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A SUMMARY OF PROCESSES WHICH ARE CONNECTED TO EVAPORATION OF RIPARIAN AND HETEROGENEOUS UPLAND VEGETATION IN ARID REGIONS

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1. INTRODUCTION

The riparian zones and the upland vegetation in adjacent regions in the San Pedro River basin are of considerable interest because of the important role they may play in the hydrology and ecology of the region. A major goal of the SALSA program is to examine the factors which govern the hydrology of these zones. The general outline of the study has been detailed in Goodrich et al., this issue.

Here we present and discuss the main factors and issues which relate to the evaporation of the riparian zones and adjacent vegetation situated in an arid landscape. The Lewis Spring study site will serve as the focus of the investigation. Further hydrologic considerations are described in Maddock et al., this issue.

Because of the particular hydrology, as well as the narrow and heterogeneous nature of these zones, they present very unique problems towards understanding and quantifying the evaporation process. The biological and physical processes governing evaporation are likely different from those in ecosystems we have experience with.

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The goals here are: (1) to elucidate the main processes which govern the evaporation rates from such an ecosystem; (2) Describe a set of measurements which will be used to attempt to quantify short-term evaporation rates at the Lewis Springs study site.

2. CRITICAL PROCESSES

To begin, we describe our current vision of the key biophysical processes relevant to this ecosystem. Indeed, the knowledge of these factors and processes remains one of the main objectives.

At Lewis Springs, the upland vegetation exists in reasonably well-defined patches of dimensions of several hundred meters. However, the woodland corridor is a narrow zone of trees 50 to 70 m wide and over 20 m tall, distributed rather heterogeneously, with some sizable gaps in the zone. The narrow dimension and spatial heterogeneity create serious obstacles to estimation of evaporation rates for the whole corridor.

Note that short-term evaporation rates for local surfaces are best done using various micrometeorological approaches. However, these approaches are predicated upon several very critical assumptions. Among these are that the surface is horizontally uniform, and extensive enough so that a boundary layer can develop which is fully adjusted to the surface.

Transpiration rates for individual trees can be estimated from sap flow measurements - see

Williams et al., this issue. However, the heterogeneous nature of the zone makes scaling and aggregation of such measurements somewhat problematic.

The main hydrologic and biophysical processes for the upland vegetation and woodland corridor are not necessarily the same. The hydrologic connections between the upland vegetation and the river need to be determined. One of the goals of the study is to determine the sources of the water transpired by the upland plant communities. This is discussed in Williams et al., this issue.

The details of the factors and processes which likely govern the evaporation of such systems are presented by Hipps et al., this issue. Figure 1, taken from that paper, illustrates our vision of the transport of water vapor from the narrow corridor.

Note that horizontal components to the fluxes are present. These are theoretically a combination of both turbulence and mean flow transport. The relative importance of such lateral transport remains to be examined.

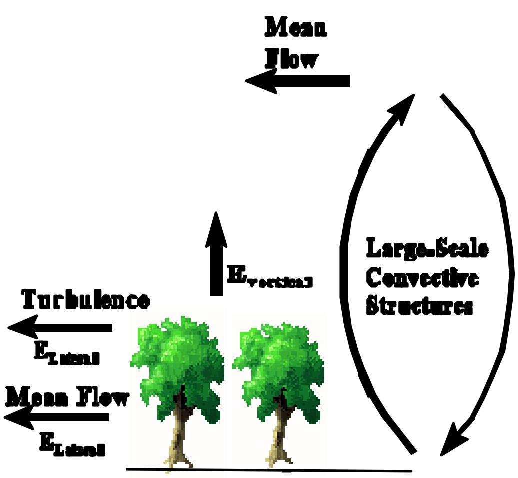

Figure 1. Conceptual view of evaporation from woodland corridor.

Also keep in mind that the small horizontal dimensions of the zone minimize any chances of feedbacks with the regional atmosphere. In general the energy balance of a surface is connected to the properties of the regional atmospheric boundary layer, as described by McNaughton and Spriggs (1986). However, in this case the zone is likely too small to affect the properties of the regional atmosphere. Hence, there is unlimited source of saturation deficit for enhancing evaporation above the available energy.

In addition to the above, there is also the question of spatial variations in critical properties and fluxes. The presence of advection suggests significant changes in saturation deficit as the air moves downwind through the porous media. Such changes can interact with stomatal conductance to result in fluxes differing from those one might expect. Such has been documented for irrigated crops by Zermeño and Hipps (1997).

3. METHODS AND MEASUREMENTS

In August 1997 a preliminary study was conducted at Lewis Springs to examine the energy balance of upland vegetation, and the water vapor exchanges between the woodland corridor and the atmosphere. The upland vegetation consisted of sacaton grass and mesquite plant communities.

3.1 Local flux estimates

Fluxes of sensible heat and water vapor were estimated locally for both the sacaton grass and mesquite/grass mixture. Both eddy covariance and Bowen Ratio approaches were utilized. The Bowen Ratio stations consisted of 10 m towers with measurements of temperature and humidity at two heights. Net radiation, soil heat flux, and wind direction and speed were also measured at these locations. Details can be found in Scott et al., this issue. The eddy covariance stations consisted of a sonic anemometer and krypton hygrometer. In 3 of the sites, a 3-d sonic was utilized, while one site had a 1-d sonic.

The location of the flux measurements is shown in Figure 2, adapted from Goodrich et al., this issue, Note that one of the eddy covariance stations was sited directly next to the edge of the woodland corridor, to examine lateral fluxes of heat and water vapor.

3.2 Lidar measurements

In order to examine the dynamics of water vapor exchanges between the vegetation and atmosphere, a Raman Lidar system was utilized. This system has been used to measure water vapor fields over a variety of ecosystems. It has also been used to examine surface fluxes and surface-atmospheric boundary layer interactions, as described in Cooper et al., (1992), Cooper et al., (1996), and Cooper et al., (1997). See Cooper et al., this issue for details

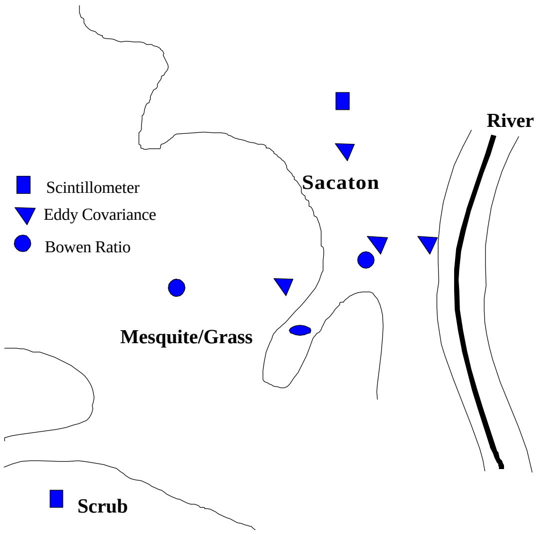

Figure 2. Flux measurements made at the site.

about the use of the system in this study. The Lidar data will quantify the spatial and temporal fields of humidity above the critical plant communities. The measurements were conducted so that the Lidar looked over the surface flux stations.

3.3 Scintillometer measurements

A large aperture scintillometer was used to determine an areal average sensible heat flux over the several upland plant communities. This device is described more fully in Chehbouni et al., this issue. The motivation here was to use the scintillometer to obtain an integrated flux value over the several plant communities. Such an estimate can be used to evaluate predictions made by aggregation models discussed in Kerr et al., this issue.

3.4 Biophysical measurements

Williams et al., this issue, describe measurements of the water status of vegetation and soil. These included sap flow of individual trees, water sources for transpiration, leaf water potential, and stomatal conductance. These measurements were made at times which coincided with the Lidar and flux measurements.

4. ISSUES AND APPROACHES

The evaporation fluxes of the upland vegetation plant communities will quantified from the flux station data. These will be integrated into the findings of sources of water for these communities made by Williams et al., this issue. Such information will suggest the role these plant communities play in the hydrology of the riparian zone.

Determination of the actual evaporation rates of the woodland corridor is more difficult. Hipps et al., this issue, discuss an approach to infer the evaporation rates of this zone, from knowledge of upwind and downwind vertical profiles of humidity and wind, when wind is perpendicular to the axis of the corridor. By combining the Lidar measurements of humidity with wind information, situations will be sought where all necessary data are available.

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