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ARAB FUND FOR ECONOMIC & SOCIAL DEVELOPMENT

Socio Economic & Environmental Impacts of Salinity: Case Study

Training Course

Impact Assessment and Livelihood Analysis in Systems Research

ICARDA, Amman - Jordan

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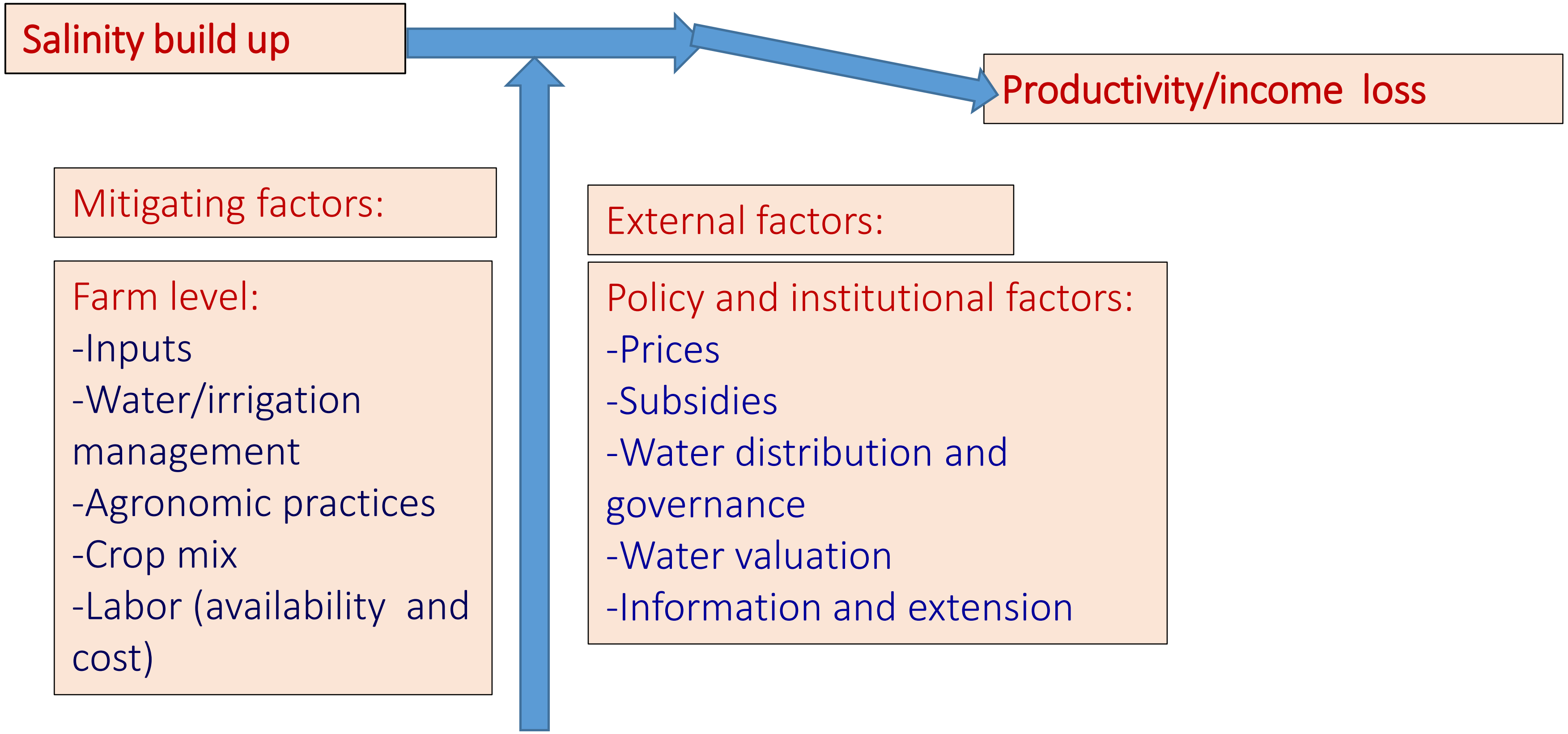
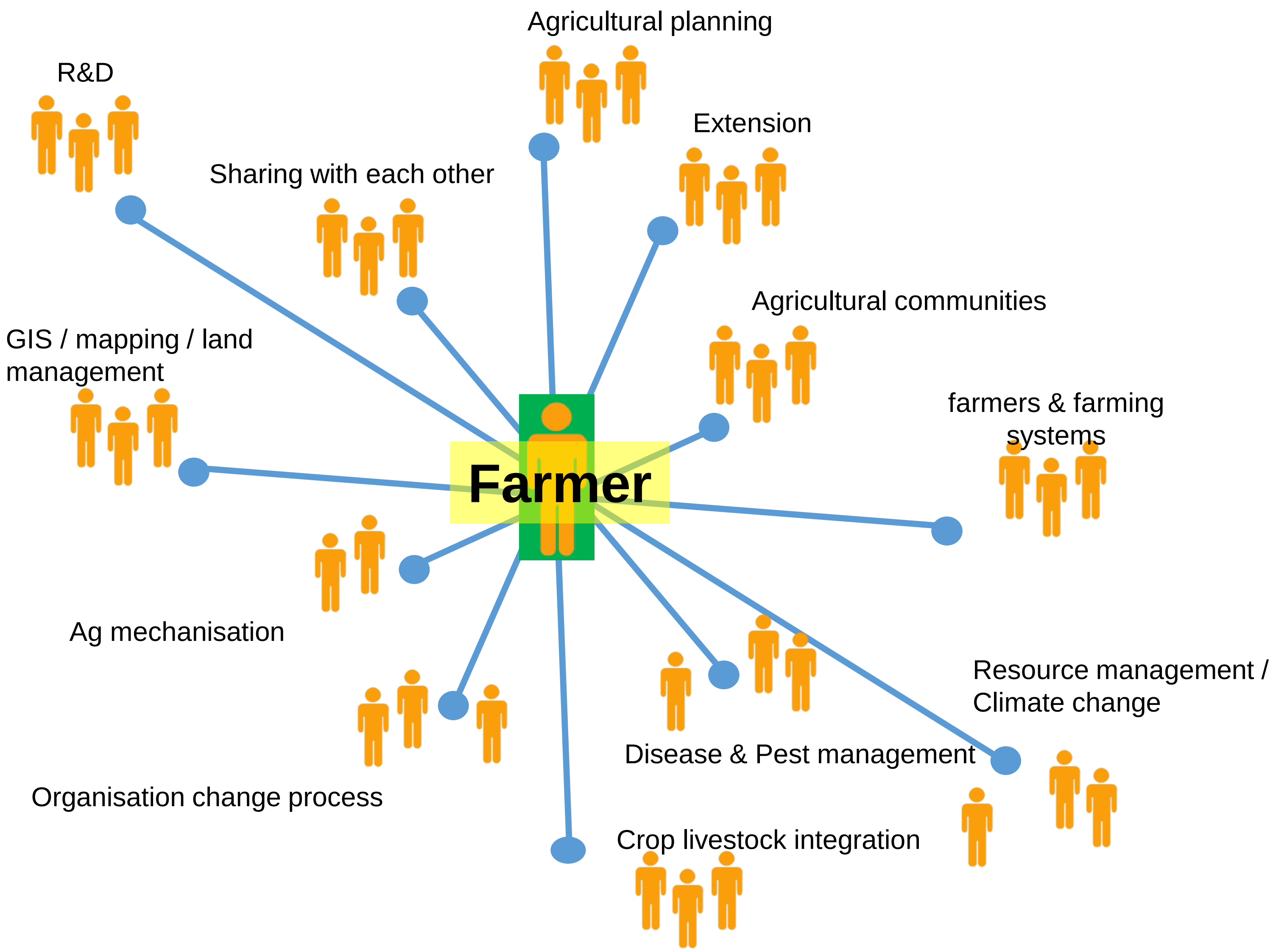
Analytical Framework Pathway



…these hands translate knowledge into practice; the survey will talk with the owners of the hands

Demands for survey design inputs from all participants to meet socio-economic and biophysical data needs



An Economic Analysis of Salinity Problems

- General objectives
  - Identify the nature of soil salinity problem
  - Investigate its impact on crop production and on the environment
  - Investigate its impact on farmer income
  - Investigate its impact on farmer well-being (health, etc.)
  - Assess the feasibility of reducing soil salinity for better water management and environment protection

- Basic hypotheses
  - Salinity has not been responsible for loss in crop production, crop yield and environmental degradation
  - The soil salinity problem cannot be reduced by improvement in drainage and water management
  - There is no environmental degradation in the specified area

- Approaches used to estimate losses caused by salinity
  - Development Indicators
  - Quantitative, Qualitative & Linear Programming Approaches

Proposed Development Indicators

- Economic and Poverty Indicators
  - Food security: Total and gender-differentiated available food in the household, Seasonal available food in the household
  - Income: Farm income, Household income/stability, Income sources (on/off farm, agricultural/nonagricultural), New products, Prices, etc
  - Equity: Farm and household income comparisons by well-being group and by gender, Distribution of economic surplus, Land tenure situation
  - Employment generation: Number of jobs, Percentage of active population employed (total, employees, self-employment, and gender-differentiated)

- Environmental Indicators
  - Production systems: Land use intensification and diversification
  - Forest: Area and map of forest area
  - Soils: Land productivity, water balance
  - Water: Water pollution, water quality, water availability
  - Others indicators: Agro-chemical use, air pollution

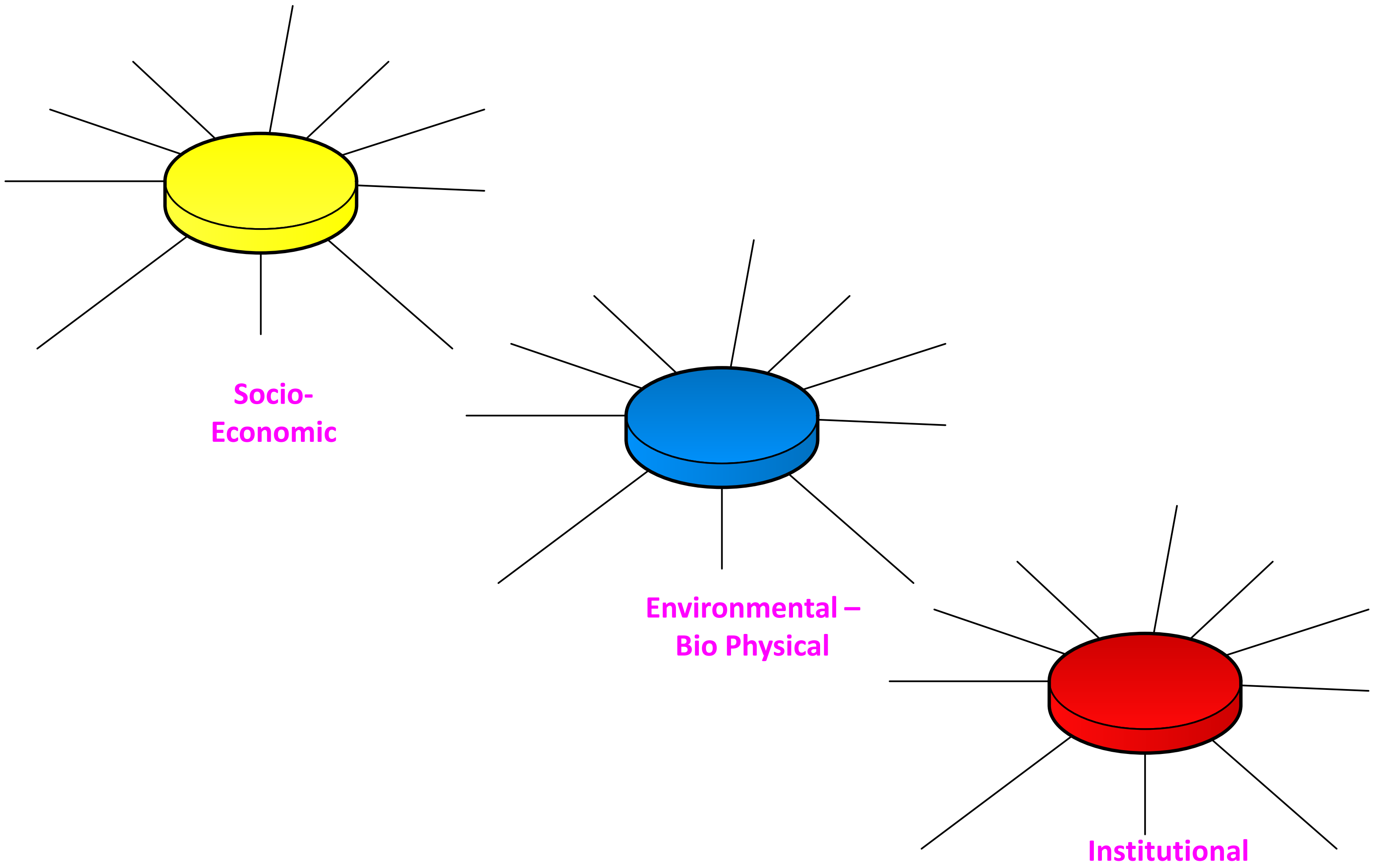
Proposed Development Indicators

- Human / Social Indicators
  - Community empowerment and equity in decision making
  - Participation in local policy decision making
  - Human capital: Education and experience, Individual capacities and Access to opportunities
  - Social Capital: Structural social capital (organizational density, networks), Cognitive social capital (conflict resolution, solidarity, cooperation, trust)
- Quality of Life Indicators
  - Nutritional levels
  - Access to health services
  - Access to consumer goods
  - Migration
  - Local well-being indicators

An Assessment of the Environmental Impacts of Salinity Problems

- General objectives
  - Assess the effects of the salinity problems on:
    - Drinking water
    - Human health
    - Vegetation
  - Estimate cost of illness related to salinity problems
- Basic hypotheses
  - Salinity has not been responsible for loss in vegetation, biodiversity ecosystems, water quality and human health
  - There is no environmental degradation in the specified area
- Data needed
  - Surveys / interviews with farmers and key personals
  - Measurement of water quality indicators (EC, PH, etc.)
- Approaches used to assess the environmental damages caused by salinity
  - Descriptive analysis (cross-tabulation, ANOVA, etc.)
  - Quantitative analysis

Soil Salinity & Livelihood Strategies



Methods for Assessing Economic and Environmental Impacts

- Indicators
- Cost benefit analysis
  - Economic surplus approach
- Econometric approach
- Bio-economic optimization modeling

An Economic Analysis of Salinity Problems

- **General objectives**
  - Identify the nature of soil salinity problem
  - Investigate its impact on crop production and on the environment
  - Assess the feasibility of reducing soil salinity for better water management and environment protection

- **Basic hypotheses**
  - Salinity has not been responsible for loss in crop production and environmental degradation
  - The soil salinity problem cannot be reduced by improvement in drainage and water management
  - There is no environmental degradation in the specified area

- **Approaches used to estimate losses caused by salinity**
  - Linear Programming Approach – LPA
  - Production Function Approach - PFA

Production Function Approach
An Empirical Guidelines Analysis

- **Technical Framework Analysis**
  - Socio, economic, agronomic and biophysical data collection at plot, farm and district levels
  - Classification of farms into low, medium, high and severe salinity affected areas (based on Electric Conductivity measures)
  - Field investigation on landscape, groundwater hydrology, water quality and drainage conditions

- **Economic Analysis: PF with salinity variable (EC)**
  - The approach assumes that salinity directly influence the crop yields
  - Several explanatory variables are included to estimate the PF
  - Cobb-Douglas form of PF is employed:

Production Function Approach

An Empirical Guidelines Analysis

- Analytical Economic Model Form

$$Q = a\, L^{b} S^{c} F^{d} K^{g} EC^{h} e^{u} \qquad (1)$$

Where;

- Q: Yield of the main crop;
- L: Cost of labor; S: cost of seed; F: cost of fertilizer; K: cost of capital
- EC: Electircal conductivity (dS/m)

- PF Decomposition Analysis: Gross income (Y) between salinity free soils and salinity affected soils

SFS $$LogY_n = LogA_n + b_nLogL_n + c_nLogS_n + d_nLogF_n + g_nLogK_n \qquad (2)$$

SAS $$LogY_s = LogA_s + b_sLogL_s + c_sLogS_s + d_sLogF_s + g_sLogK_s \qquad (3)$$

Production Function Approach
An Empirical Guidelines Analysis

- Taking the difference between (2) and (3) and rearranging:

$Log(Y_s/Y_n) = Log(A_s /A_n)$

$+[(b_s- b_n)LogL_n +(c_s-c_n)LogL_n +(d_s- d_n)LogS_n +(g_s- g_n)LogF_n +(b_s- b_n)LogK_n]$

$+ [b_sLog(L_s /L_n)+ c_sLog(S_s /S_n)+d_sLog(F_s /F_n)+g_sLog(K_s /K_n)]$ (4)

Equation (4) apportions approximately the difference in gross income/ha between SFS and SAS into two components:

1. Measure land degradation effect

2. Measure the contribution of changes in input levels between the two situations

Production Function Approach

An Empirical Guidelines Analysis

- **Factors influencing Salinity Control Effort**
    - Personal Factors – PF (risk preference, education, age, experience)
    - Economic Factors – EF (income from farming, cost of control)
    - Physical Factors – PhF (topography, groundwater table, extent of affected area)

- The amount of salinity controls depends on the effectiveness and the number of practices such as:
    - Drainage improvement
    - Water management
    - Organic matter application

- **Conceptual models for SCE**
    - Model 1: Y (cost of control of salinity/ha) = F(PF, EF, PhF)
    - Model 2: Y (Salinity control score) = F(PF, EF, PhF)
    - Model 3: Y (Management time) = F(PF, EF, PhF)

Production Function Approach
An Empirical Guidelines Analysis

- **Determining the Optimal Control of Salinity**

  - ❑ Preventive expenditure approach of salinity control
    - Depends upon the nature of physical environment, interaction between physical variables, price and technology
    - Collection and comparison of methods adopted by farmers (flushing, use of ameliorates, cultural methods, drainage practices, etc.) with technically appropriate methods to reduce soil salinity

- **Salinity Effects on Environment**
  - Interviews with farmers and key personnel
  - Assess the effects of the salinity problem on drinking water, human health and vegetation
  - Estimate cost of illness related to salinity problems

Practical case

What are we going to cover?

Part II:

- Estimation of Technical Efficiency (TE)
- Estimation of Allocative Efficiency (AE)
- Estimation of Economic Efficiency (EE)
- Identify factors affecting the level of salinity:
    - Socio economic characteristics
    - Socio demographic variables
    - Technologies, etc.
- Identify sources of inefficiency
- Input elasticities
- Total Factor Productivity and its determinants

Performance of a Farm

Variety of forms in empirical analyses:

- Cost per unit
- Profit per unit
- Usually in ratio form: $\dfrac{Output}{Input}$

- This is a commonly used measure of **efficiency**, but also of **productivity**

Objectives for the Empirical Analysis

1. **Examine the conceptual framework that underpins efficiency and productivity measurement**
2. **Introduce of the empirical method:**
    - **Index Numbers**
    - **Data Envelopment Analysis**
    - **Stochastic Frontiers**

Examine its techniques, relative merits, necessary assumptions and guidelines for its application

Objectives for the Empirical Analysis

3. **Work with computer programs :**
    - **TFPIP; EXCEL**
    - **DEAP**
    - **FRONTIER (V4.1)**
4. **Briefly review some case studies and real life applications (according to the availability of data)**

Example

Analysis of the Effects of Quality of Irrigation Water on Crop Yields

- The model is presented in terms of output of wheat, involving the three input variables, land, fertilizer and irrigation, as follows:

$$\log (Y_i) = \beta_{0i} + \beta_{1i} X_{1i} + \beta_{2i} X_{2i} + \beta_{3i} X_{3i} + V_i - U_i \quad (1)$$

Where:

- Y_i denotes the total yield of wheat for the ith farmer;
- X_{1i} denotes the logarithm of the land area under wheat;
- X_{2i} denotes the logarithm of the quantity of fertilizer applied;
- X_{3i} denotes the logarithm of the quantity of irrigation water applied;
- β_{ki} K = 0, 1,2,3, are unknown parameters for the production function for the ith farmer (to be defined below in terms of other variables);
- V_i's are random errors associated with measurement errors in the yields of wheat reported, or the combined effects of input variables not included in the production function, where the V_i's are assumed to be independent and identically distributed N (0, σ_v 2)-random variables;

Example

Analysis of the Effects of Quality of Irrigation Water on Crop Yields

- Ui's are non-negative random variables, associated with the technical inefficiency of production of the farmers, such that:

$$\mu_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} \qquad (2)$$

Where:

- Zi, are values of explanatory variables for the technical inefficiency effects for the ith farmer: Age, education, logarithm of the total land operated by the farmer, etc.

- The final component of the model, for considering for the effects of differing quality of irrigation water, is defined as follows:

$$\beta_{ki} = \beta_k + \beta_{k1} Q_{1i} + \beta_{k2} Q_{2i} \qquad (3)$$

where Q1i and Q2i are the values of variables, which measures the quality of the irrigation water applied by the ith farmer (levels of electrical conductivity (EC), sodium absorption ratio (SAR), or residual sodium carbonate (RSC)), which are important measures by which soil and water quality are classified by soil scientists.

Example

Analysis of the Effects of Quality of Irrigation Water on Crop Yields

- The specification of the parameters of the frontier model, in terms of the quality of the irrigation water, implies that the frontier model to be estimated is obtained by substitution of Equation (3) into Equation (1), which yields the model:

$$\text{Log}(Y_i) = \beta_0 + \beta_{01}Q_{1i} + \beta_{02}Q_{2i} + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_{11} X_{1i} \times Q_{1i} + \beta_{12} X_{1i} \times Q_{2i} + \beta_{21} X_{2i} \times Q_{1i} + \beta_{22} X_{2i} \times Q_{2i} + \beta_{31} X_{3i} \times Q_{1i} + \beta_{32} X_{3i} \times Q_{2i} + V_i - U_i \qquad (4)$$

- The stochastic frontier production function includes the quality variables for irrigation water as intercept shifters in the function, together with their interactions with the input variables, as additional explanatory variables in the production function.

- An implication of this model is that the elasticities of output with respect to the different inputs are a linear function of the quality variables for irrigation water.

- In the empirical application of this model, there would be interest to see if the elasticities are independent of the quality of the irrigation water applied to the crop.

Outline of the Empirical Analysis

- **Stage 1: Data collection (questionnaires)**
  - Outputs (quantities & prices)
  - Inputs (quantities & costs)
  - Others kind of data (Socio economic, socio demographic of farmers, etc.)
- **Stage 2: Empirical model**
  - Production Technology
    - Cobb Douglass (production or cost) frontier function
    - Translog (production or cost) frontier function
- **Stage 3: Techniques for Efficiency (Frontier 4.1) and Productivity (E-views 7)**

Outline of the Empirical Analysis

- **Step 1: Data transformation using Excel**
- **Step 2: Working with Frontier 4.1**
- **Step 3: Empirical Analysis**
  - **Production Technology**
    - Cobb Douglas production frontier function: TE
    - Cobb Douglas cost frontier function: AE
    - EE = TE*AE
- **Step 4: TPF and its determinants**
  - $TFP_i=Y_i/TVC_i = 1/AVC_i$..............$TFP_i = F(X_1, X_2, X_3, etc)$
  - Decomposition of TFP in Efficiency Change (EC) and Technical Change (TC)
    - **Malmquist TFP Index if T>2**

Research Objectives and Hypothesis

Research Objectives and Hypothesis

General objectives

The socio-economic aim of this research is:

* To measure the salinity impacts on crop productivity, resource use and efficiency, and profitability under different soil salinity levels,

* To identify the socio-economic factors that influences the salinity control efforts taken by individual farmers.

General Hypothesis

* The basic null hypothesis is that salinity has not been responsible for loss in crop production and environmental degradation in the considered area of the project. More specifically:

* There are no causal relationships between soil salinity and loss in crop production, resource use and allocative efficiency and income,

* The salinity control efforts taken by farmers are not related to their socio-economic conditions.

Methods and Approaches Used to Estimate Losses Caused by Salinity

Two Principal Methods:

1. **<u>Linear Programming Approach – LPA</u>**

2. **<u>Production Function Approach - PFA</u>**
    1. Cost Efficiency Analysis and Its Determinants
    2. Total Factor Productivity Measurement
    3. Explaining Drivers of Total Factor Productivity
    4. Salinity Impacts on Resource Use and Productivity
    5. Evaluation of Factors Influencing Salinity Control Efforts Taken by Farmers

Analytical Analysis, Results & Discussion

Marginal value product and damage using total gross margin (TGMC) and total variable costs (TVC) indicators

Notation	Variables	Mussayeb salinity affected area (SAE)	Dujaila salinity affected area (SAE)	Abul-Khasseb affected area (SAE)	Mussayeb salinity free area* (SFA) (Reference site)
S	Area (ha)	**11.7**	**65.01**	**1.25**	**14.67**
TGMC	Total Gross Margin (ID/ha)	**3629011**	**620525.5**	**16312184**	**4491030**
%TGMC	TGMC SAE vs SFA	**-20%**	**-20%**	**+263%**	**-**
TVC	Total Variable Cost (ID/ha)	**554553**	**180465.2**	**3680286**	**763502**
%TVC	TVC SAE vs SFA	**-28%**	**-77%**	**+382%**	**-**
FER	Total fertilizer cost (ID/ha)	**105289**	**56856.98**	**245795.2**	**119603.1**
%FER	**FER SAE vs SFA**	**-12%**	**-53%**	**+205%**	**-**

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Analytical Analysis, Results & Discussion

Mean CE, Actual and potential yields, and potential Yield loss by Salinity Groups

Project Areas	Mean CE (%)	Number of farms	Mean of Total Gross Margin (Iraqi Dinar/Ha)	Mean of Potential Gross Margin (Iraqi Dinar/Ha)	Mean of Potential Gross Margin loss (Iraqi Dinar/Ha)	Mean Gross Margin Loss (%)
Mussayeb salinity affected area (SAE)	69	117	3629011	5259436.232	1630425.232	31
Dujaila salinity affected area (SAE)	63	141	620525.5	984961.1111	364435.6111	37
Abul-Khasseb affected area (SAE)	59	124	16312184	27647769.49	11335585.49	41
Mussayeb salinity free area* (SFA) (Reference site)	76	103	4491030	5909250	1418220	24

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Analytical Analysis, Results & Discussion

Allocative Efficiency (AE) ratings & TFP estimation in Iraqi producing farms

AE & TFP (%)	Mussayeb	Dujaila	Abul-Khasseb
Allocative Efficiency	0.42	0.63	0.59
Main determinants of AE	Age, Farmer education level, family labor and land tenure	-	Farmer education level and family labor
Total Factor Productivity (%)	0.19	1.4	0.086
Main determinants of TFP	Off-farm income, farmer education level, land tenure and the source of income generated by livestock sector	Family labor and the source of income generated by livestock sector	Off-farm income, family labor and land tenure
N	220	141	124

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Analytical Analysis, Results & Discussion

Decomposition of output differences into soil salinity and input changes in Mussayeb, Dujaila and Abul-Khasseb

Variables	Percentage Attributable Salinity Free Area vs Salinity Affected Area		
	Mussayeb	Dujaila	Abul-Khasseb
Source of Change			
1. * Salinity	**-4.96**	**79.99**	**60.81**
1. * Changes in input	**-113.07**	**-2131.02**	**-118.49**
Labour	-55.55	54.55	87.88
Mechanisation	19.51	-2391.24	-293.68
Seeds	28.57	-5.98	52.15
Fertilisation	36.02	-11.75	68.89
Irrigation	-60.31	-69.78	14.34
Chemicals	-55.37	-38.63	-22.50
Others costs	-25.92	171.83	36.03
Total difference (%)explained	**-118.03**	**-2211.01**	**-57.68**

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Analytical Analysis, Results & Discussion

Determinants of Total Gross Margin between Salinity Affected Area and Salinity Free Area in Iraq

Variables	Mussayeb Salinity Affected Area	Dujaila Salinity Affected Area	AbulKhasseb Salinity Affected Area	Mussayeb Salinity Free Area
Labour	+	+	+ *	+
Mechanisation	- **	+ ***	+	- *
Seeds	+ ***	-	+ ***	+ **
Fertilisation	+ **	-	+ *	+ **
Irrigation	+	- **	+ **	+
Chemicals	+ *	-	-	+ *
Others costs	+ **	+ **	+	+ **
N	117	141	124	103
R^2	0.47	0.71	0.35	0.49

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Analytical Analysis, Results & Discussion

Determinants of Farmers' Management Strategies in Controlling Soil Salinity

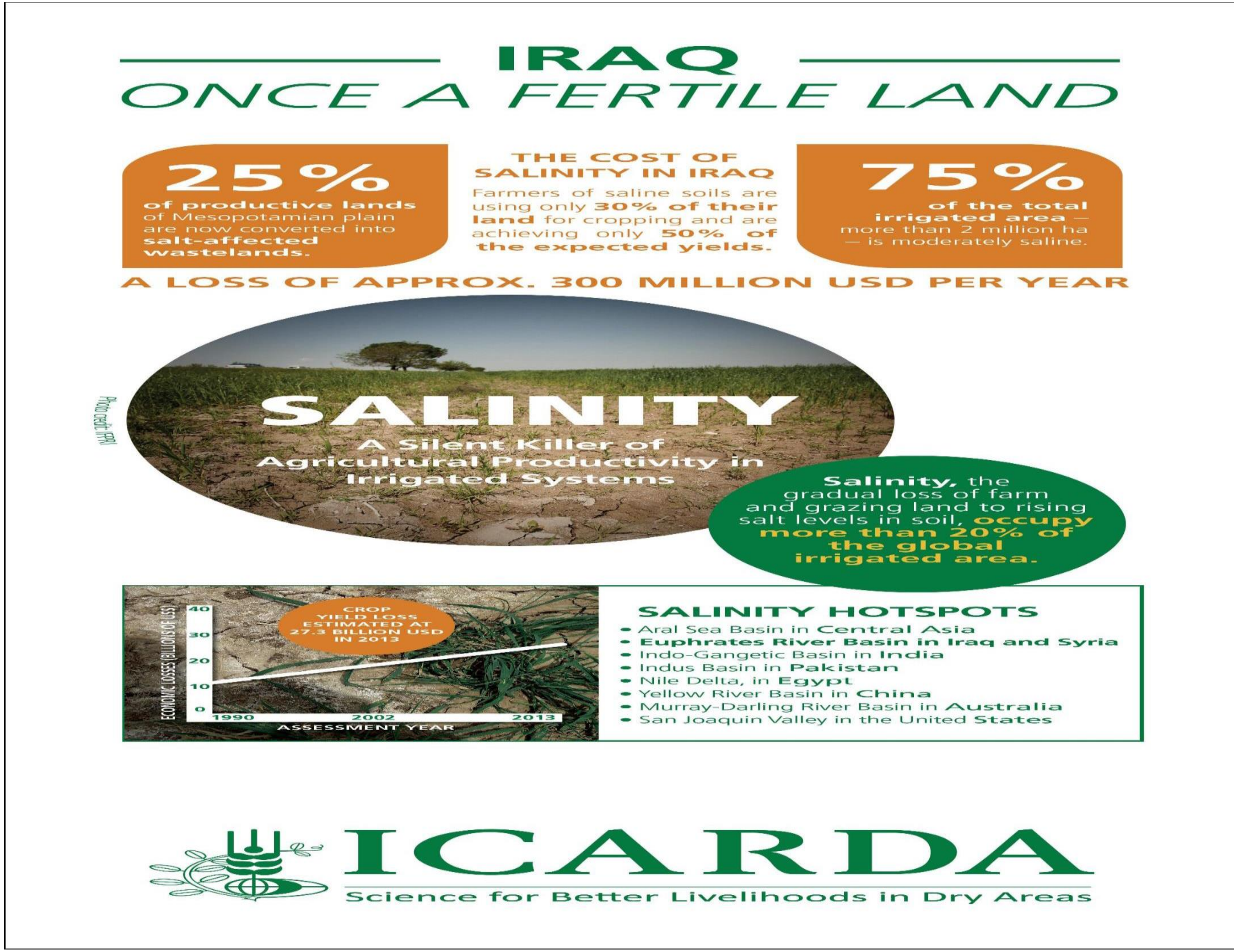
Variables	Mussayeb	Dujaila	AbulKhasseb
Farmer Education Level	+ **	-**	-*
Age	- **	-	-
Age^2	+ **	-	+ *
Income from Farm	+	-	-
N	220	141	124

Source: Computed from Frontier 4.1 MLE / Survey data, 2012.

Key Information

Welcome to the Iraq Salinity Information Platform:
http://iraq-salinity-platform.icarda.org/Pages/default.aspx

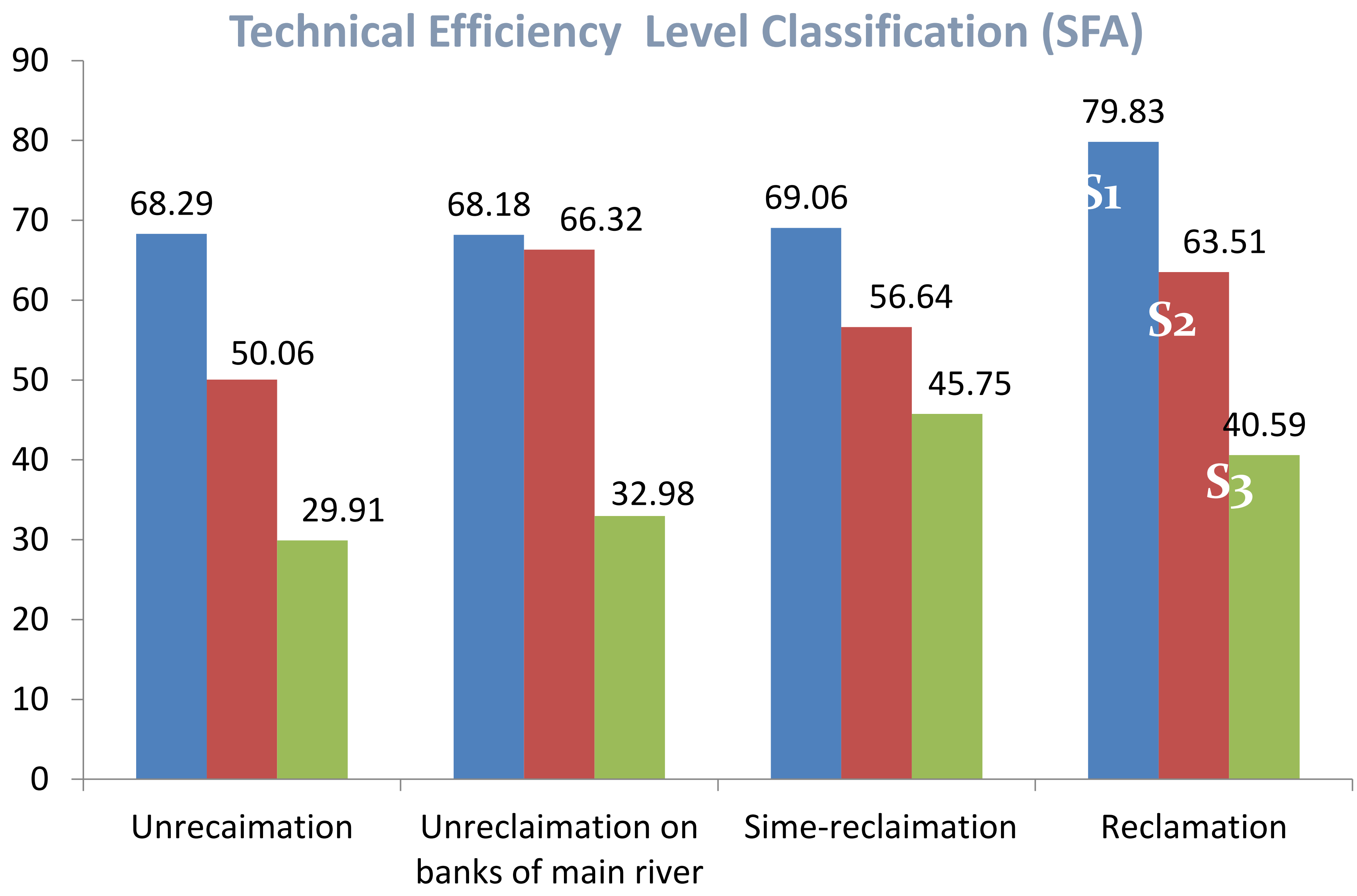
Thank You for Your Attention



Economic and Environmental Impacts of Salinity on Livelihoods in Iraq

SFA & DEA Results

PhD Student
Mohammed Jabar ABDULRADH
2017


Technical Efficiency Level Classification (SFA)
90
80
70
60
50
40
30
20
10
0
68.29
50.06
29.91
68.18
66.32
32.98
69.06
56.64
45.75
79.83
63.51
40.59
S1
S2
S3
Unrecaimation
Unreclaimation on banks of main river
Sime-reclaimation
Reclamation

Mean TE, Actual and potential yields, and potential Yield loss by EC Groups

EC-General	TE	Mean Actual yield kg/ha	Mean Potential yield kg/ha	Mean Potential yield loss kg/ha	Percent of Potential yield loss kg/ha
S_1	75	3574	4734	1160	25.20
S_2	58	2743	4716	1972	42.18
S_3	32	1416	4417	3001	68.46
Total	60	2827	4654	1827	40.28
S_1	80	3574	4395	821	19.71
S_2	79	2743	3471	728	21.43
S_3	39	1416	3595	2178	60.55
Total	70	2827	3942	1115	29.84

DEA results classification based on and soil EC

DEA

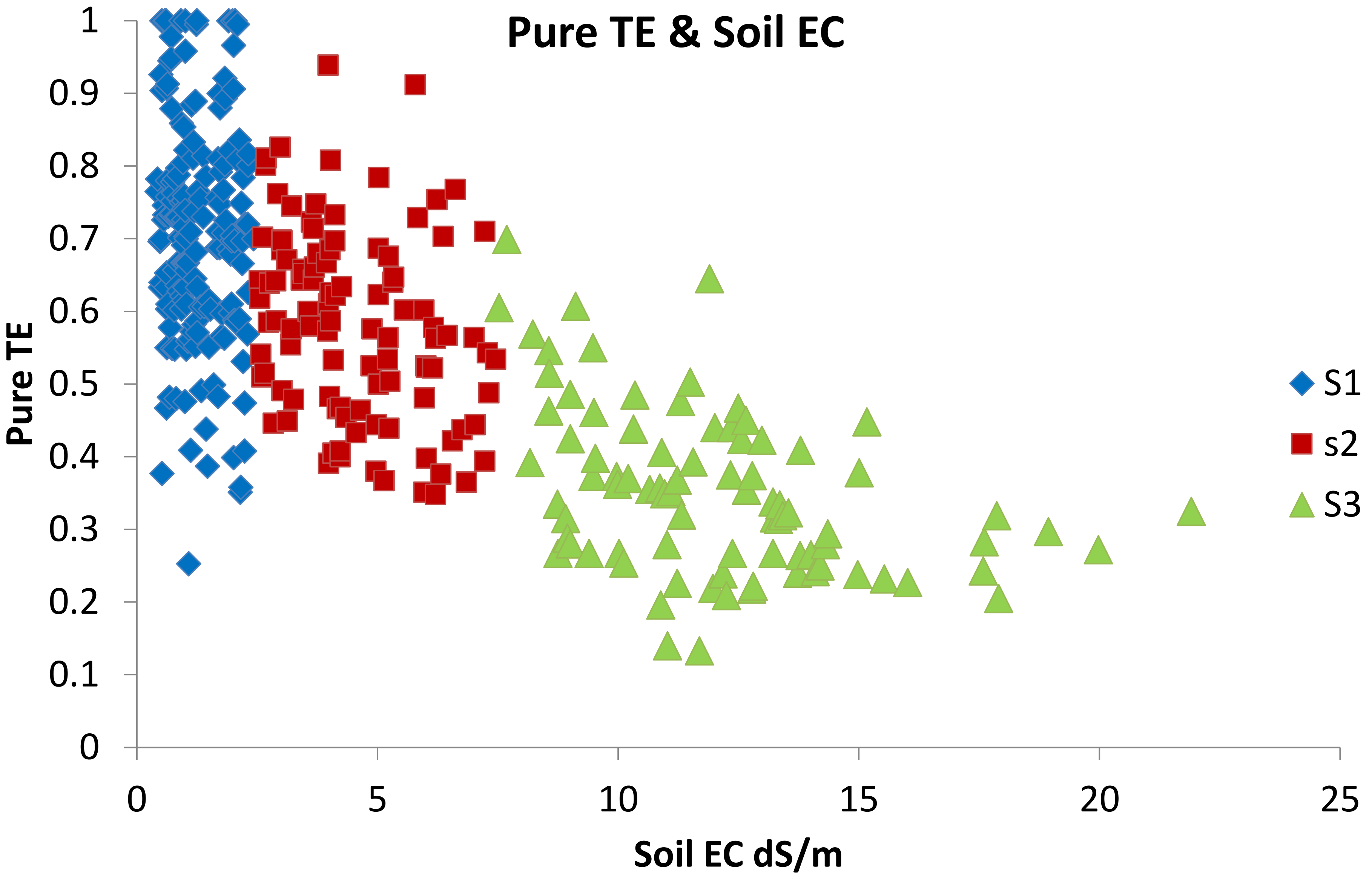
	CRS				VRS			
	S_1	S_2	S_3	MEAN	S_1	S_2	S_3	MEAN
TE	64	49	25	50	93	90	90	91
AE	63	61	56	61	70	70	62	68
EE	40	29	14	31	65	63	56	62

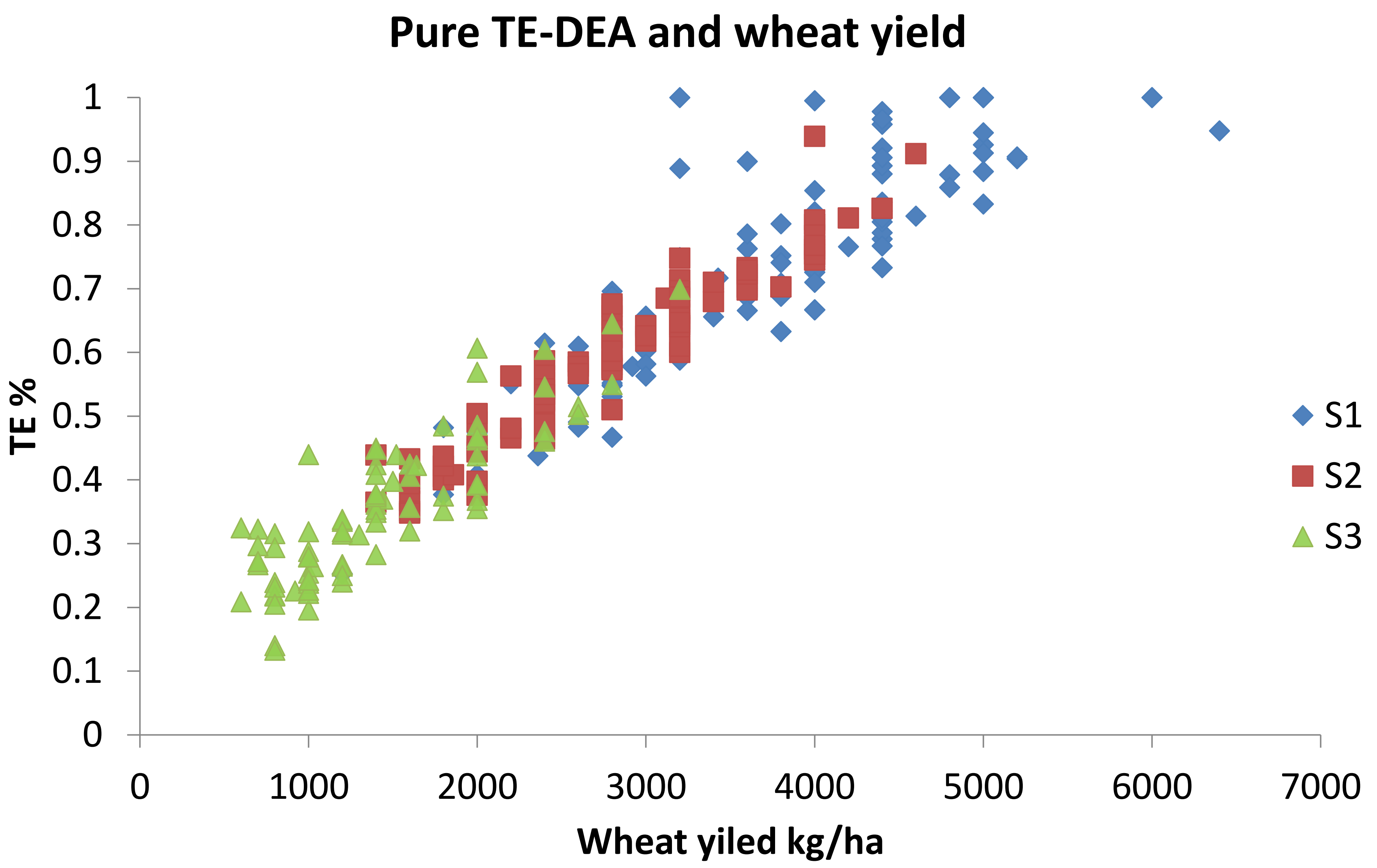
DEA results classification based on and soil EC (Maximum & Minimum values)

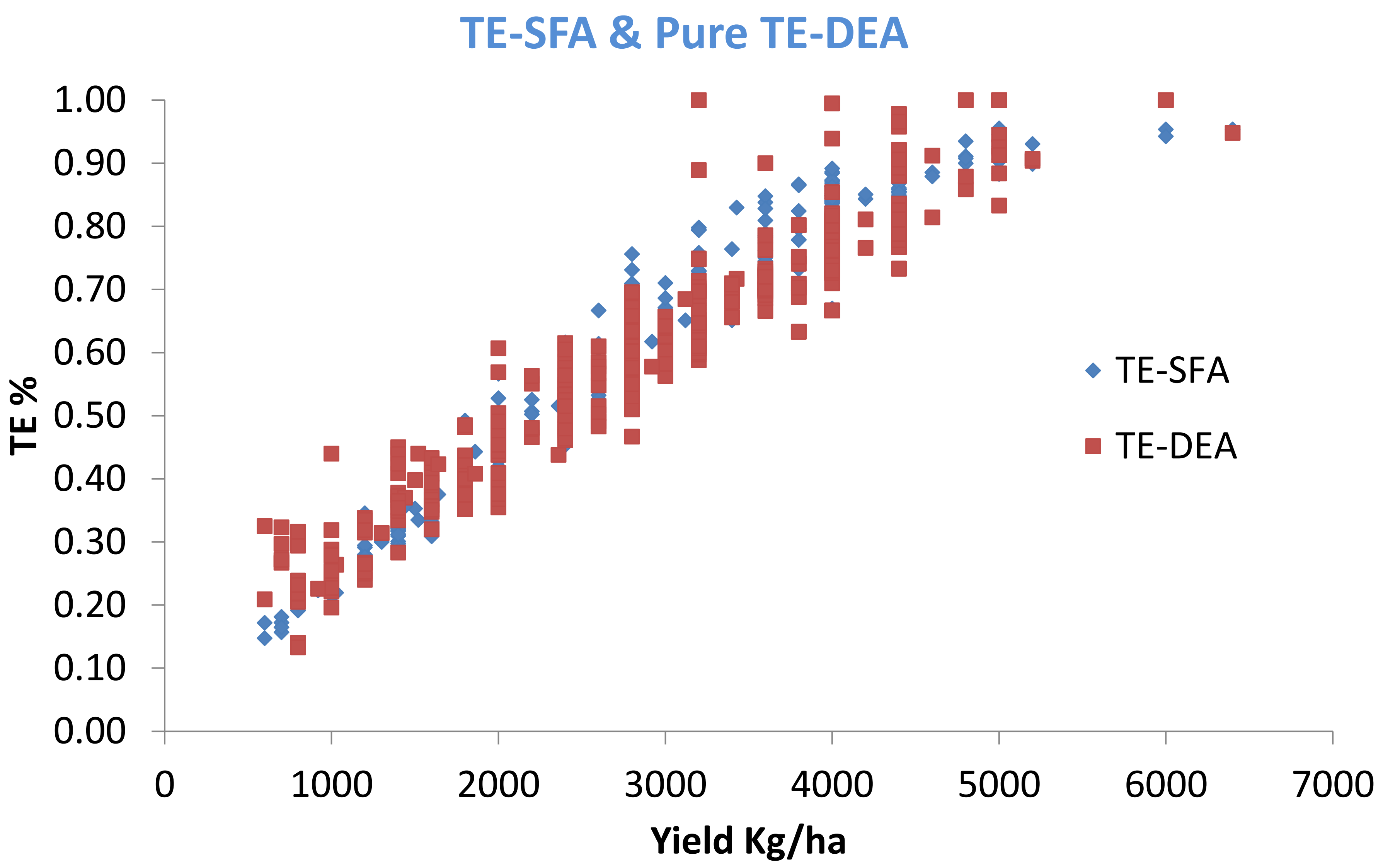
	CRS				VRS			
MIN	S_1	S_2	S_3	MEAN	S_1	S_2	S_3	MEAN
TE	25	26	8.5	8.5	77	72	63	63.8
AE	36	43	34	34	44	49	39	39
EE	10	15	5	5	41	43	36	36
TE	1	87	67	1	1	1	63	1
AE	1	89	86	1	1	96	88	1
EE	1	52	33	1	1	96	83	1

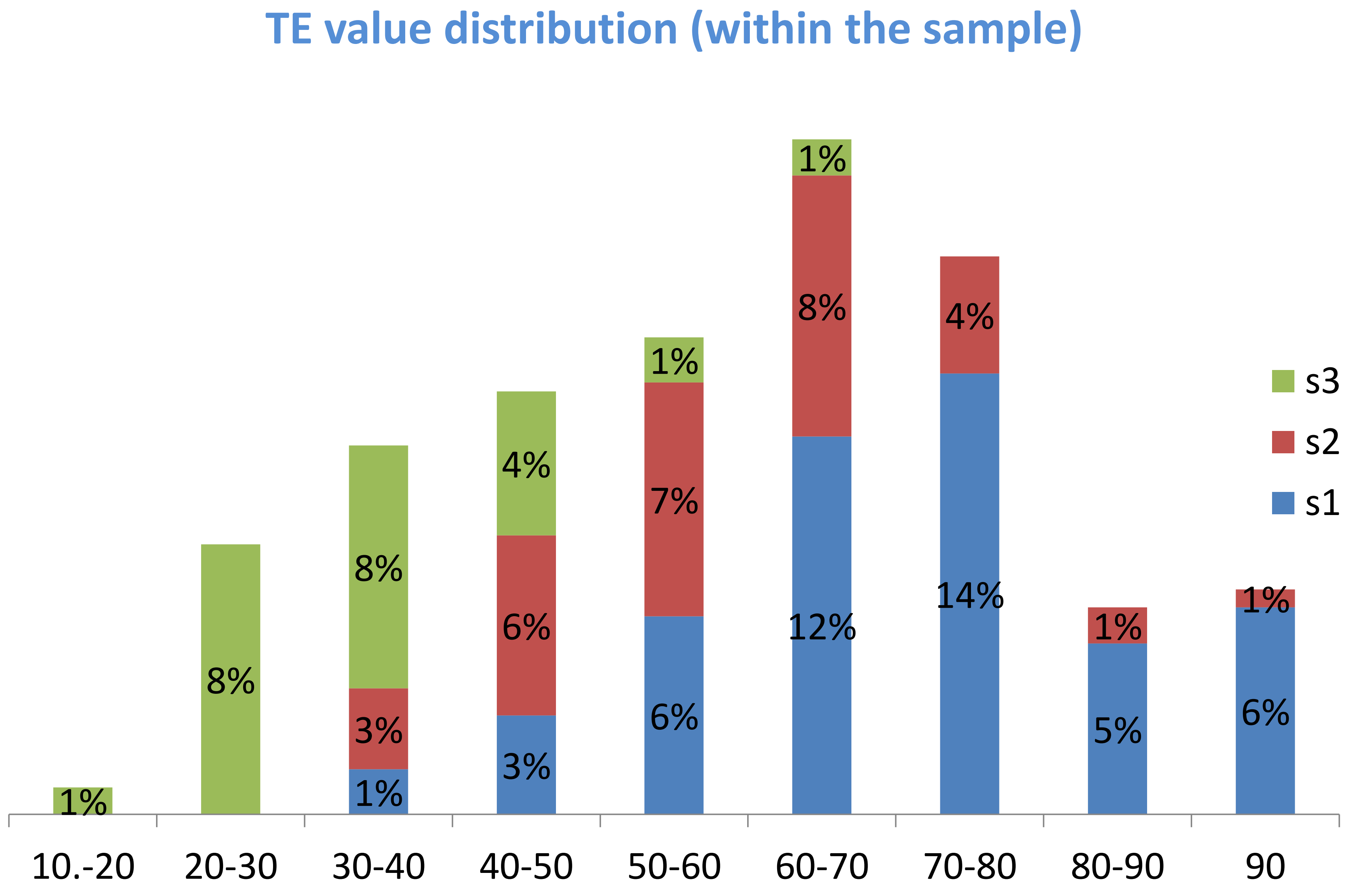
DEA results of pure TE classification based on and soil EC

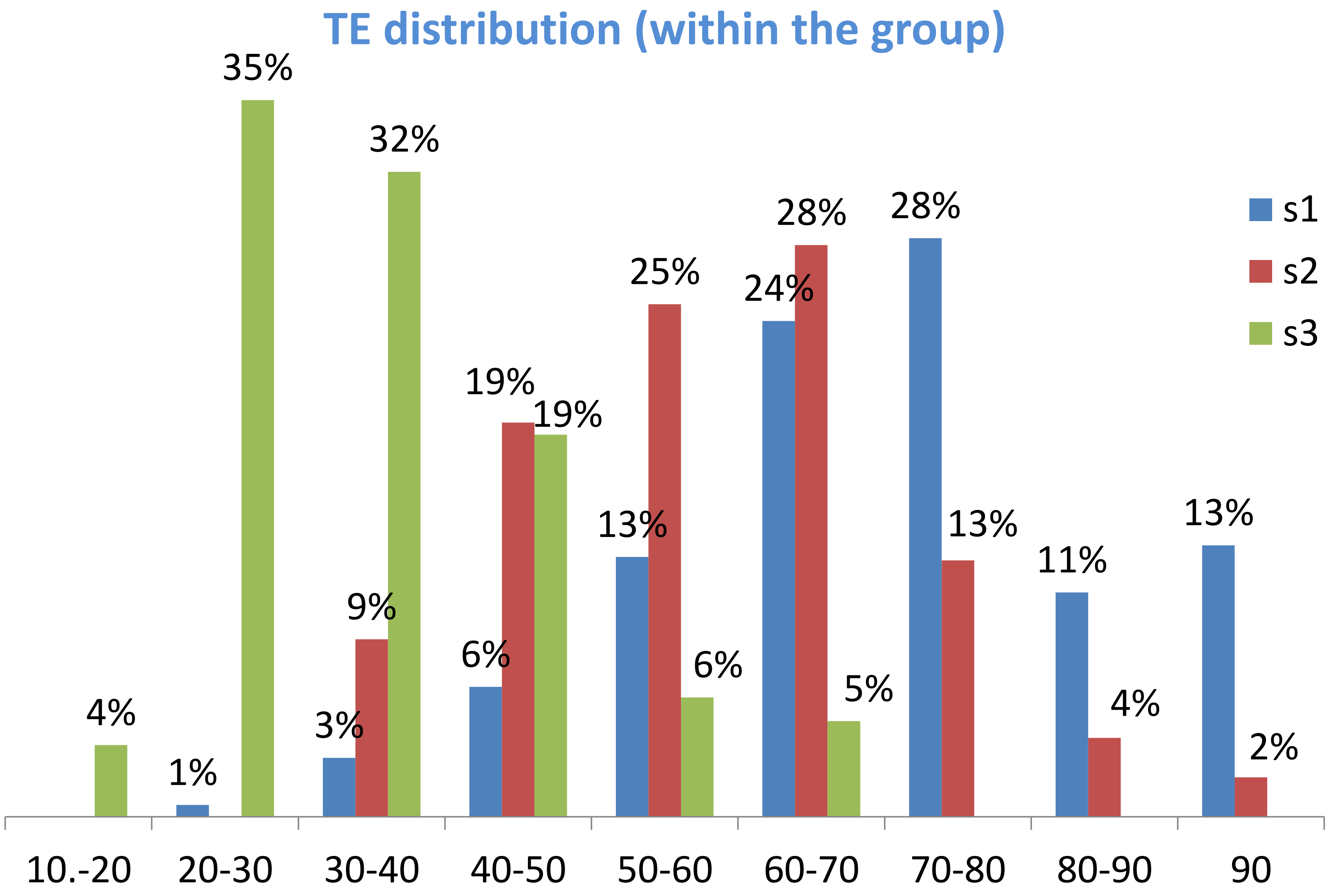
	Max	Min	Mean
S_1	**1**	**25.3**	**70.62**
S_1	**93.3**	**34.8**	**58.4**
S_1	**69.9**	**13.3**	**35.2**


Pure TE & Soil EC
Pure TE
Soil EC dS/m
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
S1
s2
S3

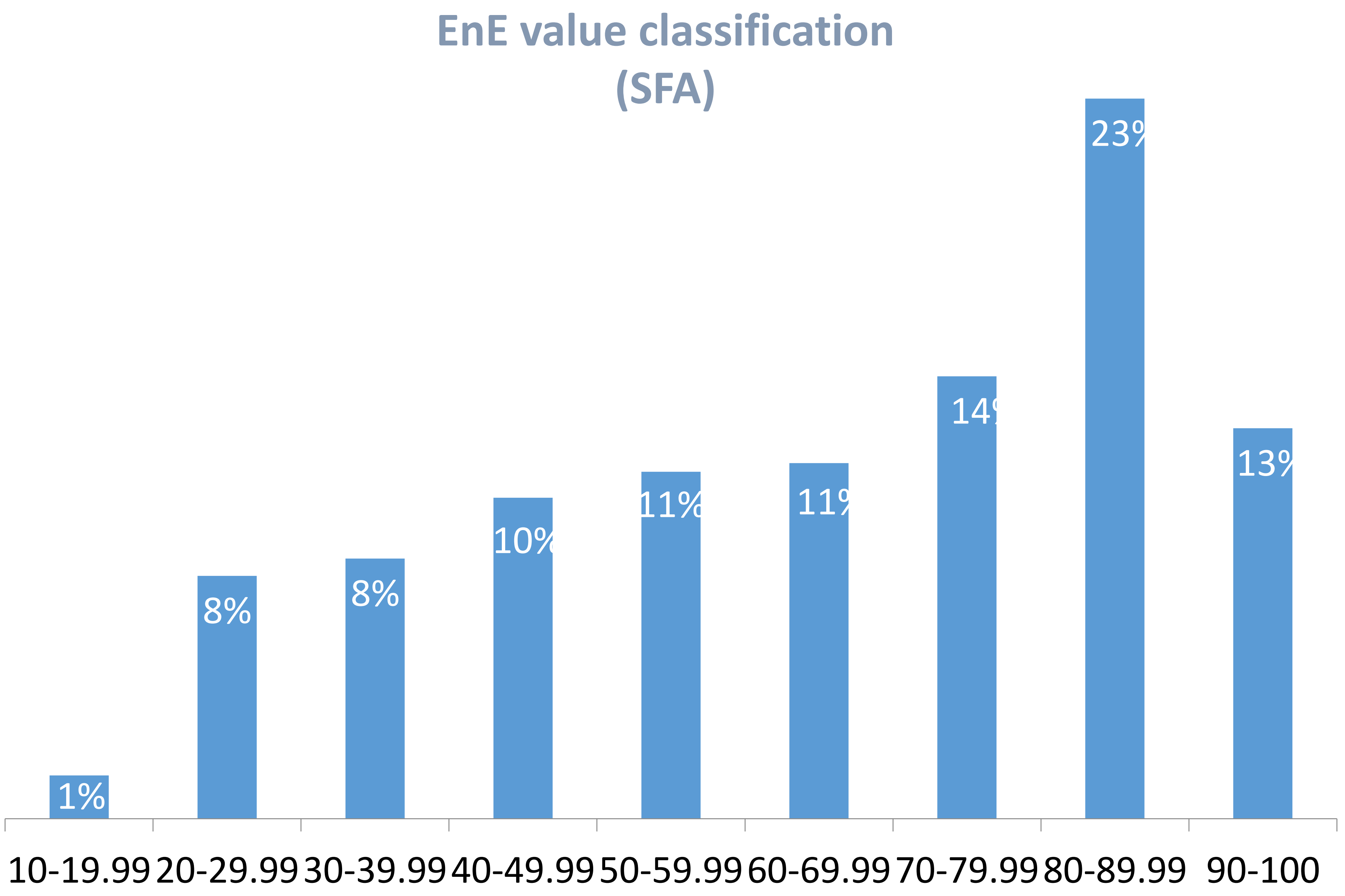

Pure TE-DEA and wheat yield
TE %
Wheat yiled kg/ha
S1
S2
S3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1000
2000
3000
4000
5000
6000
7000

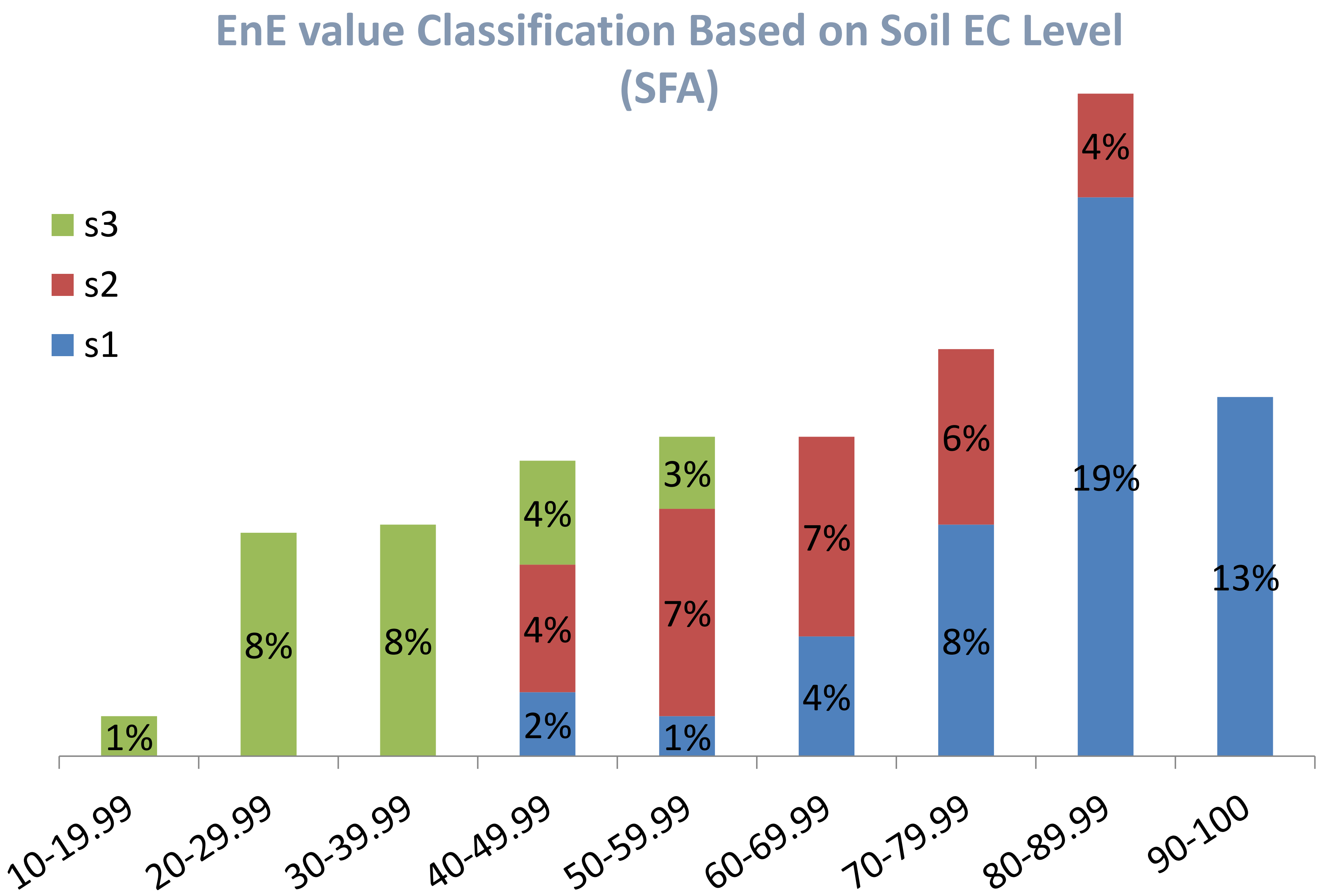

TE-SFA & Pure TE-DEA
TE %
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
1000
2000
3000
4000
5000
6000
7000
Yield Kg/ha
TE-SFA
TE-DEA


TE value distribution (within the sample)
1%
8%
8%
3%
1%
4%
6%
3%
1%
7%
6%
1%
8%
12%
4%
14%
1%
5%
1%
6%
s3
s2
s1
10.-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90


TE distribution (within the group)
35%
32%
28%
28%
25%
24%
19%
19%
13%
13%
13%
11%
9%
6%
6%
5%
4%
4%
3%
2%
1%
s1
s2
s3
10.-20
20-30
30-40
40-50
50-60
60-70
70-80
80-90
90

Environmental Efficiency
(EnE)


EnE value classification
(SFA)
1%
8%
8%
10%
11%
11%
14
23%
13%
10-19.99
20-29.99
30-39.99
40-49.99
50-59.99
60-69.99
70-79.99
80-89.99
90-100

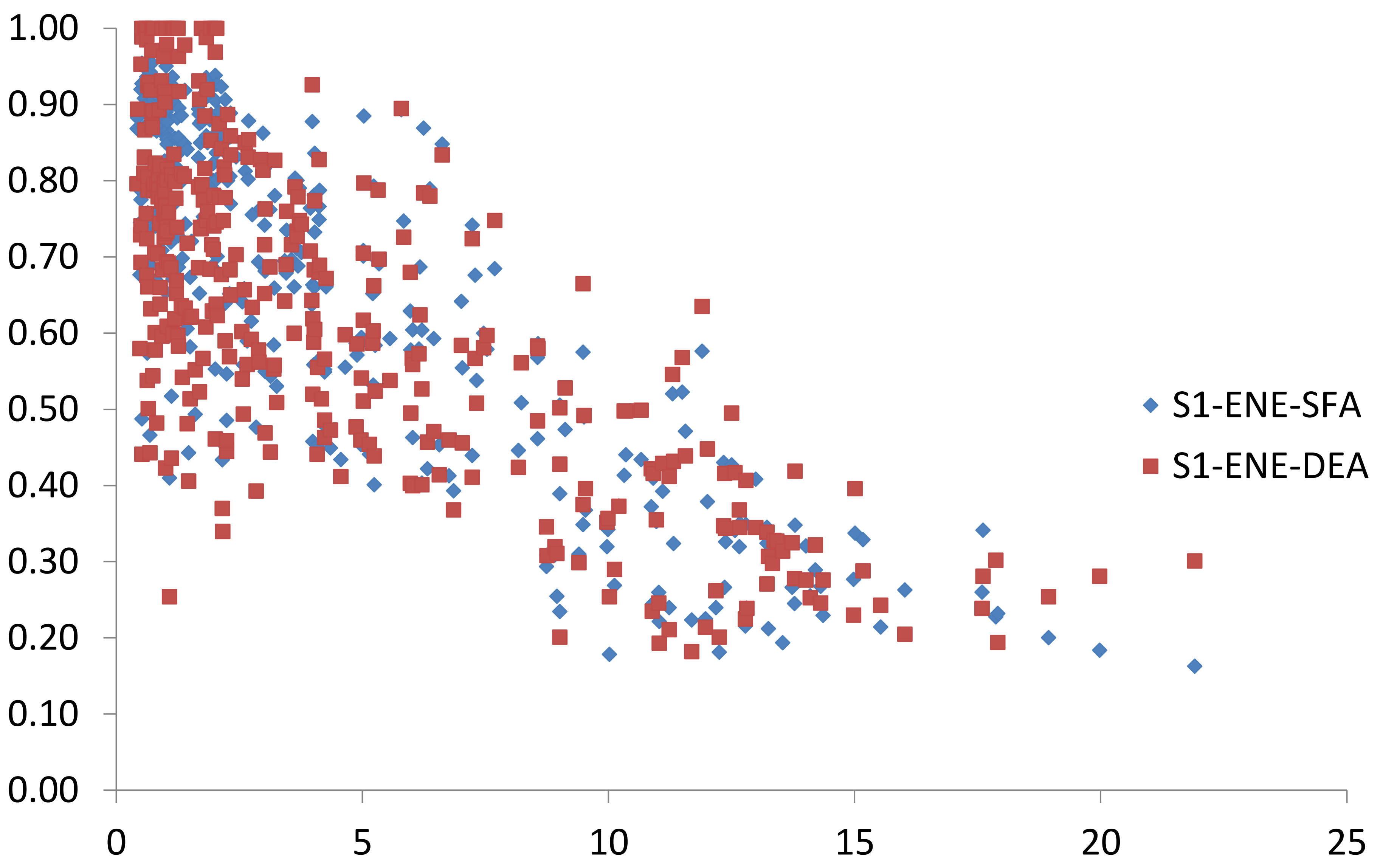

EnE value Classification Based on Soil EC Level
(SFA)
s3
s2
s1
1%
8%
8%
4%
4%
2%
3%
7%
1%
7%
4%
6%
8%
4%
19%
13%
10-19.99
20-29.99
30-39.99
40-49.99
50-59.99
60-69.99
70-79.99
80-89.99
90-100

CD parameters of environmental efficiency estimation

Costanst	**8.64**	**0.57**	**15.20**
Ln (Number of Irrigation)	**0.25**	**0.09**	**2.86**
Ln (Agri-chemical)L/ha	**-0.07**	**0.03**	**-2.40**
Ln (Fertilizer Uera) kg/ha	**-0.06**	**0.05**	**-1.19**
Ln (Fertilizer DAP) kg/ha	**-0.01**	**0.01**	**-0.67**
Ln (Seed Quantity) kg/ha	**-0.02**	**0.09**	**-0.22**
Ln (Labour) Man-days	**-0.10**	**0.06**	**-1.55**
Ln (Mechnization) Mach-hour	**-0.11**	**0.13**	**-0.79**
Soil EC level	**0.57**	**0.06**	**9.06**
Location	**-0.03**	**0.10**	**-0.30**
Position	**-0.35**	**0.09**	**-3.89**
Education Level	**0.00**	**0.08**	**0.00**
Agricultural Experience	**0.03**	**0.05**	**0.59**
Wheat Variety	**-0.02**	**0.03**	**-0.54**
Wheat share	**0.07**	**0.08**	**0.80**
sigma-squared	**0.14**	**0.02**	**7.72**
gamma	**0.83**	**0.05**	**16.26**

Environmental Efficiency Classification

SFA	S1	S2	S3	Average
Mean	76.64	64.12	34.11	65.02
Max	95.45	89.33	68.46	95.45
Min	40.99	39.31	16.30	16.30
DEA				
Mean	70.22	61.34	36.30	62.25
Max	1	92.60	74.80	1
Min	25.40	36.80	18.20	18.2


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
15
20
25
S1-ENE-SFA
S1-ENE-DEA