Simultaneous Quantification of Wind and Water Erosions within Small Grazing Sahelian Catchments (Burkina Faso – West Africa)

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Abstract: Wind and water erosions were measured simultaneously during the 2001 rainy season in northern Burkina Faso where the climate is typically Sahelian. In order to obtain measurement on exactly the same surface area, two small catchments fitting together were chosen (BV1 = 1.4 and BV2 = 0.3 ha). They are part of the grazing area of the village land and differ by their soil types and surface features. Wind blown sediment budget was obtained by using 35 masts equipped with BSNE sand traps placed on the boundaries of the catchments. Water erosion was estimated at the outlets of the two catchments by discrete sampling for suspension and by sediment trap for bedload. Wind blown sediment balance appeared to be highly positive (+32 Mg ha^{-1} yr^{-1}) for the upstream catchment (BV2) and negative (–12 Mg ha^{-1} yr^{-1}) for the downstream part of BV1 (BV1—BV2). These differences are attributed to the differences in surface features. Quantities of soil lost by water erosion are quite the same for the 2 catchments (about 5 Mg ha^{-1} yr^{-1}), but differ in sediment size distribution and type of transportation: coarse sediments transported mainly in bedload for BV2 and fine sediments transported in suspension for BV1. As for wind erosion, such differences are related to the soil surface type. These results point out at the same time the importance of spatial variability in erosion for naturally grazed area of Sahel and the need to consider both wind and water erosions to study land degradation in this region.
Keywords: sahel, grazing area, wind erosion, water erosion, surface feature

1 Introduction

In the Sahel, both wind and water erosions occur, but they are rarely studied simultaneously. Wind erosion data, scarcer than water erosion ones, can be found in the literature for cultivated area (field plus fallow). At the field scale, soil losses by wind erosion are found to reach very high values (more than 25 Mg • ha^{-1} • yr^{-1}, Bielders *et al*. 2001). However, very few studies concern non-cultivated areas where grazing is the only land use. Soil losses by water erosion in the Sahel seem to be lower (Collinet and Valentin, 1985), but, as measurements were not performed on the same surface (same surface feature and same surface size), they are difficult to compare. The objective of this work is to quantify, in the same area, the two types of erosion. It is the first step of a scientific program aiming at studying mechanisms of interaction between wind and water erosions.

2 Materials and methods

2.1 Study area

The study area is located in the north of Burkina Faso (UTM30, WGS84, 809847 m East, 155093 m North), near Dori, 250 km North East of Ouagadougou (Fig.1). The climate is of the Sahelian type, with a long dry season and a short rainy season from June to September. Average annual rainfall recorded in Dori from 1925 to 1998 is 512 mm. The grazed areas of the village land are located on a catchment of weak longitudinal slope (about 1%). They show two main surface features: i) large areas of bare crusted clayey soil patched with ii) areas of sandy soil developed on aeolian sand deposits (less than 0.7 m thick) where annual vegetation, shrubs and trees grow (Ribolzi *et al*., 2000).

Measurements of both wind and water erosions were performed during the 2001 rainy season between 1 June and 15 October.

2.2 Water erosion measurements (Fig.1)

In the case of this study, it was not possible to use classical water erosion plot because artificial boundaries act like windbreak, causing significant aeolian sand deposits. To avoid such environmental perturbation, water erosion is measured on two natural catchments fitting together. Drying crust on sandy soil is the only surface feature of the upstream catchment (BV2 = 0.3 ha) whereas both sandy (drying crust) and bare crusted soils (erosion crust) are present on the downstream part of BV1 (BV1 = 1.4 ha) (Fig.1). Rainfall was monitored using three simple rain gauges and three rainfall recorders. The stream discharge of each catchment was measured using flow recorders. Suspended matters fluxes at the outlets were estimated from discrete 1-litre water samples collected throughout runoff events with a time step varying from 2 to 5 minutes. Bedload was collected in sediment traps after each event. The totality of these materials was dried and then weighed.

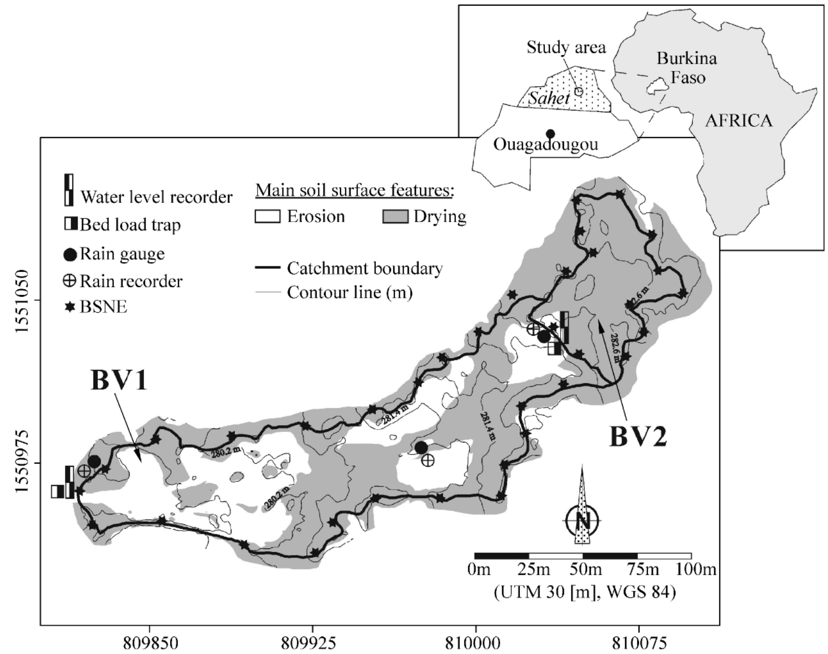

Fig.1 Location, main surface features and experimental design of the studied catchments (BV1 and BV2)

2.3 Wind erosion measurements

In Sahelian grazing land there is no clear boundary acting on wind erosion unlike in cultivated land where field / fallow transitions have to be taking into account in wind erosion studies (Bielders *et al*. in press). So the limits of the studied areas are determined by those of the water erosion ones (catchments boundaries). The mass budget within these areas was calculated by subtracting outgoing from incoming wind blown sediments. Wind blown sediment fluxes were obtained using 35 masts equipped with 3 BSNE (Fryrear, 1986) sand catchers (0.05, 0.15 and 0.3 m height). The masts were placed on the catchments boundaries every 20-m approximately (Fig.1). Wind blown sediments caught in BSNE were collected after each erosion event. The horizontal fluxes were calculated at each mast by integrating the sediment flux density profile between 0 and 0.4 m height. Wind speed and direction were measured using an automatic weather station. An acoustic saltation sensor (Saltiphone) gave the period during which the fluxes were significant. Knowing that, it was possible to estimate the mean direction of wind during each storm event, and to determine the upwind and downwind limits of catchments. The incoming and outgoing mass fluxes along these boundaries were then calculated by linear interpolation of sediment mass fluxes measured at each mast.

3 Results and discussion

Thirty-four events produced wind blown sediment flux during the study period. It was only possible to calculate mass sediment budget for a subset of 21 events because of important variations in the wind direction for the other ones. It can be estimated from the mass of sediment caught in the sand traps that the 21 computed events represented about 80% of the total mass of sediment blowing out on the catchments. There is no major event, i.e. with high sediment transport, among the ones that were not considered. So it will be assumed that results obtained with the 21 events give a good image of wind erosion on the catchments.

Fluxes were higher and more numerous at the beginning of the rainy season, until 15 July. Consequently, they represented more than 85 % of the total sediment mass flux over the study period. Such a result is well known in the Sahel and can be related to higher wind intensity and to lower soil coverage by litter and vegetation at the onset of the rainy season (see e.g. Rajot 2001).

Figure 2 presents aeolian sediment mass balance cumulated over the period of measurement for BV2 and the downstream part of BV1. They show opposite behaviours: there was net deposition for the upstream catchment (BV2) for 17 events on 21 and net erosion for the downstream part of BV1 (BV1-BV2) for 15 events on 21. The sum of soil gains or losses computed for the 21 events which allow budget calculation amounts to + 32 $Mg.ha^{-1}$ and – 12 $Mg.ha^{-1}$ for BV2 and downstream part of BV1 (BV1-BV2) respectively. This led to soil losses of about – 1.8 $Mg.ha^{-1}$ for the whole area studied BV1 due to the small size of BV2.

High wind blown sediment deposition was also reported by Bielders *et al.*(2001) in fallow land in Niger which presented the same surface feature as BV2 (dry crust with annual and perennial vegetation). The deposition was supposed to be due to the high surface roughness of these areas. In Niger, wind erosion occurred in the pearl millet field (Bielders *et al.*, 2001). In this study, wind erosion occurs on complex natural area (BV1-BV2) showing both dry and erosion crusts (Fig. 1). Thus the surface feature from where wind blown sediments originated is still unclear and need to be assessed.

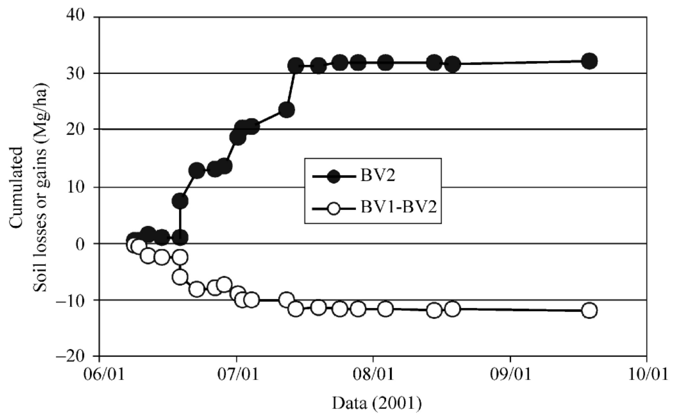

Fig.2 Wind blown sediment mass budget (Mg ha^{-1}) cumulated over the study period for upstream catchment (BV2) and downstream part of BV1 catchment (BV1-BV2)

Seventeen water erosion events occurred on BV1 and 11 on BV2. Quantities of soil lost can be estimated to 4.1 Mg ha^{-1} yr^{-1} and about 3 Mg ha^{-1} yr^{-1} for BV1 and BV2 respectively. They are of the same order of magnitude, but particle size distribution of sediment exported varies according to the catchment. On BV2 exported sediment is mainly made of sand, transported in the bedload, whereas it is mainly made of fine particles transported in suspension from BV1 (data not shown). These results suggest that clayey erosion crust could be a major source of sediment for water erosion in BV1.

Total soil losses by water and wind erosions are presented on Fig.3 for the whole studied area BV1. At this scale the two types of erosion appear to be of the same order of magnitude. Water erosion unlike wind erosion, happened during the whole season and did not show clear period of time with higher intensity. As for wind erosion, some events are responsible for large part of annual erosion.

There is net wind erosion for the 7 first events at the beginning of the season (until 23 June) then deposition dominated until mid-July and budget remained equilibrated after that date, mainly due to lack of high intensity event. Thus, at the end of the season, soil losses due to wind erosion appears to be lower than soil losses due to water erosion (Fig.3). This result masks an high spatial variability in sediment budget. In fact, considering both wind and water erosion, there is positive budget on BV2 due to wind sediment deposition. Sandy sediments accumulated on BV2 and were partially removed by water erosion in bedload exportation. Conversely, there is high negative budget on downstream part of BV1 (BV1-BV2) due to both wind and water erosions.

Such high spatial variability due to wind erosion in the Sahel was pointed out by Bielders *et al.*, 2001 in cultivated area. It appears to be also very high in grazing areas.

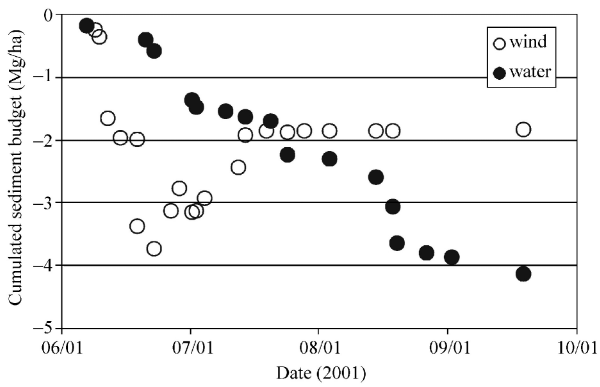

Fig.3 Comparison of sediment budget due to wind and water erosions on the whole study area (BV1)

4 Conclusion

Based on the direct measurements of wind and water erosions it was possible to estimate total mass budget for two small catchments fitting together in a grazing area of the Sahelian region. Considering the whole study area (BV1 = 1.4 ha), wind and water erosions caused soil losses of the same order of magnitude (2 and 4 Mg ha^{-1} yr^{-1} respectively). Nevertheless, this result masks a high spatial variability mainly due to wind erosion. Net sediment deposition occurred on upstream catchment BV2, where only sandy soil, covered with dry crust, are present. Both wind and water erosions occurred on downstream part of BV1 catchment that shows two very different surface features: clayey erosion crust and dry crust. Erosion crust seems to be an important source of sediment for water erosion whereas sources of sediment for wind erosion remain to be determined. These first results pointed out the difficulty to estimate land degradation in the Sahel that highly depends on the scale of area studied. They suggest a strong linkage at the scale of few meters between sediment source areas where degradation occurs and sediment sink area where vegetation develops in “islands of fertility”. They emphasise the necessity to take into account both wind and water erosions to assess the actual land degradation in the Sahel.

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