EVALUATION OF THE EFFECTS OF MINERAL DUST DEPOSITION ON VEGETATION WITH REFERENCE TO THE AUDALIA MEDCALF PROJECT

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Introduction

For most mineral dusts, their effects on vegetation responses are expressed most clearly in leaf function and its consequences (shoot growth, flowering and seed set). Dust deposition on vegetation affects plant functioning through interception of solar radiation (reducing the rate of photosynthesis in leaves), alteration of the radiant energy balance (reflection, absorption and emission of both short- and long-wave radiation), and by imposing a barrier to gas diffusion on leaf surfaces with stomata (reducing carbon dioxide and water vapour transfer and the processes of photosynthesis and transpiration).

Exact determination of dust deposition on leaf surfaces is difficult because the quantities per leaf are usually small and the composition of vegetation canopies means that there may be substantial variation in the rate of deposition of dust to different portions of the canopy. Because of the difficulty in making precise measurements of dust deposition and its effects in the field, and even in the laboratory, modelling approaches have been adopted to indicate potential effects of different dust exposure and deposition scenarios.

Site physical conditions

Rates of dust deposition in the vicinity of the project site vary, but not with any clear seasonal pattern (Figure 1).

The diameter distribution of deposited particles varies with distance from the source, and the effects of a given dust load on leaves are closely and inversely related to particle diameter (i.e. smaller particles have a greater impact than larger particles). In the modelling presented here, a uniform particle diameter of 20.22 μm has been used, based on the predicted mean particle size specified in Ramboll (2020).

Rainfall data for the project area (supplied by Audalia) indicate that most of the annual rainfall occurs in the winter months. A detailed analysis of the incidence of rain-free periods during the year has not been completed, but long rainless periods are common for any time of the year, but particularly between November and June.

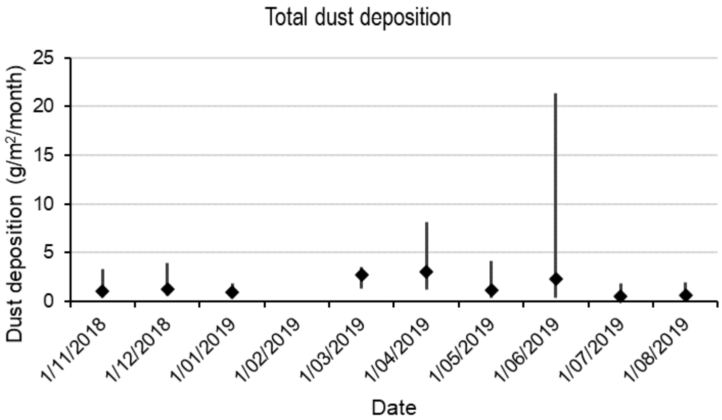

Figure 1. Monthly mean dust deposition rates (diamonds) and maximum and minimum values at up to eight sites (vertical bars) in the vicinity of the Audalia Medcalf Project area between November 2018 and August 2019. (Data supplied by Audalia).

Species of concern

The principal species of concern in this review is *Marianthus aquilonaris* (Department of Environment and Conservation 2010). It is classified as Threatened (*Biodiversity Conservation Act 2016* (Western Australia)) and Critically Endangered (IUCN), and is described as an erect straggly shrub to 1.6 m tall, with hairy stems, alternate elliptic to oblong, glabrous (hairless) leaves, which flowers between September and October. The species is perennial, and at least some foliage is assumed to persist for two years. This would provide opportunities for dust deposition at any time of the year.

No information is available on the timing and duration of shoot and leaf growth in this species, but it may be assumed to precede flowering in September. Drought conditions during the summer and autumn would be associated with very little physiological activity in leaves, so dust deposition during this period might have a reduced impact on plant functioning. In the absence of gas exchange between leaves and the air during drought, radiation balance can affect leaf vitality. Dark coloured dusts tend to elevate leaf temperatures by more than light coloured dusts, but the effect may be small compared with the cooling due to transpiration. Therefore, the period of greatest physiological activity in leaves, and susceptibility to dust deposition, is likely to be between August and November (shoot growth to seed set).

Critical processes of pollination, seed set, and germination are considered unlikely to be affected adversely by dust deposition. The flowers appear likely to be insect pollinated Prendergast K. (2019) and seed set is a function of pollination and the availability of accumulated carbohydrate reserves. Germination results in the unfolding of leaves close to the ground, where they are protected by taller vegetation or ground surface irregularities. Deposited dust would only affect germination if it were markedly acidic or alkaline. In addition, new leaves appear at short time intervals, so they are all exposed to limited dust loads while their rates of physiological activity are greatest.

Estimates of dust deposition effects

If threshold rates of dust deposition are set at 4.5 and 8 g/m^2/month, it is possible to estimate the effects of dust deposition rates and periods on dry matter production in canopies with the photosynthetic properties described by Doley and Rossato (2010), with a vegetation canopy that displayed 1 m^2 of foliage over 1 m^2 of ground surface (a Leaf Area Index of 1.0) and with the following assumptions:

- The sparse foliage of the shrub is treated as a single leaf layer, fully exposed to dust deposition throughout the period (there is no replacement of foliage at the top of the canopy).
- The canopy is dust-free at the beginning of the calculation period (for example, after it had been washed clean by >10 mm rainfall, or if the plants had been shaken by strong winds).
- Dust deposition is uniform throughout the canopy.
- Constant rates of dust deposition continue for 30 days (1 month), with the calculation of effect made at the end of this period.
- Continuous dust deposition is often assumed to lead to the occurrence of an equilibrium dust load. It is not possible to determine this equilibrium value, so calculations will be made for an accumulation period of 30 days.
- For leaves of intermediate inclination, this value is set at 0.5 (half of the dust falling into a gauge is intercepted by a leaf ($k = 0.5$). This value is commonly assumed for randomly oriented foliage. Once the dust is on the canopy, dust light extinction coefficient (*kD)* is calculated by equation: $kD = 0.3043 - 0.0555*\ln(Dd)$, *where;* Dd = Dust median diameter (μm).

Dust retention coefficient (r_D) is the fraction of intercepted dust that is retained on the leaf surface and is modelled as (a) $r_D = 0.5$ (50% retention), which is a reasonably conservative assumption for this species.

It is very well established that the photosynthetic characteristics of different species vary substantially (for example, maximum values of net photosynthesis, A_{net}, may range from 5 to 30 μmol CO_2/m^2 leaf/s), and that the shape of the photosynthetic light response curve also varies between species. However, the relative effects on dry matter production of reduced light interception by different plant canopies are likely to be smaller than the absolute differences in their photosynthetic rates. Therefore, it was considered feasible to apply estimates of relative reductions in dry matter production to species or plant canopies with different physiological characteristics but assigned structural characteristics and durations of exposure.

The scenarios presented here describe net primary production (daily total photosynthesis minus respiration of leaves) (Figure 2). Additional losses of carbon are associated with respiration attributable to plant maintenance and growth, so the effects described here would be less than might be anticipated in the field.

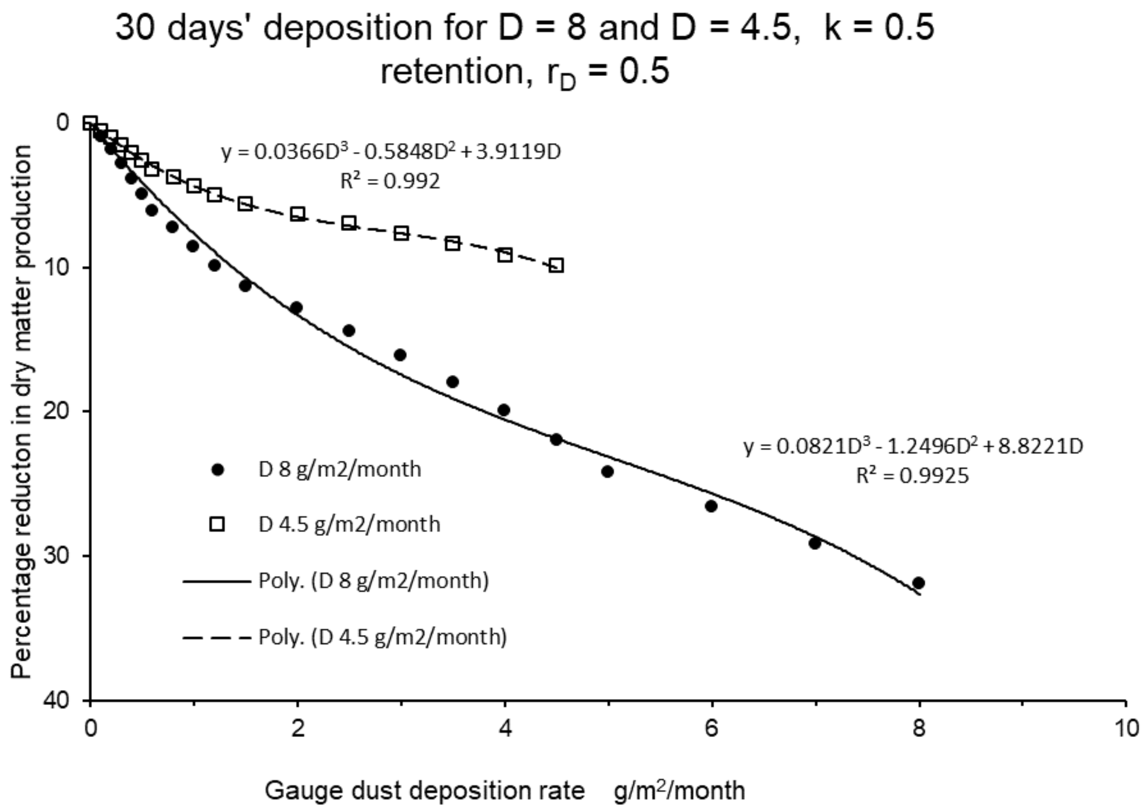

Figure 2. Estimated reductions in primary dry matter production (P) by leaves of a plant subjected to different rates of monthly dust deposition (D), assuming the conditions described above. The curves also describe the time course of effects with increasing duration of deposition, where 30 days represents a total deposition of 4.5 and 8 g/m^2 in a dust gauge.

Interpretation

The effect of dust deposition at 8 g/m^2/month on foliage with random orientation depends on the smoothness of the upper leaf surface, and on the consequent retention of dust. If the leaf surface is rough or hairy enough to retain 50% of the intercepted dust (a reasonably conservative assumption), then after one month of deposition, net dry matter production by leaves will have reduced by an estimated 32% (Figure 2). If the upper leaf surface was smooth enough to retain only 30% of the intercepted dust, the reduction in net dry matter production would have been about 15%.

Using the same assumptions, the effect of dust deposition at 4.5 g/m^2/month on foliage would result in the net dry matter production by leaves being reduced by an estimated 10% (Figure 2). If the upper leaf surface was smooth enough to retain only 30% of the intercepted dust, the reduction in net dry matter production would have been about 5%.

An important result is that, if dust is removed by rain washing or by shaking in a strong wind, the response curve is returned to zero deposition. It is suggested that close observation of plants in the field may indicate which of the above scenarios is the more feasible.

References

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