Agricultural systems and ecosystem services: trade-offs or synergies?

- Agricultural systems are managed by farmers and influenced by local, national, and international policies and markets.
- Ecosystem services flow to and from agricultural systems.
- Configuration of agricultural landscapes influences ecosystem services.
- Ecosystem services affect food security in complex ways.
Proportion of Land in Agriculture

Source: www.epa.gov/emap/gif/dataI/agro.gif
Ecosystem Services and Agriculture

Supporting services:
- Soil structure and fertility
- Nutrient cycling
- Water provision
- Genetic biodiversity

Regulating services:
- Soil retention
- Pollination
- Dung burial
- Natural control of plant pests
- Food sources & habitat for beneficial insects
- Water purification
- Atmospheric regulation

Provisioning services:
- Food, fiber, and fuel production

Non-marketed services:
- Water supply
- Soil conservation
- Climate change mitigation
- Aesthetic landscapes
- Wildlife habitat

Ecosystem dis-services:
- Pest damage
- Competition for water from other ecosystems
- Competition for pollination

Ecosystem dis-services:
- Habitat loss
- Nutrient runoff
- Pesticide poisoning of non-target species

Feedback effect of dis-services from agriculture to agricultural input (e.g., removal of natural enemy habitat can encourage pest outbreaks)

(Zhang et al. 2007)
Diversity of Agricultural Systems
Threats to Ecosystem Services

• Provisioning services influenced by:
  - Loss of biodiversity (pollinators, enemies)
  - Invasive species (pests, pathogens, weeds)
  - Climate change
  - Global markets

• Other ecosystem services influenced by:
  - All of the above
  - Impacts of agricultural practices
Landscape Configuration and Ecosystem Services

• Agroecosystems sit in a landscape, a matrix of land uses

• Ecosystem services to and from agriculture are influenced by the surrounding landscape
Landscape Configuration and Pest Control in Maize

NY Corn Regions
- High corn
- Low corn

Regional scale: 20km radius
Local scale: 1 km radius
Neighborhood: field perimeter
Western corn rootworm (Diabrotica virgifera)

Regional: County

Local: 1km

Local: Perimeter

P < .001  
P < .001  
NS
Predatory Beetle
Coleomegilla maculata

Regional: County

Local: 1km

Local: Perimeter

P < 0.05  P < 0.05  P < 0.05
“Land sparing” agriculture: coarse grain, abrupt change

“Wildlife-friendly” agriculture: fine grain, spatial continuity

Tradeoff model

Synergy model

(eg Western Australia) (eg northern Europe) (eg Coto Brus, Costa Rica)

(Fischer et al. 2008)
Methods for Increasing Productivity

- **Optimization of current practices**
  - Crop improvement (breeding)
  - Integrated pest management
  - Integrated nutrient management

- **Input substitution**
  - Nitrogen fixing cover crops
  - Biological control or biopesticides

- **System redesign**
  - Planned and unplanned diversity
  - Syndromes of production
Syndromes of Production

• A set of management practices that are mutually adaptive and lead to high performance

• Practices might include:
  - crop and varietal selection
  - planting density
  - fertility source and quantity
  - management of insects, diseases and weeds
  - water management

Andow & Hidaka 1989
Impacts of Development Projects

Projects based on:
- Integrated pest management
- Integrated nutrient management
- Conservation tillage
- Agroforestry
- Water harvesting
- Livestock integration

Change in crop yield with intervention, based on 360 yield comparisons in 198 projects in 57 countries (Pretty et al. 2006)
Private sector investment in agricultural research

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<th>Commercial</th>
<th>Transition</th>
<th>Subsistence</th>
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(Source: Pingali 2001)
Tradeoffs, Synergies and Food Security

Agricultural productivity + Access to food + Utilization of food

Intensification
Sustainable options
Agricultural systems and ecosystem services: trade-offs or synergies?

• Agricultural systems are managed by farmers and influenced by local, national, and international policies and markets

• Ecosystem services flow to and from agricultural systems

• Configuration of agricultural landscapes influences ecosystem services

• Ecosystem services interact with food security in multiple ways
Diversity of Agricultural Systems

- Low diversity
- Annual crops
- Frequent disturbance
- Low nutrient retention
- High subsidies

- Moderate to high diversity
- Annuals & perennials
- Infrequent disturbance
- High nutrient retention
- Low subsidies
**Maximum Diversity**

- Tropical rain forest
- Temperate forest
- Natural grasslands
- Boreal Forests
- Spartina marshes
- Geothermal pools

**Minimum Diversity**

- Natural Ecosystems
- Agricultural Ecosystems

- Shifting cultivation in humid forests
- Home gardens
- Traditional plantations
- Polycultures
- Genetic mixtures
- Wheat varieties
- Maize hybrids

(Adapted from Francis 1981)