Improved Wheat Yield and Production Forecasting with a Moisture Stress Index, AVHRR and MODIS data (in Western Australia)

Dr David Stephens (AEGIC)
Broad overview – Crop Forecasting

• Crop Forecasting - moisture stress
• Integration climate/crop forecasting
• Crop forecasting – moisture stress + NDVI
• Productivity gains – N Fertilizer important
• APSIM simulation modelling/climate extremes
Australian Grainbelt – STIN crop forecasting system

Variability in wheat yields at a Statistical Subdivision level 1999-2013 (except Qld excludes 2010)

Coefficient of variation

- < 0.10
- 0.10 to 0.17
- 0.17 to 0.24
- 0.24 to 0.31
- 0.31 to 0.38
- 0.38 to 0.45
- 0.45 to 0.52
- > 0.52

STATISTICAL AREAS
2006-2008

Legend

- 2008 Statistical Subdivision boundary
- 2006 Statistical Local Area boundary
- Wheat growing area
- Central Rainfall Station
1) Ritchie 2-stage Water balance  
2) FAO Crop Monitoring Model

Daily time-step

- Solar radiation
- Temperature (max., min.)
- Daily rainfall
- Energy-limiting evaporation
- Runoff
- Soil moisture in layer 1
- Soil moisture at sowing
- Drainage

Weekly time-step

- Weekly rainfall
- Sowing date
- Potential Soil Water
- Potential crop water requirement (no stress)
- Estimated wheat yield

- Percent of total water requirement exceeded (waterlogging)
- Percentage of total water requirement not met (dry)

Technology terms

- Sowing date
- Stress Index

STress INdex for wheat (STIN) - Stephens

Potential soil water

Potential crop water requirement (no stress)
Crop Monitoring

2011-12 Western Australian Estimated Wheat Yield

- DAFWA (STIN, ground survey)
- ABARE Forecast
- GIWA Forecast
- CBH Forecast

Adj R²: 87.93%

Australia Soil Moisture Ranking
16th May 2016 compared to years 1917-2015

Legend
- Shire Boundary
- Wheatbelt Boundary

Soil moisture percentile ranges
- Above average
- Average
- Below average

Kilometres (approximate only)

Based on data provided by DCM and pulished by the Government Department of Environment and Resource Management. Mapped by Geographical Information Services, Department of Agriculture and Food WA, 2016
Yield Forecasting
Water balance + Satellites
2006 Drought
Time-series of AVHRR in Western Australia
Regression analysis

- One model for all shires
- Validation with leave-year-out procedure
- Partial least squares (PLS) regression

\[ X = [Yr, SI, sNDVI, CR, SI \times NDVI, SI \times CR] \]

\[ LV = f(X, Y) \]

\[ Y = A \times LV \]

- Maximum of 10 Latent Vectors in model
- Data normalization
  - Zero mean and unit variance per shire
  - Each column of X and Y separately
Validation results for best model

Yield

Production

Predicted

Measured

ton/ha

kton/shire

1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

HN
HC
HS
MN
MCN
MC
MS
LN
LC
LS
SC
Aggregated to climatic zones

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>$Q^2$</th>
<th>RMSEP (t/ha)</th>
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<tbody>
<tr>
<td>High</td>
<td>0.5-0.8</td>
<td>0.11-0.18</td>
</tr>
<tr>
<td>Medium</td>
<td>0.8</td>
<td>0.11-0.14</td>
</tr>
<tr>
<td>Low</td>
<td>0.9-1.0</td>
<td>0.06-0.11</td>
</tr>
<tr>
<td>Southern coast</td>
<td>0.7-0.9</td>
<td>0.11-0.18</td>
</tr>
</tbody>
</table>

Area under wheat, %

Model struggled
Where mixed crops
MODIS data improves water balance model predictions

Total error for WA

<table>
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<tr>
<th></th>
<th>Sep</th>
<th>Nov</th>
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<tbody>
<tr>
<td>Current</td>
<td>0.98</td>
<td>0.75Mt</td>
</tr>
<tr>
<td>Improved</td>
<td>0.55</td>
<td>0.46Mt</td>
</tr>
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Yield, relative error, %

Aug Sept Oct Nov
Wheat Yield Trends

\[ Y = a + b \times (SI) + c \times (\text{year}) \]

National Wheat Yield Trends 1930-2014
Adding fertilizer to model:

\[ Y = a + b^\ast (SI) + c^\ast (year) + d^\ast N \]

Adjusted R\(^2\) for NSW/VIC (1993-2011)

NSW Current 0.92  new 0.95
VIC  Current 0.92  new 0.94

However, difficult to get present season application (at this stage)

Bangladesh Rice yields
Simulation Model - Yield Prophet Modelling Framework

APSIM adapted by Donald Gayman (CSIRO) – works very well for rice, wheat, maize, legumes over large majority Bangladesh.

ACIAR “Cropping system intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India”. Project LWR/2014/73.
Opportunistic Early warning System for Climate Extremes – EPI predicting May-October rain in year (+1)
Thankyou
Canadian Wheat Board model

Fig. 2. Limiting crop conductance as a function of growing degree days.

Fig. 3. Growth ($G_n$) as a function of the cumulative difference between supply and demand variables.

Fig. 4. Cumulative water supply and transpiration demand for Swift Current in the 1985 and 1986 growing seasons.

Fig. 5. Limiting growth values as a function of growing degree days and the curves of growth values calculated for Swift Current in 1984 and 1986.

Fig. 6. Western Canada average wheat yields for 1975–86 vs. corresponding calculated drought index values.