Predicting Effects of Climate and Landuse Change on Human Well-Being via Changes in Ecosystem Services

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Climate and Landuse Change Impacts on Ecosystem Services and Well-being

National Climate Assessment (2014)

- Reduced ability to regulate water quality and quantity
- Reduced ability to buffer extreme events
- Loss and degradation of soil and water assets for agriculture
- Alterations in biodiversity
- Choices about future landuse will affect vulnerability to climate change
- Expected to threaten human well-being

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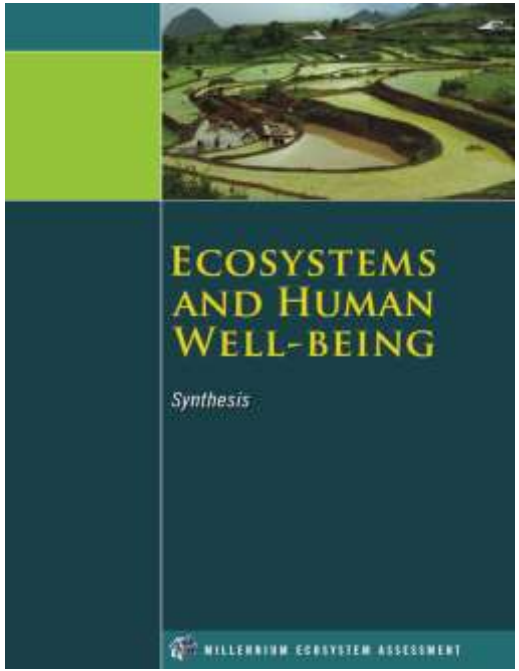
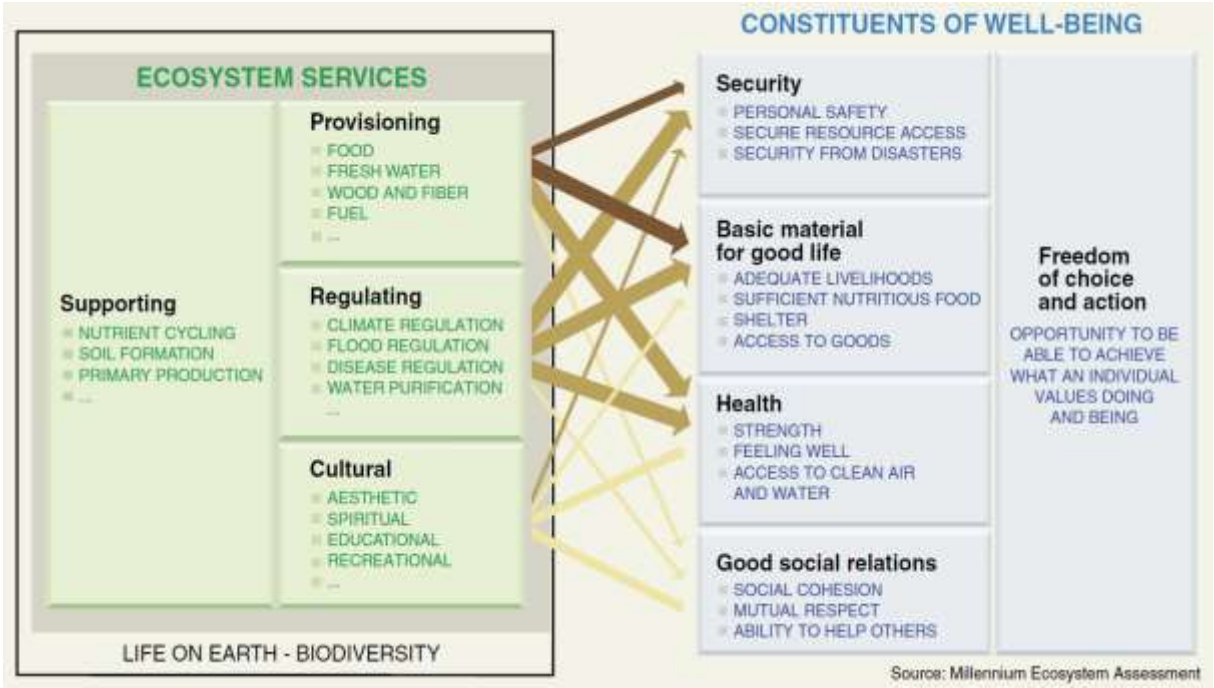
Can we quantitatively predict impacts of climate and landuse change on human well-being resulting from impacts on ecosystem services?

Ecosystem Services and Human Well-being

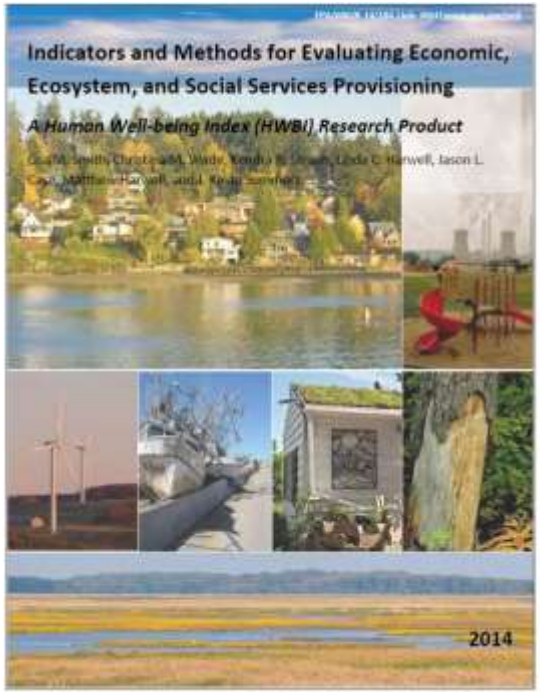




Quantifying Relationships between Ecosystem Services and Human Well-being

Human Well-Being Index (HWBI)

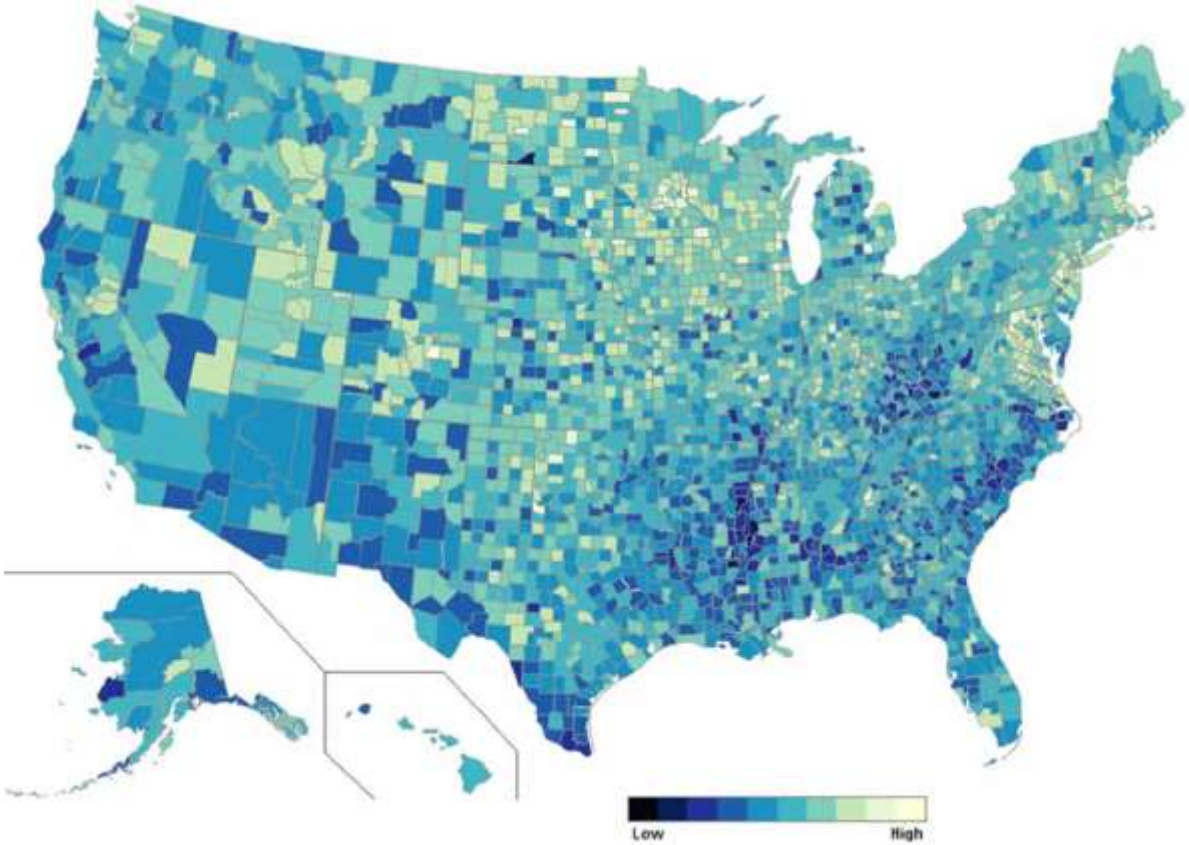
Services



Services -> Well-being

Smith et al. 2012, 2014a, 2014b

1. County-level Time-Series and Maps of HWBI, 2000-2010



Index based on 80 metrics of well-being

2. Regression Models Relating Indicators of Ecosystem Services to Domains of Human Well-being

$$HW_d = (S_e, S_s, S_{ec})$$

Ecosystem Services
- Air quality
- Food, fiber, fuel
- Greenspace
- Water quality
- Water quantity

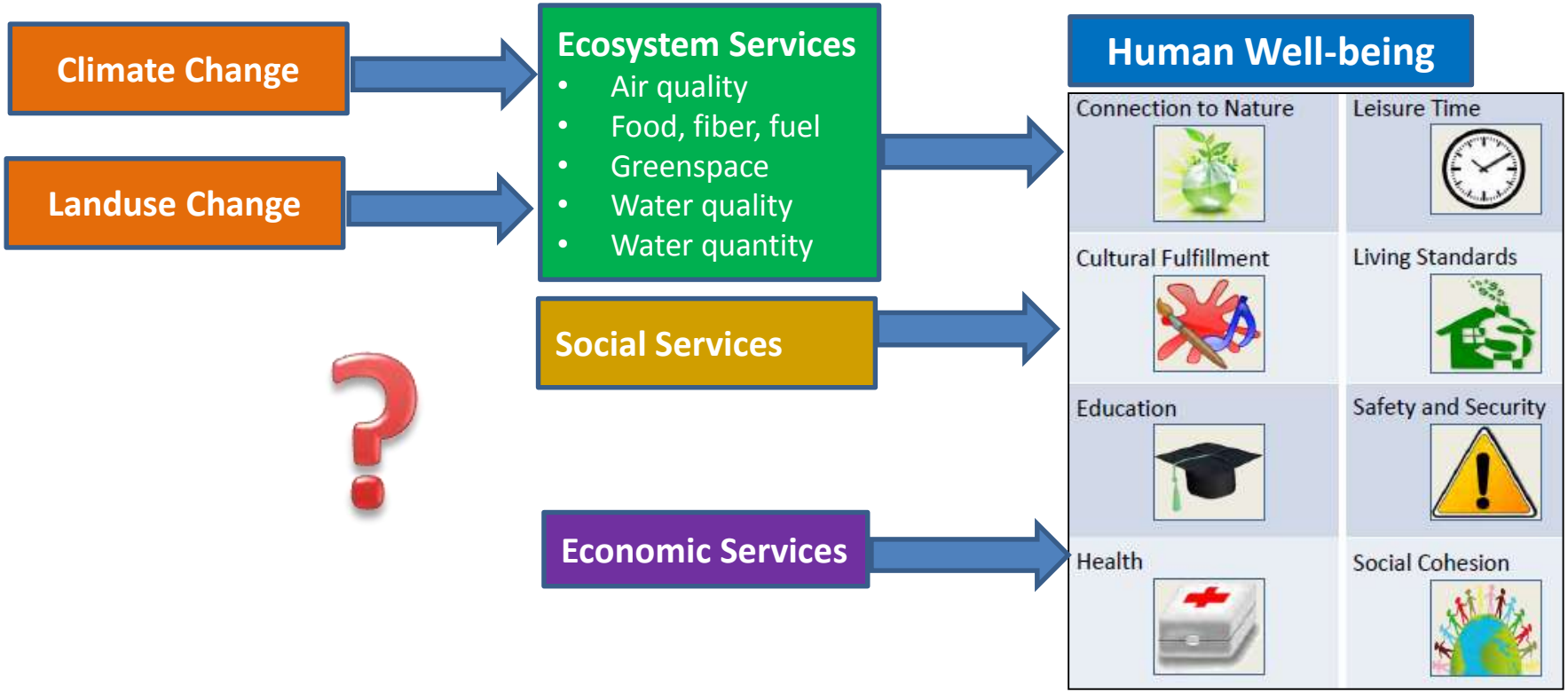
Social Services
- Activism
- Communication
- Community initiatives
- Education
- Emergency preparedness
- Family services
- Healthcare
- Justice
- Labor
- Public works

Economic Services
- Capital Investment
- Consumption
- Employment
- Finance
- Innovation
- Production
- Redistribution

Human Well-being

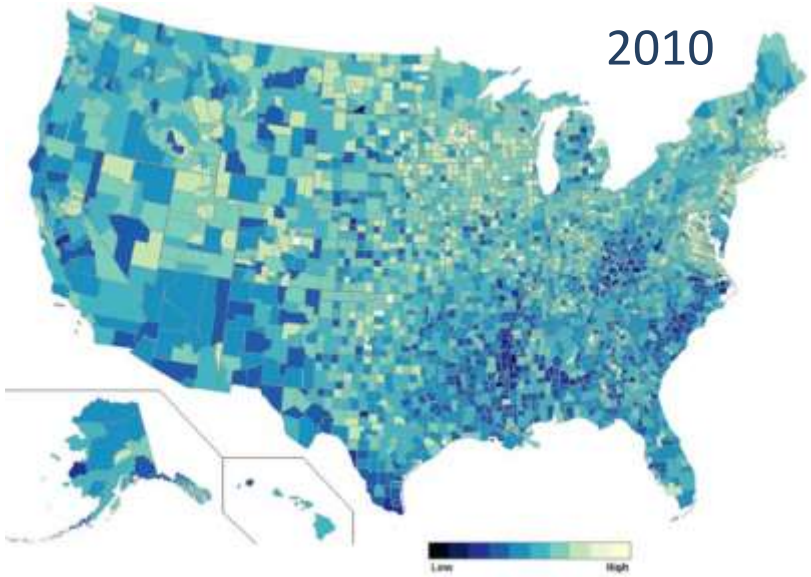
(Summers et al., 2016)

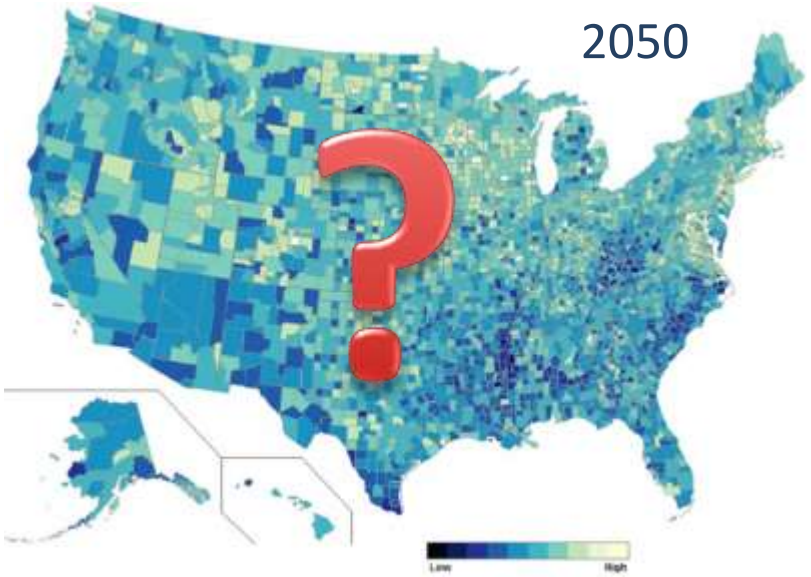
How will Climate and Landuse Change Impact Ecosystem Services and Human well-being?



Can we predict future human well-being, given expected climate & landuse impacts on ecosystem services?



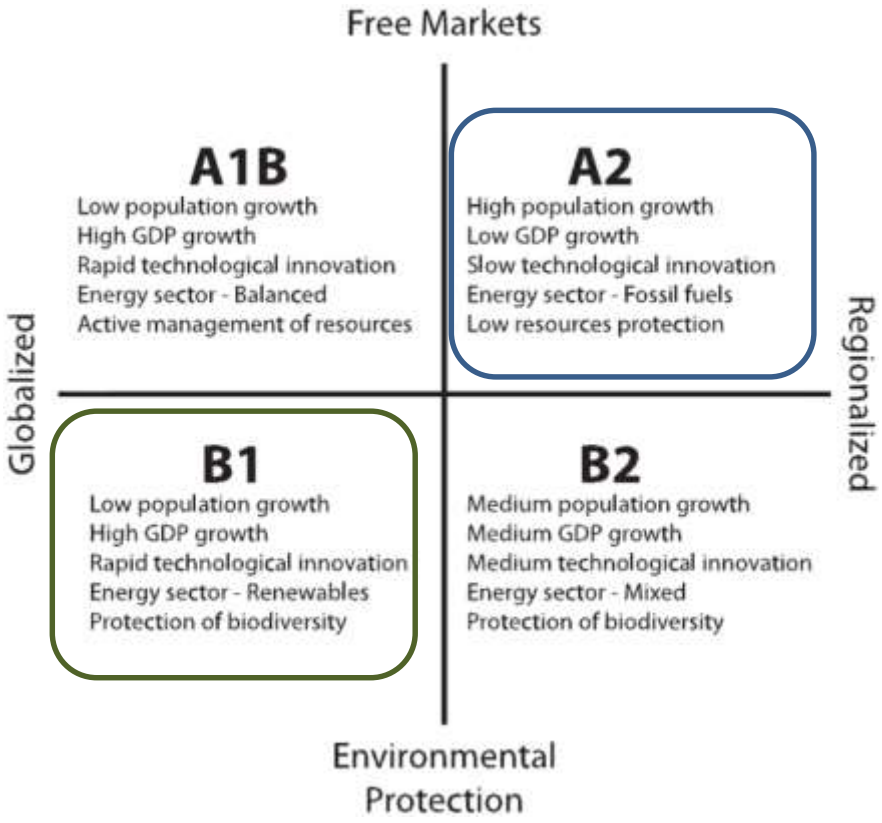




Methods

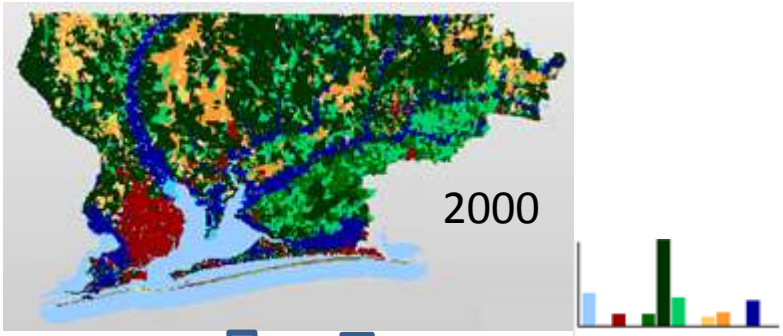
- Proof of Concept for Pensacola, FL watershed
- Identify future climate/landuse scenarios
- Identify ecological production functions to translate landcover into ecosystem services
- Apply HWBI regression models to translate ecosystem services into well-being
- Data and models integrated into spatially-explicit dynamic modelling software: Envision

Methods: Future Landuse Scenarios



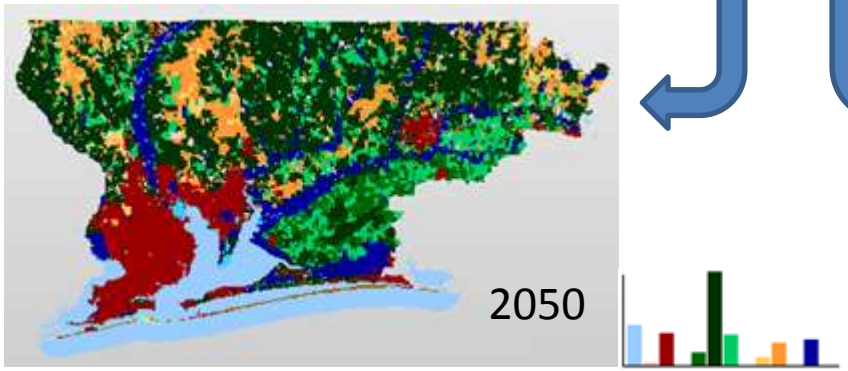
Methods: Future Landuse Scenarios

Fore-SCE (USGS)

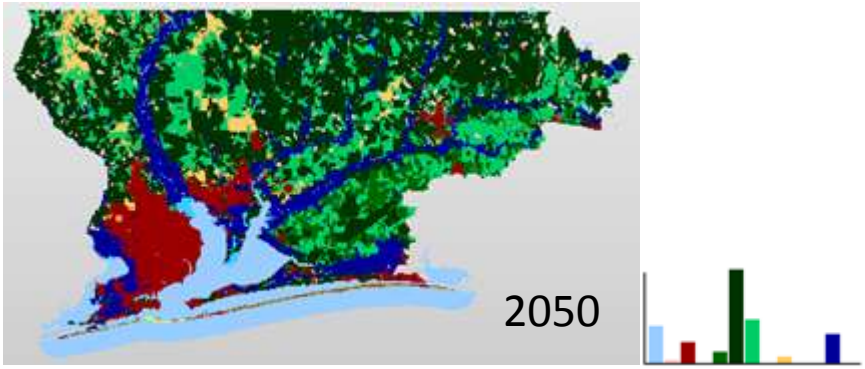


- Water
- Developed Open
- Developed
- Barren
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Grassland
- Hay and Pasture
- Agriculture
- Woody Wetland
- Herbaceous Wetland

IPCC Scenario A2

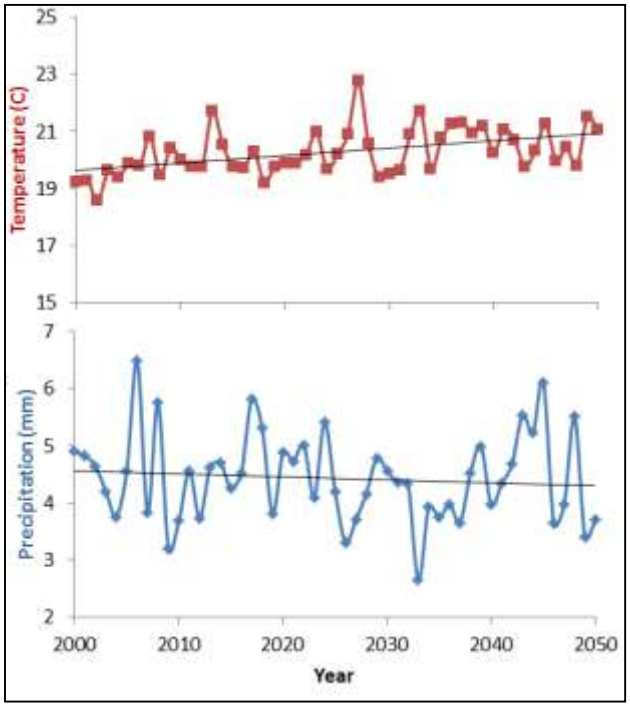


IPCC Scenario B1

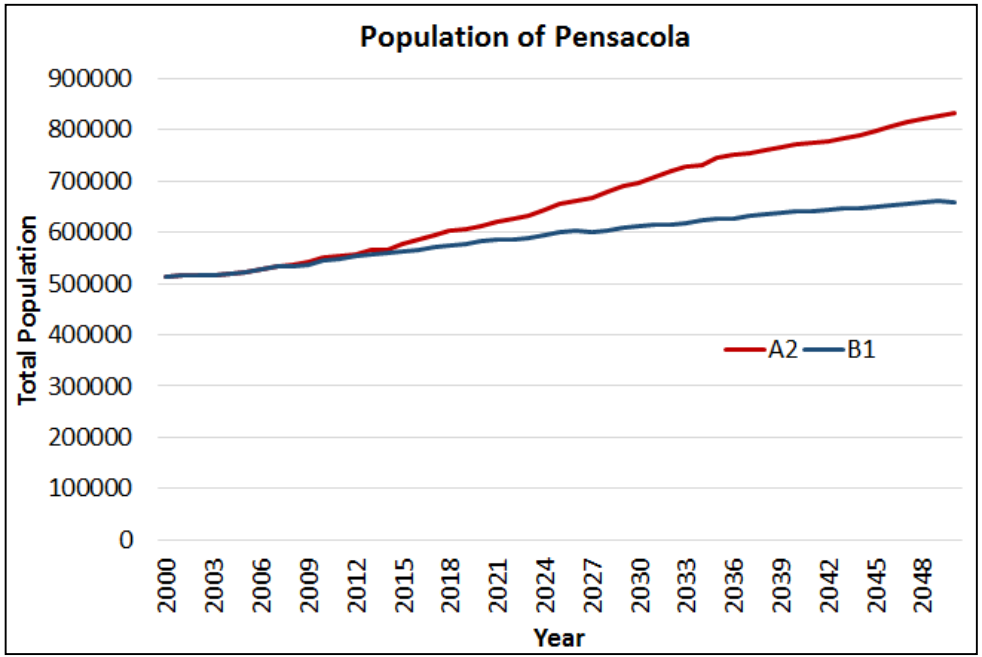


Methods: Future Scenarios

Precipitation and Temperature
(MACA Downscaled Climate Data)



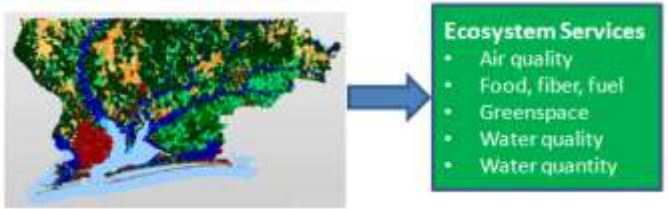
Population Density
Based on 2010 mean density per LULC



Methods: Ecosystem Services Production Functions

SERVICE	INDICATORS	NUMBER OF METRICS
Air Quality 	Usable Air	1
Food, Fuel and Fiber Provisioning 	Energy Food and Fiber Raw Materials	4 3 5
Greenspace 	Natural Areas Recreation and Aesthetics	4 3
Water Quality 	Usable Water	2
Water Quality 	Available Water	2

Identify surrogate metrics that could be modelled as a function of landuse, climate, ecosystem condition



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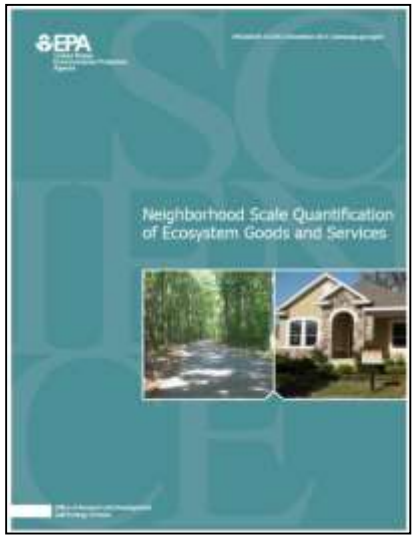
InVEST

integrated valuation of ecosystem services and tradeoffs



Russell et al. 2013

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Air pollutant removal

- Canopy cover

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Timber Volume

- Forest cover available for harvest

Agricultural Productivity

- Carbon into soil
- Nitrogen fixation
- Soil water content
- Look up tables based on LULC

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Energy & Raw Materials

- Gold, silver, coal, oil reserves
- Assumed unaffected by climate/landuse change

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Natural Areas

- Cover of greenspace
- National Parks (assumed not to change)

Recreation & Aesthetics

- Bluespace – water per population
- Biodiversity – based on mean richness per landuse type

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Water quality

- Sediment retention (USLE)
- Nutrient retention (Invest)
- Fecal coliform retention (HSPF)
- Retention rates based on landcover
- HBV to model hydrology

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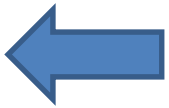
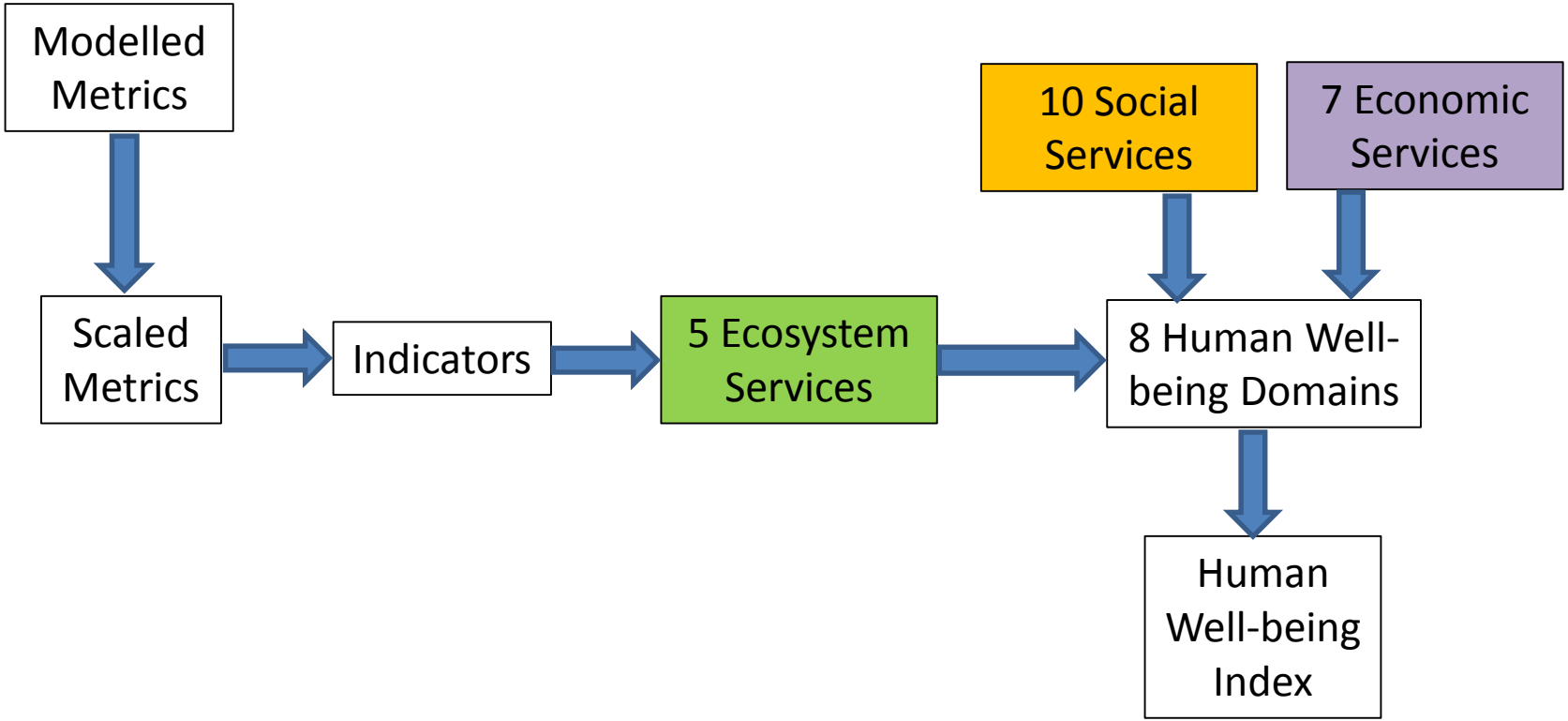


Rainwater retention
- curve number method
- based on mean soil type in each LULC

Water Sustainability Index
- assumed not to change

Methods: Calculate Human Well-Being Index



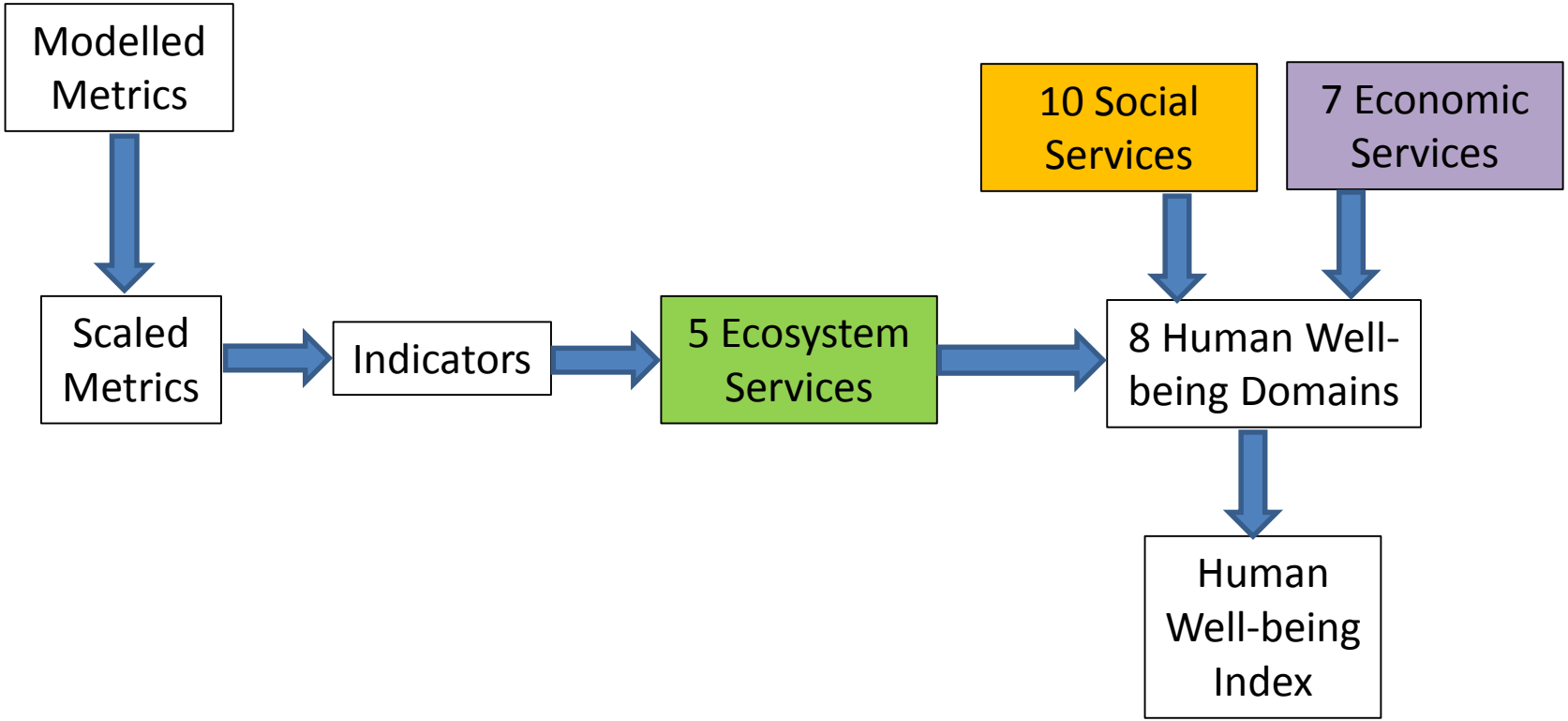
Methods: Regression Coefficients Linking Services to Domains

Regression coefficients (*Summers et al. 2016*)

	Domains							
Services	Connection to Nature	Cultural Fulfillment	Education	Health	Leisure Time	Living Standards	Safety & Security	Social Cohesion
Air Quality		-/+						+
Food/Fiber					+	+		
Greenspace	-		+		+		-	-/+
Water Quality	+				-	-	-/+	-
Water Quantity		-		+	-/+	+	+	

***includes interactions with other variables

Methods: Calculate Human Well-Being Index



Methods: Map Layers & Models Integrated in Envision

- Integrate different models into Envision software
- Open source, GIS
- Model plug-ins
- Alternative scenarios

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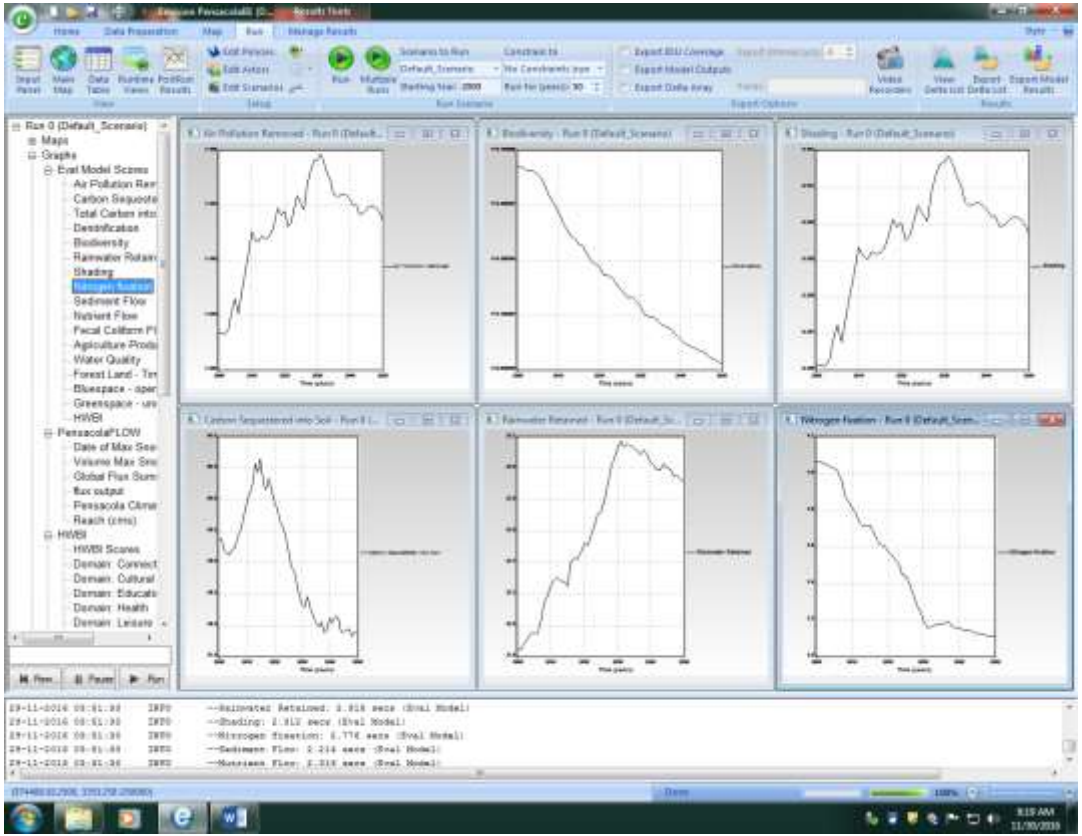
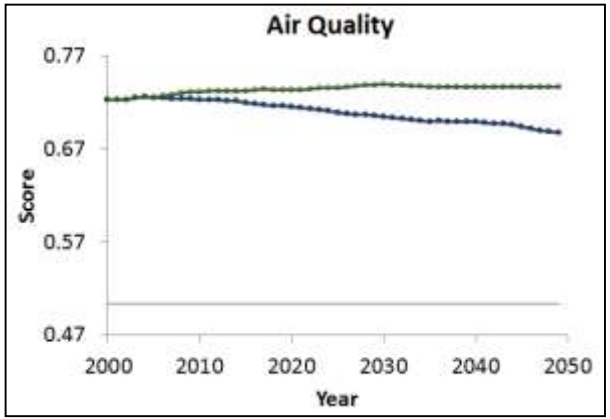
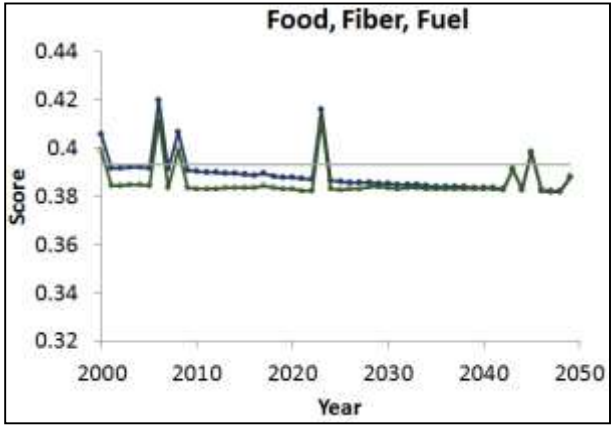
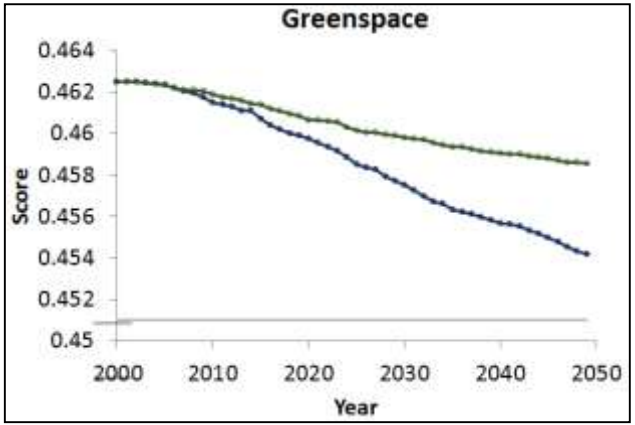
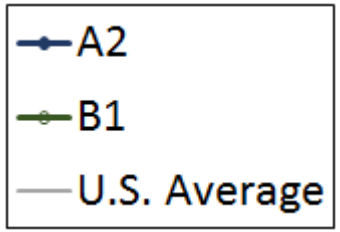


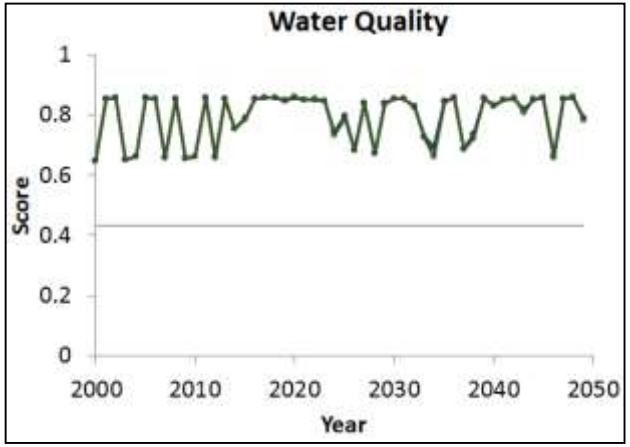
Results: Ecosystem Services under Alternate Scenarios

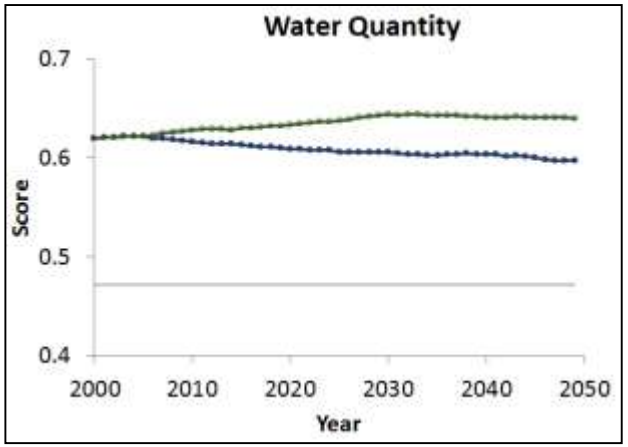




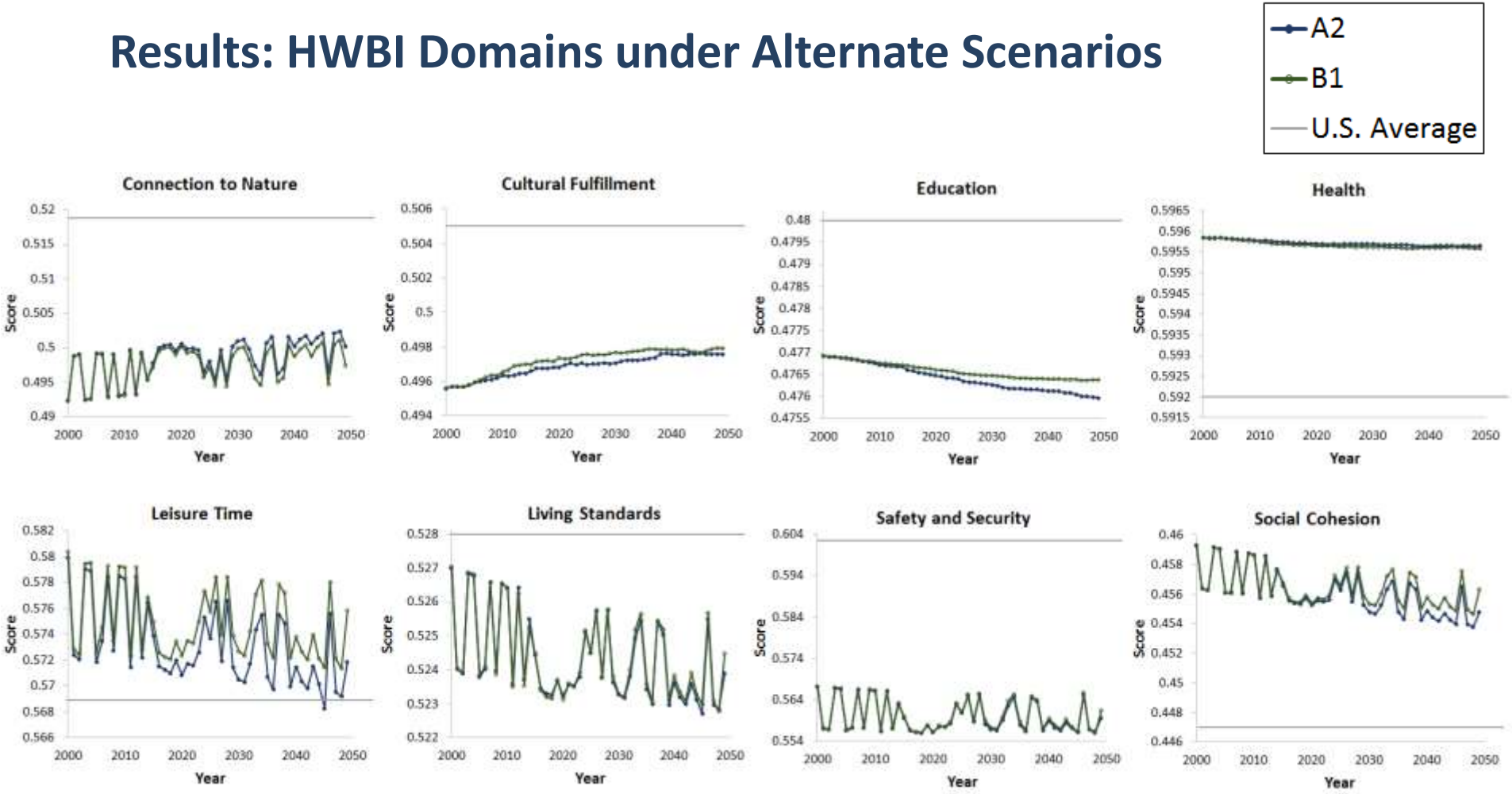




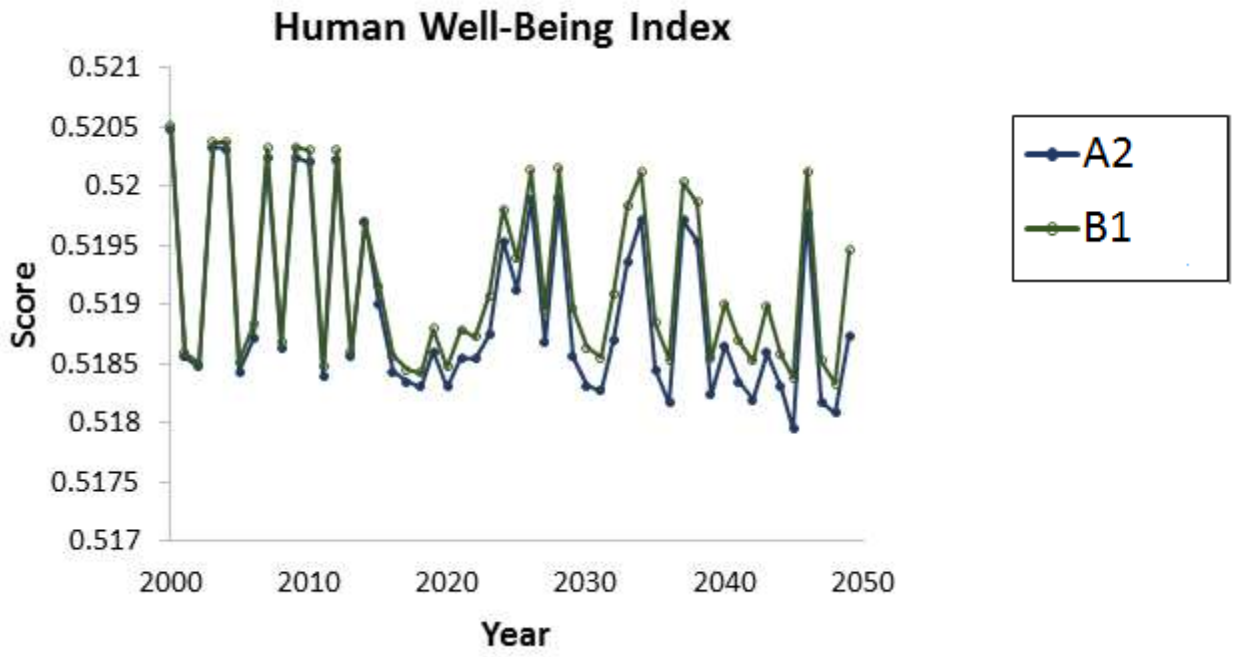




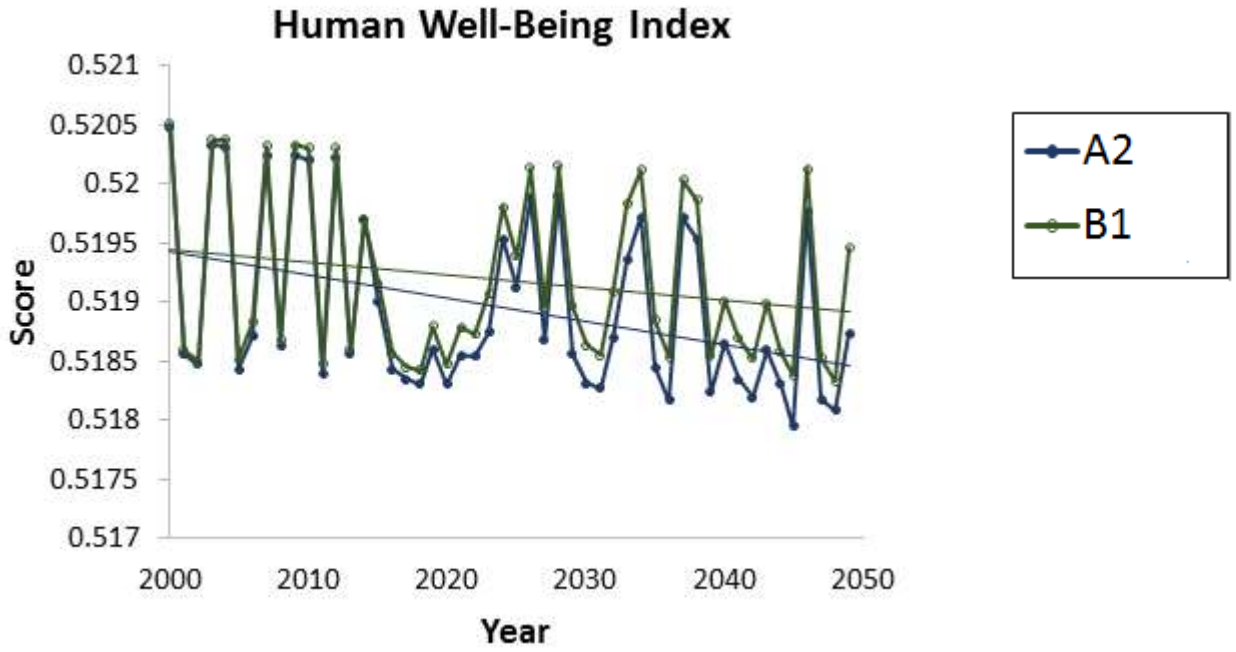
Results: HWBI Domains under Alternate Scenarios



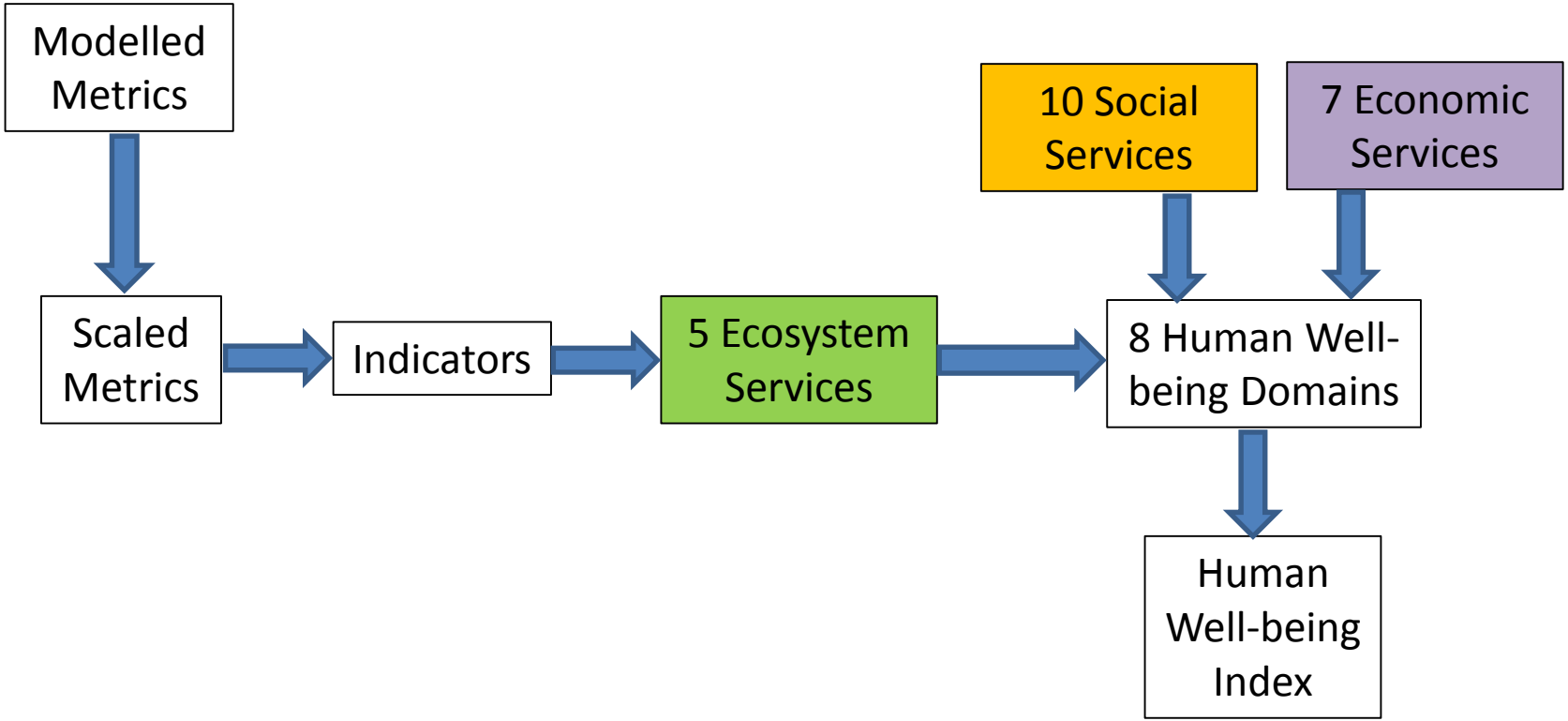
Results: Composite HWBI under Alternate Scenarios



Results: HWBI under Alternate Scenarios



Methods: Calculate Human Well-Being Index



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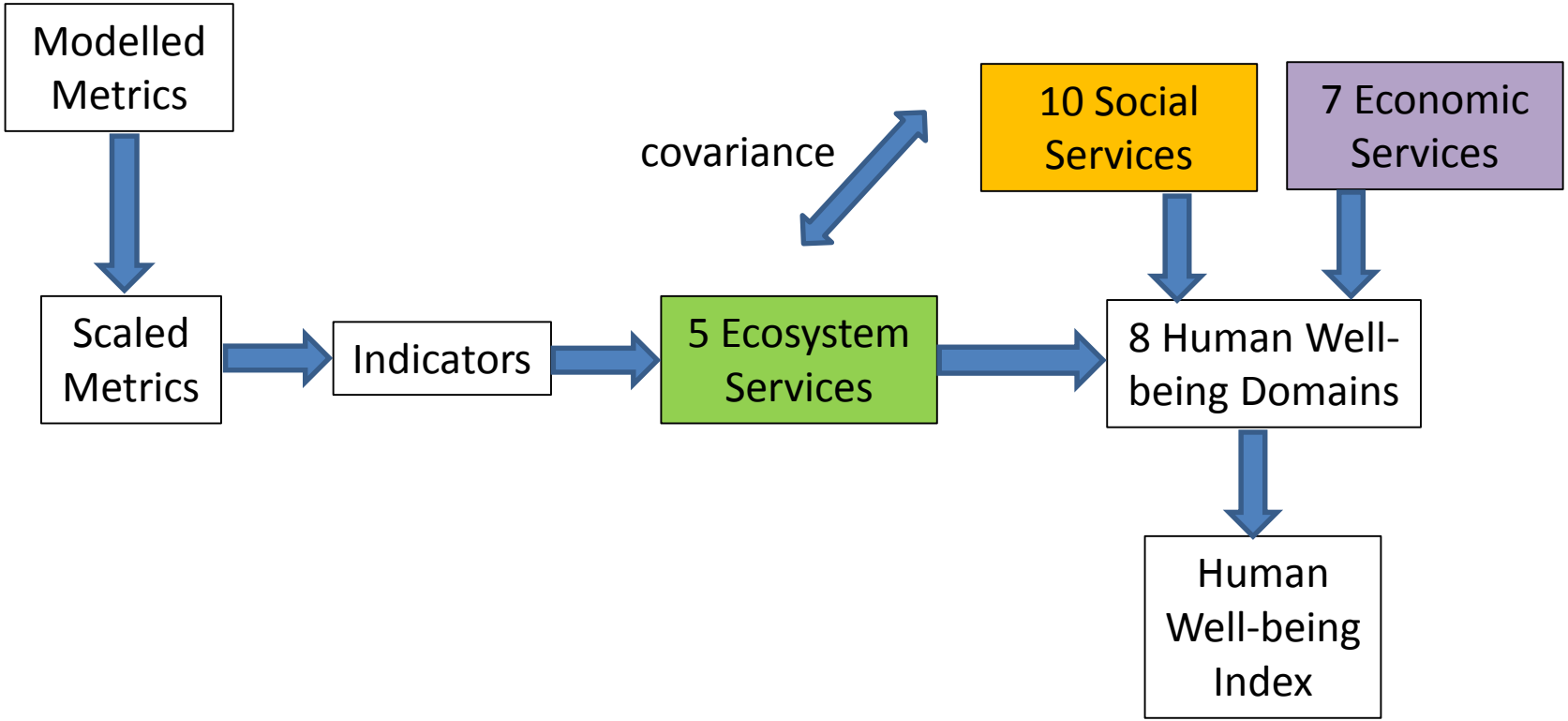
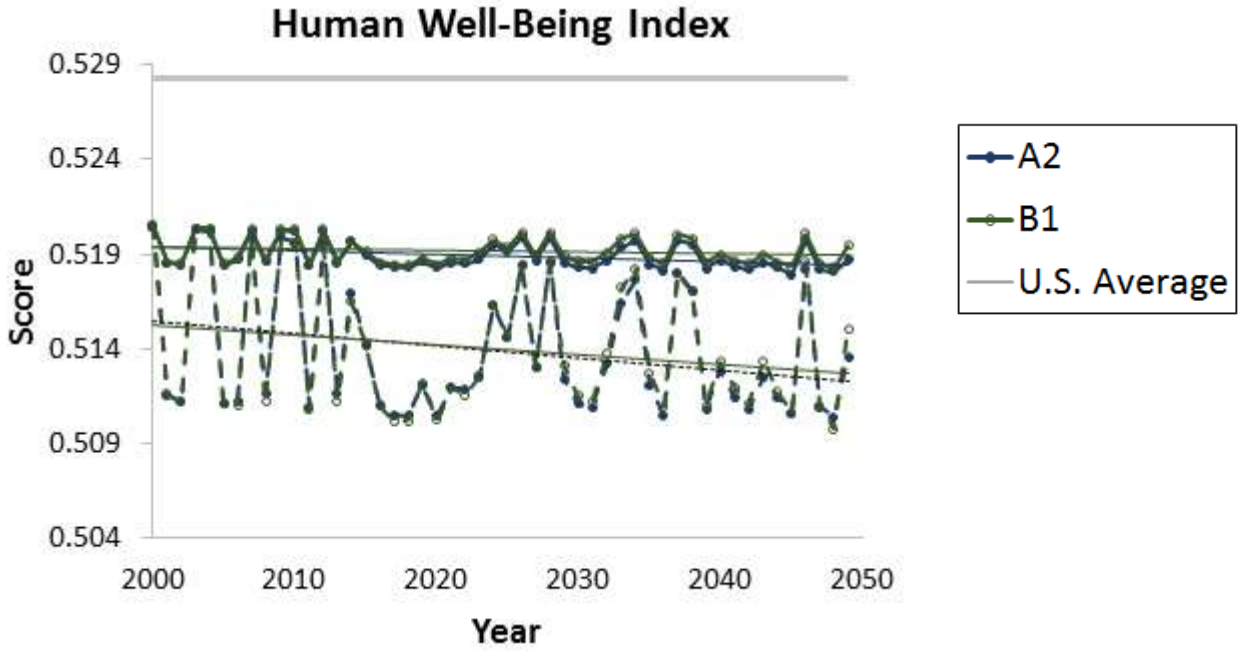


Adjustment to Economic & Social Services Based on Covariance

	Economic Services							Social Services								
Ecosystem Services	Capital investment	Consumption	Employment	Finance	Innovation	Production	Re-distribution	Activism	Communication	Community Initiatives	Education	Emergency Preparedness	Family Services	Healthcare	Justice	Labor	Public works
Air Quality							+										
Food/Fiber	+	+	+	-		-		+			-	-	-	+			
Greenspace	+	+	+	-				+			-	-	-		+	-	
Water Quality	+	+		-				+			-	-	-		+		
Water Quantity										+	+			-			

Results: HWBI under Alternate Scenarios



Summary

- The specific development scenario (A2 vs. B1) effects whether ecosystem services are predicted to degrade with climate change & landuse
  - Air quality & water quantity projected to increase under "environmentally friendly" B1 scenario, but decrease under A2
  - Greenspace projected to decrease under both scenarios

- Human Well-being projected to decrease under both scenarios
  - Decreases at a slower rate under B1 scenario
  - Largely reflects declines in education, leisure time, living standards, social cohesion

Next steps

- Apply relative importance values on HWBI domains
- Explore co-varying effects with Social & Economic Services
- Incorporate IPCC Scenario projections on energy reserves & emissions
- Investigate uncertainty associated with model parameters
- Investigate transferability to other locations
- Apply methods to investigate specific management and development scenarios (e.g., green infrastructure, restored wetlands)