Pesticide use in the Ord River Irrigation Area, Western Australia, and Risk Assessment of Off-site Impact using Pesticide Impact Rating Index (PIRI).

Danni Oliver and Rai Kookana

CSIRO Land and Water Technical Report 10/05
July 2005

www.csiro.au

Copyright and Disclaimer

Cover Photograph:

Description: Siphon irrigation of sugar crop in the Ord River Irrigation Area.
Photographer: Danielle Oliver

.

Pesticide use in the Ord River Irrigation Area, Western Australia, and Risk Assessment of Off-site Impact using Pesticide Impact Rating Index (PIRI)

Danni Oliver and Rai Kookana
CSIRO Land and Water
PMB 2 Glen Osmond SA 5064

CSIRO Land and Water Technical Report 10/05
July 2005

Acknowledgements

Sincere thanks to the growers in the Ord River Irrigation area, W.A., for providing information about chemical use on their properties. Thanks to Dick Pasfield, Ord Bonaparte Program, for co-ordinating our requests with the growers and verifying the data that was collected. Thanks also to Land and Water Australia and the Ord Bonaparte Program for providing financial support for this study.

Executive Summary

The Ord River Irrigation Area (ORIA) is a major horticultural area in Western Australia surrounded by wilderness. Concerns have arisen over time about the risk of off-site movement of pesticides in the drainage water from the fields irrigated using furrow irrigation. As a consequence, an inventory of chemicals used in the main landuses, namely sugar, hybrid seeds, melons and mangoes, was collated by interviewing several growers that were representative of "standard" practices in the respective landuse. Next a risk assessment was conducted using the screening tool, PIRI, of potential off-site movement of these chemicals and ecotoxicological impact based on LC50 values for Rainbow Trout. Several scenarios were run through PIRI for each landuse covering different rates of soil loss and soil organic carbon contents. A summary of the main chemicals of concern in each landuse, as rated by PIRI to pose a High, Very High or Exceedingly High risk potential, is given below:

Risk of surface water contamination

Landuse	Main chemicals of concern
Sugar	Diuron, atrazine
Melons	Mancozeb
Hybrid seed	Glyphosate, atrazine
Mangoes	Mancozeb

Toxicity Risk based on LC50 values for Rainbow Trout
(this assessment is restricted by the number of chemicals for which there are LC50 values for Rainbow Trout)

Landuse	Main chemicals of concern
Sugar	
Melons	Endosulfan, cypermethrin, chlorothalonil, chlorpyrifos
Hybrid seed	Endosulfan, cypermethrin, trifluralin, chlorpyrifos, pendimethalin
Mangoes	Mancozeb

It is therefore recommended that atrazine, chlorpyrifos, chlorothalonil, cypermethrin, diuron, endosulfan, glyphosate, mancozeb, trifluralin and pendimethalin be included in any monitoring programme.

Table of Contents

1. BACKGROUND

There has been concern about off-site transport of pesticides in numerous locations in Australia since pesticides have been detected in both surface and ground water at several regions. Further, there have been some fish kills in some irrigation areas, which have increased interest in developing management practices to minimize off-site movement of pesticides. In order to know which chemicals need to be targeted for monitoring and for developing management practices to minimize off-site movement it is necessary to identify which chemicals pose the greatest risk of off-site movement either to surface or ground water.

The Ord River Irrigation Area (ORIA), located in the tropical north of Western Australia near the Northern Territory border, is one of the main horticultural production areas in Western Australia. Currently 14,000 hectares of land are used to grow a range of crops, with rockmelons (*Cucumis melo* var cantalupensis), bananas (*Musa* spp.), honeydew melons (*Cucumis melo* var inodorus), watermelons (*Cirtrullus lanatus)* and pumpkins (*Cucurbita* spp.) making up the bulk of production. The most common tree crop is mangoes (*Mangifera indica)*, and commercial sugar (*Saccharum officinarum)* production commenced in 1995. Other crops include cotton (*Gossypium* spp.), sorghum (*Sorghum bicolour)*, maize (*Zea mays)* and sunflower seed (*Helianthus annus)*, and vegetable and flower seeds. An inventory of pesticides used in the main landuses, namely sugar, hybrid seeds, mangoes and melons, in the Ord River Irrigation Area (ORIA) was conducted.

2. BRIEF OVERVIEW OF PESTICIDE IMPACT RATING INDEX (PIRI)

A detailed overview of PIRI is given in Appendix 1. Briefly, PIRI is a screening tool that ranks the relative risk of pesticides to move off-site to surface or groundwater and/or the potential to have a toxic impact on a range of organisms. The tool considers site conditions such as soil texture, organic carbon content, slope, and climatic data as well as pesticide parameters, such as persistence, sorption to soil and toxicity, to rank the potential risk of off-site movement of pesticides relative to one another. Details of the input parameters required for an assessment by PIRI are given in Table 2 and discussed in more detail in the following section.

3. METHOD OF DATA COLLECTION

3.1 PESTICIDE USE DATA

The pesticide use data was obtained by one-on-one interviews with several growers for each main landuse assessed. The growers were selected upon advice by Dick Pasfield, a local who has worked on farms and with other environmental agencies and who has detailed local knowledge about grower practices in the area. Dick also provided a cross-checking reference for the data collected.

The main landuses assessed using PIRI were:

- Melons, particularly rockmelons (*Cucumis melo* var cantalupensis), honeydew melons (*Cucumis melo* var inodorus), watermelons (*Cirtrullus lanatus)*;
- Sugar (*Saccharum officinarum)*;
- Hybrid seeds, particularly sunflower seed (*Helianthus annus)*;
- Mangoes (*Mangifera indica)*.

3.2 OTHER INPUT PARAMETERS NEEDED FOR PIRI ASSESSMENT

The input parameters needed to use the PIRI tool to assess the risk of off-site movement of pesticides are given in Table 1. The sources of information for each parameter are also given in Table 1. For many of the input parameters the user has to select options from a pull-down menu e.g. for soil texture the user must select one of a selection of textural classes, while for other parameters e.g. air temperature and rainfall during the growing period, the user must provide specific values.

Table 1. Input parameters for PIRI Farm Attributes

Parameter	Importance	Comment	Source of material
Soil type	***	Texture class	Field observation or soil map
Months	**	Period of special interest	
Target species	****	Fish, daphnia, rat, alga, human, other	Ecotoxicological databases available at websites listed
Field cover	*		Field observation
Soil moisture	*	Wet/dry	Filed observation or calculation
Soil organic matter	*****	Express as %	Soil map or Measurement
Total rainfall in period	***	mm	Maps, measurement www.bom.gov.au
Irrigation in period	***	mm	Survey data
Recharge rate	**	mm	Maps, other, default
% rainfall recharging	**	mm	Measurement or default
% irrigation recharging	**	mm	Measurement or default
Average minimum air temperature	**	Degree Celscius	Maps or measurement www.bom.gov.au
Average maximum air temperature	**	Degree Celscius	Maps or measurement www.bom.gov.au
Nearest water body	**	m	Map
Width of water body	**	m	Map
Slope	**	Hard to estimate	Measure or map
Soil loss	****	t / ha / y	Map, measure or deduction
Days since application	***	Guess, trial	

Spraying data

Parameter	**Source of material**
Pesticide (chemical) name	Survey
Application rate	Survey or default
Fraction of active ingredient	Information sheets or label
Target pest class	Information sheets or label
Frequency of application	Survey
Fraction area sprayed (esp. horticulture)	Survey or industry knowledge
Droplet size	Growers or use defaults

3.3 INFORMATION REQUIRED FOR ADDITION OF A NEW PESTICIDE TO THE PIRI DATABASE

Parameter	Source material
Target pest class	Insecticide, herbicide, arachnicide, fungicide, nematicide
Koc	Information sheets or web (see Pesticide Manual, Ed. Tomlin, specific web searches for compounds, web searches with sites below)
Half life	Information sheets or web search
Toxicity (rainbow trout, daphnia, alga, rat, HAL, Water quality guidelines)	Web search (try http://www.epa.gov/ecotox/), Health advisories at http://www.epa.gov/waterscience/drinking/standards/summary.html, http://www.health.gov.au/nhmrc/publications/synopses/eh19syn.htm Calculation
Active ingredient for product used	Label; pesticide websites;

Useful references

Heller, S.R. and A.E. Herner. 1990. ARS Pesticide Properties Data base. US Department of Agriculture, Agricultural Research Service, Systems. Research Laboratory, Beltsville, Maryland

Tomlin, Clive (1994) The Pesticide Manual. 10th Edition. BCPC. 12th Edition available for $165 pounds (also on CD for a fee).

Useful websites

http://www.chemfinder.cambridgesoft.com/
http://www.ace.orst.edu/info/extoxnet/pips/ghindex.html
http://www.ent.iastate.edu/List/pesticides_and_regulations.html
http://www.pesticideinfo.org/Index.html
http://dino.wiz.uni-kassel.de/dain/search2.html
http:// www.apvma.gov.au
http://eddenet.pmra-arla.gc.ca/4.0/4.1.asp

CAUTION

When looking up information about products using a data base generated in another country it is important to check using local sources that the product is the same. For example, in Australia Topas is registered for use in vineyards and its active ingredient is penconazole. In the North American market another product is sold as Topas but its active ingredient is propiconazole.

4. DATA USED FOR THE ORD RIVER IRRIGATION AREA, W.A.

Table 2. Meteorology data for Ord Irrigation Area from O'Boy et al. 2001

Month	Average annual rainfall (mm)	Average minimum temperature (^{0}C)	Average maximum temperature (^{0}C)
January	197.0	25.1	36.4
February	213.0	24.9	35.5
March	140.0	24.1	35.3
April	21.2	21.3	35.5
May	10.0	19.1	32.9
June	1.3	15.9	30.5
July	3.9	15.0	30.2
August	0.1	17.5	33.6
September	2.8	20.8	36.4
October	25.5	23.7	38.3
November	70.9	25.4	38.8
December	105.3	25.7	38.1

Table 3. Time period of interest for separate landuses from the Ord River Irrigation Area.

Landuse	Time period of interest	Total average annual rainfall (mm)	Average minimum temperature (^{0}C)	Average maximum temperature (^{0}C)
Melons	March - November	275.7	18.28	31.15
Hybrid seeds	May – November	114.5	19.63	34.39
Mangoes	July – October	32.3	19.25	34.63
Sugar	April - November	135.7	19.84	34.53

Table 4. Input data used for PIRI assessment for each landuse

Input Parameter	Melons	Hybrid Seeds	Mangoes	Sugar
Soil	Clay	Clay	Clay	Clay
Period of interest	Mar-Nov	May-Nov	July-Oct	April-Nov
Toxicity target	Rainbow Trout	Rainbow Trout	Rainbow Trout	Rainbow Trout
Ground covered?	Covered	Covered	Covered	Covered
Soil moisture	Dry	Dry	Dry	Dry
Organic matter (%)	0.5, 2.0	0.5, 2.0	0.5, 2.0	0.5, 2.0
Rainfall (total mm)	275.7	114.5	32.3	135.7
Irrigation for period (mm)	1500	3000	1000	3000
Av. Min. temp for period (^{0}C)	18.28	19.63	19.25	19.84
Av. Max. temp. for period (^{0}C)	31.15	34.39	34.63	34.53
Width of water body (m)	2	2	2	2
Distance from crop to water body (m)	1	1	1	1
Slope (degrees)	0	0	0	0
Width of buffer zone (m)	0	0	0	0
Annual soil loss (tonnes/ha)	0.1/1.0	0.1/1.0	0.1/1.0	0.1/1.0
Days between pesticide application and irrigation	1	1	1	1

5. FACTORS THAT AFFECT THE PIRI ASSESSMENT

5.1 VARIABILITY IN PESTICIDE DATA

The amount or frequency of application of pesticides may not be constant from season to season but will vary for a number of reasons which are discussed below.

Seasonal factors play an important role in the development of fungal diseases and pest loads. The risk of a fungal outbreak is greater in seasons when there is a combination of rain and warm weather. So the number of sprays of fungicides will be greater if there is a "wet and warm" growing period. In the ORIA the high humidity means fungal diseases are a constant problem. Also the amount of fungicides like winter oil, copper hydroxide or copper oxychloride used on tree crops will vary on the size of the tree. Larger quantities are used on larger trees.

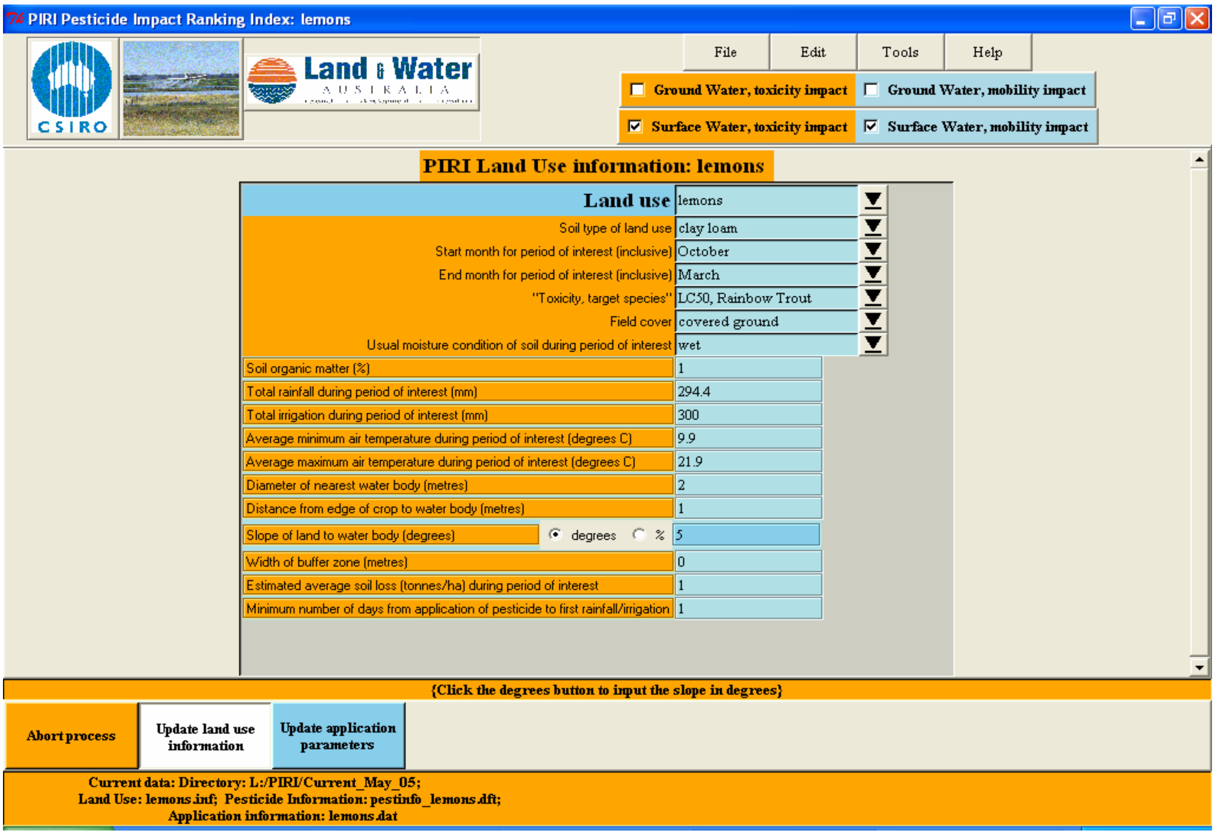
The uncertainty of active ingredients or of the fate of the components in the environment for some chemicals (e.g. petroleum oil, sulphur, copper hydroxide) can make assessment using the PIRI screening tool difficult.

5.2 EXCLUSION OF CERTAIN PESTICIDES FROM ASSESSMENT

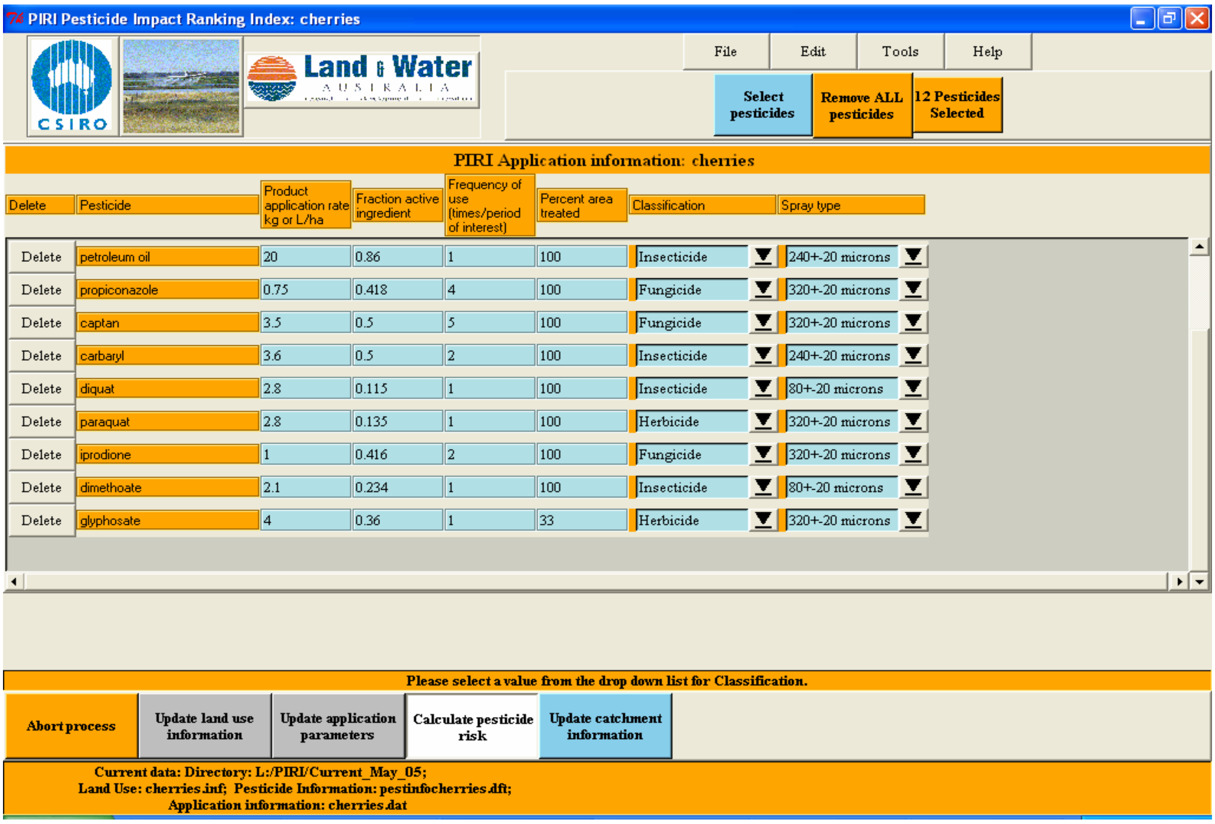
It was not possible to include some chemicals in the PIRI assessment because for the PIRI tool to run information about toxicity of the chemical to the organism of interest, degradation (half-life values), sorption behaviour (K_{OC} values) and active ingredient of chemical in the commercial product must be supplied. In some cases one or more of these parameters was not available so these pesticides were not included in the assessment. The uncertainty of active ingredients or of the fate of the components in the environment for some chemicals (e.g. petroleum oil, sulphur, copper hydroxide) can make assessment using the PIRI screening tool difficult.

EXAMPLE OF INPUT INFORMATION FOR PIRI

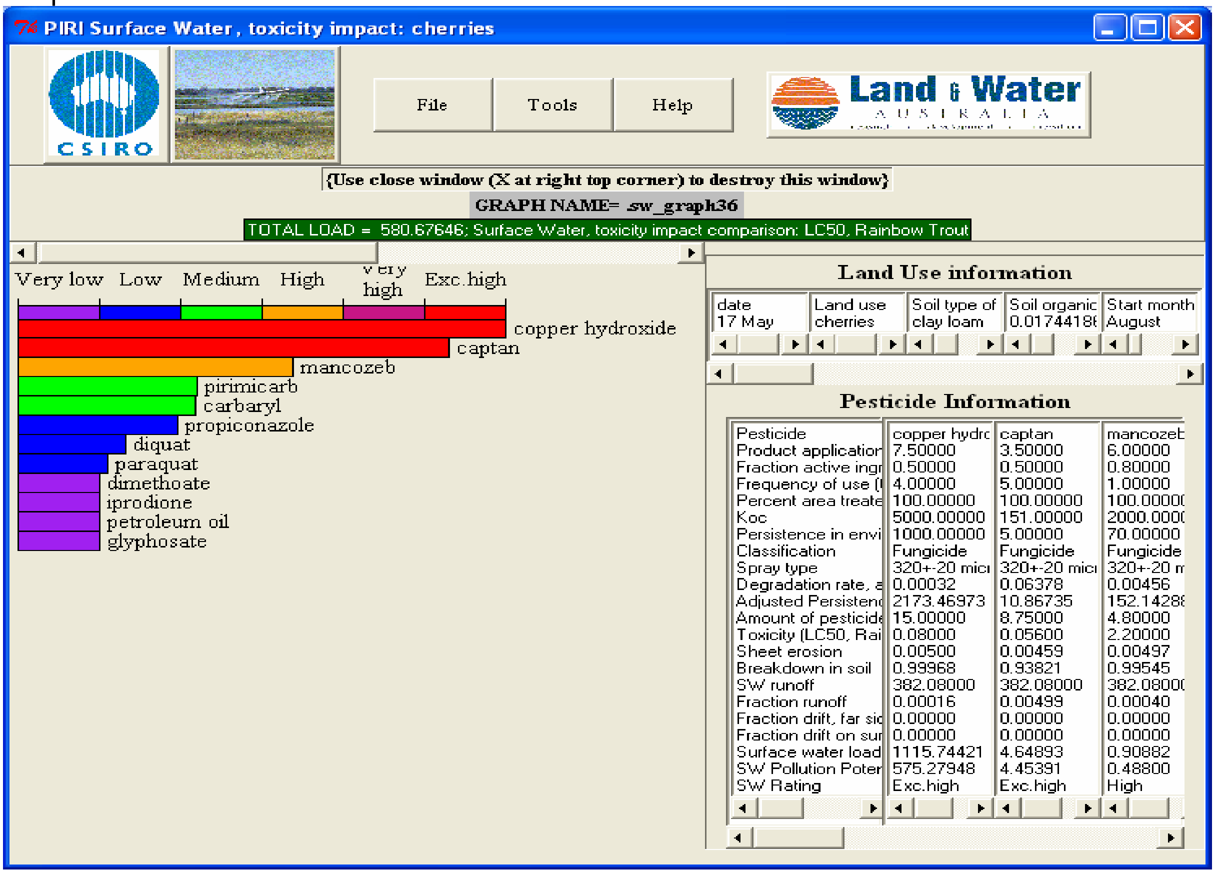
Landuse Information



Pesticide Use Information



Output Result from Assessment



6. RESULTS OF PIRI ASSESSMENT

6.1 SUGAR

In the PIRI assessment options were run using 2 soil loss rates: 0.1 t/ha and 1 t/ha, and two organic carbon contents, 0.5% and 2%. Also slope is a major factor controlling run-off. So although the fields in the ORIA are laser-levelled a scenario was run with 2 degree slope.

Table 5A.

PESTICIDE MOBILITY

SUGAR						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1				Atrazine Diuron	Ametryn 2,4-D fluroxypyr glyphosate chlorpyrifos
0.5	1.0			Diuron Atrazine	Ametryn Chloro-thalonil	Fluroxypyr Glyphosate Chlorpyrifos 2,4-D
2	0.1					Atrazine Diuron Ametryn 2,4-D fluroxypyr glyphosate chlorpyrifos
2	1.0			Diuron Atrazine	Ametryn Chloro-thalonil	Fluroxypyr Glyphosate Chlorpyrifos 2,4-D

SUGAR 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Diuron	Atrazine Ametryn	2,4-D, fluroxypyr	Glyphosate, chlorpyrifos

Table 5B.
TOXICITY based on LC50 Rainbow Trout

SUGAR						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1					Atrazine Diuron Ametryn 2,4-D fluroxypyr glyphosate chlorpyrifos
0.5	1.0				Diuron Atrazine	Ametryn 2,4-D Fluroxypyr Glyphosate
2	0.1					Atrazine Diuron Ametryn 2,4-D fluroxypyr glyphosate chlorpyrifos
2	1.0				Diuron Atrazine	Ametryn 2,4-D Fluroxypyr Glyphosate

SUGAR 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Chlorpyrifos		Diuron, atrazine, 2,4-D	Ametryn Fluroxypyr glyphosate

Increasing the organic carbon content had little or no effect on the relative risk for mobility or ecotoxicology for Rainbow Trout. When soil loss was increased 10-fold from 0.1 to 1.0 t/ha the mobility risk ranking of diuron and atrazine increased from Low to Medium.

SUGAR
Main chemicals of concern…
Mobility
Diuron, Atrazine, 2,4-D

Toxicity ~ LC50 Rainbow Trout
Chlorpyrifos

6.2 MELONS

In the PIRI assessment options were run using 2 irrigation scenarios, soil loss 0.1 t/ha and 1 t/ha, and two organic carbon contents, 0.5% and 2%.

Table 6A.

PESTICIDE MOBILITY

MELONS						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1				Mancozeb	Trichlorfon Fenarimol Methomyl Imidacloprid Endosulfan Chlorpyrifos Carbaryl Cypermethrin Chlorothalonil Bupirimate
0.5	1.0		Mancozeb		Chloro-thalonil	Trichlorfon Fenarimol Methomyl Imidacloprid Endosulfan Chlorpyrifos Carbaryl Cypermethrin Bupirimate
2	0.1				Mancozeb	Trichlorfon Fenarimol Methomyl Imidacloprid Endosulfan Chlorpyrifos Carbaryl Cypermethrin Chlorothalonil Bupirimate
2	1.0		Mancozeb		Chloro-thalonil	Trichlorfon Fenarimol Methomyl Imidacloprid Endosulfan Chlorpyrifos Carbaryl Cypermethrin Bupirimate

MELONS 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Mancozeb	Chlorothalonil	Methomyl Bupirimate	Fenarimol Endosulfan Imidacloprid Carbaryl Chlorpyrifos Cypermethrin Trichlorfon

Table 6B
TOXICITY based on LC50 Rainbow Trout

MELONS						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1		Endosulfan	Cyper-methrin Chloro-thalonil	Chlorpyrifos	Mancozeb Trichlorfon Fenarimol Methomyl Imidacloprid Carbaryl Bupirimate
0.5	1.0	Endosulfan Cyper-methrin Chloro-thalonil	Chlor-pyrifos	Mancozeb		Trichlorfon Fenarimol Methomyl Imidacloprid Carbaryl Bupirimate
2	0.1		Endosulfan	Cyper-methrin Chloro-thalonil	Chlorpyrifos	Mancozeb Trichlorfon Fenarimol Methomyl Imidacloprid Carbaryl Bupirimate
2	1.0	Endosulfan Cyper-methrin Chloro-thalonil	Chlor-pyrifos	Mancozeb		Trichlorfon Fenarimol Methomyl Imidacloprid Carbaryl Bupirimate

MELONS 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Endosulfan Cypermethrin Chlorothalonil Chlorpyrifos Mancozeb			Bupirimate Methomyl Trichlorfon Carbaryl Fenarimol Imidacloprid

Raising the organic carbon content of the soil had no effect on changing the risk ranking for mobility or ecotoxicology. Increasing the soil loss from 0.1 to 1.0 t/ha increased the mobility risk of mancozeb to High and increased the ecotoxicological risk (based on LC50 Rainbow Trout) of endosulfan, cypermethrin, chlorothalonil and chlorpyrifos.

MELONS
Main chemicals of concern…
Mobility

Mancozeb

Toxicity ~ LC50 Rainbow Trout

Endosulfan, cypermethrin, chlorothalonil, chlorpyrifos, mancozeb

6.3 HYBRID SEED

In the PIRI assessment options were run using 2 irrigation scenarios, soil loss 0.1 t/ha and 1 t/ha, and two organic carbon contents, 0.5% and 2%.

Table 7A.

PESTICIDE MOBILITY

HYBRID SEED						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1				Atrazine	Thiodicarb Pendimethalin Endosulfan Chlorpyrifos Glyphosate Cypermethrin Trifluralin
0.5	1.0			Glyphosate Atrazine	Pendimethalin Trifluralin	Thiodicarb Endosulfan Chlorpyrifos Cypermethrin
2	0.1					Atrazine Thiodicarb Pendimethalin Endosulfan Chlorpyrifos Glyphosate Cypermethrin Trifluralin
2	1.0			Glyphosate Atrazine	Pendimethalin Trifluralin	Thiodicarb Endosulfan Chlorpyrifos Cypermethrin

HYBRID SEED 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Atrazine	Glyphosate	Pendimethalin Trifluralin	Endosulfan Thiodicarb Chlorpyrifos Cypermethrin

Table 7B.
TOXICITY based on LC50 Rainbow Trout

HYBRID SEED						
% OC	Soil loss t/ha	Exc/ very high	High	Med	Low	Very Low
0.5	0.1	Endosulfan	Cypermethrin Trifluralin Chlorpyrifos		Pendimethalin	Atrazine Thiodicarb Glyphosate
0.5	1.0	Endosulfan Cyper-methrin Trifluralin Chlor-pyrifos	Pendimethalin		Atrazine	Thiodicarb Glyphosate
2	0.1	Endosulfan	Cypermethrin Trifluralin Chlorpyrifos		Pendimethalin	Atrazine Thiodicarb Glyphosate
2	1.0	Endosulfan Cyper-methrin Trifluralin Chlor-pyrifos	Pendimethalin		Atrazine	Thiodicarb Glyphosate

HYBRID SEED 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Endosulfan Cypermethrin Trifluralin Chlorpyrifos Pendimethalin	Atrazine		Thiodicarb Glyphosate

HYBRID SEED
Main chemicals of concern…
Mobility

Glyphosate, atrazine

Toxicity ~ LC50 Rainbow Trout

Endosulfan, cypermethrin, trifluralin, chlorpyrifos, pendimethalin

6.4 MANGOES

In the PIRI assessment options were run using 2 irrigation scenarios, soil loss 0.1 t/ha and 1 t/ha, and two organic carbon contents, 0.5% and 2%.

Table 8A.

PESTICIDE MOBILITY

MANGOES						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1				Mancozeb	Propiconazole Glyphosate
0.5	1.0		Mancozeb		Propicon-azole	Glyphosate
2	0.1				Mancozeb	Propiconazole Glyphosate
2	1.0		Mancozeb		Propicon-azole	Glyphosate

MANGOES 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Mancozeb		Propiconazole	Glyphosate

Table 8B.

TOXICITY based on LC50 Rainbow Trout

MANGOES						
% OC	Soil loss t/ha	Exc/very high	High	Med	Low	Very Low
0.5	0.1				Mancozeb	Propiconazole Glyphosate
0.5	1.0		Mancozeb			Propiconazole Glyphosate
2	0.1				Mancozeb	Propiconazole Glyphosate
2	1.0		Mancozeb			Propiconazole Glyphosate

MANGOES 1%OC, 2 degree slope and 1 t/ha soil loss

Exc/very high	High	Med	Low	Very Low
	Mancozeb			Propiconazole Glyphosate

Raising soil OC content made no change to the mobility or ecotoxicological ranking. Increasing the soil loss from 0.1 to 1.0 t/ha however raised the mobility ranking of mancozeb to High and the ecotoxicological risk ranking of mancozeb to High.

MANGOES
Main chemicals of concern…
Mobility
Mancozeb
Toxicity ~ LC50 Rainbow Trout
M**ancozeb**

6.5 SUMMARY OF PIRI ASSESSMENT ACROSS LANDUSES

A summary of the compounds that were ranked as posing an Excessively High, Very High or High risk for transport off-site is listed below with the landuses in which they were recorded.

Table 9. Chemicals that were assessed as posing an Excessively High, Very High or High risk for transport off-site across a number of landuses.

	Chemical	**Crops in which chemical is ranked as High or greater risk.**
MOBILITY	Mancozeb	Melons, mangoes
TOXICITY	Endosulfan	Melons, hybrid seeds, mangoes
Based on	Cypermethrin	Melons, hybrid seeds
Rainbow	Chlorpyrifos	Melons, hybrid seeds
Trout	Trifluralin	Hybrid seed
	Pendimethalin	Hybrid seed
	Chlorothalonil	Melons

APPENDIX 1
PESTICIDE IMPACT RATING INDEX (PIRI) :
FOR MINIMISING OFF-SITE IMPACTS OF PESTICIDES

Rai Kookana, CSIRO Land and Water,
Ray Correll and Ros Miller, CSIRO Mathematics and Information Sciences,

PMB No 2, Glen Osmond, 5064, Australia

Systematic methods that allow a relative assessment of potential impact of pesticides on water quality are of great value to both pesticide users and regulators in choosing the pesticides and practices with the least detrimental impact. A water quality risk indicator for pesticides, namely Pesticide Impact Rating Index (PIRI), has been developed by CSIRO with support from Land and Water Australia and other agencies.

PIRI is a simple screening tool to assess relative risk of pesticides or cropping systems in terms of their potential impact on surface water or groundwater quality and ecosystem health.

How is PIRI structured?

PIRI is based on three components, namely:
Source(s) of threat (pesticide Load) to the asset (*L*),
Transport pathways through which the threat is released to the asset (*T*), and
Value of the asset (water resources threatened) (*V*).
The detriment to water quality is assumed to be the product of *L*, *T* and *V*, where *L* and *T* are summed over all the pesticides used on a catchment, i.e.

$$\text{Detriment} = V \sum_{pesticides} (LT)$$

How are these components quantified?

The components *L* and *T* are quantified using pesticide characteristics (toxicity, amount used, sorption and persistence in soil) and soil, environmental and other site conditions (water input, soil loss, slope, recharge rate, water table depth etc.).

Pesticide load

The calculation of pesticide load (*L*) requires knowledge of the amount of pesticide applied in an area or catchment. This is determined from the total area of the crop, the dosage of active ingredient and the frequency of application during the season. Given that the chemical nature of pesticides is an important determinant of its impact on a water resource, the toxicity of each pesticide, its sorption and half-life in soil is taken into account to estimate total toxic load.

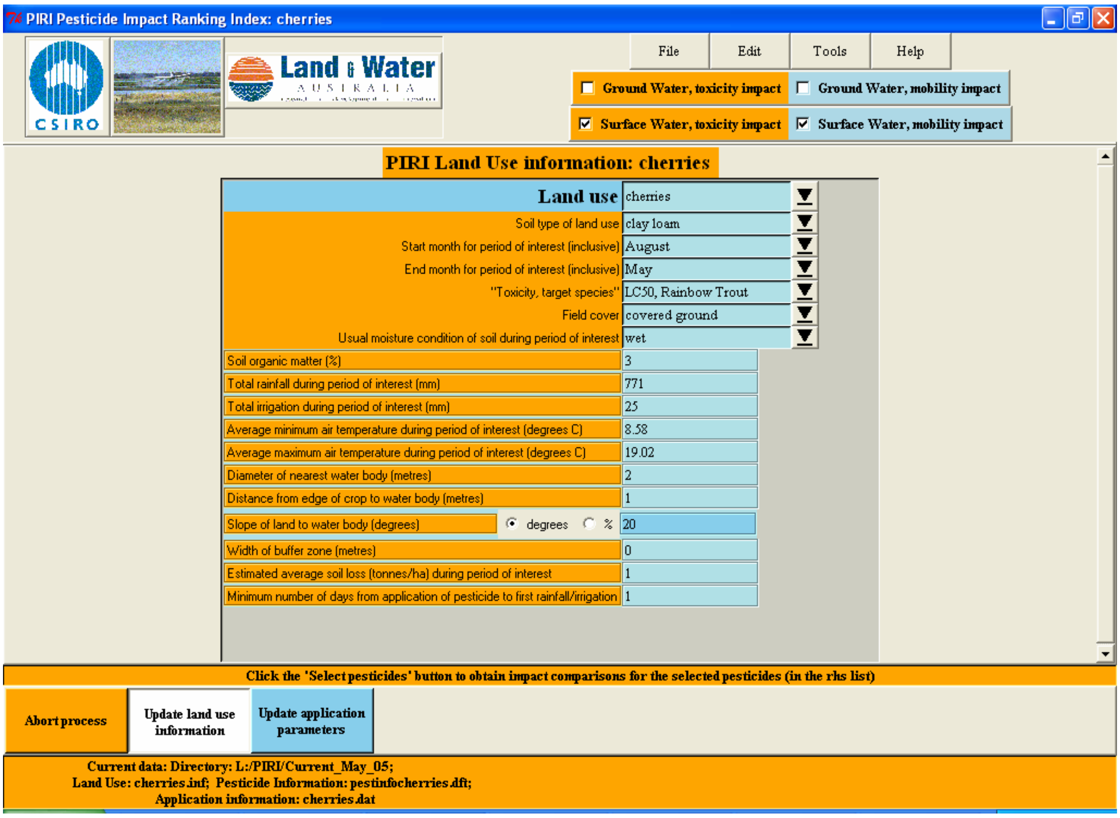
Transport

The transport factor (*T*) is assessed separately for surface and ground waters because the associated transport pathways are different.
For the ground water component of PIRI, the loss of pesticide during its transport is assessed by the modified version of the commonly used attenuation factor (AF) index, developed by University of Florida. The AF index was modified to take into account the decreasing organic carbon content with depth from soil surface to groundwater, which has major implications for movement and degradation of a pesticide during its transport to groundwater. The input parameters needed are: organic carbon content, sorption coefficient (K_{oc}) and half-life of a pesticide, as well as soil properties such as porosity, bulk density and recharge rate.
For the surface water transport factor, three separate pathways are considered in PIRI. These pathways are

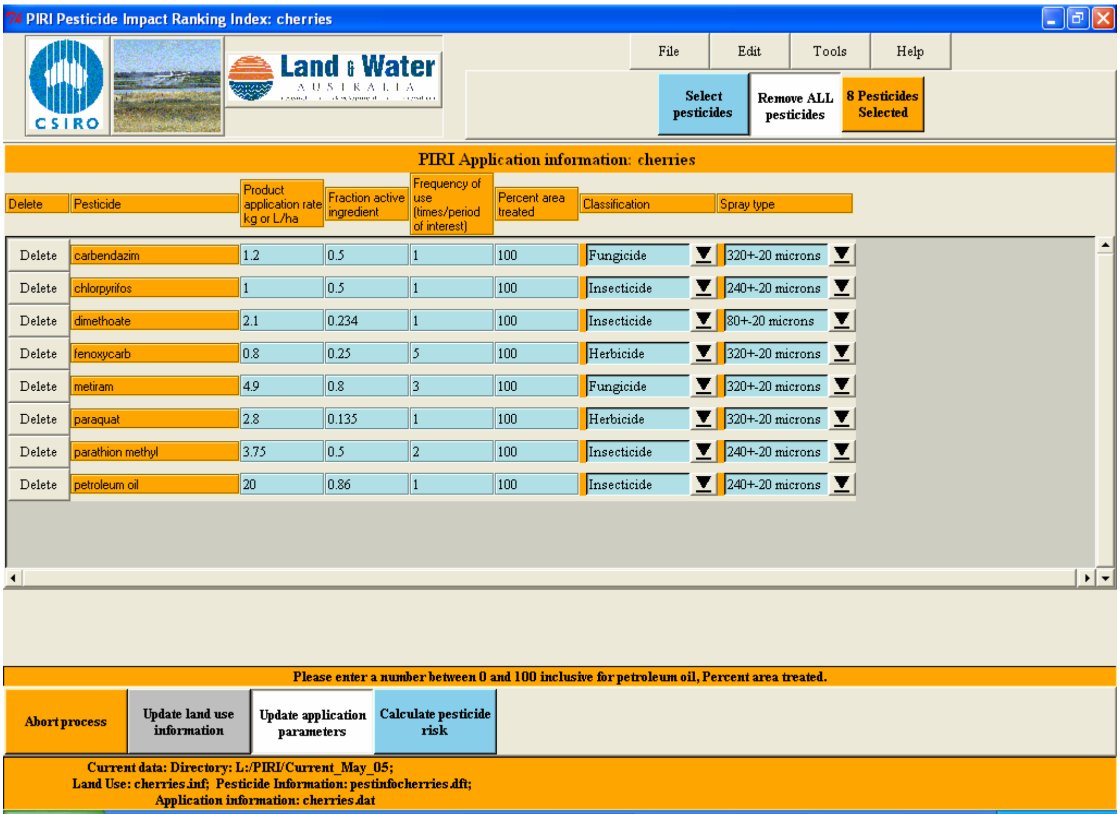
Runoff water: A pesticide showing low binding affinity to the soil particles can move in dissolved phase with runoff during a rain and/or irrigation event. The amount of runoff is derived from the amount of precipitation and/or irrigation using site specific conditions, such as soil type, moisture conditions, slope of the landscape and type of cover.
Erosion of soils: Pesticide transported with the soil particles through erosion is taken in proportion of soil loss and sorption of pesticide.
Spray Drift: Spray drift is a function of many environmental and management variables and methods of application. However, droplet size is considered to be one of the most important parameters. The drift is calculated based on droplet size, distance to a water body and its size.
The sum of the three pathways represents the overall transport parameter (*T*) for surface water.

Value of the asset
The value (*V*) of water body, which may depend on the size of the water body, its water quality, aesthetic and/or ecological importance, is assessed subjectively by a score system ranging from 1 to 100. The value parameter is only relevant when PIRI is used to assess relative risk among different sites or land-uses associated with different water bodies.

What can PIRI do?
PIRI can be used for the following.
To provide a relative rating to different pesticides at a farm scale in terms of their pollution potential to ground water or surface water, and
To develop a targeted monitoring program based on PIRI assessment.
To identify safe windows of opportunities for spraying with lower risk of off-site migration.
To assess different land uses at a catchment/sub catchment scale in terms of their relative impact on water quality.
To understand and communicate the risk profile of pesticides for different trophic levels in ecosystem: i.e. vertebrates (fish, mammals), invertebrates (daphnia), base of food chain (algae) or for drinking water.



The window for farm information input in PIRI.

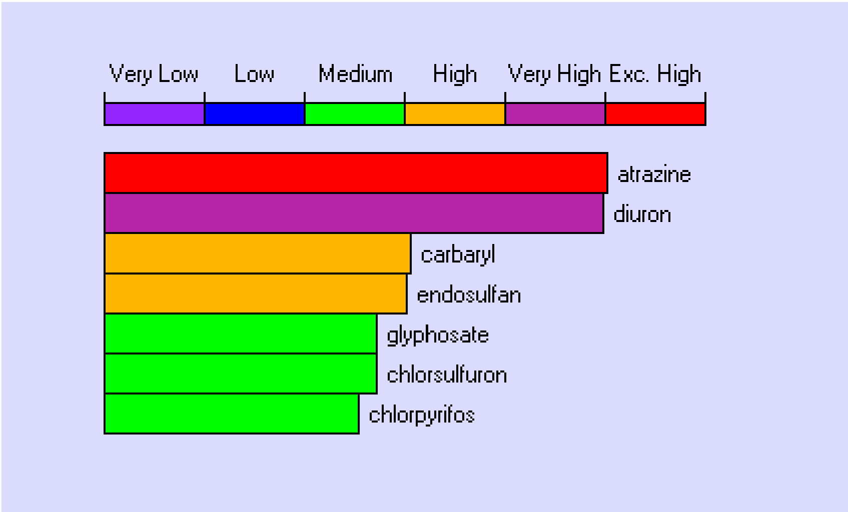


The input window for pesticide application rates and frequency.

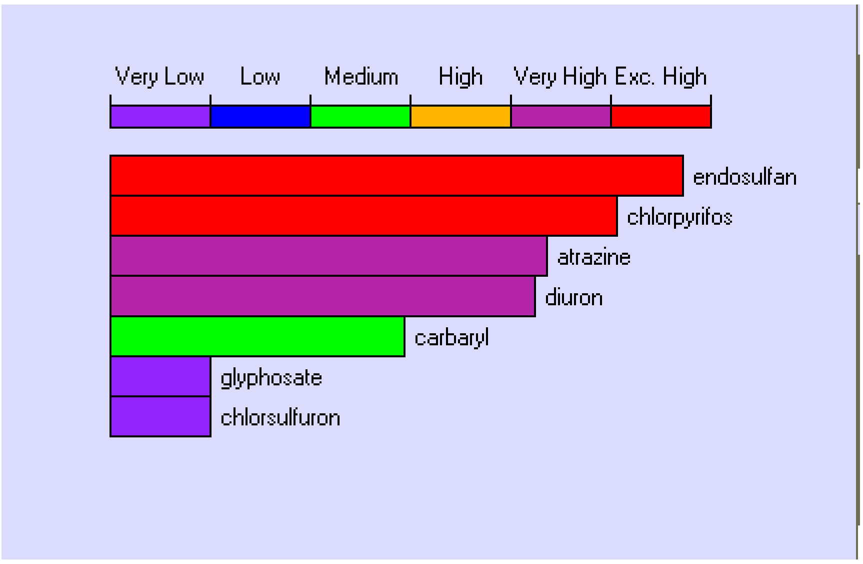
Note: the sequence of execution steps (e.g. update farm information, select pesticides etc.) are as shown by the menu at the bottom of screen.

How easy is PIRI program to use?

PIRI has been programmed using *TclTk* programming language and has been packaged in a user-friendly format. The current version is written in Tcl8.3/Tk8.3, 8.3.0 Windows NT5.1. The program is stand-alone and does not require any software to run it on a PC. PIRI draws input data both from inbuilt databases (e.g. pesticide properties), and user input in interactive mode. The input screens of PIRI have options in the form of dropdown menus. PIRI outputs are in the form of easily understood tables or graphs. For example, the output table shows the pollution potential of each pesticide in categories such as high, medium or low.



The PIRI output window showing rating for potential mobility of pesticides.



The PIRI output window showing rating for potential toxicity of pesticides to fish.

How reliable are results from PIRI?

PIRI results has been corroborated against monitoring data for at least two case studies, discussed below. These were selected on the basis of availability of good input data on pesticide use and residue monitoring data to compare with the output data from PIRI.

Case 1: PIRI was validated using a pesticide use inventory for several different types of land-uses as well as monitoring data gathered by CSIRO. For cotton production system in NSW, the rating for 14 out of 16 pesticides was consistent with the monitoring data available. Pesticides as having a high to medium pollution potential had been detected in water previously by the monitoring programs. For those pesticides the monitoring program did not detect, PIRI had placed them into the low to very low category. Statistical test indicated that PIRI's predictions were significant at the 5% level. In the following table, those pesticides that are ticked ✓were detected during monitoring and those with X were not detected. The remaining pesticides were not tested.

Rating for cotton pesticides for a NSW catchment

High	Medium	Low	Very Low
Endosulfan ✓	Profenofos ✓	Thiodicarb	2,4-D
Trifluralin ×	Metalochlor ✓	Aldicarb ×	Chlorpyrifos ✓
Pendimethalin ✓	Prometryn ✓		Omethoate ×
Diuron ✓	Parathion methyl	Dicofol ×	Dimethoate ×
	Phorate		Thidizuron ×
Fluometuron ✓	Glyphosate		Amitraz ×
			Methomyl ×

Pesticides that are ticked ✓were detected during monitoring and those with X were not detected. The remaining pesticides were not tested.

Case 2: Validation of PIRI was carried out using reliable pesticide use data and residue monitoring in Murrumbidgee Irrigation Area. These land-uses in MIA were: rice, citrus, and sorghum, soybean and some horticultural production systems.

The results showed about 84% success in predicting whether a pesticide would be detected in the surface water. Overall, out of the nineteen pesticides tested, only three were not consistent with PIRI predictions.

Rating for pesticides for MIA region in NSW

High	Medium	Low	Very Low
Benzofenap	Atrazine ✓	Maldison ✓	Bensulfuron methyl
Diuron ✓	Bromacil ✓	Cypermethrin×	Clethodim
Endosulfan ✓	Chlorpyrifos ✓	Dicamba	Methomyl×
Metolachlor ✓	Diazinon ✓	Propanil×	Monocrotophos×
Thiobencarb ✓	Molinate ✓	Methidathion×	Primicarb
Trifluralin× (detected once)	MCPA ✓	Terbufos×	
	Lambda cyhalothrin×	Thiodicarb	

Pesticides that are ticked ✓were detected during monitoring and those with X were not detected. The remaining pesticides were not tested.

Both studies showed that PIRI had a high success rate in indicating pesticide mobility and thus produce reliable results.

A summary of key features of PIRI

PIRI is simple screening tool to assess off-site migration potential of pesticide and risk to different species based on their toxicity to aquatic organisms at different trophic levels.
PIRI is not data-hungry. Most of the input data needed in PIRI is inbuilt or easily available. The inbuilt databases however, can be modified if more reliable data are available.
The comparison of PIRI results against monitoring data available shows that the predictions are generally reliable.
PIRI is easy to use and does not require modelling skills needed to run a simulation model.
PIRI provides relative risk and not designed to predict concentrations of pesticide likely to reach surface or ground water.

PIRI can be particularly useful tool in identifying safe windows for pesticide spray operations, in designing pesticide-monitoring programs and in identifying pesticides that need to be targeted for better management for minimising the off-site impacts of pesticides on water quality.

PIRI is being used not only in Australia but also in several other countries, namely, Ecuador, Thailand, Malaysia, Philippines, Sri Lanka, Syria and Bangladesh under projects sponsored by Australian Centre for International Agricultural Research (ACIAR) and International Atomic Energy Agency (IAEA) under FAO/WHO Food and Environment Program.

Currently a GIS version of PIRI is being developed that has the capability of Monte-Carlo simulations for uncertainly analysis.

Some further details on PIRI are also available on the web:
http://www.cmis.csiro.au/envir/Research/PesticideRisk/index.htm

For further details please contact:
Dr Rai Kookana or Dr Ray Correll
CSIRO PMB No 2 Glen Osmond, 5064, Australia.
Ph (+61-8) 83038450, fax (+61-8) 83038565
Email: Rai.Kookana@csiro.au or Ray.Correll@csiro.au

APPENDIX 2
PESTICIDE USE FOR SELECTED CROPS REPRESENTING THE MAIN LANDUSES IN THE ORD RIVER IRRIGATION AREA (ORIA), WESTERN AUSTRALIA.

Melons
Particularly rockmelons (*Cucumis melo* var cantalupensis), honeydew melons (*Cucumis melo* var inodorus), watermelons (*Cirtrullus lanatus)*

Chemical	Product name	Rate (kg or L/ha)	% active ingredient	Frequency
Mancozeb	Dithane	1	80%	8
Trichlorfon	Diptrex	1	50%	4
Fenarimol	Rubigan	0.2	12%	3
Methomyl	Lannate	1	22.5%	1
Imidacloprid	Confidor	0.3	20%	1
Endosulfan	Thiodan	0.4	24%	1
Chlorpyrifos	Lorsban	0.1	50%	1
Carbaryl	Bugmaster	0.4	50%	1
Cypermethrin	Ambush	0.1	50%	1
Sulphur	Thiovit	1	80%	6
Chlorothalonil	Bravo	1.8 – 2.5	72%	1
Bupirimate	Nimrod	0.6	25%	1
The following chemicals were not included in the PIRI assessment because there was no chemical fate and/or toxicity data available.				
Pyrazophos	Afugan	0.5	29.5%	1
Propineb	Antracol	2	70%	8
Oxadixyl + Propineb	Fruvit	2.5	8% + 56%	3

Hybrid Seeds
Particularly sorghum (*Sorghum bicolour)*, chickpeas (*Cicer arietinum*)and sunflower seed (*Helianthus annus)*

Chemical	Product name	Rate (kg or L/ha)	% active ingredient	Frequency
Atrazine	Atradex	3	80%	1
Thiodicarb	Larvin	2	80%	1
Pendimethalin	Stomp	2.5	33%	1
Endosulfan	Thiodan	2.1	24%	1
Chlorpyrifos	Lorsban	0.75	50%	1
Glyphosate	Roundup	3	36%	5
Cypermethrin	Scud	0.8	20%	1
Trifluralin	Trifluralin	2	40%	1
The following chemicals were not included in the PIRI assessment because there was no chemical fate and/or toxicity data available.				
Triadimenol	Bayfidan 250	0.4	25%	3
Beta cyfluthrin	Bulldock Prime	0.8	12.5%	1
Isoxaflutole	Balance		75%	

Mangoes
(*Mangifera indica)*.

Chemical	Product name	Rate (kg or L/ha)	% active ingredient	Frequency
Mancozeb	Dithane	2.2	80%	5
Propiconazole	Tilt	0.4	25%	3
Glyphosate	Roundup	1	36%	1

Sugar
(*Saccharum officinarum)*;

Chemical	Product name	Rate (kg or L/ha)	% active ingredient	Frequency
Atrazine	Gesapax Combi	3.5	25%	1
Diuron	AgSpray Die It 800	3	80%	1
Ametryn	Gesapax Combi	3.5	25%	1
2,4-D	Amicide 500	2.2	50%	1
Fluroxypyr	Starane	2	20%	1
Glyphosate	Roundup	0.8	36%	1
Chlorpyrifos	Lorsban	0.55	50%	1
The following chemicals were not included in the PIRI assessment because there was no chemical fate and/or toxicity information for these pesticides.				
Isoxaflutole	Balance		75%	