農業部動植物防疫檢疫署
ANIMAL AND PLANT HEALTH INSPECTION AGENCY
MINISTRY OF AGRICULTURE

Comparison of Methodologies for Assessing the Risk of Potential Distribution of Quarantine Pests due to Climatic Factors:

A Case Study of Taiwan's Qualitative Analysis Method and the MaxEnt Model

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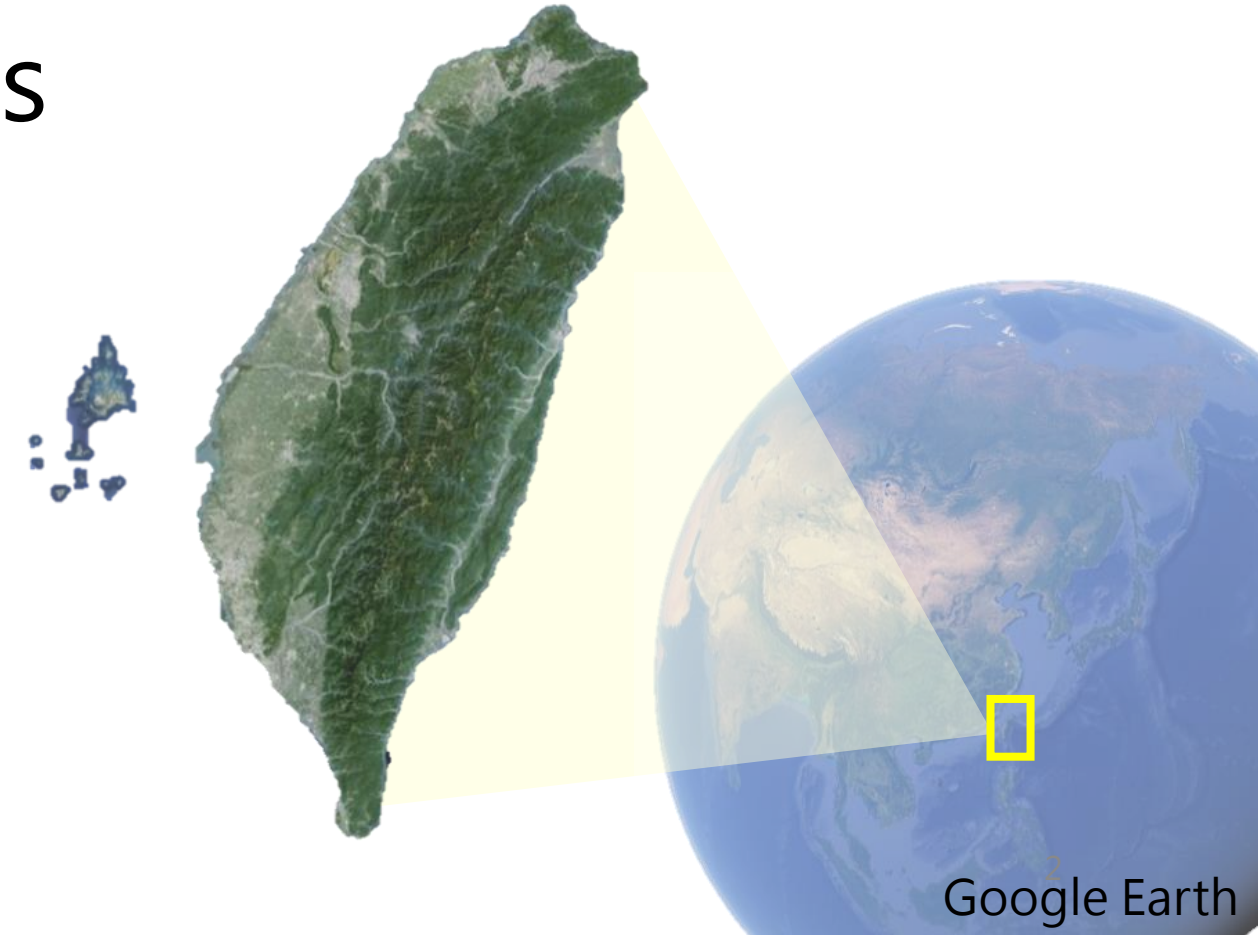
Figure from Dr. C. C. Chen

Outline

- Introduction
- Material and Methods
- Results
- Conclusion and Recommendation



Qualitative Analysis Method of PRA in Taiwan

Pest Risk Potential = Likelihood of Introduction + **Consequences of Introduction**

Pest	Risk Element 1 (climate/host interaction)	Risk Element 2 (host range)	Risk Element 3	.....	Cumulative Risk Rating
	L, M, H (1, 2, 3)	L, M, H (1, 2, 3)	L, M, H (1, 2, 3)		

(ISPM 2、ISPM11)

Deconstructing the Completed PRA Reports in Taiwan - A Case Study of Mediterranean Fruit Fly[1]

Risk Element 1 (climate/host interaction)

地中海果實蠅目前已分布於全球五大洲，包括歐洲、非洲、中南美洲大部份國家、澳洲、夏威夷、馬里亞納群島、西亞及中東地區，顯然已適應熱帶和溫帶地區各種天候環境及各種寄主植物相。在溫暖地區果實無缺的情形下，地中海果實蠅全年均可繁殖；於涼冷地區，則在冬季以蛹或成蟲越冬。成蟲產卵在寄主果皮下，卵孵化後幼蟲在果內取食，幼蟲老熟後離開寄主進入土中化蛹，成蟲羽化後爬出土面。在26℃時，卵期2-3天，幼蟲期6-10天，發育時間依季節氣溫高低而有差異，蛹期10-12天。成蟲壽命約2個月，氣溫高則縮短，氣溫低則延長。成蟲在低於12.8℃或高於36.1℃不會羽化，每年發生1-12代，因地區而異。台灣的氣候溫和，同時具有熱帶、亞熱帶和溫帶寄主植物之分布，應極適合地中海果實蠅的立足及繁衍。因此，此項風險因子評定等級為高(3分)。↵

- 世界生物地理分布區 (Biogeographic realm) and 昆蟲分布(insect distribution)
- 滯育 (diapause)
- 發育起點 (developmental / growth threshold)
- 寄主植物之分布(host plant distribution)
- 化性(Voltinism)
- 生理時間 (physiological time)

Deconstructing the Completed PRA Reports in Taiwan - A Case Study of Mediterranean Fruit Fly[2]

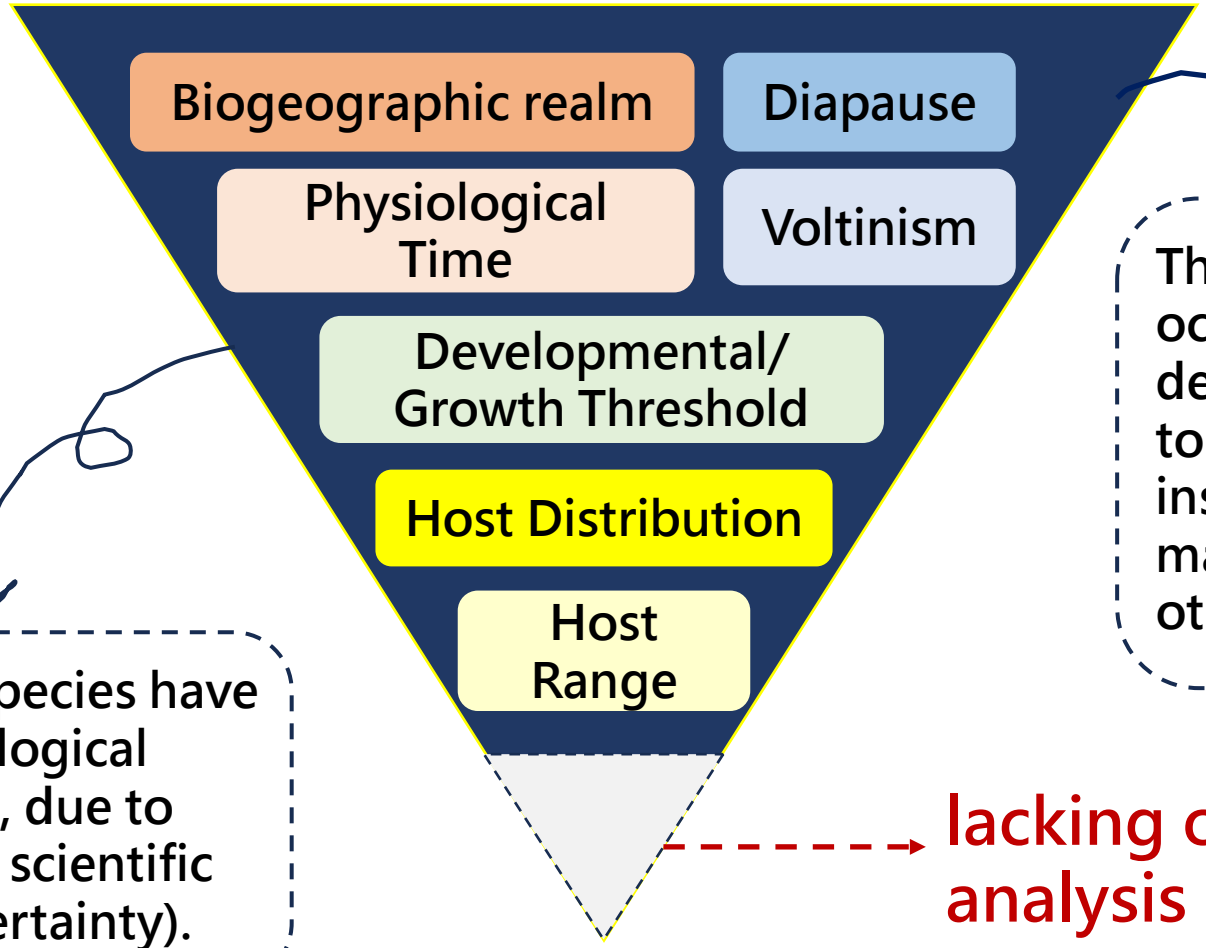
Risk Element 2 (Host range)

寄主範圍廣泛，計有67科353種，其中40%歸屬在5個科中，包括桃金孃科(Myrtaceae)佔6%、薔薇科(Rosaceae)佔10%、芸香科(Rutaceae)佔9%、山欖科(Sapotaceae)佔9%和茄科佔6%。在野外的調查中紀錄受地中海果實蠅為害的寄主則有200餘種(趙，1982；梁&姚，1998；CABI 2018；EPPO 2018)。在歐洲地區主要危害作物為蘋果、柑桔、酪梨、奇異果、芒果、梨、桃。此項風險因子評定為高(3分)。

自然條件及非自然條件下的植物寄主
(natural host and conditional host)

自然條件下的植物寄主
(natural host)

After analyzing 34 reports……



The results were occasionally contains text descriptions that unrelated to climatic factors and insect development (which may be characteristics of other risk elements).

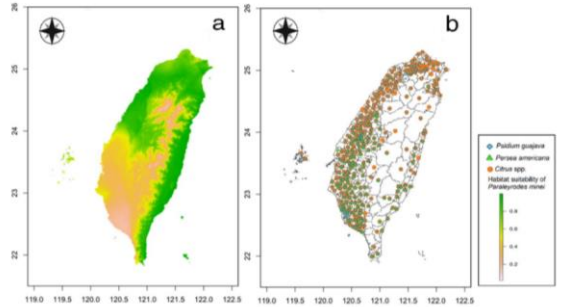
Not all analyzed species have sufficient biological characteristics, due to unavailability of scientific literature (Uncertainty).

lacking objective analysis process

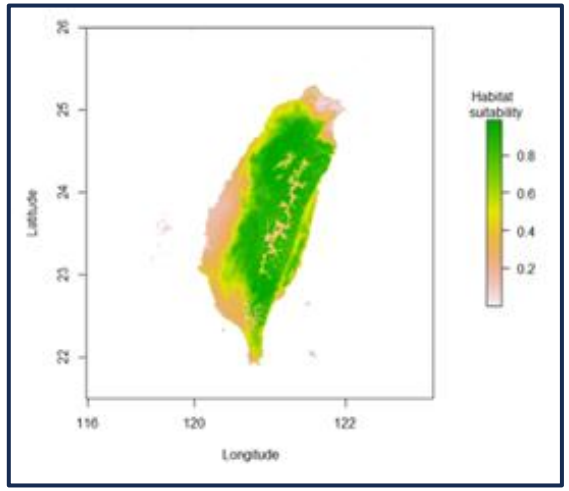
Results of Risk Rating (High, Medium, Low)

The MaxEnt model as a quantitative tool for assessing habitat suitability of invasive organisms

- The MaxEnt model was first published by Phillips *et al.* in 2004 and has been improved and refined over the past 20 years and is now widely used in biogeography, ecological conservation, and invasive biology.
- MaxEnt is one of the most popular ENM methods because of its high accuracy and the fact that only occurrence data for the predicted species are required.
- Yeh *et al.* (2021) applied MaxEnt to predict habitat suitability for six potentially invasive species to inform further monitoring.



Objective



Pest Potential Distribution Map by MaxEnt Model

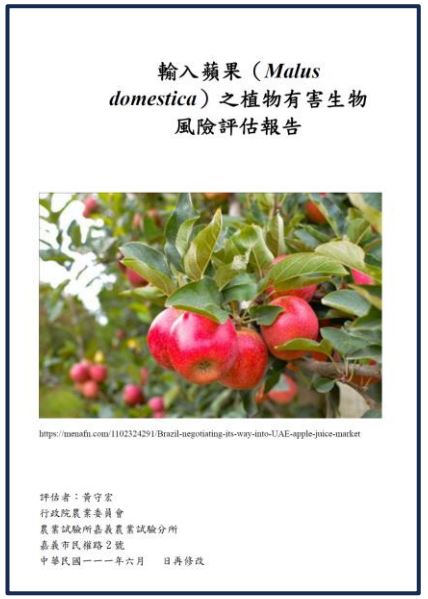
Grapholita molesta

Anarsia lineatella

Ceratitis capitata

Cydia pomonella

Dasineura mali


輸入蘋果（*Malus domestica*）之植物有害生物風險評估報告

Completed PRA Reports in Taiwan

Focusing on climatic factors and host-plant interactions, differences in the results of the two assessment methods are compared and recommendations are provided for future PRA operations.

General methods for MaxEnt

Species occurrence dataset and 19 bioclimatic variables

↓

Variable selection process

↓

Model parameter settings and optimization

↓

Model prediction and map visualization

↓

Model validation

GBIF Global Biodiversity Information Facility

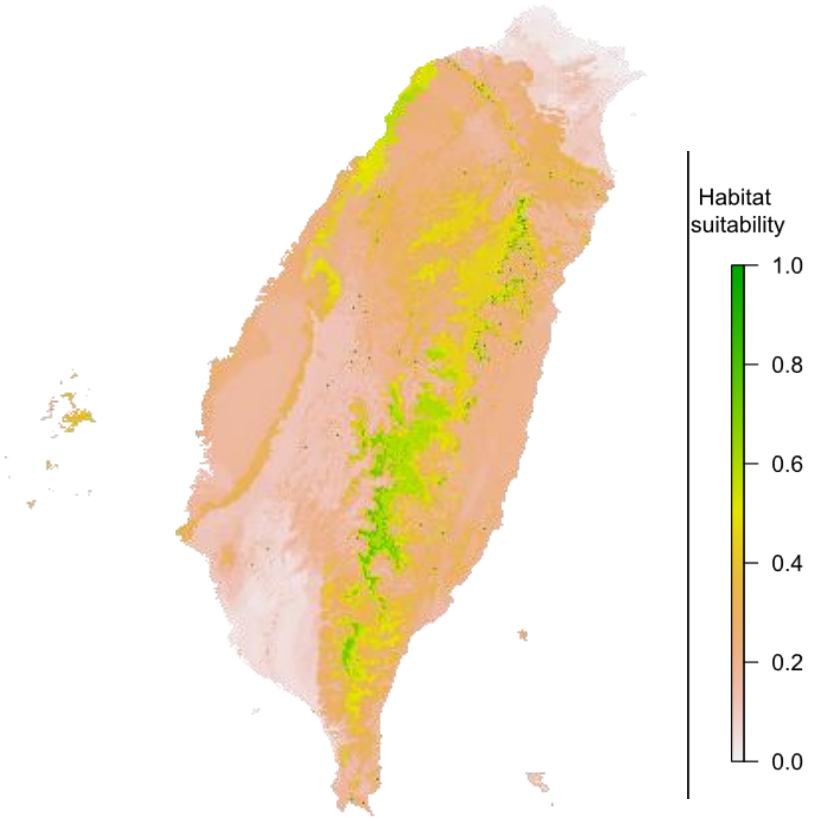
CABI

iNaturalist

WorldClim

WorldClim version 2.1

Historical climate data (1970-2000)



MaxEnt (v.3.4.4) (Phillips et al. 2023) in R (version 4.3.2) (R Core Team 2023) and RStudio (version 2023.09.01+494) (RStudio Team 2023), utilizing the R package 'dismo' (Hijmans et al. 2022)

Mapping process for cultivation area of plant hosts

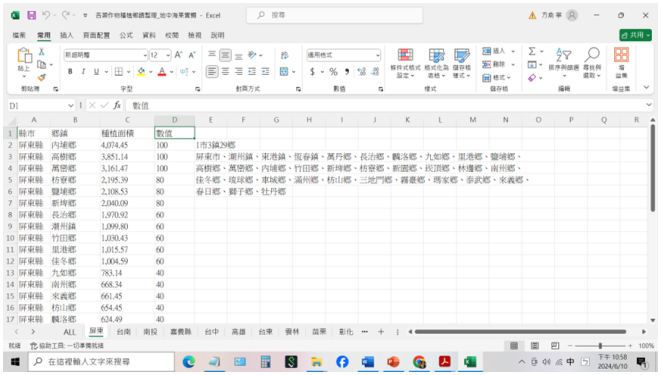
Agricultural production dataset from Agriculture and Food Agency

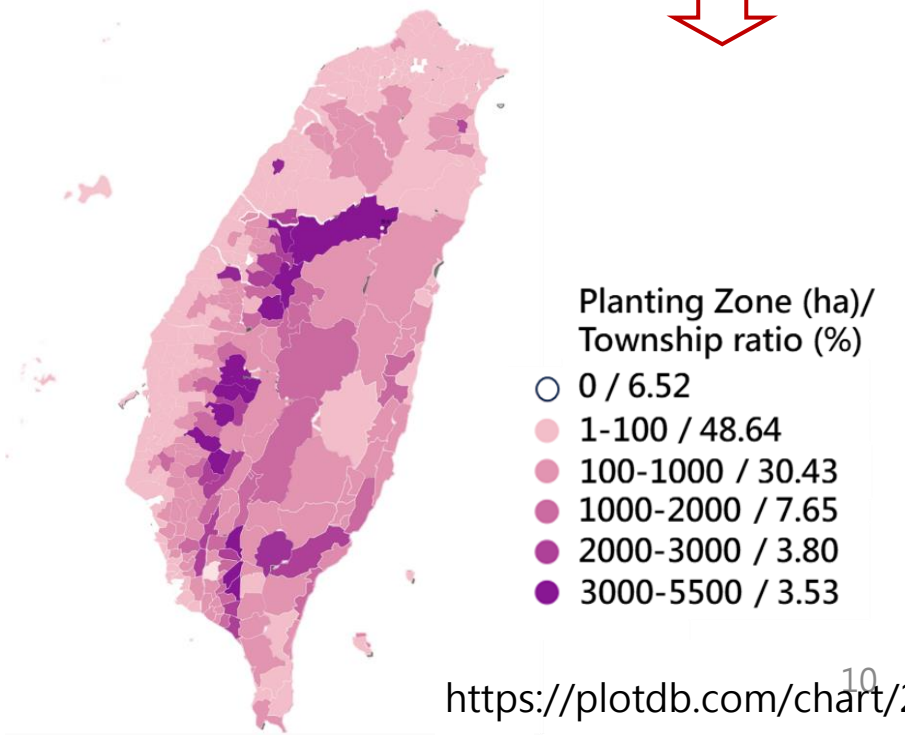
Statistics on cultivation area of host plants in 368 townships

Data standardization

Map visualization

https://agr.afa.gov.tw/afa/afa_frame.jsp





https://plotdb.com/chart/2200/#

Results of *Grapholita molesta*

(Oriental fruit moth)

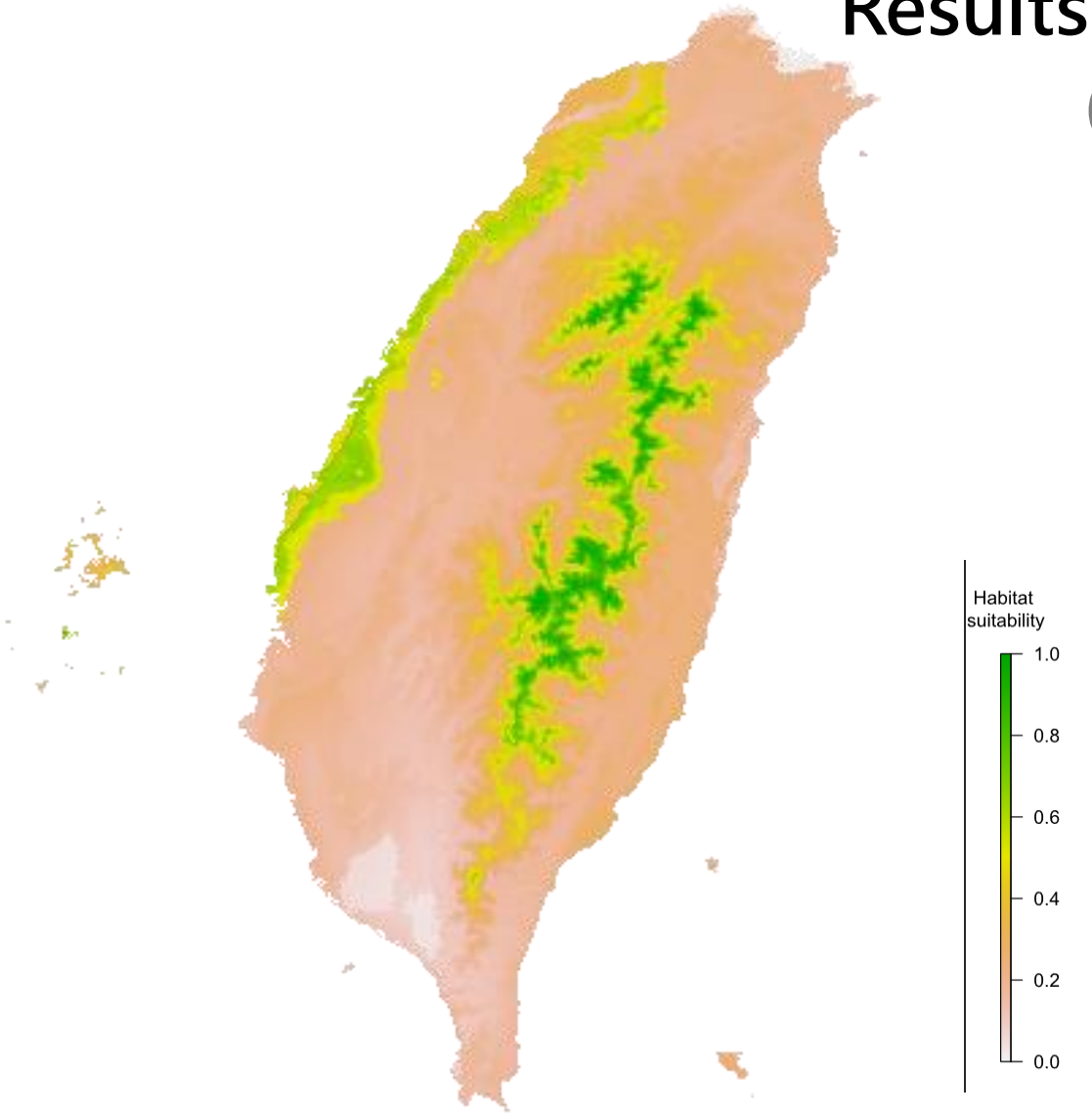


Fig. 1.1 Potential suitable distribution area of *Grapholita molesta* in Taiwan based on MaxEnt.

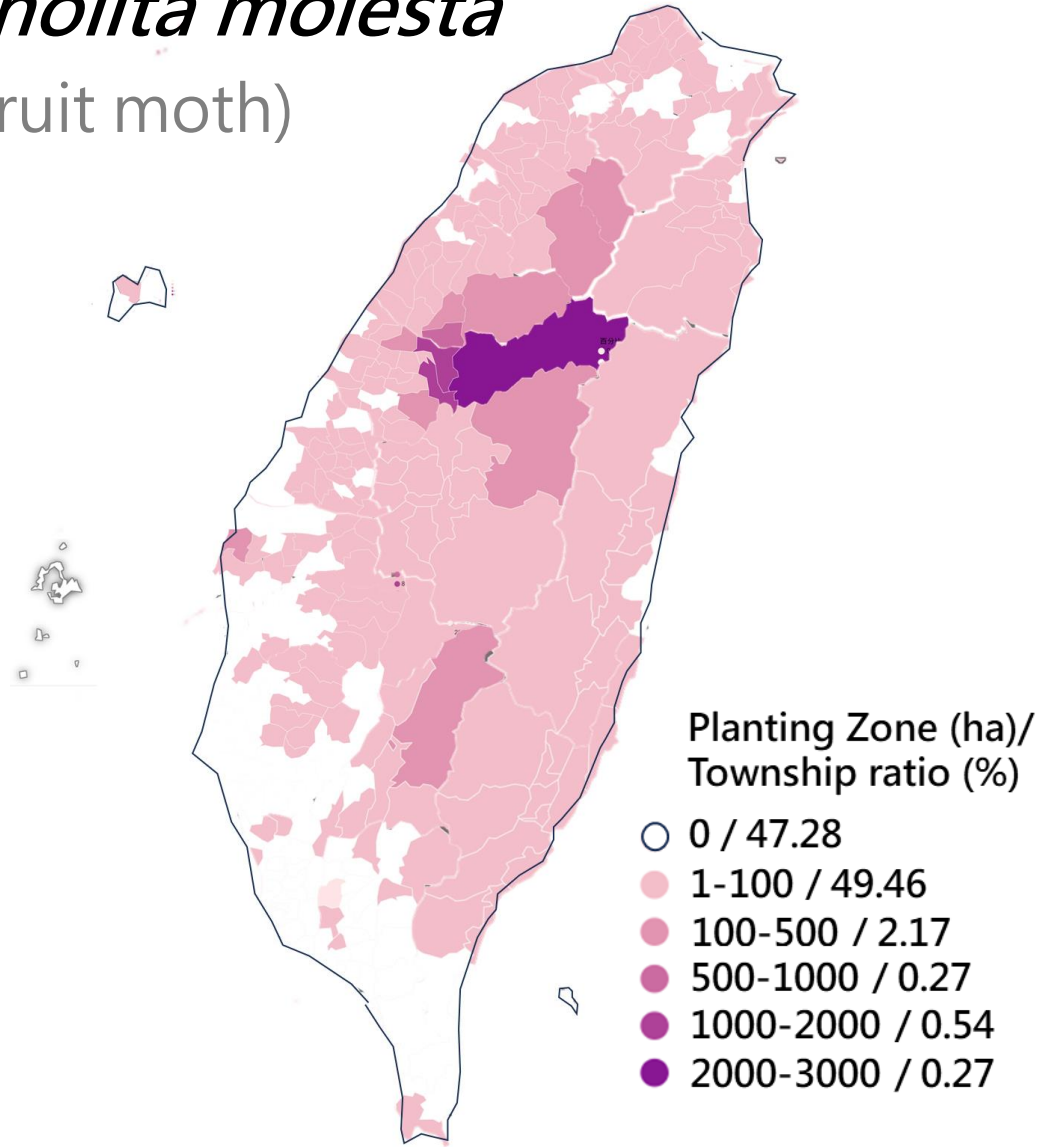


Fig. 1.2 The cultivation area of peach, pear, plum, loquat and apple in Taiwan.

Results of *Anarsia lineatella*

(Peach twig borer)

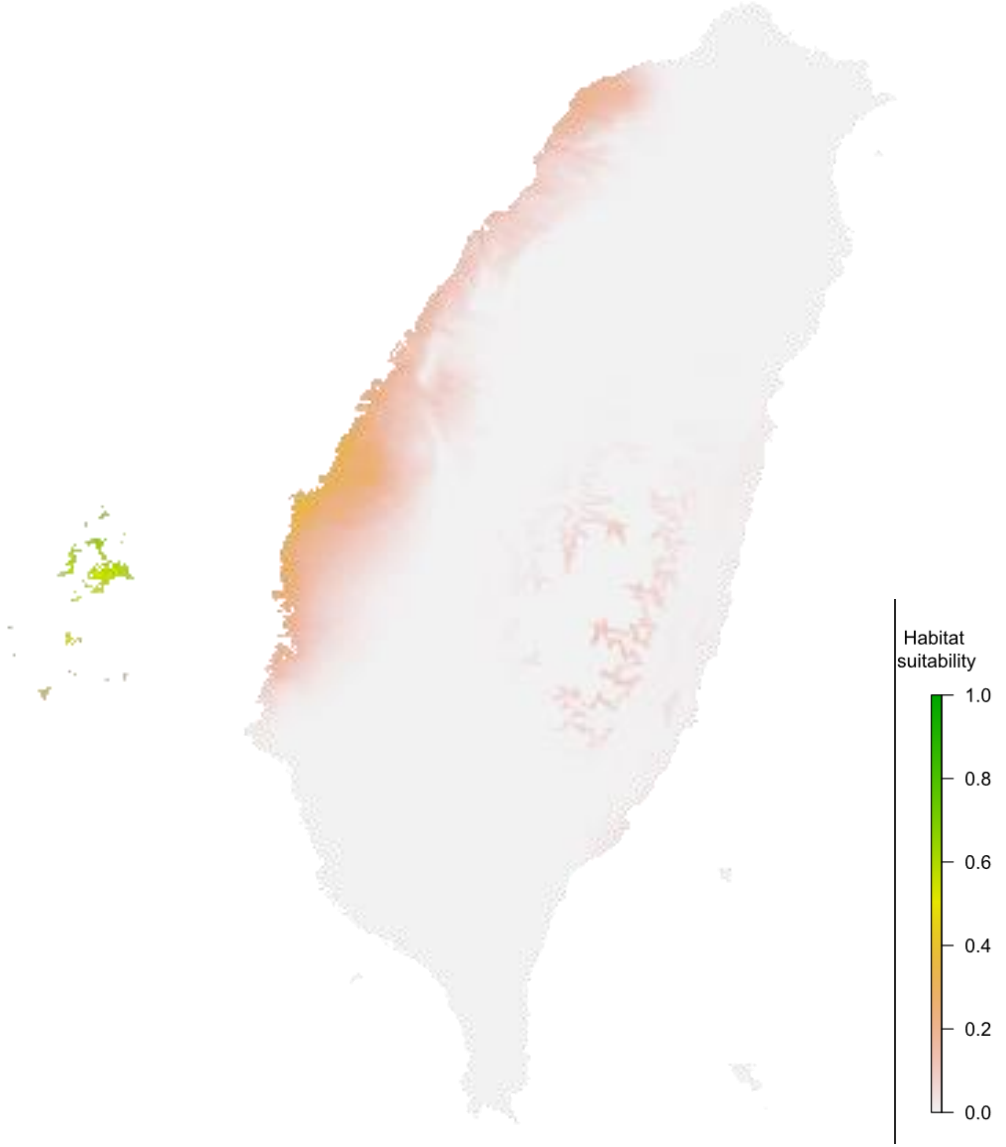


Fig. 2.1 Potential suitable distribution area of *Anarsia lineatella* in Taiwan based on MaxEnt.

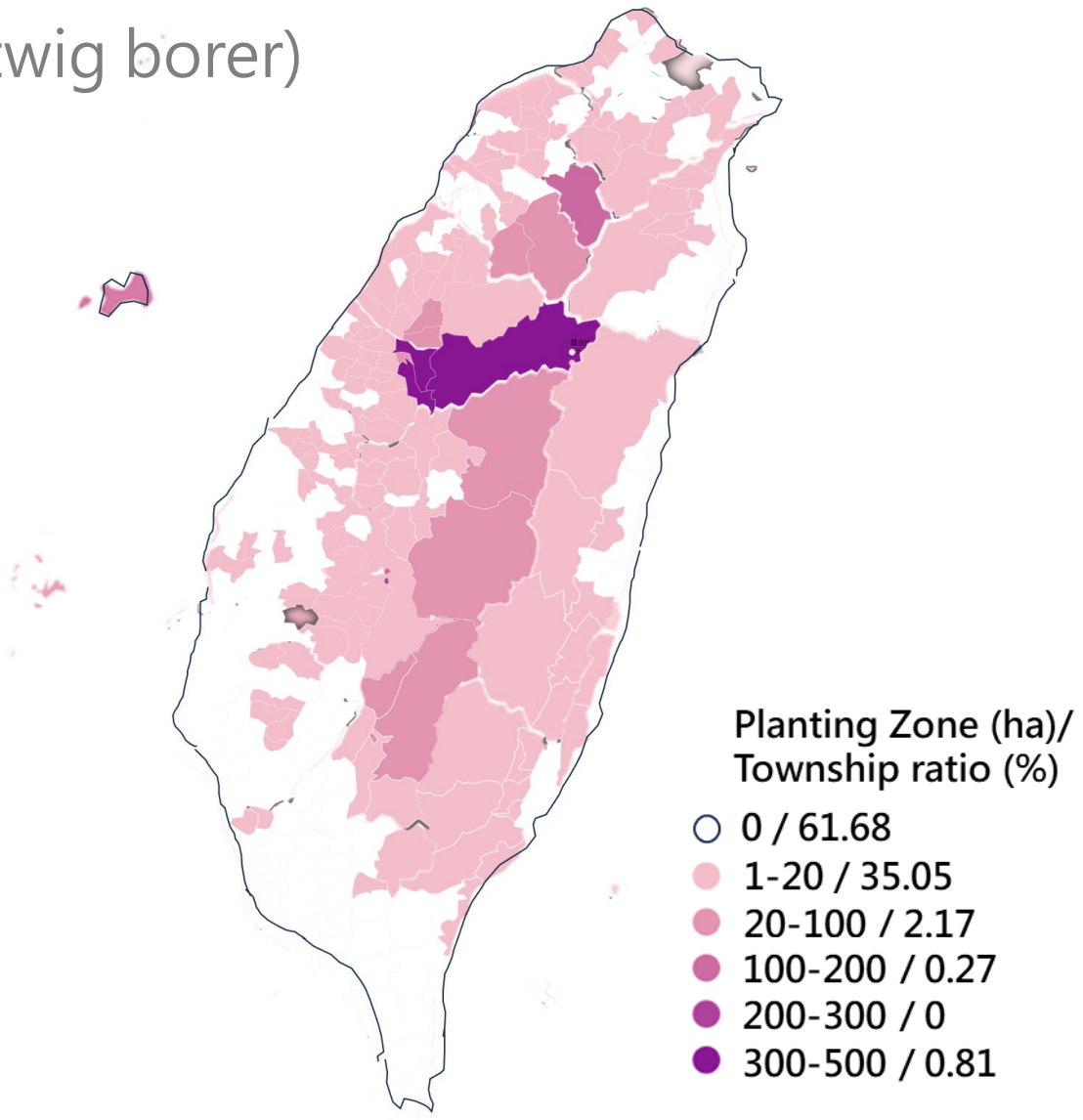


Fig. 2.2 The cultivation area of peach in Taiwan.

Results of *Ceratitis capitata*

(Mediterranean fruit fly)

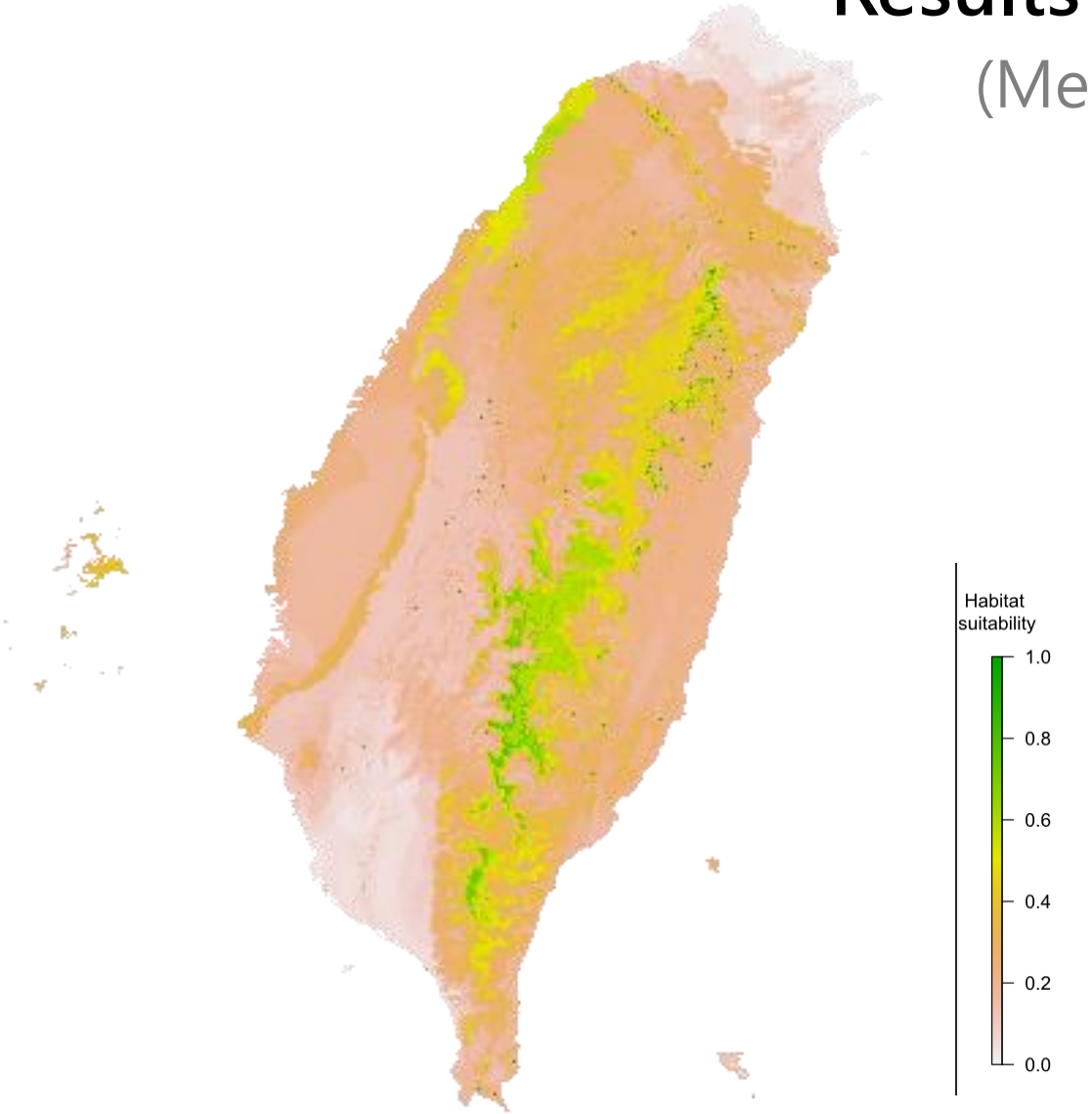


Fig. 3.1 Potential suitable distribution area of *Ceratitis capitata* in Taiwan based on MaxEnt.

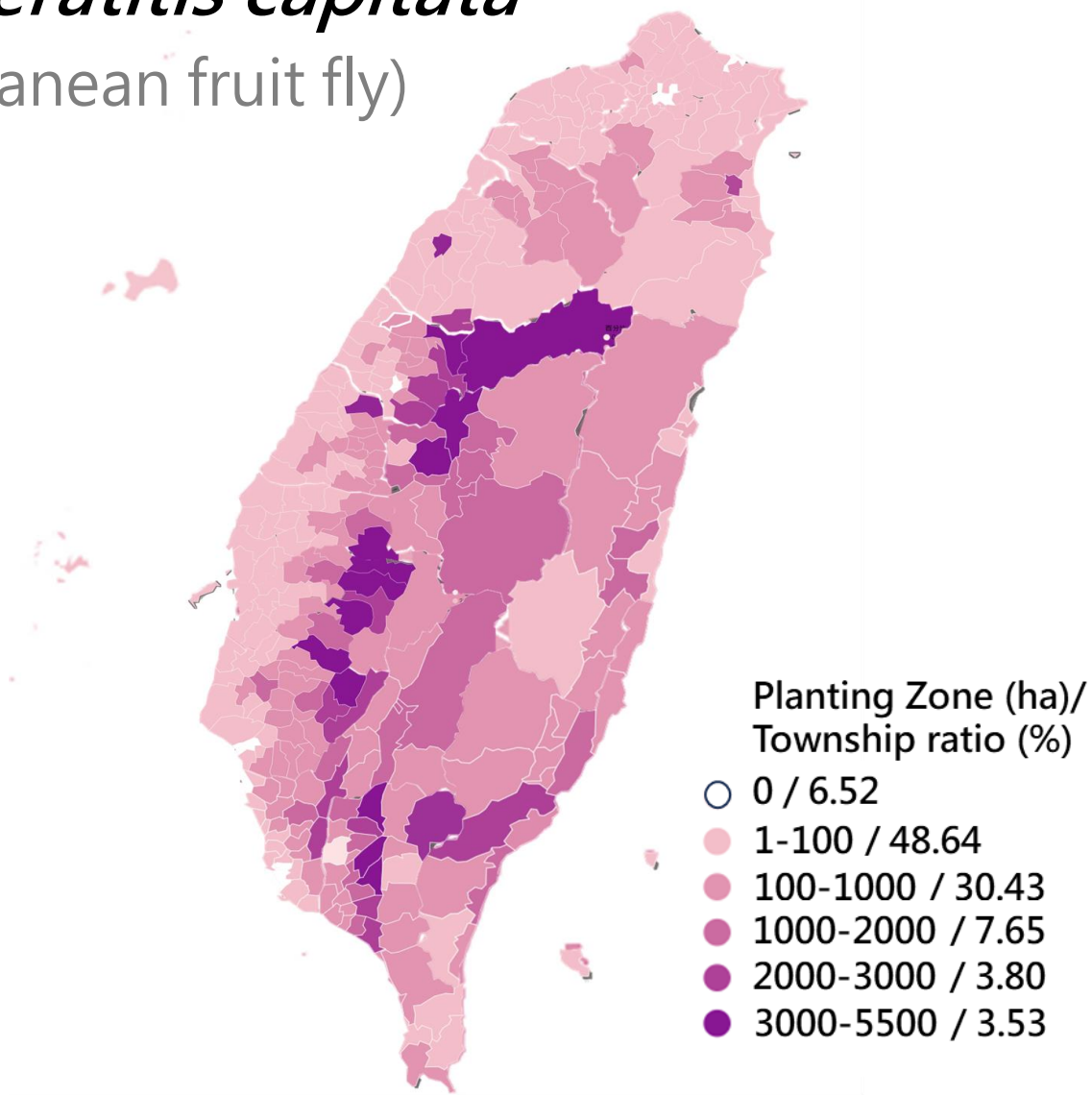


Fig. 3.2 The cultivation area of fruit in Taiwan.

Results of *Cydia pomonella*

(Codling moth)

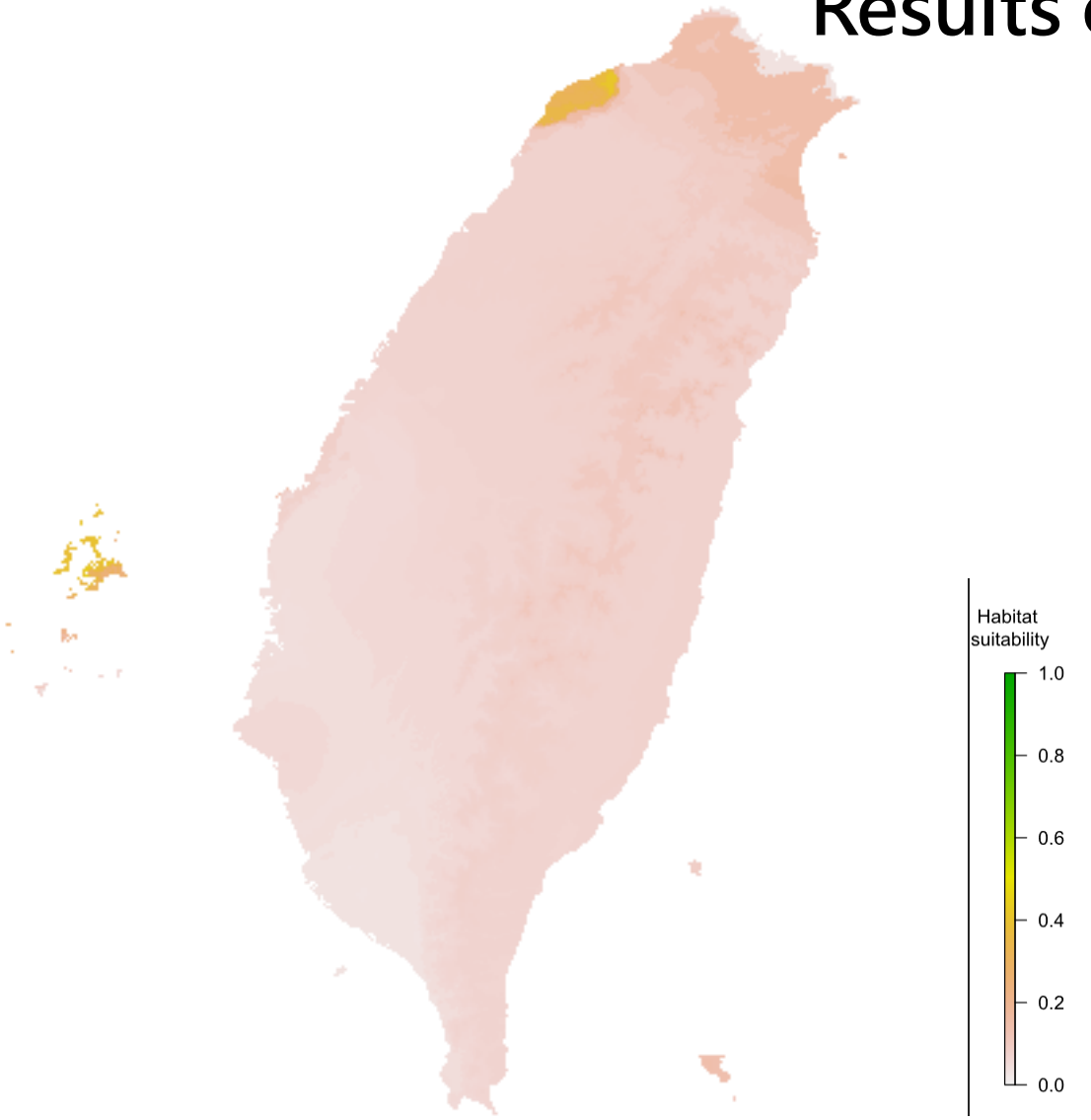


Fig. 4.1 Potential suitable distribution area of *Cydia pomonella* in Taiwan based on MaxEnt.

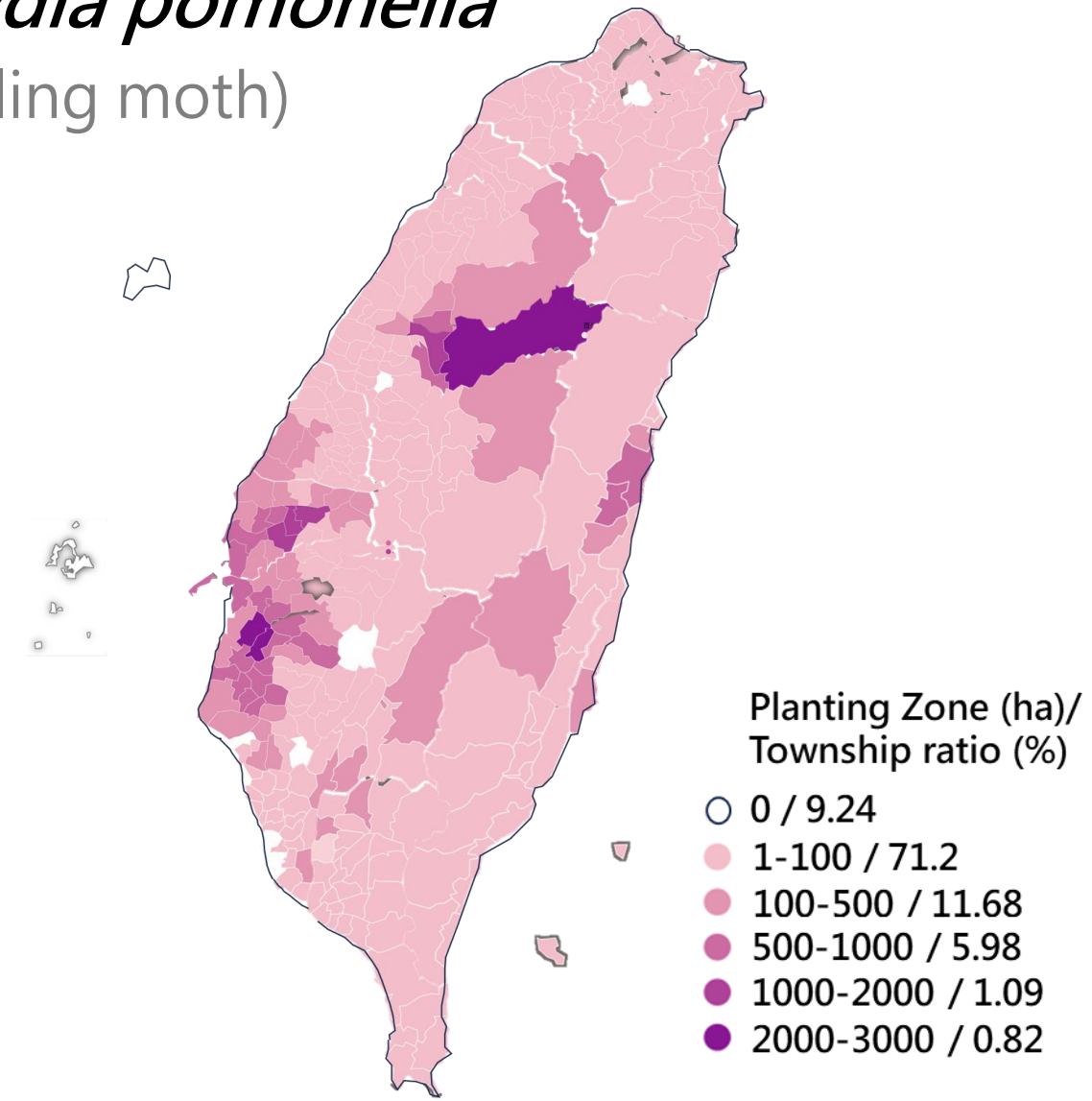


Fig. 4.2 The cultivation area of apple, peach, pear, corn and Japanese plums in Taiwan.

Results of *Dasineura mali*

(Apple leaf midge)

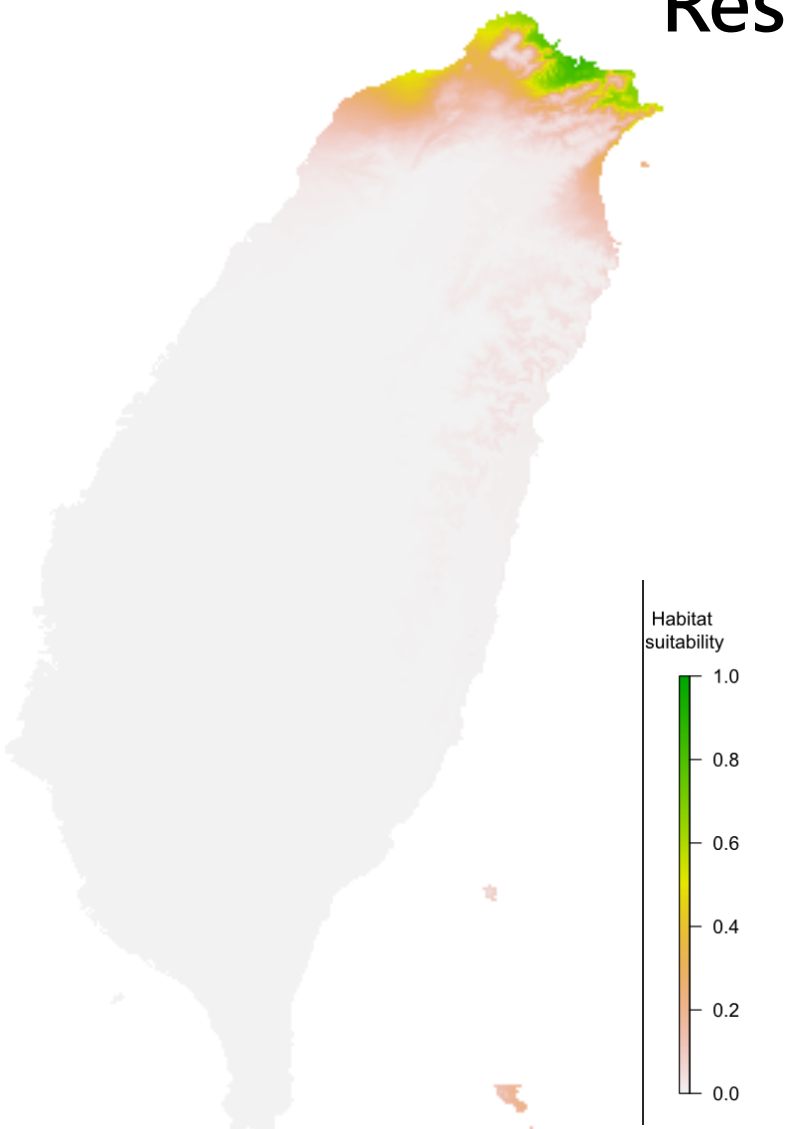


Fig. 5.1 Potential suitable distribution area of *Dasineura mali* in Taiwan based on MaxEnt.

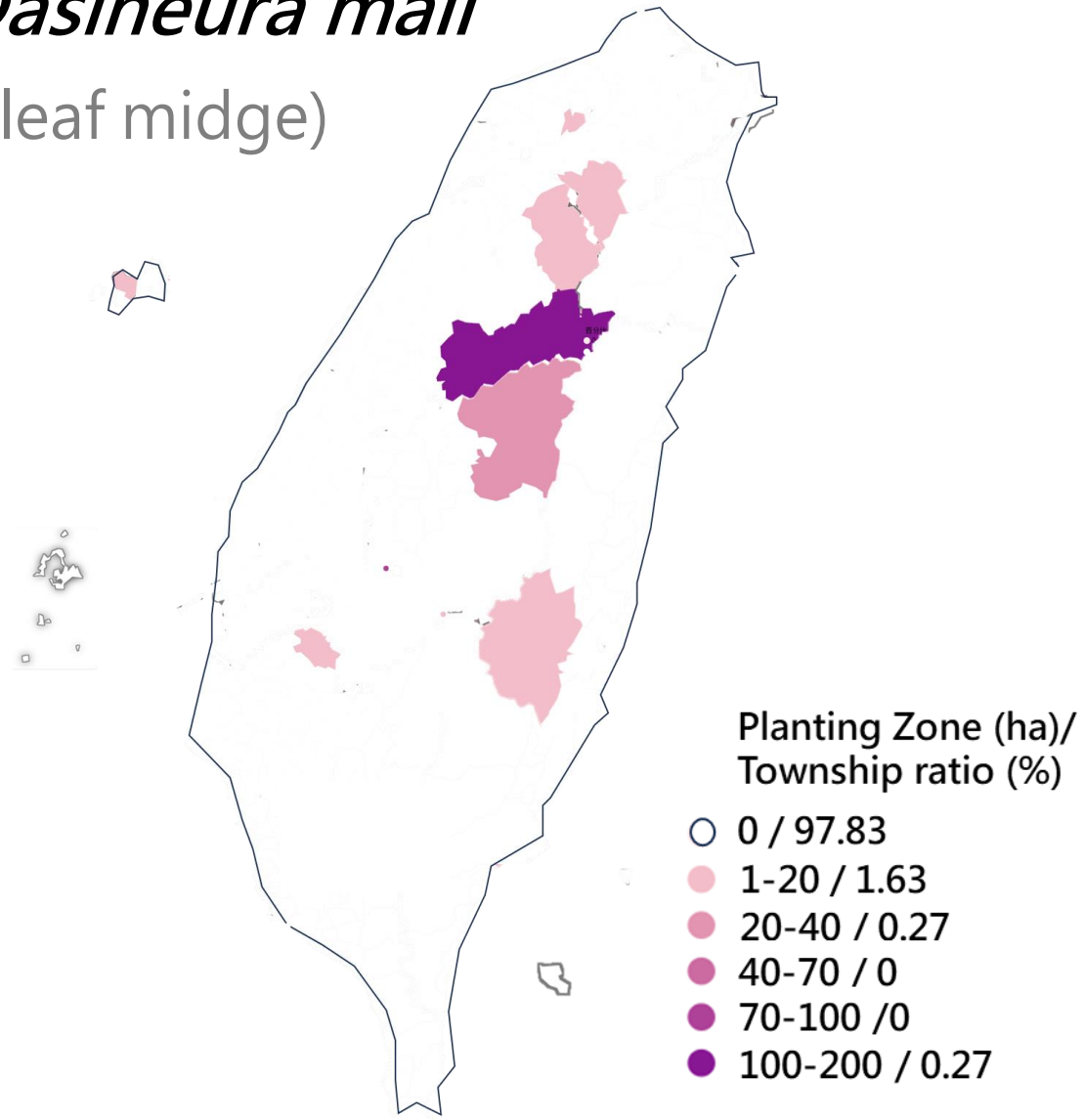


Fig. 5.2 The cultivation area of apple in Taiwan.

Table 1. Differences in the results of the two assessment methods

	The results of the completed PRA by Qualitative Analysis Method (Risk Element #1+Risk Element #2)	Risk Rating	MaxEnt Prediction model + Distribution Maps of host plants	Risk Rating
Grapholita molesta (Oriental fruit moth)	4 PRA results were analyzed, and the main characteristics underlying the qualitative analyses were, in order, insect and host distribution, voltinism, diapause and physiological time.	H(1) M(2) L(1)	High-moderate habitat suitability in more than 2/3 of the region + Nearly 53% of the townships in Taiwan grow host crops.	H
Anarsia lineatella (Peach twig borer)	7 PRA results were analyzed, and the main characteristics underlying the qualitative analyses were, in order, insect and host distribution, voltinism, diapause and physiological time.	H(3) M(4)	Moderate habitat suitability in the western coast and a few areas + Only about 3% townships in Taiwan have more than 20 hectares of peach planted area and they are concentrated in the middle and high altitude areas.	L
Ceratitis capitata (Mediterra-nean fruit fly)	11 PRA results were analyzed, and the qualitative analyses were based on the following main characteristics: insect distribution, developmental threshold and physiological time.	H(11)	High-moderate habitat suitability in more than 2/3 of the region + Nearly 94% of the townships in Taiwan grew host crops.	H Recommend

Table 1. Differences in the results of the two assessment methods (continued)

	The results of the completed PRA by Qualitative Analysis Method (Risk Element #1+Risk Element #2)	Risk Rating	MaxEnt Prediction model + Distribution Maps of host plants	Risk Rating
Cydia pomonella (Codling moth)	10 PRA results were analyzed, and the main characteristics underlying the qualitative analyses were insect and host distribution.	H(3) M(7)	Moderate habitat suitability in Taiwan + Nearly 90% of the townships in Taiwan grew host crops.	M
Dasineura mali (Apple leaf midge)	2 PRA results were analyzed, and the qualitative analyses were based on the main characteristics of insect and host distribution, voltinism, diapause, in that order.	M(1) L(1)	High-moderate habitat suitability in a few areas along the northern coast + Only about 2% townships in Taiwan have more than 20 hectares of apple planted area, and they are concentrated in the middle- and high-elevation areas.	L Recommend

Table 2. Discussion for the results of the two assessment methods

	Qualitative Analysis Method of PRA in Taiwan	MaxEnt Prediction Model + Distribution Maps of Host Plants
Advantage	1. The process is easier to follow (economical). 2. Provide more details on text information, so the result is easier to interpret. 3. It is suitable for data with high uncertainty, or the main factors are hard to describe numerically.	1. SDM provides quantitative , causal or correlation analysis results. 2. SDM provides potential distribution predictions through computer mapping, which can be analyzed interactively when combined with host plant distribution maps.
Short-coming	1. The analysis results lack an objective and quantitative approach. 2. There is no clear causal relationship between some of the qualitative descriptions and the climate factors. 3. There needs to be sufficient access to scientific papers to support the results. 4. Insufficient interactive analysis of host plant distribution and potential areas for pest establishment.	1. Operators must have data processing and information tool application capabilities. 2. The process takes more time to confirm the reliability of the data and to validate the accuracy of the model. 3. The quantity and quality of climate variables and distribution samples limit the prediction results of the model. 4. Lack of qualitative explanation, decision makers must have the ability to interpret.

Conclusion and Recommendation

1. There is no single PRA method that is universally the most accurate; each method offers valuable insights into species-environment relationships.
2. To achieve more accurate and precise predictions , it is crucial to gather comprehensive information, utilize citizen science and continuously work on reducing uncertainties.
3. We recommend combining SDM and new PRA tools with qualitative analysis methods. This integrated approach will allow for a more thorough assessment of the complex factors influencing species distribution patterns.

Thanks for your listening

Figure from Dr. C. C. Chen