A regional decision support scheme for pest risk analysis in Southeast Asia

T. Soliman[1,*], A. MacLeod[2], J.D. Mumford[3], T.P.L. Nghiem[1], H.T.W. Tan[1], S.K. Papworth[1], R.T. Corlett[4], L.R. Carrasco[1,*]

[1]Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, Singapore 117543, Republic of Singapore; [2]The Food and Environment Research Agency, Sand Hutton, York, YO41 1LZ, UK; [3]Centre for Environmental Policy, Imperial College London, London, SW7 2AZ, UK; [4]Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan 666303, China.

[*]Authors for correspondence: tariq.soliman@yahoo.com; dbsctlr@nus.edu.sg

Abstract

A key justification to support plant health regulations is the ability of quarantine services to conduct pest risk analysis (PRA). Despite the supra-national nature of biological invasions and the close proximity and connectivity of the Southeast Asian countries, PRAs are conducted at the national level. Furthermore, some countries have very little experience of producing PRAs, exposing their plant resources to pests vectored via international trade. We review existing decision support schemes for PRAs and, following international standards for phytosanitary measures, propose a new scheme that adapts existing practices to suit the unique characteristics of Southeast Asia. Using a formal written expert elicitation survey a panel of regional scientific experts was asked to identify and rate the unique traits of the Southeast Asian region with respect to PRA. Subsequently, an expert elicitation workshop with plant protection officials was used to verify the potential applicability of the scheme that had been developed. Rich biodiversity, shortage of trained personnel, social vulnerability, tropical climate, agriculture-dependent economies, high rates of land-use change, and difficulties in implementing risk management options were identified as the traits of Southeast Asia. The scheme develops a procedure which emphasises local Southeast Asian conditions and demonstrates features that could be considered by authorities responsible for carrying out PRAs within the region.

Keywords: Biosecurity protocol | Expert elicitation| Expert evaluation| Invasive alien species

INTRODUCTION

The introduction and spread of invasive species is a major worldwide concern that has been regulated by international agreements since 1878 [1]. According to the World Trade Organization, countries can use plant health regulations to restrict trade only if these regulations are justified by a science-based pest risk analysis (PRA). FAO [2] defines a PRA as ''*the process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it*''. The International Standards for Phytosanitary Measures (ISPMs) are the official reference for PRA [3]. Complying with these international standards is obligatory for developing an internationally acceptable PRA.

As the PRA concepts described by the ISPMs are generic in nature, countries and intergovernmental bodies develop decision support schemes (DSSs) to improve their applicability. Although these DSSs differ in their sophistication and details, they all follow the international standards of the International Plant Protection Convention. For instance, the European and Mediterranean Plant Protection Organization (EPPO) DSS for PRA[4] is one of the most detailed schemes used for species-initiated PRAs. The scheme has two complementary annexes on habitat categories and environmental impacts. It is available on paper and as a digital version which incorporates advanced techniques to analyse pest risks. On the other hand, a Canadian scheme[5] appears much more straightforward. The scheme is pathway-specific and based on a matrix that combines dependent risk elements. Other pathway-specific schemes are those of Australia [6], New Zealand [7], and the USA [8, 9]. The Australian and New Zealand schemes have different sections that combine plant and animal risk analysis in one scheme. The Australian scheme uses risk matrices to determine the joint probability of entry, establishment and spread, through a sequence combining the risk elements, while the American scheme adds individual independent probability scores to drive the probability of introduction (i.e. entry, establishment, and spread). In both schemes, the overall risk score is then calculated by a risk matrix rule that integrates the score for the magnitude of the impact and the score for the probability of pest introduction.

PRAs in Southeast (SE) Asian countries vary in regulation, capacity, and enforcement. Some countries, such as Laos, have a limited implementation of the ISPMs, while others, such as Malaysia, Indonesia and the Philippines, have higher implementation. For instance, according to the IPPC in 2009-2010, the numbers of PRAs completed and documented in Indonesia, the

63 Philippines, Thailand, and Vietnam were 57, 17, 12, and 42 respectively. In contrast, other
64 countries, such as Cambodia, Laos, and Myanmar, did not report any PRAs in 2009 [10].
65 Insufficient capacity building, and a shortage of qualified staff and financial resources, present
66 major challenges for raising PRAs conducted by the SE Asian national plant protection
67 organizations to international standards [10].

68 In the last decade, several studies have reviewed and enhanced the practice of PRA, but these
69 have been limited to high-income countries [11-14]. Most suggest incorporating computerized
70 quantitative techniques where appropriate to improve the consistency and reduce the
71 uncertainty of risk estimation [12, 15-17]. These quantitative techniques are highly demanding in
72 terms of skills, time and effort even in high-income countries. At the same time, rudimentary
73 qualitative analyses could be subject to challenge by trading partners [2]. There is a need for
74 practical PRA schemes that are scientifically rigorous, consistent with the ISPMs and relevant
75 for routine use, especially in low- and middle-income countries. Such schemes could also be
76 used in higher income countries where demand for faster delivery of PRA is increasing. This
77 is consistent with the comment in ISPM 2 stating "*a PRA does not necessarily need to be long*
78 *and complex. A short and concise PRA may be sufficient provided justifiable conclusions can*
79 *be reached after completing only a limited number of steps in the PRA process*" [18]. In SE Asia
80 it is especially important to have an efficient and effective PRA process for countries that must
81 work with a limited PRA budget [19].

82 Invasive pests pose risks that often surpass national boundaries [20]. For instance, the golden
83 apple snail (*Pomacea canaliculata*) was initially introduced into cement tanks, managed
84 ponds, and backyard soil pits in the Philippines and later spread to Indonesia, Malaysia,
85 Thailand, and Vietnam [21, 22]. It spread rapidly through irrigation ditches and public waterways
86 to the rest of the region. Other examples of exotic pests that have spread widely in SE Asia
87 are the fruit flies *Bactrocera cucurbitae* and *B. dorsalis*, the Lepidoptera *Helicoverpa armigera*
88 and *Plutella xylostella*, and the psyllid *Heteropsylla cubana* [23]. PRAs in SE Asia are conducted
89 at the national level [19], which has advantages, such as the ability to reach a rapid consensus
90 without the delays that would result from intergovernmental negotiation on common plant
91 health policies and related regulatory activities at the regional level. However, given the
92 supranational nature of invasive pest spread, the proximity and connectivity of SE Asian

93 countries, and the heterogeneity in the resources available for PRAs, a regional-scale PRA
94 scheme could generate more effective and efficient preventive and control strategies [24].

95 SE Asia has a unique economic, ecological and social nature, and a regional DSS should
96 account for these special traits. However, it is unclear what these traits are and how a newly
97 developed regional DSS should differ from existing schemes in high-income settings to
98 enhance its applicability. Furthermore, the low number of recent international journal
99 articles on the determinants of pest invasion success in SE Asia and the scarcity of research
100 on PRA in the region reveals the need for eliciting knowledge from experts who specialize in
101 research related to biological invasions in SE Asia [20]. The final adoption of any regional PRA
102 scheme would be the responsibility of the national authorities and their regional plant
103 protection organisation.

104 Here we develop an independent proposal for a regional PRA scheme by adopting parts of
105 existing DSSs and adapting them to the unique traits of SE Asia. Two expert panels were
106 consulted to (i) identify the characteristics of SE Asia which should be accounted for in a
107 regional PRA, and (ii) demonstrate the operation of the proposed PRA. We also introduce a
108 new approach for combining uncertainty with ratings for probability of introduction and
109 magnitude of impacts by invasive pests.

110

111 **MATERIALS AND METHODS**

112 **Expert elicitation**

113 **Regional scientific panel**

114 A panel of regional experts was asked in a formal written expert elicitation survey to identify
115 and rate the unique traits of the SE Asian region. Potential experts were identified as those
116 who have expertise in biological invasions and understanding of SE Asia as a receptor
117 environment for invasive species. Accordingly, the following roles were identified: (1)
118 academics with knowledge of pest risk analysis in SE Asia, (2) public sector employees
119 acquainted with PRA (e.g. pest risk analysts working in national plant protection agencies),
120 and (3) private sector employees acquainted with PRA (e.g. ecologists in consultancies and
121 non-profit organizations). Calls in the “PestNet” and “aliens-l” email distribution lists were

used to elicit experts, as was direct contact with biological invasion experts at the National University of Singapore (Singapore), Instituto Hórus de Desenvolvimento e Conservação Ambiental (Brazil), Xishuangbanna Tropical Botanical Garden (China), University of Potsdam (Germany), and the plant protection services of Australia, New Zealand, United Kingdom, and Singapore. Out of 15 experts directly contacted and the members of the distribution lists, eight experts participated in this expert elicitation survey. These regional experts were asked to identify and rate the unique traits of the SE Asian region in a formal written expert elicitation survey. The questionnaire starts with a general introduction and motivation, followed by a list of suggested traits that the experts are requested to rank quantitatively. To enable evaluations of the proposed traits, a detailed description of each trait was provided in an annex attached to the questionnaire. Experts were asked to give a weight between 0 (low importance) and 100 (high importance) for each trait.

The rated traits were: agriculture-dependent economies, shortage of trained personnel, rich biodiversity, social vulnerability, high rates of land use change and ecosystem degradation, tropical climate, and difficulties in implementing risk management options. These traits are represented in the proposed scheme by adopting and adapting parts of other PRA schemes. Traits with greater weight were represented in more detail in the proposed scheme. After collecting quantitative responses, experts' opinions were combined using equal weights to calculate the mean and standard deviation for each trait (Table 1). The description and weighted importance given to the traits were as follows:

1. *Agriculture-dependent economies* (weighted importance 54%). Agriculture is an important source of income and foreign currency providing a large proportion of employment capacity in SE Asia. Furthermore, most SE Asian farmers are classified as subsistence rather than large-scale farmers. The proposed scheme should reflect food security vulnerabilities if key crops are attacked by invasive plant pests.
2. *Shortage of trained personnel* (weighted importance 68%). Many SE Asian countries face serious resource constraints for managing plant health. Despite funding programs and support by international organizations, further capacity building is still needed to produce qualified plant quarantine officers [19, 25]. The scheme cannot demand highly skilled personnel given the low– middle–income nature of the SE Asian countries.

3. *Rich biodiversity* (weighted importance 68%). The high biodiversity and endemism of SE Asia is well recognised [26]. The scheme should enhance biodiversity protection, since SE Asia contains several global biodiversity hotspots. Although there are few records of species extinction in SE Asia, the increase in species classified as endangered and susceptible should be recognised within a PRA system and, where appropriate, risk mitigation should apply regionally.
4. *Social vulnerability* (weighted importance 41%). In PRA, ***s***ocial vulnerability can be interpreted as social choices which increase the vulnerability of the receptor environment to pest invasion [27]. Social vulnerability includes cultivation practices by farmers, institutional interventions, and market practices that could increase regional vulnerability to invasive plant pests and diseases.
5. *Land-use change* (weighted importance 51%). Compared to high income regions, SE Asia is characterized by higher rates of land-use change (particularly deforestation) and ecosystem degradation (e.g. logging, fire, and hunting). Both deforestation and ecosystem degradation play a key role in facilitating establishment and spread of invasions.
6. *Tropical climate* (weighted importance 59%). Compared to temperate regions, tropical climates can support the survival of very different sources and clades of invasive plant pests. Therefore, the scheme should provide a detailed analysis for potential pest establishment. Risks are highest for pests from other tropical areas that are linked to SE Asia by direct transportation routes.
7. *Difficulties in implementing risk management options* (weighted importance 24%). Structural obstacles and lack of operational capability for enforcement relevant to invasive plant pest introductions may limit the response to PRAs and their recommended risk reduction options. The scheme should account for temporary management options to support the PRA until permanent measures are successfully applied.

Panel of regional plant protection officials

To validate the traits suggested by the scientific experts and verify the proposed DSS applicable for routine PRA use in SE Asia, plant health officers in the region were consulted through an expert elicitation workshop. The workshop was held in Bangkok, Thailand, from

183 29th July to 2nd August 2013 under the project 'Beyond Compliance: Integrated Systems
184 Approach for Pest Risks Management in Southeast Asia' (STDF/PG/328) [28]. Officers from the
185 plant health ministries of Malaysia, Thailand, Vietnam and the Philippines, experts from
186 Imperial College London, Queensland University of Technology, Centre for Agriculture and
187 Biosciences International (CABI), and representatives from the FAO—International Plant
188 Protection Convention (IPPC), and the FAO—Asia and Pacific Plant Protection Commission
189 (APPPC), attended the meeting. In total, twenty experts participated in this expert elicitation
190 workshop. The consultation started with an introduction to the draft PRA scheme, then
191 developers explained how it was adapted to meet the identified criteria for SE Asia, The
192 consultation ended with a group discussion. Expert opinions were combined using the
193 behavioural aggregation approach where experts themselves aggregate judgments on the
194 validity of the suggested scheme [29]. This is achieved when the group, following discussion,
195 comes to an agreement about a particular judgement value. To avoid group domination by
196 the most confident and outspoken experts, we encouraged knowledge sharing, corrected
197 potential biases, and used feedback to aid the debate. For instance, we used direct questions
198 to prompt less confident experts to express their opinions and expressed contrary opinions
199 to the suggested points in order to enrich the discussion.

200 **Visual representation of pest risk and uncertainty**

201 In some PRA schemes, questions to evaluate and manage pest risk are rated on a qualitative scale
202 where available rating scores are expressed in descriptive and numerical terms (5, 8). In our approach,
203 each section of the DSS is rated by the risk analyst through a two-step process: first, by choosing one
204 or more ratings, and secondly, assigning a uncertainty level to each score. The rating reflects the
205 chosen level for the risk factor, while the uncertainty rating reflects the degree of confidence in the
206 rating. The ratings for the risk elements (e.g. probability of entry, establishment, spread and economic
207 impacts) and uncertainty consists of four categories (i.e., negligible, low, medium and high). The
208 overall risk score for the likelihood of introduction and magnitude of impact is calculated as the
209 median of the values for risk and uncertainty ratings separately (see Supplementary Online Material,
210 "Guidelines for expressing overall risk").

211 The risk outcome is represented through a visualizer graph that shows both the risk score and the
212 associated uncertainty for the likelihood of introduction and magnitude of impact using bubbles of
213 size proportional to the uncertainty level (Figure 1). The x-axis on the visualizer graph represents the

likelihood of introduction and the y-axis represents the magnitude of impacts. Total risk is graphically represented by a point that denotes the risk level, and determined by the median of the likelihood of introduction and the magnitude of impact.

RESULTS

SE Asian PRA scheme development

The proposed scheme is composed of seven main sections in line with the ISPM 11 guidelines [30]: (1) PRA initiation; risk assessment in terms of (2) probability of entry, (3) probability of establishment, (4) probability of spread, (5) magnitude of potential economic impacts, and (6) magnitude of potential environmental impacts; and (7) risk management (see the Supplementary Online Material). Within each section, there are several main- and sub-elements for assessors to consider. For instance, the section 'Magnitude of potential economic impacts' is divided into two main sub-sections, 'Direct impacts' and 'Indirect impacts'. Within the sub-section 'Direct impacts', there are two elements to consider: 'Crop losses, in yield and quality' and 'Significant increases in costs of production beyond normal annual fluctuations due to, for instance, additional control measures and/or costs associated with surveillance and monitoring (e.g., extra labour cost)'. Additional examples on the sections dealing with probability of entry, establishment, spread, and magnitude of impacts are provided in Table 3. Moreover, we ensured that all the terms used in the scheme are in line with the glossary of phytosanitary terms detailed in ISPM 5 and provided detailed and clear guidelines to explain the steps the analyst should follow to estimate the final risk outcome [18].

Shortage of trained personnel was suggested as the most limiting factor by the regional experts so we chose the most straightforward existing DSS as the foundation for the SE Asian DSS, based on the reviewed characteristics of existing PRA schemes (Figure 2; Table 2). We started with a relatively short and straightforward scheme that had previously been adapted within a project exploring alternative PRA protocols [12] as a base from which to develop the SE Asian scheme. We complemented this with other schemes that could represent the traits important for SE Asia. The EPPO scheme [4] can capture multiple aspects of the potential impacts on both the structural biodiversity and the functionality of the ecosystem services at

the species, community and landscape level. As this was the second most important distinctive trait of SE Asia, the EPPO scheme was used for environmental impacts and risk management. The EPPO scheme was also able to provide detailed evaluation of all existing and potential risk management measures for both exporting and importing countries. The Australian and New Zealand schemes consider both the scope (i.e. direct and indirect) and the geographical scale (i.e. local, district, regional, and national) of impacts, so they were heavily relied upon to estimate economic, environmental and social impacts. The United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS) scheme shows the factors to consider when assessing the potential entry and establishment of species and procedures for conducting risk assessments (e.g. data needed and order of analysis), so it was used to represent potential pest entry and establishment, and to provide supplementary information on risk management.

Several modifications were applied to the combined scheme to represent SE Asian traits and to improve the guidance notes (Supplementary Online Material, Appendix III). As SE Asian countries are largely agriculture-dependent economies, we added export loss, employment loss, reduction in market value of the affected host, effects on closely related industries, income reduction, foreign exchange earnings, and increased poverty rates (Supplementary Online Material, 2.19, points a, b, c, d, e, and f). Moreover, to represent social vulnerability, we added to the same section the economic values or market structures that may inflate impacts (Supplementary Online Material, 2.19, point g). To accommodate the 'rich biodiversity' trait, we extended elements in the 'environmental impact' section, such as reduction of keystone plant species, reduction of plant species that are major components of ecosystems (in terms of abundance or size), reductions of endangered native plant species, and significant reductions of plant species of high conservation value (Supplementary Online Material, 2.21, points a, b, c, and d). Indirect environmental impacts, such as changes in ecological processes and effects on plant communities, were also extended (Supplementary Online Material, 2.22, points b, d, e, f, and g). The 'social vulnerability' and 'land-use change' traits were included in the 'cultural practices' element of the 'pest establishment' section (Supplementary Online Material, 2.9). The 'land use change' trait was also included in the 'other factors' element of the 'probability of spread' section (Supplementary Online Material, 2.14). These traits were illustrated by cultivation practices of farmers and other human

activities that promote establishment and spread. 'Tropical climate' was included in point 2.8 'suitability of environment' of the 'probability of establishment' and in the introductory phrase of the 'probability of entry' section. In the 'risk management' section, the analyst is requested to suggest a temporary action that may be used in case there is difficulty in implementing longer-term risk management options. This addition is meant to cover the last identified trait 'difficulties in implementing risk management options'.

Workshop results

After collective discussion, the expert panel agreed on the identified traits and the utility of the proposed regional scheme as a possible starting point to integrate PRA practices in the region. Any actual changes to PRA schemes in the region would be the responsibility of national plant protection organisations. The new method to visualize pest risk and uncertainty was deemed adequate and simple to use by plant health officers. On the other side, the panel raised several points on the proposed DSS during the validation process. First, they mentioned the difficulty in using the rating process due to the large number of elements in each question. Secondly, the PRA development process lacked validation of the proposed scheme with the experts' perceptions. Finally, the consistency in scales and terminology of the rating system could be improved.

DISCUSSION

The threat posed by invasive pests and diseases in SE Asia has increased recently owing to the higher volume and frequency of international trade [20]. At the regional scale, accurate and rapid PRAs are needed to meet this increasing challenge as PRAs can identify pest risks and facilitate risk management measures to inhibit pest introduction or spread [31]. This paper reviews existing DSS for conducting PRAs and selects and adapts elements from the most suitable schemes to develop an independent, unofficial proposal for the SE Asian region. Parts of the other reviewed schemes were integrated into the selected scheme to better reflect the unique characteristics of SE Asia. Expert opinion was elicited to identify the unique SE Asian traits and to verify the applicability of the developed scheme.

The Canadian scheme is the core scheme of choice given the unique traits and the limited resources and capacity for plant health in the SE Asian region. Among all reviewed schemes, the Canadian scheme is the shortest and most straightforward, and thus easy to use and apply. To strengthen the SE Asian scheme, we first developed an innovative approach for combining scores and uncertainty that is simple and practical for routine use, and reflects the mechanism underpinning the risk process, therefore providing more meaningful information for decision-makers. Secondly, we improved the guidance notes for each question based on the work of MacLeod et al. [12] and extended the sub-elements considered to account for unique SE Asian traits (see the Supplementary Online Material). Parts of the other reviewed schemes which can reflect these traits were integrated into the core scheme.

Most experts at the workshop agreed on the importance of conducting PRAs at the regional level. This was supported by expectations of negotiations towards establishing a SE Asian community similar to the European Union in the near future [32]. In addition, for some pests (e.g. mango pests), analysis at the regional level is already done. The visualizer graph was seen as important tool to facilitate risk communication. A visual display of risk is valuable to decision makers as it requires relatively little cognitive effort to comprehend the risk outcome[33]. Furthermore, plant health officers in the region raised a number of concerns with the proposed scheme. The officials agreed the technique for integrating rating scores and uncertainty is transparent, simple and easy to apply. However, the large number of elements to be considered increases the difficulties of rating each question and its uncertainty, although this concern may also occur with existing schemes. There is a trade-off between reducing the number of elements considered for each question and increasing the capabilities of the scheme to capture the pest risk.

The overall risk results of the method (i.e. mean and standard deviation) also need to be validated against the level of risk perceived by the experts and estimated by other PRA approaches. The main criteria to consider when a PRA is validated are transparency, rigour of dealing with uncertainty, consistency between assessors and between assessments, and ease of use. This could be difficult in practice because few historical case studies exist and there are uncertainties involved in the assessment and observed risk. Consistent scales and terminology in the rating system were enhanced by having four scores for all questions and by providing a clear definition for each rating score in every section.

Despite social vulnerability playing a key role in promoting pest establishment and spread, it is often ignored in PRA schemes. To evaluate available management options in PRA practices, it may be necessary to determine whether an alternative management or governmental intervention would reduce the vulnerability of the receptor environment to pest invasion. Such management or intervention can only be designed if we can explain societal behaviour and understand how to change practices to make a risk area less vulnerable [27]. In SE Asia, for example, social vulnerability is found in cultivation practices such as crop seasonality, soil preparation, planting method, irrigation, surrounding crops, and harvest timing and method [4]. Social vulnerability can also be seen in institutional practices such as governmental policies that favour pest establishment or spread. For instance, increased forest fragmentation and deforestation for oil palm cultivation in SE Asia raises the region's vulnerability for invasive pests and diseases [34]. Finally, social vulnerability can be found in different market practices such as monopolistic or oligopolistic market power. Market power can raise the price of a commodity, thus artificially inflating the potential impact of a pest. Social vulnerability is not officially mentioned in the IPPC standard, and therefore cannot be used as an official justification for phytosanitary measures. This is mainly because evaluating social vulnerability can be biased and subsequently (ab)used for political or protectionist goals. However, if we could convert social vulnerability into economic terms, it could be accepted by the SPS Committee of the WTO in international trade disputes.

In addition to the traits listed above, the experts in the workshop suggested the trait "herbicide and insecticide resistance". High-income countries tend to use newer and more expensive pest control products with active ingredients still under patent, whereas low-income countries tend to use older and less costly ones, such as generics with active ingredients that are no longer under patent. There is a greater prevalence of resistance against the active ingredients in older products, leading to a higher risk of invasive plant pests in low- and middle-income countries. In addition, resistance could develop when there is more intensive chemical use and high frequency of repeated application[35]. "Greater biotic resistance to introduced species" was also suggested as a unique trait for SE Asia. This trait is often difficult to prove or quantify, but possibly associated with more biodiverse and more complex tropical natural ecosystems in which most of the available resources and niches are already occupied, preventing establishment of invasive pests [36]. These traits were included

365 in the scheme under ‘indirect environmental impacts’ by extending the element of the
366 ‘undesired effects of control measures’ (Supplementary Online Material, 2.22, point a).

367 It is important to recognise the possibility of developing a regional PRA scheme, although
368 there might be difficulties when harmonizing the outcomes. This is mainly because each SE
369 Asian country has different structures, facilities, laws and operational resources, so
370 management options available to reduce risk and their application are not homogeneous.
371 Complete harmonization is only possible when legislation, directives and operational
372 resources are also more similar, as in the EU. However, a regional DSS is a step forward
373 towards this objective. This independently proposed SE Asian scheme represents an attempt
374 to improve the current practice of PRA in low- and middle-income countries, especially in SE
375 Asia, to help reduce threats to ecosystems and food security from invasive pests.

376

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468 **Tables and Figures**

469

470 Table 1: The unique traits of the SE Asian region (st.dev, standard deviation).

Traits that make SE Asia different from high-income regions with regard to pest risk analysis (PRA)	**Weight (%)**	**St.dev**
Agriculture-dependent economies	54	27
Rich biodiversity.	68	35
Shortage of trained personnel	68	22
Social vulnerability	41	22
High rates of land-use change (particularly deforestation) and ecosystem degradation (logging, fire, and hunting).	51	36
Tropical climate.	59	36
Difficulties in implementing risk management options	24	30

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472 Table 2: Evaluating the characteristics of different pest risk analysis (PRA) schemes

	EPPO	**Canada**	**USA**	**Australia**	**New Zealand**
Dominating approach	Species/pathway based PRA	Pathway based PRA	Pathway based PRA	Pathway based PRA	Pathway based PRA
Rating system	Descriptive / numerical	Descriptive / numerical	Descriptive / numerical	Descriptive / numerical	Descriptive / numerical
Analysing uncertainty quantitatively	Yes	No	No	No	No
Guidance notes /examples	Very good	Good	Good	Good	Good
Complexity	High	Low	Medium	Medium	Medium

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475 Table 3: Examples of some changes applied to the developed regional Southeast Asian scheme.

Probability of entry
2.3. Survival during transport or storage
Examples of factors to consider are: a) Speed and conditions of transport and duration of the life cycle of the pest in relation to time in transport and storage
Probability of establishment
2.6. Availability of suitable hosts, alternate hosts and vectors in the PRA area
Examples of factors to consider are: a) Whether hosts and alternate hosts are present, how abundant or widely distributed they may be
Probability of spread
2.12. Potential for natural spread
Examples of factors to consider are: f) The existence of natural barriers to spread of the pest in the PRA area. Include variables such as vectors or natural enemies that may affect the pest's ability to spread in the PRA area. In SE Asia, distances between islands and modes of transport between them will be crucial.
Magnitude of potential economic impacts
2.18. Indirect economic impacts
For identification and characterisation of the indirect effects of the pest in the PRA area or those effects that are not host-specific, the following are examples that could be considered: a) International trade effects, including loss of markets (e.g. export loss), meeting new technical requirements to enter or maintain markets, and changes in international consumer demand. e) Effect on foreign exchange earnings and poverty rates, if the host crop contributes significantly to the exports.
Magnitude of potential environmental and social impacts
2.22. Indirect environmental and social impacts
For identification and characterisation of the indirect effects of the pest in the PRA area or those effects that are not host-specific, the following are examples that could be considered: a) Environmental and other undesired effects of control measures (e.g., pesticides). Herbicide and insecticide resistance may be developed in SE Asia owing to use of generics with active ingredients not under patent. d) Significant change in ecological processes (e.g. natural successions; trophic and mutualistic interactions such as the food web, pollination, or plant-mycorrhizal webs) and the structure, stability or processes of an ecosystem including further effects on plant species, erosion, water table changes, increased fire hazard, and nutrient cycling.

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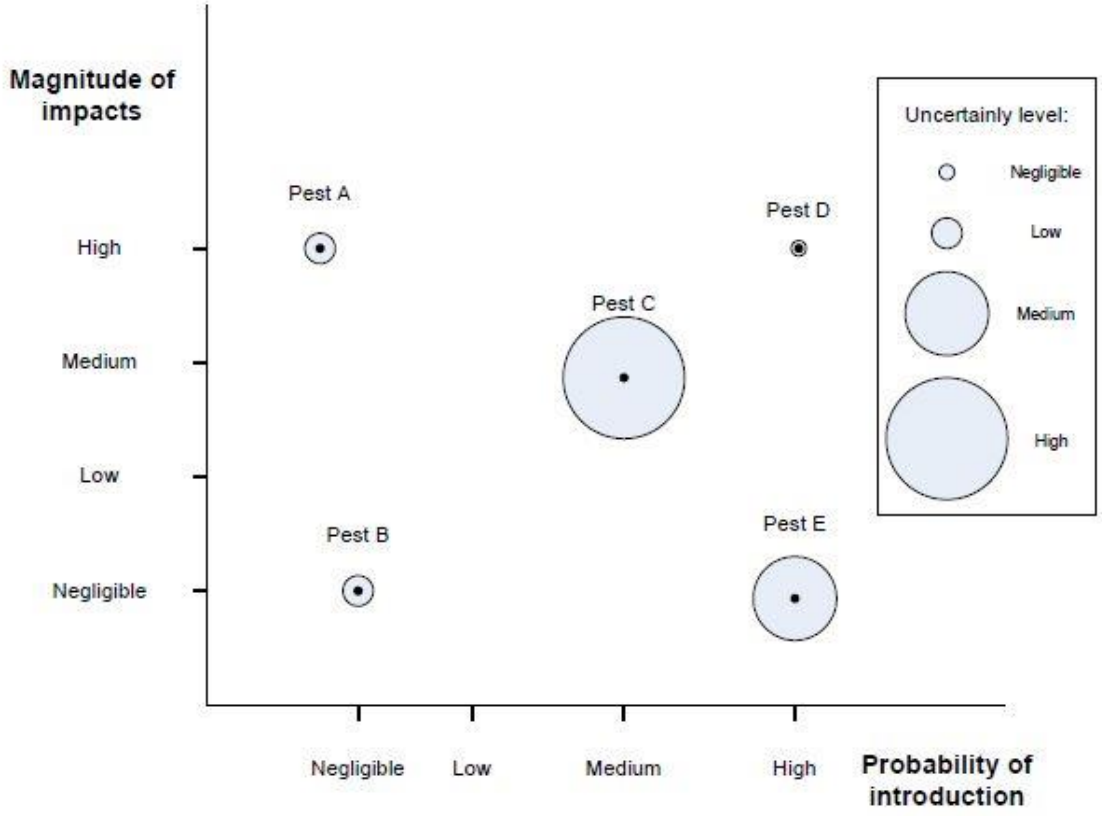
Figure 1: An illustrative example for the visualizer graph of overall risk of three different pest cases.



482 Figure 2: Structure of the developed Southeast Asian scheme. CFIA: Canadian Food Inspection
483 Agency.

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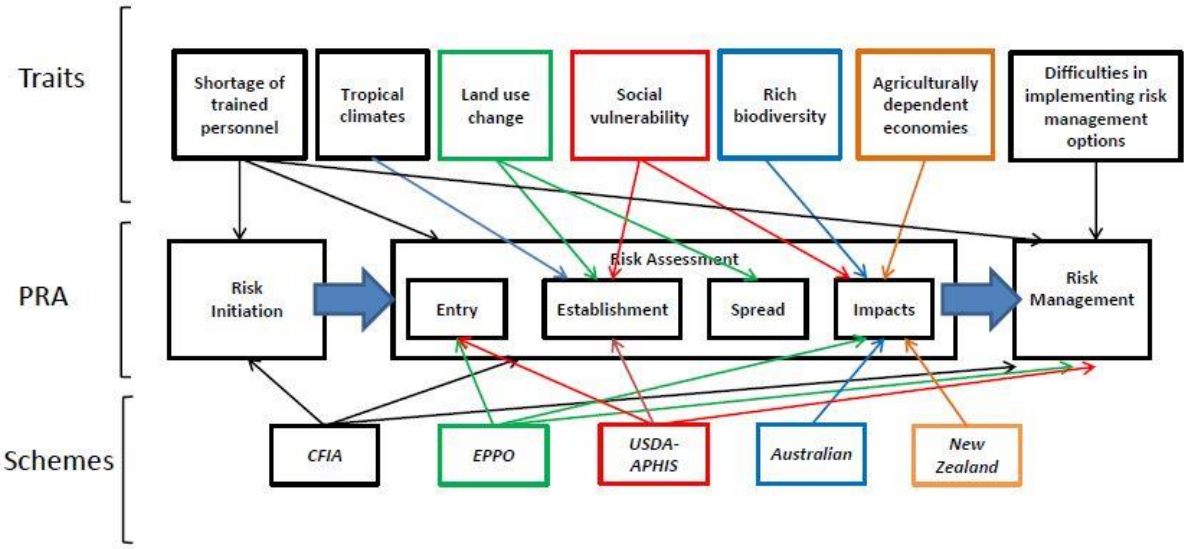

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