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Evaporation from soils below sparse crops in contour hedgerow agroforestry in semi-arid Kenya

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Abstract

In many agricultural systems in the semi-arid tropics, crops use only a small fraction of the total rainfall. Agroforestry can greatly reduce some losses, especially on hill slopes, where soil evaporation, runoff and soil losses are important. This paper reports on soil evaporation from a rotation of intercropped maize and cowpea between contour hedgerows of pruned *Senna siamea* trees as well as trimmed *Panicum maximum* grass strips on a 14% hill slope at a semi-arid site in Machakos, Kenya. There were five treatments in order to separate effects of *Senna* mulch, hedges, and grass strips. Micro-lysimeters were placed between crop rows for three seasons. It followed from their results that, for the three seasons concerned, tree prunings as mulch reduced soil evaporation as percentage of rainfall in the measuring period by absolute values of 9%, 4% and 6% compared to the control sole maize and cowpea with bare soil. The influence of the hedge added to this only insignificantly, even at 1 m distance. The non-mulched plots had soil evaporation reduced by only between on average 1% and 4% in absolute values compared to the control over all the seasons, with a maximum of 5% close to the hedge in the first season. Mulch apparently is the main evaporation reducing factor. Soil evaporation reached the highest percentage of rainfall in the long rains of 1994, becoming 65% in sole maize. It was 50% for sole cowpea in the 1994/1995 short rains and for sole maize in the next long rains. The highest value, although an upper limit could largely be understood from highest early season evaporative demands, rainfall distributions and low crop cover. The other values were in line with earlier reports for dry areas. Some advantages and disadvantages of these agroforestry systems are reviewed.

Keywords: Soil evaporation; Micro-lysimeters; Agroforestry systems; Hedgerow intercropping; Mulch; *Senna siamea*; Grass strips; Maize; Cowpea

1. Introduction

Decisions on land use, such as "being forced to use sloping land for production", belong to the strategic needs in tropical Africa, and choices of cropping

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systems, such as ‘‘one that reduces soil loss and water runoff on slopes’’ to the tactical needs (Olufayo et al., 1998). An important goal of combining trees and crops in agroforestry systems is to make better use of the environmental resources required by plants to grow (e.g. Mungai et al., 2001; Kinama et al., in press). One of the means of achieving this is to utilize resources that would otherwise be lost from the system (e.g. Ong and Black, 1992; Cannell et al., 1996). Wallace (1991) suggested that introduction of trees into a crop may lead to an overall increase in the proportion of rainfall that is used as transpiration. Van Noordwjik and Ong (1999) estimated by modeling that the potential increase in transpiration due to scattered trees in the Sahel is only about 8% of total rainfall. Although there is little information on the role of agroforestry in reducing soil evaporation, it is expected that maximum gain will be made in semi-arid and arid environments where soil evaporation forms a substantial part of the soil water balance (e.g. Stigter, 1994). Under west African conditions, Wallace et al. (1988) and Bley et al. (1991) showed that soil evaporation is a major part of the soil water balance that depends on soil wetness.

The influence of scattered tree shade on soil evaporation was studied in the Sahel savanna of Africa (Johnson, 1995; Belsky et al., 1993; Kinyamario et al., 1995). Higher topsoil moisture under woody canopies than in treeless sites appears to be common during the rainy season and sometime afterwards, as exemplified in Boffa (1999). Wallace et al. (1999) modeled the reduction of soil evaporation under a tree canopy in Kenya to be 35% on an annual basis. In general, shading has beneficial effects but total shade area may only account for about 10% of total land area. Measurements of soil evaporation under 6–8 m tall *Grevillea robusta* trees with a leaf area index of 2 at Machakos, using a micro-lysimeter technique, showed that soil evaporation is reduced by 23%, largely attributed to tree shade (Jackson and Wallace, 1999). Maintaining a large leaf area, however, is not a viable option for water limited environments since competition for soil water by dominant trees results in frequent crop failures (Lott, 1998). Pruning of branches and roots may of course reduce competition. Thus, there is a trade-off between the advantages of shade on lowering soil evaporation and improving crop aerial climate versus the negative effect of water competition from tree roots. The same applies to advantages of soil loss and run off reductions of hedgerows (Kinama et al., in press).

In our research, water lost by evaporation from soil deserved separate attention from water lost by run off in the erosion causing processes. It is a considerable loss and the influence of mulch (and to a much lesser extent the contour hedge rows) is due to completely different processes compared to their influence on run off losses. Soil cover is considered to be the dominant factor of all parameters that affect erosion. Research on contour hedgerows on sloping land in semi-arid Kenya has quantified the impact of *Senna siamea* mulch and tree barriers on runoff and soil loss (Kiepe, 1995; Kinama et al., in press). *S. siamea* mulch is ideal for mulching because of its slow decomposition rate (Mugendi et al., 1994). Measurements by Kiepe (1995) in a young *S. Siamea* based agroforestry system over 3 years showed that mulching alone reduced runoff by 50%, even during heavy storms, and soil loss by more than 80%. Kinama et al. (in press) showed that in four seasons of this same rotation of maize and cowpea with *S. siamea*, in the mulched hedgerow plots cumulative soil loss reduced from 100 to only 2 t ha^{-1}, and runoff from 100 to 20 mm. However, due to competition between crops and hedgerows, yields have better to be supported by fertilizers, otherwise losses are almost prohibitive. Ageing systems show increased competition (Kinama et al., in press).

Critical studies exist of alley cropping in the semi-arid tropics on flat land (Rao and Westley, 1989; Mungai, 1995; Sanchez, 1995; Mungai et al., 2001). But there is much more scope for increasing the use of limited rainfall in contour hedgerows on sloping lands. Hedge width and tree and hedge spacing and pruning as well as the use made of mulch are issues together with other economic ones (Kiepe, 1995; Ong et al., 1996; Kinama et al., in press), that may also affect soil evaporation. Understanding soil evaporation is necessary in the evaluation of the water balance of these agroforestry systems, just like that has been noted for rainfall interception losses (Jackson, 2000).

2. Materials and methods

2.1. Instrument

This paper describes the use of mini- or micro-lysimeters to quantify the influence of *S. siamea*