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Strengthening Soil Databases for Climate Change and Food Security Modeling Applications

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Bernardo Chaves and Gerrit Hoogenboom

AgWeatherNet

Washington State University, Prosser, Washington, USA

INTRODUCTION

Climate change is a hazard to the food security of a growing world population since it affects agriculture and likewise, agriculture and natural resource management affect the climate system. The relationships between all these factors including polices, political conditions, economical management and pest and diseases, and how they interact are not currently well-understood, nor are the advantages and disadvantages of different responses to climate change. In the face of climate change it is important to integrate knowledge about it to generate realistic solutions for agriculture, and food security in a meaningful and innovative way. Research in this topic has focused on addressing the needs for methods, models, databases and system metrics aimed at enhanced assessment and improved methodologies for the impact of climate change on agricultural systems and the development of different policy and program interventions to foster adaptation and mitigation in terms of poverty alleviation, food security and environmental health. This work should be in a framework and set of modeling tools and databases to analyze the implications of human responses to the climate challenge in terms of regional food security and the preservation of important ecosystem services, upon which the long-term sustainability of global agriculture must be based (Thornton and Cramer, 2012).

One important component of the agricultural production system is the soil that is the end product of the interaction of climate (temperature, precipitation), relief (slope), organisms (flora and fauna), parent materials (original minerals), and time. The International Soil Reference and Information Centre (ISRIC) had developed detailed geo-referenced world soil databases since 1966. The latest version of ISRIC-WISE Harmonized Global Soil Profile Database (Ver. 3.1) contains 10,253 profiles from 149 countries. The profile data were extracted from a wide range of sources and harmonized with respect to the original (1974) and revised (1988) legend of the FAO-UNESCO Soil Map of the World. Profiles have been described, sampled, and analyzed according to the methods and standards that are used in the originating countries. However, the analytical results for a given property cannot always be compared directly. Therefore the amount of measured data available for modeling is sometimes much less than expected. WISE was specifically developed for land-related applications at continental and global scales (Batjes, 2008, 2009; Romero et al., 2012).

Crop models have been used extensively to assess different environmental impacts and can be used to support policy decisions on temporal and spatial scales. The Cropping System Model (CSM) of the Decision Support System for Agrotechnology Transfer (DSSAT) can be used at a farm level to determine the impact of climate change on production and potential adaptation practices that should be developed for farmers. It can also be used at a regional level to determine the impact of climate change at different spatial scales. However, the main limitation is the availability of accurate input data to run these crop models (Jones et al., 2008; Muchena and Iglesias, 1995). Crop model simulations also have been a major source of information for the Intergovernmental Panel on Climate Change (IPCC) assessments for agriculture (Sivakumar et al., 2001; Easterling et al., 2007).

Most of the soil profiles of the WISE 3.1 database were assumed to be agricultural soils or soils suitable for crop production or rangeland. Nevertheless, an appropriate use of the data permits for a wide range of agricultural and environmental applications at regional, continental, and global scales. To dispel any concern about the possibility that DSSAT to detect temporal and spatial yield variability at global level of the WISE3.1 profiles, treatments and crops, as well as the determination of representative yield profiles for different type of soils, we have as an objectives to convert the database WISE Version 3.1 into a format that is applicable for the Decision Support System for Agrotechnology Transfer (DSSAT) version 4.5 and equivalent crop simulation models, to estimate missing values for the most important soil surface and soil profile crop model parameters, to apply rigorous quality control procedures and also to evaluate converted WISE3.1 for applications for some crops, treatments and different environmental scenarios trough time, and to summarize the soil profiles according to the FAO90 soil classification.

METHODOLOGY

Soil profile conversion

The WISE Version 3.1 database contains 10,253 profiles (47833 layers) from 149 different countries. Initially, 8,312 profiles representing 38,454 unique soil layers had complete values for soil texture, including sand, silt and clay. After estimating texture, organic carbon and nitrogen where the first, last or intermediate layers were missing 1301 profiles were added representing 6136 layers for a total of 9,613 profiles and 44,590 layers that represent 93.76% profiles of the original WISE Version 3 database. These profiles were converted into a suitable format for DSSAT following the guidelines and conversion programs developed by Gijsman et al. (2007). The original WISE Version 3.1 database included 66 soil characteristics (columns). The transformed file for DSSAT included 50 parameters, of which 14 were calculated (Table 1). The original program that was developed by Gijsman et al. (2007) was written in the computer language FORTRAN. To make the conversion process more flexible, the software SAS v9.2 was used to read the WISE v3.1 database directly and to convert it into DSSAT format. This allows for easy adaptation to create output files for different modeling systems and also to conduct a detailed statistical analysis of the original data base.

Soil profile quality control

Based on information available from the literature, the potential range of each physical and chemical parameter was checked. The parameters that had values that were out the range were correlated with other parameters and were included when the correlation was positive despite being out of the initial range. Missing values for organic carbon and total nitrogen were calculated considering traditional relationships that have been defined in the literature. Values that were out of the range and values that were missing were estimated using the mean value of that parameter within the appropriated range by soil type based on the World Reference Base for Soil Resources (WRB2006) and soil depth.

Procedures for calculating the DSSAT soil parameters

The texture code for the soil surface (SLTX) was established based on the original computer code to classify the soils as S, LS, SL, L, SIL, SI, SCL, CL, SICL, SC, SIC and C.

Latitude (LAT) and longitude (LONG) were converted from a format using degrees, minutes and seconds into decimal format. Most of the profiles had coordinates (7720 profiles). 1893 profiles had missing coordinates missing. However, the soil data were valid and suitable for analysis and crop model simulation.

Soil color SCOM was determined considering the values for HUE, VALUE and CHROMA to assign the colors: BLACK (BK), BROWN (BN), GREY (G), RED (RED) and YELLOW (Y). The color brown was assigned to those profiles with missing or erroneous values for hue, value or chroma.

Albedo and drainage rate SLDR values were calculated based on Gijsman et al. (2007).

The runoff curve number SLRO variable as defined by the US Natural Resource Conservation Service (NRCS) was created considering the hydrological conditions, which depend on the drainage rate and the type of soil texture, and the slope. The values for SLRO ranged from 61 to 94.

The lower limit of plant extractable soil water SLLL and the drained upper limit SDUL were determined using the k-Nearest Neighbor (kNN) methodology from 272 field measured profiles. They were based on the original sand and clay fractions and soil organic carbon concentration to calculate the weighted distance (1, 1.81 and 54.21 respectively) and estimated the SLLL and SDUL using the weighted mean (0.047619; 0.02381; 0.015871; 0.011905; 0.009524 and 0.007937) of the six nearest or similar layers of those measured in the field (Ritchie et al. 1987; Jagtap et al., 2004). The pedotransfer functions developed by Saxton et al. (1986) and Saxton and Rawls (2006) were also used to calculate these two variables. A comparison among these three methodologies showed that the kNN method provided a more accurate estimation for SLLL and SDUL.

Table 1. Soil data input for a daily time step crop simulation model.

Characteristic	Definition	Units
	General Data	
SLTX	Texture code of surface layer	
SLDP	Soil depth	cm
SLDESCRIP	Soil description or local classification	
COUNTRY	Country name	
LAT*	Latitude	
LONG*	Longitude	
SCSC FAMILY	Soil Class	
	Profile Data	
SCOM*	Soil color (Munsell color system)	
SALB*	Albedo	
SLU1*	Evaporation limit	cm
SLDR*	Drainage rate	Fraction day^{-1}
SLRO*	Runoff curve number	
SLNF	Mineralization factor	0-1 scale
SLPF	Soil fertility factor	0-1 scale
SMHB	pH in buffer determination method	
SMPX	Extractable phosphorus determination code	
SMKE	Potassium determination code	

	First tier	
SLB	Depth until base of layer	cm
SLMH	Master horizon	
SLLL*	Lower limit of plant extractable soil water	cm^3cm^{-3}
SDUL*	Drained upper limit	cm^3cm^{-3}
SSAT*	Saturated upper limit	cm^3cm^{-3}
SRGF*	Root growth factor	0-1 scale
SSKS*	Saturated hydraulic conductivity	$cm\ h^{-1}$
SBDM*	Bulk density (moist)	$g\ cm^{-3}$
SLOC	Soil organic carbon concentration	%
SLCL	Clay (<0.002 mm)	%
SLSI	Silt (0.002 to 0.05 mm)	%
SLCF	Coarse fraction (>2mm)	%
SLNI	Total nitrogen concentration	%
SLHW	pH in water	
SLHB	pH in buffer	
SCEC	Soil cation exchange capacity	$Cmol(+)kg^{-1}$
SADC	Soil adsorption coefficient (anion exchange cap.)	0-1 scale
	Second tier	
SLPX	Extractable soil phosphorus concentration	$mgkg^{-1}$
SLPT	Total soil phosphorus concentration	$mgkg^{-1}$
SLPO	Soil organic phosphorus concentration	$mgkg^{-1}$
CACO3	Soil $CaCO_3$ concentration	%
SLAL	Soil aluminum concentration	$mgkg^{-1}$

SLFE	Soil iron concentration	mgkg^{-1}
SLMN	Soil manganese concentration	mgkg^{-1}
SLBS	Soil base saturation	%
SLPA	Soil phosphorus isotherm A	mmol kg^{-1}
SLPB	Soil phosphorus isotherm B	mmol kg^{-1}
SLKE	Exchangeable potassium soil concentration	cmol(+) kg^{-1}
SLMG	Exchangeable magnesium concentration	cmol(+) kg^{-1}
SLNA	Exchangeable sodium concentration	cmol(+) kg^{-1}
SLSU	Soil sulfur concentration	cmol(+) kg^{-1}
SLEC	Soil electric conductivity	dSm^{-1}
SLCA	Soil calcium concentration	cmol(+) kg^{-1}

* Calculated variables

The saturated upper limit SSAT is a proportion of the porosity POR which was derived from the bulk density SBDM and the factor APD that included organic matter SOM and minimum bulk density BDMIN (Gijsman et al. 2007; Suleiman and Ritchie, 2001). The minimum bulk density BDMIN was calculated from the soil triangle with contours for the iso-bulk density lines using a simple interpolation method for the 5151 possible combinations of sand and clay (Adams, 1973; Rawls, 1983).

The variables mentioned above were calculated using the following equations and conditions:
SOM = 1.73*SLOC, where SLOC is the organic carbon concentration.
BD = 100/((SOM/0.224) + ((100-SOM)/BDMIN)), and if SOM <= 0 then BD= 100/((1.72/0.224) + ((100-SOM)/BDMIN)).
APD = 100/((SOM/1.4) + ((100-SOM)/2.65)).
IF BD > 0 and APD > 0 then POR = 1 - BD/APD.
IF BD > 0 and APD <= 0 then POR = 1 - BD/2.65.
If bulkdens = . then SBDM = BD.
IF bulkdens = ne . then SBDM = bulkdens; where bulkdens is the original bulk density of the WISE v3 data base.
IF bulkdens <0.5 or bulkdens > 1.8 then SBDM=BD.
IF texture = 'S ' or texture = 'LS ' or texture = 'SL' then SSAT = 0.93*POR.
IF texture = 'L' or texture = 'SIL' or texture = 'SI' or texture = 'SCL' or texture = 'SC' then SSAT = 0.95*POR.
IF texture = 'C' or texture = 'CL' or texture = ‘SIC’ or texture ='SICL' then SSAT = 0.97*POR.
IF SDUL >= SSAT and SSAT > 0 then SDUL= 0.95*SSAT.

Saturated hydraulic conductivity SKSS was calculated as a function of the porosity (POR) and drained upper limit (SDUL):

SSKS = (75/24)*((POR-SDUL)/SDUL)**2.

The root growth factor SRGF was calculated as an exponential function of the soil depth:

z = topdep + (botdep-topdep)/2; SRGF=exp(-0.02*z); and if botdep < 20 then SRGF = 1, where topdepth is the depth at the top of the layer and botdepth is the depth at the bottom of the layer.

The ratio C/N was used to estimate the missing values for organic carbon (SLOC) and total nitrogen concentration (SLNI) (Brady and Weil, 1999). The C/N ratio in the organic matter of arable (cultivated) surface horizons had an average relationship near 10:1. The missing value for SLOC was estimated as: SLOC=SLNI *10, when a value for SLNI was found. Missing values for SLNI were estimated as:

SLNI=SLOC*0.1, when a value for SLOC was found.

Soil nitrogen that was estimated using this approach provided a value that is not total nitrogen as required and is underestimated. In contrast, the estimated organic carbon from the soil nitrogen was overestimated.

The relationship between SLOC, SLNI and soil depth was checked and the missing values were estimated based on the mean values of the soil classification (WRB, 2006) and soil depth.

The remaining variables of the DSSAT file were assigned from the WISE v3 database. Missing values of the numeric variables were identified with the value of -99 based on DSSAT standards.

Procedures to correct errors

In order to verify if the data during evaluation were within the range of values as published in the literature, the following rules were applied. The values that were out range were not deleted, but were individually checked to determine if there was any reason why the values were out of range. If they were out of range, they were estimated based on the soil classification (WRB, 2006) and soil depth.

SALB (Albedo) was calculated following the conditions:

If color was BK then SALB=0.09.

If color was BN then SALB=0.13

If color was G then SALB=0.13

If color was RED then SALB=0.14

If color was Y then SALB=0.17

SLU1 (Evaporation limit): Values must be less or equal 12.00.

SLDR (Drainage rate) and SLRO (Runoff curve number): there is a relationship between these parameters as shown in (Table2).

Table 2. Relationship between drainage rate and runoff curve number.

Drainage rate	Hydrological group	Runoff curve number for different slope angles			
		0-2%	2-5%	5-10%	>10%

0.75-0.85	A	61	64	68	71
0.60-0.75	B	73	76	80	83
0.40-0.60	C	81	84	88	91
0.25-0.60	C	81	84	88	91
0.05	D	84	87	91	94
0.01	D	84	87	91	94

SLNF (Mineralization factor): SLNF=1.
SLNF (Soil fertility factor): SLPF=1.
SLB (Soil depth until the base of the layer): Value in first horizon must be lower than value in second horizon and so on.
SLLL, SDUL, SSAT (Lower limit, drained upper limit and saturated upper limit): SLLL<SDUL<SSAT.
SSKS (Saturated hydraulic conductivity): Values should range from 0.05 cmh^{-1}, for clayey soils, to 63 cm h^{-1} for sandy soils.
SBDM (Bulk density): The range should be from 0.5 to 1.80 g cm^{-3}.
If SLCL > 50% then SBDM ranges between 0.5 and 1.5 gcm^{-3}.
If SLCL <= 50% then SBDM ranges between 1.3 and 1.8 gcm^{-3}.
SLOC (Soil organic carbon concentration): Values between 0 to 10 %.
SLNI (Total nitrogen concentration): Values between 0 to 0.5%.
SLCL (Clay): Values less or equal 100%.
SLSI (Silt): Values less or equal 100%.
SLCF (Coarse fraction): Values less or equal 100%.
SLHW (pH in water): Values between 3.5 and 9.
SLHB (pH in buffer): Values less than 9.
SLHB < SLHW.
SCEC (Soil cation exchange capacity):
If SLHW < 6 then SCEC < 15 cmol(+)kg^{-1}
If SLHW >= 6 then (15 <= SCEC <= 45) cmol(+)kg^{-1}.
SADC (Soil adsorption coefficient): Equal -99.
SLPX (Extractable soil phosphorus concentration): Equal -99.
SLPTL (Total soil phosphorus as P concentration): Values less than 1500 mg kg^{-1}.
SLPO (Soil organic phosphorus concentration): less than 200 mg kg^{-1}.
CACO3 (soil CaCO3 concentration): Values less than 50%.
SLAL (Soil aluminum concentration): Values 10 cmol(+) kg^{-1} and SLHW less than 5.8.
SLFE and SLMN (Soil iron and manganese concentration): If there is any data, should be when SLHW is less than 6.
SLBS (Soil base saturation): Values less or equal 100%.
SLPA and SLPB (Soil phosphorus isotherm A and B): Values equal -99.
SLKE (Exchangeable potassium soil concentration): Values less than 30 cmol(+) kg^{-1}.
SLMG (Soil magnesium concentration): Values less than 20 cmol(+) kg^{-1}.
SLNA (Soil sodium concentration): Values less than 20 cmol(+) kg^{-1}.
SLSU (Soil sulfur concentration): Values less than 15 cmol(+) kg^{-1}.
SLEC (Soil electric conductivity): Values less than 16 dS m^{-1}.
SLCA (Soil calcium concentration): Values less than 35 cmol(+) kg^{-1}.

Procedure to assessment the performance of the profiles

Sensitivity analysis

In order to evaluate the performance of the converted profiles, simulations for maize, soybean, sorghum and wheat were conducted with a sensitivity analysis approach using the standard experiments of DSSAT v4.5, particularly comparing the irrigated high nitrogen (IHN) and rainfed (NON) treatments. To simulate maize yield and other variables, the rainfed low nitrogen and irrigated high nitrogen treatments of the experiment UFGA8201MZ, 2Nx3I, Gainesville Florida, 1982, was used. For soybean, the rainfed and irrigated treatments of the experiment UFGA7801SB BRAGG, Irrigated and Non-Irrigate in Gainesville Florida, 1978, were applied. For sorghum, the N check 0 N (NON) and 80 kg ha^{-1} Urea-N split application (IHN) treatments of the experiment ITHY8001 ICRISAT Alfisol N 1980 EXPT 80-1, Patancheru, India, 1980, was used. For wheat, the Dryland (NON) and Irrigated 180 kg ha^{-1} of nitrogen (IHN) treatments of the experiment KSAS8101WH N response, Kansas State, 3FE (N)*2IR, 1981, was used. The details of the standard experiments used for these simulations can be found in the DSSAT software selecting each one of the crops simulated. The weather data for each season and crop management of these experiments were kept the same, while the 9,613 soil profiles were used to simulate the yield for the crops mentioned above.

Seasonal analysis

In order to assess the behavior of the converted profiles to different environmental scenarios, 30 years of weather were automatic generated using the weather generator of DSSAT4.5 and two treatments: irrigated high nitrogen and rainfed, were evaluated for maize using the standard experiment UFGA8201MZ, 2Nx3I, Gainesville Florida. The FAO 1990 (FAO90) soil classification was included as a source of variation combined with the 30 seasons for each treatment. Analysis of variance for treatment considering year and type of soil (FAO90) and its interaction as a source of variation was conducted. The mean, median and the percentiles 10, 25, 75 and 90 for each group (FAO90) were determined, as well as the mean of each year and the interaction were calculated. For each group (FAO90), two approaches to calculate the mean profile were used: firstly, the mean of each quantitative variable was calculated weighed by the depth until base of each layer and then seasonal analysis was done. Secondly, the mean of the variables that did not require any calculation in the conversion from WISE3.1 to DSSAT format was calculated weighed by the depth until base and then the soil water content variables (SLLL, SDUL, SSAT) and (SRGF AND SSKS) were calculated as discussed previously. For both approaches, the most frequent values of qualitative variables (SLTX, SCOM, SALB, SLDR and SLRO) were used for each group (FAO90) and for each approach. The 25, 50 and 75 percentiles were also determined for the two approaches used. After that, a comparison of these statistics for the maize yield simulations and the mean and the percentiles of the mean profiles for each group (FAO90) were done. Also the percentiles of the soil depth were calculated and the mean of those profiles between 0 and 25%, 25% and 50%, 50% and 75% and 75% and 100% of the soil depth were calculated and then the simulations were done for each FAO90 group. The simulated yield of these last calculated profiles was compared with the same percentiles obtained for all profiles used to simulate the maize yield in each FAO90 groups.

Percentiles of the mean weighed by the depth until base of layer of the yield for rainfed treatment were determined and the profiles belong every inter percentile were identified. Mean of the inter-profiles for every pair of yield percentile was calculated as a representative one. A multivariate principal components analysis of the texture and water content variables, bulk density, root growth factor, saturated hydraulic conductivity, drainage rate, evaporation limit, soil organic carbon concentration and total nitrogen concentration was conducted and the percentiles were plotted to identify the correlation with the variables above mentioned. Multiple regression analysis using stepwise variables selection of the inter-percentiles rainfed yield and all the variables used in the principal components analysis was conducted.

RESULTS

General data for the entire profile

There were 1889 missing values for latitude and 2006 for longitude out of total of 9613 profiles. The frequency distribution tables of each categorical parameter for the profiles, including country, texture, Soil Reference Base for Soil Resources (WRB2006), SCOM, SALB, SLDR, SLRO and FAO90 soil classification for the entire profile, was determined (Tables 3, 4, 5, 6, 7, 8, 9 and 10).

Table 3. Frequency distribution for the number of profiles for each country.

Country	Frequency	Percentage
Afghanistan	5	0.05
Albania	31	0.32
Algeria	2	0.02
Angola	36	0.37
Antarctica	10	0.1
Argentina	247	2.57
Armenia	6	0.06
Australia	83	0.86
Azerbaijan	5	0.05
Bahrain	2	0.02
Bangladesh	18	0.19
Barbados	1	0.01
Belarus	77	0.8
Belgium	10	0.1
Benin	835	8.69
Bhutan	11	0.11
Bolivia	70	0.73
Botswana	786	8.18
Brazil	688	7.16
Bulgaria	45	0.47
Burkina Faso	2	0.02
Burundi	31	0.32

C African R	32	0.33
Cameroon	46	0.48
Canada	93	0.97
Chile	43	0.45
China	60	0.62
Colombia	153	1.59
Congo	139	1.45
Congo-Brazz	6	0.06
Costa Rica	27	0.28
Cuba	50	0.52
Czech Rep	38	0.4
Cote d'Ivoire	25	0.26
Denmark	19	0.2
Dominican Republic	7	0.07
Ecuador	54	0.56
Egypt	16	0.17
El Salvador	5	0.05
Estonia	49	0.51
Ethiopia	11	0.11
Fiji	9	0.09
Finland	15	0.16
France	50	0.52
French Guia	8	0.08
Gabon	25	0.26
Georgia	9	0.09
Germany	51	0.53
Ghana	149	1.55
Greece	12	0.12
Greenland	2	0.02
Grenada	2	0.02
Guatemala	10	0.1
Guinea	7	0.07
Guyana	37	0.38
Honduras	8	0.08
Hungary	43	0.45
Iceland	6	0.06
India	163	1.7
Indonesia	95	0.99
Iran	2	0.02
Iraq	15	0.16

Ireland	31	0.32
Israel	33	0.34
Italy	82	0.85
Jamaica	76	0.79
Japan	39	0.41
Jordan	43	0.45
Kenya	332	3.45
Korea, Democratic People's Republic of	13	0.14
Latvia	9	0.09
Lebanon	7	0.07
Lesotho	26	0.27
Liberia	18	0.19
Libya	17	0.18
Lithuania	18	0.19
Luxembourg	1	0.01
Madagascar	53	0.55
Malawi	3	0.03
Malaysia	46	0.48
Mali	20	0.21
Mauritania	11	0.11
Mexico	64	0.67
Micronesia	5	0.05
Moldova	45	0.47
Mongolia	8	0.08
Morocco	27	0.28
Mozambique	59	0.61
N Caledonia	1	0.01
Namibia	48	0.5
Nepal	155	1.61
Neth Ant	2	0.02
Netherlands	42	0.44
New Zealand	14	0.15
Nicaragua	21	0.22
Niger	456	4.74
Nigeria	37	0.38
Norway	7	0.07
Oman	15	0.16
Pakistan	38	0.4
Palau	10	0.1
Panama	14	0.15

Papua NG	29	0.3
Paraguay	43	0.45
Peru	113	1.18
Philippines	70	0.73
Poland	66	0.69
Portugal	36	0.37
Puerto Rico	17	0.18
Romania	55	0.57
Russia	145	1.51
Rwanda	58	0.6
Samoa	16	0.17
Senegal	94	0.98
Sierra Leone	11	0.11
Slovakia	34	0.35
Somalia	15	0.16
South Africa	38	0.4
South Korea	215	2.24
Spain	28	0.29
Srb & MNE	6	0.06
Sri Lanka	13	0.14
Sudan	67	0.7
Suriname	31	0.32
Sweden	14	0.15
Switzerland	14	0.15
Syria	54	0.56
Taiwan	1	0.01
Tajikistan	5	0.05
Tanzania	145	1.51
Thailand	310	3.22
Togo	24	0.25
Tonga	2	0.02
Trin & Tob	17	0.18
Tunisia	15	0.16
Turkey	66	0.69
U Kingdom	47	0.49
USA	362	3.77
Uganda	12	0.12
Ukraine	79	0.82
Uruguay	113	1.18
Uzbekistan	8	0.08

Venezuela	159	1.65
Yemen	280	2.91
Zambia	84	0.87
Zimbabwe	64	0.67

Table 4. Frequency distribution for soil texture.

Texture	Frequency	Percentage
Clay (C)	1383	14.39
Clay Loam (CL)	610	6.35
Loam (L)	947	9.85
Loamy Sand (LS)	1088	11.32
Sand (S)	912	9.49
Sand Clay (SC)	140	1.46
Silt Clay (SIC)	785	8.17
Silt (SI)	22	0.23
Silt Clay (SIC)	812	8.45
Silt Loam (SIL)	877	9.12
Sand Loam (SL)	2037	21.19

Table 5. Frequency distribution for soil type of the World Reference Base for Soil Resources 2006 (WRB2006).

WRB2006	Frequency	Percentage
AB	113	1.18
AC	835	8.69
AL	182	1.89
AN	240	2.5
AR	728	7.57
AT	19	0.2
CH	203	2.11
CL	204	2.12
CM	1133	11.79
CR	6	0.06
DU	1	0.01
FL	543	5.65
FR	521	5.42
GL	562	5.85
GY	30	0.31
Gl	1	0.01

HS	20	0.21
KS	92	0.96
LP	257	2.67
LV	1084	11.28
LX	435	4.53
NT	127	1.32
PH	417	4.34
PL	150	1.56
PT	98	1.02
PZ	197	2.05
RG	368	3.83
SC	151	1.57
SN	224	2.33
UM	162	1.69
VR	510	5.31

Table 6. Frequency distribution for soil color.

Soil Color (SCOM)	Frequency	Percentage
BK	510	5.31
BN	8075	84
G	810	8.43
RED	175	1.82
Y	43	0.45

Table 7. Frequency distribution for soil albedo.

Albedo (SALB)	Frequency	Percentage
0.09	510	5.31
0.13	8885	92.43
0.14	175	1.82
0.17	43	0.45

Table 8. Frequency distribution for soil profile drainage rate.

Drainage rate (SLDR)	Frequency	Percentage
0.01	315	3.28
0.05	886	9.22
0.25	1218	12.67
0.40	1687	17.55
0.60	4492	46.73
0.75	636	6.62
0.85	379	3.94

Table 9. Frequency distribution for the runoff curve.

Runoff curve (SLRO)	Frequency	Percent
61	8	0.08
64	5	0.05
68	1	0.01
71	2	0.02
73	1259	13.1
75	6712	69.82
76	447	4.65
80	272	2.83
81	171	1.78
83	460	4.79
84	154	1.6
87	12	0.12
88	34	0.35
91	70	0.73
94	6	0.06

Table 10. Frequency distribution for the FAO90 soil classification.

FAO90	Frequency	Percent
ACf	244	2.54
ACg	45	0.47
ACh	399	4.15
ACp	85	0.88
ACu	66	0.69
ALf	54	0.56
ALg	36	0.37
ALh	66	0.69
ALj	7	0.07
ALp	8	0.08
ALu	10	0.1
ANg	6	0.06
ANh	32	0.33
ANm	35	0.36
ANu	98	1.02
ANz	70	0.73
ARa	30	0.31
ARb	61	0.63
ARc	51	0.53
ARg	58	0.6
ARh	238	2.48

ARl	155	1.61
ARo	135	1.4
ATc	8	0.08
ATf	10	0.1
ATu	1	0.01
CHg	9	0.09
CHh	68	0.71
CHk	62	0.64
CHl	62	0.64
CHw	2	0.02
CLh	138	1.44
CLl	34	0.35
CLp	32	0.33
CMc	187	1.95
CMd	183	1.9
CMe	303	3.15
CMg	133	1.38
CMi	35	0.36
CMo	160	1.66
CMu	116	1.21
CMv	79	0.82
CMx	63	0.66
FLc	136	1.41
FLd	67	0.7
FLe	225	2.34
FLm	40	0.42
FLs	13	0.14
FLt	48	0.5
FLu	14	0.15
FRg	37	0.38
FRh	210	2.18
FRp	12	0.12
FRr	97	1.01
FRu	55	0.57
FRx	109	1.13
GLd	93	0.97
GLe	271	2.82
GLi	12	0.12
GLk	11	0.11
GLm	104	1.08

GLt	4	0.04
GLu	68	0.71
GRg	3	0.03
GRh	24	0.25
GYh	7	0.07
GYk	15	0.16
GYl	2	0.02
GYp	5	0.05
HSf	6	0.06
HSi	3	0.03
HSl	2	0.02
HSs	6	0.06
HSt	3	0.03
KSh	24	0.25
KSk	42	0.44
KSl	26	0.27
LPd	76	0.79
LPe	83	0.86
LPi	3	0.03
LPk	41	0.43
LPm	40	0.42
LPq	18	0.19
LPu	42	0.44
LVa	34	0.35
LVf	109	1.13
LVg	173	1.8
LVh	306	3.18
LVj	76	0.79
LVk	126	1.31
LVv	35	0.36
LVx	225	2.34
LXa	2	0.02
LXf	176	1.83
LXg	34	0.35
LXh	205	2.13
LXj	1	0.01
LXp	19	0.2
NTh	62	0.64
NTr	39	0.41
NTu	26	0.27

PDd	22	0.23
PDe	70	0.73
PDg	16	0.17
PDj	6	0.06
PHc	39	0.41
PHg	27	0.28
PHh	124	1.29
PHj	10	0.1
PHl	190	1.98
PLd	34	0.35
PLe	95	0.99
PLm	19	0.2
PLu	3	0.03
PTa	20	0.21
PTd	44	0.46
PTe	26	0.27
PTu	3	0.03
PZb	17	0.18
PZc	33	0.34
PZf	5	0.05
PZg	47	0.49
PZh	81	0.84
PZi	14	0.15
RGc	98	1.02
RGd	68	0.71
RGe	172	1.79
RGi	12	0.12
RGu	12	0.12
RGy	3	0.03
SCg	40	0.42
SCh	29	0.3
SCi	4	0.04
SCk	20	0.21
SCm	8	0.08
SCn	32	0.33
SCy	18	0.19
SNg	52	0.54
SNh	86	0.89
SNj	19	0.2
SNk	35	0.36

SNm	27	0.28
SNy	4	0.04
VRd	18	0.19
VRe	336	3.5
VRk	151	1.57
VRy	5	0.05
Total	9613	100

Simple descriptive statistics for the numerical variables of the profile were also calculated (Table 11).

Table 11. Simple statistics for the numerical variables of the general soil file characteristics

Variable	N	N Miss	Mean	Std Dev	Maximum	Minimum
SLU1	9613	0	8.91	1.55	11.92	5.3
SLDR	9613	0	0.47	0.225	0.85	0.01
SLRO	9613	0	75.73	2.975	94	61

N: number of data; N Miss: number of missing values

Parameters for first and second tier of the soil profiles

Some of the parameters of the first and second tier were calculated for each individual soil layer of the profiles and others were converted to DSSAT format. Descriptive statistics for the non constant and numerical parameters of the soil layers were determined (Table 12).

Table 12. Simple statistics for the numerical values of the soil parameters for the individual soil layers.

Variable	N	N Miss	Mean	Std Dev	Maximum	Minimum
SALB	44595	0	0.13	0.01	0.17	0.09
SLB	44595	0	72.28	56.95	850.00	1.00
SLLL	44595	0	0.15	0.08	0.32	0.01
SDUL	44595	0	0.27	0.09	0.45	0.07
SSAT	44595	0	0.45	0.06	0.80	0.33
SRGF	44595	0	0.46	0.32	1.00	0.00
SSKS	44595	0	7.59	13.89	132.05	0.00
SBDM	44595	0	1.38	0.20	1.80	0.22
SLOC	44595	0	1.07	2.25	60.00	0.00
SLCL	44595	0	28.73	19.96	98.00	1.00
SLSI	44595	0	26.21	18.76	96.00	0.00
SLCF	7956	36639	15.04	18.64	95.00	1.00
SLNI	44595	0	0.10	0.19	7.80	0.00
SLHW	41069	3526	6.29	1.31	9.00	3.50

SLHB	19985	24610	5.03	1.14	9.00	1.90
SCEC	40584	4011	15.28	13.36	229.00	0.10
CACO3	9412	35183	8.70	11.40	95.50	0.00
SLAL	9912	34683	1.19	2.02	35.90	0.01
SLBS	23718	20877	69.67	32.54	100.00	0.00
SLKE	31367	13228	0.50	0.99	29.90	0.00
SLMG	33101	11494	3.37	4.89	88.00	0.00
SLNA	27774	16821	0.97	2.35	20.00	0.00
SLEC	30339	14256	0.49	1.57	16.00	0.00
SLCA	33357	11238	7.54	8.24	35.00	0.00

N: number of layers; N Miss: number of missing values

The depth of each profile by the type of soil according with the World Reference Base for Soil Resources 2006 (WRB2006) was graphed in a box-plot (Figure 1 and 2)

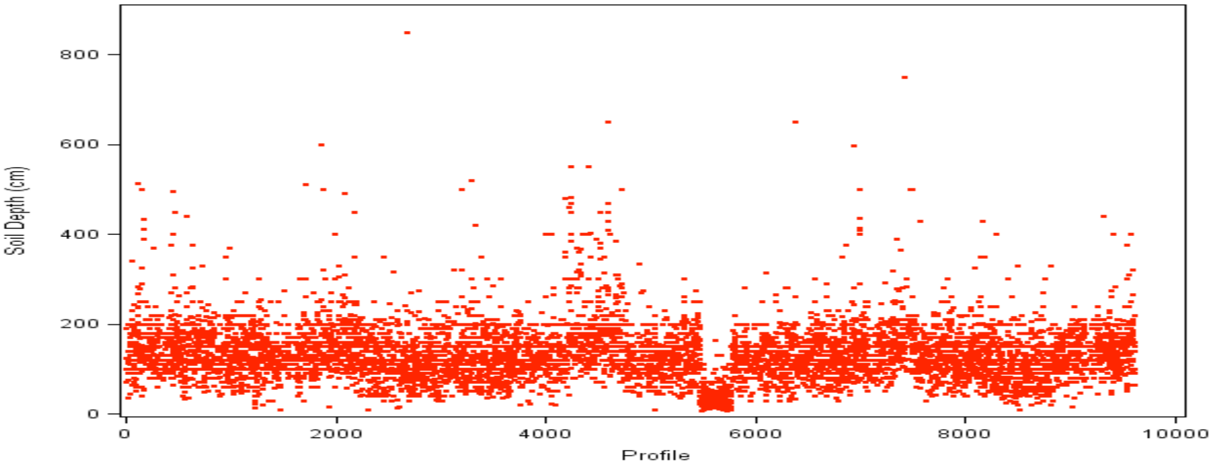


Figure 1. Soil profile depth for the 9613 profiles

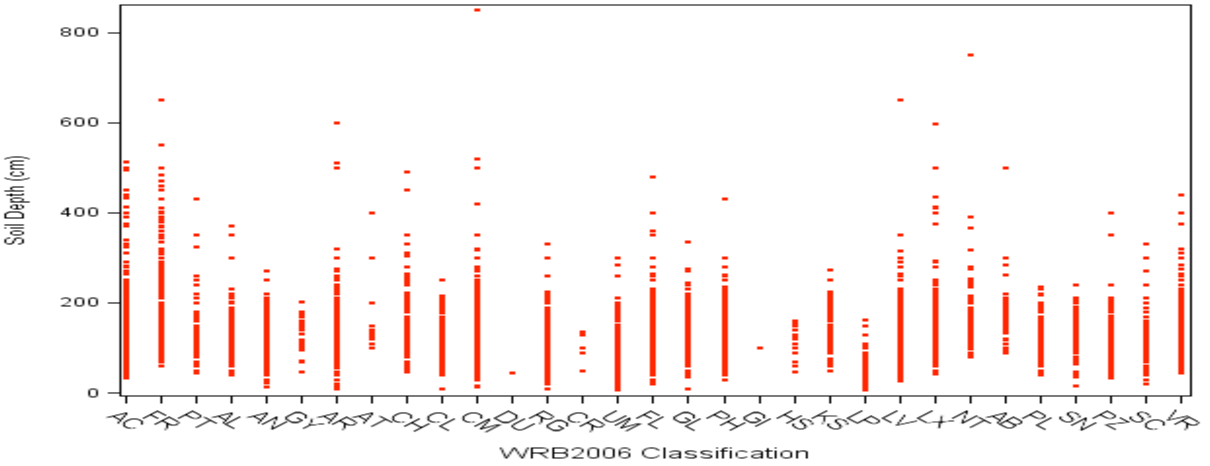


Figure 2. Soil profile depth for the 9613 profiles by type of soil WRB2006 classification

The scatter plots of the relationship of SLLL, SDUL and SSAT with texture parameters SAND, SLCL and SLSI illustrate their relationship and also the ordered relationship among SLLL, SDUL and SSAT. The plots for SLLL, SDUL and SSAT and SLOC show that the tendency of the water content variables did not change for values of SLOC that were out of range (Figures 3, 4, 5 and 6). Scatter plots for SSKS also demonstrate the relationship of this variable and texture variables, as well as for SLOC (Figures 7, 8, 9 and 10). Scatter plot for each type of soil, using WBR2006 classification, were made (not included here) where the tendency of SSAT and SLOC as well as SSKS and SLOC were similar to those made using pooled data.

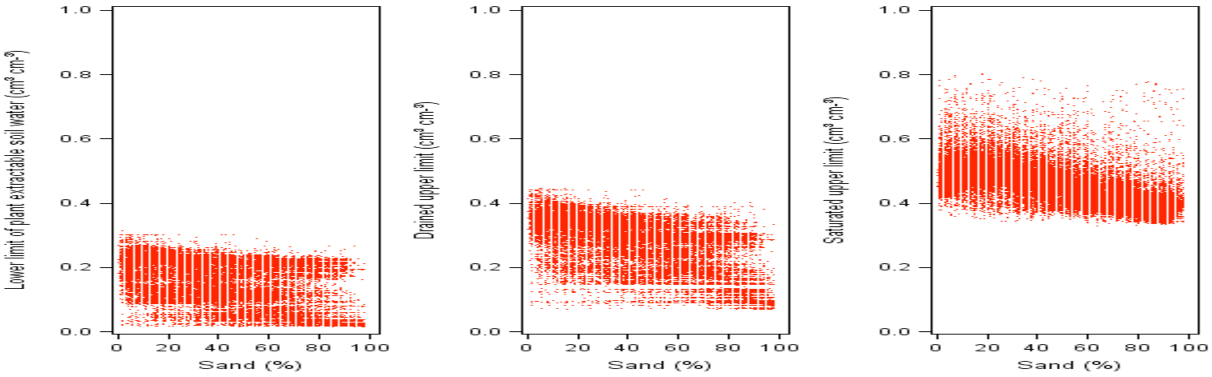


Figure 3. Relationship between soil water content and sand.

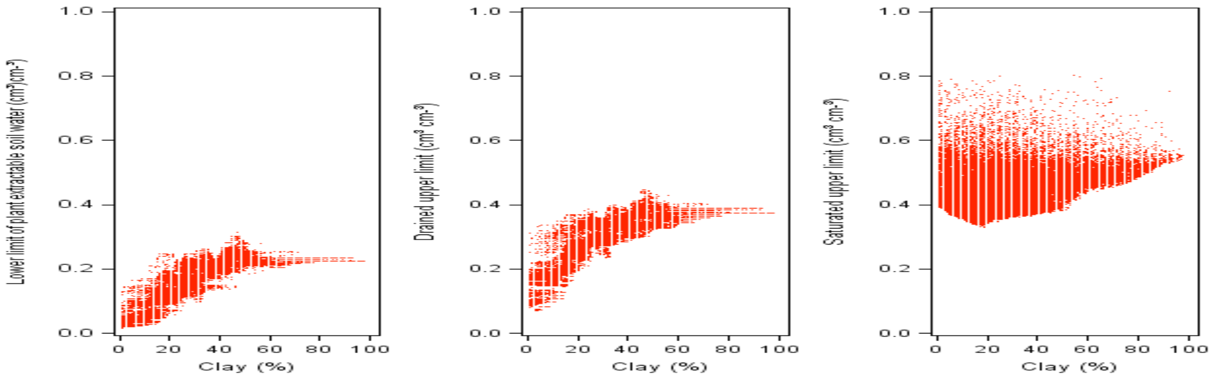


Figure 4. Relationship between soil water content and clay

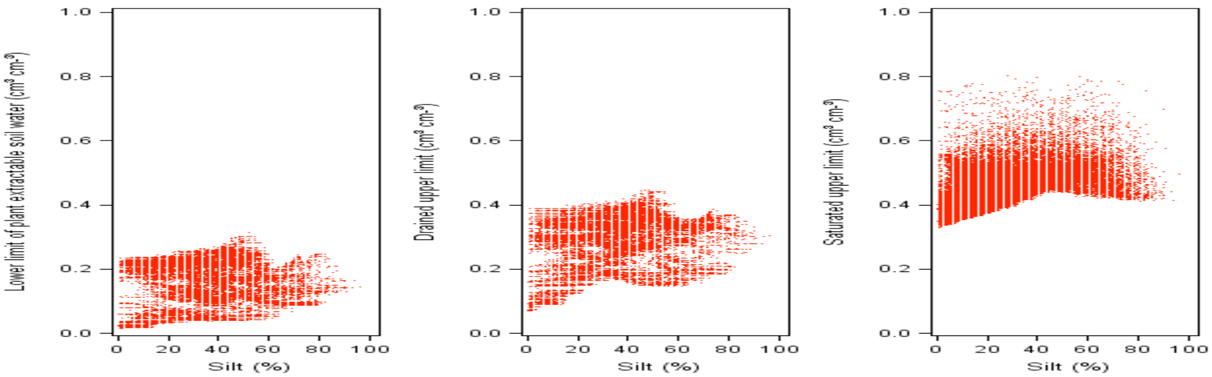


Figure 5. Relationship between soil water content and silt.

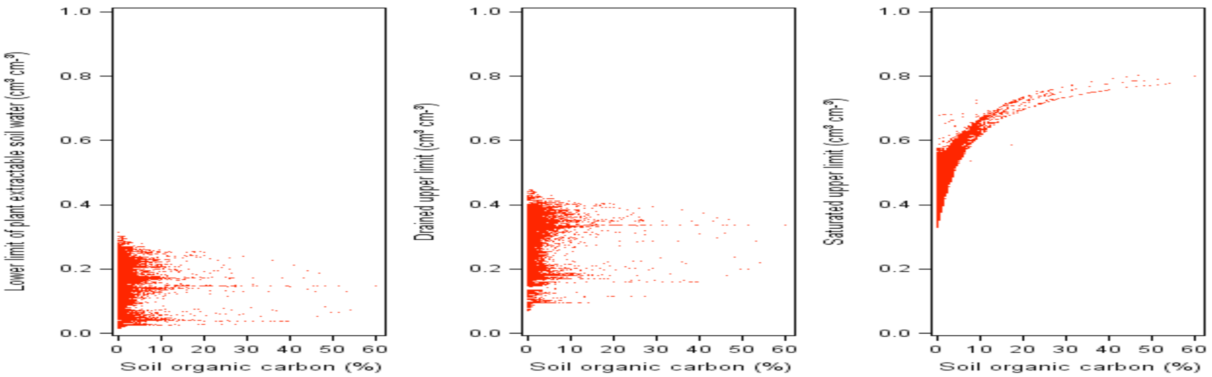


Figure 6. Relationship between soil water content and organic carbon.

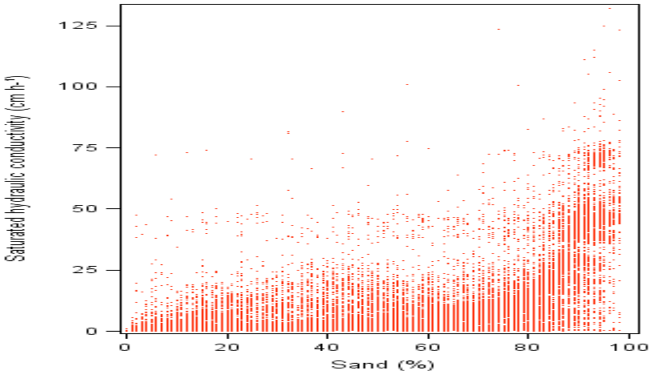


Figure 7. Relationship between saturated hydraulic conductivity and sand.

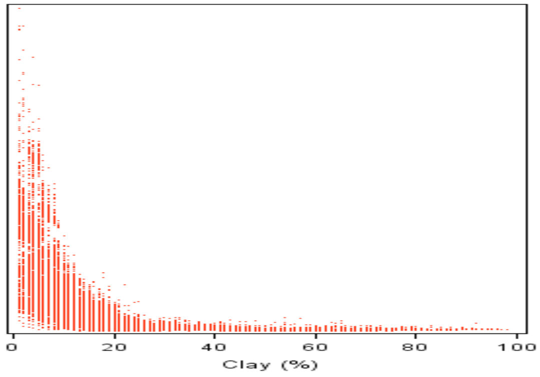
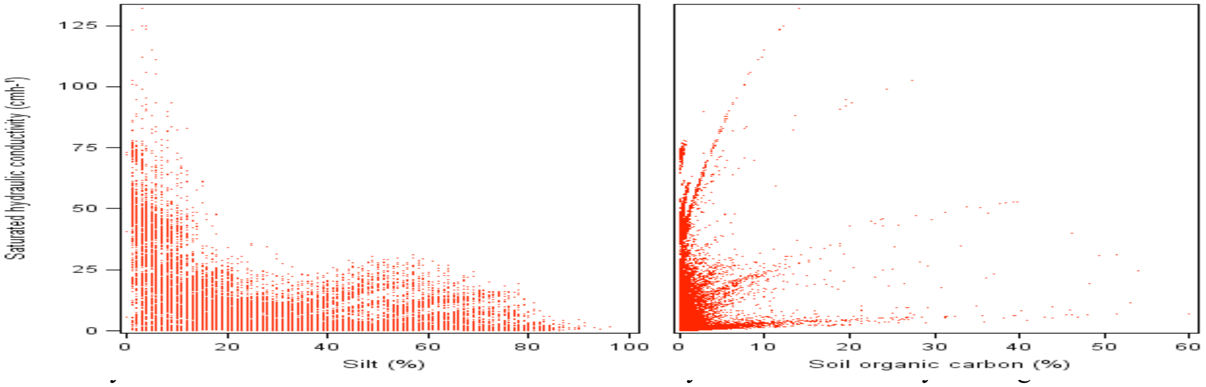


Figure 8. Relationship between saturated hydraulic conductivity and clay



Soil Profile Output File DSSAT

An example of a small portion of the soil profile DSSAT file is shown below.

```
*WICLAF0001  WISE        L       150 AF0001 Medium textured upland soil
@SITE        COUNTRY         LAT     LONG  SCS Family
 Kabul-vall  Afghanistan   34.50    69.17  Luvic    Calcisol (CLl )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13  9.60  0.60 75.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    15 -     0.108 0.288 0.459  1.00  1.45  1.35  0.76 20.00 40.00  20.0  0.06  7.90 -99.0 -99.0 -99.0
    60 -     0.183 0.332 0.466  0.47  0.62  1.37  0.23 35.00 55.00 -99.0  0.03  7.90 -99.0 -99.0 -99.0
   150 -     0.183 0.332 0.461  0.12  0.58  1.39  0.09 35.00 55.00 -99.0  0.03  7.90 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    15 -99.0 -99.0 -99.0 9.300 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   0.4 -99.0
    60 -99.0 -99.0 -99.0 17.70 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   0.3 -99.0
   150 -99.0 -99.0 -99.0 18.20 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   0.3 -99.0

*WIFLAF0003  WISE        L       110 AF0003 Grey-brown hydromorphic soil
@SITE        COUNTRY         LAT     LONG  SCS Family
 Kabul-vall  Afghanistan   34.50    69.17  Calcaric Fluvisol (FLc )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13  9.60  0.05 75.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    20 A     0.109 0.276 0.453  0.82  1.66  1.37  0.59 20.00 40.00 -99.0  0.07  8.80 -99.0 -99.0 -99.0
    50 Bg    0.058 0.189 0.404  0.50  5.22  1.49  0.24 10.00 25.00 -99.0  0.04  6.68 -99.0 -99.0 -99.0
   110 Cg    0.174 0.283 0.437  0.20  1.23  1.40  1.40 25.00 15.00 -99.0  0.14  8.90 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    20 -99.0 -99.0 -99.0 16.90 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   1.9 -99.0
    50 -99.0 -99.0 -99.0 13.80 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   0.6 -99.0
   110 -99.0 -99.0 -99.0 19.60 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   0.4 -99.0

*WISCAF0004  WISE        SIL     270 AF0004 Grey-brown hydromorphic saline soil
@SITE        COUNTRY         LAT     LONG  SCS Family
 Ghurian     Afghanistan   34.33    61.43  Gleyic   Soloncha (SCg )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13  9.20  0.40 75.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    15 -     0.097 0.185 0.548  1.00 13.96  1.10  1.46 15.00 65.00 -99.0  0.15  8.60 -99.0  21.7 -99.0
    35 -     0.157 0.282 0.488  0.61  1.91  1.30  0.84 30.00 60.00 -99.0  0.08  8.90 -99.0  26.5 -99.0
    70 -     0.108 0.288 0.445  0.35  1.24  1.40  0.39 20.00 40.00 -99.0  0.04  8.70 -99.0  13.0 -99.0
   110 -     0.212 0.298 0.383  0.17  0.39  1.57  0.27 30.00 10.00 -99.0  0.03  8.90 -99.0  17.4 -99.0
   170 -     0.212 0.298 0.385  0.06  0.40  1.57  0.30 30.00 10.00 -99.0  0.03  7.93 -99.0  13.5 -99.0
   270 -     0.248 0.379 0.453  0.01  0.17  1.40  0.35 45.00 50.00 -99.0  0.04 -99.0 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    15 -99.0 -99.0 -99.0 18.60 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   5.1 -99.0  4.48 -99.0   4.2   9.0
    35 -99.0 -99.0 -99.0 22.80 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   3.0 -99.0  5.29 -99.0  12.0  10.5
    70 -99.0 -99.0 -99.0 20.10 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   1.6 -99.0  5.61 -99.0  12.0  21.0
   110 -99.0 -99.0 -99.0 25.60 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   1.3 -99.0  7.37 -99.0  12.5  20.0
```

```
   170 -99.0 -99.0 -99.0 26.00 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   1.3 -99.0  7.30 -99.0   5.5  23.0
   270 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0

*WISCAF0005  WISE        SIC      190 AF0005 Solonchak
@SITE        COUNTRY          LAT     LONG  SCS Family
 Farah-Vall  Afghanistan   32.38    62.13  Calcic   Soloncha (SCk )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13 10.80  0.05 75.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
     4 -     0.183 0.332 0.469  1.00  0.65  1.36  0.31 35.00 55.00 -99.0  0.03  8.90 -99.0 -99.0 -99.0
    20 -     0.187 0.336 0.471  0.79  0.61  1.36  0.35 35.00 55.00 -99.0  0.04  8.80 -99.0 -99.0 -99.0
    45 -     0.183 0.332 0.469  0.52  0.65  1.36  0.31 35.00 55.00 -99.0  0.03  8.80 -99.0 -99.0 -99.0
   100 -     0.212 0.323 0.455  0.23  0.64  1.40  0.21 35.00 35.00 -99.0  0.02  7.95 -99.0 -99.0 -99.0
   160 -     0.142 0.257 0.392  0.07  1.27  1.53  0.12 15.00 25.00 -99.0  0.01  7.93 -99.0 -99.0 -99.0
   190 -     0.183 0.332 0.460  0.03  0.57  1.39  0.06 35.00 55.00 -99.0  0.01  8.60 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
     4 -99.0 -99.0 -99.0 20.80 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   4.2 -99.0
    20 -99.0 -99.0 -99.0 20.60 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   7.4 -99.0
    45 -99.0 -99.0 -99.0 21.90 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   7.8 -99.0
   100 -99.0 -99.0 -99.0 24.50 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0  14.0 -99.0
   160 -99.0 -99.0 -99.0 24.70 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   4.2 -99.0
   190 -99.0 -99.0 -99.0 24.70 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0   1.1 -99.0

*WICMAL0004  WISE        SC       120 AL0004 Marroon Grey Soil
@SITE        COUNTRY          LAT     LONG  SCS Family
 Kavaja-Rog  Albania       41.08    19.56  Calcaric Cambisol (CMc )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13 10.96  0.60 83.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
     8 Ah    0.177 0.295 0.503  1.00  1.99  1.19  3.09 37.00 17.00 -99.0  0.31  7.20 -99.0  45.0 -99.0
    22 A1    0.161 0.329 0.540  0.74  1.66  1.10  2.74 26.00 46.00 -99.0  0.27  7.40 -99.0  45.0 -99.0
    50 AB    0.217 0.348 0.503  0.49  0.75  1.25  1.14 38.00 37.00 -99.0  0.11  7.00 -99.0 -99.0 -99.0
    82 B     0.193 0.328 0.457  0.27  0.59  1.38  1.17 39.00 20.00 -99.0  0.12  7.10 -99.0 -99.0 -99.0
   104 BC    0.216 0.339 0.452  0.16  0.44  1.40  0.77 45.00 18.00 -99.0  0.08  7.00 -99.0 -99.0 -99.0
   120 C     0.216 0.339 0.452  0.11  0.44  1.40  0.77 42.00 21.00 -99.0  0.08  7.00 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
     8 -99.0 -99.0 -99.0 0.300 -99.0 -99.0 -99.0 52.00 -99.0 -99.0   0.2  0.80  0.90 -99.0 -99.0  21.9
    22 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 50.00 -99.0 -99.0   0.3  0.90  1.00 -99.0 -99.0  26.2
    50 -99.0 -99.0 -99.0 8.000  0.10 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
    82 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
   104 -99.0 -99.0 -99.0 0.100  0.10 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
   120 -99.0 -99.0 -99.0 0.100  0.10 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0

*WIFLAL0005  WISE        SL       170 AL0005 Marroon grey meadow soil
@SITE        COUNTRY           LAT     LONG  SCS Family
 Juba        Albania        41.42    19.51  Calcaric Fluvisol (FLc )
@ SCOM  SALB  SLU1  SLDR  SLRO  SLNF  SLPF  SMHB  SMPX  SMKE
    BN  0.13  8.96  0.60 73.00  1.00  1.00 SA001 SA001 SA001
@  SLB  SLMH  SLLL  SDUL  SSAT  SRGF  SSKS  SBDM  SLOC  SLCL  SLSI  SLCF  SLNI  SLHW  SLHB  SCEC  SADC
    20 1     0.069 0.206 0.451  0.82  5.73  1.34  1.26 12.00 30.00 -99.0  0.13  7.80 -99.0  38.3 -99.0
    50 2     0.121 0.241 0.434  0.50  2.52  1.43  0.65 20.00 32.00 -99.0  0.07  8.10 -99.0  23.4 -99.0
    80 3     0.037 0.148 0.393  0.27 10.72  1.52  0.26  7.00 15.00 -99.0  0.03  8.20 -99.0 -99.0 -99.0
   110 4     0.248 0.368 0.480  0.15  0.37  1.33  0.32 50.00 34.00 -99.0  0.03  8.30 -99.0 -99.0 -99.0
   170 5     0.045 0.165 0.399  0.06  8.01  1.51  0.32  9.00 20.00 -99.0  0.03  8.30 -99.0 -99.0 -99.0
@  SLB  SLPX  SLPT  SLPO CACO3  SLAL  SLFE  SLMN  SLBS  SLPA  SLPB  SLKE  SLMG  SLNA  SLSU  SLEC  SLCA
    20 -99.0 -99.0 -99.0 12.90 -99.0 -99.0 -99.0 55.00 -99.0 -99.0   0.3  0.30  0.90 -99.0 -99.0  19.4
    50 -99.0 -99.0 -99.0 13.10 -99.0 -99.0 -99.0 90.00 -99.0 -99.0   0.2  1.00  1.00 -99.0 -99.0  18.9
    80 -99.0 -99.0 -99.0 16.60 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
   110 -99.0 -99.0 -99.0 15.90 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
   170 -99.0 -99.0 -99.0 15.30 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0 -99.0
```

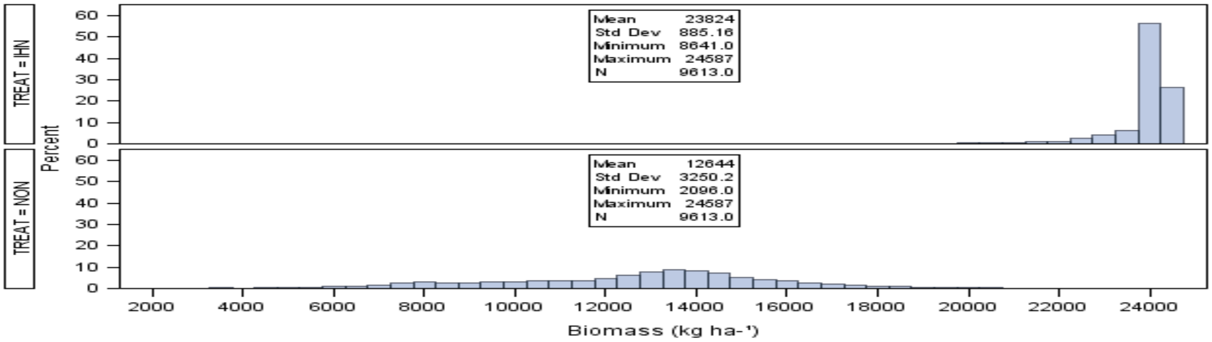
Evaluation of the determined profiles-Sensitivity analysis

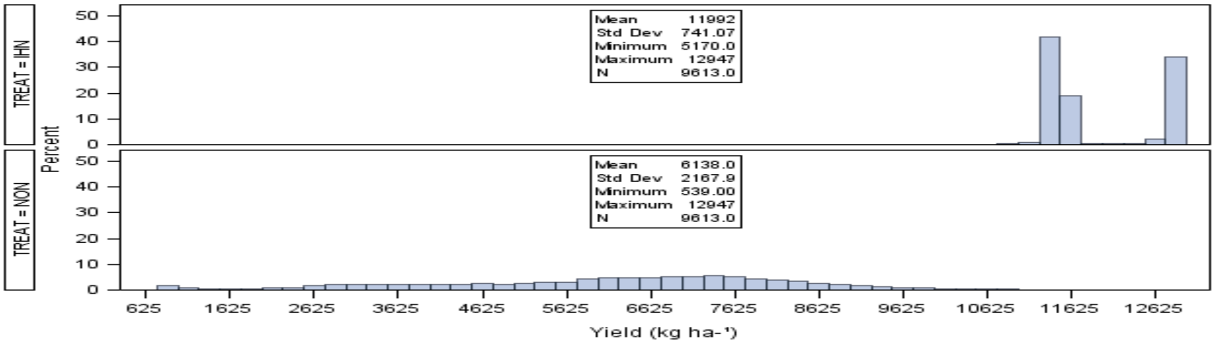
A total of 76904 simulations, 19226 for each crop, were conducted and multiple output variables (summary output) were saved in SAS dataset files. After completing the simulations, only five profiles were discarded because they consisted of only one horizon that was had a depth that was less than 5 cm.

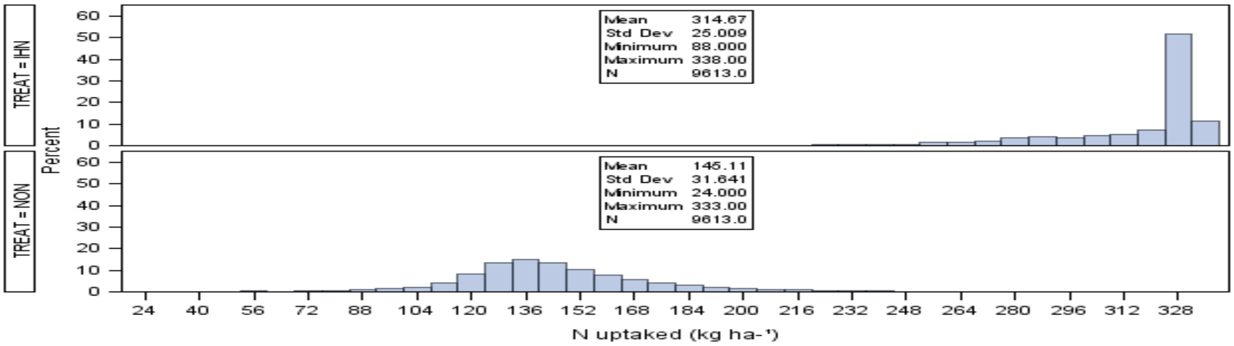
Maize simulations

The simulations of total biomass (CWAM), yield (HWAM), nitrogen uptake (NUCM) and nitrogen leached (NLCL), were summarized in empirical frequency histograms, including simple statistics, as well as empirical cumulative distribution function to compare the outputs of the two treatments used in the simulations. These graphs clearly show the impact of the fertilization and water availability increasing the yield and total biomass mean close to 50% respect to the rainfed treatment. Similarly, less variability was found for the irrigated and high nitrogen (IHN) treatment (figures 11 and 12).

The ten profiles showing the lowest and highest values of total biomass (CWAM), yield (HWAM), nitrogen leach (NLCM), nitrogen uptake (NUCM) and organic carbon at maturity (OCTAM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments were included (Table 13 and 14). A box-plot of the 9613 profiles to compare in detail the total biomass (CWAM), yield (HWAM) and the organic carbon at maturity of the two treatments was developed (figures 13, 14 and 15).







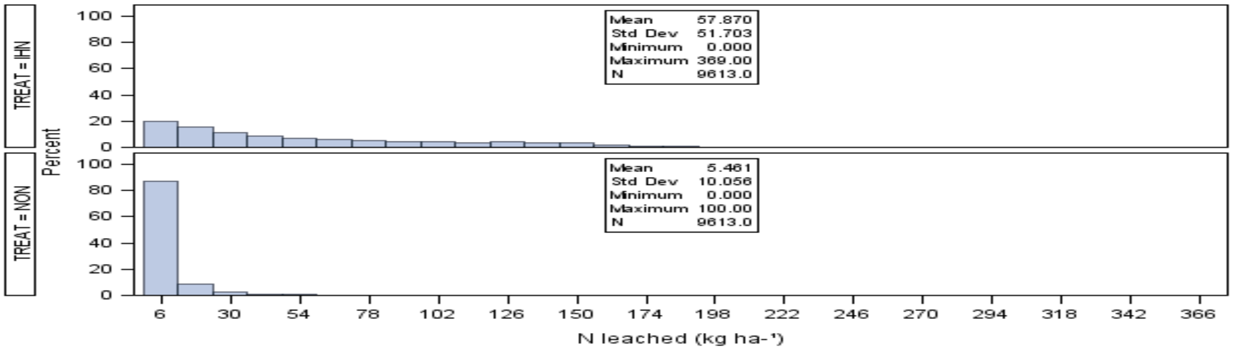
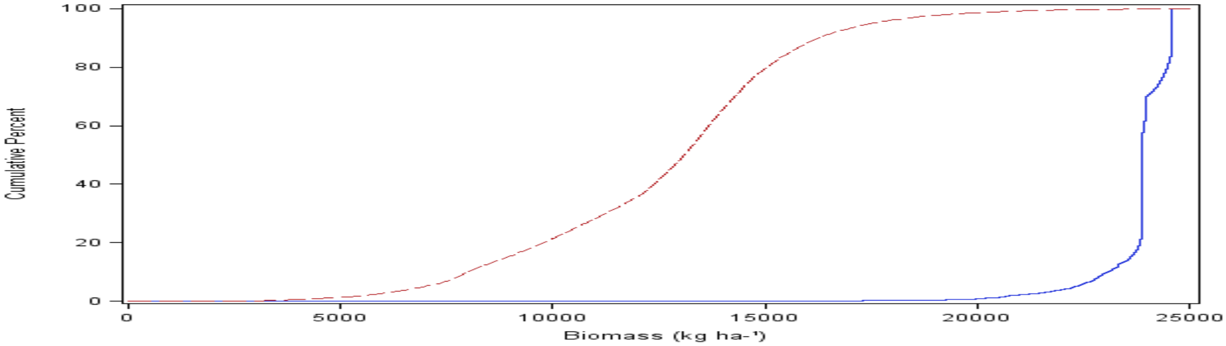


Figure 11. Frequency distribution of Irrigate High Nitrogen (IHN) and Rainfed Low Nitrogen treatments (NON) of the maize Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments.



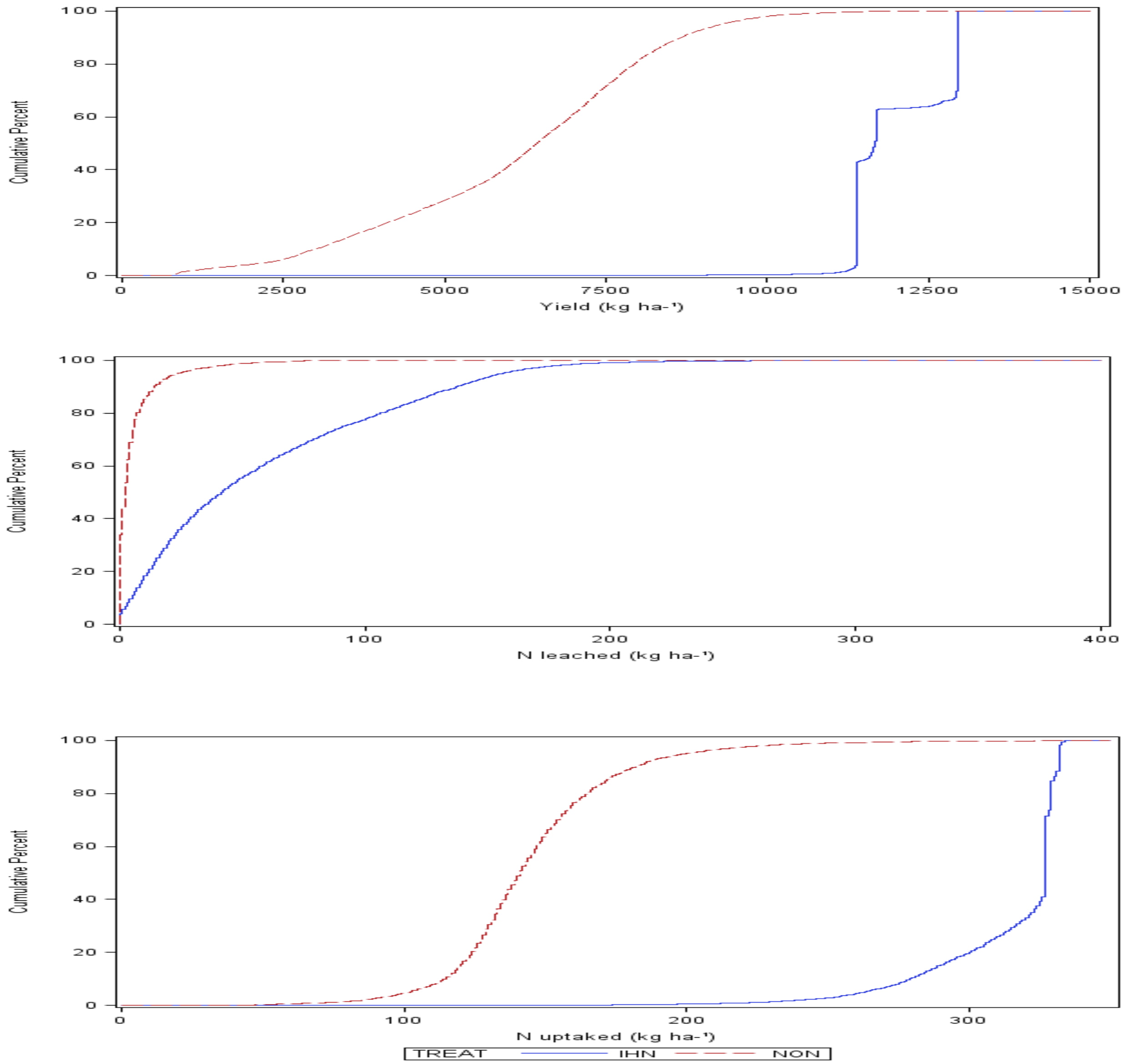


Figure 12. Cumulated Distributions Function of maize Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments.

Table 13. The ten profiles with the lowest values for maize yield, total biomass, nitrogen leaching, nitrogen uptake and organic carbon for both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Lowest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value

1	NE0268	8641	NE0268	2096	NE0268	5170	NE0268	539	ZW0060	0	ZW0067	0	NE0268	88	NE0268	24	IS0001	1530	IS0001	1505
2	LY0006	11684	MX0028	2218	ZA0039	6143	US0241	802	ZW0040	0	ZW0063	0	ZA0039	115	ZA0039	32	EG0007	1615	EG0007	1533
3	MX0028	11885	LY0006	2361	LY0006	6259	LY0006	817	ZM0066	0	ZW0061	0	LY0006	130	MX0028	32	AQ0004	1636	AQ0004	1602
4	ZA0039	11910	EC0020	2411	MX0028	6386	KE0219	819	ZM0057	0	ZW0060	0	MX0028	131	LY0006	38	PE0090	1937	PE0090	1890
5	EC0020	12550	MX0025	2557	EC0020	6799	MX0028	823	VE0116	0	ZW0059	0	IS0001	134	IS0001	38	OM0003	1985	OM0003	1923
6	PE0065	13510	EC0019	2579	IS0001	7103	EC0020	823	VE0115	0	ZW0051	0	EC0020	142	EC0020	39	ZA0039	2767	ZA0039	2749
7	IS0001	13793	BO0055	2624	PE0065	7164	EC0019	823	VE0027	0	ZW0049	0	PE0065	143	MX0025	41	EG0008	3227	EG0008	3190
8	MX0025	15516	BR0222	2694	KE0219	8415	KE0218	824	VE0023	0	ZW0048	0	AR0165	163	BO0055	41	AQ0001	3291	AQ0001	3242
9	BO0055	15551	ZA0039	2710	MX0025	8427	PY0033	825	VE0012	0	ZW0043	0	BO0055	164	EC0019	42	TR0032	3508	TR0032	3443
10	EC0019	15904	KE0218	2821	BO0055	8489	SK0027	826	VE0002	0	ZW0041	0	BW0809	165	PE0065	43	MX0028	3998	MX0028	3961

Table 14. The ten profiles with the highest values for maize yield, total biomass, nitrogen leaching, nitrogen uptake and organic carbon for both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Highest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	ZM0067	24587	AR0215	23774	ZW0044	12947	KR0033	11678	KE0219	267	CM0013	80	PA0012	335	CL0013	327	TH0156	1250175	TH0156	1251321
2	ZM0070	24587	KR0034	23828	ZW0045	12947	CM0044	11679	IS0001	268	EC0019	80	TH0250	335	KR0034	327	AR0215	1260098	AR0215	1261466
3	ZM0082	24587	CL0010	23852	ZW0047	12947	AR0215	11684	MX0028	269	EC0020	80	TH0307	335	KR0040	327	AR0234	1344033	AR0234	1345986
4	ZW0013	24587	KR0040	23875	ZW0050	12947	CL0010	11692	MX0008	271	IS0001	80	BR0468	336	CL0010	328	GB0034	1371906	GB0034	1373042
5	ZW0019	24587	AN0002	23916	ZW0052	12947	AN0002	11695	CL0033	272	LY0006	80	GB0044	336	AN0002	329	MG0016	1390777	MG0016	1390897
6	ZW0024	24587	AR0234	23952	ZW0054	12947	AR0234	11697	CH0013	277	CS0005	81	PG0030	336	AR0215	329	IT0014	1410191	IT0014	1410754
7	ZW0028	24587	UA0073	23952	ZW0057	12947	UA0073	11697	CM0040	282	PY0033	81	TH0154	336	AR0234	329	ES0014	1458315	ES0014	1459076
8	ZW0050	24587	RU0143	24508	ZW0058	12947	RU0143	12945	YE0054	313	MX0028	85	KR0054	337	UA0073	329	MG0050	1467628	MG0050	1468630
9	ZW0064	24587	YE0054	24586	ZW0064	12947	RO0009	12947	AR0234	333	KE0219	91	SK0032	337	RO0009	332	JM0040	1592161	JM0040	1593407
10	ZW0	245	RO0	245	ZW0	129	YE0	129	CL0	369	EE0	100	US0	338	YE0	333	UA0	1615	UA0	1618

	067	87	009	87	067	47	054	47	018		045		377		054		073	903	073	586

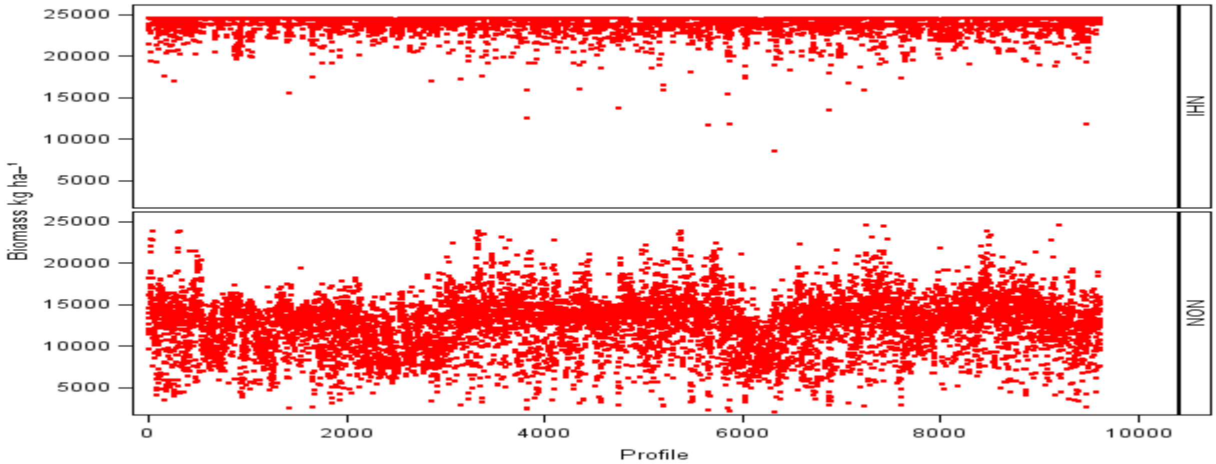


Figure 13. Box-plot comparison of total biomass for maize for the Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments.

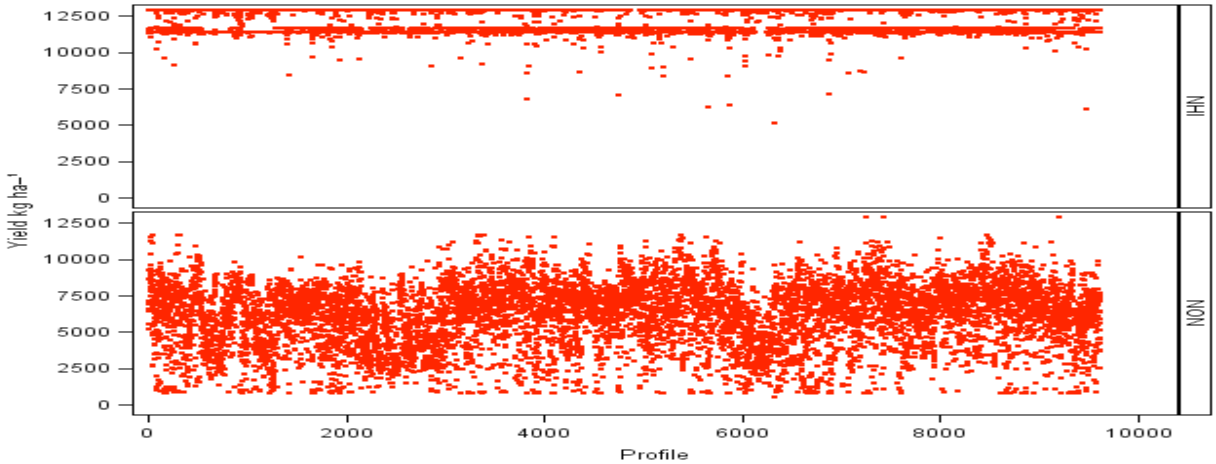


Figure 14. Box-plots comparison of yield for maize for the Irrigation High Nitrogen (IHN and Rainfed Low Nitrogen (NON).

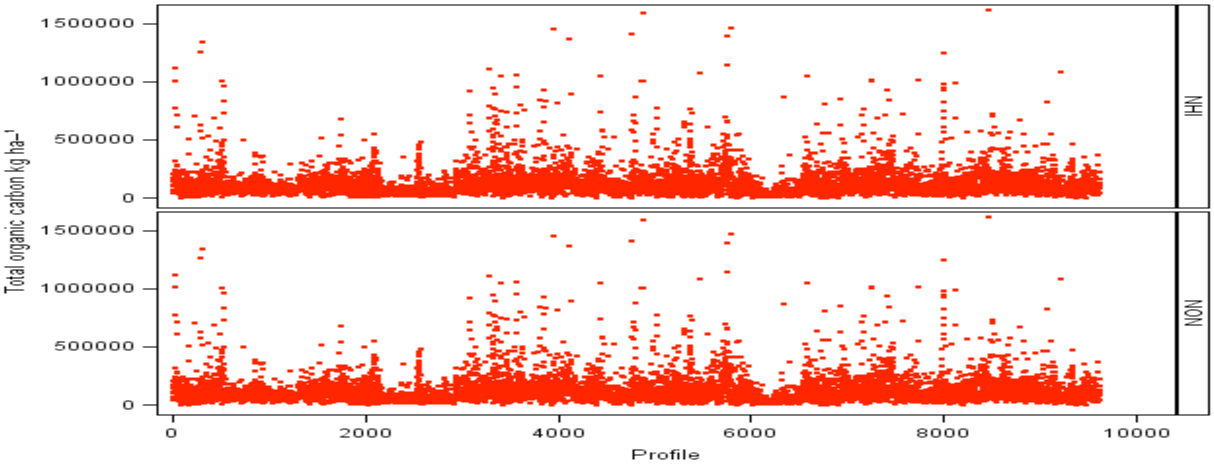
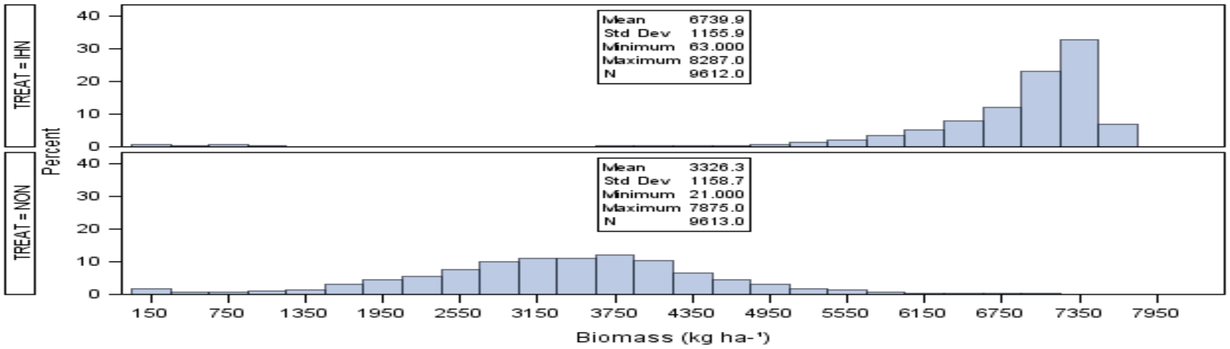


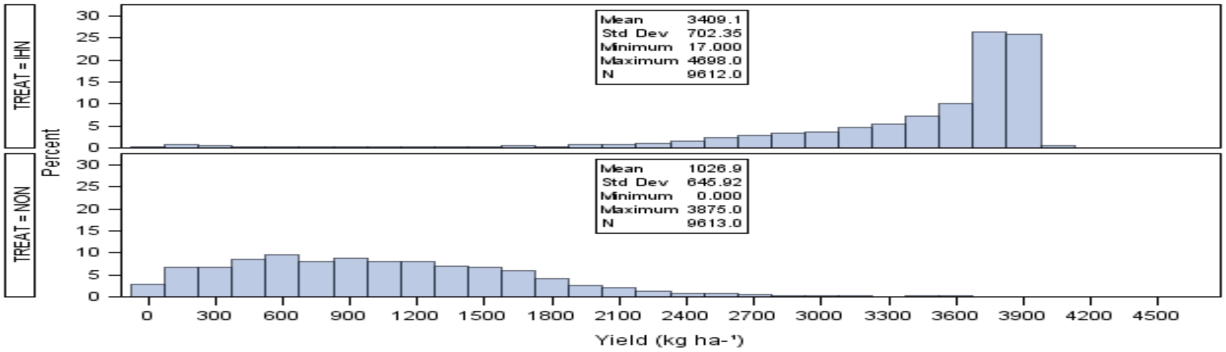
Figure 15. Box-plots comparison of the Organic Carbon at Maturity between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

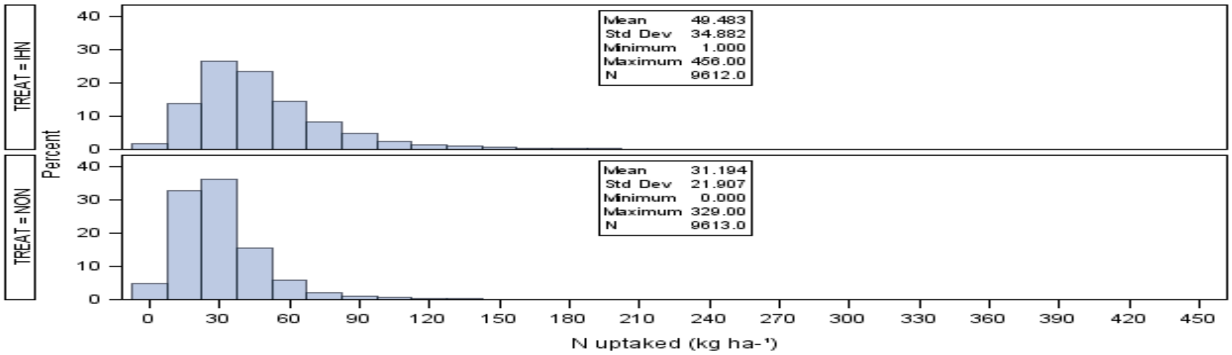
Soybean Simulations

The simulations of Total Biomass (CWAM), Yield (HWAM), Nitrogen Uptake (NUCM) and Nitrogen Leached (NLCL), were summarized in empirical frequency histograms, including simple statistics, as well as empirical cumulative distribution function to compare the outputs of the two treatments used in the simulations. These graphs clearly show the impact of the fertilization and water availability increasing the soybean yield and total biomass mean close to 50% respect to the rainfed treatment; no significant reduction in variability were found for the irrigated and high nitrogen (IHN) treatment (figures 16 and 17).

The ten profiles showing the lowest and highest values of soybean Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM), Nitrogen Uptake (NUCM) and Organic Carbon at Maturity (OCTAM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments were included (Table 15 and 16). Box-plot of the 9613 profiles to compare in detail the soybean Total Biomass (CWAM), Yield (HWAM) and the Organic Carbon at Maturity of the two treatments were done (figures 18, 19 and 20).


TREAT = IHN
TREAT = NON
Percent
Mean 6739.9
Std Dev 1155.9
Minimum 63.000
Maximum 8287.0
N 9612.0
Mean 3326.3
Std Dev 1158.7
Minimum 21.000
Maximum 7875.0
N 9613.0
0 10 20 30 40
150 750 1350 1950 2550 3150 3750 4350 4950 5550 6150 6750 7350 7950
Biomass (kg ha-¹)


TREAT = IHN
TREAT = NON
Percent
Mean 3409.1
Std Dev 702.35
Minimum 17.000
Maximum 4698.0
N 9612.0
Mean 1026.9
Std Dev 645.92
Minimum 0.000
Maximum 3875.0
N 9613.0
0 5 10 15 20 25 30
0 300 600 900 1200 1500 1800 2100 2400 2700 3000 3300 3600 3900 4200 4500
Yield (kg ha-¹)


TREAT = IHN
TREAT = NON
Percent
Mean 49.483
Std Dev 34.882
Minimum 1.000
Maximum 456.00
N 9612.0
Mean 31.194
Std Dev 21.907
Minimum 0.000
Maximum 329.00
N 9613.0
0 10 20 30 40
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450
N uptaked (kg ha-¹)

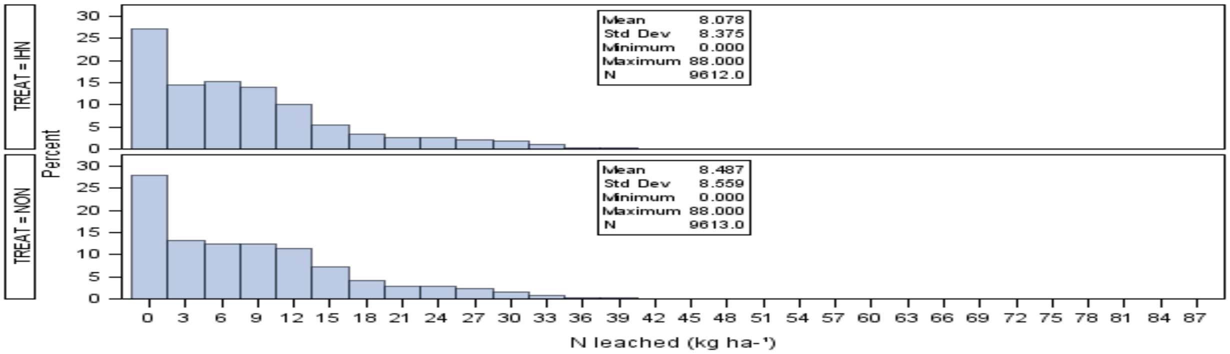

TREAT = IHN
TREAT = NON
Percent
Mean 8.078
Std Dev 8.375
Minimum 0.000
Maximum 88.000
N 9612.0
Mean 8.487
Std Dev 8.559
Minimum 0.000
Maximum 88.000
N 9613.0
0 5 10 15 20 25 30
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87
N leached (kg ha-¹)

Figure 16. Frequency distribution of Irrigate High Nitrogen (IHN) and Rainfed Low Nitrogen treatments (NON) of the soybean Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation High Nitrogen(IHN) and Rainfed Low Nitrogen (NON) treatments.

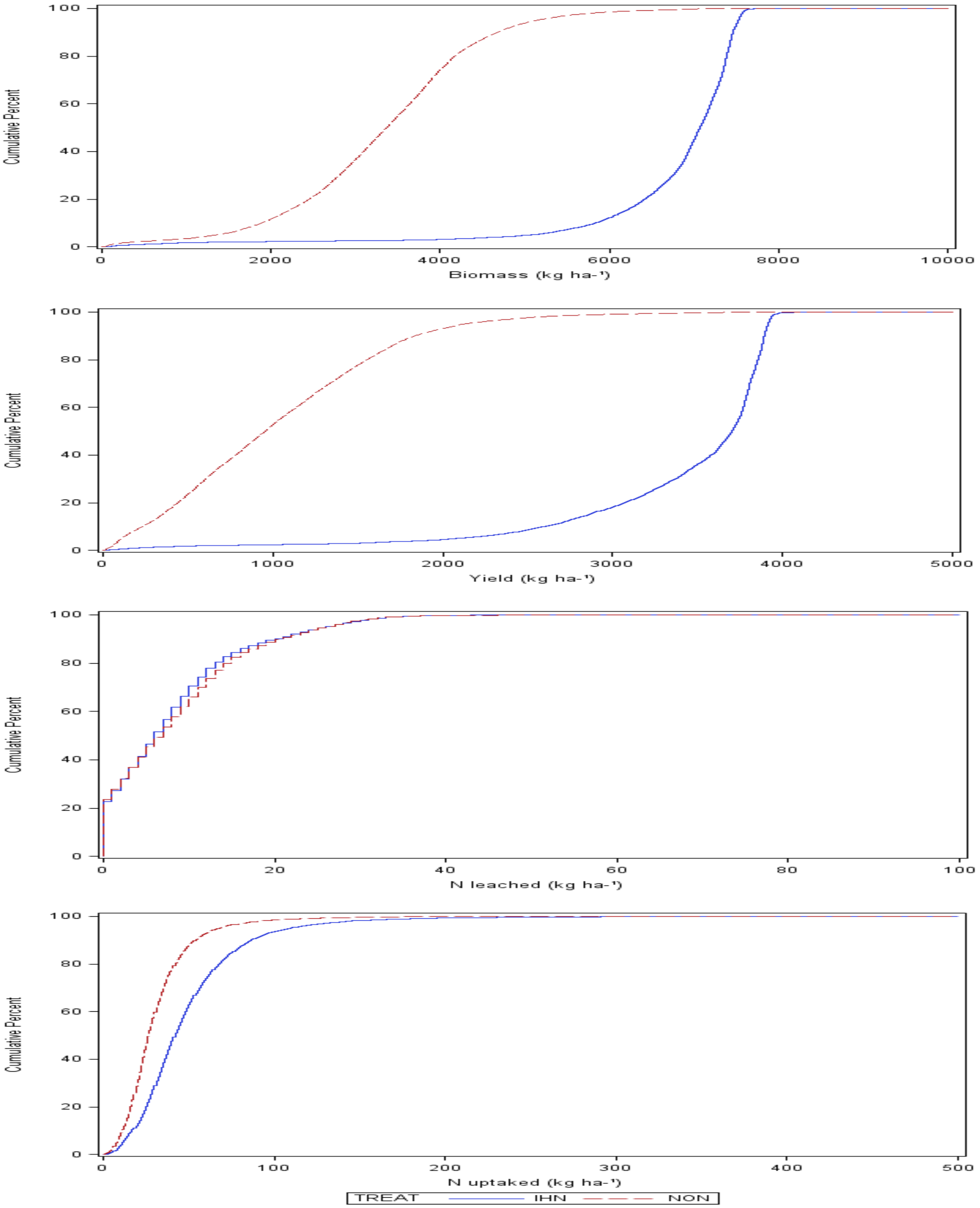


Figure 17. Cumulated Distributions Function of soybean Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation (IHN) and Rainfed (NON) treatments.

Table 15. The ten profiles with the lowest values for soybean yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon in both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Lowest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	BR0594	63	KE0084	21	ZA0039	17	PG0004	0	ZW0067	0	ZW0067	0	ZA0039	1	MX0028	0	IS0001	1203	IS0001	1256
2	ZA0039	66	MX0028	22	IS0001	18	KE0219	2	ZW0063	0	ZW0063	0	MX0028	1	BR0416	0	AQ0004	1549	PE0090	1608
3	IS0001	70	LY0006	30	MX0028	21	PH0039	6	ZW0060	0	ZW0060	0	IS0001	1	ZA0039	1	PE0090	1637	AQ0004	1624
4	KE0084	76	EC0019	31	NA0028	27	PG0010	8	ZW0059	0	ZW0059	0	GY0027	1	YE0247	1	EG0007	2202	EG0007	1741
5	KR0149	81	BR0222	32	BR0416	27	MX0028	9	ZW0043	0	ZW0051	0	PE0090	2	YE0235	1	ZA0039	2435	ZA0039	2493
6	BR0678	81	EC0020	34	PE0090	28	KE0084	9	ZW0041	0	ZW0049	0	PE0055	2	PE0090	1	OM0003	2841	OM0003	2698
7	GY0027	82	MX0025	35	HU0020	30	TH0284	12	ZW0040	0	ZW0048	0	NE0328	2	PE0055	1	AQ0001	3164	AQ0001	3254
8	NP0105	84	KE0218	39	KR0131	32	MX0025	13	ZW0025	0	ZW0043	0	NA0028	2	NP0105	1	MX0028	3629	MX0028	3613
9	PE0084	88	BO0055	39	MX0029	33	BR0416	13	ZW0006	0	ZW0041	0	NA0022	2	MX0029	1	HU0020	3860	HU0020	3821
10	BW0809	88	CD0066	42	YE0247	34	BO0055	13	ZW0001	0	ZW0040	0	KR0131	2	MX0025	1	NA0022	3991	YE0235	3986

Table 16. The profiles with the highest values for soybean yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon for both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Highest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	CL0018	7773	KR0056	7183	KR0034	4195	KR0056	3719	CL0047	51	YE0205	50	KR0034	332	KR0025	214	TH0156	1251110	TH0156	1251729
2	KR0025	7780	KR0196	7220	AR0215	4321	BJ0405	3726	DE0039	51	CL0047	52	RO0009	354	CH0014	219	AR0215	1260927	AR0215	1262217
3	KR0034	7829	BY0058	7224	RO0009	4329	BR0093	3745	EC0053	53	EC0053	52	RU0143	364	RO0009	236	AR0234	1345720	AR0234	1348043

4	AR0215	7923	BJ0405	7257	KR0040	4399	BJ0360	3794	YE0209	54	CL0018	56	KR0040	368	AL0016	242	GB0034	1372838	GB0034	1373769
5	RO0009	8001	BY0005	7287	RU0143	4412	CF0014	3796	CL0018	55	NL0008	56	CH0014	392	KR0040	242	MG0016	1391441	MG0016	1391432
6	KR0040	8016	MG0015	7345	AL0016	4456	BY0005	3800	NL0008	56	YE0189	56	AL0016	404	CH0013	246	IT0014	1410849	IT0014	1411087
7	CH0013	8040	MG0017	7348	CH0013	4589	BY0058	3803	YE0189	56	CL0048	58	YE0054	420	AR0234	277	ES0014	1458988	ES0014	1460238
8	AR0234	8064	CF0014	7367	AR0234	4626	GB0046	3854	CL0048	58	NL0003	58	CH0013	448	YE0054	297	MG0050	1468711	MG0050	1469025
9	UA0073	8180	BJ0360	7428	YE0054	4648	MG0015	3873	NL0003	58	YE0209	59	AR0234	452	UA0073	318	JM0040	1593157	JM0040	1594029
10	YE0054	8287	GB0046	7875	UA0073	4698	MG0017	3875	YE0054	88	YE0054	88	UA0073	456	RU0143	329	UA0073	1617440	UA0073	1620000

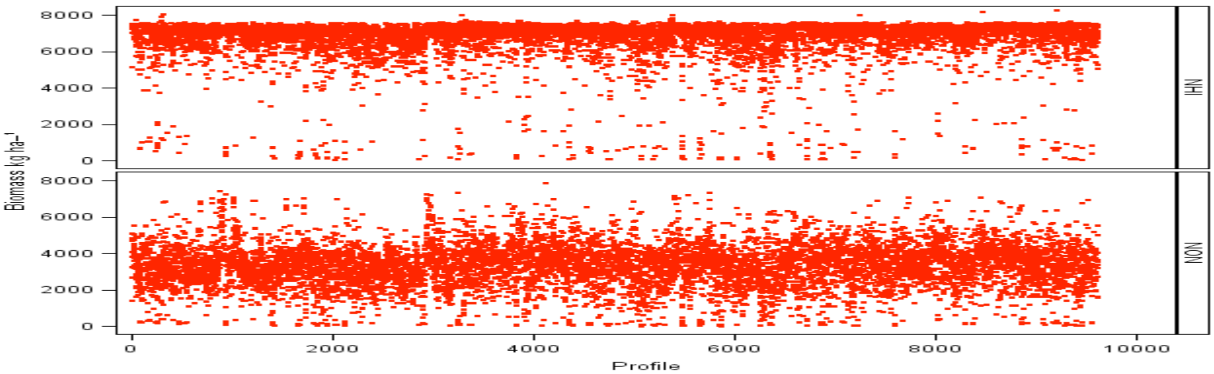


Figure 18. Box-plots comparison of the soybean Total Biomass between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

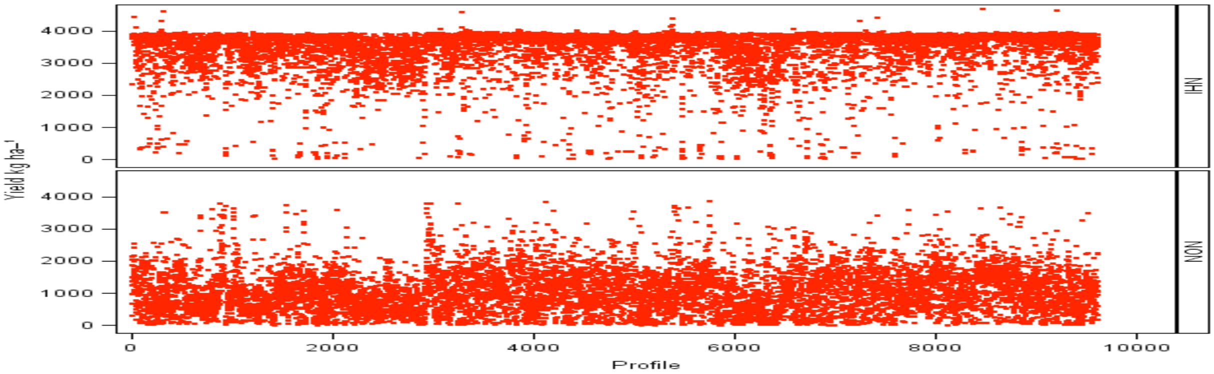


Figure 19. Box-plots comparison of the soybean Yield between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

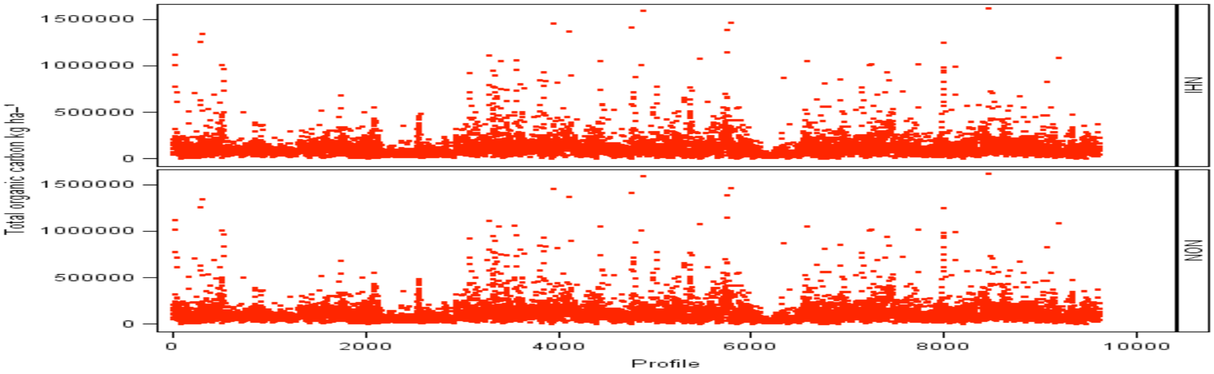
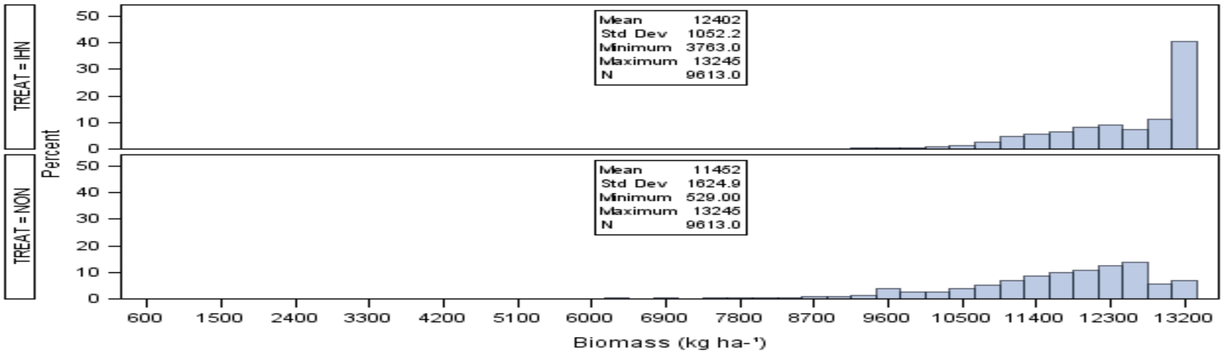


Figure 20. Box-plots comparison of the Organic Carbon at Maturity between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

Sorghum simulations

The simulations of sorghum Total Biomass (CWAM), Yield (HWAM), Nitrogen Uptake (NUCM) and Nitrogen Leached (NLCL), were summarized in empirical frequency histograms, including simple statistics, as well as empirical cumulative distribution function to compare the outputs of the two treatments used in the simulations. These graphs show the impact of the fertilization and water availability increasing the yield and total biomass mean close to 1 ton ha^{-1} respect to the rainfed treatment; significant reduction in variability were found for the irrigated and high nitrogen (IHN) treatment (figures 20 and 21).

The ten profiles showing the lowest and highest values of sorghum Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM), Nitrogen Uptake (NUCM) and Organic Carbon at Maturity (OCTAM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments were included (Table 17 and 18). Box-plot of the 9613 profiles to compare in detail the sorghum Total Biomass (CWAM), Yield (HWAM) and the Organic Carbon at Maturity of the two treatments were done (figures 22, 23 and 24).



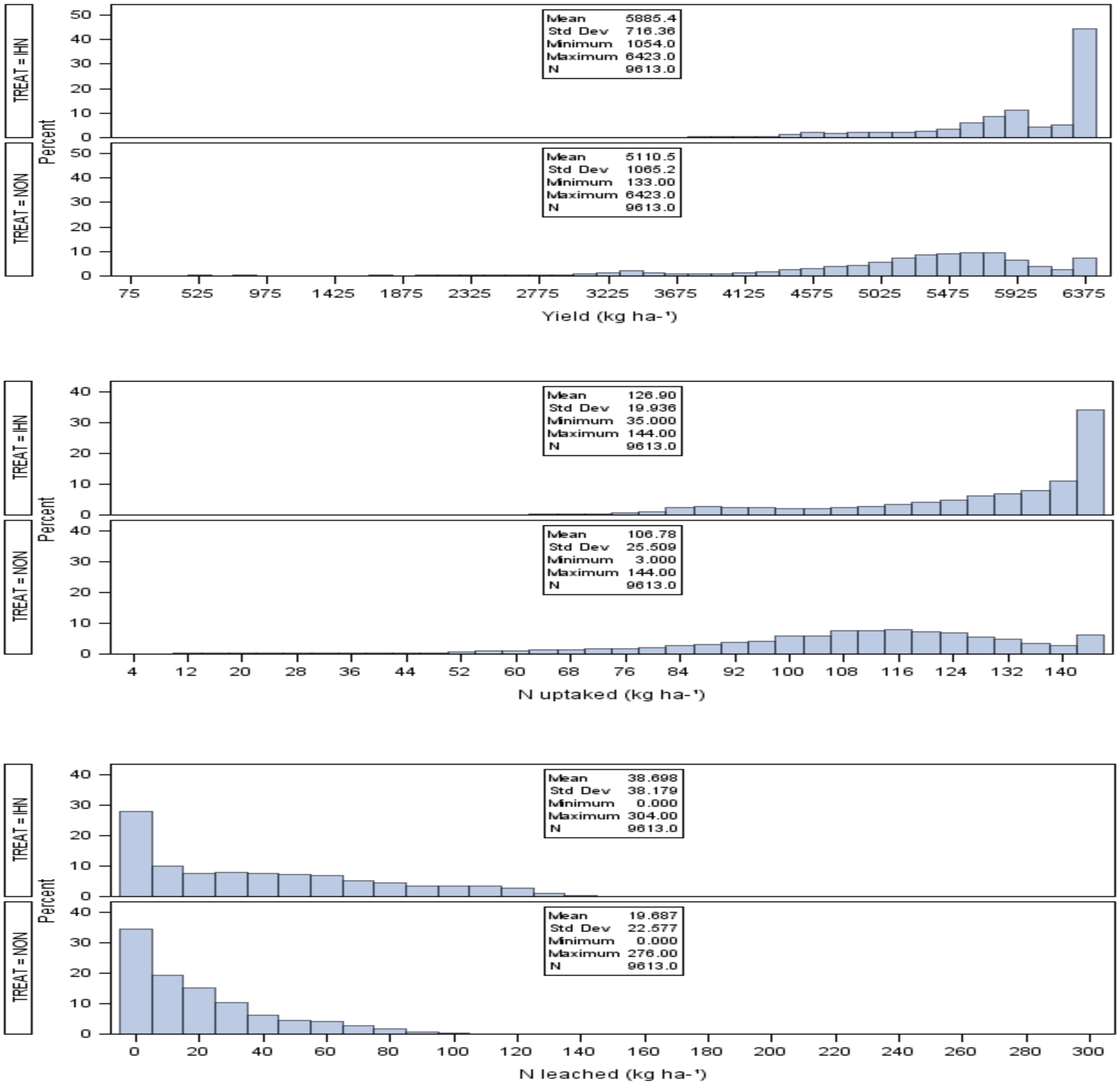


Figure 20. Frequency distribution of Irrigate High Nitrogen (IHN) and Rainfed Low Nitrogen treatments (NON) of sorghum Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation High Nitrogen(IHN) and Rainfed Low Nitrogen (NON) treatments.

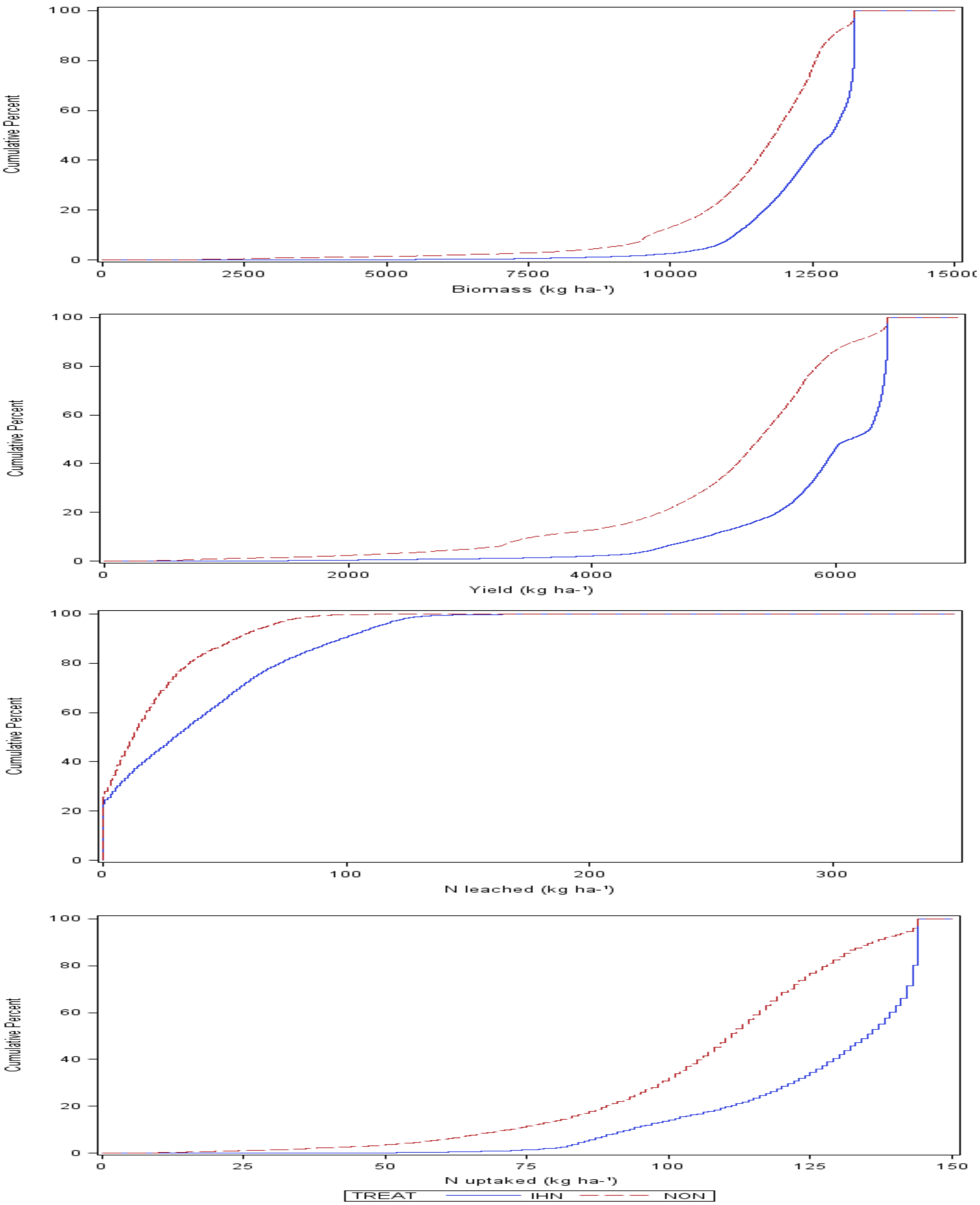


Figure 21. Cumulated Distributions Function of sorghum Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and Nitrogen Uptake (NUCM) for Irrigation (IHN) and Rainfed (NON) treatments.

Table 17. Ten lowest profiles for sorghum yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon in both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Lowest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	LY0006	3763	IS0001	529	ZA0039	1054	IS0001	133	ZW0063	0	ZW0067	0	ZA0039	35	ZA0039	3	EG0007	1197	IS0001	1190
2	EC0019	3834	ZA0039	637	PE0065	1170	ZA0039	142	ZW0060	0	ZW0063	0	LY0006	36	IS0001	3	IS0001	1283	EG0007	1203
3	MX0028	3935	PE0090	864	IS0001	1182	PE0090	218	ZW0059	0	ZW0061	0	NE0268	37	PE0090	5	AQ0004	1303	AQ0004	1266
4	EC0020	4122	NA0028	1079	PL0019	1258	NA0022	265	ZW0051	0	ZW0060	0	MX0028	37	NA0028	6	OM0003	1583	PE0090	1575
5	KE0084	4184	NA0022	1122	LY0006	1297	NA0028	271	ZW0049	0	ZW0059	0	EC0019	37	NA0022	6	PE0090	1672	OM0003	1582
6	MX0025	4422	NE0328	1200	MX0028	1304	NE0328	293	ZW0048	0	ZW0051	0	KE0084	38	NE0328	7	ZA0039	2510	ZA0039	2426
7	ZA0039	4603	KR0131	1215	GY0027	1334	AQ0001	303	ZW0043	0	ZW0049	0	EC0020	40	AQ0001	7	EG0008	2831	EG0008	2832
8	KE0218	4681	MX0029	1280	EC0019	1369	KR0131	321	ZW0041	0	ZW0048	0	MX0025	41	PE0084	8	AQ0001	2970	AQ0001	2912
9	KE0219	4821	AQ0001	1315	NA0028	1407	MX0029	322	ZW0040	0	ZW0043	0	KE0218	45	MX0029	8	TR0032	3108	TR0032	3117
10	PY0033	4855	MX0028	1368	EC0020	1409	PE0084	354	ZW0035	0	ZW0041	0	BO0055	45	KR0131	8	MX0028	3684	MX0028	3671

Table 18. Ten highest profiles for sorghum yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon in both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Highest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	ZM0012	13245	WS0006	13245	ZM0022	6423	WS0014	6423	NL0003	182	EC0055	131	ZM0084	144	YE0121	144	TH0156	1250444	TH0156	1251016
2	ZM0020	13245	WS0014	13245	ZM0065	6423	YE0054	6423	CL0048	184	NL0008	132	ZW0008	144	YE0174	144	AR0215	1260595	AR0215	1260983
3	ZM0065	13245	YE0054	13245	ZM0084	6423	YE0181	6423	KR0042	184	CL0047	141	ZW0016	144	YE0181	144	AR0234	1344882	AR0234	1345090
4	ZM0084	13245	YE0181	13245	ZW0008	6423	YE0183	6423	NL0008	191	EC0053	141	ZW0017	144	YE0183	144	GB0034	1372578	GB0034	1372583
5	ZW0008	13245	YE0183	13245	ZW0017	6423	YE0187	6423	CS0005	195	MX0008	154	ZW0019	144	YE0187	144	MG0016	1389800	MG0016	1389902

6	ZW0017	13245	YE0187	13245	ZW0019	6423	YE0189	6423	MX0008	209	CL0048	162	ZW0026	144	YE0189	144	IT0014	1410189	IT0014	1410334
7	ZW0019	13245	YE0189	13245	ZW0026	6423	YE0194	6423	YE0189	221	YE0189	170	ZW0027	144	YE0194	144	ES0014	1457184	ES0014	1457459
8	ZW0027	13245	YE0195	13245	ZW0027	6423	YE0195	6423	MX0039	245	MX0039	187	ZW0038	144	YE0195	144	MG0050	1468102	MG0050	1468125
9	ZW0038	13245	ZW0008	13245	ZW0038	6423	ZW0008	6423	CL0018	265	CL0018	203	ZW0055	144	ZW0008	144	JM0040	1592637	JM0040	1592743
10	ZW0055	13245	ZW0019	13245	ZW0055	6423	ZW0019	6423	YE0054	304	YE0054	276	ZW0064	144	ZW0019	144	UA0073	1617018	UA0073	1617981

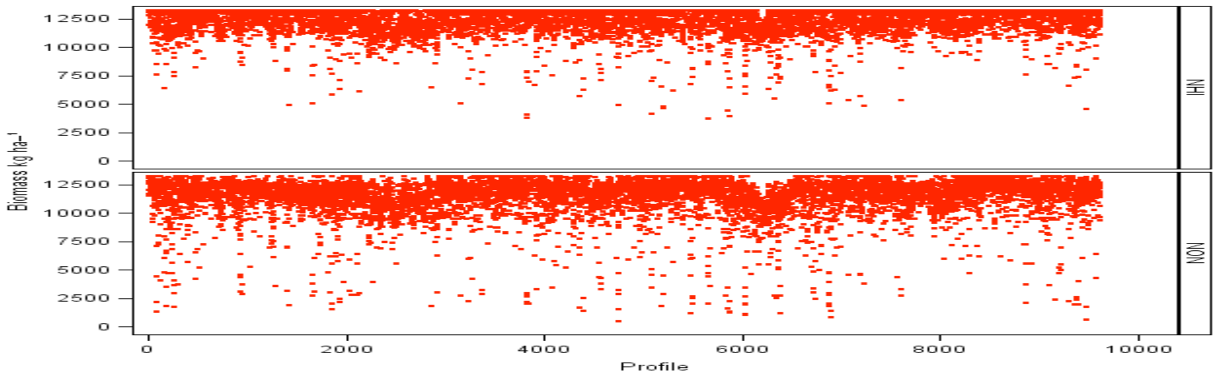


Figure 22. Box-plots comparison of the sorghum Organic Carbon at Maturity between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

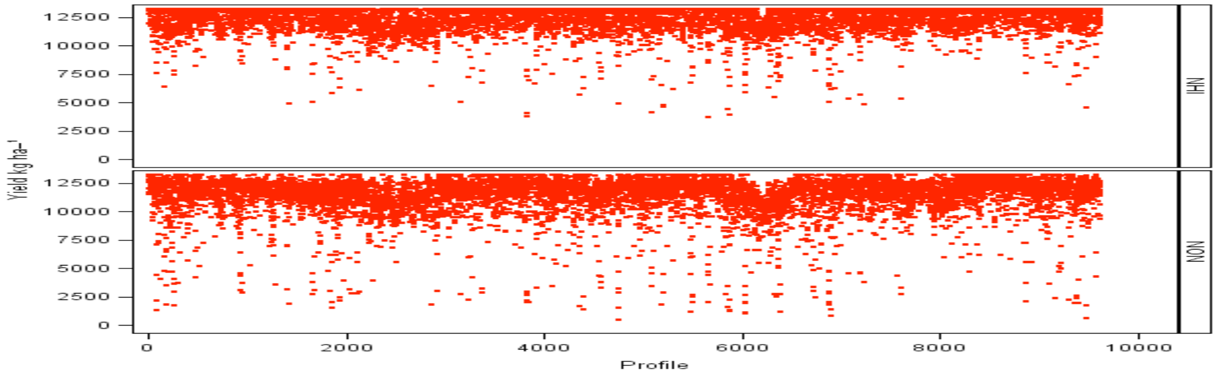


Figure 23. Box-plots comparison of the sorghum Yield between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

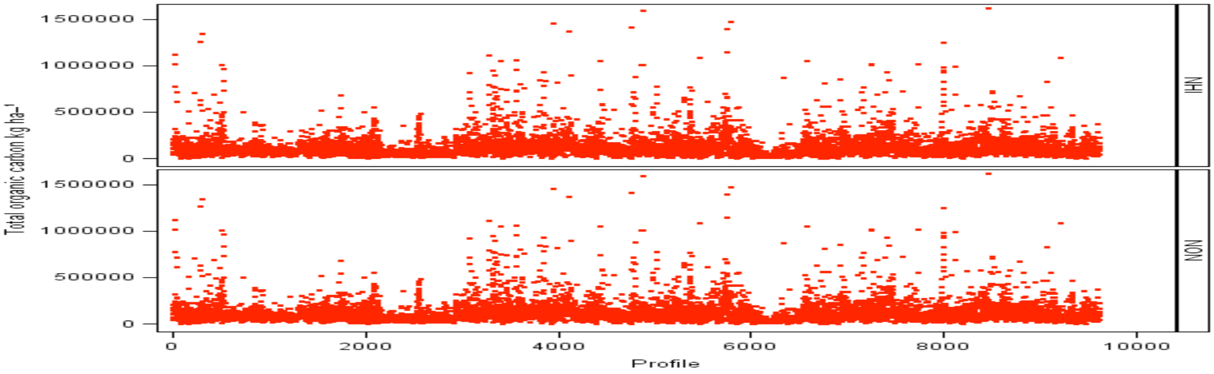
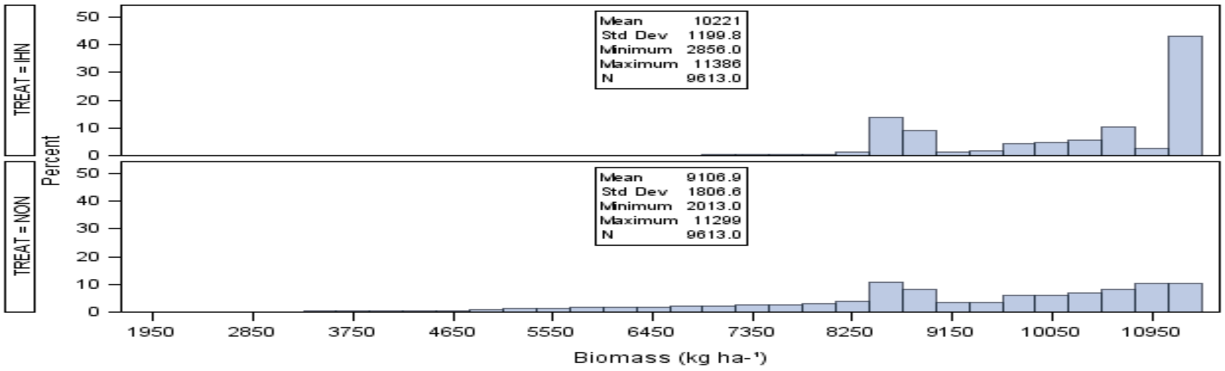


Figure 24. Box-plots comparison of the Organic Carbon at Maturity between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

Wheat simulations

The simulations of wheat Total Biomass (CWAM), Yield (HWAM), Nitrogen Uptake (NUCM) and Nitrogen Leached (NLCL), were summarized in empirical frequency histograms, including simple statistics, as well as empirical cumulative distribution function to compare the outputs of the two treatments used in the simulations. These graphs show the impact of the fertilization and water availability increasing the yield and total biomass more than 0.5ton ha^{-1} respect to the rainfed treatment; significant reduction in variability were found for the irrigated and high nitrogen (IHN) treatment (figures 25 and 26).

The ten profiles showing the lowest and highest values of wheat Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM), Nitrogen Uptake (NUCM) and Organic Carbon at Maturity (OCTAM) for Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON) treatments were included (Table 19 and 20). Box-plot of the 9613 profiles to compare in detail the Total Biomass (CWAM), Yield (HWAM) and the Organic Carbon at Maturity of the two treatments were done (figures 27, 28 and 29).



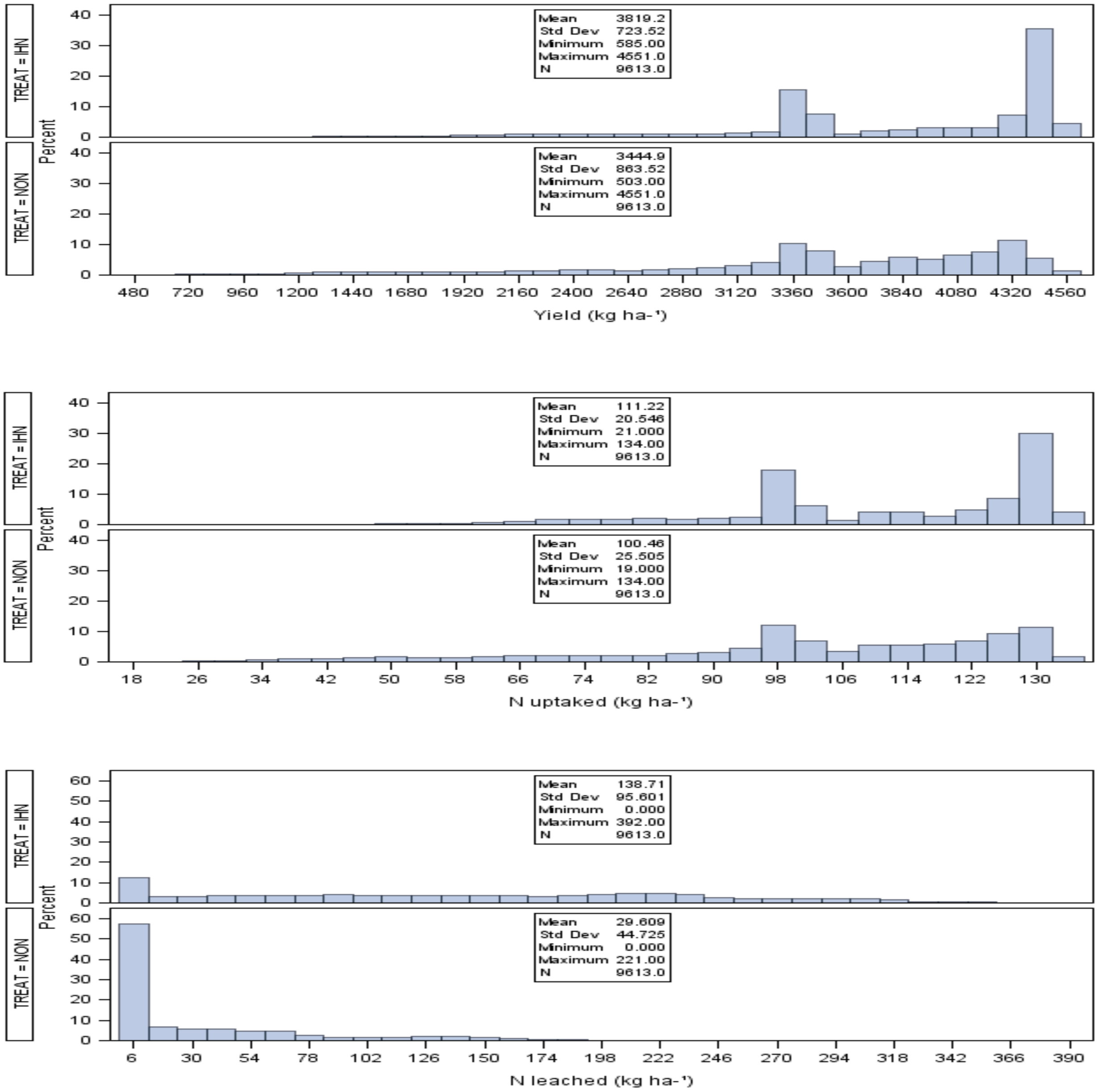


Figure 25. Frequency distribution of Irrigate High Nitrogen (IHN) and Rainfed Low Nitrogen treatments (NON) of wheat Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) andNitrogen Uptake (NUCM) for Irrigation High Nitrogen(IHN) and Rainfed Low Nitrogen (NON) treatments.

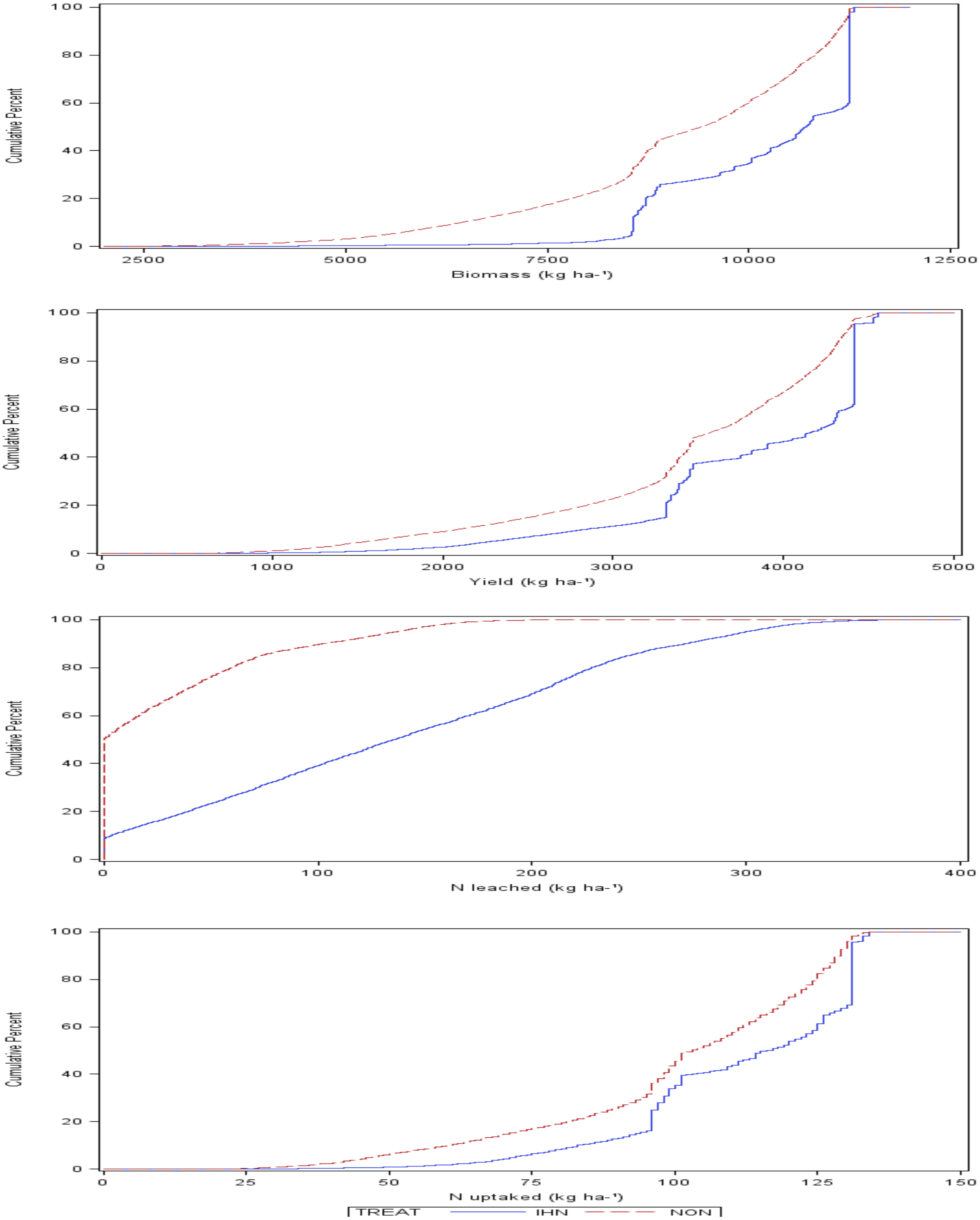


Figure 26. Cumulated Distributions Function of wheat Total Biomass (CWAM), Yield (HWAM), Nitrogen Leach (NLCM) and for Irrigation (IHN) and Rainfed (NON) treatments.

Table 19. Ten lowest profiles for wheat yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon in both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Lowest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	ZA0039	2856	LY0006	2013	ZA0039	585	EG0011	503	ZW0060	0	ZW0067	0	ZA0039	21	ZA0039	19	EG0007	1737	IS0001	1729
2	MX0028	3233	PG0004	2051	NA0022	696	AQ0001	517	ZW0040	0	ZW0066	0	NA0022	26	MX0028	20	IS0001	1744	EG0007	1762
3	LY0006	3312	MX0028	2086	IS0001	729	ZA0039	523	ZM0066	0	ZW0064	0	IS0001	26	LY0006	20	AQ0004	1811	AQ0004	1785
4	IS0001	3682	KE0084	2124	EG0011	734	MR0004	581	ZM0057	0	ZW0063	0	MX0028	28	EG0011	20	PE0090	2127	PE0090	2113
5	NA0022	3686	EC0020	2259	AQ0001	749	AQ0004	598	ZM0033	0	ZW0061	0	AR0165	28	AQ0001	20	OM0003	2156	OM0003	2176
6	EC0020	3696	SK0027	2348	AR0165	750	BW0396	602	ZA0005	0	ZW0060	0	PE0090	29	PG0004	21	ZA0039	2968	ZA0039	2965
7	AR0165	3919	EC0019	2414	NA0028	797	AR0165	604	VE0151	0	ZW0059	0	NA0028	29	IS0001	21	EG0008	3338	EG0008	3341
8	PE0090	3984	KE0218	2429	PE0090	813	NA0022	607	VE0116	0	ZW0056	0	LY0006	29	NA0022	22	AQ0001	3455	AQ0001	3433
9	NA0028	4020	ZA0039	2464	YE0009	816	IS0001	607	VE0115	0	ZW0053	0	EG0011	29	MR0004	22	TR0032	3632	TR0032	3607
10	EC0019	4117	KE0219	2465	ZA0033	858	ZA0033	650	VE0077	0	ZW0051	0	AQ0001	29	KE0084	22	AQ0009	4266	AQ0009	4260

Table 20. Ten highest profiles for wheat yield, total biomass, nitrogen leach, nitrogen uptake and organic carbon in both treatments.

	Total Biomass				Yield				N Leach				N Uptake				Organic Carbon			
	IHN		NON		IHN		NON		IHN		NON		IHN		NON		IHN		NON	
Highest	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value	ID	Value
1	YE0131	11299	KR0026	11299	WS0007	4551	KR0026	4551	NE0117	365	ML0010	201	VE0118	134	KR0028	134	TH0156	1252616	TH0156	1253127
2	YE0133	11299	KR0028	11299	YE0016	4551	KR0028	4551	NE0454	368	CD0006	203	WS0007	134	KR0029	134	AR0215	1262216	AR0215	1263250
3	YE0264	11299	KR0029	11299	YE0024	4551	KR0029	4551	LT0001	371	US0306	203	YE0016	134	KR0030	134	AR0234	1347599	AR0234	1348143
4	ZM0065	11299	KR0030	11299	YE0099	4551	KR0030	4551	US0233	371	BW0422	204	YE0131	134	KR0038	134	GB0034	1373811	GB0034	1374444
5	ZM0084	11299	KR0038	11299	YE0131	4551	KR0038	4551	ZW0058	374	ZW0058	206	YE0133	134	KR0041	134	MG0016	1392072	MG0016	1392244
6	ZW0	1129	KR0	1129	YE0	455	KR0	455	BW0	375	EG0	208	YE0	134	RW0	134	IT00	1411	IT00	14120

	005	9	041	9	133	1	041	1	422		009		171		040		14	635	14	60
7	BJ0594	11386	RW0040	11299	YE0264	4551	RW0040	4551	SN0011	375	UA0006	208	YE0264	134	RW0042	134	ES0014	1461319	ES0014	1461816
8	BR0442	11386	US0068	11299	ZM0065	4551	US0068	4551	SN0013	375	NE0454	213	ZM0065	134	US0068	134	MG0050	1469284	MG0050	1469690
9	CO0024	11386	US0257	11299	ZM0084	4551	US0257	4551	AU0090	383	AO0003	215	ZM0084	134	US0284	134	JM0040	1593743	JM0040	1594407
10	NE0224	11386	US0372	11299	ZW0005	4551	US0372	4551	UA0006	392	AU0090	221	ZW0005	134	US0372	134	UA0073	1619944	UA0073	1620979

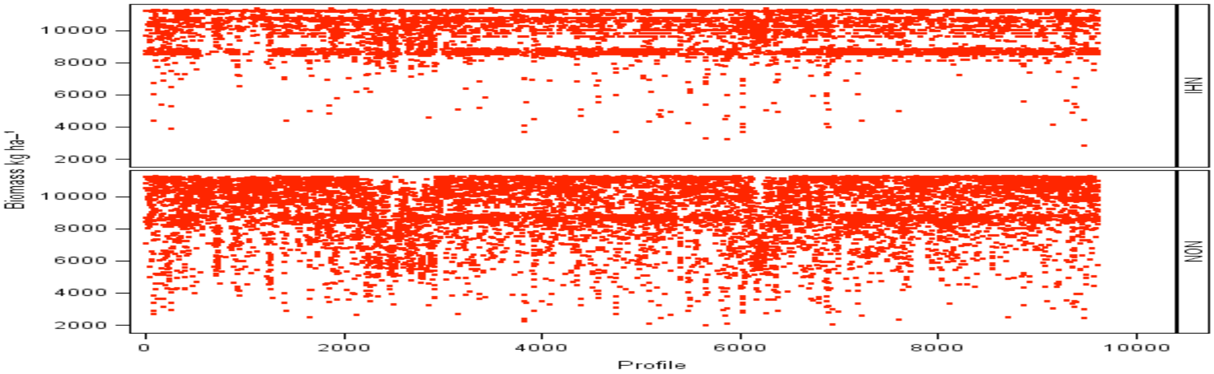


Figure 27. Box-plots comparison of the wheat Total Biomass between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

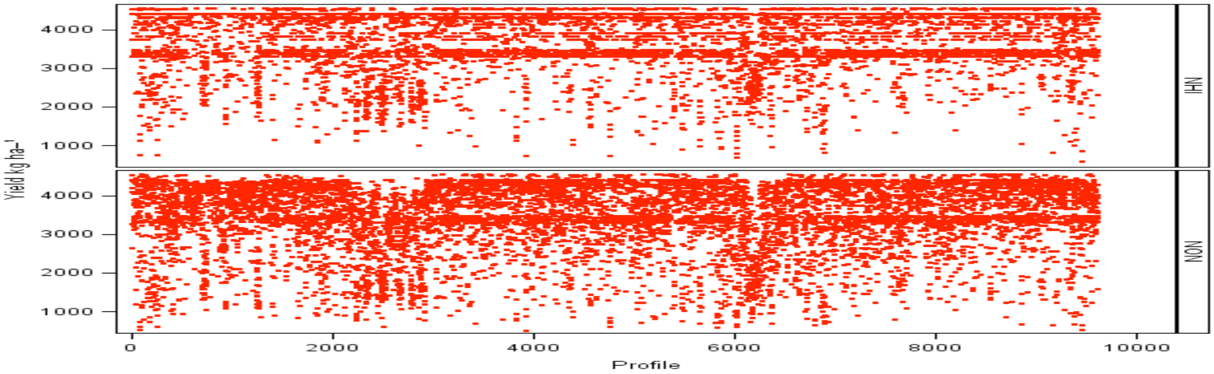


Figure 28. Box-plots comparison of the wheat Yield between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

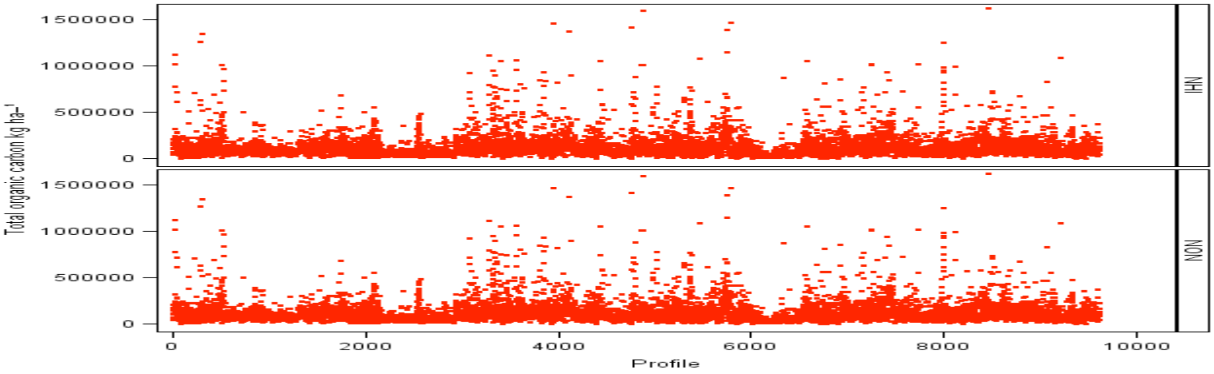


Figure 29. Box-plots comparison of the Organic Carbon at Maturity between Irrigation High Nitrogen (IHN) and Rainfed Low Nitrogen (NON).

Seasonal analysis

A total of 576780 simulations reflected the inter-annual maize yield variability and the difference between the two treatments; the analysis of variance for each treatment demonstrated as well the significant interaction between type of soil (FAO90) and year. The interaction meaning that the effect of the groups (FAO90) on maize yield depended on the year factor, assuring the pattern through the time was not the same for the groups. Therefore DSSAT simulations were capable to determine differences in yield and other characteristics to the diversity of weather (30 season of generated weather) and environmental represented by the WISE3.1 profiles (Table 21).

Table 21. Mean, standard deviation and coefficient of variation of the simulated yield per year.

Year	Mean-Rainfed	Std Dev-Rainfed	CV-Rainfed	Mean-High N-Irrigation	Std Dev-High N-Irrigation	CV-High N-Irrigation
1	1103.00	676.97	61.38	8918.78	1486.58	16.67
2	1108.58	822.49	74.19	8666.12	1434.42	16.55
3	670.66	426.66	63.62	8764.41	1248.83	14.25
4	423.51	446.55	105.44	8680.11	1374.73	15.84
5	1559.96	1833.24	117.52	9073.32	1384.13	15.25
6	1366.50	1521.14	111.32	9446.64	1629.82	17.25
7	1569.61	1520.95	96.90	9652.11	1341.89	13.90
8	1106.05	915.00	82.73	9514.80	1309.65	13.76
9	907.81	723.14	79.66	8770.39	1343.73	15.32
10	653.78	665.97	101.87	9557.79	1575.94	16.49
11	1688.17	1685.49	99.84	8865.06	1418.59	16.00
12	1123.43	988.15	87.96	9494.55	1325.36	13.96
13	490.16	490.99	100.17	8515.27	1020.90	11.99
14	696.68	511.07	73.36	8935.36	1190.14	13.32
15	1070.85	1186.03	110.76	8923.03	1496.00	16.77
16	1173.45	1367.01	116.50	8805.10	1471.23	16.71
17	1185.78	993.70	83.80	8829.60	1438.61	16.29
18	1321.78	1242.94	94.04	9609.85	1722.98	17.93

19	1310.98	1537.93	117.31	9119.66	1487.16	16.31
20	631.96	1121.39	177.45	8188.36	1183.79	14.46
21	857.71	1050.78	122.51	9094.77	1337.71	14.71
22	957.29	820.66	85.73	8805.69	1260.45	14.31
23	966.05	860.95	89.12	9182.38	1711.83	18.64
24	1055.66	847.53	80.28	8998.24	1355.19	15.06
25	1191.61	1030.02	86.44	9045.77	1665.47	18.41
26	1100.60	1175.27	106.78	9033.51	1463.13	16.20
27	1022.39	1117.53	109.31	9294.99	1586.08	17.06
28	994.50	1253.66	126.06	9221.28	1481.79	16.07
29	1310.95	1209.09	92.23	8716.78	1441.26	16.53
30	1116.44	1217.55	109.06	8914.37	1223.92	13.73

The variability of the rainfed yield through time and groups was higher than the treatment with high nitrogen and irrigation The application of nitrogen and water supply increased substantially the maize yield in more than 8 times the rainfed one (Table22).

Table 22. Mean standard deviation and coefficient of variation of the simulated yield per FAO90.

FAO 90	Mean-Rainfed	Std Dev-Rainfed	CV-Rainfed	Mean-High N-Irrigation	Std Dev-High N-Irrigation	CV-High N-Irrigation
ACf	846.42	615.53	72.72	8635.30	868.40	10.06
ACg	475.59	374.49	78.74	8058.34	638.92	7.93
ACh	791.04	588.73	74.42	8594.08	862.44	10.04
ACp	714.51	570.34	79.82	8450.37	829.69	9.82
ACu	1391.70	1388.14	99.74	9984.10	1460.87	14.63
ALf	1230.85	855.54	69.51	9077.41	1022.83	11.27
ALg	675.91	506.91	75.00	8392.08	755.82	9.01
ALh	887.89	757.45	85.31	8600.69	1081.06	12.57
ALj	759.89	1059.84	139.47	8439.26	1066.98	12.64
ALp	701.30	359.20	51.22	8416.10	494.13	5.87
ALu	2122.45	2202.73	103.78	10795.45	1537.82	14.25
ANg	1400.88	1242.27	88.68	10574.77	1413.20	13.36
ANh	2561.97	2770.97	108.16	11413.54	1973.13	17.29
ANm	2845.26	2732.78	96.05	11921.45	1532.08	12.85
ANu	3314.33	3246.69	97.96	12520.91	1346.04	10.75
ANz	2677.22	2634.53	98.41	11070.93	2231.52	20.16
ARa	409.45	195.67	47.79	7856.37	438.17	5.58
ARb	444.79	333.61	75.00	7904.63	639.03	8.08
ARc	496.75	327.69	65.97	7673.27	805.77	10.50
ARg	533.73	424.59	79.55	8006.54	733.94	9.17
ARh	462.18	365.68	79.12	7839.96	738.78	9.42

ARl	374.69	245.03	65.40	7765.32	546.92	7.04
ARo	413.34	305.73	73.97	7854.36	567.40	7.22
ATc	1746.86	1647.70	94.32	10107.04	1494.21	14.78
ATf	2368.56	1754.25	74.06	11613.31	1452.04	12.50
ATu	548.07	104.31	19.03	8063.97	318.80	3.95
CHg	1661.19	1274.73	76.74	10575.67	764.03	7.22
CHh	2349.01	2132.40	90.78	11647.72	1393.93	11.97
CHk	2041.49	1866.43	91.42	10998.66	1448.76	13.17
CHl	2066.48	1778.79	86.08	11019.03	1533.76	13.92
CHw	1589.15	1352.83	85.13	10219.98	908.53	8.89
CLh	975.25	704.69	72.26	8212.66	1186.14	14.44
CLl	941.89	658.66	69.93	8313.12	1164.59	14.01
CLp	823.13	671.55	81.58	8153.44	1119.06	13.72
CMc	1215.78	1034.15	85.06	8995.82	1484.28	16.50
CMd	1056.55	1012.79	95.86	9171.84	1347.65	14.69
CMe	1265.63	1114.20	88.03	9473.42	1268.29	13.39
CMg	1001.51	872.93	87.16	9040.78	1181.15	13.06
CMi	1091.51	945.81	86.65	9045.64	1359.53	15.03
CMo	699.57	521.08	74.49	8533.66	820.03	9.61
CMu	1589.29	1621.49	102.03	10379.73	1655.29	15.95
CMv	984.38	780.42	79.28	9043.35	1081.24	11.96
CMx	1211.91	1009.67	83.31	9493.06	1173.05	12.36
FLc	1418.24	1298.10	91.53	9152.89	1583.48	17.30
FLd	825.27	898.67	108.89	8556.64	985.85	11.52
FLe	1203.03	1244.01	103.41	9189.19	1496.38	16.28
FLm	1492.34	1257.96	84.29	9710.77	1315.93	13.55
FLs	844.54	749.47	88.74	8708.15	1150.85	13.22
FLt	780.96	1002.50	128.37	8731.16	1377.82	15.78
FLu	1388.37	1189.97	85.71	9632.04	1310.26	13.60
FRg	850.93	923.79	108.56	8916.23	1082.38	12.14
FRh	844.64	672.27	79.59	8822.13	909.22	10.31
FRp	699.47	534.05	76.35	8625.77	799.58	9.27
FRr	1000.37	785.27	78.50	9201.46	1067.52	11.60
FRu	1153.37	948.85	82.27	9586.16	1227.25	12.80
FRx	614.08	422.20	68.75	8310.81	620.06	7.46
GLd	665.44	670.18	100.71	8440.36	1024.51	12.14
GLe	863.88	862.12	99.80	8789.44	1143.30	13.01
GLi	1023.24	927.05	90.60	9036.91	1088.55	12.05
GLk	1057.13	949.04	89.77	9141.05	989.51	10.82
GLm	1221.19	1195.87	97.93	9428.89	1350.06	14.32

GLt	833.14	640.68	76.90	8836.54	719.70	8.14
GLu	1043.11	1015.35	97.34	8975.74	1453.95	16.20
GRg	1376.54	857.75	62.31	9744.54	575.73	5.91
GRh	1656.79	1197.81	72.30	9964.47	1101.82	11.06
GYh	681.85	479.86	70.38	8136.30	941.91	11.58
GYk	808.84	543.42	67.19	8154.99	1102.88	13.52
GYl	1331.28	1055.75	79.30	8280.30	2598.34	31.38
GYp	473.13	287.70	60.81	7714.39	459.29	5.95
HSf	1489.02	1825.98	122.63	10515.71	1492.80	14.20
HSi	2380.68	2605.42	109.44	11236.32	3001.46	26.71
HSl	5025.05	4879.12	97.10	13387.25	703.17	5.25
HSs	1406.72	1667.08	118.51	10328.34	1368.66	13.25
HSt	1347.78	2156.39	160.00	11124.58	2047.20	18.40
KSh	1672.67	1209.95	72.34	10417.26	1235.95	11.86
KSk	1677.80	1408.87	83.97	10260.28	1105.82	10.78
KSl	1598.94	1089.69	68.15	10108.54	1081.24	10.70
LPd	501.00	540.41	107.87	8031.16	1017.31	12.67
LPe	563.48	615.04	109.15	7757.16	1223.95	15.78
LPi	680.02	1025.94	150.87	8056.83	1861.00	23.10
LPk	1396.15	1470.23	105.31	9423.45	1810.77	19.22
LPm	1296.31	1567.94	120.95	9331.45	1882.19	20.17
LPq	293.00	321.41	109.70	6898.71	838.37	12.15
LPu	856.05	960.47	112.20	8617.69	1522.54	17.67
LVa	1065.46	673.69	63.23	8781.63	979.18	11.15
LVf	1084.20	593.07	54.70	8975.25	744.78	8.30
LVg	904.64	727.84	80.46	8752.53	939.46	10.73
LVh	1071.49	842.70	78.65	9052.85	1107.73	12.24
LVj	933.69	951.05	101.86	8831.27	1157.89	13.11
LVk	1080.04	788.99	73.05	8920.22	1104.97	12.39
LVv	1093.92	880.71	80.51	9370.14	1153.32	12.31
LVx	1133.76	803.19	70.84	9188.02	1018.07	11.08
LXa	1601.68	1374.73	85.83	9483.62	1478.07	15.59
LXf	1060.91	716.92	67.58	8987.11	976.37	10.86
LXg	843.33	817.17	96.90	8776.49	1185.44	13.51
LXh	1026.41	707.43	68.92	8961.84	994.95	11.10
LXj	661.40	394.92	59.71	8572.43	404.79	4.72
LXp	787.80	566.90	71.96	8563.71	878.34	10.26
NTh	1069.36	875.82	81.90	9241.92	1206.23	13.05
NTr	1276.84	1090.75	85.43	9649.91	1140.92	11.82
NTu	1667.86	1472.06	88.26	10760.64	1463.99	13.61

PDd	617.70	542.30	87.79	8204.94	557.29	6.79
PDe	834.81	582.18	69.74	8596.66	876.73	10.20
PDg	801.75	557.19	69.50	8613.61	800.00	9.29
PDj	757.97	829.88	109.49	8632.76	1307.43	15.15
PHc	1867.01	1597.82	85.58	10400.48	1490.32	14.33
PHg	1371.90	1159.96	84.55	9948.23	1278.99	12.86
PHh	1728.35	1575.13	91.14	10713.02	1424.41	13.30
PHj	1792.39	1717.68	95.83	10874.55	1368.28	12.58
PHl	1747.85	1485.21	84.97	10610.09	1276.88	12.03
PLd	530.66	453.73	85.50	8120.69	760.40	9.36
PLe	845.92	701.58	82.94	8674.90	948.99	10.94
PLm	1234.36	881.35	71.40	9693.29	828.82	8.55
PLu	791.91	582.14	73.51	7666.89	641.17	8.36
PTa	585.51	382.03	65.25	8213.24	582.58	7.09
PTd	616.35	463.85	75.26	8270.60	697.75	8.44
PTe	776.44	583.26	75.12	8527.94	895.73	10.50
PTu	952.41	806.58	84.69	8986.02	1077.19	11.99
PZb	1137.55	1074.50	94.46	9282.63	1715.43	18.48
PZc	880.81	1271.10	144.31	8580.54	1662.10	19.37
PZf	1370.38	1564.84	114.19	9280.74	1650.05	17.78
PZg	999.08	1036.00	103.70	8709.19	1471.98	16.90
PZh	883.65	1009.98	114.30	8680.51	1261.80	14.54
PZi	1305.75	1277.24	97.82	9248.89	1671.83	18.08
RGc	978.65	982.35	100.38	8301.54	1345.16	16.20
RGd	764.11	867.67	113.55	8586.93	1223.39	14.25
RGe	842.60	779.40	92.50	8561.18	1118.75	13.07
RGi	1360.08	1489.89	109.54	9040.41	1744.70	19.30
RGu	697.30	683.75	98.06	8489.93	1157.62	13.64
RGy	562.92	457.92	81.35	7644.44	1655.62	21.66
SCg	633.92	819.05	129.20	7710.32	1323.33	17.16
SCh	590.17	501.93	85.05	7862.20	1098.71	13.97
SCi	635.79	597.14	93.92	7777.85	1209.63	15.55
SCk	590.13	481.40	81.57	7479.99	1015.57	13.58
SCm	1015.15	950.70	93.65	9125.90	1315.34	14.41
SCn	762.68	622.87	81.67	7916.73	1076.25	13.59
SCy	582.42	416.47	71.51	7716.60	867.66	11.24
SNg	866.28	768.46	88.71	8707.74	1108.59	12.73
SNh	934.55	732.54	78.38	8497.94	1274.08	14.99
SNj	927.26	796.21	85.87	8674.99	929.74	10.72
SNk	875.67	605.60	69.16	8075.79	1139.54	14.11

SNm	1118.52	781.62	69.88	9122.39	1084.55	11.89
SNy	958.39	715.61	74.67	8218.69	1708.51	20.79
VRd	797.64	664.68	83.33	8855.36	908.71	10.26
VRe	1124.24	1160.89	103.26	9452.03	1349.92	14.28
VRk	1084.28	1080.31	99.63	9181.71	1462.94	15.93
VRy	1269.27	1343.14	105.82	9864.75	1570.39	15.92

Yield percentiles 10, 25, 50, 75 and 90, and the mean of each type of soil (FAO90) and treatment was determined; despite of the number of profiles in each group (FAO90), it is possible to calculate probabilities for obtaining determinate yield: as an example for the ACh group (Acrisol) has 399 profiles, the probability that the maize yield be less than 360.33kgha^{-1} is 0.25 when the treatment is rainfed and 7852.73kgha^{-1} when high nitrogen and irrigation were applied; or the probability that the maize yield ranges from 1978.60kgha^{-1} to 3239.67kgha^{-1} is 0.15 for rainfed treatment and 10633.23kgha^{-1} to 1261.23kgha^{-1} for high nitrogen and irrigation treatment (Table 23).

Table 23. Percentiles 10, 25, 50, 75, 90 and the mean for each type of soil (FAO90) and treatment.

	Rainfed						**High Nitrogen and Irrigation**					
FAO	**P10**	**P25**	**P50**	**P75**	**P90**	**Mean**	**P10**	**P25**	**P50**	**P75**	**P90**	**Mean**
ACf	242.00	459.83	1085.03	2101.07	3196.47	846.42	7564.87	8004.33	9032.00	10916.17	12785.37	8635.30
ACg	176.57	259.47	523.03	1221.53	1721.23	475.59	7346.47	7507.47	8191.70	9736.40	11438.60	8058.34
ACh	184.87	360.33	955.77	1978.60	3239.67	791.04	7450.47	7852.73	8765.50	10633.23	12961.23	8594.08
ACp	170.77	347.10	749.17	1725.40	3309.43	714.51	7399.53	7839.40	8547.63	10481.33	12732.03	8450.37
ACu	409.77	756.53	1536.97	2416.97	3077.43	1391.70	8004.17	8620.47	10324.23	12842.80	13461.87	9984.10
ALf	415.00	1107.83	1762.83	2003.83	2560.07	1230.85	7943.90	8799.07	9819.33	10802.40	11898.63	9077.41
ALg	208.30	362.63	975.43	1781.40	2711.53	675.91	7378.33	7654.47	9111.77	10572.03	12871.63	8392.08
ALh	171.10	400.00	908.60	2044.83	3794.10	887.89	7391.27	7928.70	8804.80	11215.77	13161.57	8600.69
ALj	221.97	233.87	657.40	1873.23	4297.63	759.89	7518.43	7581.23	8459.07	10828.87	13523.40	8439.26
ALp	270.67	438.63	662.10	1906.80	2056.00	701.30	7662.67	7922.70	8358.87	10879.10	11298.30	8416.10
ALu	838.10	1287.13	2075.53	3551.10	4009.37	2122.45	8744.50	9394.57	11030.80	13151.03	13548.23	10795.45
ANg	284.33	652.30	1440.03	3763.70	4277.53	1400.88	7705.83	8656.27	10509.13	13554.57	13569.63	10574.77
ANh	431.50	1808.97	2894.60	5660.37	4097.30	2561.97	7874.30	9427.10	12591.37	13560.10	13569.63	11413.54
ANm	1547.47	2606.63	4103.63	5213.50	4134.60	2845.26	9575.10	11281.73	13267.70	13451.40	13551.13	11921.45
ANu	1134.73	1929.43	4107.67	4481.00	4277.10	3314.33	8824.20	10960.57	13207.97	13543.97	13569.63	12520.91
ANz	234.53	1031.67	4006.73	6353.27	5540.83	2677.22	7636.60	8803.90	12522.70	13523.17	13564.67	11070.93
ARa	237.70	281.43	418.27	1094.97	2418.93	409.45	7572.27	7682.17	8000.57	8935.77	11199.60	7856.37
ARb	130.47	215.97	612.23	1308.33	1921.90	444.79	7330.70	7522.27	8292.23	9237.97	10083.93	7904.63
ARc	274.07	355.37	546.83	927.27	1308.47	496.75	7668.83	7744.97	7952.73	8443.57	8281.67	7673.27
ARg	239.63	305.63	577.27	1335.30	2176.70	533.73	7459.70	7698.50	8253.27	9387.13	10929.43	8006.54
ARh	135.00	267.07	634.43	1269.67	2903.97	462.18	7345.97	7627.60	8324.97	8614.97	9477.17	7839.96
ARl	143.43	197.60	322.20	827.03	1422.17	374.69	7363.73	7486.40	7753.33	8532.20	9281.33	7765.32
ARo	126.67	195.63	329.80	1040.37	2301.83	413.34	7290.33	7459.43	7763.47	8890.90	10624.23	7854.36
ATc	487.93	1412.50	2888.17	2953.73	3523.20	1746.86	7825.83	9084.60	11335.93	11520.47	12048.17	10107.04
ATf	1072.23	1523.30	3620.53	4621.97	3384.93	2368.56	9469.33	10496.03	13038.63	12625.63	12884.87	11613.31
ATu	514.10	514.10	514.10	514.10	514.10	548.07	8058.87	8058.87	8058.87	8058.87	8058.87	8063.97
CHg	1125.10	1631.00	1923.87	2843.13	1892.33	1661.19	9162.43	10415.97	11085.40	12282.67	12429.57	10575.67
CHh	1547.63	2196.93	2643.40	4097.47	4177.93	2349.01	9647.87	11158.77	12373.97	13095.50	13331.43	11647.72
CHk	1031.07	1672.70	2571.97	3738.23	4492.10	2041.49	9266.67	10902.37	10211.90	12210.23	13070.43	10998.66
CHl	1115.87	1949.40	3033.47	4598.33	3475.93	2066.48	8990.53	10266.27	11990.40	12983.67	13421.03	11019.03

CHw	1652.27	1652.27	1680.13	2258.90	2258.90	1589.15	9692.40	9692.40	9874.93	11446.03	11446.03	10219.98
CLh	470.80	660.80	1327.00	1870.23	2395.37	975.25	8050.60	8251.23	8617.20	9813.77	10833.20	8212.66
CLl	447.03	716.47	1452.93	1652.10	2016.87	941.89	7474.90	7930.67	8652.03	8557.37	9682.60	8313.12
CLp	457.37	841.23	1372.97	1853.80	2768.97	823.13	7894.57	8462.73	9209.33	10062.00	11985.77	8153.44
CMc	614.17	962.83	1707.47	2283.67	2895.60	1215.78	8221.23	8696.87	9703.40	10460.97	11569.73	8995.82
CMd	201.07	546.40	1328.47	2431.97	3460.77	1056.55	7521.57	8182.47	9616.43	12483.67	13519.53	9171.84
CMe	398.83	1000.17	1831.63	2569.07	3829.20	1265.63	7955.87	8722.67	10219.53	10829.33	12908.67	9473.42
CMg	254.03	599.93	1453.90	2670.30	3559.83	1001.51	7489.70	8214.27	9765.83	12534.80	13518.33	9040.78
CMi	272.33	702.90	1355.77	2801.10	4241.37	1091.51	7675.30	8277.93	10008.07	12529.97	13550.83	9045.64
CMo	225.03	441.57	938.97	1790.10	2630.03	699.57	7508.90	7967.43	8837.50	10771.10	13141.27	8533.66
CMu	354.93	990.50	1943.37	3282.57	3906.47	1589.29	7888.50	8780.83	11007.13	13218.27	13561.50	10379.73
CMv	423.10	958.30	1377.00	1977.10	2387.97	984.38	7903.23	8874.40	10094.93	11694.30	12709.07	9043.35
CMx	834.20	1187.57	1718.93	2375.17	2280.40	1211.91	8746.03	9419.60	10650.60	12307.93	12715.23	9493.06
FLc	537.77	1107.67	1828.17	2597.50	3809.20	1418.24	8012.63	8741.43	9339.37	11338.60	12658.53	9152.89
FLd	187.20	345.93	1020.30	2364.60	4637.23	825.27	7411.57	7757.03	9037.97	11947.73	13377.27	8556.64
FLe	342.40	892.80	1394.37	2676.60	3853.17	1203.03	7771.30	8621.63	10068.30	12229.30	12726.10	9189.19
FLm	496.93	1312.53	1921.53	3830.43	4780.73	1492.34	8148.77	9293.40	10554.73	12770.40	13475.23	9710.77
FLs	428.20	622.30	1171.87	2233.57	2046.70	844.54	7930.53	8368.67	9585.30	9566.80	10368.23	8708.15
FLt	149.87	175.93	615.43	1726.77	4553.90	780.96	7248.40	7410.73	8466.13	10685.03	13483.83	8731.16
FLu	345.07	806.23	1789.97	2717.13	4530.37	1388.37	7819.83	8508.17	10227.23	12397.37	13554.13	9632.04
FRg	251.50	546.13	1030.07	1658.33	2123.03	850.93	7706.50	8246.73	9116.63	11224.37	12857.97	8916.23
FRh	203.70	472.47	1109.07	1673.40	2594.30	844.64	7532.23	8086.47	9199.63	11048.83	12915.43	8822.13
FRp	283.83	433.23	838.33	1175.47	1841.13	699.47	7594.67	7980.90	8915.37	10108.40	12047.97	8625.77
FRr	347.73	749.80	1281.03	1932.27	3334.93	1000.37	7847.43	8462.10	9493.03	11589.53	13146.60	9201.46
FRu	394.93	861.60	1374.93	1468.83	2276.43	1153.37	8056.10	8839.10	9966.70	11528.43	13129.57	9586.16
FRx	174.43	266.77	679.47	1468.37	2046.20	614.08	7425.50	7696.43	8474.17	9874.20	12231.33	8310.81
GLd	158.67	287.47	766.17	1783.33	3363.73	665.44	7349.63	7630.13	8557.67	10530.30	13283.90	8440.36
GLe	333.00	489.97	1151.20	1591.53	3305.67	863.88	7643.63	7929.70	9404.83	10956.43	12589.30	8789.44
GLi	224.43	438.40	1573.80	3514.43	3049.30	1023.24	7461.53	7899.70	10376.53	13452.50	13569.63	9036.91
GLk	768.70	876.30	1182.53	2117.17	2811.63	1057.13	8394.37	8905.13	9801.50	11728.00	12972.57	9141.05
GLm	476.40	777.33	1516.83	3090.13	4247.27	1221.19	7864.43	8481.63	10661.63	13127.37	13537.17	9428.89
GLt	185.70	187.43	1006.90	1787.20	1737.50	833.14	7421.40	7489.07	9163.73	13034.50	13479.83	8836.54
GLu	226.77	410.27	1197.70	2946.10	4112.17	1043.11	7460.53	7977.57	9409.50	11783.13	13569.63	8975.74
GRg	1198.57	1201.23	1397.50	1491.60	1493.77	1376.54	9484.53	9472.03	9636.93	9812.70	9819.03	9744.54
GRh	484.17	1364.77	2359.67	3671.10	4437.83	1656.79	8206.37	9568.50	11712.57	13033.70	12696.27	9964.47
GYh	517.40	500.10	853.47	1040.57	1216.00	681.85	8060.13	8126.53	8618.73	9462.50	9895.33	8136.30
GYk	394.23	554.97	890.77	1448.77	1704.20	808.84	7676.23	8010.80	8303.33	8208.33	8757.03	8154.99
GYl	792.87	792.87	1299.07	2365.20	2365.20	1331.28	8675.30	8675.30	9583.57	11015.87	11015.87	8280.30
GYp	292.00	292.87	588.20	643.10	970.40	473.13	7390.70	7395.90	7920.30	8022.60	8566.23	7714.39
HSf	627.53	647.73	1624.40	2835.27	2576.23	1489.02	8281.77	8287.93	10622.23	13001.60	13494.60	10515.71
HSi	2069.13	2069.13	3388.97	3847.93	3847.93	2380.68	11393.07	11393.07	12986.97	13104.47	13104.47	11236.32
HSl	5800.90	5800.90	5200.07	4437.50	4437.50	5025.05	13311.33	13311.33	13434.17	13502.33	13502.33	13387.25
HSs	491.20	985.03	1087.23	3138.23	2320.13	1406.72	7990.90	9160.63	10253.47	13360.87	13550.27	10328.34
HSt	1159.07	1159.07	1978.63	1884.43	1884.43	1347.78	9822.17	9822.17	12513.73	13541.33	13541.33	11124.58
KSh	1598.70	1733.93	2098.03	3355.00	3948.57	1672.67	8911.17	9251.27	10462.37	12455.70	13218.07	10417.26
KSk	1478.20	1920.40	2182.80	2756.13	2890.87	1677.80	9508.57	10154.70	11063.53	11705.77	12707.20	10260.28
KSl	1045.53	1748.20	2229.03	2847.37	3279.23	1598.94	8827.60	9840.80	10795.87	12203.27	13053.10	10108.54
LPd	222.33	428.67	986.13	1732.27	3523.13	501.00	7618.00	7980.03	8675.23	10341.93	13248.97	8031.16
LPe	571.90	1105.77	1680.20	1844.37	2627.93	563.48	8037.53	8663.80	9631.13	11420.73	12864.33	7757.16

LPi	1619.27	1619.27	1510.03	2191.27	2191.27	680.02	9188.07	9188.07	9167.73	10585.63	10585.63	8056.83
LPk	937.47	1651.27	2636.13	3916.60	3982.50	1396.15	8346.10	9792.47	9938.03	13333.53	13569.63	9423.45
LPm	1291.20	1834.23	2397.13	5206.33	3864.67	1296.31	8991.50	10013.07	10092.07	13323.13	13553.83	9331.45
LPq	308.03	517.97	911.40	1382.60	1790.97	293.00	7609.67	8088.73	6108.53	6918.50	8334.13	6898.71
LPu	229.43	632.57	1738.60	3908.40	4569.57	856.05	7644.83	8427.53	10862.43	13129.87	13565.97	8617.69
LVa	262.90	658.80	1452.07	2302.07	4026.90	1065.46	7689.20	8379.63	9624.23	8302.13	12660.27	8781.63
LVf	548.43	1138.10	1733.97	2535.60	2897.40	1084.20	8088.13	8796.20	9861.50	11344.57	11724.27	8975.25
LVg	385.43	613.00	1157.27	2082.73	4419.77	904.64	7688.30	8169.93	9251.10	11404.87	13569.63	8752.53
LVh	325.07	657.90	1721.53	2611.97	3875.90	1071.49	7790.20	8299.13	9833.03	11661.03	12841.00	9052.85
LVj	186.73	396.10	982.50	1650.27	3379.80	933.69	7423.10	7936.93	8897.43	10786.00	12610.60	8831.27
LVk	456.20	788.00	1317.43	2261.30	2840.90	1080.04	8001.50	8453.90	9220.30	10865.10	10523.17	8920.22
LVv	520.83	1211.23	1660.83	2195.90	2138.47	1093.92	8135.60	9170.97	10093.47	11825.77	12478.63	9370.14
LVx	378.47	926.53	1831.93	2336.53	3674.27	1133.76	7900.50	8615.00	10239.33	11730.37	11521.63	9188.02
LXa	1818.40	1818.40	1977.77	2033.20	2033.20	1601.68	9932.17	9932.17	10018.87	10067.60	10067.60	9483.62
LXf	371.93	743.87	1544.80	2069.37	2647.07	1060.91	7858.77	8384.23	9526.73	10958.77	12451.13	8987.11
LXg	388.80	475.77	989.17	1774.13	3157.77	843.33	7738.43	7877.30	8836.67	10328.50	12668.73	8776.49
LXh	349.03	724.27	1701.90	2629.90	3668.93	1026.41	7829.77	8386.13	9716.27	10480.03	12144.37	8961.84
LXj	637.43	637.43	668.53	686.93	686.93	661.40	8588.80	8588.80	8670.30	8876.60	8876.60	8572.43
LXp	323.53	540.50	1014.80	1656.87	2560.53	787.80	7646.90	8069.57	8742.90	9758.13	11695.50	8563.71
NTh	316.00	618.53	1540.63	2381.27	2505.73	1069.36	7727.57	8298.30	9616.53	11831.43	12966.77	9241.92
NTr	541.47	1285.57	2099.73	3066.83	3306.67	1276.84	8144.03	9155.50	10371.40	12293.37	13153.93	9649.91
NTu	786.57	1329.70	1815.90	4014.17	3399.70	1667.86	8759.43	9722.47	11577.77	13367.63	13523.83	10760.64
PDd	205.47	303.07	644.47	1825.27	4004.23	617.70	7427.50	7702.23	8411.50	10280.40	13338.63	8204.94
PDe	211.27	458.63	1146.53	2302.10	4117.00	834.81	7563.70	8098.10	9181.23	11688.43	13373.77	8596.66
PDg	190.60	281.50	1058.73	4114.27	5230.67	801.75	7379.73	7686.33	9162.00	13467.63	13567.40	8613.61
PDj	384.37	432.03	610.83	1638.40	1704.33	757.97	7905.33	7957.90	8429.43	10686.33	11219.43	8632.76
PHc	1045.73	1657.77	1624.23	3397.20	3749.43	1867.01	8892.60	9652.57	10803.30	12611.63	13395.50	10400.48
PHg	489.87	1028.17	1838.47	2464.50	3500.53	1371.90	8108.77	9111.53	10922.37	12961.13	13283.80	9948.23
PHh	732.13	1558.20	2158.13	3301.97	3007.40	1728.35	8427.63	9703.83	11404.23	12758.70	13206.10	10713.02
PHj	783.63	1174.47	2561.57	4355.87	3945.93	1792.39	8437.53	9327.80	12074.03	13382.83	13474.73	10874.55
PHl	856.77	1619.93	2436.27	3804.83	4454.33	1747.85	8617.63	9794.60	11470.77	11955.93	13193.90	10610.09
PLd	146.63	241.03	806.73	1606.13	3513.73	530.66	7288.33	7443.60	8588.70	10262.50	13090.07	8120.69
PLe	315.37	532.77	1267.47	1799.80	3930.57	845.92	7623.30	7953.90	9220.80	10843.73	12157.70	8674.90
PLm	946.27	1391.43	1238.40	1899.13	2500.50	1234.36	8770.73	9606.30	10025.00	11148.27	12865.60	9693.29
PLu	202.90	202.90	514.93	2411.03	2411.03	791.91	7488.30	7488.30	7994.80	10825.27	10825.27	7666.89
PTa	331.27	412.97	769.97	1596.10	2609.43	585.51	7665.73	7941.80	8559.30	9953.23	12489.27	8213.24
PTd	200.70	415.70	749.33	1640.07	3030.83	616.35	7405.23	7841.30	8608.30	10336.57	12549.17	8270.60
PTe	361.50	452.20	869.20	1597.83	2195.90	776.44	7788.50	7958.77	8608.03	9597.77	10644.50	8527.94
PTu	778.77	778.77	810.33	915.67	912.83	952.41	8854.97	8854.97	9091.77	9627.63	9619.10	8986.02
PZb	114.60	376.77	1337.40	2967.57	3490.77	1137.55	7422.43	7953.37	9418.93	12537.47	13533.00	9282.63
PZc	133.87	182.40	413.57	2229.87	7955.50	880.81	7332.97	7429.13	8048.17	11461.90	13569.63	8580.54
PZf	236.67	257.23	758.60	4011.03	4310.07	1370.38	7512.83	7690.43	8853.13	13294.07	13435.17	9280.74
PZg	137.30	227.67	839.30	3240.33	3720.27	999.08	7347.80	7494.93	8598.73	12975.57	13565.30	8709.19
PZh	86.40	169.03	800.00	3465.03	4511.77	883.65	7411.17	7465.87	8633.37	12322.47	13556.90	8680.51
PZi	471.67	885.23	1740.60	3880.43	6526.73	1305.75	8160.23	8851.27	10121.00	12785.13	13552.33	9248.89
RGc	236.93	518.30	1340.50	2245.97	3185.33	978.65	7585.90	7842.30	8701.57	10143.30	11674.57	8301.54
RGd	140.70	340.90	1187.93	2415.30	3151.00	764.11	7349.03	7813.80	8962.40	12039.83	13288.10	8586.93
RGe	264.47	541.83	1612.83	2151.63	3516.37	842.60	7677.67	8194.03	9517.93	10606.63	11734.67	8561.18
RGi	258.77	388.77	2003.07	4135.63	4797.83	1360.08	7776.33	7988.00	9357.57	12724.13	13492.97	9040.41

RGu	168.47	427.47	1244.40	2442.70	3091.30	697.30	7493.70	8058.50	9395.10	11753.57	12969.33	8489.93
RGy	555.40	555.40	757.43	1264.77	1264.77	562.92	8121.50	8121.50	8508.07	7770.70	7770.70	7644.44
SCg	448.63	517.73	673.90	1104.13	2035.20	633.92	7723.13	7975.07	8307.63	9080.90	11189.40	7710.32
SCh	336.50	360.23	649.47	1325.40	2051.80	590.17	7572.53	7722.63	8298.63	9056.53	10801.50	7862.20
SCi	875.53	942.77	227.20	1056.83	1665.40	635.79	8275.33	8097.37	7385.93	8308.83	9170.27	7777.85
SCk	363.40	372.07	730.77	1177.47	1753.63	590.13	7687.87	7737.50	8365.67	8674.53	8349.23	7479.99
SCm	433.87	585.67	1364.87	1721.40	2033.10	1015.15	7838.30	8162.97	9786.67	10718.60	12315.73	9125.90
SCn	457.23	708.30	1116.37	1524.10	2687.97	762.68	7826.60	8305.57	8903.70	9534.43	11145.73	7916.73
SCy	307.93	382.53	662.40	1167.33	1379.30	582.42	7644.30	7824.83	8209.37	7703.60	8022.33	7716.60
SNg	302.33	430.70	982.10	1496.00	2792.10	866.28	7647.93	7929.17	9133.03	10361.57	10859.63	8707.74
SNh	405.43	616.80	1136.70	1757.90	2443.13	934.55	7918.70	8292.57	9176.63	9211.87	10593.10	8497.94
SNj	433.23	938.03	1178.87	1489.30	2126.03	927.26	7925.60	8681.30	9330.40	9939.63	12084.87	8674.99
SNk	412.77	536.87	973.47	1687.70	1832.90	875.67	7793.03	8010.70	8772.27	9697.13	9007.87	8075.79
SNm	763.37	933.23	1431.93	1747.10	2802.37	1118.52	8609.73	8934.20	10294.10	11332.60	13120.90	9122.39
SNy	487.90	467.97	1294.13	1718.43	1647.80	958.39	8080.23	8048.03	9749.17	9047.53	9127.30	8218.69
VRd	211.23	408.33	916.30	1455.73	3536.97	797.64	7530.43	7998.87	9302.03	10463.07	13395.17	8855.36
VRe	393.13	821.87	1342.63	1714.33	2095.40	1124.24	7967.63	8880.03	9943.13	11340.47	12666.90	9452.03
VRk	625.40	792.03	1144.77	1803.97	2377.13	1084.28	8344.37	8643.67	9297.37	10436.40	12130.80	9181.71
VRy	917.83	1180.63	1960.77	3355.87	2109.50	1269.27	9402.53	10010.37	11282.60	12476.60	12660.00	9864.75

More effort to identify the profiles corresponding with the percentiles must be done in order to summarized or find out the representatives profiles for each group, nevertheless under the hypothesis that the mean and also the percentiles of the profiles reproduces the simulated maize yield for each FAO90 groups, two approaches was assayed as described in materials and methods chapter.

The yield simulation of the profile mean of the two approaches used overestimated the mean yield of the all profiles simulated as consequence none of the mean of the approaches can be considerate as a representative profile of each group FAO90 (Table 24). Rainfed yield was the worst estimated since the relative difference was 63% and 59 % for approach one and two respectively; the differences, in the same order than rainfed treatment, for high nitrogen and automatic irrigation treatment were 13% and 12%. The maximum absolute difference for rainfed treatment was 3.21T and 2.91T and for high nitrogen and automatic irrigation was 1.29T and 1.34T for approached one and two respectively.

Table 24. Yield mean calculated for all the simulated profiles contrasting with yield from the mean profile of two approaches for rainfed and high nitrogen and automatic irrigation treatments.

		Rainfed			**High Nitrogen and Automatic Irrigation**		
FAO90	**Profiles**	**Mean Approach 1**	**Mean all Profiles**	**Mean Approach 2**	**Mean Approach 1**	**Mean all Profiles**	**Mean Approach 2**
ACf	244	1386.93	846.42	1336.80	9467.70	8635.30	9505.50
ACg	45	744.37	475.59	659.10	8594.93	8058.34	8596.03
ACh	399	1248.33	791.04	1207.00	9220.47	8594.08	9249.00
ACp	85	1000.10	714.51	962.77	8961.67	8450.37	8981.30
ACu	66	1581.33	1391.70	1416.33	11035.70	9984.10	10754.43
ALf	54	1791.57	1230.85	1531.90	9930.03	9077.41	9920.23
ALg	36	997.97	675.91	1202.33	9236.70	8392.08	9428.83
ALh	66	1495.37	887.89	1477.80	9573.33	8600.69	9641.93
ALj	7	1192.93	759.89	1079.93	9352.83	8439.26	9257.17
ALp	8	987.13	701.30	1037.33	8776.33	8416.10	8878.33

ALu	10	2940.80	2122.45	2548.00	12157.40	10795.45	12124.50
ANg	6	2109.10	1400.88	2564.77	12176.03	10574.77	12835.97
ANh	32	4631.37	2561.97	4050.13	13412.70	11413.54	13350.23
ANm	35	5172.50	2845.26	4605.97	13364.23	11921.45	13352.40
ANu	98	5218.83	3314.33	4386.13	13374.30	12520.91	13343.70
ANz	70	4906.73	2677.22	5255.77	13363.00	11070.93	13350.23
ARa	30	695.93	409.45	663.63	8484.80	7856.37	8421.50
ARb	61	803.80	444.79	747.13	8560.20	7904.63	8510.30
ARc	51	632.40	496.75	585.00	8191.63	7673.27	8129.90
ARg	58	910.80	533.73	926.87	8705.53	8006.54	8713.13
ARh	238	1107.37	462.18	1070.77	9026.53	7839.96	8978.60
ARl	155	487.77	374.69	475.93	8051.23	7765.32	8037.33
ARo	135	595.27	413.34	576.07	8265.77	7854.36	8234.43
ATc	8	2401.53	1746.86	2270.33	11626.90	10107.04	11228.53
ATf	10	2416.00	2368.56	2422.13	12698.67	11613.31	12712.50
ATu	1	514.10	548.07	512.27	8058.87	8063.97	8054.80
CHg	9	2095.27	1661.19	2397.97	11551.03	10575.67	11766.87
CHh	68	3337.30	2349.01	2982.17	12873.07	11647.72	12793.83
CHk	62	2641.03	2041.49	2775.07	12348.63	10998.66	12537.20
CHl	62	3116.77	2066.48	3370.10	12760.00	11019.03	12715.10
CHw	2	1637.17	1589.15	1781.23	10513.23	10219.98	10375.00
CLh	138	1510.40	975.25	1412.57	9248.10	8212.66	9163.87
CLl	34	1482.60	941.89	1488.50	8553.87	8313.12	8642.33
CLp	32	1346.73	823.13	1421.87	9397.47	8153.44	9452.43
CMc	187	1744.10	1215.78	1763.83	10420.23	8995.82	10354.47
CMd	183	1701.87	1056.55	1567.83	10281.87	9171.84	10146.30
CMe	303	2428.60	1265.63	2307.57	11021.80	9473.42	10880.50
CMg	133	1674.20	1001.51	1569.00	10533.67	9040.78	10481.83
CMi	35	2446.67	1091.51	2262.40	11672.23	9045.64	11510.00
CMo	160	1284.60	699.57	1220.97	9314.00	8533.66	9310.27
CMu	116	2908.17	1589.29	2790.47	12324.00	10379.73	12214.27
CMv	79	1584.20	984.38	1551.53	10646.93	9043.35	10670.63
CMx	63	1765.83	1211.91	1095.47	11207.40	9493.06	10764.47
FLc	136	2016.00	1418.24	1592.73	10438.47	9152.89	10143.63
FLd	67	1485.23	825.27	1202.67	9850.20	8556.64	9625.17
FLe	225	2290.63	1203.03	2129.33	11110.87	9189.19	10872.77
FLm	40	2425.63	1492.34	2359.60	11688.50	9710.77	11654.33
FLs	13	1479.20	844.54	1128.90	10302.50	8708.15	9460.40
FLt	48	1220.77	780.96	1058.43	9630.30	8731.16	9352.93
FLu	14	2017.77	1388.37	2656.20	11215.00	9632.04	11924.50
FRg	37	1278.00	850.93	1290.07	9521.90	8916.23	9493.10
FRh	210	1303.77	844.64	1407.23	9484.97	8822.13	9554.20

FRp	12	1027.10	699.47	1250.87	9294.93	8625.77	9433.70
FRr	97	1587.93	1000.37	1561.90	9964.07	9201.46	10006.20
FRu	55	1613.67	1153.37	1246.73	10391.57	9586.16	10214.73
FRx	109	896.53	614.08	838.07	8728.13	8310.81	8728.33
GLd	93	1009.93	665.44	947.40	9191.27	8440.36	9094.83
GLe	271	1571.50	863.88	1350.27	10152.73	8789.44	10169.70
GLi	12	3044.87	1023.24	1617.67	12356.13	9036.91	11799.37
GLk	11	1456.67	1057.13	1408.50	10532.13	9141.05	10049.90
GLm	104	1698.40	1221.19	1458.50	11532.00	9428.89	10665.20
GLt	4	1223.87	833.14	1167.13	9501.73	8836.54	9927.23
GLu	68	2086.87	1043.11	2216.00	10863.67	8975.74	11086.87
GRg	3	1393.17	1376.54	1540.80	9634.43	9744.54	9831.53
GRh	24	2537.77	1656.79	1962.10	11891.90	9964.47	11759.47
GYh	7	1019.63	681.85	946.93	8839.63	8136.30	8837.27
GYk	15	1030.93	808.84	1009.43	8366.27	8154.99	8331.00
GYl	2	1568.53	1331.28	1768.03	9789.67	8280.30	9860.70
GYp	5	626.87	473.13	595.97	7983.50	7714.39	7984.20
HSf	6	2129.50	1489.02	1184.40	11392.40	10515.71	9895.30
HSi	3	3555.83	2380.68	2218.57	12954.37	11236.32	11411.70
HSl	2	5213.30	5025.05	5110.50	13458.97	13387.25	13441.60
HSs	6	1924.53	1406.72	1683.00	11255.53	10328.34	11323.23
HSt	3	1857.63	1347.78	1762.60	12809.47	11124.58	12702.27
KSh	24	2751.00	1672.67	2235.40	11221.40	10417.26	11022.47
KSk	42	2359.23	1677.80	2090.70	11373.07	10260.28	11229.50
KSl	26	2258.33	1598.94	2099.93	10952.77	10108.54	10920.90
LPd	76	1337.33	501.00	1395.20	9389.67	8031.16	9471.07
LPe	83	1973.33	563.48	1695.80	10384.43	7757.16	10384.93
LPi	3	1702.70	680.02	1707.47	9501.60	8056.83	9519.30
LPk	41	4063.47	1396.15	3881.30	12671.80	9423.45	12655.47
LPm	40	3323.47	1296.31	2530.43	11754.23	9331.45	11434.57
LPq	18	1017.77	293.00	1013.47	8948.57	6898.71	8933.77
LPu	42	2298.63	856.05	2576.30	11816.33	8617.69	11973.13
LVa	34	1843.50	1065.46	1999.47	9155.53	8781.63	9283.67
LVf	109	1742.13	1084.20	1950.73	10106.27	8975.25	10116.27
LVg	173	2075.40	904.64	2361.33	10950.67	8752.53	11189.80
LVh	306	2087.60	1071.49	2209.70	10644.67	9052.85	10730.53
LVj	76	1302.30	933.69	1204.27	9522.03	8831.27	9475.23
LVk	126	1489.63	1080.04	1711.67	9712.77	8920.22	9805.13
LVv	35	1565.27	1093.92	1815.43	10641.67	9370.14	10780.90
LVx	225	1918.97	1133.76	2088.90	10613.27	9188.02	10659.97
LXa	2	1951.63	1601.68	1983.93	9988.30	9483.62	9993.83
LXf	176	1657.73	1060.91	1672.57	9868.83	8987.11	9904.30

LXg	34	1455.57	843.33	1385.17	9497.80	8776.49	9431.07
LXh	205	1796.07	1026.41	1810.67	9994.00	8961.84	9951.63
LXj	1	669.00	661.40	727.03	8710.37	8572.43	8652.97
LXp	19	1304.17	787.80	1354.80	9189.87	8563.71	9286.57
NTh	62	1665.87	1069.36	1485.70	9991.13	9241.92	9956.83
NTr	39	2291.83	1276.84	2224.33	11231.83	9649.91	11263.53
NTu	26	2611.83	1667.86	2469.73	12156.13	10760.64	12214.83
PDd	22	1080.43	617.70	1220.60	9203.60	8204.94	9253.27
PDe	70	1655.77	834.81	1872.20	9918.63	8596.66	10023.03
PDg	16	1856.63	801.75	1909.17	10612.30	8613.61	10706.23
PDj	6	939.97	757.97	1133.47	9139.90	8632.76	9394.57
PHc	39	2690.67	1867.01	2593.33	11905.70	10400.48	11784.70
PHg	27	2430.37	1371.90	2191.50	11644.77	9948.23	11615.57
PHh	124	2781.57	1728.35	1971.43	12402.07	10713.02	12084.77
PHj	10	2845.13	1792.39	2203.23	12498.73	10874.55	12383.90
PHl	190	3004.37	1747.85	3102.03	12657.00	10610.09	12467.77
PLd	34	1002.67	530.66	996.90	8947.20	8120.69	8912.53
PLe	95	1643.87	845.92	1606.13	9871.00	8674.90	9826.03
PLm	19	1759.87	1234.36	1514.93	10499.80	9693.29	10468.40
PLu	3	669.80	791.91	630.00	8332.47	7666.89	8241.57
PTa	20	1030.47	585.51	1040.60	9026.97	8213.24	9038.07
PTd	44	944.87	616.35	905.03	8900.80	8270.60	8934.33
PTe	26	1162.73	776.44	1152.63	8987.50	8527.94	9029.77
PTu	3	1012.67	952.41	1069.63	9390.20	8986.02	9449.37
PZb	17	1629.63	1137.55	1788.27	10075.90	9282.63	10153.33
PZc	33	1702.93	880.81	1671.13	10690.83	8580.54	10523.57
PZf	5	1594.83	1370.38	1542.53	10293.60	9280.74	10112.87
PZg	47	1825.13	999.08	2070.03	10309.50	8709.19	10451.43
PZh	81	1715.63	883.65	2002.17	10098.87	8680.51	10124.60
PZi	14	2358.80	1305.75	2461.97	11186.23	9248.89	11163.57
RGc	98	1766.97	978.65	1814.27	9606.27	8301.54	9645.50
RGd	68	1538.67	764.11	1563.37	9681.90	8586.93	9680.73
RGe	172	1821.87	842.60	2217.77	10085.27	8561.18	10132.67
RGi	12	2727.50	1360.08	2838.40	9322.17	9040.41	9663.83
RGu	12	1205.53	697.30	1206.83	9481.37	8489.93	9506.40
RGy	3	945.27	562.92	962.57	8613.27	7644.44	8600.57
SCg	40	1044.60	633.92	973.27	8973.27	7710.32	8846.37
SCh	29	994.77	590.17	1049.13	8878.70	7862.20	8897.87
SCi	4	566.60	635.79	579.33	8098.20	7777.85	8132.20
SCk	20	961.00	590.13	942.47	8699.77	7479.99	8714.90
SCm	8	1254.57	1015.15	1306.53	9585.70	9125.90	9718.47
SCn	32	1237.23	762.68	1201.67	9128.60	7916.73	9089.67

SCy	18	837.60	582.42	771.50	8393.67	7716.60	8341.13
SNg	52	1362.07	866.28	1314.17	9876.40	8707.74	9744.70
SNh	86	1444.53	934.55	1521.33	9694.23	8497.94	9788.17
SNj	19	1351.00	927.26	1380.93	9554.93	8674.99	9557.40
SNk	35	1213.63	875.67	1318.93	9052.13	8075.79	9138.27
SNm	27	1571.47	1118.52	1560.57	10758.87	9122.39	11017.37
SNy	4	1234.70	958.39	1170.23	9402.60	8218.69	9365.20
VRd	18	1136.97	797.64	904.63	9739.53	8855.36	8987.67
VRe	336	1730.17	1124.24	1756.47	10819.37	9452.03	10779.63
VRk	151	1503.03	1084.28	1462.43	10005.27	9181.71	9833.23
VRy	5	2184.53	1269.27	1996.97	11897.93	9864.75	11605.70

The maize mean of the profiles belonging to each of the soil depth quartiles were determined. The trend of these simulations did not have the pattern expected since there was not an increasing tendency as the percentiles increased. Furthermore, these means are not good estimations for the quartiles of the maize mean for all the profiles simulated in each group which means not only the soil depth addressed the yield, in other words, the correlations between soil depth and yield was not high (Table 25).

Table 25. Yield mean of the soil depth percentiles 25, 50, 75 and 100.

	Rainfed				**High Nitrogen and Irrigation**			
FAO	**P0 -25**	**P25-50**	**P50-75**	**P75-100**	**P0-25**	**P25-50**	**P50-75**	**P75-100**
ACf	1235.50	905.57	1394.20	1498.93	9360.97	8830.20	9482.73	9599.50
ACg	499.83	622.47	810.87	704.37	8068.13	8422.57	8844.97	8510.93
ACh	1325.20	1073.90	1061.27	1195.83	9495.53	9075.53	8967.77	9079.43
ACp	939.10	797.63	915.93	996.33	8725.40	8658.33	8973.33	9103.87
ACu	1552.70	1489.50	1698.60	1550.37	8325.60	10955.60	10613.23	10918.33
ALf	1447.80	1723.00	1642.80	1642.80	9837.27	9767.77	9717.83	9717.83
ALg	961.00	664.23	685.63	947.47	9048.03	8409.07	8491.97	9156.47
ALh	1246.27	1728.67	766.37	1270.87	9610.07	10021.60	8609.57	9281.20
ALj	453.27	1659.57	791.50	489.30	8060.00	10990.33	8638.03	7981.47
ALp	796.73	704.70	987.23	824.13	8381.83	8460.90	9143.73	8787.07
ALu	2862.53	1113.83	1898.03	2806.60	12622.23	9690.10	10852.03	12706.67
ANg	1940.30	1348.83	2013.47	1650.30	12240.10	9295.03	11591.00	11004.50
ANh	4428.90	4599.33	3514.60	3675.73	13484.73	13313.87	12944.37	12933.93
ANm	3616.70	4464.60	4603.73	4072.87	13061.87	13206.60	13313.03	13231.57
ANu	4237.80	3361.00	5588.47	3509.57	13398.43	13173.77	13448.03	13077.50
ANz	2544.33	4571.03	3349.17	5349.50	12481.37	13367.80	12711.80	12947.80
ARa	624.27	507.70	691.77	491.77	8370.43	8098.90	8565.33	8106.27
ARb	645.57	622.13	512.83	560.50	8297.67	8343.67	8166.83	8164.00
ARc	594.57	589.30	421.57	417.07	6768.63	8219.63	7824.97	7863.67
ARg	425.97	872.80	650.07	781.47	7948.93	8614.93	8472.37	8600.03
ARh	929.73	854.63	767.77	814.13	8778.03	8576.23	8564.77	8537.50
ARl	419.93	609.93	407.07	312.57	7903.57	8243.87	7941.03	7733.27
ARo	541.80	534.43	435.70	607.60	8129.80	8178.27	7958.43	8247.63
ATc	2292.30	2307.67	1448.87	1448.87	10719.07	10529.00	9125.17	9125.17
ATf	3311.03	3375.87	2901.63	3153.80	12582.23	12990.03	11892.67	12353.33
CHg	1938.43	2002.17	1999.80	2038.20	11181.23	11166.00	11074.97	11473.50

CHh	3045.27	3177.43	2963.23	3728.23	12853.83	12643.93	12669.60	12892.20
CHk	2407.47	1921.87	2815.97	2987.40	12049.70	11379.30	10781.63	12769.80
CHl	2630.00	2736.43	3329.37	2624.50	11717.10	12662.10	12697.70	12512.73
CLh	1190.60	1079.23	1224.10	1632.37	8918.37	8683.37	9008.17	9605.63
CLl	1248.67	1422.53	1158.87	1316.37	9077.00	9159.10	6791.97	8573.33
CLp	768.87	1107.83	1179.43	1295.77	8661.30	8741.33	8608.40	8514.33
CMc	1606.57	1462.30	2155.17	2211.20	9776.30	9610.53	8444.20	10646.10
CMd	1078.53	1564.67	1444.63	2095.13	9838.03	10533.77	9896.57	10766.03
CMe	2252.77	2532.90	1830.53	1936.67	11189.00	10013.57	10637.70	10801.43
CMg	1283.17	1463.40	1508.00	2316.50	9925.77	9878.07	10448.40	10608.17
CMi	863.53	2213.67	3324.37	2091.67	9255.70	11216.50	10815.20	11640.40
CMo	1146.73	1099.57	1049.80	1360.57	9245.93	9150.13	9130.10	9295.43
CMu	2171.00	2365.30	3240.23	2351.43	11222.27	12165.30	12424.87	12028.70
CMv	885.90	1437.37	1470.60	1739.37	9222.90	10426.70	10275.90	11043.50
CMx	1160.73	1713.23	1478.13	2099.97	9664.77	10566.10	11058.30	11633.50
FLc	1821.43	1521.00	1883.67	1736.23	10274.37	9409.30	10469.27	10502.03
FLd	754.87	1375.23	1368.17	1211.27	8620.17	10011.43	9745.27	9093.90
FLe	1524.20	1689.23	1950.93	2250.30	10253.77	10308.83	11038.23	11156.13
FLm	2084.30	2288.43	2244.53	1833.97	11905.47	11954.63	11559.70	11369.43
FLs	870.50	1270.40	545.93	1672.73	9011.07	9588.47	8402.63	11411.87
FLt	866.23	904.57	1209.47	1376.37	9005.77	8841.13	9798.93	9696.63
FLu	1722.63	1687.70	1609.77	1507.23	10514.17	10491.87	10748.50	9573.83
FRg	1088.43	1174.40	1156.17	1226.07	9801.37	9471.10	9400.23	9030.93
FRh	1178.83	1243.30	1175.17	1569.93	9357.93	9462.53	9280.43	9842.53
FRp	984.43	745.03	1156.13	657.77	9473.97	8706.60	9657.27	8552.53
FRr	1534.23	1677.40	1475.83	1525.23	10033.30	10503.53	9819.73	9859.07
FRu	1516.80	1813.93	1706.07	1496.20	10044.77	10491.03	9698.13	10120.17
FRx	1000.20	666.67	737.13	904.50	8913.33	8458.10	8521.67	8730.27
GLd	676.83	1024.53	968.27	1184.50	8467.77	9181.43	9125.03	9430.07
GLe	1141.60	1339.60	1488.87	1840.07	9454.87	9788.57	10356.37	10846.40
GLi	1169.30	754.20	2908.53	2625.07	9654.53	8684.53	11329.03	12010.77
GLk	1433.37	1025.37	2146.73	1641.53	10487.97	9432.10	11391.70	11038.07
GLm	1590.37	2127.97	1622.23	1945.53	10401.50	9227.00	8679.73	12467.10
GLt	1061.17	1121.17	690.30	440.07	9698.27	9624.40	8581.63	7922.50
GLu	1470.33	1740.13	1180.83	2202.83	10185.67	11184.23	9722.13	11135.10
GRh	2114.00	2507.10	2928.50	3976.47	11134.90	11125.17	12352.63	11292.20
GYh	1209.60	988.50	444.80	720.13	9392.13	8798.03	7972.37	6967.73
GYk	827.13	1090.93	942.07	918.57	8156.17	8785.30	6821.67	8873.87
GYp	658.53	212.63	489.83	489.83	8044.53	7149.87	7721.97	7721.97
HSf	2130.67	1054.33	2308.63	2401.23	11491.23	9909.00	11684.30	11733.03
HSs	1627.00	424.83	2109.80	1807.77	11147.00	8146.80	10774.30	11677.47
KSh	2106.47	1899.83	2821.87	2220.37	10976.33	10151.43	11716.03	11317.17
KSk	1803.13	2017.53	1982.80	2684.33	10720.50	11160.17	11341.10	11510.50
KSl	1253.83	1895.60	2012.37	2209.90	9361.67	10607.73	10758.77	11358.57
LPd	342.57	598.17	643.57	1193.37	7601.93	8341.67	8458.17	9159.30
LPe	582.10	644.73	826.87	1786.10	7884.57	8423.67	8760.70	10316.83
LPk	1427.03	2464.17	2336.20	3809.73	9663.53	10617.20	10117.13	12167.60
LPm	1299.63	1624.33	2025.83	3030.00	6735.53	10454.00	11264.53	13128.90
LPq	365.17	328.80	775.20	775.20	7314.17	7340.70	8547.33	8547.33

LPu	711.37	744.87	1623.70	2270.03	8406.67	8564.33	8680.23	11944.63
LVa	1515.03	1226.20	1859.33	2064.27	9375.80	9273.37	10986.10	8020.20
LVf	1604.87	1705.37	1471.37	1813.90	9964.00	9913.87	9521.87	10052.17
LVg	1116.63	1251.57	1551.90	3161.67	9437.67	9534.03	10179.13	12471.60
LVh	1658.43	1533.90	2060.57	2199.80	10582.20	9885.23	10389.30	10516.23
LVj	1248.87	1302.50	954.73	1185.23	9417.17	9784.60	9225.07	9320.83
LVk	1221.30	1234.13	1500.87	1865.97	9272.00	9269.10	9516.60	10037.47
LVv	1294.57	1586.03	1608.50	1991.70	9995.37	9824.43	10660.03	10667.30
LVx	1438.67	1766.73	1621.63	1887.17	10447.63	10140.67	10475.67	10114.77
LXf	1343.47	1411.13	1618.03	1934.77	9425.53	9664.73	9670.63	10307.23
LXg	986.10	1143.83	851.87	1315.67	9031.87	9396.40	8873.87	9202.93
LXh	1379.53	1463.23	1861.83	1767.57	9540.87	9704.57	10168.00	9552.23
LXp	1047.07	633.03	1168.83	1043.43	8930.27	8337.10	9032.47	8905.53
NTh	1587.93	1781.27	1653.10	1240.93	9897.93	10197.87	9999.67	9413.17
NTr	2369.87	1658.33	1873.23	2274.30	11298.73	10303.63	10683.73	9035.00
NTu	2446.00	1796.00	2270.20	1829.37	12585.03	11391.47	11743.23	10899.87
PDd	1085.77	1000.83	958.43	958.43	9114.47	9006.87	8889.43	8889.43
PDe	1662.67	1440.73	984.60	1337.67	10152.50	9774.00	8823.27	9205.50
PDg	1769.87	870.93	1671.23	1008.80	10793.83	9047.20	10484.00	9009.67
PDj	1517.20	155.43	306.47	502.17	10235.43	7280.40	7850.50	8120.80
PHc	2434.20	2401.83	1936.30	2714.17	11890.73	12052.23	10589.77	11663.37
PHg	2139.10	2186.83	1348.07	1617.10	12292.53	11272.57	10251.00	11436.03
PHh	2043.07	2674.83	1869.97	2969.10	12035.63	12417.23	11081.80	12382.17
PHj	2116.10	2385.80	2916.03	2512.40	11911.00	12032.47	12300.87	11903.83
PHl	2281.47	3297.50	2574.83	3382.13	11488.47	13181.60	12359.90	12244.63
PLd	719.73	673.37	806.80	769.73	8541.33	8477.33	8725.43	8623.40
PLe	1152.00	1183.50	1431.47	1274.20	9255.50	9529.83	9650.80	9254.37
PLm	1449.27	1478.53	1281.13	1470.40	9983.87	10620.90	9782.03	10436.27
PTa	484.00	848.10	366.50	1187.93	8253.83	8790.87	7874.80	9226.33
PTd	703.23	858.20	603.33	929.70	8407.97	8960.87	8405.20	8914.00
PTe	788.13	897.33	1159.50	1258.87	8641.97	8747.43	8898.13	9161.60
PZb	1500.23	1002.87	732.37	1601.10	10515.83	9238.17	8711.00	10127.73
PZc	1342.93	572.27	2093.50	2459.33	9642.63	8425.37	11476.03	10480.37
PZf	926.60	2134.07	2497.30	573.77	9122.60	11745.53	9372.03	8449.10
PZg	1199.53	1304.13	1160.77	3360.23	9780.97	9694.03	9117.37	12406.63
PZh	1397.90	1693.27	1221.07	1499.67	10203.33	10138.57	9217.40	9556.23
PZi	1639.03	973.97	1903.37	2384.13	10340.50	9242.10	10555.67	11110.30
RGc	1085.40	1822.67	1259.23	1511.80	9155.40	9954.70	8729.63	9124.07
RGd	735.90	1105.77	1708.67	1280.47	8728.33	9530.03	9937.07	9195.07
RGe	1420.13	1136.13	1412.70	1538.70	10219.37	9015.93	9638.50	9811.57
RGi	1955.13	649.50	4839.37	1968.07	11098.90	8003.70	12262.70	7888.77
RGu	341.10	1562.60	1245.33	399.90	7798.10	10323.07	9195.70	7943.30
SCg	505.33	665.17	1035.47	1212.93	8063.23	8302.23	9103.53	9401.33
SCh	685.70	860.10	594.53	1269.13	8485.83	8713.53	8113.67	9181.23
SCi	140.60	1467.37	1337.33	184.43	6594.57	9572.00	8344.83	7196.17
SCk	855.70	447.53	854.67	1029.07	8636.63	7930.20	8783.23	8482.00
SCm	922.60	1780.77	428.17	1636.77	8949.70	10699.77	7856.50	10193.97
SCn	729.80	1239.30	1206.13	1292.87	8496.93	9088.37	8936.37	9239.07
SCy	487.17	361.10	533.07	1111.33	7540.80	7730.40	7569.97	8886.17

SNg	1638.30	1173.67	786.10	1058.07	10423.13	9404.57	8840.70	9052.80
SNh	1096.50	1331.53	1441.53	1432.97	9255.53	9428.63	9797.20	9688.33
SNj	711.07	1033.50	1737.37	1274.40	8381.77	8956.17	11078.90	9187.77
SNk	882.10	1244.90	1077.00	1073.73	8784.50	9275.70	8591.33	8868.37
SNm	1509.03	1266.13	1621.73	1817.00	10281.37	9796.33	10662.73	10816.80
VRd	963.03	1155.43	969.87	969.87	9275.03	9959.80	9538.80	9538.80
VRe	1586.73	1567.90	1251.07	1882.57	10704.37	10468.77	10060.10	11220.77
VRk	1379.67	1315.73	1346.43	1550.33	9931.27	9673.67	9298.53	10370.70
VRy	1868.43	2318.40	449.47	1524.17	9594.40	12310.17	8213.17	11460.33

Weather conditions

For the 30 years of the automatic generated weather, the season length ranged from 180 to 197 days, total rain from 300.1 to 999.3 mm, total Photosynthetically Active Radiation (PAR) from 6390.6 to 7109.4 MJm^2, and average temperature from 17.9 to 20.8°C (Table 26).

Table 26. Annual season summary of the weather for the 30 simulated years.

Mean								Total			Standard deviation					
Year	Season	Rain	RAD	PAR	Tmax	Tmin	Tave	Rain	RAD	PAR	Rain	RAD	PAR	Tmax	Tmin	Tave
1	191	3.7	17.5	35.0	26.6	13.2	19.7	706.2	3340.6	6681.0	11.3	5.2	10.5	5.9	7.1	6.4
2	190	2.9	17.5	35.1	25.9	12.6	19.0	553.9	3332.1	6665.1	8.7	5.1	10.2	6.6	7.3	6.9
3	187	2.9	17.7	35.3	26.8	13.1	19.7	538.1	3304.0	6607.7	9.3	5.2	10.4	5.9	6.9	6.4
4	188	3.3	17.5	35.1	26.4	12.7	19.4	615.5	3297.1	6595.0	10.5	5.1	10.2	6.0	6.7	6.4
5	193	2.8	18.3	36.6	26.1	11.7	18.7	544.8	3531.4	7061.3	10.3	5.2	10.3	6.4	7.7	7.0
6	189	3.7	17.7	35.3	26.8	13.1	19.7	704.9	3338.7	6676.8	12.4	5.0	9.9	5.3	6.7	5.9
7	184	3.8	17.8	35.6	25.8	12.5	18.9	699.9	3278.8	6557.9	13.7	5.1	10.3	7.3	7.3	7.3
8	196	2.8	17.7	35.5	25.9	12.0	18.7	541.2	3476.6	6953.2	6.6	4.8	9.7	5.8	7.2	6.5
9	186	4.0	17.8	35.7	26.4	12.9	19.4	738.7	3316.8	6633.7	17.6	5.0	9.9	5.7	6.7	6.2
10	187	3.1	17.9	35.8	26.1	12.4	19.0	576.0	3343.3	6685.6	10.5	5.2	10.4	6.1	7.0	6.6
11	189	5.3	17.6	35.3	26.5	12.7	19.4	999.3	3332.8	6665.5	15.5	4.9	9.8	6.2	6.9	6.6
12	180	2.8	17.8	35.5	27.8	14.3	20.8	501.5	3195.4	6390.6	12.9	5.4	10.8	5.4	5.7	5.5
13	184	1.6	17.9	35.9	26.7	13.0	19.6	300.1	3301.2	6601.8	6.8	5.2	10.4	6.7	7.2	6.9
14	181	2.4	17.7	35.4	26.5	13.3	19.7	438.3	3206.3	6411.1	9.0	5.1	10.2	6.1	6.6	6.3
15	187	3.4	17.6	35.1	26.6	13.0	19.6	642.9	3283.1	6565.1	11.3	5.2	10.4	5.6	6.8	6.2
16	188	3.3	17.6	35.2	26.7	13.4	19.8	618.6	3305	6609.7	15.4	5.3	10.6	5.4	6.0	5.7
17	190	4.8	17.8	35.5	25.3	11.3	18	904.3	3374.2	6747.8	18.7	5.0	10.0	7.2	8.8	8.1
18	197	4.0	18.0	36.1	25.8	12.2	18.8	783	3555.3	7109.4	12.5	5.0	9.9	6.4	7.3	6.8
19	187	3.8	17.8	35.6	26.2	12.7	19.3	712.9	3328.3	6657.4	19.6	5.4	10.7	6.3	7.2	6.7
20	188	1.7	18.2	36.4	27.8	13.4	20.3	316.6	3419.4	6839.7	6.0	5.0	10.1	5.1	6.3	5.7
21	191	2.4	18.0	36.0	26.5	13.2	19.6	451.7	3436.3	6872.5	7.7	4.8	9.7	5.9	7.3	6.6
22	188	3.1	17.8	35.7	26.2	12.5	19.1	585.8	3351.1	6702.3	9.6	5.0	10.1	6.6	7.2	6.9
23	189	4.1	17.8	35.7	26.7	12.5	19.4	775.7	3370.8	6742.5	13.5	5.0	10.0	5.8	7.5	6.7
24	187	2.8	18.0	36.0	26.6	12.4	19.3	530.3	3363.7	6727	15.0	5.1	10.2	6.0	7.2	6.7

25	193	4.0	17.9	35.7	26.0	12.8	19.2	776.4	3446.8	6892.9	12.8	5.2	10.3	6.0	6.7	6.3
26	191	3.9	17.9	35.8	26.4	12.4	19.1	737.7	3414.1	6828.4	14.2	5.0	9.9	6.3	7.1	6.7
27	196	3.9	17.8	35.6	25.3	11.0	17.9	771.1	3488.4	6976.5	11.0	5.2	10.4	7.1	8.3	7.8
28	188	3.4	17.6	35.2	26.7	13.1	19.7	646.9	3312.3	6622.6	11.5	5.2	10.3	6.1	6.5	6.2
29	191	3.1	17.7	35.4	26.1	12.8	19.3	583.9	3383.9	6767.4	7.5	5.0	10.0	6.4	6.8	6.6
30	190	2.4	18.0	36.1	26.2	12.9	19.3	452.3	3424.2	6849.7	7.7	5.3	10.5	6.6	6.9	6.7
MEAN	189	3.3	17.8	35.6	26.4	12.7	19.3	625	3361.7	6723.2	11.6	5.1	10.2	6.1	7.0	6.6
STD	3.9	0.8	0.2	0.4	0.6	0.6	0.6	156.9	84.5	169	3.6	0.1	0.3	0.5	0.6	0.5

PAR: Physiological active radiation. RAD: Global radiation. Tmax: Maximum temperature. Tmin: Minimum temperature. Tave: Average temperature.

Grouping by rainfed yield

In order to classify the profiles according to the rainfed yield, the 100 percentiles were determined and the WISE3 profiles belonging to each percentile were identified. The mean of the rainfed yield, bulk density, clay, silt, root growth factor, drained upper limit, lower limit of soil extractable soil water, saturated hydraulic conductivity, organic carbon content, total nitrogen concentration, runoff curve number, evaporation limit and drained rate was calculated for interval in between each consecutive percentile (Table 27).

Table 27. Percentile of rainfed yield and the mean of the main profile variables between consecutive percentiles.

Percentile	Value	N	yieldr	sbdm	slcl	slsi	srgf	sdul	slll	ssat	ssks	sloc	slni	sldr	slu1	slro
1	51.30	443	133.57	1.46	12.05	13.87	0.51	0.15	0.07	0.41	32.85	0.42	0.03	0.62	7.22	75.93
2	160.66	450	178.41	1.46	14.38	11.06	0.46	0.16	0.07	0.41	30.89	0.39	0.03	0.59	7.29	75.64
3	192.40	440	205.49	1.44	18.73	15.65	0.44	0.19	0.09	0.42	22.99	0.53	0.04	0.54	7.55	75.51
4	218.33	454	228.63	1.41	19.57	18.16	0.42	0.20	0.10	0.42	21.15	0.57	0.04	0.50	7.69	75.25
5	239.30	446	247.59	1.44	17.77	16.16	0.46	0.19	0.09	0.42	23.57	0.56	0.05	0.49	7.87	75.38
6	256.80	440	266.31	1.42	23.99	17.78	0.45	0.22	0.12	0.43	14.65	0.65	0.05	0.48	8.11	76.33
7	276.06	447	286.20	1.42	20.85	17.37	0.46	0.21	0.11	0.42	15.70	0.63	0.06	0.54	8.12	76.13
8	296.23	449	306.17	1.40	23.35	18.65	0.45	0.22	0.12	0.43	14.66	0.82	0.06	0.50	8.26	76.01
9	313.30	443	321.29	1.45	18.91	17.38	0.46	0.20	0.10	0.42	19.04	0.50	0.05	0.47	7.98	75.46
10	329.46	446	337.51	1.41	25.06	22.03	0.45	0.24	0.13	0.44	14.41	0.69	0.06	0.43	8.55	76.10
11	344.56	444	352.07	1.41	21.99	23.38	0.50	0.22	0.12	0.44	14.77	0.76	0.07	0.46	8.47	75.25
12	361.13	453	367.23	1.44	27.34	20.28	0.47	0.24	0.13	0.43	11.43	0.53	0.05	0.45	8.45	76.45
13	375.00	437	383.58	1.46	25.95	17.03	0.43	0.23	0.13	0.42	12.05	0.51	0.05	0.41	8.40	75.95
14	390.46	450	398.18	1.41	26.76	21.65	0.45	0.24	0.13	0.43	10.87	0.57	0.05	0.47	8.47	76.54
15	405.96	449	412.81	1.42	25.32	20.64	0.44	0.24	0.13	0.43	11.33	0.66	0.06	0.49	8.77	76.63
16	419.40	443	426.89	1.43	26.62	19.17	0.45	0.24	0.13	0.43	9.38	0.83	0.06	0.46	8.62	76.40
17	432.73	448	440.00	1.39	32.25	22.90	0.44	0.27	0.15	0.44	7.26	0.54	0.05	0.47	8.87	75.91
18	446.80	441	452.55	1.43	26.26	20.10	0.45	0.24	0.13	0.43	10.63	0.66	0.05	0.45	8.66	76.09
19	457.73	454	462.66	1.42	27.62	23.23	0.45	0.25	0.14	0.43	10.06	0.56	0.05	0.45	8.60	76.54
20	469.70	439	475.54	1.41	28.92	24.93	0.43	0.26	0.14	0.44	8.92	0.68	0.06	0.42	8.69	76.74
21	482.03	445	489.12	1.41	31.34	23.45	0.44	0.27	0.15	0.44	6.62	0.64	0.06	0.39	8.61	75.61
22	496.66	445	502.40	1.43	29.14	21.12	0.45	0.26	0.15	0.43	8.60	0.63	0.06	0.46	8.76	76.16
23	507.13	457	515.28	1.42	26.34	23.66	0.46	0.25	0.14	0.43	10.84	0.74	0.06	0.39	8.65	75.19
24	523.10	441	529.98	1.45	27.31	20.75	0.44	0.25	0.14	0.42	6.81	0.52	0.05	0.46	8.92	75.72
25	535.70	440	542.05	1.43	29.42	21.77	0.45	0.26	0.15	0.43	7.15	0.58	0.05	0.45	9.34	76.77

26	547.73	449	553.00	1.43	28.08	22.16	0.45	0.26	0.15	0.43	7.12	0.67	0.06	0.43	9.13	76.28
27	558.46	445	565.87	1.42	30.45	20.57	0.45	0.26	0.15	0.43	6.90	0.59	0.05	0.40	8.77	75.99
28	572.83	451	578.89	1.43	32.32	20.39	0.45	0.27	0.15	0.44	7.05	0.71	0.06	0.45	8.67	76.38
29	586.20	440	594.34	1.38	37.50	20.90	0.42	0.28	0.16	0.45	6.56	0.73	0.06	0.46	8.50	77.45
30	601.33	445	609.39	1.38	33.61	21.30	0.43	0.27	0.15	0.44	6.28	0.67	0.06	0.49	8.72	77.50
31	615.26	447	621.17	1.41	27.29	23.65	0.45	0.26	0.14	0.44	7.66	0.83	0.08	0.43	9.03	76.16
32	627.16	452	635.29	1.44	29.54	21.00	0.44	0.26	0.15	0.43	7.04	0.58	0.05	0.40	8.92	76.10
33	642.90	443	652.22	1.41	30.83	23.72	0.42	0.27	0.15	0.44	6.83	0.62	0.06	0.46	8.90	75.56
34	659.30	443	667.24	1.39	33.31	22.48	0.45	0.28	0.16	0.44	6.29	0.73	0.07	0.42	8.87	76.19
35	675.36	449	685.06	1.39	31.48	23.90	0.43	0.28	0.16	0.44	4.36	0.74	0.06	0.46	9.19	75.76
36	694.00	446	703.56	1.42	28.04	24.84	0.41	0.26	0.15	0.44	7.40	0.66	0.06	0.43	9.28	75.42
37	712.57	444	719.01	1.43	29.31	22.66	0.42	0.27	0.16	0.43	5.86	0.73	0.06	0.43	9.18	75.63
38	725.83	447	733.68	1.44	26.14	20.32	0.41	0.25	0.14	0.42	6.25	0.63	0.05	0.46	9.15	76.18
39	739.70	438	748.18	1.37	36.90	22.29	0.45	0.29	0.16	0.46	5.38	0.94	0.08	0.49	8.84	76.46
40	756.66	462	764.84	1.41	33.81	19.70	0.44	0.28	0.16	0.44	6.00	0.68	0.06	0.45	8.77	76.33
41	772.00	433	779.30	1.41	34.15	24.24	0.45	0.28	0.16	0.45	6.23	0.72	0.07	0.44	8.89	75.86
42	787.16	445	794.61	1.39	35.44	27.38	0.42	0.29	0.17	0.45	4.39	0.70	0.06	0.45	9.08	75.59
43	802.46	446	809.35	1.38	33.81	25.08	0.43	0.28	0.16	0.45	7.29	0.99	0.08	0.47	8.70	76.07
44	816.36	450	824.00	1.39	33.05	24.25	0.41	0.28	0.16	0.45	5.39	0.83	0.08	0.46	9.04	75.53
45	832.26	448	839.42	1.42	28.45	25.12	0.46	0.26	0.14	0.44	6.71	0.76	0.07	0.44	8.96	76.10
46	846.77	446	855.90	1.40	32.02	29.89	0.43	0.29	0.17	0.45	3.90	0.75	0.07	0.42	9.32	75.98
47	863.60	446	870.66	1.40	33.24	25.26	0.45	0.28	0.16	0.45	4.86	0.75	0.07	0.49	8.94	75.86
48	879.60	448	888.02	1.37	34.25	24.38	0.44	0.29	0.17	0.45	4.59	0.93	0.09	0.44	9.07	75.52
49	895.50	442	902.93	1.41	34.03	24.23	0.41	0.29	0.17	0.44	4.04	0.77	0.07	0.46	9.10	75.99
50	911.36	449	919.06	1.39	34.23	27.31	0.43	0.29	0.16	0.46	5.23	0.82	0.08	0.42	8.88	75.74
51	926.20	444	934.32	1.40	32.92	24.79	0.45	0.29	0.17	0.45	4.21	0.88	0.08	0.42	9.52	75.84
52	944.50	444	954.13	1.39	34.24	24.25	0.43	0.28	0.16	0.45	4.67	0.93	0.08	0.49	9.08	75.77
53	961.53	446	969.38	1.37	35.94	25.51	0.46	0.29	0.17	0.46	4.64	1.13	0.10	0.45	9.01	75.90
54	978.26	444	987.76	1.38	33.55	28.01	0.44	0.29	0.17	0.46	4.10	0.80	0.08	0.46	9.24	76.22
55	996.16	446	1004.93	1.43	29.95	24.88	0.42	0.28	0.16	0.44	5.02	0.70	0.07	0.43	9.20	75.26
56	1013.23	454	1022.74	1.39	33.97	25.80	0.42	0.29	0.17	0.45	4.42	0.82	0.07	0.48	8.99	75.85
57	1030.00	437	1038.77	1.39	31.40	24.28	0.42	0.27	0.15	0.45	5.91	0.88	0.08	0.49	8.88	76.80
58	1048.03	448	1057.54	1.38	30.40	27.07	0.45	0.28	0.16	0.45	5.04	1.14	0.10	0.44	9.33	76.18
59	1067.16	446	1077.27	1.38	34.05	28.74	0.42	0.29	0.17	0.46	3.60	0.85	0.08	0.46	9.39	76.34
60	1087.96	451	1097.40	1.38	33.30	28.42	0.44	0.29	0.16	0.46	5.00	0.90	0.08	0.46	9.12	75.74
61	1107.10	434	1114.84	1.40	33.32	26.74	0.44	0.29	0.16	0.45	3.66	0.88	0.08	0.49	9.32	76.63
62	1124.46	454	1136.46	1.38	32.92	29.15	0.45	0.29	0.16	0.46	4.24	0.99	0.09	0.45	9.46	76.19
63	1147.70	445	1156.70	1.40	31.14	25.93	0.44	0.28	0.16	0.45	4.38	0.76	0.07	0.44	9.36	75.61
64	1167.23	448	1178.57	1.36	32.17	30.24	0.44	0.29	0.16	0.46	4.87	0.97	0.09	0.45	9.11	76.01
65	1187.20	442	1195.20	1.35	34.85	27.94	0.43	0.29	0.17	0.46	4.15	0.95	0.09	0.48	8.97	75.87
66	1203.96	451	1215.64	1.39	33.45	28.09	0.43	0.29	0.17	0.45	3.60	0.87	0.08	0.48	9.29	75.62
67	1226.30	444	1234.67	1.42	32.16	25.77	0.43	0.28	0.16	0.45	3.87	0.85	0.07	0.44	9.45	75.18
68	1243.30	440	1254.76	1.36	35.33	28.22	0.39	0.30	0.17	0.46	3.36	1.12	0.10	0.46	9.14	76.17
69	1263.56	451	1274.85	1.39	30.65	29.32	0.44	0.28	0.16	0.46	5.67	0.95	0.08	0.48	9.23	75.64
70	1286.96	446	1298.98	1.37	33.33	28.36	0.42	0.29	0.17	0.46	3.28	1.02	0.10	0.46	9.36	75.58
71	1307.35	452	1319.57	1.39	29.32	29.75	0.43	0.28	0.16	0.46	5.40	1.11	0.10	0.47	9.46	75.06
72	1331.10	438	1342.98	1.35	34.69	29.51	0.43	0.29	0.17	0.47	4.24	1.28	0.12	0.47	9.39	75.46
73	1352.46	443	1366.98	1.38	35.30	28.99	0.44	0.29	0.17	0.46	4.32	0.93	0.09	0.45	9.22	75.34
74	1382.53	452	1393.78	1.36	31.32	29.53	0.42	0.29	0.17	0.46	3.81	1.11	0.10	0.47	9.55	75.13

75	1403.00	444	1416.94	1.35	35.42	29.95	0.42	0.30	0.17	0.47	3.67	1.29	0.11	0.48	9.40	75.79
76	1427.56	448	1439.07	1.37	32.12	30.18	0.42	0.29	0.16	0.46	4.53	1.00	0.10	0.44	9.29	75.82
77	1453.00	444	1467.85	1.37	30.67	28.79	0.42	0.28	0.16	0.46	5.31	1.36	0.12	0.45	9.33	75.88
78	1479.16	444	1491.67	1.39	28.76	30.33	0.42	0.28	0.16	0.45	4.59	1.11	0.11	0.48	9.45	75.34
79	1506.63	450	1523.37	1.40	31.79	25.44	0.42	0.28	0.17	0.45	4.64	1.13	0.10	0.51	9.54	75.59
80	1539.00	441	1553.02	1.36	33.08	28.28	0.43	0.29	0.16	0.47	6.24	1.30	0.11	0.45	9.16	75.26
81	1567.56	444	1586.80	1.39	30.72	32.36	0.41	0.29	0.16	0.46	3.78	0.97	0.09	0.50	9.63	75.03
82	1602.46	456	1619.67	1.39	31.84	35.80	0.40	0.29	0.17	0.47	3.35	1.07	0.10	0.50	9.70	74.84
83	1635.00	437	1652.99	1.37	30.97	28.47	0.42	0.29	0.17	0.46	3.78	1.13	0.11	0.50	9.49	74.89
84	1670.33	453	1689.48	1.35	33.74	37.17	0.40	0.30	0.18	0.47	2.34	0.99	0.10	0.49	9.45	75.47
85	1707.00	447	1731.71	1.35	31.65	27.26	0.40	0.29	0.17	0.46	3.12	1.53	0.13	0.48	9.64	75.52
86	1751.80	440	1774.69	1.38	31.66	33.04	0.43	0.29	0.16	0.47	3.56	1.14	0.11	0.51	9.58	75.39
87	1797.73	443	1819.89	1.39	28.57	35.56	0.41	0.28	0.16	0.47	4.57	1.10	0.11	0.52	9.56	75.15
88	1842.43	450	1866.71	1.36	32.79	32.76	0.42	0.29	0.16	0.47	4.34	1.29	0.12	0.51	9.37	75.39
89	1889.26	447	1913.05	1.35	30.60	34.06	0.41	0.29	0.16	0.48	4.92	1.72	0.14	0.51	9.19	75.70
90	1937.30	455	1964.60	1.38	30.11	35.32	0.39	0.29	0.16	0.47	3.45	1.23	0.11	0.50	9.65	75.34
91	1990.60	432	2027.65	1.33	28.82	34.82	0.41	0.28	0.15	0.48	4.77	1.54	0.14	0.54	9.59	75.40
92	2057.13	443	2088.18	1.35	30.34	32.00	0.40	0.28	0.16	0.48	4.61	1.52	0.14	0.51	9.44	75.44
93	2131.73	456	2172.71	1.34	31.19	33.69	0.39	0.29	0.16	0.48	5.56	1.35	0.13	0.54	9.38	75.61
94	2226.10	450	2274.22	1.36	25.73	30.24	0.38	0.26	0.14	0.47	8.35	1.28	0.12	0.55	9.31	75.08
95	2324.60	440	2391.40	1.28	29.40	36.58	0.36	0.29	0.16	0.49	3.41	1.85	0.16	0.52	9.67	75.47
96	2461.00	441	2546.19	1.27	30.67	35.89	0.40	0.29	0.16	0.49	5.10	1.98	0.20	0.51	9.55	75.69
97	2645.03	453	2750.02	1.31	27.10	33.64	0.38	0.28	0.15	0.49	7.96	1.96	0.19	0.51	9.40	75.25
98	2854.90	441	3068.69	1.32	26.97	37.38	0.37	0.28	0.14	0.49	6.13	2.18	0.21	0.54	9.54	75.48
99	3286.56	445	3593.72	1.20	25.01	38.33	0.37	0.27	0.13	0.51	7.41	3.06	0.29	0.51	9.33	75.91
100	4055.76	448	4763.30	1.08	20.74	38.86	0.37	0.25	0.12	0.55	11.68	4.71	0.50	0.56	8.98	76.39

Value: Percentile value. N: Number of profiles in each percentile.

In order to analyze the relationship among variables and the rainfed yield percentiles, a multivariate analysis of principal components were done. The variables including water content calculated as SDUL-SLLL, which are the mean weighed by the depth until base of layer, were represented by vectors, where their interception or origin is the mean of all variables, and the percentiles were mapped in a two dimensional plane that explain the 77.85% of the total variation: dimension1 (54.75%) and dimension 2 (23.20%). When the angle of any pair of vectors or variables is close to cero the variables are highly positive correlated, if the angle is 90º there is no correlation and if the angle is close to 180º there is a highly negative correlation. Correlation between total nitrogen concentration (SLNI) and organic carbon concentration (SLOC) was the highest positive and the highest negative correlation was found between saturated hydraulic conductivity (SSKS) and saturated upper limit (SDUL). The first 10 rainfed yield percentiles were locate in direction of the higher values of SSKS and lower values of evaporation limit (SLU1), saturated upper limit (SDUL), lower limit of plant extractable soil water (SLLL) and clay (SLCL); therefore, low rainfed yield was obseved when high saturated hydraulic conductivity and low SLU1, SDUL, SLLL, and SLCL were found. The 10 last rainfed yield percentiles were found when there were high: nitrogen (SLNI), organic carbon (SLOC), saturated upper limit (SSAT), silt (SLSI) and drainage rate (SLDR), and low bulk density (SBDM) and root growth factor (SRGF). Rainfed yield percentiles from 60 to 90 are characterized by high contents of SLOC, SLNI, SLDR, SSAT, SLSI, SLU1 SDUL, SLLL, WC, and SLCL and low values of SSKS, SRGF and SBDM; the lowest rainfed yield profiles the opposite (Figure 30).

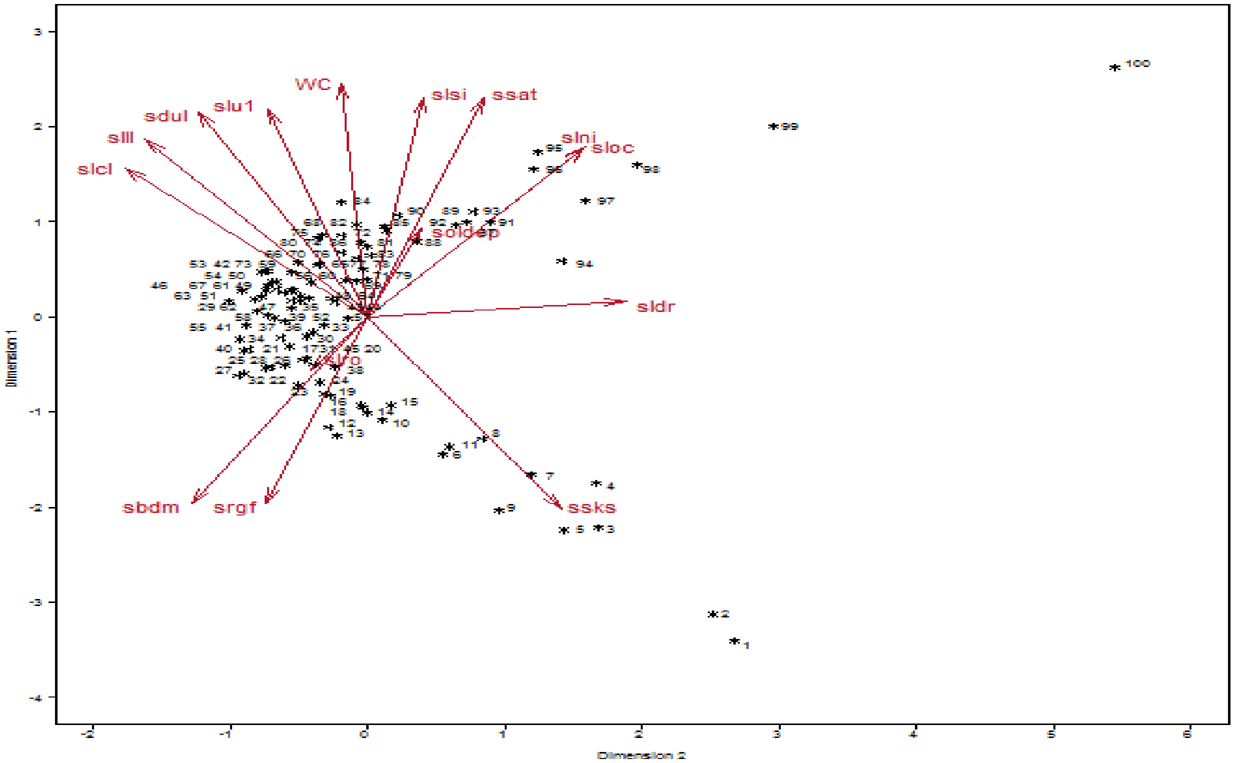
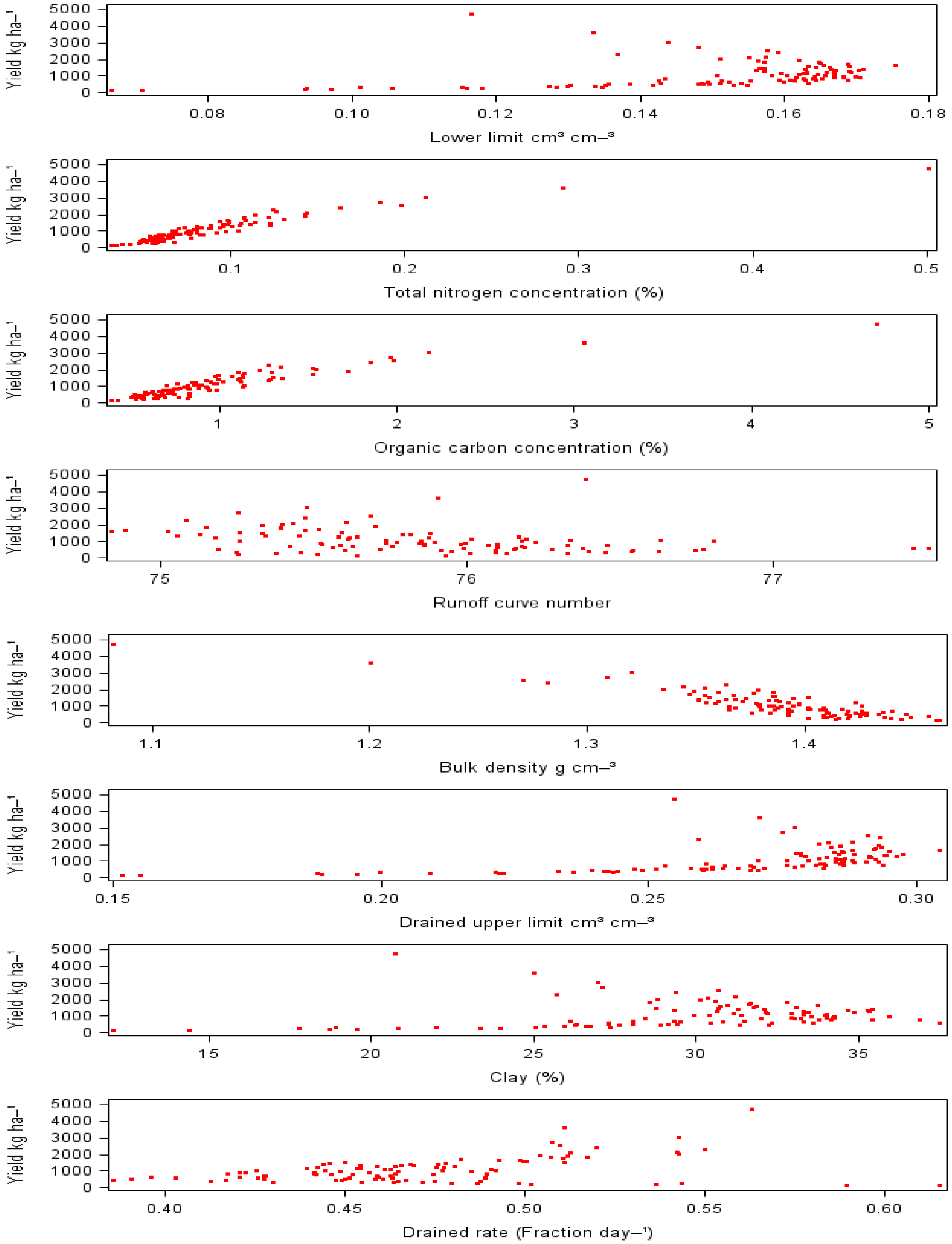


Figure 30. Correlation structure among variables and percentiles for the two first dimensions of a principal components analysis.

The relationship among the inter-percentiles rainfed yield and every main variable indicates for SSAT, SLNI, SLOC, SLSI, SLU1 and WC (=SDUL-SLLL) was linear positive correlation and for SBDM and SRGF negative (Figure 31). An empirical regression equation to predict the rainfed yield was determined trough stepwise selection method (Table 28).

Table 28. Estimated parameters of the regression to estimate rainfed yield.

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1279.824	2014.155	0.64	0.5267
wc	-104309	28475.48	-3.66	0.0004
wc^2	500316.4	138940.9	3.6	0.0005
slni	9387.659	821.8878	11.42	<.0001
slsi	41.4066	7.6013	5.45	<.0001
sbdm	3854.539	1078.139	3.58	0.0006
srgf	-5011.1	910.8967	-5.5	<.0001


Yield kg ha⁻¹
5000
4000
3000
2000
1000
0
0.08
0.10
0.12
0.14
0.16
0.18
Lower limit cm³ cm⁻³
Yield kg ha⁻¹
0.1
0.2
0.3
0.4
0.5
Total nitrogen concentration (%)
Yield kg ha⁻¹
1
2
3
4
5
Organic carbon concentration (%)
Yield kg ha⁻¹
75
76
77
Runoff curve number
Yield kg ha⁻¹
1.1
1.2
1.3
1.4
Bulk density g cm⁻³
Yield kg ha⁻¹
0.15
0.20
0.25
0.30
Drained upper limit cm³ cm⁻³
Yield kg ha⁻¹
15
20
25
30
35
Clay (%)
Yield kg ha⁻¹
0.40
0.45
0.50
0.55
0.60
Drained rate (Fraction day⁻¹)

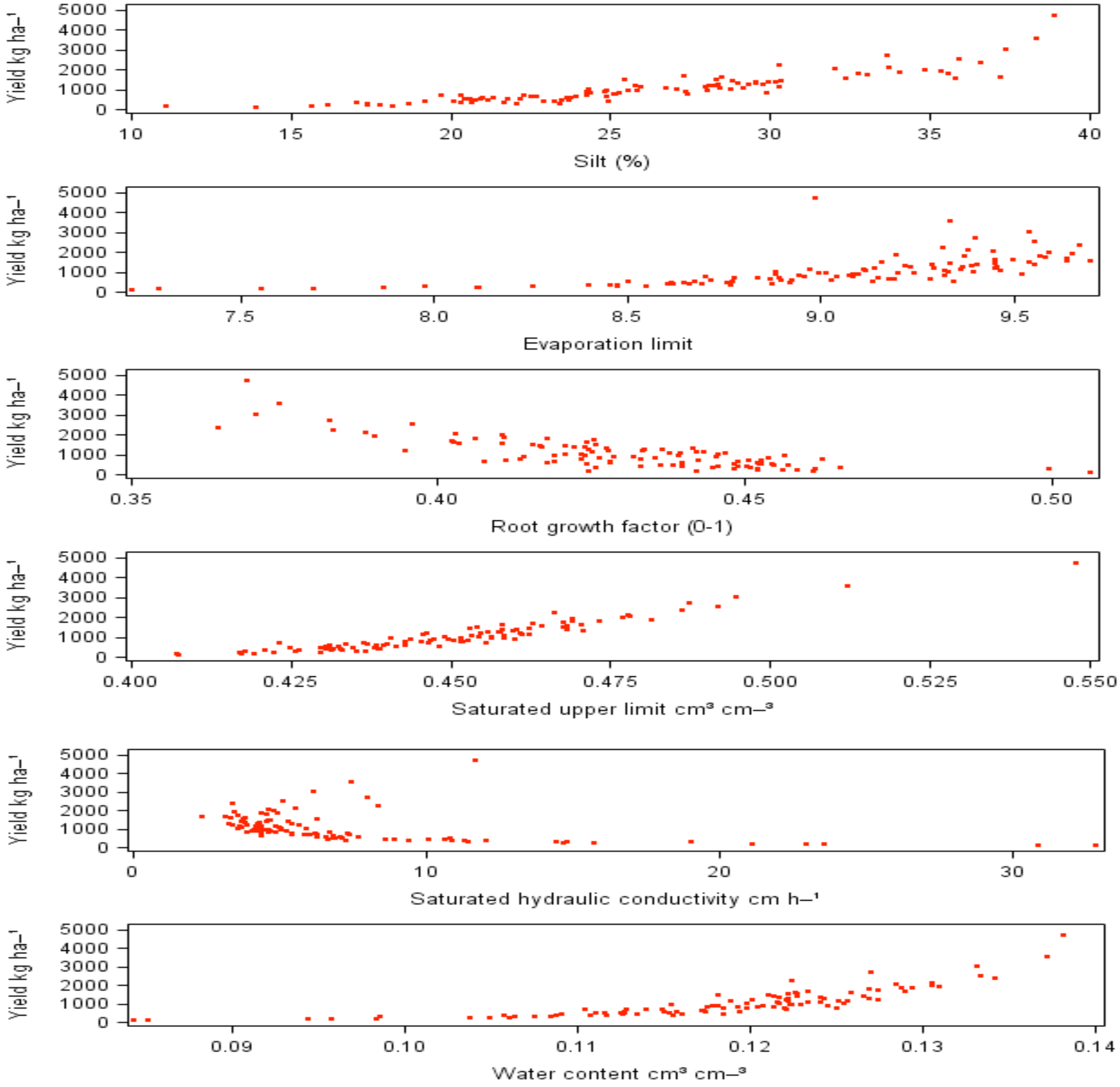


Figure 31. Relationship between the mean rainfed yield of each inter percentile and variables SLL, SLNI, SLOC, SLDR, SBDM, SDUL, SLCL, SLRO, SLSI, SLU1, SFGR, SSAT, SSKS and WC.

The prediction equation estimated very well the rainfed yield since the R2 = 96.64%, the RSME = 144.24 kg ha^{-1}, CV = 13.18%. The regression between the predicted rainfed yield (y) and the mean of the inter percentile rainfed yield was statistically significant; as we expected the intercept was not significant and the slope = 0.96 kg ha^{-1} was different from cero; however the slope was not different from one (P = 0.051) as an indication of a relative bias and an overestimation when the observed yield was high (Figure 32).

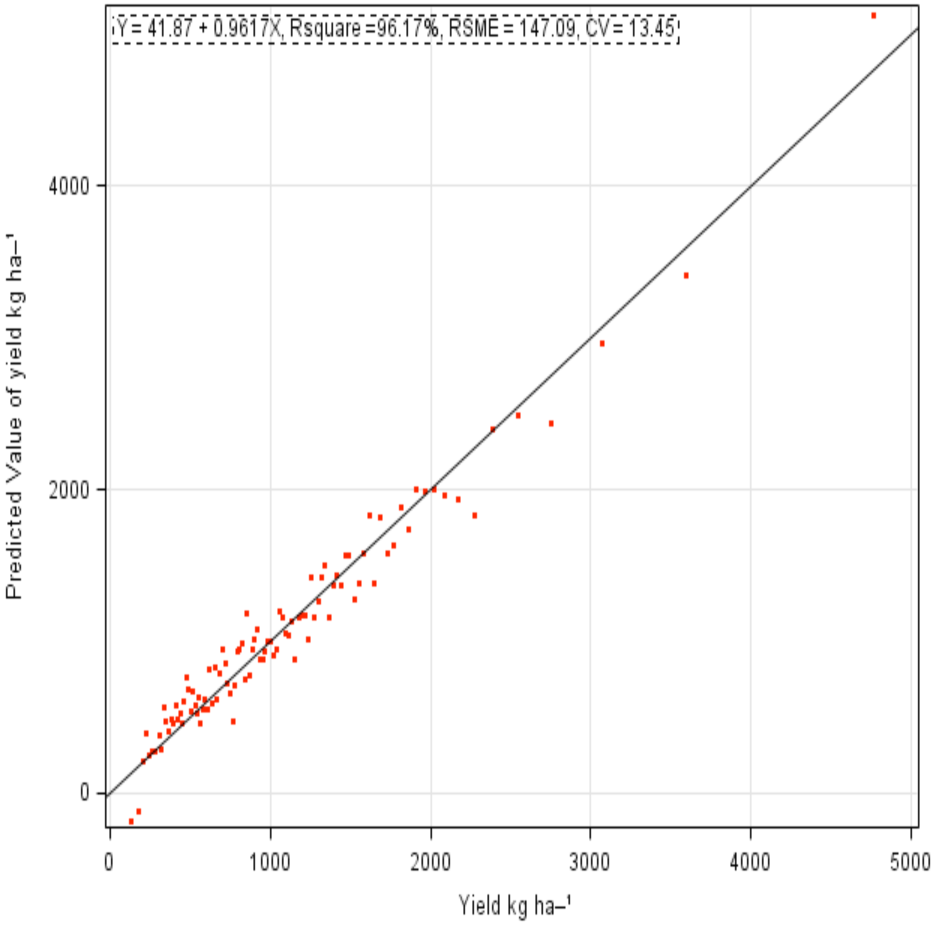


Figure 32. Regression 1:1 between the predicted rainfed yield and the mean of the inter percentile rainfed yield.

Discussion

The soil profiles from WISE3.1 database converted to a format suitable for crop simulations models within the Decision Support System for Agrotechnology Transfer (DSSAT; Jones, 1998) were suitable to run models for maize, soybean, sorghum and wheat; nevertheless, 9613 of 10253 profiles worked successfully after the estimation of missing values and the quality control analysis. Only five profiles converted were not appropriate to run the models because the soil depth was less than 6 cm. For 635 soil profiles from WISE3.1 database was not possible to run them using DSSAT because of the great quantity of missing values particularly for texture and organic carbon content that address the calculation of the water content variables needed to run DSSAT. As a result of the comparison of the Dynamic Nearest-Neighbor Method (Jagtap et al., 2004) and the Multiple Regression Pedotransfer Function (Rawl et al., 1982 and Saxton and Rawl 2006) approaches to calculate profile water content, the first one was used since it generated the lower root mean square error and bias. The WISE3.1 database includes soil profiles not considered for agricultural purposes; however it was assumed that all the profiles were suitable for food production.

Sensitivity analysis of the converted soil profiles proof the power of DSSAT to simulate different environmental conditions maintaining fixed the weather conditions. The high frequency (26.6%) of the profiles with the maximum yield for maize in IHN treatment hints the possibility to obtain greater maize yields since the DSSAT software possibly constraints the yield to a pre-determined maximum. Nonetheless, maintaining the weather conditions of the standard experiments used, the simulations for the different soil profiles showed the yield variability among and within of each treatment and crop simulated; furthermore since the ascendant yield order was not the same for the crops for each treatment, DSSAT models simulations were sensible to detect the profiles suitable for each crop growth and for what soil profiles the irrigation application and also nitrogen had the better response.

As the multiple nonparametrized factors involved in the WISE3.1 converted profiles format intervening in the DSSAT calculations to simulate yield, we did not determine the contribution of each factor to reduce the yield because the interactions among factors become very large and increase more if weather conditions are considered.

From the simulated yield comparison of the empirical cumulative distribution of the two treatments (rainfed and irrigation and high nitrogen) and the four crops simulated, the lower difference in wheat and sorghum confirm the capacity of these two crops to extract water from deeper soil layers e.g. higher water use efficiency which indicates that sorghum could be a good alternative to maize under limited in the semi-arid conditions. Farre and Faci, 2006, found under full irrigation that maize yields were greater than sorghum; however, irrigation deficit reduced vegetative growth, biomass and yield more in maize than in sorghum, giving higher yields for sorghum under moderate or severe water deficit treatments. For wheat in different locations, the literature on crop water production (CPW) function indicates that deficit irrigation (DI) should be preferred over full irrigation (Geerts and Raes, 2009; Zhang, 2004; Tavakkoli and Oweis, 2004; Tolk and Howell, 2008). For maize compared with sorghum, wheat and other crops from an agronomical point of view, full irrigation (FI) is preferable over DI. (Payero et al., 2006; Igbadun et al., 2006; Oktem et al., 2003; Tolk et al., 1999, Farré and Faci, 2006).

Cabelguenne and Debaeke, 1998, studied the water extraction of 5 crops from 1970 to 1991 and concluded that maize extracted the most water from the top 0.5 m, removing 150% of the apparent available water (AAW) falling rapidly lower down, reaching nil at 1.6 m. On the contrary, sunflower extracted less near the surface, but used all AAW up to 1.2 m, and extracted 85% of AAW at 1.6 m. Sorghum was fairly similar to sunflower, but with a lower use over the entire profile. Soybean exhibited high extraction to 1.0 m, and then much less at depth. As to wheat, its extraction capability was quite high near the surface, and then fell steadily with depth where it is still 30% of AAW at 1.6 m.

The analysis of the seasonal maize yield simulations for the weather generated of the thirty seasons demonstrated the interaction between different weather conditions and FAO90 type of soil in each one of the two treatments which indicates the capability of DSSAT to detect spatial and temporal variability at global level. Other studies have proved the capacity of DSSAT in simulating the spatial and temporal variability at regional and local levels (Jagtap et al., 1999; Singh et al., 1993; Thornton et al., 1995; 1997; Phillips et al., 1998); for example, Salazar et al. 2012, worked with 58 years of historical weather and 88 counties of the southeastern of USA and showed that the CSM-CERES-Maize was able to simulate the amount of water required for maize irrigation as a demonstration of the potential application of the model as a tool for estimating water demand for irrigation. They recommend to use the model not only to estimate water requirements for supplemental irrigation but also for both policy makers and local farmers for planning the amount of water required for supplemental irrigation as well as for improvements in irrigation management for water conservation.

Kiniry and Bockholt, 1998 evaluated, under diverse weather conditions and soils in Texas (five years and nine locations), the ability of ALMANAC (ACg ricultural Land Management Alternatives with Numerical Assessment Criteria) and CERES-Maize models to simulate grain yields of maize *(Zea mays* L.) and sorghum [*Sorghum bicolor* (L.) Moench] and concluded that CERES and ALMANAC performed adequately in simulating plot grain yields at these diverse sites.

For suitable global use of WISE3.1 data base to contribute to supply more information for food security development and mitigation to face the climate change, local weather or weather generated for every locality, cultivars, local management and spatial variability of the soil profiles must be identify in order to obtain information to lead the policy makers and farmers make right decisions on how, when and where the crops and what cultivars must be recommended to plant. In an attempt to summarized soil profiles or find representative ones, the FAO90 soil classification, based on similar physics and chemical characteristics, were used assuming different yield response among them. However, not only the physical and chemical characteristics determine the maize yield or any other crop; the weather, nutrients supply, pest, diseases and weed also affect the crop growing. Here we assumed the yield was not reduced by any sanitary problem and identical management for only one variety was applied; nevertheless, the results in this case are restricted to the range of weather conditions generated but this does not mean that different condition cannot be used since the calibration encompass a wider range of conditions and cultivars.

Given that the quartiles split the yield distribution in four zones each one including the 25% of the total profiles, for each group of the FAO90 classification, the profiles belonging to each zone of the distribution was identified and characterized. Nonetheless, because of the interaction between treatment and FAO90 group, the distribution of the profiles in each quartile changed if rainfed or irrigated high nitrogen treatment were used and as a consequence it was possible to identify for what kind of soils and profiles the supply of water and nitrogen was used more efficiently. According to the characterization of the FAO90 profiles involved in each quartile, the results permit calculate probabilities to reach quartiles or inter quartiles yields; however, some of the FAO90 groups had low absolute frequency which limits the confidence of the probabilities.

The classification of the rainfed yield mean over 30 different seasons conditions in percentiles and the identification of the profiles belonging to the inter percentile illustrated its dependence over certain profile variables, independent on the FAO90 classification because there were no clear tendency to encompass any particular FAO90 class profiles in any percentile. For example the first inter percentile contained 49 different classes of FAO90 where classes ARh ARl ARo (Arenosols) were most frequent. The last inter percentile enclosed 27 FAO90 classes profiles and the most frequent were ANu, ANz (Andosols).

The multivariate relationship among the main soil profile variables and rainfed yield showed the relative importance (length of the arrow) of each characteristic in the analysis and it is clear that the water content is one of most relevance characteristics to explain the yield variability, meanwhile the soil depth contribute the less. Based in 10 years study of a dryland crop rotation, Nielsen et al. (2009) found a predictive relationships between corn yield and available soil water; however they warm that under typical amounts of available soil water at corn planting, profitable corn production under dryland conditions is a risky and speculative activity in the central Great Plains of the United States principally because of the uncertainty about the water supply during the growth season. Therefore, whether the appropriate quantity of water by rain is supplied during the season, as in this study looks like, the water content is good predictive variable to estimate the yield. Other discriminatory characteristics to infer the rainfed yield were the total nitrogen concentration SLNI, silt content SLSI, bulk density SBDM, and root growth factor SRGF. The regression model to explain the variability of the mean of inter percentile rainfed yield reduced the error term considerably and are very good predictor under the conditions of the generated weather for the standard experiment used to simulate the yield. Nevertheless, the yield predictions may be wrong if different weather, cultivar and different crop management differ of the standard experiment used here. The total water coming from the 30 years generated rain varied from 300.1 to 776.4 mm during the season and the distribution of these quantities was also different so that the regression model is valid only for these conditions. Other different conditions could be simulated to evaluate the sensitivity of the estimated regression parameters; however, it takes long time and its significance can change or different variables can explain the rainfed yield variation.

Since the water content can be a potential rainfed yield predictor and discriminatory variable, more effort to determine the lower and upper limit water content must be done; the database, that is the foundation to estimate the water contents for 9613 profiles and 47833 layers, contains only 272 measured water contents.

According to Withe et al. 2011, several ecophysiological models have been used to predict potential impacts of climate change on future agricultural productivity and to examine options for adaptation by local stakeholders and policy makers. The adaptation predominantly examined changes in planting dates and cultivars and half of investigation emphasizes the risk mainly in relation to variability in yield or effects of water deficits, but the limited consideration of other factors affecting risk beside climate change per se suggests that impacts of climate change were overestimated relative to background variability. A coordinated crop, climate and soil data resource would allow researchers to focus on underlying science. Although in the present work we used only one variety, crop management and weather locality, CERES-DSSAT model detected changes, in terms of yield and biomass, to different weather conditions, treatments and type of soils and their interactions.

Conclusions

WISE3.1 is a soil database containing the attributes needed by DSSAT to simulate at a global scale the growth and development of any of the crops modeled in; however missing values of the texture variables and organic carbon constrain the capacity of DSSAT and maybe of any other model to simulate crop growth. In general is feasible to convert to DSSAT format any soil database containing the required attributes.

The temporal and spatial variability of the food production is one of the mayor concerns against the climate change and the fast population growth, for this reason it is imperative expand information useful to front the food security through certain make decisions. One of the ways to generate that information, if not only the unique, is to use the established databases and technology as a result of the scientific researches worldwide. With the results of this project we demonstrated at global scale that DSSAT is capable to determine the effects not only of spatial and temporal variability to produce certain crops but also the effect of treatments or different management applied. Furthermore, the type of soil and profiles producing higher and lower yields according to the treatment applied can be establish trough the simulations and also the crop more suitable for determined weather, type of soil or profile. At the same time, DSSAT can offers information about the adverse and favorable weather to growth crops like maize, soybean, sorghum and wheat as in our case but surely the similar information can be obtained for other crops.

The analysis and results here presented are not an acceptable recommendation since we used only one cultivar and generated weather for maize; however, it is an indication of a powerful tool to use having real data or information about the locally soil, cultivars and weather. In order to generate more useful information, efforts should be done to improve and update soil databases, to calibrate new cultivars according to each location and the efficiency of the software to simulate and to analyze bulk data resulted of the simulations. As the weather is one of the most important factors addressing the crops growth, also it is necessary to dispose of databases or powerful and reliable weather generators to simulate confidentially the yield at local level.

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