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

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

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INRA SCIENCE & IMPACT

cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT

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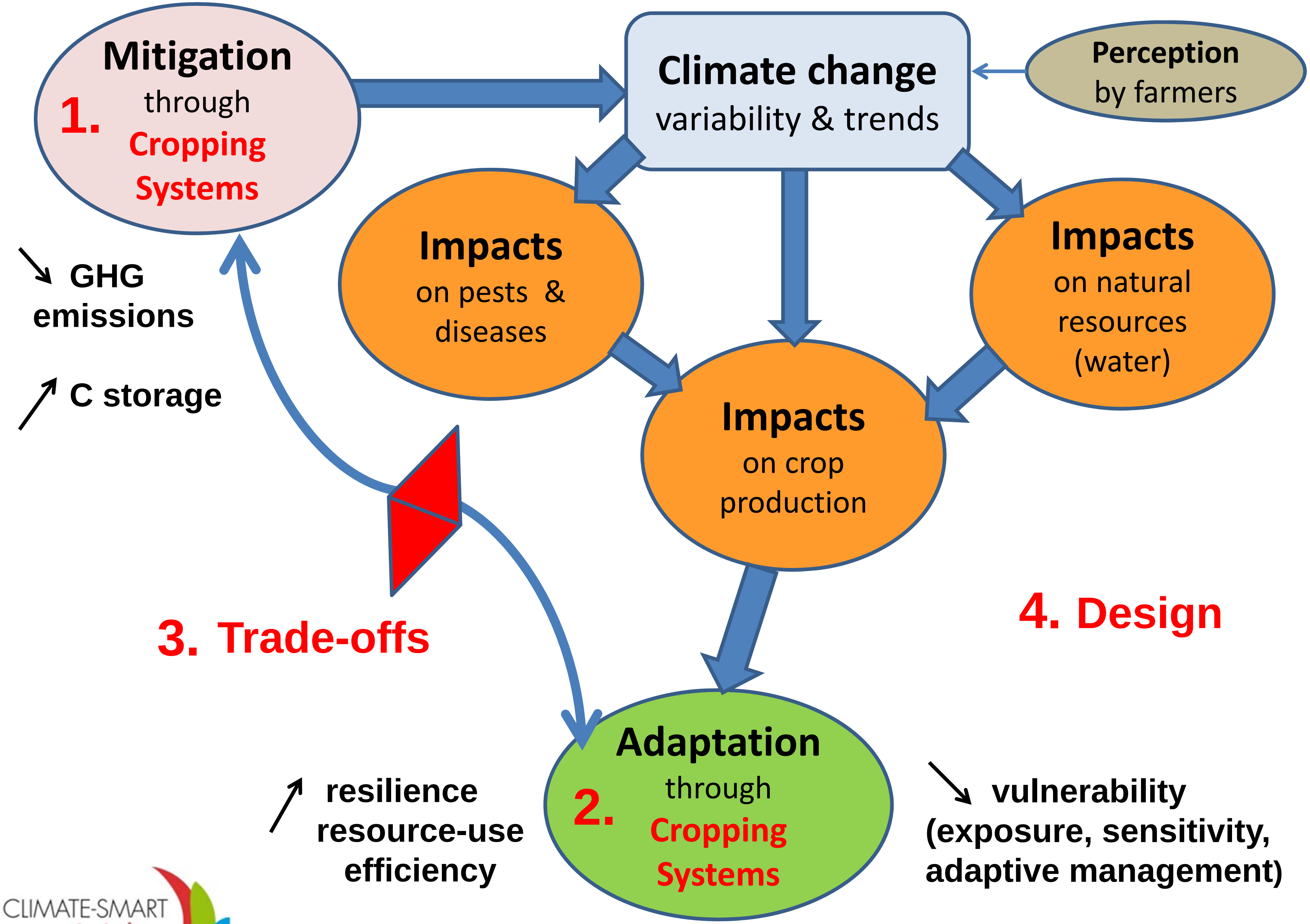

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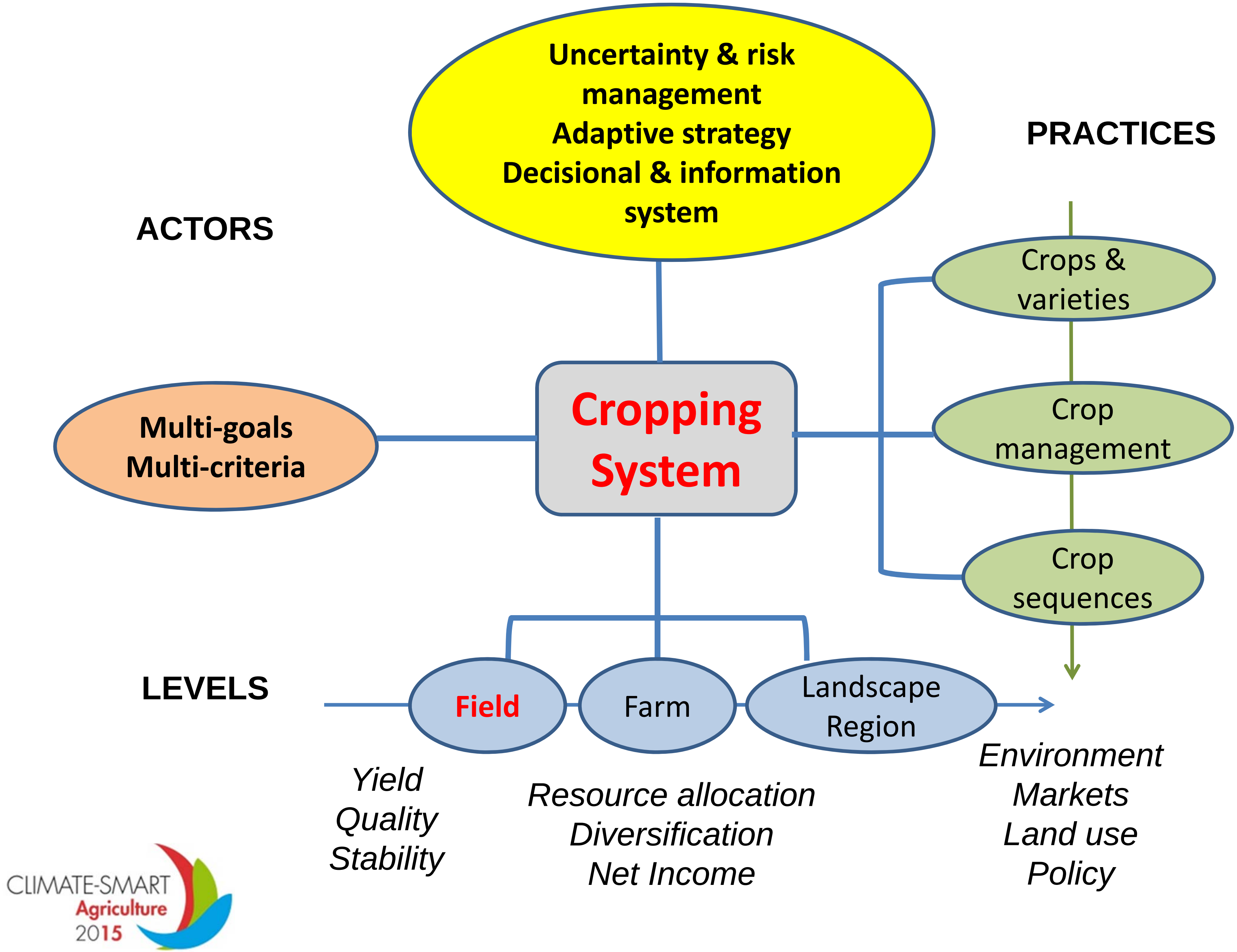
Uncertainty & risk management
Adaptive strategy
Decisional & information system
PRACTICES
ACTORS
Crops & varieties
Multi-goals
Multi-criteria
Cropping System
Crop management
Crop sequences
LEVELS
Field
Farm
Landscape Region
Yield
Quality
Stability
Resource allocation
Diversification
Net Income
Environment
Markets
Land use
Policy
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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)	↘N2O
Soil tillage	**Reduce tillage** (direct seeding, occasional tillage, shallow tillage)	↘CO2 (fuel) ↗C storage
Cover crops and residue management	**More cover crops** in arable cropping systems, in vineyards and orchards Grass buffer strips	↗C storage ↘N2O
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 ↘N2O
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,...	↘CH4

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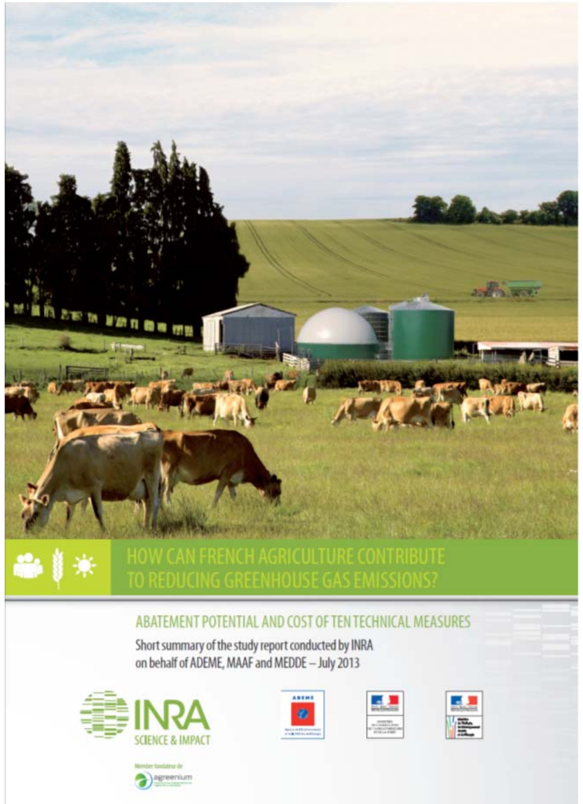
In temperate, intensive agricultural contexts a major part of the cost-effective abatement potential is related to N management



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 CO_2e avoided per year)
- Calculation of the cost to the farmer (€ per ton of CO_2e avoided)

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

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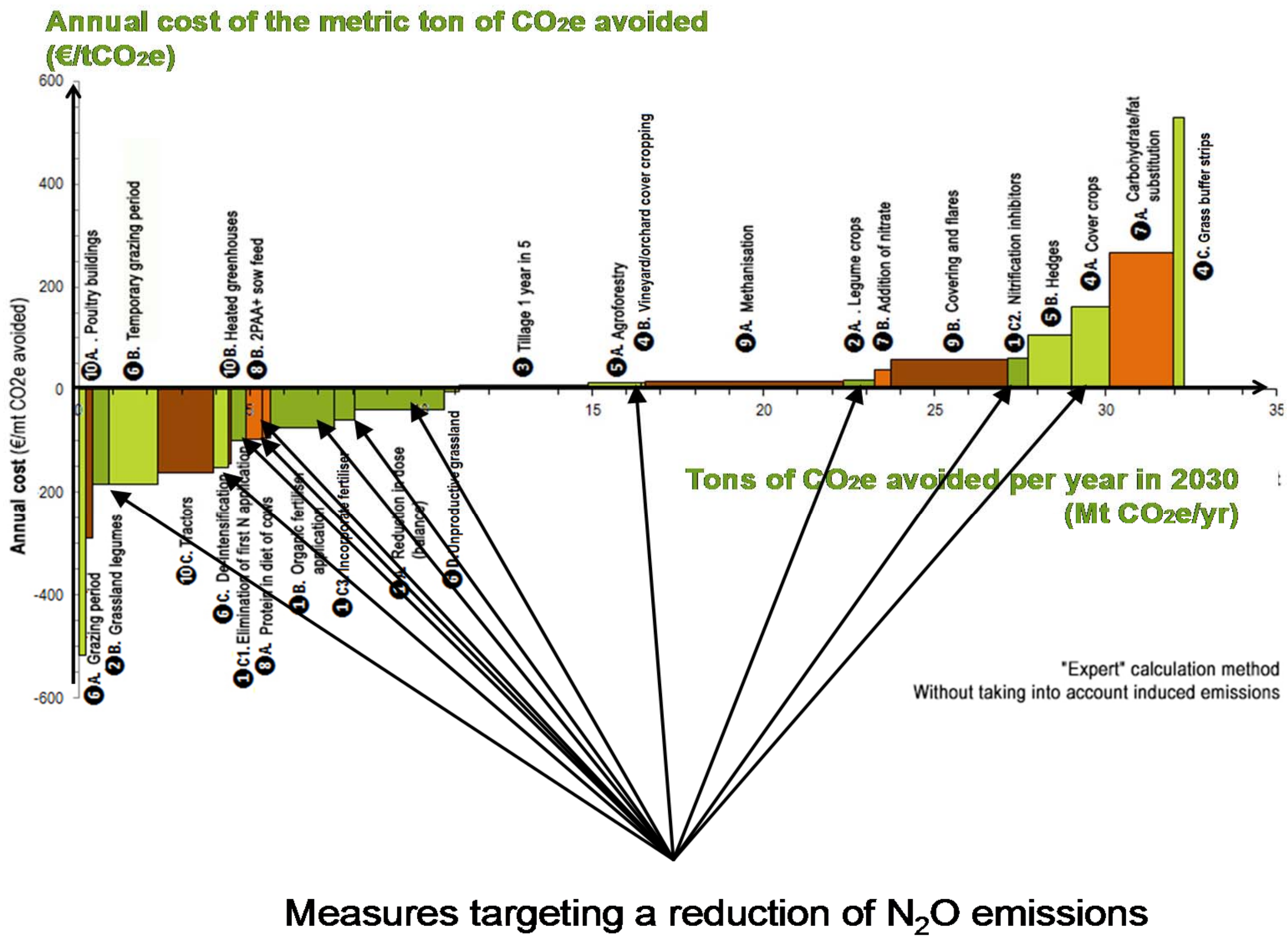
https://www6.paris.inra.fr/depe/Projets/Agriculture-et-GES

Most measures targeting a reduction of N_2O 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

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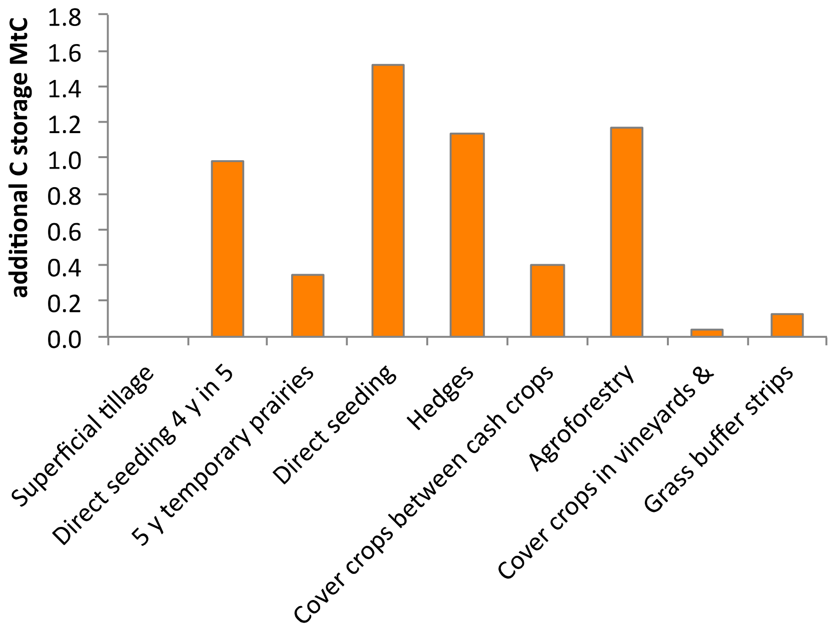
Management practices that increase effectively SOC are based on :

- 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

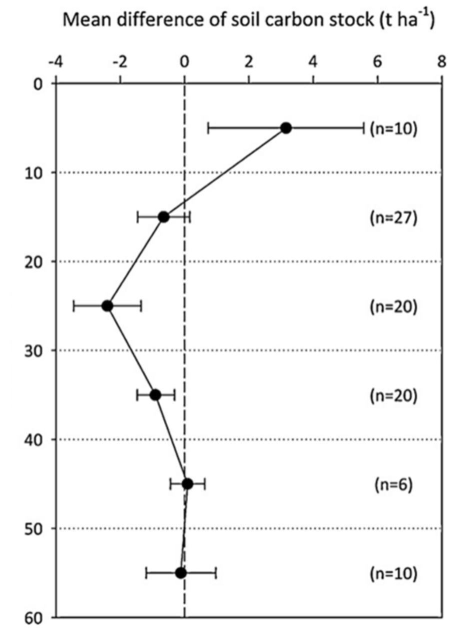
Recent meta-analyses have shown that additional C storage is not always observed under reduced tillage

Changes in soil C stocks depend on:

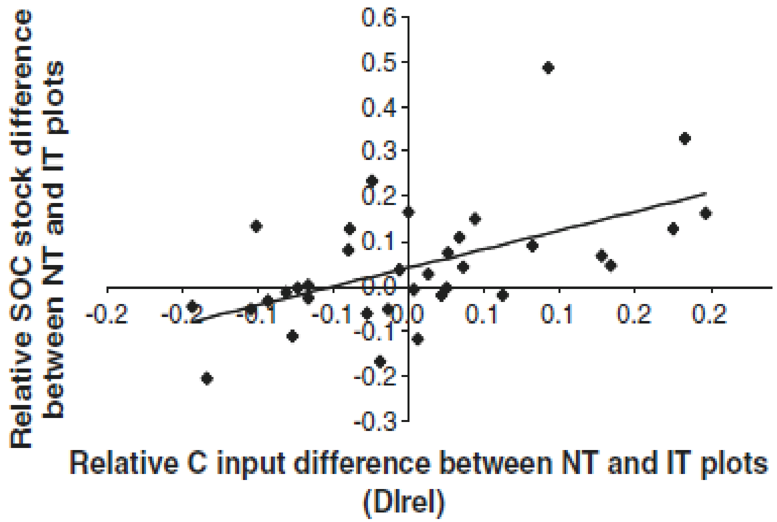
- biomass production (and subsequent C inputs as crop residues) under reduced tillage
- climatic context (more C storage under dry conditions)

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

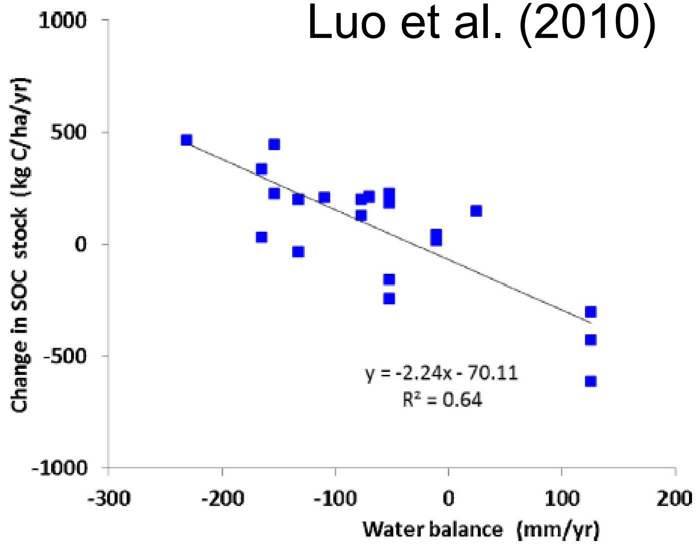
No-Till (NT) vs Full-Inversion Tillage (FIT)



Luo et al. (2010)



Virto et al. (2012)



Dimassi et al. (2014)

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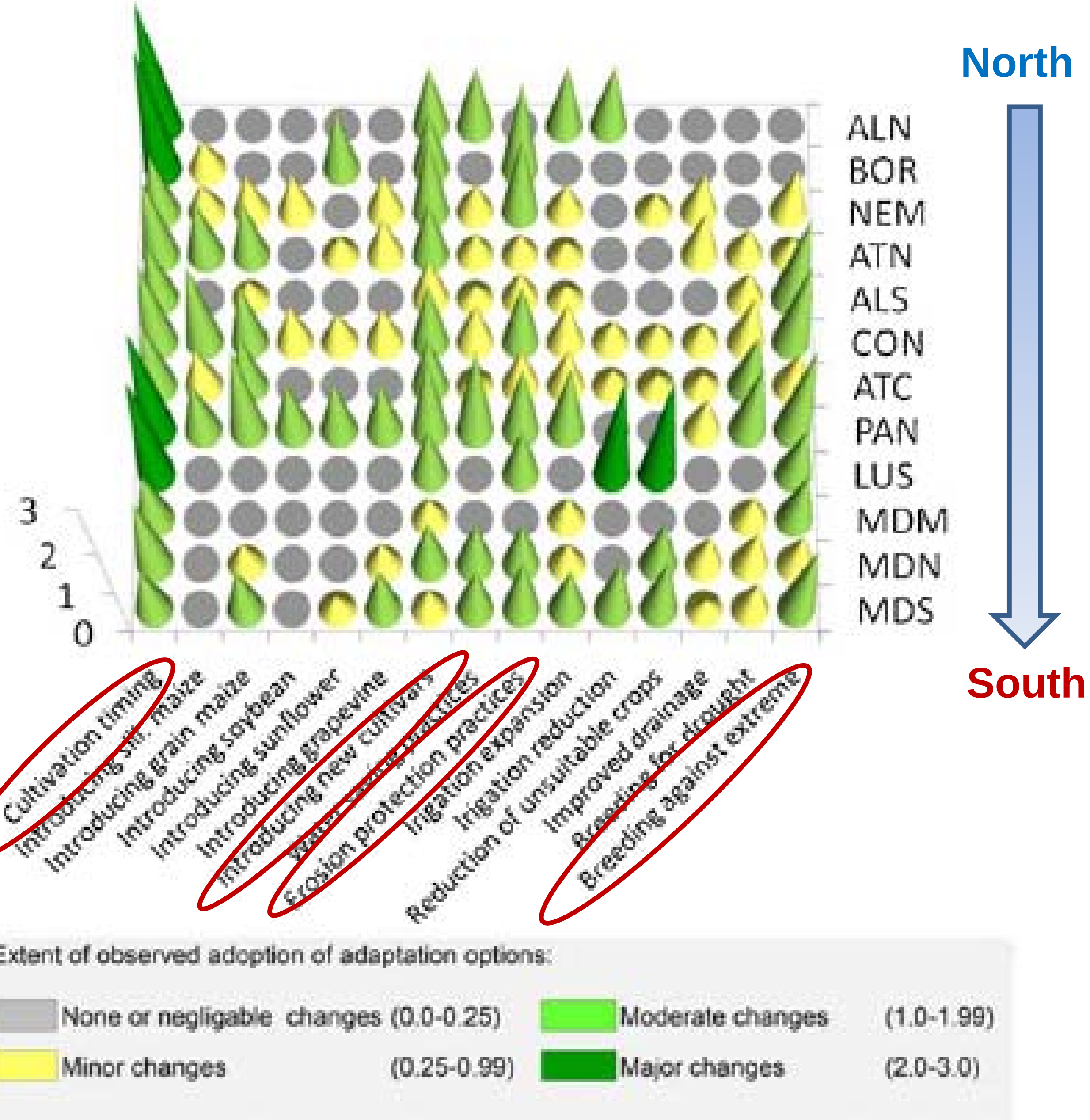
2. Adaptation options involving cropping systems

Levers	Technical options
Crop species & varieties	• (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	• (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	• Diversify crops & cultivars to increase resilience (rotation, landscape) ; variety mixtures and intercropping ; agroforestry ; flexible systems
Information & decision system	• 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



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Olesen et al. (2011), *Eur.J.Agron*

3. Some trade-offs in cropping system design

	Adaptation	Mitigation		Food Production
		reduce N2O	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/-

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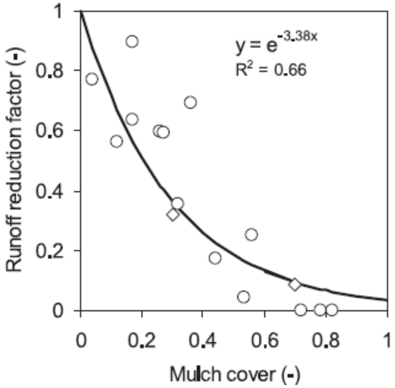
Temperature (T)
Water (W)

Impact : +, o, -

Some benefits of conservation agriculture in the tropics

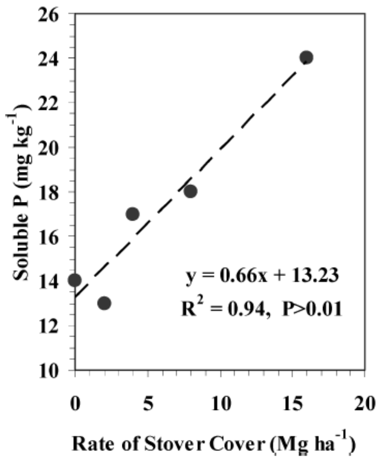
Mulch of crop residue (amount)

Run off



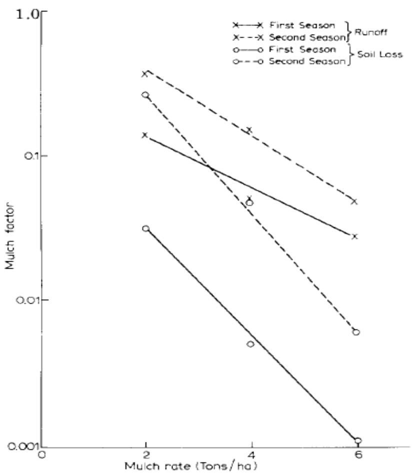
Scopel, E., F.A.M. Da Silva, M. Corbeels, F. Affholder, and F. Maraux. 2004. Modelling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions. Agronomie 24(6-7): 383–395.

Nutrient cycling



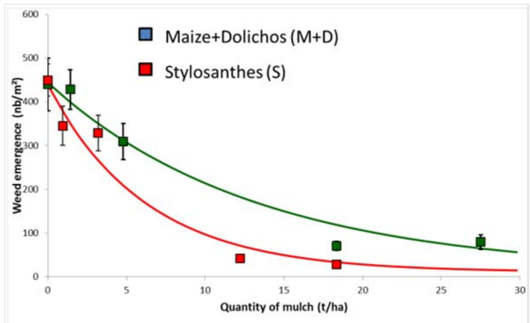
Taylor, P., H. Blanco-canqui, and R. Lal. 2009. Crop Residue Removal Impacts on Soil Productivity and CRC. Crit. Rev. Plant Sci. 28(910296550): 139–163.

Soil erosion



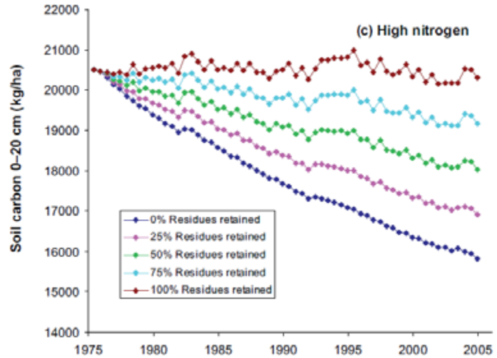
Lal, R. 1976. Soil erosion on alfisols in western Nigeria, ii. Effects of mulch rates. Geoderma 16: 377–387.

Weeds



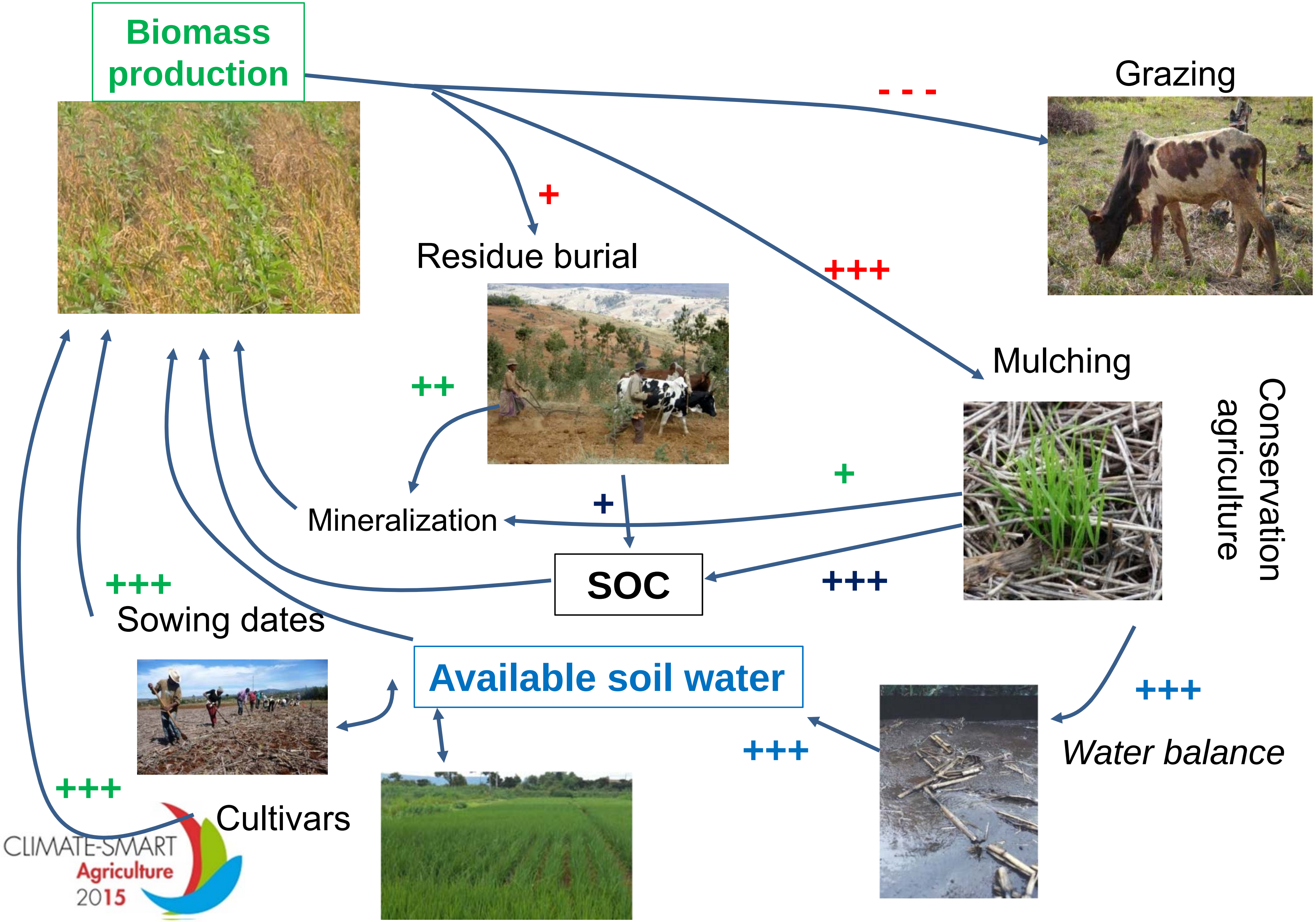
Ranaivoson L., Naudin K., Ripoche A.,Corbeels M. 2015. Effect of mulching on weed infestation in rice. Agroecology for Africa, Afa 2014. 3-5 November, Antananarivo, Madagascar

Soil C

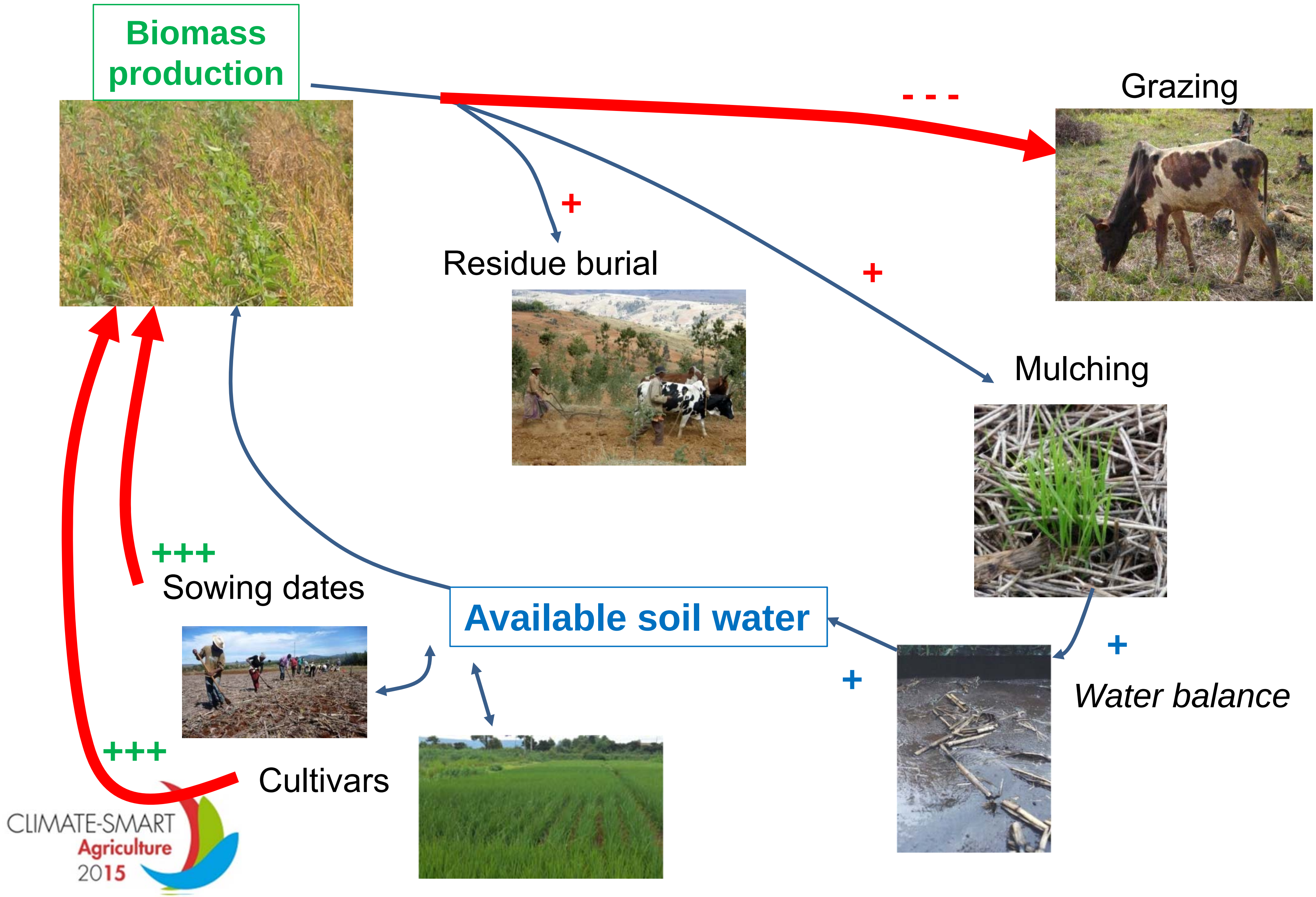


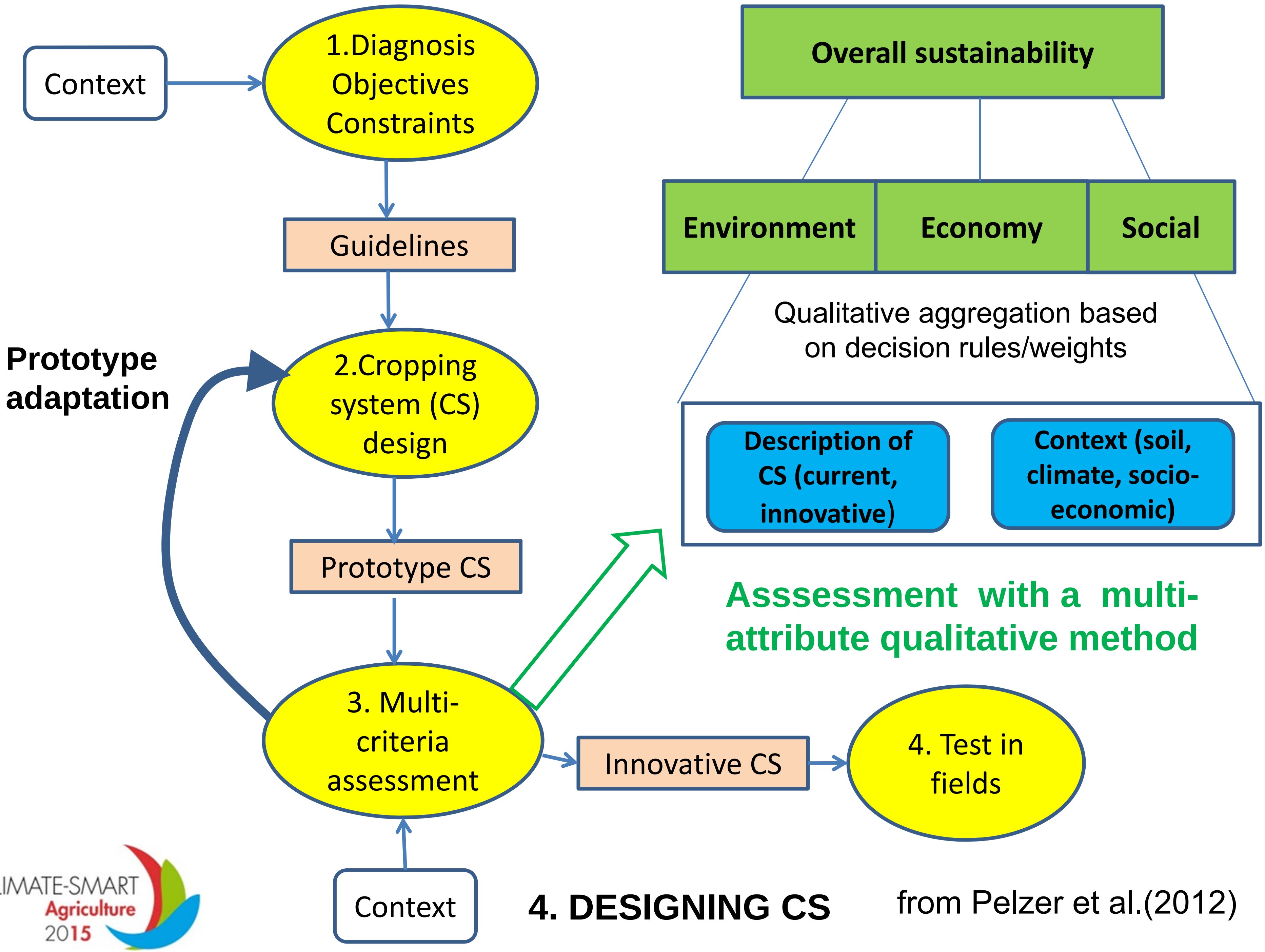
Probert, M.E. 2007. Modelling minimum residue thresholds for soil conservation benefits in tropical , semi-arid.

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



Rainfed rice in Madagascar : livestock as a priority





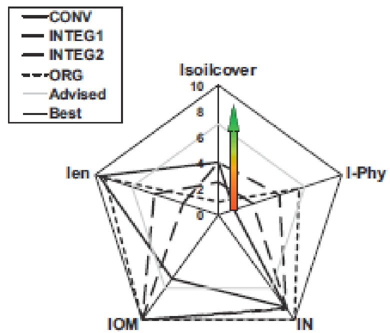
4. DESIGNING CS

from Pelzer et al.(2012)

Methods for designing cropping systems
in the context of climate change

	New variables to assess (e.g $N_2$0)	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)



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

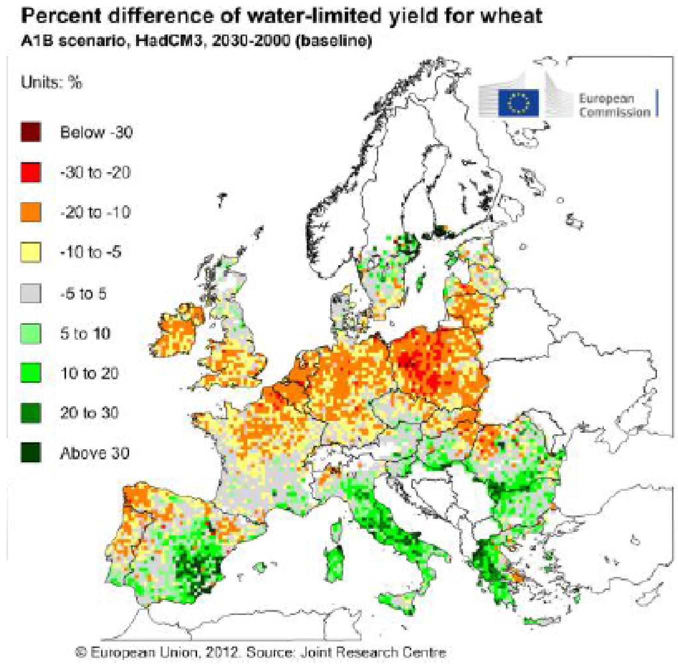
Simulation studies concluded to successful adaptation but :

- A subset of adaptation measures : sowing dates and hypothetical varieties

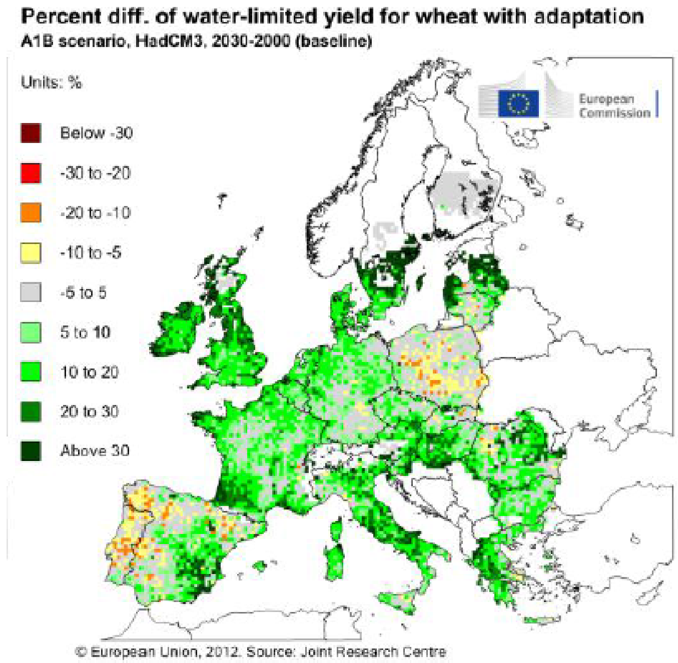
- Decision rules, feasability (workable days) and resource availability (water) are not considered

- Some important limiting factors are omitted : e.g. invasive pests and diseases

No adaptation



Adaptation



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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 N_2O 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)

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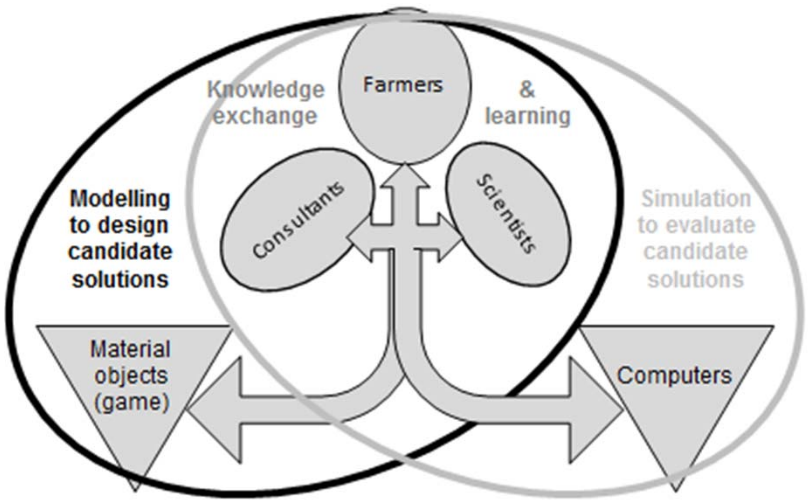
Hybrid design methods have been developed combining both participation and research based-models (via serious games) in order to develop the adaptive capacity of farmers on real-world



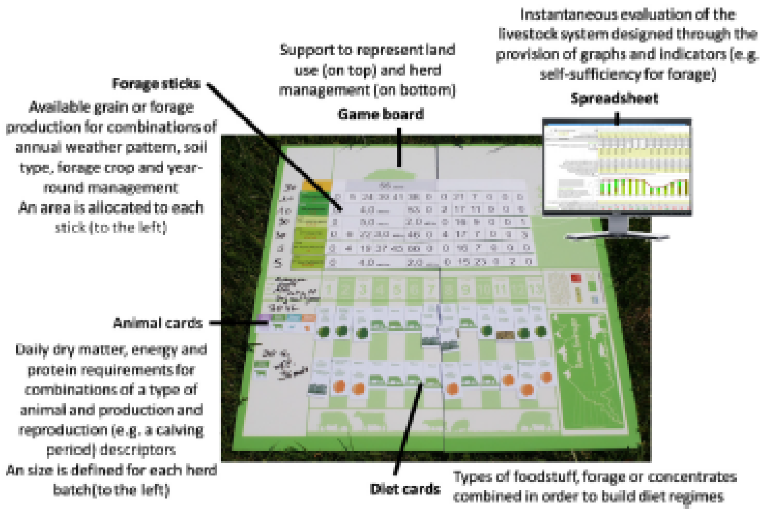


Fig. 2. Overview of Forage Rummy.

Collective workshops

Martin (2015) *Agric.Syst.*

Summary

- Cropping systems offer numerous actionnable 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 !