Workshop on
BIODIVERSITY IN AGROECOSYSTEMS
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The CYCAS-MED project: analysis at regional and local scale of climate change impacts on cereals yield in Morocco

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OUTLINE

- Biophysics/Bioclimatology: potential for land use modeling improvement

- Land Evaluation Techniques (LET)
  - Land Capability for Agriculture
  - Land Suitability for a specific crop

- Statistical crop yield modeling

- Crop growth and development models

Bioclimatology: potential for land use modeling

Final Land Allocation

Economic drivers

Land Use Change modeling

Physical & Climatic drivers

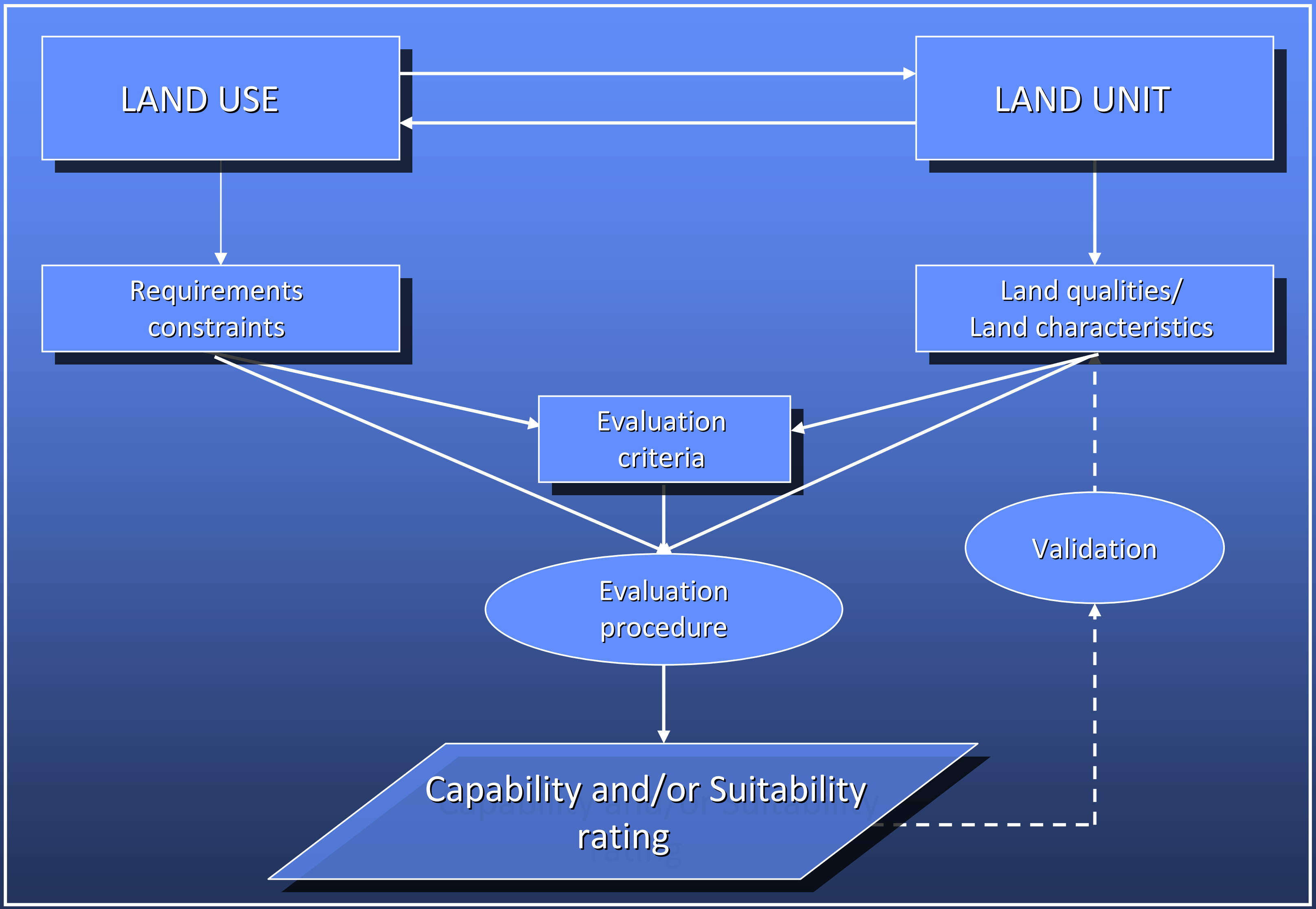
Land mobile between crop and livestock sectors regardless climatic or soil constraints

Prices, GDP growth
Population
Labor force
Capital stock
Other economic variables…

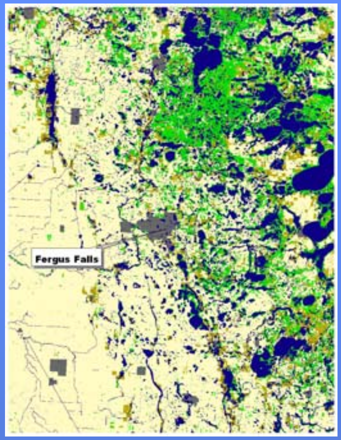
Climatic variables
- ***Precipitation***
- ***Temperature***
- ***Solar radiation***

Biophysical – Bioclimatic variables
- ***Land Capability for Agriculture***
- ***Agro-Ecological Zoning***
- ***Land Suitability***
- ***Crop modeling…***

Land Evaluation Techniques (LET)



LET – Capability & Suitability



- Land Capability (for Agriculture)

  Inherent capacity of **land** to perform at a given level for agriculture **use**

- Land Suitability (for Agriculture)

  Potential performances of **land when used** for <u>specific crop</u> or <u>group of crops</u>

Methodologies output & spatial scales

METHODOLOGY	OUTPUT	SPATIAL SCALE
Land Capability for Agriculture (LCA)	Capability Index	~ 5 km
Land Suitability	Suitability Index	~ 1 km
Statistical modeling	Yield	Field/Local scale
Crop growth models	Yield quality & quantity	Field scale

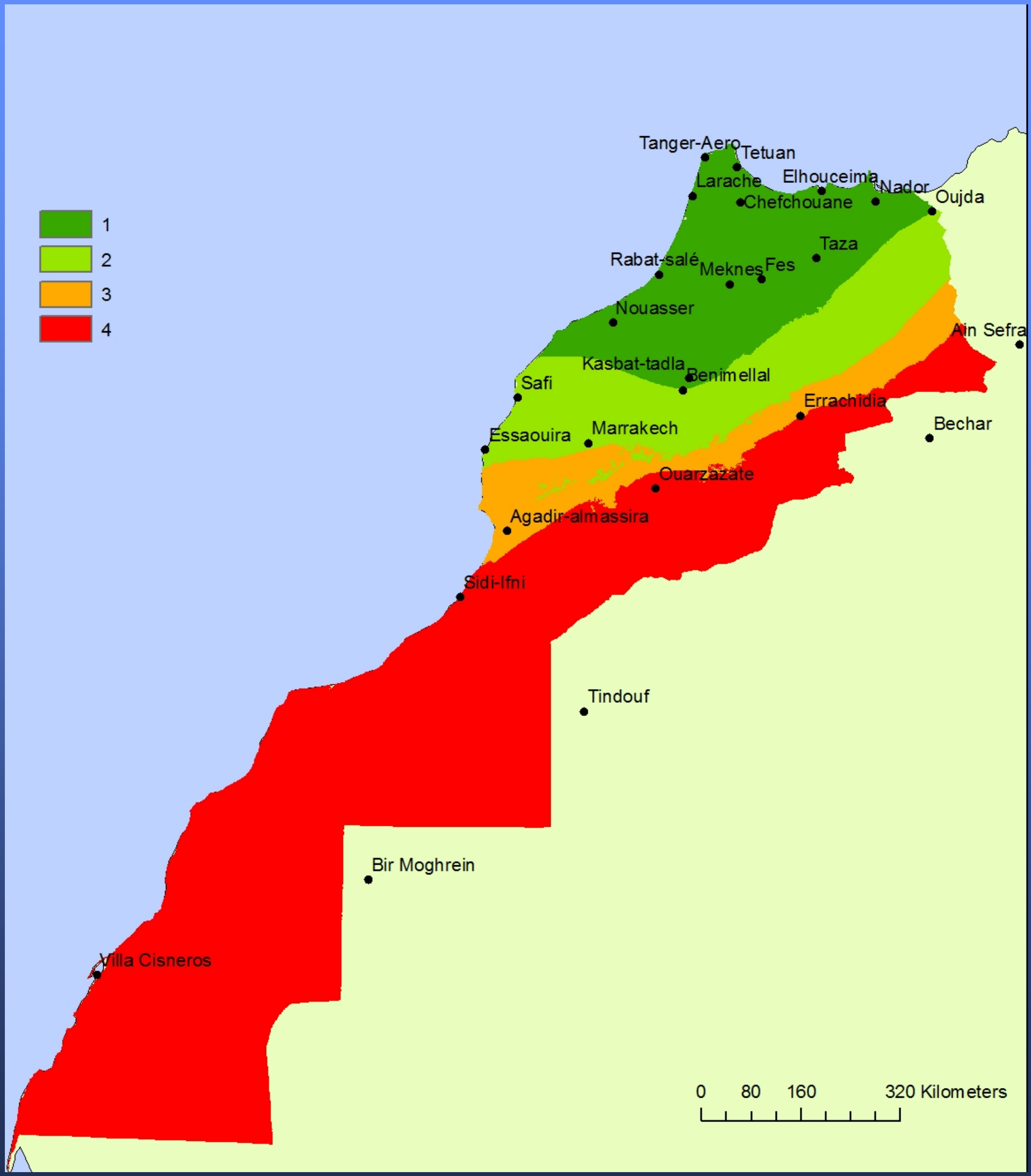
Land Capability for Agriculture (LCA)

(Kinglebiel and Montgomery, 1961; FAO)

1. Climatic Land Capability for Agriculture

2. Pedological Land Capability for Agriculture

3. Pedo-climatic Land Capability for Agriculture



Climatic LCA Morocco Baseline period 1973-2006 26 Weather station

1. **High capability 15.9%**
2. **Moderate capability 14.0%**
3. **Low capability 7.7%**
4. **Very limited or not capability 62.3%**

Pedological Land Capability
U.S.D.A. L.C. Classification System

I – IV Suitable for cultivation

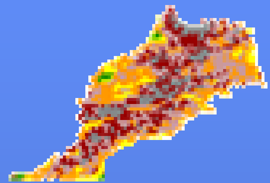
V – VIII Not suitable for cultivation

CLASSES	DESCRIPTION
I	soils have slight limitations that restrict their use.
II	soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices.
III	soils have severe limitations that restrict the choice of plants or that require special conservation practices, or both.
IV	soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.
V	soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
VI	soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
VII	soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.
VIII	soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

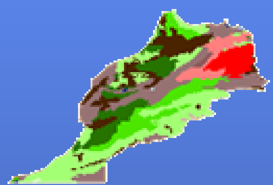
Pedological LCA

pedological map

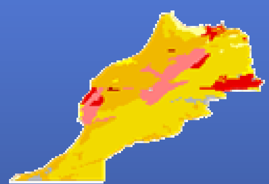
slope



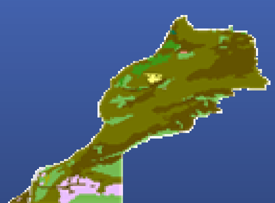
pH



depth

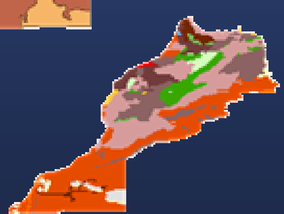


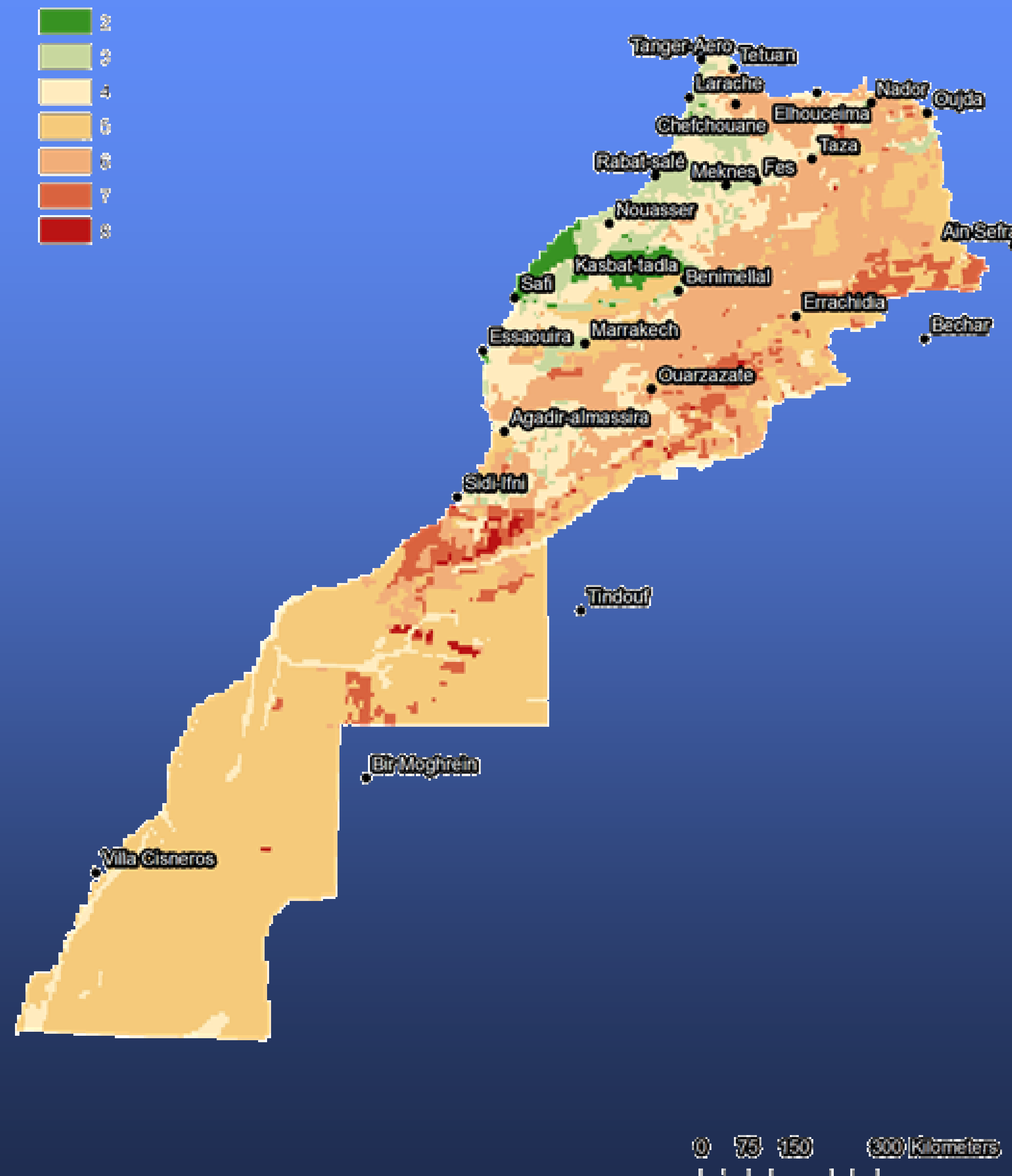
drainage



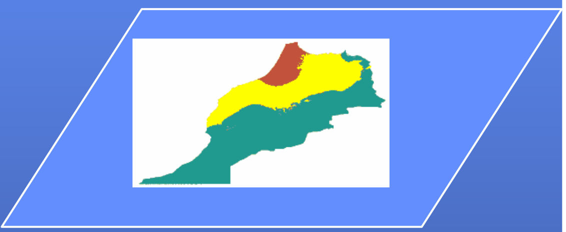
texture

organic carbon

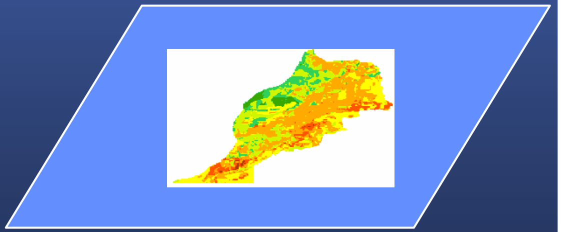




Land Capability for Agriculture



Climate LCA



Pedological LCA

Climate Class	Pedological Class	Pedoclimatic Class
1	I - II	1
1	III	2
2	I - II	
1	IV	3
2	III	
3	I - II	
2	IV	4
3	III	
4	I	
1	VI – VII	5
3	IV	
4	II - III	
2 – 3	VI – VII	6
4	IV	
4	VI	
1 – 2 – 3 – 4	V	7
4	VII	
1 – 2 – 3 - 4	VIII	

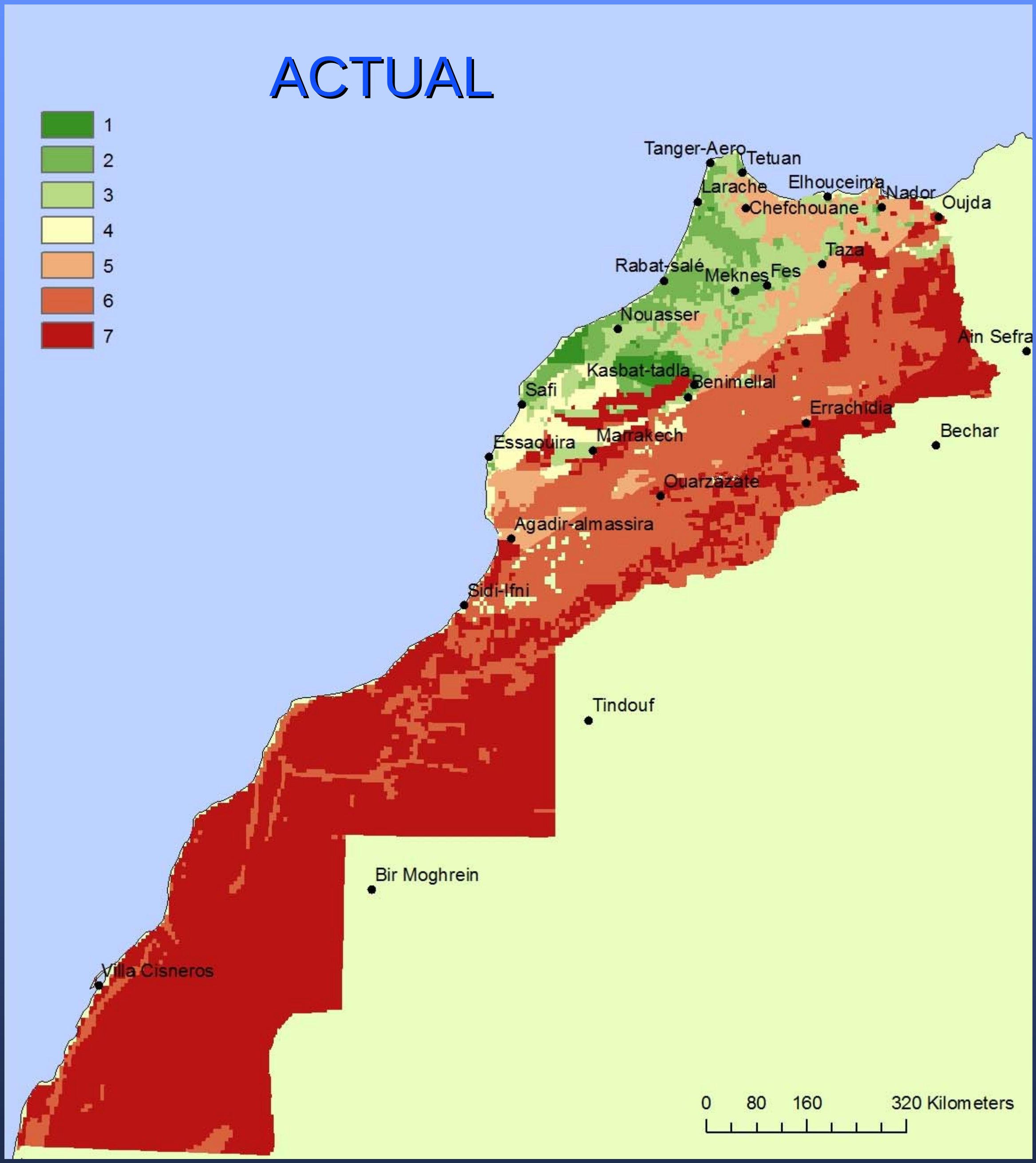
decreasing capability

Pedo-climatic LCA

Land Capability for Agriculture - Classes

Classes	Descriptions
1	Land is capable of producing the very widest range of crops. Soil and climate conditions are optimum, resulting in easy management
2	Land is capable of producing a wide range of crops. Minor restrictions of soil and climate may reduce capability but pose no major difficulties in management
3	Land is capable of producing a fairly wide range of crops under good management practices . Soil and/or climate limitations are somewhat restrictive
4	Land is capable of producing a narrow range of crops. Soil and climate conditions require special management considerations
5	Land is capable of production of cultivated perennial forage crops and specially adapted crops. Soil and/or climate conditions severely limit capability
6	Land is important in its natural state as grazing land. These lands cannot be cultivated due to soil and/or climate limitations
7	Land of very limited or no agricultural value

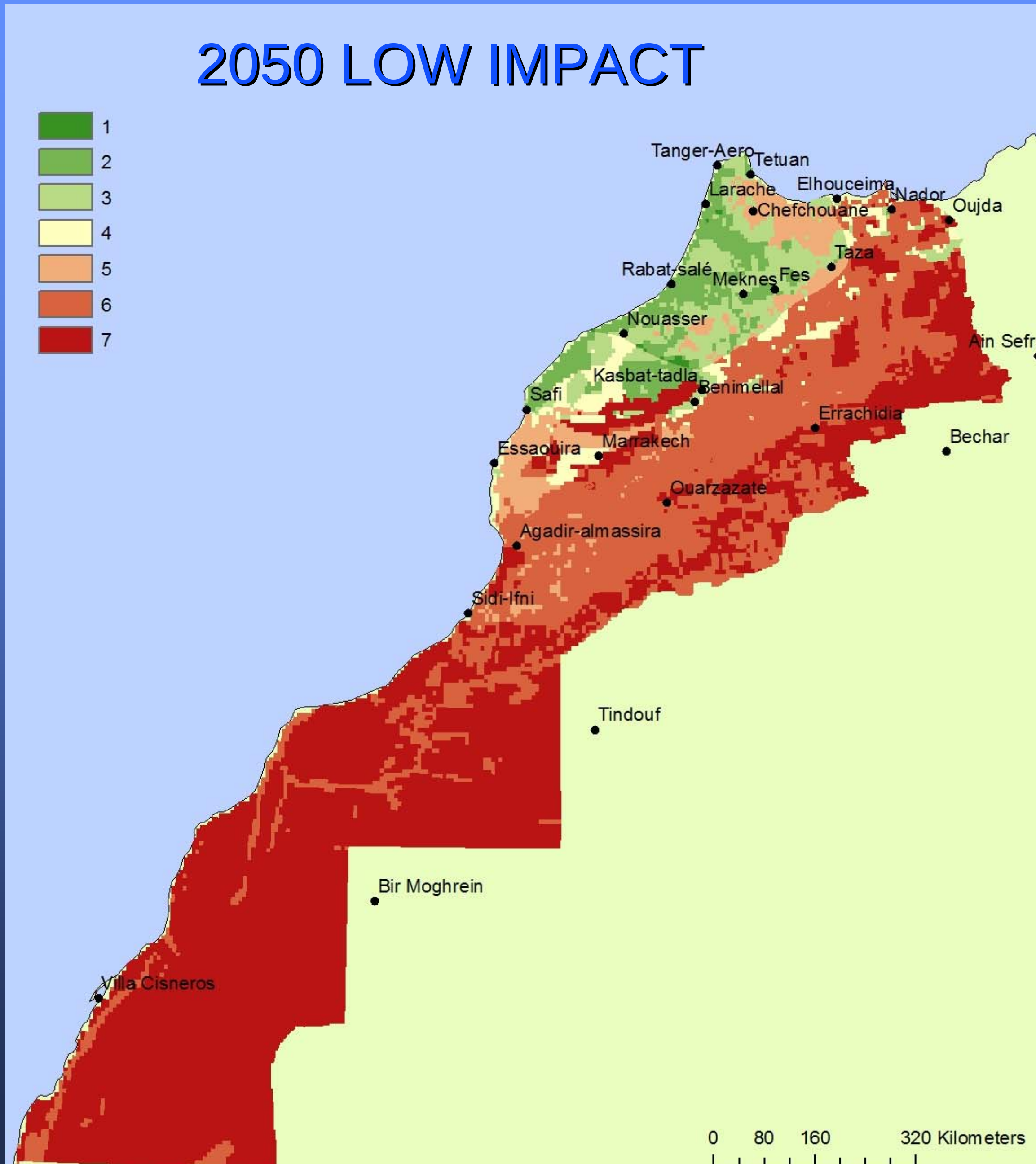
Pedo-climatic Land Capability for Agriculture

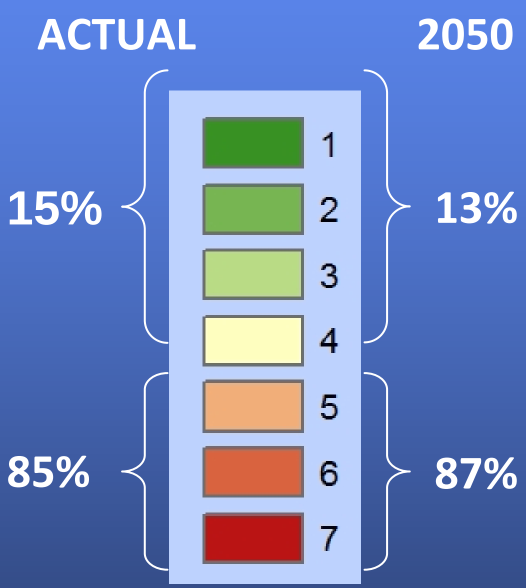


1	1.06%
2	4.38%
3	6.45%
4	2.79%
5	7.16%
6	25.27%
7	52.89%

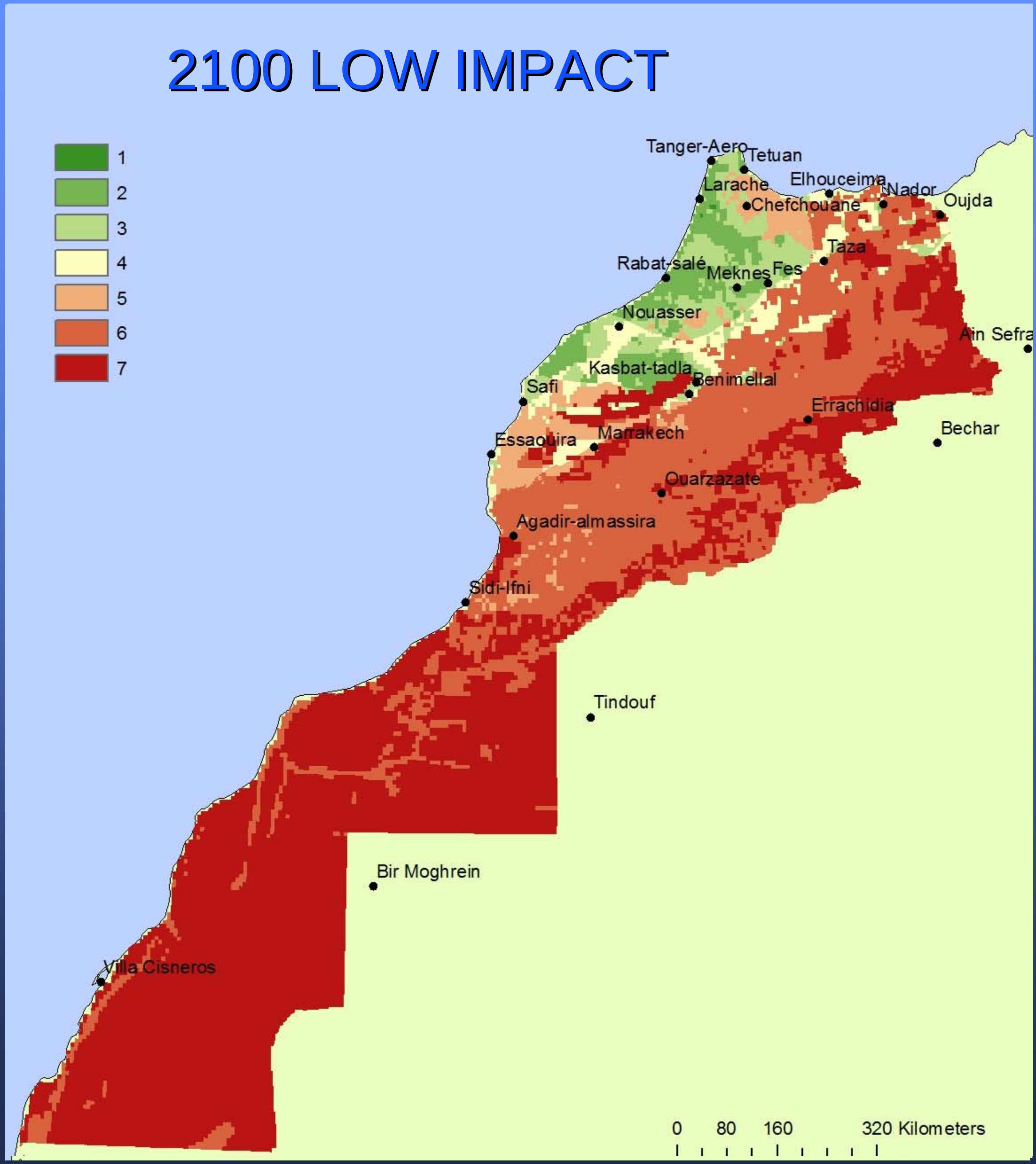
Decreasing capability

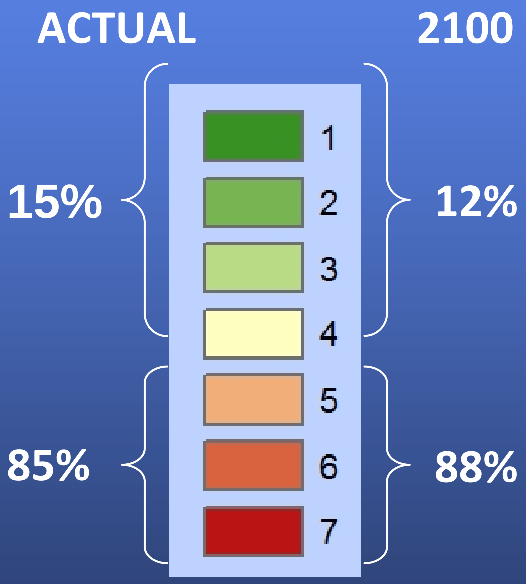
Pedo-climatic LCA – Climate change impact (1)



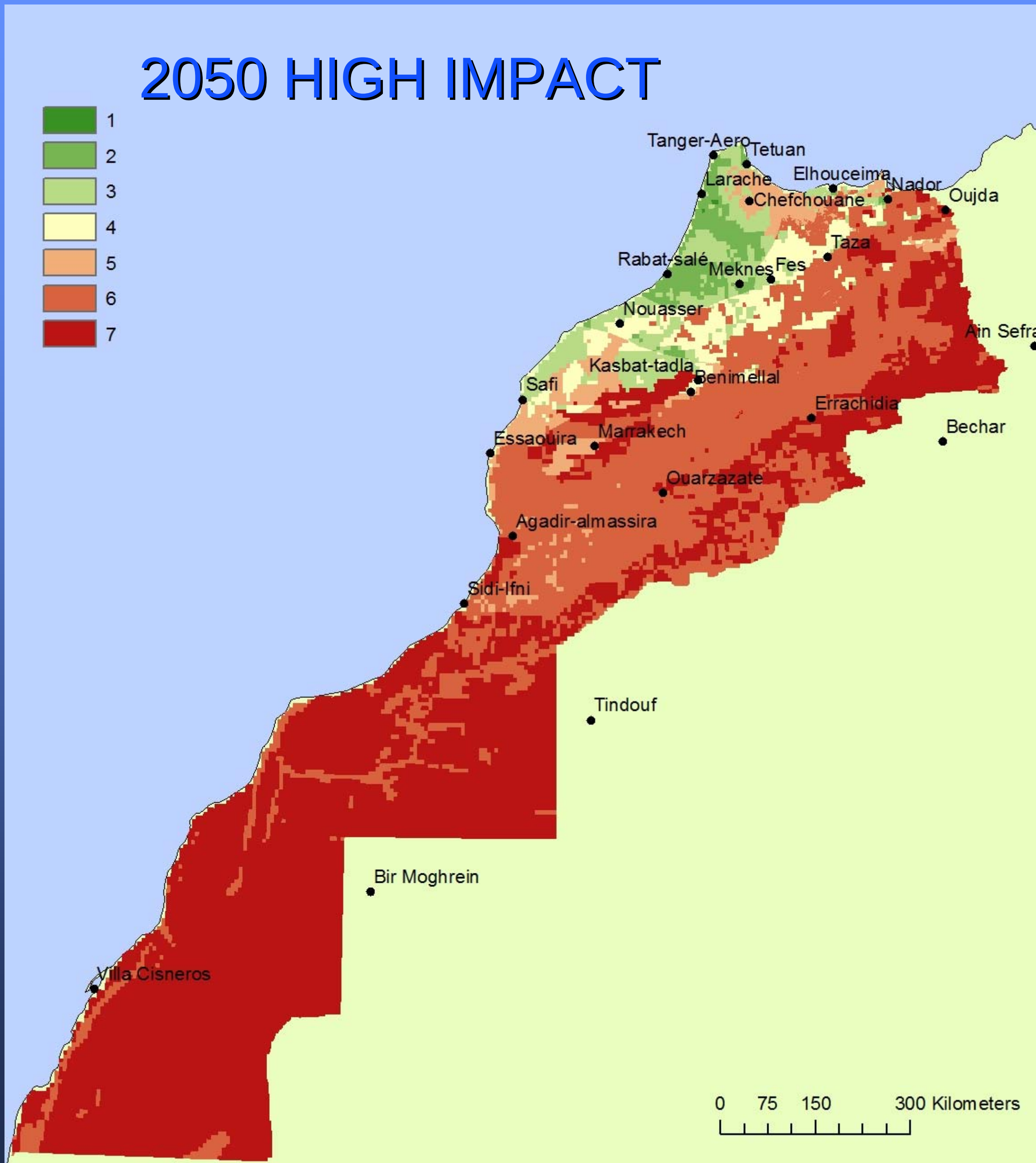


Pedo-climatic LCA – Climate change impact (2)



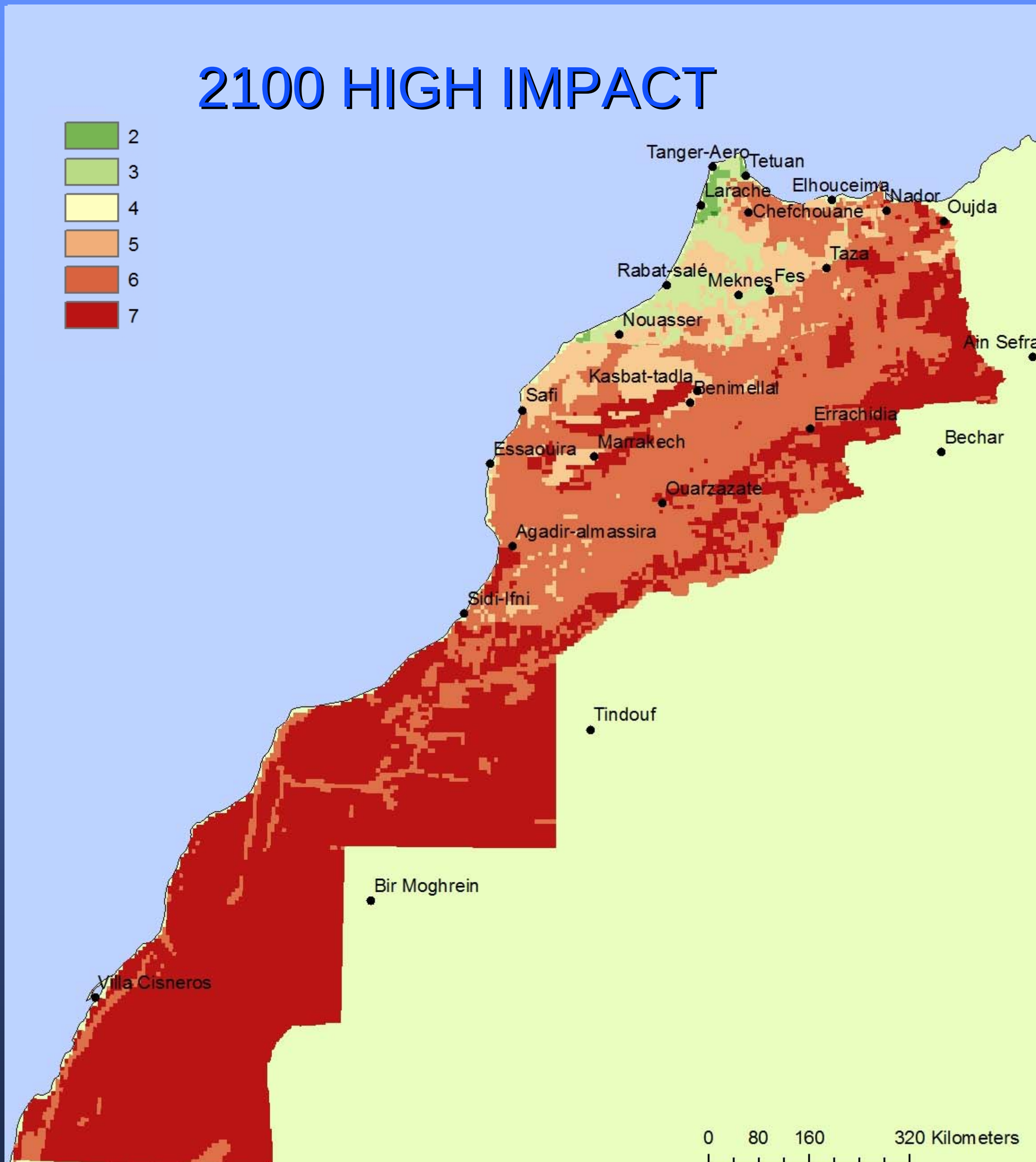


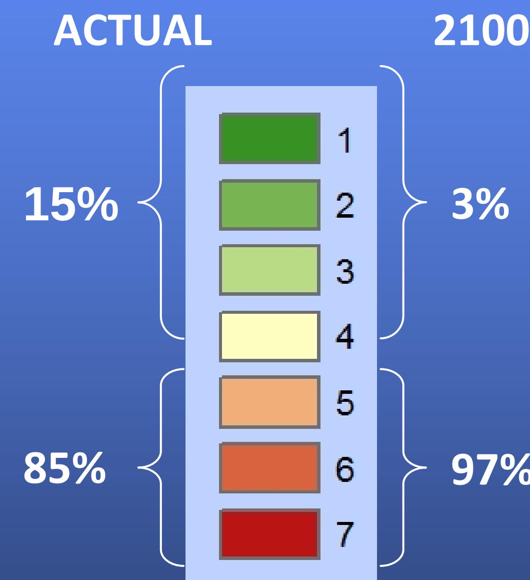
Pedo-climatic LCA – Climate change impact (3)



ACTUAL	Class	2050
15%	1, 2, 3, 4	11%
85%	5, 6, 7	89%

Pedo-climatic LCA – Climate change impact (4)

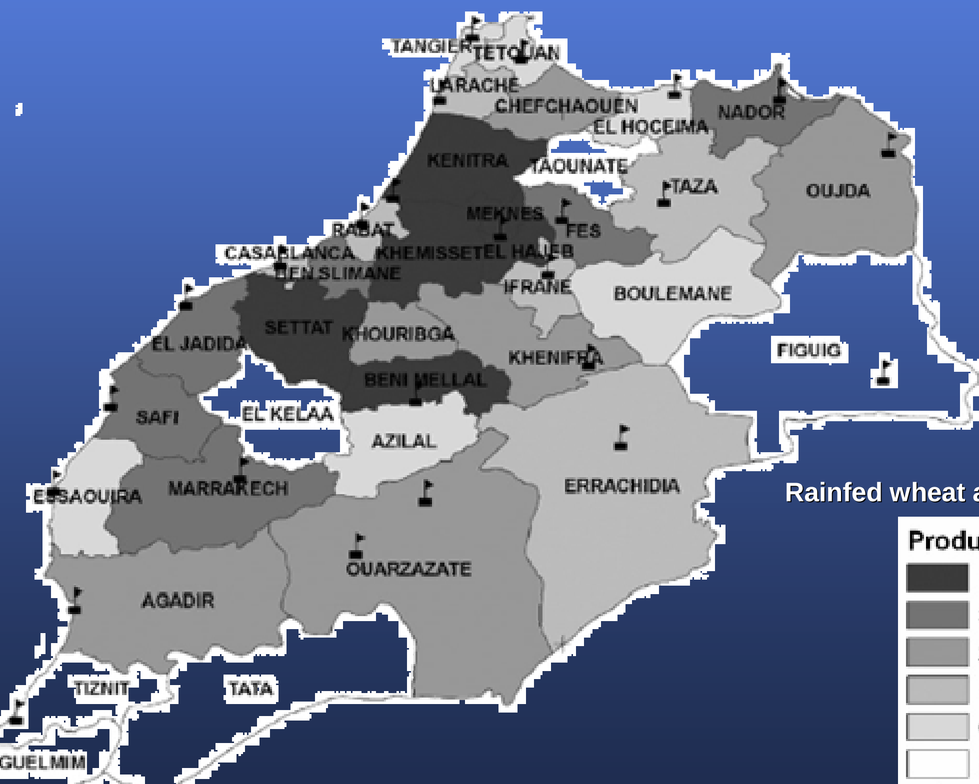




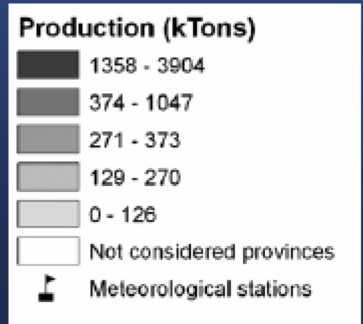
Land Suitability for rainfed wheat

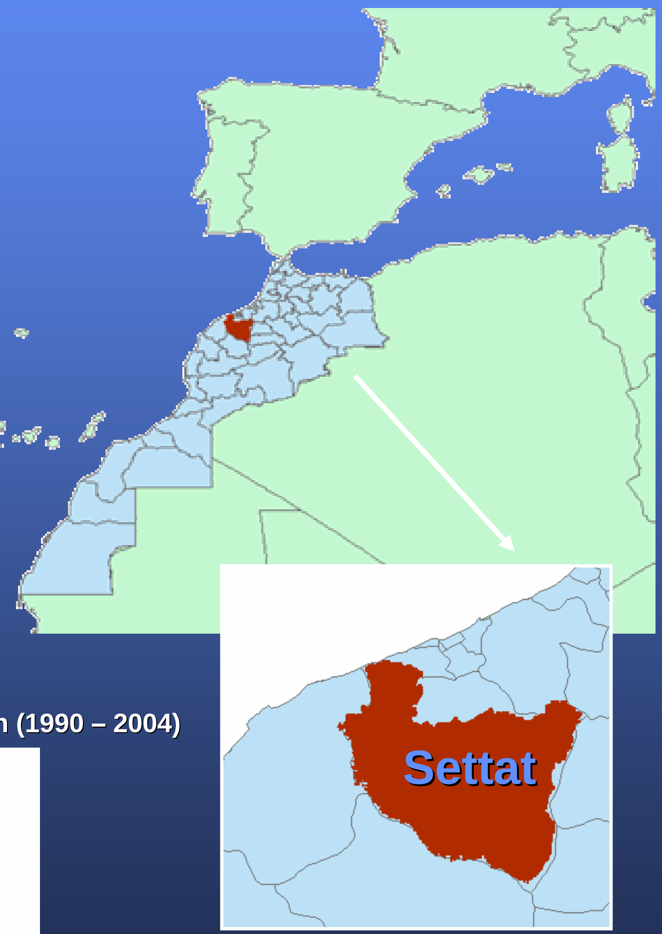
S1	Highly suitable
S2	Moderately suitable
S3	Marginally suitable
N	Unsuitable

FAO Methodology



Rainfed wheat average production (1990 – 2004)





Ha 786.423,16

Riad Balaghi *et al*, 2007

Land Suitability for rainfed wheat in Morocco

Land Requirements						
Land Qualities	Land Characteristics	Unit	S1	S2	S3	N
Moisture Availability	Total rainfall during the growing period (October -June)	mm	>350	300-350	200-300	<200
Root oxygen availability	Soil drainage class	class	well to excessively	imperfectly	poorly	very poorly
Rooting Conditions	Soil depth	cm	>60	60-40	40-25	<25
Condition affecting germination	Mean monthly temperature during germination period (November - December)	°C	10-20	8-10 20-25	6-8 25-37	<6
Nutrient Retention Capacity	Organic matter	%	>1.0	1- 0.5	<0.5	<0.2
Flowering and grain filling conditions	Mean monthly temperature during flowering period (March - April)	°C	12 - 26	10-12 26-32	8-10 32-36	<8 >36
	Mean monthly temperature during grain filling period (April - May)	°C	14 - 30	12-14 30-36	10-12 36-42	<10 >42
	Mean monthly rainfall during flowering period (March - April)	mm	50 -120	15 - 50	10- 15	< 10
	Mean monthly rainfall during grain filling period (April - May)	mm	50 - 120	10-50	<10	
Soil Workability	Texture	class	loam, sandy clay loam, clay loam, silt clay loam	sandy loam, loamy sand, silt loam, silt clay, sandy clay	clay until 70%	clay>70%, silt, sand
Potential for mechanization	Slope	%	<5	5 - 15	15-25	> 25

Land Suitability for rainfed wheat in Morocco

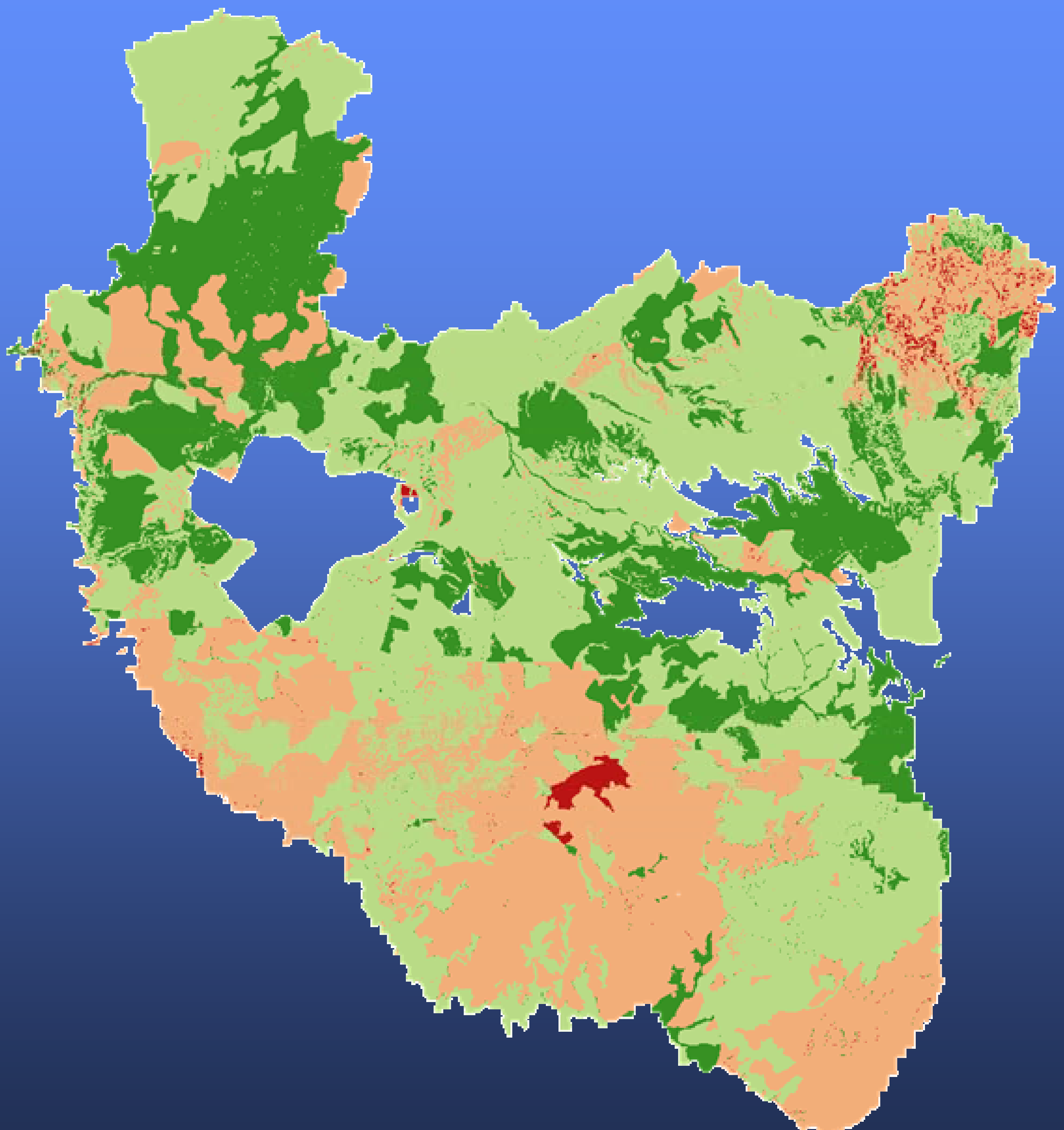
Classes	Ranking rate
S1	1
S2	0.8
S3	0.5
N	0.2

FAO Methodology

Values of Suitability Class = ([prec_grow]) * ([tmed_germ]) * ([prec_fill]) * ([drainage]) * ([organic]) * ([depth]) * ([texture]) * ([slope])

Value	Evaluation
$\geq 0.25 - \leq 1$	Very suitable (S_1)
$\geq 0.10 - < 0.25$	Moderately suitable (S_2)
$\geq 0.025 - < 0.10$	Marginally suitable (S_3)
< 0.025	Unsuitable (N)

Land Suitability for rainfed wheat - Morocco

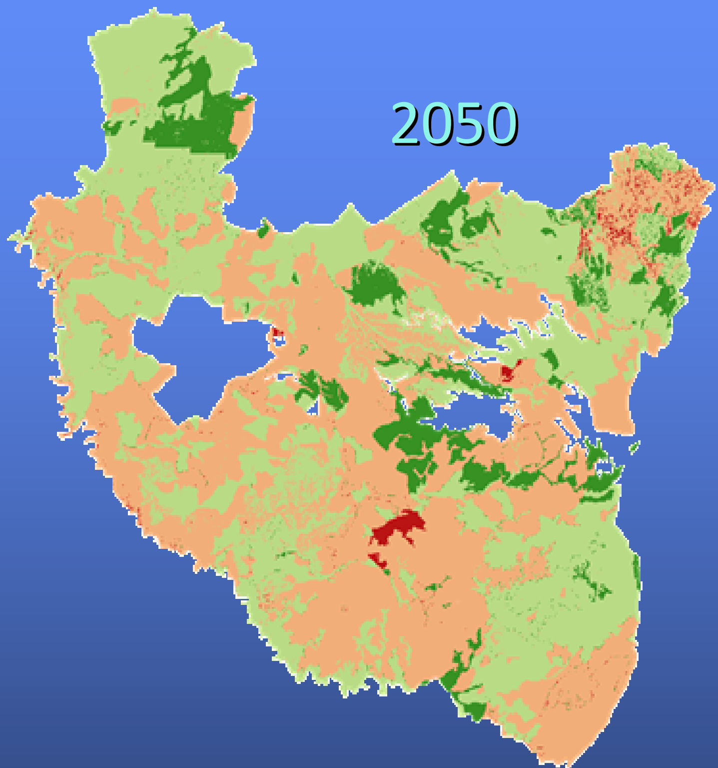


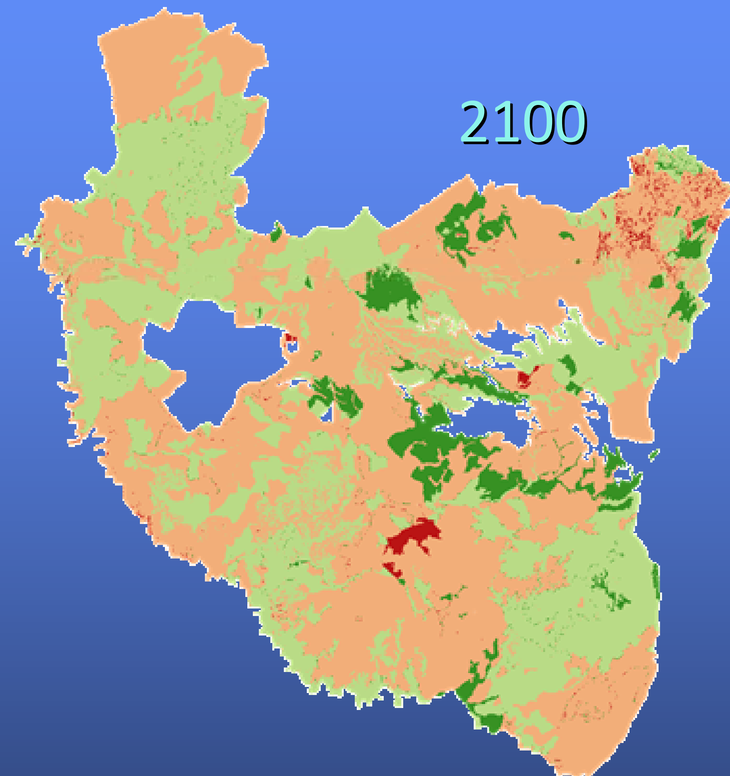
	S1	Highly suitable
	S2	Moderately suitable
	S3	Marginally suitable
	N	Unsuitable

%	LS
21%	S1
49%	S2
29%	S3
1%	N

Land Suitability for rainfed wheat – Climate Change

low impact scenario

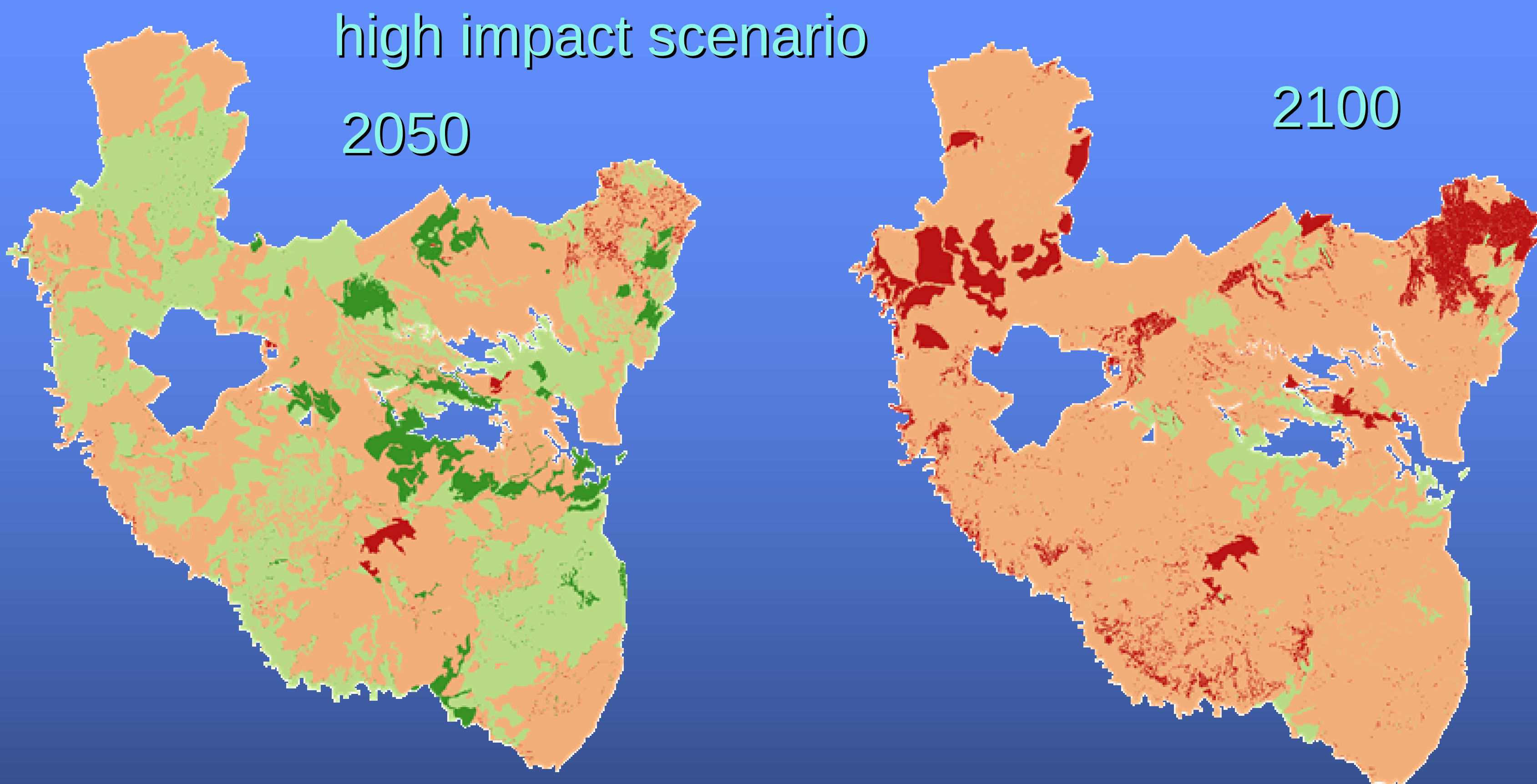




	S1	Highly suitable
	S2	Moderately suitable
	S3	Marginally suitable
	N	Unsuitable

	Now	2050 low	2100 low
S1	21%	9%	6%
S2	49%	43%	37%
S3	29%	47%	56%
N	1%	1%	1%

Land Suitability for rainfed wheat – Climate Change

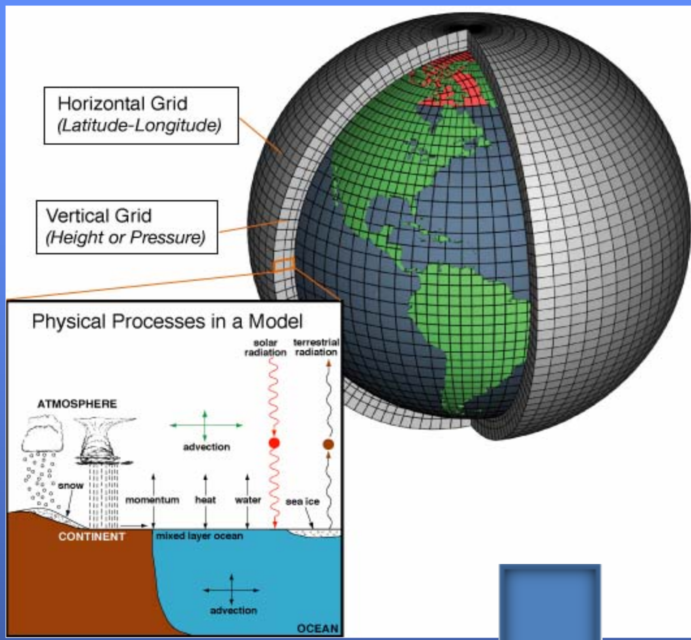


	Now	2050 high	2100 high
S1	21%	6%	0%
S2	49%	37%	6%
S3	29%	55%	84%
N	1%	2%	10%

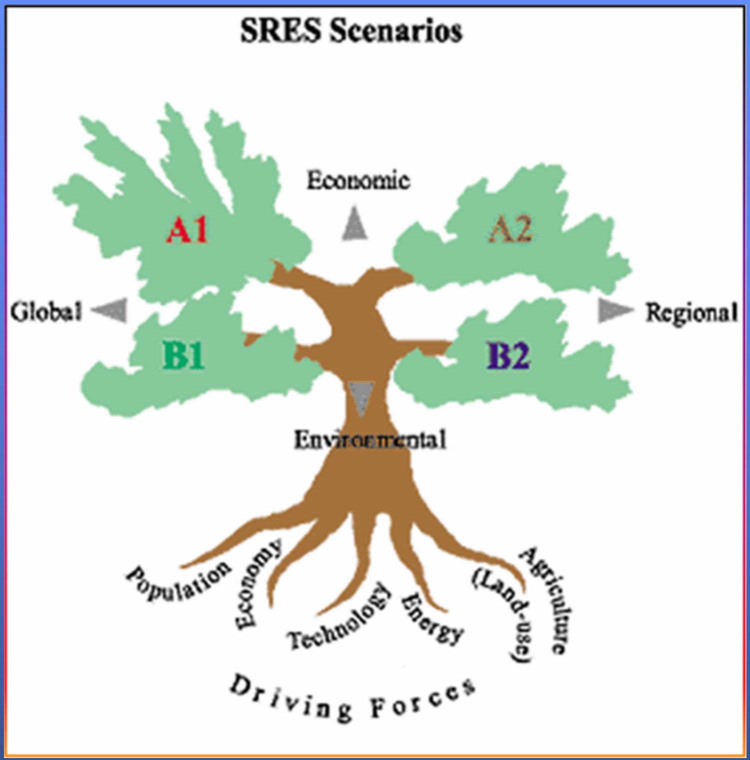
	S1	Highly suitable
	S2	Moderately suitable
	S3	Marginally suitable
	N	Unsuitable

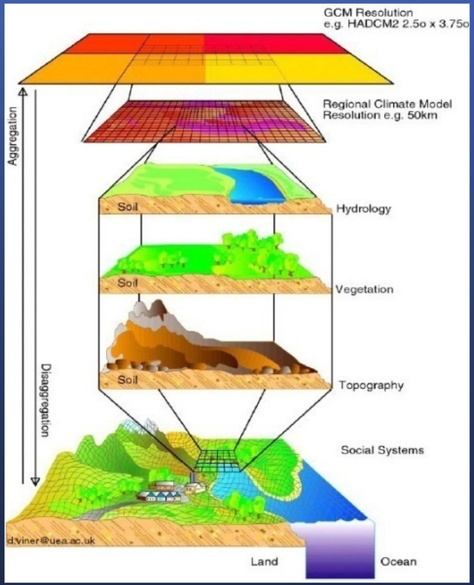
Statistical and crop growth modeling

Climate models

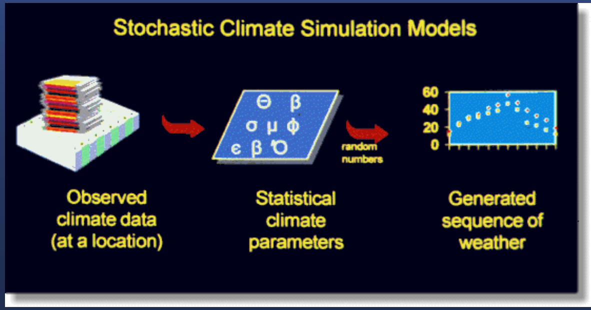


Emission Scenarios



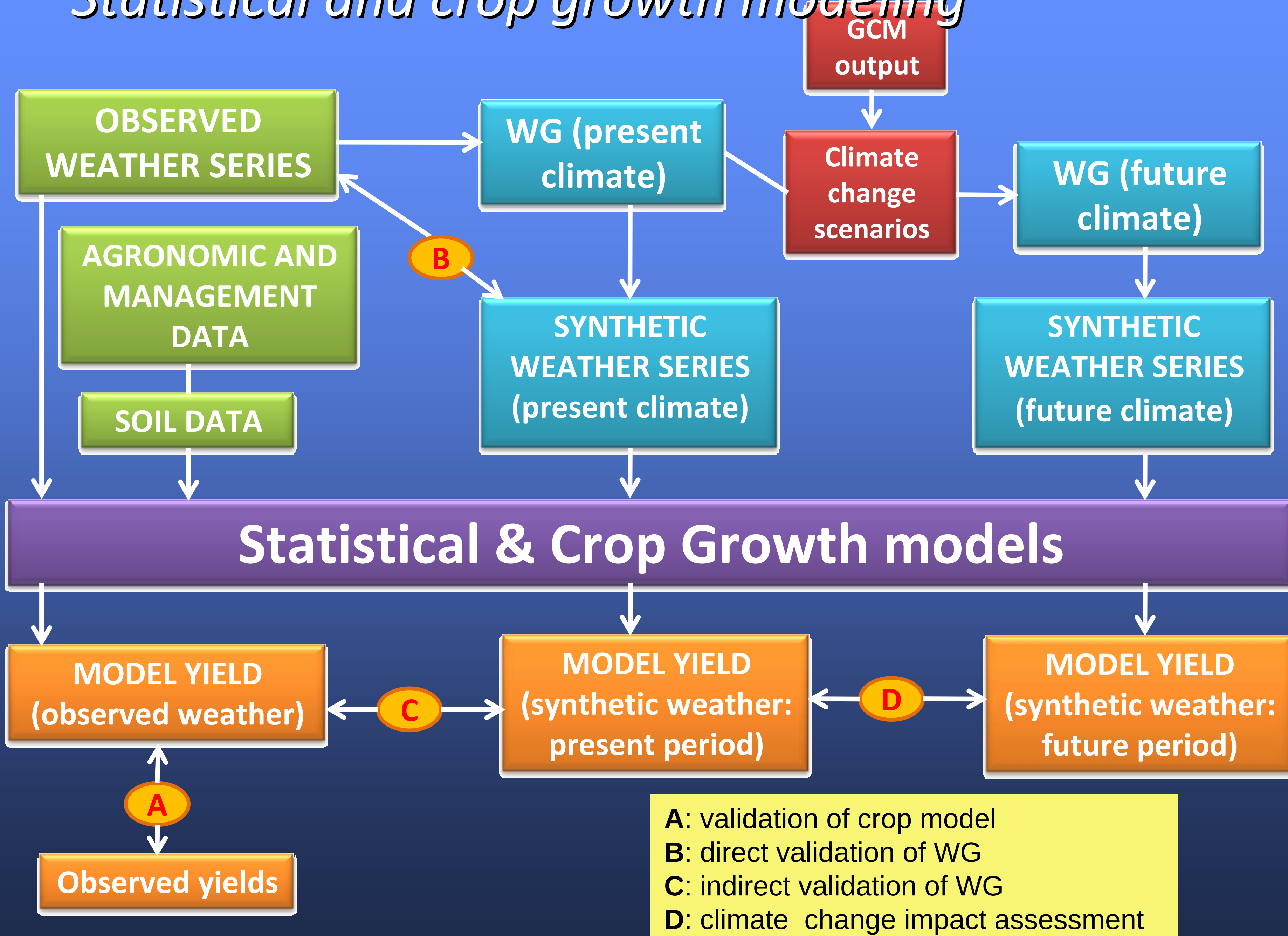


Downscaling

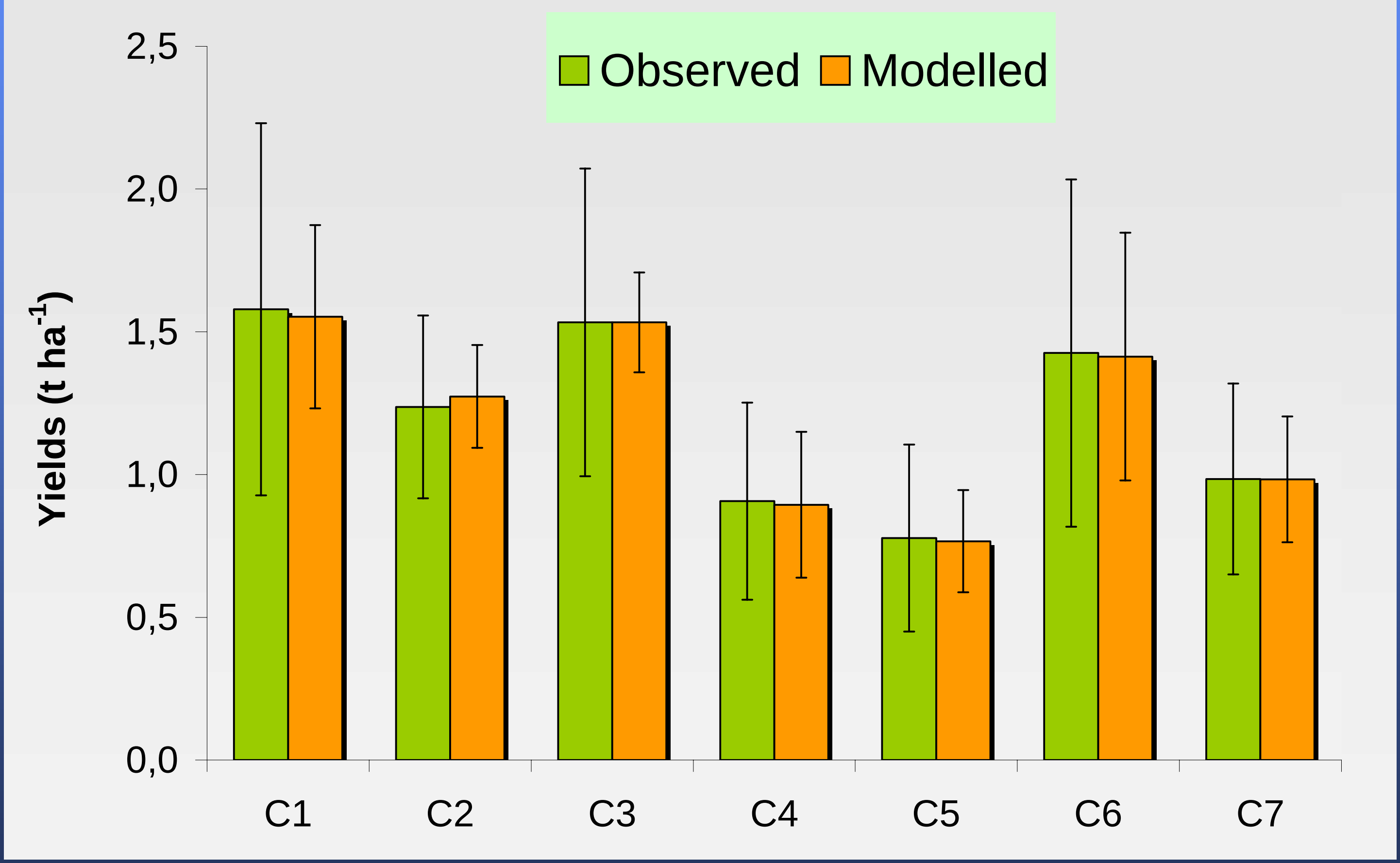


STATISTICAL & CROP GROWTH MODELS

Statistical and crop growth modeling

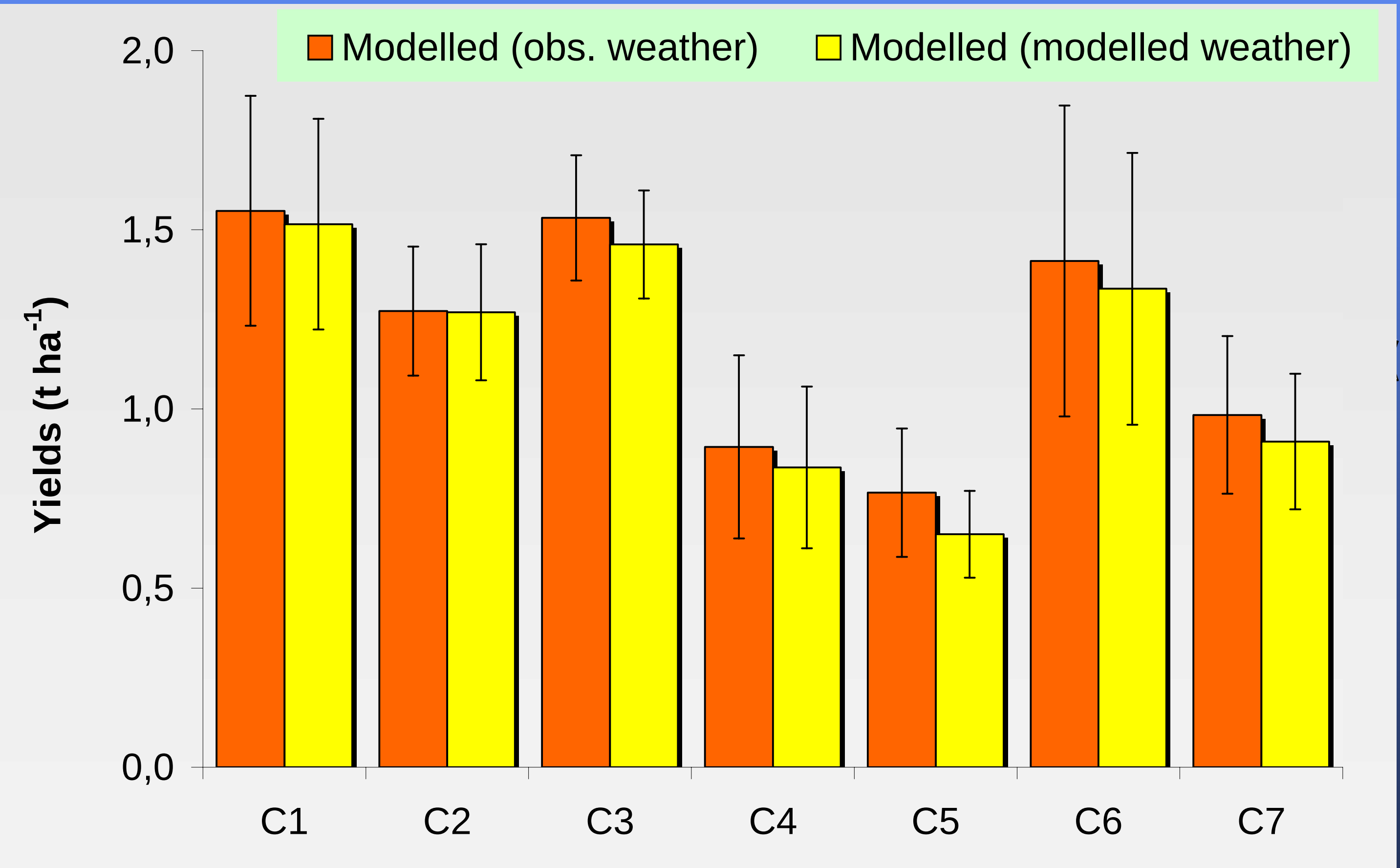


Statistical modeling
Weather Yield Function (WYF) validation



Observed yield
vs
Modeled yield

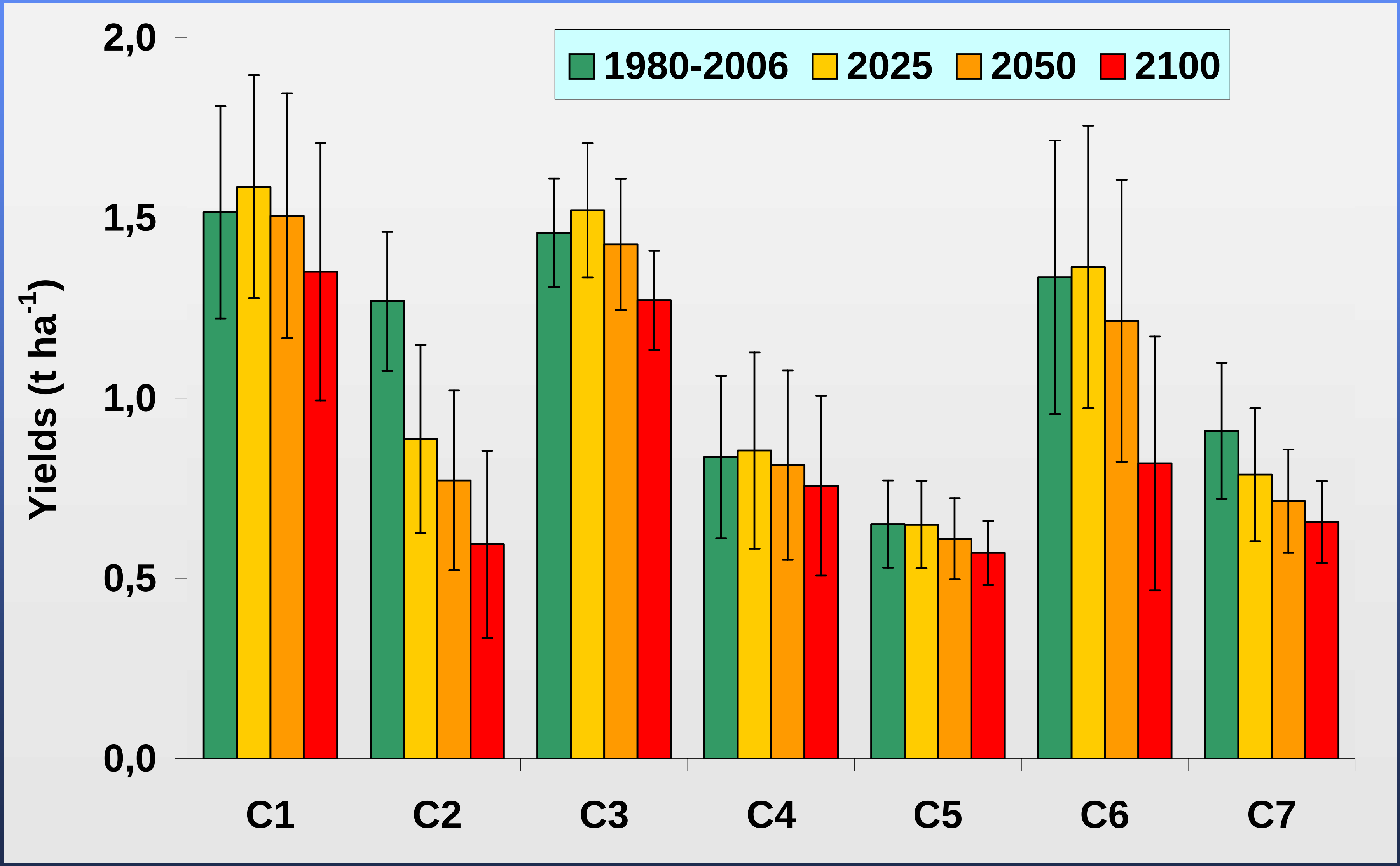
Statistical modeling
Weather Generator validation (indirect)



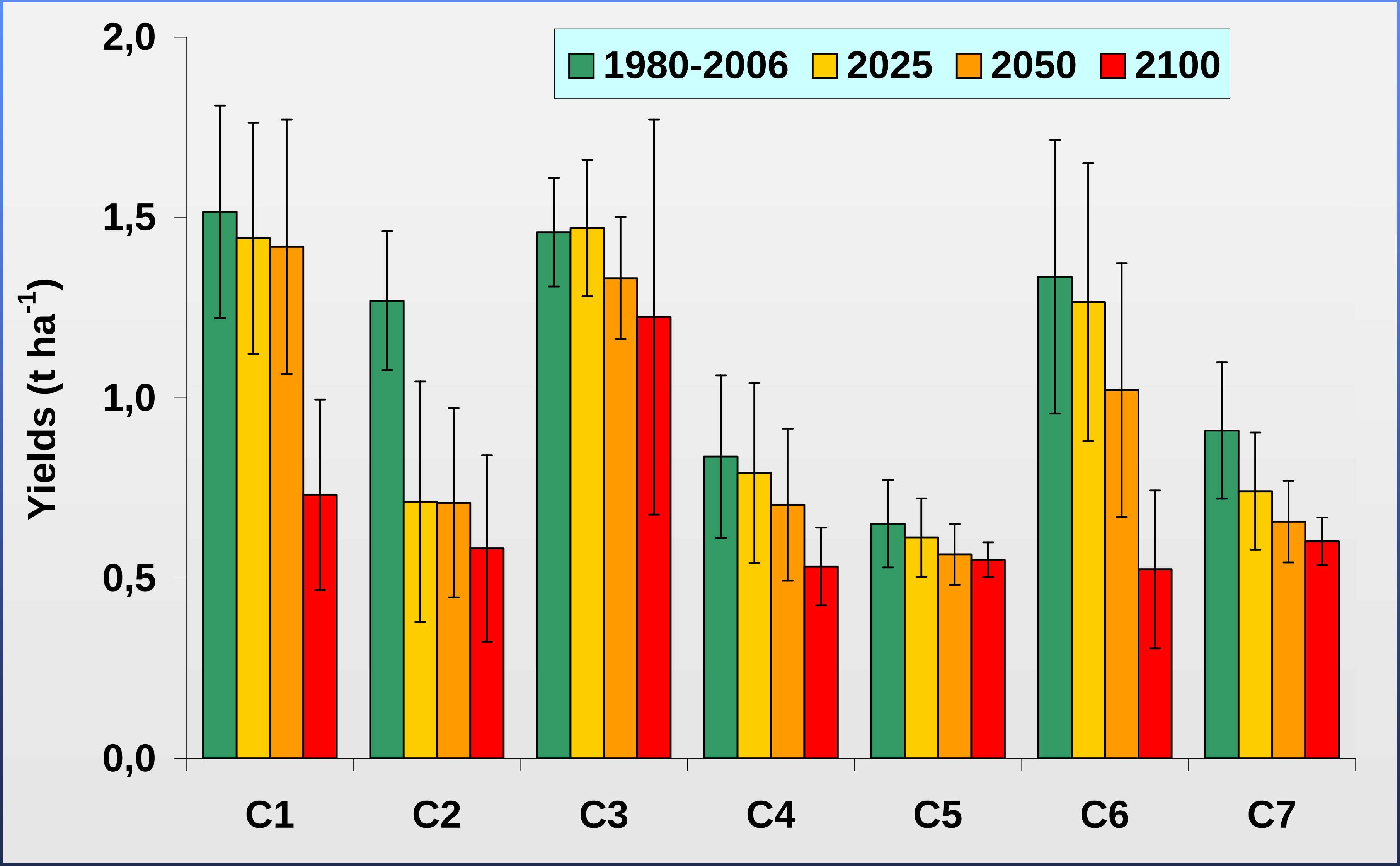
Modeled yield
(using obs weather)
vs
Modeled yield
(using modeled weather

Statistical modeling

Impact of CC on wheat yield (low impact scenario)



Statistical modeling
Impact of CC on wheat yield (high impact scenario)



Crop growth and development model

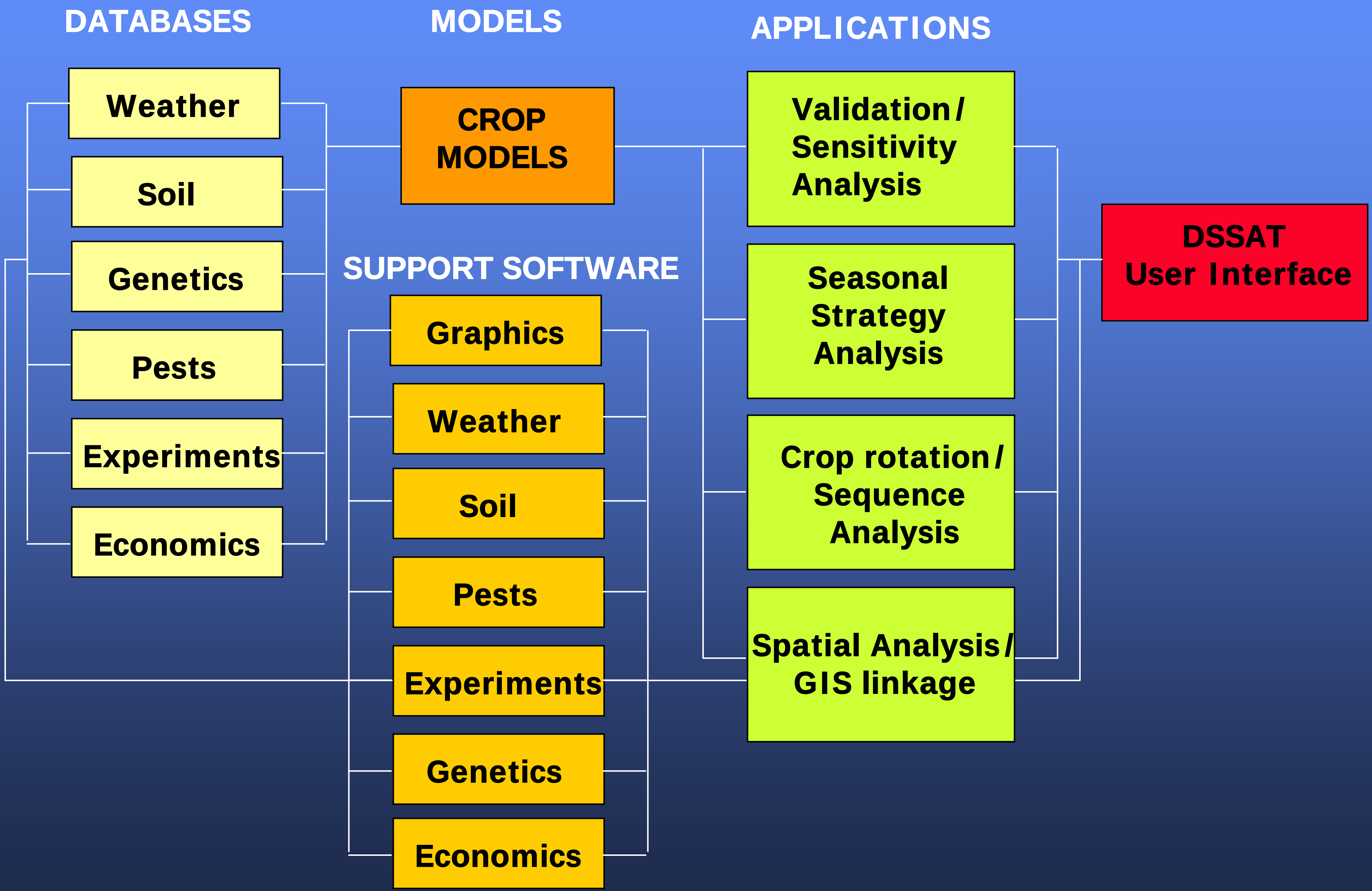
- Crop growth simulation model: CERES-Wheat model
- Data: 6 weather stations and 6 INRA experimental farms

Input Requirements

- Weather: Daily precipitation, maximum and minimum temperatures, solar radiation
- Soil: Soil texture and soil water measurements
- Management: planting date, variety, row spacing, irrigation and N fertilizer amounts and dates, if any
- Crop data: dates of anthesis and maturity, biomass and yield, measurements on growth and Leaf Area Index (LAI)

Each simulation: 99-years crop model run with synthetic weather data

DSSAT Cropping System Model



Experimental sites

Sites	Lat	Long
Afourer	32°12’ N	6°32’ W
Jemaa Shaim	32°20’ N	8°50’ W
Khemis Zemamra	32°37’ N	8°42’ W
Marchouch	33°36’ N	6°42’ W
Sidi el Aidi	33°07’ N	7°37’ W
Tessaout	31°27’N	6°53’ W

CERES-Wheat calibration (1)

Trial and Error

Genetic coefficients variation to find best set

– Estimate phenology genetic coefficients first

P1V	(days)	Days at optimum vernalizing temperature required to complete vernalization
P1D	(%)	Percentage reduction in development rate in a photoperiod 10 hour shorter than the optimum relative to that at the optimum
P5	(°D)	Grain filling period duration

– Estimate growth and yield parameters afterward

G1	(1/g)	Kernel number per unit canopy weight at anthesis
G2	(mg)	Standard kernel size under optimum conditions
G3	(g)	Standard, non-stressed dry weight of a single tiller at maturity
PHINT	(°D)	Phyllochron interval; the interval in thermal time between successive leaf tip appearances

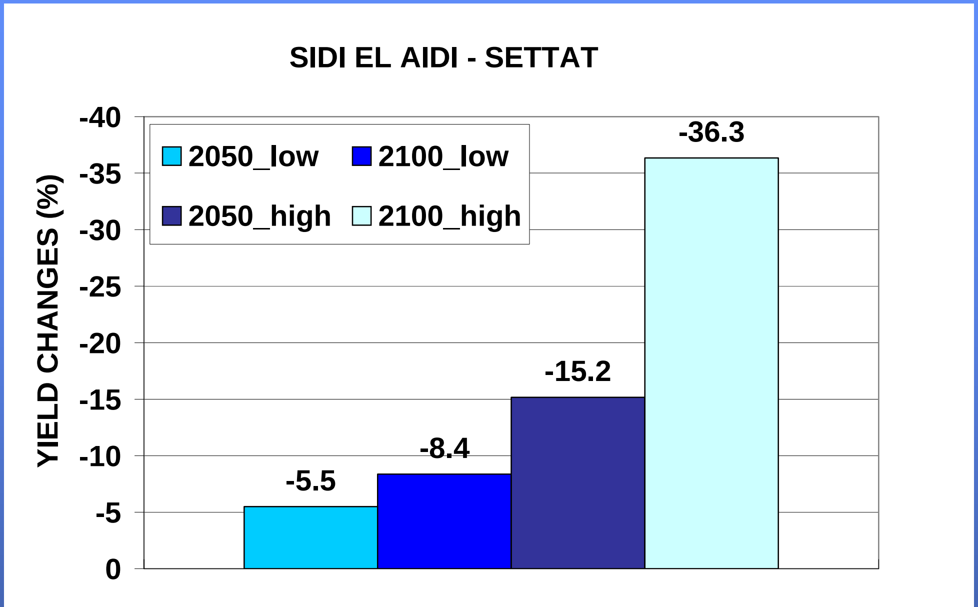
Criteria

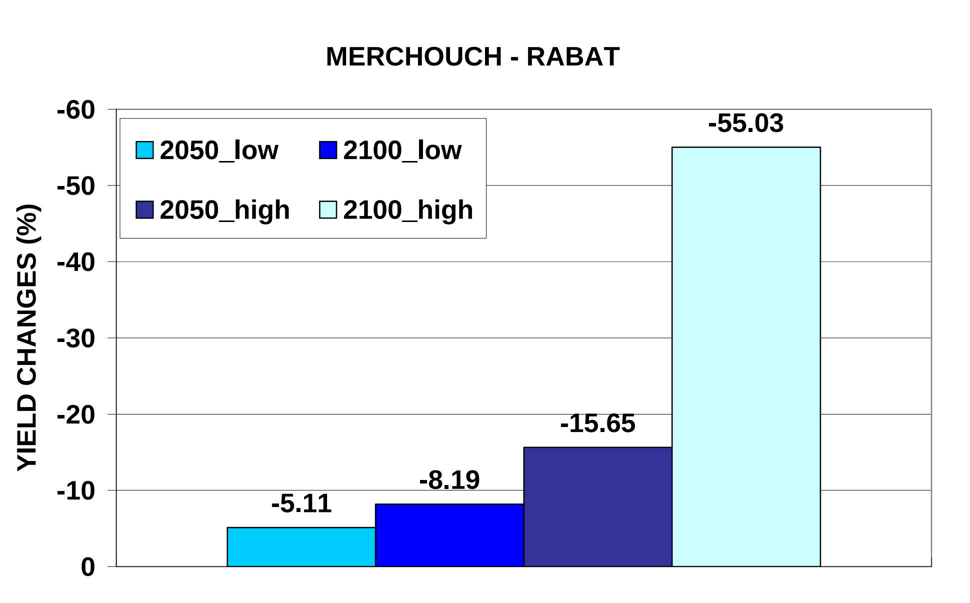
– Closeness of simulated and observed data
– Target variables (i. e., anthesis date, yield)
– Visual comparison
– Statistics (i.e., Root mean square error, Wilmott d-index)

Crop growth models – CERES-Wheat validation

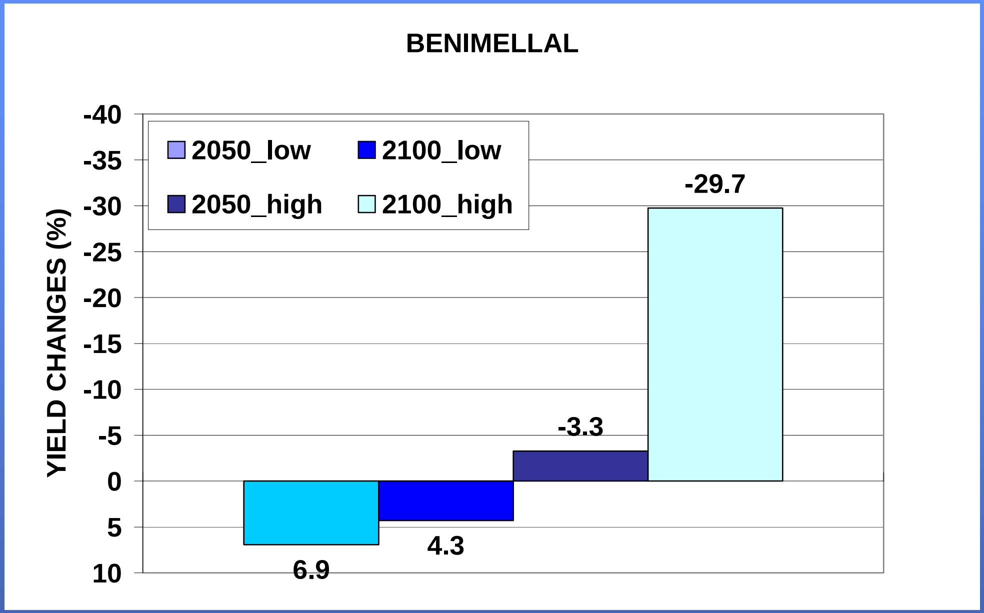
		GRAIN YIELD	ANTHESIS	SEED UNIT WEIGHT
Number of samples	N	21	18	19
Coeff. of determination	R^2	0.55	0.68	0.37
		$p<0.001$	$p<0.001$	$p<0.01$
Root mean square error	RMSE	736	5	23
General standard deviation	GSD	16	5	15
Mean bias error	MBE	207	4	17
Coefficient of residual mass	CRM	-0.08	-0.10	-0.12
Mean absolute error	MAE	541	4	19
Index of agreement	D-index	0.82	0.58	0.64

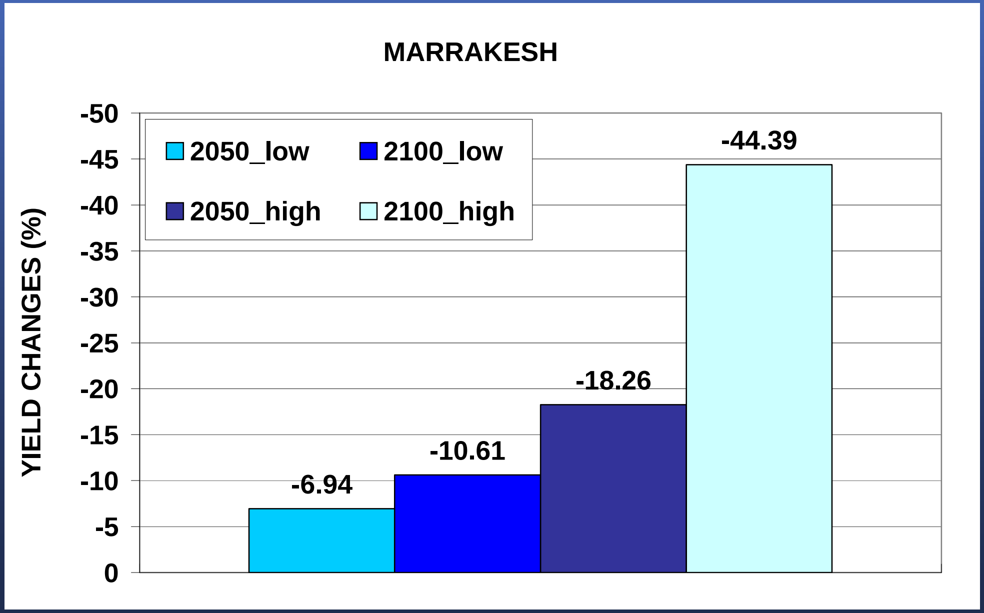
CLIMATE CHANGE IMPACTS ON YIELDS (1)





CLIMATE CHANGE IMPACTS ON YIELDS (2)





CONCLUSIONS

- The climate change impact on agriculture can be assessed at different spatial accuracy using tools and methods with very different details in input data

- Analysis of the impacts of future climate change scenarios highlighted a significant reduction of the suitable areas for agriculture in Morocco and significant reduction of rainfed wheat yield regardless of emission scenarios

FUTURE WORKS

- Adaptation strategies for responding to changes in climate regimes – mean and variability – need to be investigated to adapt agricultural systems to the new conditions

- Different options can be considered, for instance:
  - changing management of the same crop (planting dates, cultivar type, irrigation and fertilization regimes, pest control, etc.)
  - changing cropping system altogether

- From this perspective, statistical and crop growth model will be used to investigate other crops performances under changed conditions

Thanks!