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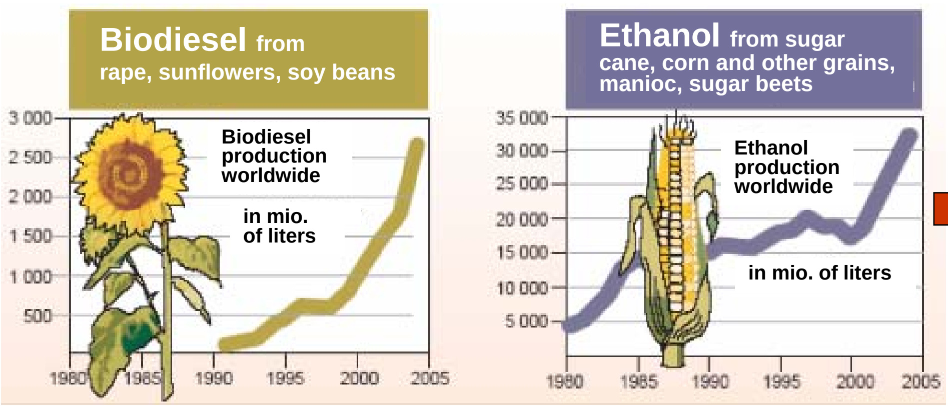
1st generation of biofuels



Source: Worldwatch

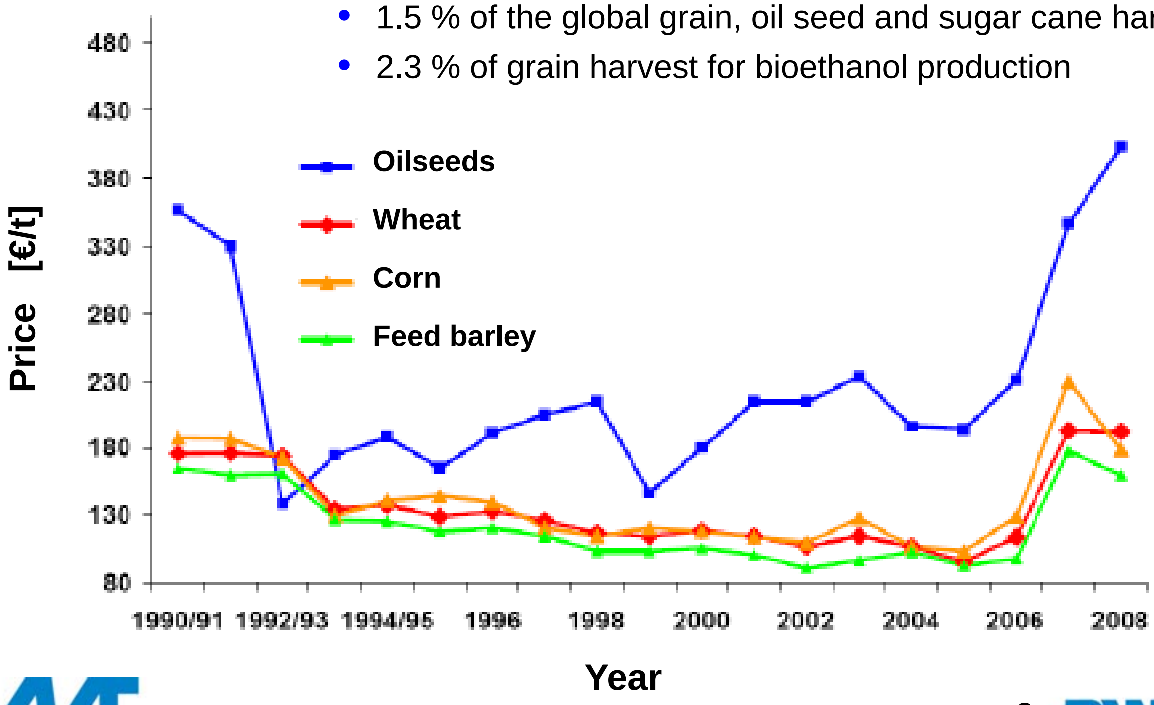
Deficiencies:

- Competition with food chain ("Tortilla crisis" in Mexico, "barley or beer crisis" in Bavaria, huge problems of vinegar and margarine producers)
- Unsatisfying $\Rightarrow$ **Biomass in terms of starch and oil not sustainable**
  - yield per area (until recently optimization criteria has been food quality)
  - only the seed is utilized, not the whole plant

Prize driver biofuel production ?

Global share of biofuels of agricultural raw material market

- 2.8 % of global grain and oil seed harvest
- 1.5 % of the global grain, oil seed and sugar cane harvest
- 2.3 % of grain harvest for bioethanol production

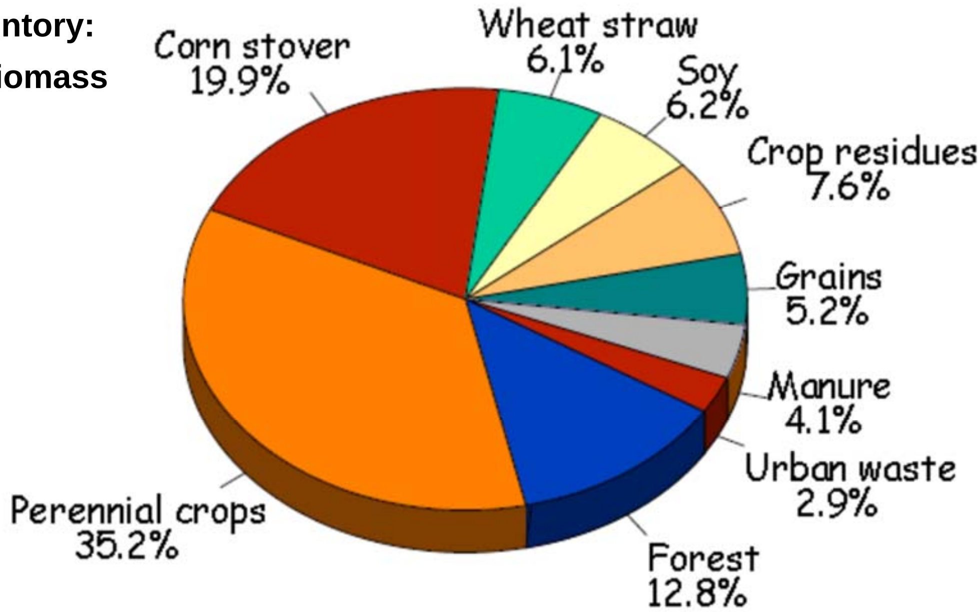


Source: Biomasse-Vorlesung ITC-C PV, KIT

Suitable biomass for chemical and biofuel industry

US Biomass inventory:

1.3 billion tons biomass



corn stover = Maisstroh; crop residues = Ernterückstände; grains = Getreide; manure = Mist; perennial = mehrjährig

from Billion ton Vision, DOE & USDA 2005

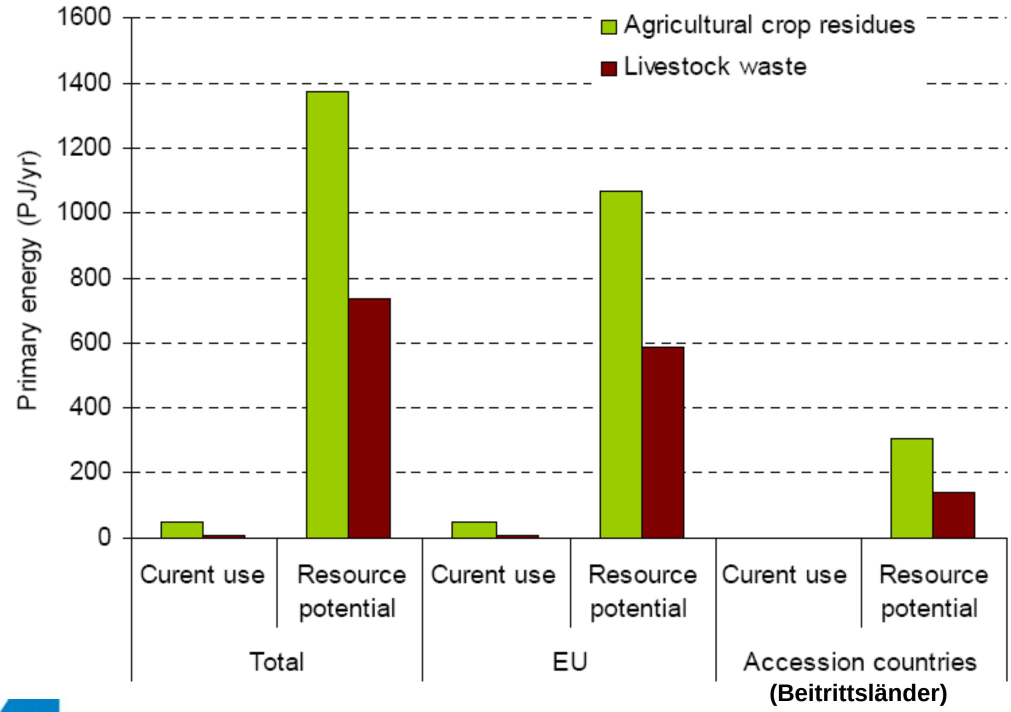
Waste biomass is currently readily available

Bamboo close to Nachi waterfall, Japan

Cedar wood close to Hongu Kumano Taisha Japan

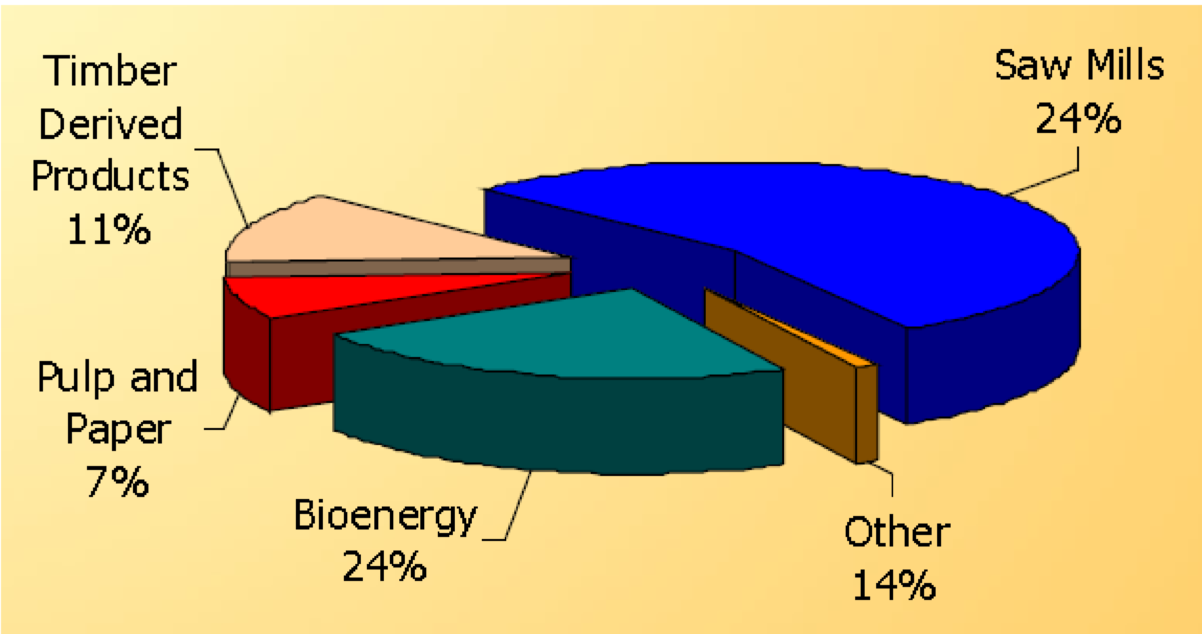
from Joachim Venus, Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V.

Current use and resources potential of agricultural crop residues and livestock waste



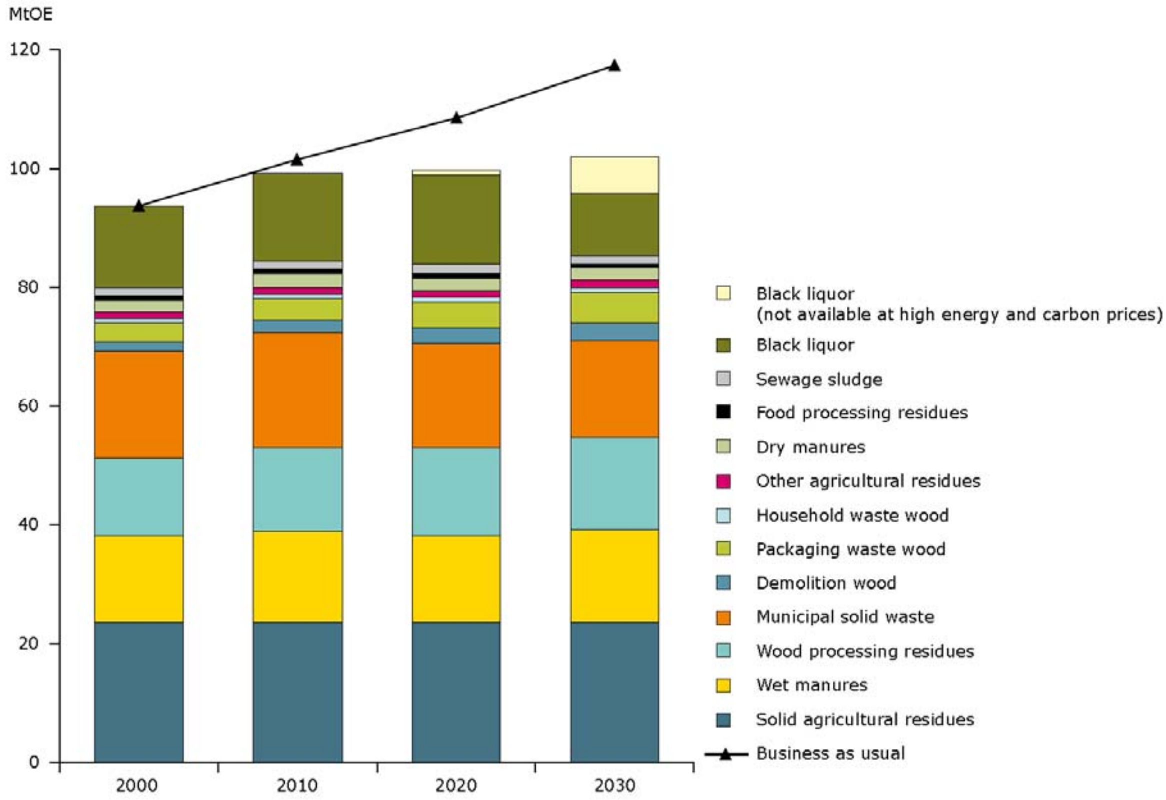
Use of German round wood (2002)

Total 55.1 Mio m^3 = 26.6 t dry

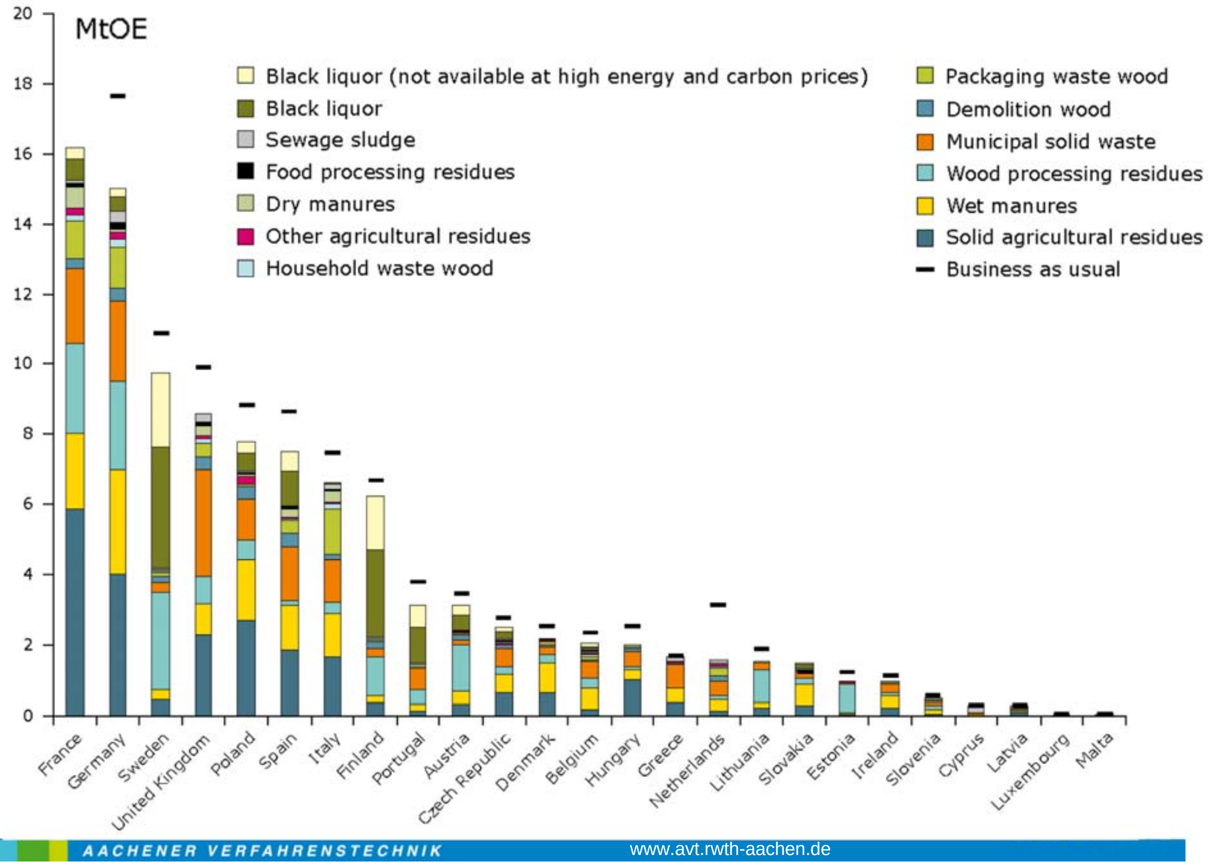


from A. Schütte, FNR, 2006

Environmentally compatible biowaste energy potential in EU-25



Environmentally compatible biowaste energy potential in 2030



Future sources of biomass

Wood & Straw

Wooden biomass
- water ↓
- lignin

Energy plants (swift grass, corn plants)

Kesten, KWS

from Joachim Venus, Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V.

Energy crops for biorefinery

Advantages	Disadvantages
Clean and consistent	Positive cost
High carbohydrate	Supply not yet established
Can increase supply with extra land (unlike waste)	Seasonal
Would boost rural economy	

from "A Case for Biorefineries", D. J. Hayes, University of Limerick

Considerations with Energy Crops for Biorefineries

- These are different than the considerations for biomass combustion.

- Energy crops should have:

- High productivity → high carbohydrate yield
- Low establishment and maintenance costs
- A high density for cheaper transportation (maximal distance for economic raw material transportation 20 - 50 km)
- Utilise existing machinery if possible
- Quite frequent harvest periods to ensure attractive cash flow
- Predictable yields even under differing climatic conditions
- Moisture content less important than in combustion schemes
- Impurities, N content and chlorine content less important than in combustions schemes

from „A Case for Biorefineries", D. J. Hayes, University of Limerick

Notes on Energy Crops

- All have similar carbohydrate profiles:

  ~40% cellulose (glucose)

  ~25% hemicellulose (xylose)

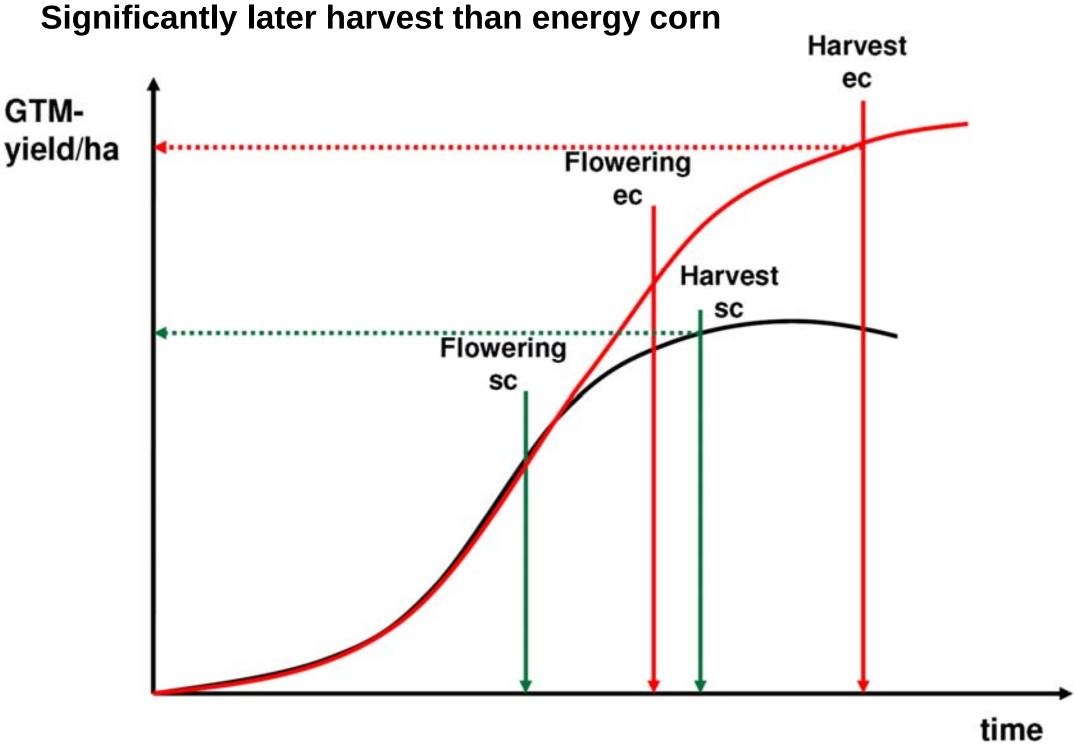
  ~25% lignin

- Coppices (Niederwald) harvest every 3-5 years, most other crops annual.
- Miscanthus has the highest potential yields (> 20 dry tones per hectare per year in the southwest).
- Coppices susceptible to yield loss due to rust/pathogens.

from "A Case for Biorefineries", D. J. Hayes, University of Limerick

Growth progression of silage corn (sc) vs energy corn (ec)

Significantly later harvest than energy corn



from E. Kesten, KWS, 2006

Suitability of other crops species for energy crop cultivation

Rye:
- undemanding with regard to soil
- high biomass yield
- broad genetic base available
- hybrid system available
- material and breeding know-how available

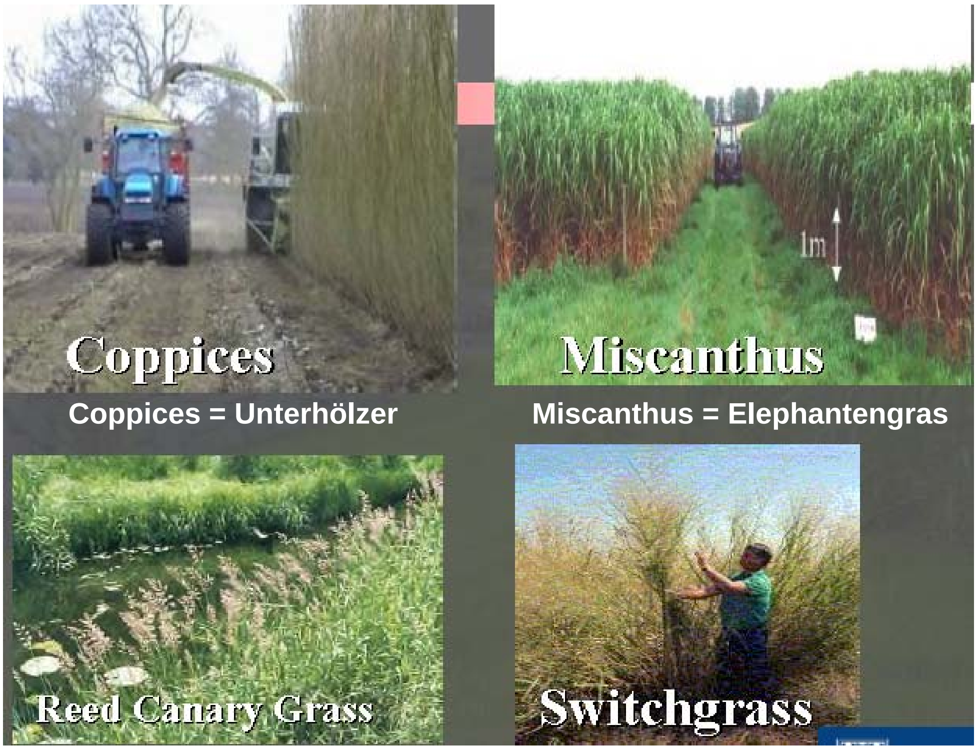
Millet:
- more water efficient than e.g. corn
- high biomass yield
- originally short day crop
- limited local material available

Sunflower:
- high yield with short growing period
- high water efficiency
- broad genetic variety available
- hybrid system available

Hemp:
- previously used as fiber plant
- undemanding with regard to soil
- high mass yield within short period
- broad genetic base available

from E. Kesten, KWS, 2006

Suitable energy crops

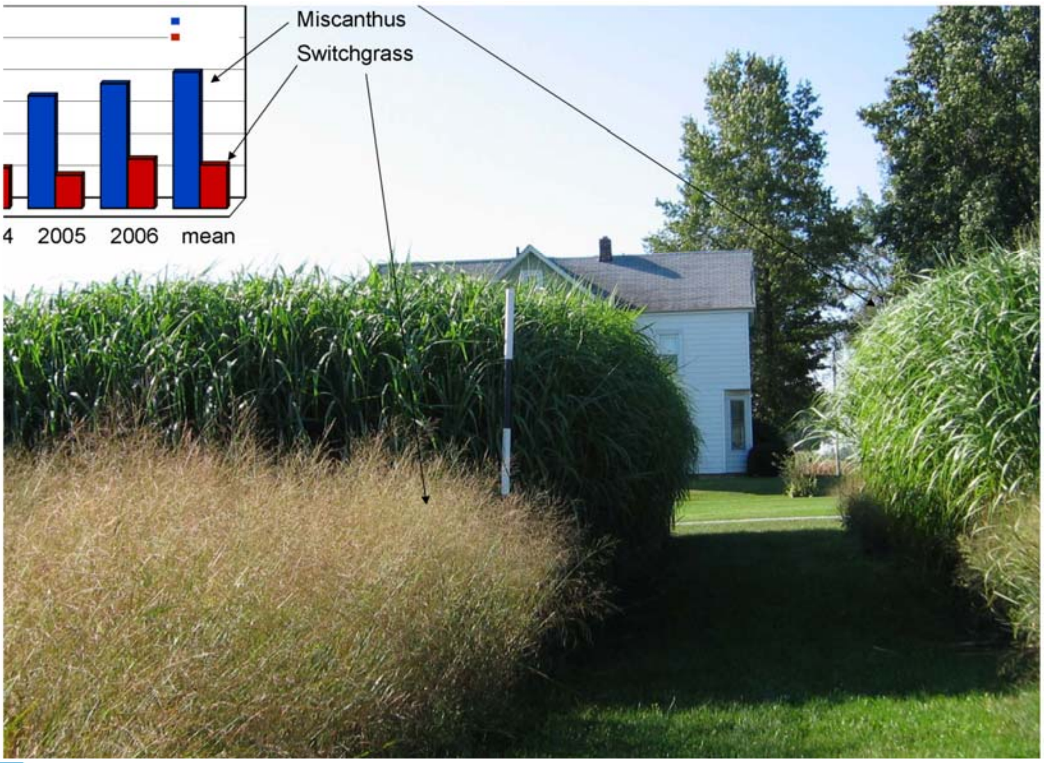


Reed Canary Grass = Schilfgras

Switchgrass = Rutenhirse

from "A Case for Biorefineries", D. J. Hayes, University of Limerick

Suitable energy crops



from “A Case for Biorefineries”, D. J. Hayes, University of Limerick

Suitable energy crops

>2% photon yield is feasible,
yield of 26.5 tons/acre observed by Young & colleagues in Illinois, without irrigation

Courtesy of Steven Long et al.

Locations of European Miscanthus trials

1. Hyperion
2. TCD
3. FAL
4. CRES
5. LWG
6. Lisboa
7. UEDB
8. BTG
9. ENEA
10. IACR
11. ADAS
12. IAGCE
13. USC
14. BFH
15. SORGHAL

from Clifton-Brown et al in: Jones and Walsh (eds) Miscanthus for Energy and Fibre, 2001

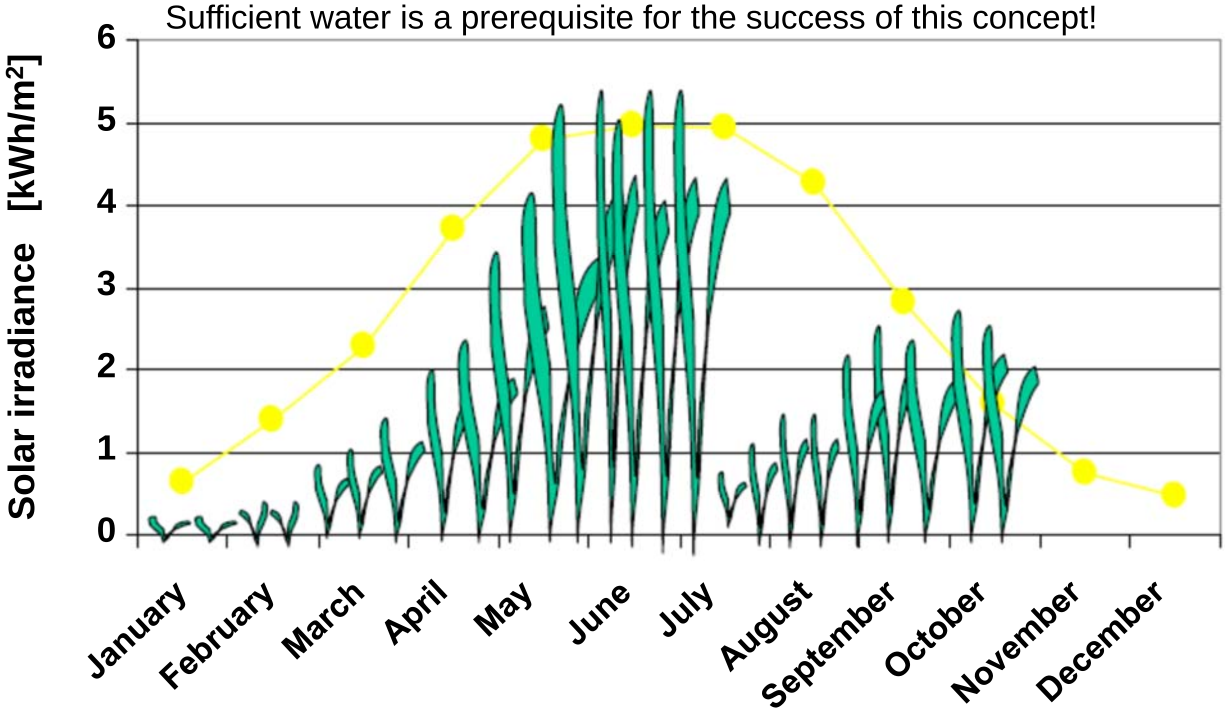
Harvesting Miscanthus

http://bioenergy.ornl.gov/gallery/index.html

Higher area based productivity by more than one harvest per year

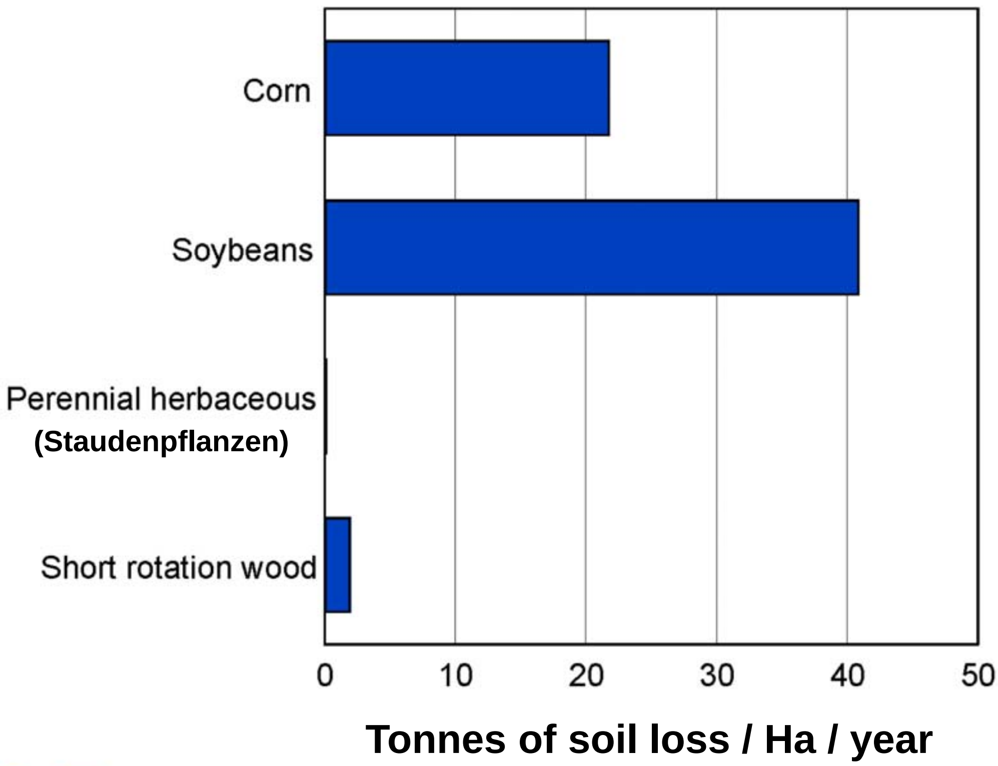
according to “Witzenhäuser” cultivation concept

Sufficient water is a prerequisite for the success of this concept!



from Scheffer et al.

Energy crops and soil loss



from Oliveira et al in: Jones and Walsh (eds) Miscanthus for Energy and Fibre, 2001

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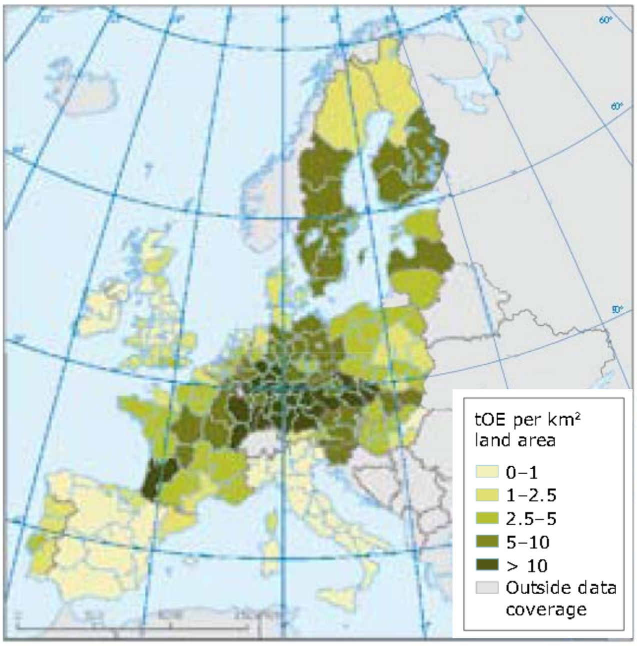
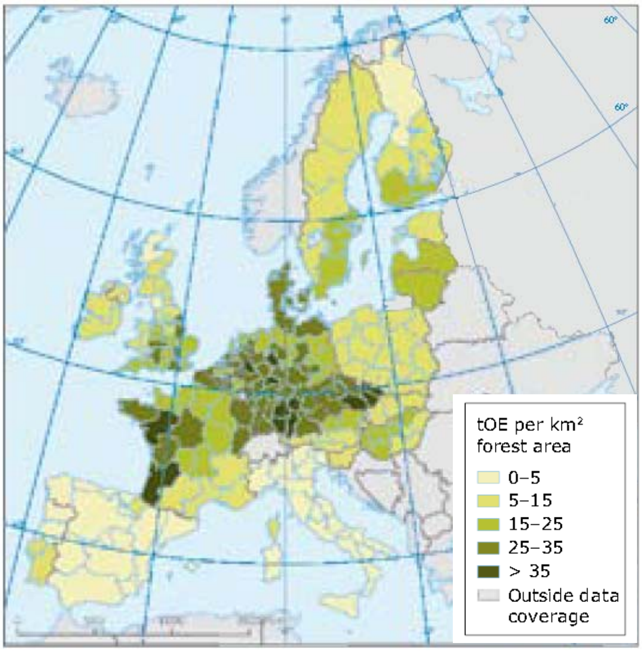
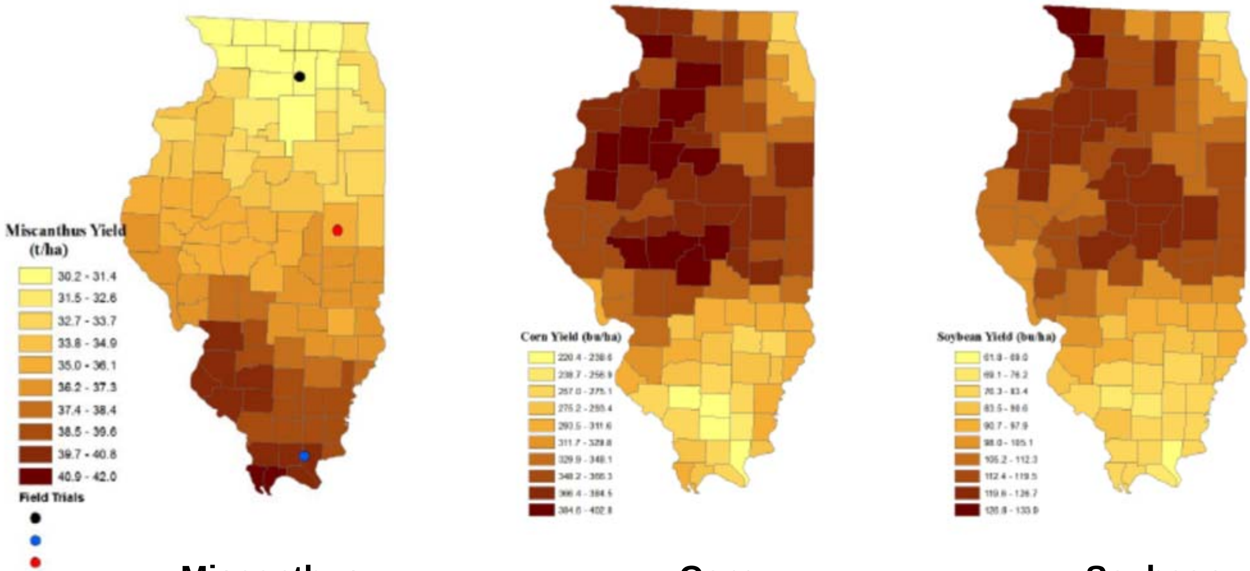
Environmentally compatible bioenergy potential from residues in 2030





Energy crops may not compete directly with food crops

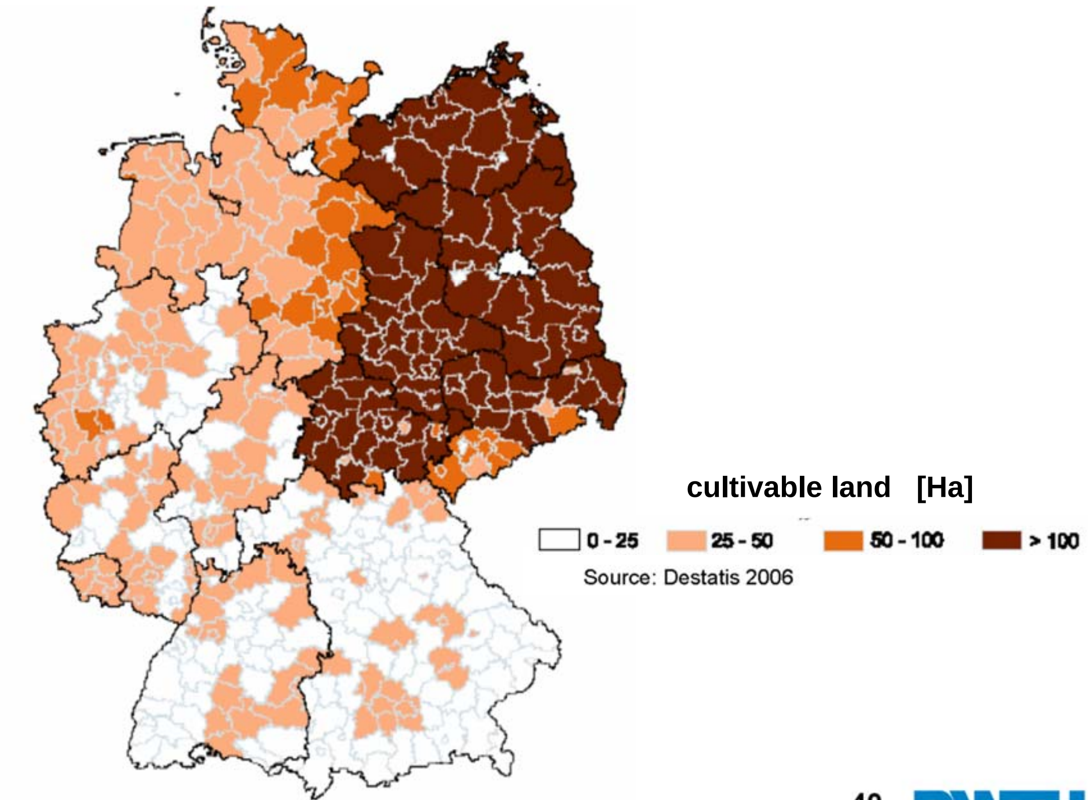
(yield per HA for Miscanthus, Corn, Soybean)



Miscanthus **Corn** **Soybean**

from Madhu Khanna, University of Illinois, Urbana

Size of farms and area of cultivable land



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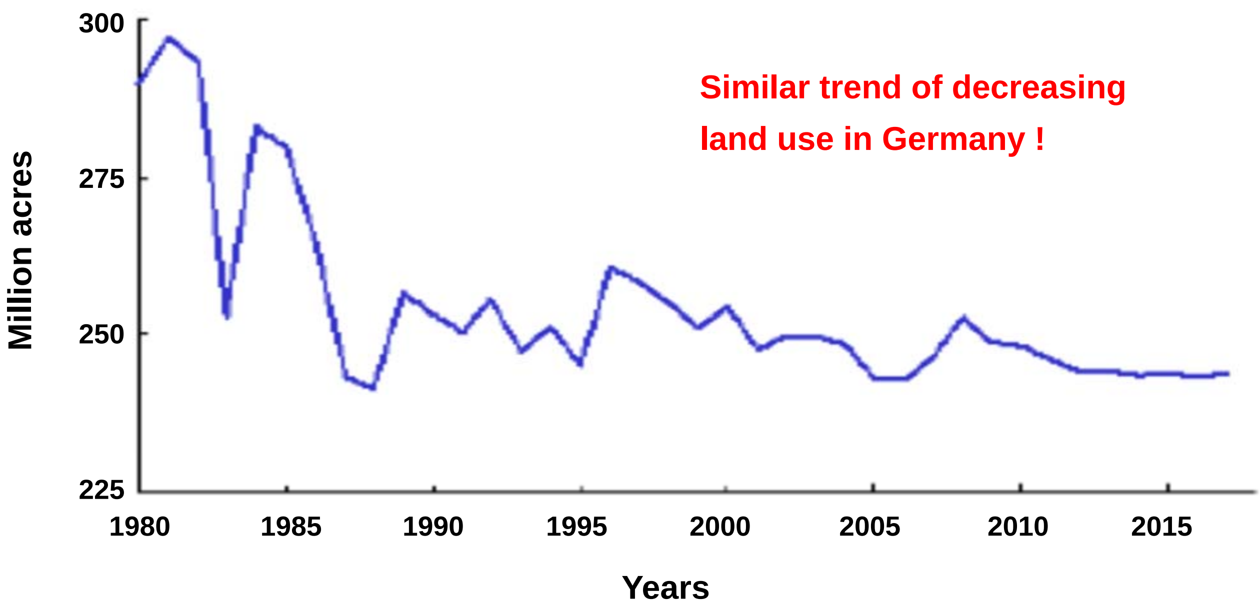
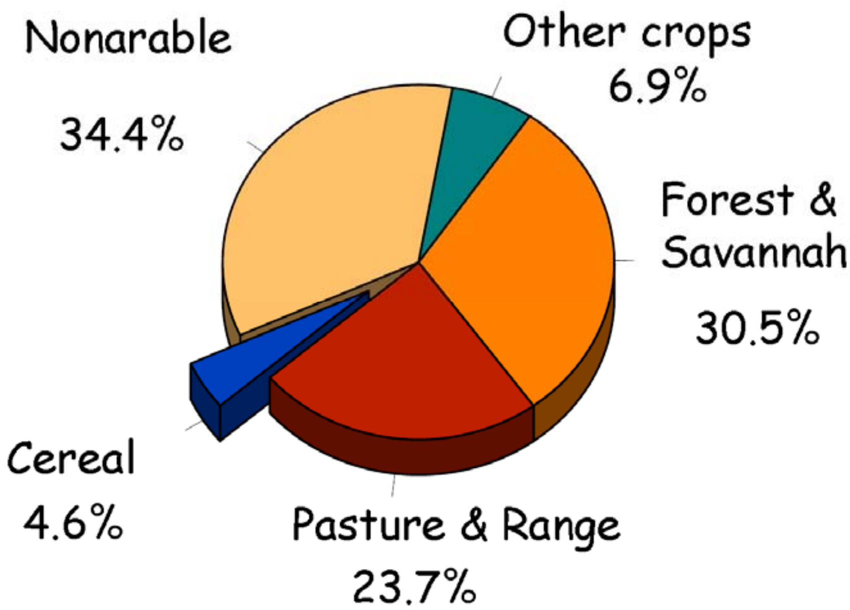
Agricultural land use in the US

US planted area of eight major crops
(corn, sorghum, barley, oats, wheat, rice, cotton, and soybeans)



Source: USDA agricultural projections to 2017,
February 2008, USDA Economic Research Service

Global land usage

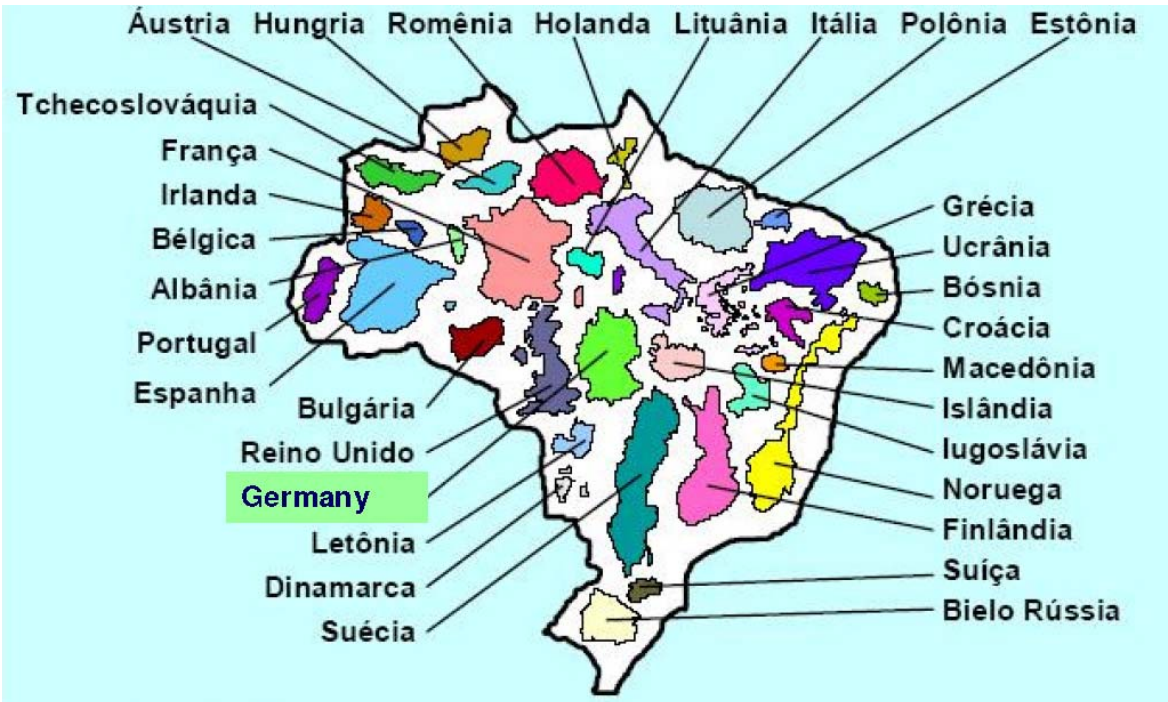


nonarable = landwirschaftlich unbebaubar; pasture = Weide; range = Gebirge; cereal = Getreide

AMBIO 23,198 (total land surface 13,000 MHa)

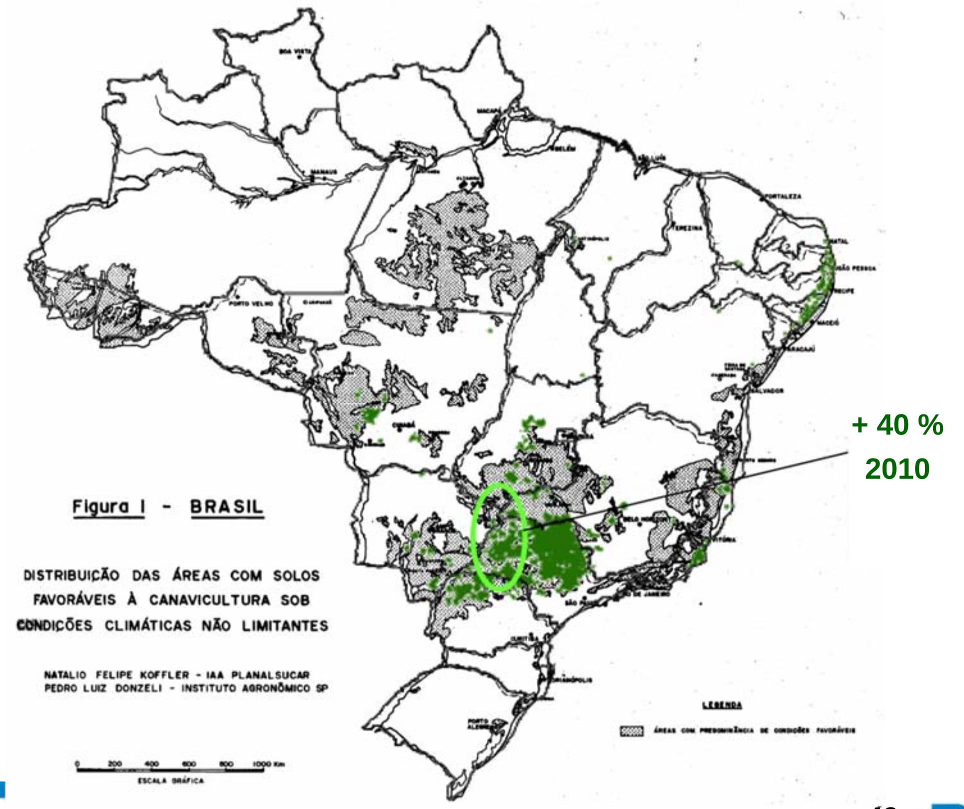
Brazilian land area

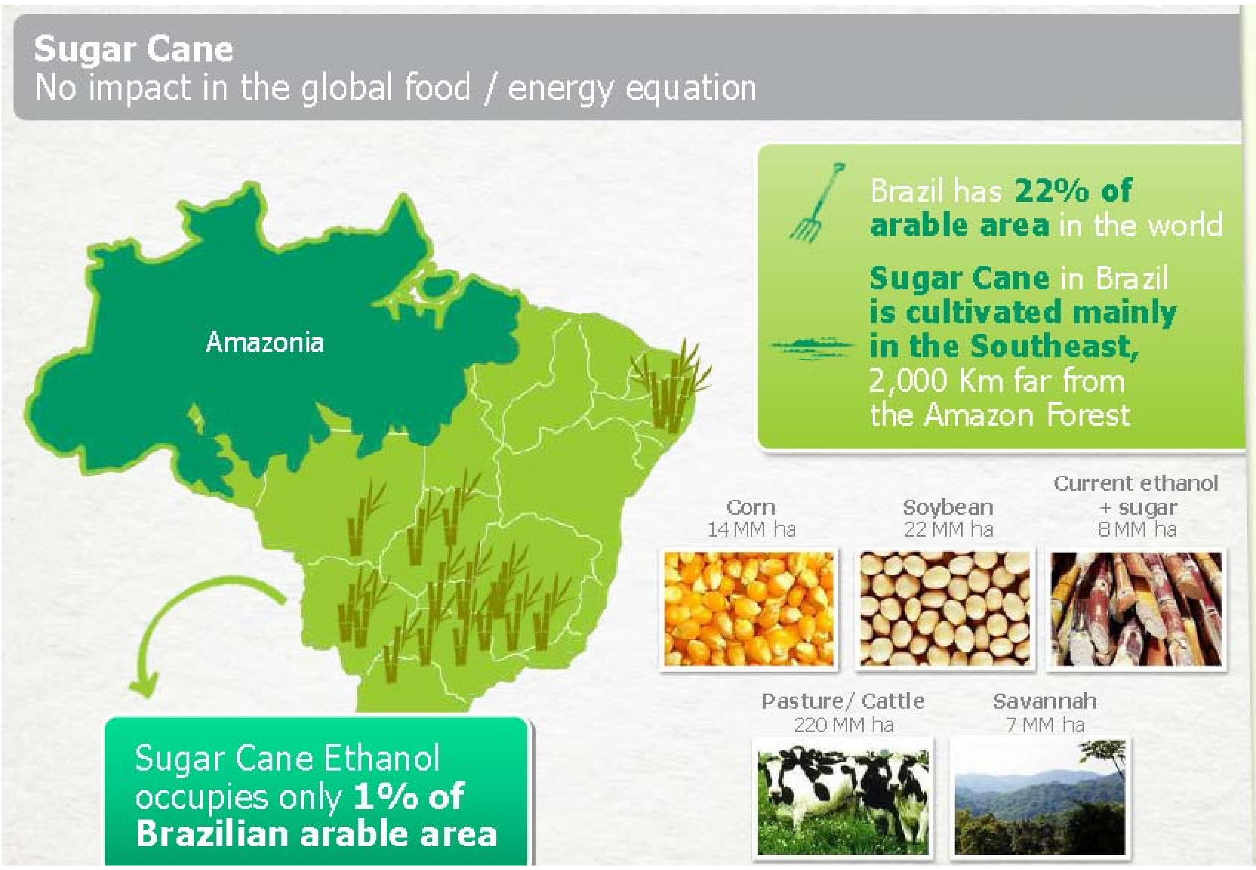
550 MHa arable land. That is approximately equal to the total area of 32 European countries



from Jaume Finguerut, Centro de Tecnologia Canavieira, J.L. Coelho, John Deere, 2001

Area distribution of sugar cane in Brazil





Braskem

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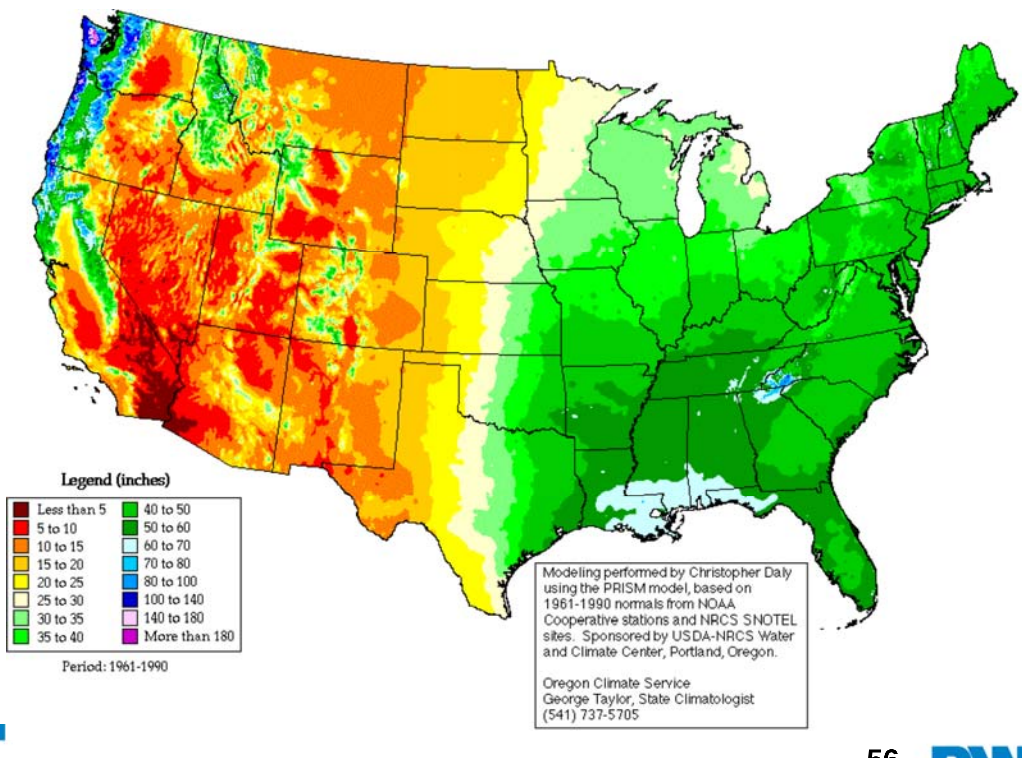
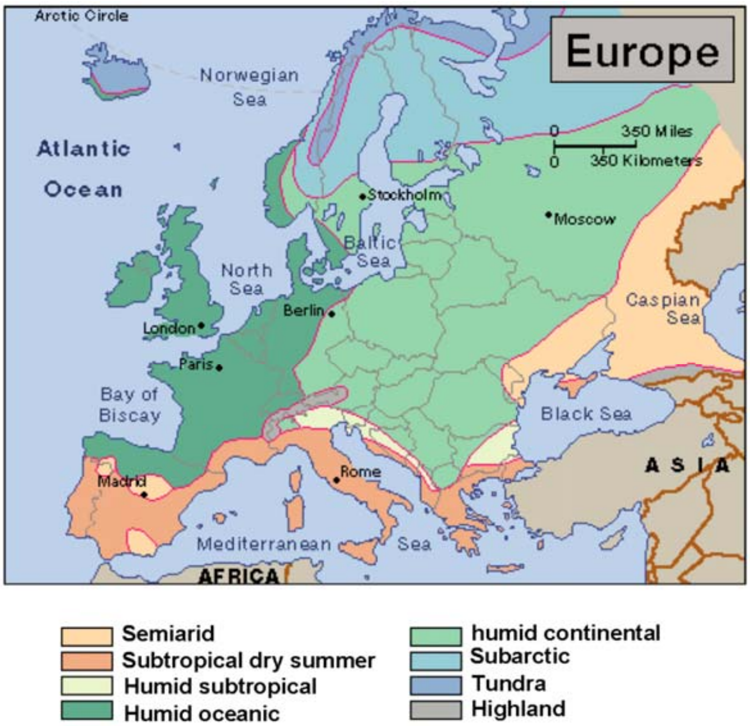
Annual average precipitation in the US



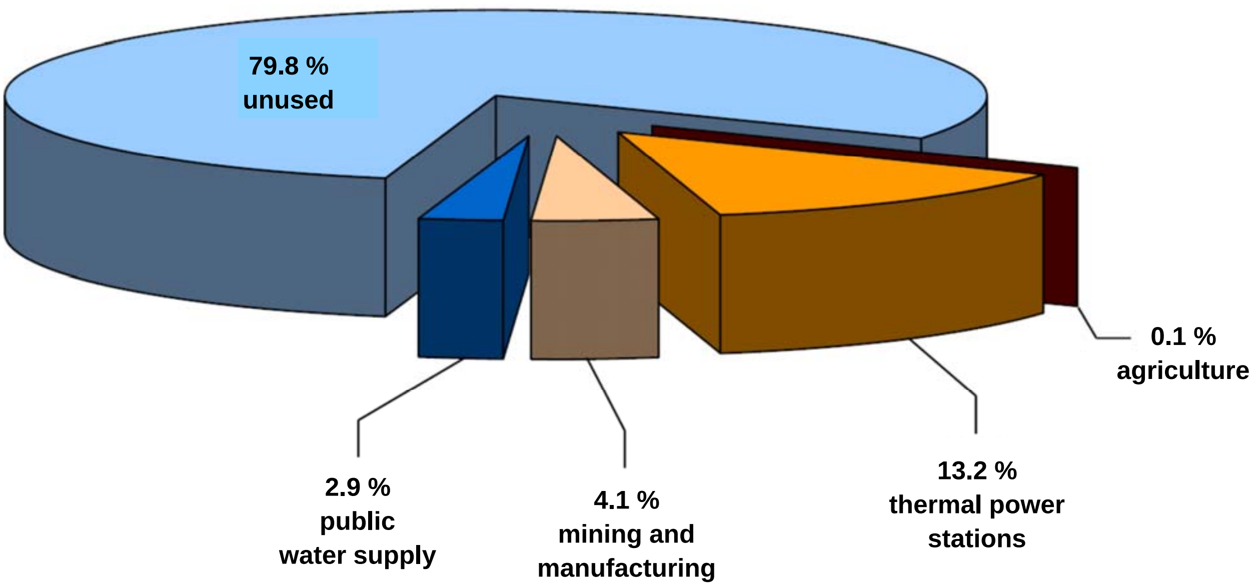
Water availability in Europe and Germany



- Germany is located in a temperate humid climate zone
- 789 mm average annual percipitation
- Strong reginal differences in percipitation
- 188 billion m^3 available water resources in Germany
- 2,278 m^3 water available per EW/a

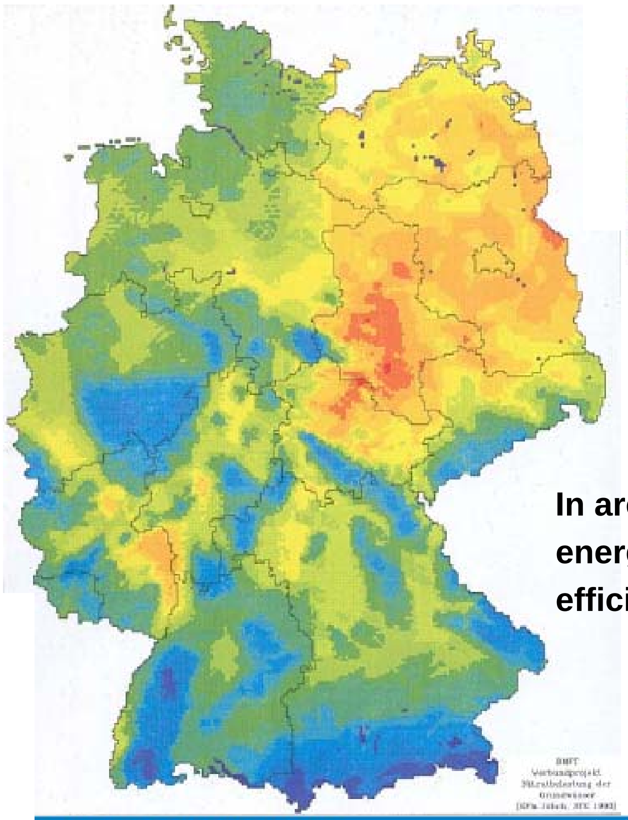
Source: http://www.worldbook.com

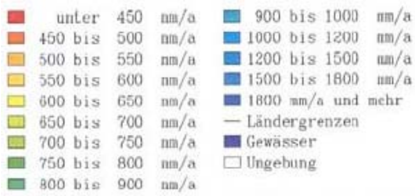
Water utilization in Germany



Source: Umweltbundesamt

Average annual rain fall in Germany



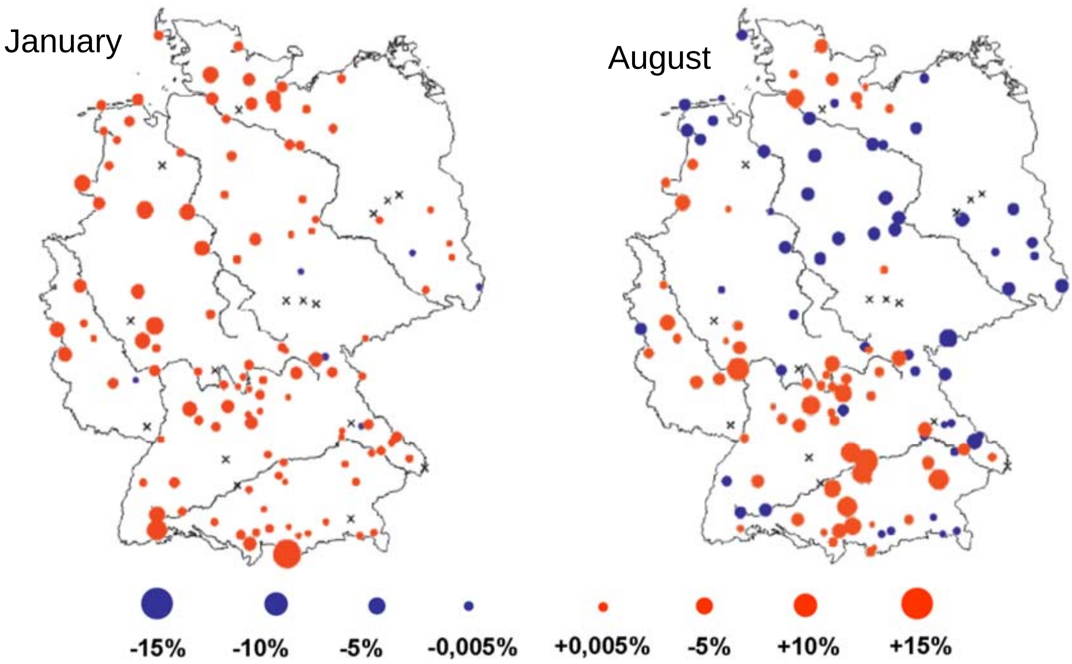


In areas with low annual rain fall energy plants can not be grown efficiently !

E. Kesten, KWS

Increase in events of extreme rain fall

trend 1901 - 2000



Source: Schönwiese et al., 2006

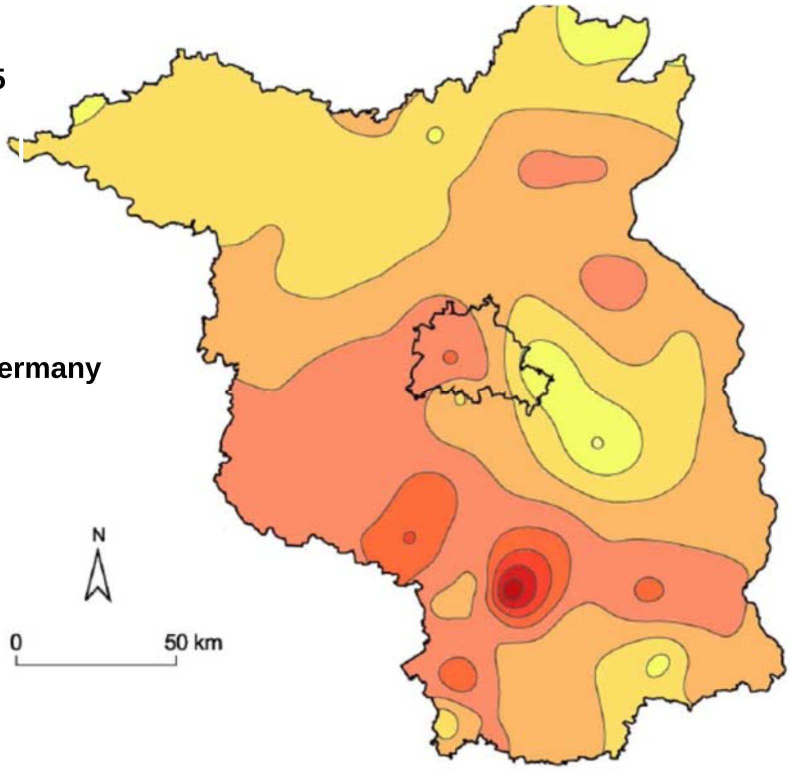
Expected change of rain fall in Brandenburg state

Change of precipitation
1951-2000 compared to 2046-2055

Difference [mm]

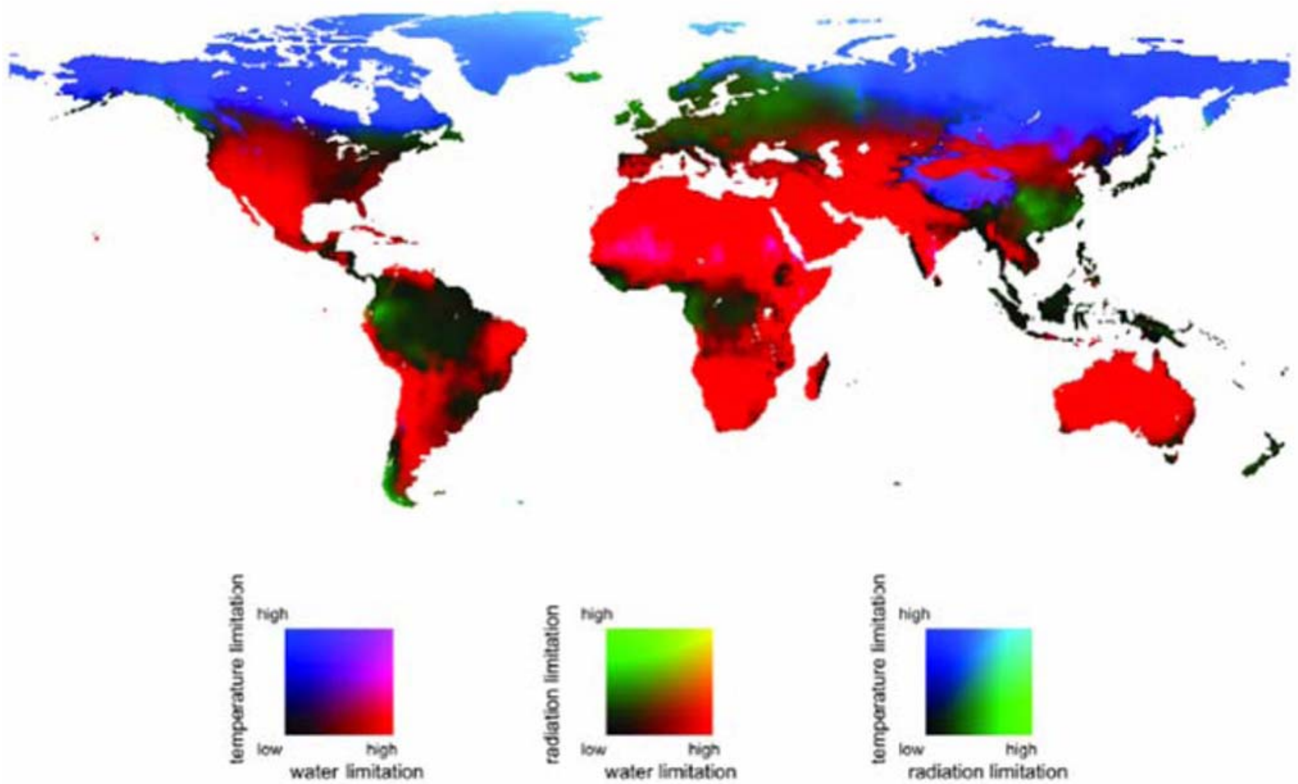
0 -100 -200

average annual percipitation in Germany
789 mm



Source: Landesumweltamt Brandenburg

Limiting factors for global net primary production



from Baldocchi et al. 2004 SCOPE 62