

*Research*

# Integrating natural and social science perspectives on plant disease risk, management and policy formulation

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Plant diseases threaten both food security and the botanical diversity of natural ecosystems. Substantial research effort is focused on pathogen detection and control, with detailed risk management available for many plant diseases. Risk can be assessed using analytical techniques that account for disease pressure both spatially and temporally. We suggest that such technical assessments of disease risk may not provide an adequate guide to the strategies undertaken by growers and government to manage plant disease. Instead, risk-management strategies need to account more fully for intuitive and normative responses that act to balance conflicting interests between stakeholder organizations concerned with plant diseases within the managed and natural environments. Modes of effective engagement between policy makers and stakeholders are explored in the paper, together with an assessment of such engagement in two case studies of contemporary non-indigenous diseases in one food and in one non-food sector. Finally, a model is proposed for greater integration of stakeholders in policy decisions.

**Keywords:** *Dickeya*; *Phytophthora*; policy formulation; risk governance; stakeholder engagement

## 1. IMPACTS OF PLANT DISEASE AND APPROACHES TO MITIGATION

Diseases, caused by a plethora of micro-organisms [1–4], are a major constraint on both food production and ecosystem services worldwide. Global food production relies heavily on 14 major crops [5] with estimated annual losses of around 15 per cent for some [6]. Catastrophic epidemics on crop species have historically had profound consequences on societies [7–9]. The impacts of disease on ecosystem services have also been considerable [10,11], including on provisioning services for timber and on the biodiversity of ancient woodlands [12]. Declines in biodiversity and ecosystem services, in turn, often result in lower human well-being [13,14]. Cultural services too have been adversely affected by invasive plant

pathogens: *Phytophthora ramorum* is ravaging historic gardens [15,16], and Dutch elm disease has changed the landscape in much of Europe [17,18].

The combined drivers of climate change and expanding global trade are increasing the likelihood of pandemics of plant pathogens [19,20]. Trade has often been responsible for the spread of devastating pathogens that threaten the world's coffee, cocoa, maize, soya and wheat production [21]. In addition, changing environmental conditions are predicted to affect the stages and rates of development of disease organisms, the resistance of host plants, the physiology of host–pathogen interactions and the geographical distribution of host plants and pathogens [22–24].

There are a range of measures used to control plant diseases [25–28]. Invasive pathogens, though, pose new challenges for those responsible for control strategies, in part, owing to a lack of experience with novel pathogens and/or a lack of effective measures. Thus, the evolution of plant protection policy has been reactive, shaped initially by attempts to control, among others, diseases of potatoes in Europe [29]. While policy development has been based on a close

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Figure 1. Technocratic model.

relationship between policy makers and regulatory scientists, political, public and commercial pressures have shaped priorities and actions [30–32]. Governance of plant disease is thus based on diverse regulations put in place over a long period of time, without a strategic framework [33].

Different approaches prevail in different countries and regions of the world. A contemporary example is genetic engineering for disease resistance, which is now feasible for some pathogens, and is a technology available in many countries but restricted in Europe. At the same time, tighter rules around chemical pesticides will result in fewer pesticides being available to control many pathogens on crops such as cereals and potatoes [34,35]. The consequence is that disease control in Europe can depend less on technological fixes and must rely more on preventative actions to reduce and contain the risk of disease spread.

Through the 172 contracting parties to the International Plant Protection Convention (IPPC), there is international cooperation to inhibit the spread of plant diseases by regulating trade in potentially infected plants. Globally, more than 1000 pests and diseases are recommended for regulation [36]. Phytosanitary principles for the protection of plants, including the principle of managing risk through risk analysis, are described in international standards [37], but these presume a rational scientific approach to disease control which is not readily apparent in practice.

Disease problems are caused by both endemic and invasive, non-indigenous plant pathogens. This paper focuses on the latter and proposes an alternative, more inclusive approach to the systematic formulation of policies governing the spread of these invasive plant pathogens. We examine why a new approach—based on the notion of risk governance—may be beneficial and the importance of inter/multi-disciplinarity in achieving consensus [29,38].

## 2. POLICY FORMULATION AND RISK GOVERNANCE

Governance is a concept that has long assumed a position of theoretical importance in several fields of social science [39]. It is developed here to inform an alternative approach to plant disease control and management that counters the shortcomings of a narrowly scientific approach. Governance is often contrasted with the more established notion of government. While the latter refers to the formal institutional apparatus and decision-making processes of the state, the former is broader in scope and relates to the distribution of decision-making power within and outwith the state [40] (F. Mantino 2009, Rural development policy delivery and governance: typologies of governance models. Deliverable 3.2, RuDI workpackage 3, unpublished report). In Western Europe and other

advanced economies, over the past three decades, the state has lessened its direct control over economic sectors, while seeking to extend its regulatory and strategic reach, in part through new forms of governance [41–45]. These modes of governance are well established in the food sector and typically involve private or societal interests exerting degrees of control within the market economy [46]. However, the shadow of the state often looms large over these arrangements, typically providing some enabling or operating context for this governance [45]. Policy formulation and decision-making in food and other economic sectors are therefore characterized by ‘an interactive process of state and public laws and policy with private interests and actors’ [45].

Public policy is often focused at the national (state) level, but many food and natural resource policies (e.g. biodiversity [47]) operate at levels below the national level and, increasingly, beyond it. In the food chain, as in many other economic sectors, governance is largely preoccupied with the management of risk, both perceived and statistically formulated [48–51], and there is an extensive literature on risk and risk perception [52–54]. This paper draws in particular on Renn’s [39] work on risk governance, which translates the core principles of governance to the concept of risk and risk-related decision-making; it provides a useful heuristic device to examine the formulation of policy for plant health. Renn’s notion of risk governance includes the three generally recognized elements of risk analysis—risk assessment, risk management and risk communication—but additionally encompasses the legal, institutional, social and economic contexts in which risk is evaluated, as well as the involvement of the actors and stakeholders who represent them. As Renn (p. 2 [39]) puts it:

Risk governance looks at the complex web of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how management decisions are taken.

By combining the risk-relevant decisions and actions of both governmental and private actors, the notion of risk governance is particularly applicable to certain situations. Not least this is so for contemporary plant health and plant disease management, where there is no one authority for risk-management decisions; instead, the nature of the risk depends upon more or less coordinated decisions taken across a range of different stakeholders and contexts. Adapted from earlier work by Millstone *et al.* [55], Renn [39] outlines three governance models, each progressively more inclusive of actors along the horizontal axis of governance. The three models are:

— *Technocratic model*: where objective science is thought to directly inform policy making and

scientists are the best judges of risks and inform policy makers directly about what they should do. This is represented in figure 1.

- *Decisionistic model*: where policy making requires inputs other than science to make decisions, with other legitimate factors (such as political and economic objectives) needing to be accounted for. There is a division between the scientific aspects ('risk assessment') and political and value aspects ('risk evaluation and management'). This is represented in figure 2.
- *Transparent (inclusive) governance model*: where the interface between assessment and management is stressed, and science, politics, economic actors and civil society representatives play a role in both assessment and management. Particularly important in this model is the inclusion of pre-assessment (framing), including socio-economic and political considerations. This is represented in figure 3.

The distinction between governance models that allow for more or less involvement of relevant actors is instructive. The third model, of transparent governance, with its explicit intention to build more inter-disciplinary approaches to risk governance, informs the plant health model developed later in the paper.

### 3. STAKEHOLDER ANALYSES

Review of the applicability of Renn's three models in relation to plant health policy suggests that formulation in the UK has often complied with the technocratic model, with policy decisions traditionally based predominantly on advice from scientific analysis of pest risk [56,57]. The approach has not always been effective, and there are examples where reliance on a single source of authoritative advice has been associated with high profile failures, such as Dutch elm disease in Britain [18].

Renn's decisionistic model, requiring additional inputs besides conventional scientific ones, has been employed within plant health, such as the case studies described below of *Dickeya solani* on potatoes in Scotland and *P. ramorum* infecting a wide range of plant hosts. However, Renn's transparent governance model proposes a greater breadth and depth of stakeholder involvement, encompassing socio-economic and political considerations that go beyond the mechanisms used routinely in plant health policy. Transparent governance requires inputs involving a wider range of stakeholders and raises questions concerning identification of these stakeholder groups. To address this shortcoming and to identify those who could provide political, economic, environmental and technological perspectives of relevance to plant health policy, a 'growing risk' stakeholder analysis was undertaken.

A focus group comprising eight plant health professionals was used to collectively identify stakeholder groups with 'interest' and 'influence' over plant health issues [58]. More than 50 stakeholder groups were identified and mapped onto an interest/influence matrix

(figure 4). The mapping exercise, not surprisingly, shows a significant separation of coordinates between organizations. Organizations falling into the high interest/high influence quadrant ('key players') include the government department responsible for policy (Defra), those delivering plant health policy and those funding research into plant diseases. These stakeholders have traditionally had a role or influence in formulating plant health policy. Also in this quadrant are organizations representing crop/plant producers such as the National Farmers Union (NFU) and the Horticultural Trades Association. The quadrant with high interest/low influence organizations ('subjects') in plant health includes organizations representing professionals within the supply chain, such as the British Crop Production Association, consultants and research providers, such as the British Society for Plant Pathology, who have appropriate facilities and skills to deliver scientific data to inform policy making, but who have limited scope to determine the outcome. Organizations with low interest/low influence are largely those that experience limited impacts from plant health issues, whereas the quadrant with low interest/high influence ('context setters') includes some key decision-makers. The major food retailers (supermarkets), for example, are seen to be in a position to establish their own policies on the acceptability of quality attributes relating to plant disease, while leaving it to other stakeholders such as producers, to take the necessary actions or precautions. Some commentators suggest that, because of their high influence but low interest, context setters ought to be prompted to be more engaged in following through the consequences of their policies if risk responsibility is to be appropriately shared [58]. The challenges associated with fostering more inclusive models of consultation and policy formulation suggested by Renn thus become apparent, given the diversity of stakeholder interests and responsibilities for food and non-food crops.

### 4. STAKEHOLDER WORKSHOP

Representatives from most of the organizations shown in figure 4 were invited to a workshop, resulting in approximately 20 attendees (stakeholder organizations that attended are underlined, and are referred to below as workshop stakeholders). Many organizations categorized as having high interest attended the workshop, whereas no representatives from organizations in the high influence/low interest group attended.

Workshop stakeholders were presented with two contemporary examples of disease governance of non-indigenous pathogens in the UK and invited to comment on the process. The first case study involved *P. ramorum*, infecting a wide range of ornamental and wild species [59,60]; and the second case study covered *D. solani*, a new aggressive pathogen infecting potatoes causing black leg and tuber soft rots that emerged in Europe around 2005–2006. These case studies, based on recent consultations by the government, were analysed for involvement of stakeholders, their influence on decision-making, modes of communication between decision-makers and stakeholders, and policy outcomes.

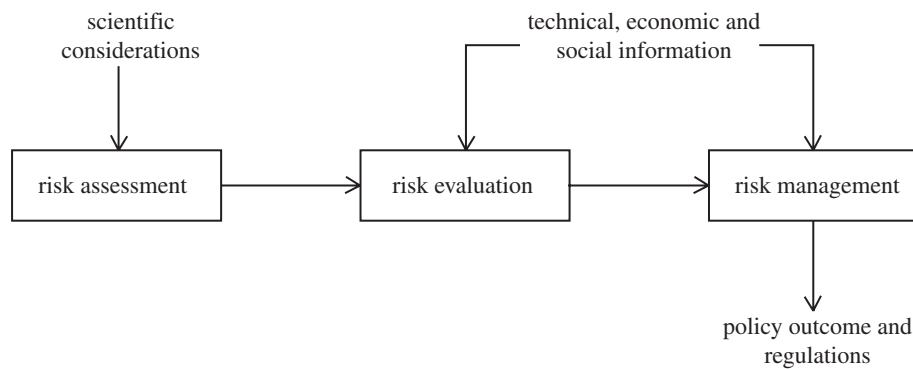


Figure 2. Decisionistic model.

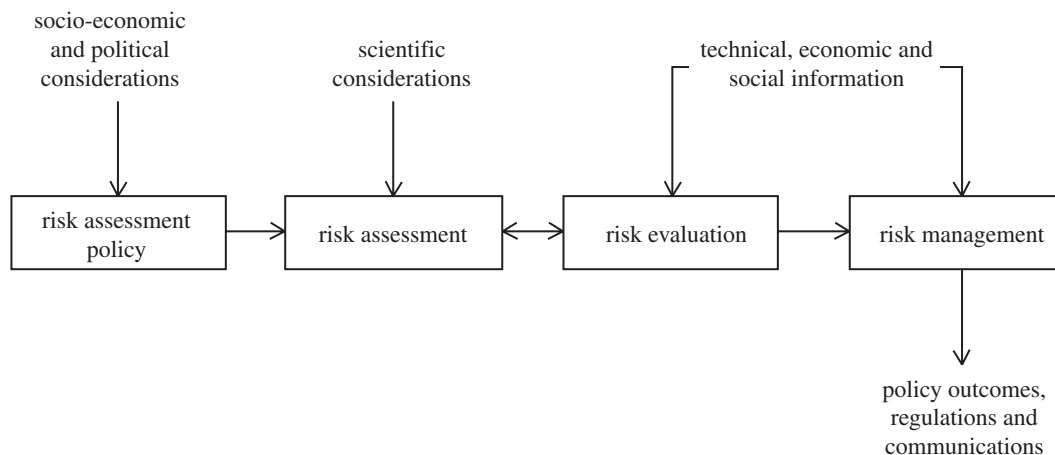


Figure 3. Transparent (inclusive) governance model.

### (a) *Phytophthora ramorum*

For *P. ramorum*, government held open national consultative meetings annually with the aim of informing a wide range of stakeholders of current disease situations and updating them on scientific and regulatory developments. These meetings provided an opportunity to take stock of the progress of the disease and official actions, but it was acknowledged that their value depended on the diversity of organizations attending. Meetings were not always able to attract key organizations that would have provided an opportunity for a well-informed and broader debate. In addition, regional meetings were organized in areas particularly impacted by the disease to explain local management actions and their implications, thus ensuring that effective local contacts were established between officials and key stakeholders. These were seen to be effective at addressing implementation issues. The meetings often led to longer term structures, some of which were led by stakeholders. An industry liaison group was also established for *Phytophthora*, to act as an informal sounding board for potential future actions; this comprised around six individuals encompassing both scientific and non-scientific expertise from key organizations, including the Horticultural Trades Association, NFU, Royal Horticultural Society and the National Trust.

Communication between government and stakeholder groups was seen as essential for successful implementation of policy outcomes. A website was established and used for scientific updates, meeting

reports, consultation papers and published literature. Effective use was also made of trade publications. The website acted as an accumulating warehouse of public information and provided a one-stop site for stakeholders.

An outcome of these consultations was that ministers concluded in February 2009 that more needed to be done to contain and eradicate *P. ramorum*. However, subsequent findings of *P. ramorum* on bilberry (*Vaccinium myrtillus*) in heathland and in Japanese larch (*Larix kaempferi*) plantations in Britain in 2009 both heightened the threat and broadened the disease context. The findings on Japanese larch [61] were the first observations on a commercial tree species, where areas of mass infection and spread to neighbouring host plants had been observed. The experience with sudden oak death in the USA would suggest that such a source of infection may undermine attempts to eradicate the disease in nearby nursery holdings. Such a situation emphasizes the futility of considering disease in crops and in wild species separately as if somehow these were different issues, with implications for the range of stakeholders to be involved. Following a European-wide pest risk analysis for the pathogen [62] and consultation with EU member states, the recommendations from the UK government for stepped-up action are currently (December 2010) awaiting a scientific opinion from the European Food Safety Authority, which is responsible for risk assessment in relation to plant health advice. Thus, while



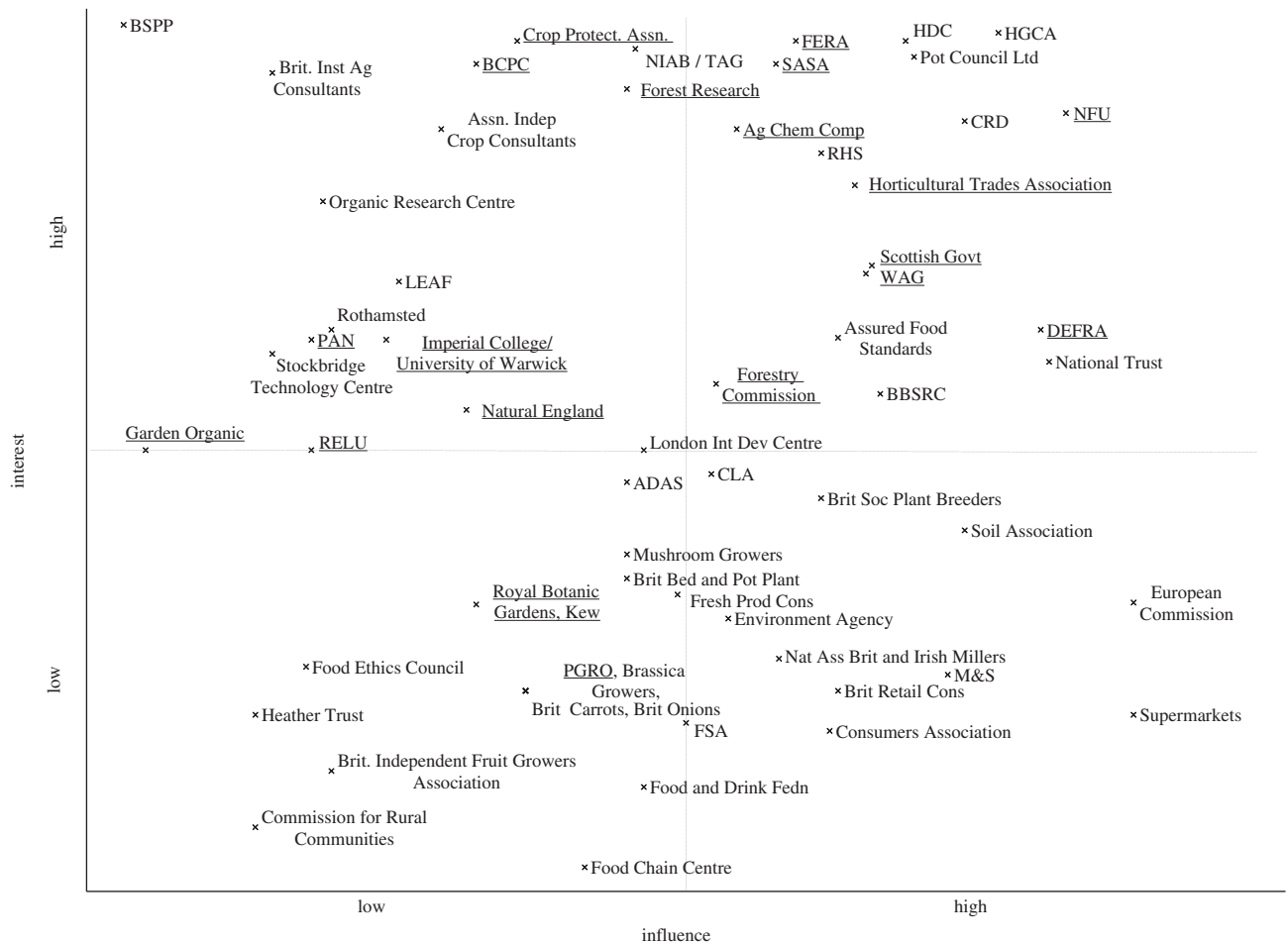


Figure 4. Interest-influence matrix for stakeholders for plant disease management/impacts. (Organization names underlined were those who took part in the stakeholder workshop described below). Acronyms for organizations as follows: BBSRC, Biotechnology and Biological Sciences Research Council; BCPC, British Crop Production Council; BSPP, British Society for Plant Pathology; CLA, Country Land and Business Association; CRD, Chemicals Regulation Directorate; DEFRA, Department for Environment, Food and Rural Affairs; FERA, The Food and Environmental Research Agency; FSA, Food Standards Agency; HDC, Horticultural Development Company; HGCA, Home Grown Cereals Authority; LEAF, Linking Environment And Farming; M&S, Marks & Spencer; NFU, National Farmers Union; NIAB/TAG, National Institute of Agricultural Botany; PAN, Pesticide Action Network; PGRO, Processors and Growers Research Organization; RELU, Rural Economy and Land Use Programme; RHS, Royal Horticultural Society; SASA, Science and Advice for Scottish Agriculture; WAG, Welsh Assembly Government.

considerable efforts have been made to broaden engagement and consultation in the UK, decisions on any change in the regulatory status of the organism (and hence the disease management practices that can be adopted) have yet to be made. This example poses the dilemma that emerging plant disease threats can sometimes change their character in a shorter time-frame than that allowed for by improved consultation and governance processes.

#### (b) *Dickeya solani*

For *D. solani*, stakeholder engagement was based on a formal consultation launched in December 2009 and included key national stakeholder organizations that were specifically targeted for their high interest/high influence status in the potato industry, such as the NFU, the British Potato Trade Association and the Potato Processors' Association. Expert involvement was focused predominantly on a single source of

expert knowledge—the Potato Council Ltd (the UK Levy Board for potato growers)—which was closely consulted on possible options and a scenario plan. Awareness was raised—through a website, trade conferences and, interestingly, through *YouTube*—to publicize interviews and presentations on *D. solani* to more than 5500 members of the supply chain, mainly growers. The outcome of this consultation was acceptance by the potato industry in Scotland of 'zero tolerance' to the presence of the pathogen. The consequence of this stance was seen as beneficial for the industry as a whole in maintaining the health of Scottish potatoes, but potentially punitive to individual growers who could suffer extreme financial losses if their crops were found to be infected.

Key components of the government consultations for both cases included engagement with stakeholders, involvement of an expert group and a communication strategy. Decisions on policy were made by the minister (on advice from a senior civil servant). However,

differences were apparent in the scale of stakeholder engagement (widespread and diffuse versus narrow and focused), the type and range of experts and the communication channels used, reflecting in part the perceived scale and complexity of the risk.

### (c) *Workshop analysis*

Based on reflections on the two case studies, workshop stakeholders made a number of general observations for policy, regarding the overall impacts to be addressed, the recognition of responsibilities and communication considerations. Summarizing the first of these, the wider impacts of a plant disease are: direct ones across the extended supply chain including, but not restricted to, profitability, wastage, product substitution, loss of confidence and safety; and indirect impacts on, for example, tourism or the rural economy. Recognition of these wider impacts might in turn entail consideration of impacts on an extended geographical scale (from the regional to the national, the European and beyond).

Such an encompassing perspective on impacts, secondly, implies widening the range and responsibilities of stakeholders. There was seen to be a requirement for wider engagement with a diverse group of experts, to supplement advice based on scientific risk analysis. This should include cost-benefit analysis, but also specialist expertise within appropriate sectors of the supply chain as demonstrated in particular by the *D. solani* case study. The most relevant expertise was generally thought to be found among organizations in the upper half of the stakeholder matrix shown in figure 4. Greater involvement of a range of expertise was seen to be central to an accurate assessment of risk and a broader acceptance of the legitimacy of that assessment. More extensive involvement was thought likely to lead to a greater propensity for responsibility sharing among stakeholders.

Thirdly, the plurality and diversity of stakeholders necessitated attention to communication strategy. Interaction between stakeholder groups and between stakeholders and policy makers was thought to need improving through ‘smarter’ communication using appropriate channels. In particular, engagement with those in the high influence/low interest quartile of the stakeholder analysis (figure 4) was thought likely to lead to more robust policy outcomes.

## 5. A NEW MODEL FOR PLANT HEALTH DECISION-MAKING?

Building on Renn’s transparent governance models [39], the stakeholder analysis presented in figure 4 and the deliberations of workshop stakeholders, a model has been proposed to improve plant health decision-making. An objective of the Plant Health Strategy for England is to establish the appropriate roles of government and other stakeholders. The outcome of this study reinforces this ambition and extends ideas for multiple interactions with stakeholders in policy decisions. Figure 5 puts forward a governance model that embraces both the key players who may need to interact (represented by the nodes) and the potential interactions/tensions between them (shown on the axes between nodes).

The model aims to capture the generic players and interactions that should form part of the decision-making process of plant health governance. It connects policy makers to those with the information to assess risks and impacts. A combination of biological and economic approaches in the modelling of (plant) disease risk has recently been demonstrated [63,64]. Economists provide estimates of the *values* attached to decisions for policy options. Pest risk analysts drawing on biological expertise quantify the *risk* of invasive/emerging species to crops and natural ecosystems. Information on the environmental impacts of disease can be provided to policy makers by environment scientists. *Prioritization* of options can be determined through interaction between various expert groups and assessment of *perceptions* of the various non-specialist groups that constitute interested ‘publics’. As our workshop demonstrated, stakeholder groups have critical roles in both identifying *impacts* of diseases across the food production and environmental supply chains and providing an opportunity to respond to policy options, following *consultation and engagement* with policy makers. Identification of relevant stakeholders can be achieved through methods outlined in this paper.

## 6. HINDSIGHT AND THE FUTURE OF REGULATORY ENGAGEMENT

There is a growing impression that the threat of invasive plant diseases is increasing owing to global trade, travel, transportation and tourism [65,66]. For example, four new diseases of potato entered Britain between 1970 and 2004 [67] and, most recently, a new strain of the bacterial pathogen *Dickeya* spp. has been detected [68]. Other recent challenges to UK biosecurity have included the introduction of *P. ramorum* and *Phytophthora kernoviae* [59,69], infecting a wide range of ornamental and wild plant species [70]. To help cope with such threats, policies have been developed at international, national and regional levels. Whereas national and regional policies aim to prevent the introduction and spread of pathogens into and within a country, thereby protecting national industries including their export activities, international policies are designed to prevent the distribution of pathogens among participating countries [36,71].

Development of these policies has been the responsibility of national plant health organizations. In December 1976, a harmonized European Community regime was created to regulate trade for plant health purposes through the Plant Health Directive 77/93/EEC [72]. Interpretation and implementation of these regulations were set out in the 2005 Plant Health Strategy for England (PHS) [73], which outlines the role of government and stakeholders. This strategy also outlines the role of consultation for stakeholder groups which is ‘usually in the form of a Pest Risk Analysis published on the (Fera)<sup>1</sup> website’, and an aspiration to develop a communication strategy with stakeholders. In the past, policy has too frequently been built on the needs of single sectors to the neglect of wider effects [74–76]. Similar limitations have been

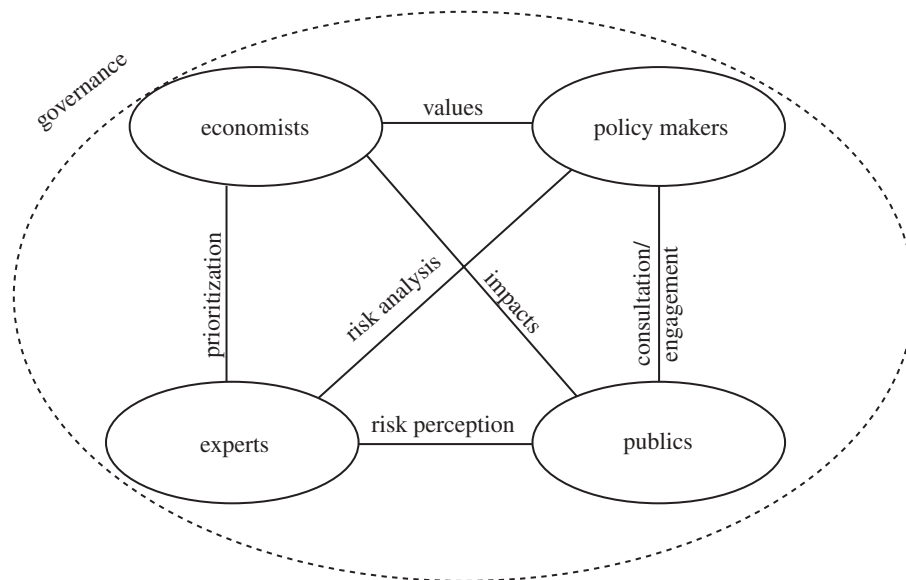


Figure 5. A model for multi-dimensional plant health policy formulation.

addressed in developing environmental policy through involvement of a greater range of expertise [36].

There is recognition that a science-centred basis for decision-making is a necessary but not sufficient condition for improved plant health governance and management of plant disease. Engagement with and understanding the perceptions and attitudes of the various parties affected by policy decisions in relation to plant health can be as much evidence-based from a social science as from a natural science perspective. Likewise, the implementation and practice of disease management as a consequence of policy decisions require a much broader engagement and understanding of farmers/growers' perceptions and attitudes to risk, especially where such decisions are seen to be made at several removes from their own circumstances. Advisors and consultants have long recognized this. A challenge for the approach we recommend arises from the question: who exactly are the various parties (the stakeholders) that should be involved with this type of engagement? This we believe can be addressed in part by the analysis presented in this paper.

Widespread consultation by government can too easily be used as an alternative to meaningful engagement, and events can sometimes outpace the consultation. For *P. ramorum*, the public consultations have led to wider information exchange, improved communications at the local level and input into the types of research initiatives that should be funded to combat the disease. However, the continuing development of the disease, especially outwith the nursery trade, has led to no decisions being taken to change the regulatory status of the organism, i.e. whether the eradication policy can be relaxed. For *D. solani*, consultation with the potato industry and supply chain resulted in the introduction of a zero tolerance policy for this pathogen in Scotland. The first use of legislation in 2010 led to the destruction of one crop with no compensation for the affected grower. Early indications suggest that the majority of stakeholders

support this strong action as necessary to protect the Scottish potato seed and ware industries.

Our model, although not a blueprint for consultation and engagement, demonstrates characteristics that we believe will strengthen the process for effective plant health policy formulation. Use of a wider science base and focused appropriate expertise, and identification of key stakeholders bringing greater involvement (and acceptance of outcomes), will help ensure that government understands the issues and implications of policy and that implementation is well grounded in reality with consequential shared responsibility. This, in turn, requires a form of risk governance that extends beyond recognized elements of risk analysis, to incorporate the wider socio-economic context within which risk is evaluated [39], and involves collaborative decision-making across a range of different stakeholders. The transparent (inclusive) governance model advocated by Renn [39], seems to be particularly appropriate to guide the formulation of plant health policy. It has been used here, in conjunction with stakeholder identification and case study analysis, to propose a model for multi-dimensional plant health policy.

Our model (figure 2) articulates the need for collaborative decisions to be taken across a range of different stakeholders. The case studies suggest that choice of stakeholders is central to timely and acceptable decision-making as perceived by the end-user community. Less emphasis should be placed on the selection of representative stakeholder groups and more on the use of individuals/organizations that will engender trust among end-users. Consideration of this model could lead to greater effectiveness in policy formulation for plant health.

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## ENDNOTE

<sup>1</sup><http://www.fera.defra.gov.uk/plants/plantHealth/pestsDiseases/prTableNew.cfm>.

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