Agriculture and Changing Climates

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Climate Change Ecology (GEOG 404)
April 3, 2015

REACCH Regional Approaches to Climate Change – Pacific Northwest Agriculture

University of Idaho

Outline

The Food Production Challenge
Climate Change and Agriculture: Trends and Projections
Agroecosystems
Pests and Diseases
Food Systems
Solutions

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FAO estimates that agricultural production must increase by 60% by 2050 to satisfy the expected demands for food and feed.

Climate change will make this task more difficult.

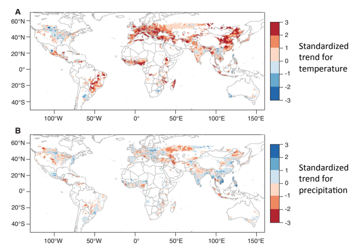
Adaptation to climate change and lower emission intensities per output will be necessary.

FAO 2013

Changes in Climate that Affect Agriculture

- Rain patterns
- Water availability
- The frequency and intensity of 'extreme events'
- Increased variability both in temperature and rain patterns
- Sea level rise and salinization
- Perturbations in ecosystems

FAO 2013



Lobell et al. 2011

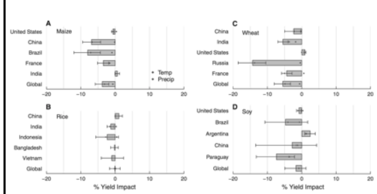
With the important exception of the United States, temperature trends from 1980 to 2008 exceeded one standard deviation of historic year-to-year variability.

Models that link yields of the four largest commodity crops to weather indicate that global maize and wheat production declined by 3.8 and 5.5%, respectively, relative to a counterfactual without climate trends.

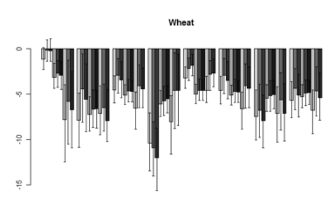
Lobell et al. 2011

Crop	Global production, 1998–2002 average (millions of metric tons)	Global yield impact of temperature trends (%)	Global yield impact of precipitation trends (%)	Subtotal	Global yield impact of CO_2 trends (%)	Total
Maize	607	-3.1	-0.7	-3.8	0.0	-3.8
Rice	591	0.1	-0.2	-0.1	3.0	2.9
Wheat	586	-4.9	-0.6	-5.5	3.0	-2.5
Soybean	168	-0.8	-0.9	-1.7	3.0	1.3

Lobell et al. 2011



Lobell et al. 2011



An ensemble of 30 different wheat crop models of the Agricultural Model Intercomparison and Improvement Project (AgMIP) indicates that warming is already slowing yield gains at a majority of wheat-growing locations globally.

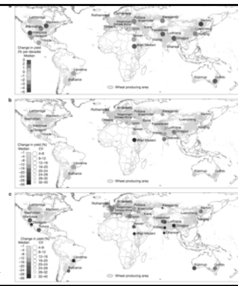
Global wheat production is estimated to fall by 6% for each ◦C of further temperature increase and become more variable over space and time**.**

Asseng et al. 2014

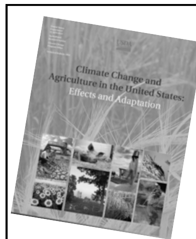
Modeled Trends 1981-2010

Projected Trends with +2°C

Projected Trends with +4°C



Asseng et al. 2014



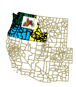
Climate change poses unprecedented challenges to U.S. agriculture because of the sensitivity of agricultural productivity and costs to changing climate conditions.

Increases of atmospheric CO_2, rising temperatures, and altered precipitation patterns will affect US agricultural productivity.

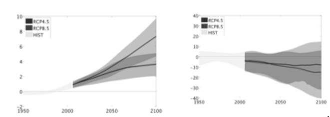
The vulnerability of agriculture to climatic change …[depends on] responses taken by humans to moderate the effects of climate change.

Walthall et al. 2013

PNW Climate



PNW Climate Projections: June-Sept. CMIP 5



J. Abatzoglou

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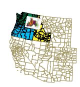
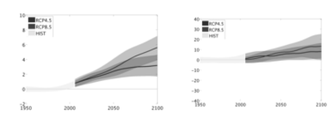
PNW Climate



PNW Climate Projections: Nov-Apr CMIP 5



J. Abatzoglou

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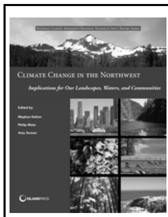

Eigenbrode et al., in Dalton et al. 2013

Climate Driver	Possible effects on NW agriculture
Increase in mean summer temperature	Heat stress-related reductions in yields and yield stability of major NW crops and livestock; changes in pressure from pests, diseases, and invasive species
Increase in mean cool-season temperature	Greater productivity or survival of winter crops and cold-sensitive perennials; changes in pressure from pests, diseases, and invasive species
Increase in length of growing season	More flexibility in crops that can be grown and cropping system design; changes in pressure from pests, diseases, and invasive species
Increase in growing degree days	Faster maturation of some crops; changes in pressure from pests, diseases, and invasive species
Increase in mean evapotranspiration	Greater risk of drought stress
Decrease in summer soil moisture	Greater risk of drought stress of rain-fed crops and those dependent on surface water irrigation
Decrease in mean summer precipitation	Greater risk of drought stress of rain-fed crops and those dependent on surface water irrigation
Increase in mean winter precipitation	Greater available soil moisture for establishing spring crops; wetter soils in spring potentially impede spring planting operations in some systems.
Increased atmospheric CO_2	Potentially increases productivity of annual and perennial crops

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Agroecosystems

Pests and Diseases

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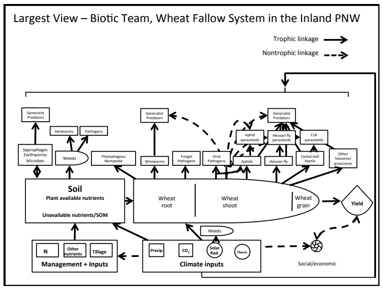
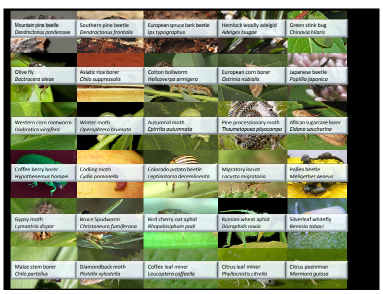
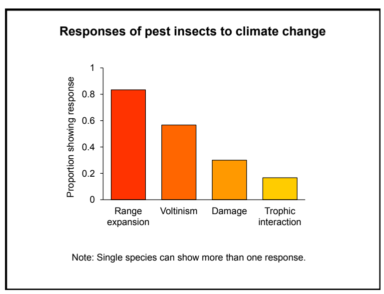
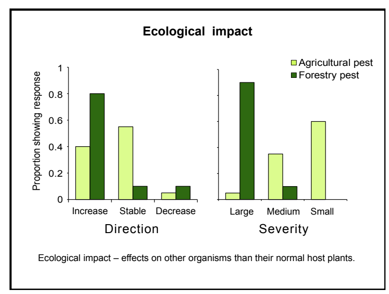
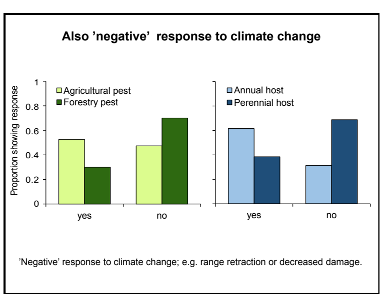






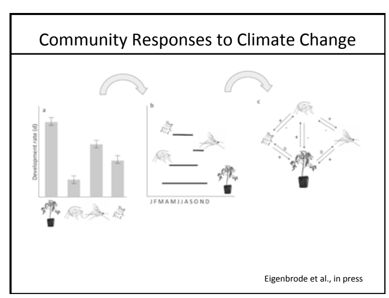


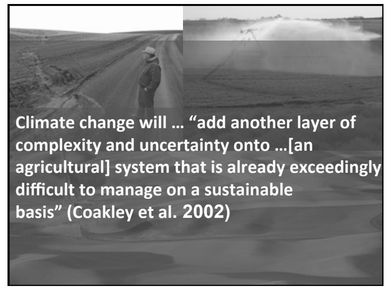


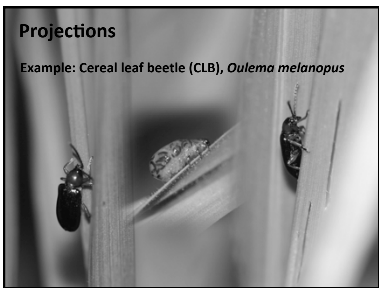
Some early conclusions

- Variation in response among pest species
- Range expansion most common response
- Many species show multiple response types
- Agricultural/annual pests ≠ forestry/perennial pests
- Almost half of all species also respond 'negatively' to climate change

Reasons?







CLB "Suitability Index" (SI)

Temperature (from MACA model)
- Limiting low (6.5 °C) and high (35.0 °C) average weekly temperature
- Lower (7.0 °C) and upper (26.0 °C) optimal average temperature

Soil Moisture (precipitation, ET, Thornwaite-Mather)
- Limiting low (0.02) and high (1.5) soil moisture
- Lower (0.10) and upper (1.0) optimal soil moisture

Diapause
- Diapause induction day length 14 h and weekly temperature (11.0 °C)
- Diapause termination temperature 6.0 °C
- Diapause development days 120

Maturation requirement
- 850 DD (base 9C)

Hosts
- NASS Cropland Data Layer (5-year run): cultivated cereals, rangeland, other grasses)

Modified from Olfert et al. (2004)

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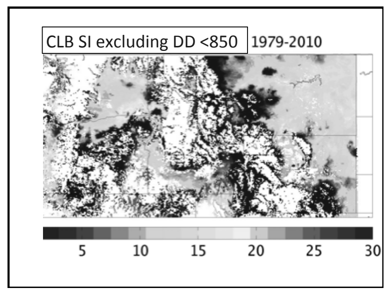

Incorporating Biological Control

- *Tetrastichus julis* (Walker) (Eulophidae)
- Successful biological control for CLB in North America.
- Released and well established in PNW (ID, WA, MT, UT) (Roberts et al. 2008)

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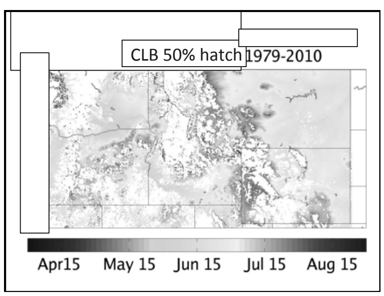
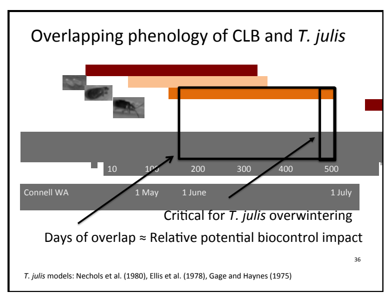
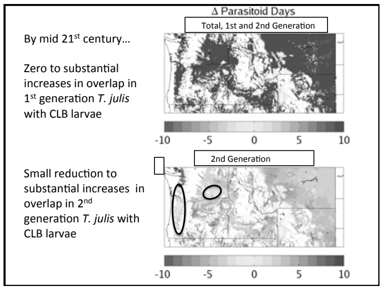
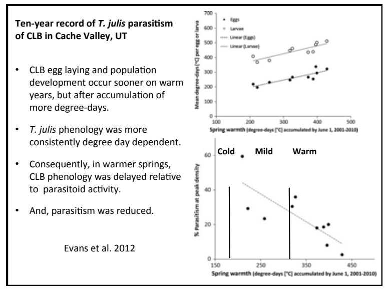
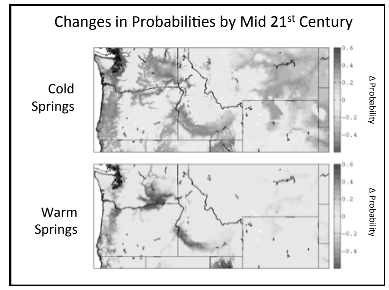
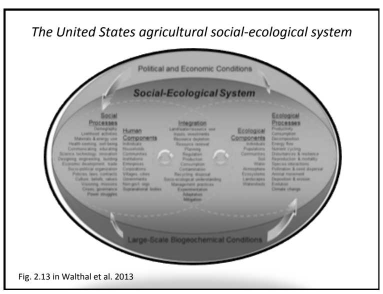


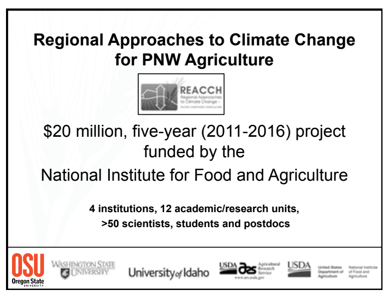


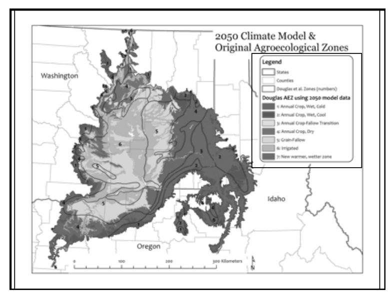

Δ Parasitoid Days
Total, 1st and 2nd Generation
By mid 21st century…
Zero to substantial increases in overlap in 1st generation T. julis with CLB larvae
-10 -5 0 5 10
2nd Generation
Small reduction to substantial increases in overlap in 2nd generation T. julis with CLB larvae
-10 -5 0 5 10

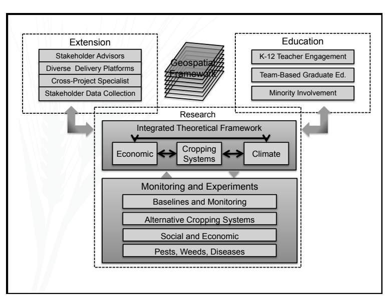

Ten-year record of T. julis parasitism of CLB in Cache Valley, UT
CLB egg laying and population development occur sooner on warm years, but after accumulation of more degree-days.
T. julis phenology was more consistently degree day dependent.
Consequently, in warmer springs, CLB phenology was delayed relative to parasitoid activity.
And, parasitism was reduced.
Evans et al. 2012
Cold
Mild
Warm


Changes in Probabilities by Mid 21st Century
Cold Springs
Warm Springs
Δ Probability
Δ Probability


The United States agricultural social-ecological system
Political and Economic Conditions
Social-Ecological System
Large-Scale Biogeochemical Conditions
Fig. 2.13 in Walthal et al. 2013


Regional Approaches to Climate Change for PNW Agriculture
REACCH
$20 million, five-year (2011-2016) project funded by the
National Institute for Food and Agriculture
4 institutions, 12 academic/research units,
>50 scientists, students and postdocs
OSU Oregon State
Washington State University
University of Idaho
USDA


2050 Climate Model & Original Agroecological Zones
Legend
Washington
Idaho
Oregon


Extension
Stakeholder Advisors
Diverse Delivery Platforms
Cross-Project Specialist
Stakeholder Data Collection
Geospatial Framework
Education
K-12 Teacher Engagement
Team-Based Graduate Ed.
Minority Involvement
Research
Integrated Theoretical Framework
Economic
Cropping Systems
Climate
Monitoring and Experiments
Baselines and Monitoring
Alternative Cropping Systems
Social and Economic
Pests, Weeds, Diseases


Year 4 Highlights
Fourth Annual Report
Targeting diverse stakeholders
Farmers
Ag industry
Teachers
Researchers
Policymakers
Regional Approaches to Climate Change for Pacific Northwest Agriculture
REACCH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Jane Jepsen
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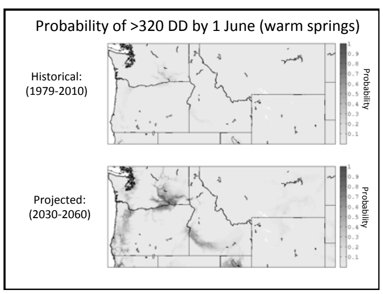
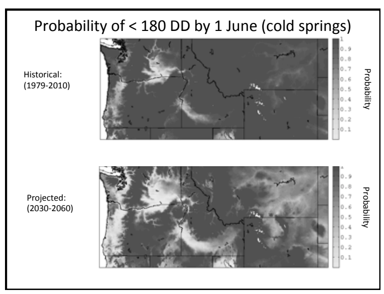
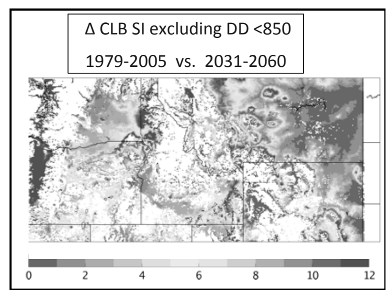
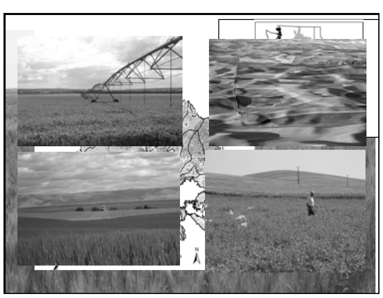
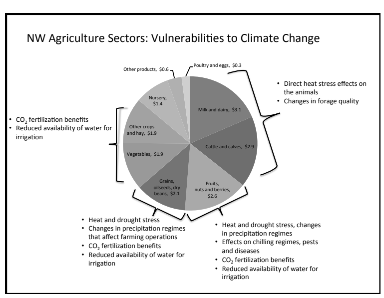

Probability of >320 DD by 1 June (warm springs)
Historical:
(1979-2010)
Projected:
(2030-2060)
Probability


Probability of < 180 DD by 1 June (cold springs)
Historical:
(1979-2010)
Projected:
(2030-2060)
Probability


Δ CLB SI excluding DD <850
1979-2005 vs. 2031-2060
0
2
4
6
8
10
12




NW Agriculture Sectors: Vulnerabilities to Climate Change
Other products, $0.6
Poultry and eggs, $0.3
Nursery, $1.4
Milk and dairy, $3.1
Other crops and hay, $1.9
Cattle and calves, $2.9
Vegetables, $1.9
Grains, oilseeds, dry beans, $2.1
Fruits, nuts and berries, $2.6
• Direct heat stress effects on the animals
• Changes in forage quality
• CO2 fertilization benefits
• Reduced availability of water for irrigation
• Heat and drought stress
• Changes in precipitation regimes that affect farming operations
• CO2 fertilization benefits
• Reduced availability of water for irrigation
• Heat and drought stress, changes in precipitation regimes
• Effects on chilling regimes, pests and diseases
• CO2 fertilization benefits
• Reduced availability of water for irrigation