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Wind Erosion Control using Windbreaks and Crop Residues: Local Knowledge and Experimental Results

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1 Introduction

One of the first attempts to map Africa's irreversible soil productivity losses due to erosion was made by DREGNE (1990). He stressed the lack of reliable data on this subject, especially on the damage caused by wind erosion to soils and crops. Therefore he utilized "*anecdotal evidence, qualitative statements in scientific reports, ... and few local and national maps*". Hence, questions arise if the knowledge of local people can be exploited to fill the knowledge gap and to estimate damages caused by wind erosion. Furthermore, when the improvement of current farming systems with regard to wind erosion problems is researched, an understanding of those systems and input from farmers by means of surveys about the innovations are imperative.

Wind erosion in the West African Sahel (WAS) with its deep sandy soils, occurs mainly early in the rainy season between May and August during short rain storms that are preceded by high winds. During the dry season there are also days or longer periods with dust in the air, which is caused by the north-eastern "Harmattan" winds. There is increasing evidence that these climatic conditions influence the soil nutrient balance in several ways. DREES et al. (1993) showed the importance of nutrient inputs by the harmattan dusts. However, also during the monsoon storms fine soil particles are suspended into the air but the amounts have not yet been quantified.

GEIGER and MANU (1993) identified three types of erosional surfaces in farmers' millet fields, created by both water and wind influences. Wind erosion in Niger and the induced damage to a pearl millet (*Pennisetum glaucum* (L.) R. Br.) crop was measured by MICHELS et al. (1993). Under severe conditions, farmers can be forced

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to replant their millet several times due to a combination of wind erosion, drought stress and extreme temperatures.

Wind erosion can be controlled by soil cover, such as a mulch of crop residues, soil roughening or by annual or perennial grass barriers, artificial barriers, strip cropping or windbreaks (TIBKE 1988). Trees and shrubs reduce the force of the wind near the ground, thus less soil is eroded while soil particles are removed by the wind stream and deposited in the sheltered zone. However, competition effects of the windbreaks can reduce the growth of an adjacent crop. Although windbreaks are not part of the traditional farming systems in Niger, trees are, and these have many purposes (LAMERS et al. 1994). A surface cover like millet crop residues increases surface roughness and partially absorbs wind drag; thus soil erosion is decreased (MICHELS 1994). The effect depends upon the residue amount and if cut on its orientation. Farmers have multiple uses for millet crop residues and they leave them in the field as animal feed or for soil fertility and conservation purposes, or use them as construction material (LAMERS and FEIL 1993). Due to the low stover production, rarely exceeding 1.5 t ha^{-1} in the dry zone of Niger (ICRISAT 1992) and the alternative uses, crop residues left in the field are scarce. Soil roughening by tillage as well as animal traction is seldom practiced in the region. The objective of this study was to survey farmers' knowledge, experience and strategies to handle wind erosion. Farmers' responses were conciliated with results of on-station wind erosion studies.

2 Materials and Methods

A field survey, using the Rapid Rural Appraisal methodology, (CARRUTHER and CHAMBERS 1981) was conducted from June through October 1992, with 29 farmers in two villages in the vicinity of the ICRISAT Sahelian Centre (ISC). The survey was based upon an open guideline interview. The criteria for including farmers were their status within the household (agricultural decision-maker) and their willingness to co-operate in the survey. The farmers were questioned on-site on the occurrence of wind erosion on their fields, the caused damages to soil and millet plants, and their current remedies.

The on-station wind erosion experiment was conducted during 1991 at the ISC, 50 km south of Nigers' capital Niamey. In an existing windbreak experiment, we compared the species *Andropogon gayanus* and *Bauhinia rufescens* with an unsheltered control treatment. A windbreak consisted of a double staggered row in a north-south direction, normal to the erosive wind direction. Plant spacing was 3 m in the row and 1.5 m between rows. The design was a randomized block design with 3 replications. An individual plot was 50 m long and distance between windbreaks was 30 m. Two tons ha^{-1} millet stover was applied on the surface of one half of each plot as an additional wind erosion control measure. Pearl millet was planted manually in pockets spaced 1 m x 1 m in each windbreak plot in May 1991. Soil erosion samplers of the BSNE type (FRYREAR 1986) were placed at 5 m, 10 m and 15 m leeward of the windbreaks and in the control plots, at a sampling height of 0.1 m. Wind eroded particles passed through the samplers' vertical opening of 20 mm wide and 50 mm high. At the end of each wind erosion event, the captured soil was weighed to obtain the season's cumulative flux.

3 Results and Discussion

3.1 The Field Survey

Farmers mentioned soil losses and plant damages as the most important nuisances of wind erosion. Soil erosion caused by wind occurred on at least one of the fields of 66% of the surveyed farmers for the period 1982 - 1992 (Fig. 1). In this case, damage was perceived as removal of the productive sandy top layer by 45% of the farmers, while 21% mentioned the subsequent formation of a surface crust. Farmers stated that soil losses due to wind occurred annually and on most fields, but soil erosion was considered harmful on specific spots within a field only, and not on entire fields. Thirty four % of the farmers had no wind erosion problem.

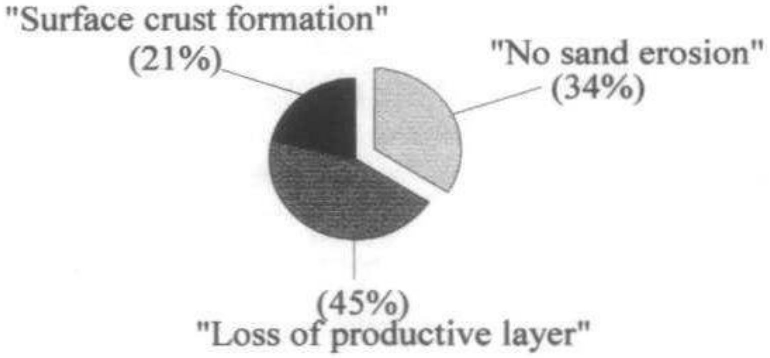

Fig. 1: Wind erosion effects to the soil as mentioned by farmers in 1992.

Most of the farmers (69%) mentioned a possible damage to the millet crop caused by high wind speed or by moving sand (Fig. 2). Within this group, 17% of the farmers were concerned most about air-blown sand burying young seedlings at the onset of the growing season. This was considered likely to occur when millet seedlings have developed less than three leaves. Mechanical damage at this stage of millet development was often observed by the farmers; but the subsequently retarded development was not considered a major concern. In addition, 52% mentioned as a possible direct effect of intensive winds the lodging of the stems, especially at the end of the growing season. This was assumed to retard millet grain ripening whereas termites and rodents were held responsible for the actual losses. No research results could be found for these observations. Nearly one third (31%) mentioned no crop damage caused by high wind speeds. During the last 10 years, most of the farmers referred only to the abnormal dry year 1984 when serious damaging wind erosion events occurred. Despite several replantings, grain yields in 1984 were extremely low;

however, the farmers attributed the yield reduction to the low precipitation rather then the damage caused by wind erosion.

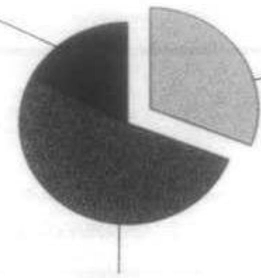

Fig. 2: Wind erosion effects to plants as mentioned by farmers in 1992.

Farmers' fields in the region are characterized by uneven surfaces, created by small elevations and depressions within short distances. Farmers considered micro-highs ("fandu" in the Djerma language) more fertile than depressions or micro-lows ("gorou"). The main difference between these spots was the size of a sand layer surface. Because of depositions of air-blown sand, micro-highs contain a more sandy top layer and retain, therefore, more water than micro-lows with thinner sandy top layers. Farmers also noted that micro-highs coincided with more intensive plant growth, such as trees and bushes, which continue to trap sand. The decomposition of the organic material was considered responsible for the increased fertility on the micro-highs.

Recently, the relationship between soil fertility and micro-elevations was confirmed by soil scientists who examined millet yields and soil characteristics in transects in farmers' fields in Niger (GEIGER and MANU 1993). Millet grain yields in sites with micro-highs, which comprised 30% of the planted millet surface, were 120% higher than on sites without micro-highs.

Farmers view wind erosion as a vicious cycle that is originally initiated with decreasing yields due to low soil fertility or inadequate rainfall. Subsequently, reduced stover yields leave the top soil layer prone to wind erosion resulting in soil being carried onto the slopes and micro-highs. After 3 to 4 years, the end stage of the erosion process was considered to be a micro-low with a surface crust ("gangani"). The crust inhibits the infiltration of rain and thus renders the spot unsuitable for plant growth as also concluded by HOOGMOED and STROOSNIJDER (1984). Although the surface crusts can be tilled with their long-handled hoes, farmers prefer an alternative solution over this labour intensive activity. Farmers are aware that millet stalks protect the soil against wind erosion. They, therefore, use stalks from more productive spots or twigs from trees and shrubs for mulching. Furthermore, this mulch traps the air-blown sand. After a period of 1-2 years, a sandy topsoil is regained and the soil structure and soil fertility are improved which also was observed by CHASE and BOUDOURESQUE (1987). Following DREGNE (1990), one would categorize these top soil losses and rebuildings as a short-term productivity loss. Farmers appreciated the sand trapping effects of millet residues more than its direct fertilizing effects. For the latter, they preferred a combination of crop residues and manure because of an increased decomposition of the straw and stronger effect on the following crop. Farmers concentrated their efforts on specific bad spots with a low productivity instead of leaving crop residues broadcasted in the field.

Tab. 1: Tree and bush species considered by farmers to specifically enhance or reduce wind erosion. Field survey 1992.

Reduces wind erosion	% of farmers	Enhances wind erosion	% of farmers
Combretum glutinosum	45	*Balanites aegyptiaca*	28
Piliostigna reticulatum	34	*Sclerocarya birrea*	10
Guiera senegalensis	31	--	
Annona senegalensis	24	--	

When asked about the effects of trees and shrubs on wind erosion, farmers mentioned several trees that reduced or enhanced wind erosion more than other species (Table 1). *Combretum glutinosum* was considered by farmers as the most effective species limiting wind and soil erosion. This was confirmed by GEIGER and MANU (1993). Farmers noticed that where *Balanites aegyptiaca* and *Sclerocarya birrea* trees grow, wind erosion increased directly underneath the canopy. Yet, they tolerated these species because they produce fruits and leaves for human consumption and animal feed. None of the surveyed farmers envisioned to plant or to cut trees for reasons of wind erosion. LAMERS et al. (1994) mentioned protection against wind erosion as the most important reason for farmer's appreciation of trees, after its role in soil enrichment. However, part of the surveyed farmers had problems understanding the meaning of a windbreak in rows.

3.2 Field Measurements

During the 1991 rainy season 8 wind erosion events occurred in less than 2 months. A summary of the cumulative sand flux is presented in Figure 3. Compared to the control, sand flux between 5 and 15 m distance leeward of the shelters was reduced by 24% for *A. gayanus* and by 58% for *B. rufescens* windbreaks. *A. gayanus* is a perennial grass with a very high porosity within the staggered rows and thus had a much smaller protective effect compared to the *B. rufescens* hedge. An additional application of 2 t ha^{-1} millet straw reduced sand flux by 71% and 81% compared to the unsheltered no-residue control. Visual observations indicated that the amounts of soil flux during the rainy season did not damage millet seedlings even in the unsheltered plots. Crop residues without windbreaks were as effective as the most effective windbreak, *B. rufescens*. However, 2 t ha^{-1} crop residues at the onset of the season are currently not realistic for the traditional low external input cropping systems in the Sahel without mineral fertilizers. Increasing the biomass production is an important means to conserve soil and reduce degradation. The effects of wind erosion and windbreaks on millet yields are reported in detail by MICHELS (1994).

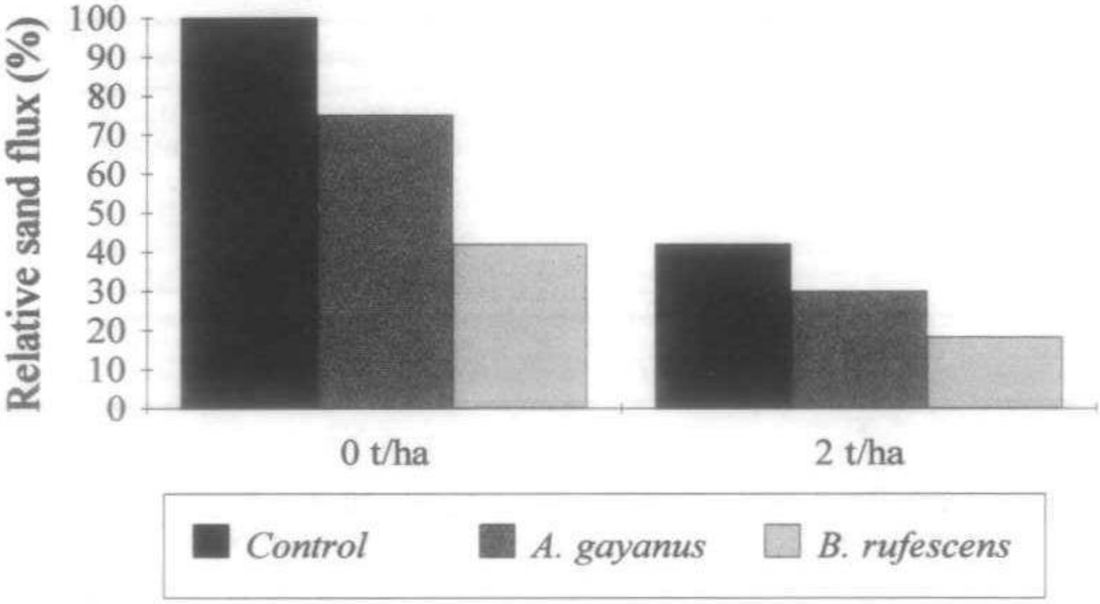

Fig. 3: Sand flux in a millet field as affected by shelter type and crop residue application (at 10 cm above the ground, means of 3 distances). ISC, Niger, 1991.

4 Conclusions

Farmers closely observe their environment, and have developed their own explanations and remedies for the occurrence and damage from wind erosion. Nevertheless, in the surveyed region wind erosion was not considered a major concern in the past 10 years, except in the development of crusted micro-depressions. Farmers were well aware of the different problems and mechanisms of wind erosion and they even have developed specific remedies based on their limited resources.

Wind erosion in millet fields in the WAS may have negative impacts on millet growth, and probably on short- and long-term soil fertility. Windbreaks and crop residues were found to be effective in reducing sand movement. However, the studied windbreak species differ widely in their effectiveness and crop residues are scarce in traditional millet production.

Future efforts should emphasize the development of sustainable methods to increase millet biomass by integrating an agroforestry component into current cropping systems and by using mineral fertilizers. Without the use of mineral fertilizers the necessary increase in biomass left in the field for wind erosion control can not be expected.

5 Summary

Wind erosion in the Southern Sahelian Zone occurs during short monsoon storms preceding rainfall events and leads to crop damage and loss of fertile topsoil. A survey with farmers was conducted near the ICRISAT Sahelian Centre (ISC) at Niamey, Niger, in order to learn about their knowledge of wind erosion and their strategies to reduce the wind erosion damage. Although 66% of the farmers have noticed wind erosion on their own fields within the last decade, it was not considered a main concern. Wind erosion caused inconveniences to millet according to 69% of the surveyed. Wind erosion changed the topography and decreased soil fertility, which resulted in spots with increased wind erosion damage within their fields. Farmers in the region have developed a strategy to deal with the restoration of these spots and used organic matter such as stover from more productive spots for mulching.

A field experiment was conducted at ISC during 1991 to assess the effects of 3 year-old *Andropogon gayanus* and *Bauhinia rufescens* windbreaks and of a crop residue application (2 t ha^{-1}) on the quantity of eroded soil. *A. gayanus* and *B. rufescens* reduced the soil flux by 24% and 58%, respectively. Crop residues decreased soil flux by 59%. Maximum protection was given by a combination of both control measures.

Control measures like windbreaks are difficult to establish and farmers have good reasons to use crop residues elsewhere. Thus, solutions must be found in close cooperation with farmers. Future research should be directed towards regional surveys and characterizations of the areas affected by wind erosion.

Verminderung von Winderosion durch Windschutzhecken und Ernterückstände: Lokales Wissen und experimentelle Ergebnisse

Zusammenfassung

Winderosion tritt in der südlichen Sahelzone während kurzer Stürmen vor Regen auf und führt zu Schäden an Kulturpflanzen und Verlust an fruchtbarem Oberboden. Eine Befragung von Bauern wurde in der Nähe des ICRISAT Sahelian Centre bei Niamey, Niger, durchgeführt, um sowohl ihre Einschätzung der Winderosion als auch ihre Strategien der Problembewältigung kennenzulernen. Obwohl 66% der Bauern innerhalb der letzten 10 Jahre Winderosion auf ihren Feldern beobachtet haben, wird sie nicht als großes Problem angesehen. Schäden an Pflanzen durch

Winderosion wurden von 69% der Befragten genannt. Winderosion veränderte das Relief der Felder und verursachte Stellen mit verringerter Fruchtbarkeit. Die Bauern der Region haben eine Strategie entwickelt, um schlechte Stellen mit der Aufbringung von Stroh von besseren Stellen wieder fruchtbarer zu machen.

In einem Feldexperiment, 1991 am ICRISAT Sahelian Centre durchgeführt, wurden die Einflüsse von 3 jährigen *A. gayanus* und *B. rufescens* Windschutzhecken sowie von Ernterückständen (2 t ha^{-1}) auf die Menge an Flugsand untersucht. *A. gayanus* reduzierte den Sandfluß um 24%, *B. rufescens* um 58%, und Mulch um 59%. Der größte Schutz erfolgte bei der Kombination aus Hecke und Mulch.

Schutzmaßnahmen gegen Winderosion wie Windschutzhecken sind nur schwer zu etablieren, und Bauern haben auch gute Gründe, Ernterückstände alternativ zu verwenden. Deshalb können im engen Kontakt mit den Bauern Strategien zur Bekämpfung der Winderosion entwickelt werden. Bei zukünftiger Forschung sollten regionale Befragungen durchgeführt und eine Übersicht der von Winderosion betroffenen Gebiete erstellt werden, um die qualitativen und punktuell erhobenen Informationen besser einordnen zu können.

Le contrôle de l'érosion éolienne par l'utilisation de brise-vent et des résidus de culture: Connaissances locales et résultats expérimentaux

Résumé

Dans la zone sud du Sahel, l'érosion éolienne qui sévit durant les orages convectifs précèdant les événements pluvieux peut provoquer des dégats aux cultures et une perte de fertiltité de l'horizon superficiel. Une étude a été réalisée auprès d'agriculteurs voisins du Centre Sahélien de l'ICRISAT (CSI) afin de déterminer leur connaissances du problème et leurs moyens de lutte. Bien que 66% des agriculteurs ont constaté, durant ces dix dernières années, des problèmes d'érosion éolienne dans leurs parcelles, ceux-ci ne considèrent pas ce phénomène comme un problème majeur. Les dommages causés par l'érosion éolienne sur les plantes de mil ont été mentionnés par 69% des agriculteurs. L'érosion éolienne engendre des changements du mico-relief et provoque une diminution de la fertilité des sols résultant, au sein des champs, en des zones de plus en plus sucesptible à l'erosion. Les agriculteurs de cette régions améliorent ces zones de faibles rendements en y applicant de la matière organique tel que la paille provenant des zones les plus productives, ceci afin d'obtenir un mulch.

En 1991, un essai a été réalisé au CSI afin d'évaluer les effets de brise-vent formés de plants d'*Andropogon gayanus* et de *Bauhinia rufescens*, agé de 3 ans, et de l'application de résidus de culture (2 t ha^{-1}) sur l'érosion éolienne. *A. gayanus* et *B. rufescens* diminuent le transport des particules de sol respectivement de 24% et

58%. Les résidus de cultures réduisent ces mouvements de 59%. Une protection maximale a été obtenue en combinant les deux méthodes de contrôle.

Les mesures de contrôle posent des problèmes d'adoption du fait de la pression de paturage et de l'utilisation des résidus de cultures à d'autres fins. En conséquence, des solutions doivent être trouvées en étroite collaboration avec les agriculteurs. Les recherches futures devront s'orienter vers des enquêtes et une caractérisation régionale des zones touchées par l'érosion éolienne.

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