**The science of ecosystem services, what we know and need to learn**

Millennium Ecosystem Assessment

## Focus: Ecosystem Services
The benefits people obtain from ecosystems

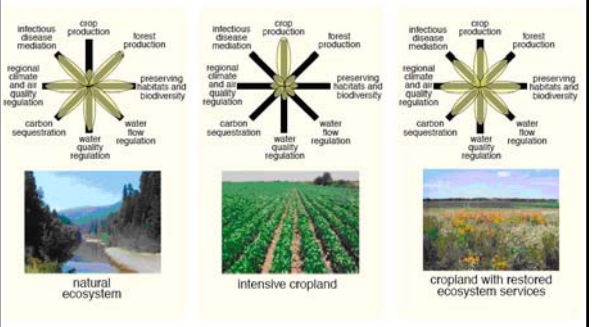

MEA 2005

## Status of Ecosystem Services

| Provisioning Services | | Status |
|---|---|---|
| Food | crops | ↑ |
| | livestock | ↑ |
| | capture fisheries | ↓ |
| | aquaculture | ↑ |
| | wild foods | ↓ |
| Fiber | timber | +/– |
| | cotton, silk | +/– |
| | wood fuel | ↓ |
| Genetic resources | | ↓ |
| Biochemicals, medicines | | ↓ |
| Fresh water | | ↓ |

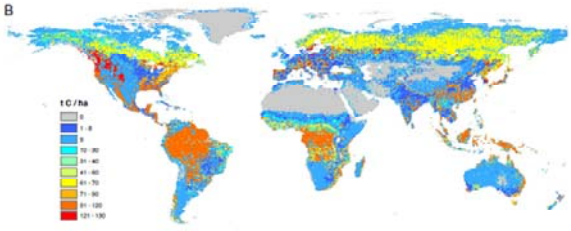
| Regulating Services | |
|---|---|
| Air quality regulation | ↓ |
| Climate regulation – global<br>regional and local | ↑<br>↓ |
| Water regulation | +/– |
| Erosion regulation | ↓ |
| Water purification and waste treatment | ↓ |
| Disease regulation | +/– |
| Pest regulation | ↓ |
| Pollination | ↓ |
| Natural hazard regulation | ↓ |
| **Cultural Services** | |
| Spiritual and religious values | ↓ |
| Aesthetic values | ↓ |
| Recreation and ecotourism | +/– |

MEA 2005



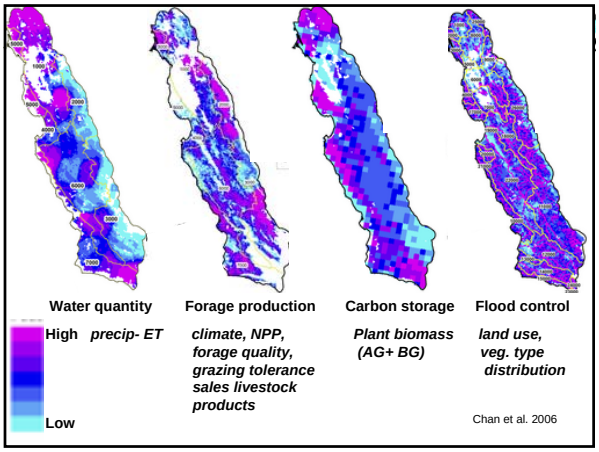

http://www.epa.gov/ncer/rfa/2009/2009_star_ecosystem_services.html

## How do we assess ecosystem services at global to regional scales?




**Global carbon storage estimated by measurements of aboveground plant biomass in each vegetation type/biome**

**Naidoo *et al. 10.1073/pnas.0707823105***

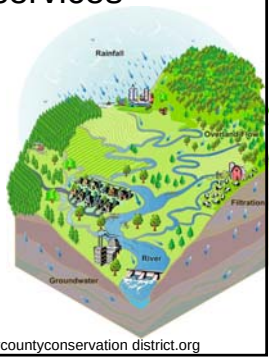



## How do we assess ecosystem services at global to regional scales?

"…because ecosystem services can be difficult to measure directly, scientists have tended to ***use land use/land cover as a proxy*** for the provision of services even though the relationships between land use/land cover and service provision ***are largely untested for most services in most regions of the world***." (Bennett et al. 2009)

## Challenges with assessing and managing services

- Quantifying services
  - Difficult to quantify most services directly
    - Large spatial and temporal scales
    - How sample to capture the variability?




www.beavercountyconservation district.org

## Challenges with assessing and managing services

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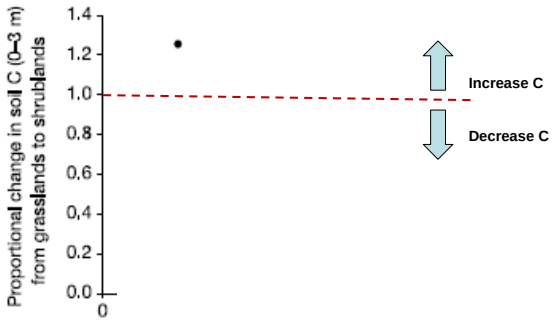
  - Difficult to quantify most services directly
  - **Large-scale estimates often based on assumptions about impacts of land use/ vegetation cover**

## Soil C impacts of planting woody species in grasslands




Jackson et al 2002

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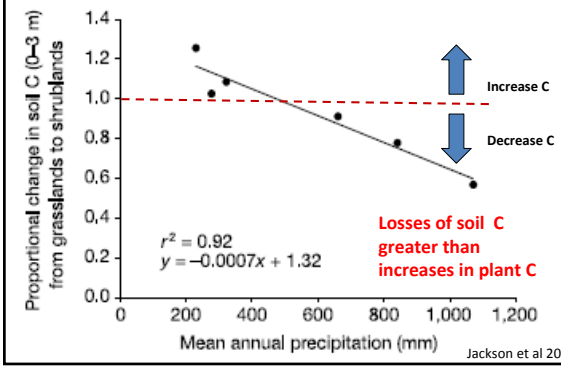


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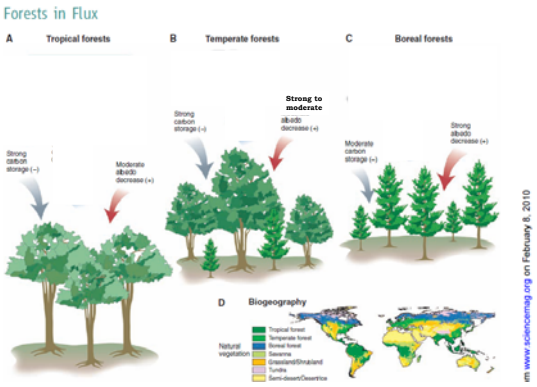
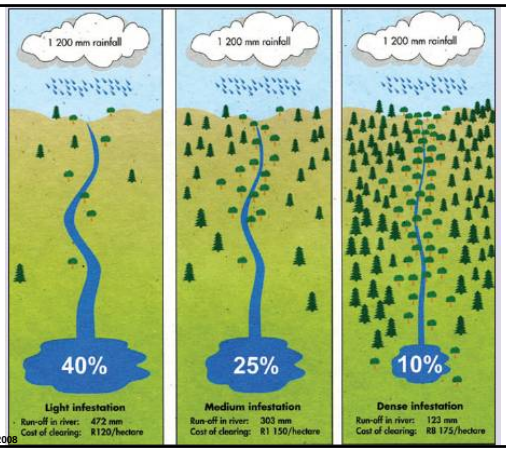



Gordon et all. 2008




## Effects of shrub encroachment into grasslands

Reviewed in Eviner & Chapin 2003

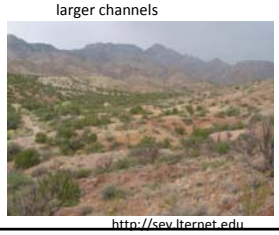
**Mediterranean climate**

- Shrubs decrease water runoff and stream flow
  - Increase ET

http://californiaagriculture.ucanr.org

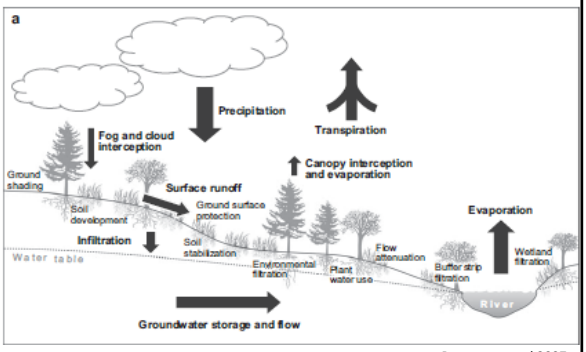
**Semi-arid climate**

- Shrubs increase water flow
  - Decrease infiltration
  - Increase overland flow
  - Concentrate flow into deeper, larger channels



http://sev.lternet.edu

## Ecosystem processes that impact water supply




Braumann et al 2007

## Challenges with assessing and managing services

- Quantifying services
  - Large-scale estimates often based on assumptions about impacts of land use/ vegetation cover
    - These impacts are context- dependent ** challenge is to determine when the rules change
  - We have the tools to tackle this complexity- use our understanding of local systems to :
    - Consider interactions between environmental controls and biotic controls
    - Consider which ecosystem processes are key drivers of a service at your site

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## Effects of removal of native tree- estimates vary by scale

Wilcox et al. 2006

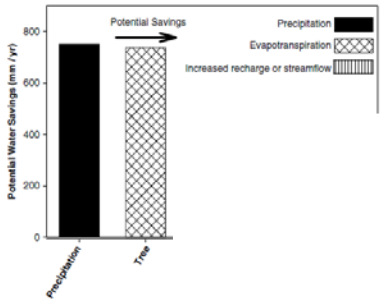


Figure 3. Hypothetical potential and realized savings of water on Ashe juniper rangelands with annual average precipitation of 750 mm year$^{-1}$. At the tree scale, the bar represents combined water use via interception and transpiration. At the stand, catchment, and landscape scales, the values represent the measured water savings (increases in recharge and/or streamflow) following the removal of Ashe juniper

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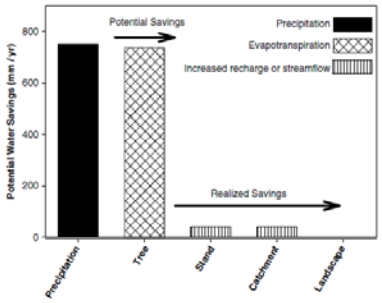


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## Can we use ecosystem functions as proxies for services?

- We already have a strong understanding of the effects of many vegetation types on ecosystem functions.
- Need to carefully select proper functions to consider as proxies based on your system (no "one size fits all" measurement)
- Consider how services integrate these component functions over space and time
- Consider "compensatory" mechanisms on landscape (e.g. other vegetation that fills in, changes in activity of an organism when another is removed)
- **Even with these caveats, predictions based on functions are likely to be an improvement over current assessment techniques (particularly when we address points to consider)**

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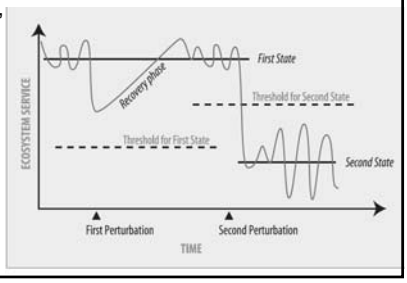
  - **When and where to measure to capture a meaningful estimate of a service?**

## When to measure:

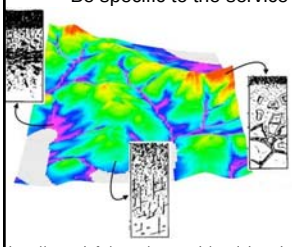
- Variability
  - Seasonal
  - Annual
- "Hot moments"
- Thresholds
- Directional shifts over time




MEA 2005

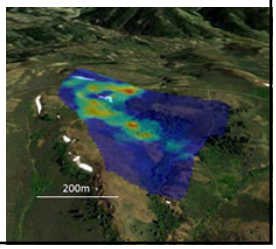
## Where to measure:

- Capture "hotspots" (and coolspots)
- Capture heterogeneity (not just based on vegetation)
- Need to consider large enough area
- Be specific to the service and system being considered

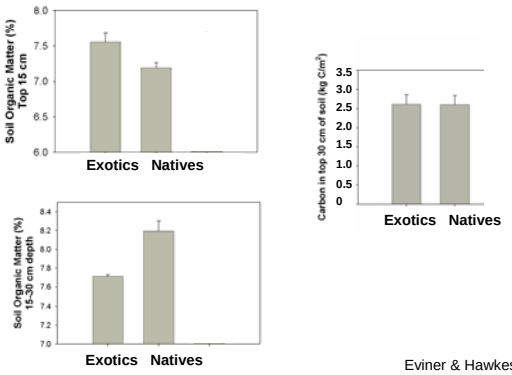


http://wess.info/wess/research/model_optimisation_monitoring/research_topics/scalable_soil_landscape_models.php

http://www.ceh.ac.uk/sci_programmes/Soil-and-Technology.html



## CA grassland invaders alter depth of soil C



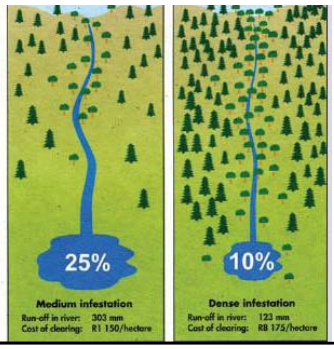

Eviner & Hawkes in prep

## How big of an area do we need to measure (or manipulate)?

*Zhu et al. 2000. Nature*

## How much change in area do we care about?

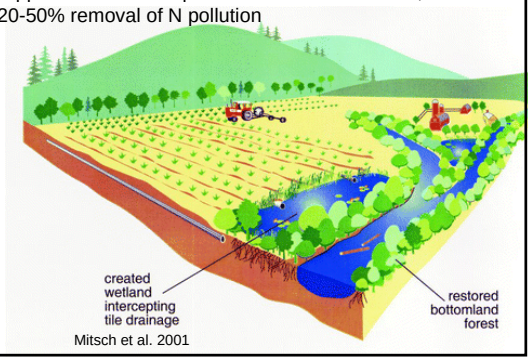
In general, need 20% land cover change to alter hydrology (range 15-50%) (Braumann et al 2007)



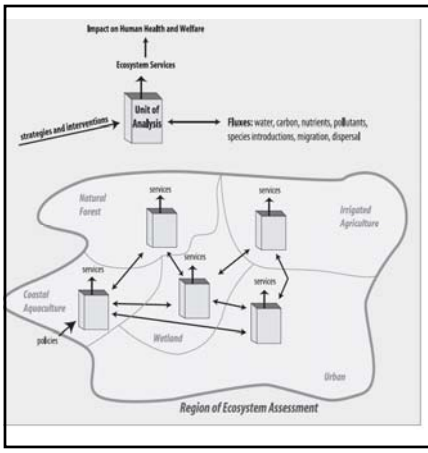

Mark and Dickinson 2008

## How small of an area may matter? (carefully located)

Mississippi- small stream riparian zones and wetlands, 1-2% area, 20-50% removal of N pollution




Mitsch et al. 2001




**How do the pieces fit together?**

- **Types of patches**
- **Size and shape**
- **Location**
- **Neighboring patches interacting (e.g. can design each patch for a piece of the process)**

MEA 2005

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**Carefully consider the system and services to assess:**

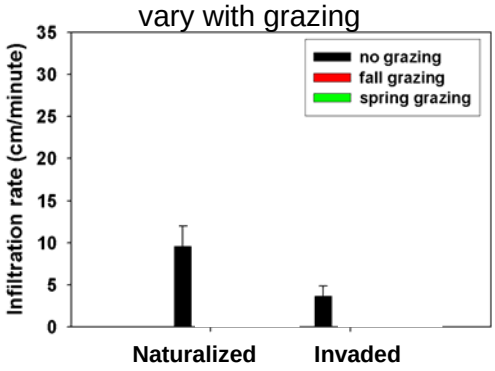
- **Heterogeneity across time**
- **Heterogeneity within vegetation types**
- **Heterogeneity across landscape**
- **Scale at which services are regulated**
- **Location at which services are needed (e.g. flood prevention may be a service near a city, flooding may be needed to maintain riparian and wetland buffer strips for water quality)**

  - **Can we take measures from one place/time/condition and extrapolate to others?**

- Cheatgrass can increase or decrease N cycling rates, depending on site Ehrenfeld 2003

http://www.imapinvasives.org/GIST/ESA/photos/brote02.jpg

## Impacts of California grassland types vary with grazing




Eviner, Malmstrom, Rice *in prep*

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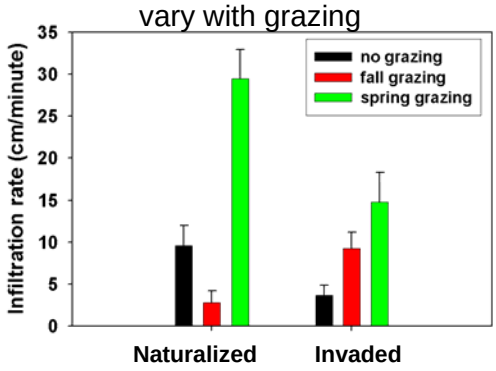


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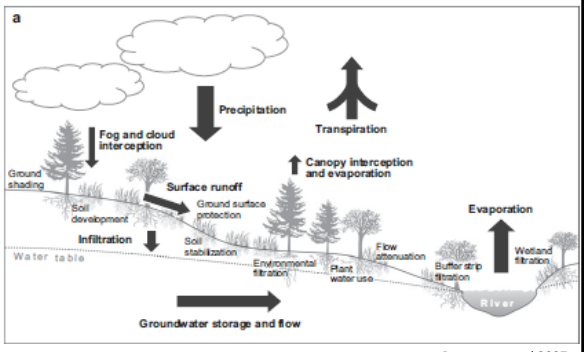



Braumann et al 2007

Determinants of water quantity: Adapted from van der Putten et al. 2004, Kremen 2005

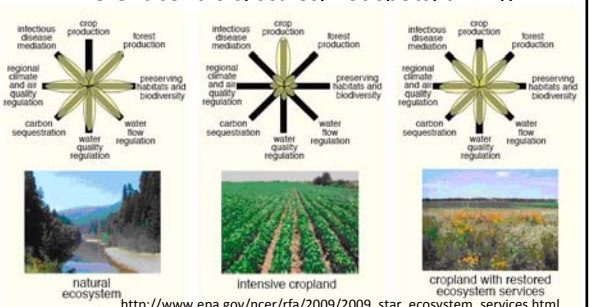
| Underlying ecosystem functions | Key environmental factors | Spatial scale | Traits of species that act as "key providers" | Abundance for trait impact | Time for impact | Other key interactors |
|---|---|---|---|---|---|---|
| Water holding capacity (SOM, pore space) | Soil<br>Climate<br>Topography | Local | Tissue chemistry, biomass, root structure | Proportional to high | Moderate to long | Soil invertebrates<br>Herbivores<br>Soil microbes |
| Evapotranspiration | Soil<br>Climate | Local to regional | Water use efficiency, biomass, leaf area, rooting depth in relation to water sources | Proportional to high | Short to moderate | Herbivores |
| Infiltration vs. runoff<br>- compaction<br>- vegetation cover<br>- soil aggregation<br>- soil pore space<br>Water flow path (e.g. channelization) | Ground water<br>Transport | Local to regional (depends on water flow) | Root structure<br>Root turnover<br>Canopy structure<br>Root exudates | Low to High | Short to moderate | Soil invertebrates<br>Herbivores<br>Soil microbes |

**Natural history and management knowledge of the system, coupled with suite of factors guide us in:**
**-Measurements**
**-Predictions based on current data available**
**-New conceptual frameworks based on new data collected**

| Ecosystem service | Underlying ecosystem functions | Key environmental factors | Spatial scale | Traits of species that act as "key providers" | Abundance for trait impact | Time for impact | Other key interactors |
|---|---|---|---|---|---|---|---|
| Water quality | Nutrient sequestration<br>Nutrient cycling<br>Nutrient leaching<br><br>Detoxification<br><br>Erosion control<br>- vegetation cover<br>- water runoff vs. infiltration<br>- soil cohesion<br>- soil layers | Soil<br>Climate<br>Topography | Local to regional (depends on water & solute flow)<br><br>Heterogeneity can have large impacts | Tissue chemistry, exudation, biomass (especially root)<br><br>Tolerance+ sequestration or ability to chemically convert<br>Root structure, canopy structure, | Low to high<br><br>Low to proportional<br>Proportional to high | Short to long<br><br>short to moderate<br><br>Short to long | Soil microbes<br>Soil invertebrates<br>Herbivores |
| Carbon sequestration | Organic matter formation/ accumulation (inputs, turnover, transformation of C forms) | Climate<br>Soils<br>Topography | Local to global | High root allocation<br>Tissue quality<br>Rooting depth<br>Exudation | Low to high | Moderate to long | Soil microbes<br>Herbivores |
| Climate regulation | Greenhouse gas emission<br>Latent vs. sensible heat flux<br>Albedo | Climate<br>Soils<br>Transport<br>Topography | Local to global | Reflectance<br>Canopy structure<br>Vegetation cover<br>Evapotranspiration<br>Rooting depth | Low<br><br>Low to high<br>Proportional? | Short to long<br>Short to moderate<br>Short to moderate | Herbivores<br>Soil microbes |
| Soil fertility | Organic matter accumulation<br>Nutrient recycling<br>Nutrient sequestration<br>Erosion control<br>Nutrient inputs | Climate<br>Soils<br>Topography | Local<br><br>Local to regional | Tissue chemistry<br>Tissue allocation<br>Biomass<br>Exudation<br>Canopy & root structure | Low to high | Short to long | Soil microbes<br>Soil invertebrates<br>Herbivores |

Challenge in managing for multiple services:

- Unintended tradeoffs
- Different controls, scales, hot spots, timing

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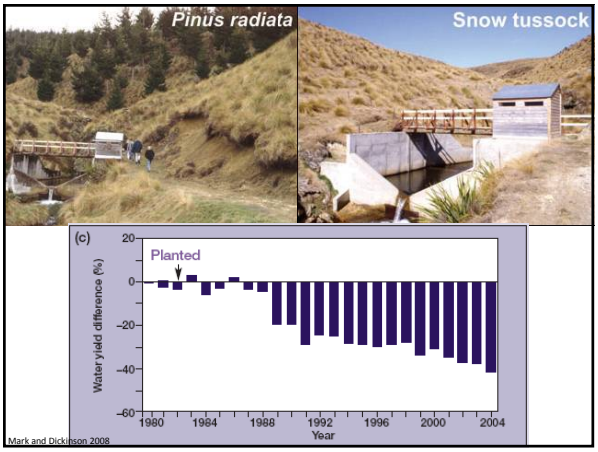


Mark and Dickinson 2008

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