UNIVERSITY OF SOUTHERN QUEENSLAND

DEVELOPMENT OF A CLIMATE-BASED COMPUTER MODEL TO REDUCE WHEAT HARVEST LOSSES IN AUSTRALIA

A dissertation submitted by

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ABSTRACT

Grain harvest represents a period of high risk and is also a bottleneck in a grain production. This study develops a climate-based systems simulation model to investigate the economics of high moisture grain harvesting in Australia. The optimum harvesting and drying strategies were determined. The role of grain aeration cooling was also examined. The model software was developed in MATLAB. This model was run on an hourly basis using 15 years of historical weather data (1991-2005) for three main wheat production areas in Australia, represented by Goondiwindi (QLD), Tamworth (NSW) and Scaddan (WA).

The Wheat Harvest System Simulation Model (WHSSM) consists of four submodels of weather data, machinery performance, crop loss and economic calculations. Each submodel is represented by mathematical functions and supported by available theoretical and field data. The weather submodel is used to predict dynamic grain moisture contents for a standing crop in the field. Machinery submodel was developed to calculate machinery performance and its operating costs at different grain and weather conditions. The main machinery involved are combine harvester, cooling aerator, and four categories of grain driers. Crop loss submodel is used to quantify grain losses involved during harvest and storage periods, including shedding (yield) losses, header losses, threshing losses, crop quality downgrading losses (due to rainfalls), and storage spoilage losses.

The model has been used to predict and compare the possible return for different harvesting and postharvest management strategies. For the reference case (a 1000 ha farm with a high-capacity harvester and medium-capacity drier in Goondiwindi), it is found that the optimum harvest moisture content for using continuous flow drier and batch drier is 14 and 13% (wet basis) respectively. For aeration simulation, it is found that the use of an aeration cooling system would slightly increase grower's return when the drier capacity is inadequate. No positive impact can be achieved on return if growers use either high or medium capacity driers. Generally, high capacity harvester travelling at lower speed is preferred.

It is also demonstrated that local weather conditions/rainfall patterns can have a very significant influence on grower returns. Growers in dry and warm

location (e.g. Goondiwindi) will gain better return. It is predicted that at the given model control values, the long-term optimum harvest moisture contents for Goondiwindi, Scaddan and Tamworth are 14, 15 and 17% respectively.

CERTIFICATION OF DISSERTATION

This is to certify that the work contained in this dissertation including model development, model application, analyses and conclusions are entirely my own effort, except where acknowledgment and reference is made. I also certify that this work is original and has not been submitted for any other award, except where otherwise acknowledged.

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NOTATIONS

B_e	burning efficiency	%
C	value of the top quality wheat	$/t
C_a	capital cost of aerated storage	$
C_c	aeration cost	$/t
C_d	capital cost of drier	$
C_e	annual drying cost	$/yr
C_f	fuel cost	$/yr
C_h	capital cost of harvester	$
C_l	cost of labour	$/yr
C_m	annual machinery cost	$/yr
C_r	rated capacity of combine harvester	ha/h
C_s	capital cost of aerated storage	$
C_t	annual total costs (fixed and variables cost) of machinery	$
C_x	annual maintenance and repair costs	$/yr
C_{ae}	annual aeration cost	$/yr
C_{ec}	effective capacity of the harvester	ha/h
c_d	specific cost of LPG	$/L
c_e	specific cost of electricity	$/kWh
c_f	specific cost of fuel (diesel)	$/L
c_l	specific cost of labour	$/h
c_p	specific heat of air	kJ/(kg ºC)
D	harvesting delay due to rainfall	d
D_a	astronomical day length	h
D_b	depth of grain bed	m
D_t	drier throughput	t/h
d_m	day since crop maturity (30% moisture content)	d
E_d	annual energy demand for drying	kWh/yr
F_a	fan power required for aeration	kW/m^2
F_d	fan power required for drier	kW
F_s	farm size	ha
f_e	fuel use rate for harvester	L/h
f_1	repair coefficient for harvester and drier	decimal
f_2	maintenance coefficient for harvester and drier	decimal
H_c	cumulative hours of using harvester and drier	h
I_p	initial purchase price	$
i	real estate interest	%/yr
i_g	annual inflation rate	%/yr

i_n	market interest rate	%/yr
L_h	header losses	t/ha
L_s	shedding losses	t/ha
L_t	threshing losses	t/ha
L_u	unharvested grain losses	t/ha
L_w	total value of grain losses	$/ha
M	grain moisture content at any time, t	% dry basis
M_a	average grain moisture content	% dry basis
M_b	grain moisture content at the start of a rain period	% dry basis
M_d	grain moisture content during dry period	% dry basis
M_h	harvest grain moisture content at any time, t	% wet basis
M_i	initial grain moisture content	% dry basis
M_o	final grain moisture content	% wet basis
M_r	grain moisture content during rain period	% dry basis
m_d	flow rate of air used for drying	kg/s
N_a	hours aeration is used per year	h/yr
N_d	hours drier is used per year	h/yr
N_h	hours harvester is used per year	h/yr
n	useful life of machine	yr
P	atmospheric pressure	kPa
Q	air flow rate per square meter of the floor	m/s
Q_d	quality losses due to degradation	$/ha
Q_s	quality losses due to spoilage	$/ha
R	annual return	$/ha
R_d	rainfall duration	h
R_q	rainfall amount	mm
r	daily rainfall	mm
S	forward speed of harvester	km/h
S_a	safe storage period of grain	d
S_c	storage capacity	t
S_o	rated speed of harvester	km/h
S_p	safe storage period of grain without aeration	d
S_v	salvage value of machine	$
T	air temperature at daytime	ºC
T_c	average grain temperature	ºC
T_d	drying temperature	ºC
T_g	mean grain temperature above ambient	ºC
T_n	night time temperature	ºC
T_{avd}	average daily ambient air temperature	ºC
T_{ave}	average of night temperature	ºC
T_{db}	dry bulb temperature	ºC
T_{max}	daily maximum temperature	ºC

T_{min}	daily minimum temperature	ºC
T_{set}	temperature at sunset	K
T_{sky}	sky temperature	K
T_{wb}	wet bulb temperature	ºC
t	24 hour clock time	h
t_h	time since the end of a rain period	h
t_{min}	time when the minimum temperature occurs	h
t_r	time of sunrise	h
t_s	time of sunset	h
t_x	time when the maximum temperature occurs	h
V	vapour pressure	kPa
V_s	saturation vapour pressure	kPa
V_{wb}	saturation vapour pressure at wet bulb temperature	kPa
W_c	comb size of combine harvester	m
W_e	equilibrium moisture content	% dry basis
W_{eo}	equilibrium moisture content at the end of a rain period	% dry basis
Y	crop yield	t/ha
Y_o	standard crop yield	t/ha
z	the elevation of location measured from the sea level	m
ψ_1, ψ_2	constant loss factor for shedding losses	decimal
ψ_3	constant loss factor for header losses	kg/ha/d
φ	grain to straw ratio	decimal
ω	speed index	decimal
ϕ	relative humidity	%
ΔP_g	static pressure drop over grain bed depth	N/m^2
γ	psychrometric constant	kPa/ ºC
δ	declination (north positive)	degrees
Γ	latitude (north positive)	degrees
χ	yield index	decimal
λ	latent heat of vaporization	MJ/kg
δM	change in grain moisture content during a rain period	% dry basis
ε	emissivity	decimal
β	ratio of molecular weight of water vapour to dry air	decimal
θ	grain moisture index	decimal
μ	field efficiency for combine harvester	%

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