

# Bioeconomic impacts of Coconut Rhinoceros Beetle (*Oryctes rhinoceros*) under current and future climates



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**IPRRG 2025**  
KUALA LUMPUR, MALAYSIA



# What's the problem?

- *Oryctes rhinoceros* (Coconut rhinoceros beetle) attacks palms
  - Coconut palm (*Cocos nucifera* L.)
  - African oil palm (*Elaeis guineensis* Jacquin 1763)
- Coconuts are the "Tree of Life" in parts of Asia and the Pacific
  - Building materials
  - Food source
  - Exports of copra and coconut flesh and milk
  - Environmental services (soil retention)
  - Structural dominant
- Palms are amenity trees in wealthy nations (e.g., Florida and California, USA)



# History of spread and control efforts

- CRB started spreading from around World War II
- In mid-1960's *Oryctes rhinoceros* Nudivirus (OrNV) was discovered (Huger 1966)
- *Oryctes rhinoceros* rearing and infection techniques developed (Bedford 1980)
- There was some good control by ORNV until resistance discovered
- Subsequently, the virulence decreased dramatically, and impacts spread
- Resistance mistakenly attributed to G-haplotype (Guam) (Talk to Tek Tay)



# Project aim

- What is the economic risk; how much is it worthwhile spending on control?



# Methods

- Exposure, hazard, risk
- CLIMEX model of CRB to establish potential distribution
  - Spatially-explicit irrigation scenarios using GMIA
- Characterize area of production of oil palms
- Collate value of production statistics
- Estimate the damage functions
- Apply the damage function to production where suitable for CRB
- Distinguish between current impacts and potential future impacts



# Exposure

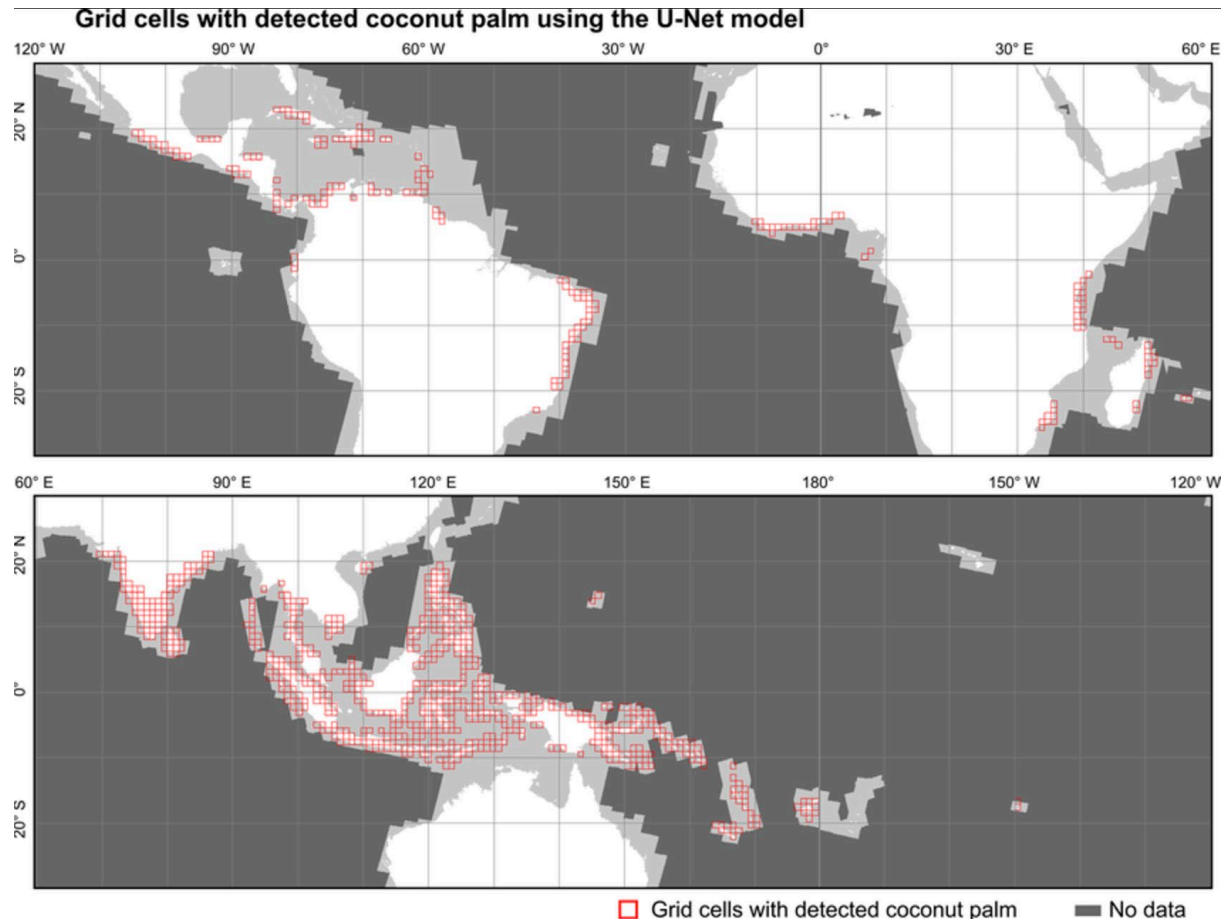


# Economic value

- In 2020
  - coconuts and derivative products worth an estimated US \$6.57 billion per annum
  - palm oil had an estimated trade worth US \$34.1 billion per annum
- Values collated on a country basis



# Coconut Palm distribution



Descals, Adrià & Wich, Serge & Szantoi, Zoltan & Struebig, Matthew & Dennis, Rona & Hatton, Zoe & Ariffin, Thina & Unus, Nabillah & Gaveau, D. & Meijaard, Erik. (2023). High-resolution global map of closed-canopy coconut palm. *Earth System Science Data*. 15. 3991-4010. 10.5194/essd-15-3991-2023.



# Social and cultural values

- Deeply important, but (too) difficult to quantify



# Hazard

Potential distribution of *Oryctes rhinoceros*



# Known distribution

- Collated from GBIF and other sources
- Assess invasion status

Continent/Country/Region	Distribution	Origin (WTT gestimate)	First Reported	Reference
<b>Africa</b>				
Mauritius	Present	Invasive		EPPO (2022)
Nigeria	Present	Invasive		Olowu et al. (2012)
Réunion	Present	Invasive		EPPO (2022)
South Africa	Absent	Invasive		<a href="#">Zengeva and Wilson (2021)</a>
<b>Asia</b>				
British Indian Ocean Territory	Present	Invasive		<a href="#">CABI (Undated a)</a>
Iran	Present	Invasive		EPPO (2022)
Japan	Present, Localized	?		<a href="#">EPPO (2022)</a>
- Ryukyu Islands	Present	?		Hosoya (2011)
• Okinawa Islands	Present	Invasive		<a href="https://www.flickr.com/photos/okinawaphotos/16848573364">https://www.flickr.com/photos/okinawaphotos/16848573364</a>
Jordan	Present	Invasive		<a href="#">Al-Antary and Al-Khawaldeh (2021)</a>
Maldives	Present	Invasive		EPPO (2022)
Nepal	Present	?		<a href="#">EPPO (2022)</a>
Oman	Present	Invasive		Anon (1986)
Pakistan	Present	?		EPPO (2022)
Taiwan	Present	?		EPPO (2022)
Yemen	Present	invasive		Al-Habshi et al. (2006)
<b>North America</b>				
Mexico	Present	Invasive		EPPO (2022)
United States	Present	Invasive		EPPO (2022)
- Hawaii	Present	Invasive		NAPPO (2014)
- Texas	Present	Invasive		<a href="#">Ohlendorf (1916)</a>



# CLIMEX model of CRB

- Parameters originally fitted in Poznan in 2019, following IPRRG
- Cold stress fitted to Taiwan and Ryukyu islands
  - Distribution limits well known
- Optimum and upper temp parameters fitted to lab data
  - Bedford (1980) & Hinckley (1973)
- Dixon et al. (2009) observed empirically that DV0 - DV3 range = 20 °C +/- 7.65 °C
  - DV0: 17 °C
- MI parameters
  - SM0: 0.25 shallow roots, poor suction
  - SM3: 2.5 can grow in extremely wet locations, well-drained soils
- Composite irrigation scenario using GMIA to indicate where irrigation is practiced
- CM10 1995H

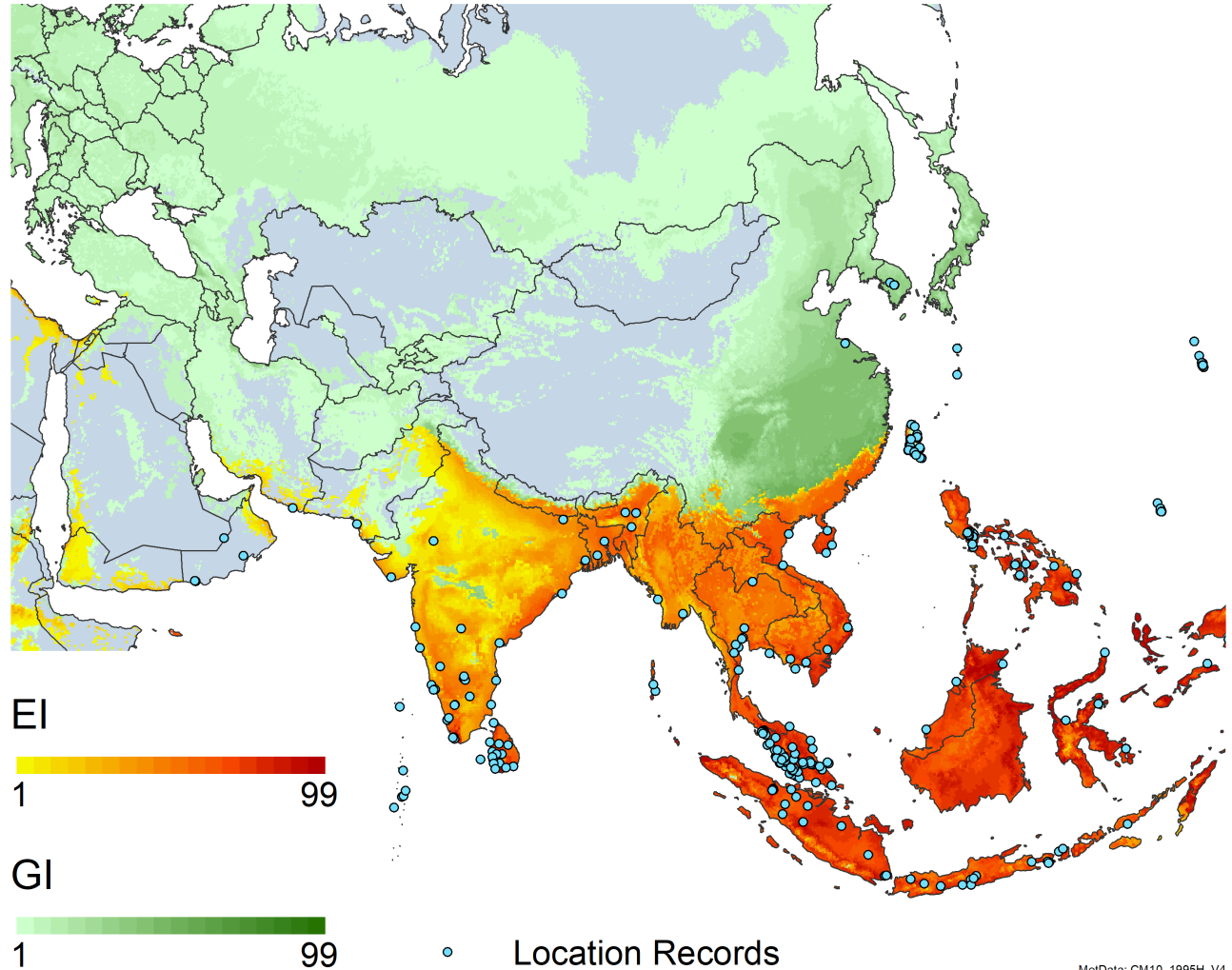


# Native Range

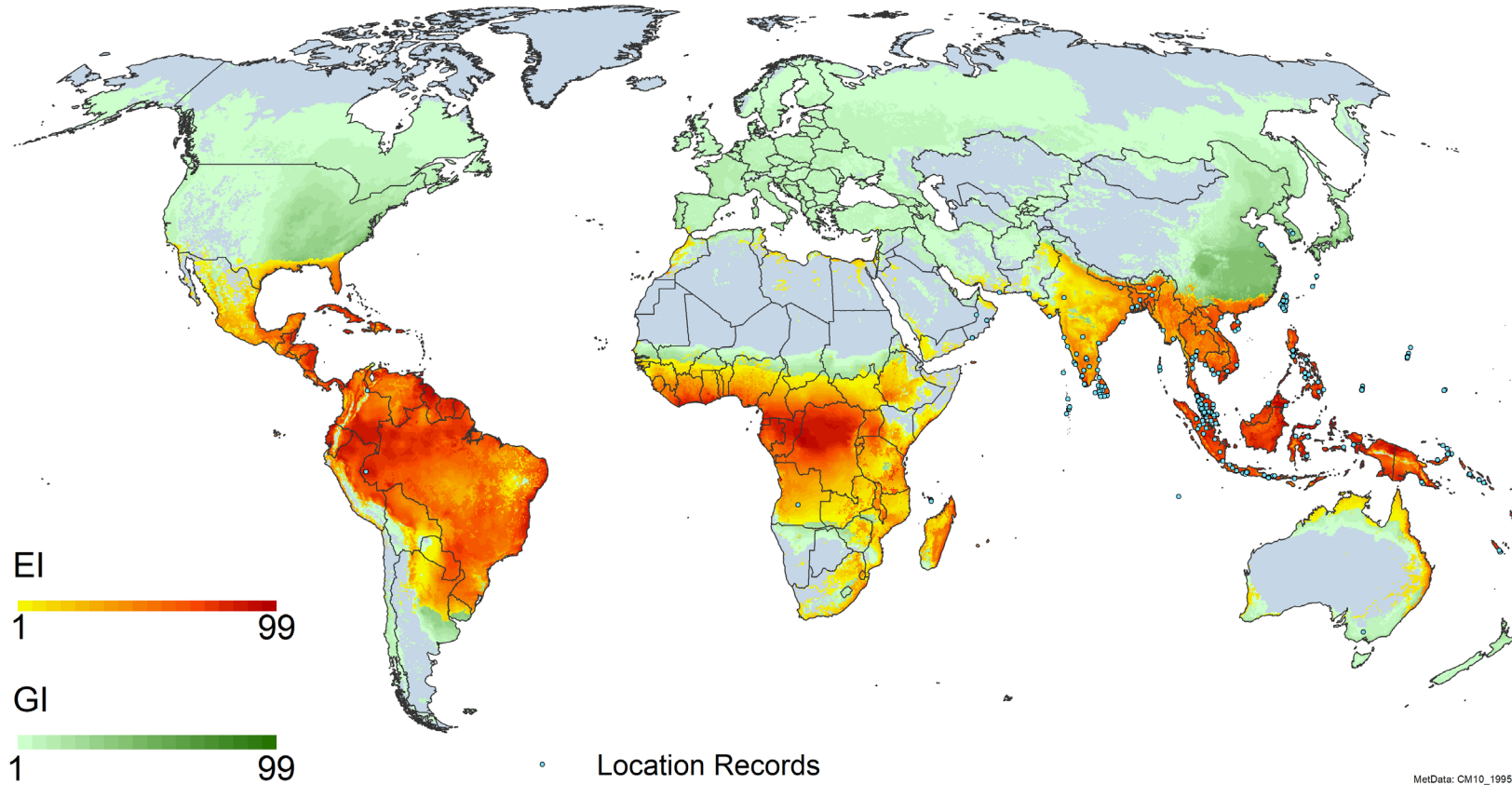
Yellow to red indicates EI > 0

Greens indicate potential for transient populations

CS fits Taiwan, Ryukyu and Okinawa islands



# Global climate suitability for *O. rhinoceros*

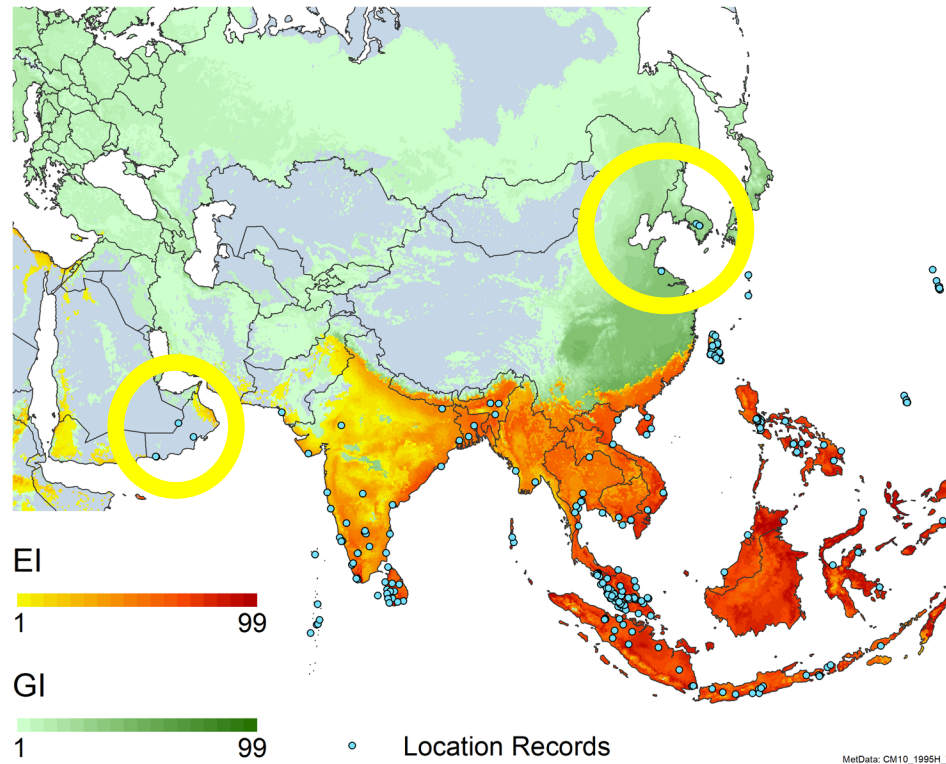


# Validation and outliers

- The model agrees with *almost* all distribution records
- Outliers were examined to test their veracity and assess need to adjust the model
  - Korea
  - Northern China
  - Oman

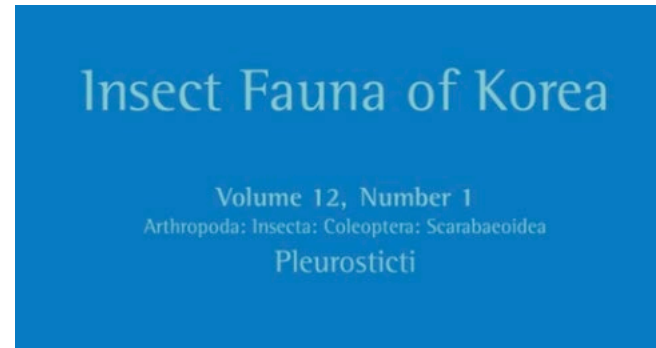


# Outliers



# Korea

- The South Korean records appear to be erroneous



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Insect Fauna of Korea · Pleurosticti

Neotropical Region, there are 29 species from 3 tribes distributed in the Palaearctic Region. In Korea, Kolbe (1886) was first record the species *Phileurus chinensis*, which was collected in Seoul by Gottsche in 1884. Nijima and Kinoshita (1923) reported *Oryctes rhinoceros* as occurring in Korean, but this report turned out to be erroneous. More recently, the imported species *Pentodon quadri-*



# Northern China

- This also appears to be an error
- Reported in Aidoo et al. Scientific Reports (2022) 12:17439  
<https://doi.org/10.1038/s41598-022-21367-1>
- This record does not appear in the list of records in the supplementary material of Aidoo et al (2022).
- Far colder than southern Chinese and Japanese (RyuKyu islands) records

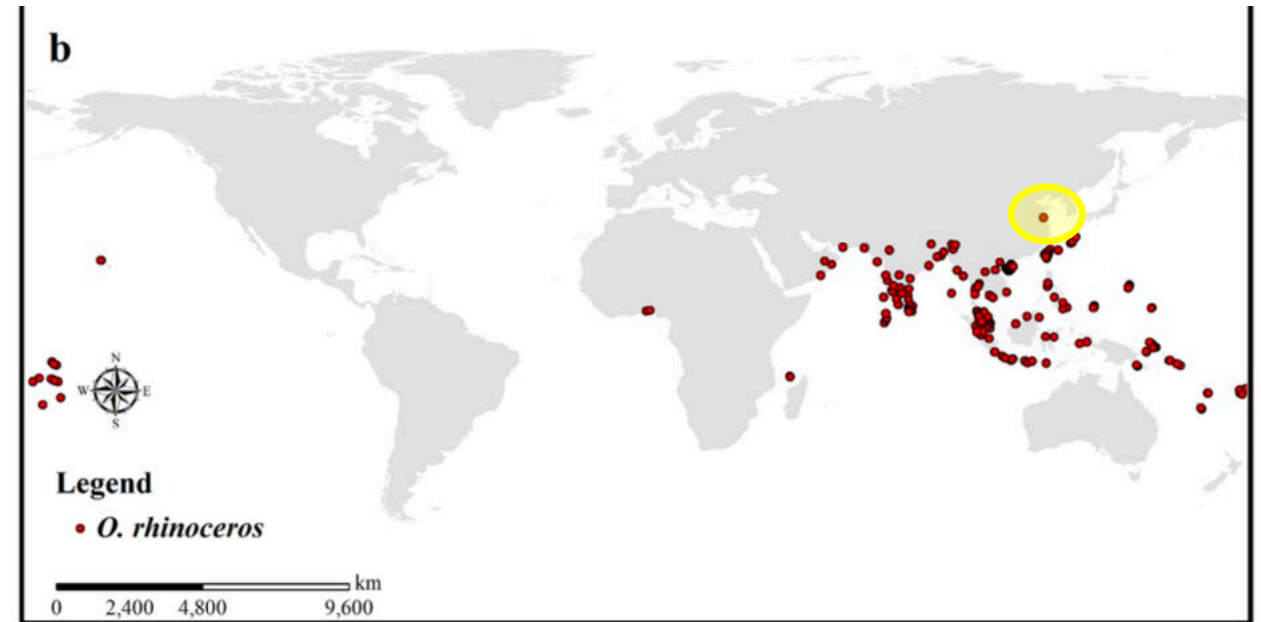


Figure 2. Occurrence records of *O. monoceros* and *O. rhinoceros*. ESRI ArcMap 10.2.2 (<https://support.esri.com/en/Products/Desktop/arcgis-desktop/arcmap/10-2-2#downloads>).



# Oman

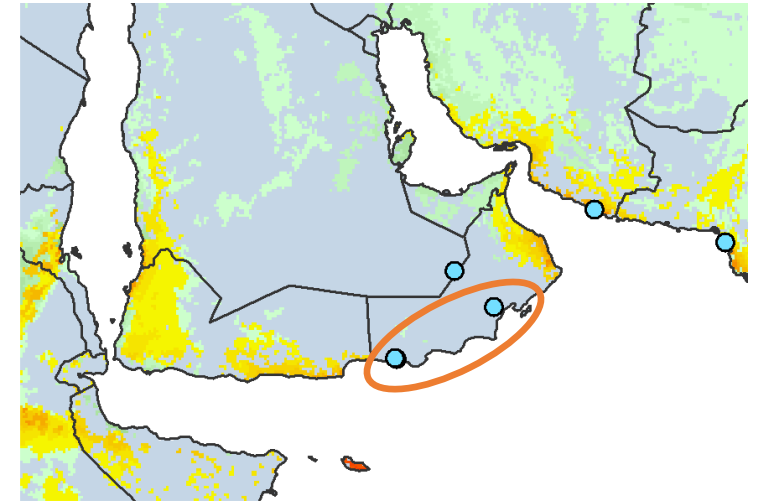
*Egyptian Journal of Biological Pest Control*, 14(1), 2004, 113-118  
*Proceeding of 1<sup>st</sup> Arab Conference for Applied Biological Pest Control, Cairo, Egypt, 5-7 April 2004*

## Biological Control of the Coconut Palm Rhinoceros Beetle (*Oryctes rhinoceros* L. Coleoptera: Scarabaeidae) Using *Rhabdionvirus oryctes* Hüger in Sultanate of Oman

**M. M. Kinawy**

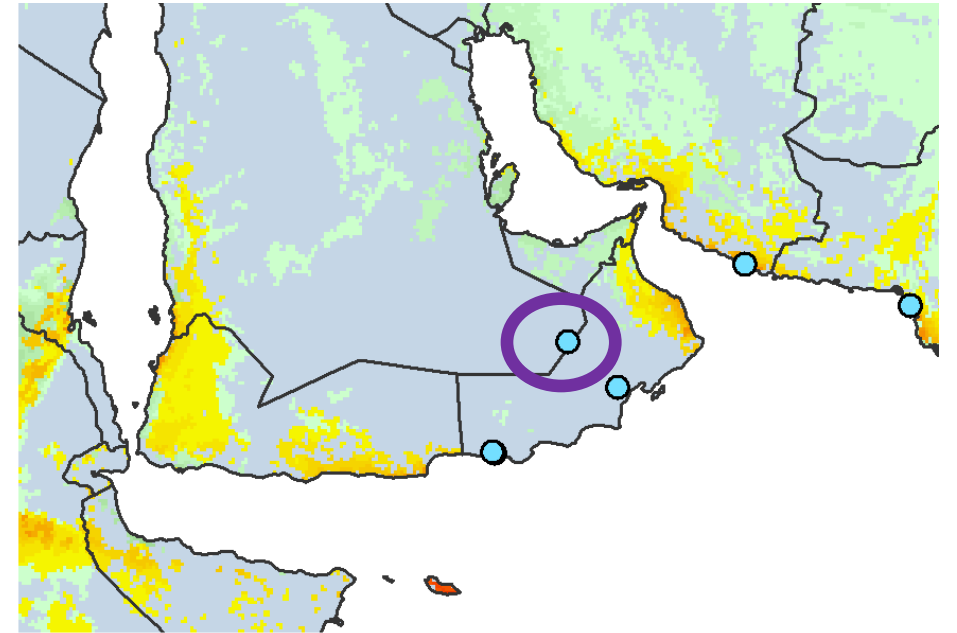
Royal Court Affairs Directorate General of Agriculture & Veterinary Services,  
P.O. Box : C.P.O. 17, Code : 111, Muscat Sultanate of Oman

- The peri-coastal distribution records seem valid
- Specimens sent to CABI for infection before being returned for a biological control programme
- The peri-coastal region of Oman is climatically suitable when run using an irrigation scenario
- The problem appears to be with the GMIA not characterizing this area as being irrigated



# Oman

- The record bordering Saudi Arabia is problematical, with substantial lethal Heat Stress modelled
- Max temperatures above 37 °C for six months of the year!
- Laboratory studies showing strong avoidance behaviour of 37 °C
- Possible transient record or geocoding error



# Economic Impacts



# Cost Framework

- $C_i = (V + R_i L Y_i P) \times A$ 
  - $V$  **value** of per-hectare increase in crop production costs
  - $R_i$  the **range** factor for *O. rhinoceros*. The range factor varies depending on whether the country is within the native, invaded, or suitable range and adjusts for the effects of coevolution with the virus
  - $Y_i$  the **yield** of the host crop in country  $i$
  - $L$  the **loss** in yield factor for the host crop
  - $P$  the world **price** for the host crop
  - $A$  the **area** harvested for the host crop in country  $i$



# Discounting

- Discounted annual cost

- $DCF = \frac{C_{i,n}}{(1+r)^n}$

- Rates  $r$  assessed between 2% and 7%, uniformly dist'd

- $NPV = \sum_{j=1}^n DCF_j = \frac{C_{i,1}}{(1+r)^1} + \frac{C_{i,2}}{(1+r)^2} + \dots + \frac{C_{i,n}}{(1+r)^n}$



# Assumed yield losses

- The reported impacts of *O. rhinoceros* on its two major host crops *Cocos nucifera* (coconut palms) and *E. guineensis* (African oil palm) vary widely
- Coconut palms: 5.0% - 15.0%, uniformly distributed
- Oil palms: 20.0% - 60.0%, uniformly distributed



# Results



# Headline Results

- Losses to oil palm production ~50x losses to coconut production
- Where *O. rhinoceros* is present
  - **coconut production** over the next 10 years (2021 through 2030) has an estimated NPV of USD \$91 billion,
  - NPV losses to **coconut production** due to *O. rhinoceros* estimated at US \$ 11 billion over 10 years (~\$1.1 billion p.a.)
  - **Palm oil production** has an estimated NPV of USD \$448 billion
  - NPV losses to **palm oil production** due to *O. rhinoceros* estimated at US \$508 billion over 10 years (**U.S. \$50.7 billion p.a.**) (mainly Indonesia and Malaysia)



# Where *Oryctes rhinoceros* not yet present

- Coconut production
  - Production NPV US \$6.4 billion or US \$641 million p.a.
  - Potential losses US \$679 million or US \$67.9 million p.a.
- Palm oil
  - Production NPV US \$ 24 billion or \$2.4 billion p.a.
  - Potential losses US \$13 billion or \$1.2 billion p.a.



# Discussion & Conclusion



# Limitations

- Cost estimates ignore supply chain impacts and impacts on derivative products
  - Estimates are conservative
- No accounting for social impacts
- Damage function ignores climate suitability
  - Would require damage assessments across a climate suitability gradient
  - May have little practical impact on conclusion



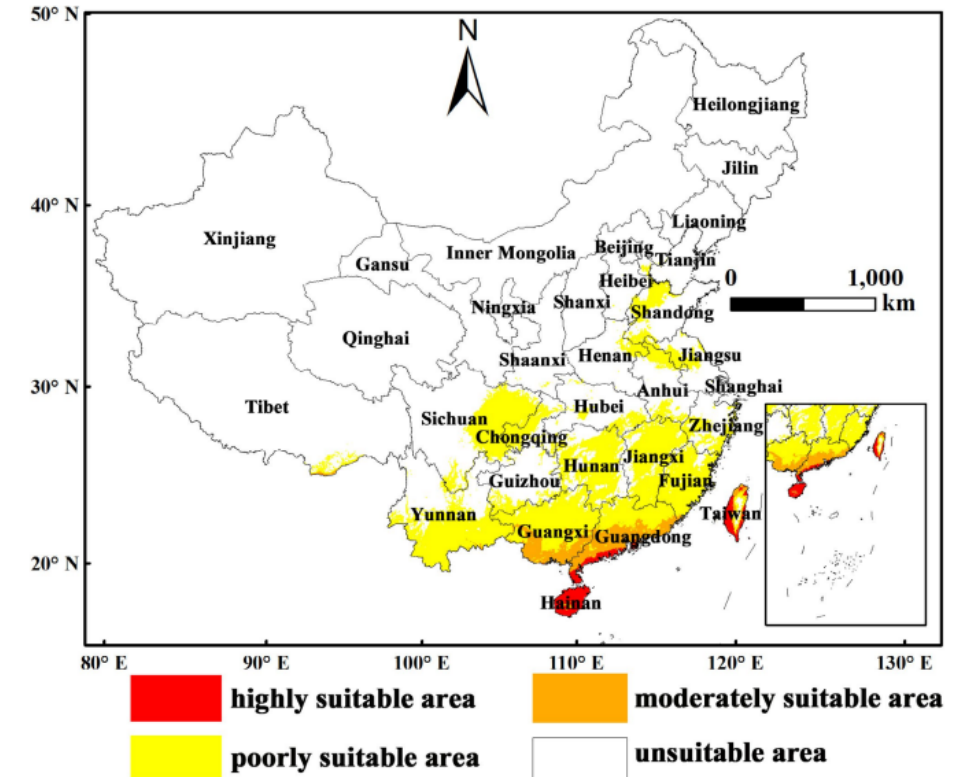
# Conclusion

- CRB is likely presently costing more than US\$51.8 billion p.a. in production losses
- This could rise by another US\$ 1.27 billion p.a. if it spreads to its potential distribution
- Palm oil production is already occurring in areas of high production potential and impacts are already occurring in these areas
- Potential further impacts from invasion are significant, but dwarfed by current impacts
- Critical need for safe affordable control, and
- Biosecurity to prevent the further spread
- Challenge is how to overcome market failure to fund solutions



# Fruit of poison trees

- The false northern Chinese record was used in Xu et al. (2022) to train a MaxEnt model
- Consequently, massively overestimating the potential distribution of CRB in high latitudes
- A single false record was responsible for  $> 2/3^{\text{rd}}$  of the area of modelled suitability



Xu, D., Zhuo, Z., Li, X., & Wang, R. (2022). Distribution and invasion risk assessment of *Oryctes rhinoceros* (L.) in China under changing climate. *Journal of Applied Entomology*, 146, 385–395. <https://doi.org/10.1111/jen.12989>



# Thank you!

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