GLOWAVolta

Predicting the Regional Onset of the Rainy Season (ORS) in the Volta Basin

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Motivation

- 70% of the West African population depend on rainfed agriculture
- Rainfall (not temperature) is the crucial factor for West African agriculture
- Rainfall is limited to few months per year
  - Sowing as early as possible to avoid wasting of valuable growth time
  - Planting too early (misinterpretation of the ORS) may lead to crop failure and high economic losses
- Farmers report of a high inter-annual variability of the ORS

Objectives

1) Development of an ORS definition for the Volta Basin considering *agricultural meaningful* and *technical* aspects:

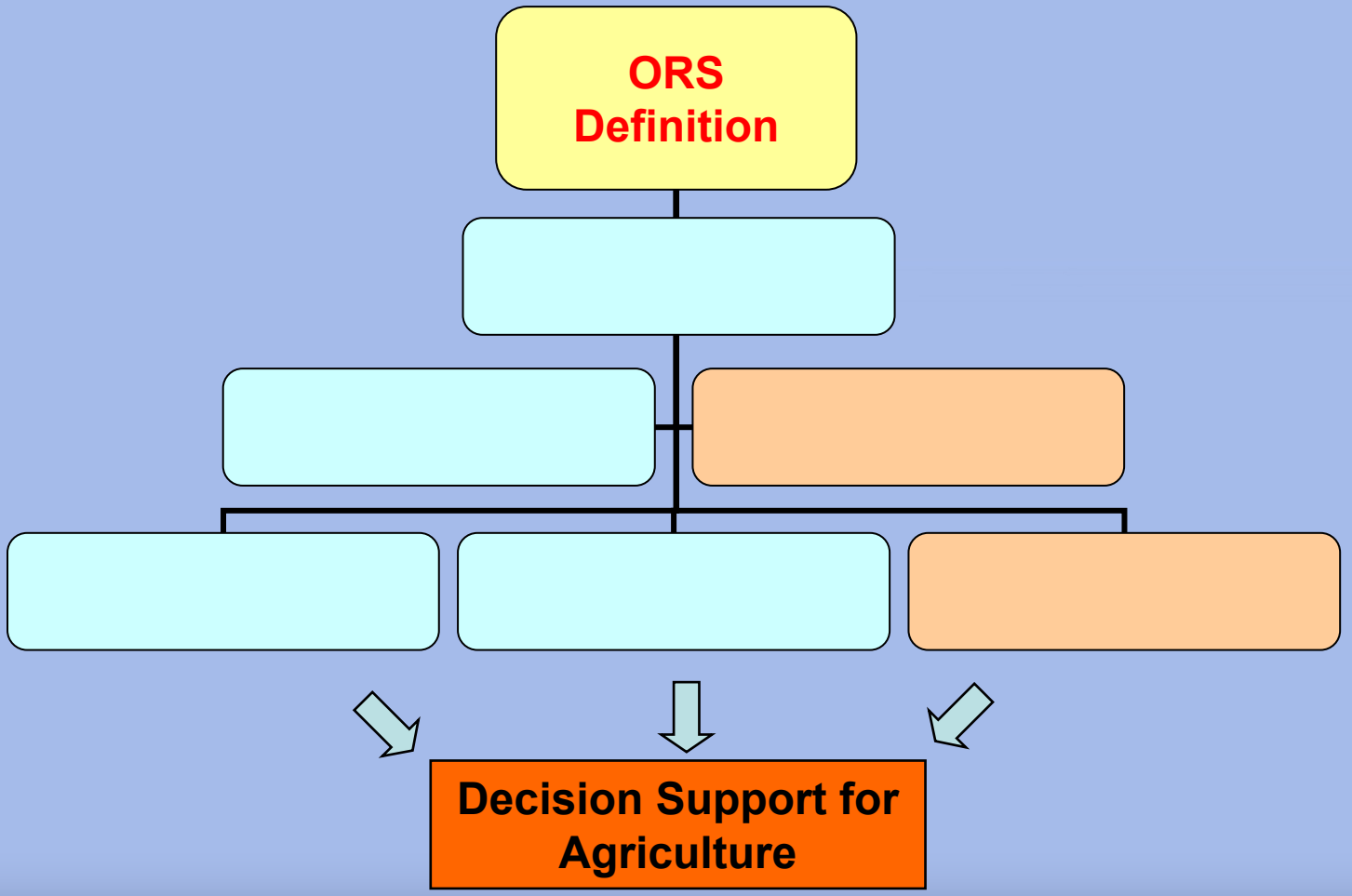
- Adequate soil moisture content at beginning of growth period
- Numerous rainy days before planting
- Avoiding dry stress during the establishing period
- Flexible definition:

  adaptable to needs of different crop varieties
- Relay on “easy-access” data

Objectives

2) **Development of maps for agricultural decision support ("risk mapping" for planting)**
   - Mean ORS dates
   - Standard deviations of ORS dates (risk of crop failure!)
   - False start probabilities
   - Exceedance probabilities of ORS dates
   - Minimum dry spell probabilities
   - Rainfall probabilities for certain rainfall amounts
   - Drought probabilities (return periods)

3) **Prediction of the ORS for ongoing season**


ORS
Definition
Decision Support for
Agriculture

ORS Definition

ORS = first day of the year, when these criterions are fulfilled simultaneously:

1. 25 mm precipitation falls within 5-day period
2. Starting day and two other days are rainy days
3. No dry period of 7 or more consecutive days allowed within following month (false start criterion!)

DEFINITION 2

DEFINITION 1

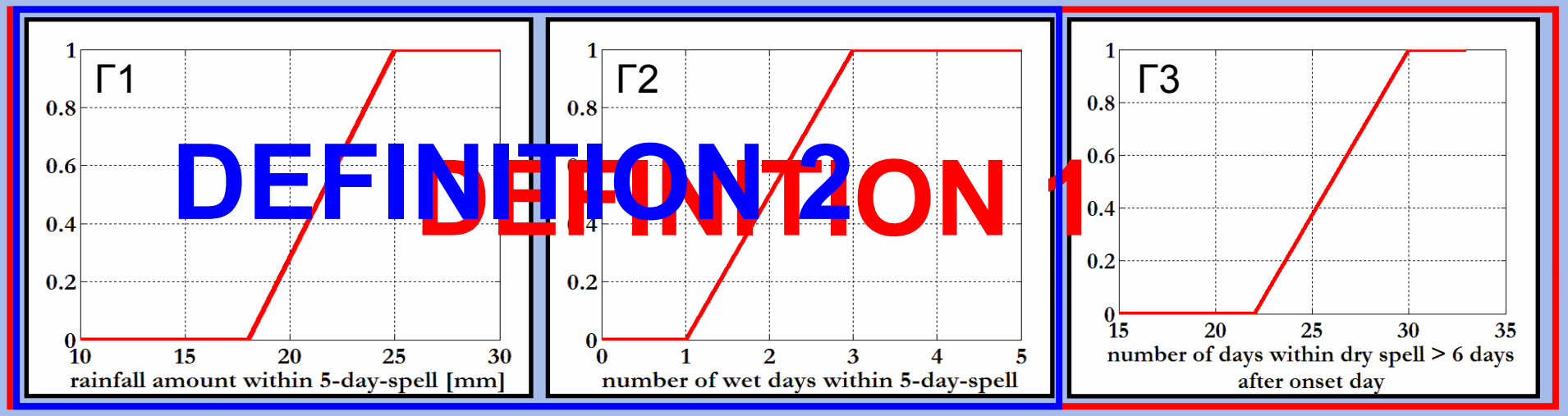
Problem: Sternness of the definition
Solution: Fuzzy-logic approach

ORS Definition

- Fuzzy logic approach:

  Step 1: Translation of the Definition arguments into membership functions

ORS Definition



False start – criterion,

only applicable EX-POST!

ORS Definition

- Fuzzy logic approach:

Step 1: Translation of the Definition arguments into membership functions

Step 2: Combining the membership functions

$\Gamma_{def1} = \Gamma 1 \cdot \Gamma 2 \cdot \Gamma 3$ $\Gamma_{def2} = \Gamma 1 \cdot \Gamma 2$

Step 3: Defuzzification:

If Γ_{def1} (Γ_{def2}) > threshold, then ORS

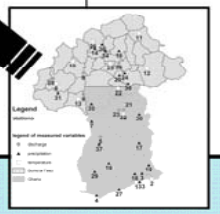
Regionalisation

Data arrangement

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1p} \\ x_{21} & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ x_{n1} & \dots & \dots & \dots \end{pmatrix}$$

A map for time t_1

A time series for location x_1



Principle Component Analysis:

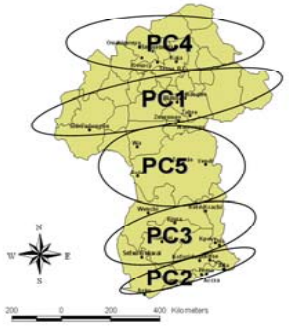
1. Covariance Matrix: $R = \frac{1}{n-1} X^T \cdot X$
2. Eigenvalue Problem: $RC = C\Lambda$
3. Expansion Coefficients: $\vec{a}_j = X\vec{c}_j$
4. Reconstruction TS: $X = \sum_{j=1}^{p} \vec{a}_j (EOF_j)$

How to come from the stations to the regions ?

Correlation original TS and PCs

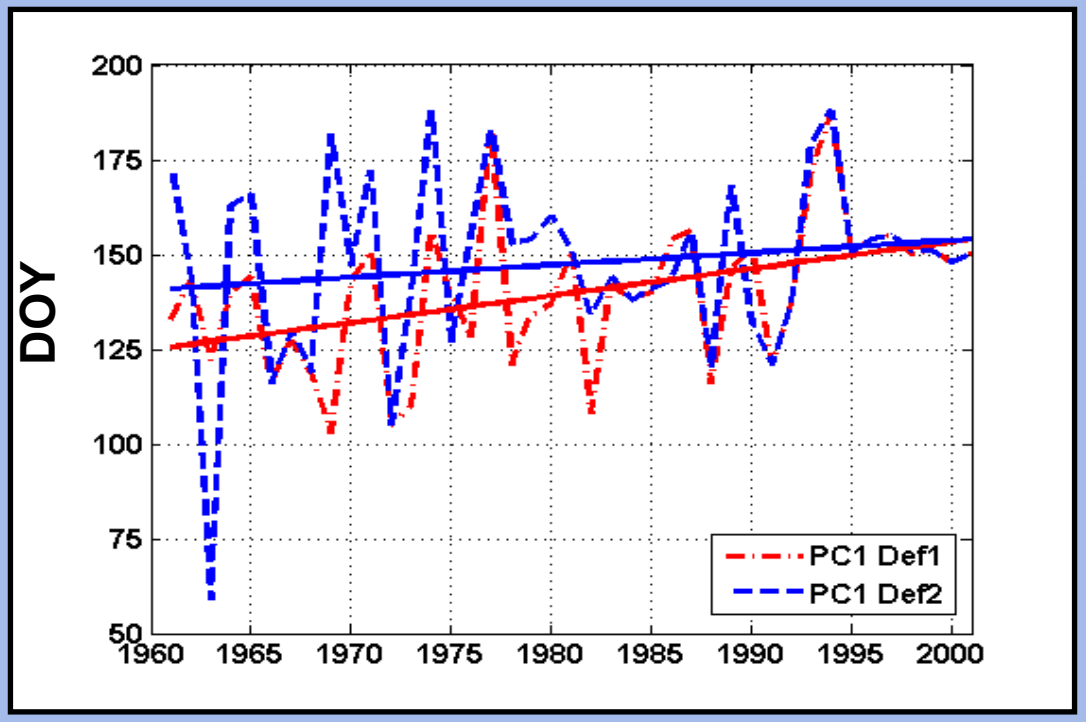
Station	pc1	pc2	pc3	pc4	pc5
Accra	**0.80**	0.00	0.03	0.04	0.14
Ada	**0.66**	0.00	0.01	0.07	0.13
Akuse	0.40	-0.03	0.09	-0.01	**0.50**
Axim	**0.51**	0.02	-0.02	0.10	0.14
Bole	0.07	0.05	0.08	**0.66**	0.10
…	…	…	…	…	…

Grouping of each station to a region



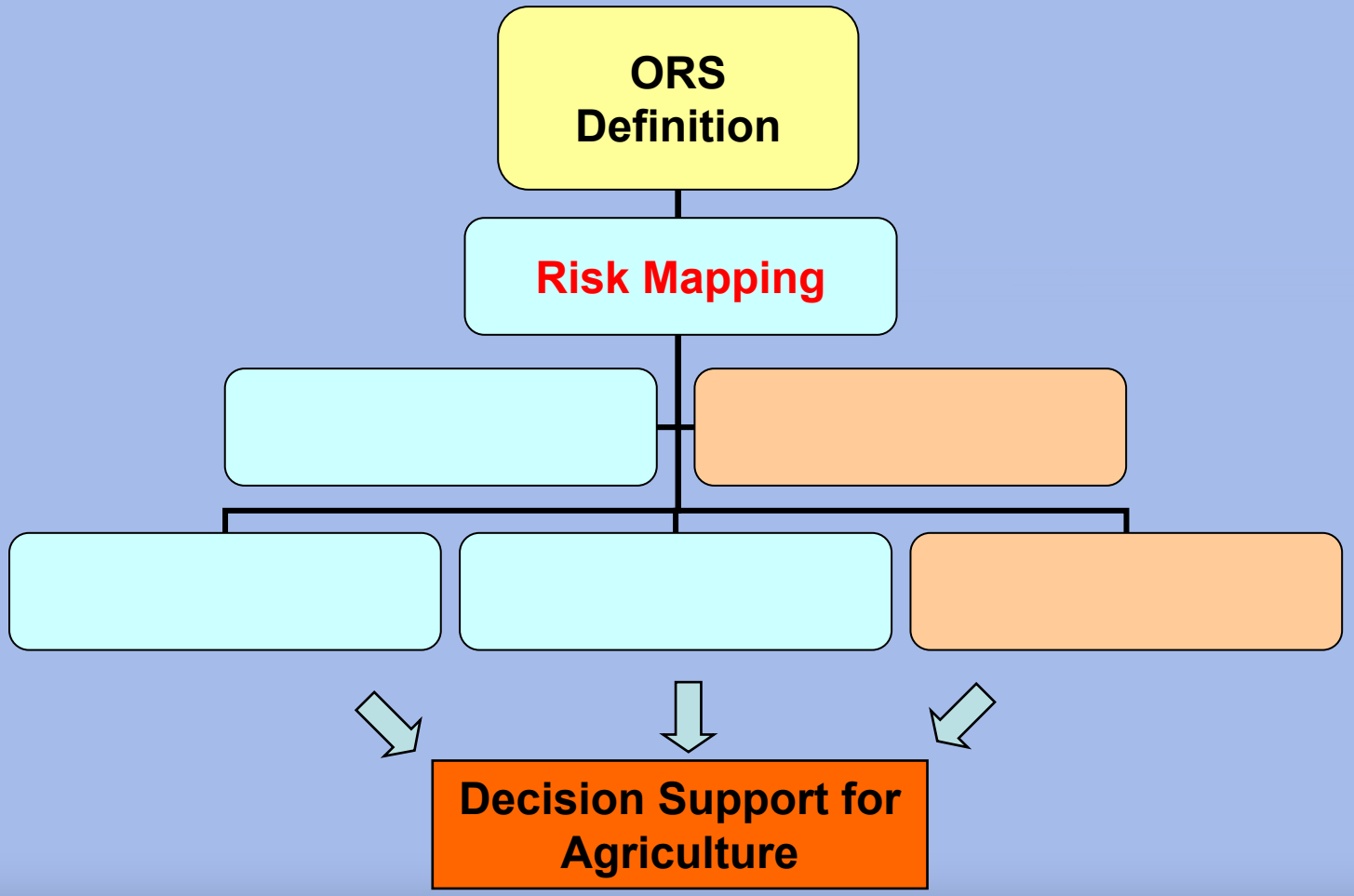
Delay of the Onset of the Rainy Season

Interannual variability of the ORS date

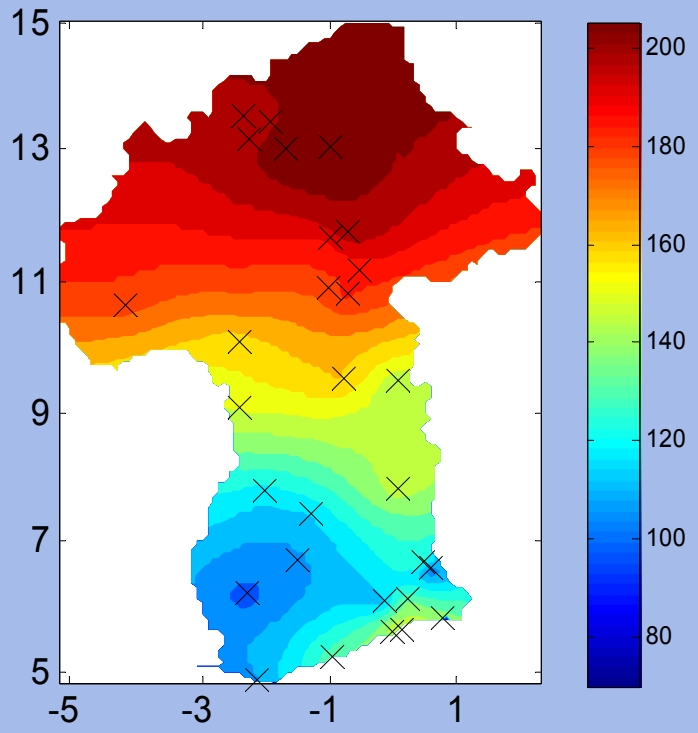


Significant ORS delay of about 3 weeks within 40 years

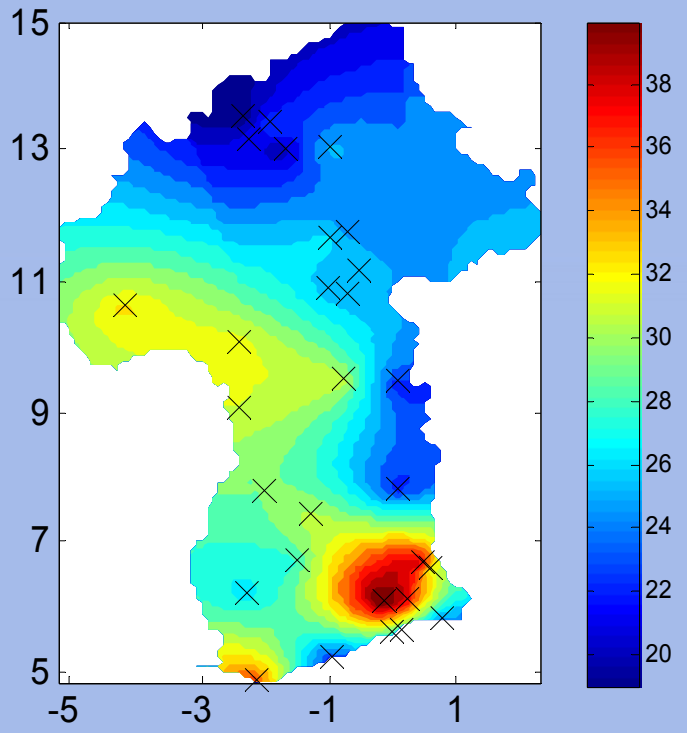
Risk Mapping



Maps for Agricultural Decision Support



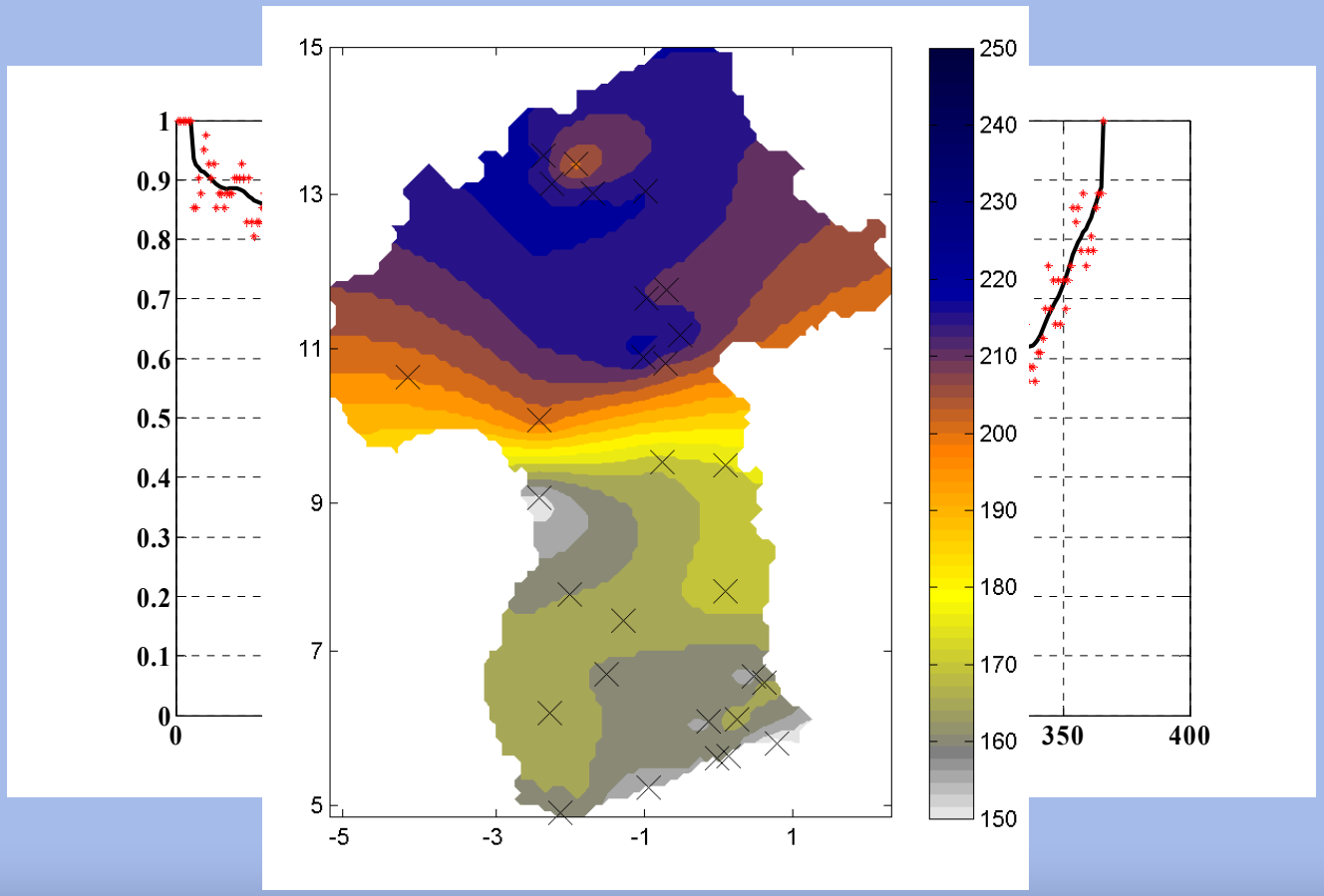
Mean date (DOY) of the Onset of Rainy Season (1961-2000)



Standard deviation (DOY) of the Onset of Rainy Season (1961-2000)

Maps for Agricultural Decision Support

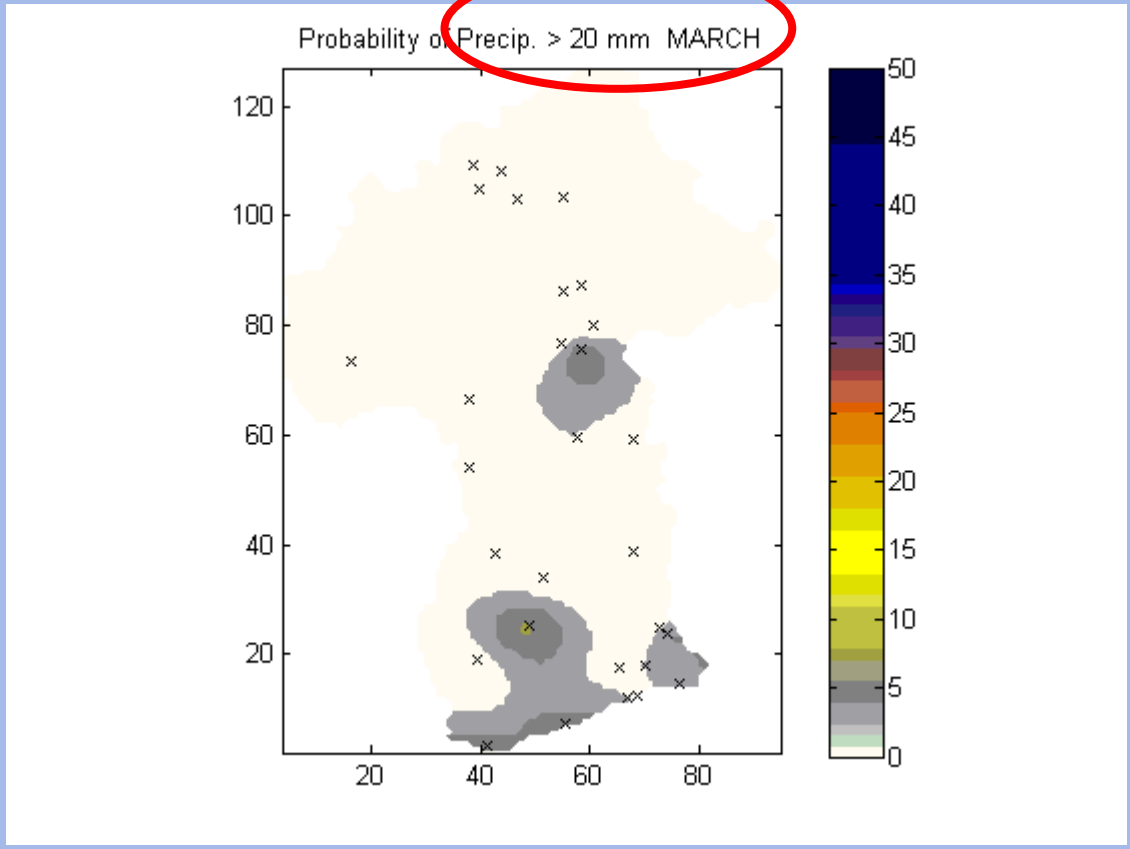
Occurrence probability of a dry spell ≥ 7 days within the following month at station Bole for each DOY (1961-2000)



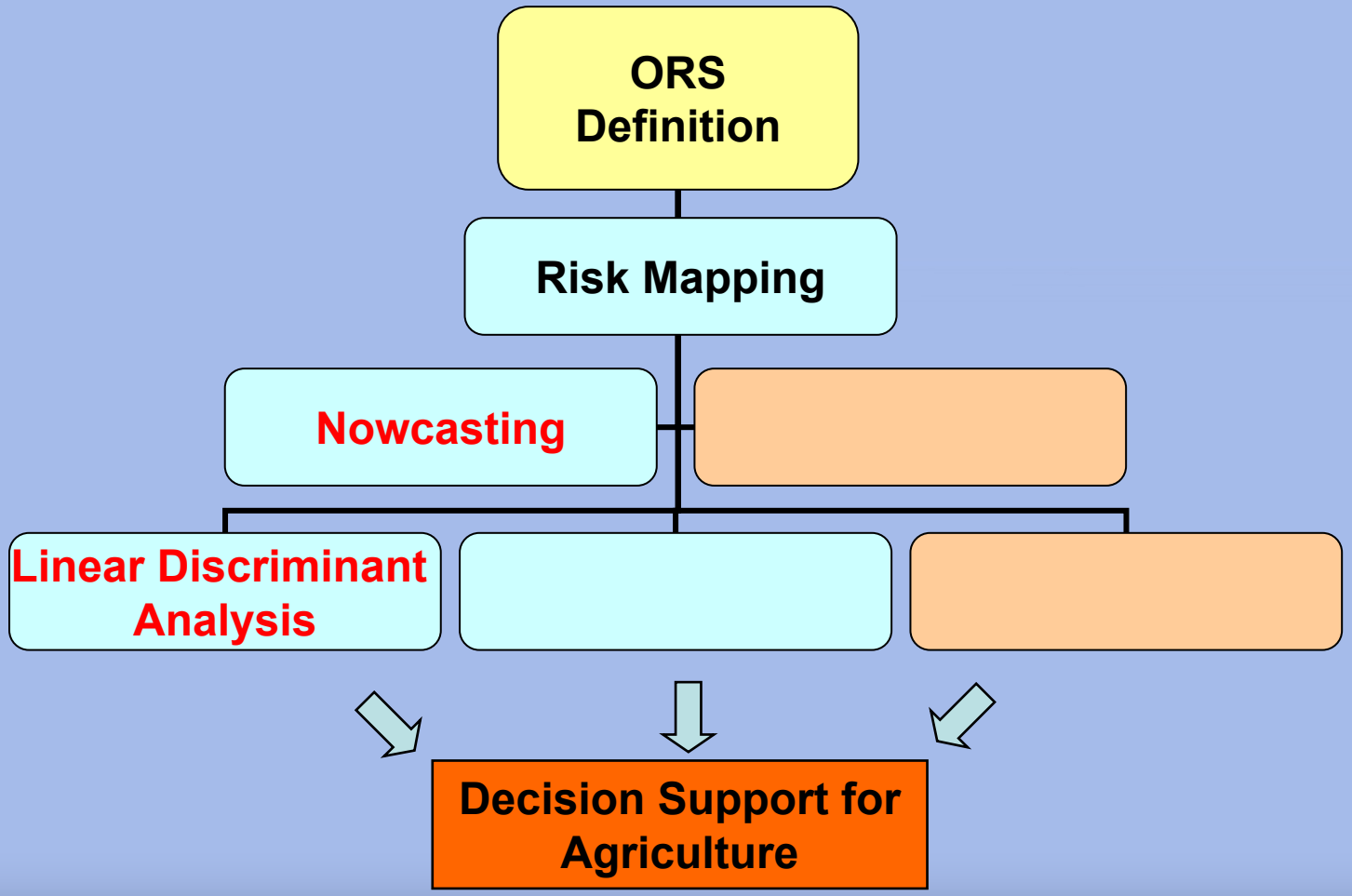
Map of minimal risk

Maps for Agricultural Decision Support

Rainfall probabilities exceeding certain amount / day



Prediction of the ORS (Ongoing Season)



Prediction of the ORS (Ongoing Season) via LDA

Predictors:

Number of rainy days & rainfall amount

various 5 day period before ORS

Performance of ORS Prediction (Ongoing Season) via LDA

		Class membership after application of linear discriminant analysis [%]			
		DRY class	TRANSITION class	ORS class	WET class
Predetermined Class Membership [%]	DRY class	**80.32**	15.86	1.38	2.44
	TRANSITION class	52.99	**27.97**	4.01	15.03
	ORS class	7.20	5.80	**79.44**	7.56
	WET class	13.94	11.50	10.57	**63.99**

Hit ratio: ~ 80% correct classified cases for the ORS

Summary Prediction ORS via LDA

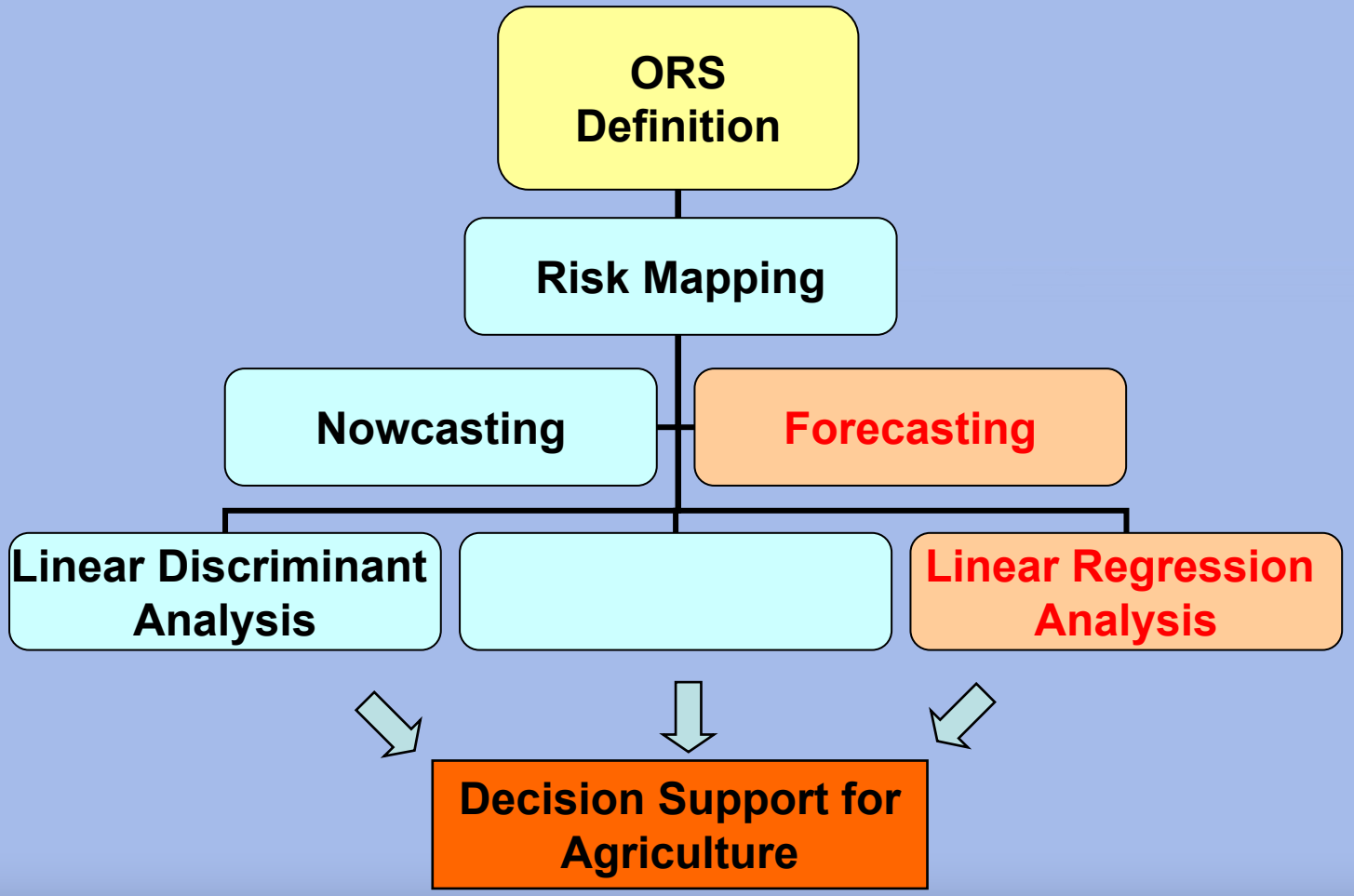
- Valuable tool to judge day by day whether the ORS has already begun
  - Current measured rainfall data
  - YES/NO-Decision about the ORS for each day
  - Alternatively usage of

    numerical 5-day weather forecast

    http://www.gap.fzk.de/de/wetter/index_wetter_africa.htm

- Performance is depending on the region
  - 60 – 80% correct classification of ORS

Prediction of the ORS (Ongoing Season)



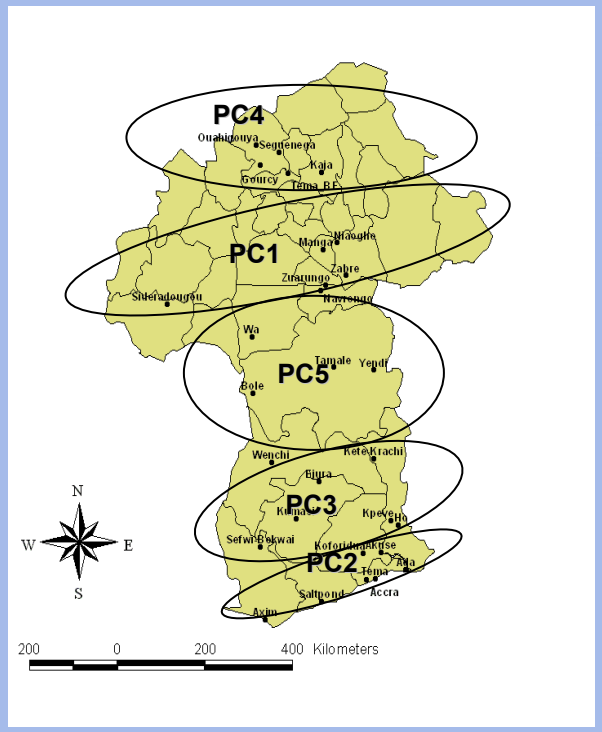
Prediction of the ORS (Ongoing Season) via LRA

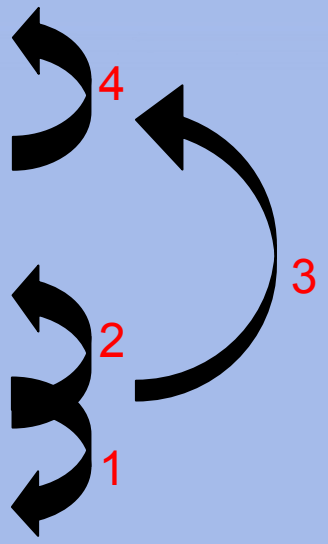
Linear Regression Analysis **(LRA)**

- Propagation time of monsoonal system from one region to another nearly constant over time
- Estimating **successively the regional ORS dates**:
  ORS dates (DOY) from regions with early ORS are predictors for regions with later ORS
- LRA is providing **lead-time**

Prediction of the ORS (Ongoing Season) via LRA

Direction of subsequent ORS prediction

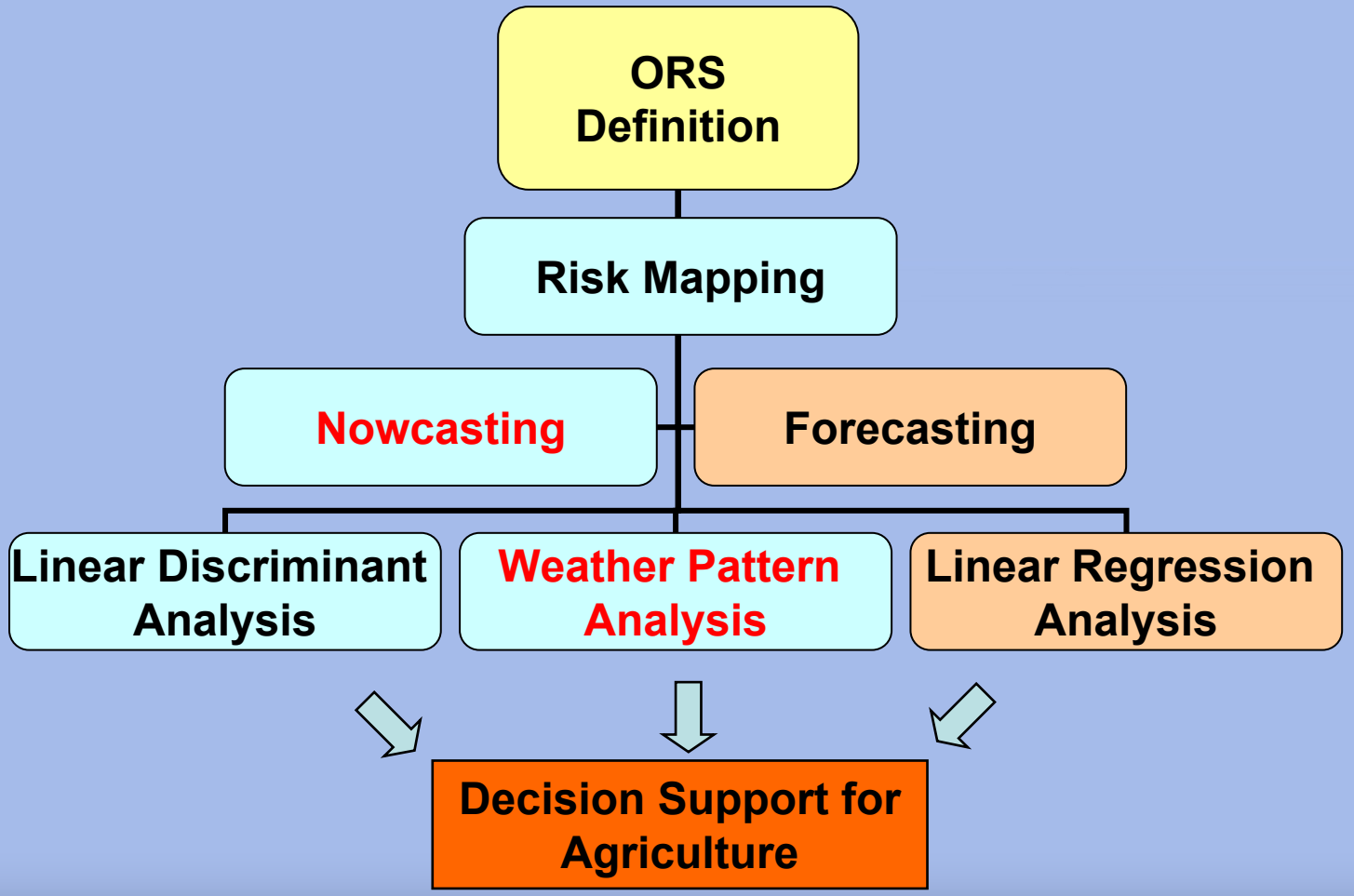




Prediction of the ORS (Ongoing Season) via LRA

Regression equations

Model Number	Target PC	Indep. PC	μ threshold target PC	μ threshold indep. PC	Regression equation	r
1	PC5	PC3	0.35	0.3	PC5 = 52.36 + 0.61 PC3	0.52
2	PC2	PC3	0.3	0.85	PC2 = 44.33 + 0.57 PC3	0.46
3	PC1	PC3	0.2	0.2	PC1 = 78.64 + 0.80 PC3	0.57
4	PC4	PC1	1	0.8	PC4 = 119.7 + 0.40 PC1	0.47


ORS Definition
Risk Mapping
Nowcasting
Forecasting
Linear Discriminant Analysis
Weather Pattern Analysis
Linear Regression Analysis
Decision Support for Agriculture

Prediction of the ORS (Ongoing Season) via WPA

- Is the regional ORS linked to specific weather patterns/circulation patterns?
- Assumption: Regional & local scale variable (e.g. ORS) are depending on large-scale meteorological information

Prediction of the ORS (Ongoing Season) via WPA

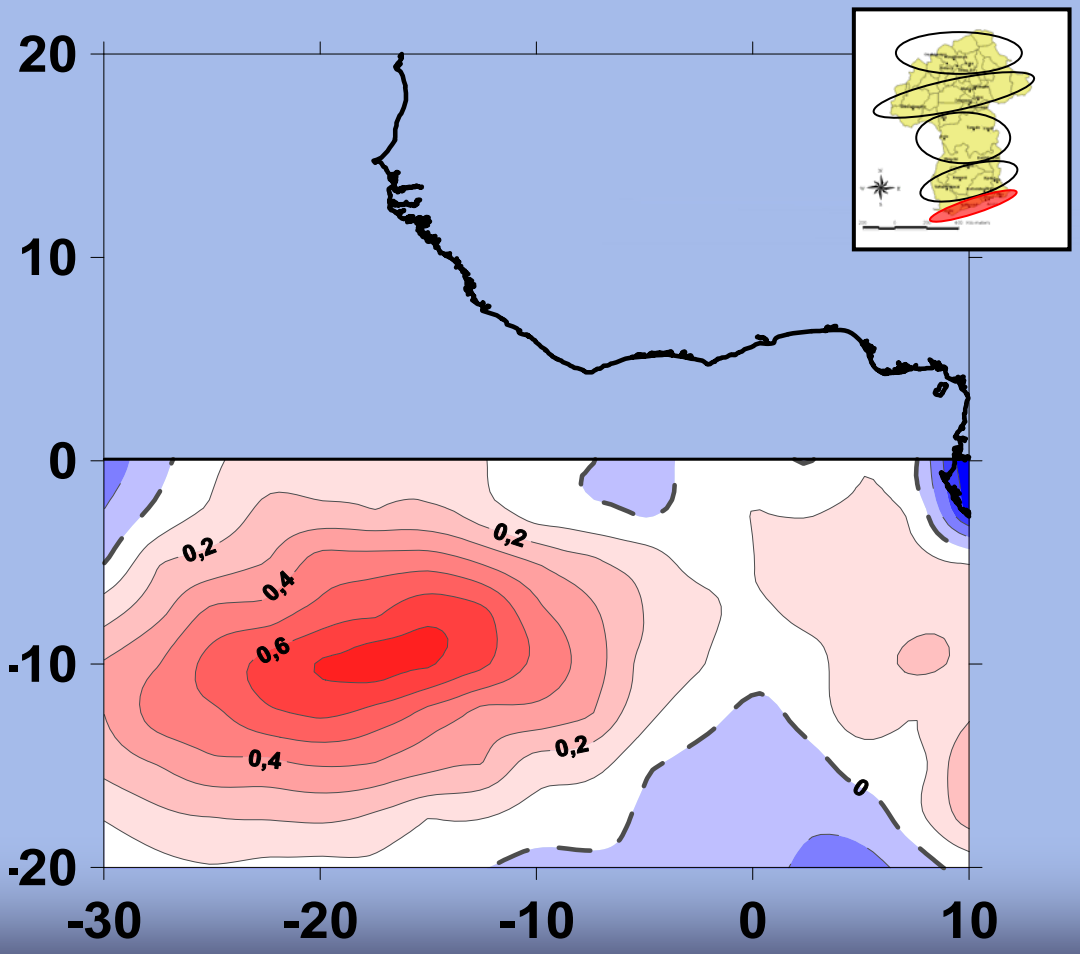
- Comprehensive screening with respect to
  - Predictor variable
  - Domain size and location of predictors
  - 5 different regions within the Volta Basin
  - Number of used weather patterns
- > 200 calculations of ~ 1 week duration each (Linux Cluster with ~200 CPUs)

SST, pc2	WP cond. Frequ. [%]	WP and Onset cond. Frequ. [%]	O_p
WP1	8.21	10.53	1.28
WP2	4.57	2.63	0.58
WP3	6.92	10.00	1.45
WP4	20.30	15.26	0.75
WP5	13.20	17.37	1.32
WP6	9.02	5.26	0.58
WP7	10.68	3.68	0.35
WP8	**9.50**	**17.89**	**1.88**
WP9	7.02	5.26	0.75
WP10	10.58	12.11	1.14

$$O_p = \frac{Frequency(WP|_{ONSET \wedge WP})}{Frequency(WP|_{WP})}$$

WP8

Composite of the **Skin Temperature (1961-2000)**

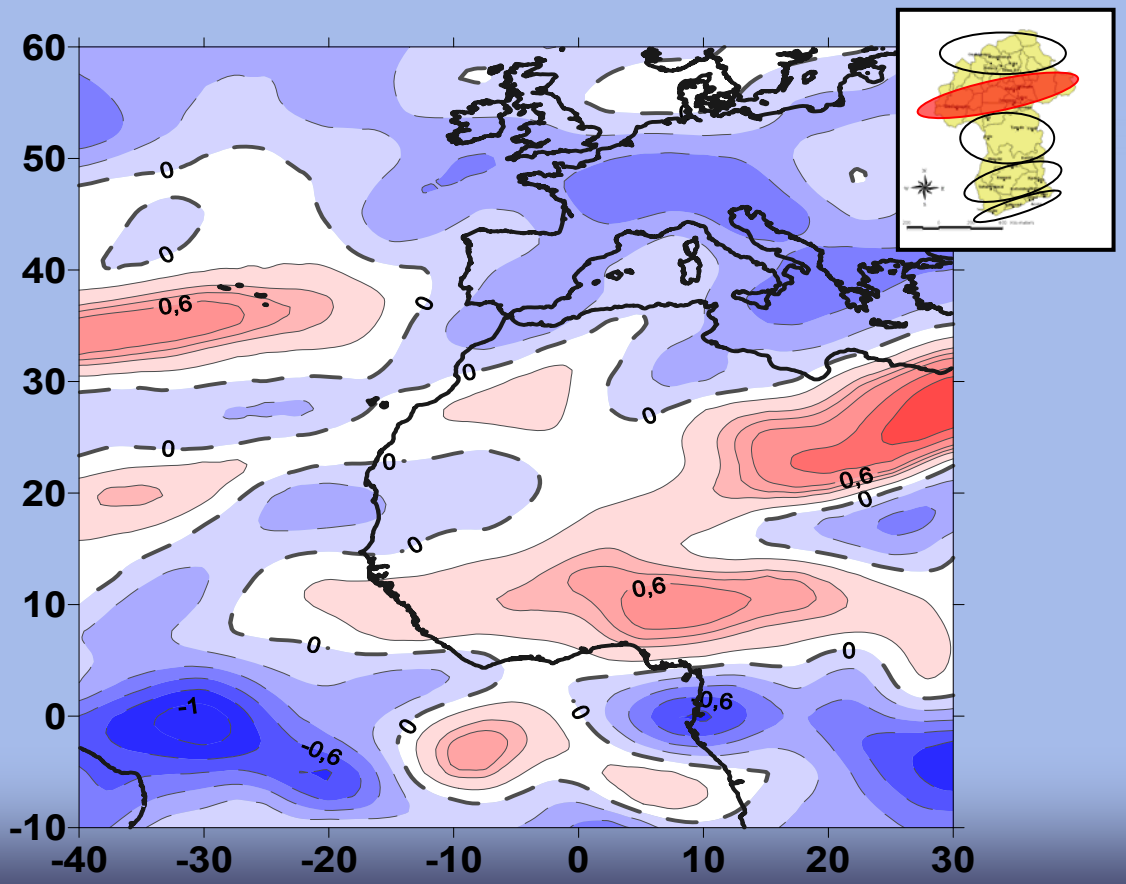


MF_U(500hPa) PC1	WP cond. Frequ. [%]	WP and Onset cond. Frequ. [%]	O_p
WP1	16.77	15.38	0.92
WP2	0.63	0.00	0
WP3	3.16	4.62	1.46
WP4	31.34	25.64	0.82
WP5	**4.55**	**11.28**	**2.48**
WP6	12.57	18.46	1.47
WP7	15.63	20.00	1.28
WP8	0.60	0.00	0
WP9	2.49	0.00	0
WP10	12.27	4.62	0.38

$$O_p = \frac{Frequency(WP|_{ONSET \wedge WP})}{Frequency(WP|_{WP})}$$

WP5

Composite of the **eastward component of Moisture Flux in 500hPa (1961-2000)**



Summary WPA

- Synoptic situation can be statistically related to the regional ORS
- Bootstrapping tests proofed significance of the identified weather patterns
- **Moisture Flux** in 500hPa, **SST** & **Skin Temperature** best predictor variables for the ORS

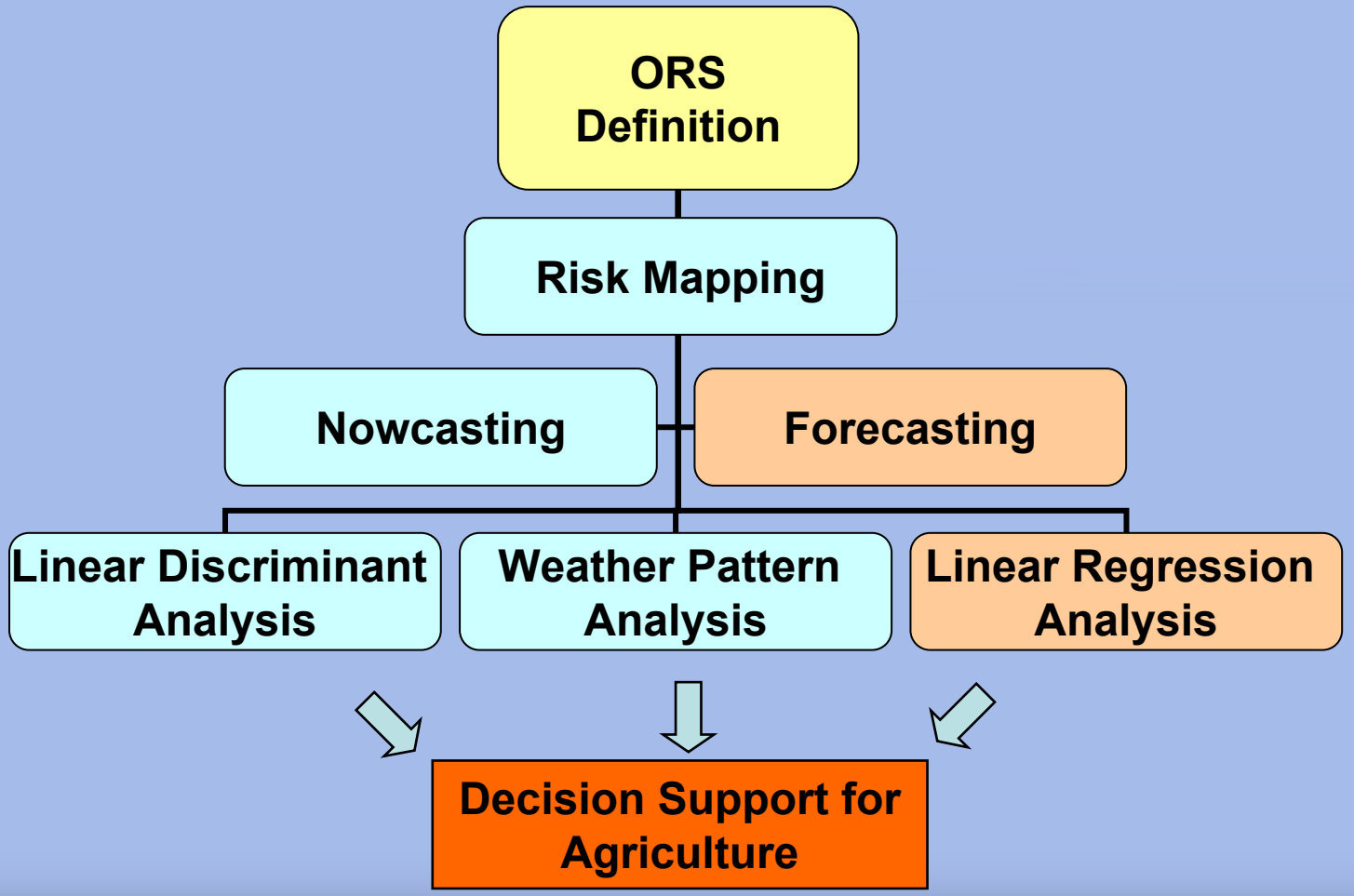
Overall Summary

- Development of a fuzzy logic-based ORS definition in order to estimate the **„optimal“ planting date**
  - Easily adoptable to different agricultural needs

- Development of **“risk maps”**

- Development of 3 suitable **tools for predicting the ORS**
  - ~80% hit ratio for the ORS
  - Identification of weather patterns significantly linked with the ORS

Overview of Methods



Transfer of Knowledge

14.01. - 18.01.08: Accra (Ghana)
22.01. - 25.01.08: Ouagadougou (Burkina Faso)

Some critical words …

- Recommendation to **use many methods** (and risk maps) for decision about planting
  - Including also traditional methods (migration of insects, birds, etc) ⇒ **"multi-cognitive framework"**

- Statistical inferences derived from 1961-2000 climate
  - But: Climate is "changing"

    ⇒ *Updating* of statistical relationships required every year

- **Risk management strategies** for coping with imperfect predictions still must be elaborated


Thank you for
your attention!