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WATERSPREADING IN SOUTH-WESTERN QUEENSLAND—NATIVE PASTURE PRODUCTION AND FORAGE CROPPING

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SUMMARY

Waterspreading was investigated as a means of improving growth of native pasture and of growing forage crops in semi-arid south-western Queensland.

Dry matter yields of oats, barley, safflower and rape over winter, and forage sorghums, sudan grass and bulrush millet over summer were recorded on an area receiving the full flow of water diverted by an earth bank from a flowing watercourse. Yields of native pasture—predominantly *Eragrostis parviflora*—were recorded on areas receiving the full flow of diverted water, a partial flow of water, and no flow.

Dry matter yields in 1970 of oats, barley, safflower and rape were 700, 290, 315 and 60 kg ha^{-1} respectively; while in 1973 yields of oats grown at 15 and 30-cm row spacing and barley grown at 30-cm row spacing were 6310, 8900 and 7050 kg ha^{-1} respectively.

Germination of summer crops was so low that no worthwhile data were recorded.

Native pasture yields of 1980, 1230 and 450 kg ha^{-1} were recorded on the fully flooded, partially flooded and unflooded areas respectively. Yields on the fully flooded area were increased with the addition of 40 kg ha^{-1} of nitrogen.

Although several problems still exist, it is concluded that waterspreading can be useful in suitable areas of south-western Queensland as a means of increasing yields of native pasture and of growing winter forage crops.

I. INTRODUCTION

Improving soil moisture for plant growth by diverting run-off water with earth banks to areas favourable for cultivation dates back to the early inhabitants of the Middle East and the Incas of South America (Cull 1964a; Evenari, Shanan and Tadmor 1968). Similar schemes have been described and are being promoted in western New South Wales (Quilty 1972a, b) and to a lesser degree in south-western Queensland (Cull 1964a). Such schemes are of greatest benefit to semi-arid and arid areas where pasture and crop production is restricted by limited moisture availability.

Waterspreaders are used not only for crop production (Quilty 1972b) but also to increase the productivity of native pastures (Branson 1956) and improved pasture (Cull 1964b; Miller *et al.* 1969; Tadmor, Evenari and Shanan 1970).

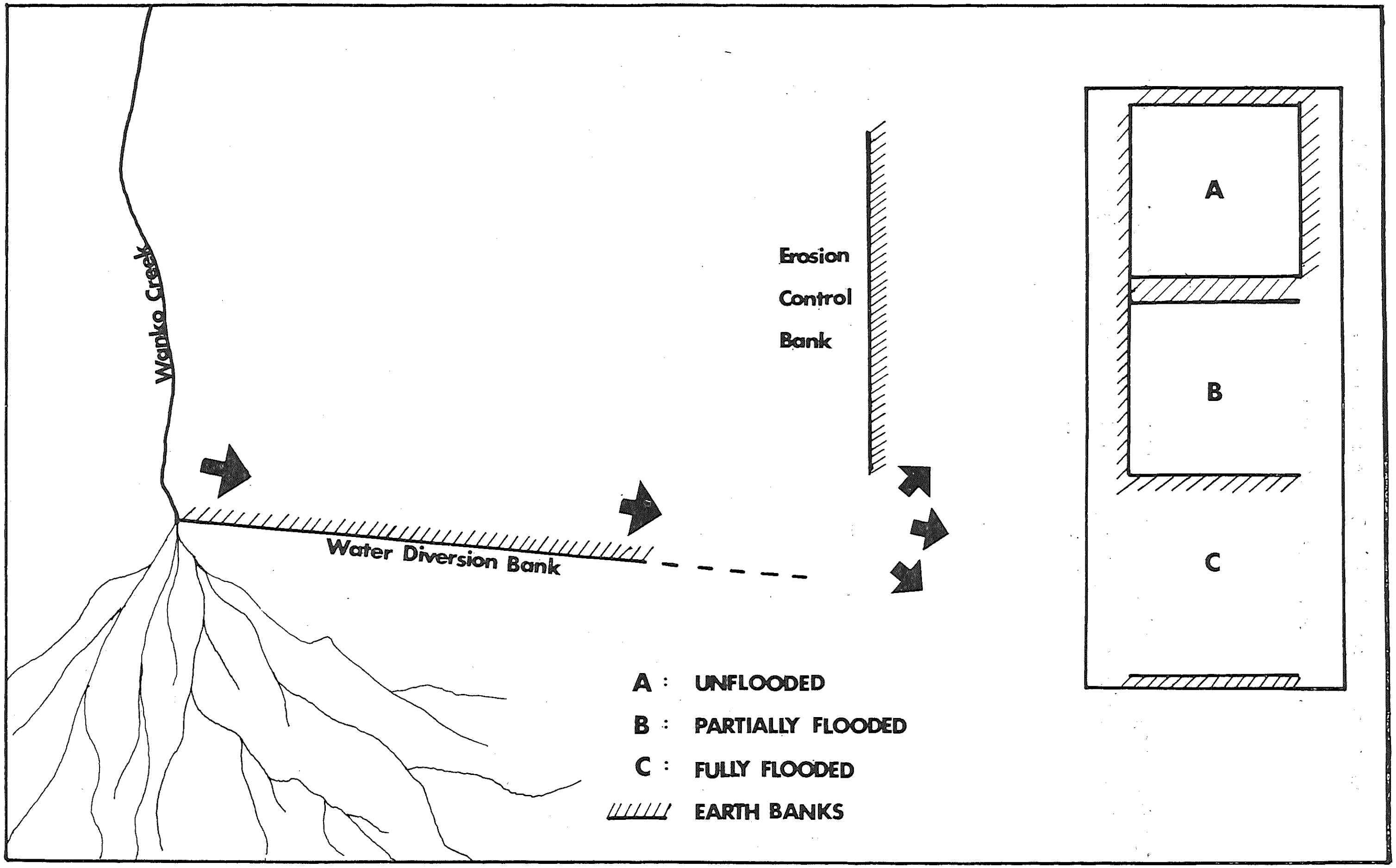

Figure 1. Diagram of the experimental site showing the position of the main diversion bank, the erosion control bank, and the study area.

Two important aspects of waterspreading in inland Australia are the supply of additional moisture to suitable areas and the reduction of sedimentation and erosion damage in watercourses (Burrows, Cull and Ebersohn 1966). Skinner and Kelsey (1964) estimated that 5 to 10% (i.e. 1 to 2 million hectares), of the mulga lands of south-western Queensland could benefit from water redistribution schemes. The following studies were designed to supply quantitative data on native pasture yield and to investigate the potential for forage crop production in the region.

II. METHODS

Site

Experiments were located on an existing water redistribution scheme at 'Beechal' Cheepie, 190 km south-west of Charleville. An area of approximately 2 ha was fenced in 1967 at the end of a 3-m high earth bank 400 m long which effectively diverts run-off waters from an ephemeral watercourse over approximately 400 ha of native pasture. Mean annual rainfall at the site is 350 mm and annual evaporation recorded at the nearest meteorological office (Charleville) is 2 300 mm.

Within the fenced area, three adjacent 100-m square blocks were marked out (figure 1). One block was enclosed on all sides by earth banks 1·5 m high and 2 m wide at the base to prevent flooding; the middle block was enclosed on three sides, leaving the down stream side open to allow partial flooding; the third block was not enclosed, enabling the full flow of water to inundate it. In 1969, an earth bank 3 m high and 200 m long was constructed on the upstream side of the blocks in an attempt to reduce the force of water on the banks at the trial site.

The soil was a shallow (<1 m) red brown earth of medium texture. There was a marked natural gradient of available phosphorus in the surface soil across the blocks with the lowest level being recorded on the unflooded block. The water content of the soil profile (mean depth 90 cm) at pressures of -1500 J kg^{-1} and -10 J kg^{-1} is 17 cm and 31 cm respectively. As flood water generally remains over the fully flooded block for at least 3 days, and often up to 5 days, the total soil profile is recharged with water at each flooding. Chemical and physical soil properties are summarized in table 1. All experiments except 1 and 8 were carried out sequentially on the fully flooded block only.

Native pasture production

EXPERIMENT 1

Water flowed across the trial area on 2 and 21 February 1971, 5 March 1971 and 18 February 1973. A small area of the fully flooded block was fertilized with 40 kg ha^{-1} of nitrogen (as ammonium nitrate) on 9 February 1971. Native pasture growing on the three blocks was harvested 14 and 23 days following the flood of 2 February 1971, and 22 days after the 1973 flood. At the first two harvests pasture growing on the fertilized area was also harvested. On 5 May 1971 (92 days after the 2 February flood), pasture growing on the fully flooded site was again harvested to provide a comparison with the summer crop harvested on the same day (experiments 4 and 5).

Standing dry matter yields were recorded using the ranked-set method (Halls and Dell 1966). At each of 12 randomly selected points, 3 adjoining 0·5-m^2 quadrats were visually assessed as high, medium or low on a standing biomass basis. Either the high, medium or low quadrat was harvested according to a predetermined randomly selected pattern.

TABLE 1

SOIL PROPERTIES OF THE EXPERIMENTAL SITE*

Block	pH	Avail. P_2O_5 (ppm)	Replaceable Bases (m. equiv. %)				Total N (%)	Org. C. (%)	Mechanical Analysis			
			Ca	Mg	Na	K			Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)
A. Unflooded	6·4	14	10·1	3·4	0·6	1·1	0·03	0·24	13·8	31·5	13·7	36·5
B. Partially flooded	6·8	27	12·4	6·9	1·2	1·0	0·04	0·27	11·3	29·4	13·2	40·7
C. Fully flooded	6·9	61	9·2	4·8	1·9	0·9	0·04	0·33	7·1	33·5	21·6	37·8

* Surface 7·5 cm only.

Winter crop production

EXPERIMENT 2

The fully flooded block was inundated in April 1970. On 5 May 1970 the area was fertilized with 40 kg ha^{-1} of both nitrogen and phosphorus in the form of ammonium nitrate and superphosphate respectively, applied through a fertilizer drill. Bentland oats, Black barley, Horowitz safflower and Aphis Resistant rape were then planted in a 4 x 3 randomized block. All were sown into 15-cm rows, the oats and barley at a rate of 20 kg ha^{-1}, the safflower at 15 kg ha^{-1} and rape at 2 kg ha^{-1}.

Plant densities were recorded 17, 36 and 73 days following sowing. Dry matter harvests were taken 36 and 73 days after sowing when the plants were actively growing and water stressed respectively. All samples were analysed for nitrogen and phosphorus content.

EXPERIMENT 3

Following the higher yields of oats compared with the tap rooted crops in 1970, the cereals were selected for further study. The fully flooded block was inundated in April 1973, and on 23 May, 40 kg ha^{-1} of nitrogen as ammonium nitrate was drilled into the experimental area. Bentland oats and Skinless barley were sown in a 2 x 2 x 5 randomized block at two row spacings (15 cm and 30 cm) and at a rate of 20 kg ha^{-1}.

Plant densities were recorded 78 days from sowing (9 August 1973), and forage yields taken at preflowering (78 days) and the hard grain stage (154 days from sowing). On 9 August 1973 a comparative harvest of the native pasture on adjacent flooded country outside the experimental area was also taken. All samples were analysed for nitrogen and phosphorus content.

Summer crop production

EXPERIMENTS 4 TO 7

Following rain in January and February 1971, the fully flooded block was inaccessible until 9 February. An area was then fertilized with 40 kg ha^{-1} each of nitrogen and phosphorus (as ammonium nitrate and superphosphate); Sudax and sudan grass were sown in a randomized block design of 2 species x 2 sowing rates x 3 row spacings x 2 replications. The rates, calculated to give similar plant numbers between species, were 4 and 12 kg ha^{-1} for Sudax and 3 and 9 kg ha^{-1} for sudan grass. Row spacings were 30, 60 and 90 cm.

Rain on 21 February 1971 resulted in a further flow of water over the site.

On 3 March 1971, a second area was prepared and sown in the same manner as described in the previous experiment. Inundation followed 2 days later.

Plant counts of the two sowings (experiments 4 and 5) were made on 24 March (43 and 21 days from the respective floods), and a harvest was taken on 5 May 1971 (55 days and 33 days from the respective floods).

On 7 December 1971 the site was ploughed and experiment 6, similar to the previous two, was established. Tamworth bulrush millet, which replaced the Sudax, was sown into a dry seed-bed at rates of 6 and 12 kg ha^{-1}, and the sudan grass at 9 and 20 kg ha^{-1}. The site was inundated on 28 December 1971. This experiment was repeated on an adjacent block following the December flooding. Sowing was undertaken on 20 January 1972 into moist soil (experiment 7).

Experiment 8

It was thought that germination of Sudax and sudan grass in 1971 was impaired by the period of inundation. Consequently seeds of these species were immersed in distilled water in petri dishes, and held in a germination cabinet at a constant 27°C, for nil, 1, 8, 16, 24, 48 and 72 h. Ten replications of 100 seeds each were subjected to the treatments. After immersion for the prescribed period, the seeds were transferred to moist filter paper in petri dishes and returned to the cabinet until germination was completed.

III. RESULTS

Experiment 1

Full flooding resulted in substantial yield increases compared with the partial and unflooded blocks. Yields were further increased by the addition of nitrogen (table 2). Botanical composition was influenced by the degree of flooding (table 3); *Eragrostis parviflora, Alternanthera angustifolia* and *Uranthoecium truncatum* increased in dominance as the degree of flooding increased. The first two species were absent from the unflooded block.

TABLE 2

NATIVE PASTURE YIELDS* (kg ha^{-1}) (EXPERIMENT 1)

Flood Date	Days Since Flooding	Unflooded (A)	Partial Flood (B)	Full Flood (C)	
				Fertilized	Unfertilized
2 Feb 71	14	130 ± 55	360 ± 45	820 ± 70	350 ± 50
2 Feb 71	23	190 ± 90	510 ± 80	2 200 ± 200	810 ± 65
2 Feb 71	92	NR**	NR	NR	1 350 ± 150
18 Mar 73	22	450 ± 100	1 230 ± 165	NR	1 980 ± 210

* Means of 12 harvested quadrats.
** Not Recorded.

TABLE 3

SPECIES PRESENT IN EACH BLOCK, RANKED VISUALLY ACCORDING TO DENSITY

Fully Flooded	Partially Flooded	Unflooded
*Eragrostis parviflora**	*Dactyloctenium radulans**	*Bassia* spp.*
*Alternanthera angustifolia**	*Eragrostis parviflora**	*Dactyloctenium radulans**
Cyperus iria	*Uranthoecium truncatum**	*Calotis* spp.*
Centipeda spp.	*Bassia* spp.	*Solanum* spp.
Uranthoecium truncatum	*Alternanthera angustifolia*	*Sida* spp.
Chenopodium spp.	*Solanum* spp.	*Aristida contorta*
Calotis spp.	*Calotis* spp.	*Neurachne munroi*
	Centipeda spp.	*Uranthoecium truncatum*
	Iseilema spp.	
	Psoralea cinerea	
	Cyperus iria	

* Together these species contributed approximately 95% of the pasture yields.

Experiment 2

Plant density of Bentland oats was considerably higher than that of the other crops, while the forage yield of oats was approximately double that of barley and safflower. The performance of rape was poor (table 4). The nitrogen and phosphorus contents of the top growth varied with species (table 4).

TABLE 4

PLANT DENSITY, DRY MATTER YIELD AND NUTRIENT CONTENT OF THE 1970 WINTER CROPS (EXPERIMENT 2)

Crop	Days from Sowing						
	17 Days	36 Days				73 Days	
	Plant Density ('000 per ha)	Plant Density ('000 per ha)	Yield (kg ha^{-1})	N (%)*	P (%)*	Plant Density ('000 per ha)	Yield (kg ha^{-1})
Bentland oats	735 ± 179	916 ± 113	140 ± 50	4·48 ± 0·48	0·27 ± 0·06	909 ± 155	700 ± 290
Black barley	88 ± 37	166 ± 61	60 ± 25	4·82 ± 0·38	0·36 ± 0·02	127 ± 45	290 ± 10
Horowitz safflower	154 ± 51	270 ± 43	60 ± 4	4·01	0·31	220 ± 60	315 ± 75
Aphis Resistant rape	27 ± 48	48 ± 41	25**	5·39	0·31	62 ± 16	60**

* Moisture Free Values. Sufficient material was available for only one analysis of both safflower and rape.

** Yield from rape was so low that all samples were bulked to obtain a reasonable estimate.

TABLE 5

PLANT DENSITY, DRY MATTER YIELD AND NUTRIENT CONTENT OF THE 1973 WINTER CROPS (EXPERIMENT 3)

Crop	Days from Sowing						
	78 Days		154 Days	78 Days		154 Days	
	Plant Density ('000 per ha)	Yield (kg ha^{-1})	Yield (kg ha^{-1})	N (%)	P (%)	N (%)	P (%)
Bentland oats 15 cm rows	556 ± 115	1 380 ± 490	6 310 ± 470	2·46 ± 0·29	0·31 ± 0·02	1·11 ± 0·34	0·25 ± 0·02
Bentland oats 30 cm rows	570 ± 75	2 050 ± 340	8 900 ± 3 370	3·19 ± 0·46	0·31 ± 0·02	0·90 ± 0·03	0·28 ± 0·02
Skinless barley 30 cm rows ..	509 ± 100	2 070 ± 530	7 050 ± 750	2·50 ± 0·81	0·31 ± 0·02	0·87 ± 0·05	0·14 ± 0·03
Native pasture	NR*	611 ± 72	NR	0·78 ± 0·07	0·07 ± 0·02	NR	NR

* Not Recorded.

Experiment 3

Results of the plant density counts, yield estimates and nitrogen and phosphorus contents are presented in table 5. Although plant numbers for both species at both row spacings were similar, yield of oats sown at 30-cm row spacing was higher than for barley at the same spacing and oats at 15-cm spacing. The nitrogen and phosphorus contents of the top growth varied with row spacing and time of harvest.

Experiments 4 to 7

Germination of the summer crops was exceptionally low at all times, and only in 1971 (experiments 4 and 5) were plant numbers sufficiently high to warrant counting and later, a harvest. Any effect of treatment however, was lost because of the large variability not only between replications but also within individual plots. Highest yield recorded was 2 040 kg ha^{-1} from Sudax sown at 12 kg ha^{-1} in rows 60 cm apart and harvested at flowering.

Experiment 8

There was no consistent effect of immersion in water for various periods on germination of sudan grass. However, Sudax germination (table 6) decreased slightly with increasing time under water.

TABLE 6

GERMINATION (%) OF SEEDS OF SUDAX AND SUDAN GRASS IMMERSED IN WATER FOR VARIOUS PERIODS (EXPERIMENT 8)

Immersion in Water (h)	Sudan Grass		Sudax	
Nil	69·7*	(11·7)**	83·7	(6·8)
1	80·8	(8·0)	85·3	(5·7)
8	76·8	(3·9)	83·0	(4·0)
16	80·6	(7·6)	81·9	(4·8)
24	73·3	(6·8)	78·8	(4·9)
48	74·5	(5·5)	79·7	(5·4)
72	78·4	(4·2)	74·1	(5·1)

* Figures are means of 10 replications of 100 seeds.
** Standard errors of the means.

IV. DISCUSSION

The objectives of these studies were to assess the feasibility of forage cropping on waterspreaders, define associated problems and to quantify native pasture yields from such areas.

Native pasture

The beneficial effects of additional soil water on native pasture are highlighted by the results shown in table 2. A change in species composition occurred such that species with a higher level of production (and probably moisture use) colonized the flooded block and to a lesser extent the partially flooded block (table 3). This could be due partly to the lower soil phosphorus level in the unflooded block (table 1), although an adjacent flooded area supported a plant community similar in composition to the partially flooded block. The addition of nitrogenous fertilizer to the flooded block however, resulted in almost three times the dry weight of native pasture being produced (table 2).

Winter forage crops

Results from the winter crop studies of 1970 (experiment 2) indicate that oats are superior to barley and the tap rooted crops safflower and rape, though a comparison is difficult because of the wide differences in plant numbers (table 4). Rape in particular performed poorly. The higher yields from the 1973 cereal crops (experiment 3) compared with the 1970 crops are a reflection of the rainfall received during the growth of the crops. Only 12 mm of rain were received from sowing until harvest in 1970, whereas 175 mm were received between sowing and harvest in 1973. The excellent growing conditions in 1973 are reflected in the similarity of cereal density (table 5). By contrast, the marginal seasonal conditions in 1970 resulted in large variations in plant densities between species leading to difficulties in interpreting the dry weight yields (table 4).

In terms of yield and quality of the forage, 30-cm row spacings were superior to 15-cm spacings (table 5). Oat and barley biomass and nitrogen and phosphorus contents were considerably higher than those of native pasture at the same time (table 5). The superiority of winter crops over native pasture in yield is obviously considerable. Such crops could be effectively utilized as conserved fodder by selected stock at stress periods (lambing and weaning) or for grazing by stud animals at times of low nutrient levels of native pasture.

Summer forage crops

Poor germination of the summer crops precluded any worthwhile conclusions on suitability of species and of the feasibility of summer cropping. Sowing before rather than after a flood did not appear to increase the number of seedlings emerging. Loss of seed through flotation was thought at first to have contributed to the low seedling numbers; but, although on 7 December 1971 seed was sown 7 to 8 cm deep, seedling emergence was still low.

The decrease in germination of Sudax in the laboratory was insufficient to account for the poor field germination. This, together with the inconsistencies in the sudan grass germination (table 6), makes it unlikely that water immersion is a major factor limiting germination in the field. The inability of the seedling to penetrate the surface crust formed as the soil dries is a possible alternative reason for the failure of seedling emergence.

The results of these preliminary studies have demonstrated that water-spreading:

1. increases the yield of native pastures;
2. alters the composition of the native pasture; and
3. allows the production of satisfactory winter cereal crops.

However, several problems still requiring solutions include:

1. low germination or emergence of summer growing hybrid sorghums, bulrush millet and sudan grass;
2. encroachment into waterspread country of useless woody species (Batianoff and Burrows 1973); and
3. loss of surface soil by the force of the spreading water, particularly where soils have been cultivated.

Yields of crops grown on waterspreaders would be increased, and certainly much of the risk would be removed, if a second irrigation was provided 4 to 6 weeks after emergence. Water stored at the time of flooding in a reasonably sized depression close to the area to be cropped could be used to furrow-irrigate the crop. Capital expenditure on earthworks and machinery would be minimal. A scheme such as this operated at "Beechal" for a number of years and oat and barley forage yields as high as 12 t ha^{-1} were recorded (M. C. Crotty, personal communication).

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