Climate Change and food security

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Earth system analysis through interdisciplinary research

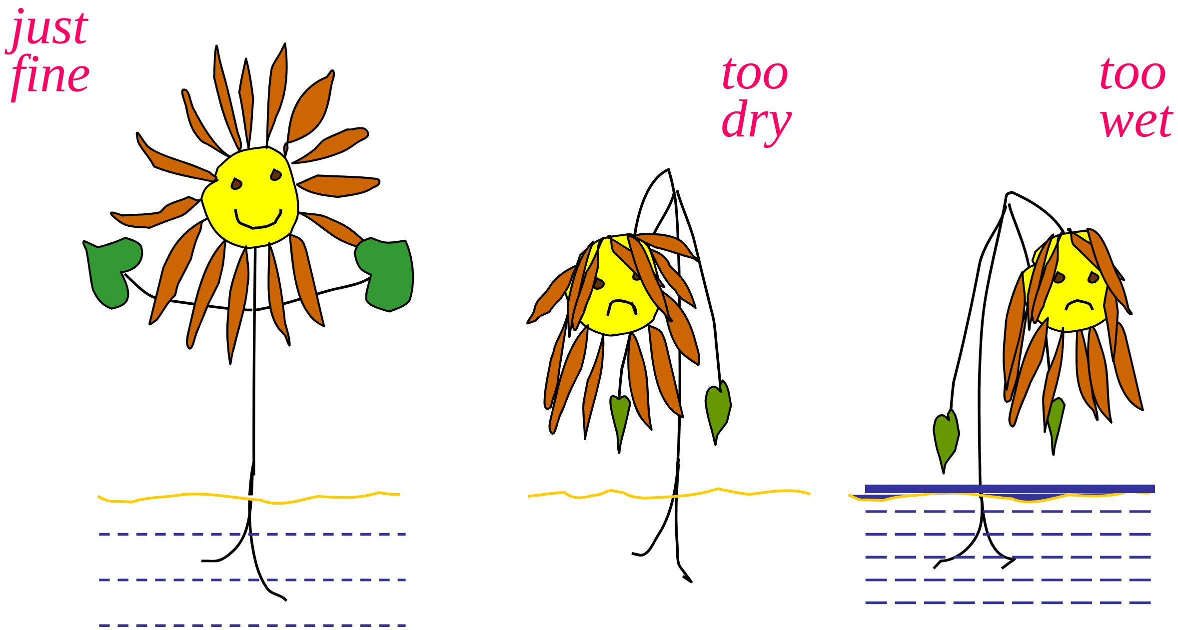
- to better understand and model the interactions:
climate-biosphere-economy-society

- to determine, within a global change context:
vulnerabilities, mitigation & adaptation strategies

Climate impact on agricultural production

Food security depends not only on climate (also on policies, gouvernance, life style (diet), poverty, population pressure, etc) …

… but an appropriate climate is, with soil, a fundamental requirement for growing crops, grass, fruits, i.e. our food.



- How climate change impact crop production
- How is that represented within global crop model - uncertainties
- Problems for future food security
- How alternative farming systems may respond differently & increase food security.

Climate change

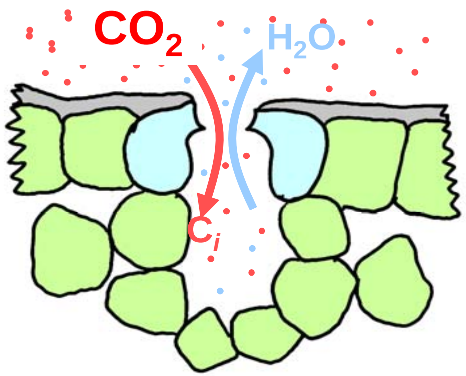
- CO_2 is increasing
- tropospheric O_3 is increasing
- N deposition
- Temperate is increasing (night T increasing more than daily T)
- Precipitation pattern is changing
- increase frequency of extreme events (flood, drought, heat wave, …)
- if aerosol pollution, solar radiation is decreasing

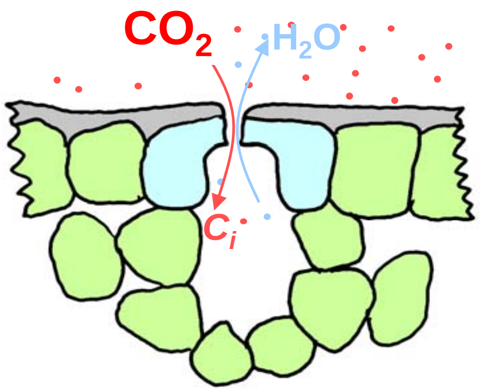
The direct CO_2 effects upon plants

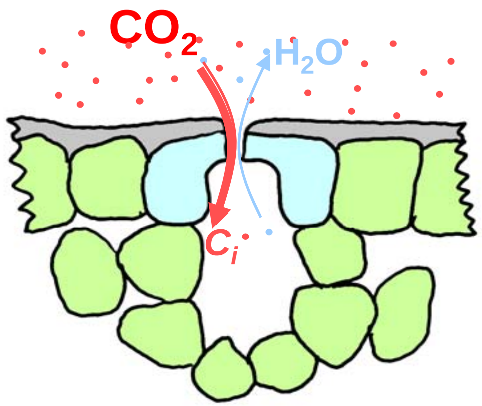
Humid conditions

Arid conditions

High [CO_2] (future)







(Dieter Gerten, PIK)

=> CO_2 fertilization effect

The damageable effect of O_3 is reduced under high CO_2

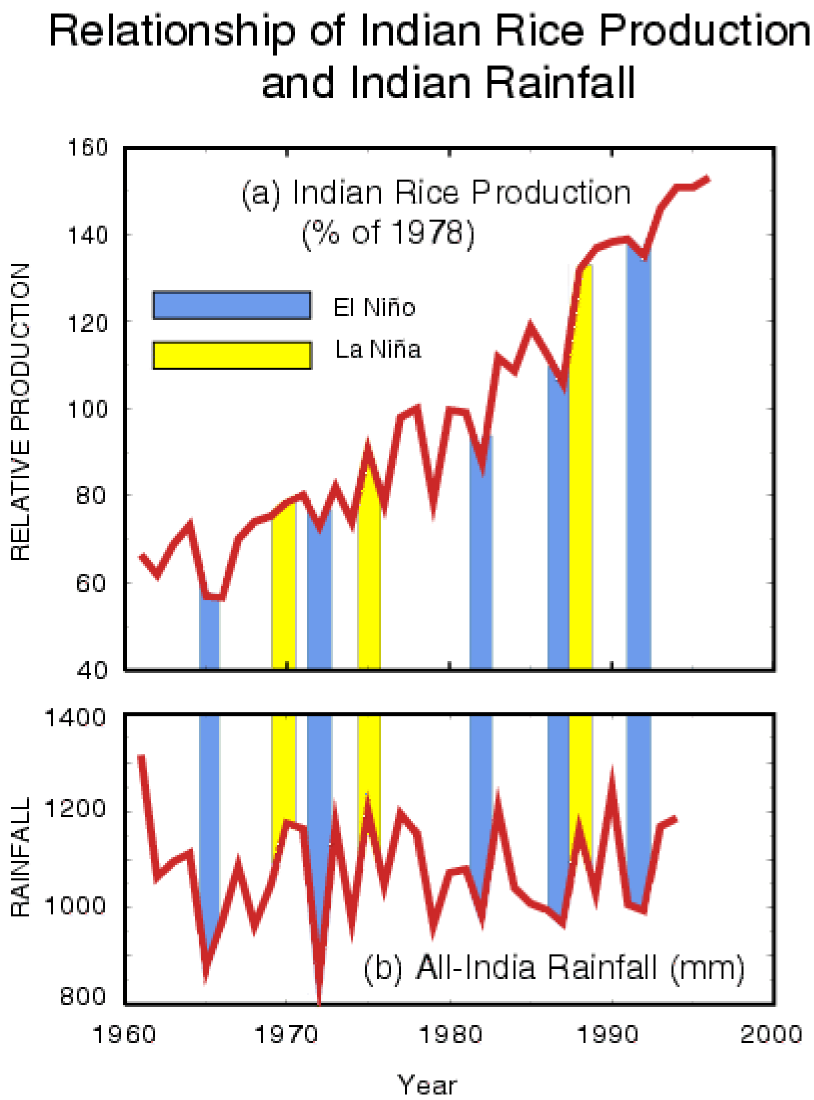
Quantification highly debated

Trade-offs (N content)

Temperature increase is good and bad

- allows increase of the growing season length in the actually temperature limited regions
- may allow more double cropping
- may favour a switch from summer wheat to winter wheat
- may reach temperature domain outside of the optimum for photosynthesis
- increases the respiration cost (less net primary production)
- accelerates the phenological development: a specific cultivar has less time to accumulate net primary production
- increases the evapotranspiration demand
- may damage crops (animals)
- increases the incidence of pest

Precipitation Fluctuations



(from Webster et al. 1998)

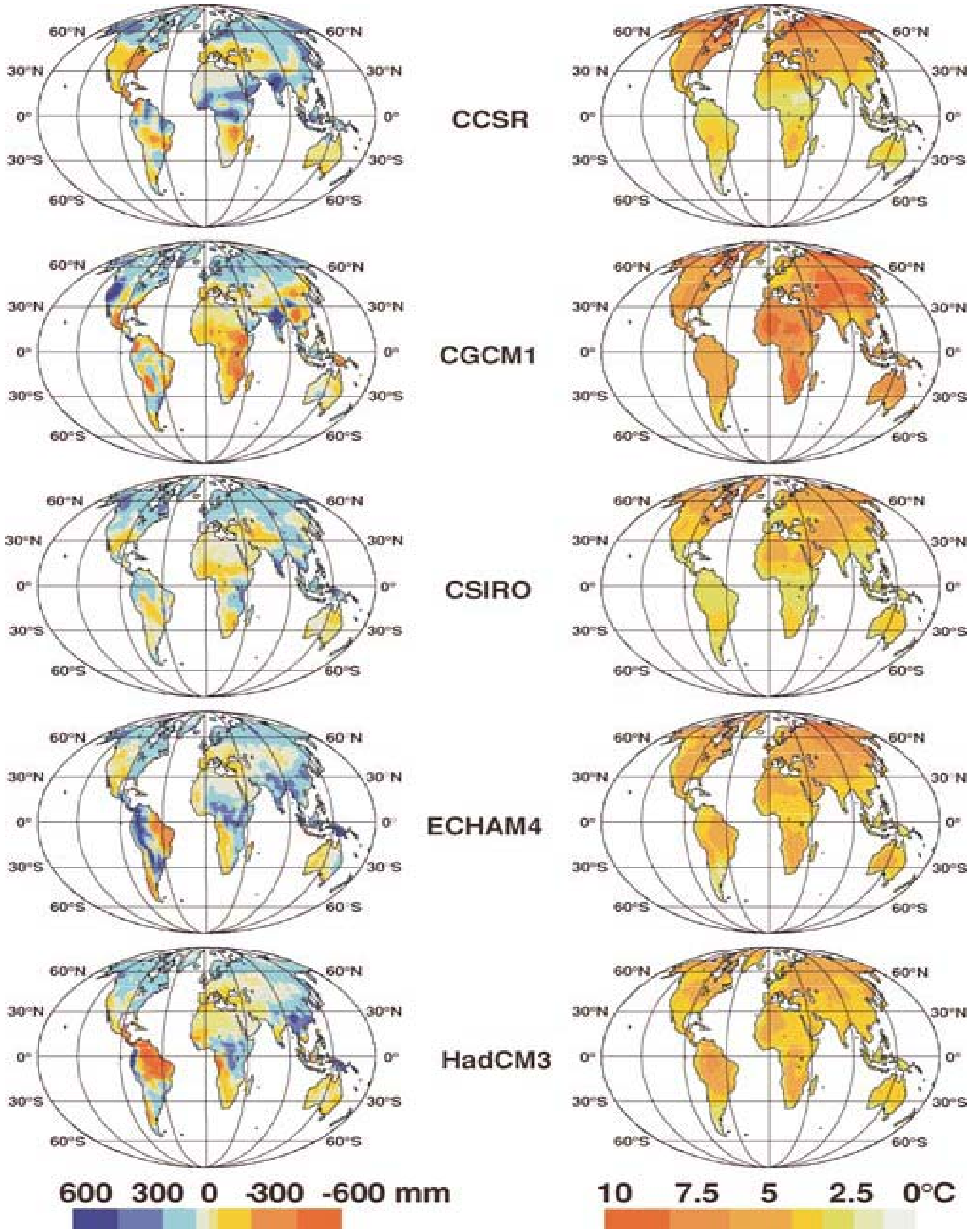
2009: the worse monsoon since 30 years:

- No rice export (apart Basmati)

- Farmers got advices to plant other crops requiring less water (pulses, legumes, etc)

Modelling future crop production **?**

Modelling food security **??**



Climate

Different GHGs emission scenarios

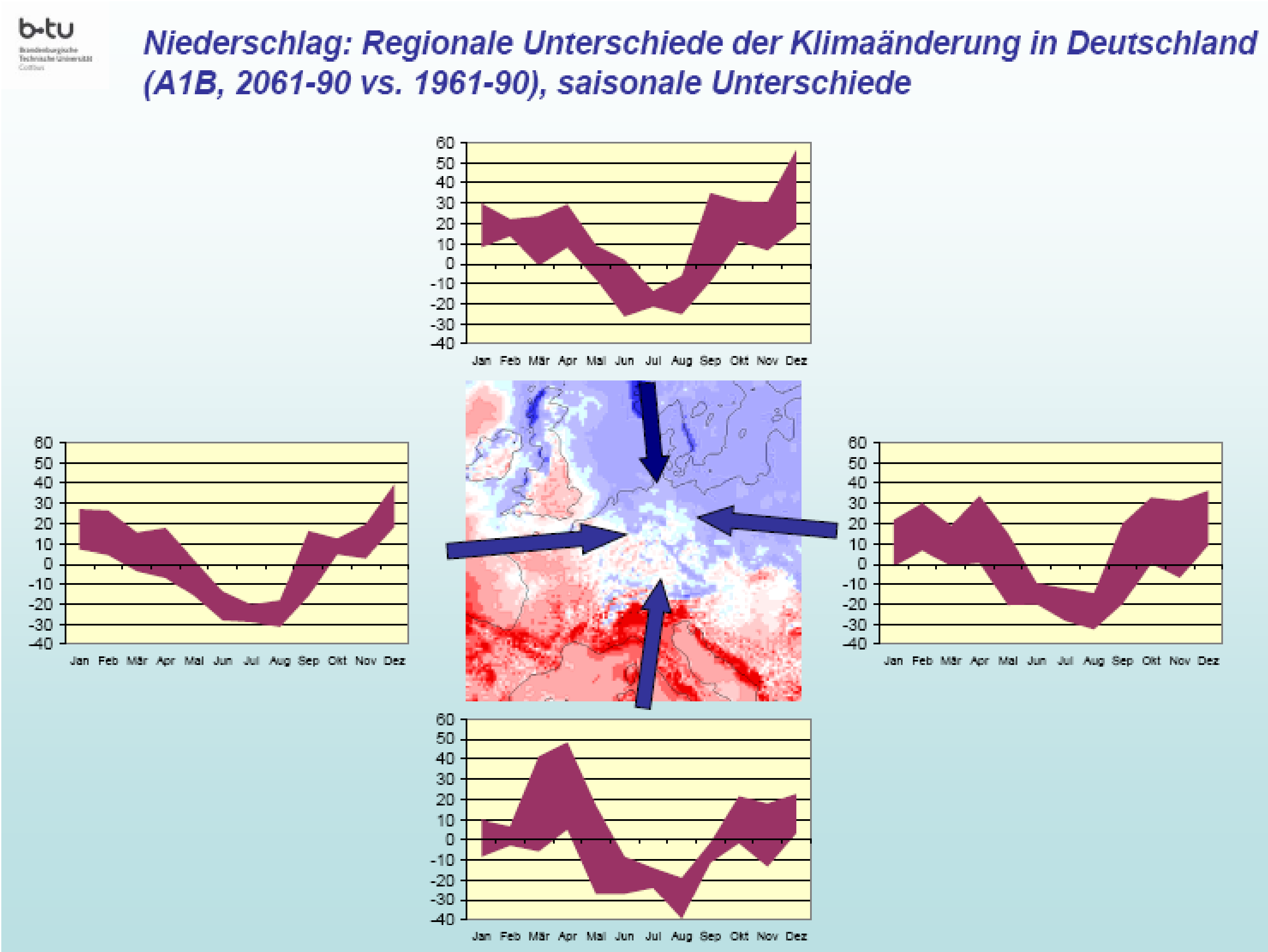
+

Different climate models (GCMs)

=> A large range of predicted future climates

Changes in annual precipitation [mm] and in annual mean surface air temperature [◦C], 2071–2100 vs. 1971–2000. Business as usual scenario IS92a
(Schaphoff et al. 2006)

Seasonal Climate



(Badeck, 2009)

Impact on agriculture
crops + grassland responses ?

- statistical models
- crop process-based models

Crop models

Imputs:

Soil

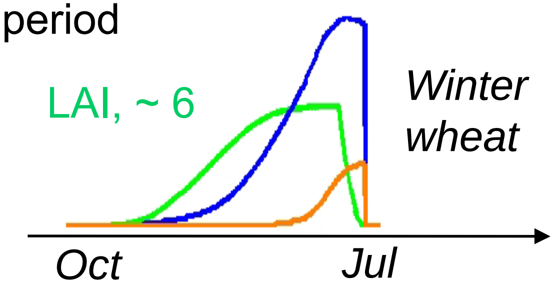
Monthly climate:

- Temperature
- Precipitation
- Solar radiation

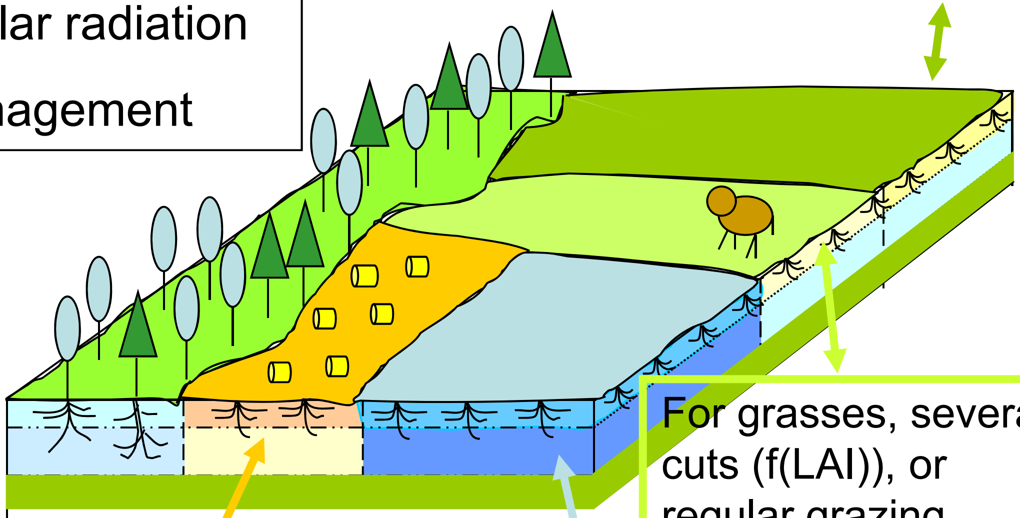
Management

Sowing date estimation:
for 4 temperate CFTs = f(T),
for 4 tropical CFTs = f(P)
Adaptation of heat sum and vernalization requirement

Daily coupled growth and development simulation:
Phenology, LAI change, carbon allocation to leaves, roots, storage organs, ...
Estimation of the harvesting period



Total biomass, ~ 15 tDM/ha
Grain harvested, ~ 6 tDM/ha



For grasses, several cuts (f(LAI)), or regular grazing

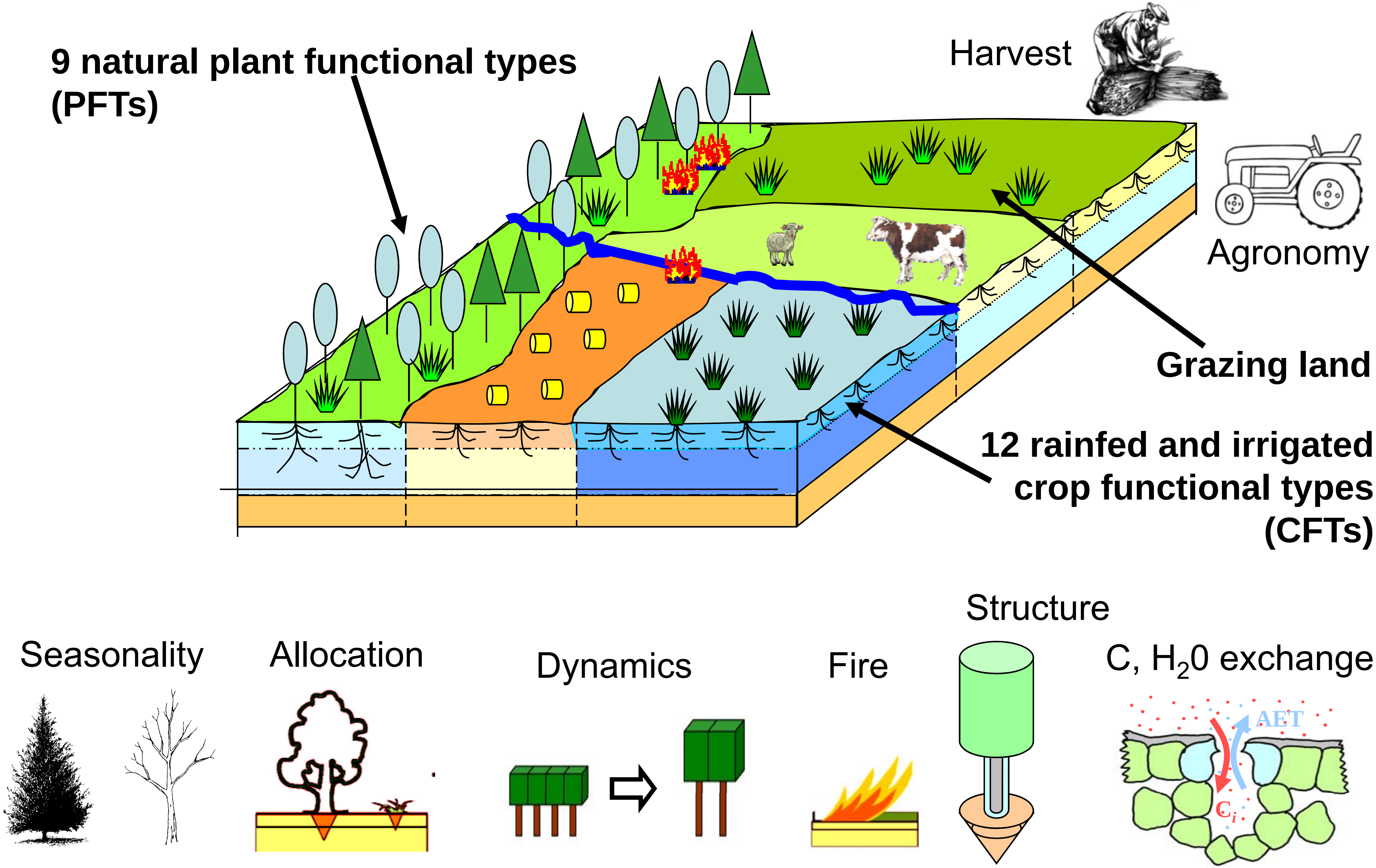
Multiple cropping (e.g. rice)
Grass as intercrop

Harvested biomass removed, residues added to the litter pool or removed (fodder, biofuel, ...)

No water stress for irrigated crops, computation of the water requirement and of irrigation

Deforestation
Afforestation

LPJmL dynamic vegetation and water balance model



Sitch et al 2003; Gerten et al. 2004; Bondeau et al. 2007

Sustainability: Alternatives to industrial agriculture?

The 'Western', technocratic view

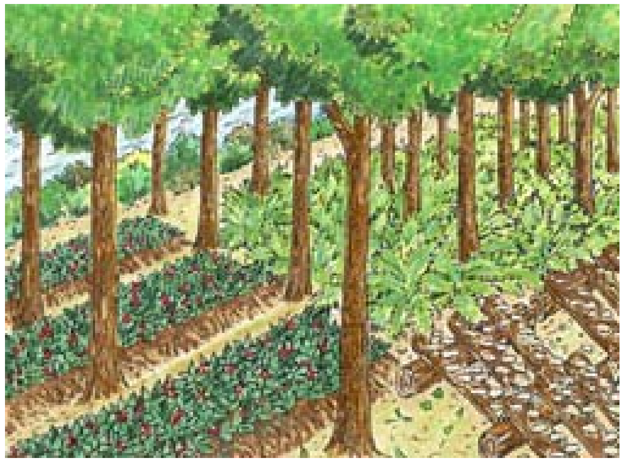
- Macro-irrigation
- Large dams
- River diversions
- etc.

- Fertiliser
- Breeding
- Genetic engineer.
- etc.

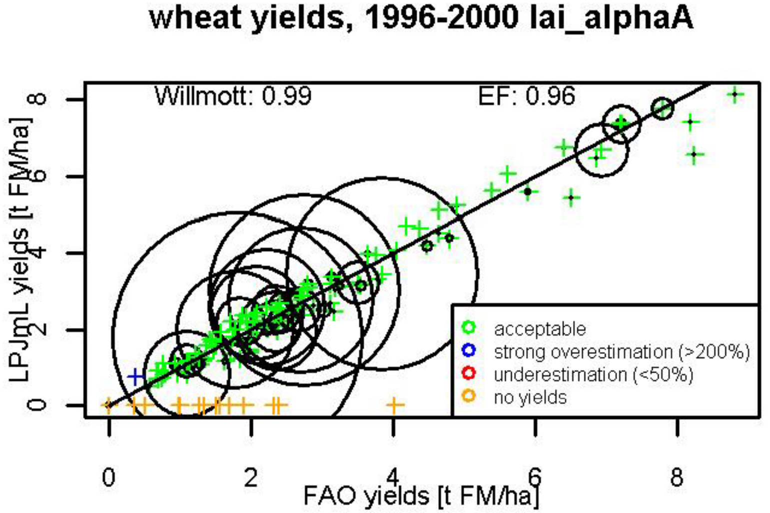
"Soft" water management

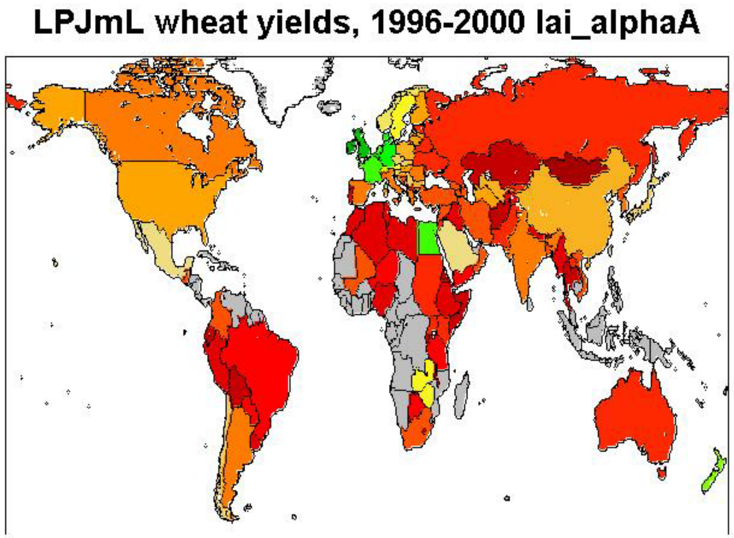
Agroecologic systems

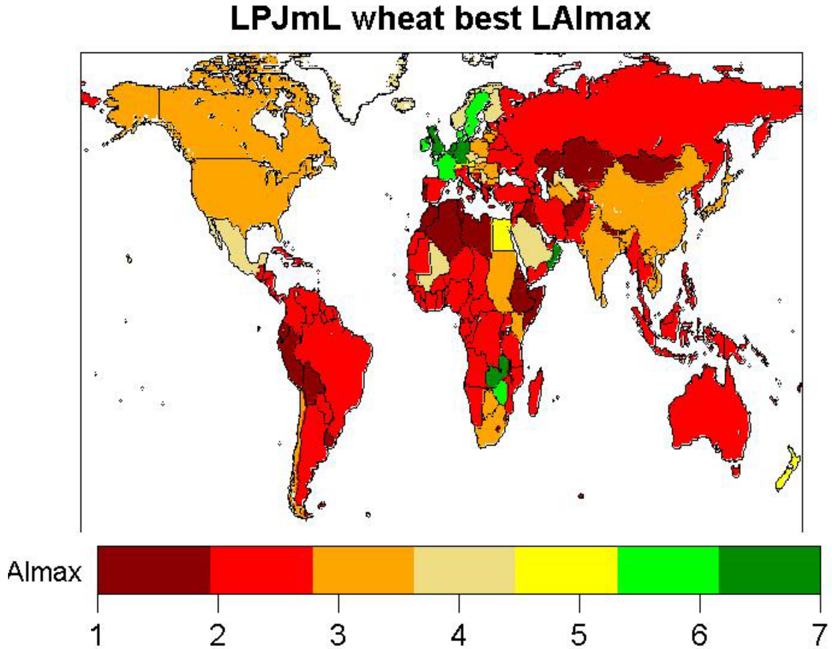
/ organic agriculture

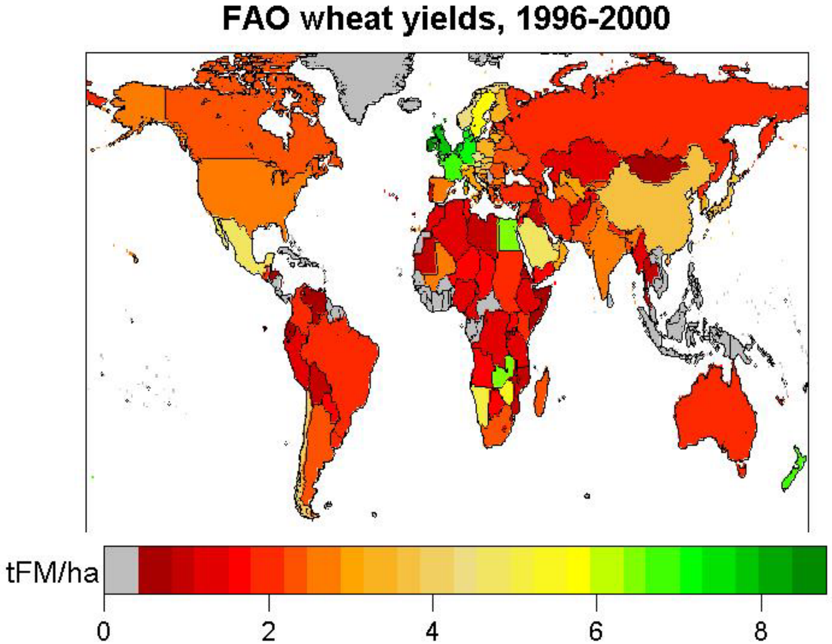


Yields validations



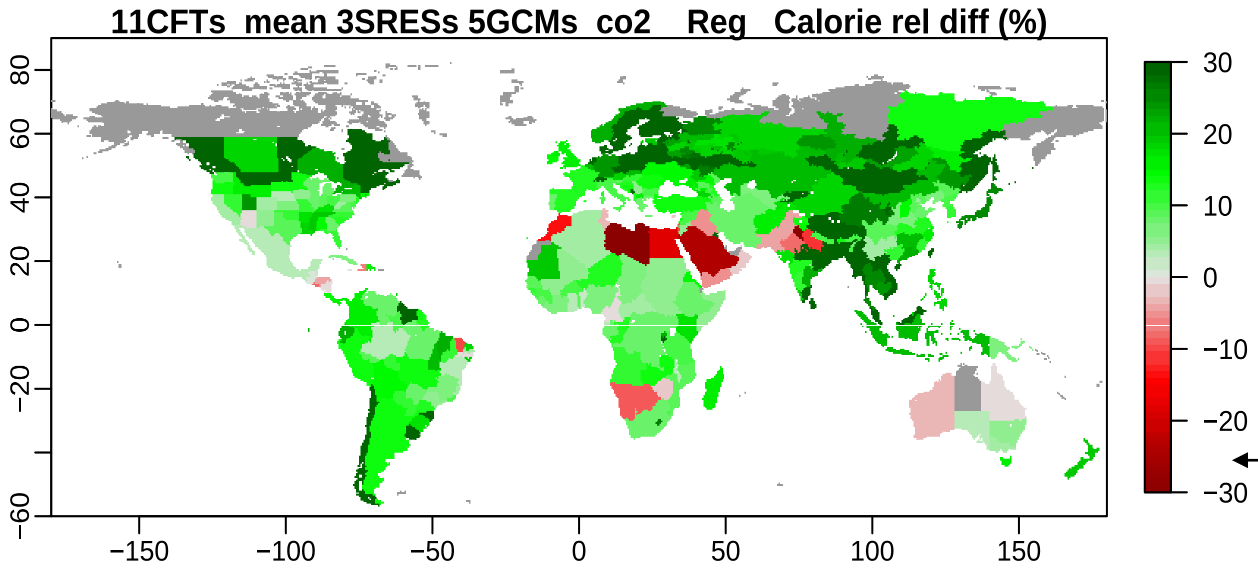






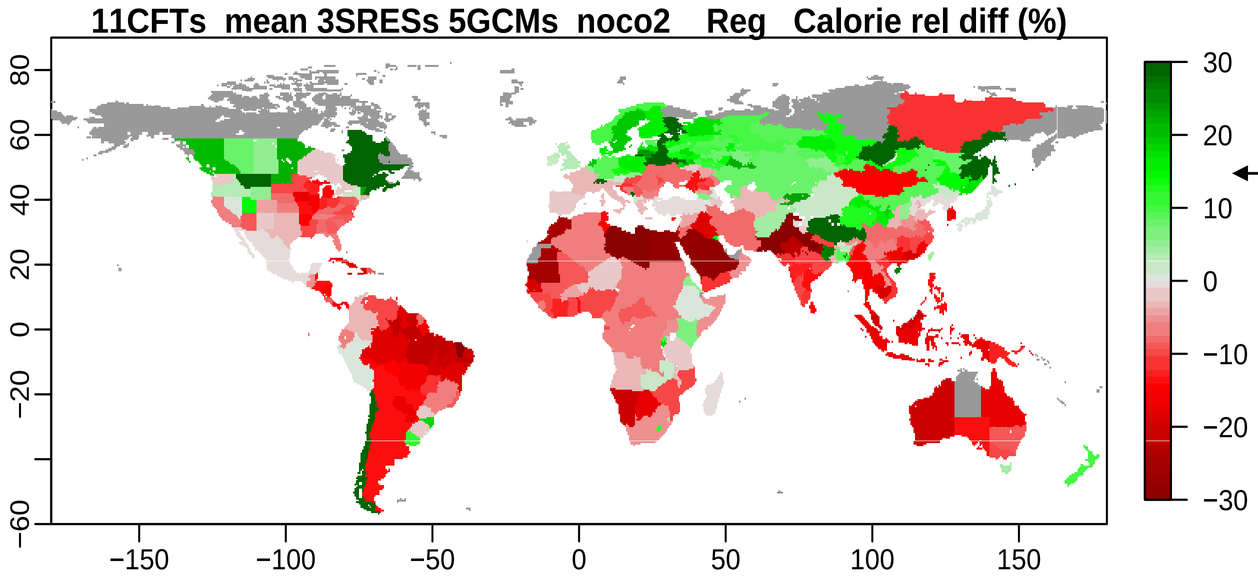
(Christoph Müller)

Change in relative calorie production under climate change



Management change: slight level of adaptation

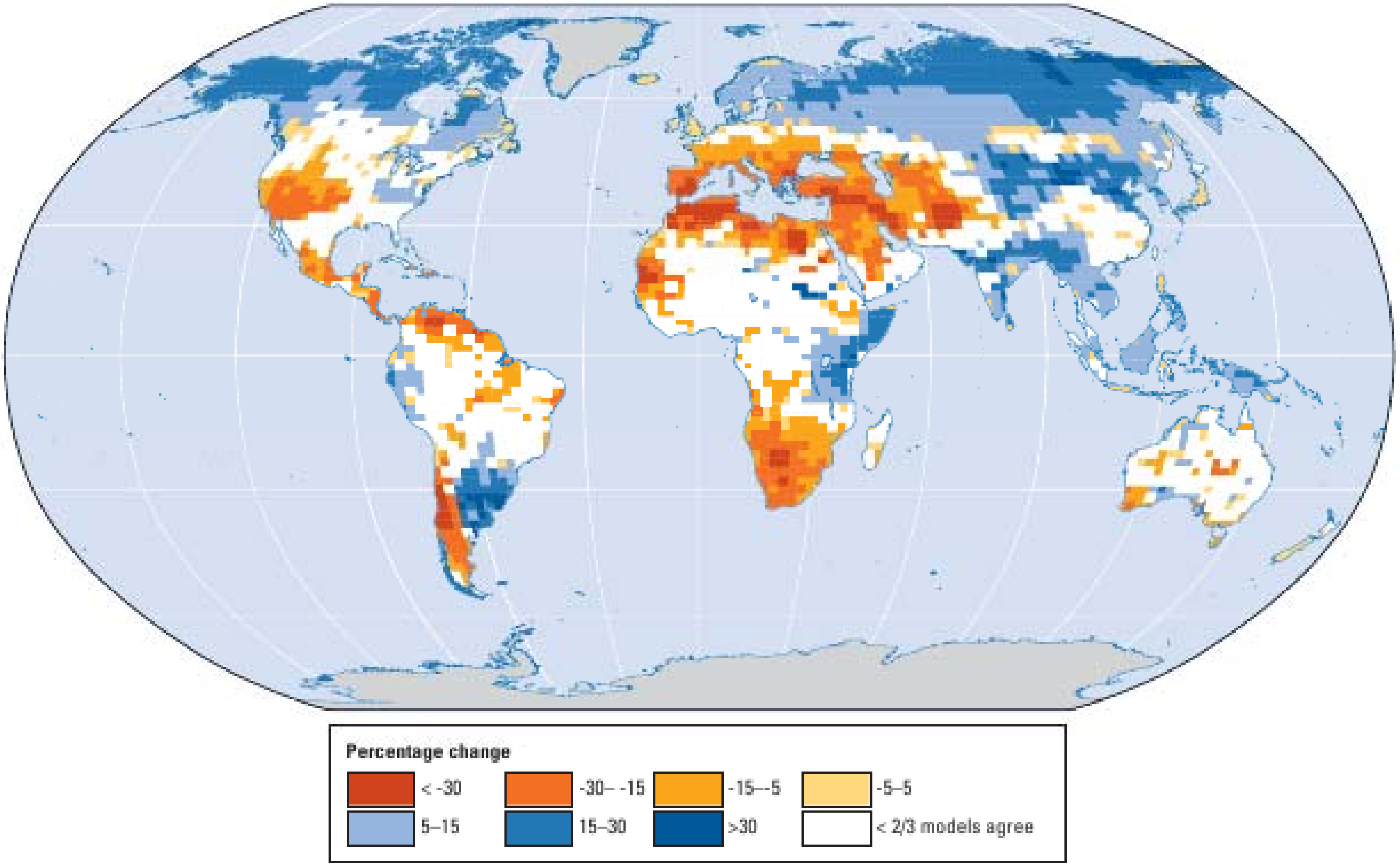
With CO_2 fertilization



Without CO_2 fertilization

(Müller et al, 2009, World Bank)

Future water avalability?

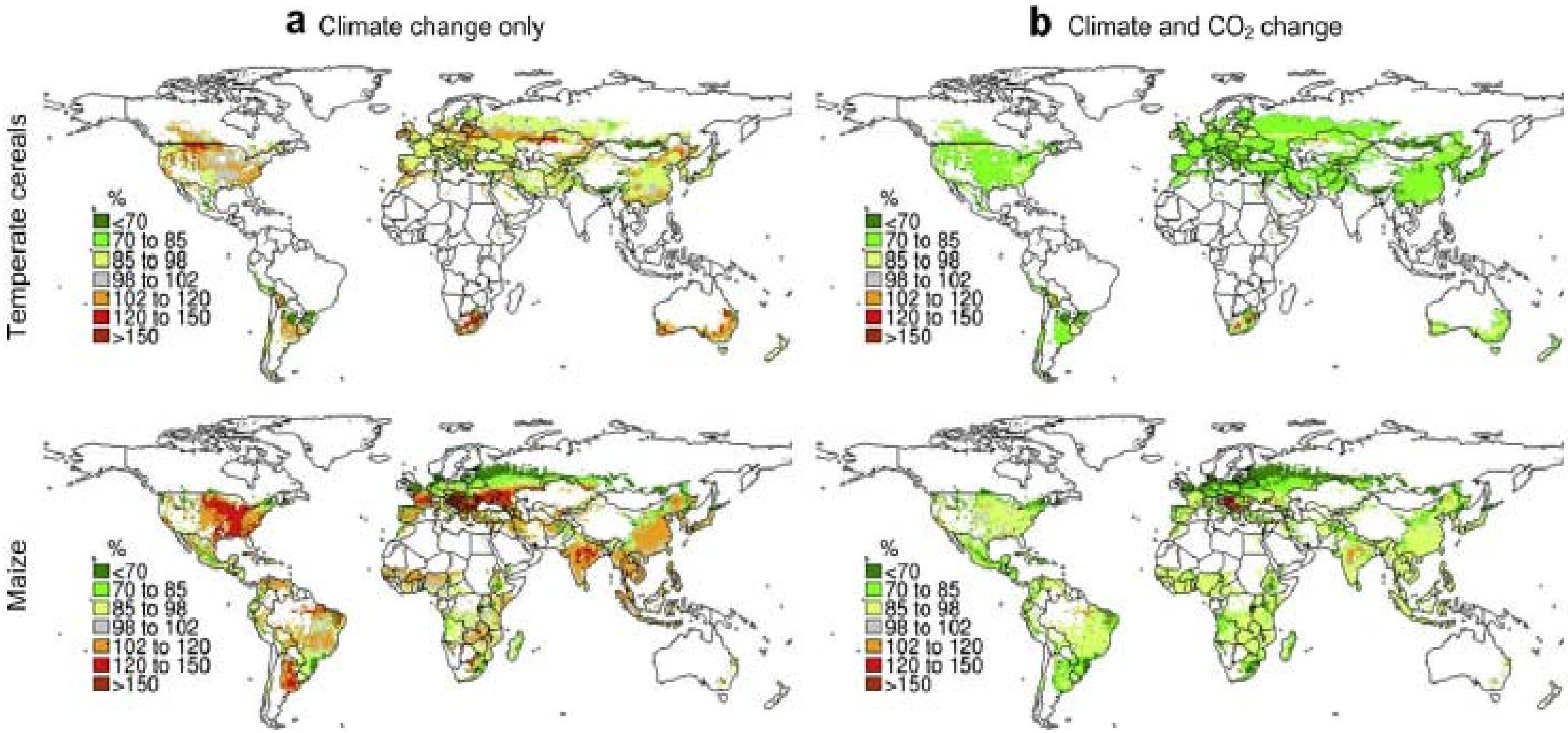


Water availability is projected to change dramatically by the middle of the 21st century in many parts of the world

(World Development Report 2009)

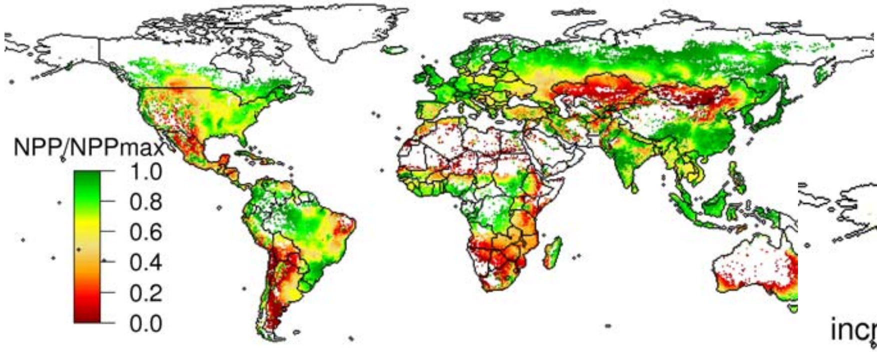
Virtual Water Content - water required per Kg grain: Changes under future climate and [CO_2] ?

Fader et al. "Virtual water content of temperate cereals and maize: Present and potential future patterns" *(Journal of Hydrology 2010)*



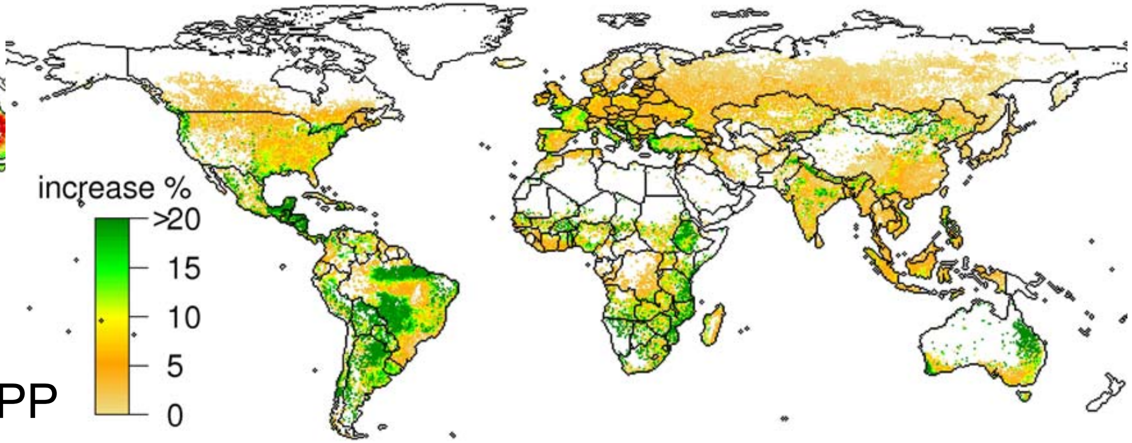
VWC change from 1971–2000 to 2041–2070 under HadCM3/A2

"Soft" paths to counter crop water limitation

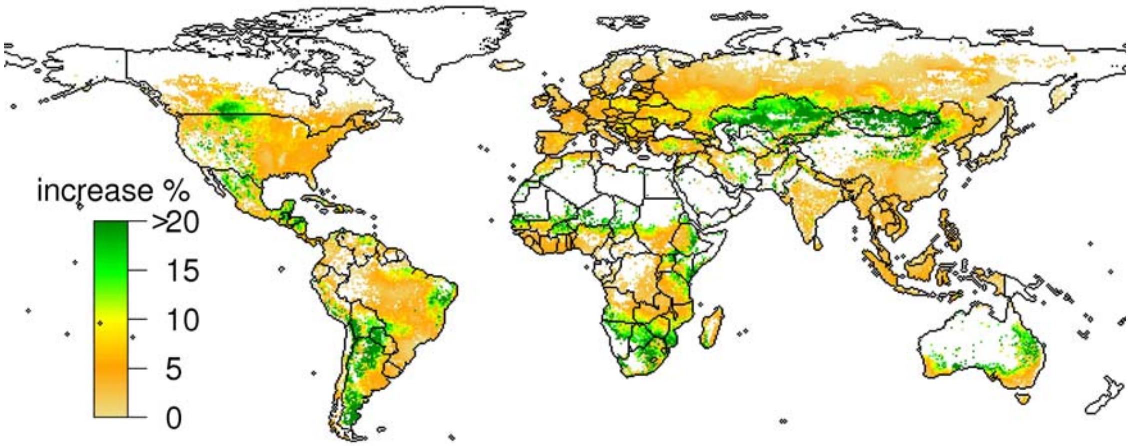


Current NPP water limitation

Percent increase in NPP



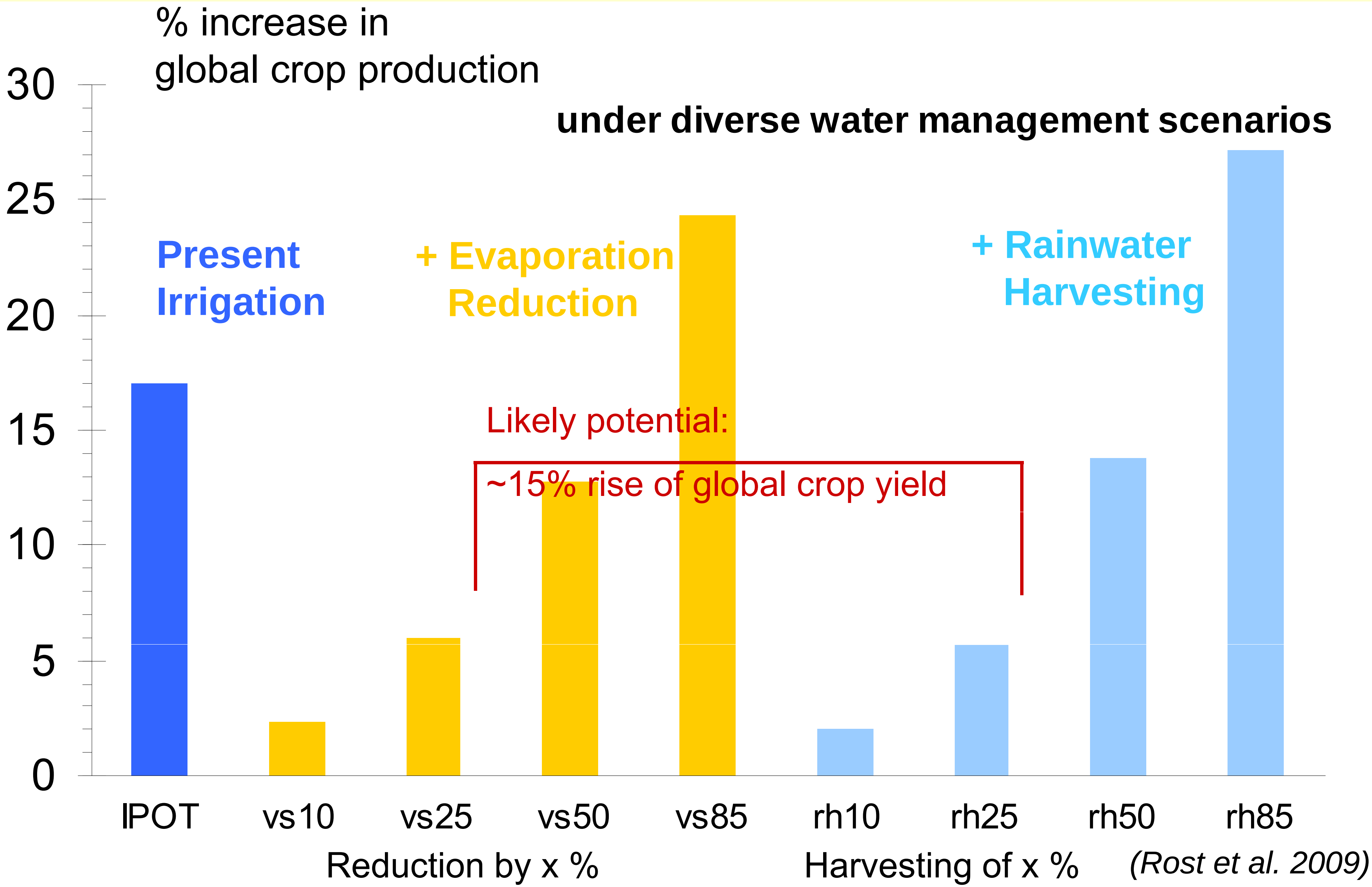
25% of rainfall harvested for irrigation



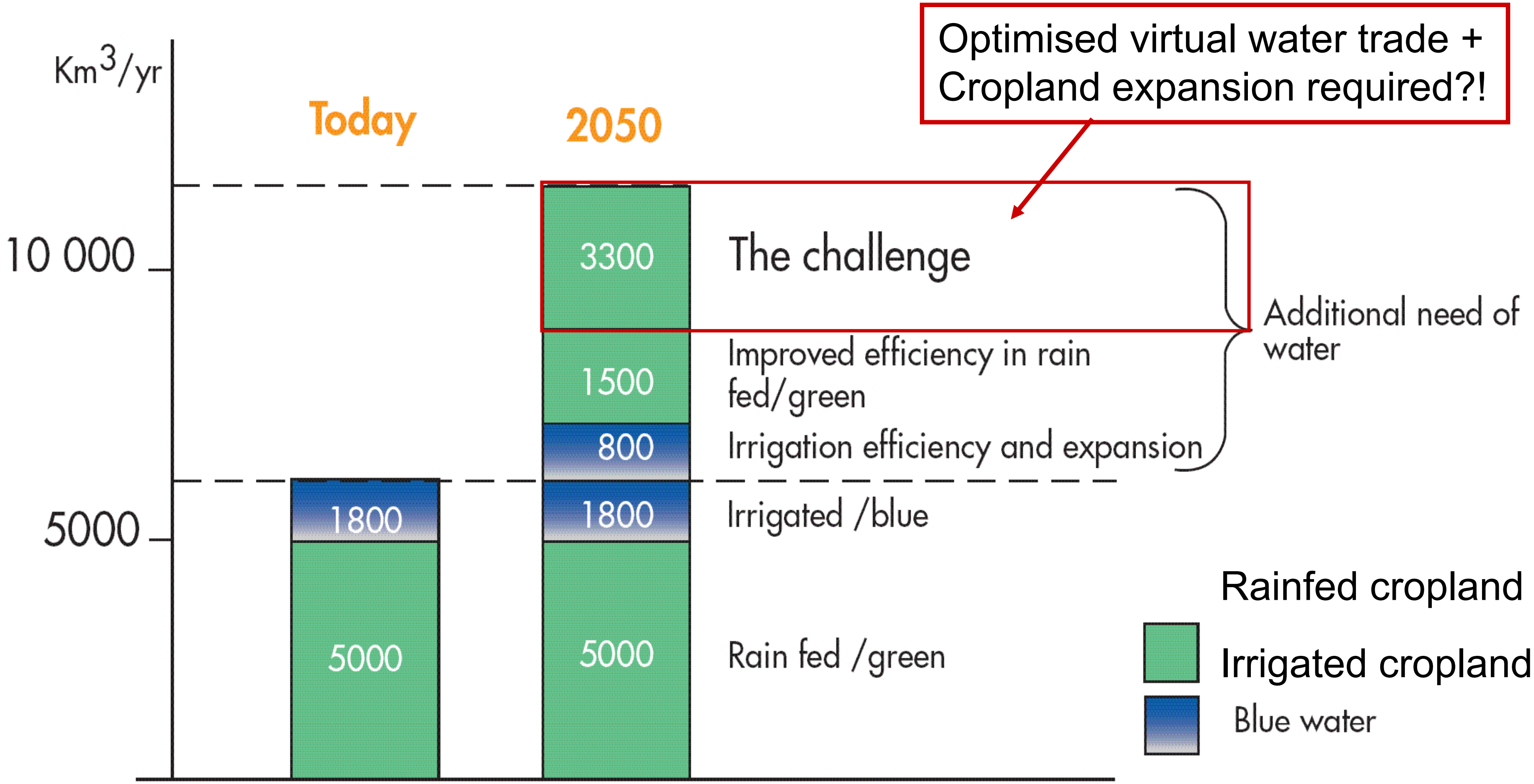
25% of soil evaporation reduced

(Rost et al. 2009)

Increase of crop production through water management



Will there be enough water for global food production?



Assumptions: 1300 km^3 yr^{-1} of water required for 3000 kcal cap^{-1}; no climate change; 9 billion people in 2050s

(after SIWI 2005)

System of Rice Intensification

SRI : methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients.

Originated: early 1980s, Fr. Henri de Laulanié (more than 34 years in Madagascar working with farmers)

SRI practices lead to healthier, more productive soil and plants by supporting greater root growth and by nurturing the abundance and diversity of soil organisms.

- Seed costs are cut by 80-90%

- Water savings of 25 to 50%

- Rice plants better able to resist damage from pests and diseases, reducing or eliminating need for agrochemical protection.

- Organic materials (compost, manure or any decomposed vegetation) can give good or even better results than fertilizers at low cost

- Yields increase (50-100%)

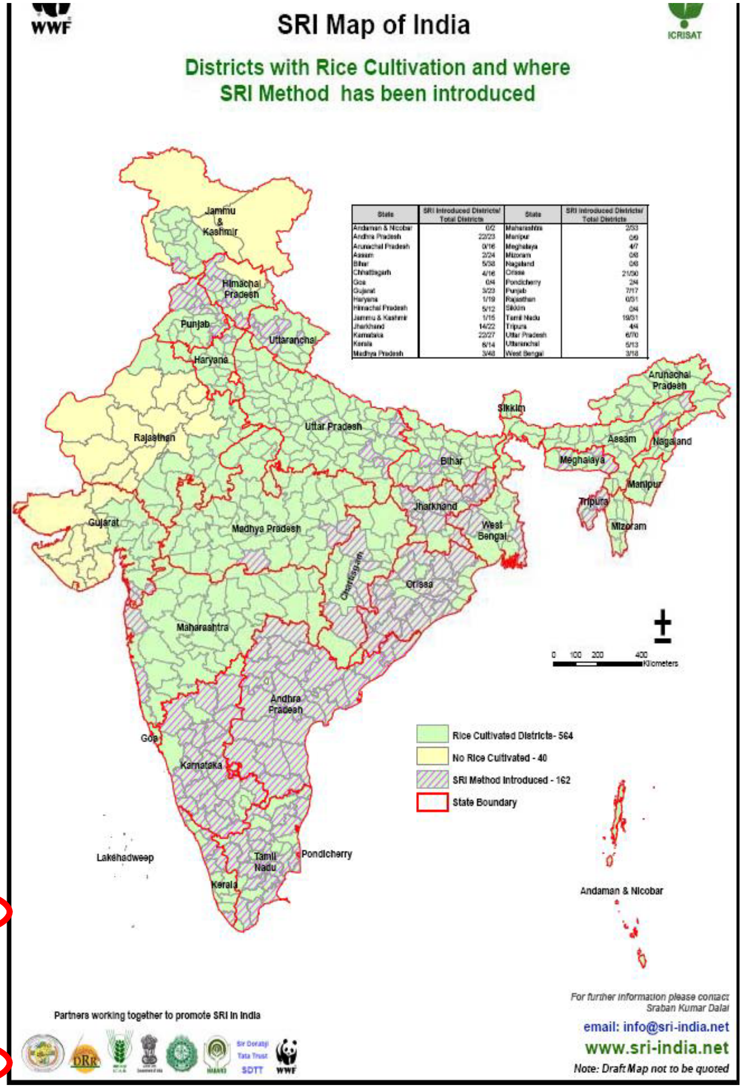
- SRI does require skillful management, and initially more labor.

System of Rice Intensification

Table 3.2: Economics of SRI vs. conventional method

Parameter		Unit	Conventional Method	SRI
Seed Rate		kg.	50	5
		Rate (Rs./kg.)	15.00	15.00
		Total Cost (Rs.)	750.00	75.00
Seedling per hill		Nos.	3-4	1
Seedling age		days	21-30	8-12
Spacing		sq. cm.	15X15	25X25
		sq. cm.	20X15	30X30
NPK Requirement		kg./ha.	80:40:40 (Kharif)	20:10:10 (Kharif)
			100:50:50 (Rabi)	25:12:12 (Rabi)
In terms of Fertiliser (Kharif)	Urea	kg.	174	64
	SSP		250	63
	MOP		65	17
	FYM		10000	10000
In terms of Fertiliser (Rabi)	Urea	kg.	217	54
	SSP		312	75
	MOP		83	20
	FYM		10000	10000
Rate per Kg	Urea	Rs./kg.	5.25	5.25
	SSP		5.00	5.00
	MOP		6.49	6.49
	FYM		0.30	0.30
Total Fund involvement for Fertiliser (Kharif)	Urea	Rs.	913.50	231.00
	SSP		1250.00	315.00
	MOP		421.85	110.33
	FYM		3000.00	3000.00
	Total		5585.35	3656.33

Parameter		Unit	Conventional Method	SRI
Total Fund involvement for Fertiliser (Rabi)	Urea	Rs.	1139.25	283.50
	SSP		1560.00	375.00
	MOP		538.67	129.80
	FYM		3000.00	3000.00
	Total		6237.92	3788.30
Water Requirement	Kharif	mm	1800	900
	Rabi	mm	2000	1000
No. of irrigation to be given		Nos.	7	3
Rate per irrigation per hectare		Rs.	300.00	300.00
Total requirement for irrigation		Rs.	2100.00	900.00
Labour requirement		Nos. days	125	115
Rate per Labour		Rs.	63.00	63.00
Total requirement for Labour		Rs.	7875.00	7245.00
PPC (Lump sum)		Rs./ha.	500.00	500.00
Tillage Operation		Rs./ha.	2500.00	2500.00
Grand Total Cost of Cultivation			19962.92	15008.30
			20000.00	15000.00
Average Yield (M.T./ha.)		M.T.	5.0	7.5
Market Value		Rs./M.T.	7000.00	7000.00
Gross return		Rs./ha.	35000.00	52500.00
Net return		Rs./ha.	15000.00	37500.00
Benefit-Cost Ratio			1.75	3.50



WWF 2007, Experience of SRI in Tripura, India

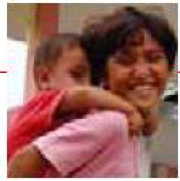
SRI methods: success after the Tsunami

réalisés en Inde, vous pouvez vous rendre sur le site www.asie.croix-rouge.fr rubrique « Terrain », onglet « Inde ».

EXEMPLE :

● « **Des terres à nouveau fertiles** »

L'objectif de ce projet est, à court terme, d'assurer des revenus aux agriculteurs et à long terme, de former les 4 000 agriculteurs de la région de Pondichéry aux méthodes agricoles organiques, à la fertilisation des terres et à la prévention de la malnutrition. Les rendements des rizières ont doublé grâce aux méthodes biologiques employées pour relancer la culture dans cette région ravagée par le tsunami.



TSUNAMI 3 ANS APRÈS :
État des lieux des actions engagées par la Croix-Rouge française

9

Urgence secourisme
Action sociale
Santé - Dépendance
Formation
✚ Action internationale

croix-rouge française

(French red cross press release „Tsunami 3 years later" December 2007)

With the use of exclusively agroecological methods and important labor:

In one year: higher yields than before and than in the conventional fields of neighboring villages not part of the project.

YouTube video: „800 familles pour une rizière"

http://asie.croix-rouge.fr/article.php3?id_article=249

SRI & climate fluctuations

- more stable yields

$\Rightarrow$ less vulnerability to bad monsoons (The Hindu, 2009)

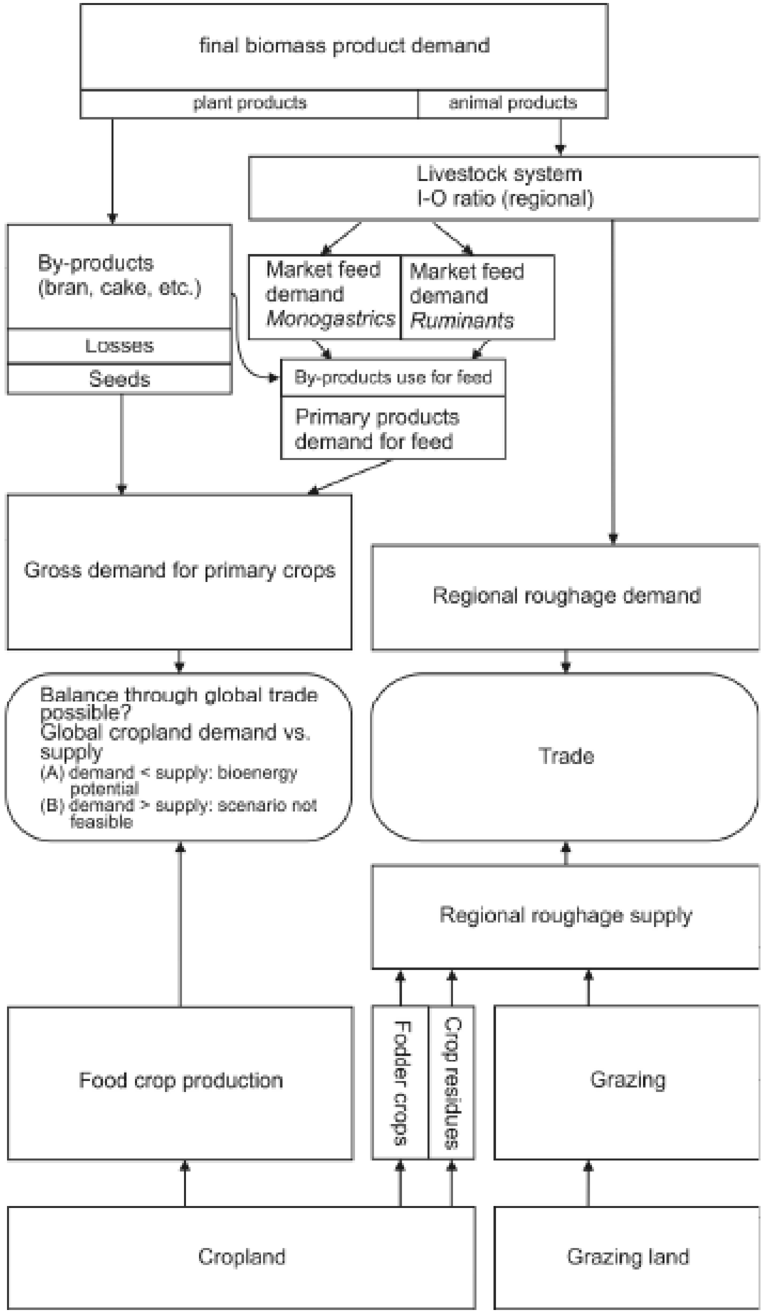
$\Rightarrow$ extension supported by the World Bank

SOCIAL ECOLOGY WORKING PAPER 116

Karl-Heinz Erb • Helmut Haberl • Fridolin Krausmann • Christian Lauk • Christoph Plutzar • Julia K. Steinberger • Christoph Müller • Alberte Bondeau • Katharina Waha • Gudrun Pollack

Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely– a scoping study

November 2009



Biomass-balance model

…

From the literature review, we conclude that organic yields per harvest event (i.e. the yield of a wheat field harvested once) are only slightly (approximately 10%) lower than those of industrialised agriculture (see also IAASTD, 2009). However, organic agriculture requires additional area for planting of leguminous crops and other intercrops that are required to maintain soil fertility; most of these crops have to be ploughed into the soil and are not, or only to a limited extent, available as feed. **We estimate that yields in organic agriculture are about 40% lower than those of industrialised agriculture, if calculated over the whole crop rotation cycle**. This comparison is only valid for regions with highly intensive cropland systems. **In developing countries, we conclude from our review of the literature that organic agriculture could allow for considerable increases in yields**, because the nutrient status of croplands is often very poor and can be improved significantly with organic techniques.

…

Table S3. Diet scenarios for 2050 compared to the situation in the year 2000.

	Dietary energy		Protein		Share of protein from animal products	Business-as-usual evolution of diet	Globally equitable distribution of food
	[kcal/cap/ day]	[fraction of 2000 value]	[g/cap/ day]	[fraction of 2000 value]			
Status in 2000	2 788		75		37%		
Western high meat	3 171	(114%)	92	(122%)	44%	X	
Current trend	2 993	(107%)	79	(106%)	38%	X	
Less meat	2 993	(107%)	74	(98%)	30%		
Fair less meat	2 800	(100%)	75	(100%)	20%		X

Diet

Conclusion: Our findings strongly underline the view that the share of animal products in human diets has a strong effect on environmental impact, the possibility to produce animal products humanely or through organic livestock rearing.

Recommendation: Any effective measures to reduce the level of consumption of animal products (including those derived from eggs and milk) are beneficial in terms of environmental impacts, animal welfare, biodiversity, and bioenergy potential.

Organic Agriculture

Conclusion: We provide evidence that organic agriculture can probably feed a world population of 9.2 billion in 2050, if relatively modest diets are adopted, where a low level of inequality in food distribution is required in order to avoid malnutrition. This conclusion is based on the best currently available data on system-wide yield levels of organic cropland agriculture as compared to intensive crop production systems. If agricultural research were to succeed in developing higher-yielding variants of organic agriculture, richer diets based on organic agriculture could be achieved. Judging to what extent this is feasible is beyond the scope of this study. We clearly show that the extent to which foreseen diet trajectories have to be modified towards less rich diets strongly depends on the ability to reach higher yields in organic or environmentally less demanding agriculture.

Recommendation: We therefore recommend to direct research and technical development towards agricultural practices that follow organic standards or are otherwise environmentally less destructive and are nevertheless able to achieve high yield levels.

Humane and environmentally friendly farming

Conclusion: We provide strong evidence that neither humane livestock rearing systems nor environmental objectives in cropland farming should be discarded based on claims that these practices would jeopardize food security. To the contrary, we did not find a strong effect on the feasibility of scenarios of feeding efficiencies and the additional area demand of free-range systems for monogastric species associated with humane or even organic livestock rearing standards. While a transition to wholly organic cropland agriculture (100% of the area planted according to organic standards) seems to be challenging in terms of the changes in diets and the need for an equitable distribution of food in such a scenario, we find that even the intermediate yield scenario (that might, for example, be achieved by organic agriculture on 50% of the area, if the other 50% were as intensively cultivated as foreseen by the FAO) would be able to deliver a 'current trend' diet in 2050.

Recommendation: We therefore recommend a continuation of support for organic and other environmentally benign agricultural management practices, while at the same time trying to optimize yields and efficiencies without adopting unsustainable or inhumane technologies and practices. Our calculations suggest that there is no need to boost yields and efficiencies regardless of the costs in terms of environmental pressures and animal welfare