IMPACT OF LANDUSE ON AGRICULTURAL HYDROLOGY IN THE NORTHERN TERRITORY SEMI ARID TROPICS

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ABSTRACT

The impact of tillage, grazing, native woodland and the soil conservation bank spacing on surface runoff was studied. Seven catchments ranging in size from 4.1 to 7.8ha were developed, using narrow based soil conservation banks, to accommodate commercial landuse practices. Results obtained showed that, in each season, the conventionally tilled bays produced the greatest volume and depth of runoff and the highest number of runoff events. At the other extreme the woodland produced the least number of runoff events (4%) and between 80 and 150 times lower runoff depth than the conventional bays and on average, converted less than 1% of the rainfall to runoff compared with up to 25% by the conventional bays. For every water year, statistical tests showed that the paired responses of the conventional and no tillage bays to runoff causing rainfall events, were significantly different with the no tillage bays producing lower runoff depths. The responses from the pasture bay were 'in between' those of the woodland and no tillage bays. For each water year, statistical tests at a Significance Level (SL) of 0.05 showed that runoff depth, in response to runoff causing rainfall events, was not influenced by bank spacing.

INTRODUCTION

In the Semi arid tropics (SAT) of the NT the most widespread soils with agricultural potential are massive sesquioxide soils which include Red, Yellow and Grey Earths and some podzolic soils (1). On these massive soils, surface runoff and erosion present a serious problem under conventional cultivation (2). Soil erosion on these soils is endemic even on slopes of 1%. Reconnaissance surveys conducted by the Conservation Commission of the Northern Territory suggest that some NT croplands with light sandy soils and without soil conservation measures, may be losing up to 100t/ha/y [van Cuylenburg, pers comm.].

High energy rainfall is the primary cause of soil erosion in the SAT of the NT. On exposed soil surfaces, these storms detach large amounts of soil by rain splash and once surface hydraulic properties have declined (often after surface sealing) there is sufficient velocity for runoff to transport and detach further material (1).

In the mid 1980's the Conservation Commission of the Northern Territory initiated, in collaboration with the NT Dept. of Primary Industries and Fisheries, the Cropland Erosion Research Project (CERP) to study the influences of landuse on soil erosion and agricultural hydrology.

Before CERP began, it was accepted that soil conservation banks would be necessary to stabilise the croplands of the region. Little data, however, was available on soil responses to rainfall, the subsequent runoff and the effectiveness of structures in handling runoff and reducing erosion. Therefore, CERP was also designed as a base study of hydrology and hydraulics to provide local data for design criteria. The effect of bank spacing was also tested for conventional and no tillage systems using single and double spaced banks.
This paper presents some preliminary hydrological results.

EXPERIMENT DESCRIPTION

Location
CERP is located at the Douglas Daly Research Farm (DDRF), at latitude 13° 51' and longitude 131° 12'. Its grid references for the access gate is sheet 517, 405685.

Soil
An intensive soil survey (47 profiles in 40 ha) showed that the soils are Loamy Red Earths (Northcote factual key Gn 2.12 and Gn 2.15) (3).

Geomorphology
CERP is located on a low slope below a large dome of sandy red earths. It is above the drainage floor backplain and levees associated with the Douglas River. The site has a northerly aspect, slopes of 1-2% and an elevation of approximately 50m above sea level.

Rainfall and Evaporation
The SAT of the NT is characterised by a distinct wet and dry season with more than 90% of the rain recorded between November and March. These are the only months when the mean monthly rainfall exceeds mean monthly evaporation (1,3).

Vegetation
Prior to clearing, the area was composed mainly of Eucalyptus foelscheana, with some E. confertiflora and E. tectifica. The main grasses include Sotira nervosum, Themeda triandra and Heteropogon contortus, with some Sorghum species (3).

Experimental Design and Instrumentation
CERP covers an area of 40.1 ha, on 1-2% slope, divided into 7 bays ranging in size from 4.1 to 7.8 ha (fig 1). These are separated by narrow based soil conservation banks on 0.6% slopes. The NT Soil Conservation Design Manual was used to determine the catchment sizes and inter bank slope lengths for a storm with an average recurrence interval (ARI) of 10 years. The bays, therefore, are real scale agricultural catchments and are representative of commercial agriculture in the region. With surface hydrology so inherently scale dependent, these bays provide a realistic scale for the study of surface runoff and its erosion potential in agricultural catchments.

METHODOLOGY

The cropping bays (bays 1 to 5) were cropped on a maize/soybean rotation with conventional inversion type tillage using discs, reduced surface tillage using tykes and no tillage systems. Following the 1985 sowing and establishment of a verano (Stylosanthes hamata) based pasture cattle (0.8 beasts/ha) were introduced in December 1987. The native woodland had virtually been undisturbed during the project except for a fire in mid 1987.

Figure 1 illustrates the instrumentation and project layout for CERP. Each bay has a Parshall flume to accommodate a stage height of 1.5m. At maximum stage heights, bays 1, 4, 5, 6 and 7 will have a flow rate of 1.98 cumecs and bays 2 and 3, 2.68 cumecs. At each flume is an ISCO 2300 flowmeter which outputs on an ISCO 2310 plotter the total flow volumes, runoff hydrographs and sediment sampling times. It also digitally outputs the data onto 64k TAUPO-RF data loggers. Linked to the flowmeter is an ISCO 1860 sediment
sampler programmed to take representative runoff samples, from total flow depths, once the flowmeter senses predetermined volumes of flow exiting the flume.

At each flume there is also a mechanical Stevenson Stage Height Recorder which is a backup to the ISCO 2310 flowmeter.

Figure 1. The project layout and instrumentation (not to scale).

Six 8 inch tipping bucket pluviometers (Meteorological Bureau issue) encircle CERP and RIMCO digital raingauges, which output onto the TAUPO-RF dataloggers, have also been commissioned.

A weather station with a Class A evaporation pan and devices to measure minimum and maximum temperatures, humidity and precipitation exist on site. Within the bays are six 16 x 30m study sites, each having 2x1.2m and 1x2.2m neutron access tubes.

The establishment of CERP has been a long and complex process. In 1984/85 the cropping bays (1-5) were instrumented with ISCO equipment with Bays 6 and 7 being established with Stevenson Recorder. Pluviometers were installed. In 1985/86 bays 6 and 7 were also instrumented with ISCO equipment and the weather station established. The following year the computing infrastructure was developed. In 1987/88 the dataloggers, digital raingauges and neutron access tubes were introduced.
RESULTS AND ANALYSIS

Runoff Events
In the period November 1984 to May 1988, a total of 226 runoff events resulted from all the bays. Figure 2 ranks these by treatment.

Figure 2. The percentages of the total number of runoff events (over the period Nov. 1984 to May 1988) produced by each treatment. The (s) and (d) represent bays with single and double spaced conservation banks, respectively.

Over 95% of all the events occurred in December, January and February generating 14.35 and 48% respectively. Less than 5% occurred in November, March, April and May. This positively skewed relationship is closely mirrored by the monthly rainfall figures.

The conventional tillage bays (bays 2 and 5) produced nearly half (47%) of all the runoff events and the no-till bays just over a quarter (26.5%). The conventional (double) produced 1.65 times more events than the no-till (double) and the conventional (single) 1.9 times more than the no-till (single).

The pasture and woodland blocks produced respectively 9.7 and 4.0% of the events in the 3 seasons.

Runoff Volume and Depth
The two conventional bays produced, in each season, larger volumes of runoff than the no-till, woodland and pasture blocks. The combined total runoff volume produced by all bays were 22062.2, 89427.8 and 40881.9 cubic meters for the 85/86, 86/87 and 87/88 seasons, respectively. The two conventional bays produced between 45.7 and 57.1% of the total runoff volumes in the three seasons. The no-till bays produced between 21.6 and 25.1% with the pasture and native woodland bays producing, on average, 7.4 and 0.5% of the total runoff volumes, respectively.

To overcome the area factor the runoff volumes were converted to flow depths (mm). Table 1 details the runoff depth for each treatment over the three seasons and Table 2 converts the responses as a percentage of the total runoff losses produced by all treatments over the season.
Table 1. The total runoff (mm) produced by each treatment each season.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1985/86</th>
<th>1986/87</th>
<th>1987/88</th>
</tr>
</thead>
<tbody>
<tr>
<td>no-till(s)</td>
<td>40.18</td>
<td>180.4</td>
<td>89.3</td>
</tr>
<tr>
<td>conventional(d)</td>
<td>84.9</td>
<td>272.5</td>
<td>149.6</td>
</tr>
<tr>
<td>no-till(d)</td>
<td>65.7</td>
<td>248.8</td>
<td>99.6</td>
</tr>
<tr>
<td>minimum till(s)</td>
<td>47.7</td>
<td>253.6</td>
<td>114.2</td>
</tr>
<tr>
<td>conventional(s)</td>
<td>87.5</td>
<td>300.0</td>
<td>152.8</td>
</tr>
<tr>
<td>woodlands(s)</td>
<td>&lt; 1</td>
<td>&lt; 5</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>pasture(s)</td>
<td>22.9</td>
<td>172.4</td>
<td>55.2</td>
</tr>
<tr>
<td>total</td>
<td>349.1</td>
<td>1431.2</td>
<td>660.8</td>
</tr>
</tbody>
</table>

Table 2. The total ratio (%) of runoff (mm) produced by a treatment to the total runoff (mm) produced by all bays in that season.

<table>
<thead>
<tr>
<th>treatment</th>
<th>1985/86</th>
<th>1986/87</th>
<th>1987/88</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>no-till(s)</td>
<td>11.5</td>
<td>12.6</td>
<td>13.5</td>
<td>12.5</td>
</tr>
<tr>
<td>conventional(d)</td>
<td>24.3</td>
<td>19.3</td>
<td>22.6</td>
<td>22.1</td>
</tr>
<tr>
<td>no-till(d)</td>
<td>18.8</td>
<td>17.4</td>
<td>15.1</td>
<td>17.1</td>
</tr>
<tr>
<td>minimum till(s)</td>
<td>13.7</td>
<td>17.7</td>
<td>17.3</td>
<td>16.2</td>
</tr>
<tr>
<td>conventional(s)</td>
<td>25.1</td>
<td>21.0</td>
<td>23.1</td>
<td>23.1</td>
</tr>
<tr>
<td>woodlands(s)</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>pasture(s)</td>
<td>6.6</td>
<td>12.0</td>
<td>8.4</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 2 shows that, on average, the no-till(s) produced 12.5% of the total seasonal runoff produced by all treatments over the three seasons. The conventional(s) produced 1.8 times as much. The responses from the native woodland bay very vividly stand out as in each season less than 1% of the combined runoff depth came from it.

The paired responses of a set of two treatments, to each runoff causing rainfall event in a season, were statistically analysed. It should be clearly understood that in some of the rows of the paired data matrix, one or both of the treatments may have a zero response.

In none of the three seasons were the differences in runoff depths of the no-till(s) and conventional(s) bays (in response to runoff causing rainfall events) normally distributed at a significance level (SL) of 0.05 (Wilk-Shapiro Test). Using Paired Sample Wilcoxon Signed Rank Test it was shown that at a SL of 0.05, the null hypothesis that the median runoff depth from the no-till(s) bay was greater than or equal to the conventional(s) bay can be rejected for each of the three seasons. Thus the two samples came from different populations with no-till(s) bay producing significantly smaller response than the conventional(s) bay in each of the three seasons.
Similar tests showed that in each of the three seasons the no-till(d) produced significantly smaller runoff (depth) than the conventional(d) and conventional(s) bays ($SL = 0.05$).

For each of the three seasons, statistical tests also showed that the runoff responses (depth) from the no-till(s) and the no-till(d) came from the same population. The same conclusion was drawn for the two conventional bays in each of the three seasons ($SL = 0.05$).

At a $SL$ of 0.05, it was found that runoff responses from the pasture and the conventional(s) bays came from significantly different populations, with the conventional(s) producing larger events than the pasture bay in all three seasons.

Test conducted for the pasture and the no-till(s) bays showed that in 1985/86 and 87/88 the pasture block produced runoff events with significantly lower depths than the no-till(s). In 1986/86, however the two samples were found to come from the same population.

**Water conservation**

1986/87 was the wettest season, receiving 1216 mm of rain for the water year (1 November – 15 May). This was 116mm more than the historic mean and 1.67 and 1.69 times more than the 85/86 and 87/88 seasons, respectively which received below average rainfall totals.

During the water year, the woodland block, converted less than 0.5% of the rain to runoff in any of the three seasons. In the adjacent (conventional(s)) block up to 25% was. The no-till and pasture bays were more efficient water conservers than the conventional bays (Table 3). Of the three seasons the no-till(s), no-till(d) and the pasture bays were, on average, able to respectively convert only 55, 71 and 44% of the amount converted to runoff by the conventional(s) bay.

Table 3. Percent rain that became runoff (mm) over the water year (1 Nov – 15 May). Refer Figure 1 for the landuse referred to by the bay number.

<table>
<thead>
<tr>
<th>Year</th>
<th>Bay1</th>
<th>Bay2</th>
<th>Bay3</th>
<th>Bay4</th>
<th>Bay5</th>
<th>Bay6</th>
<th>Bay7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985/86</td>
<td>5.5</td>
<td>11.7</td>
<td>9.0</td>
<td>6.6</td>
<td>12.0</td>
<td>.03</td>
<td>3.2</td>
</tr>
<tr>
<td>1986/87</td>
<td>14.9</td>
<td>22.4</td>
<td>20.5</td>
<td>20.9</td>
<td>24.7</td>
<td>.31</td>
<td>17.2</td>
</tr>
<tr>
<td>1987/88</td>
<td>12.5</td>
<td>20.8</td>
<td>13.8</td>
<td>15.9</td>
<td>21.2</td>
<td>.03</td>
<td>9.3</td>
</tr>
</tbody>
</table>

A detailed study of rainfall partitioning on an event basis is beyond the scope of this paper.
DISCUSSION AND CONCLUSION

The treatments are predetermined in size and slope length by the NT Soil Conservation Design Manual. All treatments with single spaced soil conservation banks should have the same potential for surface runoff responses to rainfall. The same should apply to both the double spaced bays which perhaps would be expected to produce greater water and soil losses than their single bank spaced counterparts.

The basic difference between the treatments is cultural. The other factors that may have some possible influence are a very minor catenary effect and rainfall variability.

For almost every rainfall event, the responses from different pluviometers varied between 0-3mm, with rare higher variations. Between 50 and 73% of the variation between pluviometers, for runoff causing rainfall events, was restricted to between 0-5% of the mean. Between 83 and 95% was restricted to 0-10% of the mean.

Whilst, there is no doubt that there are inter and intra bank variability in rainfall, most of the consistant variation of between 0-3mm can be attributed to digitising operator errors and pluviometer calibration factors.

The digitising software and hardware system was sophisticated enough to digitise on either side of the solid line produced by the standard pluviometer pen. The tolerance range of the pluviometers were also greater than that of the digitising system and there were differences in the tolerance levels between the pluviometers themselves, depending on their history of calibration.

With rainfall variation being relatively minor it is very unlikely that these variations would be responsible for the significant differences in response to the treatments.

The two no-till bays, in each season, produced significantly similar responses to the runoff causing rainfall events. The conventional(d) bay, sandwiched between the two no-till bays, produced significantly different responses. In each of the three seasons, however, the conventional(d) bay produced responses significantly similar to that of the conventional(s). The latter is two bays away. The native woodland and the conventional(s) bays are next to each other with almost identical soil surface and profile textures. Yet the latter produced over 25 times more runoff (total depth) each season.

It, therefore, appears unlikely that the minor soil catenary factor is playing a significantly dominant role in influencing the hydrological responses to landuse. It would seem that whatever localised conditions are created by landuse practices are predominantly responsible for the runoff responses.

The obvious visible differences between treatments are the degree of land disturbance and vegetation cover.

The no till bays, in the beginning of the cropping season, have ground cover of between 29.3 to 66.5% composed mainly of grasses and broad leaf weeds and litter. The viable cover is sprayed with Roundup before planting which turns it into surface mulch.
The conventional and minimum tillage bays are worked from around early November through till late December, early January when planting takes place. For most of this period the grounds are bare with weeds destroying by spraying or cultivation. It is not until early March that these bays attain ground cover approaching the nc-till bays. At no time during these months, however, do the conventional and min-till bays attain surface mulch levels equal to or greater than the nc-till bays.

During the rainy season the woodland block has a minimum ground cover of 92% (not taking into account tree and shrub cover). The understorey is composed of thick tussocky native grasses and some broad leaved weeds. Ground litter composed of leaves and twigs is very prevalent and appear to provide great resistance to flow and help reduce the transport capacities of flow.

During the wet season the pasture bay has a ground cover ranging from 70 to 100%. The bay is generally managed by slashing and grazing and does not have a tree canopy. Like the woodland, but to a smaller degree, the pasture also provides strong resistance to flow.

Over 95% of the runoff events occur in December, January and February. More than a third of all rainfall events responsible, experienced a maximum thirty minute intensity of greater than 50mm/h. Over twenty percent experienced a maximum six minute intensity of greater than 100mm/h, with 200mm/h storms occurring more than once every year.

With these high energy storms the exposed ground surface is subject to intense pounding by raindrops which cause soil splash and surface sealing as a result of the splash and sorting processes. Numerous studies conducted elsewhere have shown that soil compaction by raindrops is reduced by surface mulch and ground cover. This helps maintain greater infiltration rates and produce smaller runoff discharge and soil loss (4,5,6,7,8,10,11,12,13).

Results obtained do suggest that localised conditions created by landuse practices significantly influence the surface runoff responses of the treatments.

ACKNOWLEDGEMENTS

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REFERENCES


