Abstract

The main objective of the project was to adapt and validate the Gembloux Dynamic Greenhouse Climate Model for the prediction and control of the microclimate of an operational greenhouse in Zimbabwe. The use of modelling as a microclimate control strategy is aimed at achieving optimal climate control through the provision of a more affordable alternative. Measurements of climate variables were taken in a central position within as well as outside a commercial rose greenhouse at Floraline Pvt. Ltd over the period November 2004 to February 2005. The first stage of the project involved assessing the homogeneity of the greenhouse air by comparing temperature and humidity measurements taken at five positions within the greenhouse structure. It was found that the greenhouse air was not homogeneous and the placement of air temperature and humidity sensors in the greenhouse was important for correct decision making. The model performance was analyzed by comparing the measured climate variables (air temperature and humidity) inside the greenhouse with those from the simulation using the Gembloux Dynamic Greenhouse Climate Model. This was done for two data sets, 3 to 11 November 2004 and 25 November 2004 to 01 December 2004; these were used as the calibration and validation periods respectively. In the study, both the direct and diffuse solar radiation had to be simulated as only the global radiation was measured whilst the stomatal resistance values used for the transpiration sub-model were 1800 s m^{-1} (maximum) and 200 s m^{-1}(minimum).

Overall, the model underestimated the air temperature by up to 6 °C whilst the humidity was overestimated by up to 60 %. The root mean square errors (RMSE) for the calibration period were in the range 1.0 - 2.0 °C (daytime) and 0.2 - 0.8 °C (nighttime) for the air temperature. The vapour pressure had RMSE in the range 0.6 - 1.0 kPa (daytime) and 0.1 - 0.2 kPa (nighttime). The model deviated more from the actual measurements during the daytime because of increased temperature and vapour pressure differences between the inside and outside of the greenhouse. The differences between the simulated and measured air temperature was attributed to their volumetric heat capacities, arising from those of pressure (1013 hPa and 850 hPa respectively). There was a notable improvement in the nighttime simulation of the air temperature and vapour pressure during the validation period. The differences between the calibration and validation periods indicated errors in the simulation programme that were not picked up during the runs. Based on the air temperature results, the model has shown its potential for use in greenhouse microclimate prediction in Zimbabwe. The high correlation (r^2=0.96) between the simulated and measured air temperature shows that the model has the potential for use in decision making. The model can be reliably used to determine the weekly greenhouse air temperatures because of the observed maximum difference of 2 °C between the simulation and actual measurements. However the model cannot be implemented without further calibration of the model parameters to improve the simulation of humidity, which was significantly different from the actual measurements. Humidity is an important variable in disease forecasting for greenhouse production.

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Latin symbols

A	surface area	(m^2)
c_p	specific heat capacity of air at constant pressure	(J m^{-2} K^{-1})
C	water vapour concentration	(kg m^{-3})
$c^{'}$	heat capacity per unit area	(J m^{-2} K^{-1})
d	characteristic length	(m)
D	diffusion coefficient	(m^2 s^{-1})
e	partial pressure of water vapour in air	(kPa)
$e_s(T)$	saturation vapour pressure of water at temperature T	(kPa)
δe	saturation deficit i.e. $e_s(T)-e$	(kPa)
E	flux of water per unit area; evaporation rate	(mm day^{-1})
F	mass flux of a gas per unit area; flux of radiant energy	
g	acceleration by gravity	(9.81 m s^{-2})
h	heat transfer coefficient	(W m^{-2} K^{-1})
H	solar time	(hr)
I	intensity of radiation	
l	thickness	(m)
L	long wave radiation flux	(W m^{-2})
m'	mass surface density	(kg m^{-2})
q	heat flux density	(W m^{-2})
Q	heat flux	(W)
r	mass transfer resistance	
R_a	air renewal rate	(hr^{-1})
R'_a	ventilation rate	(m^{-3} s^{-1})
R_n	net radiation flux density	(W m^{-2})
t	time	(s)
T	temperature	(^{O}C)
u	air velocity, wind speed	(m s^{-1})
V	volume	(m^3)

Greek symbols

α	absorptivity at wavelength λ
γ	psychrometric constant $\left(c_p p \middle/ \lambda\varepsilon \right)$
Δ	rate of change of saturation vapour pressure with temperature $\partial e_s(T)\partial T$
ε	emissivity at wavelength λ
λ	wavelength of electromagnetic radiation
κ	thermal diffusivity of still air
v'	coefficient of kinematic viscocity
ρ	reflectivity at wavelength λ

ρ'	density	(kg m^{-3})
σ	Stefan-Boltzmann constant	(5.67×10^{-8} W m^{-2} K^{-4})
τ	transmissivity at wavelength λ	

Subscripts

a	air
b	bulk
c	cover
ce	outer cover surface
ci	inner cover surface
cf	condensation film
D	conduction
day	day defined as the period between sunrise and sunset
e	external air
gr	greenhouse
i	internal air
P	phase change (evaporation and condensation)
R	far infrared radiation
s	soil surface
sd	soil
set	set point
sky	sky, treated as a full black body radiator,
ss	subsoil
$s1, s2, s3, s4$	$s1$ and ss one soil layers and subsoil
$s12, s23, s34$	interfaces between the soil layers
$s4s$	soil layer interface between soil layer 4 and the subsoil
v	vegetation
V	convection
vent	ventilation

Dimensionless groups

Biot number $\dfrac{h_{V+R.}d}{\lambda}$

Grashof number $\dfrac{b.g.d^3.\left|T_{sd} - T_b\right|}{v'^2}$

Nusselt number $\dfrac{q_V}{\lambda.\dfrac{T_{sd} - T_b}{d}}$

Prandtl number $\dfrac{v}{\kappa}$

Reynolds number $\frac{u.d}{v}$

Schmidt number $\frac{v'}{D}$

Sherwood number $\frac{q'_p}{D.\frac{C_{sd}-C_b}{d}}$

List of Acronyms

AWS	Automatic Weather Station
CF	Cloudiness Factor
DOY	Day Of Year
EFGAZ	Export Flower Growers Association of Zimbabwe
FAO	Food and Agricultural Organisation
GDGCM	Gembloux Dynamic Greenhouse Climate Model
GCM	Greenhouse Climate Model
IPM	Integrated Pest Management
LAI	Leaf area index
LWD	Leaf wetness duration
PAR	Photosynthetically active radiation
RD	rooting density distribution
RMSE	Root mean square error
TRNSYS	Transient system simulation programme
VPD	Vapour pressure deficit