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Climatic Suitability Risk Mapping Decision Support Scheme

Please note that annexes mentioned in this document can be downloaded through hyperlinks included in the table of annexes at the end.

Objectives

This decision support scheme (DSS) is intended for use by risk assessors who have already undertaken a qualitative assessment of the suitability of the climate for pest establishment. The DSS is designed to help assessors:

1. determine whether it is appropriate to model and map climatic suitability in the PRA area based on the extent to which:
    a. climatic suitability (or unsuitability) is already self-evident so that the extra resources needed for climatic modelling and mapping may not be required;
    b. there is sufficient relevant information to conduct a quantitative analysis of the climatic suitability of the PRA area for pest establishment using models and mapping software;
2. justify why, if not done, the modelling and mapping of climatic suitability has not been undertaken;
3. evaluate the type, quantity, accuracy, reliability and precision of available pest climate response and distribution data and relate this to the performance of the different modelling and mapping methods;
4. distinguish between the different methods by comparing their general usability, functionality, applicability and relationship to ecological processes;
5. link climatic suitability risk maps to other factors determining:
    a. the area suitable for establishment, e.g. hosts
    b. the endangered area, e.g. where plant hosts of high economic or environmental value occur.

Relationship to the EPPO Decision Support Scheme for PRA

The climatic suitability risk mapping DSS is not designed as a stand-alone procedure. It is linked to the EPPO DSS for PRA[1] and requires responses to question 3.11 which addresses climatic suitability:

"**Based on the area of potential establishment already identified, how similar are the climatic conditions that would affect pest establishment to those in the current area of distribution?**"Although the climatic suitability DSS links directly to question 3.11 in the EPPO DSS for PRA that provides a qualitative assessment of the suitability of the climate for establishment, the outputs may also be useful in (a) assessing spread, impacts and the timing of pest threats and (b) defining the endangered area.

[1]Accessible here: http://capra.eppo.org/

As noted in the climatic suitability DSS (see Stage 1, Question 1.5), the decision to spend the time and resources on modelling and mapping the climatic suitability of the risk assessment area is not only based on whether the suitability is already obvious or whether a sufficient amount of relevant information is available but also on the importance of the pest in terms of its likely impacts and the severity of management measures. If this decision is unclear it is recommended that a rapid, preliminary PRA is completed before using this DSS to assess whether the potential impacts are of sufficient magnitude or the answers sufficiently unclear as to justify the effort of a full evaluation. This is a general principle: there is rarely a need to conduct additional detailed quantitative analyses, e.g. risk modelling and mapping, when conducting PRAs for pests posing a minor risk.

Introduction to the Climatic Suitability Pest Risk Mapping Decision Support Scheme

The DSS consists of a series of questions in six stages. Supporting information and examples are provided.

The DSS currently has five stages that are designed to answer five questions:

Stage 1: *"Is it appropriate to map climatic suitability?"*

> Stage 1 is designed to ensure that risk assessors carefully consider whether it is appropriate to devote the time and resources to mapping climatic suitability when the assessment is already clear-cut or the information available is likely to produce results that are difficult to interpret and are therefore unhelpful to the assessment of pest risk.

Stage 2: *"What type of organism is being assessed and what are the key climatic factors affecting distribution?"*

Stage 3: "*How much reliable information is available on the key climatic factors affecting distribution?"*

Stage 4: "*What category of location data is available?"*

> Stages 2-4 are used to review the information available on a pest's climatic responses and its distribution.

Stage 5: "*Based on the type of organism, the information available on its climatic responses and the category of location data, how well is each climatic mapping method likely to perform*?"

> Stage 5 outlines the implications of using each method based on the information assembled in stages 2-4.

An example (*Drosophila suzukii*) is provided to show how the DSS can be applied.

The Climatic Mapping Decision Support Scheme (DSS)[2]

Before using this DSS, please answer question 3.11 in the EPPO PRA scheme:

"Based on the area of potential establishment already identified, how similar are the climatic conditions that would affect pest establishment to those in the current area of distribution?"

not similar, slightly similar, moderately similar, largely similar, completely similar

Level of uncertainty:	**Low**	**Medium**	**High**

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Stage 1: "Is it appropriate to map climatic suitability?"

Please answer the following four questions.

1.1 Based on the response to Question 3.11, is there low uncertainty that the climate in the area suitable for establishment is completely or largely similar to the climate where the pest is currently present?

> *Note:* Answer "yes" if the climate is completely or largely similar to areas where the pest is already present, especially if it is widespread and abundant. This is particularly likely to be true if the species is present and common in a neighbouring country with a similar climate or the climatic responses of the pest and the host species that occur in the PRA area are known to be very similar. Climatic mapping may also not be required if the PRA area has a relatively uniform climate or the pest is known to be able to adapt to a very wide range of climatic conditions. For example, pests that are widespread and common in one area with a Mediterranean climate, e.g. California, are likely to find at least part of other areas with a Mediterranean climate, e.g. in Europe, climatically suitable for establishment. The global and regional maps of Köppen-Geiger climate zones, hardiness zones and growing degree days can be used to help answer this question (see guidance on answering question 3.11 in the main qualitative scheme, also available as Annex 4).

If Yes: Mapping climatic suitability may not be needed unless it is important to highlight areas where the climate is particularly suitable, e.g. to identify the endangered area.
Provide a justification for not mapping climatic suitability & Return to the PRA Scheme

If No or there is a need to highlight areas where the climate is particularly suitable:
Mapping may be appropriate
Provide a justification & Go to Question 1.2

[2] Draft answers have been provided for *Drosophila suzukii*, a pest of soft fruit, native to eastern Asia.

Example
Drosophila suzukii: **NO**
Although the PRA area where hosts are present has a very suitable climate for establishment, it is appropriate to undertake more detailed climatic mapping to determine whether the northern limit to the potential distribution can be identified with more accuracy.

1.2 Based on the response to Question 3.11, is there low uncertainty that the climate in the area suitable for establishment is not similar or slightly similar to the climate where the pest is currently present?

Note: Answer “yes” if the climate is not similar or slightly similar to areas where the pest is already present, e.g. a pest with a tropical distribution that has never been found in protected conditions being assessed for a PRA area with a temperate climate. This is particularly likely to be true if the climatic responses of the pest and the potential host species that occur in the PRA area are known to be very different. Even if the climate is very unsuitable, climatic risk mapping methods may still be employed to identify areas where transient populations might occur.
This question is particularly relevant if, in the categorisation stage of the PRA, you have answered UNCERTAIN to question 1.16: “Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?”

If Yes: climatic mapping can be used to confirm such a conclusion but the time and effort required may not be appropriate if the evidence is very clear.
Provide a justification for not mapping climatic suitability & Return to the PRA Scheme

If No: Mapping may be appropriate
Provide a justification & Go to Question 1.3

Example
Drosophila suzukii: **NO**
The climate is suitable in the PRA area.

1.3 Does the species spend a large part of its life cycle experiencing climatic conditions significantly different to those measured at weather stations?

Note: Consider situations where climate, as measured at weather stations, is likely to be dissimilar to the microclimate inhabited by the species because it undertakes much of its life cycle in protected or irrigated cultivation, submerged aquatic habitats, the soil, thick woody plant tissue or vectors. In such microhabitats, the microclimate may still be influenced by the external climate but daily and seasonal conditions are less likely to vary. For example, mound-building ants may experience constant temperatures which are approximately the same as daily average air temperatures (Sutherst & Maywald, 2005).The survival of species overwintering on the soil surface may be greater in areas with predictable snow cover that insulates the ground from extreme temperature minima. Arthropods may exhibit behavioural thermoregulation, e.g. by moving to more favourable microhabitats, aggregating into colonies or forming structures such as silken webs. Some organisms have stages in their life cycle when the climate has little influence, e.g. resistant fungal spores and insects in winter or summer diapause.

If Yes: climatic mapping may be irrelevant or the results may be difficult to interpret
Provide a justification for not mapping climatic suitability & Return to the PRA Scheme

If No OR Uncertain: Mapping may be appropriate
Provide a justification & Go to Question 1.4

Example
Drosophila suzukii: **NO**
However, adult overwintering in very cold areas may only occur in favourable refuge habitats, e.g. waste associated with human habitation. During development the species is protected to some extent within the fruit.

1.4 Are the climatic limits to the distribution very unclear or very difficult to infer because the distribution of the pest is very poorly known, the pest is known to be spreading very rapidly or its distribution is extremely dependent on the distribution of factors other than climatic conditions?

Note: The distribution of the pest may be very poorly known if there are very few unambiguous current records in scientific databases and the literature. Factors other than climatic conditions that can significantly affect distribution include, for example, the presence of hosts, specific habitats, vectors, geographical barriers (such as the sea or mountains), competitors, natural enemies, pest or crop management measures, e.g. irrigation. In such situations, climatic mapping may only indicate the minimum area likely to be climatically suitable for the pest at risk and interpretation of the risk maps may therefore be problematic.

If Yes: climatic mapping may provide results that are difficult to interpret
Provide a justification for not mapping climatic suitability & Return to the PRA Scheme

If No OR Uncertain: Mapping is likely to be appropriate

Provide a justification & Go to 1.5

Example *Drosophila suzukii*: **NO** The species distribution is sufficiently well known.

1.5 Decide whether to model and map climatic suitability

If your answers have led you to this point, modelling and mapping climatic suitability is likely to be appropriate. Take into account the following notes and:

GO TO STAGE 2

Note: It is important to recognise that climatic modelling and mapping methods may require significant time and effort. The availability of suitably trained and experienced modellers is an important factor in deciding whether to model and map climatic suitability. Experience is particularly important when modelling and mapping species for which you have answered "uncertain" in questions 1.3 or 1.4. In some cases, experienced modellers may be able to produce useful and informative risk maps even when the answer is "yes" to questions 1.3 and 1.4.

Climatic modelling and mapping is likely to be a particularly useful addition to PRAs in situations where:

- The climatic suitability of the PRA area is unclear, e.g. because the pest has not invaded neighbouring countries or other areas with similar climates or because there is no clear relationship between the climate responses of the host and the pest;
- The climate is marginal for establishment and there is a likelihood that establishment will not be possible under current climatic conditions;
- The PRA area includes a large variety of different climates, only some of which could be suitable for establishment. If the PRA area is small and has a relatively uniform climate, climatic risk maps are likely to show that the risk is similar everywhere within the PRA area.
- Impacts, even at low population densities, could be severe;
- The establishment potential of a pest or the imposition of phytosanitary measures to particular parts of the PRA area is likely to be challenged
- Climatic risk models and maps already exist and need to be reinterpreted with different parameter values, climatic datasets and methods or extended to other areas and time periods.

If it is decided not to model and map climatic suitability, the answers to Stage 1 can be used to justify this decision.

Stage 2: What type of organism is being assessed and what are the key climatic factors limiting its distribution?

Please fill in the following two tables based on the type of organism and the importance of the climatic factors that will affect its distribution in the PRA area. If the climatic factors listed in the second table are incomplete, too broad or relate to a different time period, additional factors can be added (as “Other”). In Stage 3, the availability of the key climatic factors limiting distribution is assessed in more detail.

[The tables have been filled in for a diapausing arthropod (*Drosophila suzukii*) in the EU for which the completion of its life cycle is principally dependent on summer temperatures above its minimum threshold for development.]

Arthropod	**Nematode**	**Plant**	**Virus or Viroid**	**Bacteria**	**Fungus & Fungal-Like Organisms**	**Other**
✓						

Climatic Factor	**Note**	**Rating**	***Drosophila suzukii***
Winter Temperature)	*Consider whether the species distribution is known to be limited by minimum winter temperatures and whether the species can survive low temperatures by diapausing or forming cold-resistant stages (e.g. spores, pupae, seeds and bulbs.*	++	*Drosophila suzukii* can persist in areas with extreme winter temperatures (hardiness zone 4 (-35°C)) but low winter survival is thought to occur in these areas in Hokkaido with populations maintained by survival in habitats associated with human habitation (see PRA[3]).
Summer Temperature	*Consider whether the species distribution is known to be limited by summer temperatures, particularly whether it may be difficult for it to complete its life cycle due to insufficient degree days above its minimum temperature threshold. Temperature maxima may be limiting in some areas.*	+++	The minimum heat sum over the summer growing season (growing degree days) for *D. suzukii* to complete one generation are available widely in the PRA area but play a key role in determining the latitude and altitude limits to the distribution. Summer temperatures above 30°C are considered to cause sterility or death, but the presence of this species in warm areas of the world (e.g. Florida) indicates that

[3] This will be available on the EPPO website in due course: http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_documents.htm

			this may be less important than the literature suggests (see PRA).
Rainfall	*Rainfall is particularly likely to be critical for pathogen infection and plant survival (with indirect effects on insect populations). Extreme rainfall events may affect invertebrate populations.*	-	
Humidity	*Humidity plays a particularly important role in pathogen life cycles. For invertebrates and plants, humidity may also significantly affect survival depending on the ambient temperature. Invertebrates can avoid desiccation by diapausing, pathogens by forming drought resistant spores, and plants by using seeds, bulbs or losing their leaves.*	-	
Leaf Wetness	*Leaf wetness duration is particularly important for infection by foliar plant pathogens.*	-	
Soil or substrate temperatures	*Consider how much of the life cycle is spent in the soil or other substrates (e.g. aquatic habitats or thick woody plant tissue – see Stage 1 question 1.3). Soil temperatures may be correlated with average daily air temperatures depending on soil depth, plant cover, type, moisture, drainage, etc.*	-	
Soil or substrate moisture	*Soil moisture is likely to be particularly important for plants. Pathogen and invertebrate life cycles may also be affected through their plant host.*	++	*D. suzukii* requires host plants that will not tolerate soil moisture below permanent wilting point for prolonged periods. This will prevent it from persisting in xeric environments unless irrigation is practised.
Other (please specify)	*Other abiotic factors include, e.g. solar radiation, snow cover and late spring frosts.*	-	

Rating	Description
-	Climatic factor not directly relevant to species distribution
+	Minor factor determining species distribution
++	Important factor determining species distribution
+++	Critical factor determining species distribution

Stage 3: How much information is available on the key climatic factors affecting distribution?

[The table has been filled in for a diapausing arthropod (*Drosophila suzukii*) in the EU for which the completion of its life cycle is principally dependent on the effective heat sum during summer necessary for completing development. The comment column needs to be completed.]

Climatic Factor	Known?	Uncertainty	*Drosophila suzukii*
Temperature: minimum threshold for development	++	low	The minimum threshold for development is considered to be 10ºC with an egg to adult development time of 254 degree days (Coop, unpublished) who analysed development data from Kanzawa (1936 & 1939) and Sakai and Sato (1996). The 254 degree days required for development is supported by Uchino (2005) who calculated that *D. suzukii* needed 250 days for development at Chiba (near Tokyo) in 2003. The studies by Kanzawa (1939) were based on only two temperatures (15ºC and 25ºC) and with only 10 individuals at 15 ºC and 7 individuals at 25ºC. The Sakai and Sato (1996) paper has not been obtained and so we cannot verify the experimental conditions or confirm whether the experiments were actually undertaken on *D. suzukii* (the paper is apparently based on *D. pulchrella*, a very closely related species). Damus (unpublished) used 9.1ºC for the minimum threshold for development and 268 days for the completion of development. Kimura (pers. comm., 2010) confirms that a

			base temperature of 10ºC with an egg to adult development time of 250 degree days is appropriate for *D. suzukii*.
Temperature: optimum for development	+	medium	
Temperature: maximum threshold for development	++	low	Adult activity is reduced above 30ºC (Kanzawa, 1939) Damus (unpublished) used a higher development threshold of 32ºC. *Drosophila suzukii* is known to move to higher altitudes in summer but this is to take advantage of additional resources rather than an avoidance of summer heat (Mitsui *et al.*, 2010). Kimura (2004) found that the lethal hot temperature (LT) that killed 25, 50 and 75% of the population following the 24 hour exposure of male and female *D. suzukii* was between 31.6ºC and 32.9ºC. Smyth (pers. comm., 2010) found that at 32ºC adults cannot emerge from pupae and males become sterile and that adults die after 3 hours of exposure to temperatures higher than 35ºC.
Temperature: degree days to complete life cycle	+++	low	See comments for minimum temperature. The degree day development threshold needs to be related to the period when fruit becomes naturally available (usually mid-summer in northern Europe), although, like D. melanogaster, the species spends winter and spring in refuse associated with human habitation.
Temperature minimum survival	+	medium	Below 5ºC adults are motionless (Kanzawa, 1939). Kimura (2004) found that the lethal cold temperature (LT) that killed 25, 50 and 75% of the population following the 24 hour exposure of male and female *D. suzukii* was between -1.6ºC and 0.5ºC. However, it is difficult to extrapolate

			these data to an assessment of overwintering because insect cold tolerance is known to be highly dependent on the temperature conditions exposed to insects prior to the experiment and the rate of cooling. Kimura (pers. comm., 2010) considers that in Hokkaido, the severe winter causes high mortality but that the population survives in habitats associated with human habitation and is augmented by entry with fruit imports from elsewhere in Japan.
Rainfall: minimum annual total	N/A		
Relative Humidity optimum	N/A		
Leaf Wetness duration	N/A		
Soil temperature	N/A		
Soil moisture	++	High	D. suzukii requires host plants that will not tolerate soil moisture below permanent wilting point for prolonged periods. This will prevent it from persisting in xeric environments unless irrigation is practised.
Other	N/A		

Note:
The ability to apply climatic modelling and mapping programs for a particular species depends on the extent to which its climatic responses for development and survival:

- can be inferred from its current distribution.
- are available from field or laboratory experiments;
- can be calculated or inferred from field studies at known locations where climatic factors have been recorded;

Even for the very few species that have known climatic responses obtained from experiments in the laboratory, evidence from field studies and knowledge of their current distribution are still important because

- Climate factors may limit the distribution of a species indirectly.. For example, *Dothistroma pini* is a plant pathogen that forms cold tolerant spores that can be safely stored at -80 °C, but it’s poleward range appears limited by the ability of its host plants to tolerate temperatures below -30 °C (Watt *et al.* 2009)

- laboratory experiments, often conducted under constant temperatures, cannot emulate field conditions in which temperature and other climatic variables fluctuate and interact.
- the laboratory data may have been generated from small sample sizes and the genetic composition of the populations may be different from the potential invaders considered by the PRA.

Rating	Description
N/A	Climatic factor not directly relevant to species distribution
-	No information
+	Very little data or high uncertainty on climatic responses. Information often inferred from field studies or related species.
++	Data from one study or from more than one study but with no clear consensus.
+++	Information based on detailed experiments consistently supported by more than one study.

Uncertainty	Description
low	Low Uncertainty
medium	Medium Uncertainty
high	High Uncertainty

Stage 4: What category of location data is available?

Select one or more of the following location data categories.
See diagrams in Annex 2B to help distinguish location categories.

[The table has been filled in for *Drosophila suzukii.]*

N	Pest location data category	*Notes*	Implications for modelling	Category Choice	*Drosophila suzukii*
1	**Native range locations only**	*This category refers to situations where the distribution in its native range is well known but the species may not have invaded new areas or locations in the new areas are unknown.*	The native range of a species represents its *realised* niche, which may be more climatically conservative that its *fundamental* niche. A species' realised niche includes the negative effects of its natural enemies, which can reduce its population growth rate and reduce its ability to persist in marginal habitats. For models built using only the native range, the data should be considered to be conservative unless supported by ecophysiological data that indicate that it is persisting in all areas that it can tolerate. Natural enemies include parasites, parasitoids, predators and competitors affecting the pest or its host(s).		
2	**Native plus exotic range locations**	*In this category, the distribution of the species in both the native and*	Where we have knowledge of a species in its native and its exotic range, we may be able to detect evidence of climatic range expansion due to release from the	✓	Some knowledge of the native distribution in China. Unclear whether the species is native in

		invaded region is well known.	effects of its natural enemies. This effect is most likely to be observed when and where climatic resources are most abundant. We can be most confident that we are seeing a species expressing its full range of climatic tolerance where it has spread in an exotic range without encountering geographic dispersal barriers and its distribution appears to be at dynamic equilibrium. The resulting distribution may still be conservative, but this is the best field-based data that we can usually draw upon.		Japan. Locations available from exotic locations in North America and Europe.
3	**Locations biased to the periphery of the range**	*The periphery of the range is similar to the zone of occasional abundance defined by Hill (1987[4]) where climatic conditions are less suitable, e.g. cooler or drier, with greater variation in suitability than in the centre of its range. Here, the population may be kept low by*	Peripherally-biased species distribution data will not affect those techniques that utilise the outer ranges of a species climatic tolerances to describe its range. This includes the climate envelope models (e.g. Bioclim and Habitat) and the niche models (CLIMEX Compare Locations). Floramap will probably indicate the core suitability appropriately. Other regression-based models will tend to under-represent the risk in the core suitability area and over-represent it in the marginally suitable habitat.		

[4] Hill DS (1987) Agricultural Insect Pests of Temperature Regions and their Control. Cambridge University Press. Cambridge. Page 21

		climatic conditions and the pest only rarely causes significant damage.			
4	**Locations biased to the centre of the range**	*The centre of the range is similar to the (endemic) zone of natural abundance (Hill, 1987) where the pest is always present often at high density. Here climatic conditions are relatively favourable and the species is regularly a pest of some importance.*	All models that rely solely upon the species distribution data to infer climate suitability will underestimate its potential distribution. Models built using ecophysiological observations can use the distribution data as a fuzzy validation. CLIMEX Compare Locations can still use climate responses and some knowledge of biology to estimate the range periphery.	✓	Periphery in mainland China unknown. Hokkaido, British Colombia and northern Italy represent the current northern limits.
5	**Few location data points**	*The pest has been recorded at only a few locations.*	All models that rely solely upon the species distribution data to infer climate suitability will underestimate its potential distribution. Models built using ecophysiological observations can use the distribution data as a fuzzy validation. CLIMEX Compare Locations can still use climate responses and some knowledge of biology to estimate the range periphery.		

6	**Very few location data points**	*The pest has been recorded at very few locations.*	All models that rely solely upon the species distribution data to infer climate suitability will underestimate its potential distribution. Models built using ecophysiological observations can use the distribution data as a fuzzy validation, CLIMEX Compare Locations can still use climate responses and some knowledge of biology to estimate the range periphery. Climate similarity (e.g. CLIMEX Match Climates and Domain) and Climate Envelope models (Bioclim and Envelope Score) may usefully indicate broad geographic areas of concern. These results should be considered as conservative if high thresholds are used. Using low thresholds with climate similarity and envelope models should be avoided, as it is just as likely to include false positive locations as it is to infill suitable locations (Csurhes & Kriticos 1994)		
7	**Erroneous locations included**	*It is known that the list of pest locations includes some that are erroneous but these cannot be directly identified and deleted.*	Erroneous locations have the potential to significantly bias the results of the climatic modelling, resulting in a model that overstates the geographic risk. Ideally, location records should be scrutinised to check that they represent an established population, although this is not always easy or possible. Few models provide useful diagnostic		

			techniques to identify climatic outliers in the species distribution data. Diva GIS provides a set of graphical tools to visualise climatic outliers. CLIMEX Compare Locations confronts the modeller with the challenge of fitting outlying points with biologically reasonable climatic response functions. The outputs of phenology models could be checked for locations when a location point appears unreasonable. If a distribution point requires unreasonable parameter values, a range of techniques are available to explore whether this is due to geocoding error, a favourable land use overcoming climatic limitations or another factor.		
8	**Locations influenced by land use (e.g. irrigation practices) and other non-climatic factors**	*The distribution is influenced by non-climatic factors apart from host distribution (see Stage 1, question 1.4). Host distribution is considered in category 10. It includes situations where the pest distribution is constrained by*	Models built solely using distribution data may overstate the geographic risk, if the non-climatic range-influencing factor is promoting the species' persistence in a location. If the land use is also present in the PRA area in a similar climate then this may be an appropriate indication of risk. Reviewing the biology and ecology of the pest species should provide an indication of whether or not land use factors will be important. It is possible to model the distribution with and without the presence of the land use factor. Models	✓	Northern limits in Hokkaido affected by the sea and by mountains in British Colombia and northern Italy

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		major geographical features, e.g. mountain ranges and the sea, and expanded by crop management measures such as irrigation.	that include consideration of ecophysiological data may identify these outliers, enabling their effect to be gauged (e.g. CLIMEX Compare Locations). Where this type of effect is suspected, the land use should be confirmed through other sources (e.g. by contacting local experts or consulting land use datasets), or by using a model to simulate its effect (e.g. the irrigation scenario in CLIMEX Compare Locations or a temperature modification scenario in a phenology model). Southern hemisphere distributions for terrestrial species may be constrained by a lack of land extending into high latitudes. Competition (e.g. from species in the same genus) may preclude a species from expressing its full climatic range potential in areas where the natural enemies are not present. In this case, all models that rely solely upon the species distribution data to infer climate suitability will underestimate its potential distribution. Regression-based models will usually provide conservative results when trained on location data affected by this form of bias. Models informed by ecophysiological observations may identify and overcome this problem. The problem may become apparent if the		

			model requires parameter values that are excessively conservative for the organism type being considered.		
9	**Locations influenced by seasonal invasion**	*The locations include some points from areas where the species is only transient (not established) and its presence is dependent on seasonal invasion.*	Models may overstate the risk if ephemeral (transient) distribution records are treated as if they represented established populations. Suspicious points may be identified by considering ecophysiological data. If the species needs to survive excessively stressful climatic conditions through part of the year at a location and it has no obvious resting stage (e.g. pupa or seed) or refugia in the vicinity and there is a likely source population within a reasonable dispersal distance then it may be likely that the record represents a transient population.	✓	In northern areas with very cold winters, overwintering is considered to occur in habitats associated with human habitation from which the fly spreads to surrounding areas.
10	**Distribution constrained by hosts**	*The pest's current distribution is limited to areas where the host is present despite other areas being known to be climatically suitable.*	All models that rely solely upon species distribution data to infer climate suitability will underestimate its potential distribution. Producing a map of host and pest distribution may help to determine whether this is a factor. Models may also underestimate the pest risk if other hosts are present in the PRA area, and they are able to inhabit a wider climatic range than the host in the training dataset. A requirement for biological reasonability in parameters may overcome this problem.		

11	**Regional distribution data only**	*Precise location data based on latitudes and longitudes (or named locations from which latitudes and longitudes can be derived) are unavailable and the distribution is only available at the regional (state, province, department, county, etc) level.*	Fuzzy input data can be used to inform a similarly fuzzy estimate of pest risk. Be aware that country records can both over-estimate, as well as underestimate risk if a country is not noted as being inhabited by a species because its presence is of insufficient consequence or it has insufficient scientific infrastructure, etc.		
12	**Locations influenced by climate change**	*The location dataset includes data from areas that have only recently become suitable due to climate change. Where historical data are available, it is possible that climatic conditions are no longer suitable at these locations.*	A mismatch of climate data and distribution records can result in either over- or under-estimating pest risk. Modellers should carefully consider the effect of recent range expansion or contraction due perhaps to climatic warming, and the effect that this may have on the perceived pest risk. The time period represented by the climatic dataset used in modelling will influence the model predictions.		

13	**Location category unknown**	*Location data are available but cannot be assigned to categories 1-12 because too little is known about what they represent.*	Extreme caution should be exercised with using these data.		

Stage 5: Based on the type of organism, the information available on its climatic responses and the availability of location data, *how well is each climatic mapping method likely to perform in assessing current and future pest risk*?

Objectives of Stage 5:
In this stage, the likely performance of each climatic mapping method is compared based on the information summarised in Stages 2-4. Armed with this knowledge, risk assessors should be able to judge how well each model is likely to perform for the pest and for the area being studied and then make an appropriate selection taking into account other more general attributes of each model, e.g. usability and functionality.

5.1 Summarise the information obtained in Stages 2-4 in the following table:

Organism	Limiting climate factor	Limiting climate factor responses known?	Location Data Category
Arthropod	Summer temperature sum Winter temperature minima Soil moisture	++ + ++	2. Native plus exotic locations 4. Locations biased to the centre of the range 8. Locations influenced by land use (and other non-climatic)factors 9. Locations influenced by seasonal invasion

[This table has been completed for *Drosophila suzukii* in Europe.]

5.2 *Refer to the Table in Annex 2C that provides a summary of model performance based on climate response information and location data.*

This table does not indicate whether one model is better than another in estimating potential distribution. It compares the susceptibility of each modelling system to problems that can arise from different input data quality issues. It is intended as a cautionary guide to alert the assessor to data quality issues that can arise with using each model system. It is important to note that, in practice, input data may suffer from more than one type of bias or data quality issue at the same time. The assessor should be vigilant to these issues and seek to understand the behaviour of the selected modelling system sufficiently well as to understand signs that the input data may be suffering from biases. Some modelling systems provide information tools to identify such problems.

5.3 Refer to the Table in Annex 2D which provides general information on the differences and similarities of each climate risk modelling and mapping method

The similarities and differences are described for each of the following headings:

Functionality, e.g.:

- *whether climate data are included*
- *the number of climatic variables*
- *the time step*
- *ability to modify parameter variables*

Ease of use, e.g.:

- *complexity*
- *training requirements*
- *availability*
- *cost*
- *speed*

Quality assurance and user confidence, e.g.:

- *sensitivity analysis and outlier identification*
- *relationship between model methodology and known biological/ecological processes*

Appropriateness for location data categories, e.g.:

- *locations biased to the range periphery*
- *few data.*

5.4 Choose your Climatic Mapping Method

Having made your choice, additional assistance is given in the following annexes to select datasets, parameterise and run the models, interpret outputs and combine outputs with other factors to map the area of potential establishment and the endangered area:

Section	Title
Annex 2B	Location data category diagrams
Annex 2C	Summary of model performance based on climate response information and location data categories
Annex 2D	Qualitative comparisons of different species distribution modelling techniques
Annex 2E	Links to climatic mapping data, software and explanations of methods
Annex 2F	Comparison of the performance of nine species distribution models for *Diabrotica virgifera virgifera*
Annex 2G	Instructions for the Use and Interpretation of CLIMEX
Annex 2H	Climatic mapping in PRA – A draft tutorial
Annex 2I	R functions related to Ecological Modelling: Setting thresholds and rescaling model outputs
Annex 2J	Getting started MCAS-S for PRATIQUE
Annex 2K	Bayesian selection of parameters for the Generic Infection Model
Annex 2L	Thermal requirements in phenological models
Annex 3A	PRATIQUE (MCAS-S) Datapack
Annex 3B	The files available from the link below are in a format that is designed to be read by MCAS-S and GIS software. Host & Alternate Hosts Distribution maps Image files that can be easily inserted into e.g. Microsoft Office programs here
Annex 3C	Guidance to rescale data to 10 km x 10 km resolution using GIS for MCAS-S
Annex 3D	CliMond Database for climatic mapping

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