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Spatial variability of the English agricultural landscape and its effect on evaporation

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Abstract

The variability of leaf area index, canopy height and albedo is measured across an agricultural landscape in lowland Britain. The dependency of the variability with spatial sampling is quantified and the sensitivity of modelled evaporation to the variability is assessed. From this study, it appears that the leaf area index can display significant variability between fields of growing crops as their plant and harvest times may differ by the order of a month. In addition the albedo variability is high. Both these quantities have an influence on the resulting evaporation (between 1% and 40% depending on assumptions) and need to be accounted for. Although the crop height varies considerably, it does not have a big impact on evaporation (less than 4%).

Keywords: Albedo; Leaf area index; Crops; Evaporation modelling

1. Introduction

Establishing the water balance of a catchment is an essential prerequisite to good management of water resources. One major component of that water balance is the evaporation. However, unlike the river-flow, there is no integrative measure of the water leaving the catchment in the form of water vapour. Instead, it is usually estimated by modelling the energy and water balance within the soil and vegetation layer (Monteith, 1965; Hough and Jones, 1997).

There are some key vegetation characteristics that are observable, that affect evaporation from the surface. These are: the leaf area index (LAI) which is a measure of the area of evaporating leaf surface per unit area of ground, the albedo which is a measure of the amount of incoming radiation reflected by the vegetation and the canopy height which has an impact on the efficiency of the turbulent fluxes (in combination with the wind). Montheith and Unsworth (1973) give a comprehensive summary of how these characteristics impact the evaporation.

Typical evaporation models parameterise only a few categories of land cover; for example ‘broad-leaved trees’ and ‘grass’, and the total evaporation obtained by area-weighting the results. Within each category, it is assumed that vegetation is uniform. The most detailed model used operationally in the UK in terms of specifying the spatial variability of land cover has been MORECS (Hough and Jones, 1997). Fourteen different land cover types, including six arable crops are represented in it, each crop having a geographically distributed sowing and harvesting date which affect the LAI and the canopy height. However, within each 40 km × 40 km grid, all the fields of a given crop are modelled as growing at the same rate at the same time. The new MOSES system which replaces the MORECS

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model has far fewer land cover types (10), although the spatial resolution is higher (5 km) (Smith et al., 2004).

An alternative to this set planting/harvesting time is to use an estimate of LAI and albedo derived from satellite observations but, at present, this is only an aspiration for operational systems. Even in this ideal case, the measurement is an average over the area of the pixel of the satellite sensor, typically ranging between 0.25 and 25 km^2, within which it is assumed that all fields have a uniform LAI and albedo.

The impact of this assumption of within-grid uniformity is explored in this paper. Both natural vegetation and crops was studied. For crops each field has a different planting time so they mature at different times with the result that, during the growing season, the landscape consists of a patchwork of different LAIs, crop heights and albedos. We have studied such a patchwork, on the Berkshire Downs, in southern England, over the summer of 2003. Clustered measurements of albedo, LAI and crop height, were taken in groups in several positions within a field and several fields were sampled. The variation in these measurements represent the uncertainty with which one can identify model parameters for a land-cover type in an evaporation model at a point in time.

This paper describes the data collected and uses a simple model to identify the effect that such variation would have on the estimated evaporation. The questions addressed are:

1 What is the typical variation in observed LAI, albedo and canopy height in lowland Britain?
   Is the variation scale-dependent? Is there correlation between variables?
2 What is the sensitivity of evaporation to the variation?
   Is the evaporation sensitive to the correlation?

2. Site and observations

The study site is located on the Berkshire Downs of southern England (Latitute of 51.5° North and a Longitude of 1.5° West), within the catchment of the river Lambourn. The topography is gently undulating, ranging between 75 and 270 m above sea level over a distance of about 1 km (see Fig. 1) with the majority of the valley bottoms being dry. The soils are Andover Series (Jarvis et al., 1984), variably flinty and chalky silty brown rendzinas over Chalk. The area is rural with the land cover dominated by agricultural activities. Land use is dominantly cereals, grass leys, permanent pasture and rotational horticultural crops. In addition, there are hedgelines and isolated small woodlands.

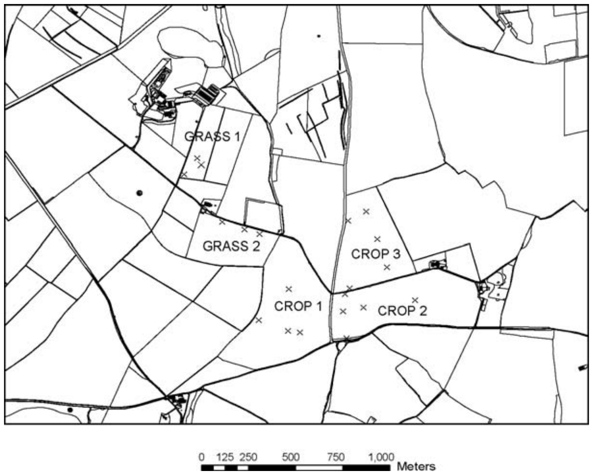

Fig. 1. Map of the study area showing the relative locations of the fields.

The farm is run on organic principles and so will not be exactly characteristic of all agricultural landscapes: for instance the crops are taller than non-organic crops and sparser.

2.1. Fields and planting dates

Measurements were made at a number of locations in five fields selected to be representative of different land uses in the area, see Fig. 1. The land cover of the fields is given in Table 1. Note that all of the fields are part of Sheepdrove Organic Farm.

Table 1
Name, land cover and planting/harvesting dates of fields sampled in 2003

Field	Crop	Planting date	Harvest date
Crop 1	Triticali Tricolor	October 10, 2002	August 10, 2003
Crop 2	Spring Wheat Axona/undersown with White Clover	March 25, 2003	August 16, 2003
Crop 3	Winter Wheat Xi19	January 14, 2003	August 16, 2003
Grass 1	Permanent pasture		
Grass 2	Permanent pasture		