The effects of vegetation on wind erosion in the West African Sahel

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Introduction

Wind erosion is an important soil degradation problem in the Sahel (Fig. 1A). Much research has focused on control measures like mulching, ridging, strip cropping and growing shelterbelts. Most measures are difficult to adopt by farmers and there is a need for alternative strategies to reduce wind erosion. Potentially, the Sahelian vegetation with scattered trees and shrubs (Fig. 1B) can provide wind erosion control, but so far adequate quantification of vegetation impacts is lacking. In this study a field-scale model was developed to simulate the effects of scattered trees and shrubs on sediment transport in a typical Sahelian environment.

Methods

Vegetation has three effects on wind erosion (Fig. 2). The model partitions the total drag into surface drag and vegetation drag. The surface drag is used to calculate average sediment transport. The model is based on:

1) The Lettau (1969) approach for assessment of aero-dynamic roughness of vegetated terrain;
2) The Raupach (1992) shear stress partitioning theory;
3) The Lettau & Lettau (1978) sediment transport equation.

The model was used for both hypothetical and actual vegetated surfaces in the Sahel. The performance of the developed model was verified by using field measurements of sediment transport on two farmers' fields in Burkina Faso.

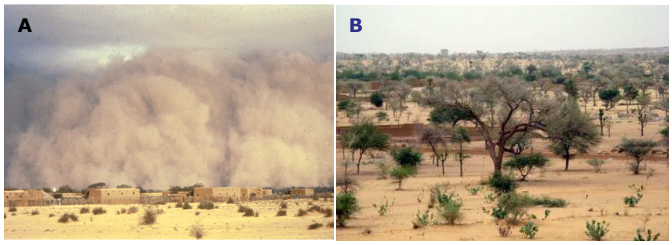

Fig. 1. A dust storm in the Sahelian zone of Senegal (A); scattered woody vegetation near Zinder in the Sahelian zone of Niger (B).

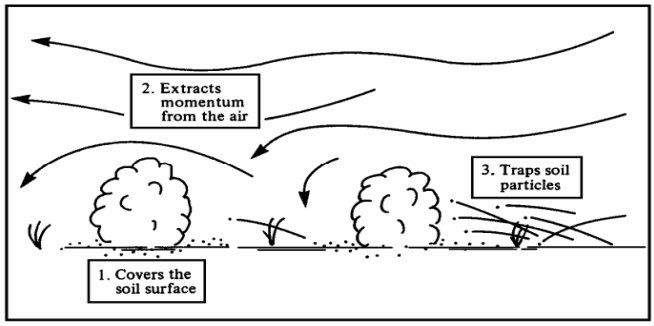

Fig. 2. Three effects of shrubs on wind erosion processes. (Source: Wolfe SA, Nickling WG. 1996. Shear stress partitioning in sparsely vegetated desert canopies. Earth Surface Processes and Landforms 21: 607–619

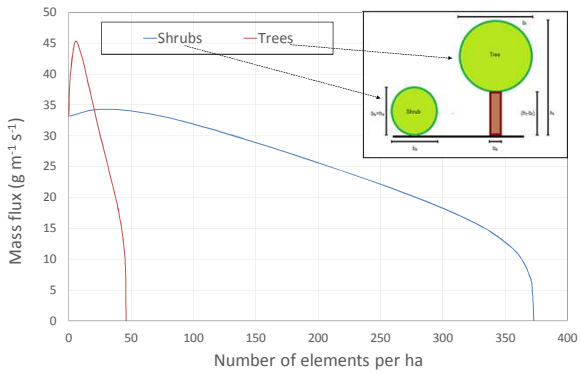

Fig. 3. The impacts of trees (4 m high; canopy diameter 3 m) and shrubs (1 m high; canopy diameter 1 m) on Aeolian sediment transport in the Sahel. Wind speed is 10 m s^{-1}; sandy soil.

Table 1. Measured and modelled sediment transport rates (Q) in two fields in northern Burkina Faso. Field 1 had 101 shrubs and 28 trees (z_o = 26 mm) and Field 2 had 62 shrubs and 8 trees (z_o = 6 mm).

Date	Field 1			Field 2		
	Wind speed	$Q_{measured}$	$Q_{modelled}$	Wind speed	$Q_{measured}$	$Q_{modelled}$
	m s^{-1}	g m^{-1} s^{-1}	g m^{-1} s^{-1}	m s^{-1}	g m^{-1} s^{-1}	g m^{-1} s^{-1}
27/05/03	9.6	42.9	20.9	10.1	10.6	24.8
26/06/03	12.5	73.6	60.7	12.7	29.1	60.3
01/07/03	9.7	17.1	22.8	12.9	66.9	62.2

Results

The model was used to test the effects of height, number, and type of vegetation elements (tree versus shrub) on sediment transport. The scenarios show that trees reduce wind speed and sediment transport much stronger than shrubs (Fig. 3), due to their higher aerodynamic roughness. But, the model also predicts an increase in sediment transport when only a few trees (<20 trees/ha) are growing in the field. This effect also occurs with a low number of shrubs (<80 shrubs/ha). The measured and modelled sediment transport rates show reasonable agreement for two fields with different vegetation cover densities (Table 1).

Conclusions

It is concluded that scattered woody vegetation can be used to reduce sediment transport in the Sahel, but only if a substantial number of trees and/or shrubs is used. Trees are more effective in reducing wind speed and sediment transport than shrubs, because of their larger and higher canopy. A low cover of trees (< 20 per ha) or shrubs (< 80 per ha) can actually cause more wind erosion. Applying scattered woody vegetation to reduce sediment transport effectively requires cooperation of farmers and management of vegetation at village level.