Potential Impact of Regional Drought on Vulnerable Agriculture in Greece

Nicolas R. Dalezios, N. V. Spyropoulos, A. Blanta and E. Kanellou

Laboratory of Agrometeorology
Faculty of Agricultural Sciences
University of Thessaly

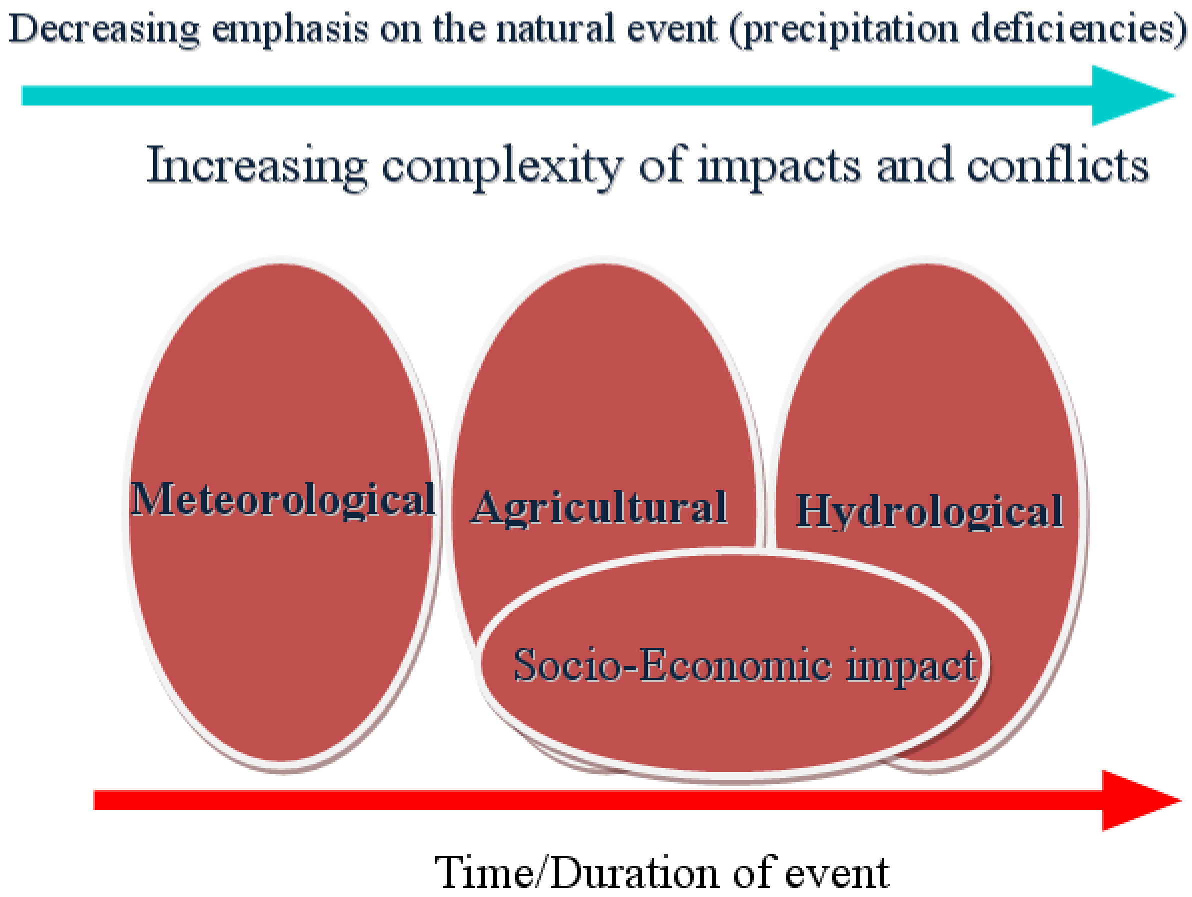
Cambridge 2010

Types of Drought

(by American Meteorological Society)

- Meteorological or climatological drought is generally regarded as precipitation being lower than average for some time period; in some cases air temperature and precipitation anomalies may be combined.
- Agricultural drought, occurs when plant available water, from precipitation and water stored in the soil, falls below that required by a plant community during a critical growth stage. This leads to below average yields in both pastoral and grain-producing regions.
- Hydrologic drought is generally defined by one or a combination of factors such as stream flow, reservoir storage and groundwater.
- Socioeconomic impacts of drought is defined in terms of loss from an average or expected return. It can be measured by both social and economic indicators, of which profit is only one.

Natural and Social Dimensions of Drought



(From Wilwhite, 2005)

Drought indicators and indices

- Based on meteorological and hydrological variables (precipitation, streamflows, soil moisture, reservoir storage, and groundwater levels).
- Describe the magnitude, duration, severity, and spatial extent of drought.
- Estimate, monitor and assess of drought using one single number.
- Several indicators can be also synthesized into a single indicator on a quantitative scale.

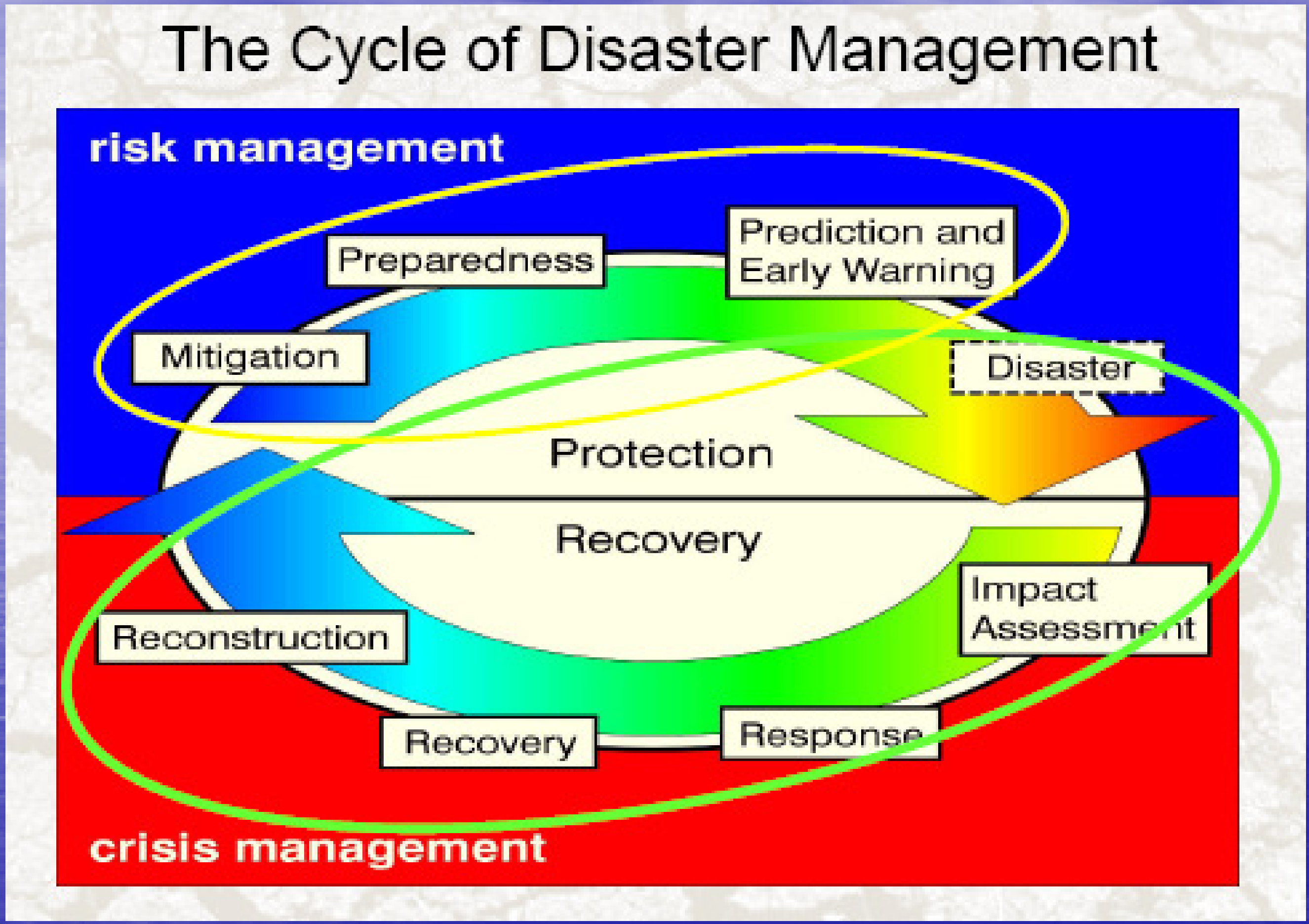
Commonly used drought indices based on conventional data

1. Percent of normal.
2. Discrete and cumulative precipitation anomalies.
3. Rainfall deciles.
4. Drought Area Index.
5. Rainfall Anomaly Index.
6. Standardized Precipitation Index.
7. Effective Drought Index.
8. Palmer Drought Severity Index.
9. Crop Moisture Index.
10. Bhalme- Mooley Drought Index.
11. Surface Water Supply Index
12. Reclamation Drought Index.
13. Total water deficit.
14. Cumulative streamflow anomaly.
15. Computed soil moisture.
16. Soil Moisture Anomaly Index.
17. Drought Indices derived from flow data
18. Agro-Hydro Potential.
19. Standardised Water-Level Index
20. Reconnaissance Drought Index
21. Streamflow Drought Index

Commonly used drought indices based on satellite data

1. Normalized Difference Vegetation Index.
2. Deviation NDVI index.
3. Enhanced Vegetation Index.
4. Vegetation Condition Index.
5. Monthly Vegetation Condition Index.
6. Temperature Condition Index.
7. Vegetation Health Index.
8. Normalised Difference Temperature Index.
9. Crop Water Stress Index.
10. Drought Severity Index.
11. Temperature- Vegetation Dryness Index.
12. Normalized Difference Water Index.

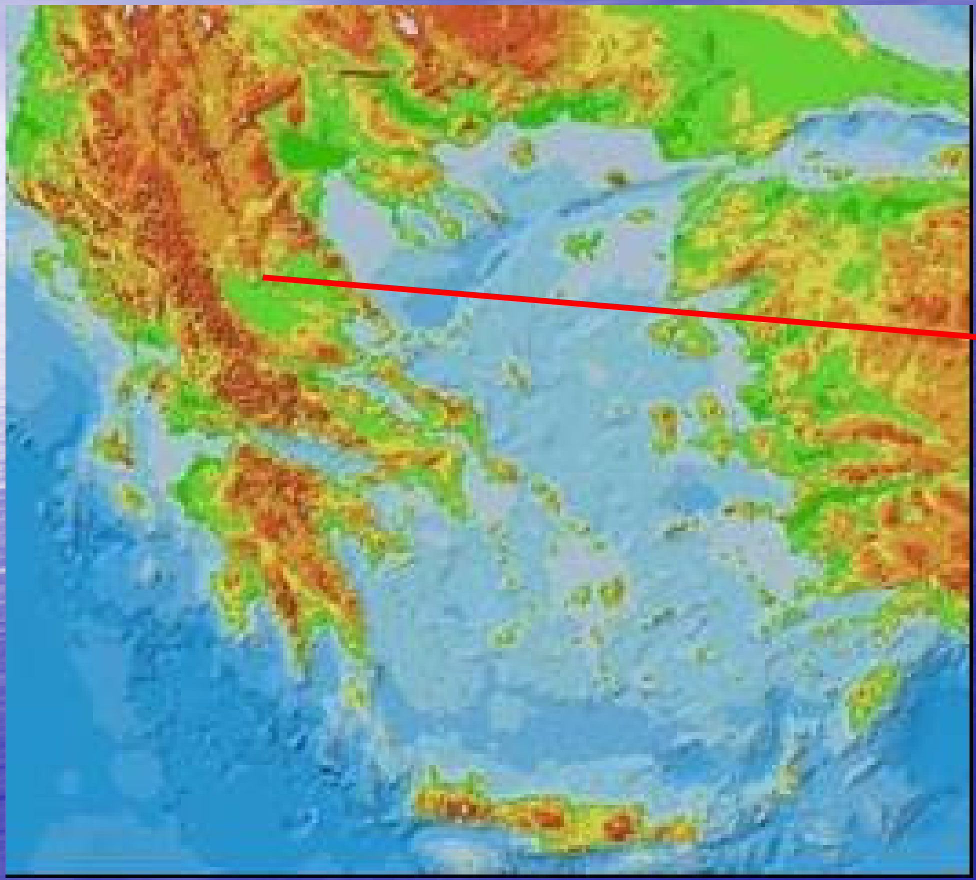
- They are calculated from the reflectance in different bands and may be obtained for each pixel, derived from AVHRR, MODIS and other satellite data.


The Cycle of Disaster Management
risk management
Prediction and Early Warning
Preparedness
Mitigation
Disaster
Protection
Recovery
Impact Assessment
Reconstruction
Recovery
Response
crisis management

Objectives

- Spatially distributed drought estimation
- Use of Remote Sensing and GIS
- Extent of a conventional drought index by the use of remotely sensed data
- Estimation and comparison of two types of drought indices
- Assessment of cotton production during drought years

Study Area



The study is the Thessaly water district, central Greece.

Data Set

Satellite Data

- Monthly Brightness Temperature (BT) from channels 4 and 5 of NOAA/ AVHRR satellite of 21years (1981-2001), 8x8 km spatial resolution.
- Monthly NDVI images for the same time period and pixel size.
- Monthly air temperature extracted by LST images

Ground measurements

- Daily precipitation of Thessaly water district in 50 x 50 km grid size.

Drought Indices

- *Reconnaissance Drought Index (RDI)*

  Estimate Meteorological Drought conditions based on hydro-meteorological parameters.

- *Vegetation Health Index (VHI)*

  Agricultural Drought asses using vegetation conditions satellite images.

Reconnaissance Drought Index

The RDI_{st} is calculated by the equation:

$$RDI_{st}(k) = \frac{y_k - \bar{y}_k}{\hat{\sigma}_k}$$

y_k is the $\ln a_k$, y_k (upper line) is its arithmetic mean and σ_k is its standard deviation

a_k = the initial value for the index (For October $a_k = 1$) and is calculated by:

$$a_k = \frac{\sum_{j=1}^{j=k} p_j}{\sum_{j=1}^{j=k} PET_J}$$

P_j and PET_j are the precipitation and potential evapotranspiration respectively of the j-th month of the hydrological year.

RDI Drought classes

Drought Categories	RDI Values
Extremely Wet	>2.00
Very Wet	1.50 to 1.99
Moderately Wet	1.00 to 1.49
Near Normal	-0.99 to 0.99
Moderately Dry	-1.00 to -1.49
Severely Dry	-1.50 to -1.99
Extremely Dry	<-2.00

RDI methodology

- Land Surface Temperature (LST) calculation from channels 4 and 5 of satellite.
- Air temperature extraction from LST images using air temperature data from meteorological stations.
- Estimation of potential evapotraspiration (ET_p) with Blaney-Criddle method.
- Combination of precipitation maps derived from ground measurements with ET_p maps for RDI extraction.

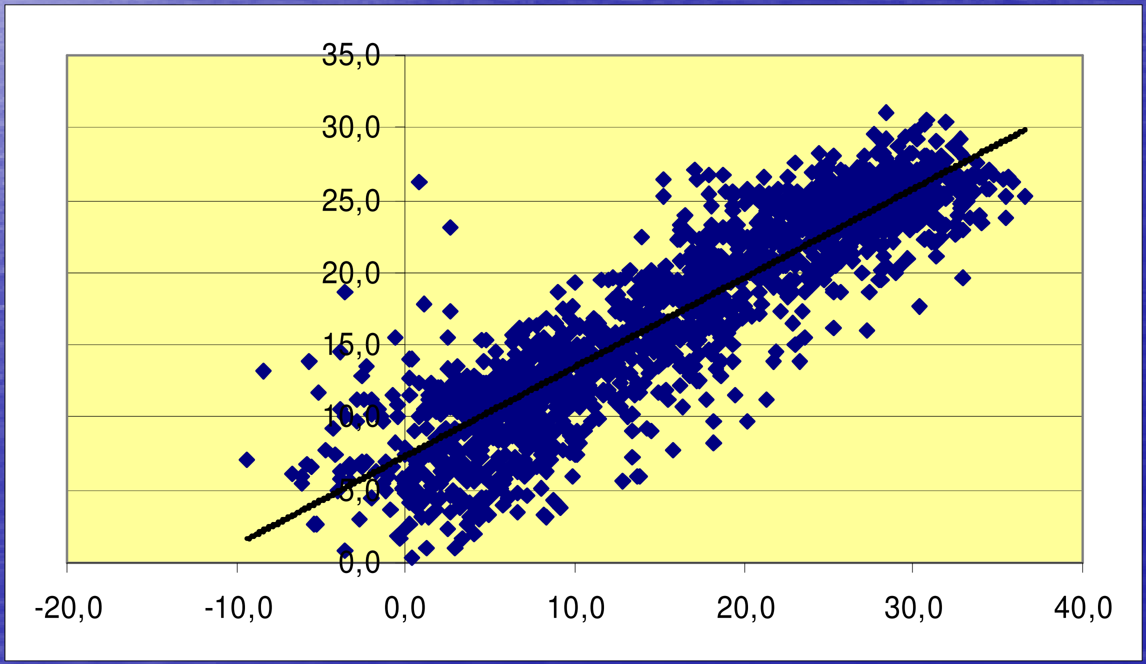
LST

LST extraction for the whole timeseries (1981-2001) in 8 x 8 km pixel size

Air Temperature estimation

- Empirical relationship between LST and air temperature (T_{air}) ($R^2 \approx 0.82$):

$$T_{air} = 0,6143 * LST + 7,3674$$



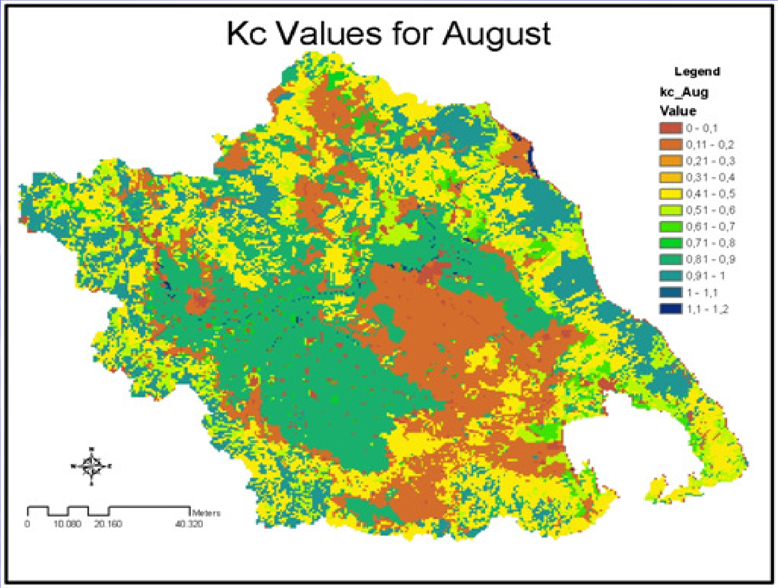
ET_p Blaney- Criddle

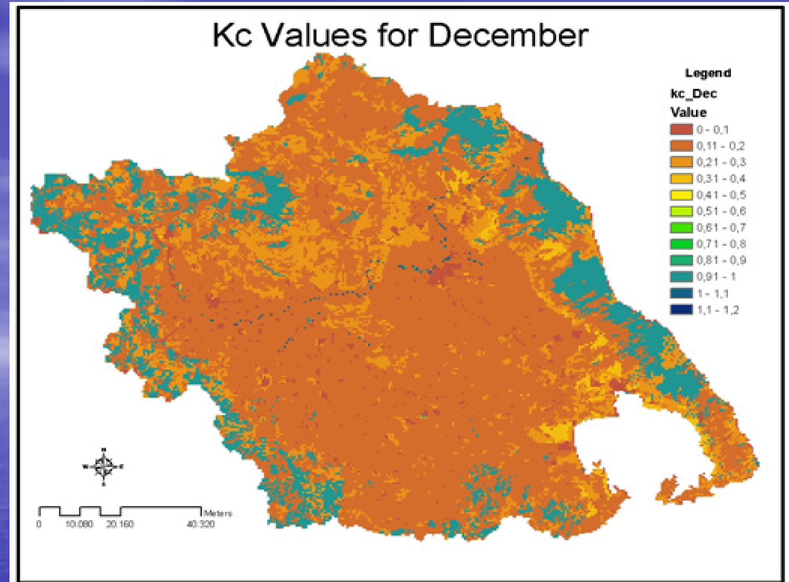
Estimation of ET_p by the Blaney-Criddle method:

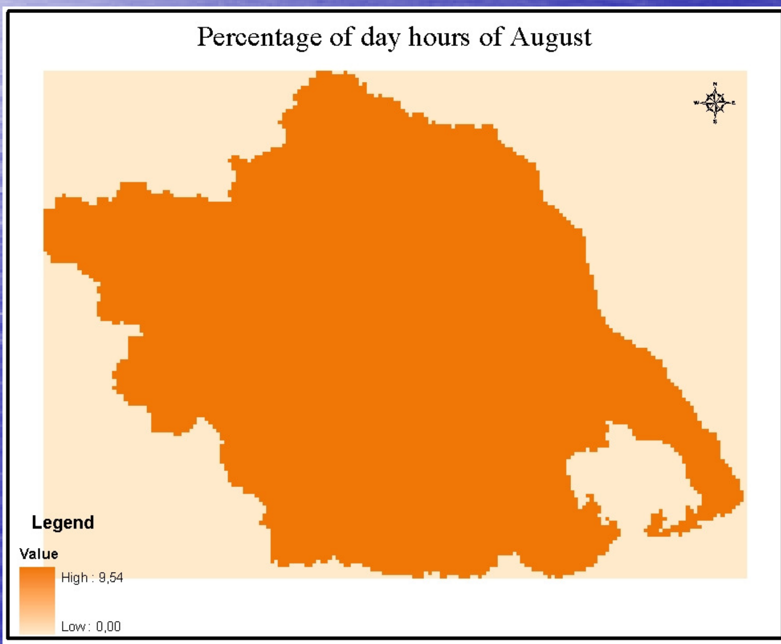
$ET_p = k * [0.46T+8.16]*p$

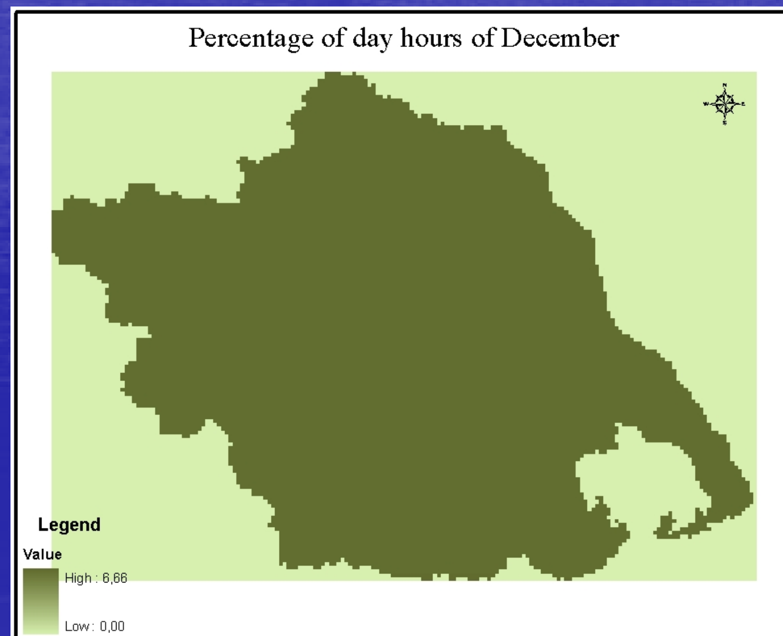
ET_p is the monthly potential evapotranspiration in mm, k is the monthly crop coefficient, T is the mean monthly air temperature (^{o} C) and p is the percentage of day hours

- The Crop coefficients k are calculated for each different vegetation type of the study area based on Corine Hellas 2000 and for each month of the year.
- Extract day hours percentages (p) maps for every month for the region middle Latitude (39^o).
- Both k and p maps are extracted in GIS environment (ArcMap 9.1).

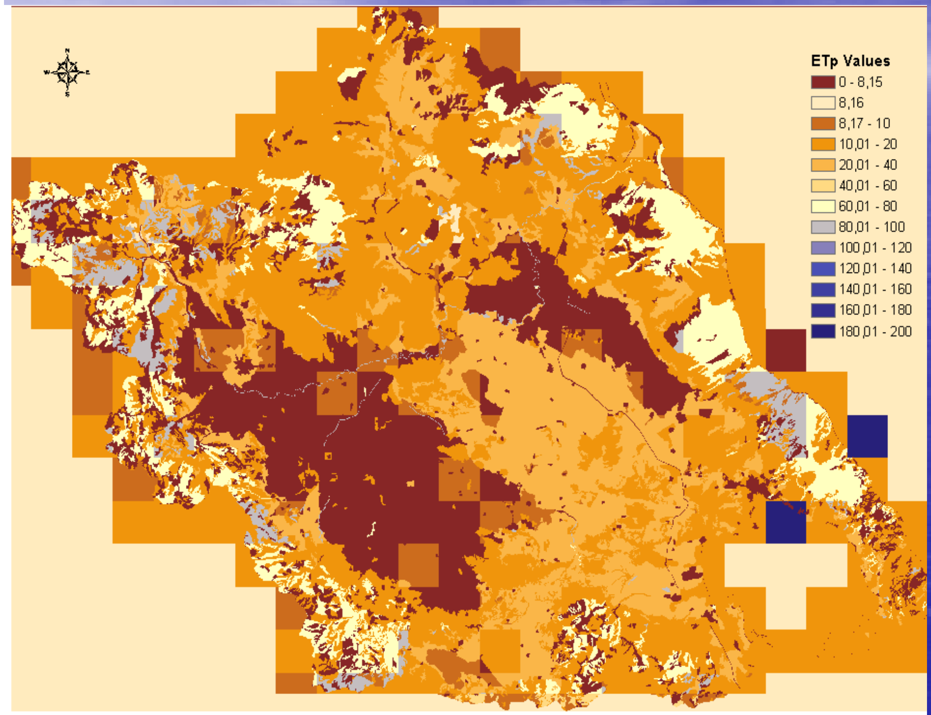

Kc Values for August
Legend
kc_Aug
Value
0 - 0,1
0,11 - 0,2
0,21 - 0,3
0,31 - 0,4
0,41 - 0,5
0,51 - 0,6
0,61 - 0,7
0,71 - 0,8
0,81 - 0,9
0,91 - 1
1 - 1,1
1,1 - 1,2
0 10.080 20.160 40.320 Meters


Kc Values for December
Legend
kc_Dec
Value
0 - 0,1
0,11 - 0,2
0,21 - 0,3
0,31 - 0,4
0,41 - 0,5
0,51 - 0,6
0,61 - 0,7
0,71 - 0,8
0,81 - 0,9
0,91 - 1
1 - 1,1
1,1 - 1,2
0 10.080 20.160 40.320 Meters

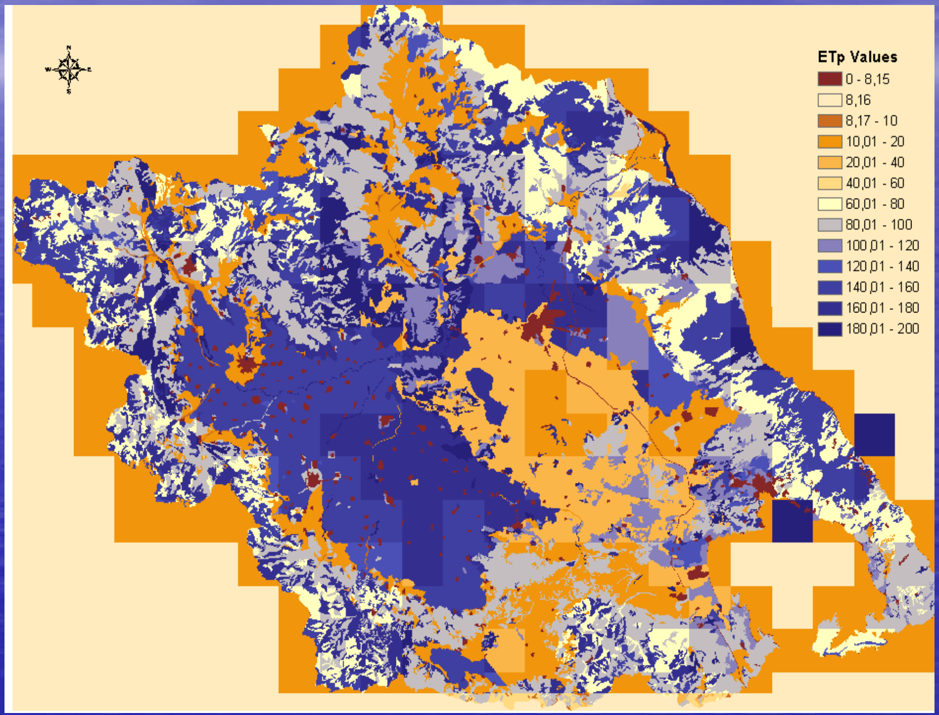

Percentage of day hours of August
Legend
Value
High : 9,54
Low : 0,00


Percentage of day hours of December
Legend
Value
High : 6,66
Low : 0,00

Remotelly sensed ETp Blaney-Criddle



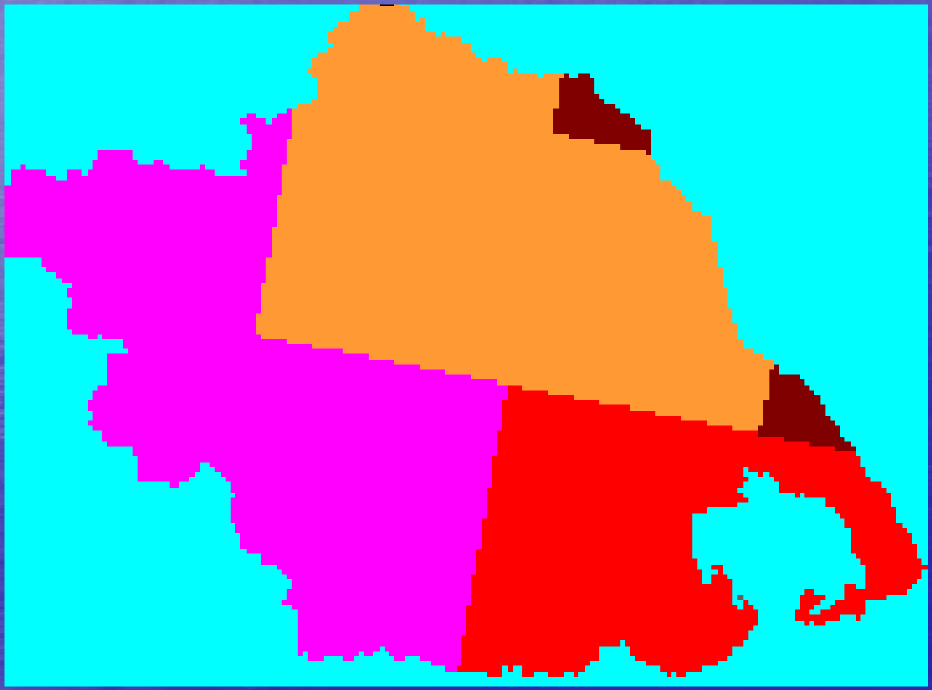
ET_p map of January 1982



ET_p map of July 1982

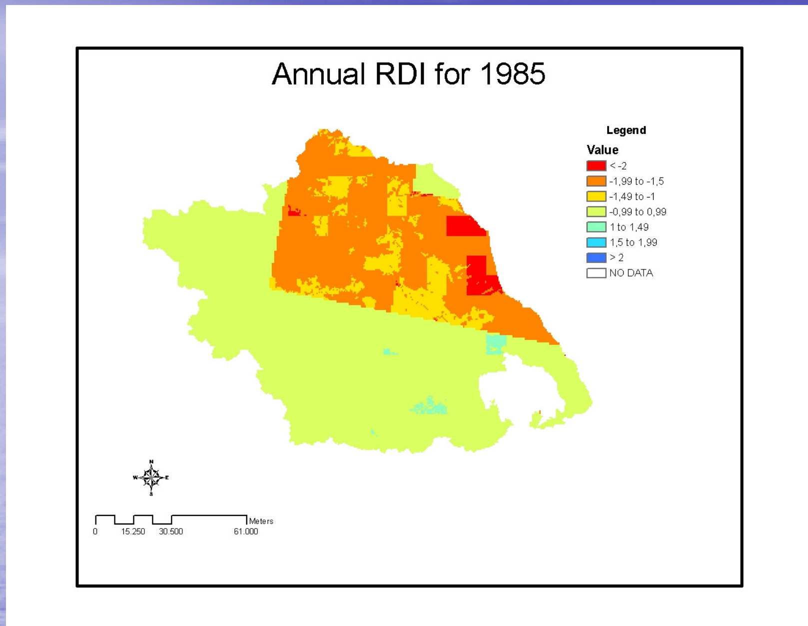
Precipitation maps

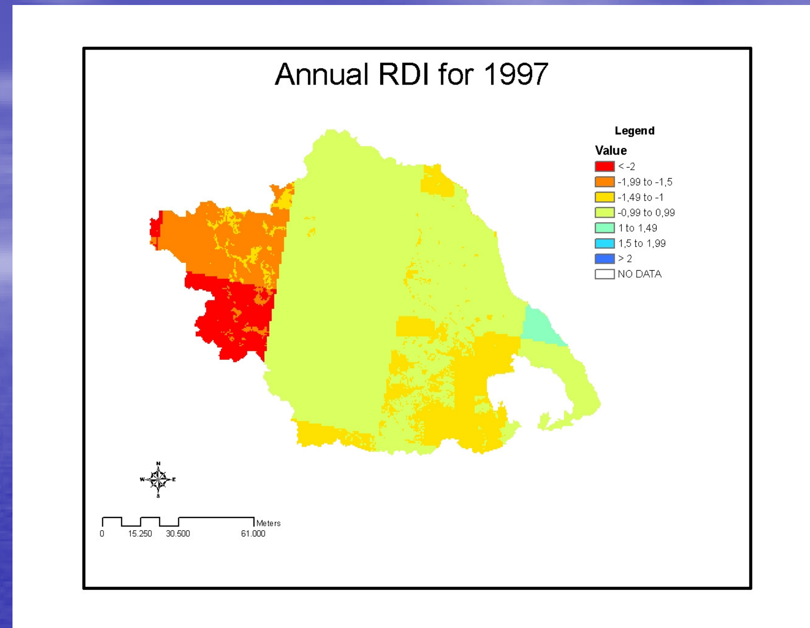
Extraction of monthly rainfall maps based on conventional daily data in 50 x 50 km grid size from 1981 to 2001.

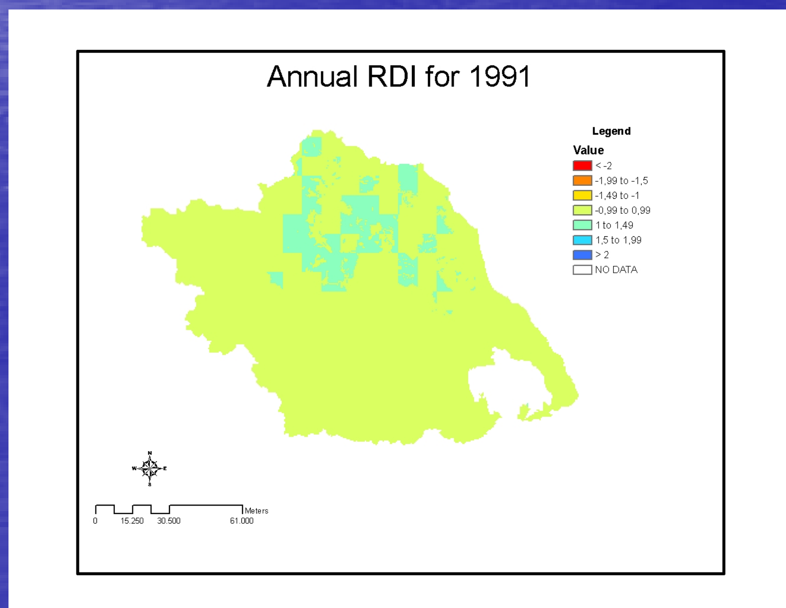


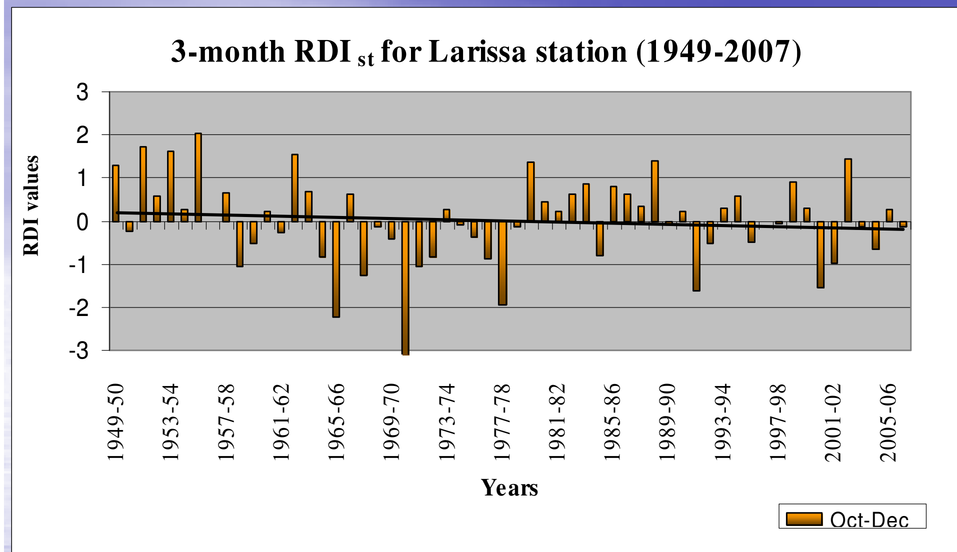
Precipitation map for January 1984

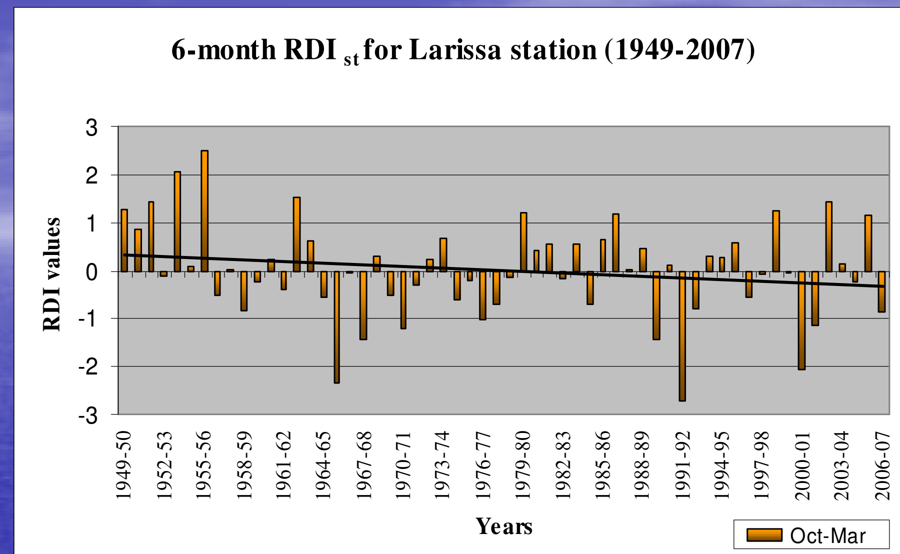
RDI maps

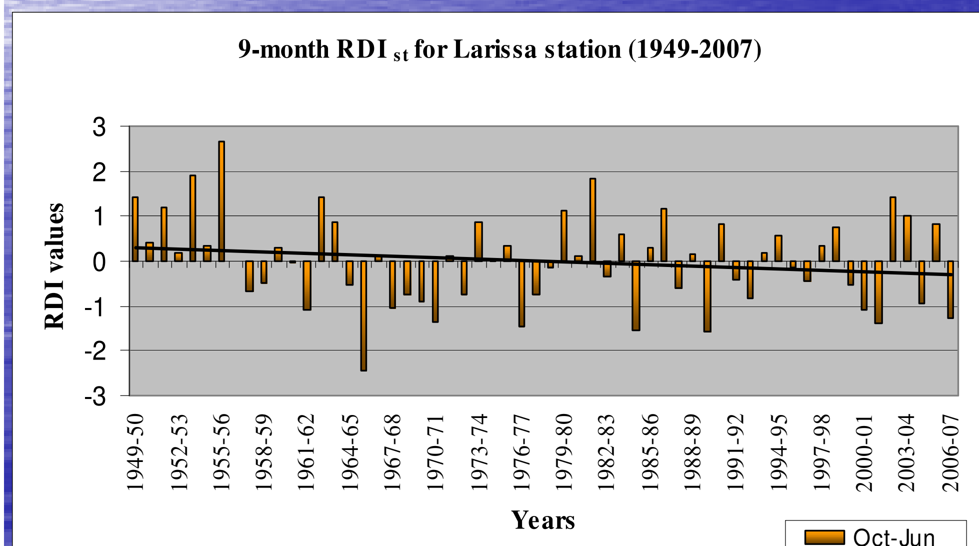

Annual RDI for 1985
Legend
Value
< -2
-1,99 to -1,5
-1,49 to -1
-0,99 to 0,99
1 to 1,49
1,5 to 1,99
> 2
NO DATA
Meters
0 15.250 30.500 61.000

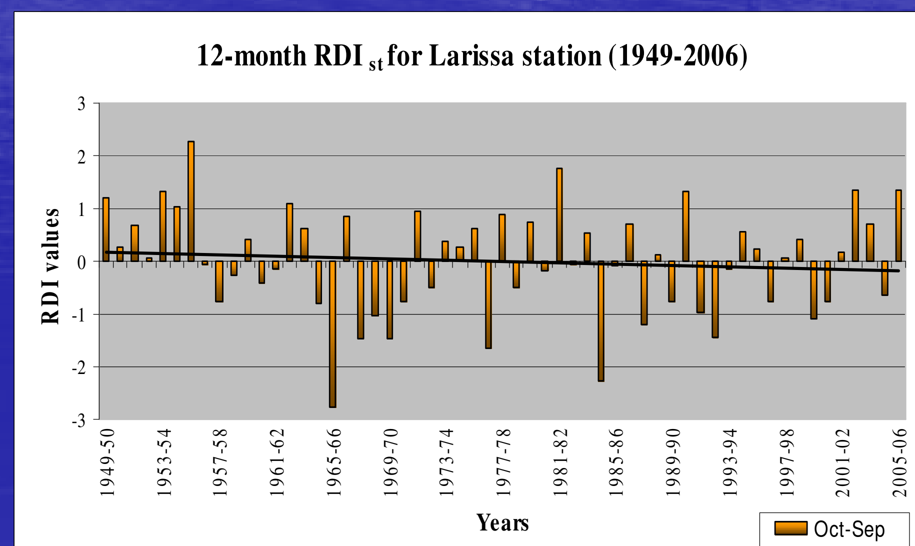

Annual RDI for 1997
Legend
Value
< -2
-1,99 to -1,5
-1,49 to -1
-0,99 to 0,99
1 to 1,49
1,5 to 1,99
> 2
NO DATA
Meters
0 15.250 30.500 61.000


Annual RDI for 1991
Legend
Value
< -2
-1,99 to -1,5
-1,49 to -1
-0,99 to 0,99
1 to 1,49
1,5 to 1,99
> 2
NO DATA
Meters
0 15.250 30.500 61.000



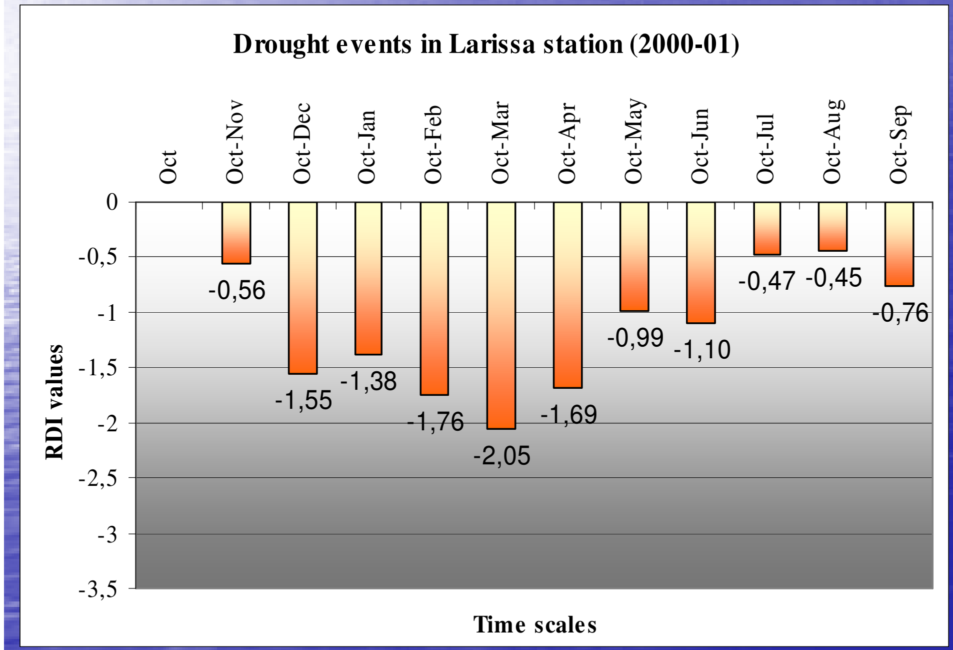


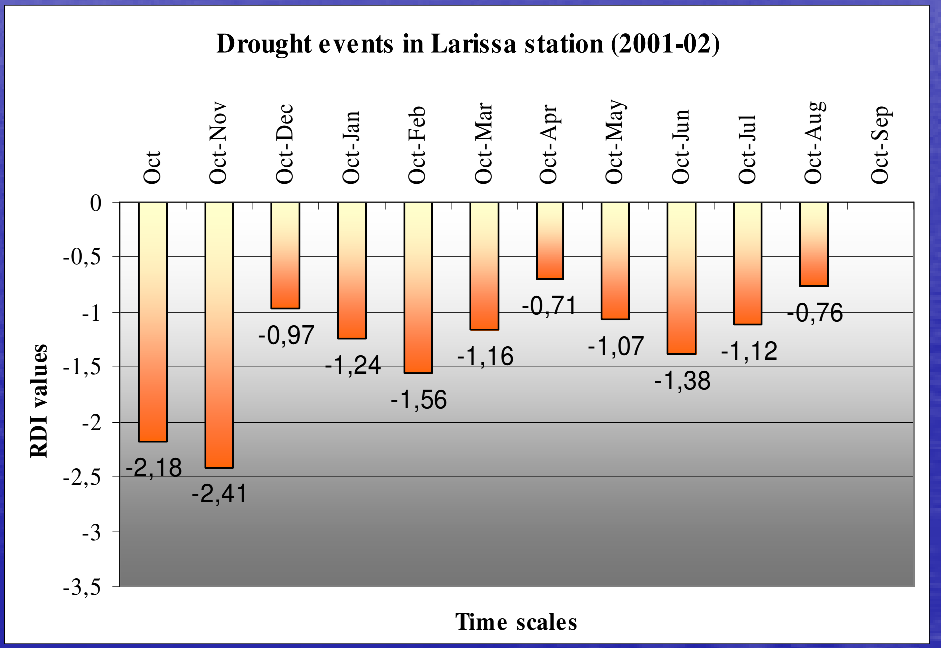


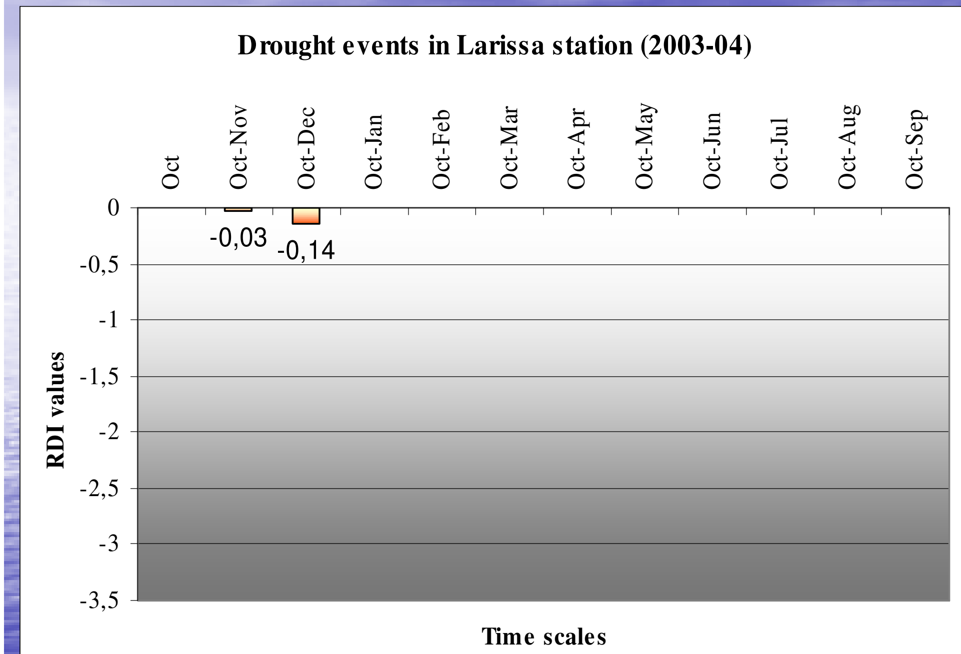


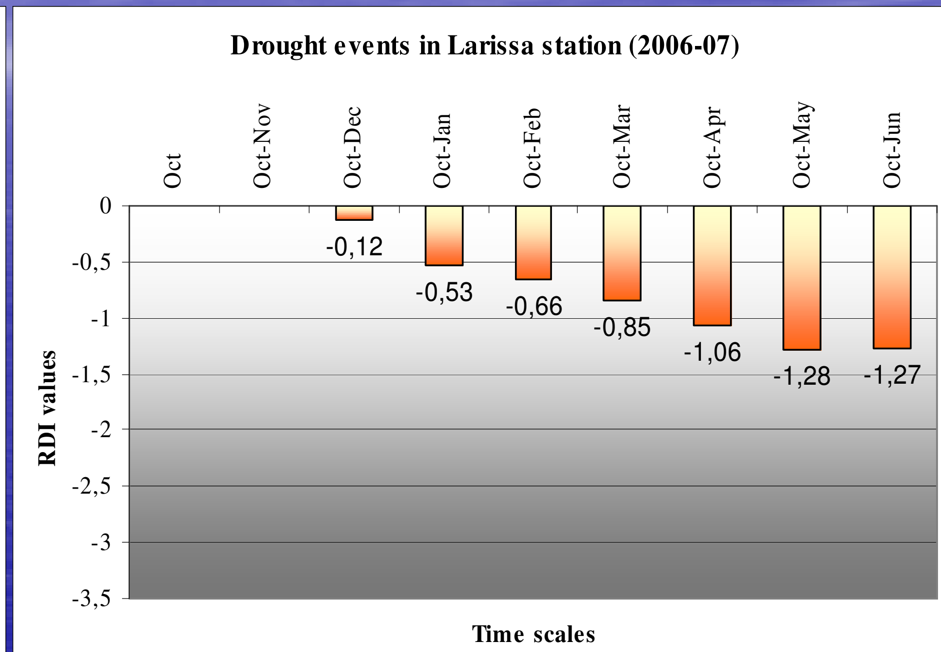
University of Thessaly *Laboratory of Agrometeorology*

Drought Events in Larissa Station






Drought events in Larissa station (2003-04)
Oct
Oct-Nov
Oct-Dec
Oct-Jan
Oct-Feb
Oct-Mar
Oct-Apr
Oct-May
Oct-Jun
Oct-Jul
Oct-Aug
Oct-Sep
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
-0,03
-0,14
RDI values
Time scales


Drought events in Larissa station (2006-07)
Oct
Oct-Nov
Oct-Dec
Oct-Jan
Oct-Feb
Oct-Mar
Oct-Apr
Oct-May
Oct-Jun
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
-0,12
-0,53
-0,66
-0,85
-1,06
-1,28
-1,27
RDI values
Time scales

Vegetation Health Index (VHI)

- Kogan (2001) proposed the VHI which and used it for agricultural drought mapping.
- VHI is expressed by the following equation:

$$VHI = 0.5 * (VCI) + 0.5 * (TCI)$$

- VHI represents overall vegetation health.

VHI drought classification schemes (Kogan, 2001)

VHI VALUES	VEGETATIVE DROUGHT CLASSES
<10	Extreme drought
<20	Severe drought
<30	Moderate drought
<40	Mild drought
>40	No drought

Vegetation Condition Index (VCI)

$$VCI = 100 \cdot \left(\frac{NDVI\text{-}NDVI_{min}}{NDVI_{max}\text{-}NDVI_{min}} \right)$$

VCI:

- is an extension of the NDVI
- provides a quantitative estimation of weather impact on vegetation
- is based on the concept of ecological potential of an area given by geographical resources such as climate, soil variation, vegetation type and quantity, and topography of the area
- characterises the moisture conditions of vegetation.

Advanced Very High Resolution Radiometer

The Advanced Very High Resolution Radiometer (AVHRR) is a broad-band, four or five channel (depending on the model) scanner.

Channels	Wavelength (μm)	Band	IFOV (km)
1	0.55 – 0.9	Visible (VIS)	1.1
2	0.725 – 1.0	Near Infrared (NIR)	1.1
3	3.55 – 3.93	Middle Infrared (MIR)	1.1
4	10.3 – 11.3	Thermal Infrared (TIR)	1.1
5	11.5 – 12.5	Thermal Infrared (TIR)	1.1

Normalized Difference Vegetation Index

From NOAA/AVHRR data NDVI is given by the following equation:

$$NDVI = \frac{CH_2 - CH_1}{CH_2 + CH_1}$$

LAND COVER	NDVI	PIXEL VALUE (0-255 gray scale)
Dense Vegetation	0.500	210
Intermediate Green Vegetation	0.140	118
Sparse Vegetation	0.090	105
Bare Soil	0.025	88
Clouds	0.002	83
Snow and Ice	-0.046	70
Water Surface	-0.257	16

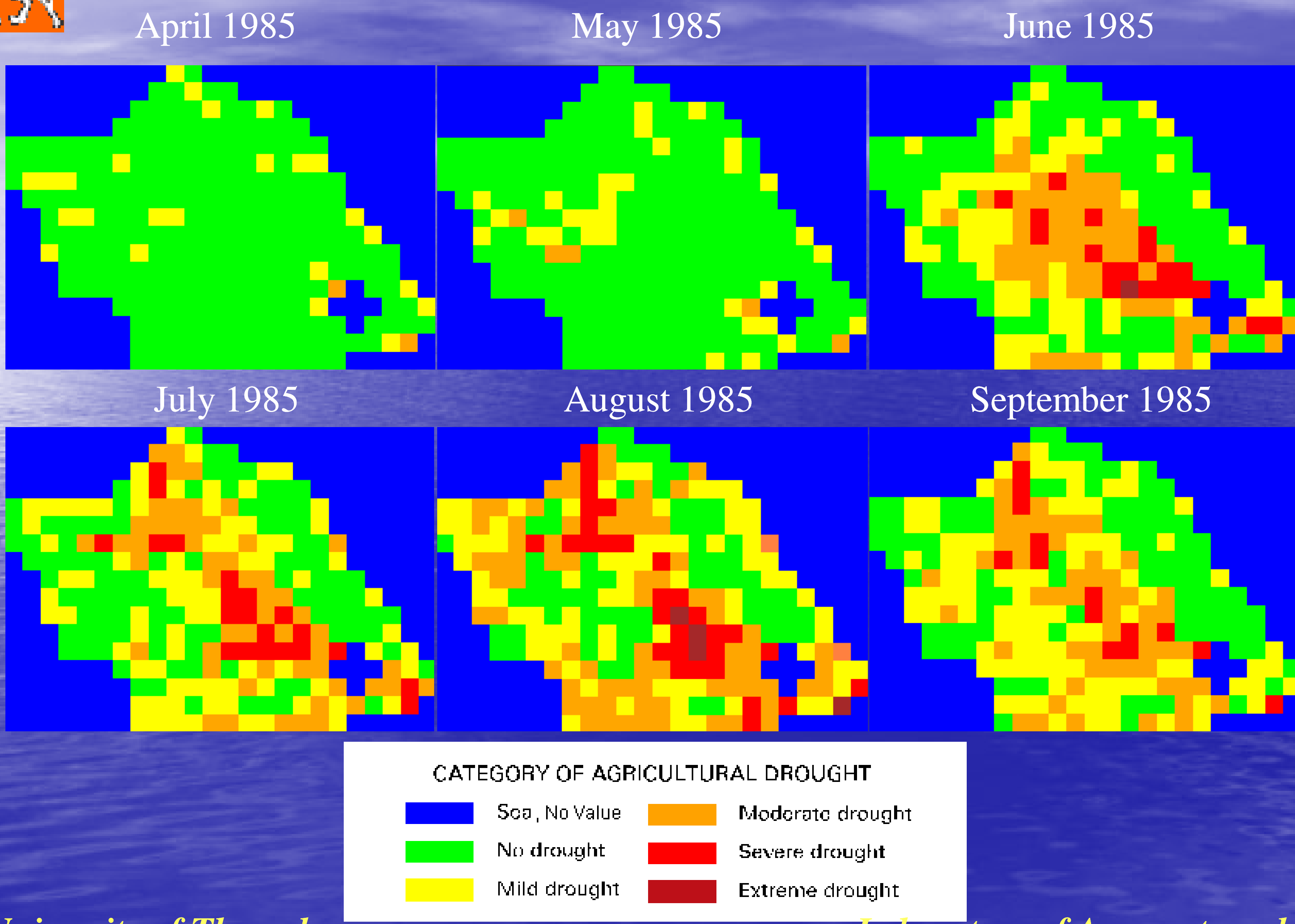
Temperature Condition Index (TCI)

$$TCI = 100 \cdot \left(\frac{BT_{max} - BT}{BT_{max} - BT_{min}} \right)$$

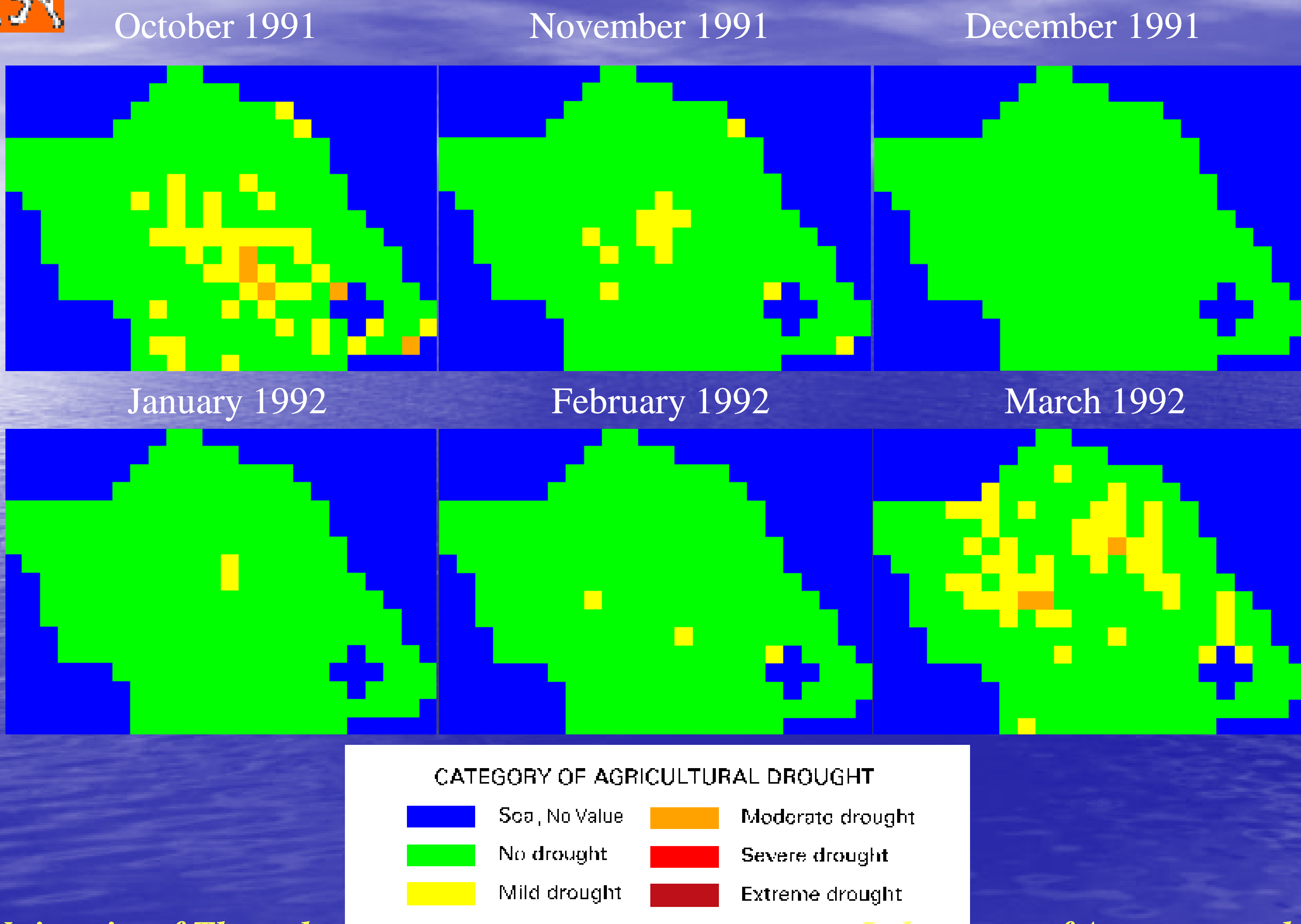
- TCI is an index, which shows the impact of temperature of the ground.
- TCI characterises the thermal conditions of vegetation.

- VCI and the TCI varies from zero, for extremely unfavorable conditions, to 100, for optimal conditions.

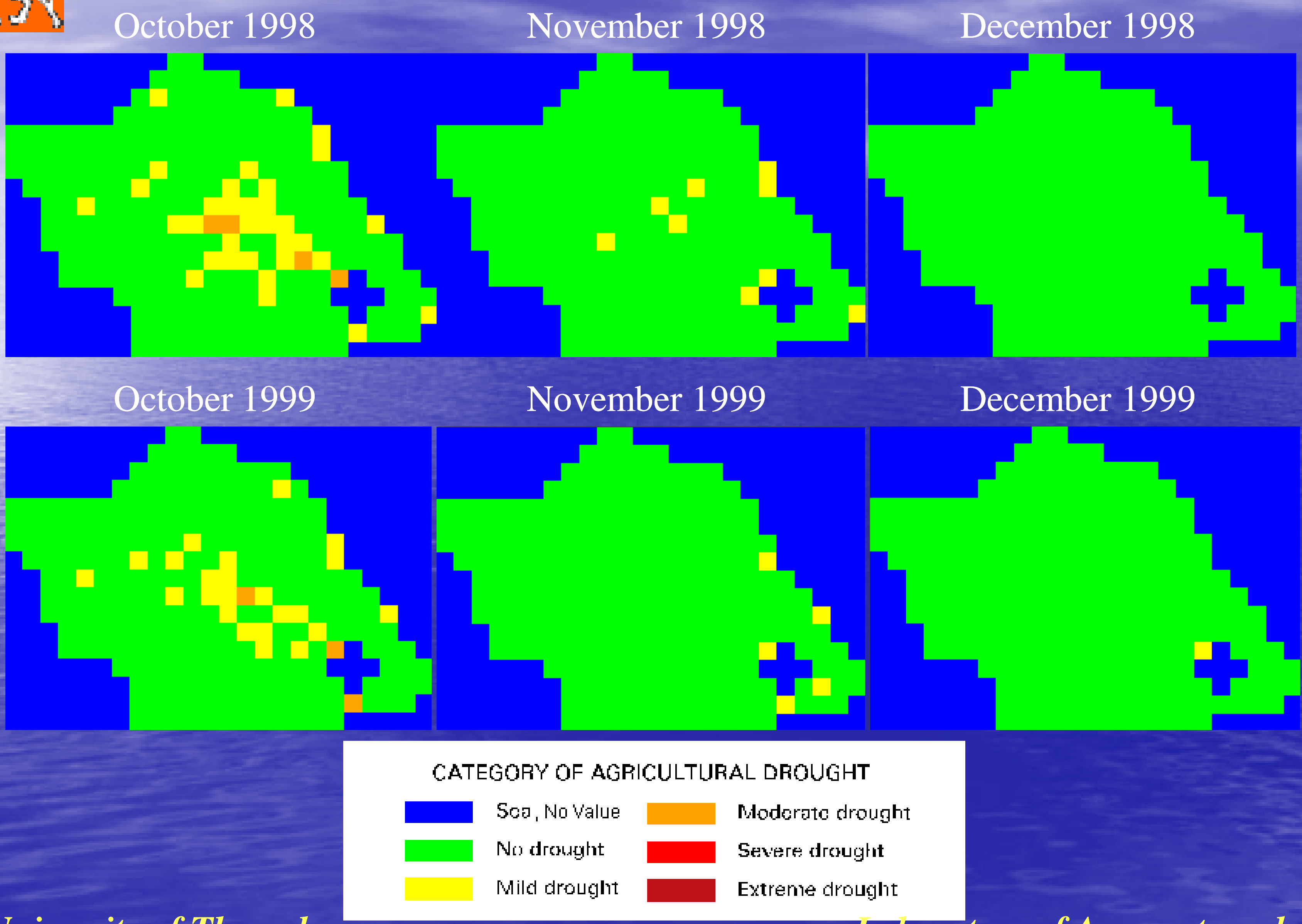
Vegetation Health Index (VHI)



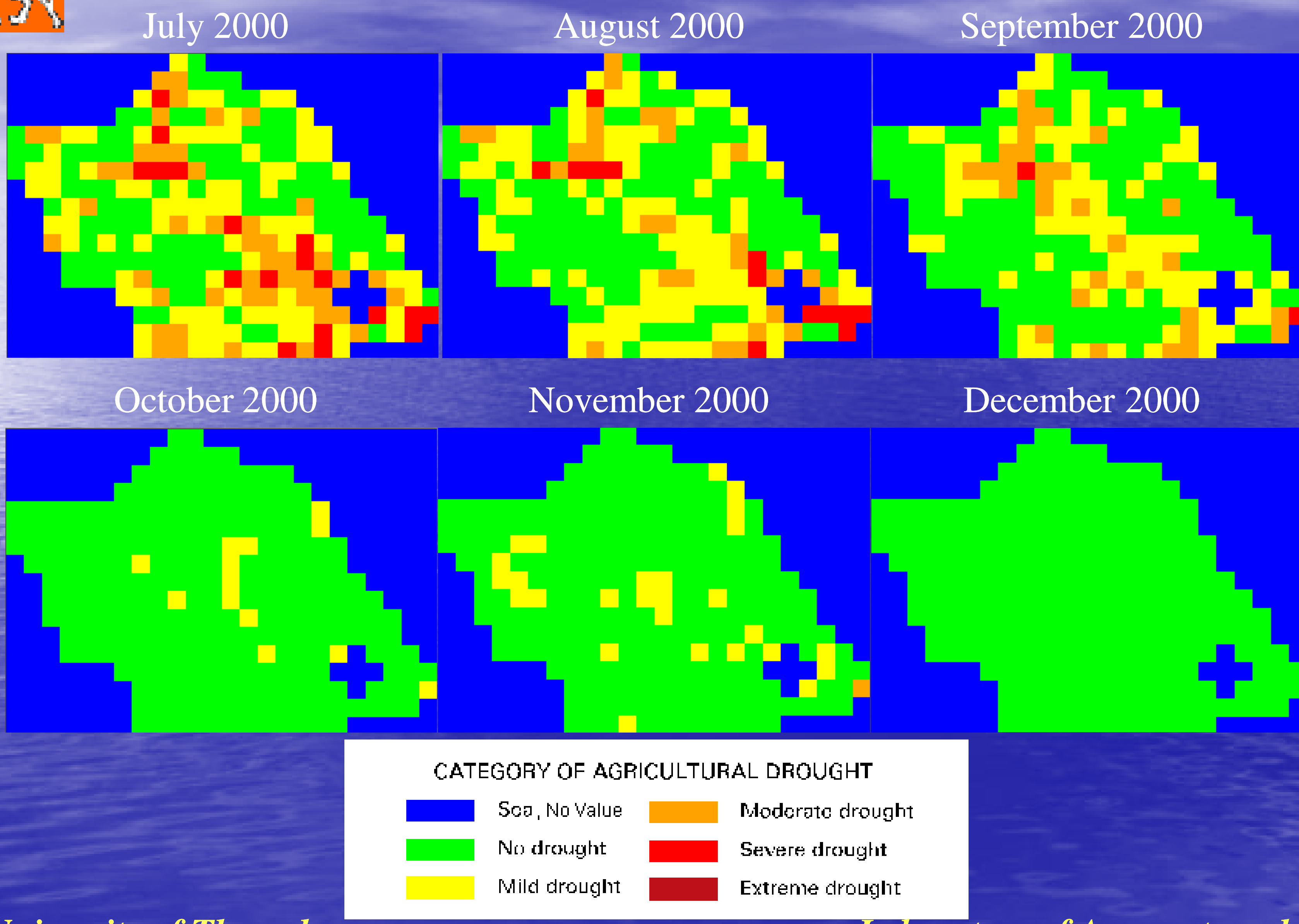
Vegetation Health Index (VHI)



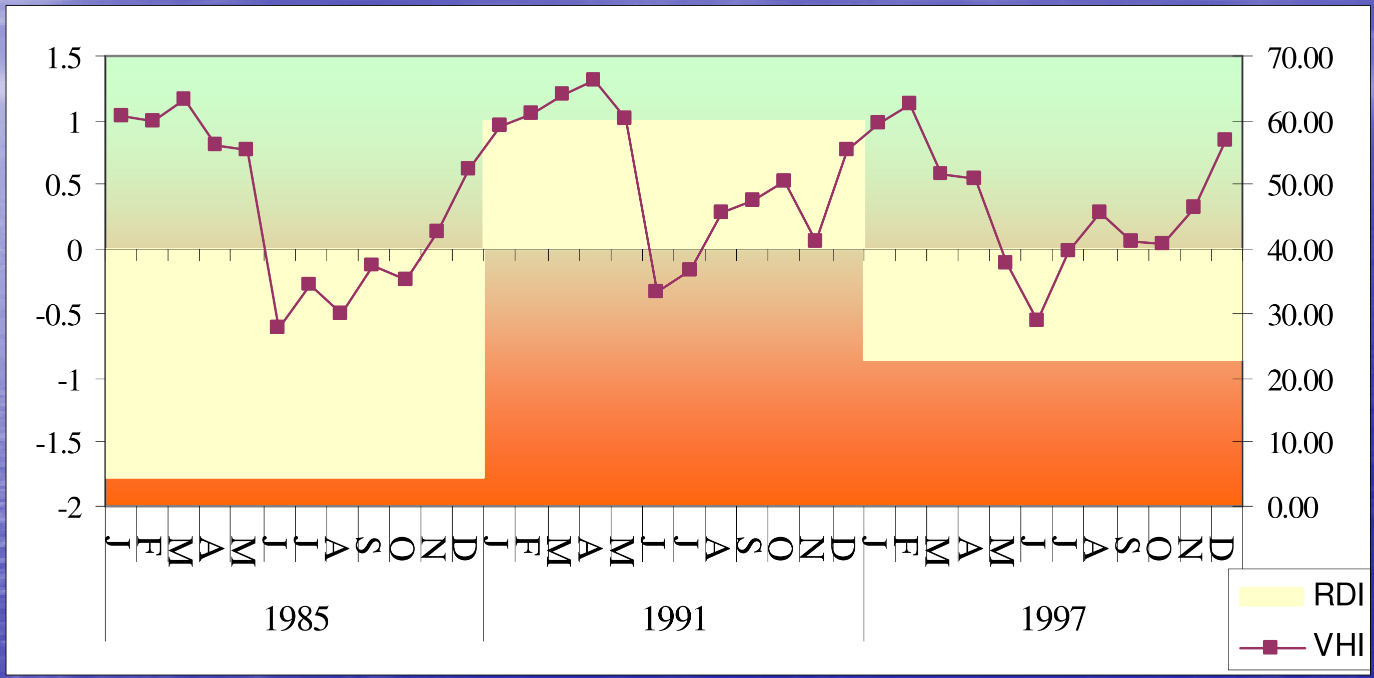
University of Thessaly *Laboratory of Agrometeorology*



University of Thessaly *Laboratory of Agrometeorology*


July 2000
August 2000
September 2000
October 2000
November 2000
December 2000
CATEGORY OF AGRICULTURAL DROUGHT
Sea , No Value
No drought
Mild drought
Moderate drought
Severe drought
Extreme drought

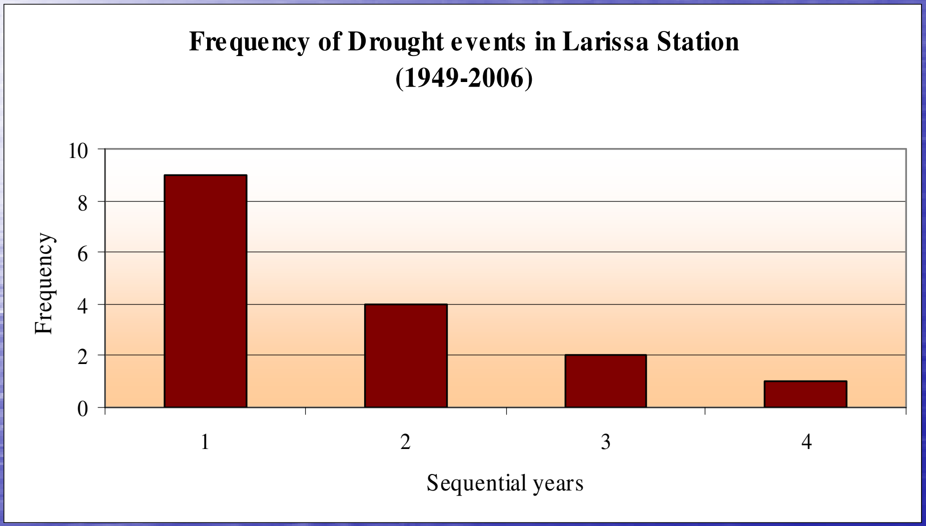
Indices comparison

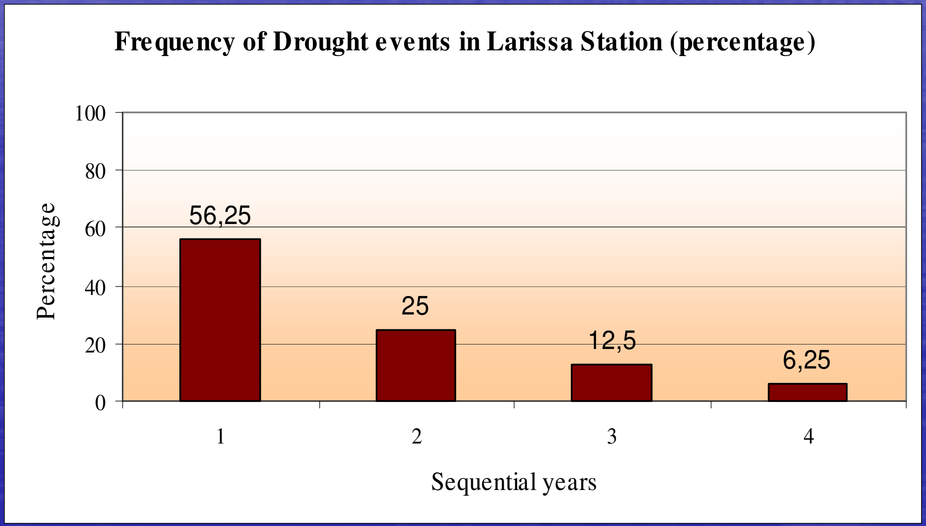


Comparison of RDI and VHI values in Larisa station for three different indicative years (1985, 1991, 1997) selected of the data set.

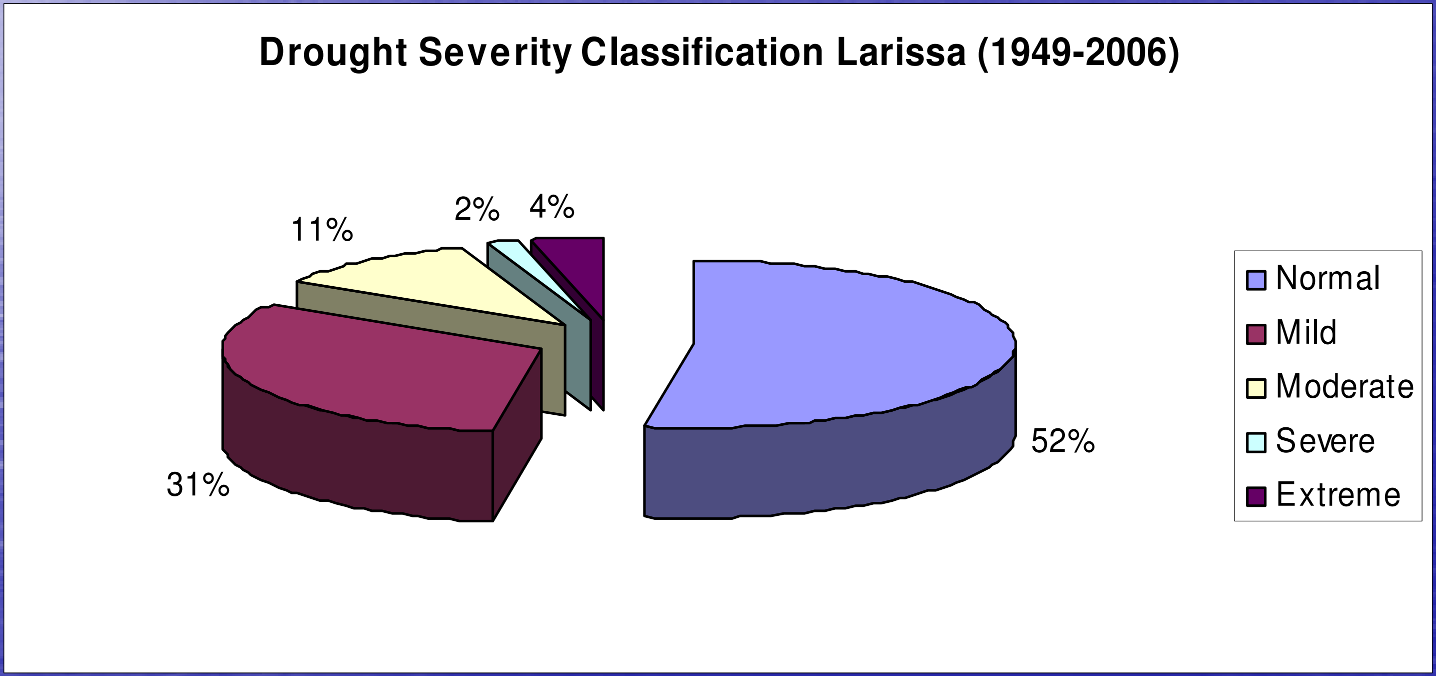
✓ RDI is calculated in annual basis while VHI is estimation in monthly basis.

Drought for Sequential Years In Larissa Station



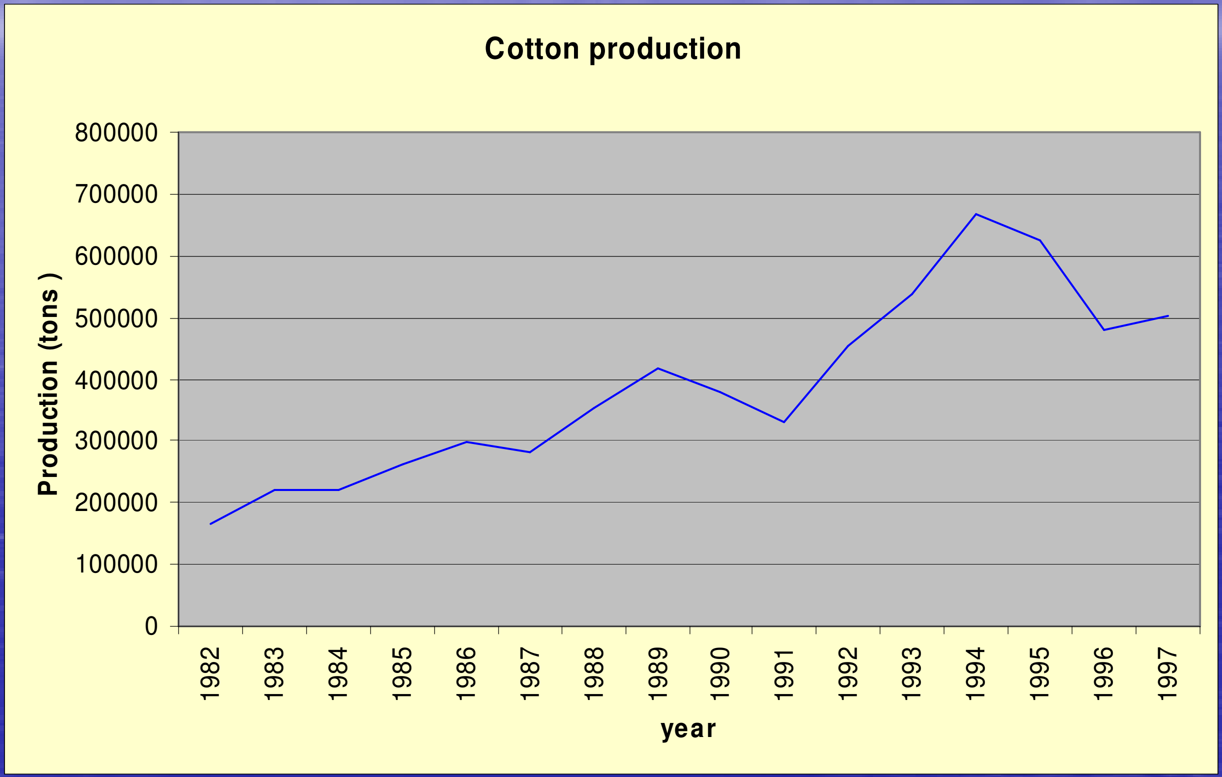


Drought Severity Classification Larissa



Cotton Production time series

Total cotton production in Thessaly	
Year	Production (tons)
1982	164362
1983	221730
1984	220875
1985	262731
1986	297966
1987	283137
1988	353687
1989	416914
1990	377665
1991	330817
1992	452921
1993	536743
1994	667436
1995	626491
1996	479517
1997	501929



Cotton Production summaries

AREA/ PRODUCTION	1993	1994	1995	1996	1997
KARDITSA	+10,5%	+18,4%	+13,5%	-37,3%	-5,5%
LARISA	-3,1%	+34,2%	-14,1%	-9,5%	-7,5%

Area	Production (kg/10 ha)	Production (kg/10 ha)	Production (kg/10 ha)
	1985	1990	1995
LARISA	234.83	315.90	357.00
KARDITSA	213.49	288.06	309.79
TRIKALA	243.32	290.58	292.19

Conclusions

- Remote sensing and GIS are useful tools for the study of spatial and temporal variability of drought indices.
- Both indices indentify the dry and wet events in the area.
- The RDI and VHI are examined in different time scales.
- Differences in drought intensities may be caused by vegetation conditions in the irrigated areas.
- There is relationship between drought years and cotton production, although crops are irrigated.

RELEVANT PUBLICATIONS

1. Domenikiotis C, Spiliotopoulos M, Loukas A, Sarakatsanos S, Dalezios N (2004a) Early cotton production assessment in Greece based on the combination of the Drought Vegetation Condition Index (VCI) and Bhalme and Mooley Drought Index (BMDI). International Journal of Remote Sensing, Vol. 25 (23), pp. 5373-5388.
2. Domenikiotis C, Spiliotopoulos M, Tsiros E, Sarakatsanos S, Dalezios N (2004b) Early cotton yield assessment by the use of the NOAA/AVHRR derived Drought Vegetation Condition Index in Greece. International Journal of Remote Sensing, Vol. 25(14), pp. 2807-2819.
3. Domenikiotis C, Tsiros E, Spiliotopoulos M, Dalezios N (2005) Zoning of cotton production areas based on NOAA/AVHRR images. International Symposium in GIS and Remote Sensing: Environmental Applications, Volos, Greece, 7-9 November 2003, pp. 119-132
4. Kanellou, E., C. Domenikiotis, A. Blanta, E. Hondronikou and N. R. Dalezios, (2008b). Intercomparison of drought indices in semi-arid areas of Greece using conventional data. Proceedings of the International Symposium of Water Shortage Management, Athens, 20 June 2008, pp. 167-179.

5. Kanellou E, Domenikiotis C, Blanta A, Hondronikou E, Dalezios N (2008c) Index-based Drought Assessment in Semi-Arid Areas of Greece based on Conventional Data. European Water (EWRA) 23/24, pp. 87-98.
6. Kanellou E, Tsiros E, Domenikiotis C, Dalezios N (2008d) Drought monitoring using several indices. 4th International Conference on Information and Communication Technologies in Bio and Earth Sciences HAICTA 2008, 18-20 September 2008, Athens, Greece, pp. 32-37.
7. Tsiros E, Domenikiotis C, Spiliotopoulos M, Dalezios N (2004) Use of NOAA/AVHRR-based vegetation condition index (VCI) and temperature condition index (TCI) for drought monitoring in Thessaly, Greece. EWRA Symposium on water resources management: risks and challenges for the 21st century, Izmir, Turkey, 2-4 September 2004, pp. 769-782

Thank you for your attention

ΕΥΧΑΡΙΣΤΩ