Cooperative Research Centre
for National Plant Biosecurity

Final Report

CRC10184

Using likelihood of arrival and establishment to assess the world threat of invasive species

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31 September 2011

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1. Executive Summary

There are hundreds, perhaps thousands, of invasive species that have the potential to arrive and establish in any particular region or country. Identifying which species are more likely than others to arrive and establish is extremely difficult, yet the capacity to do so is vitally important to the biosecurity of a nation.

Arrival and establishment likelihood for Australia was estimated for 1,486 invasive insect pests and fungal plant pathogens. Arrival likelihood was estimated from the level of trade occurring between Australia and all other countries in millions of US$. Establishment likelihood for each species was estimated by completing a SOM analysis of the worldwide distribution of the 1,486 invasive species. These two estimates were combined to generate a value for the invasion threat of all species in millions of US$. It should be noted that this value is NOT a measure of the impact of a species, but a measure of the arrival and establishment of a species. Considering all plant invasive species, China, USA and Japan poses the highest source of risk.

Biosecurity agencies can use this information for further refinement of import risk assessments and inspection protocols. Further, the methodology presented here could be applied to any number of invasive species and the outputs generated could be incorporated into any consultative process currently used to prioritise pest lists.

Based on the work presented here, five recommendations have been made:

1. An assessment of the reliability of this methodology for predicting arrival and establishment likelihoods.

2. The development of a communication strategy with Australian and international biosecurity agencies to encourage the uptake of SOM and DOT data as an effective risk identification technology.

3. An online or PC-based SOM tool be developed that is capable of producing country and (where possible) region-based estimates of exotic species potential to establish.

4. The results of this analysis that quantitatively express species arrival and establishment likelihoods should be incorporated into traditional forms of quantitative risk assessment.

5. SOM/DOT analysis be incorporated into existing pest risk analysis and import risk analysis methodologies.

2. Aims and objectives

The aim of this project was to combine arrival likelihood with establishment likelihood to generate the invasion threat to Australia for 1,486 invasive fungal pathogens and insect pests, from all countries of the world.

The project objectives were:

1. Collate and clean the CABI Crop Protection Compendium database of invasive insect pests and fungal pathogens
2. Analyse this worldwide dataset of invasive species using SOM to generate establishment likelihood for all species in all regions
3. Use direction of trade data to generate estimates of arrival likelihood for all invasive species
4. Combine establishment likelihood with arrival likelihood to generate invasion threat for all invasive species in the dataset

This information could be used by the Department of Forestry and Fisheries (DAFF), when prioritising biosecurity planning and response activities. Risk return will be optimised by determining which pests/diseases and pathways to focus on.

3. Key findings

The likelihood of invasion for any species is a two stage process – arrival and establishment. The work presented here combines the likelihood of establishment, with the likelihood of arrival to generate estimates of likelihood of invasion, or invasion threat for all species in the analysis. The likelihood of establishment was estimated using a SOM analysis of invasive species worldwide distribution. The likelihood of arrival was estimated using a proxy, the Direction of Trade (DOT) data, which shows the value of imports and exports between any two countries in millions of US$. This was used to estimate the level of connectance between any two countries and hence a relative measure of likelihood of arrival. The final value generated was therefore in millions of US$ and used as a measure of invasion threat for any species in the analysis.

3.1. SOM analysis of invasive species (establishment likelihood)

A SOM (self organising map) is a type of artificial neural network, or machine learning, which allows for the evaluation of species distributions and subsequent estimations of establishment likelihood. The SOM analysis uses species associations to predict the likelihood of any species establishing in a given region/location. For example, if region A contains the invasive species 1 to 10 and region B contains the invasive species 1 to 9, it is possible to say, with reasonable certainty, that because species 10 is found with species 1 to 9 in region A, then it has a high likelihood of also being able to establish in region B. The SOM is able to make similar assessments except at the world wide level and with many more species, generating establishment likelihoods (between 0 and 1), for all species in all regions.

Presence/absence data of invasive species from the CABI Crop Protection Compendium (CABI 2007) was provided by Associate Professor Sue Worner (Lincoln University, New Zealand). This data was checked and edited, generating a presence/absence matrix (in which a ‘1’ means the species is present and a ‘0’ means the species is absent) for 1,486 invasive insect pests and fungal plant pathogens in 178 countries of the world.

A SOM analysis was then performed to generate establishment likelihoods for all species in all 178 countries and used to rank each species. Details of the methodology used for this analysis can be found in the previous CRC report (Paini et al 2010a) and peer reviewed published papers (Paini et al 2010b,c; Paini et al 2011). This analysis generated 178 lists, one for each country, ranking all species by establishment likelihood. As an illustration, I provide here the top 100 absent species for Australia (Table 3-1).

Table 3-1. Top 100 species ranked by the SOM analysis for likelihood of establishing in Australia.

Rank	Species Name	SOM likelihood	Rank	Species Name	SOM likelihood	Rank	Species Name	SOM likelihood
1	*Puccinia triticina*	0.88374	35	*Guignardia bidwellii*	0.64370	69	*Mycosphaerella gibsonii*	0.53645
2	*Golovinomyces cichoracearum*	0.88115	36	*Chrysoperla carnea*	0.63636	70	*Dinoderus minutus*	0.53640
3	*Aphis fabae*	0.86385	37	*Armillaria mellea*	0.62906	71	*Mamestra brassicae*	0.53419
4	*Puccinia sorghi*	0.85840	38	*Fomitopsis pinicola*	0.62890	72	*Cryphonectria parasitica*	0.53264
5	*Venturia inaequalis*	0.85457	39	*Gloeocercospora sorghi*	0.62538	73	*Dioryctria abietella*	0.53260
6	*Sporisorium cruentum*	0.84568	40	*Ascochyta sorghi*	0.62054	74	*Agrilus planipennis*	0.53248
7	*Trichoplusia ni*	0.83959	41	*Pinnaspis strachani*	0.62028	75	*Aulacophora indica*	0.53248
8	*Ustilago scitaminea*	0.78787	42	*Diaphorina citri*	0.61116	76	*Autographa nigrisigna*	0.53248
9	*Colletotrichum lindemuthianum*	0.78720	43	*Monosporascus cannonballus*	0.60032	77	*Chlorophorus annularis*	0.53248
10	*Cercospora kikuchii*	0.77141	44	*Hydrellia philippina*	0.59389	78	*Parnara guttatus*	0.53248
11	*Sitobion avenae*	0.76886	45	*Leucinodes orbonalis*	0.59362	79	*Pseudodendrothrips mori*	0.53248
12	*Alternaria sesami*	0.76530	46	*Delia antiqua*	0.58709	80	*Stephanitis typica*	0.53248
13	*Cochliobolus lunatus*	0.75832	47	*Aleurocanthus woglumi*	0.58577	81	*Pleurotus ostreatus*	0.53248
14	*Alternaria longipes*	0.75128	48	*Xylosandrus crassiusculus*	0.58492	82	*Lecanicillium lecanii*	0.52330
15	*Cladosporium cucumerinum*	0.74920	49	*Aphis pomi*	0.58463	83	*Aschersonia aleyrodis*	0.52238
16	*Liriomyza trifolii*	0.74107	50	*Xylosandrus compactus*	0.58221	84	*Dialeurodes citrifolii*	0.52237
17	*Podosphaera fusca*	0.71674	51	*Erysiphe cruciferarum*	0.58149	85	*Fusarium oxysporum f.sp. batat*	0.52119
18	*Dialeurodes citri*	0.71286	52	*Fomes fomentarius*	0.57937	86	*Encarsia lutea*	0.52111
19	*Fusarium oxysporum f.sp. niveum*	0.69930	53	*Bactrocera latifrons*	0.57796	87	*Kabatiella zeae*	0.51948
20	*Dysaphis plantaginea*	0.69766	54	*Trichogramma chilonis*	0.57796	88	*Diuraphis noxia*	0.51860
21	*Rosellinia necatrix*	0.69258	55	*Erysiphe diffusa*	0.57426	89	*Golovinomyces orontii*	0.51743
22	*Agrotis segetum*	0.68737	56	*Parlatoria oleae*	0.56962	90	*Oidium neolycopersici*	0.51549
23	*Aspergillus flavus*	0.66917	57	*Alternaria japonica*	0.56744	91	*Didymella lycopersici*	0.51402
24	*Xestia c-nigrum*	0.66516	58	*Phyllotreta striolata*	0.55835	92	*Aphidoletes aphidimyza*	0.49899
25	*Passalora sojina*	0.65931	59	*Hadula trifolii*	0.55670	93	*Encarsia inaron*	0.49631
26	*Frankliniella intonsa*	0.65300	60	*Liriomyza sativae*	0.55612	94	*Encarsia formosa*	0.49506
27	*Lopholeucaspis japonica*	0.64939	61	*Lissorhoptrus oryzophilus*	0.55087	95	*Erysiphe heraclei*	0.49469
28	*Cronartium ribicola*	0.64939	62	*Erysiphe adunca*	0.55081	96	*Fusarium oxysporum f.sp. cucun*	0.49058
29	*Septoria cannabis*	0.64815	63	*Cronartium quercuum*	0.54831	97	*Anarsia lineatella*	0.48601
30	*Grapholita delineana*	0.64811	64	*Armillaria ostoyae*	0.54816	98	*Paranthrene tabaniformis*	0.48425
31	*Sesamia inferens*	0.64807	65	*Lymantria dispar*	0.54018	99	*Podosphaera macularis*	0.48423
32	*Sinoxylon conigerum*	0.64780	66	*Chromatomyia horticola*	0.53921	100	*Aleurothrixus floccosus*	0.48312
33	*Orthezia insignis*	0.64565	67	*Asperisporium caricae*	0.53787			
34	*Nomuraea rileyi*	0.64375	68	*Acherontia styx*	0.53759			

3.2. *Direction of Trade (DOT) data (arrival likelihood)*

Direction of trade (DOT) data was purchased and extracted from the International Monetary Fund (http://elibrary-data.imf.org/). This information shows the value of all trade per year between any two of the 178 countries in millions of US$. I extracted this data for years 2001-2010 and took the mean from those ten years. Any trade between countries that was not available was assumed to be zero, though there were no absences for Australia. There were subsequently 178 lists, one for each country, ranking exporting countries by their export value into the country in question. As an illustration, I provide the export data to Australia of the top 100 countries (**Table 3-2**).

Table 3-2. The top 100 countries ranked by mean exports per year (in millions of US$) to Australia. Mean values derived from annual exports, 2001-2010.

Exporter	millions US$	Exporter	millions US$	Exporter	millions US$
China	$17,293.443	Chile	$250.423	Oman	$14.717
USA	$16,803.210	Turkey	$236.397	Myanmar	$14.012
Japan	$12,245.610	Kuwait	$195.165	Romania	$13.679
Singapore	$8,468.628	Norway	$192.294	Azerbaijan	$13.591
Germany	$6,481.787	Qatar	$176.619	Croatia	$12.865
New Zealand	$4,854.969	Argentina	$170.853	Bulgaria	$12.532
Malaysia	$4,755.158	Poland	$159.586	Cote d'Ivoire	$11.062
Thailand	$4,631.052	Czech Republic	$154.751	Egypt	$10.939
United Kingdom	$4,222.102	Fiji	$134.175	Kenya	$10.252
Korea Republic of	$4,134.008	Hungary	$127.987	Estonia	$9.745
Italy	$3,087.534	Pakistan	$123.004	Mongolia	$8.974
France	$2,993.005	Portugal	$97.427	Uruguay	$8.841
Indonesia	$2,746.125	Nigeria	$97.068	Cambodia	$8.674
Vietnam	$2,544.122	Greece	$90.850	Korea DPR	$8.660
Papua New Guinea	$1,645.725	Bahrain	$82.320	Belarus	$8.515
Sweden	$1,498.664	Peru	$70.747	Lebanon	$8.353
Belgium	$1,463.208	Sri Lanka	$69.670	Lithuania	$7.342
Netherlands	$1,350.895	Samoa	$66.605	Kazakhstan	$6.698
Canada	$1,340.934	Russian Federation	$64.695	Ecuador	$6.265
Switzerland	$1,315.760	Slovakia	$51.923	Tunisia	$6.127
United Arab Emirates	$1,084.431	Gabon	$51.134	Iceland	$5.399
Spain	$985.977	Iran	$48.804	Trinidad and Tobago	$5.330
South Africa	$981.743	Algeria	$47.810	Mauritius	$5.079
India	$933.671	Morocco	$42.528	Malawi	$5.063
Ireland	$913.587	Libya	$40.326	Zimbabwe	$5.045
Saudi Arabia	$704.153	Bangladesh	$38.633	Angola	$5.044
Austria	$685.504	Slovenia	$34.532	Uganda	$5.030
Denmark	$650.318	Congo	$26.052	Ghana	$5.002
Brunei Darussalam	$620.943	Luxembourg	$25.981	Dominican Republic	$4.952
Finland	$517.419	Costa Rica	$21.245	Cuba	$4.769
Brazil	$507.753	Iraq	$21.093	Malta	$4.752
Mexico	$455.093	Colombia	$19.207	Mali	$4.465
Israel	$419.052	Yemen	$16.057		
Philippines	$408.764	Ukraine	$14.867		

3.3. *Invasion Threat*

The SOM analysis and the DOT data were combined for every species to generate an invasion threat (IT) matrix for each species showing the invasion threat of that species from every country to every other country. There were therefore 1,486 IT matrices, one for each species. As an illustration, I provide part of the IT matrix for *Aphis fabae* (**Table 3-3**), the third ranked species for establishment likelihood in Australia (Table 3-1).

To illustrate how these values in Table 3-3 were generated, we can use Table 3-1 and Table 3-2. The invasion threat of *Aphis fabae* from the USA to Australia is valued at US$14,515 million (Table 3-3). This is the product of the establishment likelihood for *Aphis fabae* in Australia, 0.86385 (Table 3-1) and the value of exports coming from USA into Australia, US$16,803.210 million (Table 3-2).

0.86385 x $16,803.210 = $14,515.452

It should be noted that this value is NOT a measure of impact, but a measure of arrival and establishment for a species.

Only those regions in which *Aphis fabae* is present could be a threat to an importing region. For example, *Aphis fabae* is not found in the United Arab Emirates and so all values for this row are zero. Further, a region cannot be a threat to itself so this was set at zero (e.g. see Afghanistan exporting to Afghanistan). Finally, a region which already has this species cannot be threatened by it and so all values for this column were set to zero (e.g. see the column labelled Afghanistan).

Table 3-3. Part of the invasion matrix for the invasive pest, *Aphis fabae*. Values are in millions of US$ and are the product of the value of exports from the exporting region to the importing region and the SOM establishment likelihood for *Aphis fabae* in the importing region.

	Importing region					
Exporting region	United Arab Emirates	Afghanistan	...	Australia	...	Zimbabwe
United Arab Emirates	$0.000	$0.000		$0.000		$0.000
Afghanistan	$0.315	$0.000		$0.143		$0.000
...	...	...	...	...	...	...
Argentina	$11.360	$0.000		$147.590		$0.000
Austria	$26.858	$0.000		$592.170		$0.000
Australia	$0.000	$0.000		$0.000		$0.000
...	...	...	...	...	...	...
Belgium	$92.499	$0.000		$1,264.000		$0.000
Burkina Faso	$0.000	$0.000		$0.000		$0.000
Bulgaria	$2.894	$0.000		$10.826		$0.000
Bahrain	$0.000	$0.000		$0.000		$0.000
Burundi	$0.018	$0.000		$0.008		$0.000
...	...	...	...	...	...	...
Papua New Guinea	$0.000	$0.000		$0.000		$0.000
Philippines	$9.213	$0.000		$353.110		$0.000
Pakistan	$80.540	$0.000		$106.260		$0.000
Poland	$13.532	$0.000		$137.860		$0.000
Portugal	$3.618	$0.000		$84.162		$0.000
...	...	...	...	...	...	...
USA	$485.060	$0.000		$14,515.000		$0.000
Uruguay	$0.080	$0.000		$7.638		$0.000
Uzbekistan	$0.000	$0.000		$0.076		$0.000
Saint Vincent and the Grenadines	$0.000	$0.000		$0.000		$0.000
Venezuela	$0.000	$0.000		$0.000		$0.000
Vietnam	$0.000	$0.000		$0.000		$0.000
Vanuatu	$0.000	$0.000		$0.000		$0.000
Samoa	$0.000	$0.000		$0.000		$0.000
Yemen	$0.000	$0.000		$0.000		$0.000
Serbia and Montenegro	$0.000	$0.000		$0.000		$0.000
South Africa	$26.797	$0.000		$848.080		$0.000
Zambia	$0.000	$0.000		$0.000		$0.000
Congo Democratic Republic	$0.000	$0.000		$0.000		$0.000
Zimbabwe	$0.639	$0.000		$4.358		$0.000

3.4. *Summary of threats to Australia*

Using the invasion matrices it was possible to generate a regional threat list for any species. This would generate 1,486 regional threat lists for Australia. I include the top 20 countries from the regional threat list for *Aphis fabae* as an example (Table 3-4). This table identifies which countries are of the greatest threat to Australia with this species.

While Table 3-4 is very similar to the largest exporters into Australia (Table 3-2), these rankings are dependent on the invasive species being assessed. For example, *Acraea acerata* is a pest of sweet potato, found in Africa and the rankings of countries by invasion threat would look very different to Table 3-2 (see Table 3-5).

Table 3-4. Top 20 countries ranked by invasion threat (IT) in millions of US$, to Australia from *Aphis fabae*.

Country	IT
China	$14,939
USA	$14,515
Japan	$10,578
Germany	$5,599
Malaysia	$4,108
United Kingdom	$3,647
Korea Republic of	$3,571
Italy	$2,667
France	$2,586
Sweden	$1,295
Belgium	$1,264
Netherlands	$1,167
Canada	$1,158
Switzerland	$1,137
Spain	$852
South Africa	$848
India	$807
Ireland	$789
Austria	$592
Denmark	$562

Table 3-5. Top 10 countries ranked by invasion threat (IT) in millions of US$, to Australia from *Acraea acerata*.

Country	IT
Nigeria	$7.650
Kenya	$0.808
Uganda	$0.396
Tanzania	$0.311
Ethiopia	$0.300
Sudan	$0.225
Zambia	$0.176
Congo Democratic Republic	$0.108
Rwanda	$0.005
Burundi	$0.001

In addition to ranking countries, it is also possible to generate a species invasion threat for any region threatening Australia. This would generate 177 lists, one for each country. I include the top 20 species invasion threat to Australia from China as an example (Table 3-6).

Table 3-6. Top 20 species ranked by invasion threat (IT) in millions of US$ to Australia, from China.

Species name	IT
Puccinia triticina	$15,283
Golovinomyces cichoracearum	$15,238
Aphis fabae	$14,939
Puccinia sorghi	$14,845
Venturia inaequalis	$14,778
Sporisorium cruentum	$14,625
Trichoplusia ni	$14,519
Ustilago scitaminea	$13,625
Colletotrichum lindemuthianum	$13,613
Cercospora kikuchii	$13,340
Sitobion avenae	$13,296
Alternaria sesami	$13,235
Cochliobolus lunatus	$13,114
Alternaria longipes	$12,992
Cladosporium cucumerinum	$12,956
Liriomyza trifolii	$12,816
Podosphaera fusca	$12,395
Dialeurodes citri	$12,328
Fusarium oxysporum f.sp. niveum	$12,093
Dysaphis plantaginea	$12,065

Once all invasion matrices have been compiled, the total threat tables to Australia can be generated. By taking the sum of the column for Australia from an invasion matrix (see Table 3-3), the total threat to Australia from a species can be summed. This represents the total threat from all regions in which the species is present. Doing this for all invasion matrices (i.e. all species) will generate a table ranking each species by their invasion threat to Australia (Table 3-7).

Table 3-7. Top 20 species ranked by total invasion threat (millions of US$) to Australia. Estimated from 177 countries.

species name	total threat
Puccinia triticina	$85,838
Puccinia sorghi	$84,152
Aphis fabae	$76,749
Golovinomyces cichoracearum	$76,691
Venturia inaequalis	$74,962
Trichoplusia ni	$73,542
Colletotrichum lindemuthianum	$67,980
Alternaria longipes	$65,877
Sitobion avenae	$65,156
Cochliobolus lunatus	$64,388
Podosphaera fusca	$62,081
Cladosporium cucumerinum	$61,752
Phyllotreta striolata	$58,061
Dysaphis plantaginea	$56,494
Xestia c-nigrum	$55,456
Frankliniella intonsa	$55,403
Rosellinia necatrix	$55,255
Liriomyza trifolii	$54,897
Sporisorium cruentum	$54,678
Cercospora kikuchii	$53,324

In addition, by summing each region's invasion threat to Australia, across all species, an estimate of each region's invasion threat to Australia, for all 1,486 invasive species combined, can be generated (Table 3-8).

Table 3-8. Top 20 ranked regions by total invasion threat (millions of US$) to Australia. Estimated from 1,486 species.

Region	Total Threat
China	$2,522,183
USA	$2,174,986
Japan	$1,413,139
Germany	$487,679
Italy	$298,060
United Kingdom	$293,785
Korea Republic of	$284,675
Thailand	$261,076
France	$260,093
Malaysia	$240,141
Singapore	$157,832
Indonesia	$139,505
Vietnam	$112,530
India	$112,466
New Zealand	$106,531
Canada	$105,542
Netherlands	$84,463
Switzerland	$83,265
Sweden	$81,689
Belgium	$76,804
Spain	$71,853

4. Implications for stakeholders

As can be seen from Table 3-8 the three countries with the largest invasion threat to Australia are China, USA and Japan. Australian biosecurity agencies, such as Quarantine Operations Division (QOD), may be able to consider the risk posed by these three countries in their risk profiling of imported goods. Considering the large amount being imported from these countries however, it will no doubt be necessary to target a proportion of imports from these countries when determining inspection regimes.

Alternately, these biosecurity agencies might only want to consider a small proportion of the invasive species assessed here, or some other species not included, which could alter the total invasion threats from countries.

Although, Table 3-8 has ranked country threat, Table 3-7, which ranks invasive species by invasion threat, may be more important. This table allows the identification of those species most likely to arrive and establish in Australia. Economic impact analysis of these 20 top invasive species may refine their rankings and provide further information as to the risk these species pose to Australia.

Finally, as Table 3-4 illustrated, once a smaller proportion of species are identified, a specific country ranking can be determined for that species and utilised by government biosecurity agencies for more refined risk assessments, and inspection protocols.

5. Recommendations

1. **An assessment of the reliability of this methodology for predicting arrival and establishment likelihoods.**

   A method to test and validate the predictions of this work should be explored. This may include a comparison with border interception records and/or establishment records for species whose source and arrival time are known.

2. **The development of a communication strategy with Australian and international biosecurity agencies to encourage the uptake of SOM and DOT data as an effective risk identification technology.**

   Further interactions with Australian and international biosecurity agencies to encourage the uptake of this technology are recommended. This method represents a cost effective method of generating quantitative measures of species invasion threat that equip biosecurity agencies with a pre-invasion early-warning device for risk management planning.

3. **An online or PC-based SOM device be developed that is capable of producing country and (where possible) region-based estimates of exotic species potential to establish.**

   The development of an online or 'off the shelf' product that could be made available to these biosecurity agencies would further enhance the likelihood of uptake and we strongly recommend this focus.

4. **The results of this analysis that quantitatively express species arrival and establishment likelihoods should be incorporated into traditional forms of quantitative risk assessment.**

   Given the cost effectiveness of this method for generating invasion threat measures for invasive species, the use of SOM and DOT data to supplement other predictive decision-support tools is to be encouraged. These include epidemiological models and economic impact assessment models. Arrival and establishment likelihood is a critical parameter most often characterised by complete ignorance or profound uncertainty, and is therefore the cause of significant disturbances in predictive models. The ability of this method to generate results that can be directly applied in these models will prove of great benefit in this regard.

5. **SOM/DOT analysis be incorporated into existing pest risk analysis and import risk analysis methodologies.**

   This methodology potentially has two functions in import risk analysis and pest risk analysis. The first is to use as an initial screening process, which can reduce the list of potential invasive species to a more manageable list for expert and stakeholder solicitation. Secondly, the invasion threat values generated from this method can be used in the solicitation process as an unbiased and objective assessment of the relative invasion threat for potential invasive pests.

6. Abbreviations/glossary

ABBREVIATION	FULL TITLE
CABI	Centre for Agriculture and Biosciences International
CPC	Crop Protection Compendium
CRCNPB	Cooperative Research Centre for National Plant Biosecurity
DAFF	Department of Agriculture, Fisheries and Forestry
EPP	Emergency plant pest
IT	Invasion Threat
QOD	Quarantine Operations Division
SOM	Self Organising Map

7. Plain English website summary

CRC project no:	CRC10184
Project title:	Using likelihood of arrival and establishment to assess the world threat of invasive species
Project leader:	Dr Dean Paini
Project team:	Dr Dean Paini, Dr Paul De Barro
Research outcomes:	Arrival and establishment likelihood for Australia was estimated for 1,486 invasive insect pests and fungal plant pathogens. Arrival likelihood was estimated from the level of trade occurring between Australia and all other countries in millions of US$. Establishment likelihood was estimated by completing a SOM analysis of the worldwide distribution of the 1,486 invasive species. These two estimates were combined to generate a value for the invasion threat of all species in millions of US$. Considering all plant invasive species, China, USA and Japan poses the highest source of risk.
Research implications:	Biosecurity agencies can use this information for further refinement of import risk assessments and inspection protocols. Further, the methodology presented here could be applied to any number of invasive species and the outputs generated be incorporated into any consultative process currently used to prioritise pest lists.
Research publications:	n/a
Acknowledgements:	I would like to thank CABI and Sue Worner for providing the CABI data. Liam Thammavongsa for collating and editing the CABI and the IMF DOT data.

8. References

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