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Point of view

Developing a methodology for the prioritisation of pests in plant health

Bénédicte Moignot (1) (benedicte.moignot@anses.fr), Philippe Reynaud (2)

(1) French Agency for Food, Environmental and Occupational Health and Safety. Plant Health Laboratory, Expertise and Biological Risk Unit, Angers, France

(2) Entomology and Invasive Plant Unit, Center for Biology and Management of Populations, Montferrier-sur-Lez, France

With the aim of optimising resource allocation for the prevention, surveillance and control of pests, the authorities in France have chosen to develop a tool to classify pests by priority. This tool has been developed by the ANSES Plant Health Laboratory. The method involves evaluation of the invasiveness of pests that are absent or of limited distribution in mainland France. To this end, multiple criteria are used in an evaluation method based on the principles of pest risk analysis. Using a semi-quantitative model rapidly provides a classification of pests. The tool is available *via* an intuitive IT interface, facilitating use and interpretation of results. For most of the top-ranked pests in the current classification, the Plant Health Laboratory has suitable analytical methods for their detection. However, the classification also singles out pests that deserve specific attention. The aim of this article is to present the regulatory framework of the study in more detail, and to describe the principles underlying the prioritisation methodology.

Purpose of classifying pests by priority in the area of plant health

To promote the reactivity and competitiveness of the agricultural sector in France in a context of globalisation of trade, climate change and evolution of agricultural practices, France modernised its health policy strategy following the National consultation on the health sector of 2010. Priority classification of pests in plant health is part of these efforts. One of the main objectives of the new scheme is to optimise management and funding of health policy. With this in mind, risk managers aim to set up priorities for allocation of the available resources for prevention, surveillance and control activities based on the seriousness of the health risk. This is precisely the purpose of the French Ordinance of 23 July 2011, which provides for classification of health hazards. This requires that pests that threaten plant health be divided into three categories with decreasing degrees of danger, 1, 2 and 3, with the associated funding being the responsibility of either administrative authorities and/or private organisations. In order to establish the necessary categorisation of health risks, the Ministry of Agriculture addressed a formal request to the Agency for Food, Environmental and Occupational Health and Safety (ANSES) concerning development of an objective and transparent prioritisation methodology adapted to the specific biological risks that threaten plant health.

Specific characteristics of biological risks in plant health

The wide taxonomic range of pest organisms, i.e. viroids, viruses, phytoplasmas, bacteria, fungi, nematodes, arthropods and plants, along with the extremely high number of plant hosts, poses a real challenge to the development of a general prioritisation model. Fortunately, an invariable biological principle mitigates this apparent complexity: regardless of the host-organism interaction in question, the risk level for plant health is always dependent on certain key factors for the development of pests. As a result, the prioritisation method involved setting up a classification based on evaluation of these factors that are common to all pests, in the context of mainland France.

Pests of interest for the development of a prioritisation method

Pests inherent to international trade

Globalisation of trade is recognised as a major factor contributing to the introduction and spread of species outside their indigenous distribution area [1]. Import of living plants and plant products from other countries is a key entry pathway for exotic pest species. The greater volumes of imported products and their increased frequency, as well as the cryptic life stages of pests, hinder systematic interception by the health control services [2, 3]. Among these accidentally introduced pests, some prove to be invasive with a negative impact on the health of crops and/or wild plants [4]. More specifically, they may result in economic losses, such as reduced agricultural yields and eradication costs, or undermine the natural ecological balance, or even become a concern for public health [5]. The total economic impact of exotic species in Europe is very roughly estimated to be about 10 billion euros annually [6].

Pests subject to regulatory phytosanitary measures

To prevent introduction and spread of alien pests that pose a risk to plant health, the European Union has implemented specific regulatory provisions. As part of this framework, Directive 2000/29/EC lists several hundred regulated organisms and potential host plants and plant products for which introduction and spread are strictly prohibited. This European directive was transposed into French law by the Ministerial Order of 24 May 2006 concerning health requirements for plants, plant products and other items. Its application involves implementation of mandatory prevention, surveillance and control measures, regardless of the level of phytosanitary risk.
In parallel to the European regulatory context, the European and Mediterranean Plant Protection Organization (EPPO) under the authority of the International Plant Protection Convention (IPPC), recommends that pests be considered regulated

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organisms in national regulations, where member countries consider this appropriate. These organisms are included in two distinct lists designated as List A1 and List A2. List A1 organisms are entirely absent from the EPPO region, while those in List A2 are found locally. The EPPO has also set up an Alert List that contains pests with invasive properties and for which surveillance is strongly recommended. In France, organisms on the EPPO Alert List are mandatory control organisms under certain conditions since their inclusion further to revision of the Ministerial Order of 31 July 2000.

Currently, operational implementation of these regulatory texts is hindered by inadequate resources available in view of the large number of regulated pests. Certain publications propose a list of the top 10 bacterial, fungal and viral agents in terms of risk for plant health based on their scientific and economic importance worldwide [7-9]. These approaches are however not sufficient to prioritise management actions for regulated organisms nationally. As a result, the prioritisation methodology developed here involves pest that are alien, absent or of limited distribution in mainland France which are currently managed on a regulatory basis, and for which it is necessary to evaluate and compare their invasive potential and the impact they represent to wild plants and crops.

Basic principles underlying the development of a prioritisation method for pests in plant health

A method based on procedures for pest risk analysis

To assess the risk related to organisms inherent to the trade in plants and plant products, the reference text is the FAO's standard on Pest Risk Analysis (PRA) [10]. This text harmonises assessment of phytosanitary risk related to organisms that are absent or of limited distribution in a given region to provide all the justifications required for the implementation of regulatory measures that may restrict international trade. Once the geographic area of study has been determined, the PRA uses a questionnaire to determine both the probability of its exposure to an alien organism and the extent of potential negative impacts. The probability of exposure of a given region to an alien organism takes into account the probability of entry, establishment and spread. At the same time, the assessor specifies the degree of uncertainty concerning the risk assessment in view of the available data. When the phytosanitary risk is considered unacceptable, management measures are listed and evaluated. The prioritisation method follows the general structure of the PRA to evaluate the phytosanitary risk.

Biological invasion as the common factor

Beyond its regulatory application, PRA is a method recognised for the way it addresses the concept of biological invasion of alien species [11]. Recently, this concept was formalised to attempt to impose a unified framework on the way it has been applied over the past 20 years [12]. The authors identify four successive stages in describing the process of biological invasion (Figure 1). The fulfilment of each of these stages is dependent on the organism successfully counteracting a wide range of biotic and abiotic forces. The first stage is transport of the organism that enables it to cross biogeographic barriers that would naturally be impassable. A second stage can involve the organism being maintained in a controlled environment (captivity or cultivation). However, in plant health, entry of a pest is primarily accidental with direct passage from stage 1 (transport) to stage 3 (establishment). The PRA standard groups together stages 1 (transport) and 2 (maintenance in a controlled environment) into a single stage called "entry" [10] (Figure 1). Once present in the environment, a local viable population can be established with individuals multiplying and adapting to new conditions. The fourth stage is characterised by spread over a wider area after reproduction of the established population. In this model, the authors do not take account of impacts, considering that they do not determine the invasive nature of an organism.

Characteristics of the prioritisation method

A multiple criteria approach

Unlike PRA, the prioritisation method developed here has the added feature that it generates a classification of pests based on the assessment of phytosanitary risks. As a result, the general structure of the method revolves around "criteria" that characterise the phytosanitary risk of pests. These criteria were defined by adapting the questions in the PRA and by consulting experts. Criteria must differentiate the invasiveness capacity and impact of pests effectively from one another. In the end, 24 criteria were selected and organised into five metacriteria, three corresponding to biological invasion stages, and two concerning impacts (Figure 2). The chosen criteria are often found to be indirect indicators for which data are available rather than variables measuring the phytosanitary risk directly. For example, the volume of import of plants and plant products is regularly used as an indirect indicator of the flow of potentially associated organisms [11].

Semi-quantitative evaluation of criteria

In the PRA model, the assessor measures the components of biological invasion based on a qualitative scale with the following terms: "very unlikely", "unlikely", "moderately likely", "likely", "very likely", and related uncertainty with the terms "low", "moderate", and "high". Although this approach is pragmatic, the final result of the phytosanitary risk assessment is expressed in the form of summaries that are sometimes complex. In the framework of the European research project PRATIQUE, the EPPO has developed a tool enabling conversion and aggregation of qualitative measurements into a probability of entry, establishment, spread and impact [13]. For a given PRA, this innovative assessment method facilitates overall understanding of phytosanitary risk. However, this tool does not make it possible to rank several pests for which the risk was evaluated using PRAs carried out independently from one another.

With the aim of developing a simple operational tool that can prioritise the numerous pests based on multiple criteria, the evaluation method retained here is a semi-quantitative model. This approach has been applied in several models of priority classification of invasive species [14]. The principle is to evaluate heterogeneous criteria by attributing numerical scores to quantify the level of risk. In this way, despite the diversity of criteria, they are aggregated using a single mathematical formula. In the method of prioritisation developed, the scores are between zero for the absence of information, and a maximum score for a major risk. Aggregation of criteria for the same metacriteria is cumulative, while aggregation of entry, establishment, spread, and impact metacriteria is multiplicative. The overall phytosanitary risk index calculated in this way is therefore not only consistent with the notion of phytosanitary risk explained above, but also determines the classification rank of the pest.

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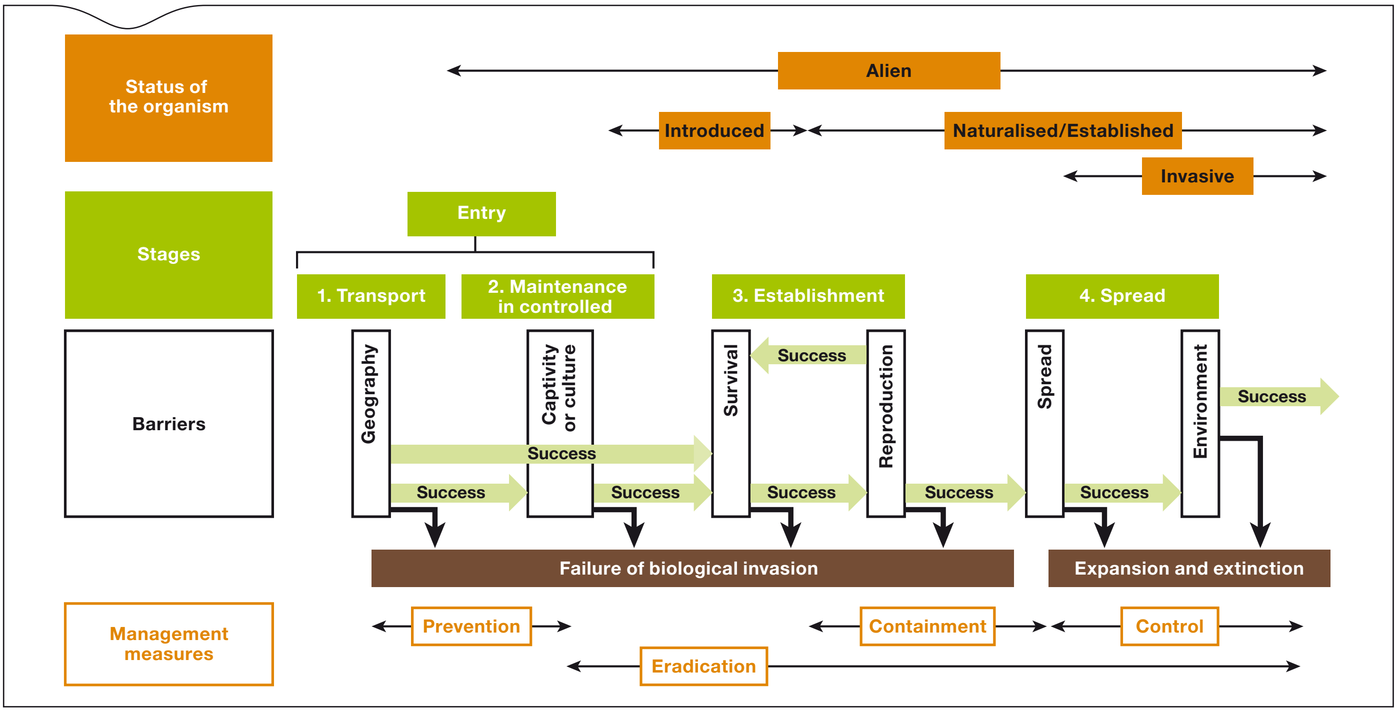

Figure 1. Concept of biological invasion formalised by Blackburn.
An organism is considered invasive in a novel area of introduction once it has overcome several barriers during the four successive stages. In plant health, entry of pests is primarily accidental with direct passage from stage 1 (transport) to stage 3 (establishment). The PRA standard groups together stages 1 (transport) and 2 (maintenance in a controlled environment) into a single stage called "entry" [10] (adapted from Blackburn et al.*, 2011).*

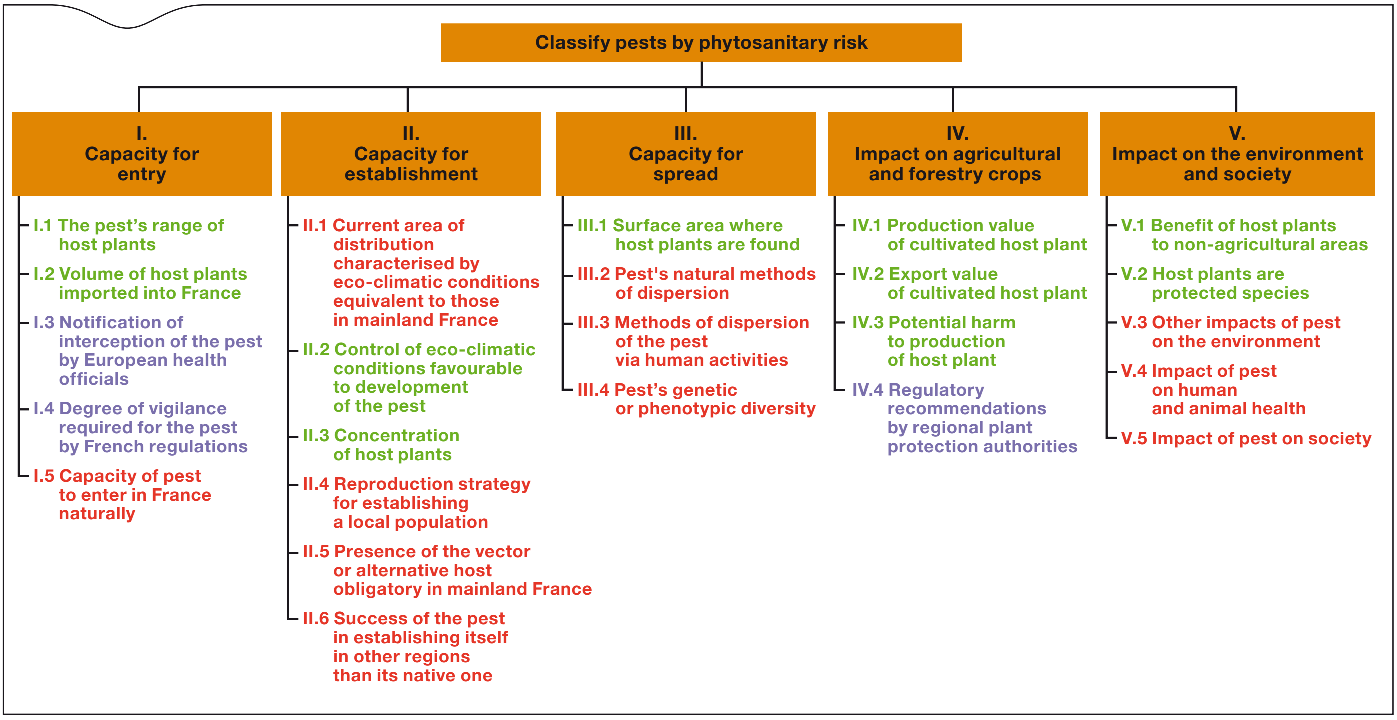

Figure 2. Diagram of metacriteria (orange blocks) and criteria (in colour) selected for the prioritisation method.
The red, green, and purple titles refer to the biology of the organism, host plants, and regulatory measures, respectively.

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A criteria evaluation system based on prior analysis of available data

In the prioritisation model developed, attribution of scores for each criterion is correlated with selection of predefined risk classes. The usefulness of selecting explicit risk classes rather than attributing a score between two values is that it retains consistent grading between the different pests evaluated, but also between different assessors. The clarity of the criteria descriptions and the risk classes was given special attention to limit differences in interpretation of meaning. This is why four to five classes of increasing risk were defined for each criterion. For example, for the criterion "Host plant range", four classes of increasing risk were defined: (1) the host plant for the pest is a single species; (2) the host plants for the pest are species belonging to the same genus; (3) the host plants for the pest belong to several genera within the same family; and (4) the host plants for the pest belong to several families. For quantitative criteria such as volumes imported, production areas, and production and export values, specific statistical data were collected in advance for as many reference host plants as possible. On the basis of this set of data, five statistical classes of equal size were established for each of the criteria. The risk classes then correspond to those statistical classes.. The purpose of this approach is to discriminate between the attributes of the classes in a consistent manner. In addition, the assessor can easily select the class corresponding to the available data.

A deterministic evaluation of the invasive profile of pests that integrates uncertainty

Given that evaluation of the criteria is based on known data, the prioritisation method is deterministic. Its main advantage is that it highlights the relative differences in invasive capacity of regulated pests. The key point is therefore the robustness of the groups of pests in the classification, rather than the rank in the classification, strictly speaking. Furthermore, this approach requires regular data update so that the classification of pests remains relevant in view of new knowledge described by the scientific and technical community. This is because the aim of the prioritisation method is to provide a structured scientific basis supporting decision-makers and other stakeholders in categorising pests in the area of plant health.
Moreover, during criteria evaluation, the available data may sometimes be contradictory or not sufficiently relevant: this is the notion of uncertainty. Uncertainty is taken into account and evaluated in our method by selecting several risk classes for the same criterion. The scores for the minimum and maximum risk classes selected thus define the limits of an interval quantifying the uncertainty of an evaluation. The greater the interval, the higher the uncertainty of criteria evaluation. The rank in the classification determined on the basis of these intervals makes it possible to single out pests with more uncertain invasion profiles.

A method integrated into an operational and instructive IT system

In order to classify a wide range of pests while building an evaluation of their invasion profile, the prioritisation method was implemented using a computer application functioning in Microsoft Excel®. The advantage of this interface is that it enables automatic aggregation of criteria once all the data have been entered by the assessor. In addition, a macro updates the overall classification as and when a new harmful organism is evaluated. The criteria evaluation procedure was developed with fast and intuitive operability in mind. Therefore, an integrated guide provides details on the criteria evaluation procedures. The clarity of the prioritisation method and the user-friendliness of the IT format have been confirmed by several assessors. As a result, the prioritisation method developed not only enables easy interpretation of results, but also transparent consultation of evaluations through an instructive tool.

The main characteristics of the classification obtained with the prioritisation method

Preliminary results validated by experts

The relevance of the pest classification established using the prioritisation method has been evaluated by experts. To begin, 25 alien and indigenous pests covering all taxa and targeting major plant sectors were selected. The phytosanitary profile of these pests was subsequently qualified by experts as high, moderate or low, with no attribution instructions. The 25 pests were then classified using the prioritisation method. The results showed significant correlation between the rank in the classification and the risk profile as determined by experts. More specifically, the prioritisation method made it possible to identify without ambiguity pests with a high risk profile and those with a low risk profile. For example, *Diabrotica virgifera virgifera*, *Tilletia indica* and *Meloidogyne chitwoodi* classified at the highest rank were considered high risk by the experts, while Aculops fuchsiae and *Pseudomonas syringae* pv. *aesculi* qualified as low risk by the experts were ranked at the lowest level. However, pests with moderate risk profiles were positioned more widely in the classification, such as *Phytophthora ramorum* and *Erwinia amylora*. This result is not surprising given how subjective the term "moderate" is in qualifying risk.

Clear correlation between the rank of a pest and the availability of an analytical method

With the aim of prioritising analytical method development within the Laboratory for Plant Health, it was ascertained whether official analytical methods, EPPO diagnostic protocols and validated in-house methods were available for each harmful organism, alongside evaluation of the criteria described above. This enquiry indicated that the pests for which analytical methods are available were ranked at high levels in the classification. As a result, this finding corroborates the relevance of the current working priorities of the Laboratory for Plant Health, and increases confidence in the prioritisation method.

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Limitations of the prioritisation method

The prioritisation method includes five evaluation metacriteria which are relevant only to pests that have not occupied their entire potential ecological niche in France. In other words, evaluation of the entry, establishment and spread metacriteria is not suitable for pests that are indigenous to the country or naturalised over their entire potential establishment area. As a result, defining the status(1) of the harmful organism in mainland France is an essential prerequisite.

The prioritisation method is based on a semi-quantitative model that includes neither temporal dynamics nor spatial heterogeneity of the biological invasion from an overall country perspective. To compensate for this limitation, several studies propose quantitative evaluation of key factors for biological invasion on the basis of equations that model their evolution over time and in space [11]. Nonetheless, as these authors highlight, this type of approach uses specific complex resources which restrict generalised application.

Conclusion

This pest prioritisation method provides an essential scientific basis for progress in French phytosanitary policy. In addition to categorisation of risks to plant health, the prioritisation method opens up other possibilities. With a view to anticipating phytosanitary risks, this approach provides a valuable basis for identifying pests that require closer risk assessment, and in the longer term, that require specific analytical methods. Moreover, the flexibility of this method means that it can be used in other biogeographical contexts. As such, since the second semester of 2012, an adapted prioritisation method is being deployed in the overseas departments and territories of France, to take account of their island context. Finally, the project is clearly an asset supporting the point of view of France during revision of the plant protection scheme at the European level.

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