Recent Advances and Gaps in Agroforestry in the Temperate Zone

A Look at the Past Decade of Research (2000-2010)

Brandenburg
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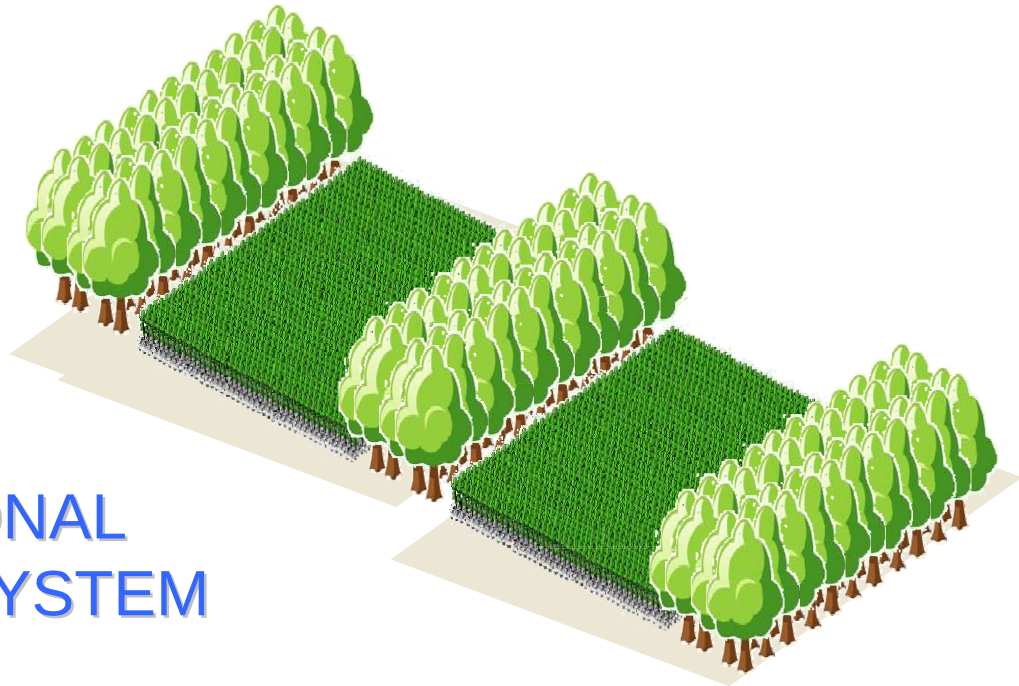
Outline

- Agroforestry systems – a multifunctional land use option
- Research projects related to land use and agroforestry
- The Way to Ecosystem Services via Ecosystem Functions

Agroforestry is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock.

It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems.



= MULTIFUNCTIONAL
LAND USE SYSTEM

5 Types of Agroforestry Practices

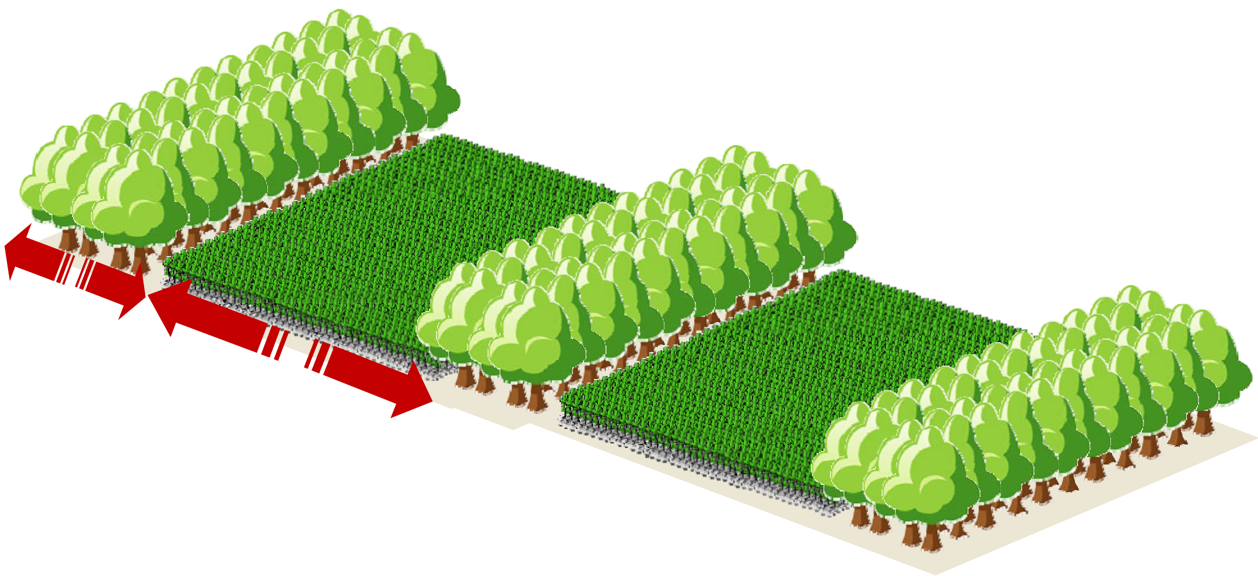
- Alley Cropping/Intercropping
  - rows of trees among rows of crops
- Forest Farming
  - shade-tolerant crops planted in forests
- Riparian Forest Buffer
  - forest along perimeter of streams and lakes
- Silvopasture
  - pasture in the forest
- Windbreak
  - forest around perimeter of agricultural field

(USDA National Agroforestry Center)

Main Focus of Recent Research

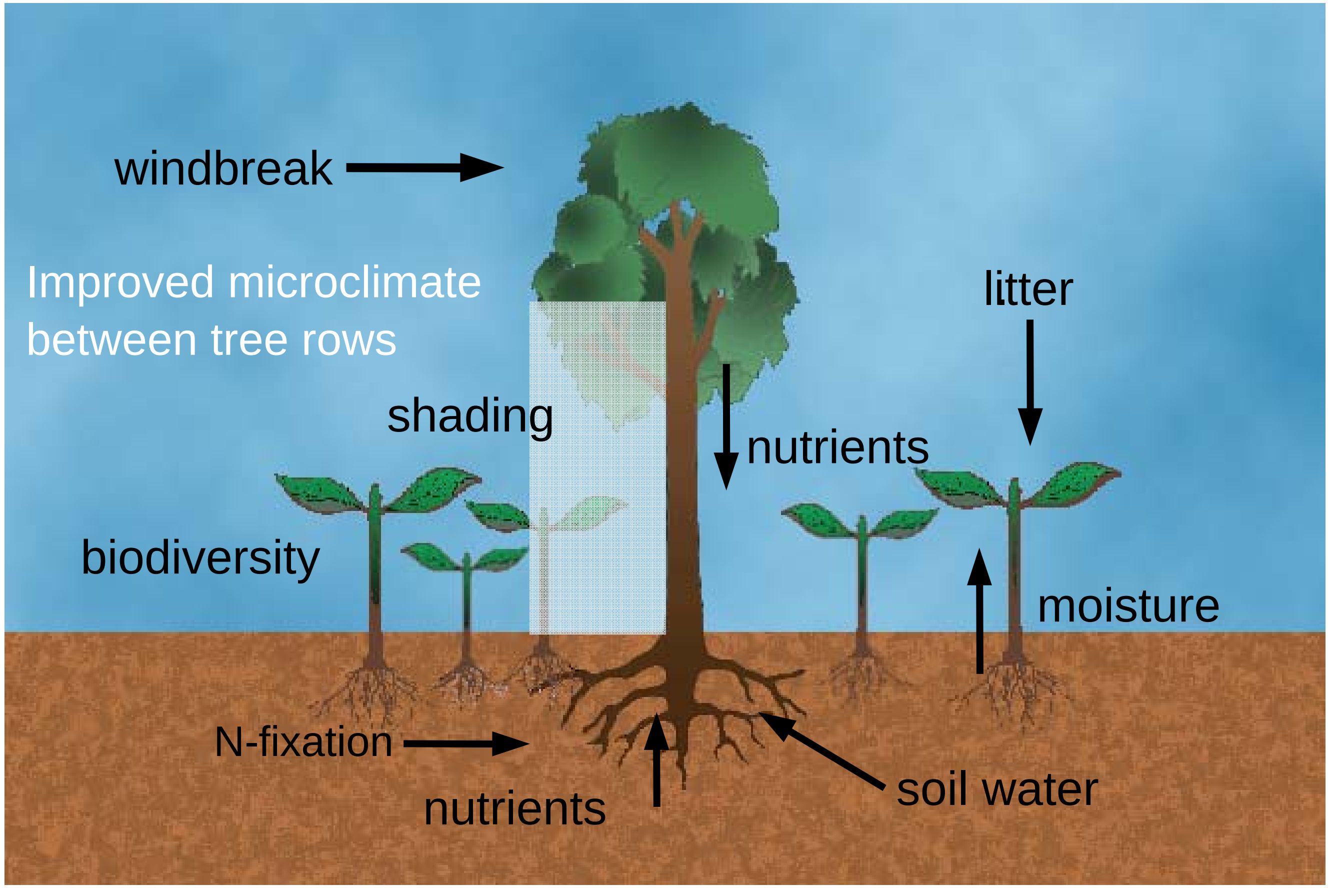
Alley Cropping

→ Alley Cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs (hedgerows) in wide spacings, creating alleys within which agricultural, horticultural or forage crops are cultivated.



Interactions between tree and non-tree components

General aspects



Benefits of Agroforestry systems

- On-site benefits:
  - **Promote soil fertility**
  - Provide shade
  - Provide fodder
  - Provide additional products (timber, fruit, etc)
- Biodiversity benefits:
  - Host larger number and wider variety of species
  - Help connect remaining natural habitats
- Carbon benefits:
  - Sequester more carbon in soil and biomass
- Water benefits:
  - Higher water availability (microclimate)
  - Improved water filtration

Approach to Sustainable Land Use

Ignored by land users

Thematic Strategy for Soil Protection (EC 2006)

= declares that for sustainable development, soils (soil functions) need to be protected from degradation.

- The main threats to soil functioning abilities are identified as
- (1) decline in organic matter
- (2) soil erosion
- (3) compaction
- (4) salinisation
- (5) landslides
- (6) floods
- (7) contamination
- (8) sealing

Threats 1-5 are area and soil specific in their appearance

Research projects related to Agroforestry, Biomass and Ecosystem

- Initial Ecosystem Development (SFB-Transregio 38), German Research Foundation
- Innovative Network of Climate Adaptation in the Region Brandenburg Berlin (INKA BB) (BMBF)
- Economic and Ecological Assessment of Agroforestry Systems in Agricultural Practice (FNR)
- BAtroS: Soil Melioration and Land Use Systems for dry sites (BMBF)
- Biomass production and Phytoremediation (German Railway, DB)
- ANFOREK, Energy landscape and agriculture, Vattenfall Mining&Generation AG
- ELKE (FNR)

- Agronetwork Biomass
- Dendrom „Future Resource Dendromass"(BMBF)
- Sensor - Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions: Module 6: Sustainability issues in sensitive regions, EU
- Optimum Humus Content of Soils in Germany (UBA)
- Agrowood

Literature Review
2000-2010

Articles chosen from search engine search of „Agroforestry“ based upon criteria of *ecological* relevance to agroforestry

Article Theme	Frequency (out of 42 articles)
Carbon Storage	7
Soil Fertility	6
Competition	6
Nutrient Accumulation	3
Light Issues	3
Water Quality	3

Current Ambitions in Agroforestry

- Carbon storage/sequestration to fulfill the Kyoto Protocol
  - Data needed for carbon accounting and modeling tools (Montagnini and Nair, 2004)
- Improve the nutrient cycle to support long-term soil fertility (Bambo et al., 2009)
- Create tree biomass for economic purposes (Fang et al., 2010)

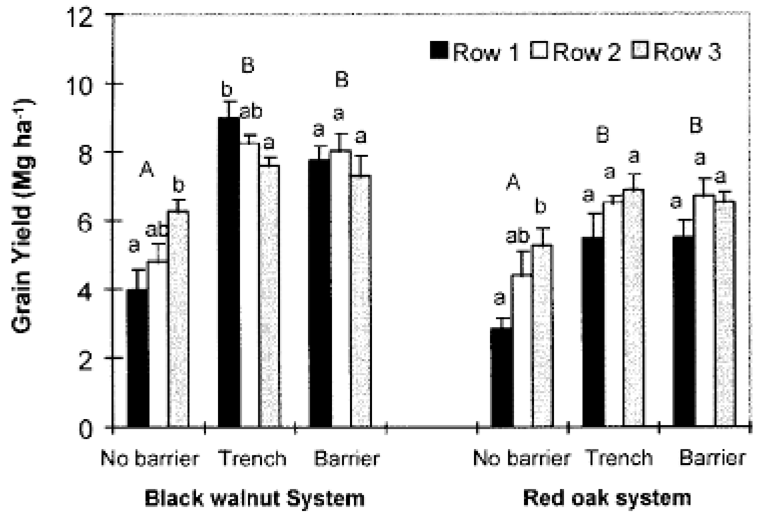
Estimated C sequestration potential through agroforestry practices in the USA by 2025

Agroforestry Practice	Current or potential agroforestry area (ha)	Potential C sequestration Tg C yr-1 (sum of above and belowground storage)
Alleycropping	80 x 10E6	73.8
Silvopasture	70 x 10E6	9.0
Windbreaks	85 x 10E6	4.0
Riparian Buffer	0.8 x 10E6 km of 30-m-wide forested riparian buffers	1.5
Short rotation woody crops, forest farming, etc.	2.4 x 10E6 km conservation buffer	2.0
Total		90.3

Source: Montagnini and Nair, 2004

Main Research Themes which have shown Advances

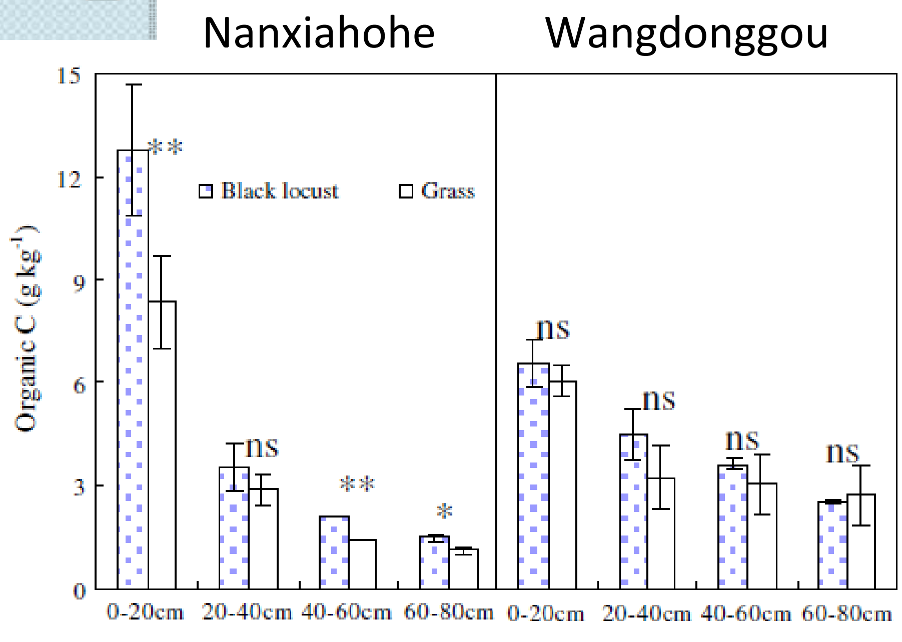
- Carbon storage/sequestration
  - Optimizing carbon storage/sequestration potentials for various intercrop combinations and environmental pre-conditions (Montagnini and Nair, 2004)
- Soil fertility
  - Nutrient cycling through tree roots and litterfall to minimize nutrient loss (Nair and Graetz, 2004)
- Interspecies competition
  - Above-ground → light (i.e. shading) (Gillespie et al., 2000)
  - Below-ground → nutrients and water (Jose et al., 2000)
- Water Quality
  - Effective agroforestry buffer locations (Tomer et al., 2009)

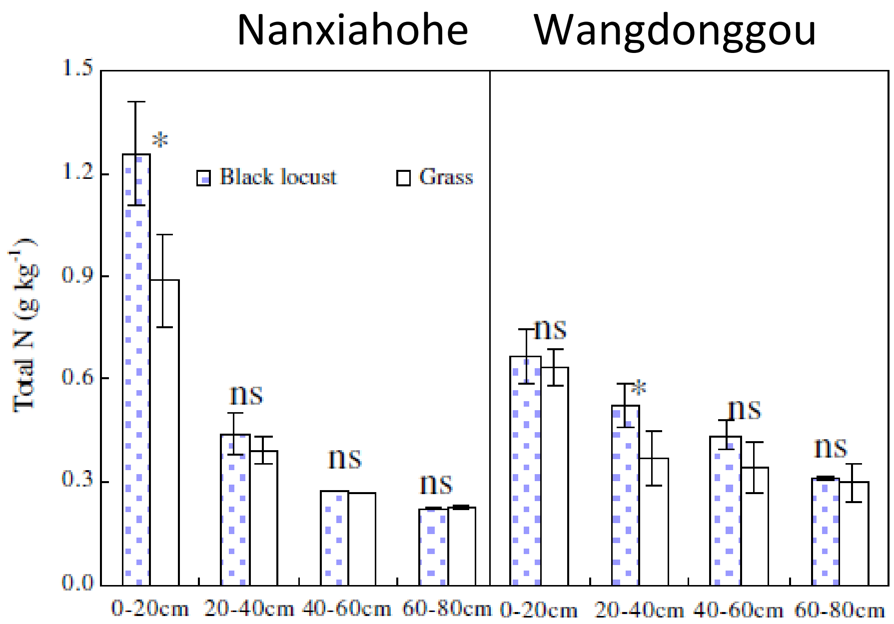


Grain yield by row (row 1 is closest to the tree row and row 3 is farthest) in Indiana, USA alley cropping. Trenches and barriers employed to reduce below-ground competition between grains and trees. (Gillespie et al., 2000)

Effects of Black Locust on Soil Properties

Loess Plateau, China





(Qiu et al., 2010)

- Nanxiahohe planted in 1955; Wangdongou planted in 1985
- Organic Carbon and Total Nitrogen benefits increase with age of trees

CO_2 sequestration on a hypothetical farm in Saunders County, Nebraska

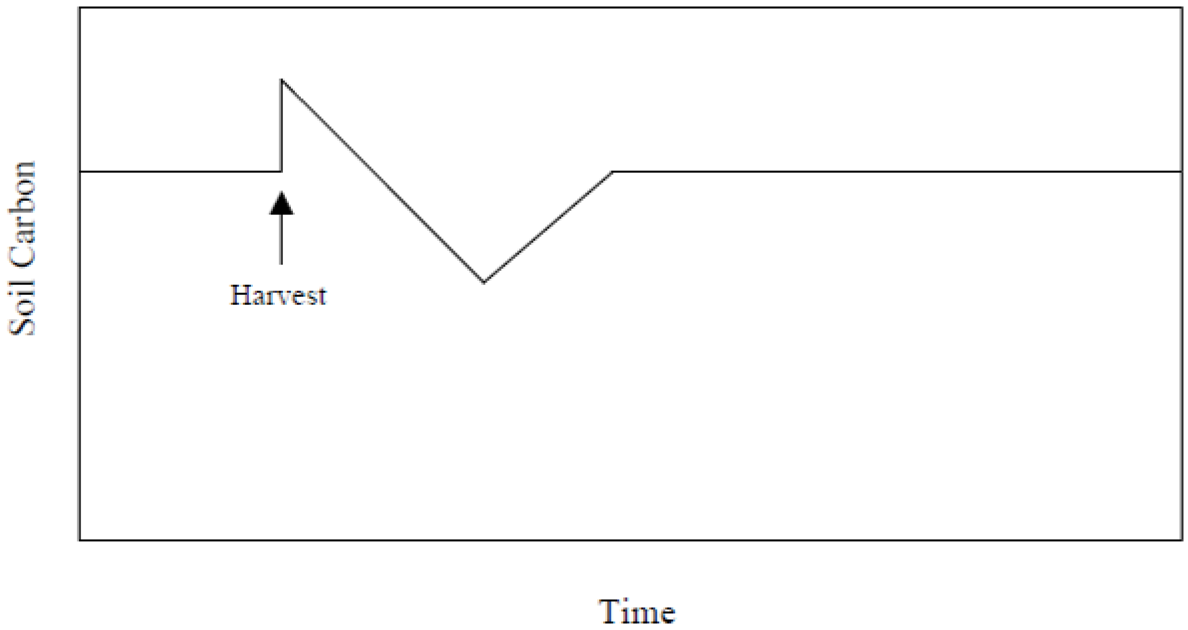
Crop: Corn/soy bean rotation

Practice	**% Total Land Coverage (256 ha farm)**	**Total Metric Tons CO_2 (after 50 years)**
Option A: no-till		
Cropland in no-till	100	
Option A Total		9,203
Option B: no-till and crop windbreaks		
Cropland in no-till	~95	
Cropland in windbreaks	~5	
Option B Total		16,128

(Schoeneberger, 2008)

~ 75% increase in CO_2 sequestration with windbreaks

Soil carbon content following harvest of trees



- Death of roots after coppicing causes spike in soil carbon
  (Samson et al., 1999, p. 15)

Mean SOC and Total N in Poplar and Norway Spruce TBI Systems vs. Conventional

Guelph, Ontario, Canada

- 21-year old Tree-based Intercropping (TBI) system and nearby conventionally managed agroecosystem (Sampling 0-20 cm depth)

Treatment	Mean SOC (Mg C ha^{-1})	Mean Total N (Mg N ha^{-1})
Hybrid Poplar	57.0	5.08
Norway Spruce	50.9	4.95
Conventional	50.8	4.51

(Bambrick et al., 2010)

- Hybrid Poplar greater mean SOC than Norway Spruce and Conventional management – difference of 6.2 Mg C ha^{-1} to hybrid

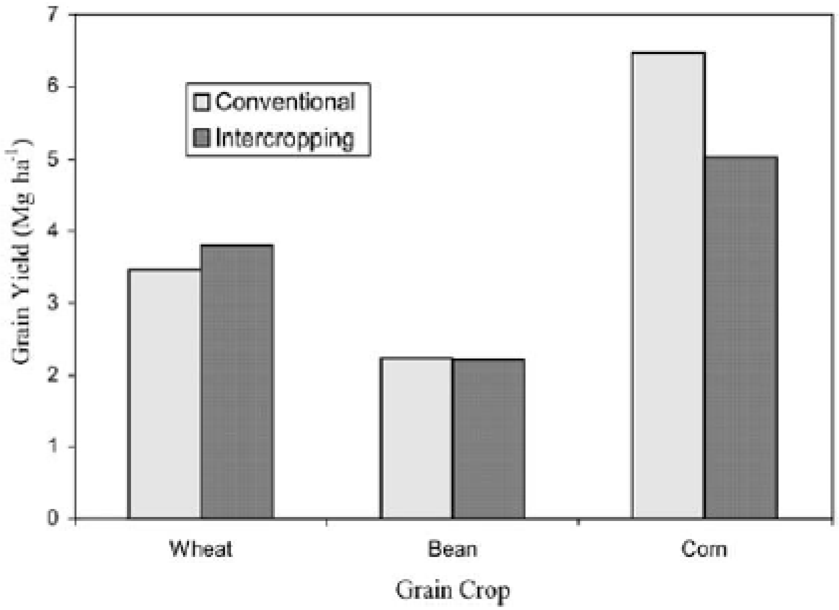
Nitrogen fixation potential of selected tree and crop species suitable for temperate agroforestry systems

Species	Typical levels of N_2-fixation (kg ha^{-1} yr^{-1})	Source
Leguminous		
Trees/shrubs		
Black locust (*Robinia pseudoacacia*)	30–35	Boring and Swank (1984)
Leucaena (*Leucaena leucocephala*)	100–500	Sanginga et al. (1995)
Mesquite (*Prosopis glandulosa*)	20–50	Sharifi et al. (1982)
Silk tree (*Albizia julibrissin*)	60–70[a]	Rhoades et al. (1997)
Herbaceous species		
Alfalfa (*Medicago sativa*)	148	Butler and Evers (2003[b])
Clover (*Trifolium* spp.)	42–400	Butler and Evers (2003)
Hairy vetch (*Vicia villosa*)	90–100	Butler and Evers (2003)
Soybeans (*Glycine max*)	60	Troeh and Thompson (1993)
Non-leguminous trees and shrubs Alder (*Alnus* spp.)	48–185	Daniere et al. (1986)
Autumn olive (*Elaeagnus umbellata*)	236	Paschke et al. (1989)
Snowbrush (*Ceanothus velutinus*)	24–101	McNabb and Cromack (1985)

(Jose et al., 2004)

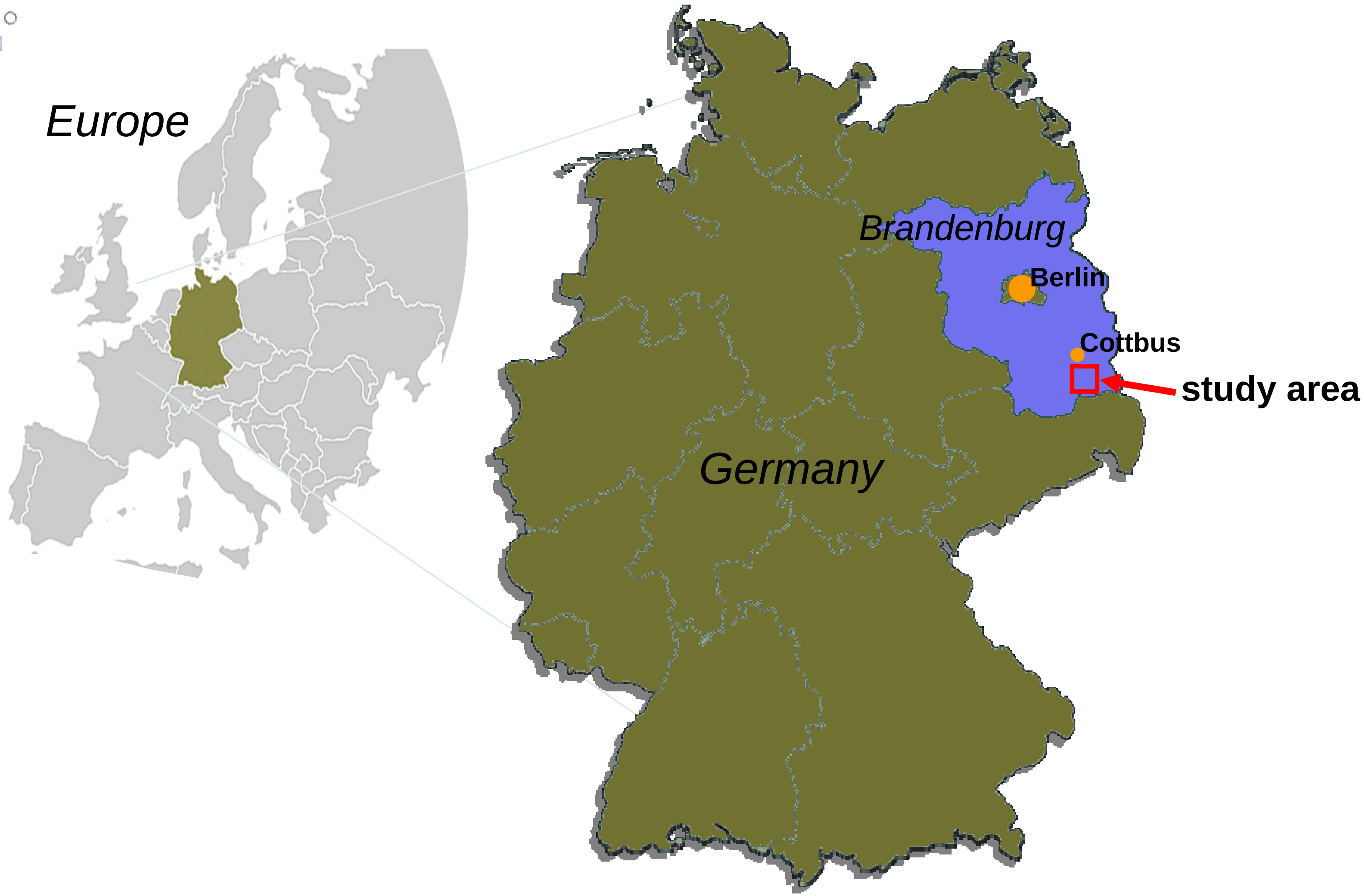
Gaps in Research

- Quantifying individual carbon storage/sequestering abilities
  - For different tree species, tree densities, cutting cycles, crop combinations, and soils (Peichl et al., 2006)
- Identifying which plants and trees can be intercropped together with beneficial biomass outcomes (Thavathasan and Gordon, 2004)
- Impacts of agroforestry on nutrient cycling in individual soil types (Nair and Graetz, 2004)



Overall yields of intercropped grain crops compared with conventional cropping at Guelph, Ontario, Canada. (Thavathasan and Gordon, 2004)

Location of study site in Brandenburg state (Germany)

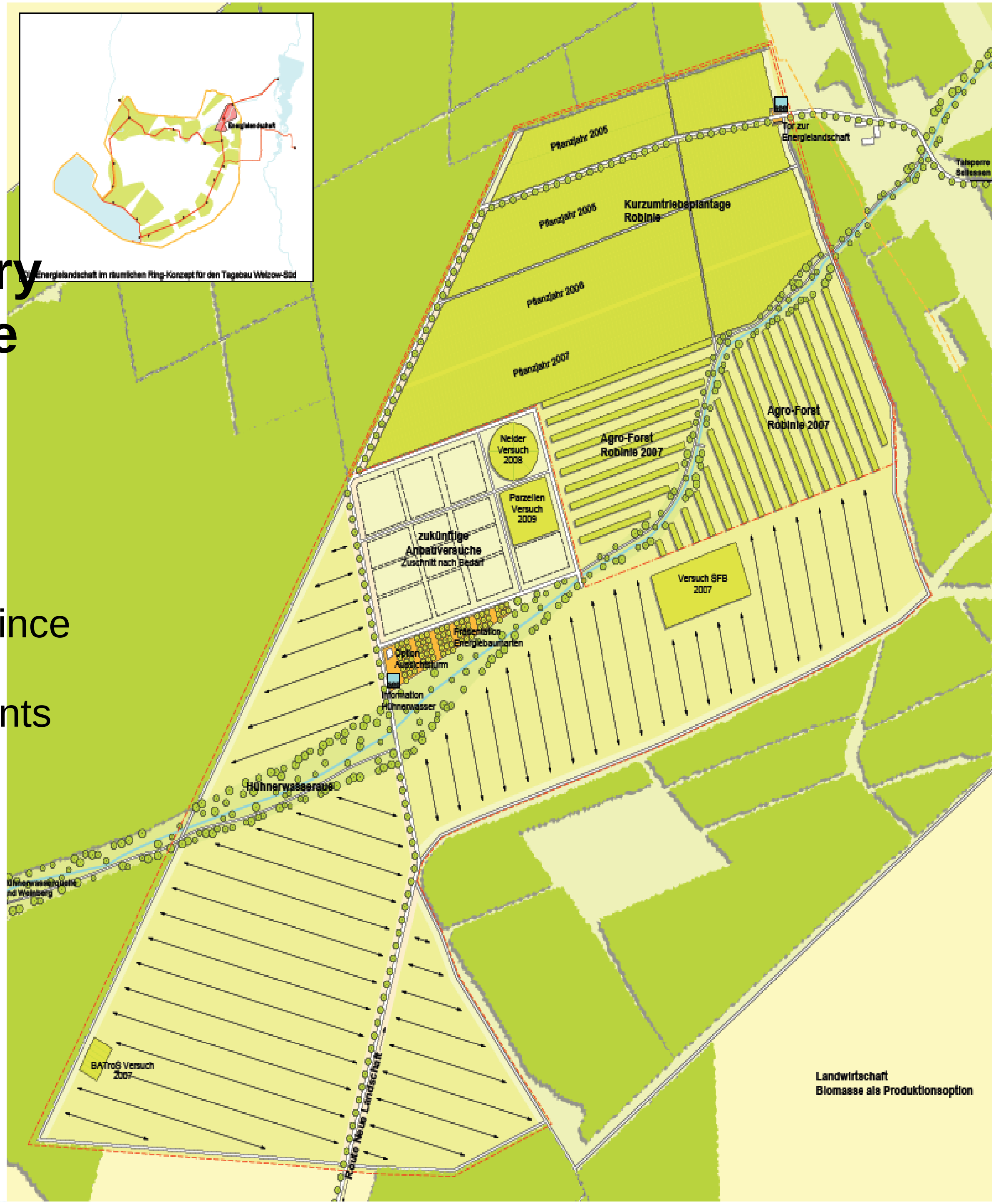


Böhm et al., 2009


Drebkau
Talsperre
Findlingslager
Renaturierung
Endmoräne
Initialraum
Energielandschaft Welzow
Petershainer Fließ
Neupetershain
Weinberg
Hühnerwasser
Stradower
Höhe
Sellessen/
Neu-Haidemühl
Biomasse
Heizkraftwerk
Stadtrand
Welzow
Aussicht
MotoCross-Gelände
Welzow
Stradower
Aussicht
Spremberg
Spree
Welzow-See

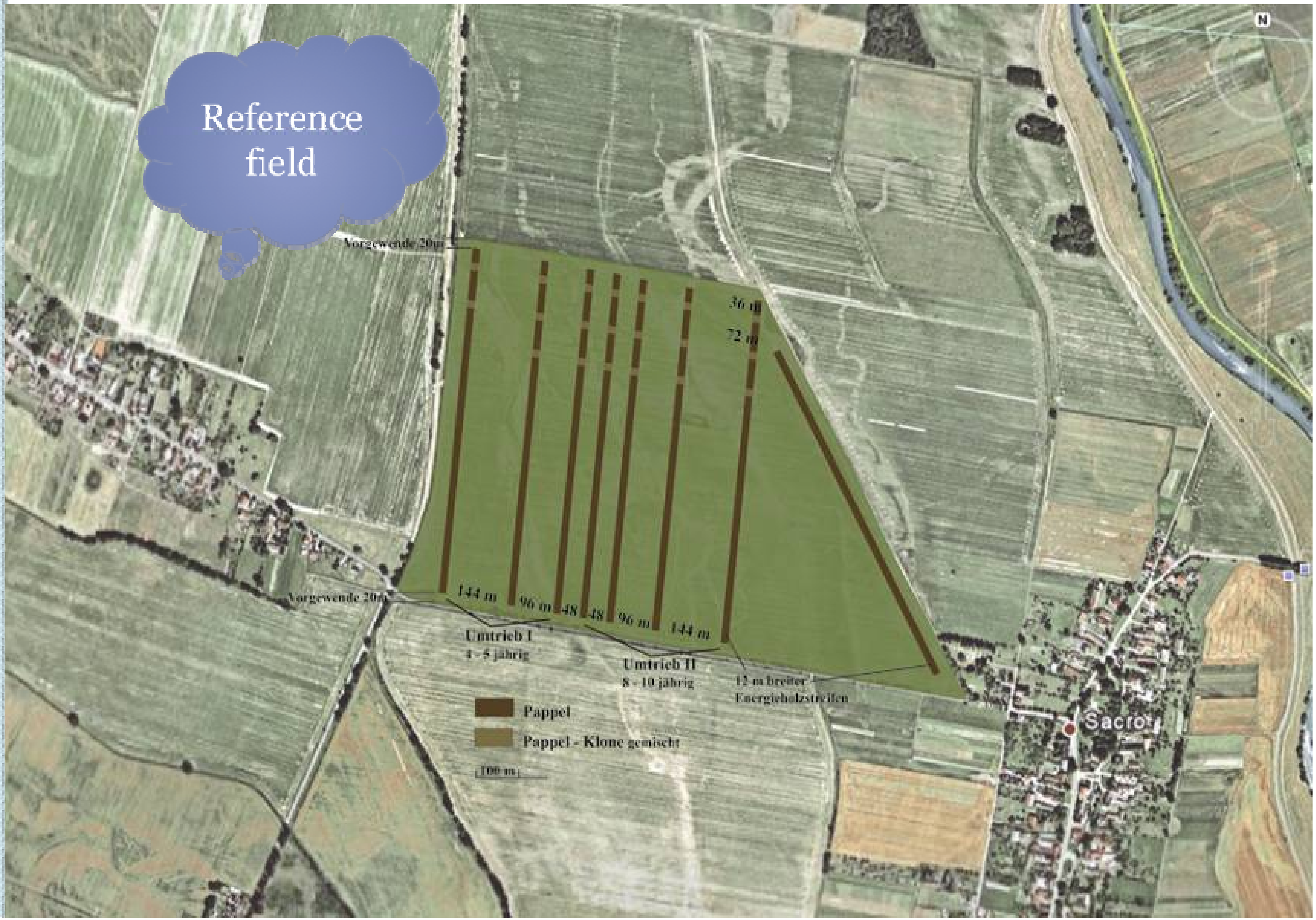
„Real“ Laboratory in the Landscape (Welzow-South)

- area: 170 ha
- establishment: since 2005
- Actual 7 experiments



Alley Cropping Design

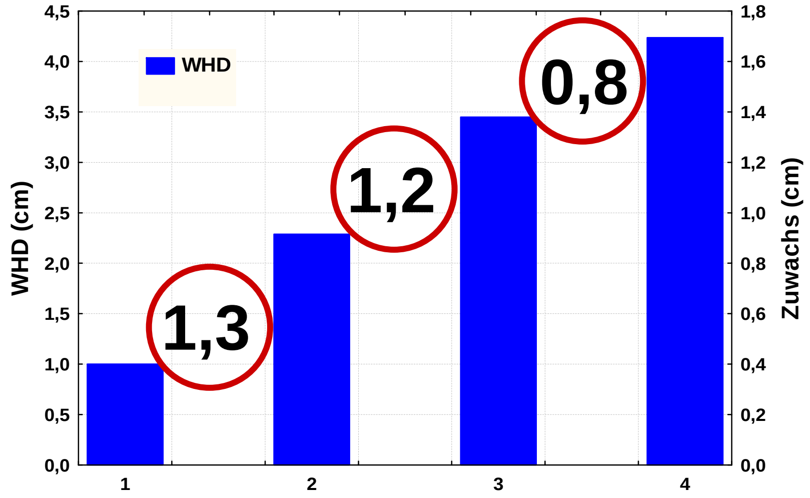
2010: 70 ha Alley Cropping AG Forst e.G. (Germany)



Increment of Black locust growing at short rotation plantations (first rotation)

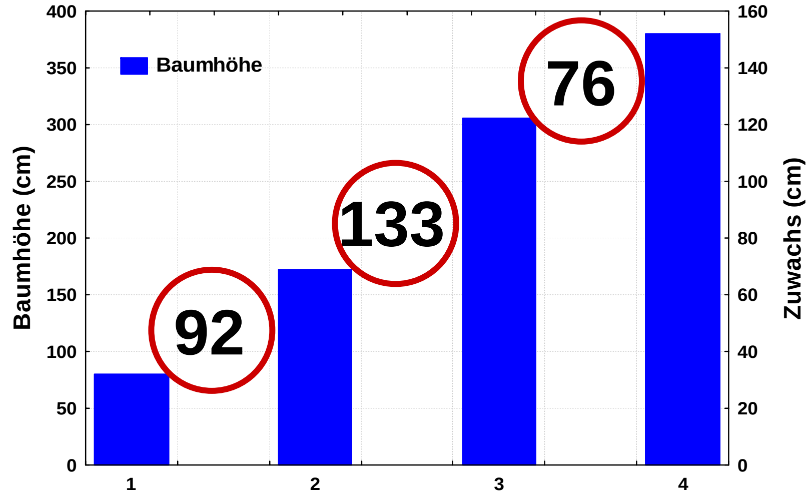
lignite opencast mining “Welzow-Süd”

Increase of shoot basal diameter during 4 years



Vegetation period

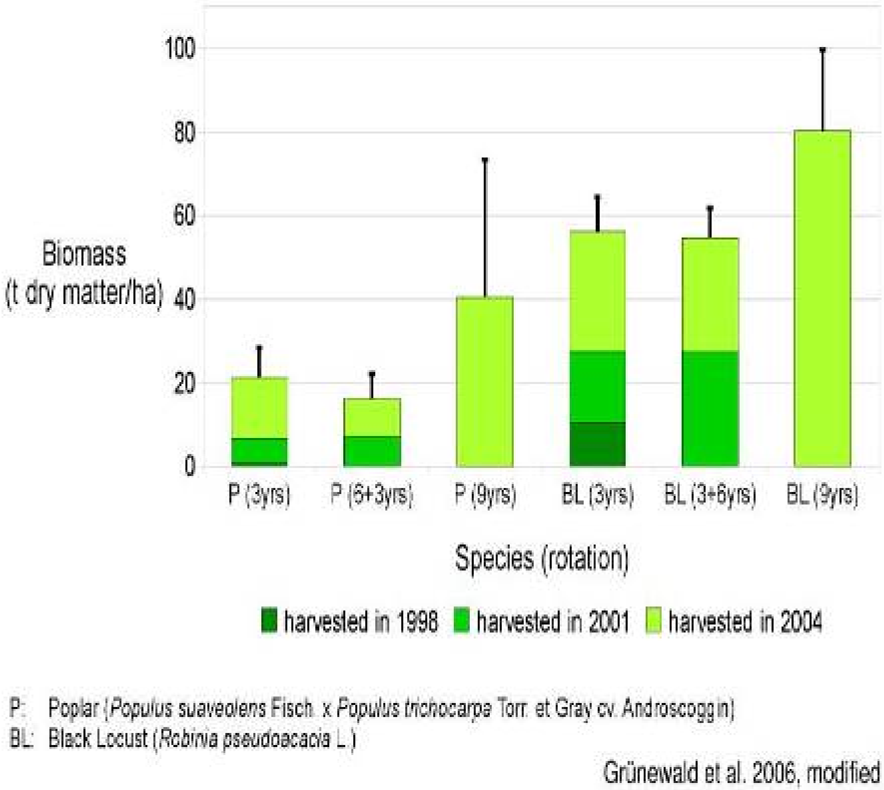
Increase of tree height during 4 years



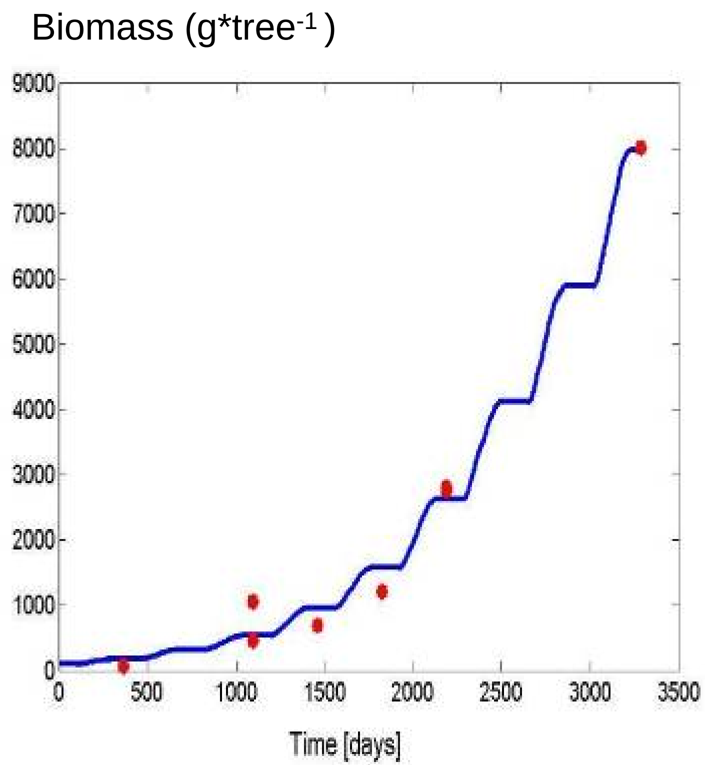
Vegetation period

Numbers in red cycles represent yearly increments in cm

Yearly yield of woody biomass after 4 years: 3 t dry matter ha^{-1} year^{-1}

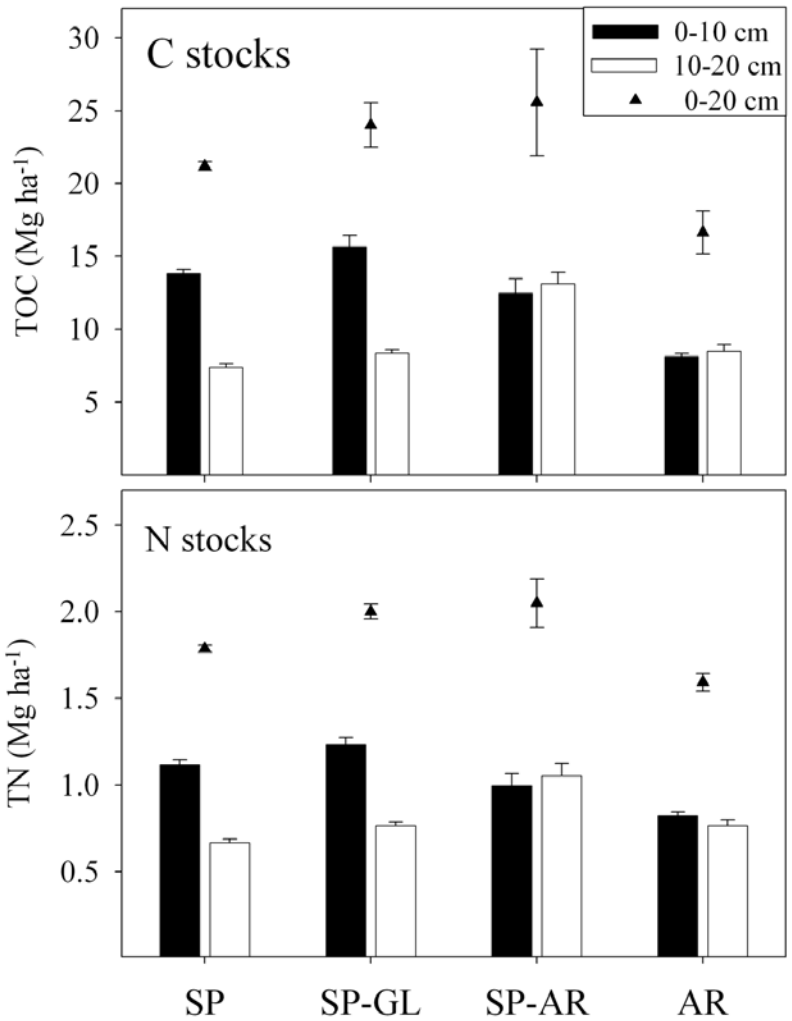


Biomass yield of Robinia pseud. and populus after different years of rotation



Prediction of yield of Robinia pseud. with the yieldsafe model (up to 10 years; red dots measured data)

Soil C and N stocks in soil under different land use systems in the 0-10 and 10-20 cm layers.

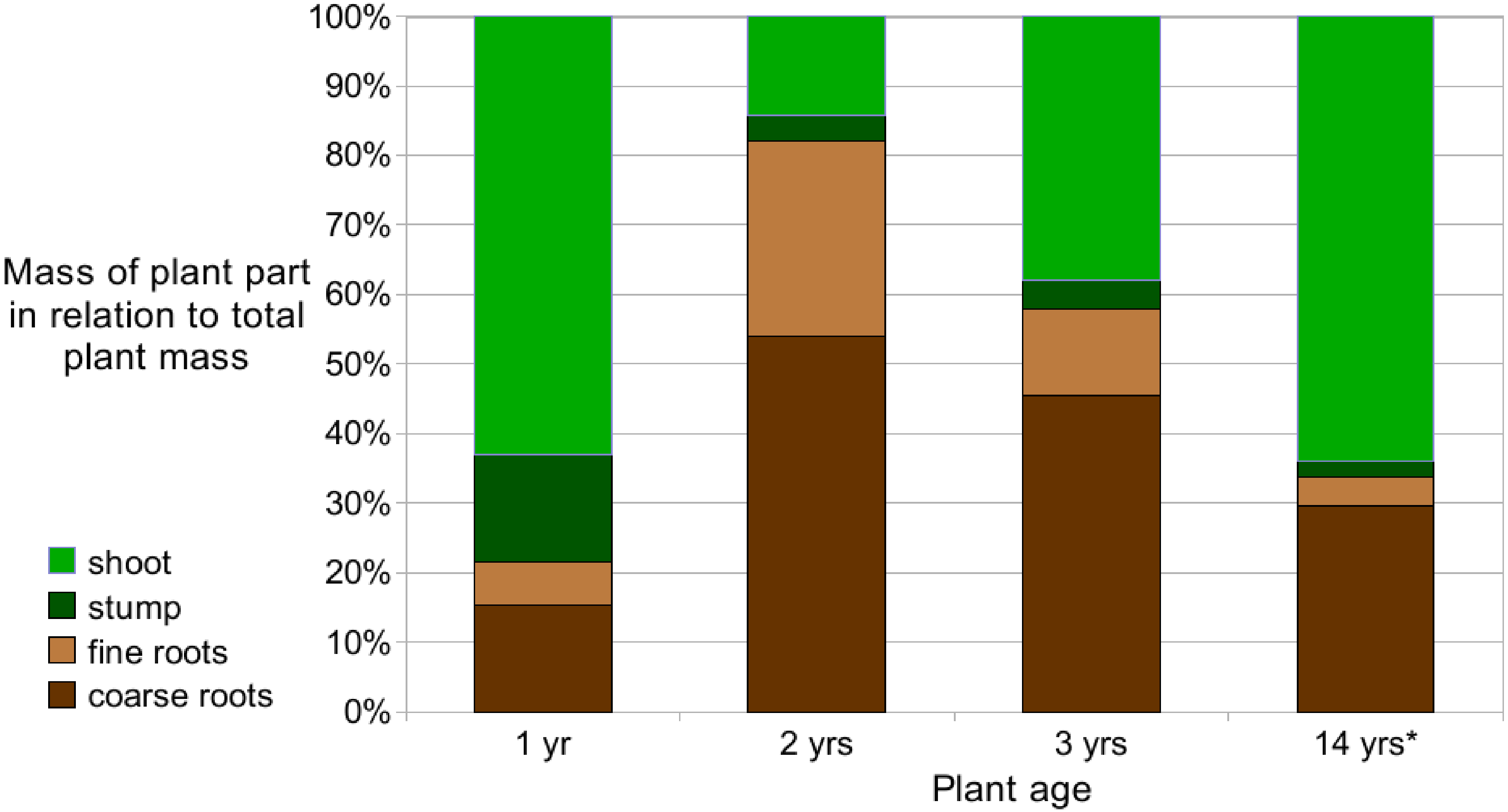


SP: Silvopasture, apple tree and grass use for > 50 years;
SP-GL: Grassland for 4 years of use after > 46 years of silvopasture (apple tree + grass);
SP-AR: Arable land for 4 years of use after > 46 years of silvopasture (apple tree + grass);
AR: Arable land use for > 50 years.

(Matos et al., 2010, Agroforestry Systems)

Carbon Allocation

Biomass allocation in a 14-year-old plantation of black locust on a post-mining site in Welzow-South

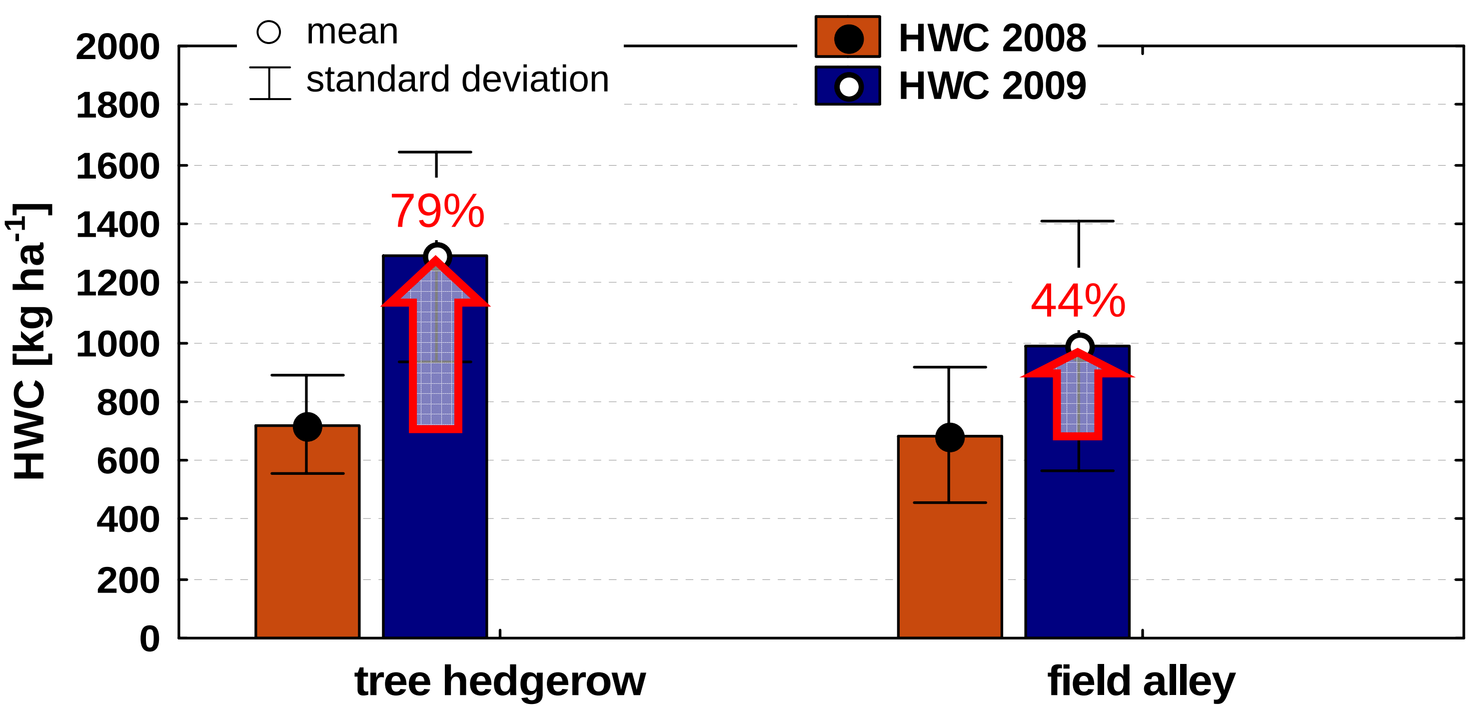


Soil organic carbon:

average increase of 2–4 t ha^{-1} yr^{-1} (0–30 cm soil depth)

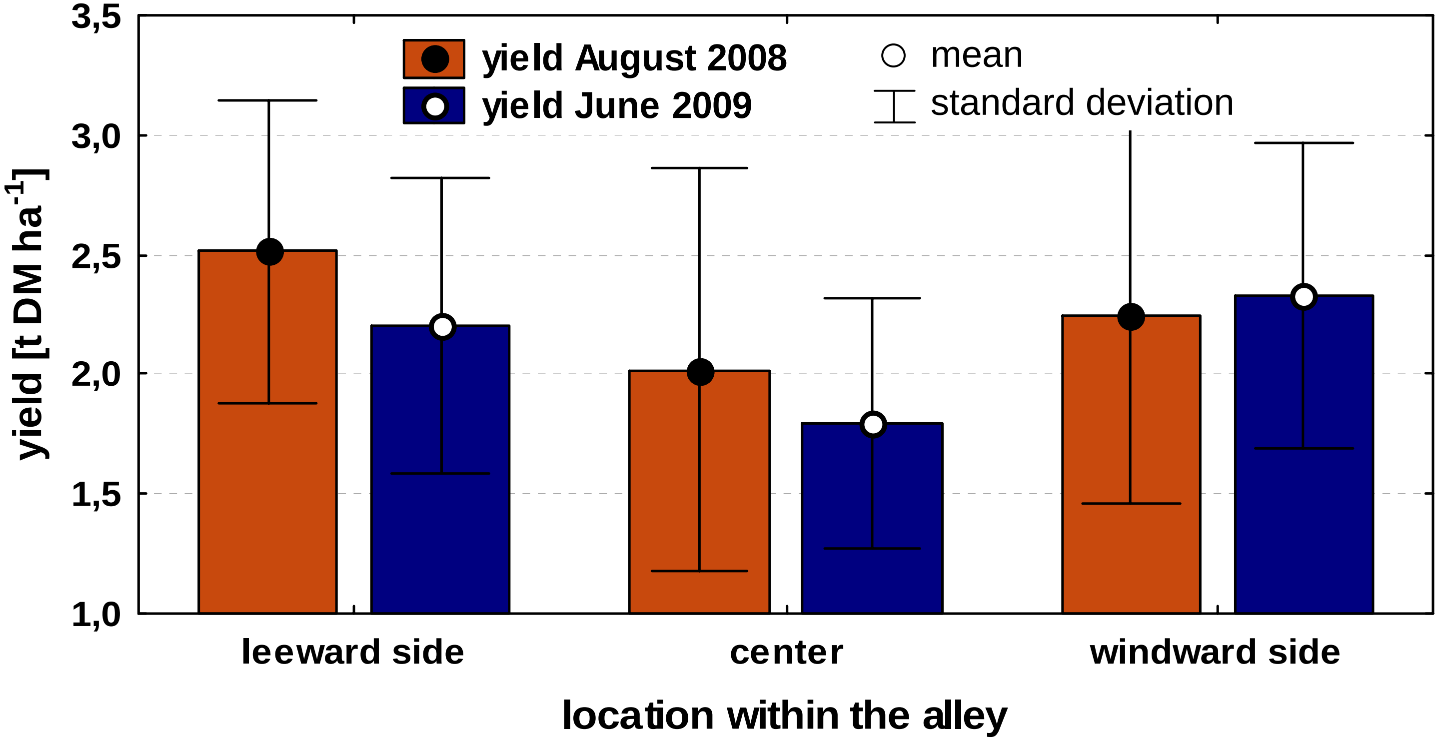
source: Quinkenstein et al. (2009), World Congress of Agroforestry 2009

Hot water extractable carbon (HWC) and nitrogen (HWN) 1 and 2 year(s) after establishing the alley cropping system (soil depth 0-30 cm; separated into tree hedgerow and field alleys of a AC)



- Increase of HWC is higher under trees than under crops

Yield of alfalfa at the 24 m wide alleys of the alley cropping system depending on the distances to hedgerows



• Yield of alfalfa is lower at the center of alleys than near the hedgerows

Implementation of Alley Cropping / SRC in Germany

Advantages

- Low-input system over long-term (fertilization, soil tillage etc.)
- Combination with organic farming
- Ecological benefits
- Economic benefits

Protestzug der Milchbauern am 4. Juni 2008.

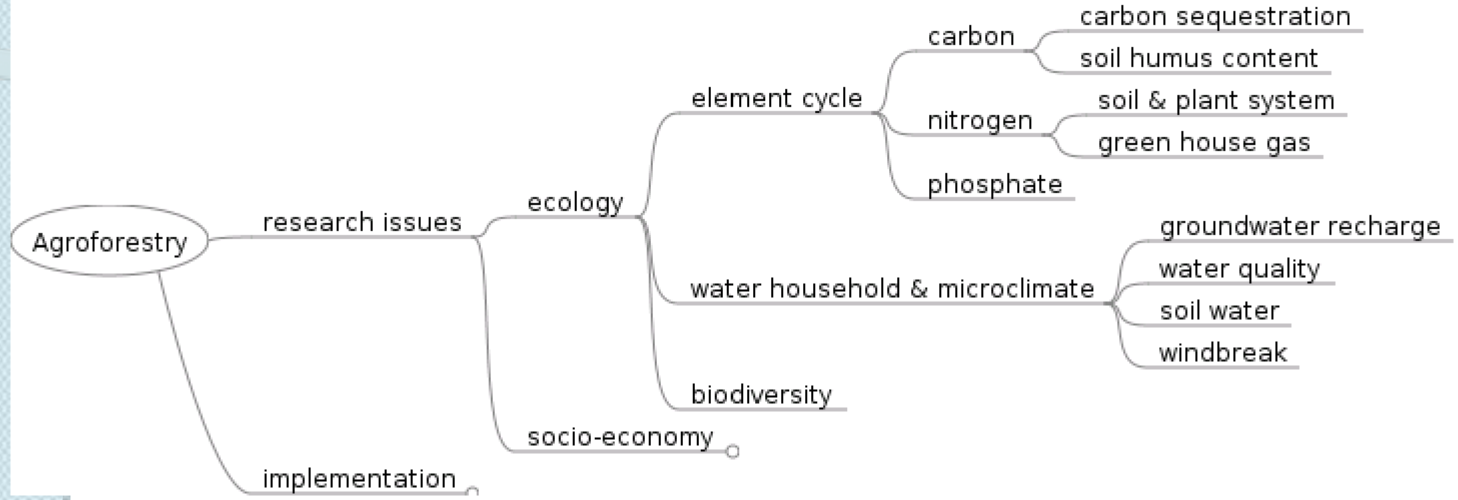
Farmers protest

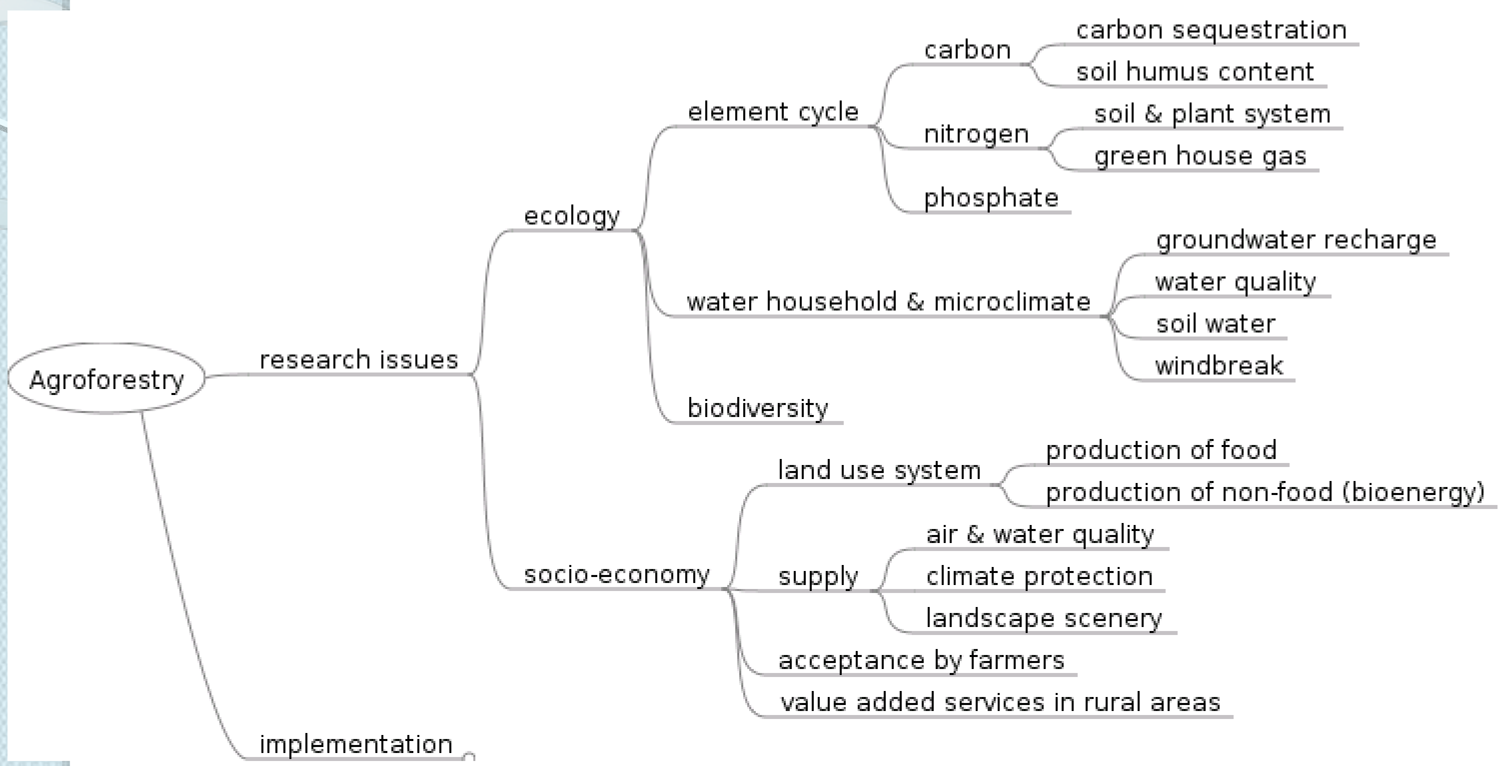
Disadvantages

- High investment per ha
- Long-term return of money
- No long-term lease contracts (>20 years)
- Modern crop production technology/ machinery
- Maintenance of EU area subsidy ?
- Low flexibility to agricultural policy
- Relatively low yields

Research issues

Brain Storming


Agroforestry
research issues
ecology
element cycle
carbon
carbon sequestration
soil humus content
nitrogen
soil & plant system
green house gas
phosphate
water household & microclimate
groundwater recharge
water quality
soil water
windbreak
biodiversity
socio-economy
implementation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windbreak
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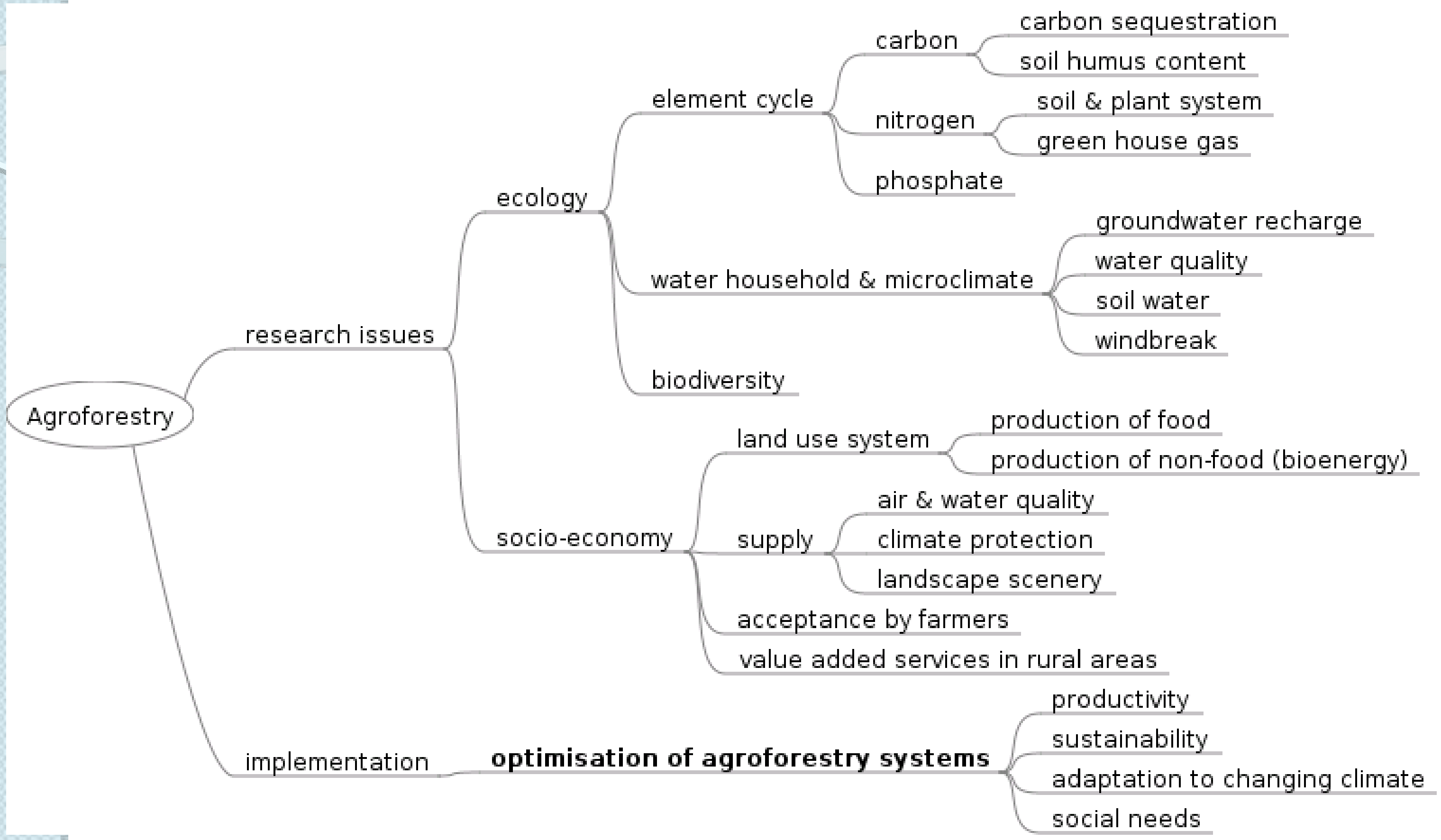
socio-economy
land use system
production of food
production of non-food (bioenergy)
supply
air & water quality
climate protection
landscape scenery
acceptance by farmers
value added services in rural areas
implementation



Development of a decision support system for valuing Ecosystem Services

- **quality criteria of ecosystem functions**
- **criteria for selecting indicators** (SWOT analysis)

Outlook

- Determine main parameters identifying relevant ecosystem services

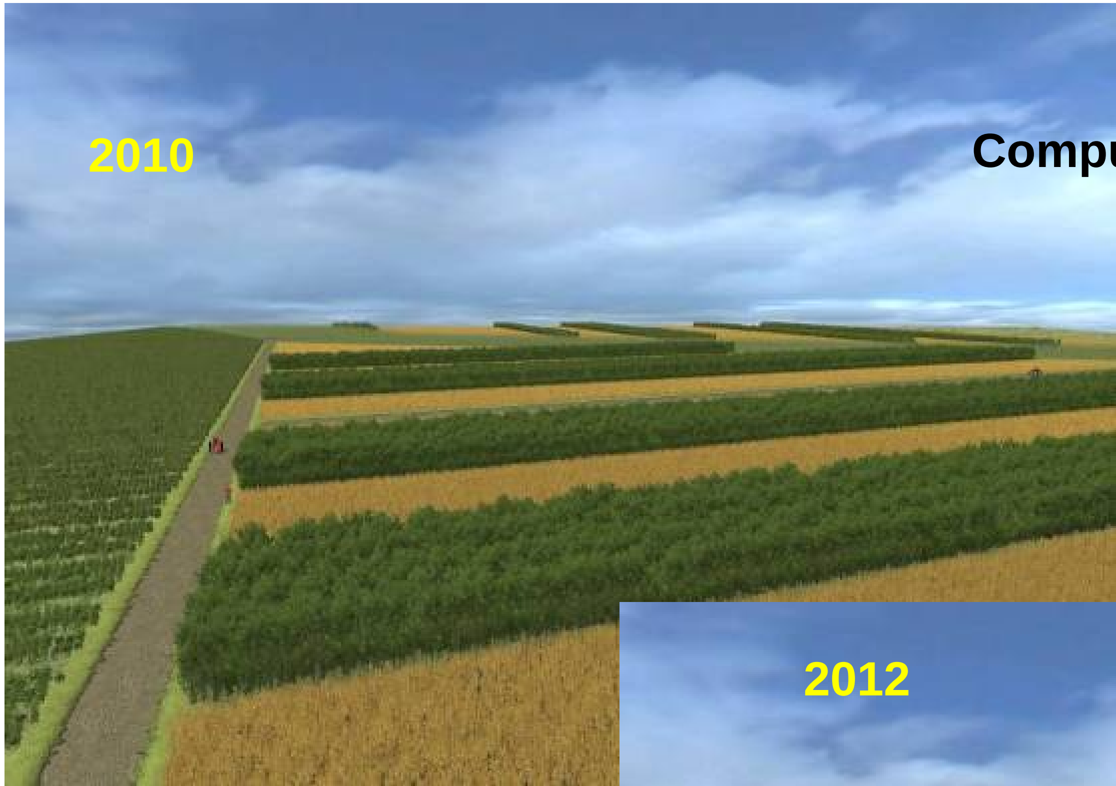
- Create assessment criteria for ecosystem services in agroforestry

-Create indicator systems assessing the benefits of ecosystem services in agroforestry

- Analyze and quantify the importance of agroforestry ecosystem services in comparison to conventional agricultural practices in order to facilitate decision making regarding their sustainable use and land management

-Identify best practice agroforestry models/technologies in the temperate region

Computer simulation



Thank you for your attention !

Agroforestry.EU

Information on European Agroforestry, Farm Woodlands and Farm Forestry

„ Currently this links the activities of the three EU Countries with formal Agroforestry Networks (France, UK and Greece), but the Society is growing.“

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