Review

Design norms for soil and water conservation structures in the sugar industry of South Africa

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ABSTRACT

This paper contains a critical review of the norms employed in the design of soil and water conservation structures in the South African sugar industry and highlights research needs in order to update them. Sugarcane in South Africa is grown on wide-ranging soils, sometimes in non-ideal climates and on steep topographies where soils are vulnerable to erosion. A consequence of unsustainable soil loss is reduction in field production capacity. Sugarcane fields are protected against erosion through, inter alia, the use of engineered waterways, contour banks and spill-over roads. The South African Sugarcane Research Institute (SASRI), previously known as the South African Sugar Experiment Station (SASEX), developed a nomograph to easily compute the maximum width of field panels based on soil type, tillage method, replant method, surface structures to control runoff, surface cover and slope. This was followed by guidelines and norms for the design of soil and water conservation structures. However, the nomograph was developed based on an acceptable soil loss of 20 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$, yet soil formation rates in South Africa range between 0.25 and 0.38 $t{\cdot}ha^{-1}{\cdot}yr^{-1}$. Comparisons between design norms in the National Soil Conservation Manual and norms used in the sugar industry clearly show discrepancies that need to be investigated. The design of soil conservation structures includes the design of both contour bank spacing and hydraulic capacity. The sustainable soil loss method is recommended in the design of contour spacing and it determines contour spacing based on evaluation of site-specific sheet and rill erosion potential of the planned contour spacing while the hydraulic design employs Manning's equation. Considering that increases in both design rainfall and design floods are anticipated in South Africa, it is necessary to incorporate these projections in the design of soil and water conservation structures. Many soil loss models exist, of which empirical models are the most robust and provide stable performances. The majority of empirical models are lumped models which estimate average annual soil loss. The Modified Universal Soil Loss Equation (MUSLE) estimates event-based erosion and, given that the majority of soil erosion occurs during a few extreme events annually, the design norms should be updated using the MUSLE.

Keywords: contour banks, hydraulic, hydrologic, soil erosion, USLE, waterways

INTRODUCTION

Soil conservation is defined as the prevention and reduction of the amount of soil lost through erosion (Sustainet, 2010). The purpose of soil conservation is to ensure that the rate of soil formation is not exceeded by the rate of soil loss (Morgan, 2005), and it ensures increases in the amount of water seeping into the soil, thereby slowing down and reducing the amount of water running off (Sustainet, 2010). Soil is the most important resource on which agriculture is based. Thus, the proper management of soil is vital to ensuring long-term sustainability of agricultural productivity. According to Morgan (2005), soil erosion control is dependent on the selection of appropriate strategies for soil conservation, which in turn requires a thorough understanding of the processes and mechanics of erosion. Many soil conservation practices exist and they include mechanical structures (e.g. contour bunds, terraces, check dams), soil management practices and agronomic measures (e.g. cover crops, tillage, mulching, vegetation strips, re- vegetation, and agroforestry) (Krois and Schulte, 2014). It is recommended that all approaches to soil conservation, i.e., agronomic, soil management and mechanical means, be used to manage runoff from cultivated lands (Reinders et al., 2016).

Erosion is the process by which soil particles are detached and transported by erosive agents (Ellison, 1944). When the erosive agent is rainfall and/or runoff, the process is referred to as soil erosion by water (Ferro, 2010). Erosion of soil is a serious problem that emanates from a combination of agricultural intensification, soil degradation and intense rainstorms (Amore et al., 2004). Soil is functionally a non-renewable resource and while topsoil develops over centuries, the world's growing human population has actively depleted the resource over decades (Cohen et al., 2006). According to Cogo et al. (1984), soil erosion from cultivated cropland continues to be a major concern with significant associated problems, which range from the losses of a non-renewable resource and nutrients at its source to the contamination that occurs in the downstream areas (Guo et al., 2015). Shabani et al. (2014) reported that soil erosion is one of the most important factors degrading fertile agricultural soils around the world. According to Lewis (1981) and Nyakatawa et al. (2001), erosion may lead to the development of a rough and thin soil layer having little or no capacity to store water. This

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Received 12 March 2018; accepted in revised form 4 December 2018.

https://doi.org/10.4314/wsa.v45i1.04
Available on website http://www.wrc.org.za
ISSN 1816-7950 (Online) = Water SA Vol. 45 No. 1 January 2019

National Soil Conservation Manual (e.g. maximum slope, cover factors for sugarcane and maximum contour spacing) and norms employed in the USA and Australia. The design norms for soil and water conservation structures in the sugar industry also advocate for specific designs whenever slopes are less than 3% or greater than 30% although the design nomograph used in the sugar industry caters for slopes up to 40%. Some slopes in the sugar production industry exceed 40% and yet the nomograph has a maximum slope of 40% and cannot be used to design structures on land where slopes are greater than 40% or less than 3%. The 40% slope is also greater than the 20% maximum slope contained in the National Soil Conservation Manual (Van Staden and Smithen, 1989). Hence, these anomalies need to be revised and harmonised in the updated design norms for the design of soil and water conservation structures.

The nomograph used in the local sugar industry further assumes strip planting, which is generally no longer practiced in South Africa. Failure to practice strip cropping exposes the soils to erosion and hence recommendations for practices like mulching would limit the amount of soil loss.

Accidental and runaway fires are common occurrences in sugarcane harvesting in South Africa and often spread over entire hillsides, thereby exposing the land under sugarcane production to potential erosion (SASRI, 2014). Such an unforeseen occurrence is not accounted for in the design norms for soil and water conservation structures in the sugar industry and should be considered in future design norms.

Crop rotation is important in sugar production, ensuring soil fertility and reduction of pests and diseases, yet this important practice is not included in the design norms for soil and water conservation structures in the sugar industry. During the rotation period, the cover factor of the rotation crops is different to the sugarcane cover factors. Hence, some practices allowed during sugar production, like spraying pests and diseases and burning at harvest, may not be performed as a result of crop rotation. The design nomograph used in the sugar industry does not include vulnerability during break cropping where the cover may be reduced as a result of field rejuvenation and replanting of sugarcane. The sugarcane cover factors in the National Soil Conservation Manual range between 0.15 and 0.20 (DAWS, 1990), while the factors in the sugar industry design norms range between 0.09 and 0.15 (Platford, 1987).

In conclusion, there is a need to accommodate climate change variations, significant events of soil erosion, production and management practices, unforeseen occurrences which may occur, and regional differences in climate, soils and slopes in future design norms for soil and water conservation structures in the sugar industry of South Africa.

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