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ASPECTS OF THE WATER BALANCE OF AN OATS CROP GROWN ON A LAYERED SOIL

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ABSTRACT

The increasing pressure on our water resources, for irrigation in particular, has resulted in a growing awareness of the importance of water balance studies. In this thesis three aspects of the field water balance are investigated; evapotranspiration (ET) from well-watered crops, the upper limit of soil water storage in the field, and drainage.

Daily ET values, measured by the Bowen ratio-energy balance method, are presented for an oats crop grown in winter and also for a number of summer crops, all of which were well-watered. ET measurements were also made over longer periods using a drainage lysimeter. It was found that the Penman, and Priestley and Taylor ET estimation procedures predicted ET with an accuracy of 15-20% and 8% for daily and weekly periods, respectively. The Priestley and Taylor method is simpler to use but requires an empirical constant to relate the 'equilibrium ET' to ET. This constant was found to be 1.21 for winter, spring and summer over a range of crops in the Manawatu. Net radiation data on a daylight basis were used to evaluate this constant, as seasonal variations in the constant were introduced when 24-hour data were used. Also it is easier to empirically estimate daylight than 24-hour net radiation. Long term ET estimates using the Priestley and Taylor method with net radiation calculated from incoming solar radiation, were in reasonable agreement with the drainage lysimeter measurements of ET for the oats crop.

A theoretical development is presented that describes water retention in soils underlain by a coarse-textured stratum. This development accounts for the physical character of the overlying soil, the depth to the coarse layer, and the coarseness of the underlay. Field data are presented for the Manawatu fine sandy loam, a soil with a coarse-textured layer at 90 cm. For this soil the layering resulted in an additional 55 mm of water storage at the cessation of drainage, an increase of 31% over a similar hypothetical soil with the coarse stratum absent.

Drainage from a permeable soil underlain by a coarse-textured layer is investigated. Simplified theory is used to develop a model relating the drainage flux at the base of the soil to the water stored in the overlying soil. Despite significant hysteresis in both the water retentivity curve of the overlying soil and the hydraulic conductivity-pressure potential relationship of the coarse layer, hysteresis had little effect on the storage-flux relation. The model simulated both the field drainage in the Manawatu fine sandy loam measured by a lysimeter, and field profile water storage found by neutron probe moisture measurements. The model indicates that only simple field measurements are needed to find the storage-flux relationship.

The components of the water balance of an autumn-sown oats crop grown in the Manawatu are resolved. Drainage loss was found to constitute 60% of the rainfall, with the remaining amount being lost as ET.

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LIST OF SYMBOLS

		UNITS
a	empirical constant in Eq. 1.3	
b	exponent in Eq. 1.3	dimensionless
C	convective term in the combination evaporation equation	mm day^{-1}
C.R.	counts per second in soil/counts per second in neutron probe radiation shield	dimensionless
C_p	specific heat capacity of air	J g^{-1} C^{-1}
d	soil depth	cm
D	soil water diffusivity	cm^2 day^{-1}
Dm	plant dry matter %	dimensionless
ΔD	change in surface water detention	mm
e	vapour pressure	mb
Δe	difference in vapour pressure between two levels above crop	mb
e_s	saturated vapour pressure	mb
ET	evapotranspiration	mm day^{-1} or Wm^{-2}
ET_p	Penman's evapotranspiration estimate	mm day^{-1}
ET_{eq}	equilibrium evapotranspiration rate	mm day^{-1}
ET'_{eq}	daylight equilibrium evapotranspiration rate	mm day^{-1}
ET''_{eq}	nocturnal equilibrium evapotranspiration rate	mm day^{-1}
f(u)	wind function in Penman's equation	mm day^{-1} mb^{-1}
f(w)	drainage flux-profile storage relationship	mm day^{-1}
G	soil heat flux	mm day^{-1} or Wm^{-2}
H	sensible heat flux	mm day^{-1} or Wm^{-2}
J	drainage flux	mm day^{-1}
J_i	drainage flux in coarse underlay	mm day^{-1}

		UNITS
K	hydraulic conductivity	cm day^{-1}
K_i	hydraulic conductivity of the coarse underlay	cm day^{-1}
K_f	hydraulic conductivity of the overlying soil	cm day^{-1}
K_s	saturated hydraulic conductivity	cm day^{-1}
$K\downarrow$	incoming solar radiation	mm day^{-1} or Wm^{-2}
L	latent heat of vapourization	Wm^{-3}
LAI	leaf area index	dimensionless
L_1, L_2	characteristic length of soil particles	mm
m	slope of the K-$\log_e(\theta)$ curve	
P	atmospheric pressure	mb
Ph	energy used in CO_2 fixation by photosynthesis	mm day^{-1} or Wm^{-2}
r_s	crop resistance to water vapour	sec cm^{-1}
R_n	net radiation	mm day^{-1} or Wm^{-2}
RO	run off	mm
RF	rainfall	mm
R	simple correlation coefficient	dimensionless
S.D.	standard deviation	
ΔS	crop heat storage change	mm day^{-1} or Wm^{-2}
s	slope of the saturated vapour pressure-temperature curve	mb C^{-1}
S_{yx}	standard error of the regression estimate	
$\bar{T}$	mean daily temperature	C
T_{max}	maximum daily temperature	C
T_{min}	minimum daily temperature	C
T_d, T_W	dry bulb, wet bulb temperature	C
ΔT_d, ΔT_W	dry bulb, wet bulb temperature difference between two levels above crop	C

		UNITS
t	time	day
u	windspeed	m sec^{-1} or km day^{-1}
VPD	saturation vapour pressure deficit	mb
W	profile soil water storage	cm
W_t	profile soil water storage at time t	cm
W_u	uniform soil profile water storage	cm
W_L	layered soil profile water storage	cm
ΔW	$W_L - W_u$	cm
W_{max}	maximum profile soil water storage	cm
W_{min}	minimum profile soil water storage	cm
z	soil depth measured from soil surface	cm
z_i	soil depth to coarse layer interface	cm
z_L	soil depth to secondary layering	cm
z_o	aerodynamic surface roughness	cm
z^*	depth defined by Eq. 3.8	cm

α	empirical constant, ET/ET_{eq}	dimensionless
β	Bowen ratio	dimensionless
γ	psychrometric constant	mb C^{-1}
γ^*	psychrometer constant	mb C^{-1}
δ	error operator	
η	slope of the log K- logθ curve	
θ	volumetric soil water content	$cm^3\ cm^{-3}$
θ_t	volumetric soil water content at time t	$cm^3\ cm^{-3}$
θ_s	saturated volumetric water content	$cm^3 cm^{-3}$
Λ	difference between γ^* and γ (Eq.A1.12)	mb C^{-1}
λ	pore size distribution index	dimensionless
λ_{max}	pore size distribution index when $d\ (\Delta W)/d\lambda = 0$	dimensionless

		UNITS
ξ	ratio of the molecular weight of water to air	dimensionless
ρ_b	soil bulk density	g cm^{-3}
τ	time	day
ψ	tensiometer pressure potential	cm
ψ_e	air entry pressure potential	cm
ψ_c	pressure potential when $J = 1$ mm day^{-1}	cm
ψ_i	pressure potential when $J_i = 1$ mm day^{-1}	cm