Climate Change, Sea Level Rise, and Implications for Florida Agriculture and Natural Resources

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The mission of the Southeast Climate Consortium is to support decisions so that people can better manage climate-related risks that threaten the Southeast USA.
AgroClimate.org: Disease risk forecasting
Blueberries: Managing applications of plant growth regulators

- Temperate fruit need to “rest” in winter to produce abundant fruit.
- If “chill units” do not accumulate, need to apply a synthetic to induce dormancy.
- Chill tool allows planning input purchases and approximate application periods.

http://agroclimate.org/
## Climate forecast-based Beef Cattle Management

<table>
<thead>
<tr>
<th>Climate Forecast</th>
<th>Rancher Decision Plant or Not Plant</th>
<th>AGRONOMIC RESULT</th>
<th>MANAGEMENT ADJUSTMENT</th>
<th>COWS</th>
<th>HEIFERS</th>
<th>CALVES</th>
<th>GROSS MORPH% - HERD VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>El Niño</strong></td>
<td>Established</td>
<td>No Need to Buy Hay</td>
<td>150.94 27.43 105.70</td>
<td>-11,690.56</td>
<td></td>
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<tr>
<td>(cooler-wet fall/winter)</td>
<td>Failure</td>
<td>Buy Expensive Hay in Winter (328.48 Rolls)</td>
<td>150.94 27.43 105.70</td>
<td>-11,977.44</td>
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<tr>
<td><strong>La Niña</strong></td>
<td>Established</td>
<td>No Need to Buy Hay</td>
<td>150.94 27.43 105.70</td>
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<tr>
<td>(hot-dry winter/spring)</td>
<td>Failure</td>
<td>Buy Expensive Hay in Winter (328.48 Rolls)</td>
<td>150.94 27.43 105.70</td>
<td>-11,977.44</td>
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<tr>
<td><strong>Neutral</strong></td>
<td>Established</td>
<td>No Need to Buy Hay</td>
<td>150.94 27.43 105.70</td>
<td>-11,690.56</td>
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<tr>
<td>(21.80 116)</td>
<td>Failure</td>
<td>Buy Expensive Hay in Winter (328.48 Rolls)</td>
<td>150.94 27.43 105.70</td>
<td>-11,977.44</td>
<td></td>
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</tbody>
</table>

### Decisions

- **El Niño**: Buy expensive hay in winter (328.48 rolls) if failure.
- **La Niña**: Buy expensive hay in winter (328.48 rolls) if failure.
- **Neutral**: Buy expensive hay in winter (328.48 rolls) if failure.
El Niño: What is it and How Does it Affect Florida?

• The World Meteorological Organization has a simple 3-minute video which explains what El Niño is and how it affects global climate at https://www.youtube.com/watch?v=v92Iqihct98.

• The NWS office in Tampa Bay, Florida has provided a new “map journal” of the impacts of El Niño on Florida. You can view it here.
A Wet December for Some

Climate is defined as long-term averages and variations in weather measured over a period of several decades.
What Would You Like to Know about the Future?
Where I Live

• As an economist & long-term resident (20 years!) of South Florida, I am concerned about how our decision making & flood risks influence one another.

• South Florida will face increasing exposure to flooding in the coming decades.

• We can, to some extent, build defenses to protect ourselves.

• But doing so will be extremely costly & will merely transfer risks from frequent, low intensity events to rarer, high intensity risks.

• We should train ourselves to expect coastal floods to arrive not gradually but in sudden discontinuities that reshape us.

• Can our ability to cope keep up with the changing climate system?
Getting Warmer Out There

• In 2015, the average temperature on land & ocean surfaces around the world was “1.6° F (0.9° C) above the 20th century average,” according to NOAA.

• That makes 2015 the hottest since instrument records began being kept in 1880, beating the record set in 2014 by 0.3° F (0.16° C).

• Northern Hemisphere saw the biggest rise in land temps, finishing 2.6° F hotter than the 20th century average.

• In the US, NOAA said that for the 19th consecutive year, the annual average temperature for the continental US was hotter than the 20th century average.

• The last year with a below-average temperature was 1996.

• Globally, 10 months in 2015 tied or broke monthly temperature records, culminating in a December that was more than half a degree F warmer than its predecessor in 2014 — a record margin, NOAA says.
What About Limits to Predictability?

Source: Ben Smith, SEI Oxford.
Climate is Harder to Predict than Weather

- Decadal scale climate systems, at least for now, have limited predictability.
- Should I purchase 100 excellent umbrellas (a 20-year supply, for me) at the nice price of $250?
- Where I can store them? What if I move in a few years?
- Also, perhaps precipitation will be much less and I won’t really need that many (but I don’t know whether I can trust long-term prediction of a drier climate).
- Furthermore, umbrella technology may improve over the next two decades.
- I also need to consider the cost of committing $250 now; compared with gradual spending across 20 years, while earning 5% interest, the true cost of buying the 100 umbrellas now comes to nearly $20 per year, rather than $12.50.
- In any case, should someone my age even be thinking 20 years ahead?
- Best to plan for a range of possible futures.
The National Climate Assessment collects, integrates, and assesses observations and research from around the country, helping us to see what is actually happening and understand what it means for our lives, our livelihoods & our future.

The report includes analyses of impacts on seven sectors – human health, water, energy, agriculture, transportation, forests & ecosystems – and the interactions among sectors at the national level.

The report also assesses key impacts on all US regions: Northeast, Southeast and Caribbean, Midwest, Great Plains, Southwest, Northwest, Alaska, Hawai‘i and Pacific Islands, as well as the country’s coastal areas, oceans & marine resources.
Observed Southeast Temperature Change

Temperature Change (°F)

Decade

Temperature Change (°F)

< -1.5  -1.5 to -1.0  -1.0 to -0.5  -0.5 to 0.0  0.0 to 0.5  0.5 to 1.0  1.0 to 1.5  > 1.5
Observed Southeast Precipitation Change

Southeast

Precipitation Change (%)
- >15
- 10 to 15
- 5 to 10
- 0 to 5
- -5 to 0
- -10 to -5
- -15 to -10
- <=-15

Decade
- 1900s
- 20s
- 40s
- 60s
- 80s
- 00s

Precipitation Change (%)
Upward U.S. Trends in Extreme Precipitation

Number of 48 hour, 5-year events

Event Number (% from normal)


1 in 3.7 yrs
1 in 4 yrs
1 in 5 yrs (Normal)
1 in 6 yrs
Southeast Extreme Precipitation Trends

The graph shows the relative number of extreme events (% of normal) in the Southeast from 1905 to 2005. The data indicates a trend of increasing extreme precipitation events over time, particularly noticeable in the last few decades.
What Do We Know – Key Messages

- **Observed changes in extremes**
  - Increase in extreme rainfall events
  - Data insufficient to determine trends in severe thunderstorms
  - Increase in number of intense hurricanes
  - No trends in winter storm severity
  - Increase in warm nights and decrease in unusual cold

- **Future projections**
  - Increases in hot extreme temperatures and precipitation extremes; decreases in cold extremes
  - Uncertainty about trends in certain types of extremes, most notably severe thunderstorms and tornadoes
  - Possible increase in intensity of most extreme hurricanes
  - Regional changes in winter storms
Agriculture

Climate disruptions to agricultural production have increased in the past 40 years and are projected to increase over the next 25 years. By mid-century and beyond, these impacts will be increasingly negative on most crops & livestock.

- **Extreme Precipitation**: Current loss and degradation of critical agricultural soil and water assets due to increasing extremes in precipitation will continue to challenge both rainfed and irrigated agriculture unless innovative conservation methods are implemented.

- **Heat and Drought**: The rising incidence of weather extremes will have increasingly negative impacts on crop and livestock productivity because critical thresholds are already being exceeded.

- **Technology**: increased innovation will be needed to ensure that the rate of adaptation of agriculture & the associated socioeconomic system can keep pace with climate change over the next 25 years.

- **Food Security**: changes in crop yields and food prices and effects on food processing, storage, transportation & retailing.

- Hot nights are defined as nights with a minimum temperature higher than 98% of the minimum temperatures between 1971-2000.

- Such nights are projected to increase throughout the nation.

- High nighttime temperatures can reduce grain yields & increase stress on animals, resulting in reduced rates of meat, milk & egg production.

Projections are shown under an emissions scenario that assumes continued increases in heat-trapping gases (A2). (Figure source: NOAA NCDC/CICS-NC).
Forests

• Forests provide opportunities to reduce future climate change by capturing and storing carbon, as well as by providing resources for bioenergy production (the use of forest-derived plant-based materials for energy production).

• Climate change is increasing the vulnerability of forests to ecosystem changes and tree mortality through fire, insect infestations, drought & disease outbreaks.

• On public, private & tribal lands, management practices can reduce disturbance effects include:
  • altering tree planting and harvest strategies through species selection and timing;
  • factoring in genetic variation;
  • managing for reduced stand densities, which could reduce wildfire risk;
  • reducing other stressors such as poor air quality;
  • using forest management practices to minimize drought stress; and
  • developing regional networks to mitigate impacts on ecosystem goods and services.
Ecosystems provide a rich array of benefits and services to humanity, including habitat for fish and wildlife, drinking water storage and filtration, fertile soils for growing crops, buffering against a range of stressors including climate change impacts, and aesthetic & cultural values.

Salt marshes, reefs, mangrove forests and barrier islands defend coastal ecosystems & infrastructure, such as roads & buildings, against storm surges.

• The loss of these natural buffers due to coastal development, erosion, and sea level rise increases the risk of catastrophic damage during or after extreme weather events.
Cascading Events: Energy, Land and Water

• Texans in 2011 experienced the hottest and driest summer on record. Summer average temps were 5.2°F higher than normal, and precipitation was lower than previous records set in 1956.

• The associated heat wave, with temps above 100°F for 40 consecutive days, together with drought, strained the region’s energy and water resources.

• Drought reduced crop yields and affected livestock, costing Texas farmers and ranchers more than $5 billion, a 28% loss compared to average revenues of the previous four years.

• Drought increased tree mortality, providing more fuel for record wildfires that burned 3.8 million acres (an area about the size of Connecticut) and destroyed 2,763 homes.
The Paris Climate Agreement: What It Means for Food and Farming

- The Paris Agreement of Dec 2015 opens the door for more adaptation & mitigation in agriculture.

- Countries must take urgent action to reduce emissions from the agriculture sector in order to limit global warming below 2 degrees C.

- On the whole, country commitments to reducing emissions will not limit global temperature rise to 2 degrees C.

- Reducing emissions from agriculture will be imperative as it will be impossible to stay within either a 1.5 or 2 degrees C target if agriculture does not contribute to emissions reductions.

- No binding requirement for countries to implement their intended contributions, but much emphasis on cooperation & public investment.
Florida Faces Risk from Sea Level Rise

Two main processes are causing sea level to rise: the expansion of ocean water caused by increasing ocean temperature, and the addition of “new” water from melting reservoirs of ice.

Much has yet to be learned before sea level can be projected with greater precision and certainty, but the differences are largely a matter of when, not whether, economically & ecologically critical levels will be reached.

Florida is especially vulnerable to the effects of sea-level rise. It has more than 1,200 miles of coastline, almost 4,500 square miles of estuaries and bays, and more than 6,700 square miles of other coastal waters.

The entire state lies within the Atlantic Coastal Plain, with a maximum elevation less than 400 feet, and most of Florida’s 19.8 million residents live less than 60 miles from the Atlantic Ocean or the Gulf of Mexico.
Miami Beach

• $300M - $500M in local funding over five years.

• Mayor Levine has a three-part program that he claims should address the issue for the next 30 to 50 years.

• First, one-way flex valves for all the city’s outfall pipes, allowing floodwater out but not back in.

• Next, a high-power pump program that seems to have worked well this past fall using four to six pumps.
  • Ultimately, 50 to 70 more pumps will be installed around the city.

• The third part involves changing building codes.
  • “We’re going to require all new construction to be built at a higher level. We’re going to raise our sea walls in our code,” says Levine.
Global Sea Level Rise

For the past ~150 years, sea level change has been recorded at tide gauge stations, and for the past ~20 years, with satellite altimeters. Results of these two data sets are consistent.

The globally averaged rate of sea level rise of $1.7 \pm 0.2 \text{ mm yr}^{-1}$ over the 20th century—and about twice that over the past two decades—may seem small compared with observations of wave and tidal oscillations around the globe that can be orders of magnitude larger.

However, if these rates persist over long time intervals, the magnitude carries important consequences for heavily populated, low-lying coastal regions, where even a small increase in sea level can inundate large land areas.
Global sea level rise in
- the 20th century,
- the last 20 years, and
- in the geologic record.
IPCC 2100 Sea Level Rise Projection (AR5)

- Sea level rise in the 5th IPCC assessment report (2014).

- We tend to focus on the center of a range, but to be truly prepared we should consider all possibilities.

- For high emissions, IPCC predicts a global SLR by 52-98 cm by 2100, which would threaten the survival of coastal cities & entire island nations.

- Even with aggressive emissions reductions, a rise by 28-61 cm is predicted.

- Half a meter of SLR would mean serious impacts on many coastal areas, including erosion & flood risk.

Fig. 1. Past & future sea-level rise. For the past, proxy data are shown in light purple & tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.
How Will Sea Level Rise Affect Florida?

1. Low-lying coastal areas will be increasingly prone to coastal flooding, especially during spring and fall high tides and during sea swells due to seaward storms and strong onshore winds.

2. A serious concern for agriculture is that rising sea level will cause groundwater near the coast to become more saline and groundwater levels to increase.

3. Because Florida’s storm water drainage systems rely mainly on gravity, sea-level rise will reduce their effectiveness.

4. Storm surge and wave heights during hurricanes will increase as coastal water depths increase with sea-level rise, amplifying the damage potential of hurricanes.

5. Agriculture will be affected by the northward shift of insects and weeds, flooding from sea level rise, and hurricane storm surges. A warmer and drier climate will also increase the agricultural demand for water, competing with other users for water resources that will become more limited.

6. For forestry, the distribution of forest species will change. For many species, the temperature will rise above their survival limits. Decreased soil moisture & increased evapotranspiration (i.e., the combination of evaporation and plant transpiration) due to warmer weather will also affect many species. Coastal and low-lying forests will be affected by sea level rises.

Source: Union of Concerned Scientists
Critical Infrastructure at Risk

At risk from sea level rise includes:

- 2 nuclear power plants,
- 3 state prisons,
- 68 hospitals,
- 74 airports,
- 115 solid waste disposal sites,
- 140 water treatment facilities,
- 334 public schools, and
- 341 hazardous-material cleanup sites, including 5 Superfund sites.

Local Sea Level Rise vs the Global Average

Stockholm: regional uplift
Antofagasta: tectonic lift
Charlottetown: land subsidence
Manilla: groundwater pumping
Florida: Gulf Stream changes

Map of rates of change in sea surface height (geocentric sea level) for the period 1993–2012 from satellite altimetry. Also shown are relative sea level changes (grey lines) from selected tide gauge stations for the period 1950–2012. For comparison, an estimate of global mean sea level change is also shown (red lines) with each tide gauge time series. The relatively large, short-term oscillations in local sea level (grey lines) are due to the natural climate variability described in the main text. For example, the large, regular deviations at Pago Pago are associated with the El Niño-Southern Oscillation.
Two Sorts of Coastal Flooding Risks

• **Nuisance flooding**: frequent, but low impact.
  • By 2050, $152 B of property will likely be below mean high tide in Florida.

• **Storm-Related Losses**: rare, but catastrophic.
  • In any decade, a handful of the strongest events do more property damage than the rest put together.

Source: http://riskybusiness.org/national-report/pdf
Sea Level Rise in 2050: A Thought Experiment

• Avg annual global coastal flood losses (2005): US$6 B per yr. Miami’s share: $672M.

• $52 B by 2050 with projected socio-economic change alone. Miami’s share: $2.1B.
  • The good news is Miami’s economy will also be larger, so avg losses as a share of city GDP stay 0.30%.

• But….sea level rise and land subsidence could greatly increase that total.

• Failure to adapt is not an option: $1 trillion in losses globally, annually in 2050.
  • Miami’s share: $7.3B for 20cm SLR.
  • Miami’s share: $25.7B for 40cm SLR.

Sea Level Rise in 2050: A Thought Experiment

• So, we will build flood defenses; the questions are, how much and how safe?

• Adapting to coastal flooding means choosing a threshold of acceptable risk.

• To avoid higher coastal flood risk, an adaptation policy has to do more than maintain present flood probability.
  • Rather, maintaining present risk levels (as share of local GDP) in the context of rising sea levels, subsidence & socio-economic changes requires adaptation policy that reduces flood probability over time.

• To keep avg annual losses at $52B in 2050, defense upgrades must cancel the environmental impacts.
  • Miami must increase its flood protection from current level of 100 year event to: 125 year event under 20cm (8’’) SLR; and 147 year event under 40cm (16’’) SLR.

• Assumes that degree of flood protection is both feasible and desired.
The Cost of Storm Surge in 2050.

• More financial exposure for coastal cities.

• If sea levels rise just 16’’ by 2050, flood damage in port cities could cost a trillion $ a year.

• Coastal cities to become more dependent on flood defenses.

• More vulnerable to the inevitable extreme weather event that will overwhelm defenses.
Every Florida acre is precious.

We must quickly move beyond recommendations & into tangible and meaningful action, so that the economic viability of growing more than 250 crops in our region continues well into the century.

We can raise agricultural fields. The Maya did it. The Aztecs did it. We can do it too.

For more information, please contact Mitchell A. Chester, Esq. at: 954.465.1223 or MChester@MitchellChester.com
Wetlands Watch: Sea Level Rise App

• Citizen Science: [https://youtu.be/ofjAPccIVCA](https://youtu.be/ofjAPccIVCA)

• The goal is to crowdsource flooding information for use by researchers, emergency managers, people working on predictive flood models, and citizens seeking control of the flooding impacts in their coastal communities - so we can start to take action on flooding and sea level rise.

• Through the app trained volunteers can capture and document what’s happening, and everyday citizens can see how it effects them in terms of finding common “Trouble” spots and as well as follow larger “Events."
Prepare, Predict, Recover

- Climate disruptions to agricultural production have increased in the past 40 years and are projected to increase over the next 25 years. By mid-century & beyond, these impacts will be increasingly negative on most crops & livestock.

- Can our ability to cope keep up with the changing climate system?

- Increased innovation will be needed to ensure that the rate of adaptation of agriculture & the associated socioeconomic system can keep pace with climate change over the next 25 years.

- Given the difficulties in preparing for & predicting sea level rise, we must consider how we will recover.

- Who will have an appetite for our coastal flood risk in 2050?
  - The National Flood Insurance Program?
  - Catastrophe Bonds?
  - Good Samaritans?
Thanks!

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Mid-Florida Research and Education Center, Apopka, Florida
More than 35 elected officials from all three coasts met to discuss coastal flooding impacts, share best practices and lessons learned to protect and prepare for rising tides & engage federal officials from:

• NOAA,
• FEMA,
• US Army Corp of Engineers and
• the Department of Defense around the need for additional support and vertically integrated efforts to address the issue.

Located fewer than 3 feet above current sea level

Rising Tides

- Coastal shoreline counties are home to more than 123 million Americans and account for nearly half the US GDP. Homes, property and critical infrastructure within these communities face a growing threat from coastal flooding as sea levels continue to rise.

- According to a 2014 NOAA report, the frequency of days with “nuisance flooding,” or flooding that causes road closures, overwhelmed storm drains and other public inconveniences, has increased dramatically in many US coastal cities since the mid-1960s.

- This trend provides an indicator that coastal communities are being more and more impacted by rising seas in the absence of sufficient action.
If sea levels rise five feet, nearly one million of the current homes near the coast will be below the average day’s high tide.

In total, some $390 billion worth of property could be damaged or lost—a sum five times as great as Florida’s state budget.

HURRICANES: Storm surges will be significantly more damaging by 2100. They’re often the biggest threat to life and property.

*INCLUDES RESIDENTIAL, COMMERCIAL, AND PUBLIC FACILITIES (IN 2012 DOLLARS)
**INCLUDES MIAMI, PEMBROKE PINES, HOLLYWOOD, AND HIALEAH.
SOURCES: CLIMATE CENTRAL; SOUTH FLORIDA WATER MANAGEMENT DISTRICT

MAPS AND GRAPHICS BY RYAN MORRIS, ALEXANDER STEGMAIER, AND JOHN TOMANIO. SOURCES: CLIMATE CENTRAL; U.S. ARMY CORPS OF ENGINEERS; NOAA.
THE ECONOMIC TOLL: THREATENED INDUSTRIES

The effects of climate change on FL’s major industries will be felt nationwide. FL was the 4th largest contributor to the US economy in 2013.

**Agriculture:** Two key agricultural crops in FL, oranges & sugarcane, were worth $952 million and $677 million in the 2012-13 growing season.

**Tourism:** 94 million tourists visited in 2013; together with in-state tourists, they spent $76 billion.

**Construction:** $65.6 billion worth of housing has been built in Florida since the US housing bubble burst in 2008. FL is now the 8th fastest state.

**ERODING BEACHES:** Most of FL’s 825 miles of beaches are already eroding. The US Army Corps of Engineers spent $150 million in 2013 replenishing just 39 miles of sandy shoreline.

*REVENUE INCLUDES ENTIRE COUNTY SOURCES: USGS; USDA; U.S. CENSUS BUREAU; COUNTY GOVERNMENTS; JULIE HARRINGTON, FSU

Credit: MAPS & GRAPHICS BY RYAN MORRIS, ALEXANDER STEGMAIER, AND JOHN TOMANIO.

SOURCES: CLIMATE CENTRAL; U.S. ARMY CORPS OF ENGINEERS; NOAA.