fallow. The principal herbicides used were glyphosate, and 2,4D amine and ester.

During 1983–85, monoculture cropping was practiced. Sorghum, sunflower, and wheat were grown in S1, S2, and S3. Initially, wheat was planned for S1 and sorghum for S3. However, due to inadequate winter rainfall, wheat was not sown in 1982. When rainfall occurred in January 1983, it was decided to sow sorghum in S1, so that tillage practices could begin. Tillage practices began a year earlier, in 1982, in S2 and S3 when sunflower and sorghum were harvested (Fig. 2).

During this monoculture cropping stage, soil moisture was often too low to sow at the optimum sowing time, resulting in late sowings of wheat in 1984 and sunflower in 1985. From 1986 to 1993 an ‘opportunity cropping’ rotation (growing a crop when there is adequate soil water and a reliable planting window) was adopted at the site. Wheat–sunflower–sorghum–wheat was the preferred rotation. However, rainfall dictated rotations and cropping opportunities. Even with opportunity cropping, wheat could not be sown due to lack of rainfall in 1992, and was sown on marginal soil moisture in 1993 (Fig. 2). Likewise, planned summer crops were unable to be sown in 1990, 1992, and 1993. There was a sequence of 4 years, between 1986 and 1989, where the distribution of rainfall allowed both summer and winter crops, and 1 spring sorghum crop to be grown (Fig. 2).

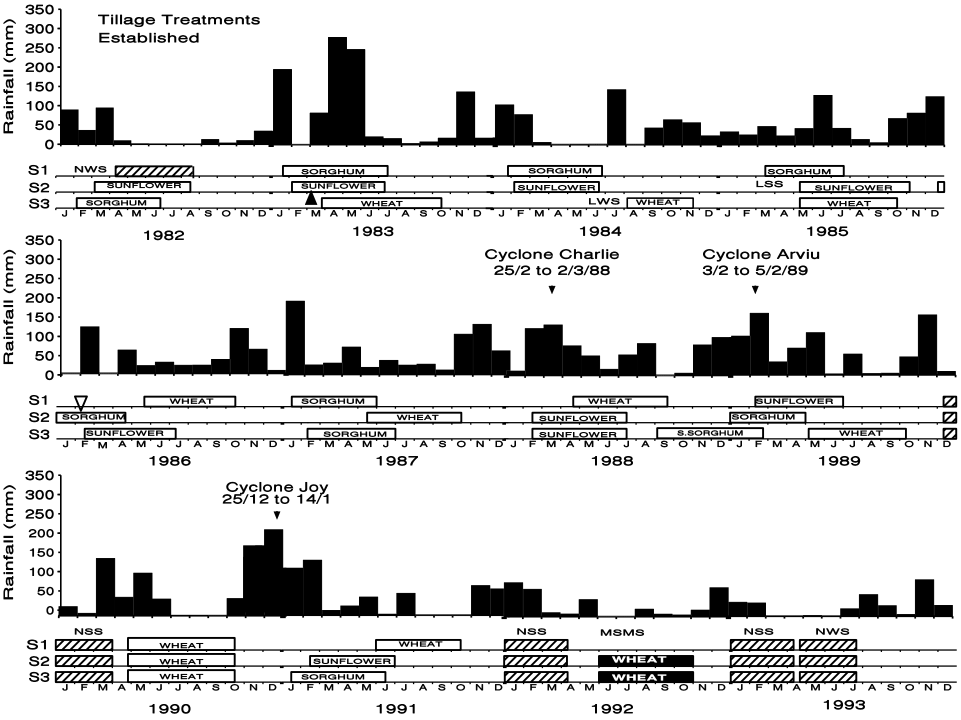

Fig. 2. Crop sequences S1, S2, and S3 and monthly rainfall for the Capella site. NWS, no winter sowing; NSS, no summer sowing; LWS, late winter sowing; LSS, late summer sowing; MSMS, marginal soil moisture at sowing; S.sorghum, spring sorghum. Conventional till resown in S2, 22 March 1983 (▲); conventional and reduced till resown in S2, 11 February 1986 (▽).

Pattern of tillage operations and herbicide applications

During the study, conventional tillage averaged 3 tillage operations per year. In contrast, reduced tillage averaged 2 tillage operations, and less than 1 herbicide application. Three herbicide sprays were used on average during zero tillage fallows (Table 4).

Just 1 or 2 herbicide sprays were required on 7 occasions when double-cropping with zero and reduced tillage: S1 in 1986–87 and 1988–89; S2 in 1985–86, 1987–88, and 1990–91; and S3 in 1988–89 and 1990–91. When double cropping with conventional tillage, 1 disc plough operation was used in S1 in 1988–89, and S3 in 1990–91.

Instrumentation and measurements

Meteorology

A weather station consisting of a class A pan evaporation tank, a 203 mm rain gauge, a Rimco wind run vane, a chart-recording thermohydrograph, a Rimco pyrenometer, and a tipping bucket rain gauge was positioned south of the site (Fig. 1). Rain was recorded at 6-min intervals, and the pyrenometer recorded net daily radiation. Rainfall intensity was also recorded at 2 other positions within the experimental area, and four 127-mm rainfall gauges were installed at the extremities of the area to aid interpretation of rainfall patterns.

Runoff

Runoff was measured from each catchment as it discharged into a grassed waterway through a 2·4-m parshall flume. Flumes with a discharge rating curve similar to that calculated for the contour channel were chosen to cause minimum interference to flow at the bank outlet.

Table 4. Number of herbicide sprays (H) and tillage operations (T) during fallows (1983–93) for crop sequences S1, S2, and S3

ZT, zero tillage; RT, reduced tillage; CT, conventional tillage

Fallow	S1				S2				S3			
	ZT	RT		CT	ZT	RT		CT	ZT	RT		CT
	H	H	T	T	H	H	T	T	H	H	T	T
1983–84	4	0	3	3	4	1	2	3	2	0	4	3
1984–85	3	0	5	7	5	1	4	5	2	0	5	4
1985–86	4	0	4	5	2	0	2	2	3	1	2	3
1986–87	2	1	1	3	4	1	3	3	3	1	3	3
1987–88	3	0	3	6	1	2	1	4	3	2	1	4
1988–89	2	1	1	1	2	1	2	4	4	0	2	2
1989–90	2	2	2	3	5	1	3	4^{A}	4	2	1	2^{A}
1990–91	3	2	0	3	1	1	0	1^{B}	1	1	0	1^{A}
1991–92	3	1	1	2	4	1	2	4	4	0	4	5
1992–93	1	0	1	3	1	1	1	3	2	1	1	2
Average	2·7	<1	2	3·6	2·9	1	1·9	3·3	3·0	<1	2·3	3·0

[A] Herbicide sprays applied once in conventional tillage fallow.

[B] Herbicide sprays applied twice in conventional tillage fallow.

Table 5. Event number and date for rainstorms that caused erosion at the Capella experimental site

Event no.	Date	Event no.	Date	Event no.	Date
1	12·i·83	19	14·xii.84	37	26·xii.88
2	14.i.83	20	25.i.85	38	27.xii.88
3	27.i.83	21	28.ii.85	39	22.i.89
4	19.iii.83	22	10.iii.85	40	24.i.89
5	26.iv.83	23	03.vi.85	41	03.ii.89
6	27.iv.83	24	04.xii.85	42	04.ii.89
7	29.iv.83	25	09.xii.85	43	05.ii.89
8	01.v.83	26	29.xii.85	44	22.ii.89
9	02.v.83	27	05.ii.86	45	16.v.89
10	20.v.83	28	22.ii.86	46	03.xi.89
11	09.xi.83	29	22.x.86	47	05.xi.89
12	11.xi.83	30	07.i.87	48	10.xi.89
13	14.xi.83	31	28.i.87	49	22.v.90
14	28.xi.83	32	31.i.87	50	07.vi.90
15	23.i.84	33	10.xi.87	51	05.i.91
16	27.i.84	34	01.iii.88	52	08.ii.91
17	05.vii.84	35	02.iii.88	53	27.i.92
18	03.xi.84	36	22.xii.88	54	09.ii.92

Flow height in the flume was recorded at 6-min intervals with a capacity-to-frequency flow height recorder and a float-driven height meter and stored on a data logger. There were 54 rainstorm events that produced runoff during the study (Table 5).

Fig. 3. Parshall flume at outlet of contour bank. Sediment sampling arm is seen in flow. Sediment dispenser is positioned on the right of the flume (white container).

Soil loss

Total soil loss from the contour bays was measured by pumping sampler (Catchment Instrumentation Mk IV), with the sampling arm positioned in the turbulent discharge section of the flume (Fig. 3). It was assumed that, due to turbulence, both bedload and suspended sediment were sampled. The sample volume was approximately 1 L, the sampling interval was 6 min, and the instrument held 50 bottles. Sediment concentration was determined by oven-drying.

Surface cover

Sallaway *et al.* (1988*a*) have described the photographic technique used to quantify projected soil surface cover. Cover measurements were taken after every major runoff event and during wheat–sunflower crop rotation.

Data analysis

Annual runoff and soil loss data from 1984 to 1990 were analysed by analysis of variance, for unbalanced data. The factors considered were contour bay, tillage practice, crop type, and previous years stubble, and their 2-way interactions. Data for 1983 were excluded because tillage treatments had not been established in S1. Estimates of missing runoff data were made by reconstructing hydrographs from observed peak flow heights. Missing soil loss data were estimated from measured peak flow rates.

Results and discussion

Effects of crop type and tillage on runoff and soil loss

This study showed there was lower average annual runoff and soil loss ($P < 0 \cdot 01$) following wheat than following sorghum and sunflower (Table 6). When wheat is harvested (September–October), there is a large mass of crop stubble (90%

soil cover), and the Vertisol soil is often dry and deeply cracked. When cracks and stubble cover are present, almost all early summer rainfall infiltrates. This was evident in 1990–91 following wheat harvest, when just 3 mm runoff occurred from 250 mm rainfall. At the time, all bays had grown wheat and had >60% stubble cover.

Table 6. Effect of tillage and previous crop stubble on annual mean runoff and soil loss (1984–90)

Within columns, means followed by the same letter are not significantly different at $P = 0{\cdot}05$

Treatment	Runoff (mm)	s.e.m.	Soil loss (t/ha)	s.e.m.
Tillage				
Zero	19·1a	2·44	1·42a	0·444
Reduced	26·4b	2·81	1·92a	0·454
Conventional	33·3b	2·81	4·01b	0·454
Previous crop stubble				
Wheat	19·1a	2·54	1·34a	0·441
Sorghum	26·7b	2·61	2·95b	0·449
Sunflower	33·2b	3·03	3·04b	0·481

Once cracks close, infiltration rate is determined by the amount of stubble protecting the soil from rainfall impact. Zero tillage retained the greatest stubble cover (Fig. 4) and produced the least average annual runoff ($P < 0{\cdot}05$) during the study (Table 6). Loch and Foley (1994) found that stubble cover prevents the disruption and detachment of soil aggregates that causes macropores to block, infiltration to decline, and runoff to increase. Fig. 5*a* shows a near-linear relationship between cover and runoff, with the magnitude of the cover effect determined by the soil-water deficit at the time of the event (Sallaway *et al.* 1990).

Zero and reduced tillage had consistently greater stubble cover (median cover >50%) and lower average annual soil loss ($P < 0{\cdot}05$) than conventional tillage (Table 6). Rose and Freebairn (1983) showed that stubble cover in contact with the soil reduced erosion by reducing overland flow velocity, stream power, and thus the ability of the water to detach and transport sediment. Fig. 5*b* shows that soil cover levels >30% are critical for erosion control. The steepest part of the cover–soil loss relationship is at cover levels <30%. The exception was S1 zero tillage where there was insufficient contact cover to prevent ephemeral rills eroding (this is discussed in the next Section.)

The region is most susceptible to large episodic erosion when crops are unable to be sown and the subsequent long fallow is conventionally tilled. Such conditions occurred at the start of the study in 1982, when wheat was not sown in S1, following the driest winter–spring on record.

Episodic runoff and soil loss

The largest annual runoff and soil loss occurred in 1983 and followed an 18-month fallow when wheat was unable to be sown in S1, and before tillage

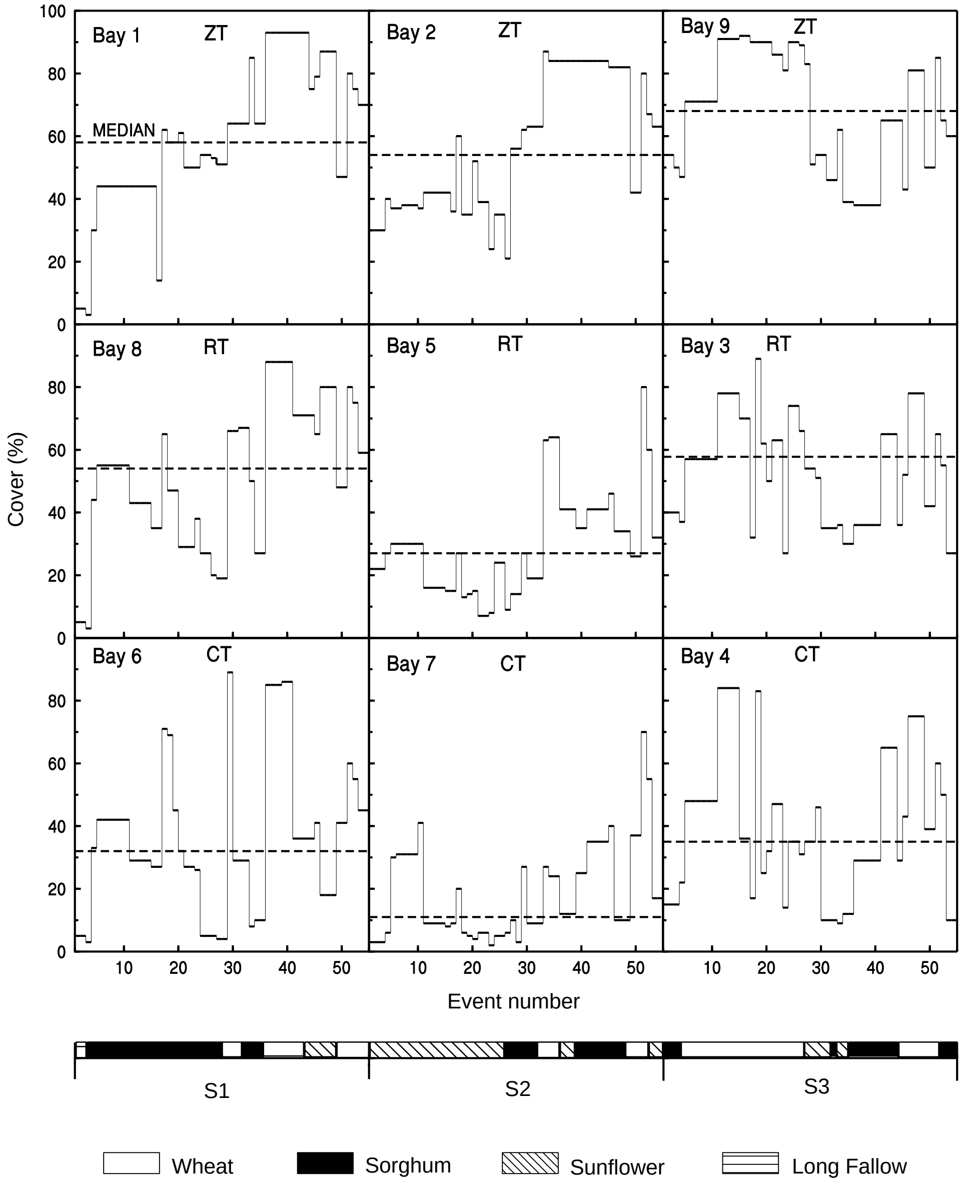

Fig. 4. Projected soil cover for crop sequences S1, S2, and S3 for zero (ZT), reduced (RT), and conventional tillage (CT).

practices were established. More than 65% of the total runoff and soil loss (284 mm and 30 t/ha) occurred before zero tillage began in S1 (bay 1), with just 3 storms in January 1983 producing 30% (13·3 t/ha) of the bay's total soil loss (Fig. 6). However, once S1 zero tillage was established, cumulative runoff and soil loss declined. From 1984 to 1992, S1 zero till had 74 mm less runoff and almost half the soil loss of S1 conventional tillage (29 t/ha).

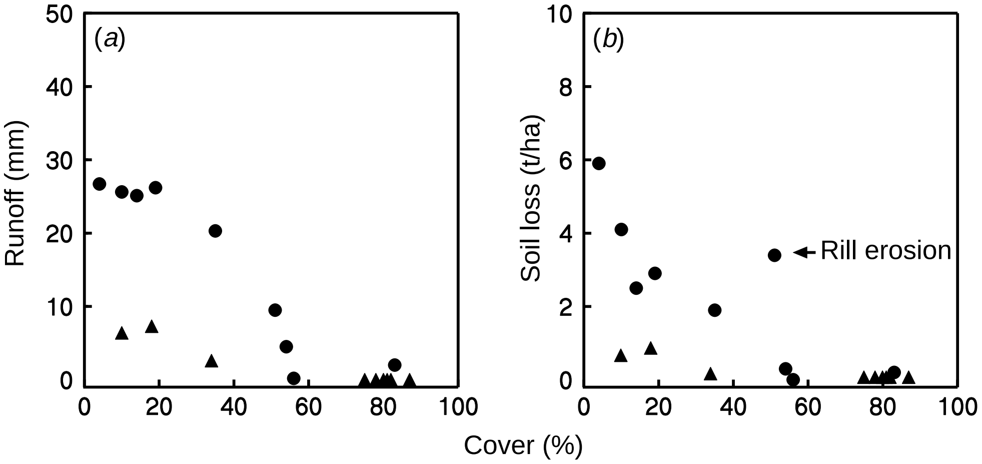

Fig. 5. Effect of soil water deficit and stubble cover on (*a*) runoff and (*b*) soil loss for 2 similar rainstorm events. Event 27 (moist soil, ●) had 57 mm rainfall and 30 min maximum intensity of 84 mm/h. Event 46 (dry soil, ▲) had 61 mm rainfall and 30 min maximum intensity of 95 mm/h.

The large erosion rate in bay 1 in 1983 was due to ephemeral rills, and these were the main reason S1 zero till had periodically larger erosion rates than reduced and conventional tillage (Fig. 6). The S1 zero tillage was most susceptible to rill erosion when stubble was disturbed following sowing, and when there was insufficient stubble in flow lines to resist erosion. Rill erosion contributes approximately 65% of eroded sediment of Vertisol soils, with susceptibility to rill erosion increasing following cultivation (Foster *et al.* 1982*a*, 1982*b*; Loch and Donnellan 1983).

Most erosion from S1 and S2 conventional tillage was caused by a few events that produced large increases in cumulative runoff and soil loss. In contrast, S2 conventional tillage had more erosion events and a near-linear increase in cumulative runoff and soil loss where sunflowers were predominantly grown and where soil cover was consistently low (Figs 4 and 6). Sunflower production is important to the economy of the region; consequently, cropping systems need to be devised to reduce the erosion risk associated with this crop.

Crop rotation to control erosion from sunflowers

One strategy to reduce soil erosion when growing sunflowers is to ‘build-up’ crop stubble by crop rotation. Sallaway *et al.* (1988*a*) found that after sunflower harvest there is typically <40% soil cover, with very little stubble remaining following cultivation. In contrast, after wheat harvest there is typically 90% soil cover.

When wheat is harvested, there is an opportunity to rotate the crop to sunflower. Thus, a high stubble-producing crop is followed by a low stubble-producing crop. In this study, zero and reduced tillage retained wheat stubble for up to 15 months, through 2 successive fallows (Fig. 7). Fig. 8 shows that zero and reduced tillage at the end of a 4-month fallow, and prior to sowing sunflowers, had retained 85 and 60% wheat stubble, respectively. Since stubble decay rates are very

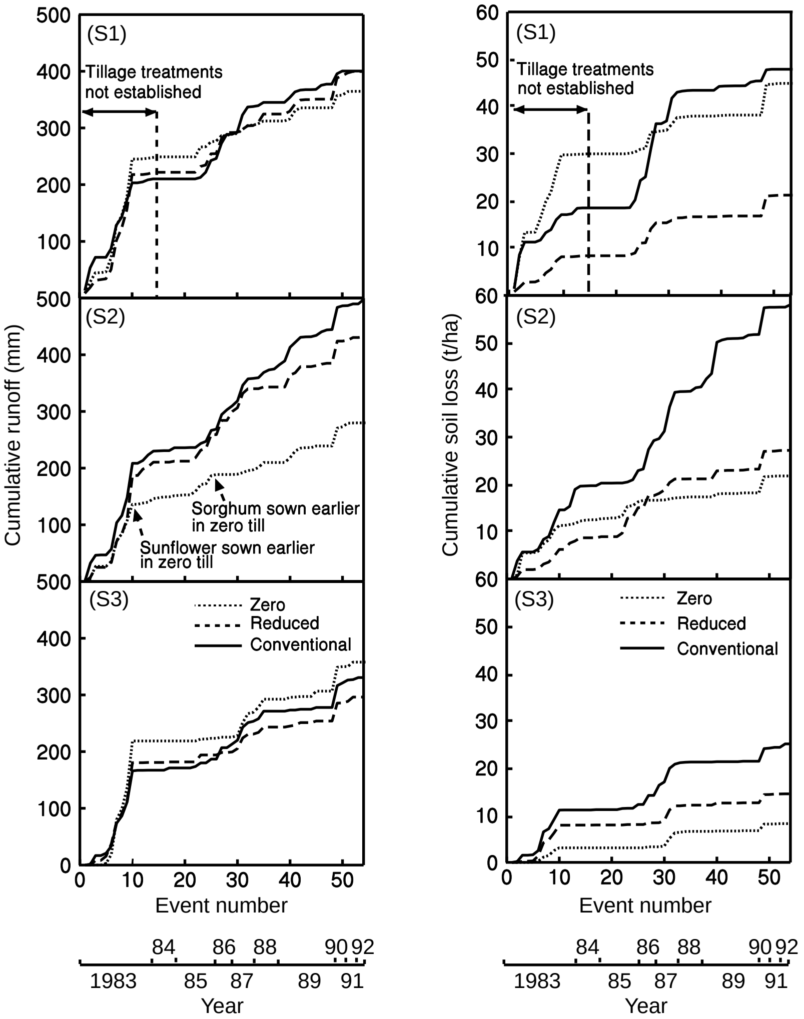

Fig. 6. Cumulative runoff and soil loss (1983–1992) for crop sequences S1, S2, and S3, with zero, reduced, and conventional tillage.

slow (0·01 kg/ha·day) in the region (Sallaway *et al.* 1988*a*), most wheat stubble retained at sowing was present at sunflower harvest. When sorghum was sown, zero and reduced tillage had retained 80 and 40% stubble cover, respectively. In contrast, only 12% stubble cover was retained with conventional till.

At the end of the second fallow, there were 6 storms that produced 130 mm rainfall. Zero and reduced tillage in S2 had <1 t/ha soil loss. In contrast, there was 10 t/ha soil loss from S2 conventional tillage. More importantly, zero tillage produced just 5 mm runoff from the 6 storms, compared with 39 mm runoff from conventional tillage. Zero tillage had a subsequent sorghum yield of 2 t/ha compared with 1·7 t/ha from conventional tillage.

For 1 year in every 3 years during this study, wheat could not be sown or was unreliably sown, due to insufficient rainfall. Therefore, it is important that the retention of wheat stubble is maximised by conservative fallow management practices and flexible crop rotation.

Fig. 7. Stubble retained in a conventional (top) and a zero till (bottom) wheat–sunflower rotation, 15 months after wheat harvest.

Opportunity cropping

The region's unpredictable rainfall means rigid crop rotations are impossible to adhere to, and a more flexible approach to rotation is required. During the study, 11 crops were not sown, or were sown on inadequate soil moisture. Carroll

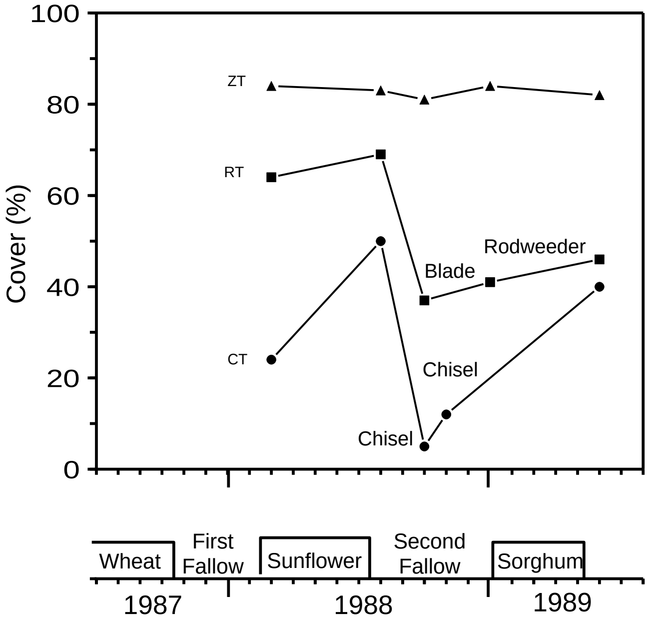

Fig. 8. Percentage stubble cover retained through a wheat–sunflower–sorghum rotation (1987–1989, S2).

et al. (1992*a*), using the cropping systems model PERFECT (Littleboy *et al.* 1989), showed that opportunity cropping [growing a crop when there is adequate soil water (75 mm PAWC) and a reliable sowing window] will produce more crops than a rigid monoculture cropping rotation. Carroll *et al.* (1992*b*) also showed that opportunity cropping was the best management practice to reduce erosion when undertaking a wheat–sunflower rotation. Hence, increased cropping intensity leads to increased crop water use, more stubble cover, and less runoff and erosion. The greatest reduction in runoff and soil loss during the study occurred on 2 occasions in S2 zero tillage when rainstorms fell during a growing crop (Fig. 6). No crop was present in S2 reduced and conventional tillage due to poor plant establishment, possibly a result of incorporated stubble causing a phytotoxic effect on seedling growth (Schon and Einhellig 1982). Morris and Parrish (1992) found less inhibition of seedling growth in zero tillage.

PERFECT simulations in conjunction with this study found there was little evidence to suggest that zero tillage produced more cropping opportunities through better soil water accumulation. The more likely benefit of zero tillage with opportunity cropping is the ability to control weeds and sow a crop with minimum seedbed preparations and little soil disturbance and stubble incorporation. Nevertheless, for individual storms, zero tillage had up to 90% less runoff than conventional tillage, which in some seasons could be the difference between sowing and not sowing a crop.

Zero tillage is the major fallow management practice that can retain sufficient stubble cover when crops cannot be sown and there are unplanned long fallows. Reduced tillage systems are another option, but require careful fallow management to retain sufficient stubble to control soil erosion during extended fallows.

Conclusions

The combination of an unreliable cropping environment and the episodic nature of erosion events is the most challenging aspect to farming, and to achieving a sustainable farming system, in a semi-arid environment. Selections of tillage practice, tillage implement, crop type, and crop rotation are some of the management options available to farmers to control soil erosion.

High stubble cover needs to be consistently retained over successive fallows to control soil erosion, and bare fallows should be avoided. Insufficient stubble to control episodic erosion occurs when sunflowers are grown, crops are not sown, and the subsequent long fallow is conventionally tilled. Zero and reduced tillage have shown that sufficient soil cover is retained to manage for episodic events, particularly when wheat stubble is present.

Wheat is a valuable crop for controlling runoff and soil erosion and, when rotated with sunflower, reduces the erosion risk associated with this crop. Monoculture sunflower must be avoided.

Opportunity cropping is the most appropriate system to manage the regions variable rainfall. By taking advantage of available cropping opportunities, crop water use and soil cover are maximised, and runoff and soil loss are decreased.

During this study, there was little evidence that zero tillage produced more cropping opportunities through better water accumulation. However, with less seedbed preparation, zero tillage is the best fallow management practice to undertake with opportunity cropping.

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