Increasing Smallholder Resilience through Agroforestry

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P. K. Nair
Distinguished Professor of Agroforestry
University of Florida, Gainesville, FL 32611

Resilience

… the capacity for ecological systems to persist and absorb changes.

In other words, the ecosystem's ***stability and capacity of tolerating disturbance and restoring itself***.

Disturbances caused by:

Stochastic events

fires, flooding, windstorms, insect population explosion, …

Human activities

agriculture, deforestation, fracking for oil exploration, introduction of exotic plant/animal species, that lead to pollution, natural-resource mismanagement, biodiversity decline, anthropogenic climate change, …

Resilience is important to ALL, but particularly to Smallholders

Small Farm and Family Farm

- The terms are often used synonymously
- Family Farm:
  - owned and operated by a *family.*
  - the basic unit of agri. economy of much of human history and continues to be so in developing nations.
- Small Farm or Smallholder Farm:
  - A more subjective term (than FF).
  - The focus of small farm is on *farm size,* whereas *in FF,* it is on *ownership and control* of the farm in the latter.
- An estimated 2.6 billion people produce more than 70% of the world's food on more than 500 million smallholder (family) farms

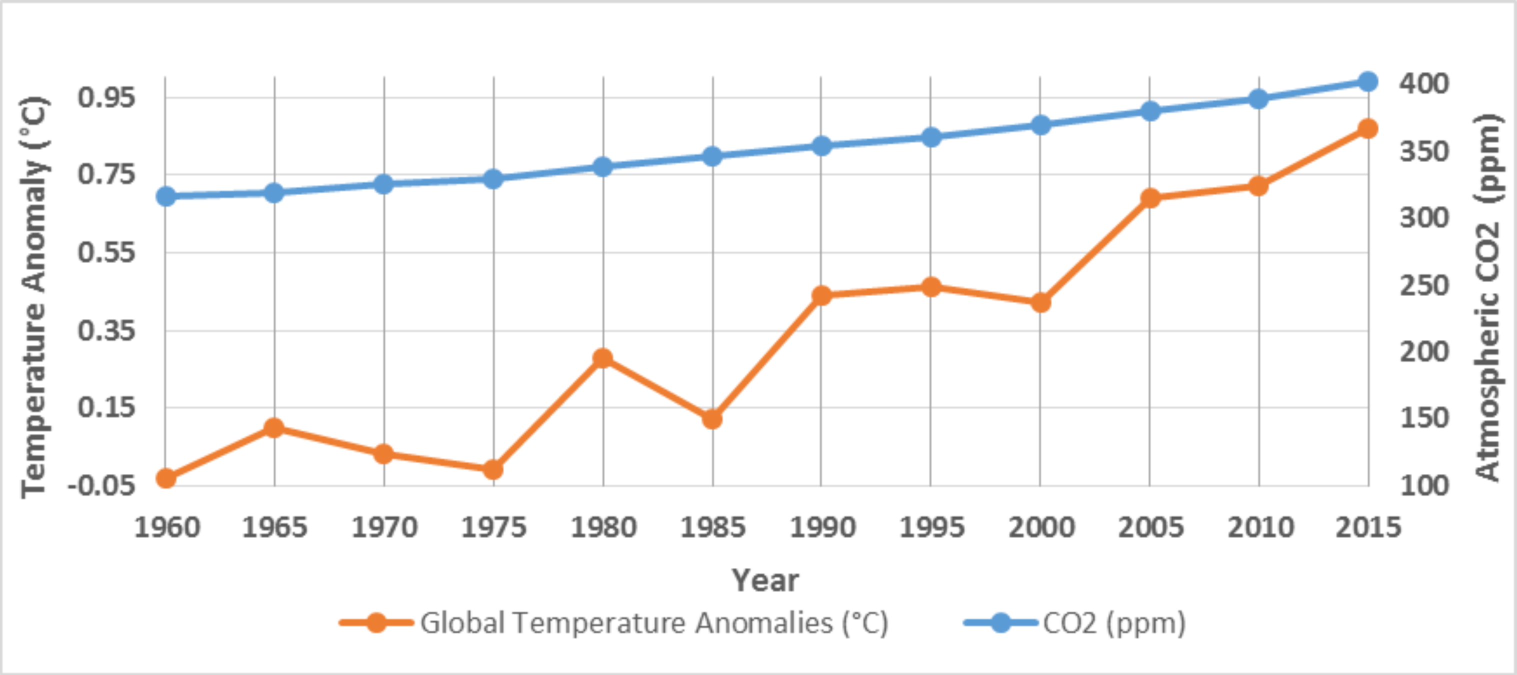
(CIRAD; FAO: 2014)

Global Distribution of Agricultural Land

	Agri. land (M ha)	# Farms (Mill)	# Small farms (Mill)	Agri. land in small holder (M ha)	% agri. land by small-holders	Av size of small farms (ha)
Africa	1,242	94.6	84.7	182.7	14.7	2.2
Asia Pac	1.990	447.6	420.3	689.7	34.7	1.6
(India)	179.8	138.3	127.6	71.1	39.6	1.8
Europe	474.5	42.0	37.2	82.3	17.4	2.2
LAC	894.3	22.3	17.9	172.6	19.3	9.7
N Am	478.4	2.4	1.85	125.1	26.1	67.6
GLOBAL	5,080	608.9	562.0	1,252	24.7	2.2

Compiled from FAOSTAT
(http://faostat3.fao.org/faostat-gateway/go/to/home/E).
Data on number and size of farms obtained from national authorities.

Global Temperature Anomalies and Atmospheric CO_2 Concentrations (1960–2015)



Temp anomaly = departure from a reference value or long-term average.
(Ref value in the graph is relative to 1951 – 1980 base period.)
Positive anomaly indicates warmer; negative indicates cooler than ref value.

Source: NASA (National Aeronautics and Space Administration) http://pubs.giss.nasa.gov/

The Ecology – Economy Conflict

Ecologists' view:

- Economy is a subset of the environment
- All economic activities, indeed life, depends on earth's ecosystem
- Recognizes limits, constraints, and cycles – nutrients, water, …
- Ecological deficits mean we take (not borrow) from future generations

Economists' view:

- Environment as a part of the economy
- Econ. theory does not explain the economy-driven destruction of earth's natural systems
- Works linearly or curvilinearly
- Economic deficits mean we borrow from each other

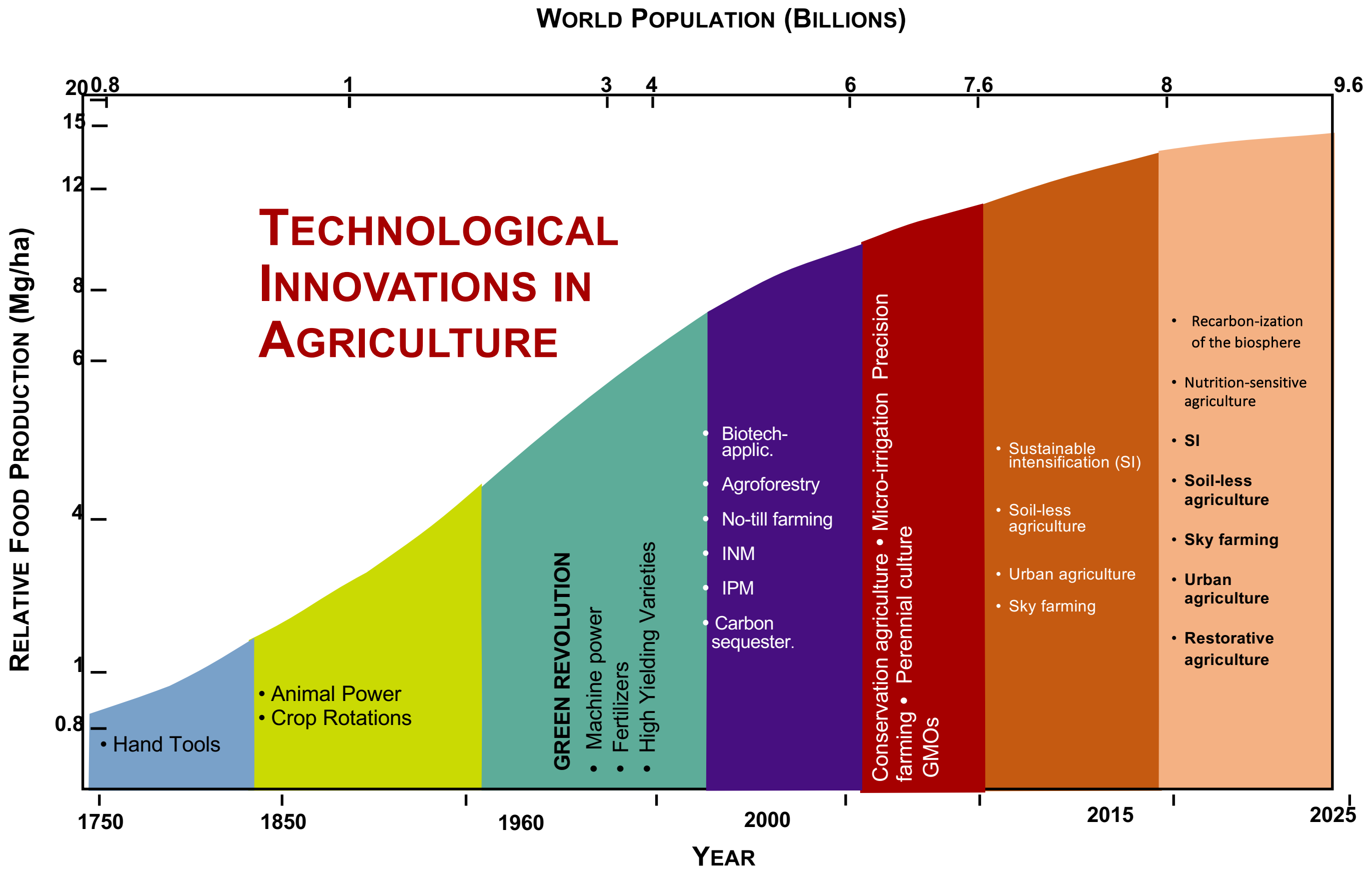
Ecological Cost of Economic Development

Food shortages caused by environmental destruction have undermined ancient civilizations:

- Sumer (Lower Valley of the Euphrates River, Near East, 5^{th} to 3^{rd} millenia BC): Crop failures caused by rising salt levels in soils due to a flaw in the irrigation system
- Maya Empire (Mexico, 2000 BC – 600 AD): forest clearing led to soil erosion and loss of soil fertility

These declines can be traced to one or two damaging environmental trends.

Today we (have to) deal with several.



World Population (Billions)
0.8
1
3
4
6
7.6
8
9.6
Relative Food Production (Mg/ha)
20
15
12
8
6
4
1
0.8
Technological Innovations in Agriculture
• Hand Tools
• Animal Power
• Crop Rotations
GREEN REVOLUTION
• Machine power
• Fertilizers
• High Yielding Varieties
• Biotech-applic.
• Agroforestry
• No-till farming
• INM
• IPM
• Carbon sequester.
Precision
Conservation agriculture • Micro-irrigation
farming • Perennial culture
GMOs
• Sustainable intensification (SI)
• Soil-less agriculture
• Urban agriculture
• Sky farming
• Recarbon-ization of the biosphere
• Nutrition-sensitive agriculture
• SI
• Soil-less agriculture
• Sky farming
• Urban agriculture
• Restorative agriculture
1750
1850
1960
2000
2015
2025
Year

Lal, 2015

Has Science Helped?

- Yes, indeed
- The Green Revolution has helped avert large scale hunger and malnutrition:
  - ✓Better seeds
  - ✓More fertilizers and other agrochemicals
  - ✓Adequate irrigation
  - ✓Improved implements and machinery
  - ✓Better infrastructure and marketing
  - ✓Enabling policies …

Yes, Science has helped. However,…

Costly side effects

- Eroding soils
- Declining soil fertility
- Advancing deserts
- Polluting the environment
- Diminishing biodiversity
- Increasing disease incidence
- Wrecking the climate
- Widening rich–poor divide

Modern industrialized farming looks good because it measures its own success narrowly – and ignores the costly side-effects.

Ecological Agriculture

- Feeding the world sustainably requires that we protect the ecological resources that are essential for producing food now and in the future
- Environmental harm caused by industrial agri. costs the world $3 trillion each year including $ 1.8 trillion in costs from livestock production (FAO 2015)
- Using sustainable farming methods is not a choice, but a necessity; we cannot continue agriculture that disregards its very basis: soils, water, biodiversity
- To feed the world while also confronting climate change, we need policies, incentives, and investments that promote ecologically sustainable, diversified farming systems focused on smallholder farmers.

Agroforestry:

Bridging the Economy–Ecology Divide in Fragile Ecosystems

- The purposeful growing of trees and crops and/or animals in interacting combinations for multiple products and services
- Represents an example of transforming traditional practices into robust, science-based technologies to provide answers to some land-management problems under resource-poor conditions
- Globally ~ 1.6 billion ha of land under various AF systems

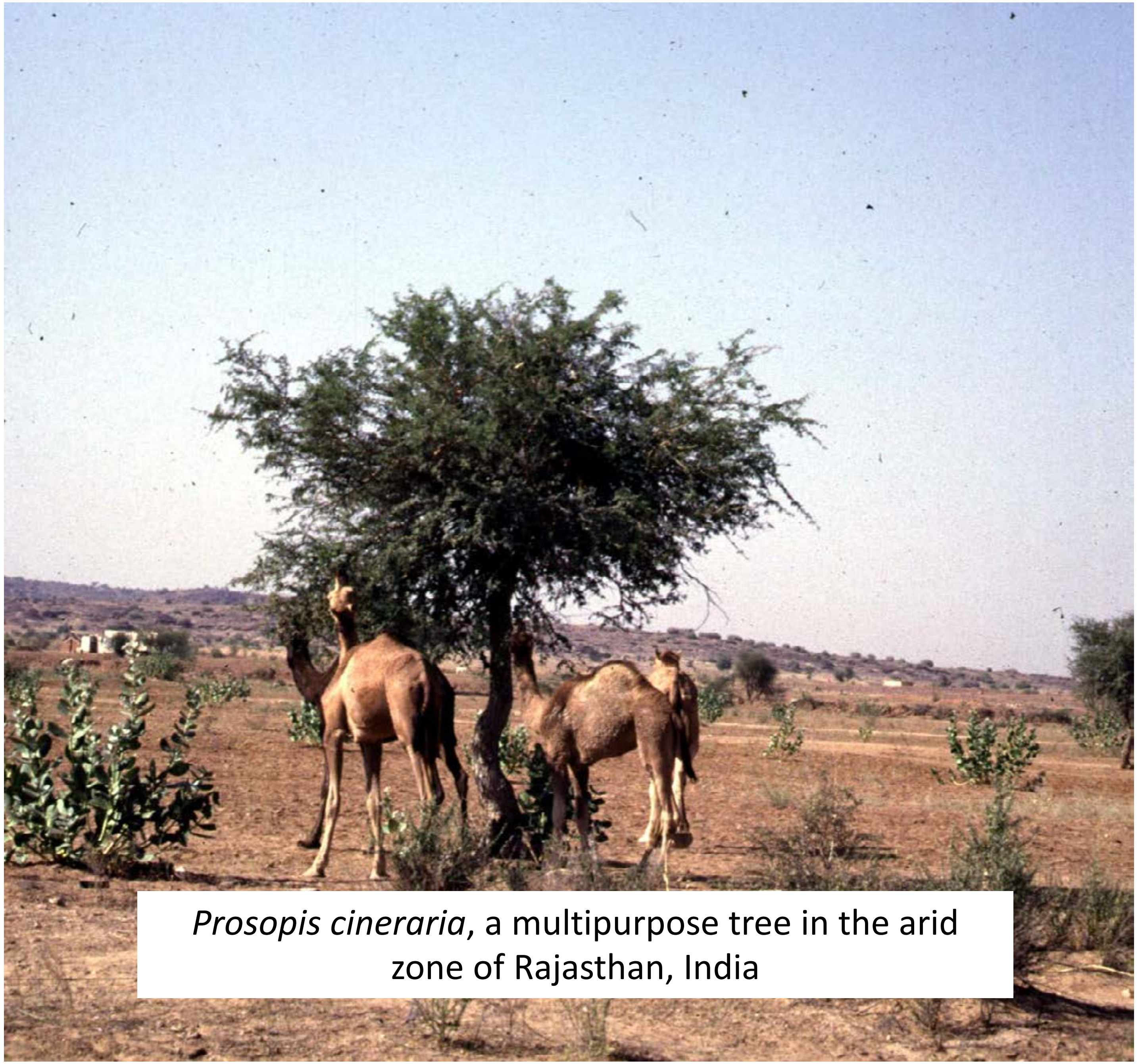


Modern Agroforestry emerged in the tropics in the 1970s and 1980s as an approach to addressing the pressing land-management problems such as deforestation, land degradation, and food- , fodder-, and fuelwood shortages.

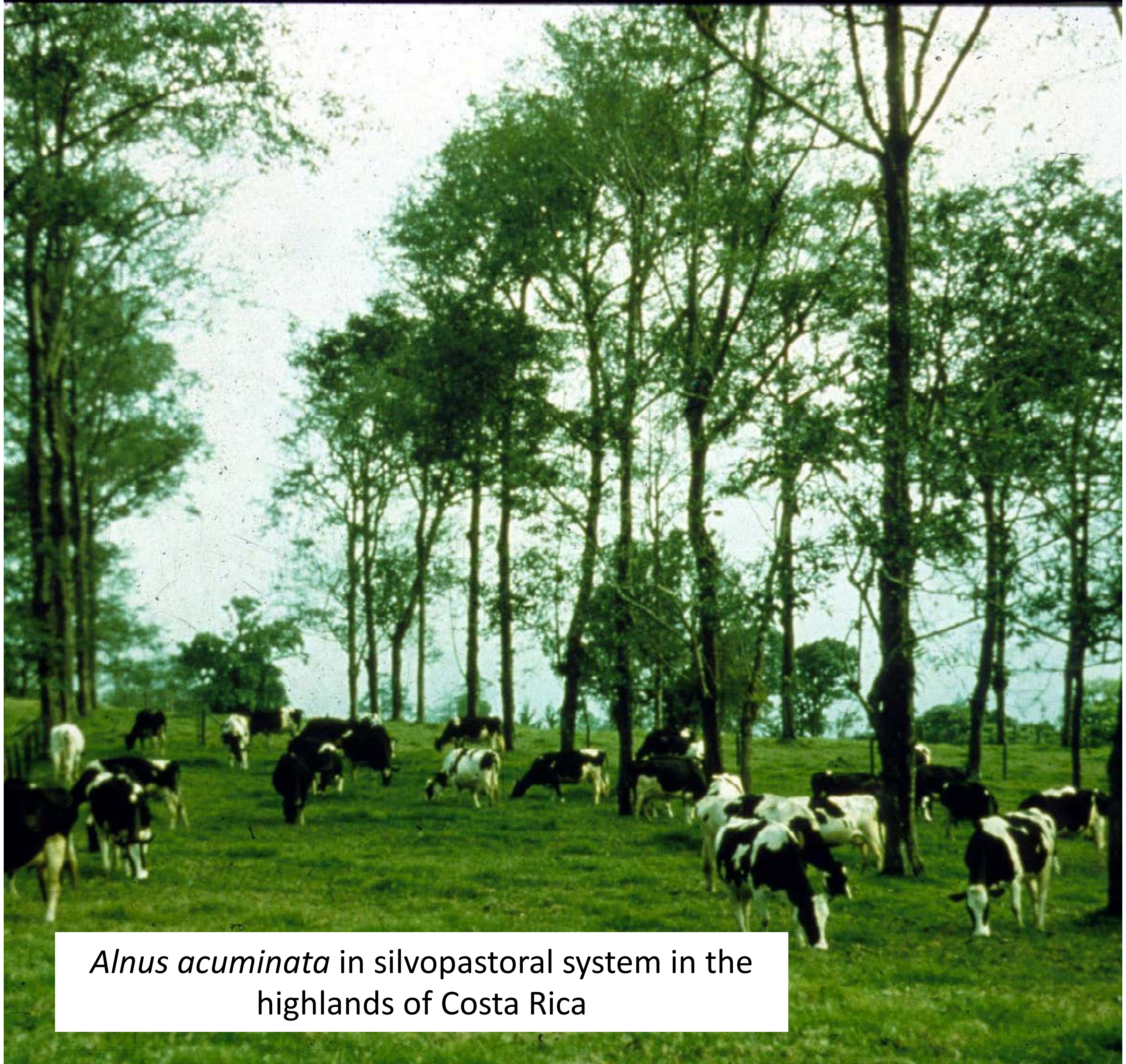



Integrated land-use system, Kerala, India

Homegarden, Jamaica

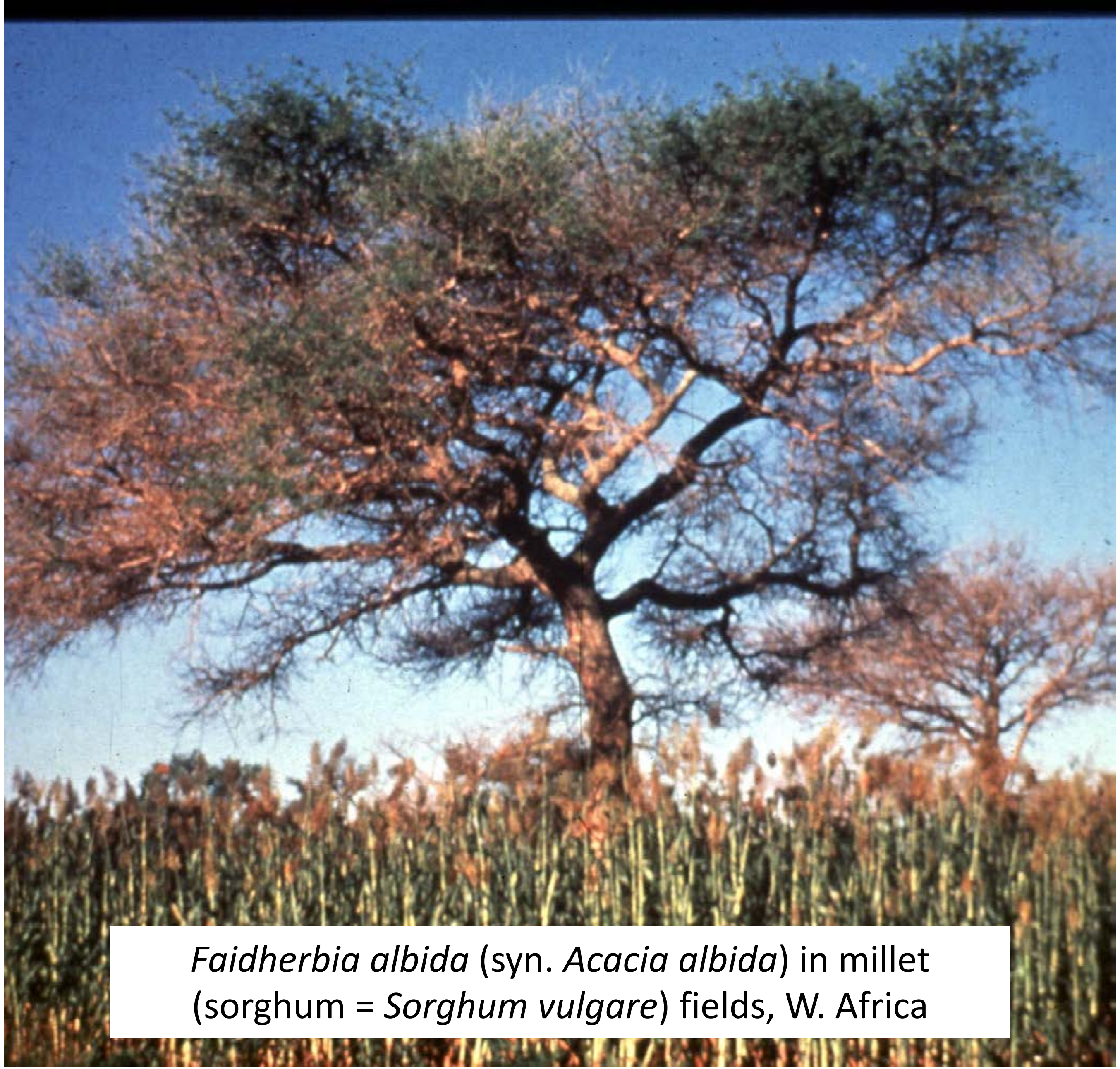


Prosopis cineraria, a multipurpose tree in the arid zone of Rajasthan, India



Alnus acuminata in silvopastoral system in the highlands of Costa Rica

Beef cattle in the silvopastoral system of eucalyptus and *Brachiaria brizantha*



Faidherbia albida (syn. *Acacia albida*) in millet (sorghum = *Sorghum vulgare*) fields, W. Africa

Faidherbia albida (syn. *Acacia albida*) in crop fields; rainy season, Mali, W. Africa

The Shea Tree in the Parkland System of Sub-Saharan Africa

Photo: P. Lovett

Five million hectares of millet production in Faidherbia parklands in Niger: A transformed agricultural landscape

Maize farming in a *Faidherbia* agroforest in Southern Highlands, Tanzania (ICRAF, 2008)

Acacia nilotica trees in rice fields, with sesame (*Sesamum indicum*); Central India

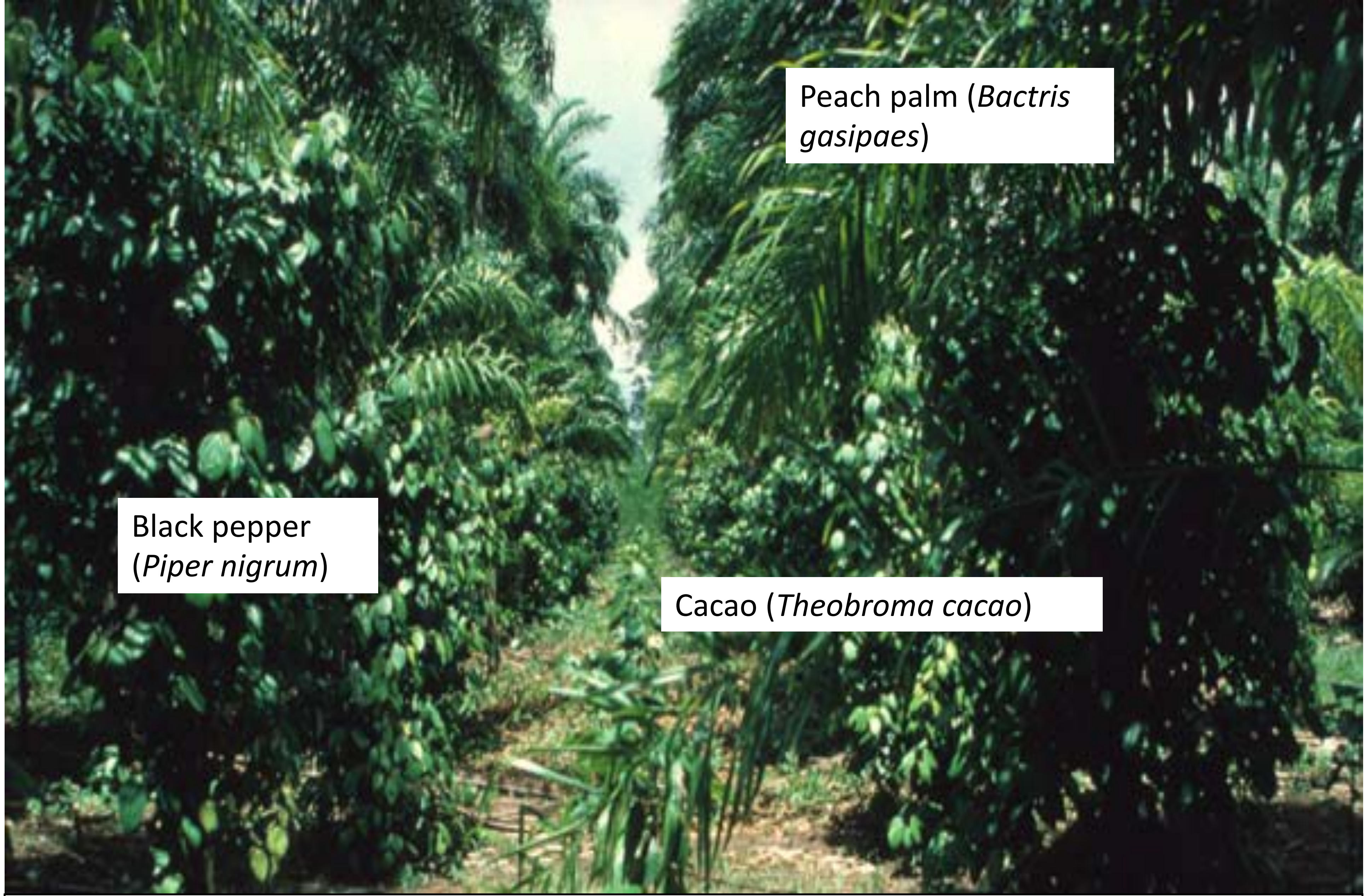
Coffee *(Coffea* spp.) with *Cordia alliodora*; Costa Rica e

Tea+ *Grevillea robusta* (silver oak) in Munnar, Kerala, India (photo: BM Kumar)

Caca

Cacao
(Theobroma cacao)

Black pepper (*Piper nigrum*) + rubber tree (*Hevea brasiliensis*); Manaus, Brazil



A multistrata system of peach palm (*Bactris gasipaes*), black pepper (*Piper nigrum*) and cacao (*Theobroma cacao*) in Bahia, Brazil


Coconut palm
(*Cocos nucifera*)
Areca (betel) palm
(Areca catechu)
Moringa
(*Moringa oleifera)*
Papaya
Carica papaya)
Banana
(*Musa* sp.)
Black pepper
(Piper nigrum)

AFS developed by farmers of Japanese descent in Tomé-Açu, Pará, Brazil: paricá (*Schizolobium amazonicum*), açaí (*Euterpe oleracea*) and cupuaçu (*Theobroma grandiflorum*). (Porro et al. 2012).

Ecosystem Services of Agroforestry

Soil Productivity

Water-Quality Enhancement and degraded-land reclamation

Biodiversity Conservation

Climate Change Miti & Adapt:

C Sequestration

– Local

– Landscape

– Regional

– Regional → Global

The Scientific Foundation of Mixed Species Systems

The ‘‘niche-complementarity hypothesis’’

(Harper, 1977):

A larger array of species in a system leads to a broader spectrum of resource utilization and more efficient use and sharing of resources, making the system more productive

Ecosystem Services of Multi-species Systems

- Provisioning
  - Production of fruits, nuts, vegies, spices, medicinal etc.
- Regulatory
  - Better soil-coverage by foliage of multiple species

  → reduced soil temp. and higher water-holding capacity
  → higher soil organic matter, reduced soil erosion
- Supporting
  - biodiversity conservation, pest/disease management
- Social
  - cultural heritage values, recreation and ecotourism

UN-MEA (2005)

Global distribution and area under different agroforestry system sub-groups

AFS sub-group	Major AF Practices	Distribution (major agro-ecol./ geographical regions) ¶		Approx. area (million ha) ¶	
		Tropical	Temperate	Tropical	Temperate
Multistrata systems	Homegardens	Humid: wet, moist, and montane (rainfall >1000 mm yr^{-1})		100	
	Shaded perennials		Forest farming		
Tree intercropping	Alley cropping	Rainfall > 800 mm yr^{-1}		50	50
	Trees on farmlands	Throughout tropics		550	50
Silvopasture	Cut-and –carry and browsing	Wet and moist; rainfall >1000 mm yr^{-1}		300	150
	Grazing under trees	Semiarid to arid	N. America, Europe, subtropical highlands		
Protective systems	Windbreaks, shelterbelts	Semiarid and arid lands; coastal areas	N. America, Europe, China	200	100
	Soil conserv. hedges	Sloping lands in higher rainfall areas	N. America (Riparian buffer strips)		
	Boundary planting	Throughout	Windbreaks		
AF Tree woodlots	Firewood and fodder	Drylands		50	
	Land reclamation	Degraded lands (eroded, salt-affected)			
TOTAL				1,250	350

Estimates based on the reported values in literature ¶ Including potential areas for adoption

Source: Nair (2012).

Cinderella Agroforestry Systems

- “An AF system that has been practiced for a long time but rarely reported in literature”
- Examples can be found all over the world
- An epitome of ecological sustainability and social acceptability
- Not been scientifically studied and therefore the values are seldom quantified and recognized
- Criticized and denigrated in official and technical discussions for lack of the “Green-Revolution type” management prescriptions of “modern” systems

Some Examples of Cinderella AF Systems

System		Reference
Khejri system	Rajasthan, India: arid	Shankarnarayn et al. 1987
Chattisgarh system	Chattisgarh, India; semiarid	Viswanath et al. 2000
Pacific Island AF systems	Pacific Islands; Humid coastal	Elevitch 2011
Global heritage AF syst - Africa	Semiarid African highlands	Kitalyi et al. 2013
Parkland system	West African drylands	Boffa et al. 1999
Quezungal system	Humid lowlands, C. America	Hellin et al. 1999
Ribeirno system	Humid Peruvian Amazon	Paddoch & de Jong 1987
Amazonian systems	Humid Brazilian lowlands	Johnson & Nair 1986
Streubobst	Fruit trees: Central Europe	Herzog 1998
Wood-pasture system	Pan-European	Bergmeier et al. 2010

A SWOT Analysis

Strengths, Weaknesses, Opportunities, and Threats

- Forty Cinderella AF Systems from different parts of the world (examples in the next slide)
- A qualitative assessment of their Strengths, Weaknesses, Opportunities, and Threats
- Analysis based on the limited reports available in literature and numerous personal communications.

Cinderella Agroforestry Systems: SWOT

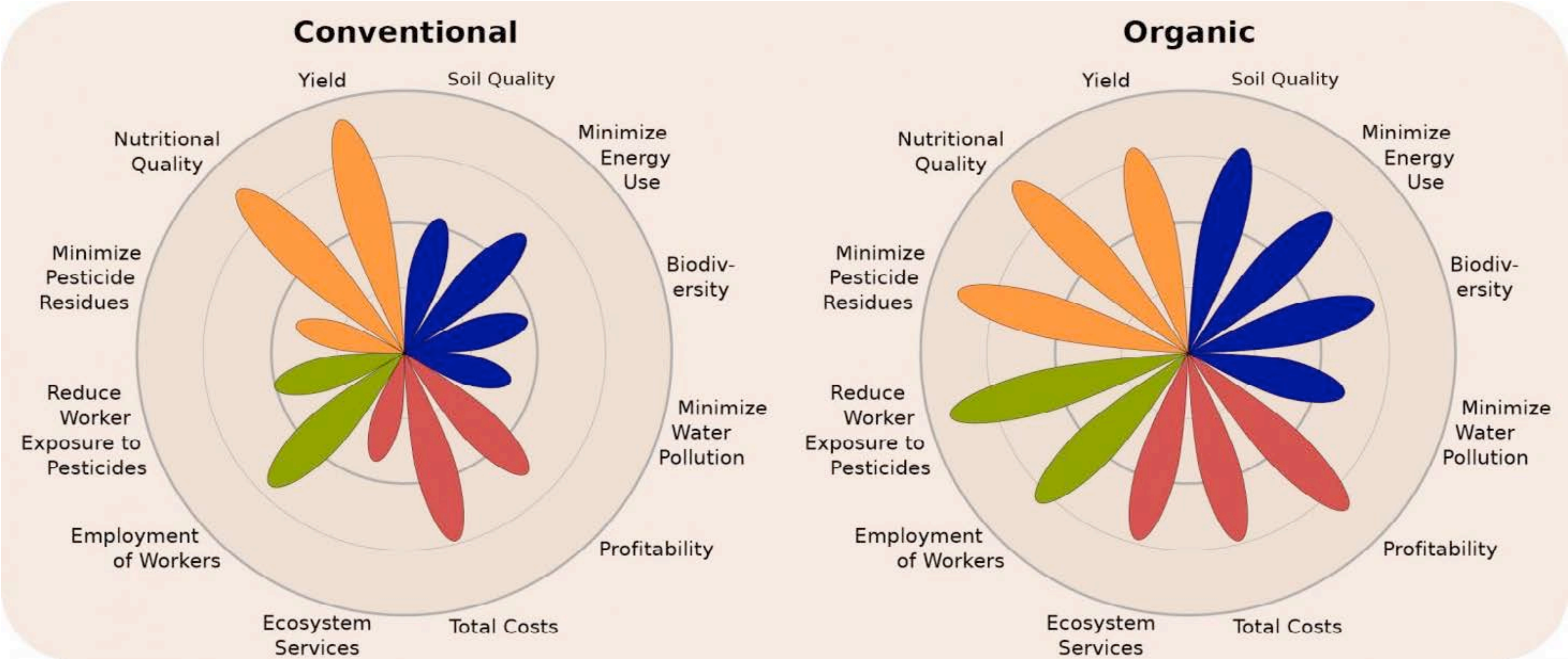
	POSITIVE	NEGATIVE
INTERNAL ⇒	**Strengths**	**Weaknesses**
	❖ Food- and nutritional security	❖ Long-term investment
	❖ Monetary: higher and diversified farm incomes	❖ Relatively unimproved farming practices
	❖ Risk reduction; Satisfaction	❖ Difficulty in commercialization
	❖ Multifunctionality	❖ Lack of research and technical skills
	❖ Niche complementarity in maximum utilization of natural resources	❖ Lack of institutional recognition and policy support
	❖ Ecological diversity	❖ Difficulty in extrapolation
	❖ Ecosystem stability/sustainability	
	❖ Landscape aesthetics	
EXTERNAL ⇒	**Opportunities**	**Threats**
	❖ Potential government support	❖ Potential future tax on "subsidiary income"
	❖ Increase in land value	❖ Uncertainty about future government regulations
	❖ Environmental and recreational benefits	❖ Excessive lopping and exploitation of preferred species
	❖ Climate-smart agriculture and climate-change mitigation	❖ Changes in Wood import policies
	❖ Enhancement of socio-cultural values and land ethics	❖ Policy and governance issues related to input subsidies

Nair et al. (2016)

Cinderella Systems: Strengths and Opportunities

- Sustainability
- Multi-functionality
- Niche Complementarity and Resource-Use Efficiency
- Ecosystem Services
  - Climate Change Mitigation (Carbon sequestration)
  - Biodiversity Conservation
- Sociocultural Recreational Values
- Traditional Ecological Knowledge

Conventional ("Chemical") vs. Organic Agriculture



Credit: Reganold and Wachter (2016). Organic agriculture in the twenty-first century. In: Cook et al. (2016) Source: Nature Plants.

The impact of hurricaneMitch in CentralAmerica, 2005.

Honduran farms under monoculture had higher levels of damage in the form of mudslides (*top photo*)

than neighboring biodiverse farms featuring agroforestry systems, contour farming, and cover crops.

(*bottom photo*)
Source:
Altieri et al. (2015)

“Take-Home” Message

- Traditional agricultural systems of mixed-species stands, although ignored and even ridiculed in agricultural development paradigms, are still practised by large numbers of smallholder farmers around the world.
- Single-species systems are “ecological deserts” – a legacy of the sole-crop agri systems; that should not be applied to tree-crop-based systems.
- The best strategy for climate-change resilience seems to be one of promoting multi-species combinations.
- A holistic approach is needed: the emphasis on planning solely for one species or commodity has to give way to one that considers a crop as just one, maybe central, component – not the only one – of an ecosystem.