Agrometeorological Risk Management: Opportunities and Challenges

Examples of coping strategies with agrometeorological risks and uncertainties for Integrated Pest Management


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New South Wales Department of Primary Industries
Most Variable Climate

- Australia has the most variable continental climate in the world with extreme temporal and spatial rainfall variation.
- Australian industries, businesses and communities have historically been subject to greatly fluctuating incomes due to seasonal climate variation, and incur enormous recurrent costs from drought, storms and floods.
Australia’s longest river has not been flowing (Seiler, 12 Oct 2006)
Drought impact
Some diverse agriculture in Australia
Economic Growth

- Australia’s economic growth is strongly affected by climatic variation and extreme events.
- For example, the 2002-03 drought reduced Australia’s GDP by $6.6B or economic growth by 1%.
- There are worrying signs that the severity of drought could be increasing.
Two Climate Sensitive Diseases

- Two climate-sensitive diseases of Australian field crops are stripe rust of wheat and Sclerotinia rot of canola.
- Both diseases having a high risk-ranking on the list of Australian crop diseases.
- Stripe rust of wheat is estimated to cause a loss of AU$ 181 million per annum (Brennan and Murray 1998), and stem rot a loss of up to AU$ 47 million in a favourable year (Hind-Lanoiselet 2006).
Estimated value of annual crop losses due to pests and diseases

<table>
<thead>
<tr>
<th>Crop</th>
<th>Percentage loss (average)</th>
<th>Value (Rs. in million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>20</td>
<td>13,078</td>
</tr>
<tr>
<td>Cotton</td>
<td>50</td>
<td>3,400</td>
</tr>
<tr>
<td>Mustard</td>
<td>35-73</td>
<td>613</td>
</tr>
<tr>
<td>Groundnut</td>
<td>10</td>
<td>2,380</td>
</tr>
<tr>
<td>Pulses</td>
<td>10</td>
<td>5,000</td>
</tr>
</tbody>
</table>

India
Consumption pattern of insecticides and fungicides

<table>
<thead>
<tr>
<th>Crop</th>
<th>Consumption (%)</th>
<th>Cropped area share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>52-55</td>
<td>5</td>
</tr>
<tr>
<td>Rice</td>
<td>17-18</td>
<td>24</td>
</tr>
<tr>
<td>Vegetables / Fruits</td>
<td>13-14</td>
<td>3</td>
</tr>
<tr>
<td>Plantation crops</td>
<td>7-8</td>
<td>2</td>
</tr>
<tr>
<td>Cereals / Millets / Oilseeds / Pulses</td>
<td>6-7</td>
<td>58</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>2-3</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>1-2</td>
<td>6</td>
</tr>
</tbody>
</table>

India
Canola in Australia

Canola area sown
(Hectares per Local Government Area in 2000)

1 - 1000
1001 - 5000
5001 - 10000
10001 - 20000
20001 - 30000
30001 - 48000

GM canola field trials
(Up to and including January 2003)

Map derivation
Canola data reported as totals per Statistical Local Area (SLA) were converted to totals per Local Government Area (LGA), except unincorporated LGAs in South Australia which were depicted as SLAs. In some cases, one LGA represents the sum of more than one SLA.

Information on locations of field trials has been provided by the Office of the Gene Technology Regulator (OGTR) on 30 January 2003 for visualisation purposes only. Mapping coordinates are provided by Accredited Organisations as part of applying for and managing requirements under a licence for GMO field trials. There is on-going validation of the data as part of the OGTR’s monitoring activities, and updated coordinates are provided on the OGTR internet site Intentional Release Record (http://www.ogtr.gov.au/gmores/ir.htm) linked within interactive maps (http://www.ogtr.gov.au/maps/index.htm).

Data sources
Wheat Growing Areas in Australia
Climate Classification of Australia

Climate Classes

- Equatorial
  - rainforest (monsoonal)
  - savanna

- Tropical
  - rainforest (persistently wet)
  - rainforest (monsoonal)
  - savanna

- Subtropical
  - no dry season
  - distinctly dry summer
  - distinctly dry winter
  - moderately dry winter

- Desert
  - hot (persistently dry)
  - hot (summer drought)
  - hot (winter drought)
  - warm (persistently dry)

- Grassland
  - hot (persistently dry)
  - hot (summer drought)
  - hot (winter drought)
  - warm (persistently dry)
  - warm (summer drought)

- Temperate
  - no dry season (hot summer)
  - moderately dry winter (hot summer)
  - distinctly dry (and hot) summer
  - no dry season (warm summer)
  - moderately dry winter (warm summer)
  - distinctly dry (and warm) summer
  - no dry season (mild summer)
  - distinctly dry (and mild) summer
  - no dry season (cool summer)

Based on a modified Köppen classification system.
Classification derived from 0.025 x 0.025 degree resolution mean rainfall, mean maximum temperature and mean minimum temperature gridded data.
All means are based on a standard 30-year climatology (1961 to 1990).
• Primary producers use climate information to assist with many decisions:

Crop choice
Choice of cultivar (early or late)
Mixture of crops
Fertiliser use
Pest and disease control
Timing of the harvest
Irrigation scheduling
Area planted to a given crop (and/or rotation of fields);
Timing and amount of tillage
Stocking rates.
Indiscriminate use of pesticides led to

- Resistance to pesticides
- Pesticide residues
- Environmental pollution
Strategy

Integrated Pest Management

**Most relevant strategy for combating severity of pest / disease damage**

Weather based prediction and control of pests is a part of the broader IPM strategy

**Pest / disease forecasting models based on weather will play a greater role in successful implementation of IPM**

Weather based pest / disease forecasting models can help provide advance information for need based crop protection by farmers
Integrated disease management

- Stubble burning to destroy sclerotia
- Triazine herbicides to prevent apothecial disk differentiation
- Fungicides to prevent lesion development
- Burial of sclerotia
- Biological control of sclerotia
- Chemicals to prevent germination of sclerotia

• Breeding for resistance
• Good sanitation
• Crop rotation

Sclerotia in soil → Apothecia under canola canopy → Spores land on flower petals

Flower petals → Lesion → Spores land on flower petals
Stubble burning
Stubble burning

• Burning of stubble does not appear to be an effective measure of control for Sclerotinia stem rot in the field
  – Temperatures reached in the fire are usually not hot enough to prevent germination of sclerotia
  – Sclerotia and thermal melt crayons put into field/oven
    • Most ground surface temperatures did not reach 93°C
    • Most sclerotia (> 98%) survived exposure to temperatures less than 93°C
    • Very few sclerotia survived temperatures above 121°C

• Negative environmental impacts
Control of *Sclerotinia sclerotiorum*

- Disease caused by *Sclerotinia* spp. has been difficult to consistently and economically control
  - Wide host range, including sunflowers, lupins, mustard, pea and faba bean (broad leaf crops and weeds)
  - Sporadic disease occurring about one in five years when environmental conditions are favourable
  - Long lived survival structures called sclerotia
- Most successful control measures include chemical control and cultural practices
- Biological control and disease resistance show promise for the future
Sclerotinia stem rot on canola

- Caused by *Sclerotinia sclerotiorum*
- In Australia
  - Up to 24% yield loss
  - Higher rainfall zones
  - NSW, WA

Lesion on main stem
Canola prematurely ripens

Sclerotia (survival structure)
Update on prediction and management (NSW DPI, Wagga)

- **Management**
  - Management Research
  - Trial results for 2003 and 2004
  - Economics of Spraying

- **Prediction**
  - Epidemiological data
  - Disease prediction

- **Future Research**
Fungicides for Sclerotinia control

- Rovral (iprodione) and Sumisclex (procymidone)
  - Both chemicals controlled Sclerotinia stem rot in 2003 and 2004
  - Best application time ≈ 30% flowering or before a rainfall event
  - Note: 2003 and 2004 were low disease years

- No significant yield (or economic) benefit in using fungicides in either year

- www.agric.nsw.gov.au
- www.canolaaustralia.com
Trial Results

- In 2003/2004 early fungicide treatments reduced disease development
  - 2003 and 2004 were dry years
- Very little Sclerotinia stem rot developed
- No yield effects in 2003
- Yield effects in some trials in 2004
  - Not significantly different to nil treatment control
  - Greenethorpe post rainfall Rovral greater than nil treatment
  - Unknown Sumisclex yield reduction cf Rovral?
- No economic benefit in applying fungicides
Economics of spraying

<table>
<thead>
<tr>
<th>Rovral® liquid fungicide (2 litres/ha)</th>
<th>$31/litre</th>
<th>$62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average cost of Ground Rig/Aerial spraying costs $12/ha</td>
<td>$12</td>
<td>$12</td>
</tr>
<tr>
<td>Total Cost (August 2004)</td>
<td>$74/ha</td>
<td></td>
</tr>
</tbody>
</table>

Consider the current price of both chemical and canola to determine the viability of Sclerotinia control.

<table>
<thead>
<tr>
<th>% yield loss</th>
<th>yield loss (t/ha) at 2 t/ha potential</th>
<th>On Farm Price Canola ($/tonne)</th>
<th>$270/t</th>
<th>$280/t</th>
<th>$290/t</th>
<th>$300/t</th>
<th>$310/t</th>
<th>$320/t</th>
<th>$330/t</th>
<th>$340/t</th>
<th>$350/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.1</td>
<td>-$47</td>
<td>-$46</td>
<td>-$45</td>
<td>-$44</td>
<td>-$43</td>
<td>-$42</td>
<td>-$41</td>
<td>-$40</td>
<td>-$39</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.2</td>
<td>-$20</td>
<td>-$18</td>
<td>-$16</td>
<td>-$14</td>
<td>-$12</td>
<td>-$10</td>
<td>-$8</td>
<td>-$6</td>
<td>-$4</td>
<td></td>
</tr>
<tr>
<td><strong>15</strong></td>
<td><strong>0.3</strong></td>
<td><strong>$7</strong></td>
<td><strong>$10</strong></td>
<td><strong>$13</strong></td>
<td><strong>$16</strong></td>
<td><strong>$19</strong></td>
<td><strong>$22</strong></td>
<td><strong>$25</strong></td>
<td><strong>$28</strong></td>
<td><strong>$31</strong></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.4</td>
<td>$34</td>
<td>$38</td>
<td>$42</td>
<td>$46</td>
<td>$50</td>
<td>$54</td>
<td>$58</td>
<td>$62</td>
<td>$66</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.5</td>
<td>$61</td>
<td>$66</td>
<td>$71</td>
<td>$76</td>
<td>$81</td>
<td>$86</td>
<td>$91</td>
<td>$96</td>
<td>$101</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.6</td>
<td>$88</td>
<td>$94</td>
<td>$100</td>
<td>$106</td>
<td>$112</td>
<td>$118</td>
<td>$124</td>
<td>$130</td>
<td>$136</td>
<td></td>
</tr>
</tbody>
</table>
Why didn’t disease develop?

Rutherglen 2003

Petal infestation = 58.54%

Sclerotinia stem rot = 0.41%
Future

Diagram:

- Host
- Agent
- Environment
In deciding pest management strategy

• Consider the following before application of fungicides
  – Disease
  – Economics of application
  – Environmental impacts

• Investigate other methods of control
  – Do they effectively control the disease?
  – What costs are associated with implementing them?
Disease cycle

Apothecia under plant canopy

Spores land on flower petals

Flower petals

Wilted leaf

Lesion

Sclerotia forming inside stem

Bleached brittle stems

Direct mycelial infection through soil

Sclerotia in soil

Lesion progressing up and down stem
Ongoing Research

• Sophisticated and effective climate prediction procedures are now emerging rapidly and finding increasingly greater use.

• Through crop simulation models in a decision systems framework alternative decisions are being generated.

• Comprehensive profiling of the user community and regular dialogue with the users could help identify the opportunities for agricultural applications.

• Active collaboration between climate forecasters, agrometeorologists, ag research and extension agencies essential.
Research Sites for Asia-Pacific Network (APN) Project:
Climate and Crop Disease Risk Management

Collaborating sites
Climate Information-Disease Risk

A conceptual framework

Historical climate data

Medium range weather forecast

Crop yield model

Crop-disease risk model

Disease risk management tool

Crop Management advisory system

Microclimate data

Met station data

Econ input

Econ benefit
KEY ISSUES THAT MUST BE UNDERSTOOD AND ADDRESSED

• decision makers
• decision options
• climate prediction
• communication
• institutional and policy environment
Theoretical basis – participative action research

Planning → Acting → Reflecting → Observing → Planning

Acting → Reflecting → Observing → Planning → Acting

...
Risk Management Cycle

1. Hazard identification
2. Risk perception and communication
3. Evaluation
4. Risk assessment
5. Policy development
6. Policy implementation
Policy - Related Strategies

- In terms of the model some envisaged policy-related strategies are:
- The assistance of agricultural development by anticipating short-term climatic variations, in order to improve economic yield, and hence security relating to food supply with positive outcomes on socioeconomic conditions and population health.
- The provision of a suitable framework for policy modification in the anticipation of important, short-term climatic change, enabling the incorporation of proactive intervention in agricultural practice.
Managing Crop Diseases

• The exploration of new approaches to managing crop diseases and the application of pesticides and herbicides to ensure economic use, and prevent overuse, as an important component in human health and aquatic ecosystem protection.

• The encouragement of multilateral agricultural risk communication and dialogue between all stakeholders in the agrometeorological process.
Collaborative Approach

- collaborative activity is required between scientists, risk managers, government and local farmers to determine best practice approaches for addressing pest management, with the aim of achieving economically-sound and ecologically-sustainable outcomes.
Minimisation of Pesticide Application

• A major focus of Australian research is the optimisation of natural controls relating to informed planting strategies, and the minimisation of pesticide application through the prediction of climatic influences, which can in turn lead to optimal effectiveness in the control of disease agents.
Macro and Microclimate

• The relationship between macro- and microclimate, and the effects on the cycles of disease agents, needs special attention if quantity of applied pesticide is to be minimised, while optimising disease control outcomes.
2005 climate summary (BoM 2006)

Annual Mean Temperature Anomalies For Australia

Temperature Anomalies (°C)

Departures from 1961-90 mean

Year
Mean Temperature Anomaly (°C)
1 January 2005 to 31 December 2005
Climate Change Effects

- Crop models do not generally account for impacts of pests and pathogens linked to climate change.
- Warmer climates favour pathogens and pests.
- Eliminating population controlling cold temperatures allows for successful overwintering of larvae and/or development of multiple generations within one growing season (United States Global Change Research Program (available: [www.usgcrp.gov/usgcrp/Library/national_assessment/](http://www.usgcrp.gov/usgcrp/Library/national_assessment/) (verified 6 Sept 2006)).
Climate Change Impacts

- Additionally, changes in weather patterns, including wind-borne pests into new areas.
- For example, the introduction of Asian soybean rust into the south-eastern U.S. is linked with the strong fall 2004 hurricane season.
Climate Change Impacts

• Our understanding of how elevated CO2 will affect crop yield in conjunction with changes in temperature, precipitation, and pests/pathogens is still limited, and the generally positive predictions of the U.S. Crop models may be painting a rosier picture than will actually occur (Kit Batten, Congressional Science Fellow; Crops, Soils and Agronomy News, October 2006)
Climate Change Impacts

• More research into these interactions is needed so that farmers can make informed choices in the face of climate change


Acknowledgements

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