What is the Economic Value of Ecosystem Services? The Case of Chaparral Landscapes

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3rd Chaparral
Symposium
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Motivation

- USFS managers evaluate trade-offs when making resource management and planning decisions
  - Liability considerations

- Knowledge gaps:
  - Economic value of ecosystem services from national forests
  - Variation of ecosystem service values with changing climate

- Supports USFS efforts to manage natural assets in face of climate change

Research Questions

What is the baseline economic value of ecosystem services?

How will climate change affect these values over time?

Baseline, 2050, 2099

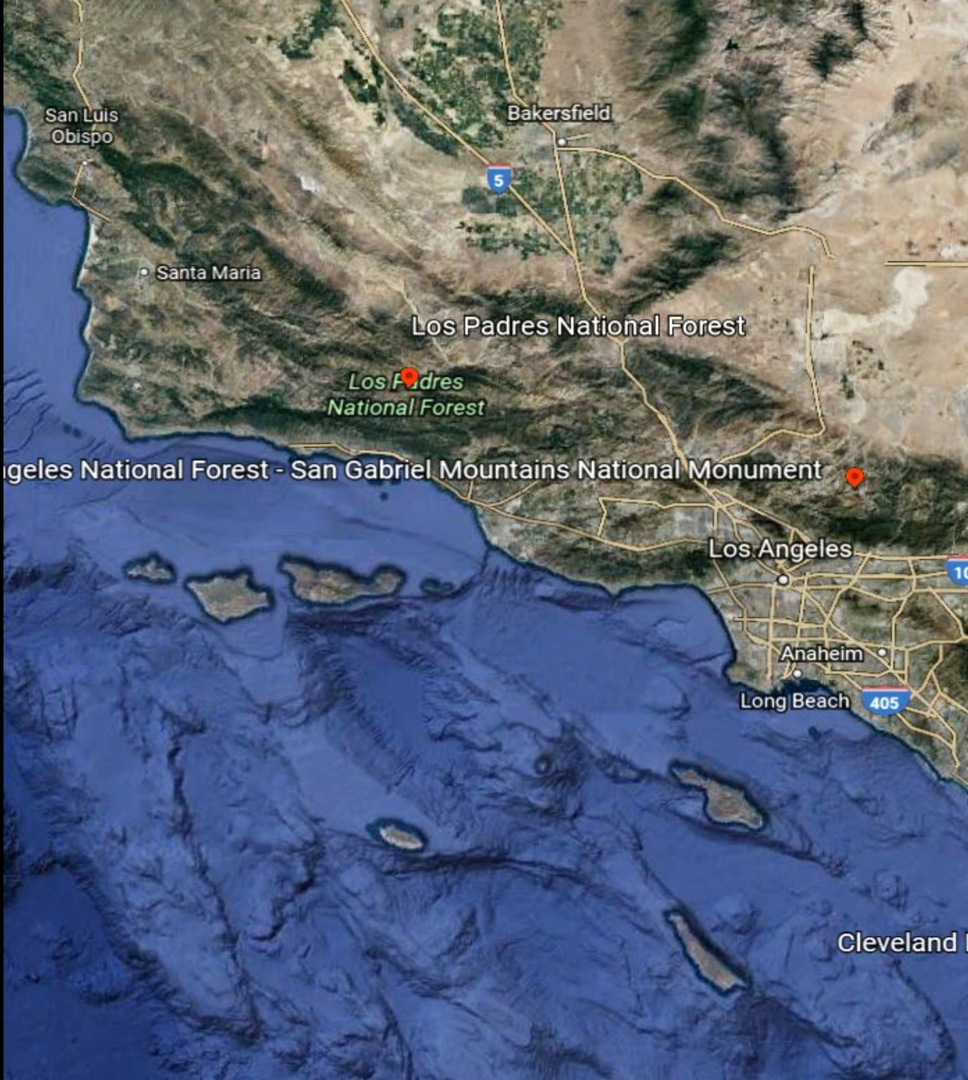
Study Area

Over 5,500 mile^2 (3.5 million ac/1.4 million ha)

Over 23 million people, droughts, wildfires, air quality

Chaparral vegetation, hardwoods, conifers, grasslands

Semi-arid Mediterranean climate



Linking Economics to Ecosystem Services

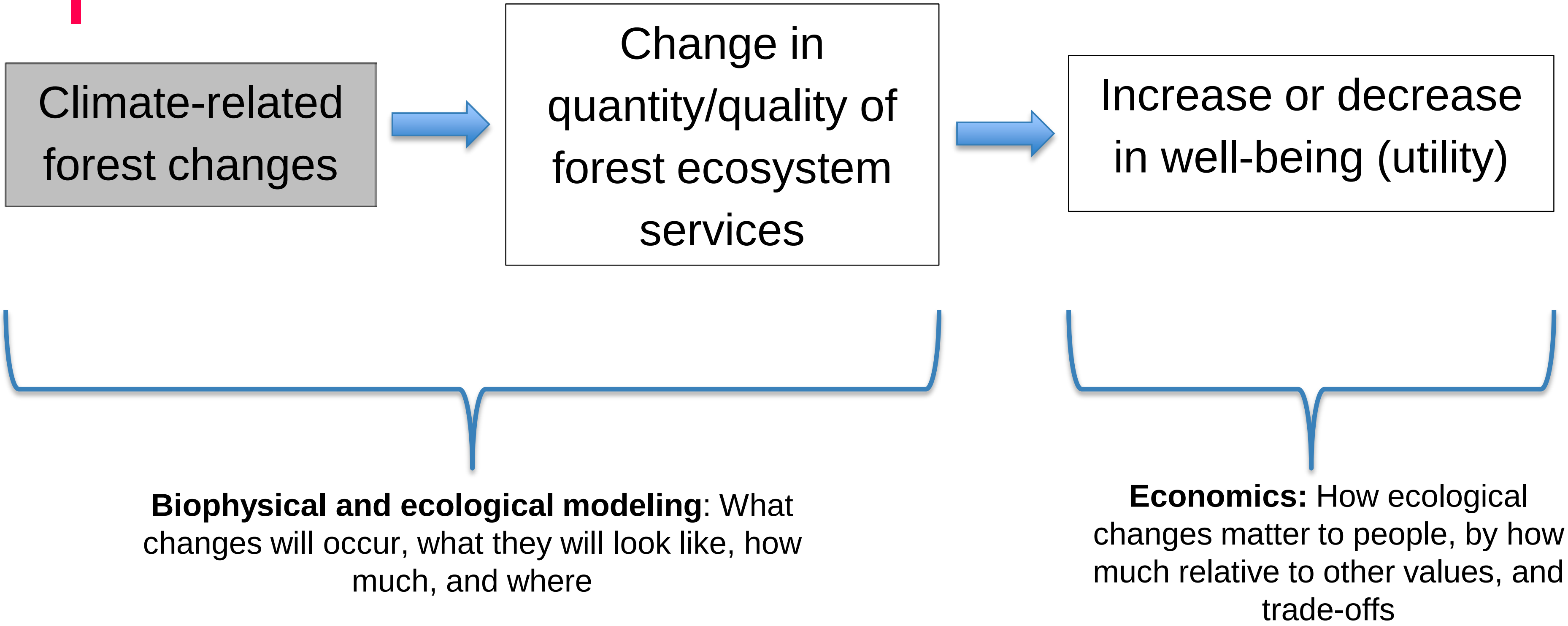
- Ecosystem services framework links ecosystems and human well-being (Millenium Ecosystem Assessment, 2005)

- Supply side determined by ecological processes (may be influence by human activities)
  - Measured by biophysical modeling

- Demand side largely determined by characteristics human beneficiaries
  - Population, preferences, etc. measured by economic modeling

- Different estimation methods used for ecosystem services

Ecosystem Services Approach



Climate-related forest changes

Change in quantity/quality of forest ecosystem services

Increase or decrease in well-being (utility)

Biophysical and ecological modeling: What changes will occur, what they will look like, how much, and where

Economics: How ecological changes matter to people, by how much relative to other values, and trade-offs

Ecosystem Services

Carbon squestration

Water provisioning

Sediment retention

Air quality

Recreation services

Ecosystem Services

Carbon squestration	Benefit function transfer
Water provisioning	Demand model welfare analysis
Sediment retention	Cost function
Air quality	Benefit function transfer
Recreation services	Demand model (MSU)

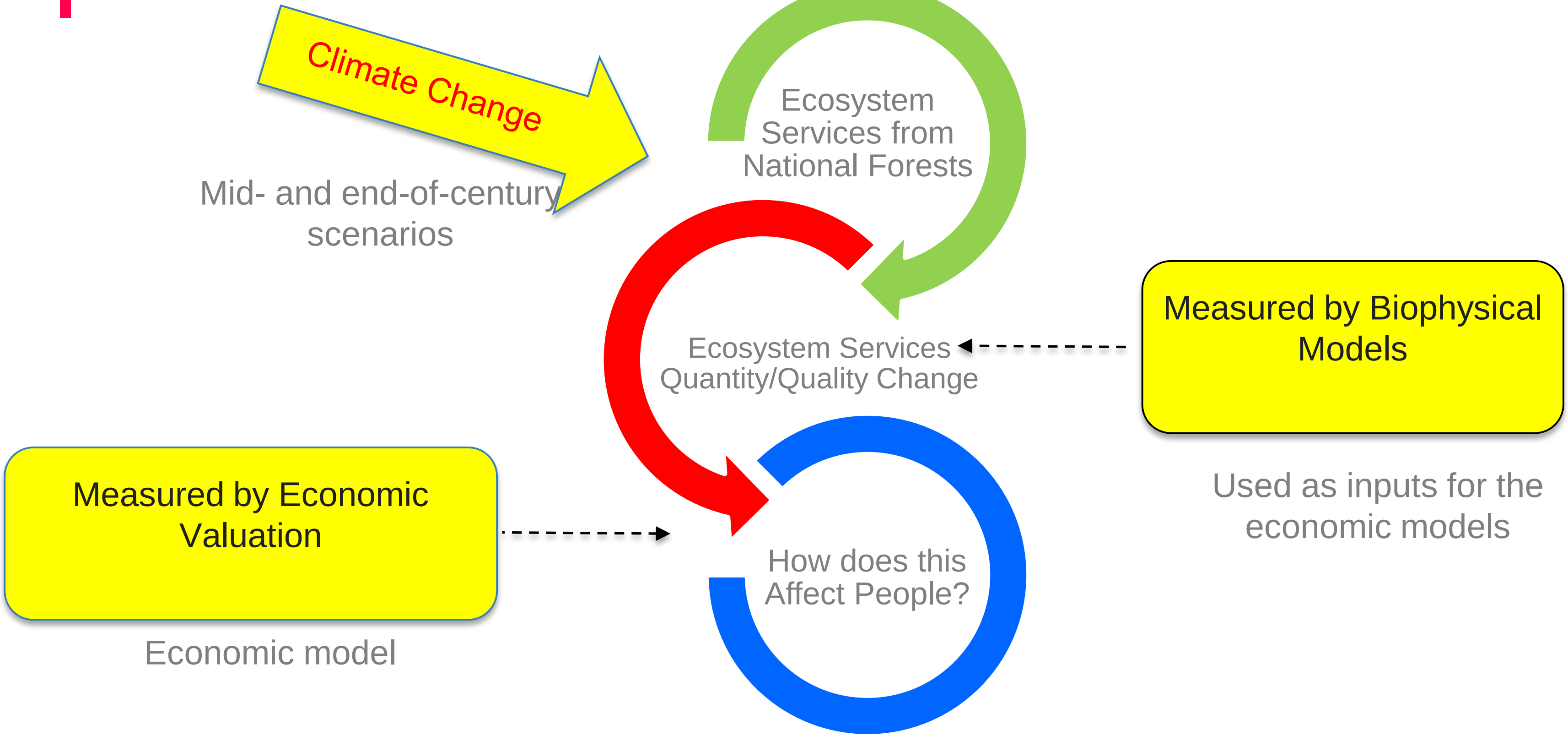
What is Economics?

- Economics is a study of values
- Scarcity and choice (individuals, firms, governments, public agencies)

- Economic values reflect how ecosystem services contribute to human well-being

- Economic value ≠ cost

Conceptual Approach



Climate Change

Mid- and end-of-century scenarios

Ecosystem Services from National Forests

Ecosystem Services Quantity/Quality Change

How does this Affect People?

Measured by Biophysical Models

Used as inputs for the economic models

Measured by Economic Valuation

Economic model

Eric Joyner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Method

- Three possible future climate scenarios:
    - CNRM-CM5 (hot-wet), CCSM4 (ensemble mean), MIROC (hot-dry)

- Under RCP8.5
    - Highest population, slow income growth, modest technological change
    - Absence of climate change policies, highest GHG emissions

- Economic method
    - Monetize ecosystem values
    - Apply discount rates to derive pecuniary values in present real dollar terms

Carbon Sequestration

MC2 dynamic vegetation model

Benefit Unit Transfer

Social cost of carbon

GHG emissions not local

Which Social Cost of Carbon?

Interagency Working Group (IWG)

To be updated regularly

Average three GCMs

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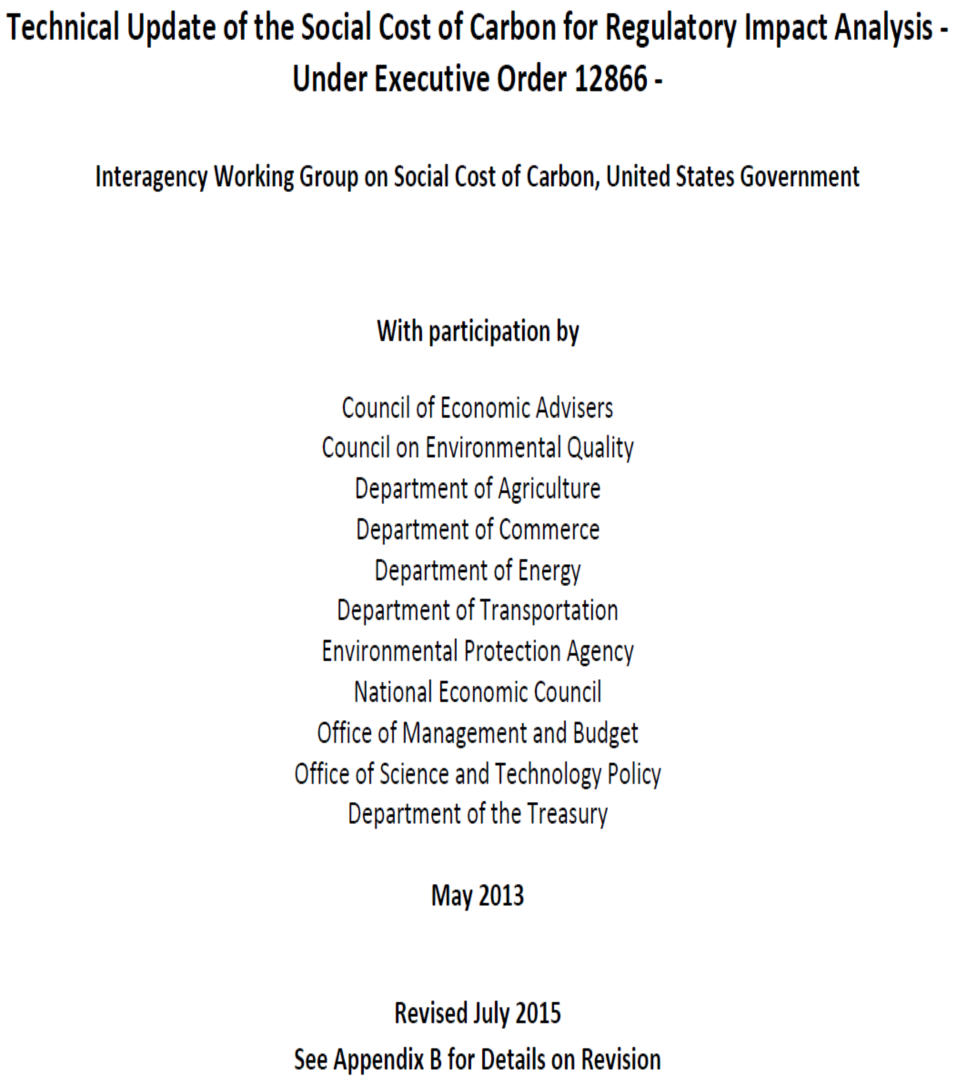

Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866 -

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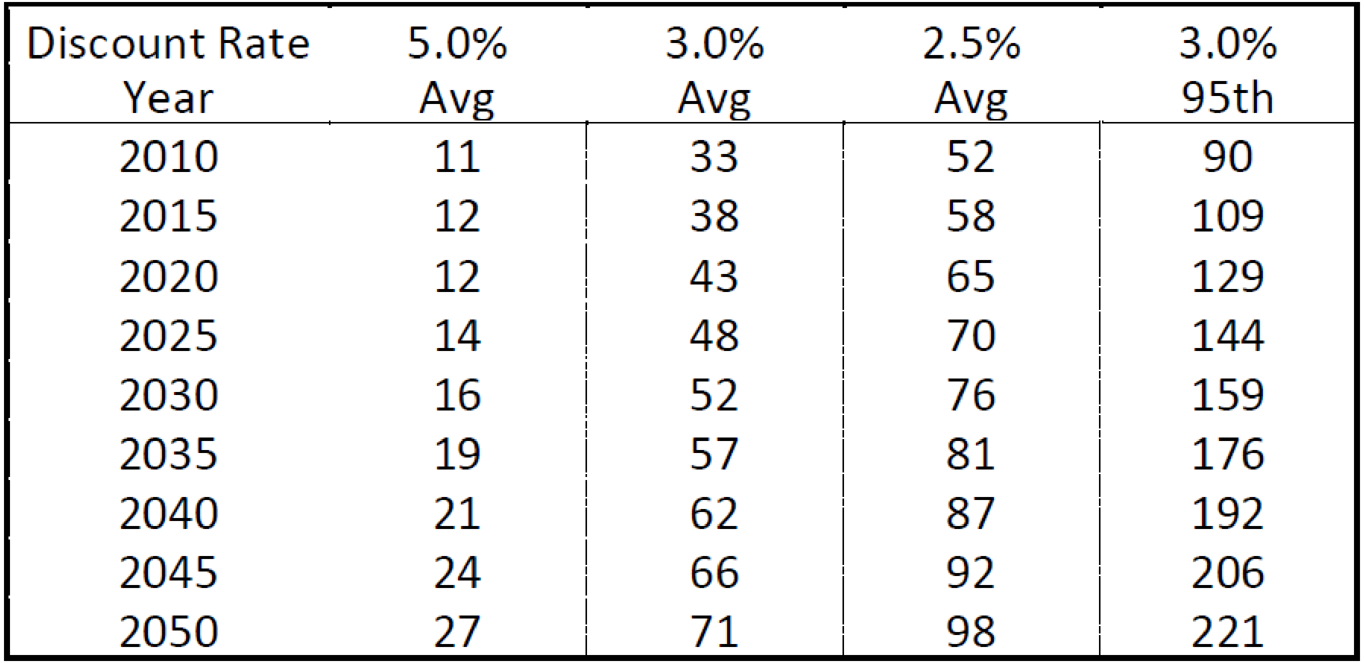
May 2013

Revised July 2015
See Appendix B for Details on Revision

Social Cost of Carbon

Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per metric ton of CO_2)



Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
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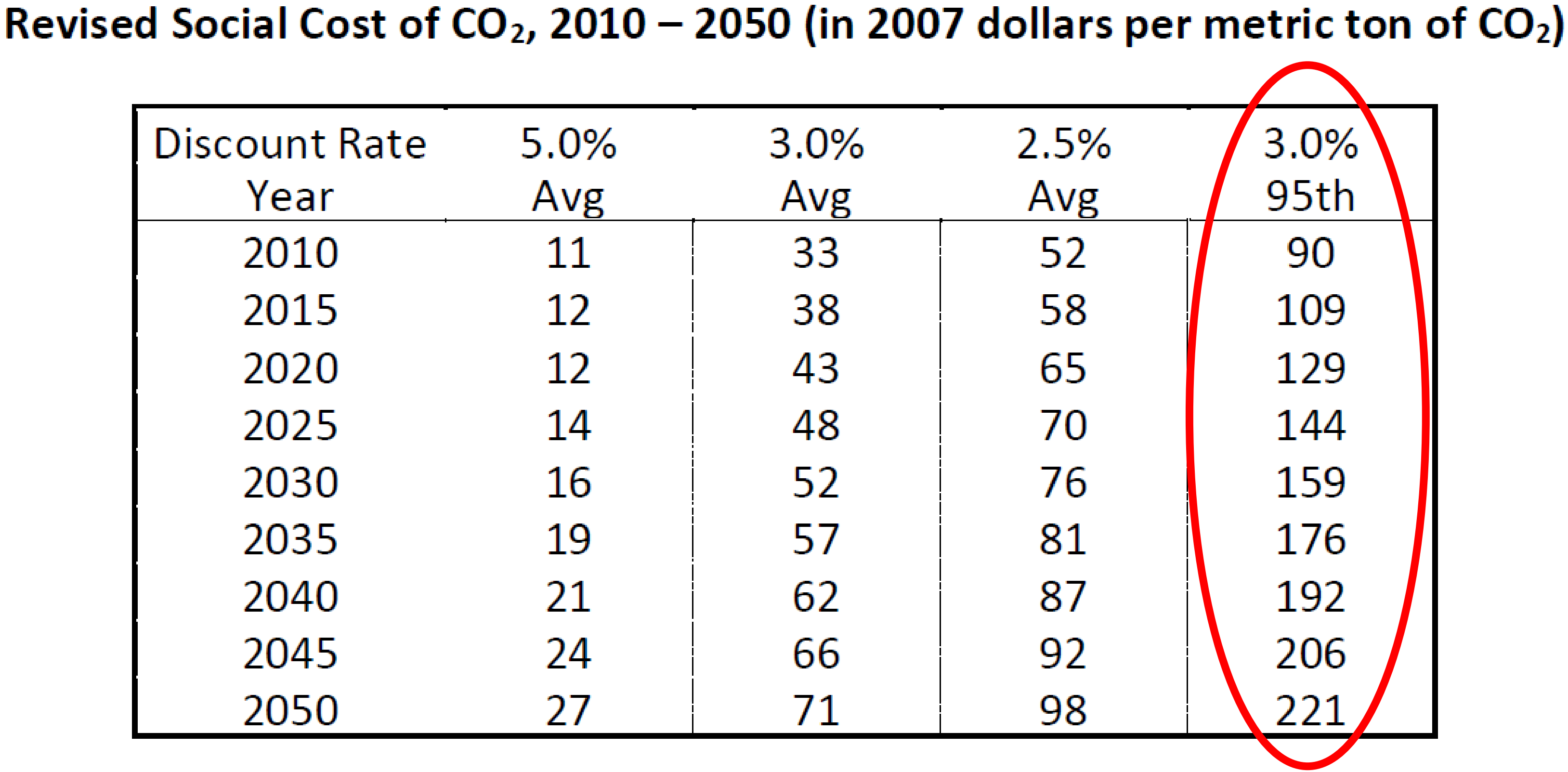
Social Cost of Carbon



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Preliminary Findings from MC2 Dynamic Veg Model

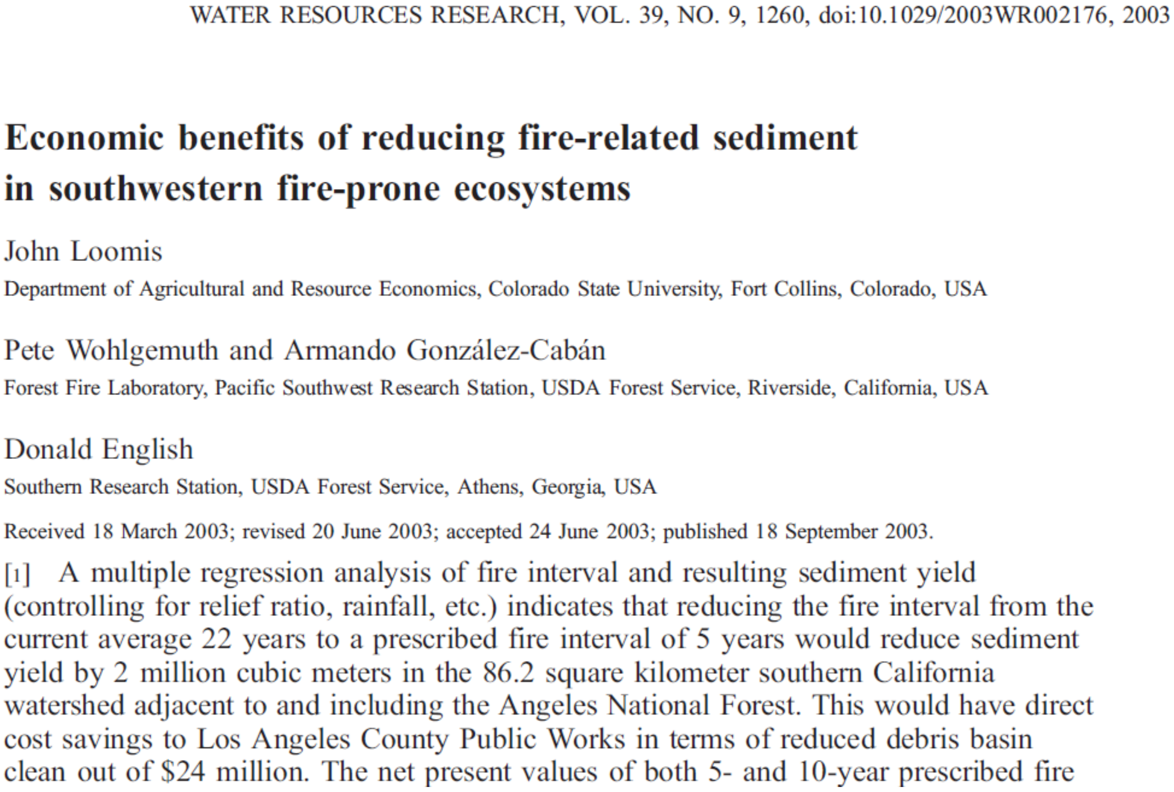
	CNRM-CM5 (warm-wet)		**CCSM4 (ensemble mean)**		**MIROC (hot-dry)**	
	2050	2099	2050	2099	2050	2099
CO_2 (million t)	22%	56%	1%	7%	-18%	-27%

Sediment Retention

Mudslides in January 2018

21 deaths, $421 million insured losses, over 1500 homes damaged/destroyed

Sediment Retention



WATER RESOURCES RESEARCH, VOL. 39, NO. 9, 1260, doi:10.1029/2003WR002176, 2003

Economic benefits of reducing fire-related sediment in southwestern fire-prone ecosystems

John Loomis
Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, Colorado, USA

Pete Wohlgemuth and Armando González-Cabán
Forest Fire Laboratory, Pacific Southwest Research Station, USDA Forest Service, Riverside, California, USA

Donald English
Southern Research Station, USDA Forest Service, Athens, Georgia, USA

Received 18 March 2003; revised 20 June 2003; accepted 24 June 2003; published 18 September 2003.

[1] A multiple regression analysis of fire interval and resulting sediment yield (controlling for relief ratio, rainfall, etc.) indicates that reducing the fire interval from the current average 22 years to a prescribed fire interval of 5 years would reduce sediment yield by 2 million cubic meters in the 86.2 square kilometer southern California watershed adjacent to and including the Angeles National Forest. This would have direct cost savings to Los Angeles County Public Works in terms of reduced debris basin clean out of $24 million. The net present values of both 5- and 10-year prescribed fire

Sediment Retention

- San Gabriel Mountains are fastest growing mountains in U.S., release most sediment
- Debris basins collect rainwater used by water agencies
- If rainfall after a fire, sediment released orders of magnitude higher

Sediment Retention

- Focus on Angeles National Forest

- 41 watersheds in San Gabriel Mountains in LA County

- Cost data from LA County and Power
  - 30-70 years of data

- 2 models:
  - Sediment yield model (Loomis et al., plus a vegetation variable)
  - Cost function to estimate financial cost to dredge debris basins
  - Simulate changes in fire interval to mid- and end-of-century

Water Provisioning

- Spatial estimates over time of water quantity for 4 national forests

- Estimate use value to urban users

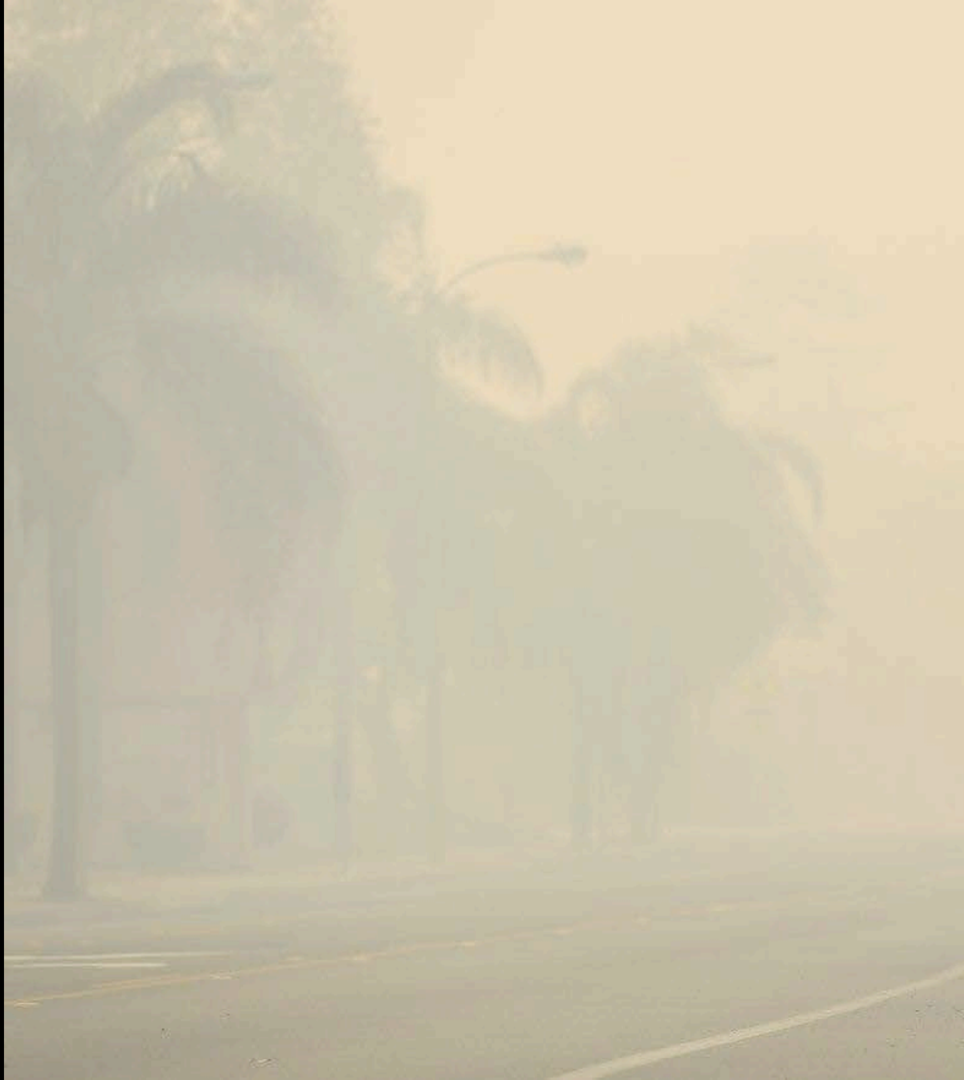
- No willingness-to-pay studies for municipal water for soCal
- No budget to do survey
- Leverage existing water demand studies

- Quantify how economic value changes as quantity supplied changes due to climate change, through time

Air Quality

Thomas fire in Ventura County

December 2017, Wally Skalij (LA Times)



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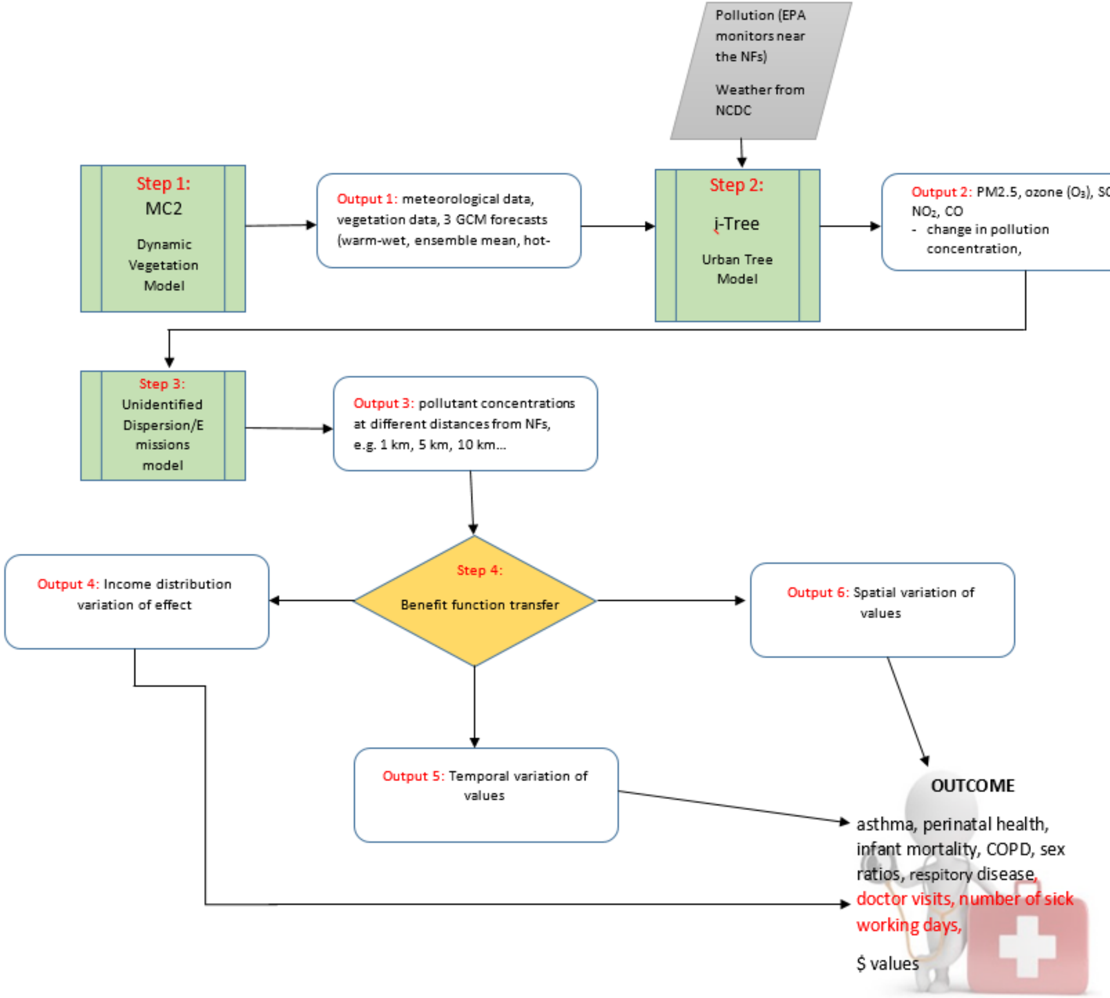
Air Quality

- Large green spaces may improve air quality by removing pollutants

- Susceptible to wildfires
- Spikes of decreased air quality

- Economic valuation with respect to human health effects
- 3 models used

- MC2 meteorological data feeds into i-Tree
- i-Tree calculates pollutant removal air by national forests
- Pollutant levels put into BenMap to estimate economic value



Pollution (EPA monitors near the NFs)

Weather from NCDC

Step 1: MC2

Dynamic Vegetation Model

Output 1: meteorological data, vegetation data, 3 GCM forecasts (warm-wet, ensemble mean, hot-

Step 2: i-Tree

Urban Tree Model

Output 2: PM2.5, ozone (O_3), SO_2, NO_2, CO

- change in pollution concentration,

Step 3: Unidentified Dispersion/Emissions model

Output 3: pollutant concentrations at different distances from NFs, e.g. 1 km, 5 km, 10 km…

Step 4: Benefit function transfer

Output 4: Income distribution variation of effect

Output 5: Temporal variation of values

Output 6: Spatial variation of values

OUTCOME

asthma, perinatal health, infant mortality, COPD, sex ratios, respitory disease, doctor visits, number of sick working days,

$ values

Summary

- Economic values will change with climate change
- In some cases, in expected ways, in others, perhaps not
- Biophysical, spatial modelling days away from completion

- Exciting!
- More to come!

Partners and Collaborators

Research Team

Lorie Srivastava (UC Davis)
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John Kim (USDA Forest Service)
José Sánchez (USDA Forest Service)
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Nancy Grulke (USDA Forest Service)
Hugh Safford (USDA Forest Service)
Nicole Molinari (USDA Forest Service)

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Questions?

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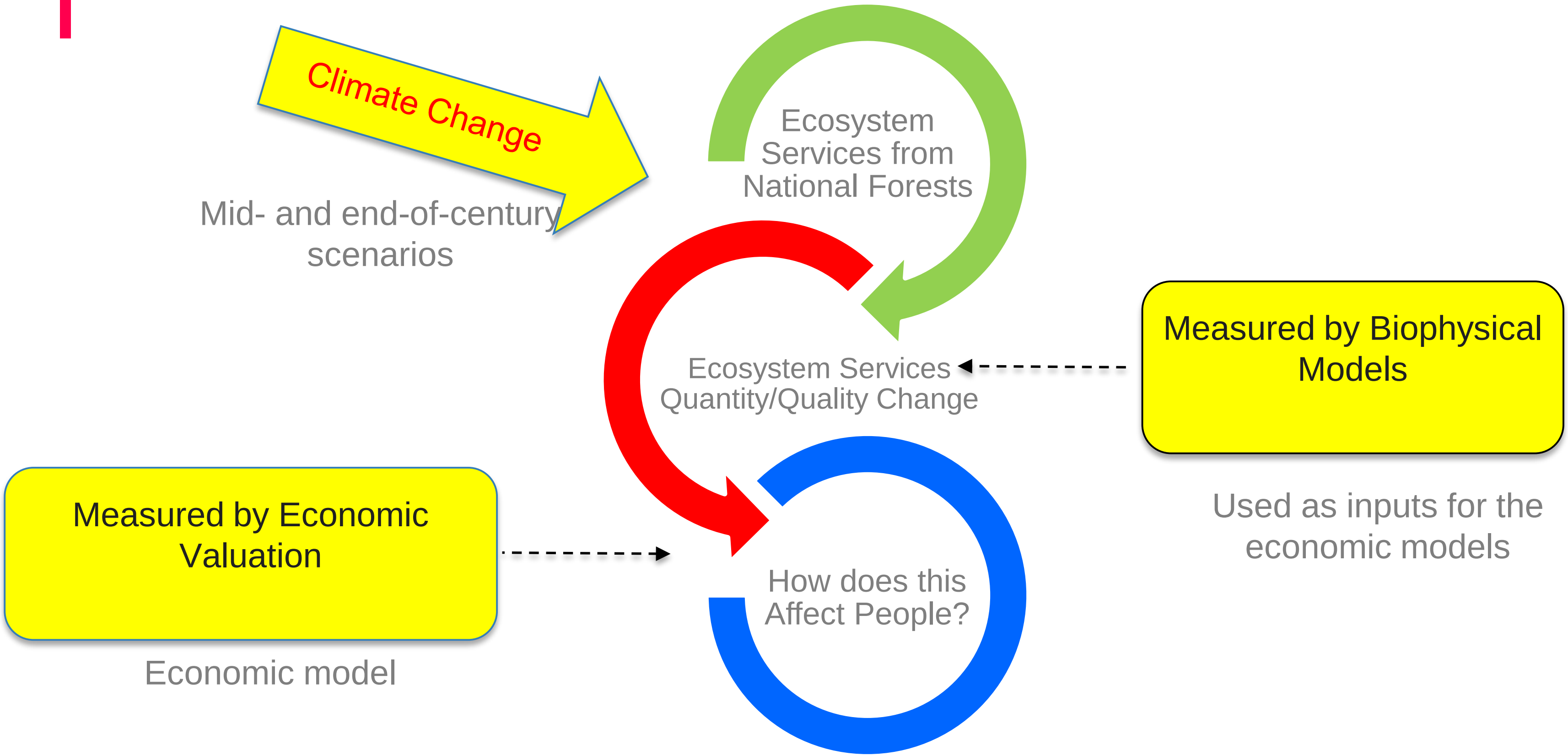
Conceptual Model



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Measured by Biophysical Models

Used as inputs for the economic models

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Economic model

How does this Affect People?

Economic Value of Sequestered Carbon

- Quantity of sequestered carbon from MC2 model

    - Dynamic global vegetation model (DGVM)
    - DGVM Group (PI John B. Kim) at USFS Pacific Northwest Research Station

Economic Value of Sequestered Carbon

- Meteorological data:
- Gridded monthly climate data from from 1895-2100
- 20 year average of min and max temperature, precipitation, vapour pressure
- 12 values per year for each of the four National Forests

- Vegetation data:
- Tree leaf area index (LAI), % tree cover, evergreen vs. deciduous

- Outputs: Gridded vegetation characteristics, including carbon

Economic Value of Sequestered Carbon

- Forecast future vegetation conditions using five general circulation models as input
- Use three general circulation model (GCM) outputs for RCP8.5 climate change scenario (no mitigation):

    - CNRM-CM5 – warm-wet
    - CCSM4 – mean (middle) of temperature and precipitation
    - MIROC – hot and dry

Economic Value of Sequestered Carbon

- Forecasts based on three different GCMs, all under RCP8.5

  - Highest population
  - Slow income growth
  - Modest technological change
  - Absence of climate change policies
  - Highest GHG emissions

- Apply different discount rates to different scenarios
- Reflect inherent uncertainty of future realisations

Benefit Unit Transfer

Social cost of carbon

Frowned upon

But OK for this application

Carbon is not local

Socal Cost of Carbon

Monetised damages for marginal increases in CO_2e

Example: human health, property damages from flood risk, etc.

Global value

Which Social Cost of Carbon?

Interagency Working Group (IWG)

To be updated regularly

Average three GCMs

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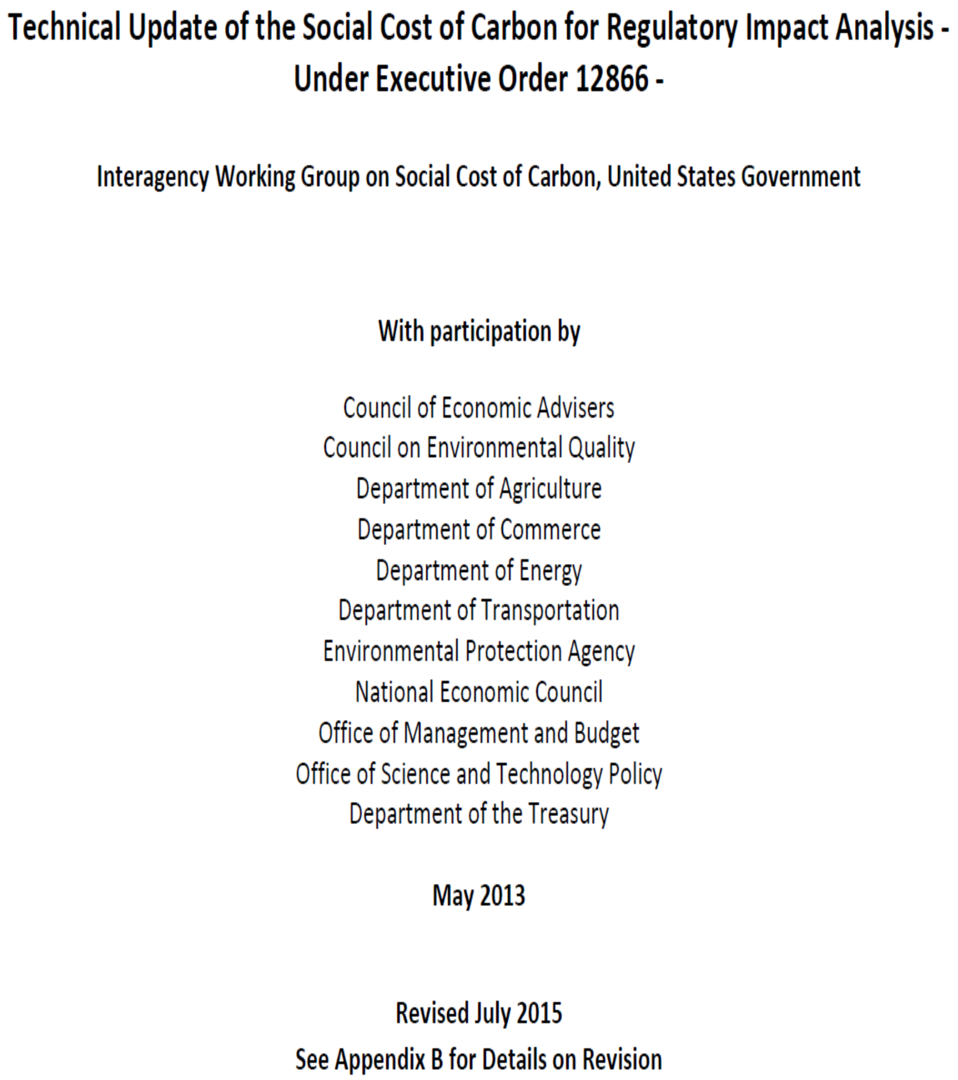

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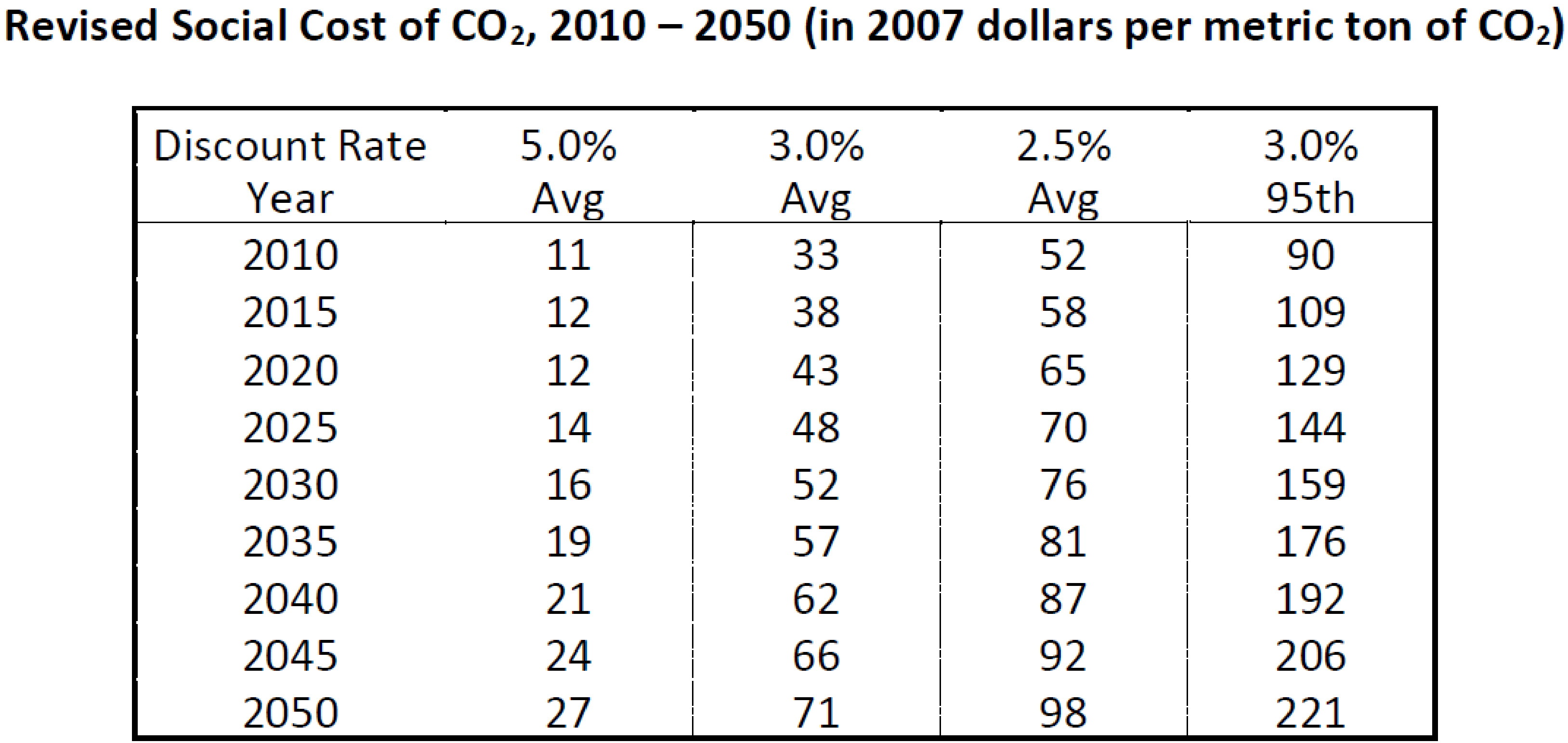

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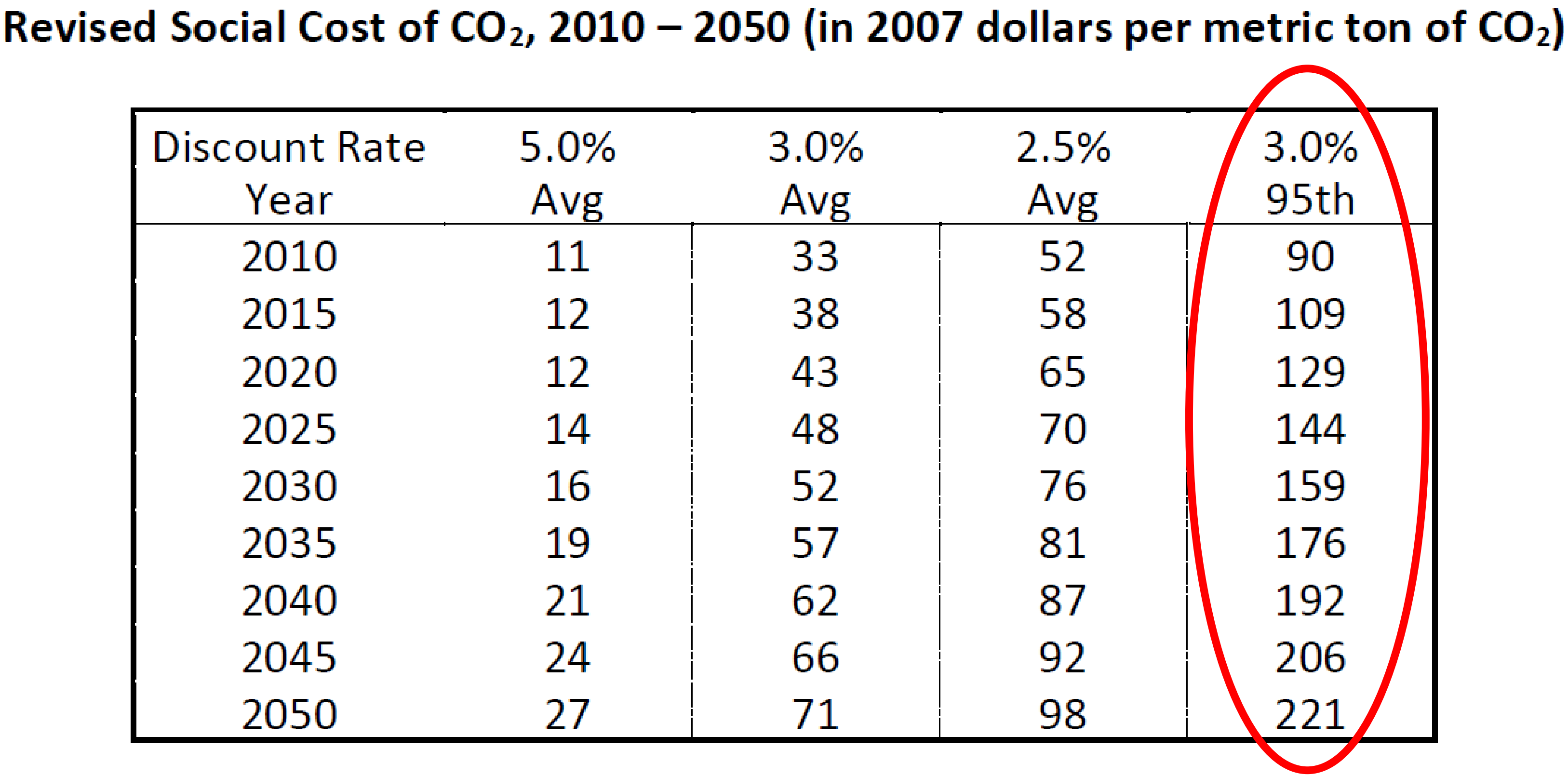

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Sequestered Carbon Value

Carbon pools: live, dead, soil carbon

Calculate total carbon across all 4 National Forests

Illustrative Findings Pricing Carbon CO2

	CNRM-CM5 (warm-wet)			CCSM4 (ensemble mean)			MIROC (hot-dry)		
	2016	2050	2099	2016	2050	2099	2016	2050	2099
CO_2 (million t)	832	874	931	822	860	916	824	854	880

Illustrative Findings Pricing Carbon CO2

	CNRM-CM5 (warm-wet) 5%			**CCSM4 (ensemble mean) 3%**			**MIROC (hot-dry) 3%**		
	2016	2050	2099	2016	2050	2099	2016	2050	2099
SCC (2016$/t CO_2e)	$13	$30	$79	$44	$79	$209	$124	$244	$643
Value (billion 2016$)	$11	$26	$74	$36	$68	$191	$102	$208	$566

California Carbon market: $14.61/t CO_2e (February 2018)

Illustrative Findings Comparing Discount Rates

	CNRM-CM5 (warm-wet)			**CCSM4 (ensemble mean)**			**MIROC (hot-dry)**		
	2016	2050	2099	2016	2050	2099	2016	2050	2099
SCC (2016$/t CO_2e) 7%	$1	$10	$291	$1	$10	$291	$1	$10	$291
Value (billion 2016$) 7%	$1	$9	$271	$1	$9	$267	$1	$9	$256
Value (billion 2016$)	$11	$26	$74	$36	$68	$191	$102	$208	$566

California Carbon market: $14.61/t CO_2e (February 2018)

Summary

- Pricing of externalities can be done smartly
- Consider desired outcomes
- Take into account resource constraints, political realities
- Programme design can be changed

- Economic value of sequestered carbon depends upon climate realisation, and discount rate
- Ranges from $1 billion - $556 billion (2016$)
- Caveats:
  - Compare with other values of sequestered carbon
  - MC2 simulated grass characteristic poorly in this region
  - May not fully account for uncertainty

Future Climate Scenarios

- Forecasts based on three different GCMs, all under RCP8.5

  - Highest population
  - Slow income growth
  - Modest technological change
  - Absence of climate change policies
  - Highest GHG emissions

- Apply different discount rates to different scenarios
- Reflect inherent uncertainty of future realisations

What Will Happen in Southern California?

- Ecosystem services framework links ecosystems and human well-being (Millenium Ecosystem Assessment, 2005)

- Supply side determined by ecological processes (may be influence by human activities)
  - Measured by biophysical modeling

- Demand side largely determined by characteristics human beneficiaries
  - Population, preferences, etc. measured by economic modeling

- Different estimation methods used for ecosystem services

Demand and Supply

- As something gets more expensive, people want less
- Law of Demand: P ↑ → Q ↓
- Demand curves are downward sloping

- As something gets more expensive, firms want to produce more
- P ↑ → Q ↑
- Supply curves are upward sloping

- Perfectly competitive markets do not account for externalities