Επιδράσεις των κλιματικών αλλαγών σε γεωργικές καλλιέργειες, φυτοφάγα αρθρόποδα και στους φυσικούς τους εχθρούς

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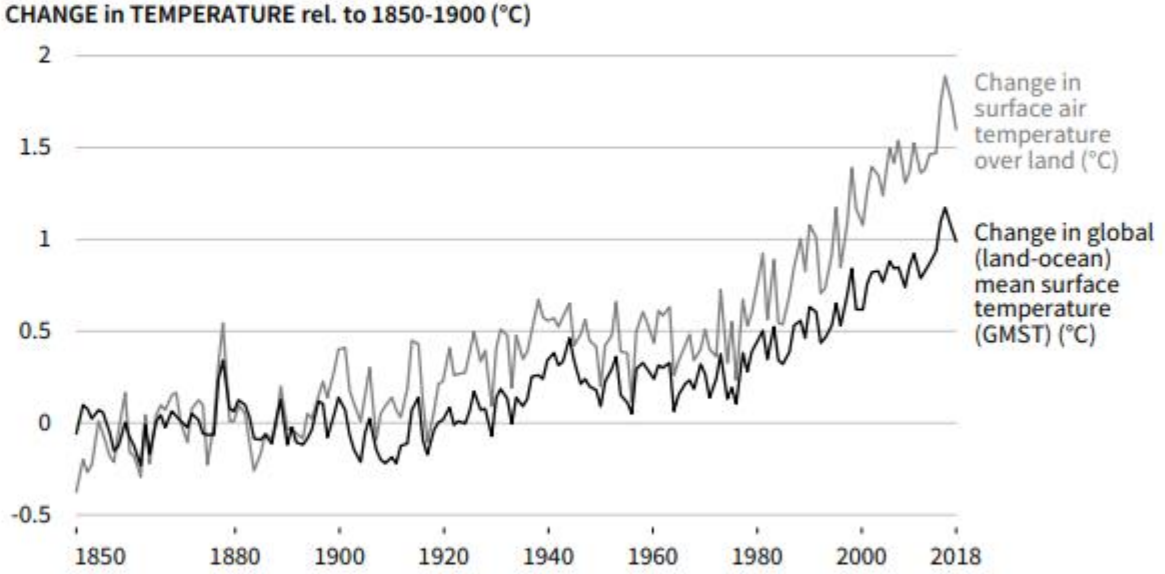
Ανοικτό Πανεπιστήμιο Κύπρου, Πέμπτη, 13 Φεβρουαρίου 2019

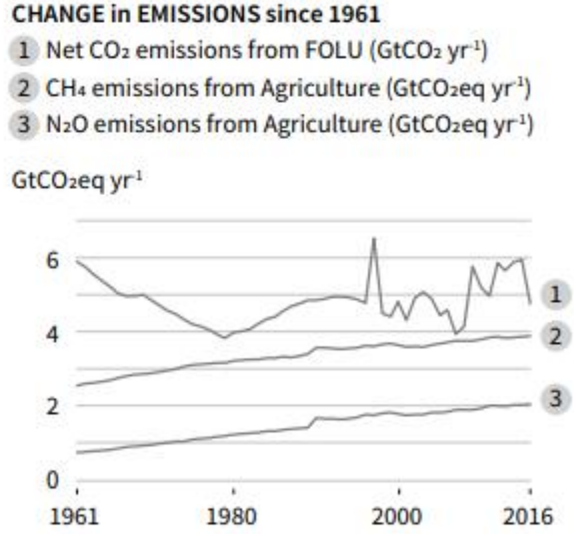
The planet is warming

Land use and observed climate change

A. Observed temperature change relative to 1850-1900
Since the pre-industrial period (1850-1900) the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (GMST).

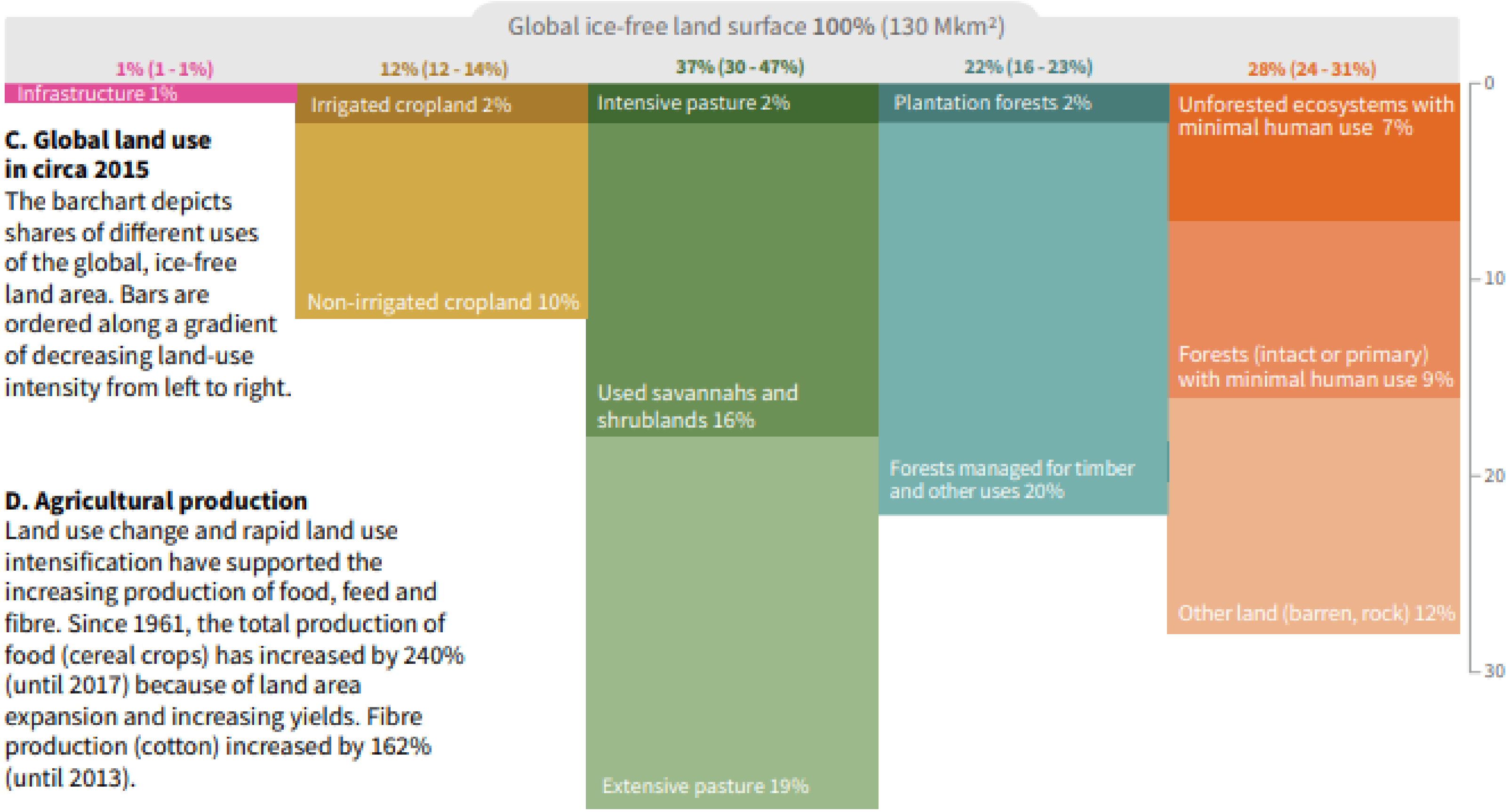


B. GHG emissions
An estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from Agriculture, Forestry and Other Land Use (AFOLU).



IPCC 2019

Resources are limited



C. Global land use in circa 2015
The barchart depicts shares of different uses of the global, ice-free land area. Bars are ordered along a gradient of decreasing land-use intensity from left to right.

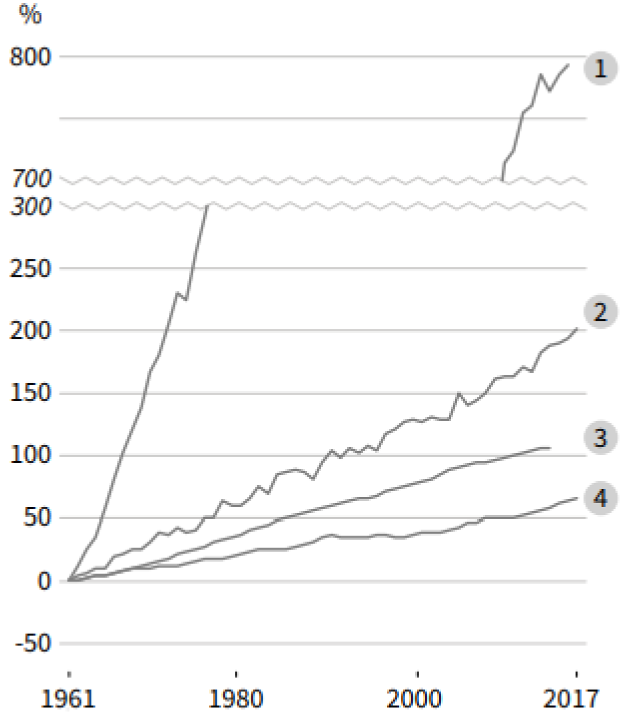
D. Agricultural production
Land use change and rapid land use intensification have supported the increasing production of food, feed and fibre. Since 1961, the total production of food (cereal crops) has increased by 240% (until 2017) because of land area expansion and increasing yields. Fibre production (cotton) increased by 162% (until 2013).

IPCC 2019

We use, produce, eat and destroy more…

CHANGE in % rel. to 1961

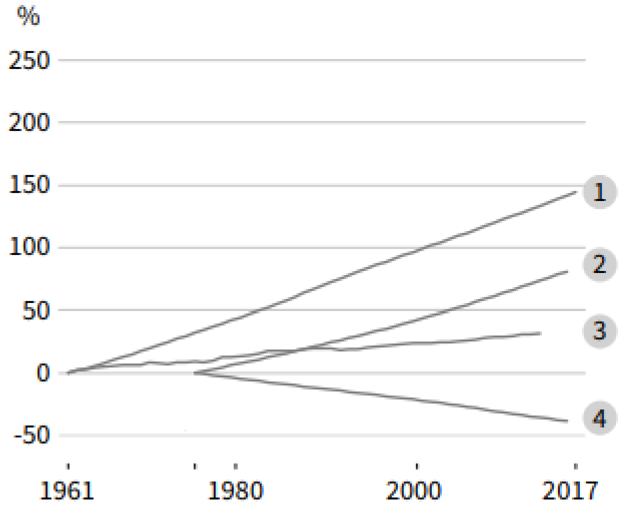
1. Inorganic N fertiliser use
2. Cereal yields
3. Irrigation water volume
4. Total number of ruminant livestock



E. Food demand
Increases in production are linked to consumption changes.

CHANGE in % rel. to 1961 and 1975

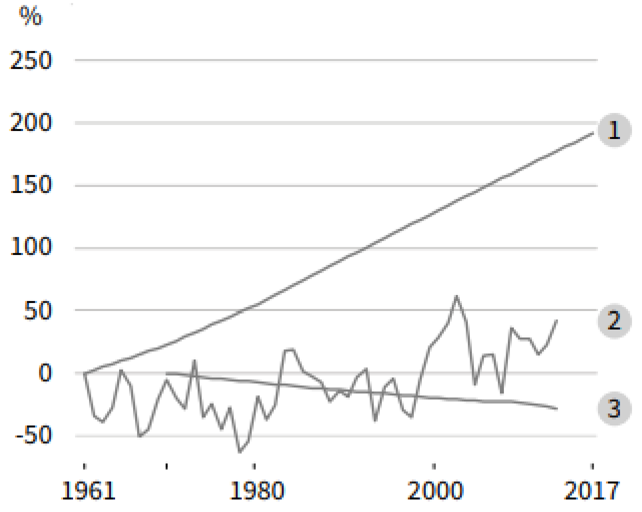
1. Population
2. Prevalence of overweight + obese
3. Total calories per capita
4. Prevalence of underweight



F. Desertification and land degradation
Land-use change, land-use intensification and climate change have contributed to desertification and land degradation.

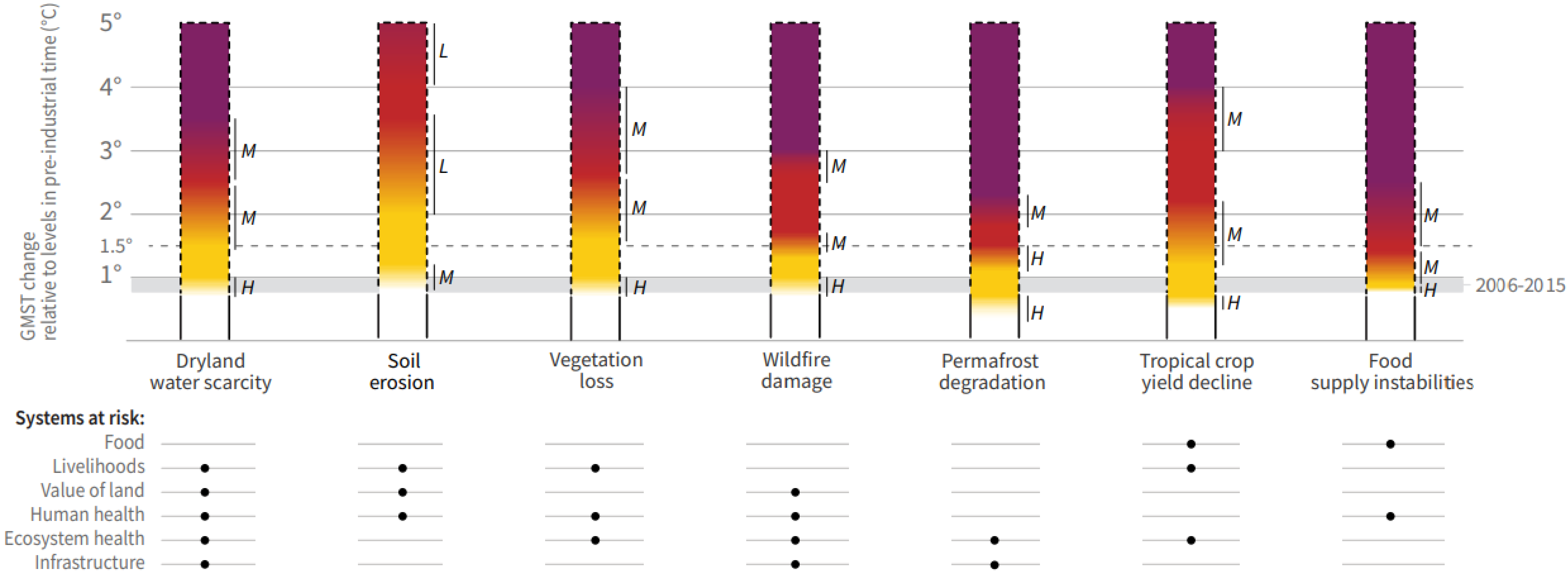
CHANGE in % rel. to 1961 and 1970

1. Population in areas experiencing desertification
2. Dryland areas in drought annually
3. Inland wetland extent



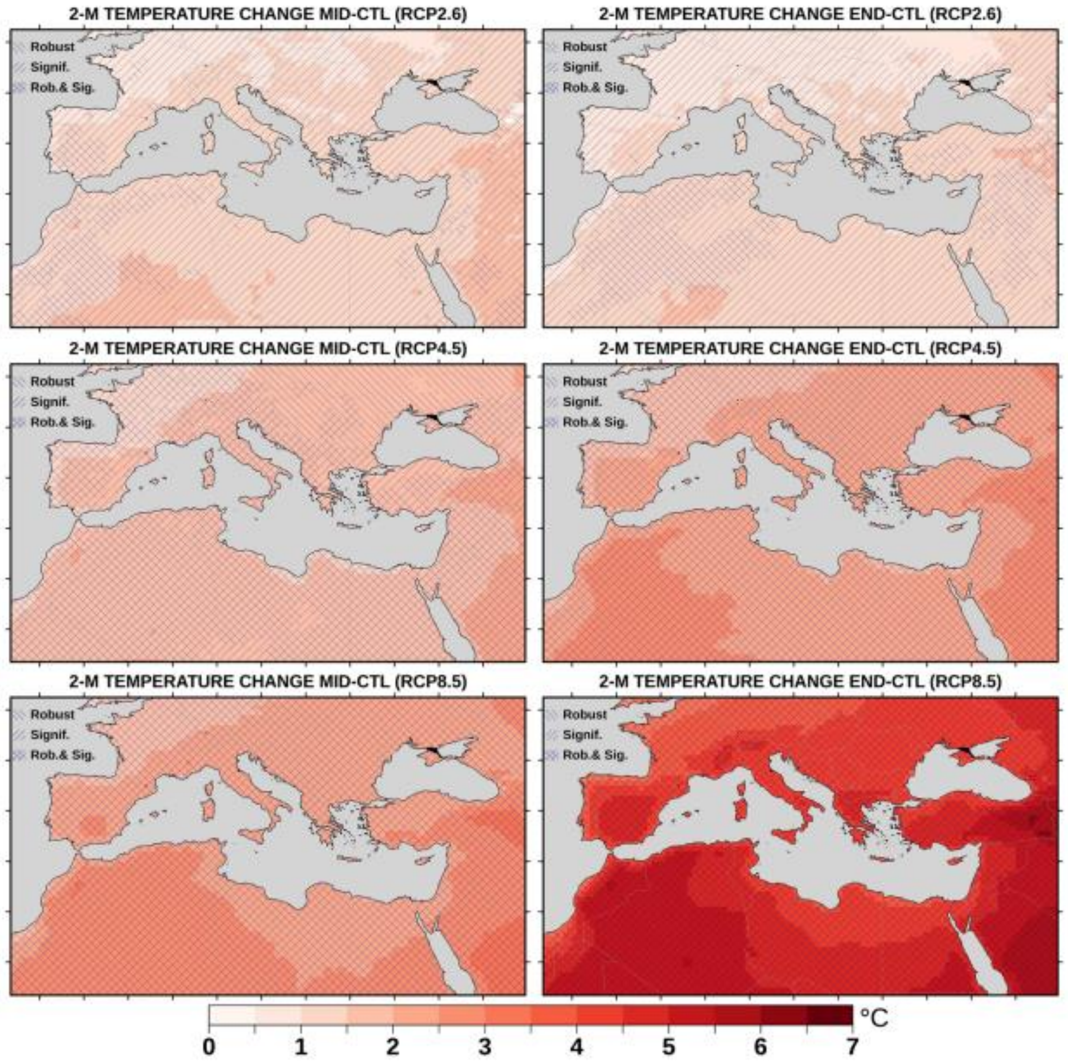
IPCC 2019

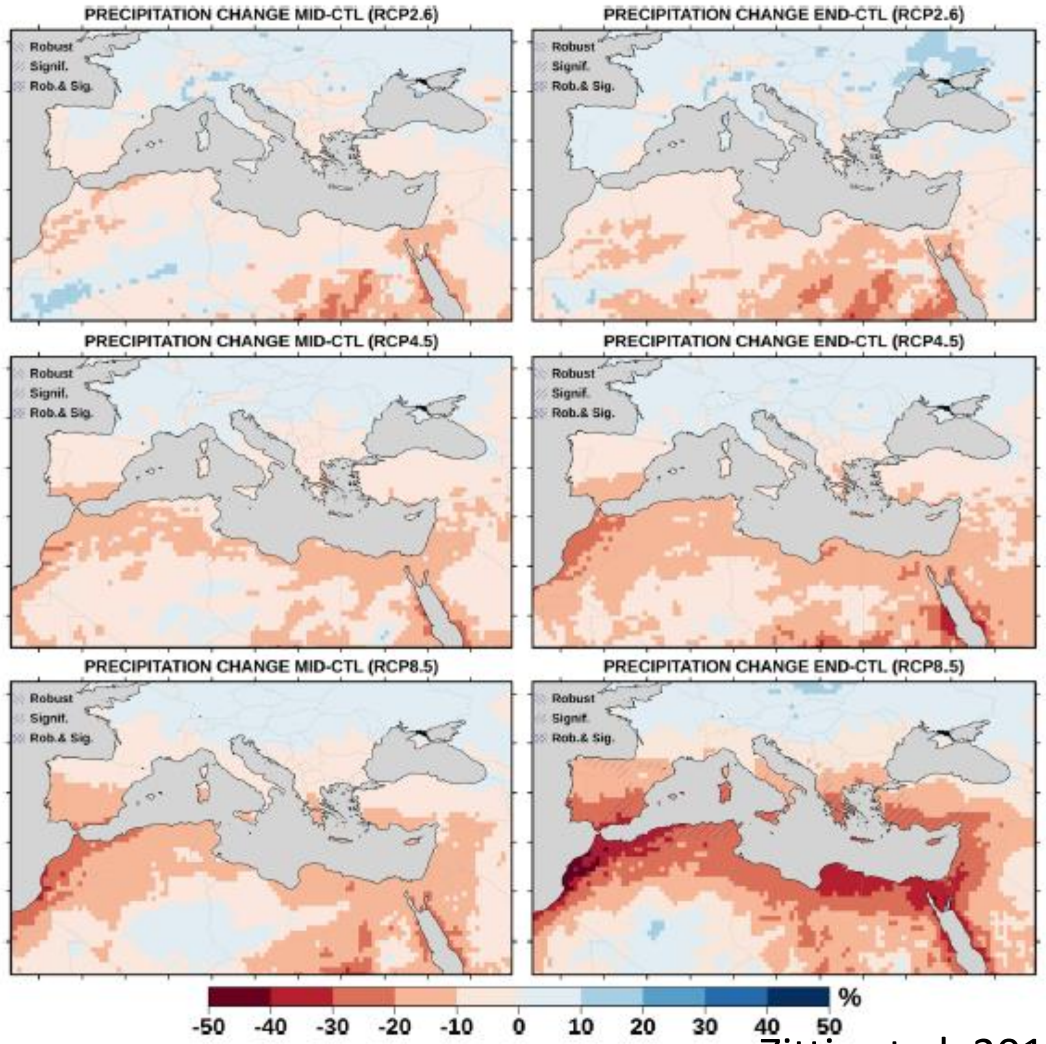
Expected impacts increase with temperature



IPCC 2019

Our corner of the world will experience severe impacts

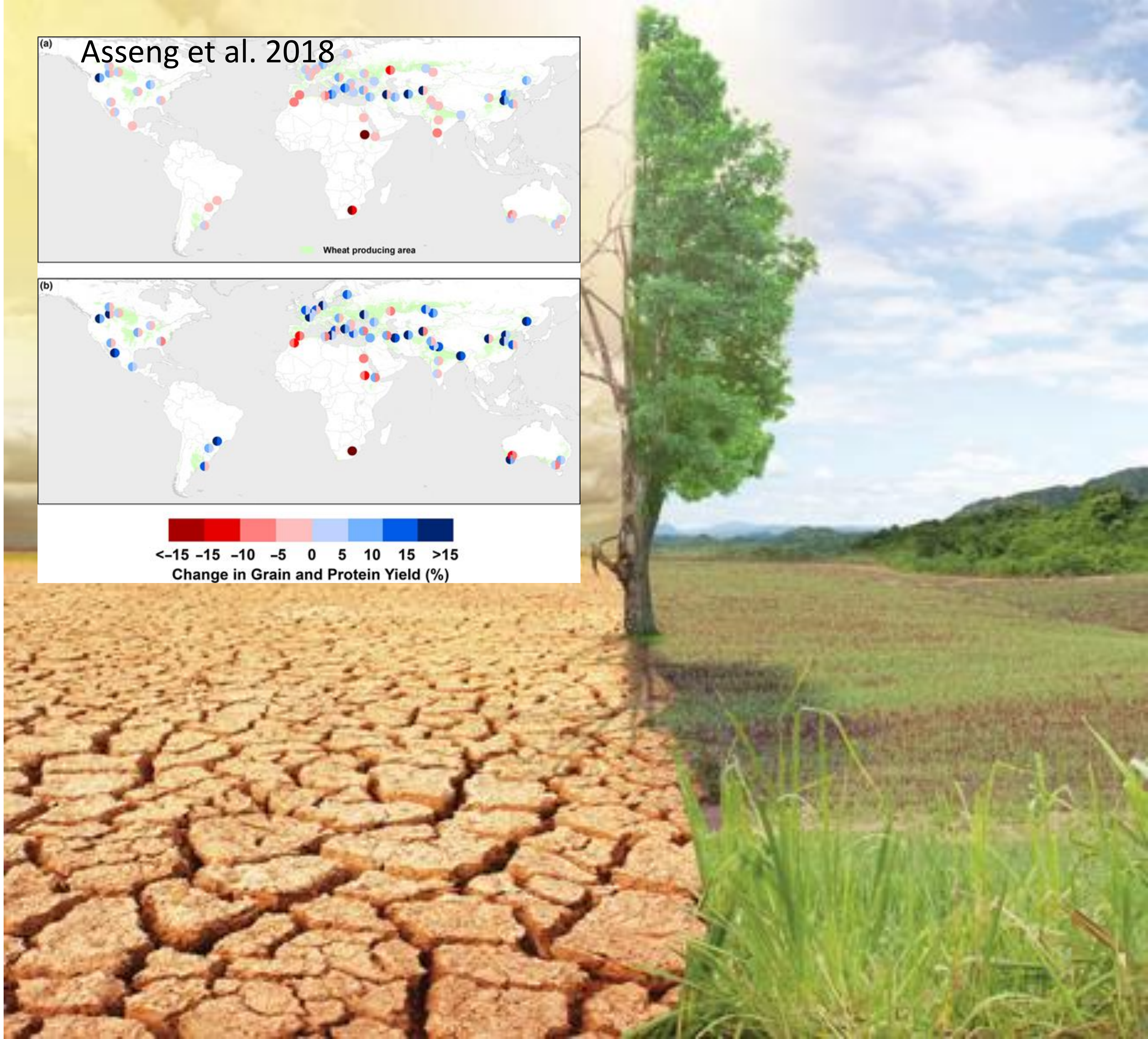




Zittis et al. 2019

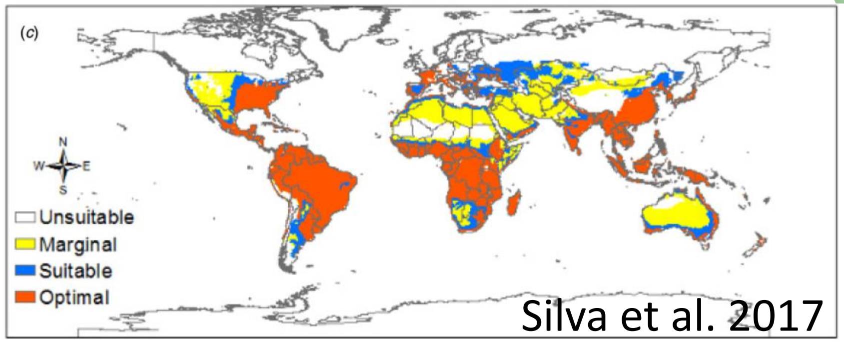
Climate change and agriculture

- Climate change (CC) impacts global agricultural production (e.g. Fleisher et al., 2017; Yoon et al., 2019; Moat et al., 2019)
- Considerable effort on exploring CC risks on stable crops
- Vegetables, pests, natural enemies underrepresented in the literature (Porter et al., 2017, Savary et al. 2019)
- Substantial interest in evaluating impacts of 1.5 °C warming on agricultural systems – IPCC special report, Hoegh-Guldberg et al. 2019



Tomato

- Highest value fruit-vegetable in the world,
- Annual value of over 90 billion USD (FAOSTAT 2016).
- 5 million ha in 2015,
- 166 million tonnes per year (FAO 2017).
- Outdoor tomato production faces a potential risk from climate change – worst case scenaria (Saadi et al. 2015; Silva et al. 2017)



Silva et al. 2017

Two-spotted spider mite (*Tetranychus urticae*)

- A pest of major importance globally, for more than 200 species of crops (Migeon and Dorkeld 2015)
- Highly resistant to pesticides (more than 90 active ingredients – APRD, 2019)
- $400 million annually for pesticides alone (van Leeuwen et al., 2015)

***T. urticae* : female, male (left) eggs and a larva (right)**

Predatory mite
Phytoseiulus persimilis

- Among first examples of successful biological control (Knapp et al., 2018)
- Among most widely used natural enemies
- Mediterranean origin, natural populations in several parts of the world

P. persimilis **: adult and egg (left) - larva (right)**

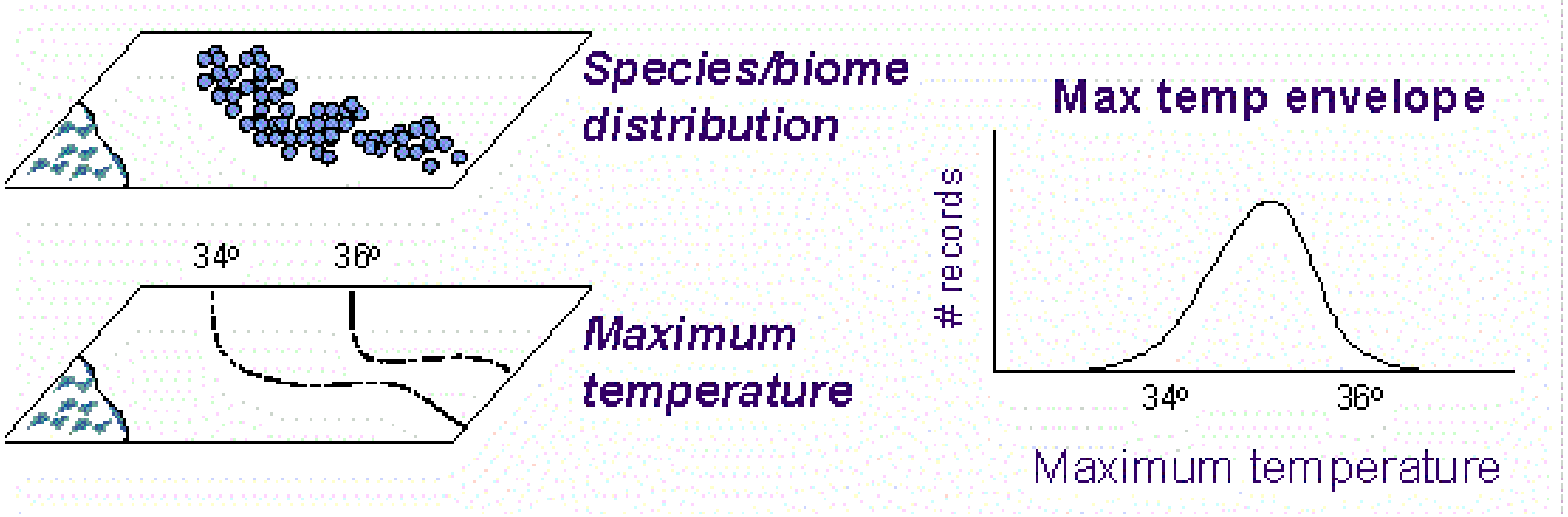
Study aims

- Develop a global bioclimatic niche model for tomato, the two-spotted spider mite, and *P. persimilis*
- Evaluate the effects of CC by 2050 on the three species for all global areas equipped with irrigation facilities (AEI)
- Validate the models using outdoor experiments and a farmer survey

Methods

Evaluating CC impacts on agricultural crops and their pests

- **Bioclimatic envelope models:** Based on species presence and climatic conditions in a specific area.
- **Climex model** (Suthrest et al. 2015). Used for several species of agricultural importance, including crops and pests/pathogens



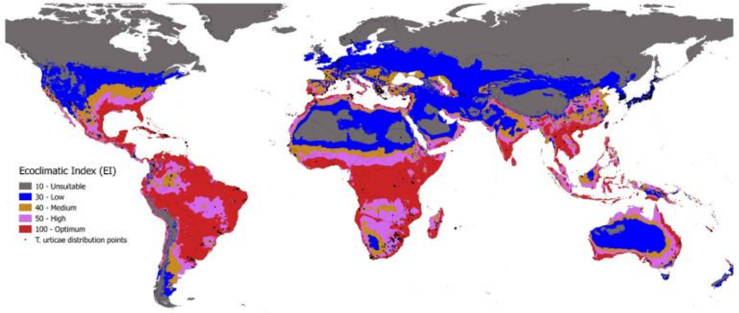
Presence and climate data

- **Mites**

- *T. urticae* - Spider Mites Web (Migeon and Dorkeld 2006-2015).
- *P. persimilis* - Literature and personal records (INRA Tixier, Migeon).

- **Tomato (field crops).**

- GBIF (Global Biodiversity Information Facility)

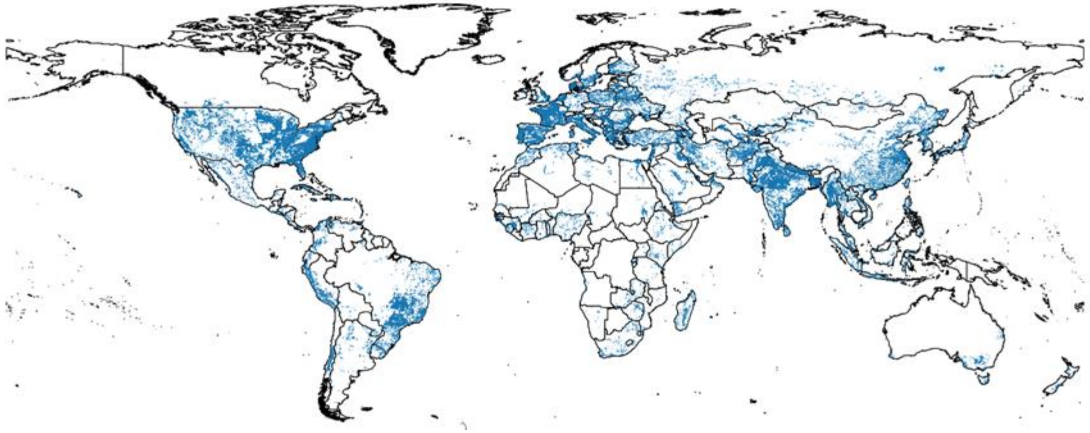


- **General Circulation Model (GCM)**

- A1B in CSIRO-MK3.0 (CSIRO, Australia) - 1.61 °C increase by 2050 relative to pre-industrial levels, - Paris agreement relevant.
- CliMond (Kriticos et al. 2012) at a 10 arcminutes global data grid (18.5 x 18.5 km).

Spatial mapping

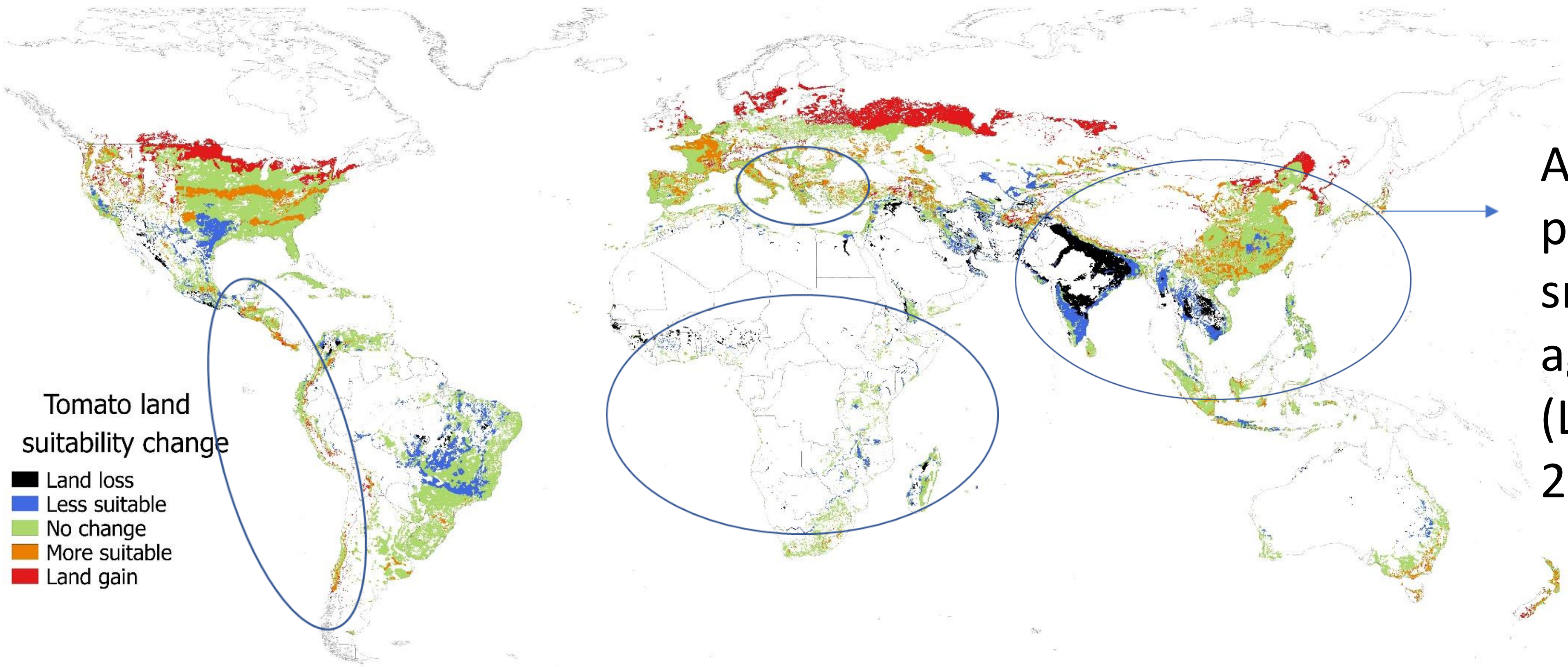
- FAO Global Map of Irrigation Areas v.5 - 5 arc minute (Salmon et al., 2015)



- Software: R (v. 3.4.0) – libraries raster and rgdal QGIS v.2.18.5

Results

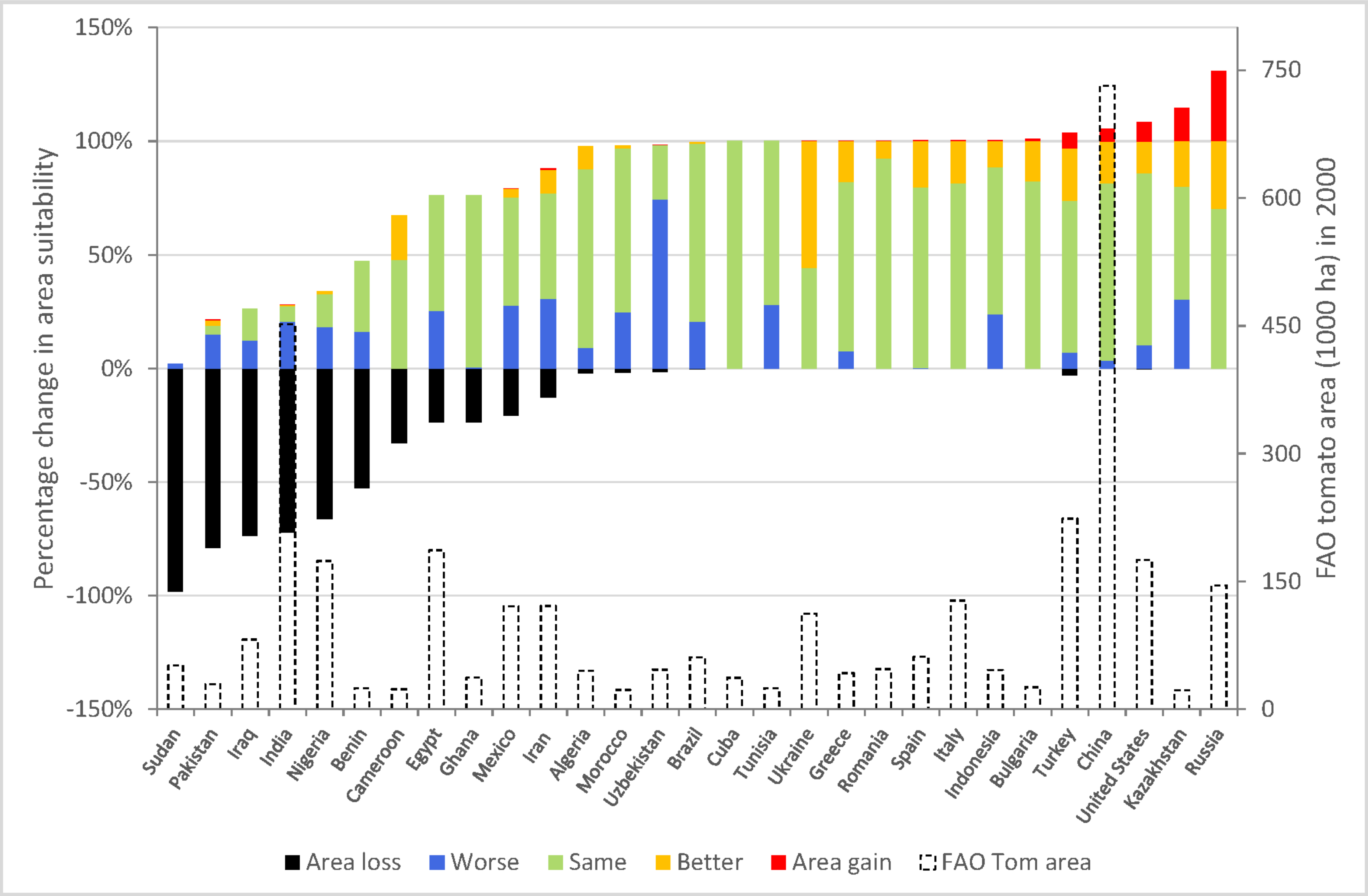
Suitability of land for tomato production decreases in Asia-Africa and improves at northern latitudes



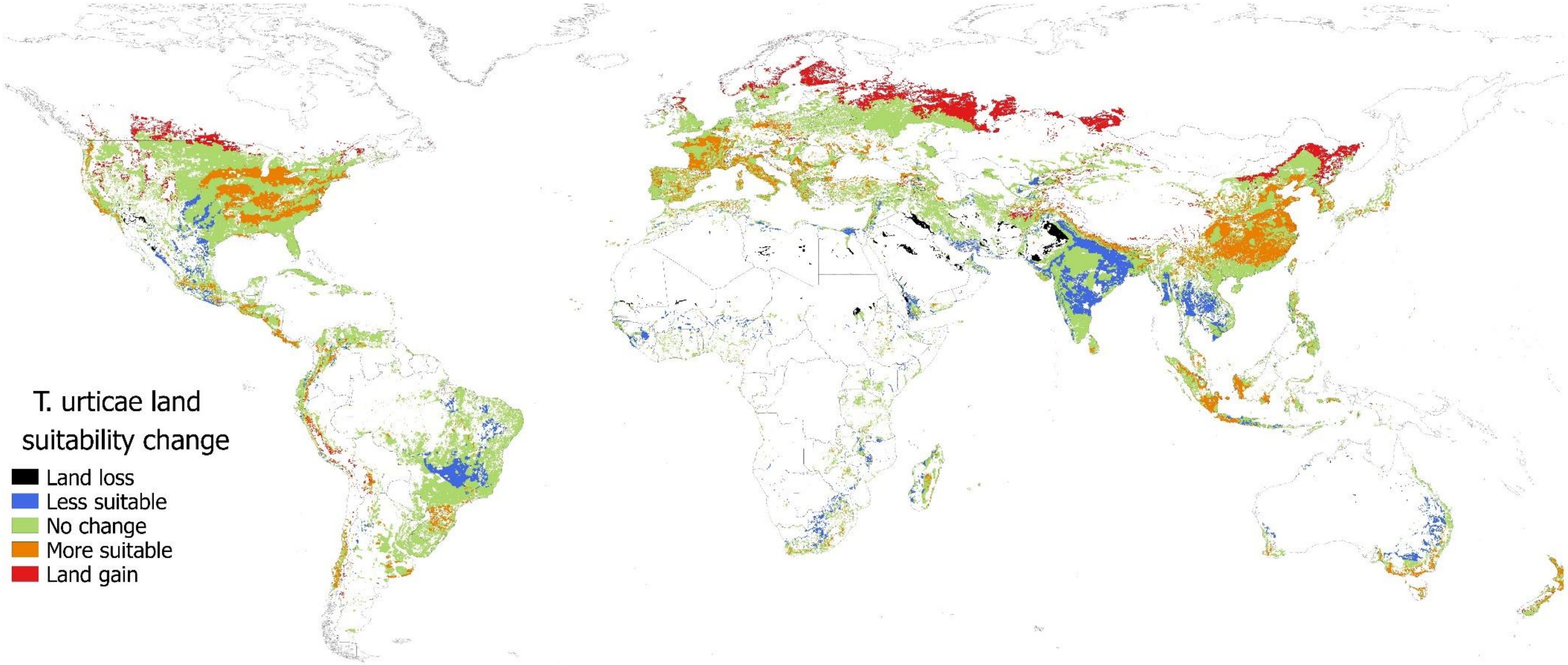
Areas with prevalent small-scale agriculture (Lesiv et al. 2019)

1975H: 80% of AEI. By 2050 -> Loss: 18%, Worse: 16%, Same: 54%, Better: 17%, Gain: 4%

Worst affected nations: Africa and Asia

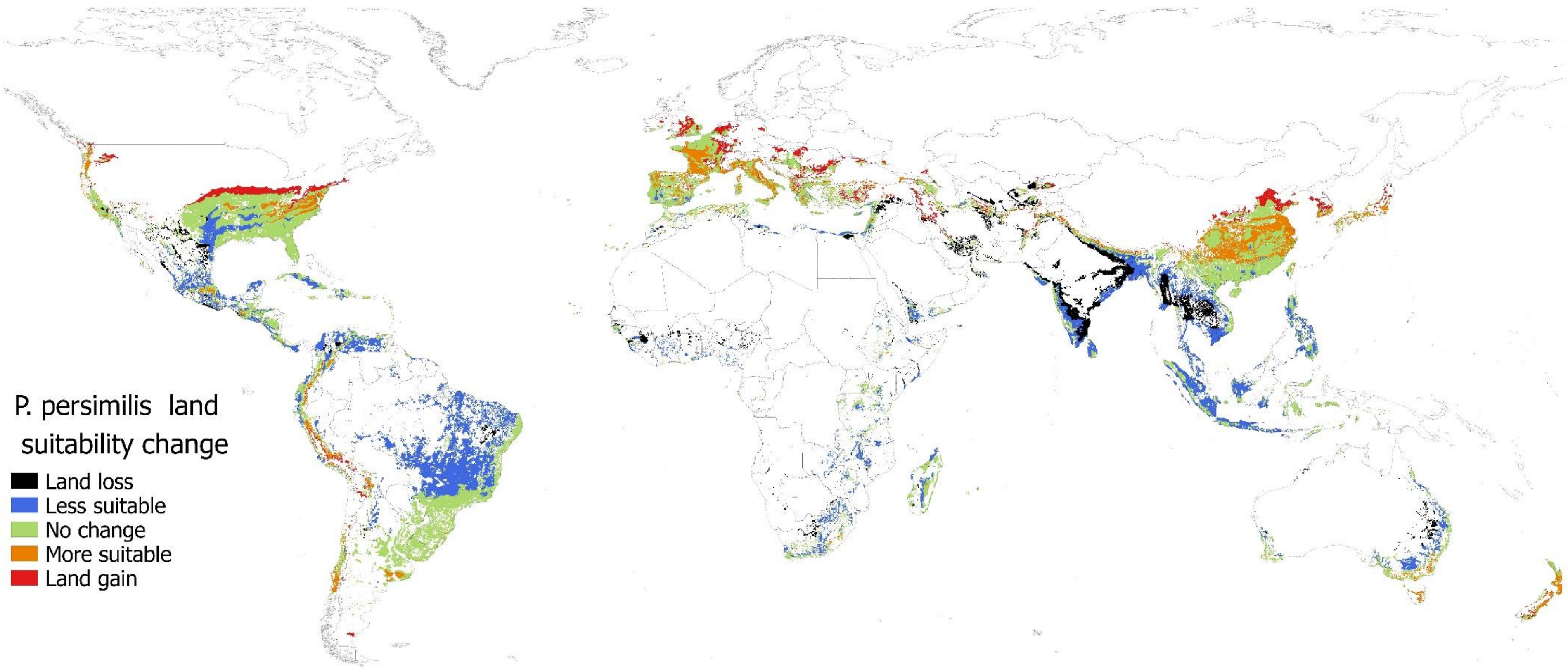


Two-spotted spider mite: Northward expansion, increase in suitability of land (with exceptions)



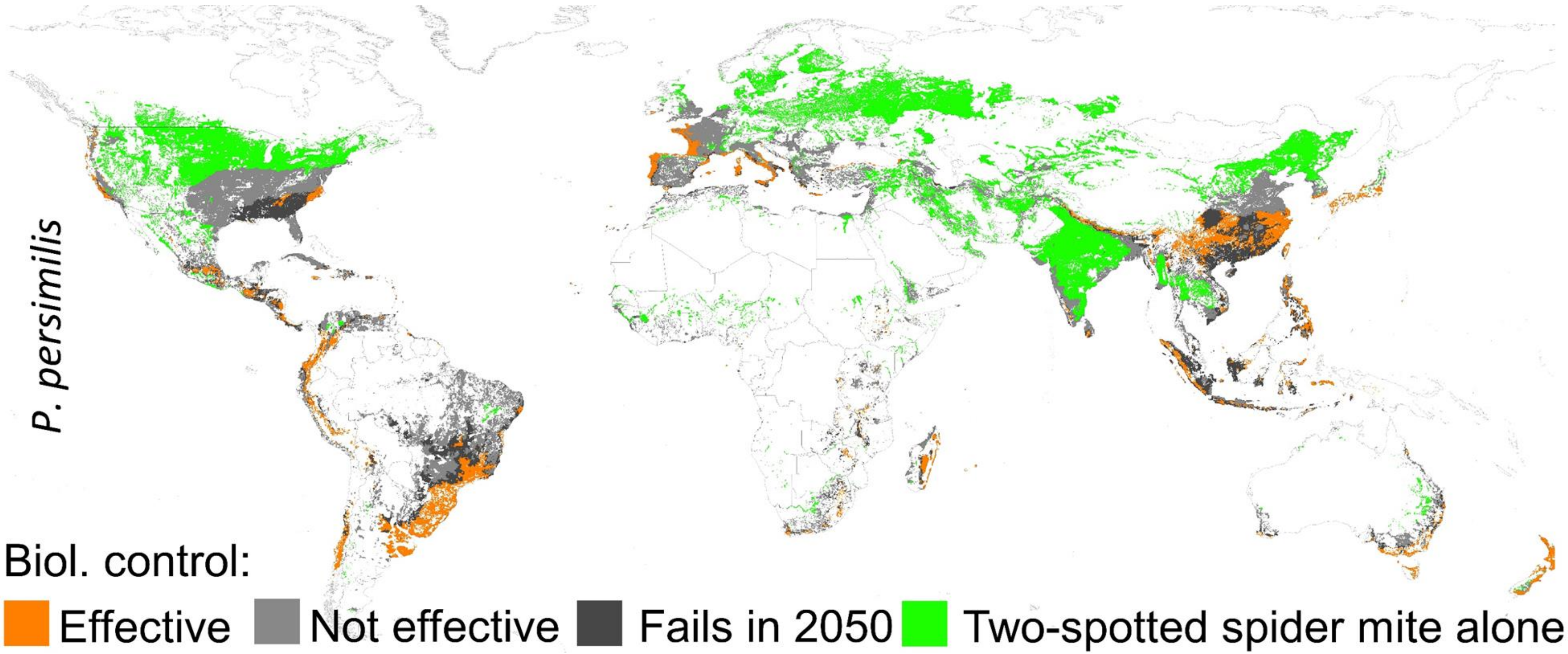
1975H: 95% of AEI. By 2050 -> Loss: 4%, Worse: 16%, Same: 57%, Better: 17%, Gain: 2.0%

P. persimilis: Land loss and substantial worsening of land suitability



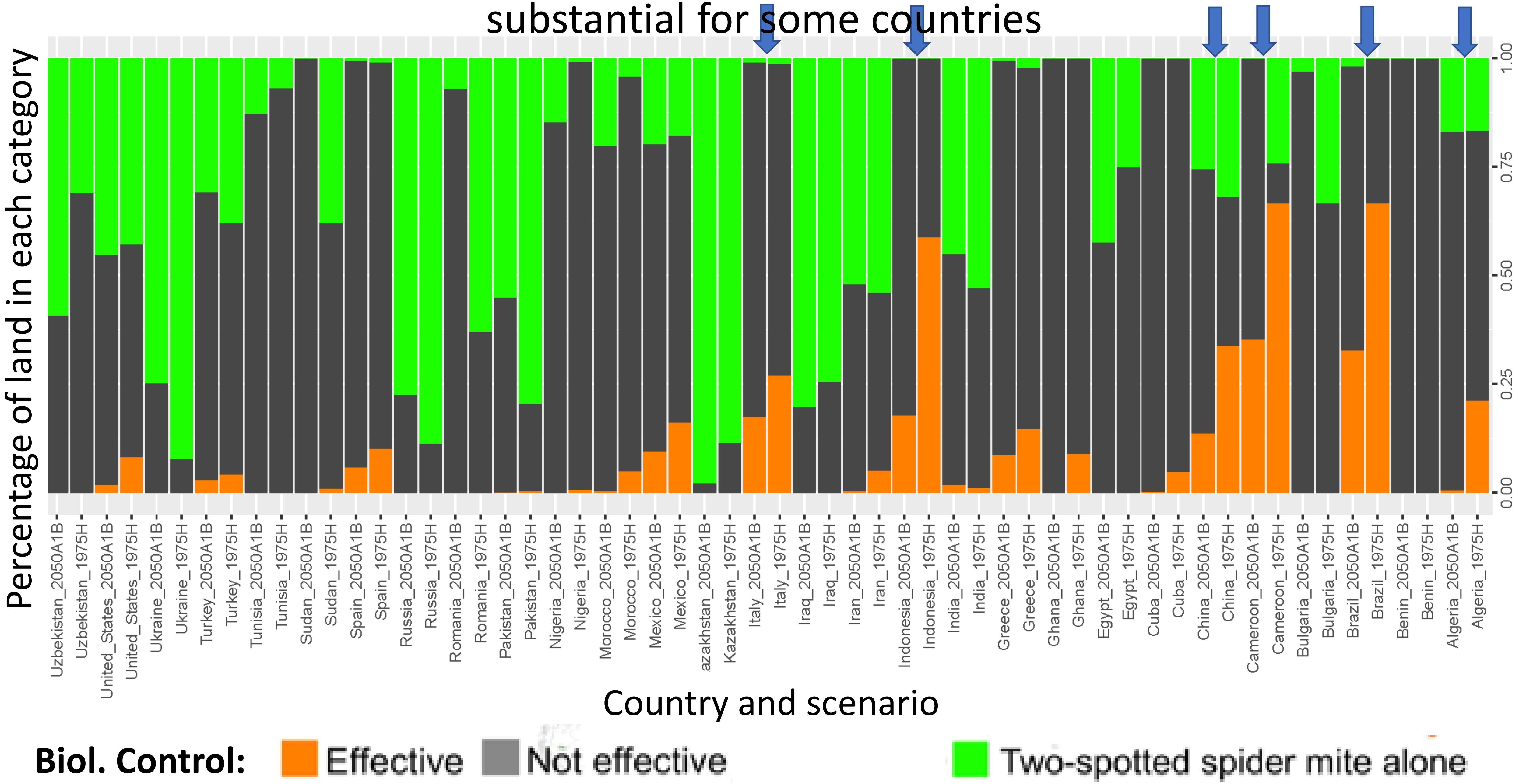
1975H: 56% of AEI. By 2050 -> Loss: 10%, Worse: 7%, Same: 25%, Better: 14%, Gain:5%

CC expected to disrupt biological control

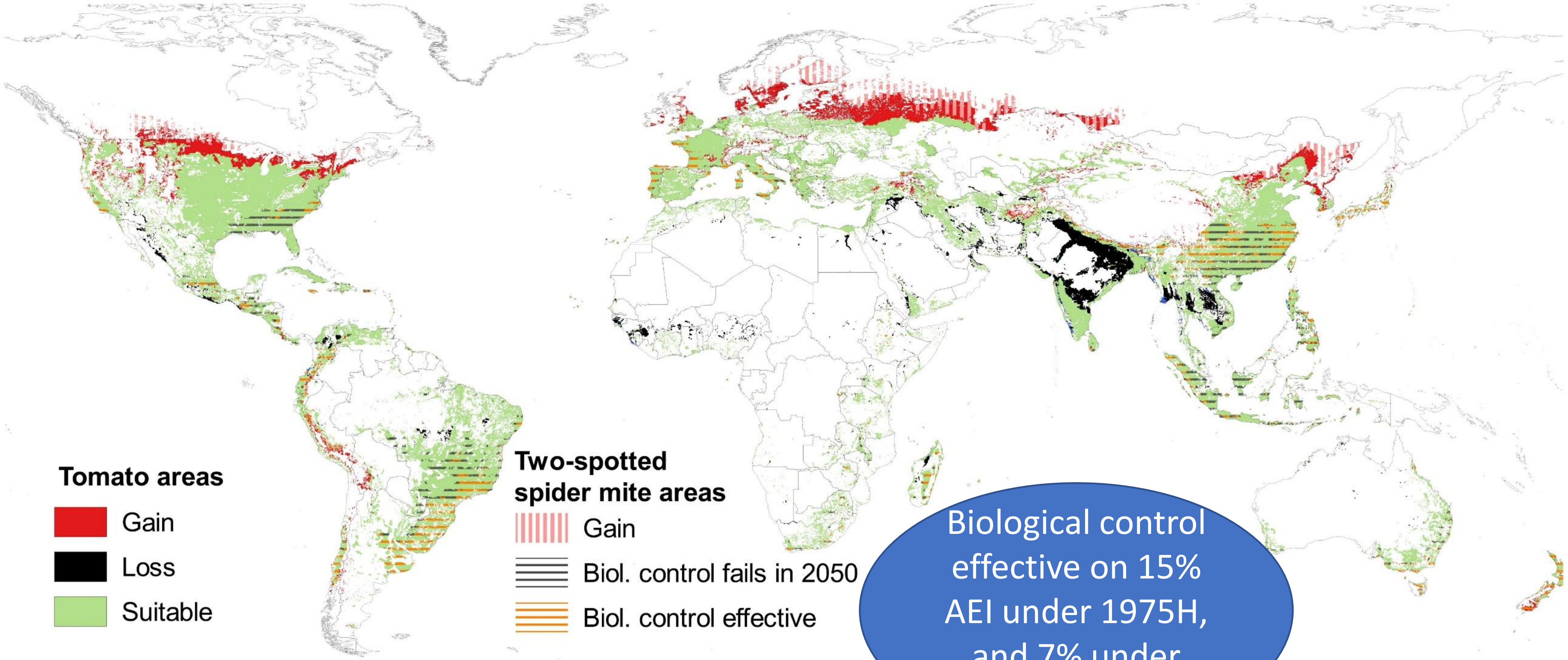


1975H -> Effective: 18%, Not effective: 67%, Two-spotted spider mite alone: 9%
2050 -> 9%, 66%, 17%

Impacts on biological control on areas suitable for tomato cultivation substantial for some countries



Synthesis: Impacts on biol. control more severe on areas suitable for tomato cultivation

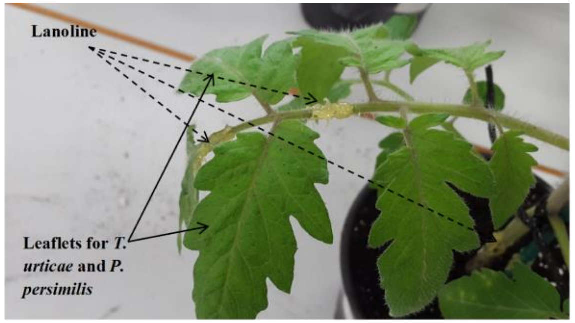


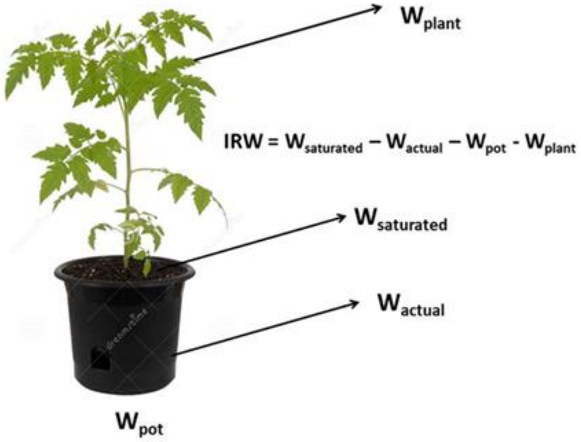
Biological control effective on 15% AEI under 1975H, and 7% under 2050

Model validation

Validation of model through outdoor experiments

- Tomato plants alone
- Tomato plants with two-spotted spider mite
- Tomato plants with two-spotted spider mite and *P. persimilis*
- 2016 and 2017





- Plants infested in the laboratory and transferred to outdoor locations for six days
- Watered daily based on evapotranspiration losses

Plant and population growth parameters

Relative Growth Rate $$\mathrm{RGR} = \frac{\ln(\text{final plant above ground biomass}) - \ln(\text{initial plant aboveground biomass})}{\text{Plant duration at field site}}.$$

(Pattison and Mack 2008; Global Change Biology)

Instantaneous rate of increase: $$r = \left[\ln\left(\frac{N_{Final}}{N_{Initial}}\right)\right] / \mathrm{t}$$

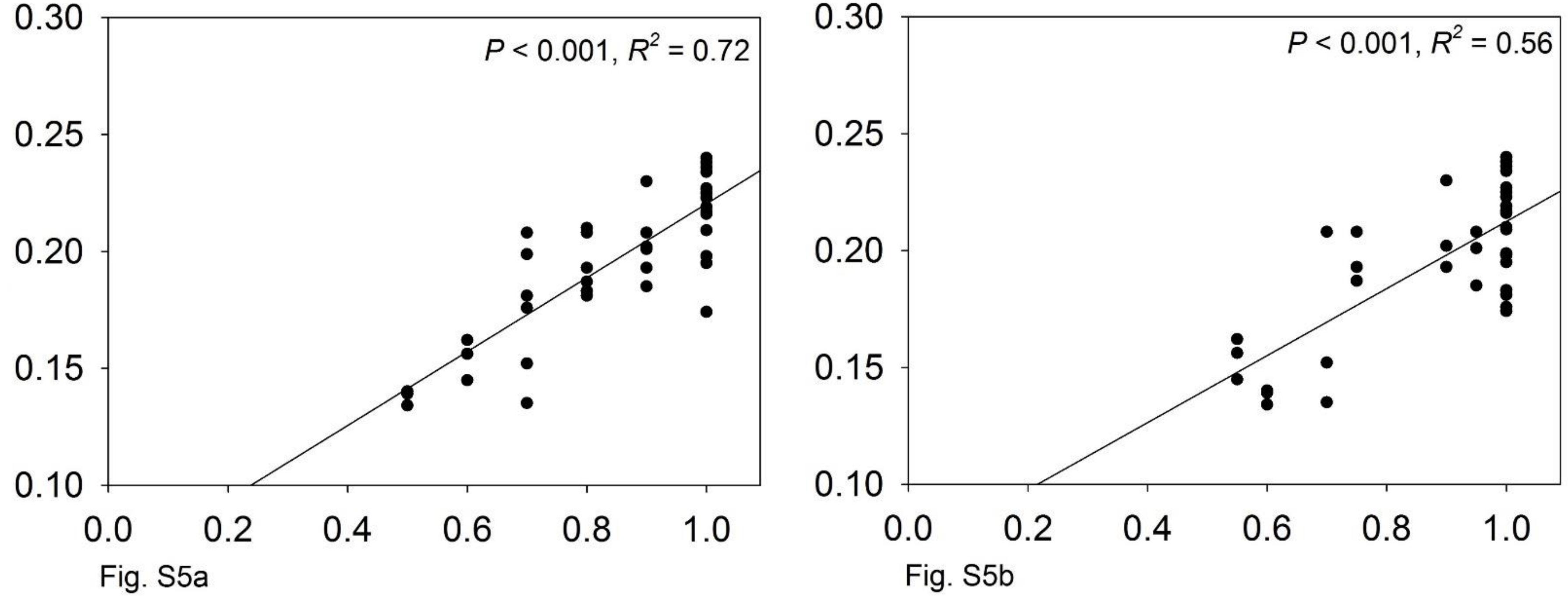
Where: N_{Final} is the population of all stages of mites after 6 days and $N_{Initial}$ is the initial population (=20 females) (Stavrinides and Mills, 2009).

Significant relationship between model results and field growth for tomato

Irrigation adjusted to site-based evapotranspiration

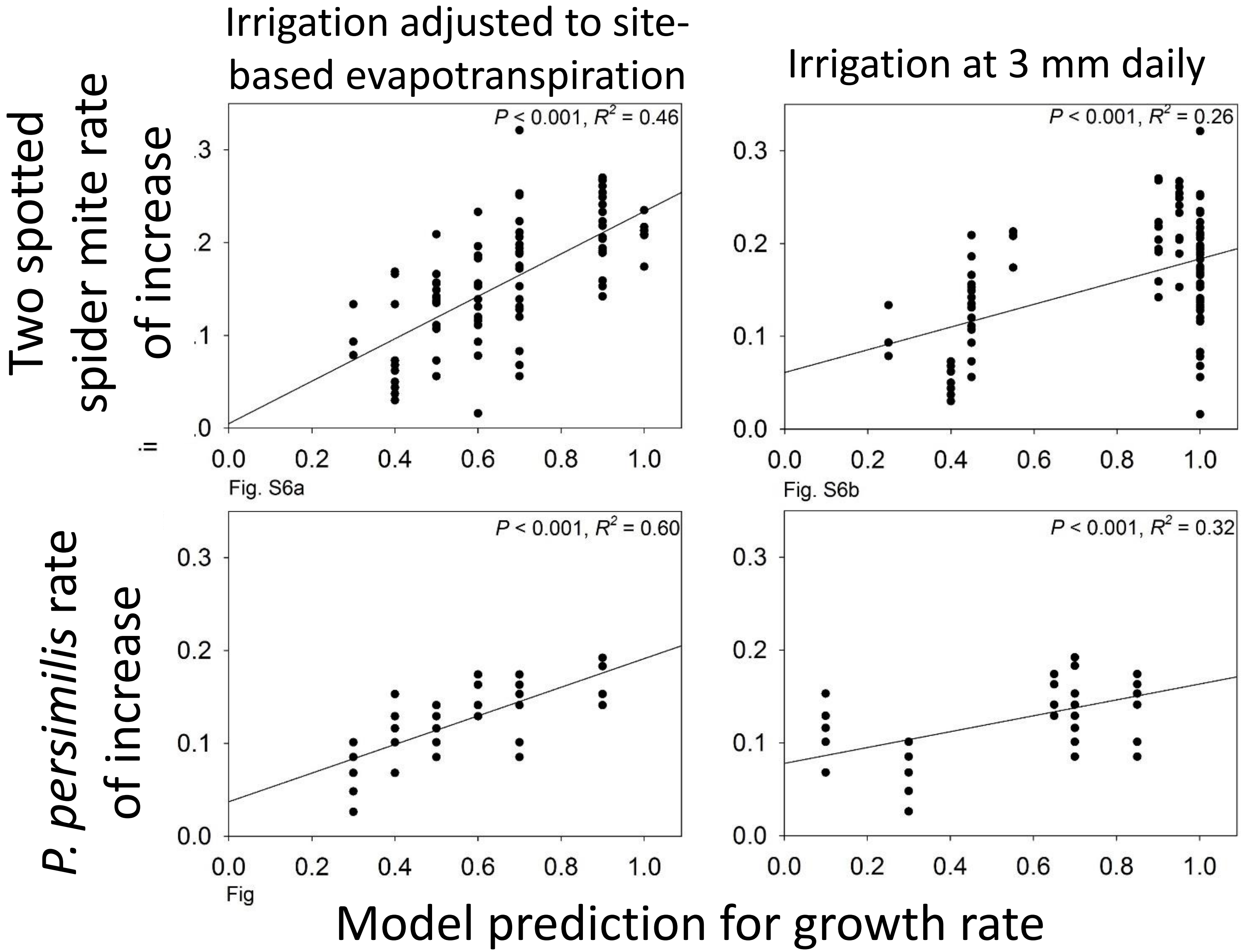
Irrigation at 3 mm daily

Tomato growth rate



Model prediction for growth rate

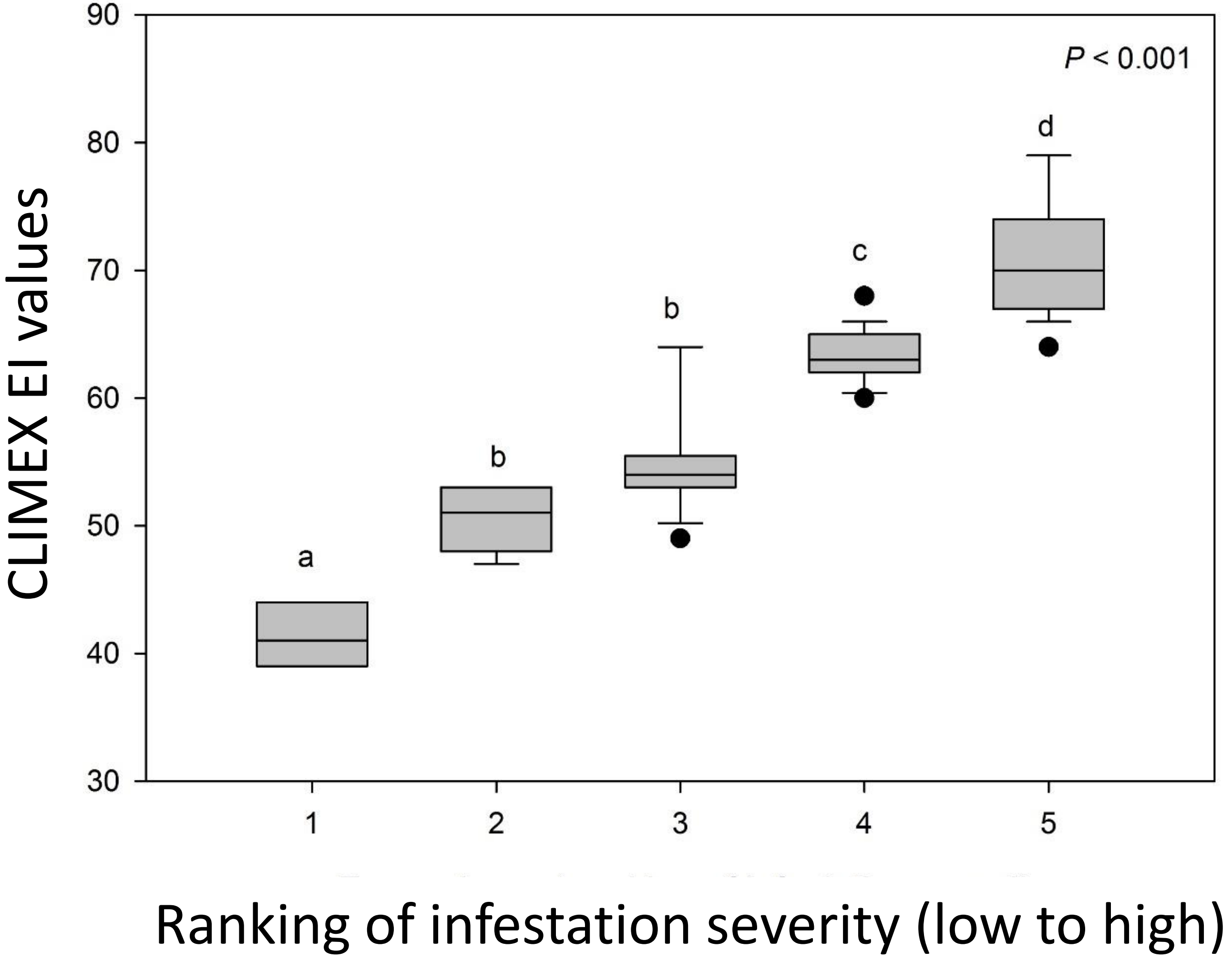
Significant relationship between model results and field observations for the two-spotted spider mite and *P. persimilis*



Validation of model results through a farmer survey

- 80 farmers in main agricultural areas of Cyprus
- Asked to rank two-spotted spider mite infestation severity from 1 to 5
- Used bioclim data centered on 1985 (1 km grid resolution) for Cyprus to obtain climate favorability for the pest from the CLIMEX model
- Evaluated relationship between model predictions and farmer responses using one-way ANOVA.

Significant relationship between farmer perception on two-spotted spider mite infestation severity and model predictions



(*F* = 399.21; *df* = 1,78; *P* <0.001)

Conclusions

- Unfavorable effects of CC on **tomato**, especially for nations in Africa and Asia (adaptation efforts more complicated)
- Favorable impacts at northern latitudes
- CC expected to disrupt **biological control** on ca. 10% of land suitable for tomato production
- Work needs to focus on identifying heat and drought resistant tomato varieties (e.g. Ximenez-Embun et al., 2017) and natural enemies adapted to the changing climate

Future work

- Use of ensemble models from AR5 to evaluate CC impacts on pest-natural enemy complex of key crops
- Link model results to observed change in management practices, e.g. pesticide use
- Identify natural enemies potentially effective under CC conditions
- Building strong collaborations a prerequisite for this type of research

IOP Publishing Environ. Res. Lett. 14 (2019) 084041 https://doi.org/10.1088/1748-9326/ab3313

Environmental Research Letters

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RECEIVED
22 February 2019

REVISED
2 July 2019

ACCEPTED FOR PUBLICATION
17 July 2019

PUBLISHED
12 August 2019

Original content from this

LETTER

Impacts of climate change on tomato, a notorious pest and its natural enemy: small scale agriculture at higher risk

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Acknowledgements

GENOMITE : An ERANET+ FACCE project

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