



Designing and assessing climate-smart cropping systems in temperate and tropical agriculture

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CLIMATE-SMART
Agriculture
20**15**



Global Science Conference

March 16-18, 2015
Le Corum, Montpellier France

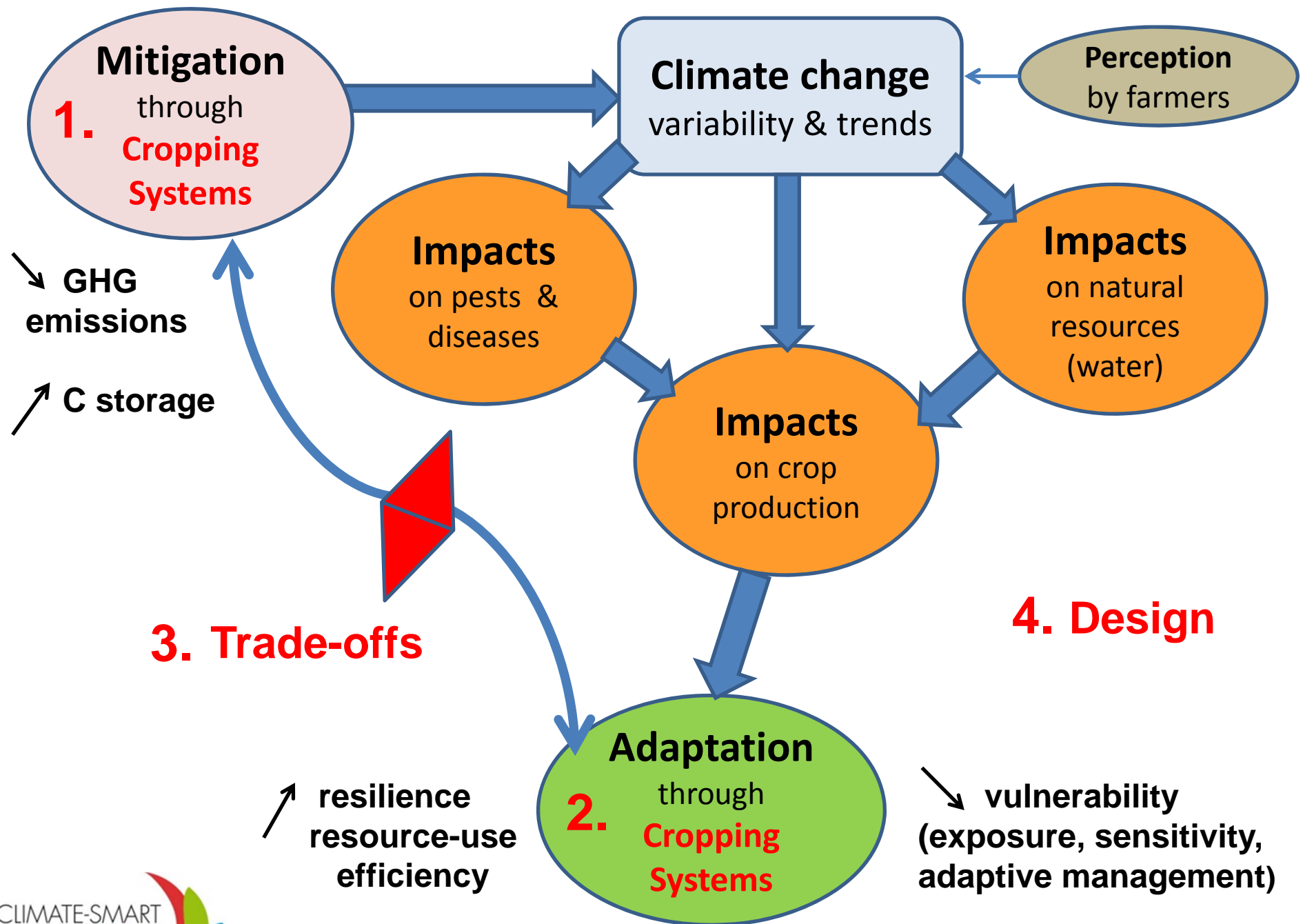
Designing and assessing climate-smart cropping systems in temperate and tropical agriculture

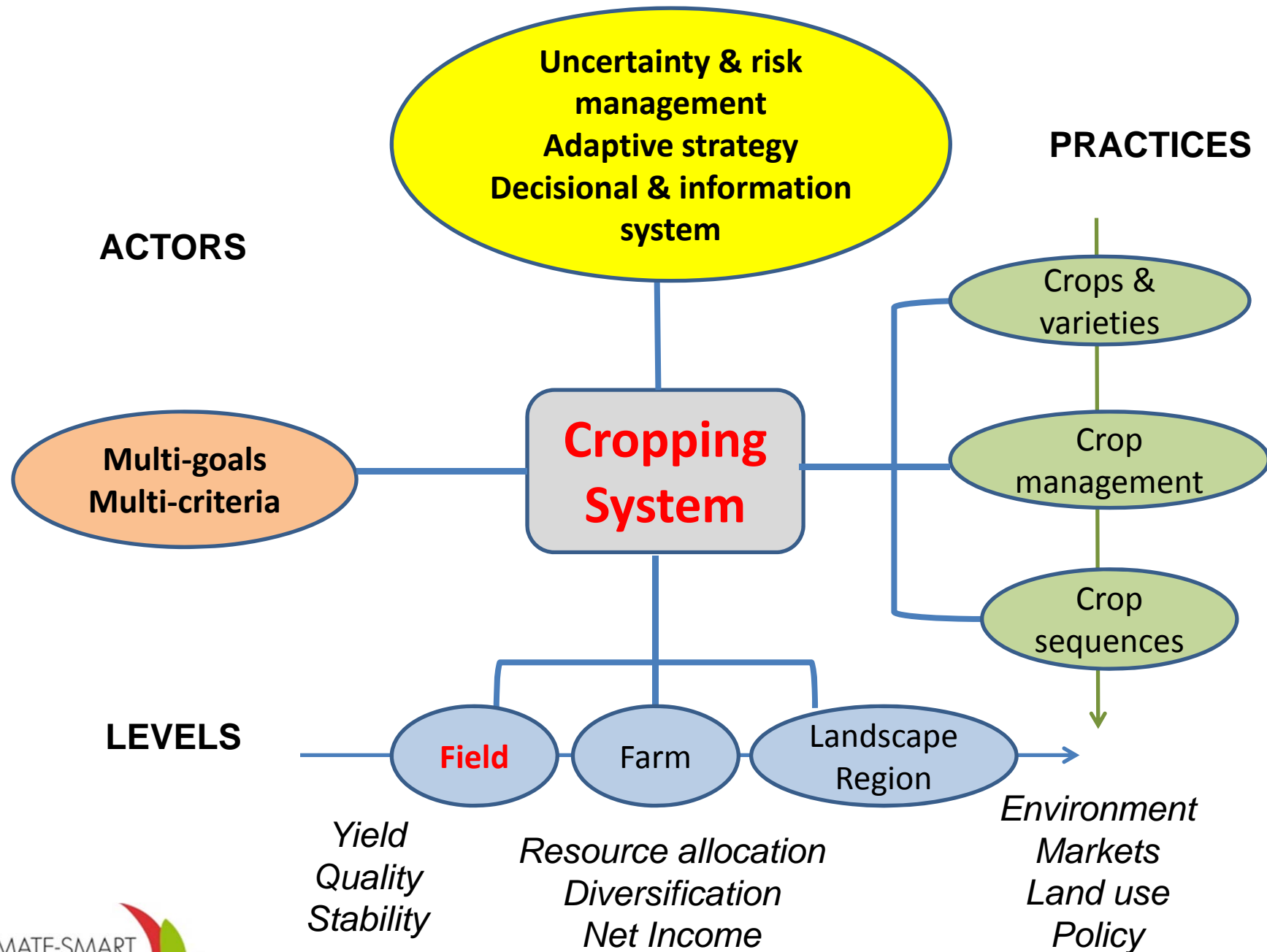
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¹INRA ²CIRAD



Montpellier
March 16-18, 2015





1. Mitigation options involving cropping systems

Levers	Technical options	Expected effect
N fertilisation	More legumes in crop rotations Adjust N mineral fertiliser application rates & dates, make better use of organic fertiliser, use nitrification inhibitors, incorporate fertilisers (to reduce losses)	↘N ₂ O
Soil tillage	Reduce tillage (direct seeding, occasional tillage, shallow tillage)	↘CO ₂ (fuel) ↗C storage
Cover crops and residue management	More cover crops in arable cropping systems, in vineyards and orchards Grass buffer strips	↗C storage ↘N ₂ O
Trees in agrosystems	Agroforestry (low planting density) (Re)-planting field hedgerows	↗C storage
Grassland management	Extend the grazing period, increase the lifespan of temporary grazing, extensify the most intensive grasslands, make unproductive grasslands more intensive	↗C storage ↘N ₂ O
Paddy rice management	Promote aeration of rice-growing soil to reduce fermentation reactions: reduce the depth of paddy fields, empty them several times a year,...	↘CH ₄

In temperate, intensive agricultural contexts a major part of the cost-effective abatement potential is related to N management



A recent advanced study by INRA on French agriculture (Pellerin et al., 2013)

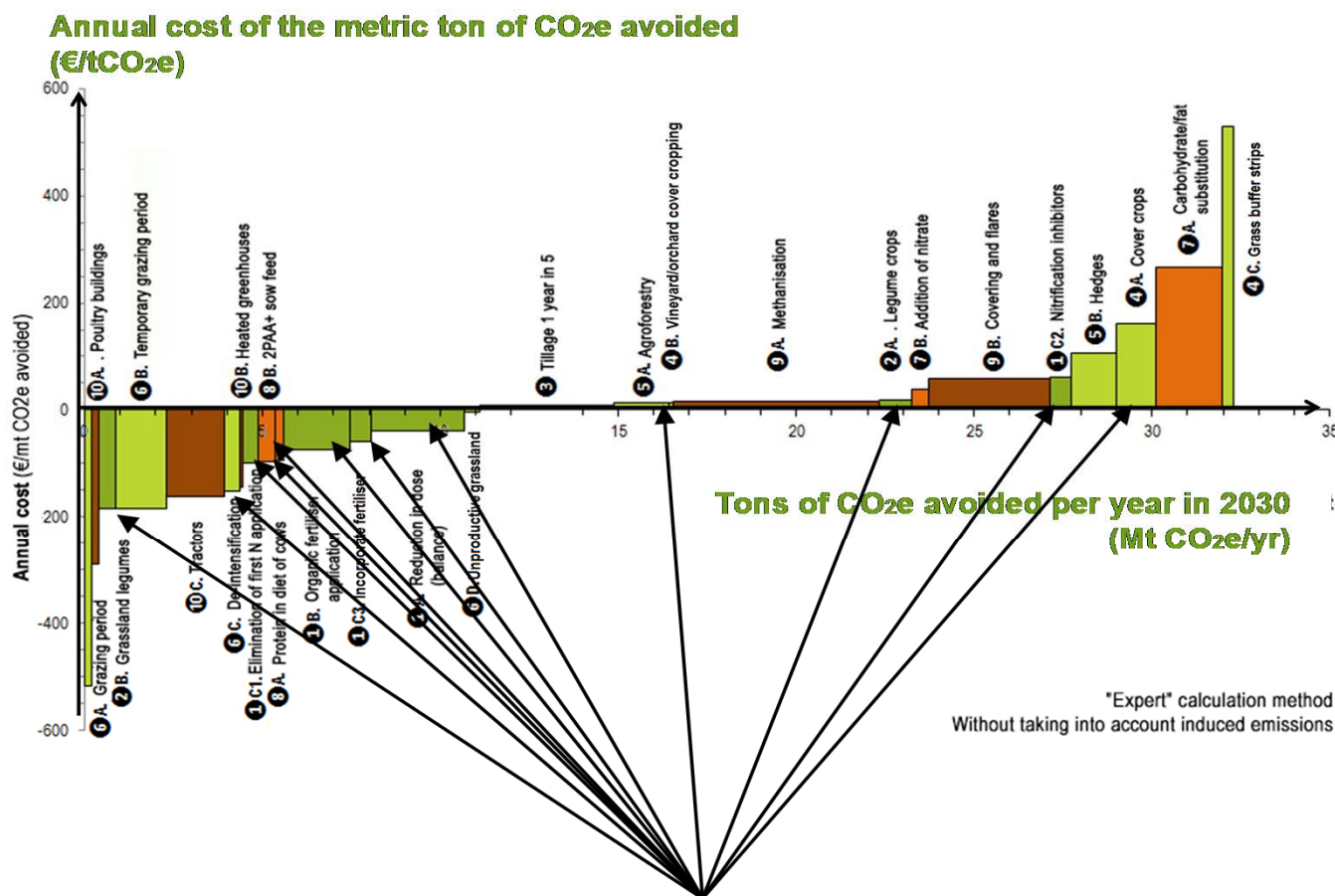
26 proposed technical measures to reduce agricultural GHG emissions :

- Calculation of the abatement potential (Mtons of CO₂e avoided per year)
- Calculation of the cost to the farmer (€ per ton of CO₂e avoided)

► **26% of the cumulated abatement potential was related to N management (N fertilization, legumes, cover crops,...)**

Most measures targeting a reduction of N₂O emissions were characterised by a negative cost (input savings, no yield losses) → **“win-win measures”**

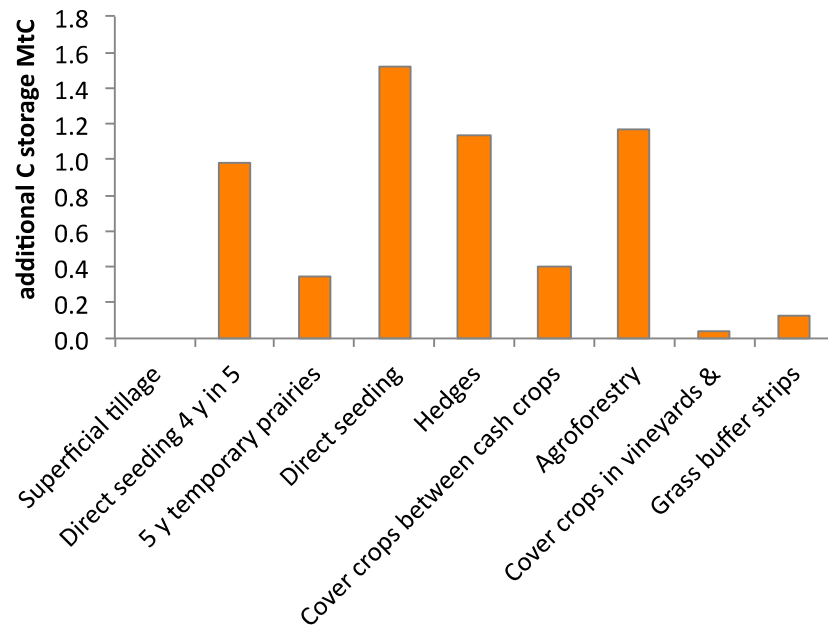
However, the assessment of their potential abatement was characterized by a very high uncertainty



Measures targeting a reduction of N₂O emissions

Management practices that increase effectively SOC are based on :

- a reduction of mineralisation rate (e.g reduced tillage)
- an increase of C inputs in soils (e.g. organic fertilisers, cover crops, agroforestry...)



**Total
France (2030) :
30% abatement
potential**

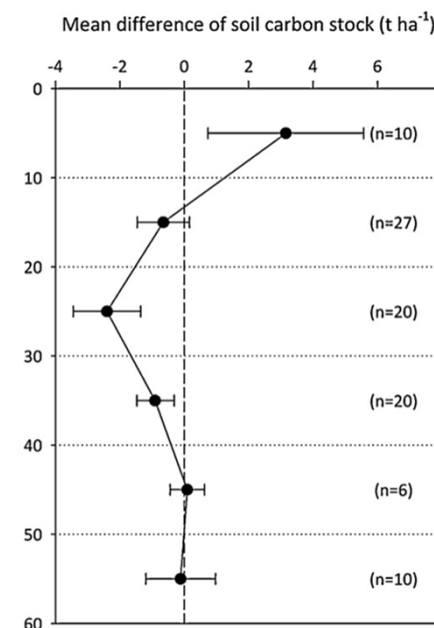
Recent meta-analyses have shown that additional C storage is not always observed under reduced tillage

Changes in soil C stocks depend on:

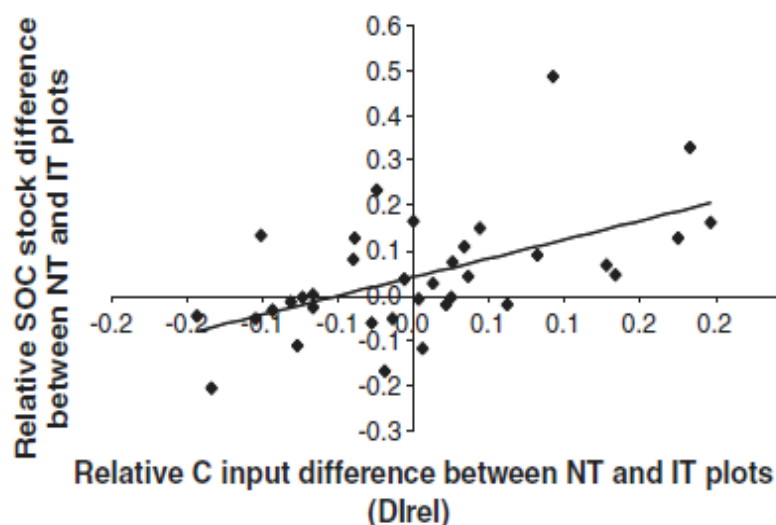
- biomass production (and subsequent C inputs as crop residues) under reduced tillage
- climatic context (more C storage under dry conditions)

Even where no additional C storage is observed, reduced tillage reduces GHG emissions thanks to less energy consumption

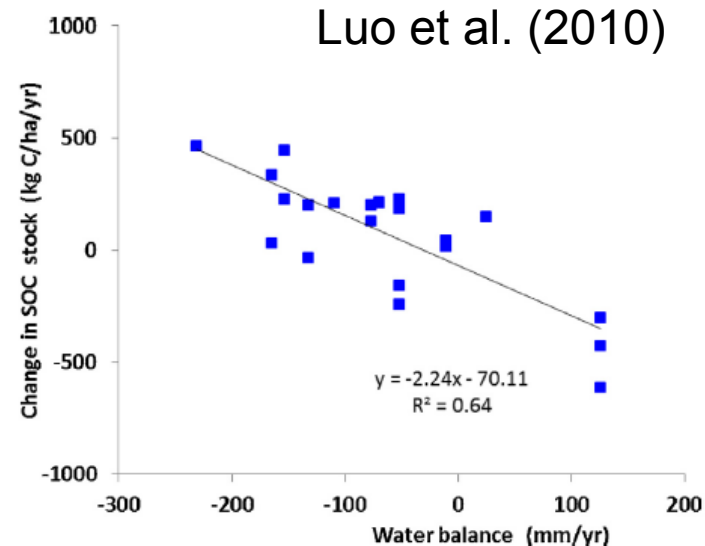
No-Till (NT) vs Full-Inversion Tillage (FIT)



Luo et al. (2010)



Virto et al. (2012)

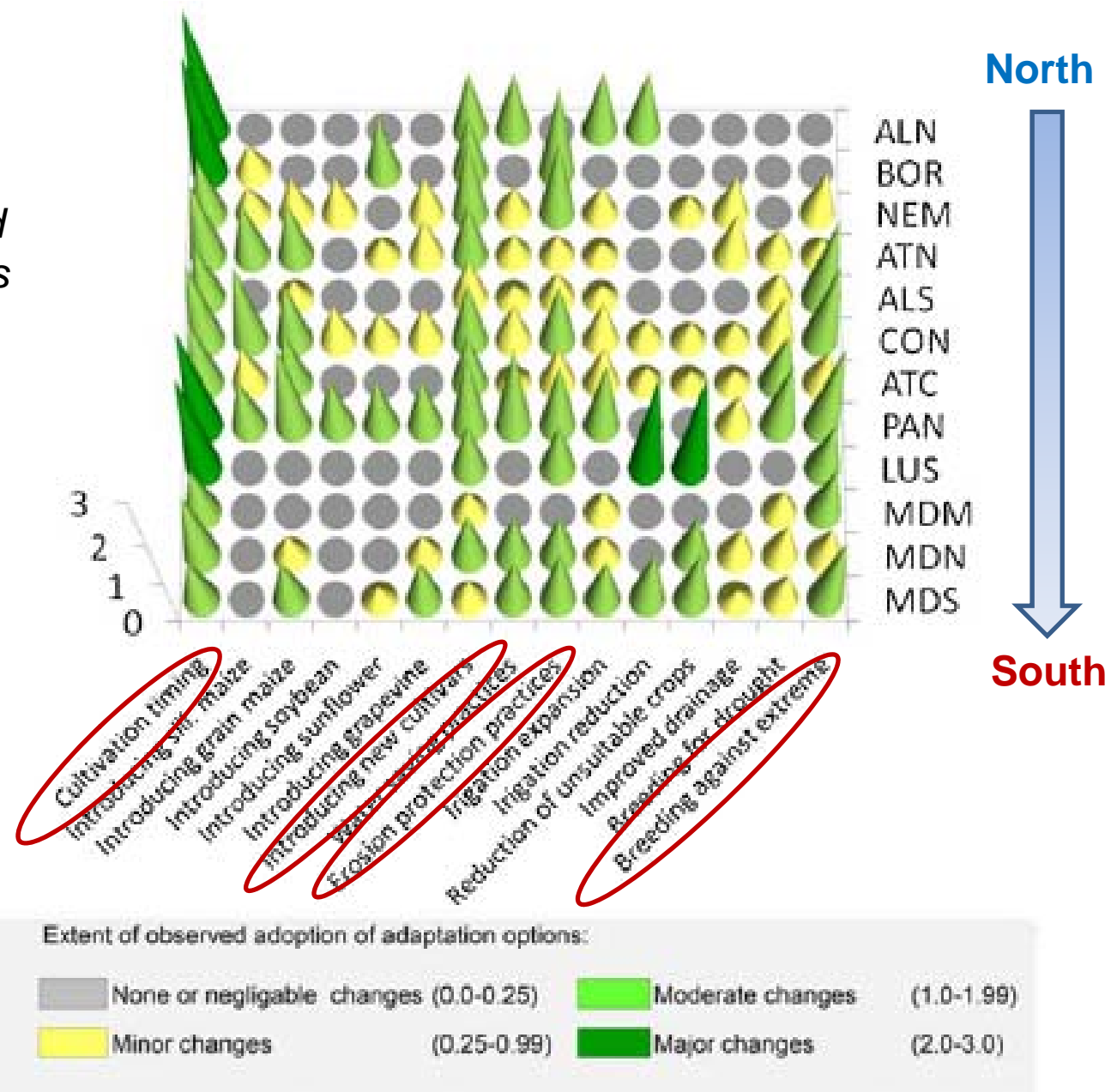


Dimassi et al. (2014)

2. Adaptation options involving cropping systems

Levers	Technical options
Crop species & varieties	<ul style="list-style-type: none"> • (stress escape) more appropriate thermal time and vernalization requirements • (stress tolerance) increased tolerance to heat shock, drought, low temperature, emergent pests and diseases... • (stress avoidance) lower water needs, optimal water use pattern
Crop management	<ul style="list-style-type: none"> • (escape) shifting sowing date to escape water and thermal stresses • (avoidance) nutrient applications, planting density and spatial arrangements (e.g skip row) adjusted to precipitation patterns and yield goals • (attenuation) supplementary/deficit irrigation if available • (conservation) soil tillage and residue management to maximize soil water storage, reduce evaporation, runoff and erosion
Cropping pattern	<ul style="list-style-type: none"> • Diversify crops & cultivars to increase resilience (rotation, landscape) ; variety mixtures and intercropping ; agroforestry ; flexible systems
Information & decision system	<ul style="list-style-type: none"> • Use seasonal weather forecasting ; model-based decision support systems (DSS)

Observed adaptation responses as reported by survey respondents (50 experts) for individual environmental zones in Europe

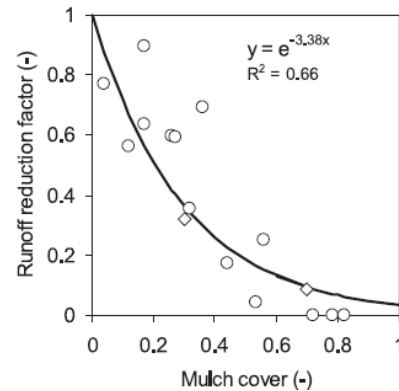


3. Some trade-offs in cropping system design

	Adaptation	Mitigation		Food Production
		reduce N ₂ O	increase SOC	
Reduce the use of mineral N fertilizer	+ (W)	+	-	o/-
No till and mulching	+ (W)	o	+	o
Legumes in crop rotations	- (W)	+	o	o
Catch crops, multiple cropping	- (W)	o	+	+
Agroforestry, intercropping	+(T), -(W)	o	+	+
Bioenergy crops	-/o (W)	o	+	o/-

Some benefits of conservation agriculture in the tropics

Run off

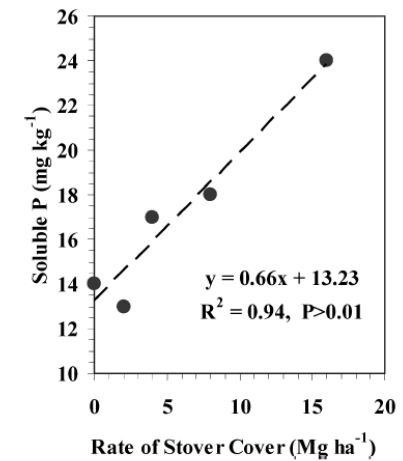


Scopel, E., F.A.M. Da Silva, M. Corbeels, F. Affholder, and F. Maraux. 2004. Modelling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions. *Agronomie* 24(6-7): 383–395.

Mulch of crop residue (amount)

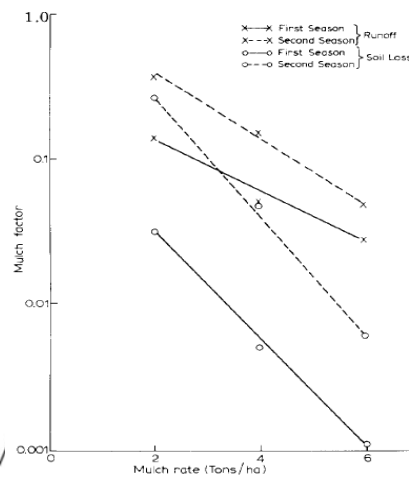


Nutrient cycling



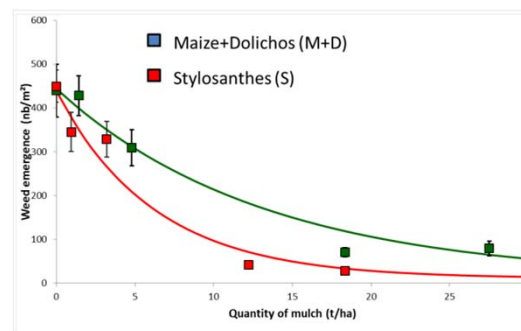
Taylor, P., H. Blanco-canqui, and R. Lal. 2009. Crop Residue Removal Impacts on Soil Productivity and CRC. *Crit. Rev. Plant Sci.* 28(910296550): 139–163.

Soil erosion



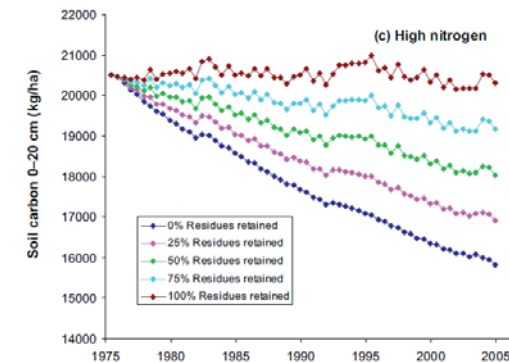
Lal, R. 1976. Soil erosion on alfisols in western Nigeria, ii. Effects of mulch rates. *Geoderma* 16: 377–387.

Weeds



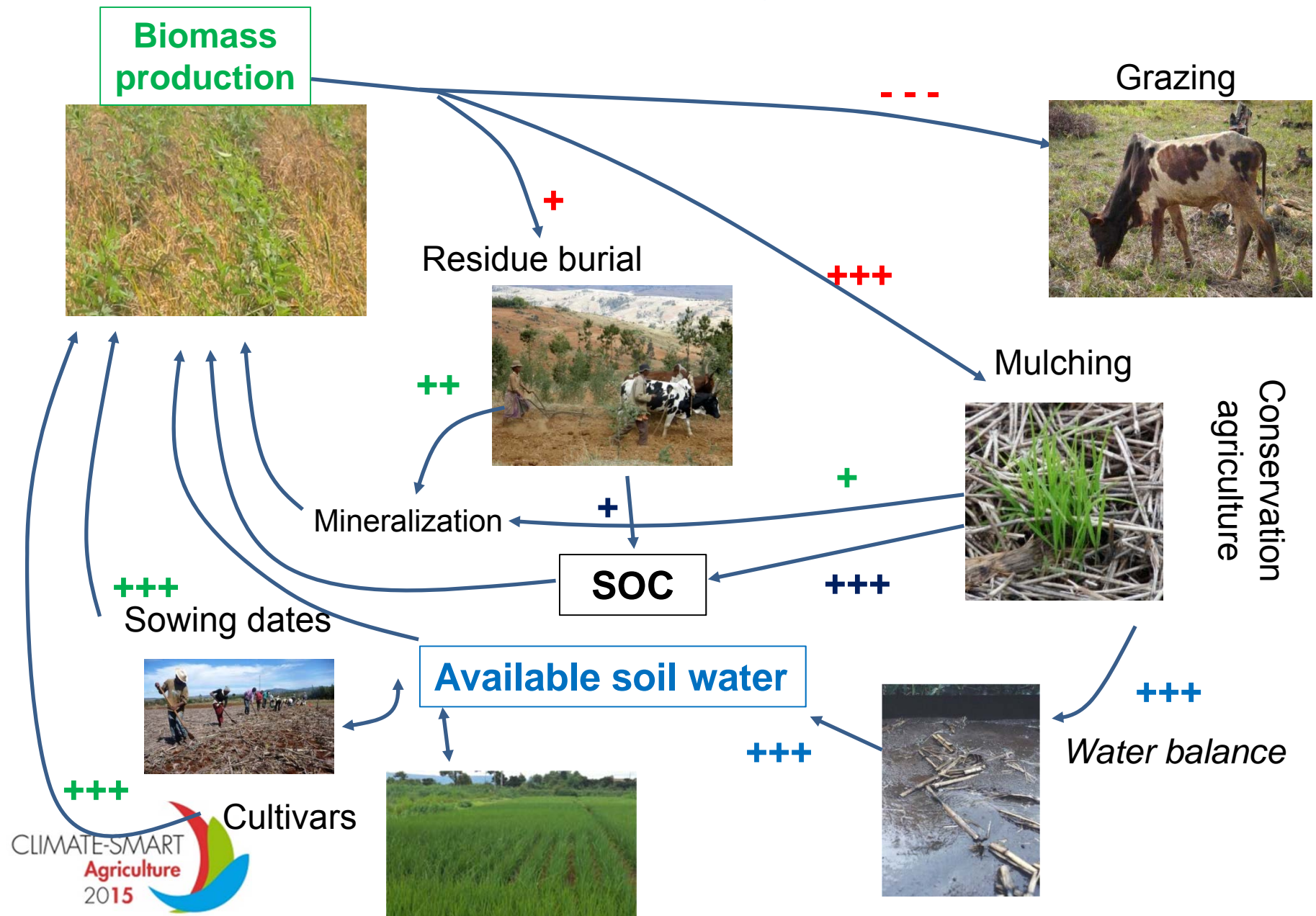
Ranaivoson L., Naudin K., Ripoche A., Corbeels M. 2015. Effect of mulching on weed infestation in rice. *Agroecology for Africa*, Afa 2014. 3-5 November, Antananarivo, Madagascar

Soil C

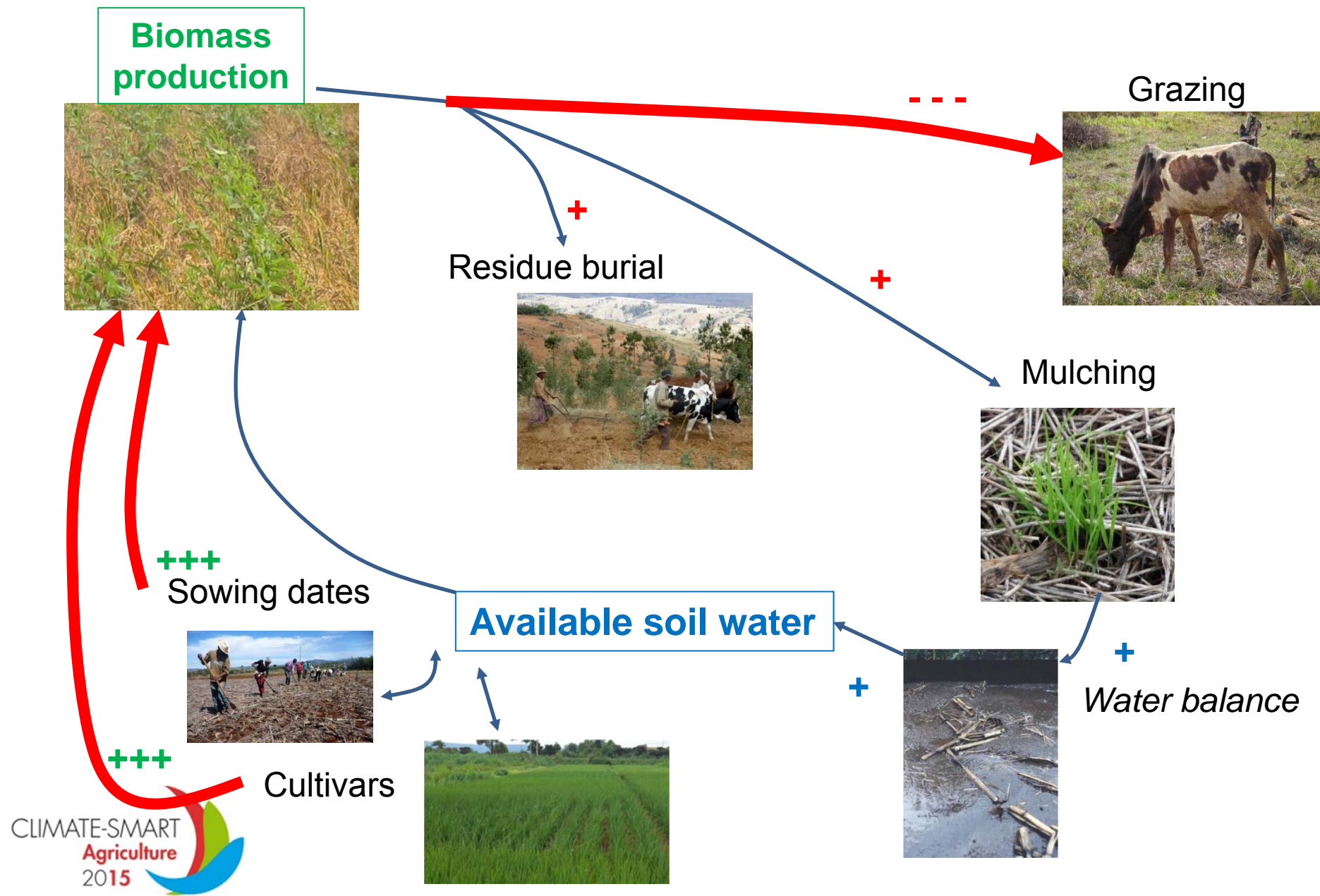


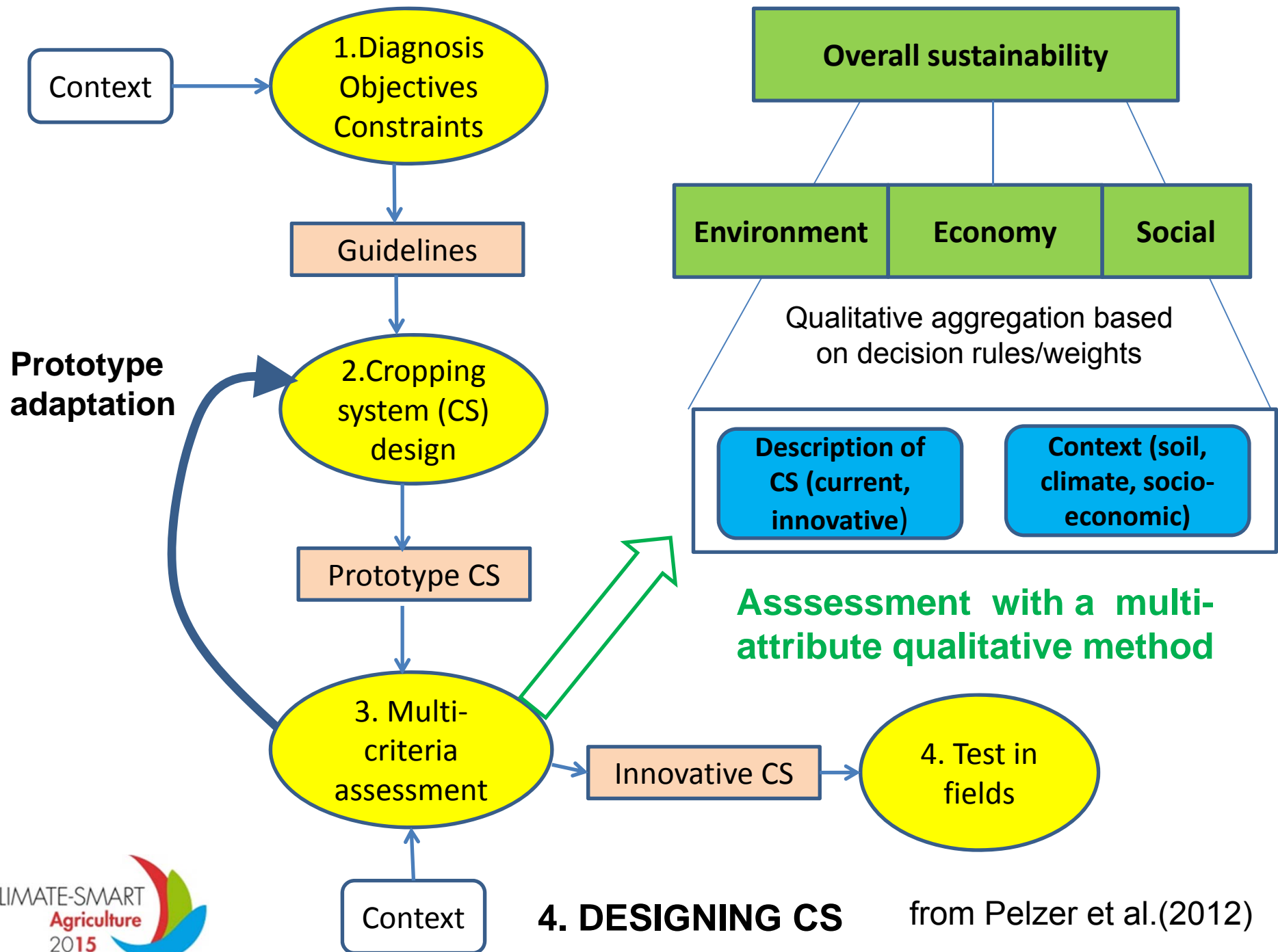
Probert, M.E. 2007. Modelling minimum residue thresholds for soil conservation benefits in tropical, semi-arid.

A case-study of multiple trade-offs: rainfed rice in Madagascar (hillsides)



Rainfed rice in Madagascar : livestock as a priority

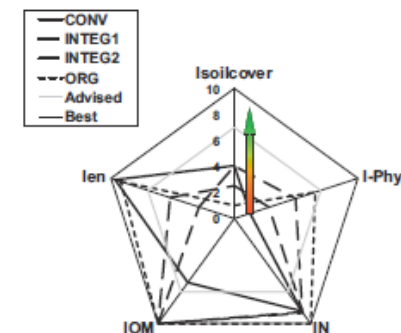




Methods for designing cropping systems in the context of climate change

	New variables to assess (e.g N ₂ O)	Multiple solutions to explore	More uncertainty to consider	Actors to involve
Cropping system experiments	+++	+	+	+
Simulation & optimization studies (in silico)	++	+++	+++	+
Prototyping methods	+	+	+	++
Participatory modelling (games)	+	++	++	+++

Coupled with assessment methods
(indicators, multi-criteria decision-aid)

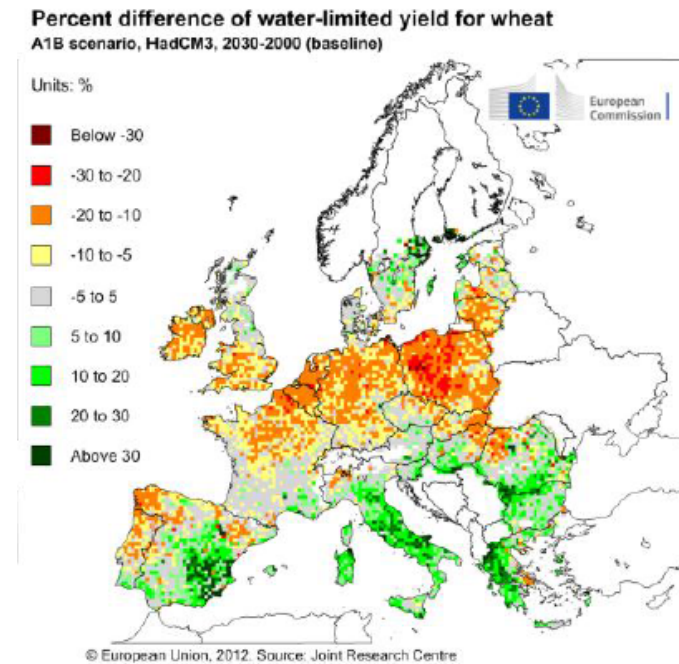


CropSyst model implemented within the BioMA modelling platform of the European Commission (JRC): e.g wheat Donatelli et al. (2012), *IEMSs*

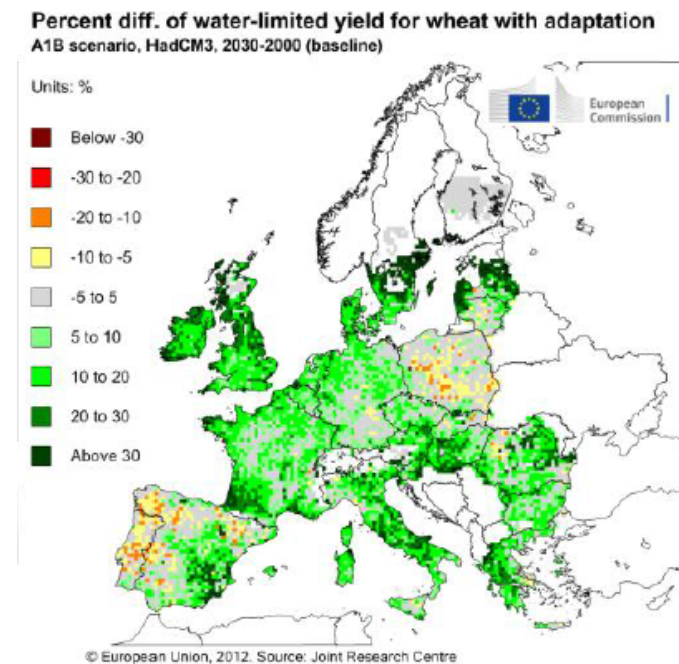
Simulation studies concluded to successful adaptation but :

- A subset of adaptation measures : sowing dates and hypothetical varieties
- Decision rules, feasibility (workable days) and resource availability (water) are not considered
- Some important limiting factors are omitted : e.g. invasive pests and diseases

No adaptation



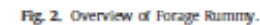
Adaptation



Simulation models for assessing and designing cropping systems with a CSA perspective

- Crop models generally do not consider yield impacts from extreme frost and heat events (Barlow et al., 2015). Intercomparison of crop models (e.g. AgMip) revealed uncertainties in simulating yield under CO₂ and high temperatures (Asseng et al., 2013) ;
- Major CS models (e.g CropSyst, DSSAT, EPIC, Stics...) can theoretically simulate a wide range of adaptation options at field level (e.g conservation agriculture with residue management and minimum tillage) but plurispecific stands still need new modelling achievements ;
- The ability of simulation models to account for the effect of cropping systems on N₂O emissions must be better assessed ;
- Some progress is also expected concerning the emergence, incidence and damage of weeds, pests and diseases under future agriculture (only a few contributions)

The diagram illustrates an integrated approach for the design of a game, centered around a thick black oval. Inside this oval, at the top, is an oval labeled "Farmers & learning". Below it are two ovals: "Consultants" on the left and "Scientists" on the right. A central vertical line with arrows at both ends connects the "Farmers & learning" oval to the space between the "Consultants" and "Scientists" ovals. To the left of the central oval is the text "Modelling to design candidate solutions". To the right is "Simulation to evaluate candidate solutions". Below the central oval, outside the thick black oval, are two triangles: "Material objects (game)" on the left and "Computers" on the right. A large, light gray oval encircles the entire central structure. Arrows point from the "Material objects (game)" triangle to the central area and from the central area to the "Computers" triangle.



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Martin (2015) *Agric.Syst.*

Summary

- Cropping systems offer numerous actionable options for CSA
- Multiple trade-offs to consider when designing cropping systems for CSA objectives
- A range of methods for designing and assessing CS (based on multicriteria decision-aid) that could be combined
- Underlying simulation models have to be completed to widen the set of options to explore
- Farm constraints should be considered explicitly when testing the adaptation and mitigation solutions

Thank you for your attention !

