Development of Agricultural Drought Risk Assessment Model for Kermanshah Province (Iran), using Satellite data and Intelligent Methods

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First International Conference

Drought management: scientific and technological innovations

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DROUGHT – Importance and Necessity

- Develop an operational model to assess agricultural drought risk in Kermanshsh province (Iran).
- Drought is a natural disaster that has a major economic impact on agriculture productions.
- It is concentrated on the areas of rainfed wheat, which is the major crop in the study area.
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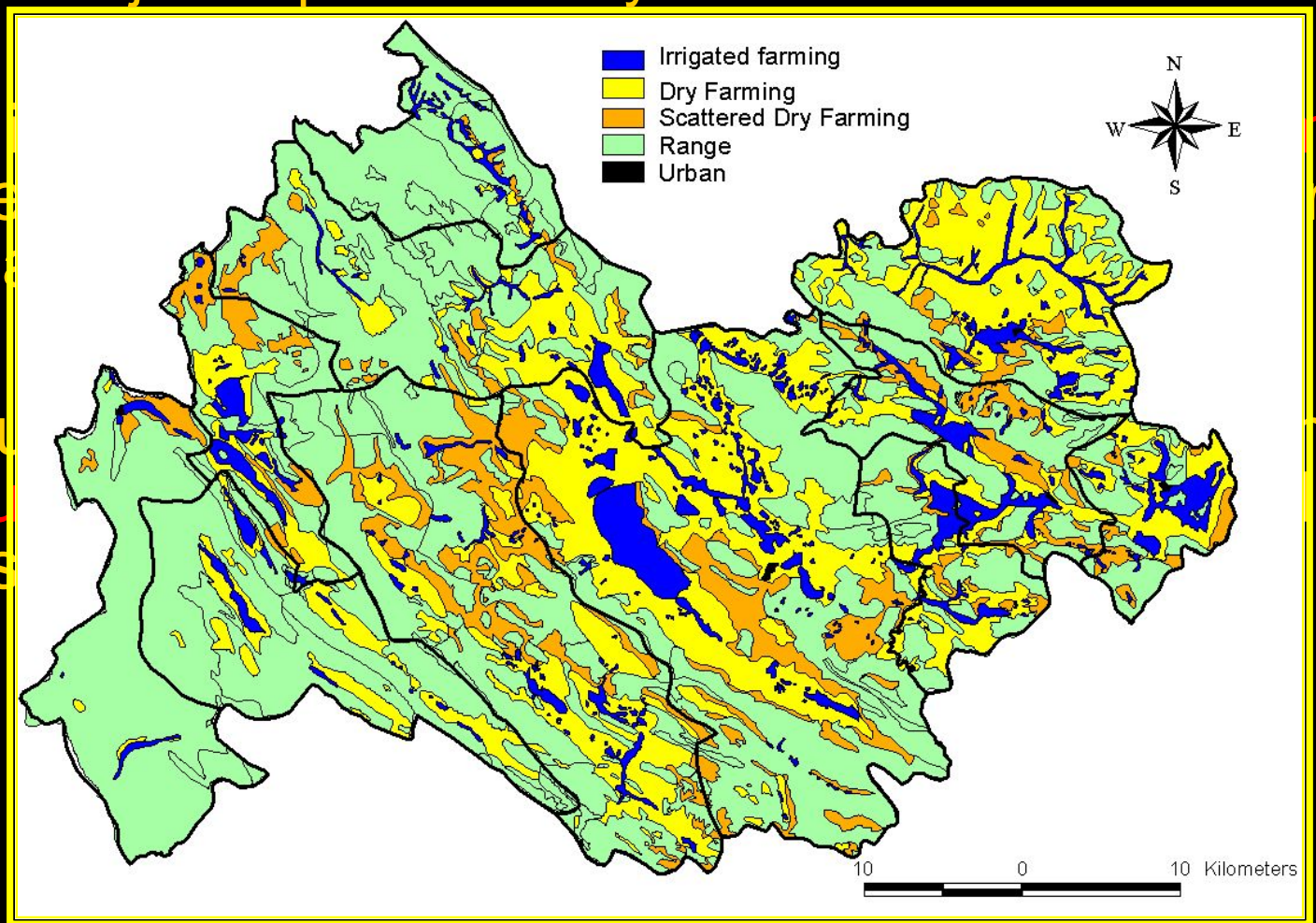


Characteristics of the Drought Risk Assessment Model

- ***First :*** **The risk assessment will be specifically based on rainfed wheat as the region's major crop to exhibit different sensitivities to water stress.**
- ***Second :*** **This study will integrate a few well-known meteorological and satellite data indices as moisture supply indicators.**
- ***Third :*** **The intelligent techniques will be applied to selection of the best suitable indices.**
- ***Fourth :*** **The risk will be assessed at critical crop times during the growing season, and the moisture indicators will be updated as the crop develops.**
- ***Finally:*** **The model will be enhanced with geographical information system (GIS).**

Updating of the Model

Stage	Period	Date
First	Germination	10th week
Secound	Vegetative Growth	19th week
Thierd	initiation of Flowering	20th week
Fourth	Grain Filling	22th week
Fifth	Maturity	25th week

Crop Yield

EDI-1
SPI-1
Z-index-1
PDSI-1

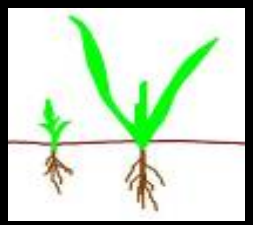
EDI-2
SPI-2
Z-index-2
PDSI-2

EDI-3
SPI-3
Z-index-3
PDSI-3

EDI-4
SPI-4
Z-index-4
PDSI-4

EDI-5
SPI-5
Z-index-5
PDSI-5

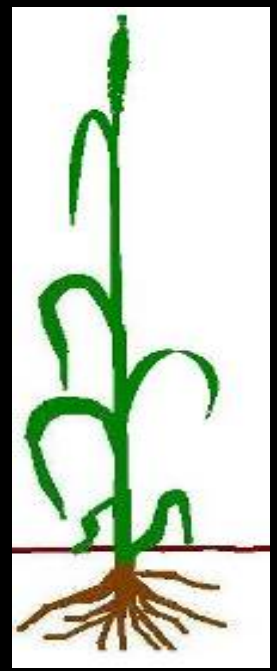
Germination



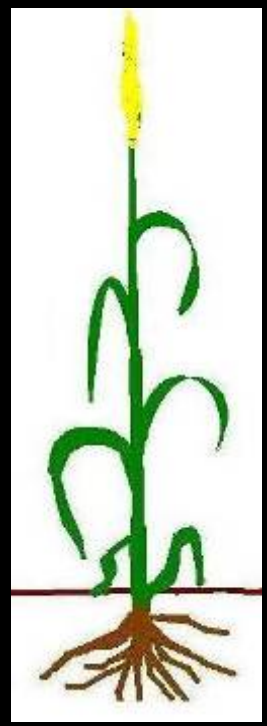
Vegetative Growth

Initiation of Flowering

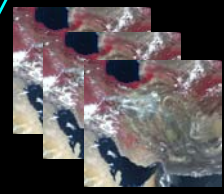
Grain Filling



Maturity



Wu and Wilhite (2004)



√ Preparing crop database
√ Yield detrending
√ Calculation of yield residual

√ Preparing weather database
√Correction and completion data
√Extraction of daily, weekly data

√ Calibration of NOAA-AVHRR image
√ Atmospheric correction
√ Geometric correction & registration image

√ Taking field data at satellite passing
√ Taking weather data at satellite passing

GDD

DIP

Wells

NDVI

BT4

SEBAL

√Visible band
√NIR band
√Thermal band

√Analysis of data collection
√Determination of soil heat flux direction
√Determination of sensible heat flux direction
√Comparison of field data & station data

Calculation critical phenological stages

√ Calculation SPI, EDI, PDSI, Z-Index, CMI
√ Spatialized indices by IDW at county level

VCI

TCI

√Surface albedo
√Vegetation index
√Surface Temperature

√Principle component analysis at drought index
√Variable selection by Genetic algorithm

Transform

Model Development

√ Multiple regression technique
√ ANFIS system
√ Fit goodness tests
√ Result Spatialized by GIS

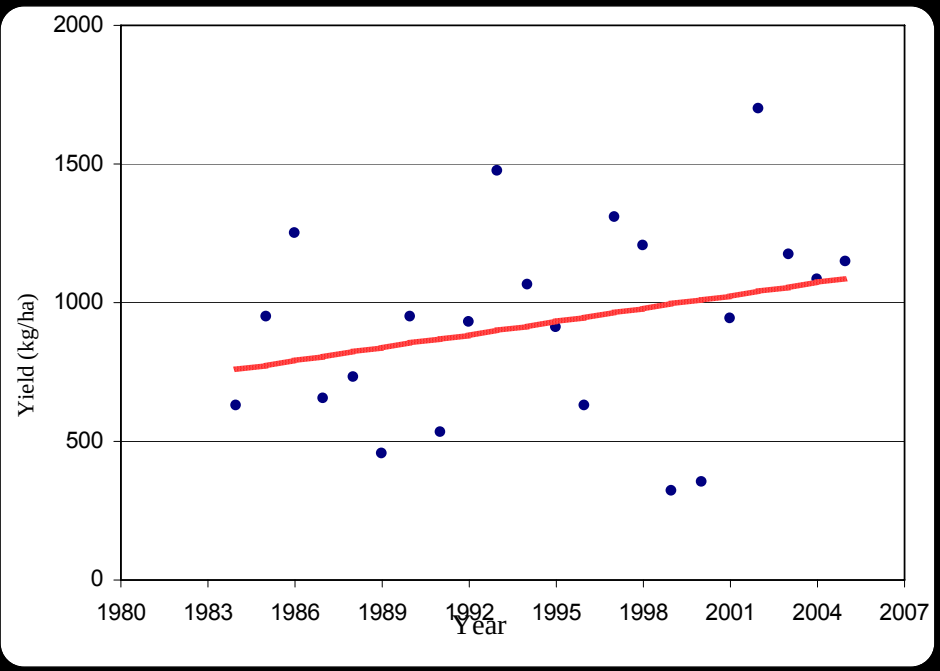
ETr

√Net radiation flux
√Soil heat flux
√Sensible heat flux
√Latent heat flux

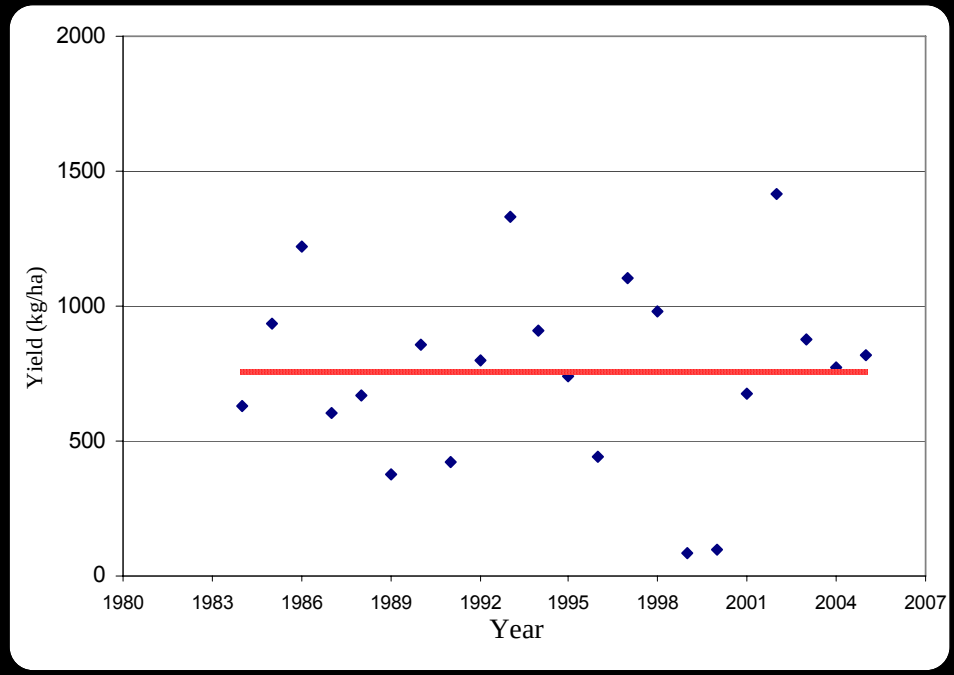
CSDI

ETa

Critical Phenological Stages and Yield Residual



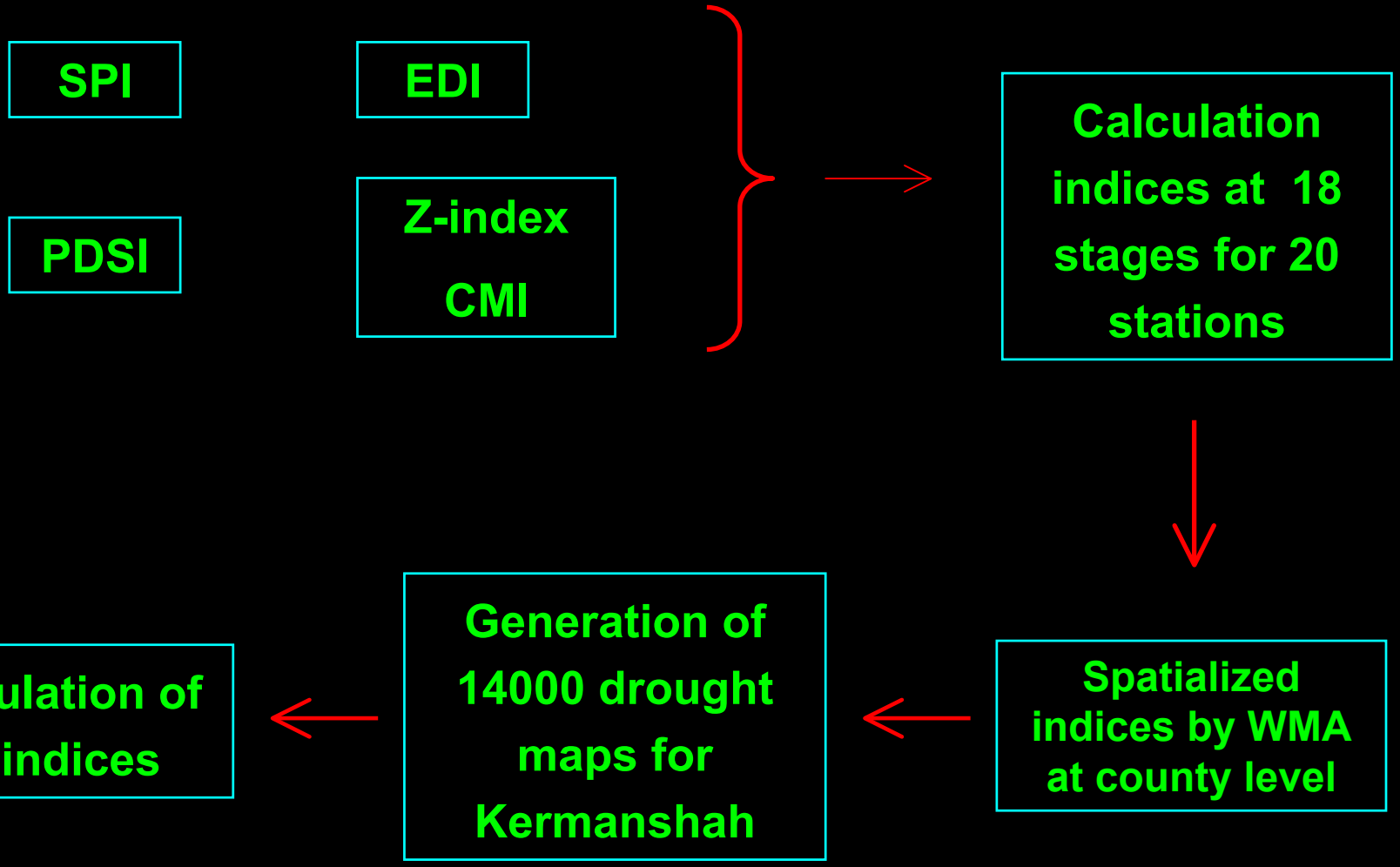
Quiring et al. (2003)



Zhang (2004)

Yeild Category	Yeild Residual
Extremely Loss	$> 1.17\ \sigma$
Moderately Loss	$1.17\ \sigma > Y > 0.33\sigma$
Normal	$0.33\ \sigma > Y > -0.33\sigma$
Moderately Increase	$-0.33\ \sigma > Y > -1.17\sigma$
Extremely Increase	$< -1.17\ \sigma$

Drought Indices



Satellite Indices

$$VCI = \frac{(NDVI - NDVI_{\min})}{(NDVI_{\max} - NDVI_{\min})} \times 100$$

Vegetation Condition Index (Kogan,1993)

$$TCI = \frac{(BT_{\max} - BT)}{(BT_{\max} - BT_{\min})}$$

)Vegetation Condition Index (Kogan,1995

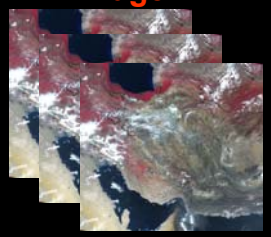
$$CSDI = \prod_{i=1}^{n} \left(\frac{\sum ET_{act}}{\sum ET_{pc}} \right)_i^{\lambda_i}$$

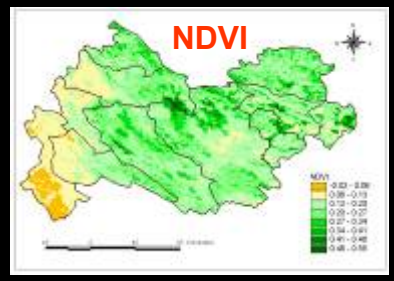
Crop-Specific Drought Index (Meyer et al.,1993)

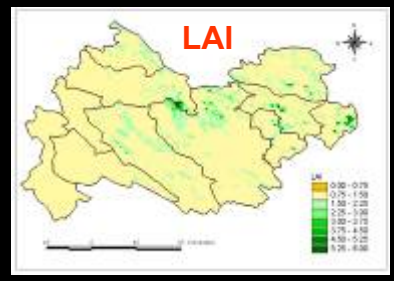
Calculation of actual evapotranspiration → Use satellite image → SEBAL algorithm

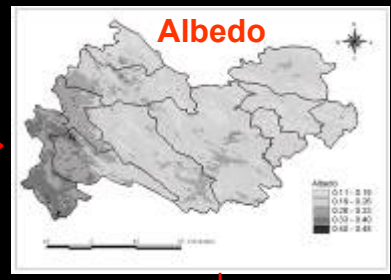
SEBAL Procedure

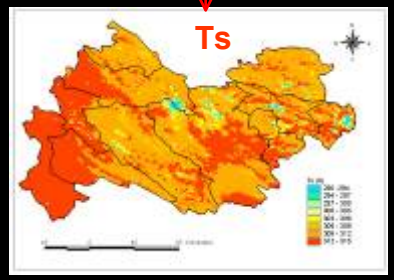
Image

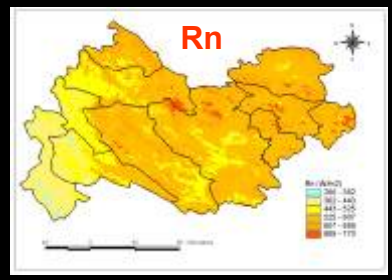


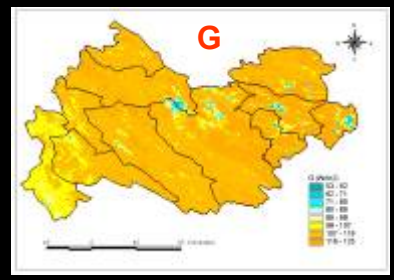




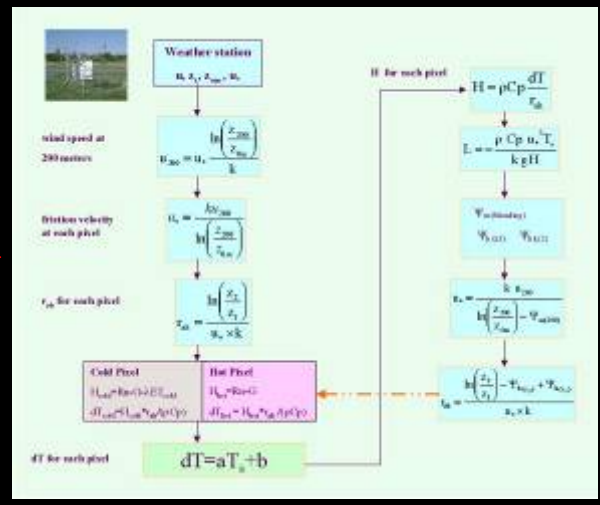


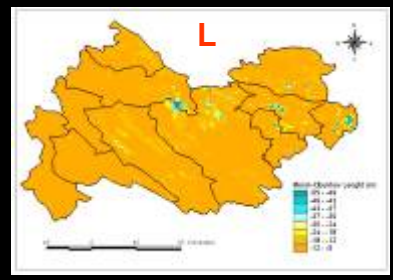


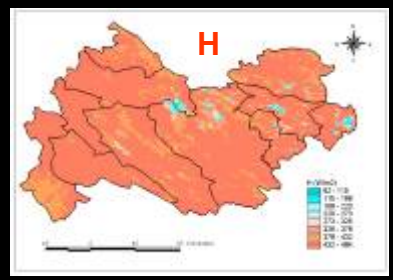


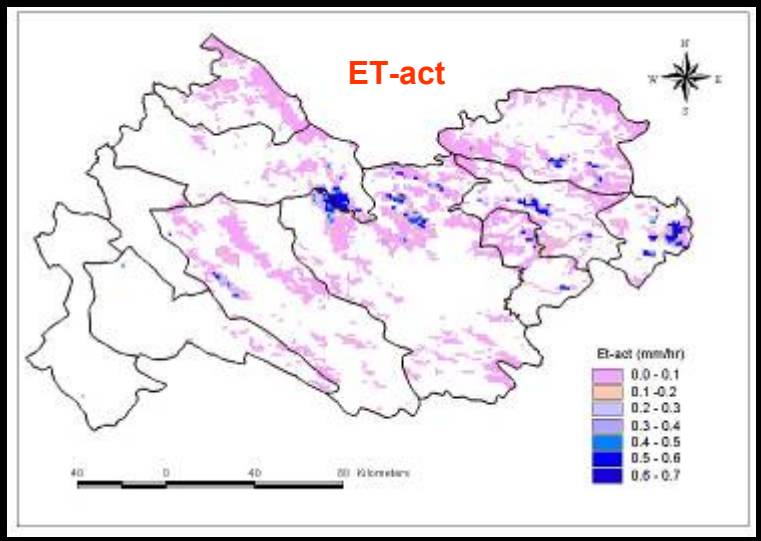


Cold & hot pixel selection

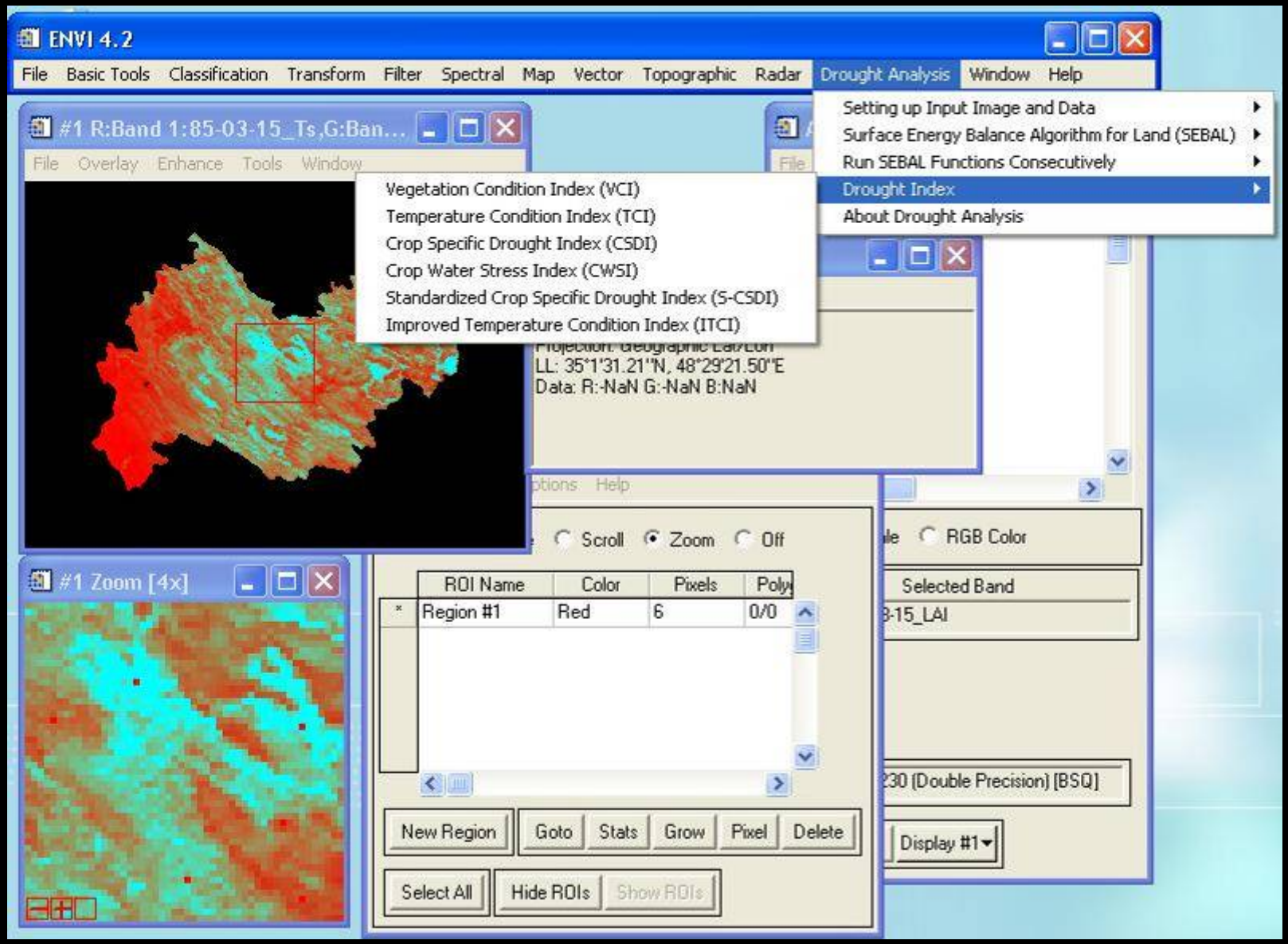








The Developed Software for Calculation of VCI, TCI, ET_act, CSDI, S_CSDI

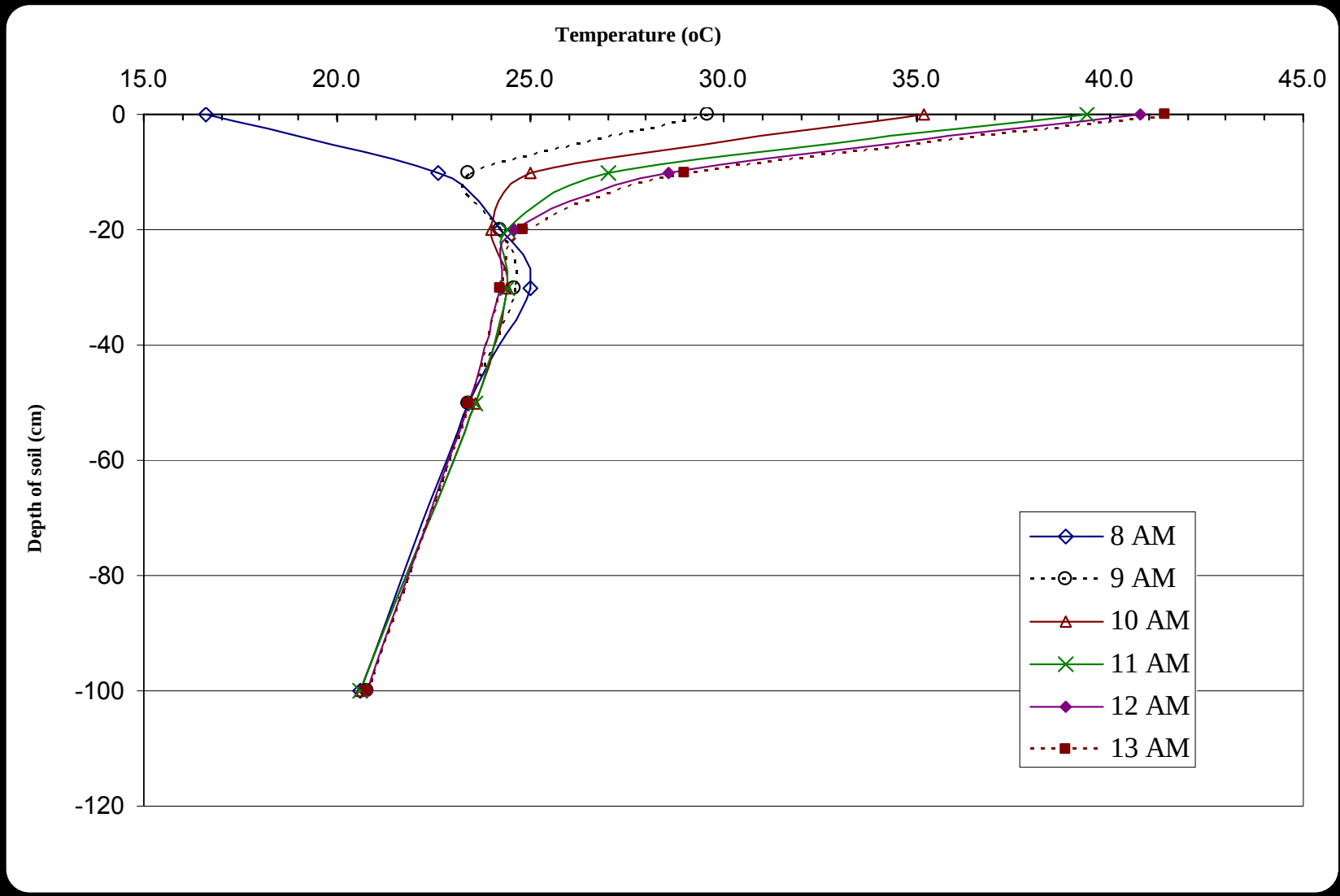


Estimation of the SEBAL Parameters, using Local Climatic Information

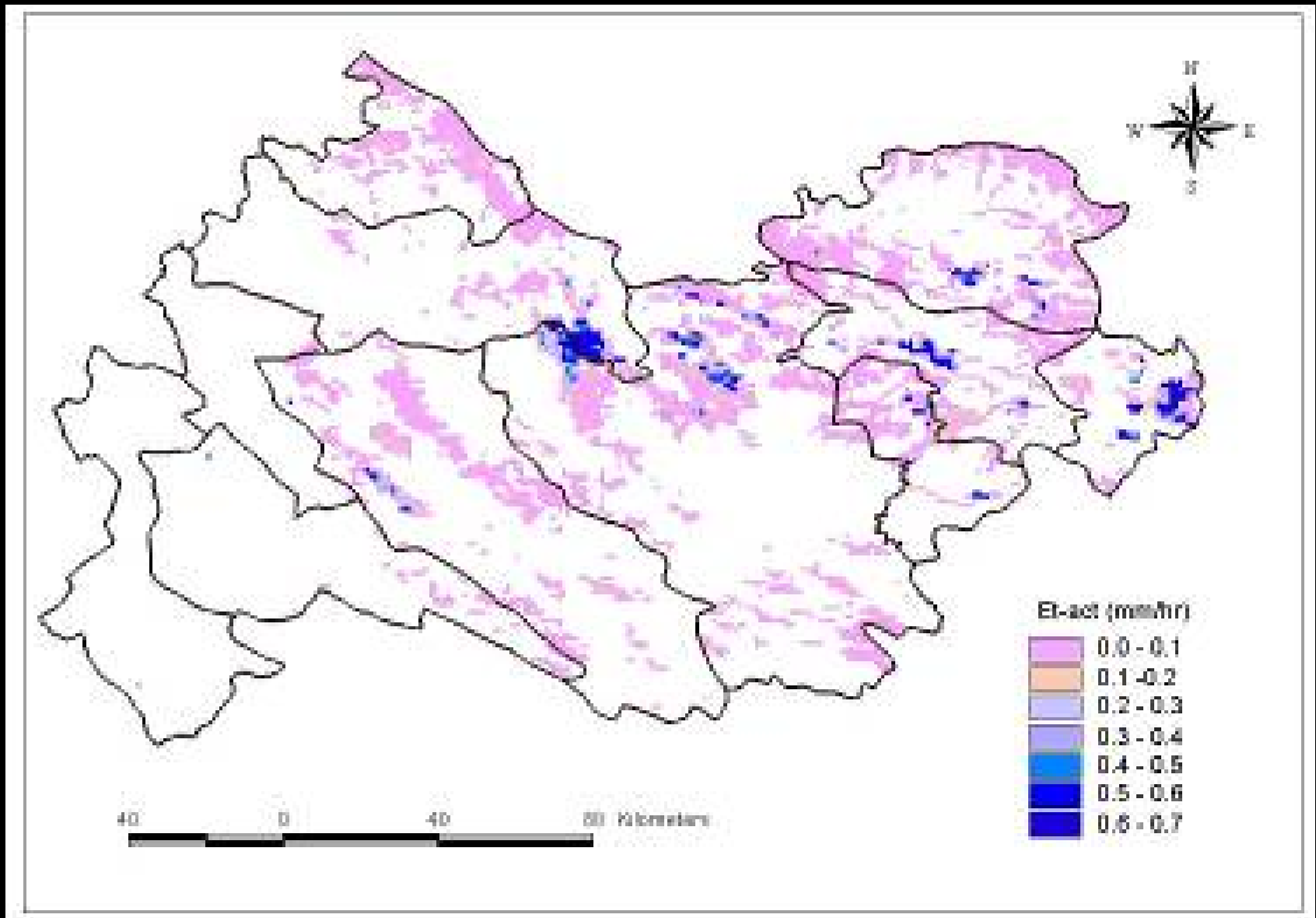
Cold pixel

Hot pixel

Estimation of the SEBAL Parameters, using Local Soil Information



Final ET map,12 Jun 2004



Analysis of Indices

Drought Index	Wheat Yield	Barley Yield
CMI	43.5%	43.1%
Z-index	43.3%	44.5%
EDI	32.1%	30.9%
PDSI	23.1%	18.1%
SPI	22.7%	23.9%

Satellite Index	Wheat Yield		Barley Yield	
VCI-1	-0.9%	24.2%	-2.3%	18.0%
VCI-2	18.0%		16.3%	
VCI-3	48.7%		38.1%	
VCI-4	32.0%		25.5%	
VCI-5	23.1%		12.4%	
TCI-1	-7.8%	14.3%	-5.4%	9.1%
TCI-2	48.1%		33.2%	
TCI-3	7.7%		3.9%	
TCI-4	25.6%		15.3%	
TCI-5	-2.3%		-1.4%	
CSDI-1	15.0%	46.8%	9.8%	38.2%
CSDI-2	55.7%		40.2%	
CSDI-3	57.7%		43.8%	
CSDI-4	57.2%		48.4%	
CSDI-5	48.6%		48.9%	

Development of New Satellite Index

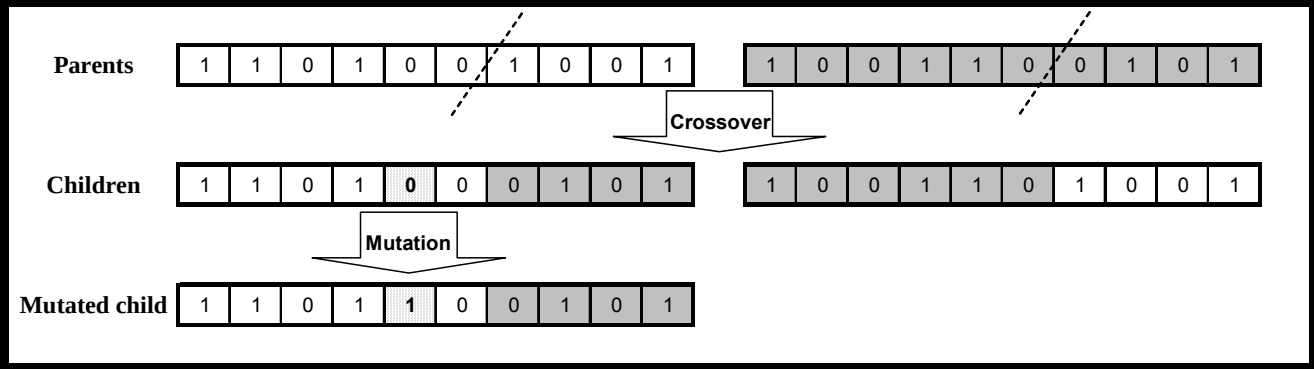
A new satellite index suggested, which is a modified form of the CDSI namely S_CSDI .

$$S\_CSDI = \frac{(CSDI - CSDI_{\min})}{(CSDI_{\max} - CSDI_{\min})} \times 100$$

Satellite Index	Wheat Yield		Barley Yield	
CSDI-1	15.0%	46.8%	9.8%	38.2%
CSDI-2	55.7%		40.2%	
CSDI-3	57.7%		43.8%	
CSDI-4	57.2%		48.4%	
CSDI-5	48.6%		48.9%	
S-CSDI-1	9.5%	48.5%	9.0%	40.6%
S-CSDI-2	58.3%		44.0%	
S-CSDI-3	67.0%		53.6%	
S-CSDI-4	60.1%		49.6%	
S-CSDI-5	47.4%		47.0%	

Selection of the Inputs, using GA-ANN Algorithm Approach

CMI-w30	PDSI-w30	ZIND-w30	EDI-w30			
CMI-w31	PDSI-w31	ZIND-w31	EDI-w31	spi-1m2	pdsi-m2	zind-m2
CMI-w32	PDSI-w32	ZIND-w32	EDI-w32	spi-1m6	pdsi-m6	zind-m6
CMI-w33	PDSI-w33	ZIND-w33	EDI-w33	spi-1m7	pdsi-m7	zind-m7
CMI-w34	PDSI-w34	ZIND-w34	EDI-w34	spi-1m8	pdsi-m8	zind-m8
CMI-w35	PDSI-w35	ZIND-w35	EDI-w35	spi-1m9	pdsi-m9	zind-m9
CMI-w36	PDSI-w36	ZIND-w36	EDI-w36	spi-3m6	pdsi-3m6	zind-3m6
CMI-w37	PDSI-w37	ZIND-w37	EDI-w37	spi-3m7	pdsi-3m7	zind-3m7
CMI-w38	PDSI-w38	ZIND-w38	EDI-w38	spi-3m9	pdsi-3m9	zind-3m9
CMI-w39	PDSI-w39	ZIND-w39	EDI-w39			



ANN clustering → Best performance

Create a population

Selection of the Inputs

Variables (STB)	St.1	St.2	St.3	St.4	St.5
3rd month's SPI	√+				
3rd month's PDSI	√				
3rd month's Z-index	√				
3rd month's SPI-3	√ ++	√ ++	√ ++		
3rd month's PDSI-3	√				
3rd month's Z-index-3	√ ++	√ ++			
19th week's CMI		√			
19th week's PDSI		√			
19th week's Z-indexI		√			
19th week's EDI		√ +	√ ++		
5th month's SPI		√ +			
5th month's PDSI			√		
5th month's Z-index		√ ++	√ ++		
20th week's CMI			√ +	√ ++	√ ++
20th week's PDSI			√		
20th week's Z-index			√		
20th week's EDI			√		
22nd week's CMI				√	√
22nd week's PDSI				√	√ +
22nd week's Z-index				√ +	√
22nd week's EDI				√ +	√
23rd week's CMI					√ ++

Variables (STB)	St.1	St.2	St.3	St.4	St.5
23rd week's Z-index					√++
24th week's CMI					√
24th week's Z-index					√ +
25th week's CMI					√+
25th week's Z-index					√
5th month's SPI					√
5th month's Z-index					√
First PC of 3rd month	√+				
Second PC of 3rd month	√++				
Third PC of 3rd month	√				
First PC of 19th week		√			
Second PC of 19th week		√			
Third PC of 19th week		√			
First PC of 5th month		√	√		
Second PC of 5th month			√ +		√ ++
Third PC of 5th month		√	√ +		
First PC of 20th week			√		
Second PC of 20th week			√ +		
Third PC of 20th week			√		
First PC of 22nd week				√	
Second PC of 22nd week				√ +	
Third PC of 22nd week				√	

Variables (SB)	St.1	St.2	St.3	St.4	St.5
VCI-stage 1	√				
VCI-stage 2		√			
VCI-stage 3			√		
VCI-stage 4				√	
VCI-stage 5					√
TCI-stage 1	√				
TCI-stage 2		√			
TCI-stage 3			√		
TCI-stage 4				√	
TCI-stage 5					√
CSDI-stage 1	√				
CSDI-stage 2		√			
CSDI-stage 3			√		
CSDI-stage 4				√	
CSDI-stage 5					√
S-CSDI-stage 1	√				
S-CSDI-stage 2		√			
S-CSDI-stage 3			√		
S-CSDI-stage 4				√	
S-CSDI-stage 5					√

St. = Stage

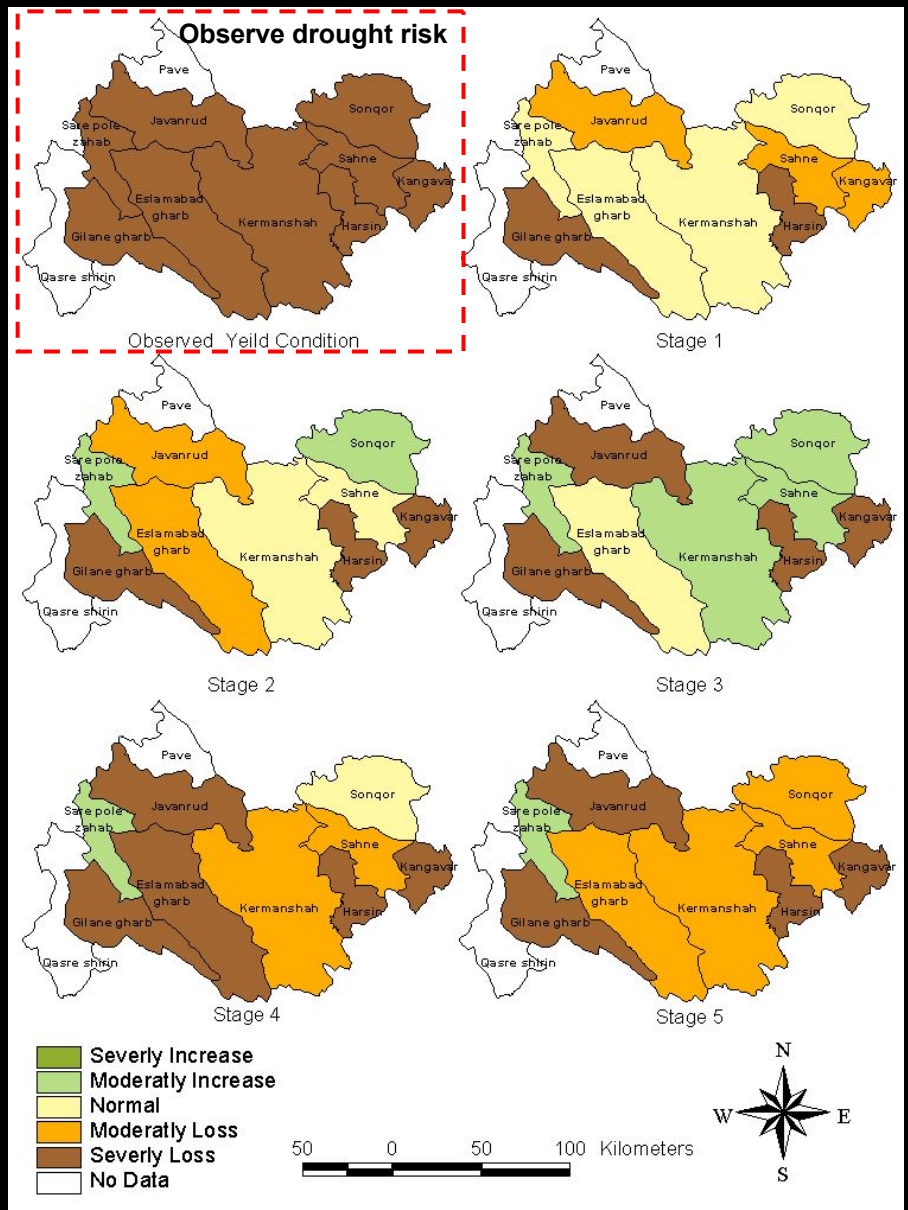
Intital Varibales √

Step 1: Selected variables by GA-ANN √ +

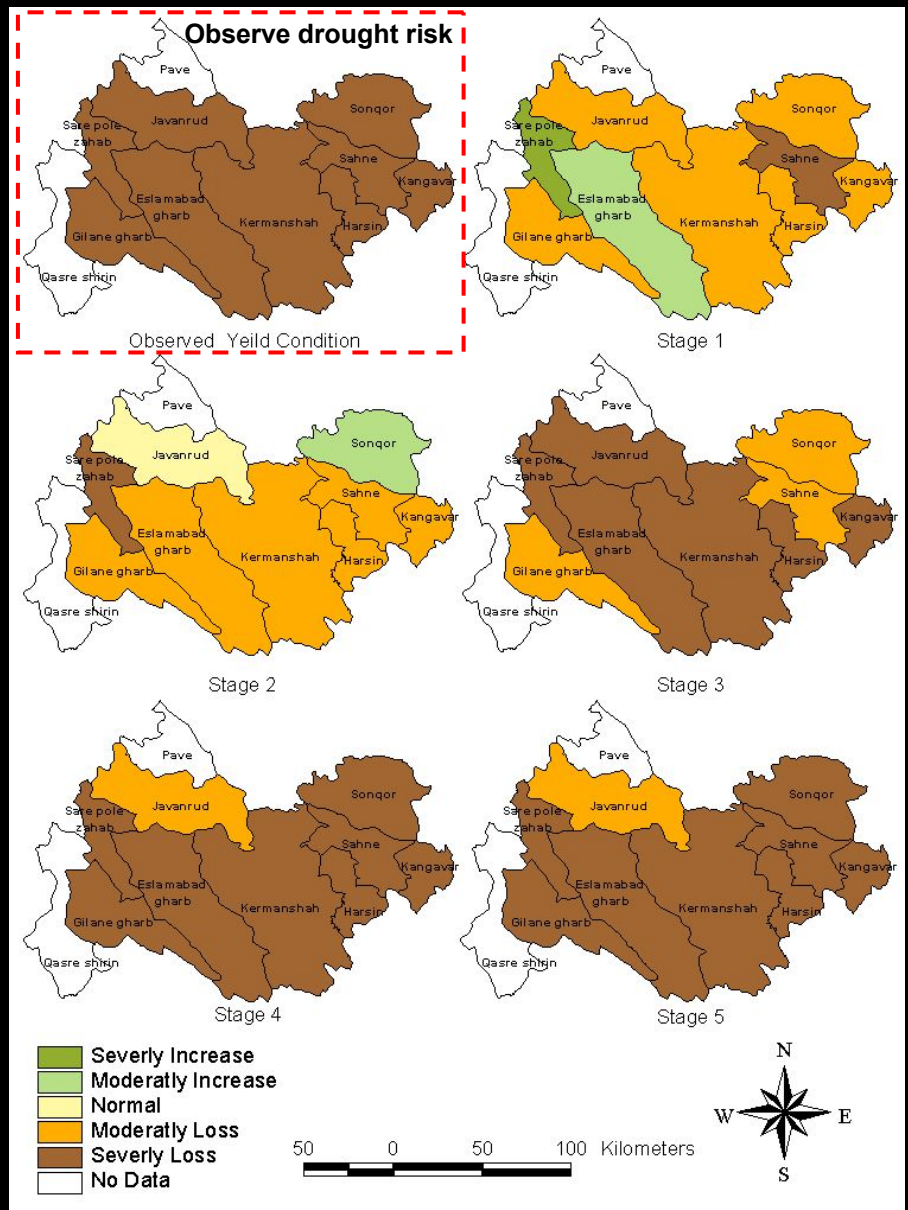
Step 2: Slected variables by Stepwise Reg. √ ++

Results of the Risk-assessment using ANFIS

Model with information of weather station



Model with information of satellite image

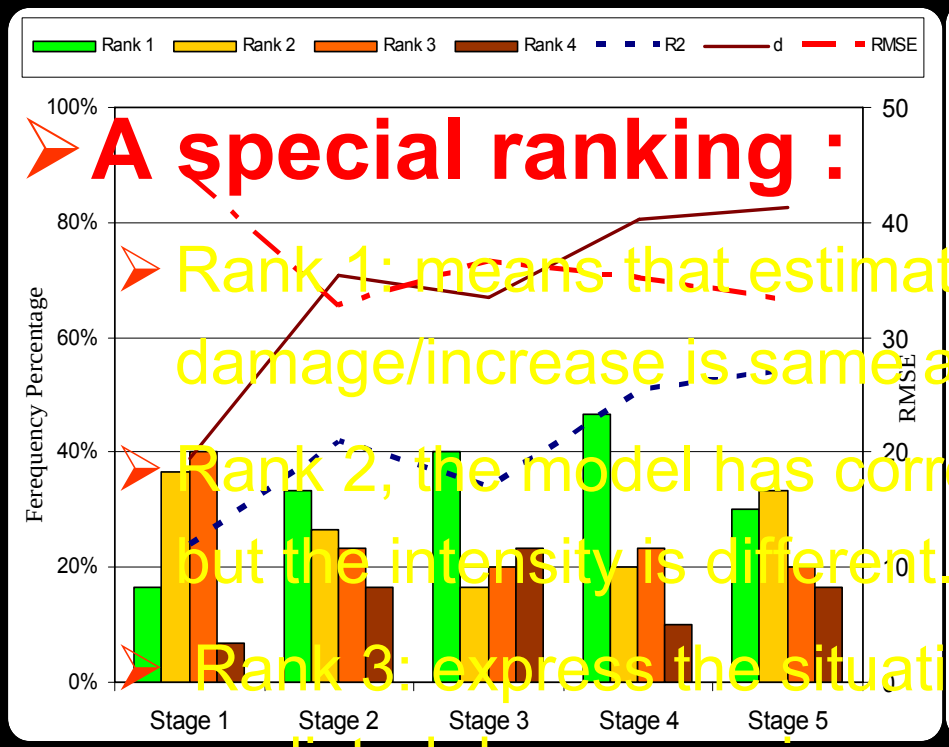


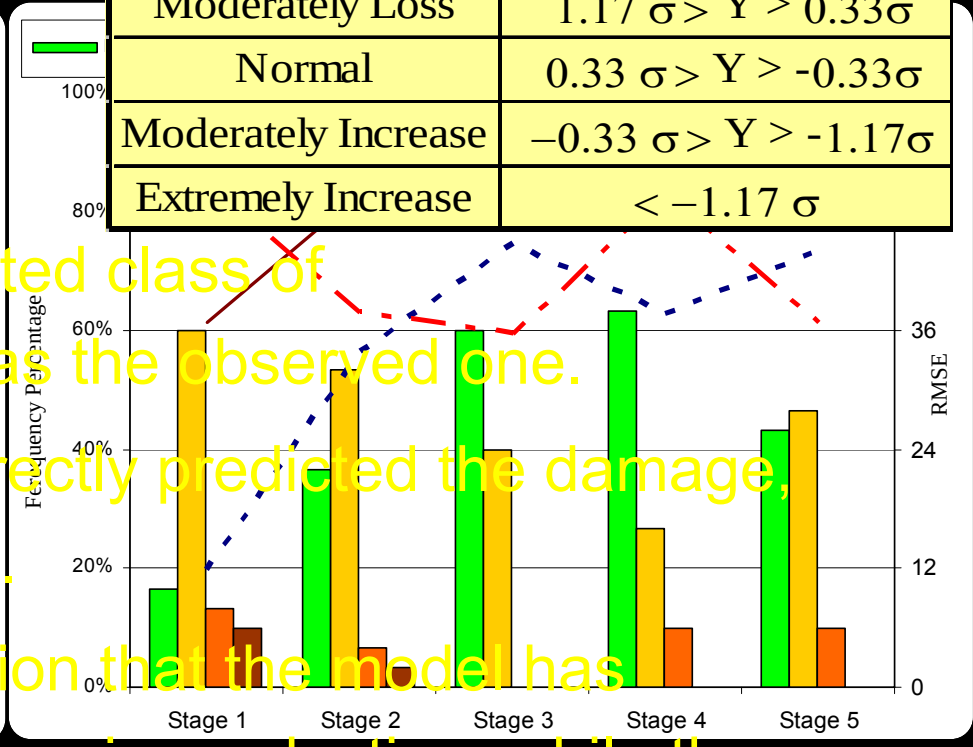
Evaluation of the Risk-assessment Model

Zhang (2004)

Yeild Category	Yeild Residual
Extremely Loss	$> 1.17\ \sigma$
Moderately Loss	$1.17\ \sigma > Y > 0.33\sigma$
Normal	$0.33\ \sigma > Y > -0.33\sigma$
Moderately Increase	$-0.33\ \sigma > Y > -1.17\sigma$
Extremely Increase	$< -1.17\ \sigma$

Model with information of weather station





- **A special ranking :**
- Rank 1: means that estimated class of damage/increase is same as the observed one.
- Rank 2, the model has correctly predicted the damage, but the intensity is different.
- Rank 3: express the situation that the model has predicted damage or increase in production, while the normal condition has been observed.
- Rank 4, the model has predicted damage or increase in production, while it is vise versa in reality.

Conclusion

1. Among the meteorological indices Z-index, CMI, EDI, SPI and PDSI had the best performance, respectively.
2. The satellite indices based model performed better. Also, Among the applied satellite indices, S-CDSI that is suggested through this research work, improved significantly the results.
3. The GA-ANN algorithm, is an effective approach to select the suitable input variable for the risk assessment model.
4. The accuracy of the risk assessment model improves with the growth stages as the crop develops. Especially after early May, when wheat reaches at initiation of flowering stage, assessment accuracy improves significantly.
5. The developed modeling system is capable to evaluate agriculture drought risk assessment in a near real time manner and recommendable for other regions.


Beautiful cap cloud phenomena
Damavand mountain (5761 m),
IRAN
Thank you for
your attention