SHORT, NON-REFEREED PAPER

ASSESSMENT OF TRENDS IN RUN-OFF AND SEDIMENT YIELD FROM CATCHMENTS UNDER SUGARCANE PRODUCTION AND MANAGEMENT PRACTICES

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Abstract

Run-off is dependent on interactions between rainfall intensity, antecedent soil moisture conditions and land cover while peak discharge from a catchment is closely related to the run-off volume generated. Both run-off volume and peak discharge are drivers to sediment yield. The purpose of this study was to increase understanding of run-off and soil erosion processes from catchments under sugarcane production and various management practices (i.e. tillage and land cover). The study area was located at La Mercy on the site that now hosts the King Shaka International airport in South Africa. It consisted of four research catchments which were under sugarcane production and various management practices for the period 1986-1995. The data consisted of daily run-off and sediment yield for the same period. A comparison of run-off from the four catchments showed that effects of minimum tillage and strip planting on run-off reduction were evident while effects of conservation structures (i.e. spill-over roads and water carrying terraces) on run-off reduction were not evident. Hence, it is hypothesised that crop cover masked the effects of conservation structures on run-off reduction. With respect to sediment yield, low soil erodibility, sugarcane land cover and management practices had greater impact on the reduction of sediment yield than conservation structures while effects of catchment steepness on sediment yield were not evident. This is because soil erodibility neutralises the effects of catchment steepness on sediment yield production.

Keywords: run-off, sediment yield, sugarcane production, management practices, La Mercy catchments, South Africa

Introduction

Rainfall is a dominant and driving variable in initiating and sustaining most hydrological processes (Schulze *et al.*, 1995; Schulze and Smithers, 1995). The relationship between rainfall and run-off is non-linear and an increasing fraction of rainfall is converted to run-off as a catchment becomes wetter (Schulze *et al.*, 1995). Smithers *et al.* (1996) and Maher (2000) reported that catchment run-off response to rainfall events is dependent on interactions between rainfall intensity, antecedent soil moisture conditions and land cover. According to McPhee *et al.* (1983), the initial abstraction, also known as the depth of water which infiltrates into the soil profile before commencement of run-off, and the average infiltration depth during run-off events greatly influence the amount of run-off generated. On the other hand, peak discharge from a catchment depends on catchment slope, run-off volume, rainfall depth, rainfall intensity and area of catchment (Schulze, 2011). Both run-off volume and peak discharge are drivers to sediment yield. Soil texture is significant in causing erosion (Manyevere *et al.*, 2016) and in South Africa, soil parent material erodibility is the overriding erosion risk factor and not the slope gradient as established in the US (Le Roux *et al.*, 2007).

Run-off from cultivated lands is frequently controlled and managed through the use of agronomic, soil management and mechanical means, and all approaches of soil conservation should be used in the management of run-off from cultivated lands (Reinders *et al.*, 2016). Generally, crop cover and management practices (i.e. crop rotations, conservation tillage and applied mulch) reduce run-off to a greater extent than do soil and water conservation structures (Maher, 1990). Nonetheless, conservation structures are necessary to reduce both Run-off and erosion after the crop cover has been removed. According to Foster *et al.* (2003) and USDA-ARS (2008), cultural and supporting land use practices are used to control soil loss. Cultural practices, also known as crop cover and management practices, include vegetative cover, crop rotations, conservation tillage and applied mulch while supporting practices (i.e. conservation structures) include contouring, strip cropping and terraces (USDA-ARS, 2008; USDA-ARS, 2013). Similar to run-off reduction, cover and management practices reduce soil loss to a greater extent than conservation structures in sugarcane fields (Maher, 2000). However, crop cover is more effective in reducing soil loss than run-off (Maher, 1990). In general, conservation structures become important when crop cover is removed at harvest and at planting (Maher, 2000).

The objective of this study was to increase understanding of run-off and soil erosion processes from catchments under sugarcane production and various management practices.

Data and Methods

The study area was located at La Mercy, 28 km north of Durban in South Africa on the site that now hosts the King Shaka International airport. The research catchments were established by the South African Sugarcane Research Institute (SASRI) (formerly SASEX) in May 1977 and were monitored under sugarcane production and various management practices. The experiment comprised of four small catchments numbered from south to north, with Catchment 101 the southernmost catchment and Catchment 104 the northernmost catchment (Platford, 1979; Platford and Thomas, 1985; Haywood and Schulze, 1990; Maher, 1990; Haywood, 1991; Maher, 2000). Catchments 101, 102, 103 and 104 had areas of 2.7 ha, 4.7 ha, 4.4 ha and 6.6 ha respectively, while the respective slopes were 29%, 21%, 12% and 17%.

Catchment 101 consisted of 29% Swartland soil series (high erodibility) and 71% Arcadia soil series (low erodibility), Catchment 102 consisted of 3% Swartland and 97% Arcadia, Catchment 103 consisted of 2% Swartland and 98% Arcadia and Catchment 104 consisted of 53% Swartland, 37% Arcadia and 10% Clansthal (moderate erodibility) soil series.

Catchments 101 and 104 were each divided into five equal panels (strips). Minimum tillage was employed on Catchment 101 while Catchments 102, 103 and 104 were conventionally tilled. Sugarcane was planted on all the four catchments, although two panels of Catchment 104 were permanently under bare fallow conditions and the panels on Catchment 101 were planted at different times. Three of the catchments had soil and water conservation structures with Catchment 101 having spill-over roads, while Catchments 102 and 104 had water carrying terraces. Construction of conservation structures was by a caterpillar bulldozer and a tractor pulling reversible two-disc ploughs. Harvesting was by trashing and burning with the burnt trash scattered on the surface.

The data comprised of daily observed rainfall, run-off and sediment yield for the period 1986-1995. Rainfall was measured with a single rain gauge centrally located, while run-off and sediment yield were measured with flumes and splitters, respectively, and located downstream of each catchment. The data also includes historical information on the management practices (i.e. dates of tillage, sugarcane planting and harvesting) at the La Mercy catchments for the period 1986-1995.

Plots of run-off against rainfall and sediment yield against time were made and assessed for effects of tillage, sugarcane land cover, conservation structures and catchment steepness on run-off and sediment yield generation. In addition, effects soil erodibility on sediment yield were assessed. The assessment was in terms of run-off-rainfall ratios and accumulated sediment yield exhibited over the period.

Results and Discussion

During periods for which the four catchments were under sugarcane land cover, Catchment 101 which was under minimum tillage practice, recorded the lowest run-off followed by Catchments 103, 102 and 104 which were conventionally tilled. In general, the respective average run-off-rainfall relationships for Catchments 101, 103, 102 and 104 were 0.17, 0.24, 0.29 and 0.31 and the standard deviation was 0.06, hence the respective run-off-rainfall relationships are not statistically different. The trend exhibited by Catchment 101, which registered the lowest run-off, conformed to studies conducted by Haywood and Mitchell (1987) who showed that minimum tillage practices greatly reduced Run-off compared to conventional tillage practices. In addition, Catchment 101 was under strip planting and harvesting, implying that sugarcane cover was always present on some of the panels while the harvested panels were covered with mulch or burnt tops, hence generating less run-off. Catchment 104 which only had three strips under sugarcane land cover and the remaining two strips under permanent bare fallow conditions, generally recorded the highest run-off. This observation resonates with Maher (1990) who stressed the need for maintenance of crop cover through strip planting so as to minimise generation of run-off. The run-off from Catchment 103 was generally lower than run-off from Catchments 102 and 104 and all the three catchments were conventionally tilled. Catchment 103 had no water conservation structures while Catchments 102 and 104 had water carrying terraces. Thus, it is postulated that the construction of water carrying terraces with the use of heavy machinery could have led to the formation of hard surfaces which could have inhibited infiltration and increased run-off generation in Catchments 102 and 104. In addition, the effect of water conservation structures was generally not evident. This was because crop cover reduced run-off to a greater extent than soil and water conservation structures, which concurred with conclusions drawn by Maher (1990). Similar to soil and water conservation structures, the effects of catchment slope on run-off were not evident and this could be attributed to crop cover masking the effects of catchment slope on run-off.

In relation to sediment yield, Catchment 104 consistently registered the highest sediment yield, followed by Catchments 101, 103 and 102 with sediment yield values of 60.8 $t.ha^{-1}$, 2.9 $t.ha^{-1}$, 1.4 $t.ha^{-1}$ and 1.0 $t.ha^{-1}$ respectively. The highly erodible soils, the two permanent bare fallow strips and the conventional tillage practice in Catchment 104 were responsible for the highest sediment yield registered in Catchment 104. The sediment yield response registered in Catchment 101 was attributed to the highly erodible soils and the strip planting/harvesting practice while the sediment yield response exhibited in Catchment 103 is attributed to the conventional tillage practice and the lack of conservation structures. Finally, the lowest sediment yield response in Catchment 102 is attributed to the low erodibility soils and the water carrying terraces which trap sediment yield. In general, the effects of low soil erodibility and cover and management practices were more pronounced in the reduction of sediment yield than the effect of conservation structures, which is in agreement with observations made by Maher (1990). In addition, effects of catchment steepness on sediment yield were not evident and it is because soil erodibility neutralised effects of catchment steepness on sediment yield production which is in agreement with observations made by Le Roux *et al.* (2007).

Conclusions

Minimum tillage caused a reduction in run-off as compared to conventional tillage with Catchment 101 registering the lowest run-off and Catchment 104 registering the highest Run-off. In addition, sugarcane cover reduced run-off to a greater extent than surfaces not fully under sugarcane land cover. Generally, the effect of conservation structures and catchment slope on run-off was not evident. Therefore, it was hypothesised that crop cover masked the effects of conservation structures and catchment slope on run-off.

In relation to sediment yield, low soil erodibility and cover and management practices had a greater effect on the reduction of sediment yield than conservation structures while the effects of catchment steepness on sediment yield were not evident. This is because soil erodibility neutralises the effects of catchment steepness on sediment yield production.

In conclusion, further research by way of sensitivity analysis needs to be conducted so as to establish the individual effects of catchment steepness and conservation structures on run-off and sediment yield.

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