WATER USAGE AND MICROCLIMATE

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Abstract. Energy and water budget analyses are employed as methods for assessing the effects of vegetation type, cultivation practices, and irrigation methods on the microclimate. A comparison is made of vegetation types that employ water received from (1) natural precipitation and (2) irrigation.

Forest lands are compared to corn cultivated by conventional tillage and no tillage methods. The forest canopy generally has a lower surface albedo, greater surface roughness, higher transpiration rates, and increased water storage than the bare soil, mulched, and vegetated surfaces of a corn field. No tillage cultivation reduces wind and water erosion, lowers soil temperatures, and improves water retention compared to standard tillage used on corn fields.

Irrigated agriculture has replaced much of the drought resistant vegetation of the Central Valley of California. The energy and water budgets of irrigated crops grown in the semi-arid climate of the Central Valley and irrigated by flood or sprinkler methods exhibit microclimates in which evapotranspiration dominates the energy and mass fluxes. Drip irrigation methods, by contrast, have reduced water losses compared to flood and sprinkler methods. The drip system supplies metered amounts of water to the base of each plant; low soil evaporation and improved water supply to the growing plant results from this method. The latent heat flux is reduced over that found in fields irrigated by flooding or spraying.

Generally, agricultural transformation of large stands of natural vegetation is expected to change the micro- and macroclimate of the areas affected.

1. Introduction

Agricultural systems typically are established through removal of antecedent vegetation, if present, followed by alteration and manipulation of the soil and then cultivation of a crop. The level of crop–environment management varies, depending on tillage practices, crop phenology, water resources, and mechanization methods employed. The efficiency and productivity of various management practices, especially those related to plant genetics, pest control, soil fertility, and irrigation are undergoing scrutiny throughout the world. The incentive for reevaluation in recent years has been the concern that projected food production will not be adequate to cope with a growing world population (Wortman, 1976; NRC, 1976) in the face of climatic variability (Kellogg, 1977; Thompson, 1975), finite fuel resources (Larson and Fangmeier, 1978; Odum and Odum, 1976), and environmental degradation (Woodwell, 1978; NRC, 1974). Water usage and management in agricultural systems have been reevaluated in light of the above concerns (Angelides and Bardach, 1978; Rawlins and Raats, 1975). In this context, the agrometeorologist has applied energy and water budgeting techniques in order to assess the efficiencies and impacts of water usage on agricultural systems and its attendant microclimate (Ryhiner and Matsuda, 1978; Nash, 1976; Waggoner, 1975).

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The purpose of this paper is to compare the microclimatic energy and water budgets of several agricultural cover types under different water usage and management conditions. The photo-, thermo-, and hydro-fields of these different surfaces illustrate some of the microclimatic effects produced by human alteration of the Earth's surface.

2. Vegetation Types with Naturally Supplied Water from Precipitation

In many regions of the world family groups have cleared forested areas for agriculture using variations of the 'slash and burn' techniques (Sanchez and Buol, 1975). The method in its simplest form requires little cultivation in comparison with mechanized methods, provided soil nutrients, water supply, and growing season are not limiting factors. Mulch for the surface is provided by the residue of ash produced by burning the remnant slash after land clearing and, with subsequent plantings, the residue of crop stubble left in the fields after harvesting (Rappaport, 1971). Labor intensive, mechanized farming techniques, by comparison, employ intensive surface preparation and cultivation. Initially, the prepared soil remains bare until the growing plants increasingly shade the underlying surface. Natural and artificial mulches in mechanized farming are used only for selected crops (Martin et al., 1976). Experiments with chemical farming in the 1950s led to a combination of surface mulches, chemical application, and no tillage for selected crops and locales in the United States (Gersmehl, 1978). Residue from previous crops or the weed-covered, undisturbed sod remained in place, acting as a surface mulch. A specialized mechanical planter loosened a narrow strip of soil, emplanted a seed along with a measured amount of insecticide, and recovered the slot; the land between slots remained mulched but uncultivated, although it may receive applications of fertilizer and herbicide (Triplett et al., 1977). A comparison is made of the energy and water budgets of a forest cover, bare soil, mulched soil, and corn crop to illustrate the microclimatic features associated with antecedent vegetation and agricultural management practices under natural precipitation regimes.

Overall, the forest canopy is a more efficient absorber of incoming solar radiation than the closed canopy of a corn field (Lee, 1978; Stewart, 1971; Brown and Covey, 1966; Allen and Brown, 1965). Individual measurements and comparisons of albedo over various types of plant stands are in general agreement with the relationship between vegetation height and albedo found by Stanhill (1970); as height of vegetation increases its surface albedo decreases. The generally taller, rougher forest canopy has a range of albedo values typically falling between 0.05 and 0.20, while the shorter, smoother corn canopy has a range typically between 0.18 and 0.28 (Lee, 1978; Oke, 1978). Measured values of albedo, of course, undergo daily, seasonal, latitudinal changes as a function of solar elevation angle and degree of crop cover (Arnfield, 1975; Brown and Covey, 1966). By contrast to the above vegetation types, the albedo of bare soil has reported values between 0.05 and 0.40 and is indicative of the complex effects of soil texture, color, and moisture content (Oke, 1978). However, if soils with extreme surface