MARRAKECH
جامعة القاضي عياض
UNIVERSITÉ CADI AYYAD

Institut de Recherche pour le Développement
FRANCE

Remote Sensing Tools for irrigation managements

Chehbouni A. et co-authors.
Research Director at IRD
IRD Representative in Morocco

TREMA
Laboratoire Mixte International
ABHT - CNESTEN - DMN - IRD - ORMVAH - UCAM

MAROC METEO

Agence de Bassin Hydraulique du Tensift

ORMVAH

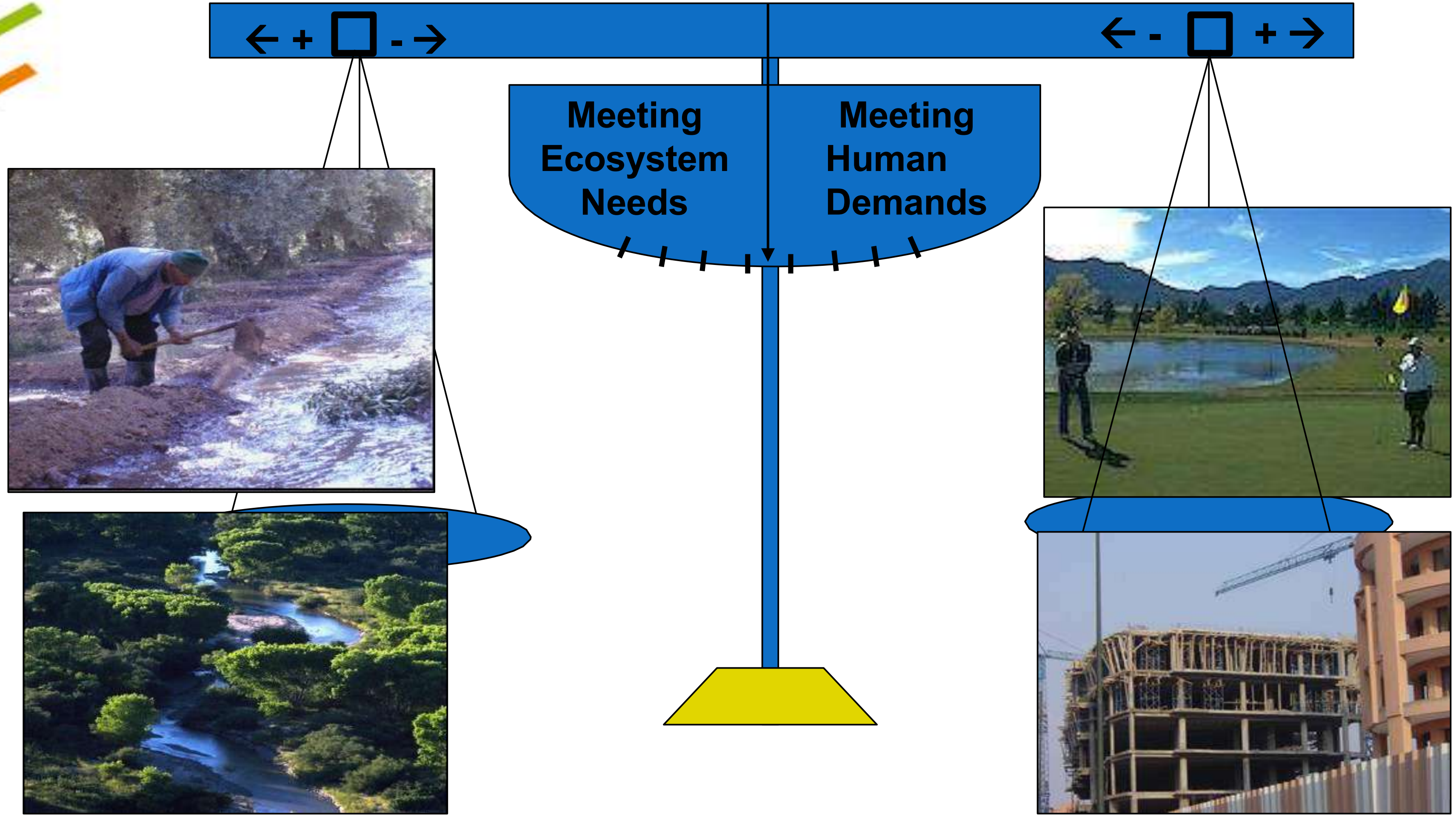
CNESTEN

General Context

- Arid and semi-arid region is faced with the critical challege of how to develop a policy that ensures economic growth/human well being, while managing water resources in a sustainable way ?

Encounter the equilibrium

Under changing climate and socio-economical drivers



Key Questions ?

How can knowledge, understanding, predictive modeling and remote sensing be used to improve the management and design of water resource, agro-hydrologic and eco-hydrologic systems ?

how innovative technology can be used as metrics for public policy efficiency regarding adaptation to climate change ?

“ In the history of earth and environmental sciences as in other sciences, most of the significant advances have resulted from new measurements. ”

p.214, *Opportunities in the Hydrologic Sciences*, NAS, 1991.

New data types force the rethinking of conceptual frameworks and analysis approaches in science as well as in applications.

Emerging technological advances in sensors and remote platforms allow measurements with coverage, and cost-and quality-effectiveness.

But

Remote Sensing technology is not meant and should not replace ground truth. It adds a value to it.

European Space Agency

Pôle THEIA

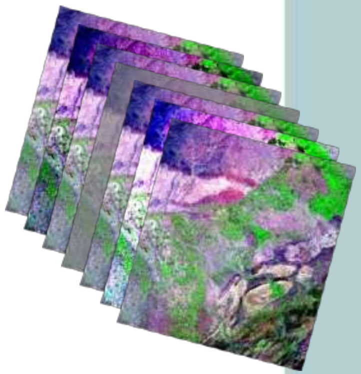
⇒images ready to use

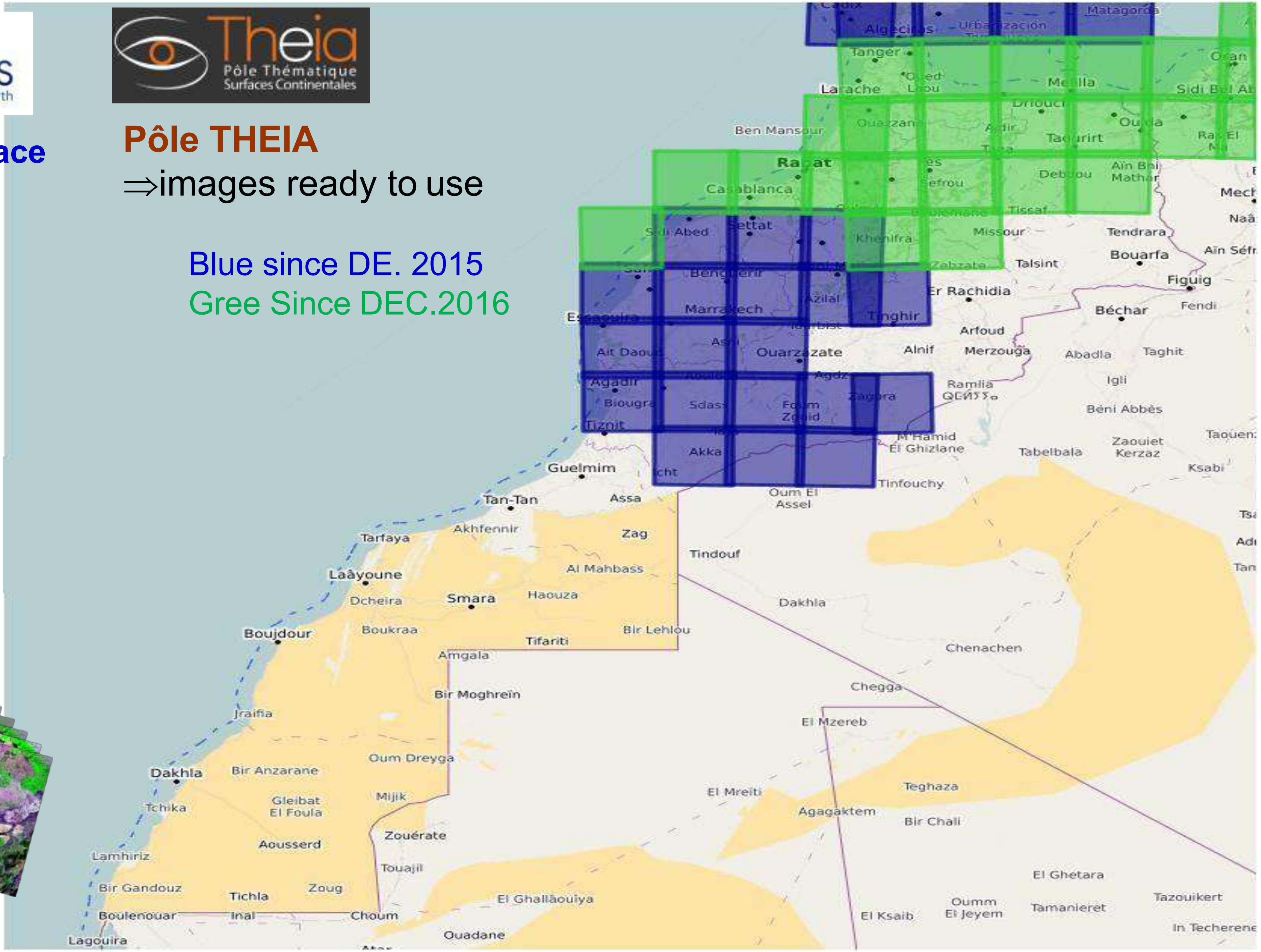
Blue since DE. 2015

Gree Since DEC.2016

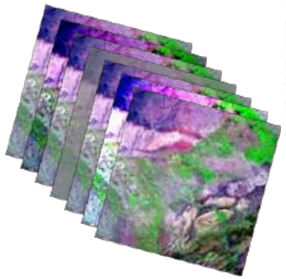
Sentinel-1 et Sentinel-2 Images (Spatial resolution 10-20m- tempral resoltion 5 days)

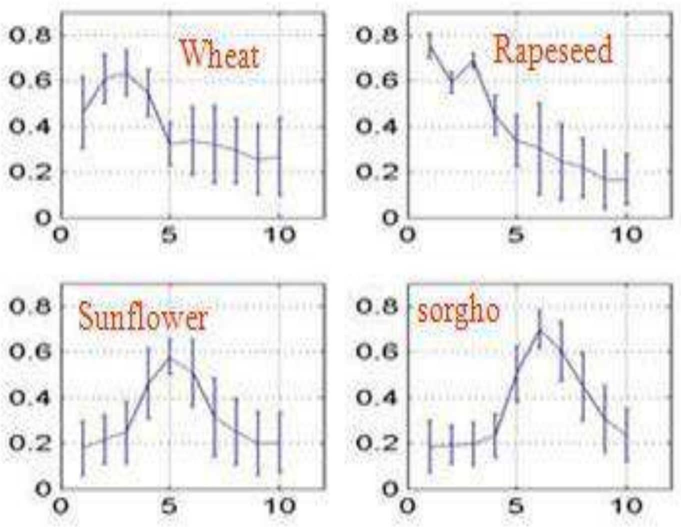
Free Access





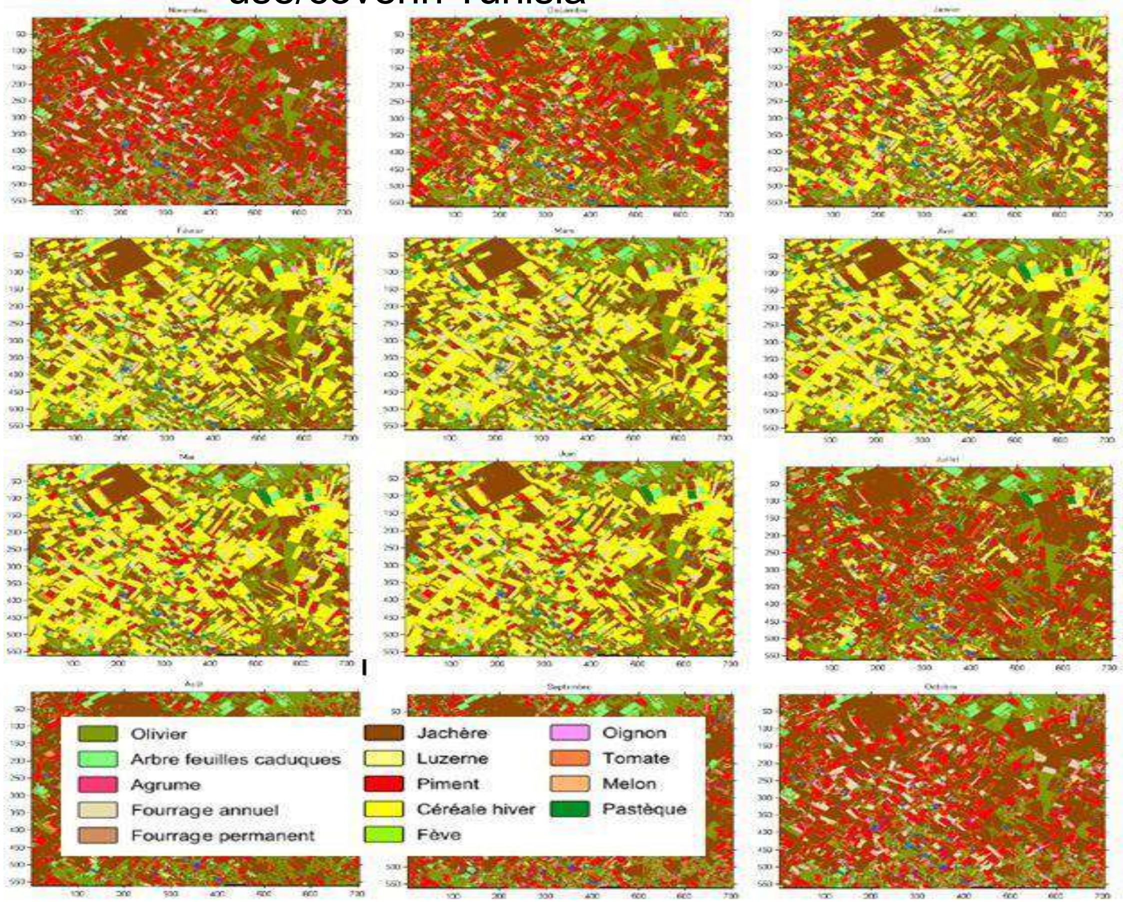
Land Use Monitoring





Extraction de NDVI Profiles

Example : mapping land use/coverin Tunisia

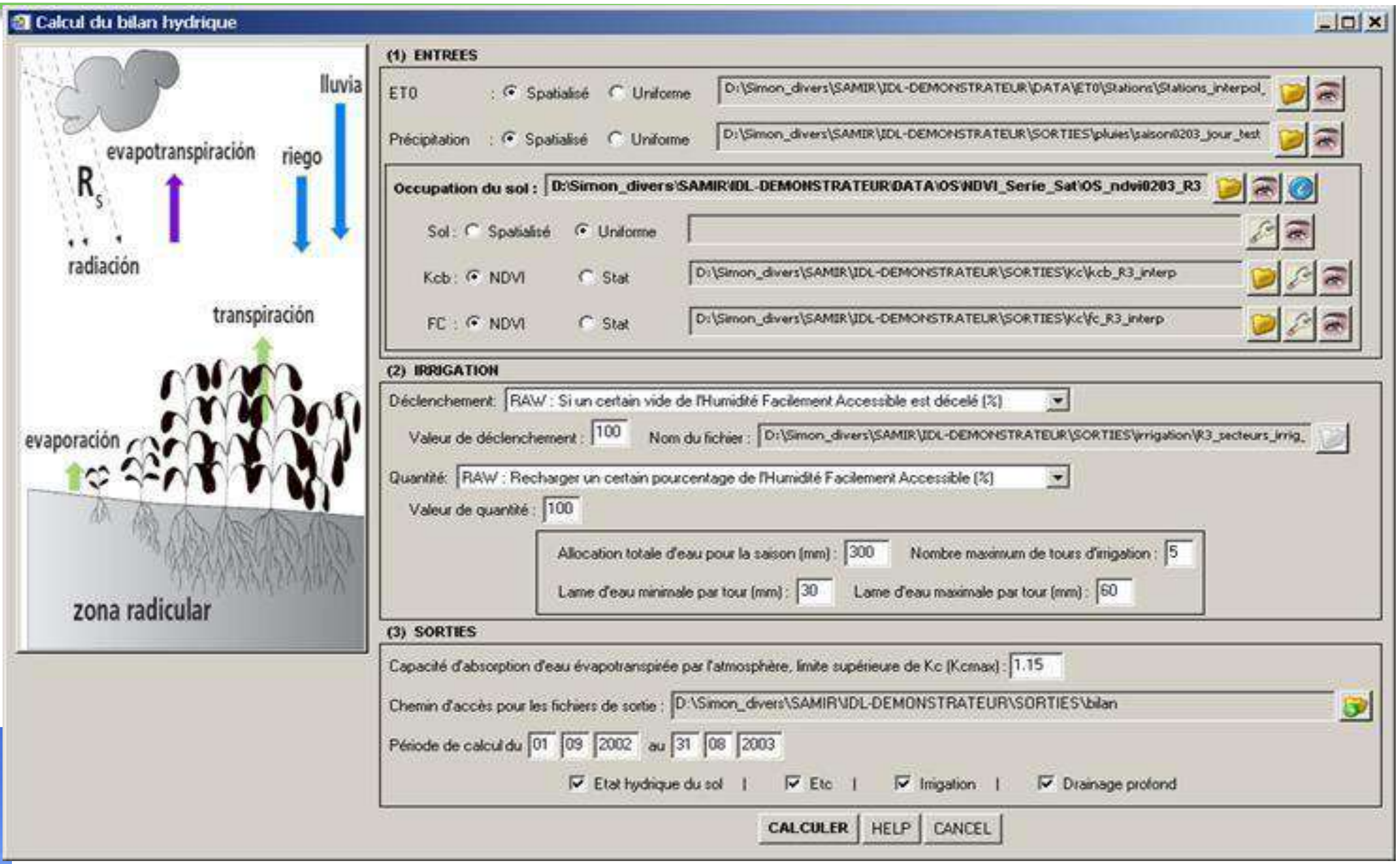


SAMIR (SAtellite Monitoring of IRrigation)

A tool for irrigated perimeters water budget monitoring

Assumption:

Irrigations are not known at field scale but simulated



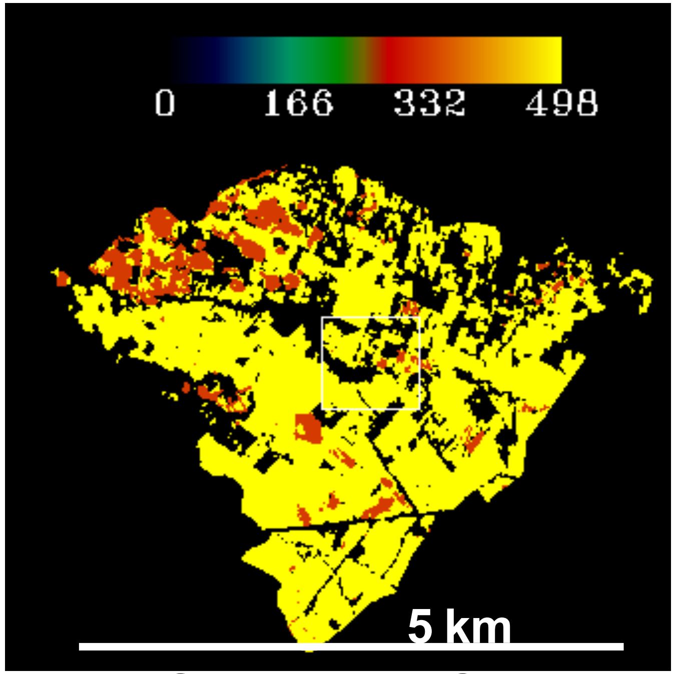
→ *spatialisation of ET based on Remote sensing*

→ *irrigation water management*

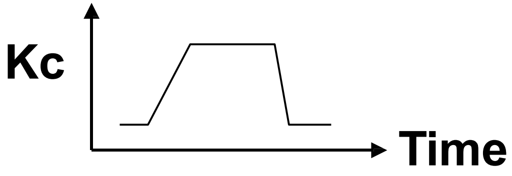
→ ***Groundwater pumping estimates***

Interest of SAMIR remote sensing approach
=> Closer to Actual Evapotranspiration

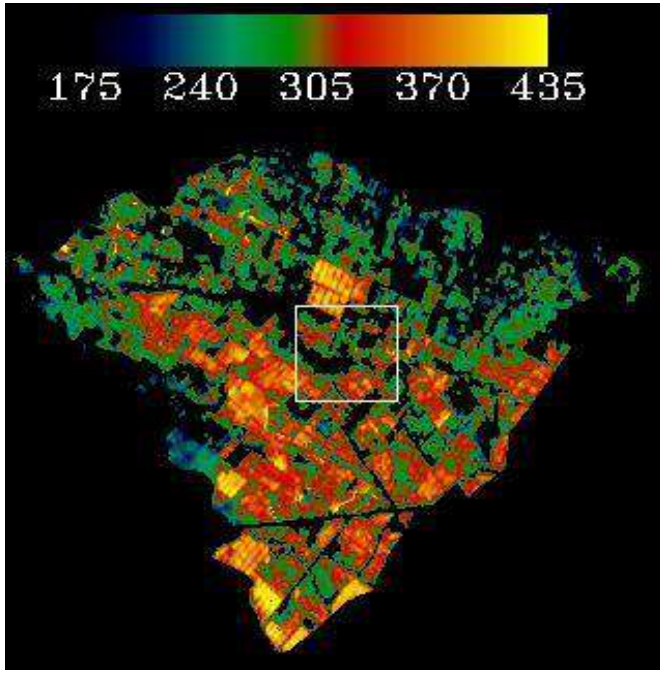
Theoritical water requirements (from bibliographic parameters ETC = 13 133 204 m3



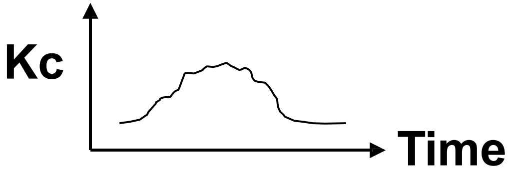
Standard FAO Kc



Remote sensing estimated Consumption ET = 8 213 056 m3



Remote Sensing Kc



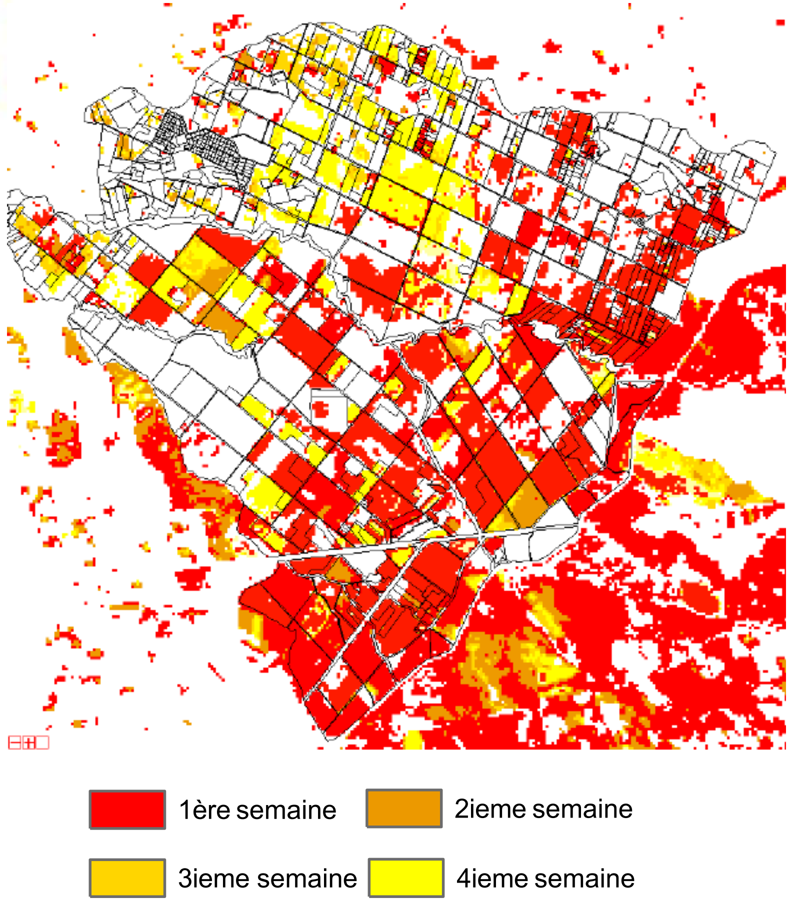
Cumulated Evapotranspiration from 17/12/2002 to 31/05/2003

SAMIR (SAtellite Monitoring of IRrigation)

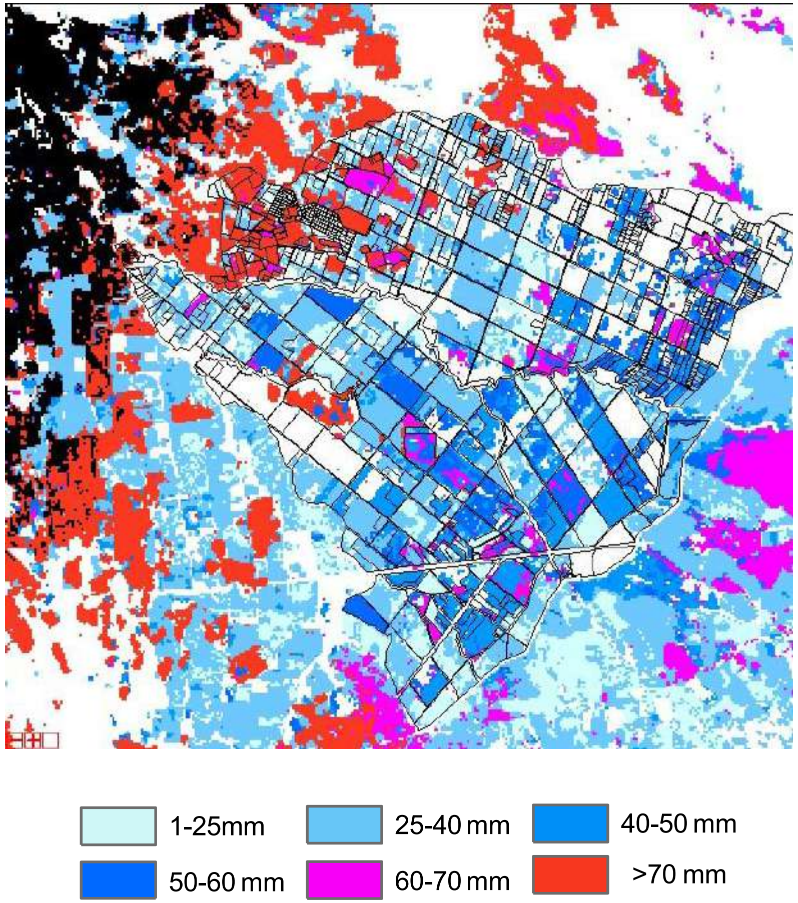
A tool for irrigated perimeters water budget monitoring

Decision support system for water distribution inside perimeters

Time to next water turn…



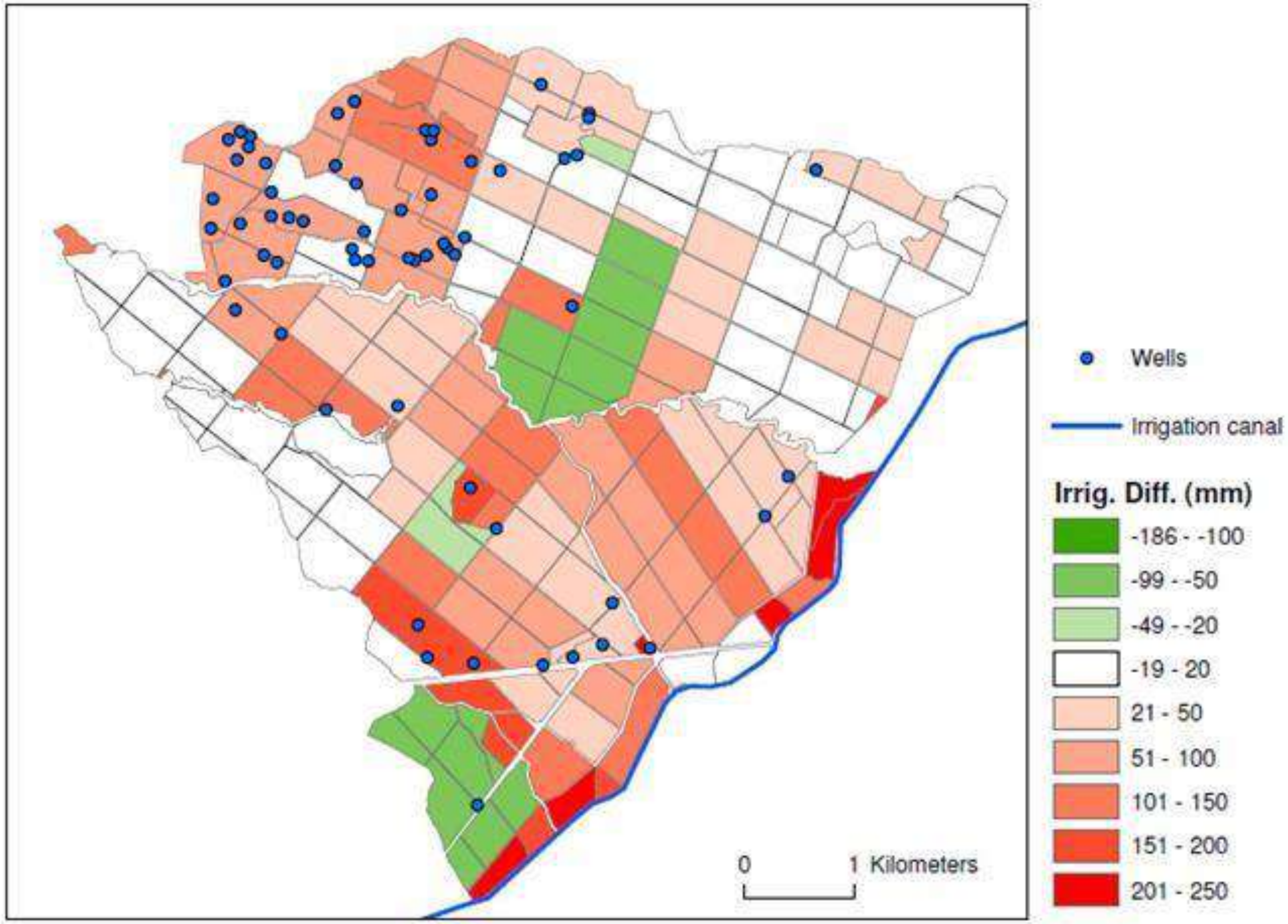
Water height to input…



Simulation in the R3 sector (Haouz plain, 2800 ha)

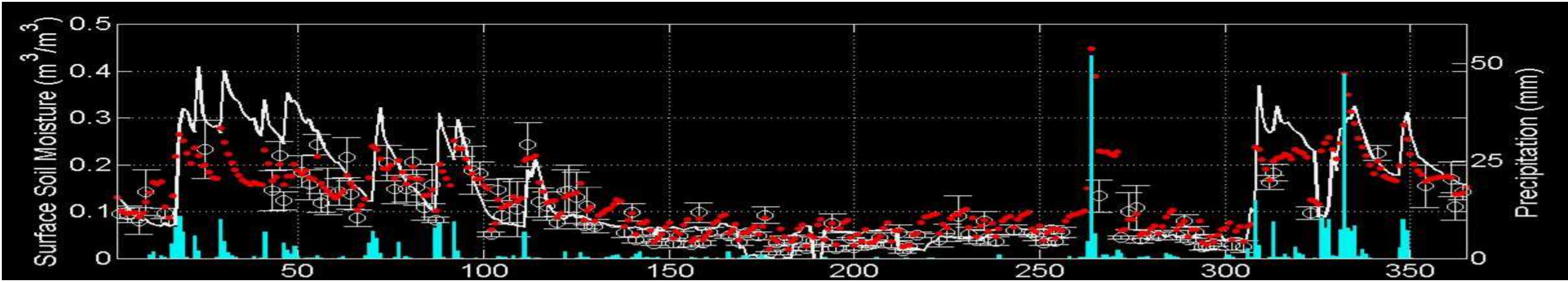
Example of validation of pumping estimates in the Haouz plain around Marrakech

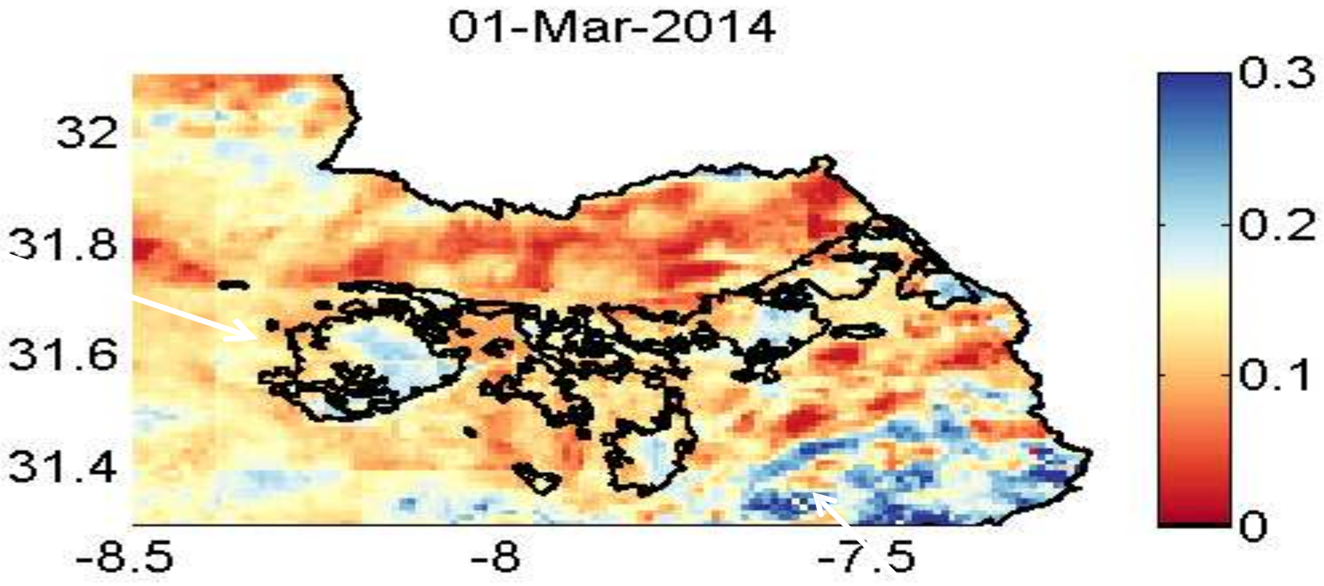
Satellite pumping estimates are correlated with the observed wells distribution and with direct uptake in the main irrigation canal



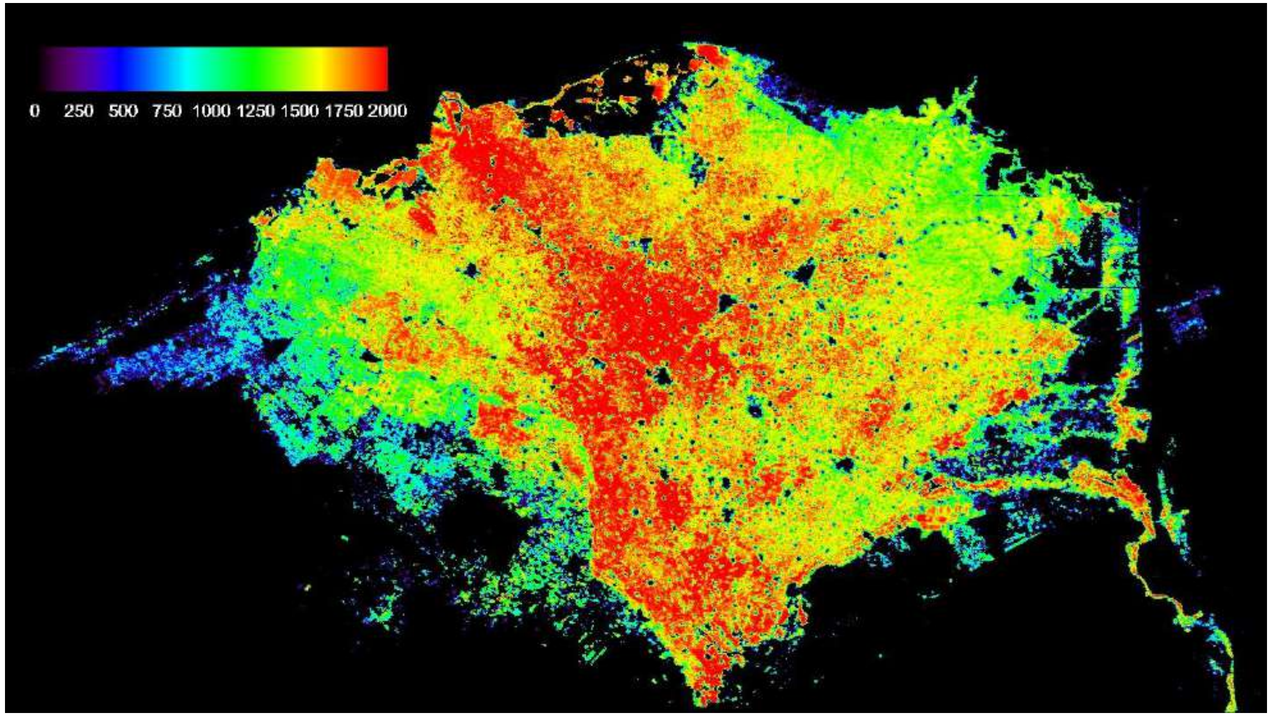
Use of Microwave based soil Moisture

Daily Soil Moisture at 1 km de resolution





Map of Annual water consumption in the Nile Delta from 10/2008 to 09/2009



The average evapotranspiration from irrigation for the whole delta is 1150 mm, with marked heterogeneities.

The area of crops obtained from MODIS images is 2.58 Mha

=> ~30 billions m^3 of water are consumed by irrigation

Concluding remarks

- Science is necessary to inform actions and proposals, but does not provide the entire prioritized integrated analysis needed

- Societal and political considerations are also important fact in determining the most appropriate policy regarding the adaptation

- State has to be an actor in stead of a moderator

Saved wealth, saved health: approach, methodology and case study of adaptation benefits in the agricultural sector in Kenya

Matthias Krey
Senior Advisor, Perspectives Climate Group

International Conference on Adaptation Metrics for Water & Agriculture
Ben-Guerir, Morocco
07.10.2017

IN CONTRAST TO MITIGATION (TCO2) UNIVERSAL METRICS FOR QUANTIFYING ADAPTATION BENEFITS CURRENTLY MISSING (IPCC 2007, UNFCCC 2012)

Universal metrics for CC adaptation

Advantages

- Transparency and comparability
- Ex-ante: Project identification
- Improves and facilitates Cost-Benefit Analysis (CBA)
- Ex-post: Enables M&E allowing corrections / adjustments and lessons learned

Quality criteria for a universal metric

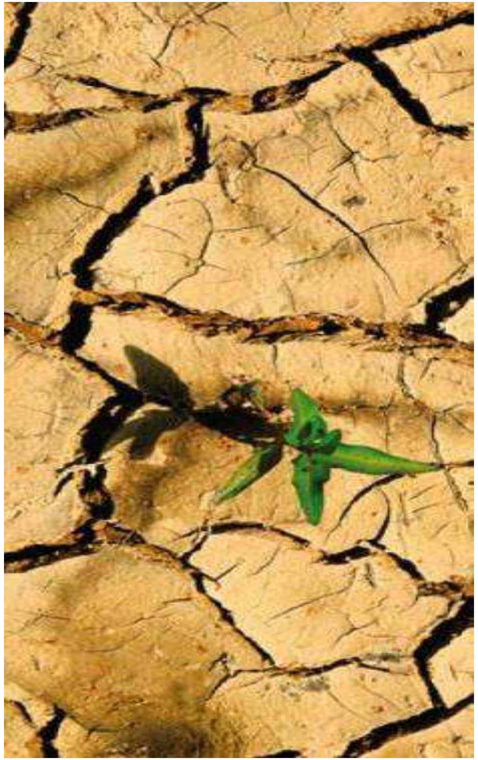
- Quantifies adaptation benefits based on the losses due to climate change impacts without the adaptation project („baseline scenario“)
- Balances need for quantification with amount of categories of benefits
- Avoids debate on value of life of individuals
- Is as objective and robust as possible

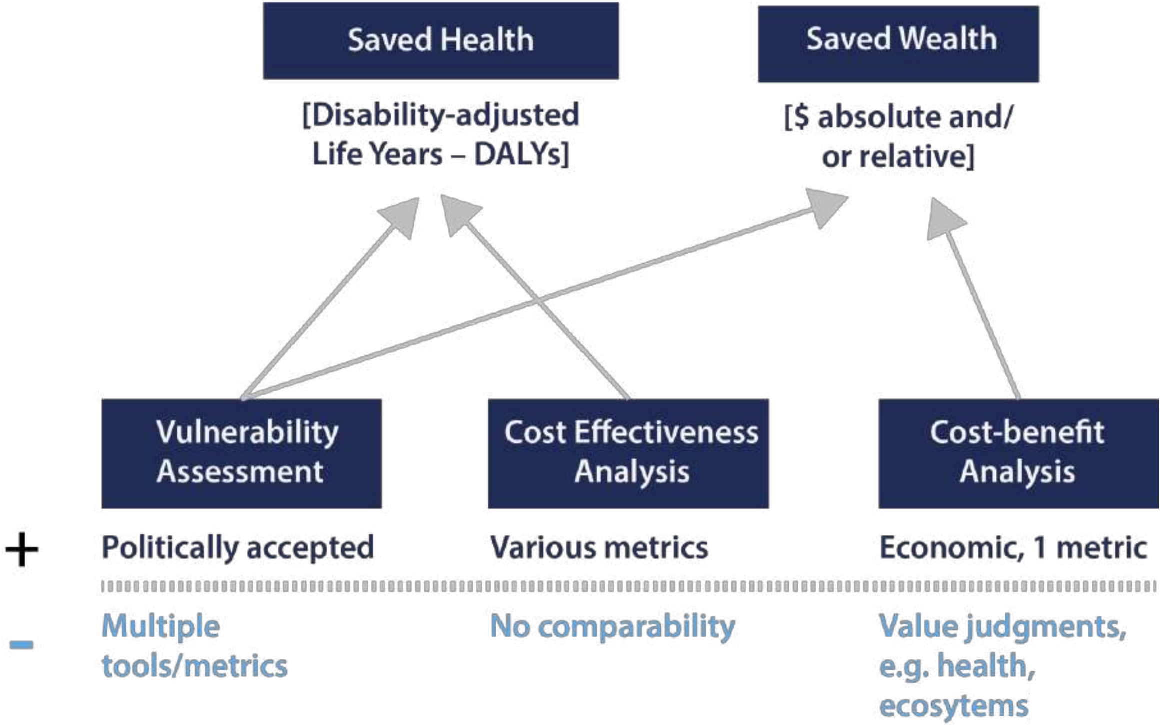
perspectives climate group

Approaches to Prioritising Different Adaptation Projects

Method	Quantified in monetary terms	Quantified in non monetary terms	Qualitative assessment	Output Indicators
CBA (Cost-benefit analysis)	Costs and benefits must be quantified in monetary terms			- Net present value (NPV) - Benefit-cost ratio - Internal rate of return (IRR)
CEA (Cost – effectiveness-analysis)	Costs must be quantified in monetary terms	Benefits may be quantified in non monetary terms but must all be expressed in the same unit		- Cost-Benefit Ratio Does not quantify adaptation benefits
MCA (Multi-criteria-analysis)			Scoring of benefits qualitatively	- Weighted scoring of different projects to produce a ranking Does not quantify adaptation benefits
SW/SH	**Saved Wealth (USD) (including natural capital, avoided erosion and salination)**	**Averted DALYs**	**Environmental Impact checklist**	**- Wealth Saved (NPV) - Health Saved (DALYs) - Environmental benefits**

Integrating 3 approaches into 2 possible metrics





Indicator 1: Saved Wealth

- **Applied for:**
  - Public **infrastructure**
  - Private **property**
- **Natural resources and services are included in public property**
- **Frequency distribution of damage from climate change driven extreme events taken into account for the "baseline scenario"**

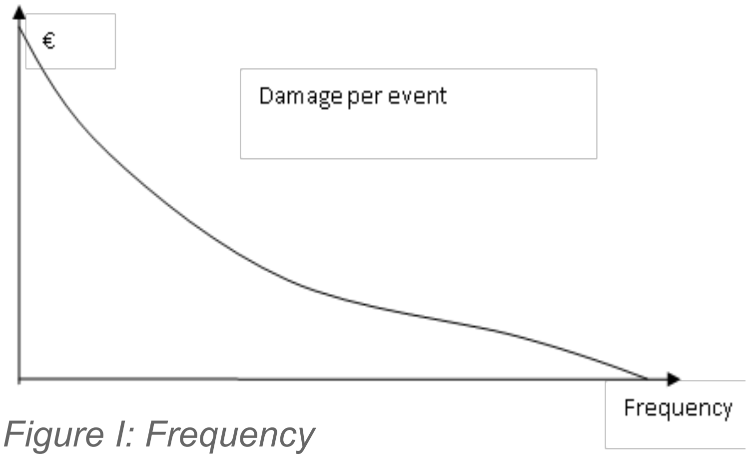


Figure I: Frequency

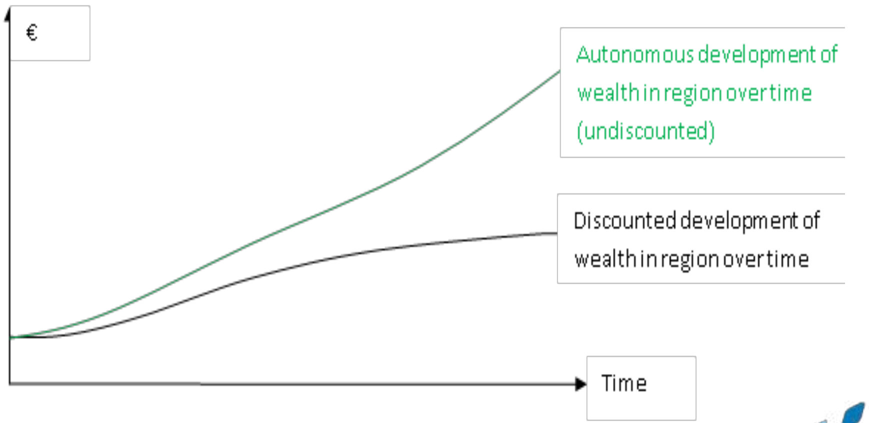
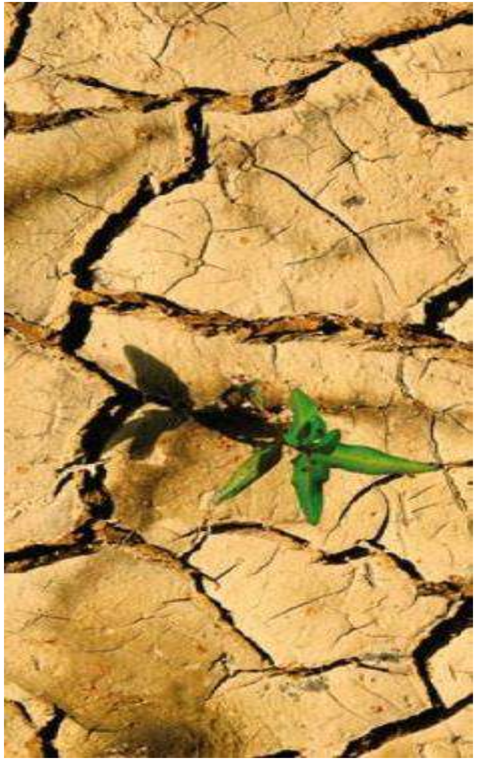


Figure II: change of wealth over time

Indicator 2: Saved Health



- **Valuation of human life** is fraught with ethical challenges
- Alternative quantification indicator: **DALYs**

$$DALY = \underbrace{N \cdot L}_{\text{Years of life lost}} + \underbrace{\sum_i I_i \cdot DW_i \cdot D_i}_{\text{Years lived with disability}}$$

Where:

- DALY — Disability-adjusted Life Years (Introduced by World Bank (1993); used by the WHO)
- N — Numbers of deaths
- L — Standard life expectancy at age of death (in years).
- I_i — Cases of disease / injury i
- DW_i — Disability weight of disease / injury i.
- D_i Average duration of disease / injury in (years)

Applying SW/SH

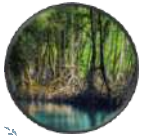
1. Definition of applicability and methodological boundaries
2. Deriving a baseline scenario
3. Describing project scenario(s)
4. Assessment of Saved Wealth and Saved Health and Environmental Benefits

- **For each** project type a **new methodology** needs to be developed
- Once the methodology has been developed, **data needs to be gathered**
  - Project data preferable
  - Regional/national/international defaults are second choice
- The methodology can then be applied to **calculate SW/SH**

Application of SW/SH to date

Vietnam: Dyke or Mangroves?

Methodology: Adapting coastal zones to rising sea levels
Dyke: USD 0.5m (SW), no additional SH
Mangroves: USD 2.3m (SW), 243 DALYs (SH)



Philippines: Mangroves and substitution of pumping station

Methodology: Adapting coastal zones to rising sea levels
Results: Processing ongoing

Nicaragua: Drip Irrigation

Methodology: Irrigation technology in the agricultural sector
Donor Budget: USD 350,000
SW: USD 10.5m
SH: 670 DALYs

Kenya: Solar Irrigation

Methodology: Irrigation technology in the agricultural sector
Donor Budget: USD 115,000
SW: USD13.43m
SH: 570 DALYs

Indonesia: Increasing energy efficiency in food processing

Methodology: energy efficiency in the traditional food processing sector
Donor Budget: USD 200,000
SW: USD 2.1m
SH: 201 DALYs

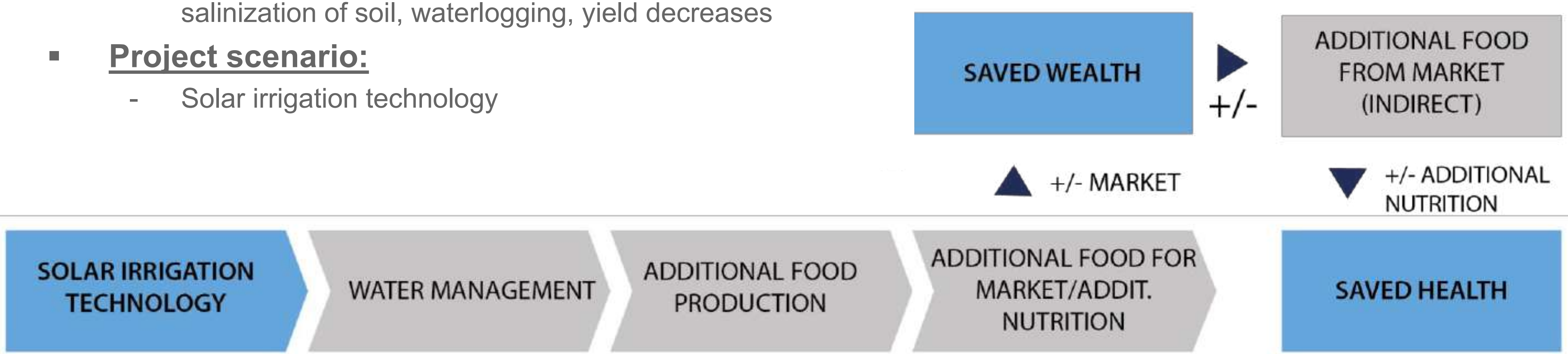
No adaptation project!

Application to real world projects: Solar Irrigation in Kenya

Project Model

- **SW/SH methodology:**
  "Irrigation technology in the agricultural sector"
- **Baseline scenario:**
  - Rain-fed agriculture (4% irrigated), insufficient water distribution and storage
  - Manually operated irrigation systems are common practice (some diesel-driven pumps)
  - Crops: Cabbage, onions, pepper and tomatoes
  - Negative impacts of current irrigation practices: salinization of soil, waterlogging, yield decreases
- **Project scenario:**
  - Solar irrigation technology

Credit: Sunculture



Source: REEEP IMPAQT

Irrigation technology methodology baseline data I

INPUT COMPONENTS: Wealth losses due to climate change during project lifetime (WLCplt)

Population in start year (POP0)

1. Total impacted population
- *Household size*
- *Total households in project area*

2. Population growth rate per year

Baseline Income

1. Income per capita in project area
- *Producer's price for crop x, y, z (USD/tonne)*
- *Average yield over 5 years for crops x,y,z (t/ha)*
- *Project area (ha)*
- *Total impacted population*

2. Total impacted population (see left for data needs)

Income per capita growth rate

- *IGR (income p.c. growth rate (source: World Bank)*

Autonomous Adaptation

- *Default worldwide value of 10%*

Percentage of income projected to be lost to climate change

- *Default worldwide value of 1%*

TOGETHER GENERATE WEALTH LOSSES DUE TO CLIMATE CHANGE VIA EXCEL TOOL

Real local data more preferable

Irrigation technology methodology baseline data II

INPUT COMPONENTS: Health losses due to climate change during project lifetime (HLCplt)

Population in start year (POP0)

1. Total impacted population
- *Household size*
- *Total households in project area*

Percentage of income/health projected to be lost due to climate change

- *Default worldwide value of 1%*

DALYs per year (kcal malnutrition)

- *Life years saved due to additional food calories*
- *Life years saved due to additional protein*
- *Live years saved due to additional fat*
- *Food supply deficit (kcal/cap/day)*
- *% of average undernourishment (compared to minimum requirements)*
- *Estimated Minimum Fat, g/cap/day estimated minimum proteins (g/cap/day)*
- *Life expectancy at birth*

Population with disability due to CC (DALYs per year: Kcal malnutrition)

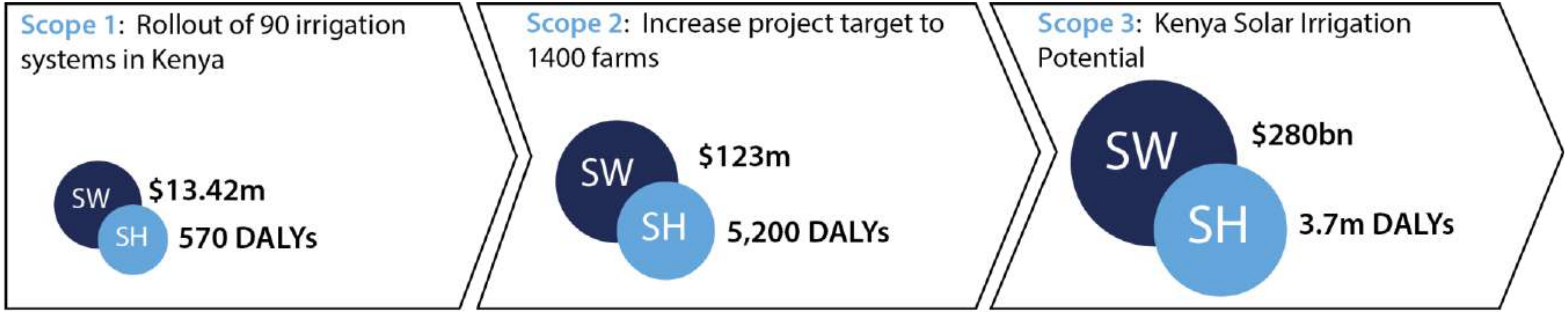
- *Life years saved due to additional food calories*
- *Life years saved due to additional protein*
- *Food supply deficit (kcal/cap/day)*
- *% of average undernourishment (compared to minimum requirements)*
- *Estimated Minimum Fat, g/cap/day estimated minimum proteins (g/cap/day)*
- *Life expectancy at birth*
- *Average disability weight*

Project Lifetime in years

TOGETHER GENERATE HEALTH LOSSES DUE TO CLIMATE CHANGE VIA EXCEL TOOL

Real local data more preferable

Project adaptation benefits over ten years at different scales



Donor Budget: USD 115,000

Donor Budget: USD 1.5m

Imaage sources: Sunculture ASIK 2016 (Left), Futurepump 2016 (Right)

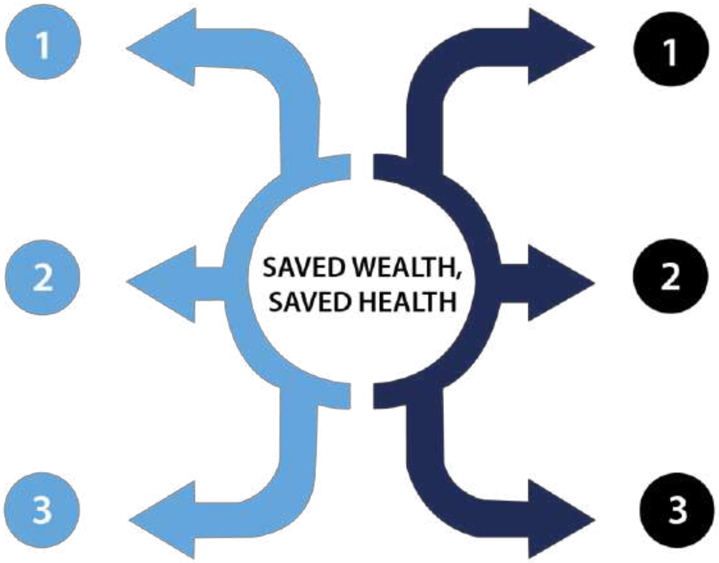
Strenghts and challenges

STRENGHTS

Ex-ante: Allows comparison of project types among each other and against a baseline

Ex-post: If monitoring parameters are defined properly and consistent for several projects the concept can be applied as a useful tool for M&E that improves transparency and comparability

Planning and target definition and communication across levels



CHALLENGES

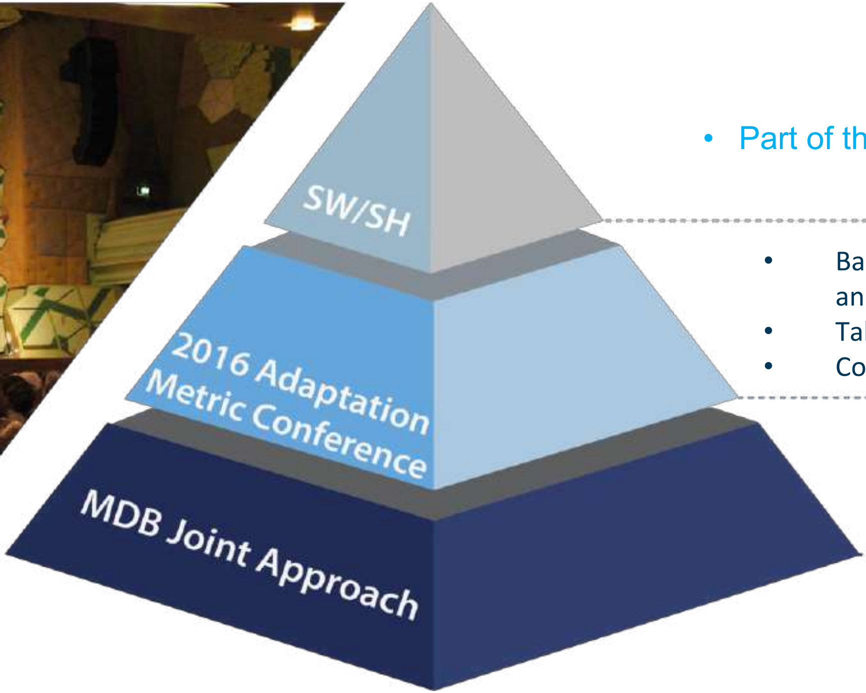
Data gathering can be challenging on the local level

Uncertainty of climate change projections

Application of the complex tool **requires good understanding of economic methods** (CBA) and impacts of climate change.

SW/SH: Building on emerging consensus

ource: www.flickr.com/photos/takver/10078222064

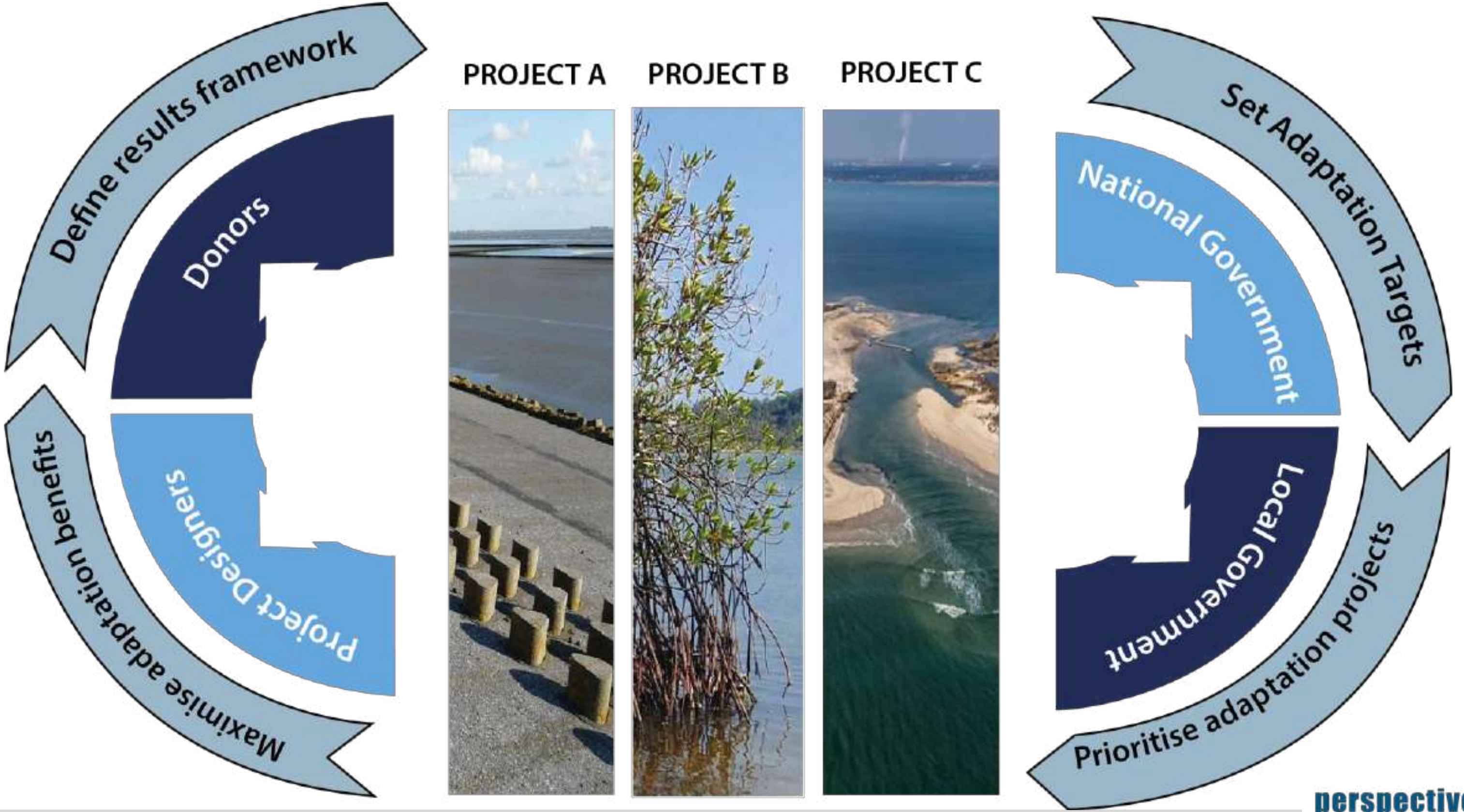


- Part of the solution

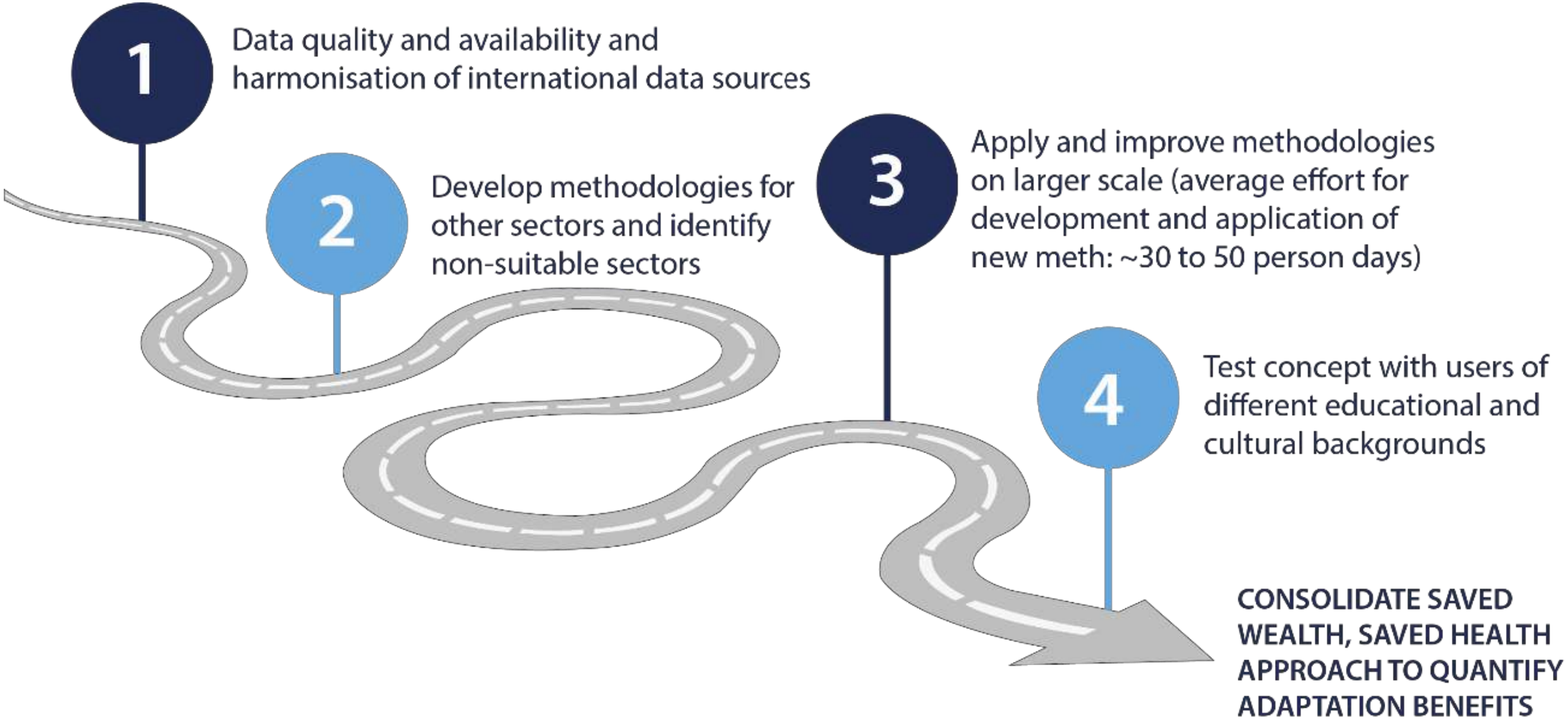
- Balance needs of global multilateral donors, national and sectoral level
- Takes into account territories, regions, nations
- Contextualisation and regional differentiation

- Set out the climate vulnerability context of the project
- Explicit statement of intent to address climate vulnerability
- Direct link between climate vulnerability context and the specific project activities.”

SW/SH: A multi-use and multi-level approach



Next Steps for Saved Wealth, Saved Health



perspectives climate group

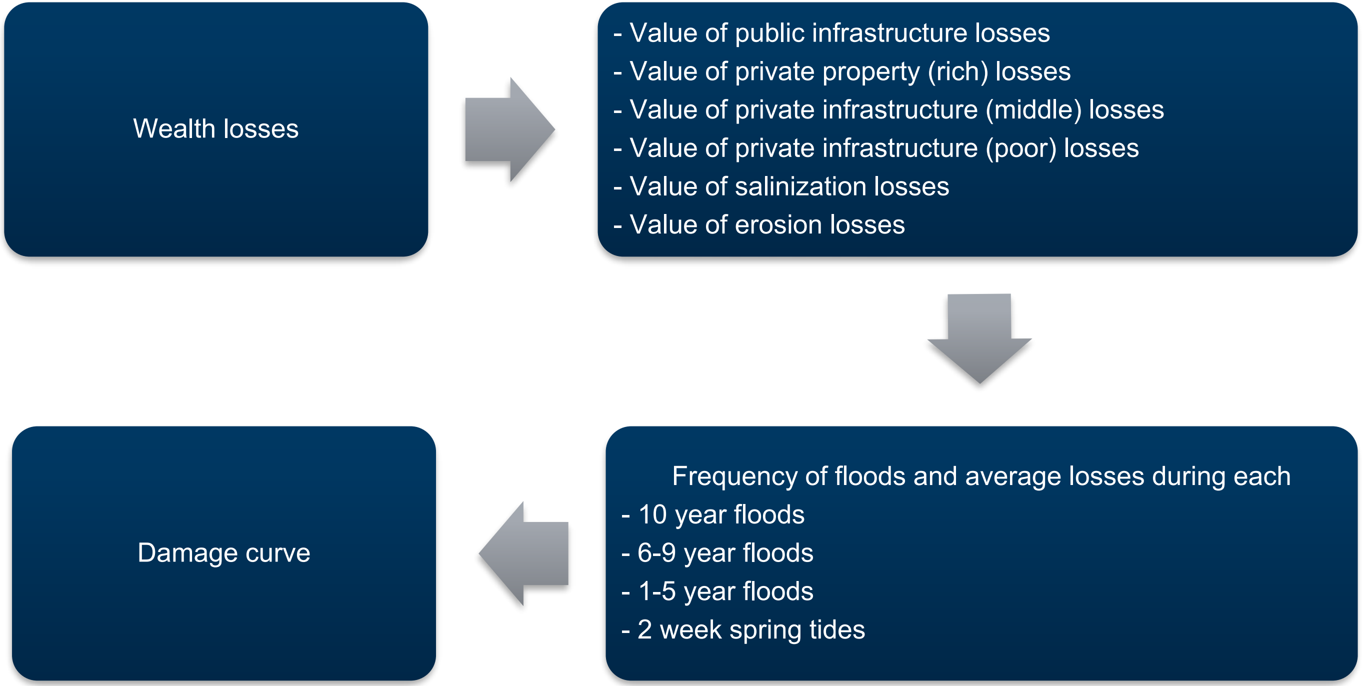
THANK YOU FOR LISTENING

Matthias Krey
Senior Advisor

Perspectives Climate Group GmbH
krey@perspectives.cc | www.perspectives.cc

Annex 1: Coastal Protection methodology baseline

- **Wealth losses**



Annex 1: Coastal Protection methodology baseline

- ## Health losses

- Population at start of the project
- Population growth rate
- Project lifetime in years
- Life expectancy at birth (DALYs from death)
- Standard life expectancy at death (DALYs from death)

→

Frequency of floods and % of population affected during each
- 10 year floods
- 6-9 year floods
- 1-5 year floods
- 2 week spring tides

↓

Disability weight of death, fractures and diarrhea

←

Health losses (DALYs from death, fractures and diarrhea per annum)

INTERNATIONAL CONFERENCE ON
ADAPTATION METRICS FOR WATER & AGRICULTURE
October 6th and 7th 2017

COP23 FIJI UN CLIMATE CHANGE CONFERENCE BONN 2017 ENDORSED EVENT

MARRAKECH 2016 COP22 | CMP12 | CMA1 UN CLIMATE CHANGE CONFERENCE

جامعة محمد السادس متعددة التخصصات التقنية
MOHAMMED VI POLYTECHNIC UNIVERSITY
UNIVERSITÉ MOHAMMED VI POLYTECHNIQUE

Harnessing and transitioning to ecological intensification to improve performances and efficiency of dryland agricultural systems

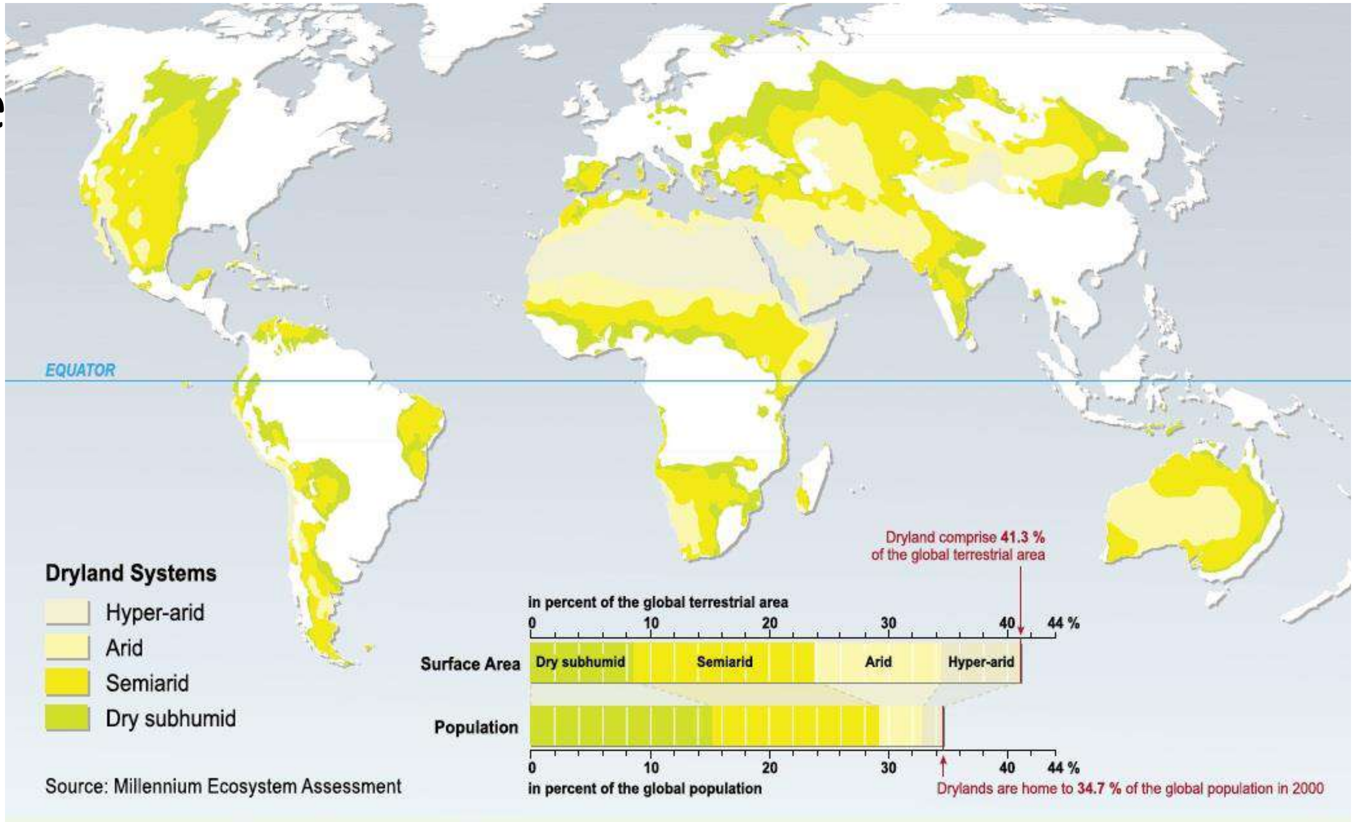
المعهد الوطني للبحث الزراعي
Institut National de la Recherche Agronomique

Dr. Rachid MRABET
Research Director
INRA Morocco

Drylands are the largest biome on Earth

No clear boundary

Global Map of drylands



41.3 % of the Earth's continental are
(430 Millions ha) **and is expanding.**
38% of the world's population
(2.5 billion inhabitants).

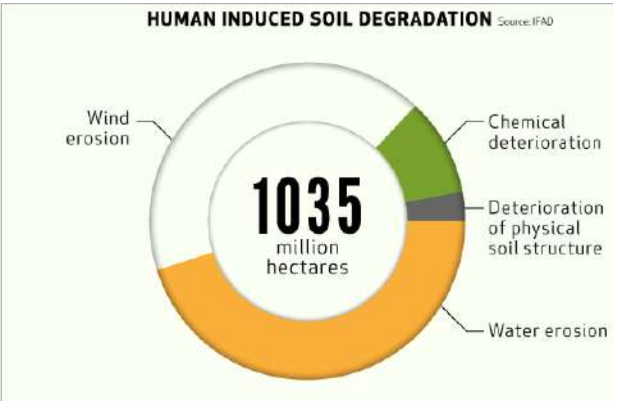
84% of world cultivated area.
67% of the world's food production.

Hotspots are sub-Saharan Africa (the Sahel, the horn of Africa and South-East Africa) and Southern Asia.

Hyper-arid (AI < 0.05)
Arid (0.05 ≤ AI < 0.2)
Semiarid (0.2 ≤ AI < 0.5)
Dry subhumid (0.5 ≤ AI < 0.65)

Dryland degradation & Sparse vegetation cover

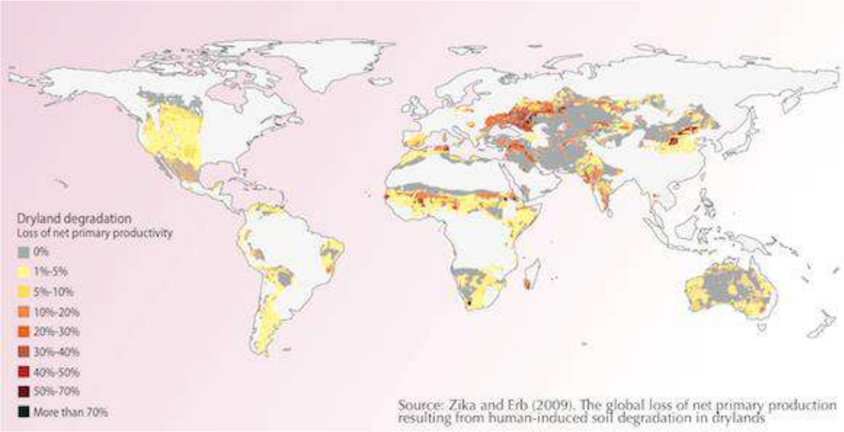
Droughts and desertification threaten the livelihoods and well-being of more than **1.2 billion people in 110 countries**

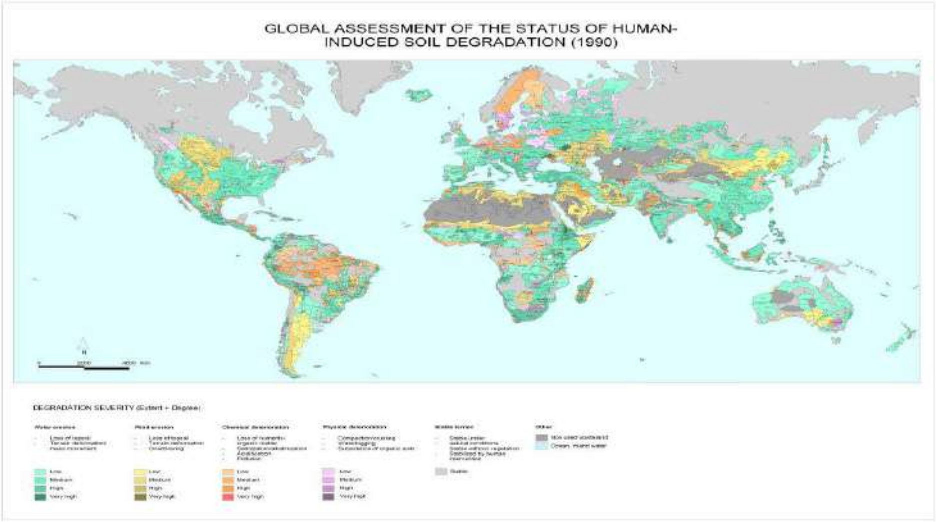


One and half billion people are dependent on degrading land.

Ten to twenty per cent of drylands are degraded.

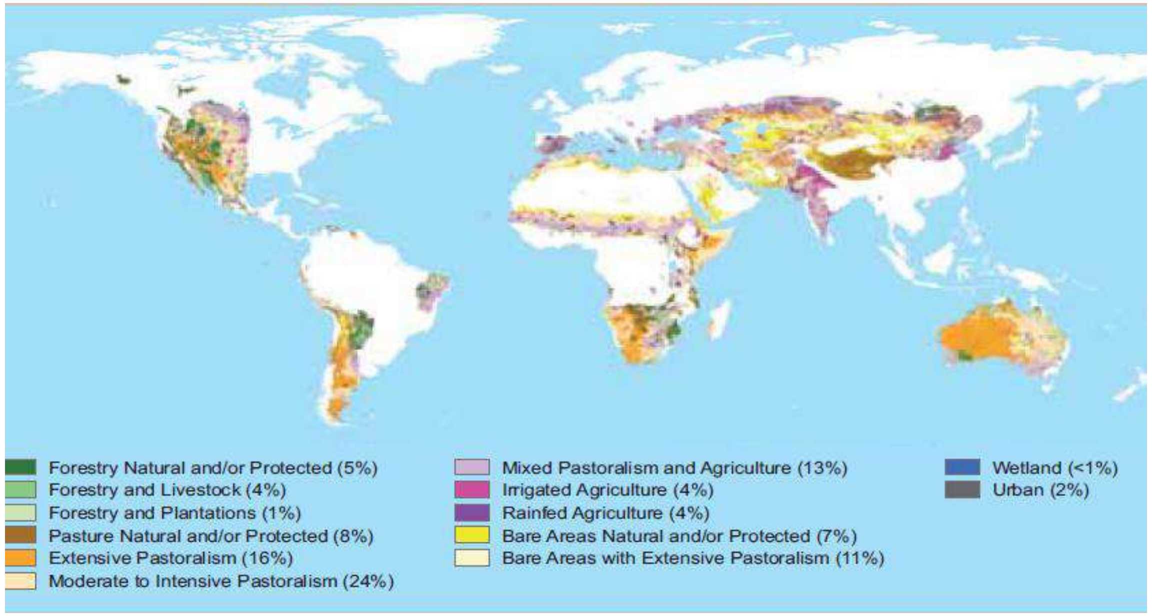
Prevent the aggravation of global desertification

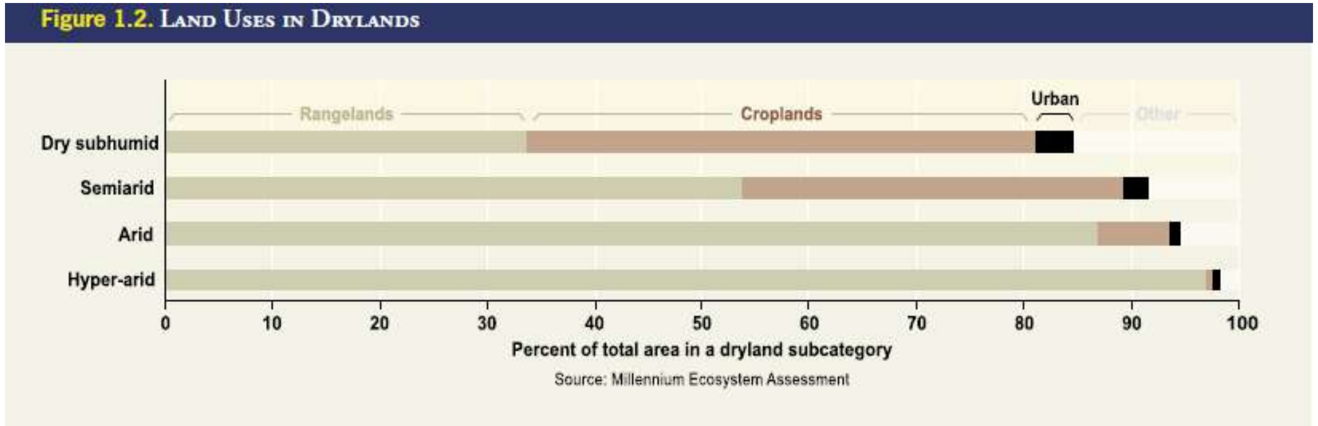




Land use systems in the drylands

Supporting 50% of the world's livestock, **rangelands** – vast natural landscapes - are habitats for wildlife.





Source: http://www.eoearth.org/view/article/152297/; http://www.un.org/en/events/desertification_decade/whynow.shtml

FAO "Draylands, People and Land use"
http://www.fao.org/docrep/012/i0372e/i0372e01.pdf;
http://passthrough.fw-notify.net/download/341043
http://www.unep.org/maweb/documents/document.291.aspx.pd
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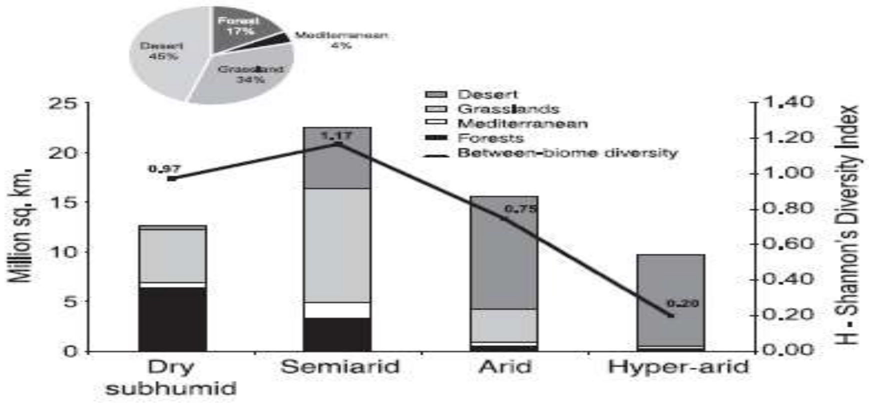
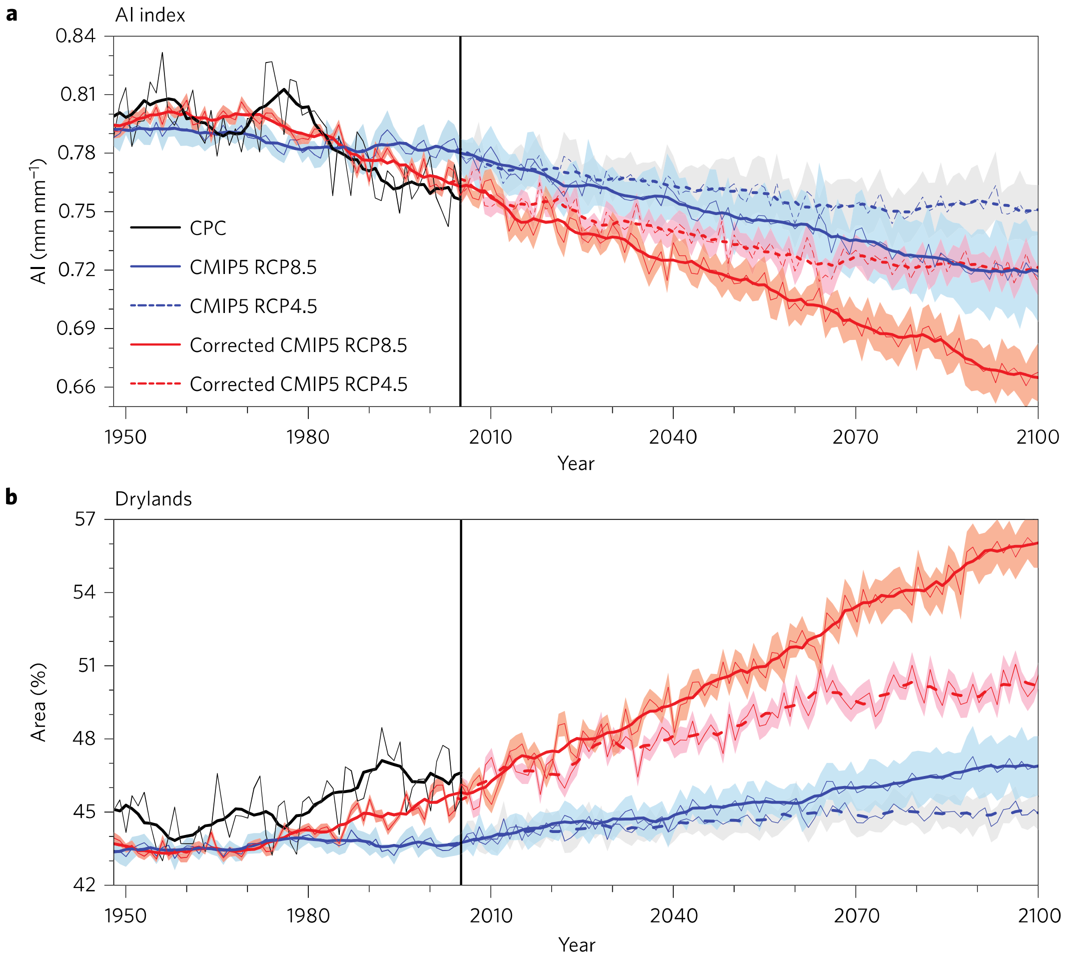
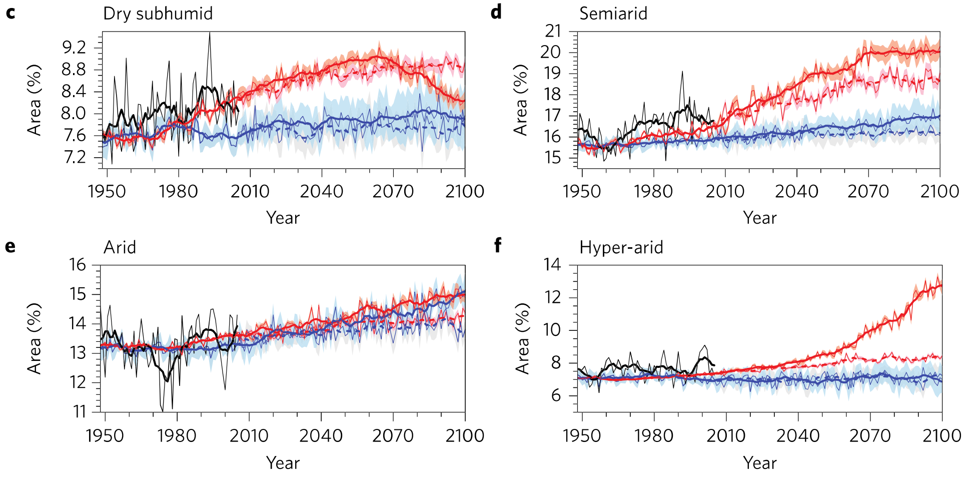


Due to climate change, the area covered by rangelands will grow.

Temporal variation in the aridity index and the areal coverage of drylands



Huang et al. 2015

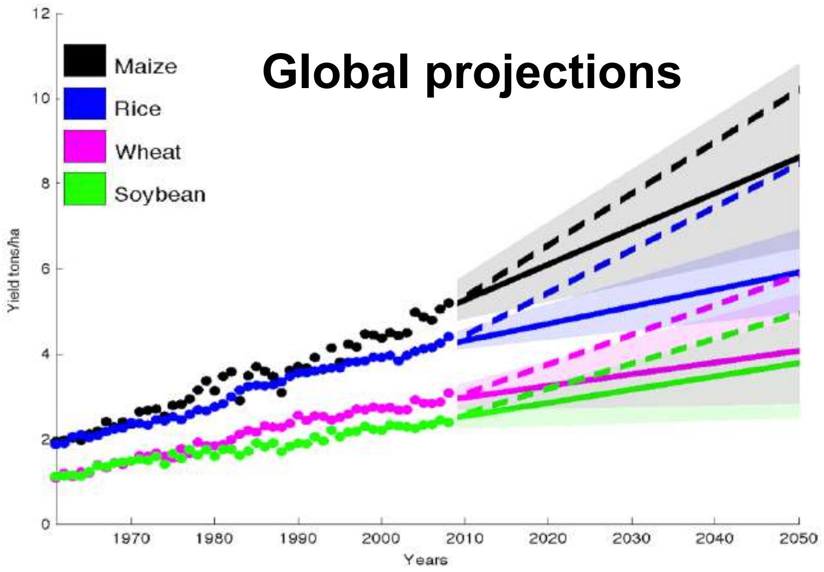


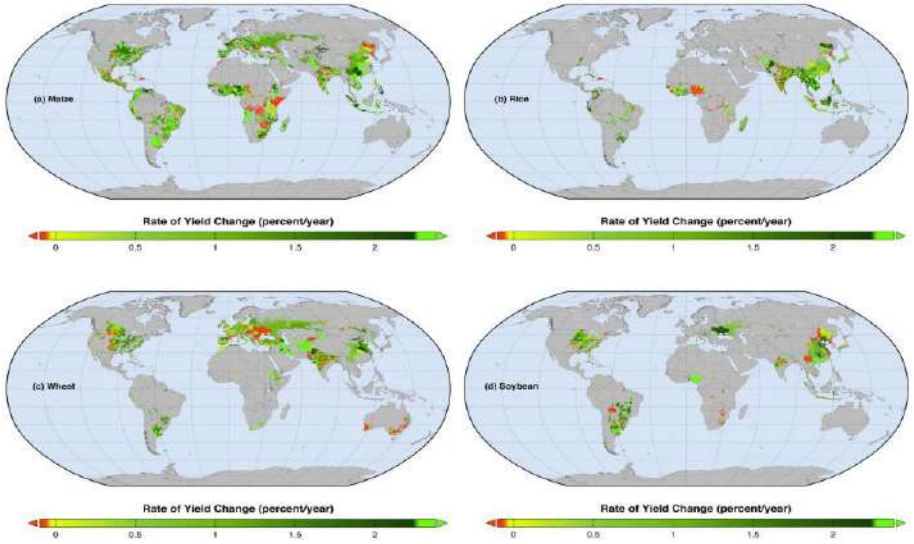
Predictions include a growth in the land mass of dryland ecosystems by 11 to 23 % before the year 2100.

The challenge to produce enough food is more urgent than ever

Ray et al. 2013

- By 2050, global agricultural production may need to be increased by 60%–110% to meet increasing demands.
- Yield Trends Are Insufficient to Double Global Crop Production by 2050
  - The global average rates of yield increase are 1.6%, 1.0%, 0.9%, and 1.3% per year for maize, rice, wheat, and soybean, respectively.
  - A ,2.4% per year rate of yield gains is needed to double crop production by 2050.
  - Yields are no longer improving on 24–39% of most important cropland areas.



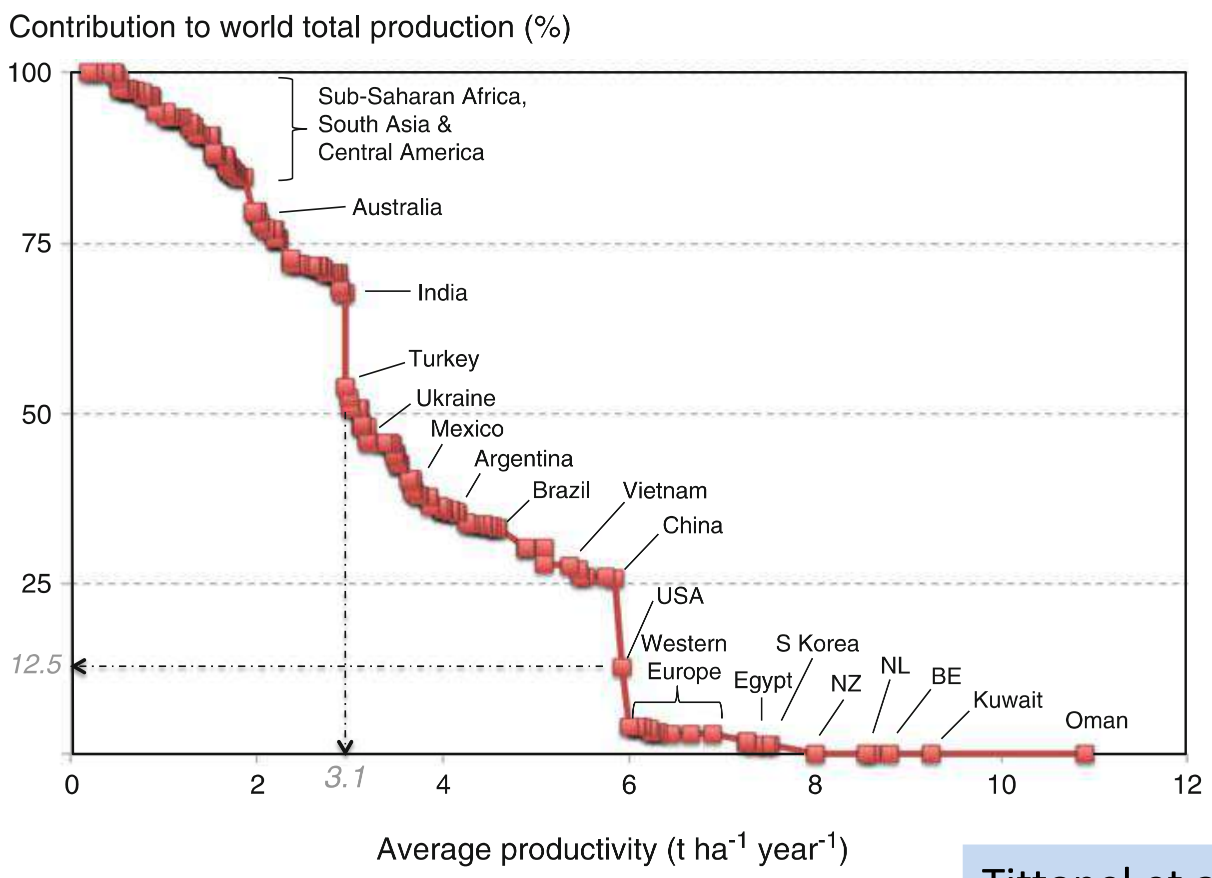


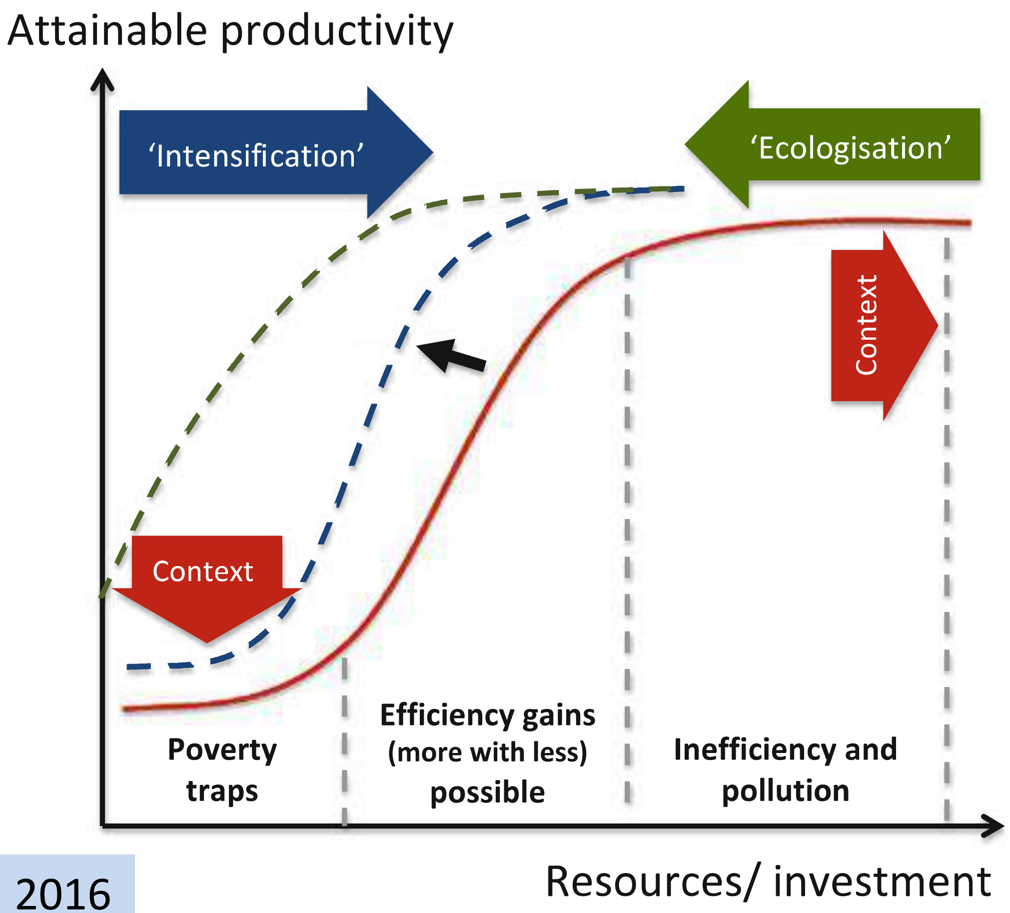
Maps of observed rates of percent yield changes per

Grand mobilization for ecological intensification

Rockstrom et al. 2017

Repositioning agriculture from driving environmental degradation to mainstreaming ecological intensification.





Tittonel et al. 2016

Terminologies: Conceptualizing food systems for global environmental change

Interlinked concepts

- **Sustainable intensification**: '(. . .) producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services'

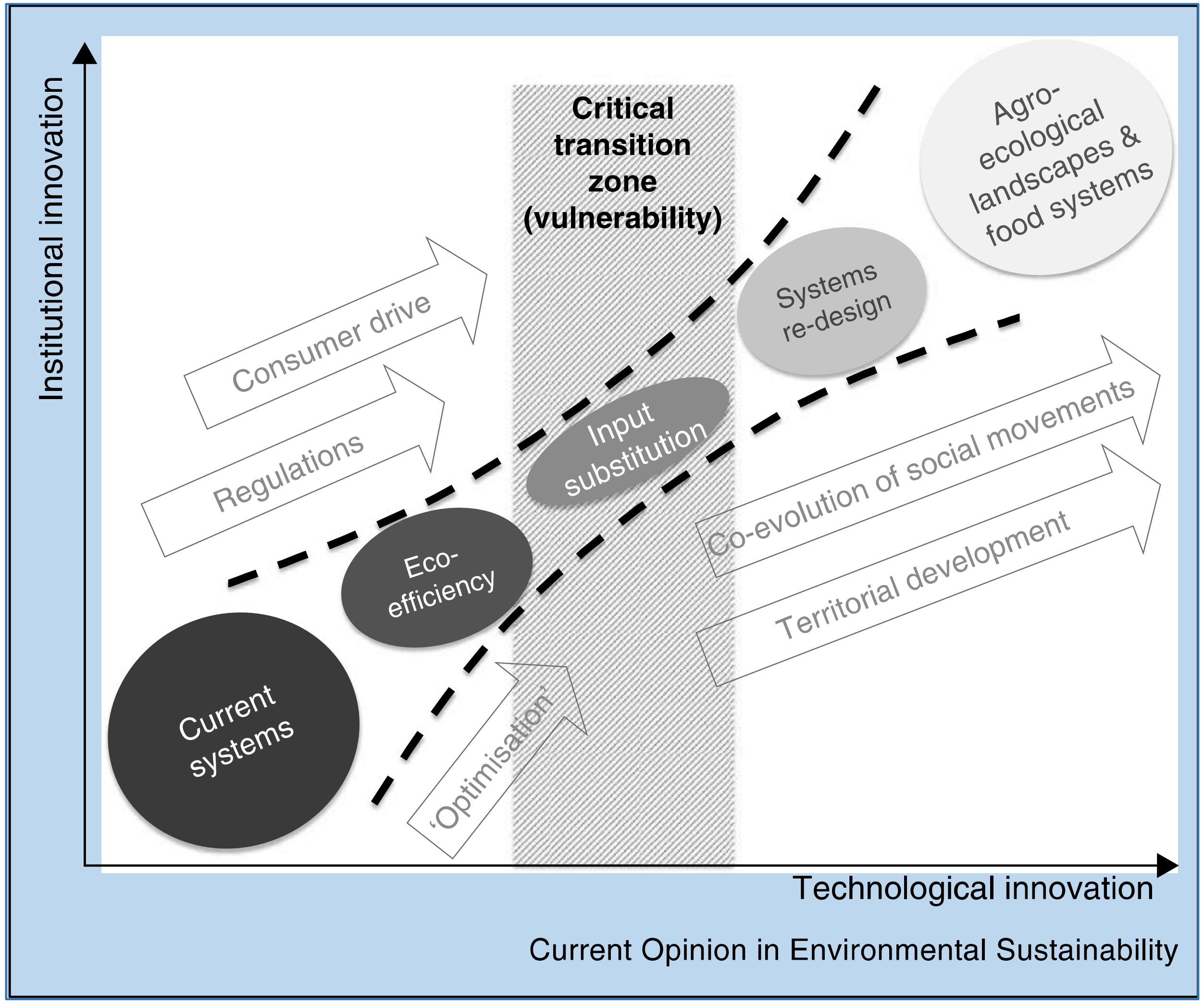
- **Ecological intensification**: is defined as the means to make intensive and smart use of the natural functionalities of the ecosystem (support, regulation) to produce food, fibre, energy and ecological services in a sustainable way.
  - 'imply producing more but producing differently, and producing new things ':
  - Current models include conservation agriculture, agroecology, organic, bio-diverse and restorative agriculture.

Eco-efficiency : producing more value with less impact

Agro-ecology: Four plillars ➔ diversity, efficiency, recycling, regulation

Climate Smart Agriculture is defined by three objectives: i) increasing agricultural productivity to support increased incomes, food security and development; ii) increasing adaptive capacity at multiple levels (from farm to nation); and iii) decreasing greenhouse gas emissions and increasing carbon sinks.

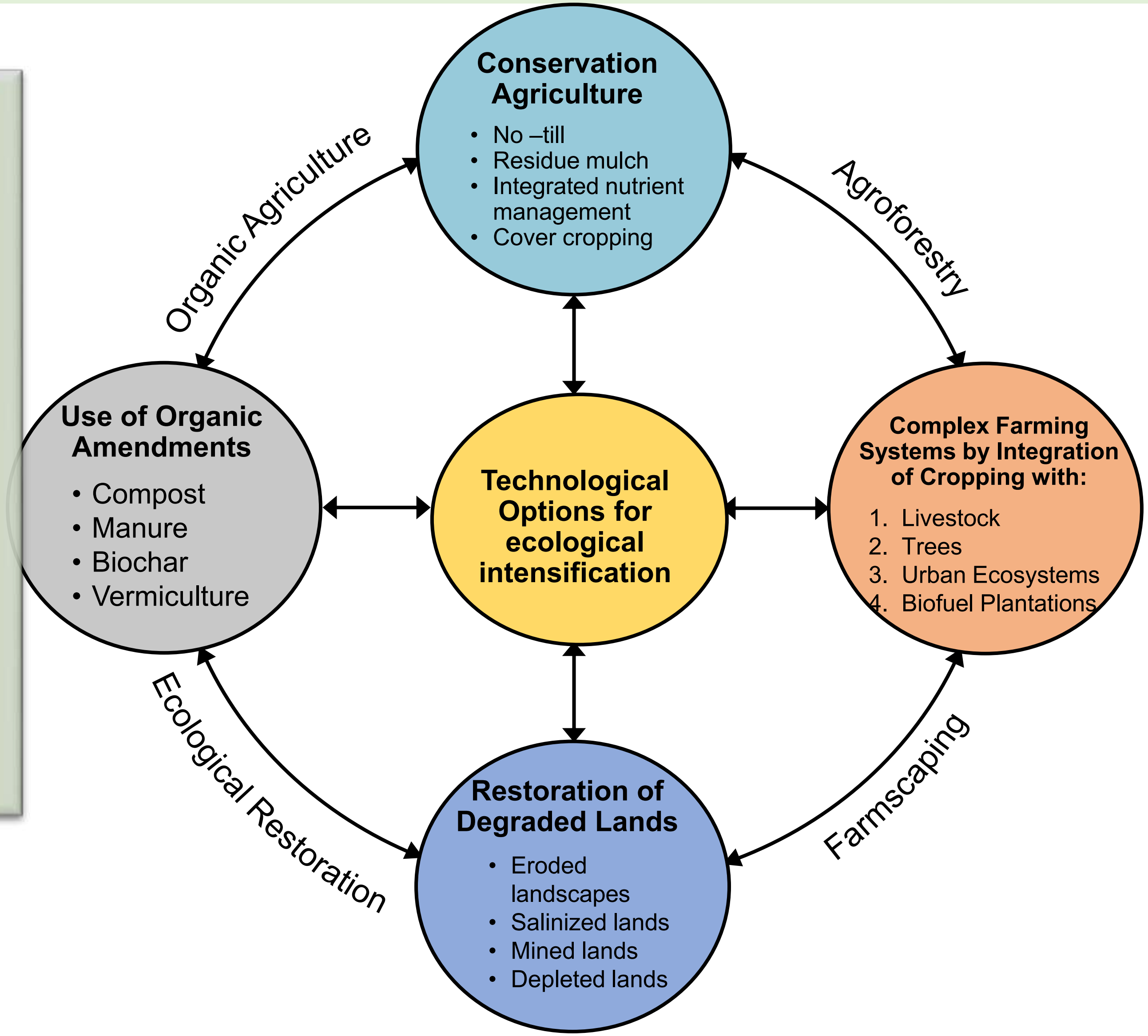
Transition pathway to ecological intensification



Lescourret et al., 2014

TECHNOLOGICAL OPTIONS FOR ECOLOGICAL INTENSIFICATION

Ecological intensification lies in harnessing the power of agriculture, soil, and natural resources.



Improvements in agriculture performances through targeted and efficient uses of resources.

Adaptation pathways: Resilience – Transition – Transformation

Conservation Agriculture (CA)

Crops do not ask for plow or disk ... they demand a good soil condition for germination and growth.

is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment

① Minimizing soil disturbance, consistent with sustainable production.

② Maximizing soil surface cover by managing crops, pastures and crop residues.

③ Stimulating biological activity through crop rotations, cover crops and integrated nutrient and pest management.

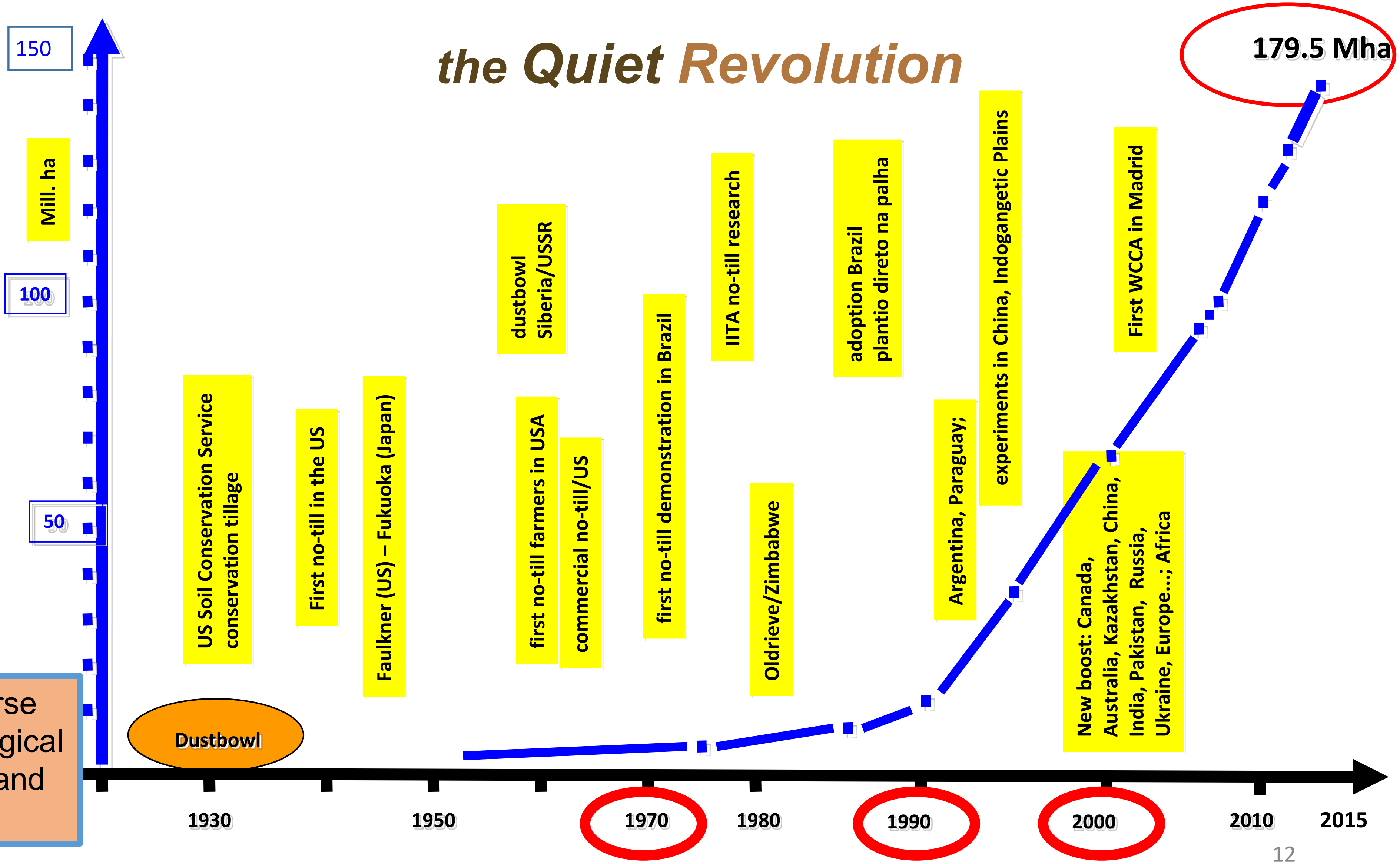




History and Adoption of CA (2015/16).
Since 2008/09 increasing at 10 M ha annually

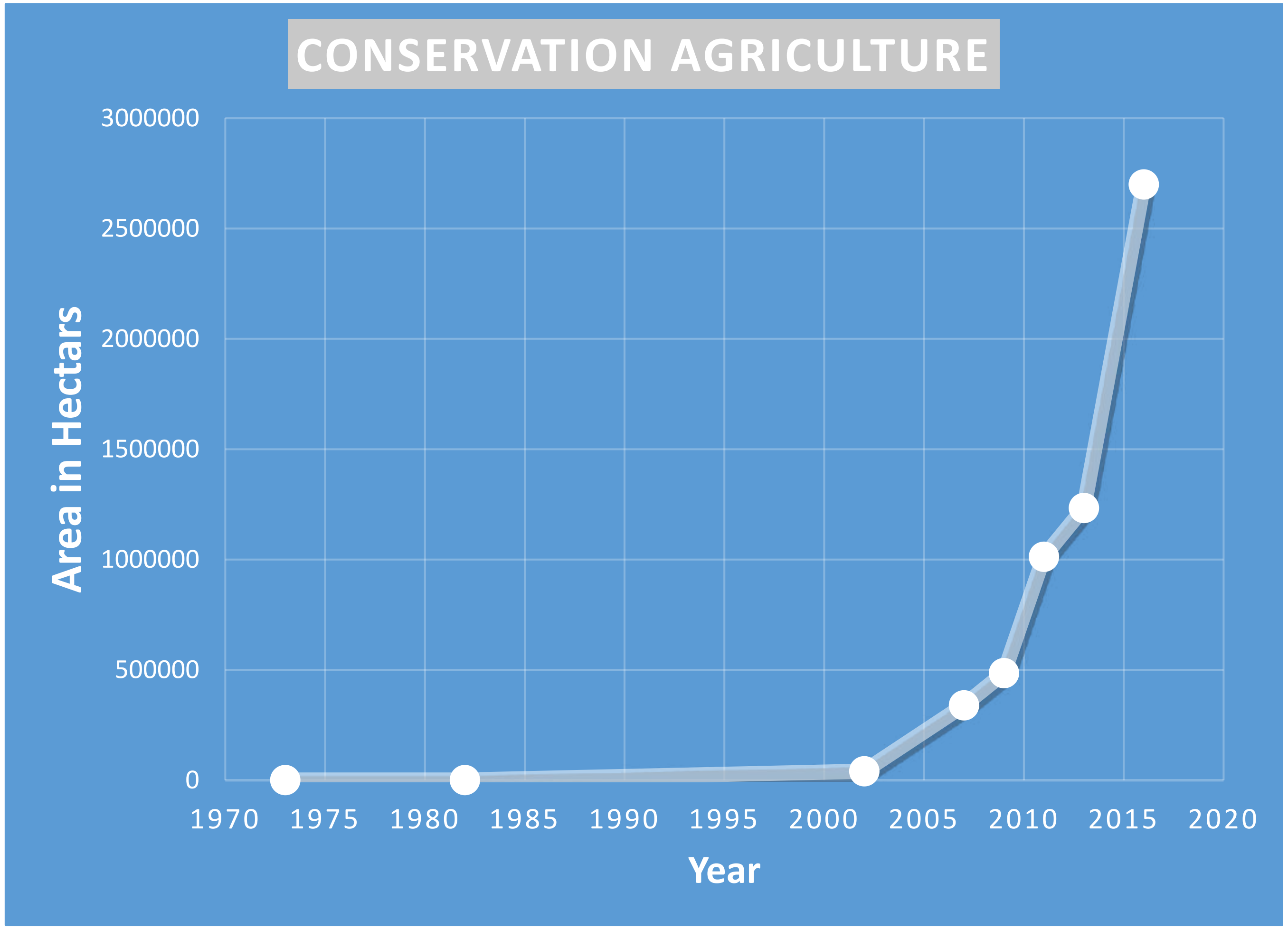
Continent	Area (Million ha)
South America	69.9 (49.6)*
North America	63.2 (40.0)
Australia & NZ	22.7 (12.2)
Asia	13.2 (2.6)
Russia & Ukraine	5.2 (0.1)
Africa	2.7 (0.5)
Europe	2.5 (1.6)
Global total	179.5 (107)* ( )* 2008/9

CA is applicable across diverse geographic regions, agroecological zones, soil types, plot sizes, and crops.



Conservation agriculture holds great promise for Africa

Drought mitigation
Erosion reduction
Ecosystem services
High biodiversity



2.7 million ha

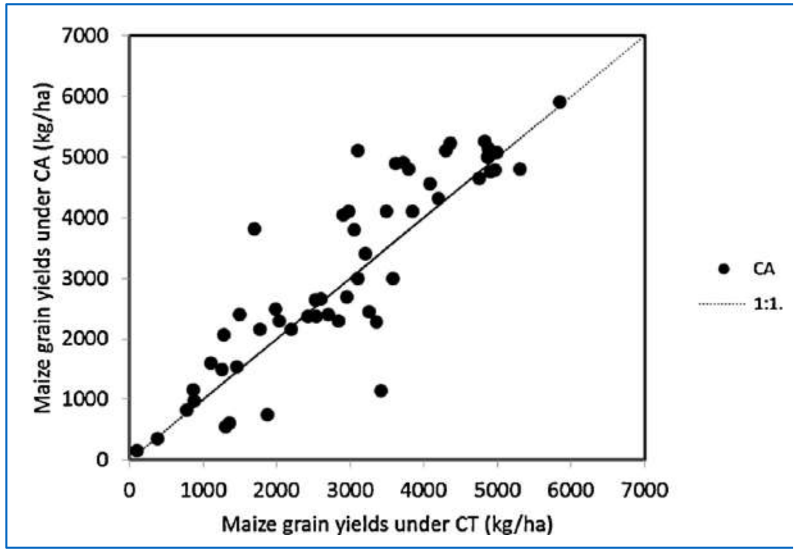
Yield increase
Reduced Gaps
Reduced production costs
Farmer incomes
Resource efficiency
Energy efficiency
Spare time
Reduced Dragdery

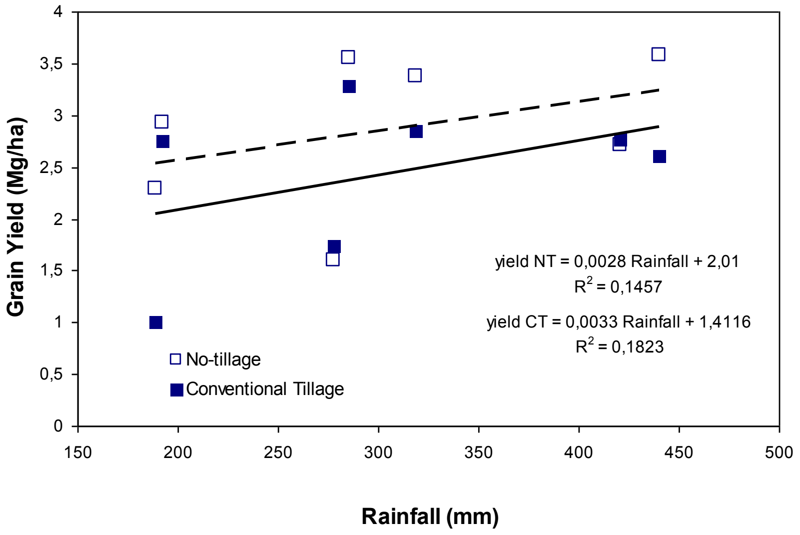
Coping technologies to lower/sporadic rainfall, floods and rising temperatures.

Kassam et al, 2017

Closing the yield gaps with CA while driving resource use efficiency

Africa will never feed itself without conservation agriculture





- **Increased productivity** (for small, medium and large scale farmers).
- **Savings in labour** (up to 60%).

Zimbabwe, Malawi, Zambia, Kenya and Tanzania

Corbeels, M., et al., 2013

Central Morocco

Mrabet, 2011

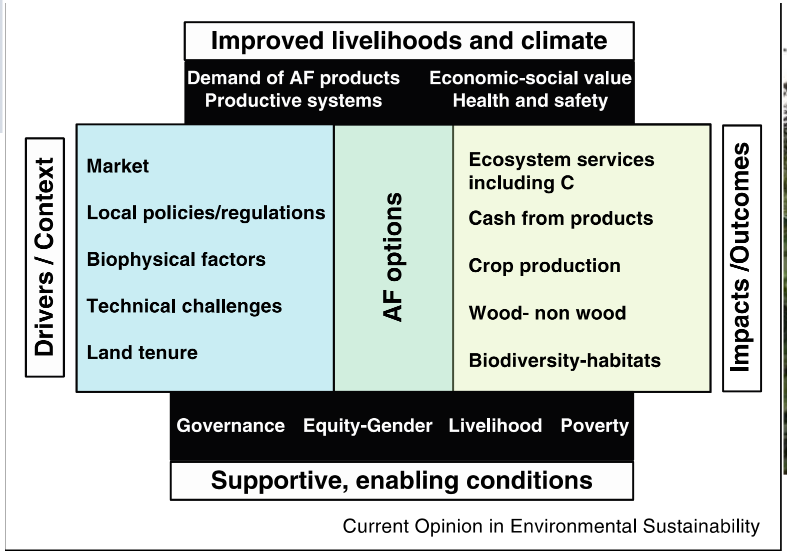
To stabilise yields in years of extreme weather

Agroforestry systems: wide variety of shapes and forms.

Agroforestry or **agro-sylviculture** is a land use management system in which trees or shrubs are grown around or among crops or pastureland.

Wood, fruits, medicine and a variety of ecological services.

Olive-based agroforestry systems



43% of all agricultural land globally had at least 10% tree cover and that this has increased by 2% over the previous ten years.

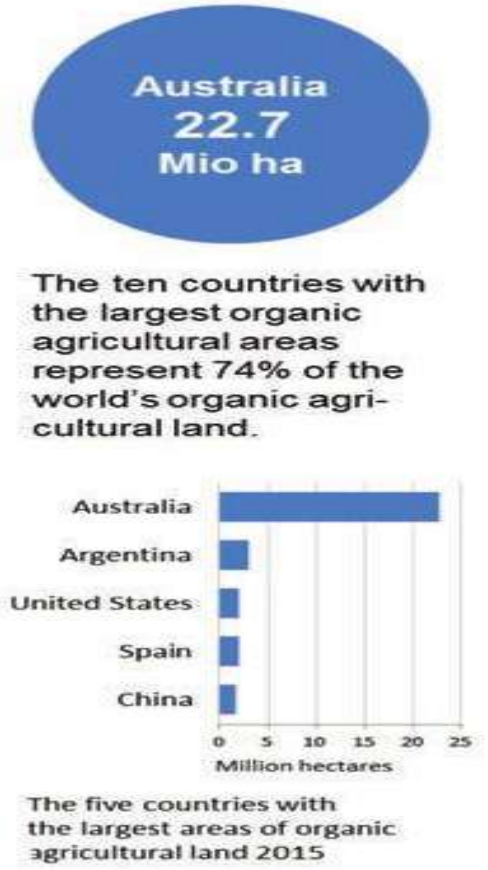
cost-effective solutions to enhance food security

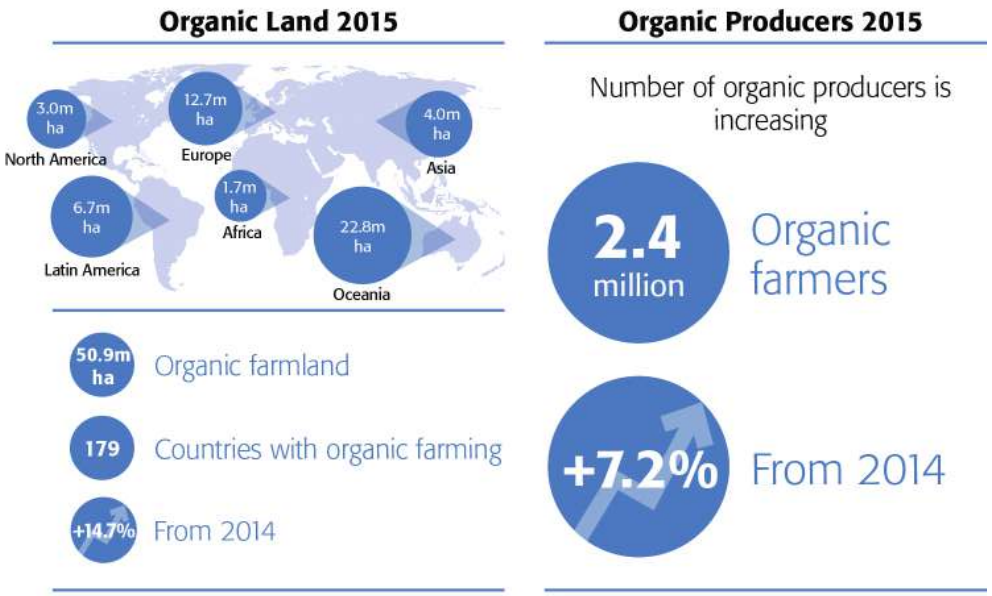
Banana agroforestry system

Farm household resilience
Animal husbandry
Social wealth
Water cycling
Soil cover and fertility
Carbon sequestration
Fighting desert progression

1.2 billion people around the world dependent upon agroforestry farming systems

Organic Farming (certified & by-default)

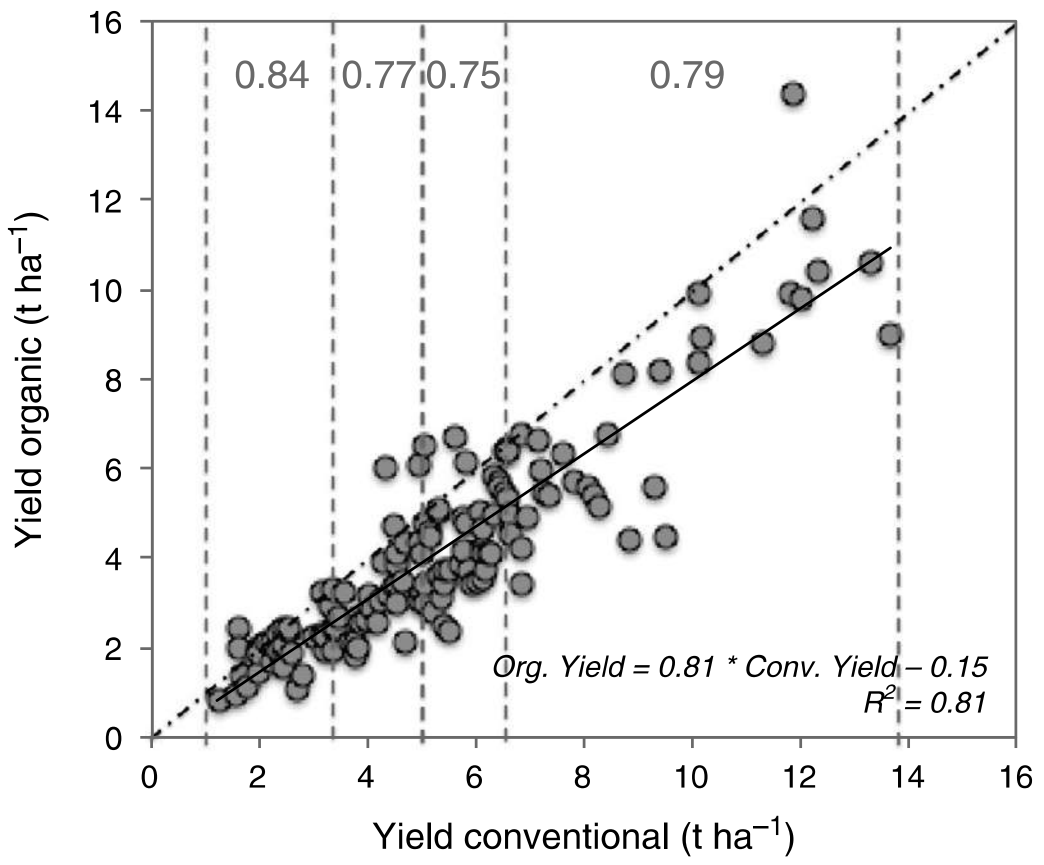




Organic share of total agricultural land	2015: 1.1 %

Organic Farming (certified & by-default): *greatest potential for combating climate change*

Tillage practices may shadow some benefits



Current Opinion in Environmental Sustainability

Higher yields
Quality product
Healthier products
Value-added products
Environmental steardship

Sustainable Soils
Nitrogen self-sufficiency
Maintaining biodiversity
Water conservation
Animal welfare & health

Adaptation metrics (attributs) & ecological intensification models

A. Agroecosytem robustness

B. Livelihood sustainability

C. Institutional capacity development & strengthening

Adaptation attributs with Ecologically Intensive Agriculture models: CA, AF and OF

CROP & FARM

- Increased & stable yields, productivity, profit (depending on level and degradation)
- Less fertilizer use (-50%), also no fertilizer less pesticides (-20->50%), also no pesticides
- Less machinery, energy & labour cost (50-70%)
- Less water needs (-30-40%) – higher water use efficiency

Agroecosystem robustness

Sustainably mobilize greater crop and land potentials with increased efficiency and resilience

LAND

- Greater livestock and human carrying capacity
- Lower impact of climate (drought, floods, heat, cold) & climate change adaptation & mitigation
- Lower environmental cost & footprint (water, infrastructure)
- Rehabilitation of degraded lands & ecosystem services

Adaptation attributs with Ecologically Intensive Agriculture models: CA, AF and OF

Household livelihoods & Labor

Nutritional diversification from increased crop diversity
Product diversification
Lower total labor requirement
More seasonal flexibility in labor needs
income options

Livelihood options

Institutional capacity

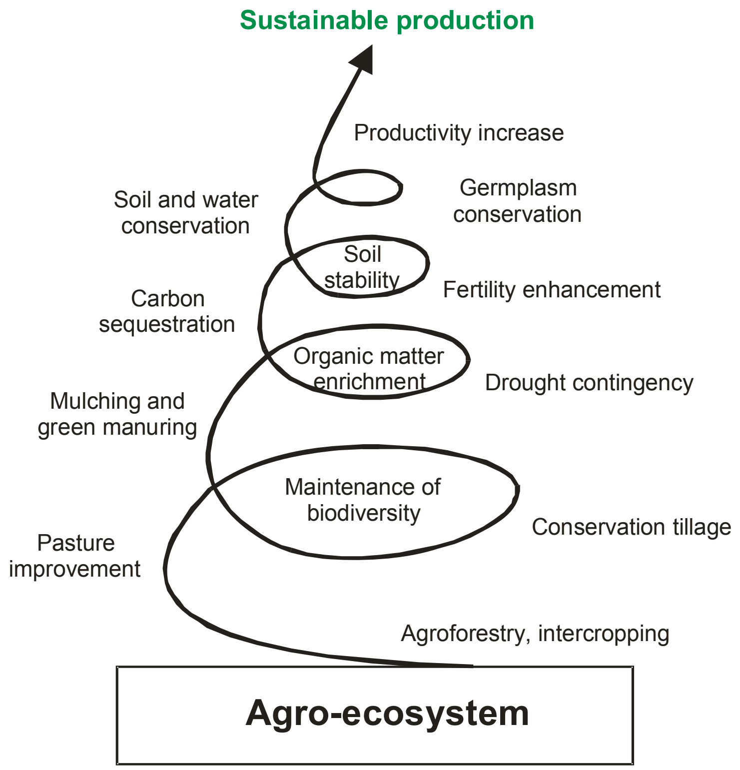
Human capital and social capital & Institutional/policy/market

Increased farmer knowledge, innovation
Increased opportunities for social learning
Increased access to equipment, seeds, and inputs
Availability of credit and financial services
Gender equity

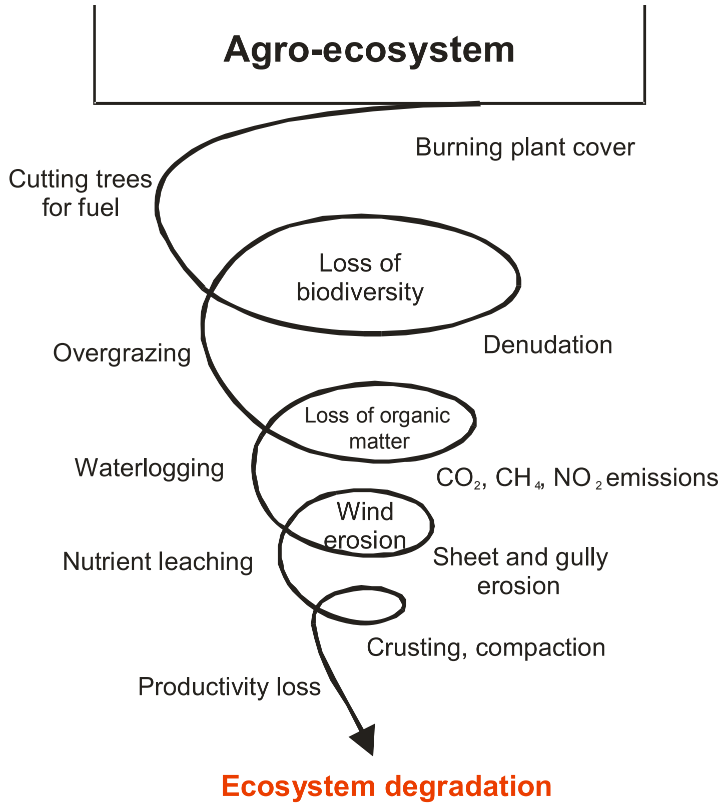
Shifting from degradation to sustainability

Integrated social–ecological (Sharing) framework

Sustainability spirale



Degradation spirale



Land Sparing framework

In Drylands, ecological intensification is not just an opportunity, it must become a mandate.

Spatiotemporal monitoring of meteorological and agricultural drought in Morocco

Use of open satellite short time-series

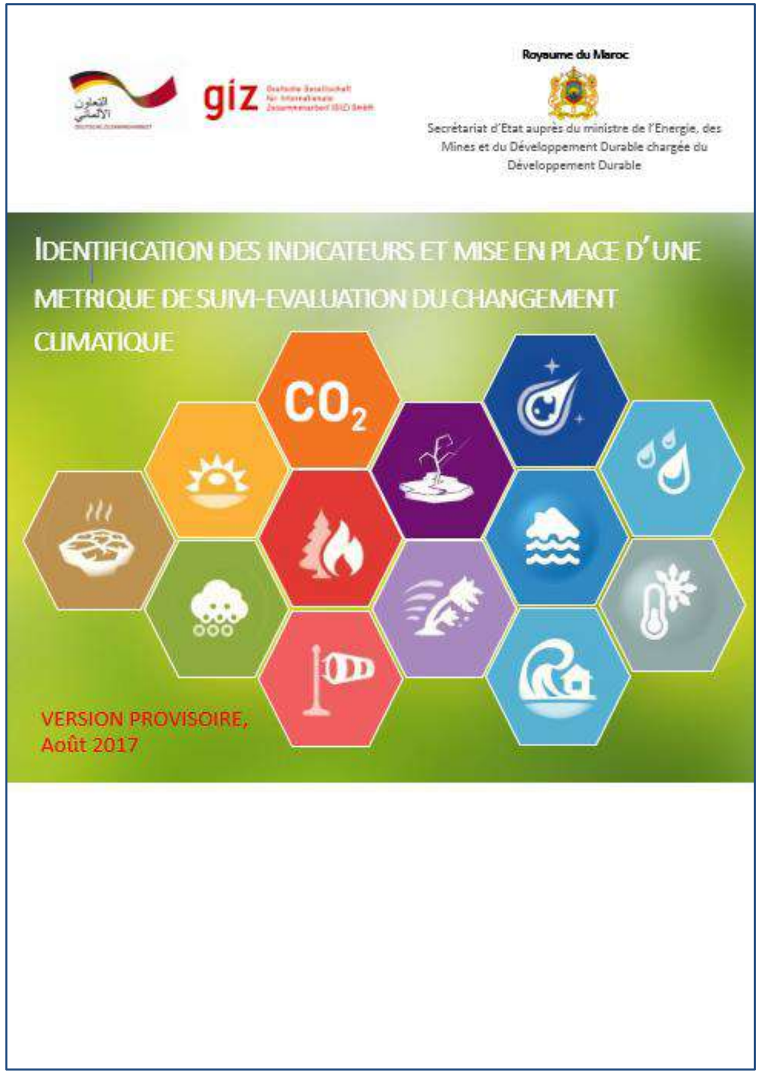
Hicham Ezzine, Ahmed Bouziane, Driss Ouazar

Sommaire

- Introduction
- Methodology (monitoring & downscaling)
- Results
- Conclusion

Introduction

- Toward a Moroccan CC Metrics

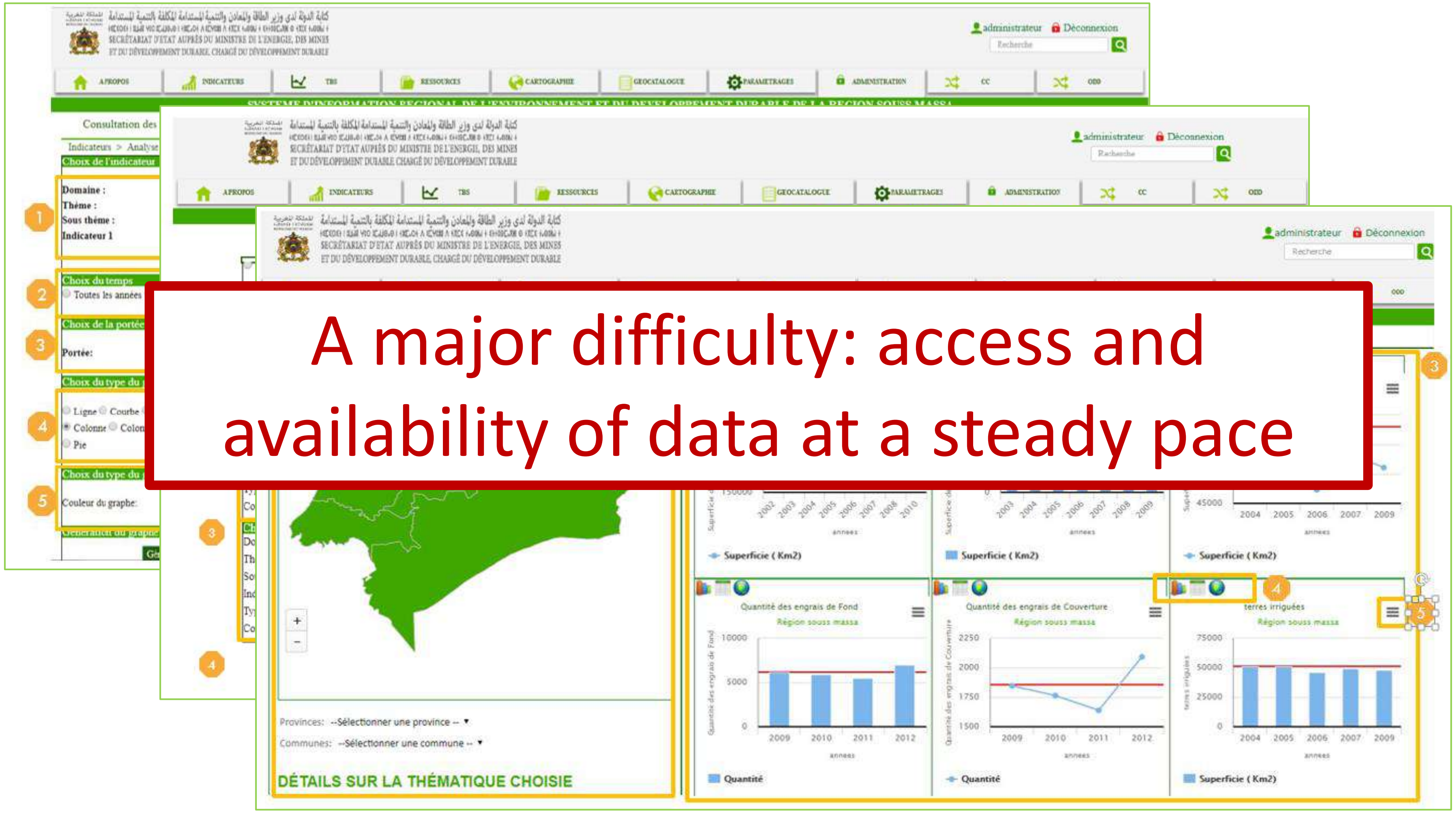


- PRO GEC (Gouvernance Environnementale et Climatique)
- **Participatory and highly concerted approach**
- Capitalize on several projects related to "gathering and analyzing of CC indicators"
- 150 "Indicators" (adaptation and mitigation),
  - Exposure,
  - Sensitivity to climate change,
  - Impacts of climate change,
  - Adaptive capacity,
  - Climate finance,
  - Mitigation

Agriculture	Water	Forest and biodiversity	…..

Introduction

- Toward a Moroccan CC Metrics

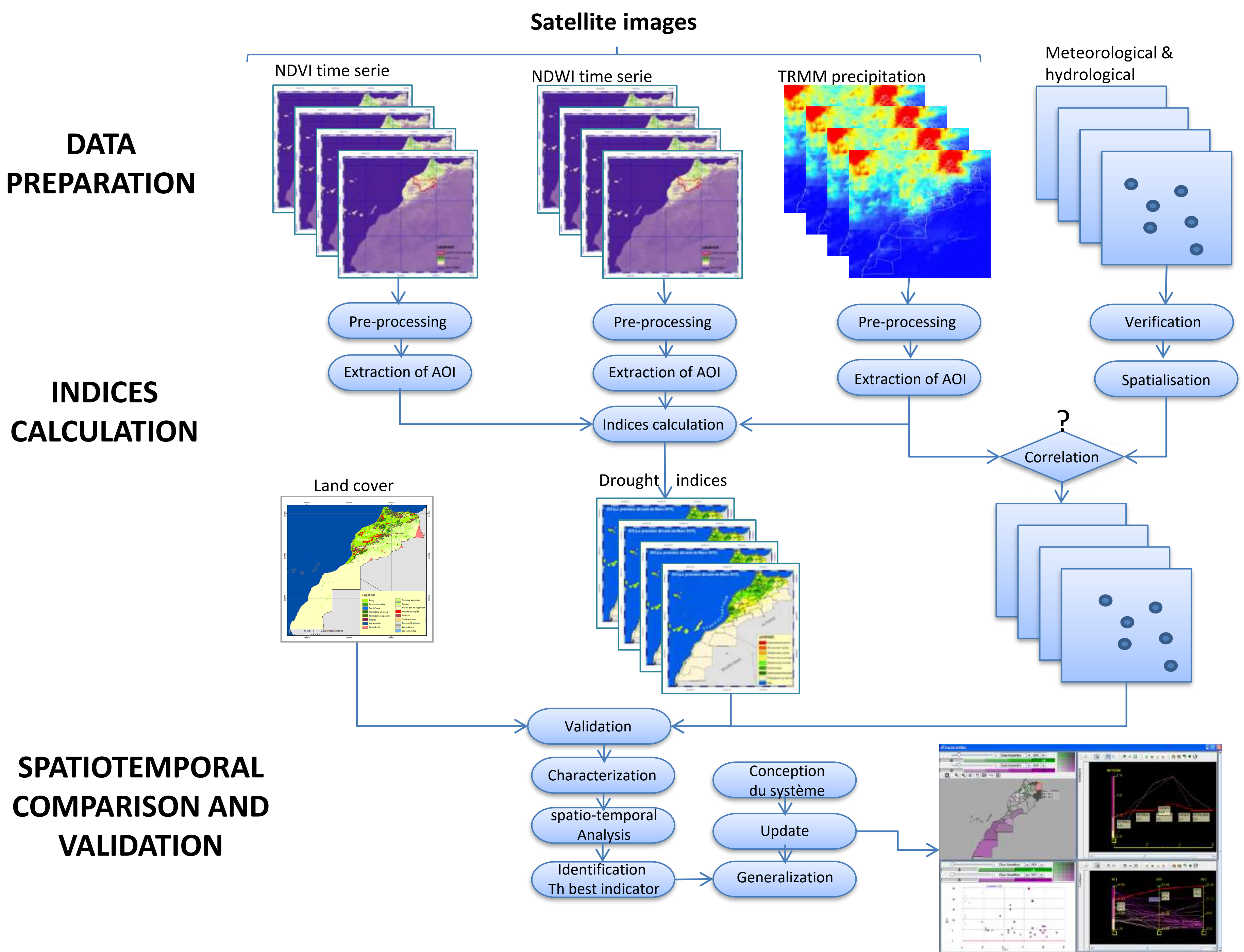


A major difficulty: access and availability of data at a steady pace

Objectifs

Demonstrate the potentialities of open short satellite times series for spatiotemporal monitoring of climate change indicators, with a focus meteorological and agricultural drought indices:

- Explore the spatiotemporal concordance of meteorological and agricultural drought indices.
- Compare the concordance of meteorological and agricultural drought indices over two land cover classes (rainfed agricultural and vegetation cover).
- Downscale of TRMM time-series to regional and local level.


Satellite images
DATA PREPARATION
NDVI time serie
NDWI time serie
TRMM precipitation
Meteorological & hydrological
Pre-processing
Pre-processing
Pre-processing
Verification
INDICES CALCULATION
Extraction of AOI
Extraction of AOI
Extraction of AOI
Spatialisation
Indices calculation
?
Correlation
Land cover
Drought indices
Validation
SPATIOTEMPORAL COMPARISON AND VALIDATION
Characterization
Conception du système
spatio-temporal Analysis
Update
Identification Th best indicator
Generalization

Dataset

→ TRMM

Monthly | 1998 – 2012 | 0.25 °

→ SPOTVEGETATION

Decadal | 1998 – 2012 | 1 km

→ Precipitation

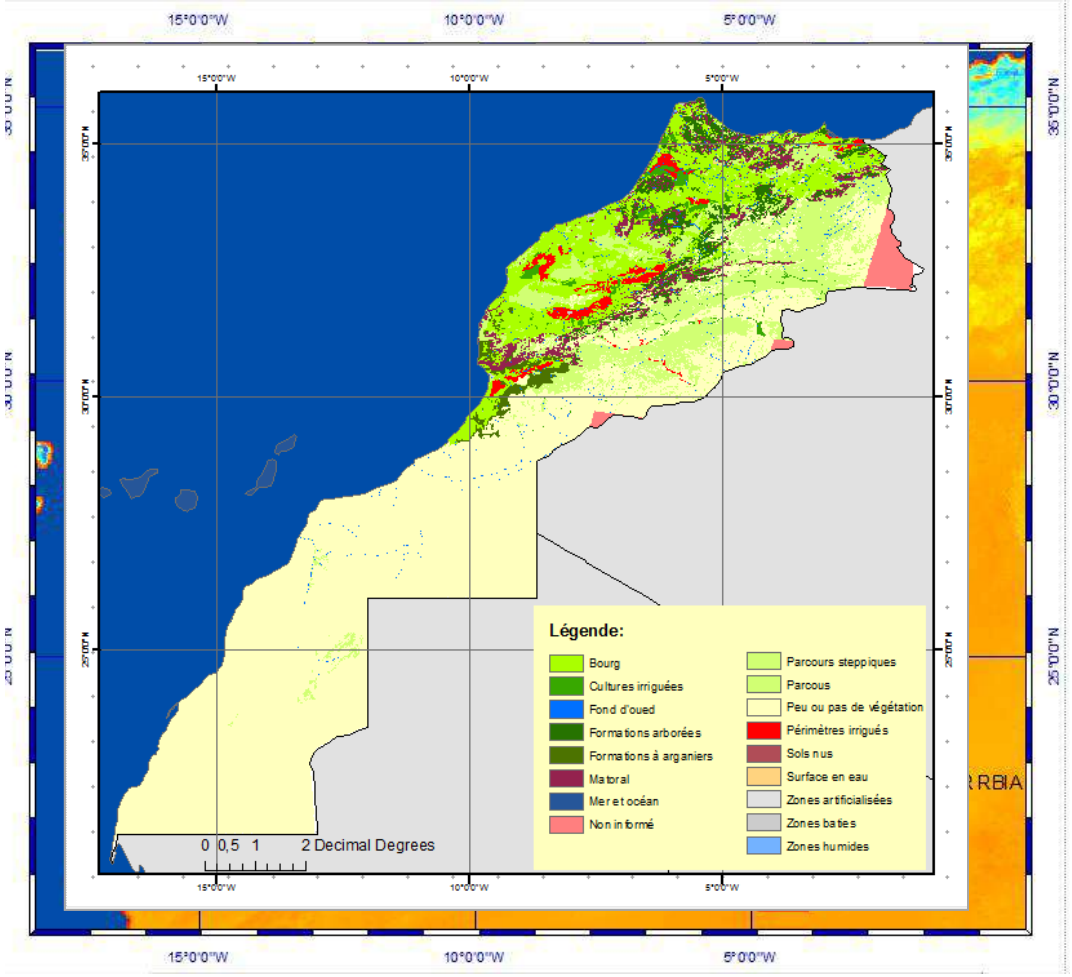
Monthly | different | 90 Stations

→ Land cover

Static | 2000 | 1 km

→ Cereal production

Annual | 1998 – 2010 |

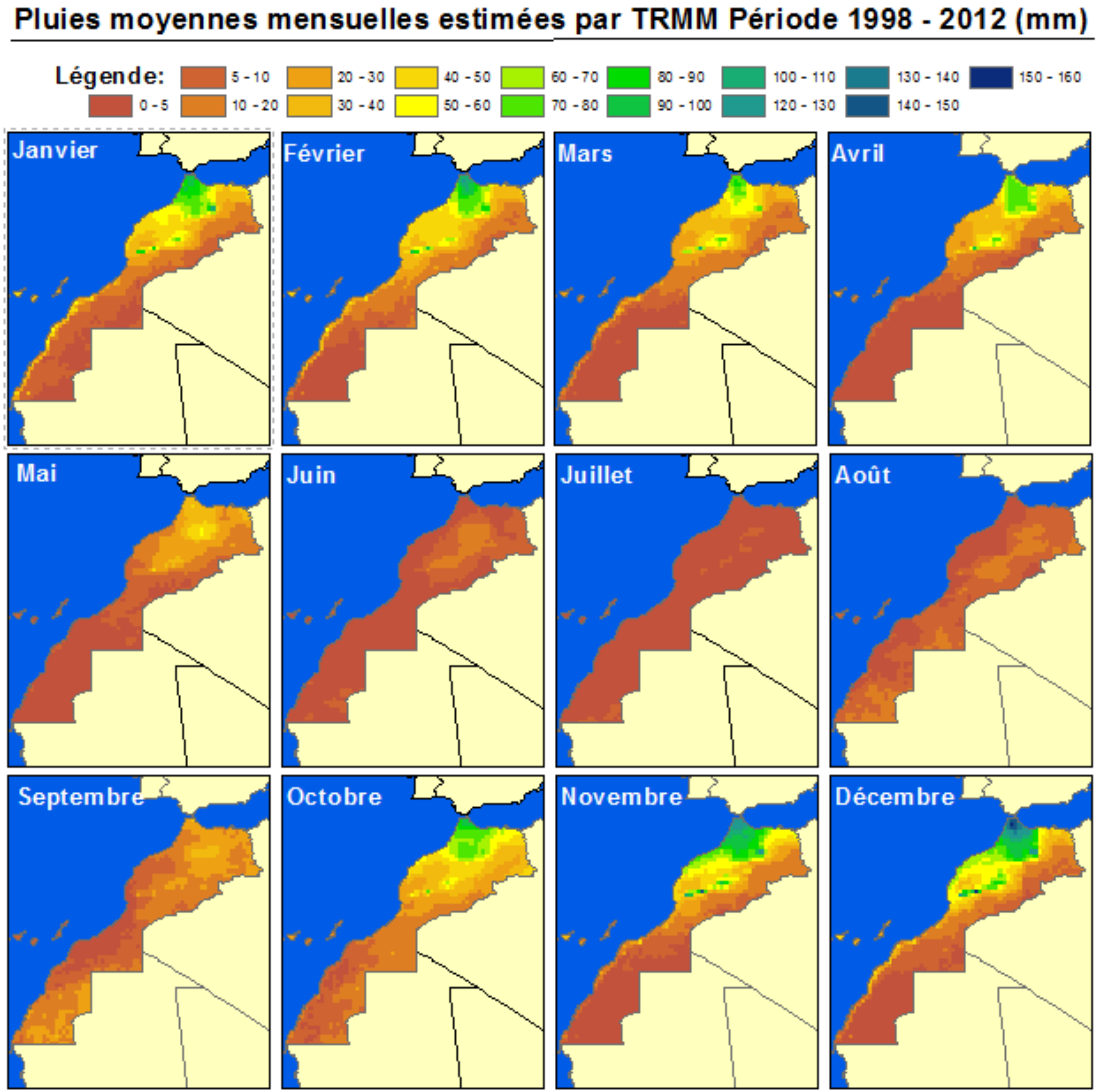


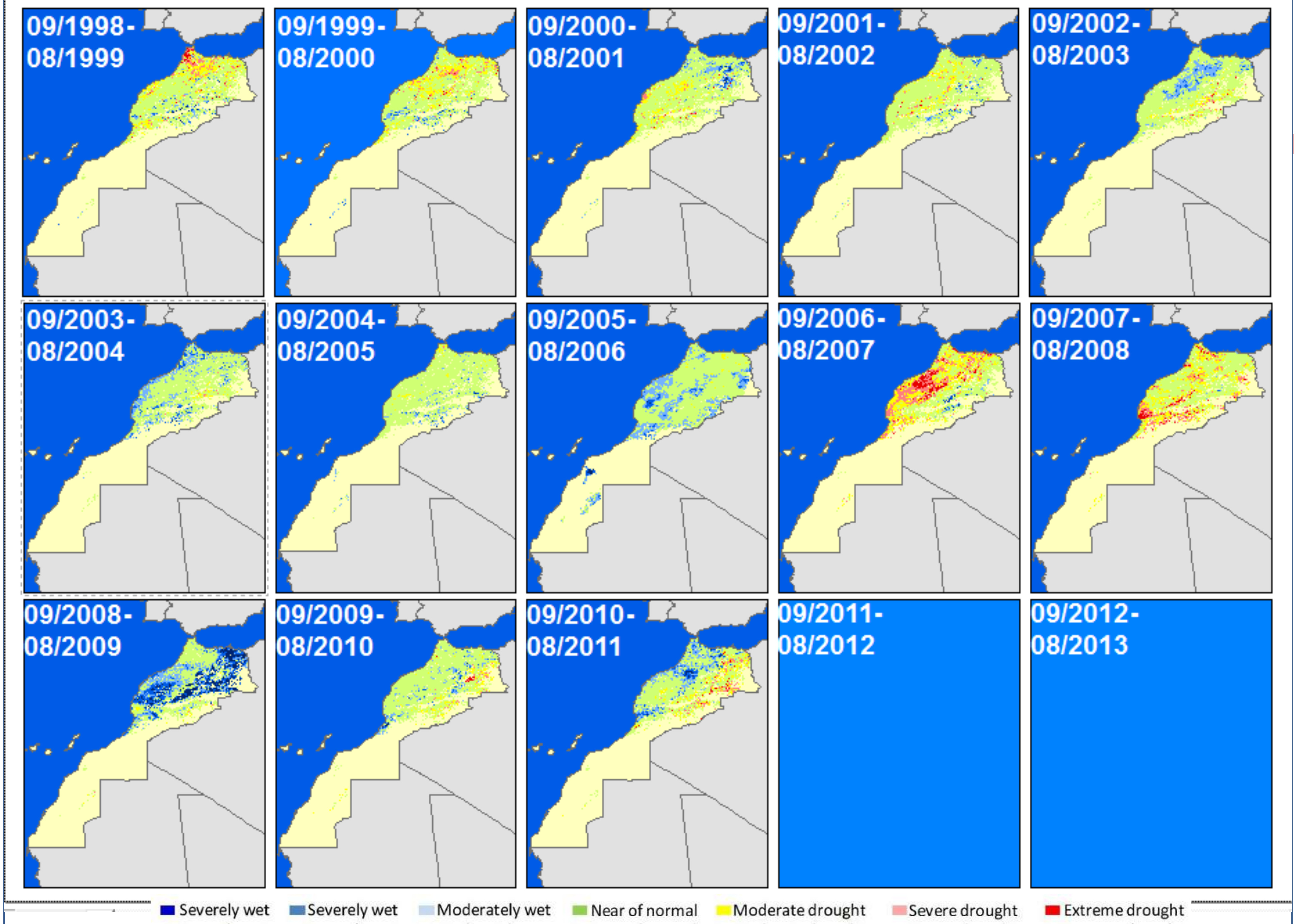
Drought indices

- SPI : Standardized precipitation index (McKee et al. (1993), calculated in function of precipitations.
- SVI : Standardized Vegetation Index (Peters et al, 2002), calculated in function of NDVI.
- SWI: Standardized Water Index (Ezzine et al., 2014), calculated in function of NDWI

$$NDWI_{ijk} = \frac{NIR_{ijk} - SWIR_{ijk}}{NIR_{ijk} + SWIR_{ijk}}$$

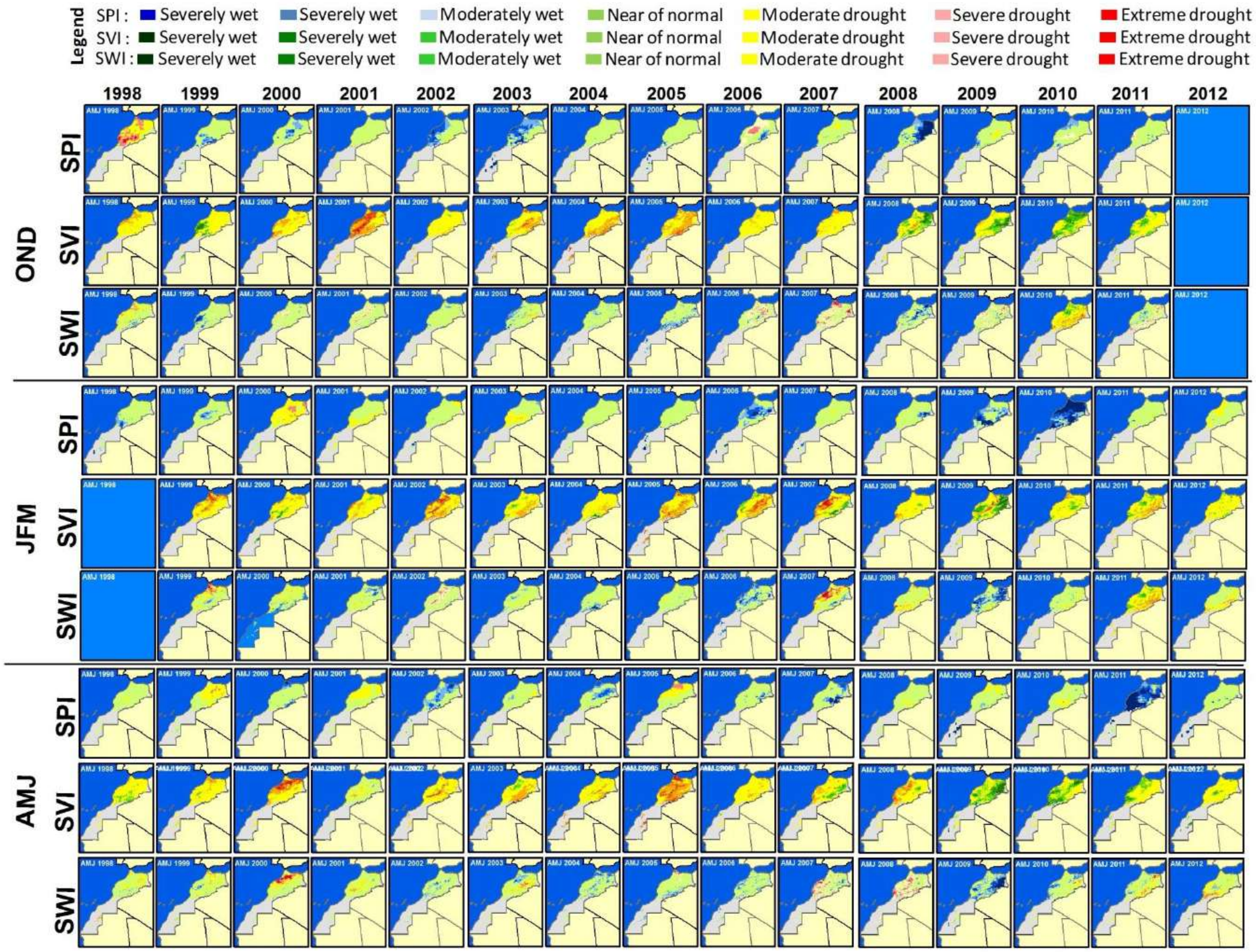
Spatial distribution of monthly average of TRMM precipitation over Morocco during the period of 1998–2012 (mm).





SWI - Hydrological years

Seasonal monitoring of drought using SPI, SVI and SWI over Morocco (1998 – 2012)



Comparison and validation

Kappa

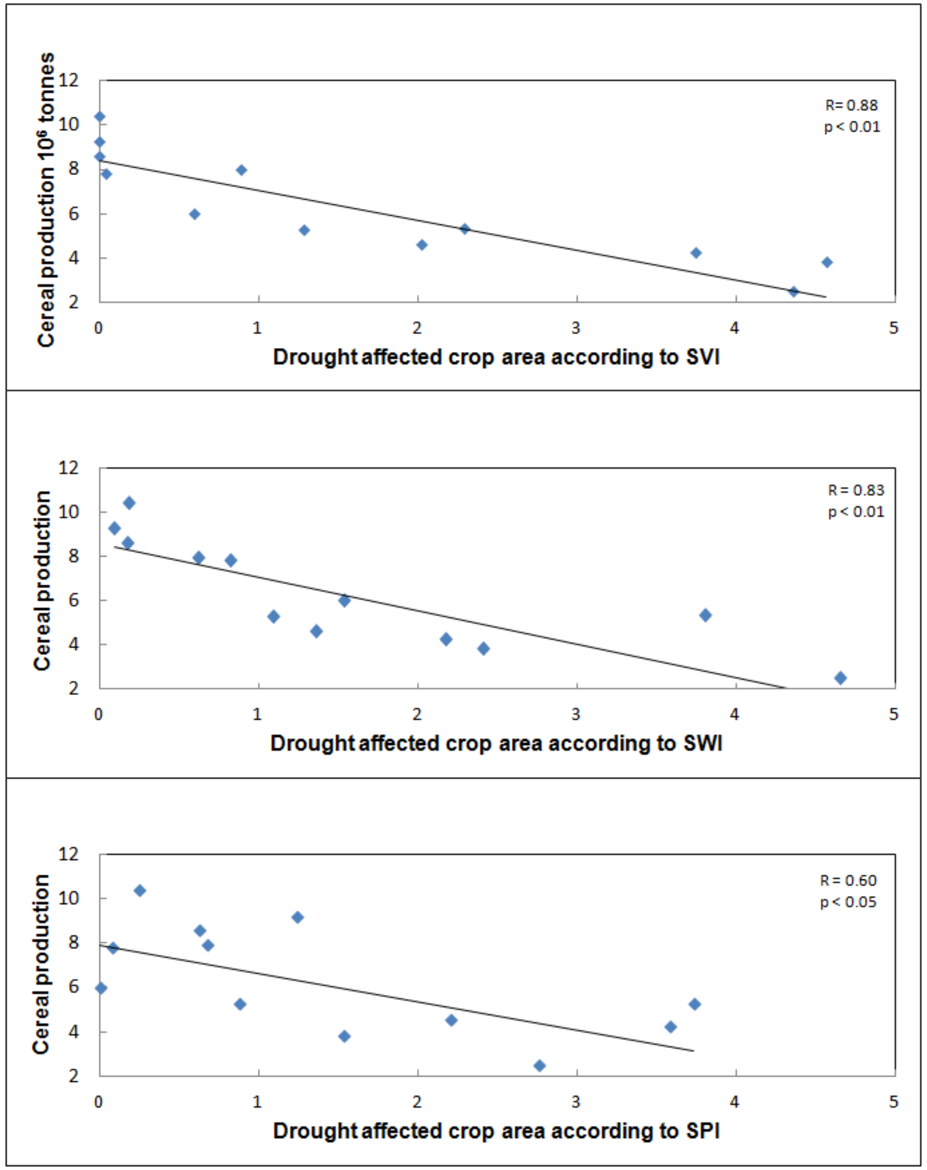
			97_98	98_99	99_00	00_01	01_02	02_03	03_04	04_05	05_06	06_07	07_08	08_09	09_10	10_11	11_12	Moy
				TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	TC	
	VGT	SPI et SVI		0,53	0,69	0,67	0,59	0,79	0,68	0,46	0,70	0,48	0,71	0,40	0,23	0,38		0,56
		SPI et SWI		0,50	0,65	0,61	0,83	0,73	0,60	0,46	0,57	0,40	0,51	0,36	0,15	0,49		0,53
		SWI et SVI		0,72	0,72	0,70	0,56	0,78	0,69	0,59	0,50	0,40	0,59	0,54	0,51	0,20		0,58
	CP	SPI et SVI		0,66	0,66	0,67	0,52	0,82	0,72	0,43	0,75	0,49	0,63	0,42	0,16	0,35		0,56
		SPI et SWI		0,61	0,65	0,62	0,86	0,74	0,60	0,51	0,51	0,34	0,53	0,43	0,11	0,45		0,54
		SWI et SVI		0,72	0,68	0,66	0,54	0,84	0,71	0,74	0,48	0,37	0,76	0,68	0,74	0,17		0,62

			1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Moy
JFM	VGT	SPI / SVI		0,60	0,13	0,67	0,52	0,56	0,88	0,65	0,30	0,53	0,81	0,33	0,10	0,47	0,63	0,51
		SPI / SWI		0,51	0,17	0,58	0,65	0,57	0,84	0,90	0,39	0,45	0,73	0,34	0,08	0,65	0,56	0,53
		SWI / SVI		0,71	0,75	0,69	0,63	0,75	0,82	0,66	0,42	0,58	0,75	0,57	0,72	0,45	0,63	0,65
	CP	SPI / SVI		0,43	0,14	0,66	0,40	0,57	0,93	0,77	0,33	0,45	0,88	0,41	0,04	0,41	0,54	0,50
		SPI / SWI		0,39	0,17	0,62	0,57	0,56	0,90	0,92	0,41	0,32	0,89	0,43	0,03	0,66	0,51	0,53
		SWI / SVI		0,74	0,80	0,65	0,65	0,89	0,94	0,81	0,52	0,64	0,90	0,72	0,85	0,52	0,74	0,74
AMJ	VGT	SPI / SVI	0,79	0,39	0,45	0,47	0,42	0,66	0,57	0,44	0,86	0,55	0,66	0,33	0,38	0,17	0,84	0,53
		SPI / SWI	0,77	0,37	0,50	0,47	0,43	0,65	0,50	0,41	0,62	0,38	0,51	0,48	0,59	0,08	0,67	0,50
		SWI / SVI	0,69	0,78	0,68	0,67	0,64	0,65	0,60	0,36	0,64	0,51	0,58	0,52	0,45	0,46	0,63	0,59
	CP	SPI / SVI	0,90	0,46	0,18	0,45	0,44	0,70	0,68	0,47	0,92	0,65	0,60	0,41	0,38	0,22	0,88	0,56
		SPI / SWI	0,84	0,43	0,30	0,39	0,40	0,65	0,56	0,28	0,58	0,38	0,54	0,51	0,60	0,06	0,70	0,48
		SWI / SVI	0,82	0,80	0,61	0,68	0,74	0,77	0,62	0,39	0,58	0,56	0,66	0,67	0,51	0,39	0,68	0,63
OND	VGT	SPI / SVI	0,15	0,71	0,58	0,32	0,50	0,22	0,77	0,62	0,45	0,81	0,39	0,58	0,32	0,60		0,50
		SPI / SWI	0,18	0,69	0,61	0,74	0,46	0,31	0,77	0,75	0,43	0,53	0,36	0,56	0,56	0,61		0,54
		SWI / SVI	0,66	0,75	0,75	0,36	0,83	0,58	0,63	0,50	0,63	0,57	0,55	0,48	0,34	0,53		0,58
	CP	SPI / SVI	0,19	0,63	0,57	0,22	0,29	0,15	0,92	0,75	0,36	0,77	0,48	0,78	0,34	0,47		0,49
		SPI / SWI	0,22	0,69	0,62	0,72	0,28	0,25	0,78	0,81	0,47	0,52	0,45	0,50	0,57	0,65		0,54
		SWI / SVI	[illegible]	0,75	0,72	0,28	[illegible]35	0,60	0,77	[illegible]	0,67	0,58	0,68	0,57	0,38	0,57		0,62

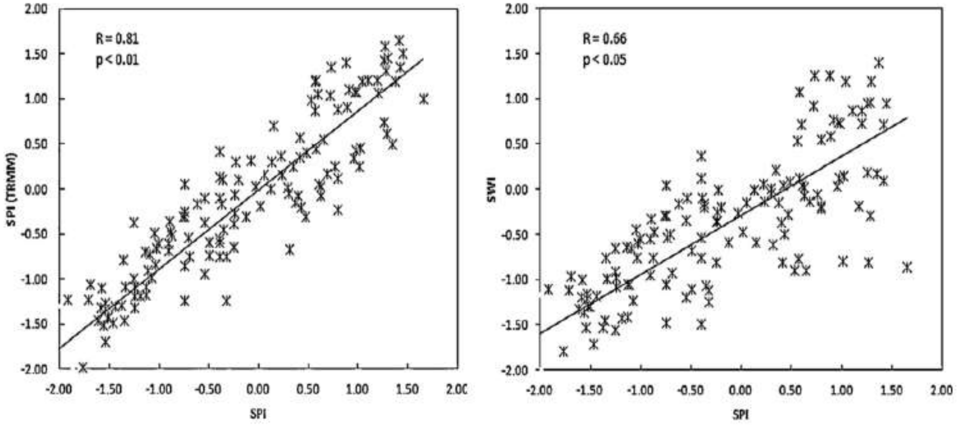
Légende: TC > 0.6 | 0.5 ≤ TC ≤ 0.6 | 0.25 ≤ TC < 0.5 | TC < 0.25

Comparison and validation

Scatter plots and correlation coefficient (R values) betweens seasonal SPI (gauge stations), SPI (TRMM) and SWI (SPOT Vegetation) for the years 2004–2007.

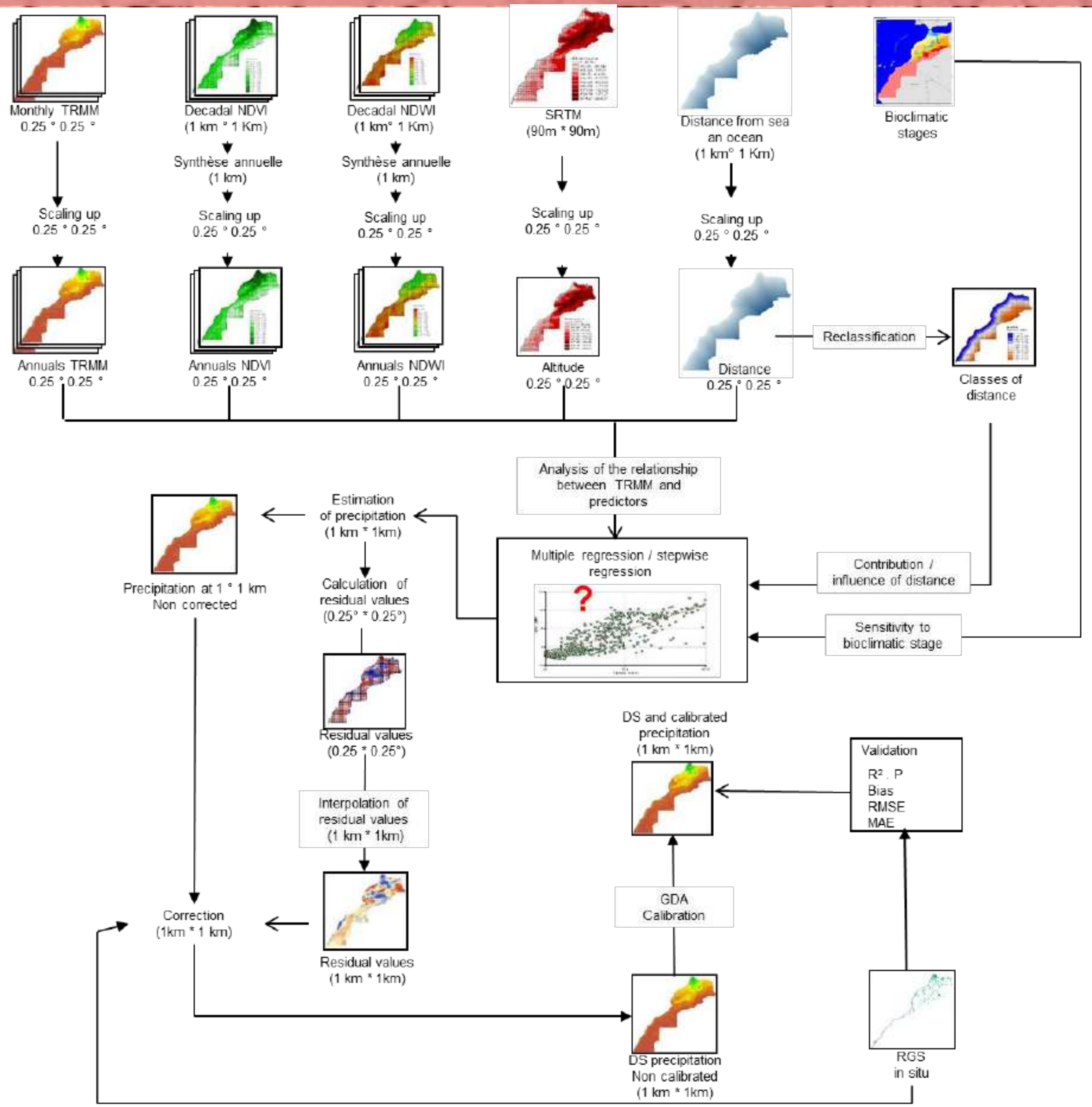


Scatter plots and correlation coefficient R values betweens seasonal SPI (gauge stations), SPI (TRMM) and SWI (SPOT Vegetation).



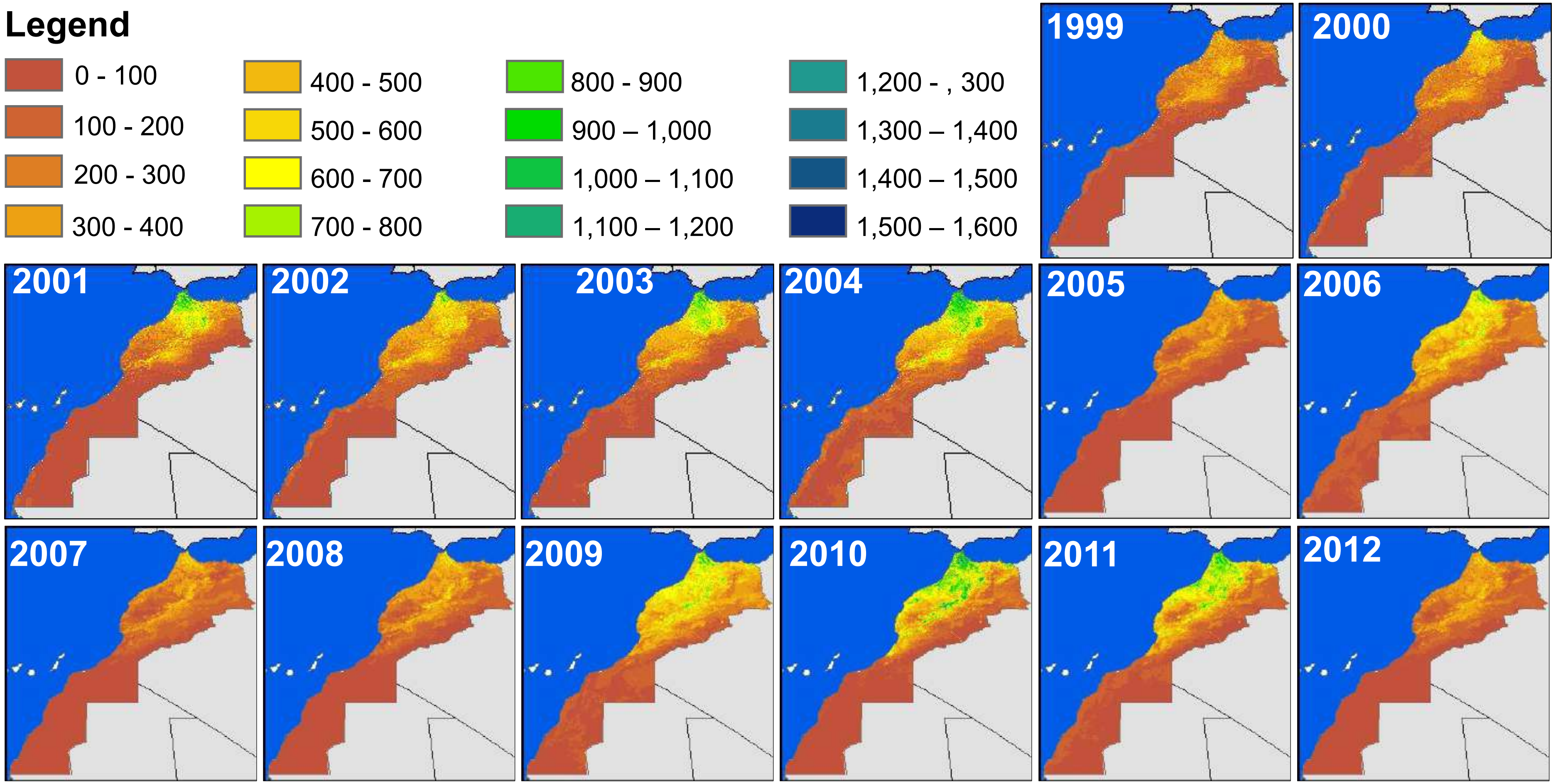
Downscaling of coarse satellite precipitation

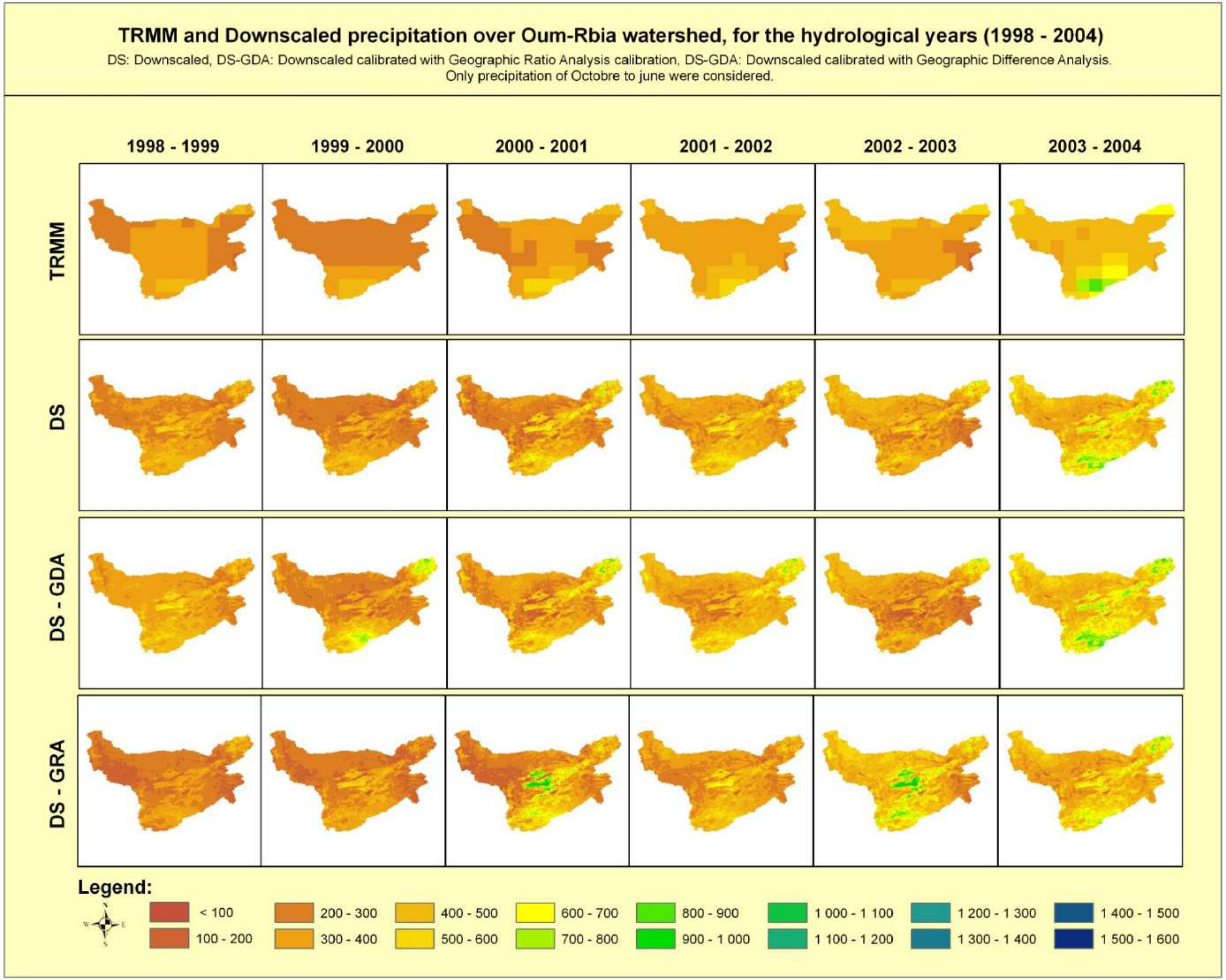
Downscaling methodology



Downscaling of coarse satellite precipitation

- Spatiotemporal distribution of downscaled and calibrated precipitation (in mm) over Morocco – 1999 -2012

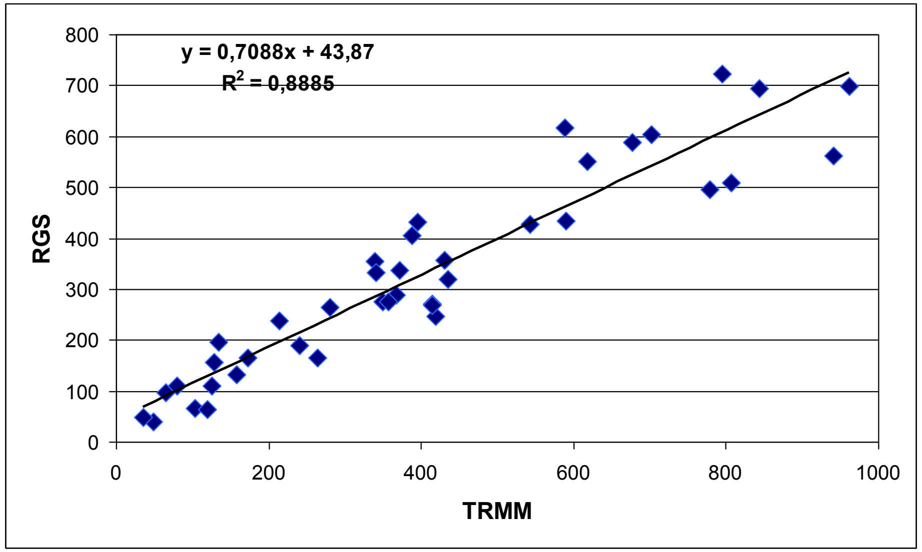


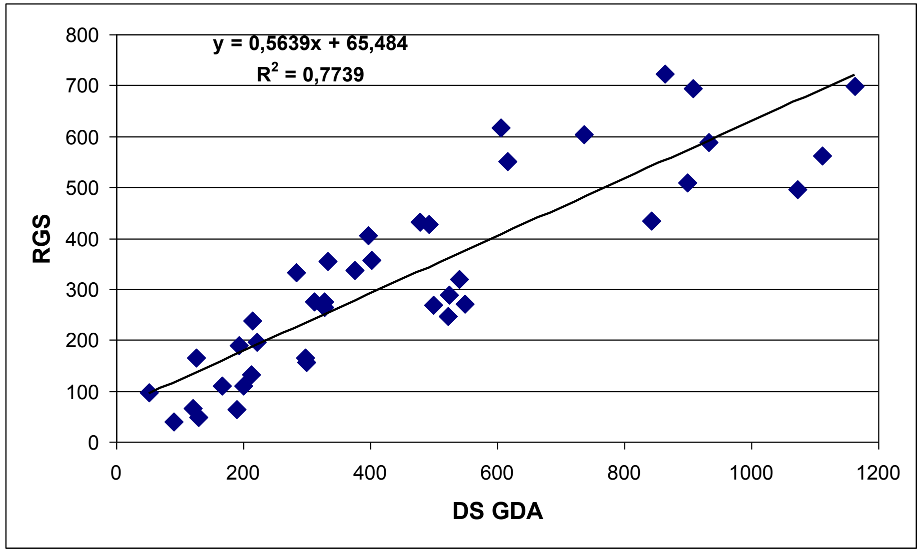

TRMM and Downscaled precipitation over Oum-Rbia watershed, for the hydrological years (1998 - 2004)
DS: Downscaled, DS-GDA: Downscaled calibrated with Geographic Ratio Analysis calibration, DS-GDA: Downscaled calibrated with Geographic Difference Analysis.
Only precipitation of Octobre to june were considered.
1998 - 1999
1999 - 2000
2000 - 2001
2001 - 2002
2002 - 2003
2003 - 2004
TRMM
DS
DS - GDA
DS - GRA
Legend:
< 100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1 000
1 000 - 1 100
1 100 - 1 200
1 200 - 1 300
1 300 - 1 400
1 400 - 1 500
1 500 - 1 600

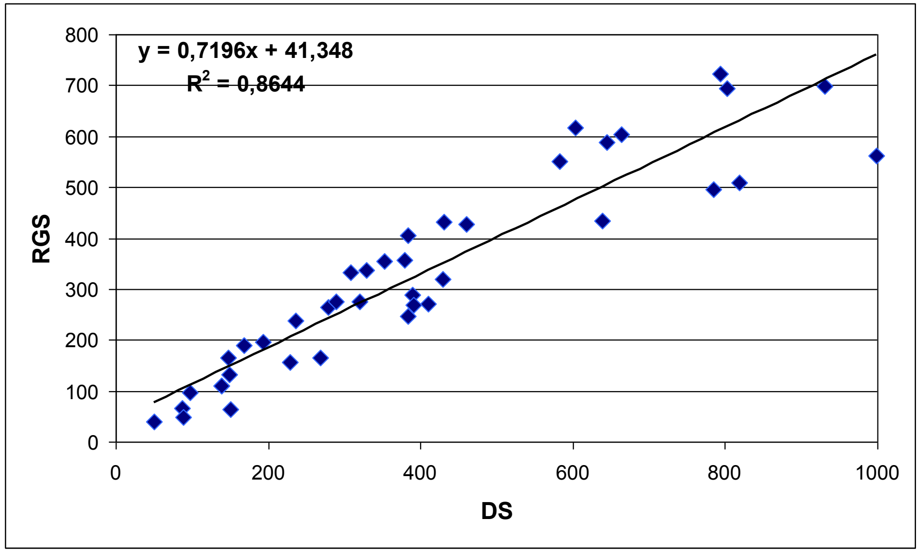
Downscaling of coarse satellite precipitation

- **Validation of downscaled precipitation**

Example of validation parameters of annual downscaled precipitation (DS) using independent Rain Gauge Stations (1998 – 1999 hydrological year)







Conclusion

- Open satellite short time-series constitute a good source of information (as input for metrics) and useful tool for spatiotemporal monitoring of meteorological and agricultural drought;
  - Study revealed a great conformity between SVI and SWI ,
  - Conformity between SPI and SWI is low but relatively more important in rainfed agriculture.

- Downscaled technique allowed to improve the spatial resolution of TRMM 3B43 product and help to monitor spatial distribution of rainfall over Morocco and at scale of watershed

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ADAPTATION METRICS for WATER &
AGRICULTURE
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Les ressources microbiennes telluriques : des outils biologiques pour réhabiliter des sols dégradés

Par Robin DUPONNOIS

Directeur de Recherche à l'IRD

Directeur de Laboratoire des Symbioses Tropicales & Méditerranéennes

Laboratoire des Symbioses Tropicales et Méditerranéennes
UMR IRD-INRA-CIRAD-SupAgro-Université de Montpellier
TA A-82/J, Campus International de Baillarguet, 34398 Montpellier Cedex 5, France
Tel: 04 67 59 38 82. Fax: 04 67 59 38 02. http://umr-lstm.cirad.fr/

Comité Scientifique Français de la Désertification

CONSTAT

Pour nourrir une population mondiale, en pleine expansion, nous n'avons pas d'autre choix que d'intensifier les cultures. Mais les agriculteurs sont confrontés à des contraintes sans précédent. Il leur faudra donc apprendre à produire plus avec moins (FAO, 2011)

PRODUIRE PLUS AVEC MOINS

UNE AGRICULTURE RESPECTUEUSE DES ÉCOSYSTÈMES POUR ATTEINDRE LES OBJECTIFS DE DÉVELOPPEMENT DURABLE

→ **LA SANTÉ DES SOLS: DES TECHNOLOGIES POUR PRODUIRE PLUS AVEC MOINS**

Laboratoire des Symbioses Tropicales et Méditerranéennes
UMR IRD-INRA-CIRAD-SupAgro-Université de Montpellier
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Une des clés pour atteindre ces objectifs:

La Gestion durable des sols (GDT)

- ❑ Sources d'importants bénéfices locaux, régionaux et mondiaux

- ❑ Contribution à la fourniture de services environnementaux essentiels

Les services environnementaux fournis par la GDT

- **Les services d'approvisionnement**
  - ❑ Apport de nourriture, de fourrage, de fibres, de combustible et d'eau douce
- **Les services de régulation**
  - ❑ Amélioration des sols et recyclage des éléments nutritifs
  - ❑ Séquestration du carbone dans le sol
  - ❑ Régulation des eaux
- **Les services culturels et sociaux**
  - ❑ Préserver les paysages culturel et naturel ainsi qu'à protéger cet héritage
  - ❑ Valoriser les connaissances et méthodes locales de production
  - ❑ Développer l'écotourisme.

Une Ingénierie Ecologique au service de la productivité, stabilité et résistance des Agro-Ecosystèmes

- ***Agriculture écologiquement intensive***
  Agro-écologie, agriculture de conservation, valorisation des services écosystémiques et de la biodiversité, sélection participative, production intégrée..
  Optimisation durable de la PRODUCTIVITÉ I^{aire} et II^{aire} des agrosystèmes

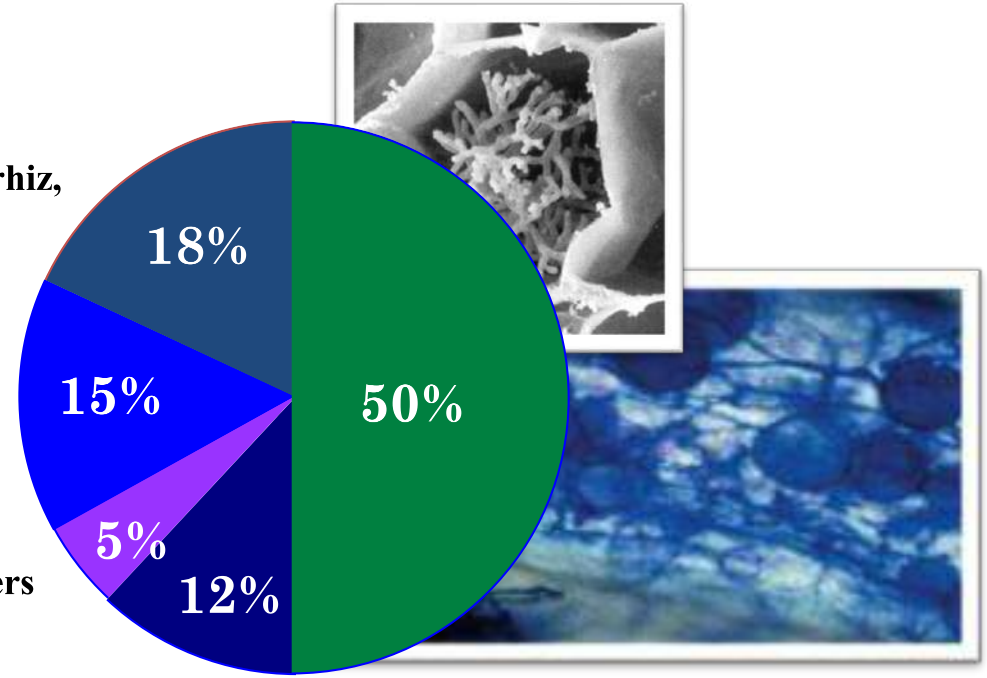
- ***Une Ingénierie ecologique innovante pour réhabiliter les sols dégradés (Ex: Phytostabilisation de sites miniers)***

➡ **Des approches innovantes basées sur la valorisation de processus biologiques et écologiques régissant l'évolution spatio-temporelle des écosystèmes**

Laboratoire des symbioses tropicales et méditerranéennes

LA SYMBIOSE MYCORHIZIENNE:

Une composante majeure dans les processus biologiques assurant la productivité et la stabilité des écosystèmes



LA MAJORITÉ DES PLANTES NE PEUVENT SE DÉVELOPPER SANS LA PRÉSENCE DE CHAMPIGNONS MYCORHIZIENS

Répartition des principaux types de symbioses mycorhiziennes dans le règne végétal ***(Brundrett, 2002** – New Phytologist**)***

cirad

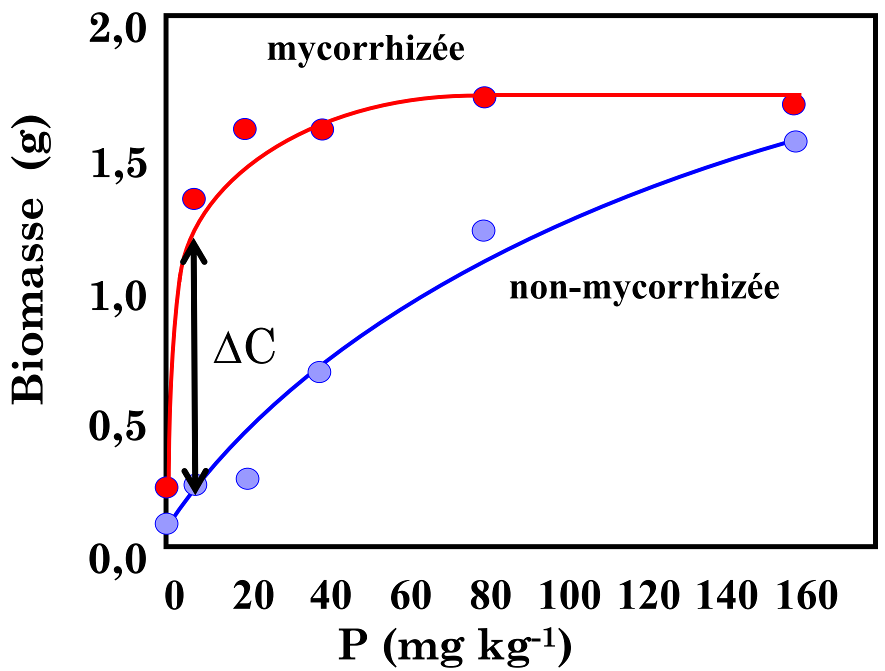
IRD Institut de Recherche pour le Développement FRANCE

Montpellier SupAgro

INRA

UNIVERSITÉ DE MONTPELLIER

EFFET MYCORHIZIEN ET CROISSANCE VÉGÉTALE



Un outil biologique particulièrement adapté aux conditions sous contraintes (Ex: carences minérales)

LA MYCORHIZATION CONTRÔLÉE

Mycorhization du Cyprès de l'Atlas par un complexe mycorhizien

!

!

ELEVAGE EN PÉPINIÈRE

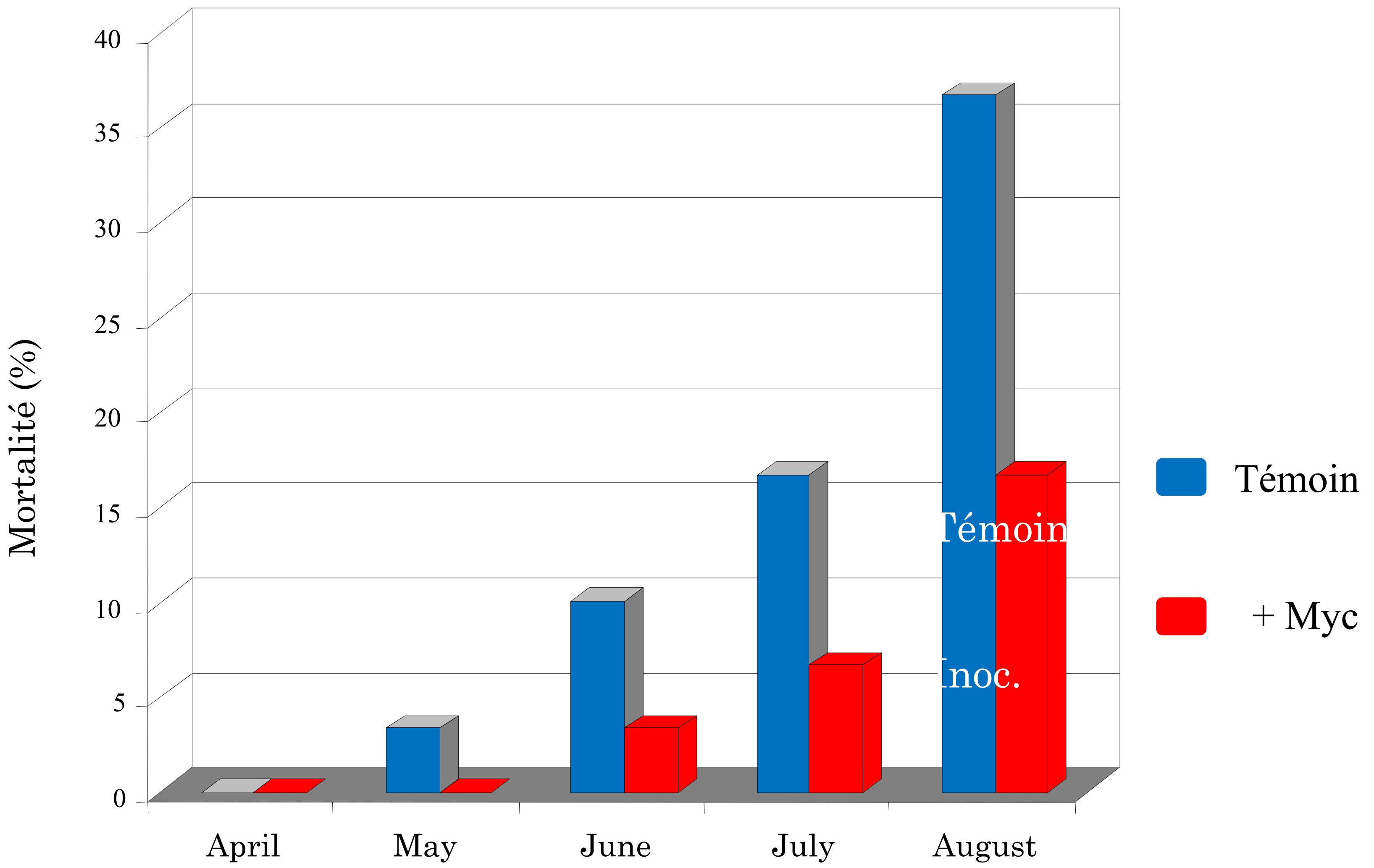
	Traitements		
	Témoin	Complexe mycorhizien	
Hauteur (cm)	12,3 (0,46) a	16,1 (0,71) b	
Biomasse aérienne (mg)	1163 (20) a	1893 (264) b	+ 38,5%)
Biomasse racinaire (mg)	740 (64) a	1183 (132) b	
Biomasse totale (mg)	1903 (62) a	3077 (392) b	+ 38,1%)
Teneur en P (mg g^{-1} MS)	0,09 (0,01) a	0,167 (0,03) b	
Teneur en N (mg g^{-1} MS)	2,23 (0,23) a	3,50 (0,1) b	
Taux de mycorhization (%)	-	41,2 (2,3)	

PLANTATION EN MILIEU NATUREL (1ère ANNÉE)

Témoin

Inoculé

CRISE DE TRANSPLANTATION



Effects of *R. irregularis* application one year (2012) and two years (2013) after the AMF inoculation in the field experiment located in the Haouz valley at about 30 km at the West of Marrakech (Morocco).

	Treatments			
	Control		+ R. irregularis	
	2012	2013	2012	2013
Total biomass Yield (kg.ha^{-1})	4312 (20.4) [(1)] a [(2)]	4184 (28.7) a	4662 (25.6) a	**5401 (71.6) b**
Spike number per ha (x 10^4)	177.1 (27.5) a	167.3 (29.1) a	**227.7 (18.8) b**	**236.7 (26.9) b**
Thousand-seed weight	42.3 (2.5) a	41.7 (2.8) a	42.7 (2.5) a	**45.2 (2.5) b**
Shoot N content (%)	nd [(3)]	5.31 (0.60) a	nd	5.39 (0.11) a
Shoot P content (mg.g-^{1})	nd	6.25 (0.91) a	nd	**7.62 (0.29) b**
Mycorrhizal colonization (%)	46.7 (5.8) a	54.7 (4.7) a	53.9 (5.6) a	**66.9 (3.9) b**
Hyphal length (m g^{-1} dry soil)	1.66 (0.08) a	1.83 (0.09) a	1.72 (0.07)a	**2.89 (0.07) b**

LES CONDITIONS DE LA VALORISATION DE LA SYMBIOSE MYCORHIZIENNE EN AGROÉCOLOGIE

Malgré un potentiel indéniable, la valorisation de la symbiose mycorhizienne en agriculture reste trop simpliste en ignorant les fondamentaux de l'écologie microbienne des sols

- **Comprendre les déterminants biotiques et abiotiques de la réceptivité des sols à l'inoculation mycorhizienne**
- **Décrire et comprendre la réponse de la microflore du sol à l'inoculation ou à la gestion des symbiotes mycorhiziens**
- **Résoudre les problèmes liés à la biotechnologie de l'inoculation (production en masse & formulation d'inocula fongiques, etc)**

UNE NÉCESSITÉ D'INTERAGIR AVEC LA SPHÈRE SOCIO-ÉCONOMIQUE EN MATIÈRE DE RECHERCHE SCIENTIFIQUE ET D'INNOVATIONS EN INGÉNIERIE MICROBIENNE APPLIQUÉE À L'AGROÉCOLOGIE

Pour assurer un compromis avec les missions académiques d'un institut ou d'une université à savoir :

- ✓ **Elaboration de solutions adaptées aux défis globaux fondées sur l'évidence scientifique**
- ✓ **Conception d'innovations responsables**
- ✓ **Transfert d'expertises et de savoir-faire spécifiques**
- ✓ **Formation**

Nécessité de CO-CONSTRUIRE des projets de R&D dans un périmètre Public/Privé pour définir conjointement :

- ✓ **La pertinence des modèles étudiés**
- ✓ **La pertinence de la méthodologie retenue**
- ✓ **Les perspectives de transfert de technologie (Scaling-up, formation, etc)**
- ✓ **Les perspectives en termes d'innovations futures**