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Determination of dust deposition and associated nutrients in natural forest and plantation - A case study from the moist semi-deciduous forest zone in Ghana

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ABSTRACT

Every year in December to February the dust laden Harmattan blows from Sahara towards southwest to the countries along the east west going coast of the Gulf of Guinea. Only few investigations have quantified external dust deposition in forests and plantations in that region and hereby the nutrient input by dust. This paper investigates three different methods for sampling and quantifying dust deposition in natural forests and plantations in the moist semi-deciduous forest zone in Ghana. The three methods tested were the following: bowls with water, plastic mats with straws and funnels for determining canopy drip. The study shows that the canopy drip method overestimates the external dust deposition due to a significant enrichment of organic matter during the throughfall. Therefore, it is necessary to combine the canopy drip method with sampling from outside the forest to determine the external organic matter content in the dust deposited to a forest. The study showed that the dust deposition in the forest and in the rubber and cocoa plantations was 1.5 to 2.0 times bigger than on the plastic mats located outside the forested area and further, that the external nutrient input by dust to the natural forests is very low in the Kade area, only about 0.2 kg ha^{-1} total P and the readily available Ca, Mg and K are respectively 0.4 kg ha^{-1}, 0.2 kg ha^{-1} and 0.7 kg ha^{-1}.

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1. Introduction

Aeolian dust provides nutrients and alkalinity to terrestrial and aquatic ecosystems (Koren et al., 2006; Lequy et al., 2012; Breuning-Madsen et al., 2012; Breuning-Madsen et al., 2015). The amount of dust settled in the landscape is highly dependent on the type of surface, and therefore great care must be taken to make the dust collectors represent the surface of the ground or vegetation as closely as possible (Breuning-Madsen et al., 2012; Sow et al., 2006). Dust or particle sampling can either be performed by active or passive collectors. The active samplers measure dust in suspension per volumes e.g. g m^{-3}, whereas passive samplers measure deposited dust per area e.g. g m^{-2}. If the goal is to estimate dust deposition, passive samplers should be used. Different types of passive samples have been used, mostly containers, funnels or different types of plates (McTainsh and Walker, 1982; Tiessen et al., 1991; Adetunji et al., 2001; Breuning-Madsen and Awadzi, 2005; Goossens and Rajot, 2008; Zeng et al., 2005; Lequy et al., 2014a).

Only few investigations have quantified actual dust and thereby nutrient deposition in natural forests and plantations (Lequy et al., 2012). Stoorvogel et al. (1997) determined dust deposition in a natural forest in Ivory Coast by use of the drip canopy method, and found that this method gave twice the amount of dust compared to bowls with water. Total deposited dust (TDD) to an area without canopy cover, e.g. a grass field, consists of external mineral dust (MD) and external organic matter (OM), whereas dust collected under a canopy will consist of both external MD and OM, but also OM from the canopy itself (internal OM). As early as 1961 Nye showed that the chemical composition of the precipitation changed when passing the canopy. Thus, estimation of external TDD and nutrient deposition to a forest system is not trivial.

The aim of this study is to find the best proxy for determining the total amount of external dust and nutrients settled in a canopy forest. This has been done by collecting dust samples in three Harmattan periods in a natural semi-deciduous tropical forest, a cocoa plantation and a rubber plantation in the Kade area in Ghana, West Africa. The total amount of dust collected and the chemical composition of the dust are compared to dust samples collected outside the forest areas in the same Harmattan periods.

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2. Study area

Every year the West African countries along the Gulf of Guinea are covered by a dust plume that is carried by the NE Harmattan wind during the northern hemisphere winter (Kalu, 1979; McTainsh, 1980; Afeti and Resch, 2000). When the Harmattan is strongest, the climatic conditions of the southern part of Ghana are affected by the Inter Tropical Discontinuity (ITD). (Engelstaedter et al., 2006; Klose et al., 2010; Lyngsie et al., 2013). The ITD is defined as the build-up where the dry Harmattan wind converges with the wet SW Monsoon. Engelstaedter et al. (2006) suggest that these converging winds favor dust emission by surface turbulences from dry convection, a phenomenon that results in vertical air currents. This disturbance will cause higher frequencies of events where the wind speed exceeds the threshold value required to bring a particle in suspension. This in turn leads to higher dust emissions under dry convection.

The investigation was carried out at the University of Ghana's research station close to the town Kade (6°24'N, 0°50'W, Fig. 1). Kade is located near the southern ITD turning point (Sunnu et al., 2008) and is therefore affected by the ITD climate conditions around January when the Harmattan is strongest in Ghana. The Kade sampling site is located in the moist semi-deciduous tropical forest zone and the climate is humid tropical with two pronounced rainy seasons, one in April-June and the other in September-November. The minor and the major dry seasons are in July-August, and December-February respectively. The latter is also called the Harmattan season. The annual precipitation is about 1400 mm and the annual monthly mean temperature is between 25°C and 30°C. According to Soil Survey Staff (1999), the soil moisture regime is udic and the soil temperature isohyperthermic. According to Lawson et al. (1970), the natural vegetation type is the Antiaris-Chlorophora association. The sampling sites are located away from public roads (4 km) and urban areas (2.5 km to nearest village and 7 km to

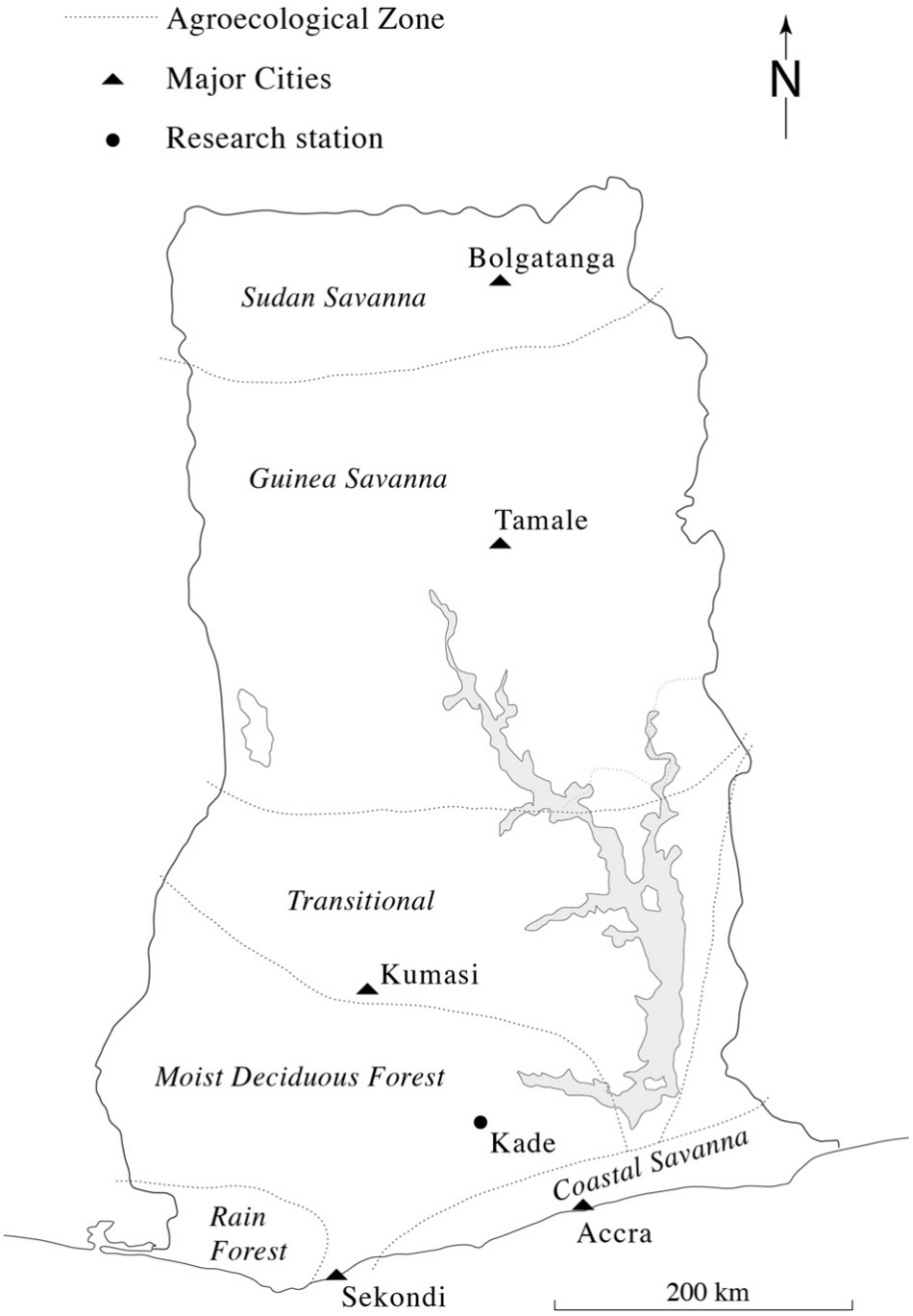

Fig. 1. Agroecology map of Ghana. Sample location Kade (6°24'N, 0°50'W) is marked with a red ring. For the spatial arrangement of the different samplers, see SI Fig. S1.

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