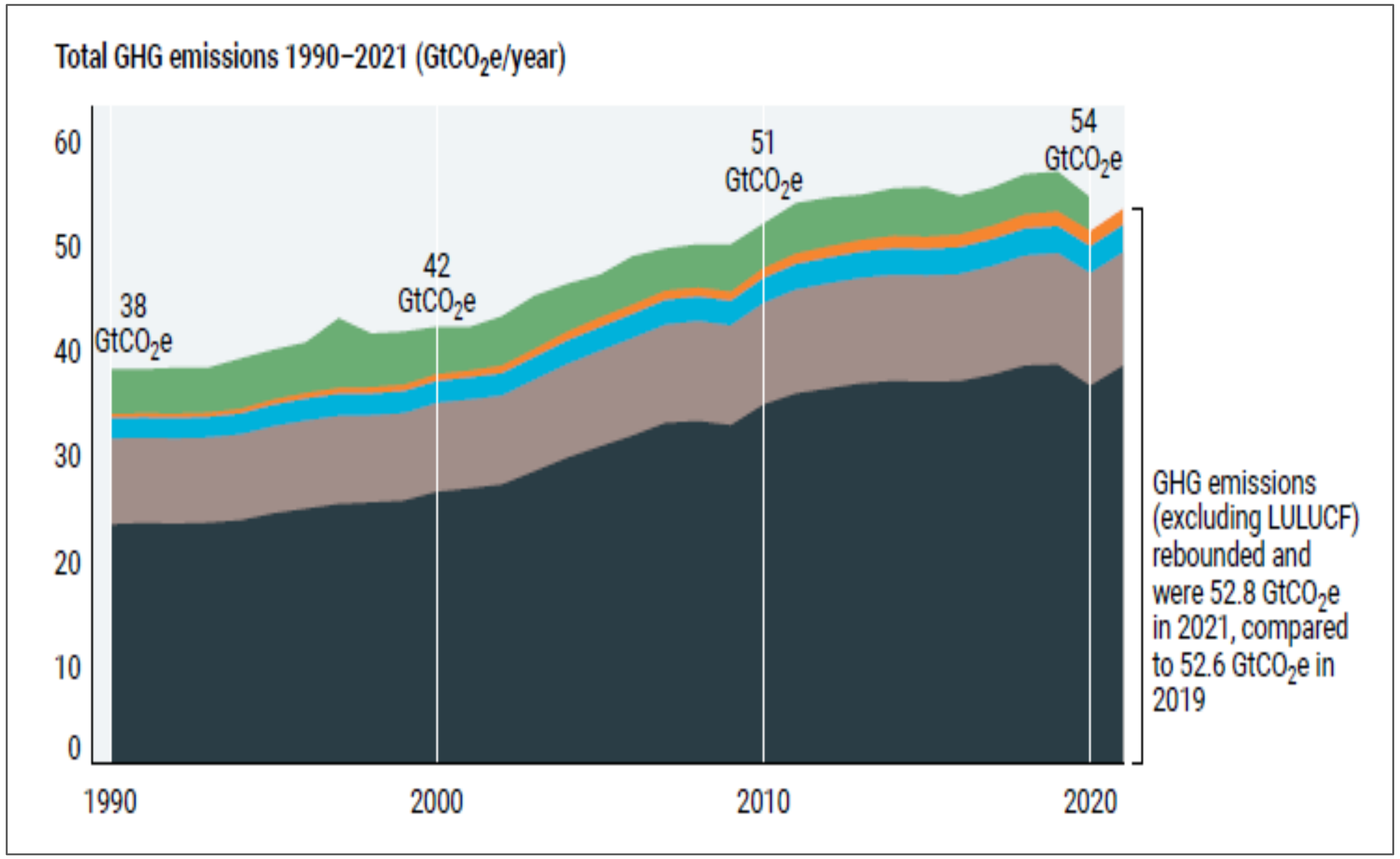
Simulating the effect of crop management strategies under a changing climate in Ethiopia.

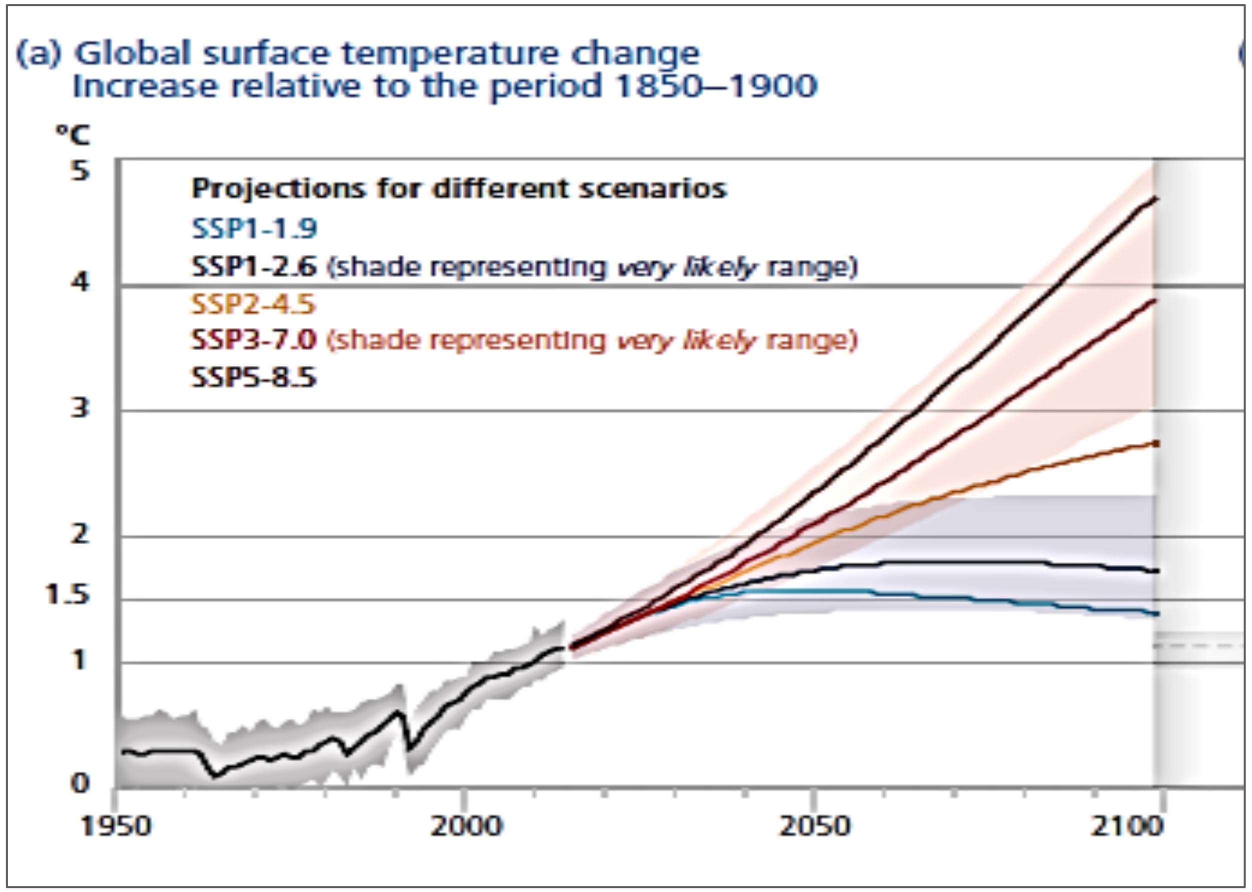
Ethiopian Institute of Agricultural Research
Debre Zeit Center

Climate, Geospatial and Biometrics Research program
By
Endalew Assefa Abera

Monday, May 8, 2023
Addis Ababa, Ethiopia

Global GHG Emission and temperature projection





Source: IPCC, 2022 report

- The increasing greenhouse emission, increasing surface air temperature, declining levels and high variability of rainfall are becoming the most hardness to agricultural production *(Hazell, 1985)*
- The adverse effects of climate change on food production will become more severe, notably in sub-Saharan Africa *(IPCC, 2022)*
- As result, farming system, crop pest and disease, crop variety and crop by itself are under relocated due to climate change *(Yumbya et al., 2011).*

Climate trend in Ethiopia

Journal of Climatology & Weather Forecasting

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Research Article

Temperature and Rainfall Trends in North Eastern Ethiopia

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ABSTRACT

North-eastern Ethiopia is one of the sensitive regions to climate variation particularly to temperature and rainfall changes. Rainfall and temperature are one of the most determinant climate patterns for the study area because more

Table 4: Trends of annual and seasonal rainfall in the two stations.

Seasons	Kombolcha			Dessie		
	ZMK	Q	P	ZMK	Q	P
Annual	0.01	0.1	0.97	-0.03	-0.56	0.82
Kiremt	0.19	4.2	0.09	0.06	2	0.59
Belg	-0.22	-2.4	0.06	-0.12	-1.73	0.29
Bega	0.01	0.1	0.95	0.21	1.58	0.07

Journal of Climatology & Weather Forecasting

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Research Article

Seasonal and Annual Rainfall Trend Detection in Eastern Amhara, Ethiopia

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ABSTRACT

Precipitation is one of the most important climate variables that could influence the climatological, agricultural, and hydrological studies. This paper presents several test statistics to detect the effects of autocorrelation and its

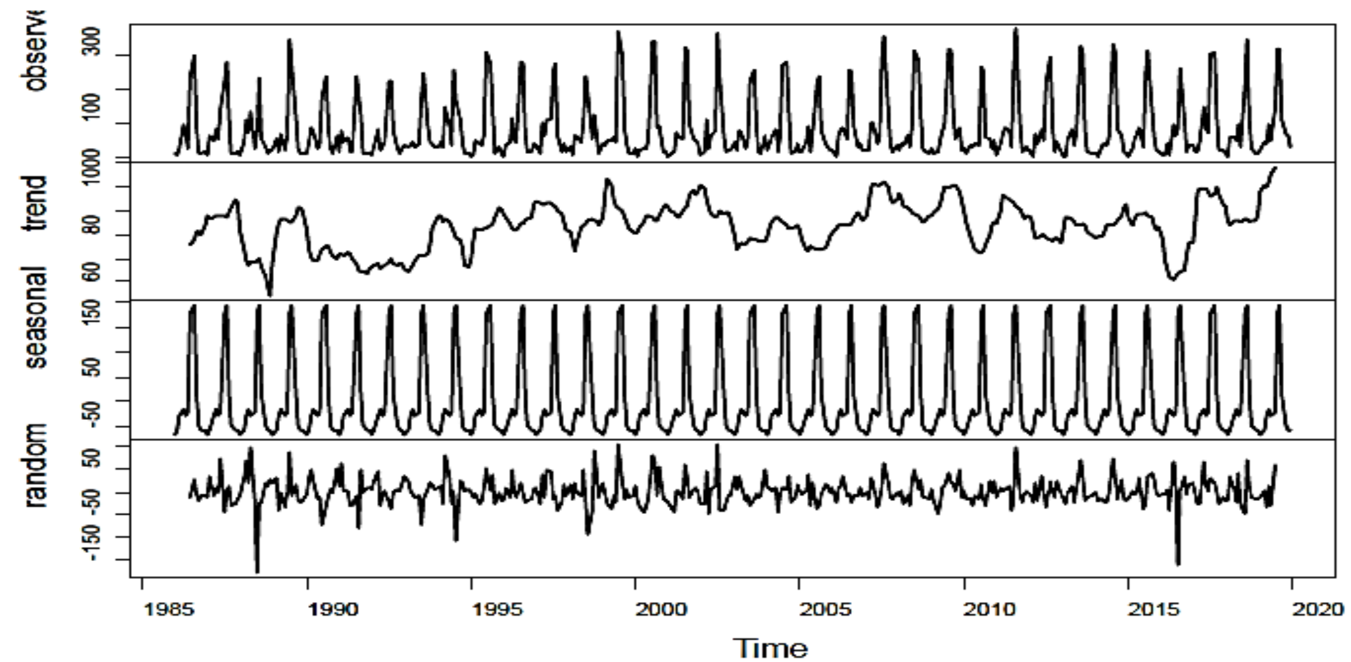

Figure 3: Components of seasonal rainfall (mm) (random or error, seasonal, trend, and original data distribution).

Climate change impact in crop productions

Wheat under future climate in Ethiopia

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ACADEMIC JOURNALS
African Journal of Agricultural Research

Full Length Research Paper

Calibration and validation of CERES-wheat in DSSAT model for yield simulation under future climate in Adet, North Western Ethiopia

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Crop models are highly useful for simulating crop and soil processes in response to variations in climate and crop management. However, well estimated crop genetic coefficients are required. So the purpose of this study is to calibrate and evaluate the performance of CERES-wheat model and to simulate the climate change impacts on phenological stages and grain yield of bread wheat (Tay and

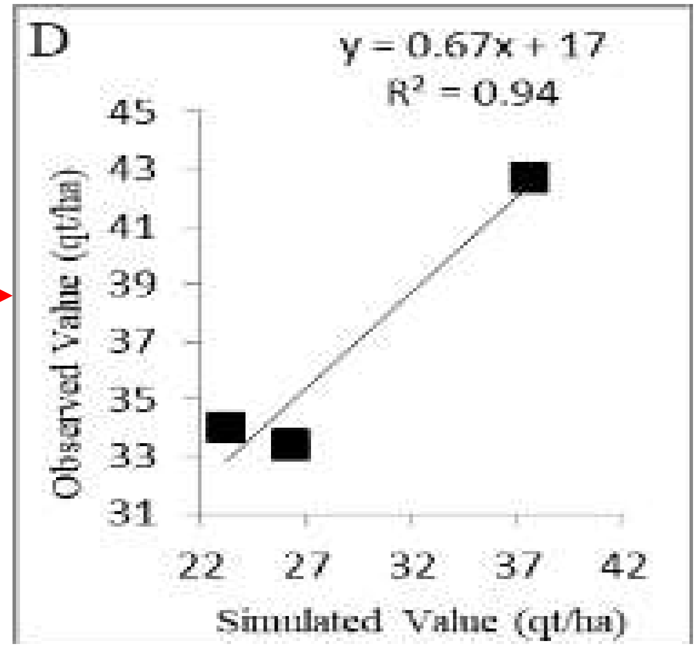

Table 9. Variability grain yield (qt ha^{-1}) for Tay wheat at different time slice under RCP4.5 and RCP8.5 scenarios in Adet, North Western Ethiopia.

Statistical parameter	Baseline	RCP4.5			RCP8.5		
		2030	2050	2080	2030	2050	2080
Minimum	30.57	31.02	31.21	26.11	30.21	27.80	18.03
1st quadrant	32.89	32.97	33.84	33.68	32.66	33.26	33.48
Median	36.82	37.86	36.61	37.48	37.63	37.97	35.39
3rd quadrant	42.81	43.60	41.67	43.75	43.59	43.12	40.08
Maximum	49.13	49.19	50.14	49.48	49.77	49.05	45.42
Mean	38.20	39.05	38.25	38.48	38.81	38.47	36.10
SD	59.7	6.11	5.70	5.95	6.49	5.98	5.37
CV (%)	15.6	15.6	14.9	15.5	16.7	15.5	14.9

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Journal of Petroleum & Environmental Biotechnology

Research Article

Impacts of Climate Change on Bread Wheat (*Triticum aestivum* L) Yield in Adet, North Western Ethiopia

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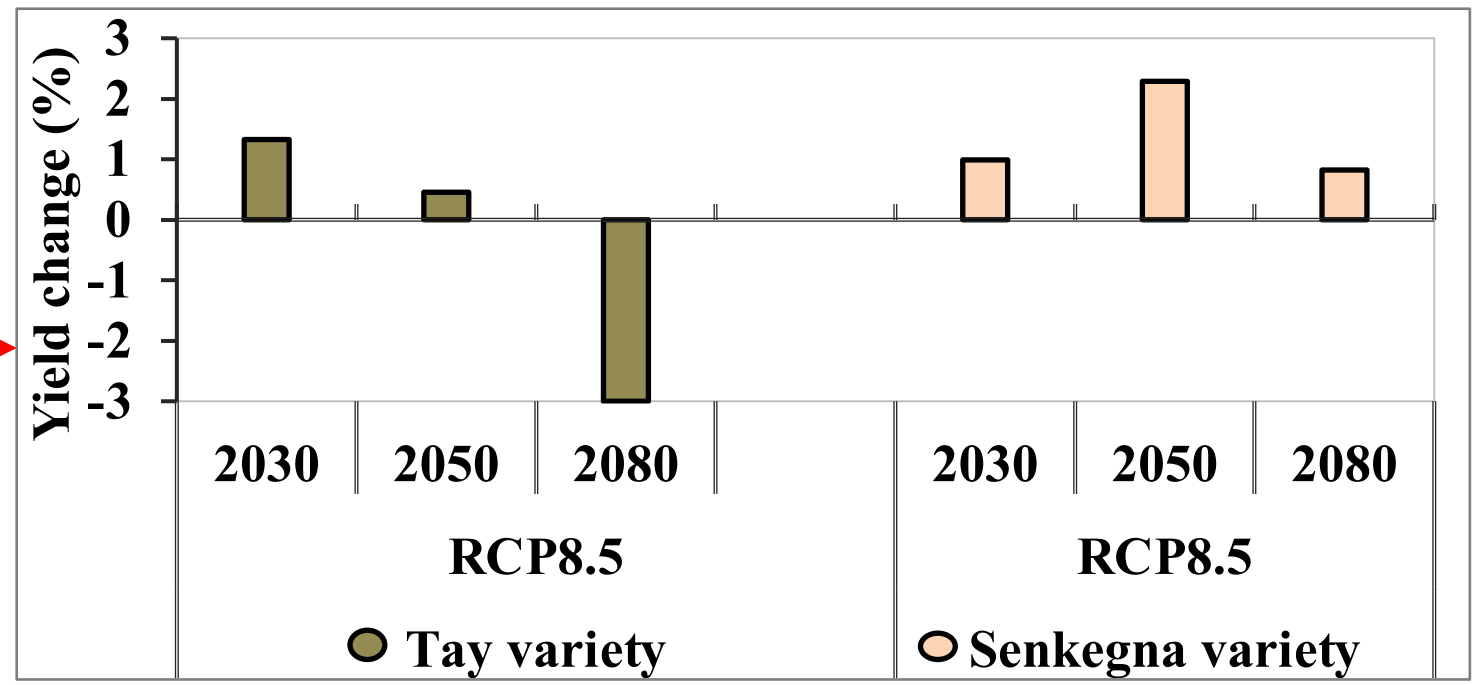
ABSTRACT

Quantifying the extent and direction of climate change and its impacts is important on crop production as earth's



Climate change impact in crop productions……

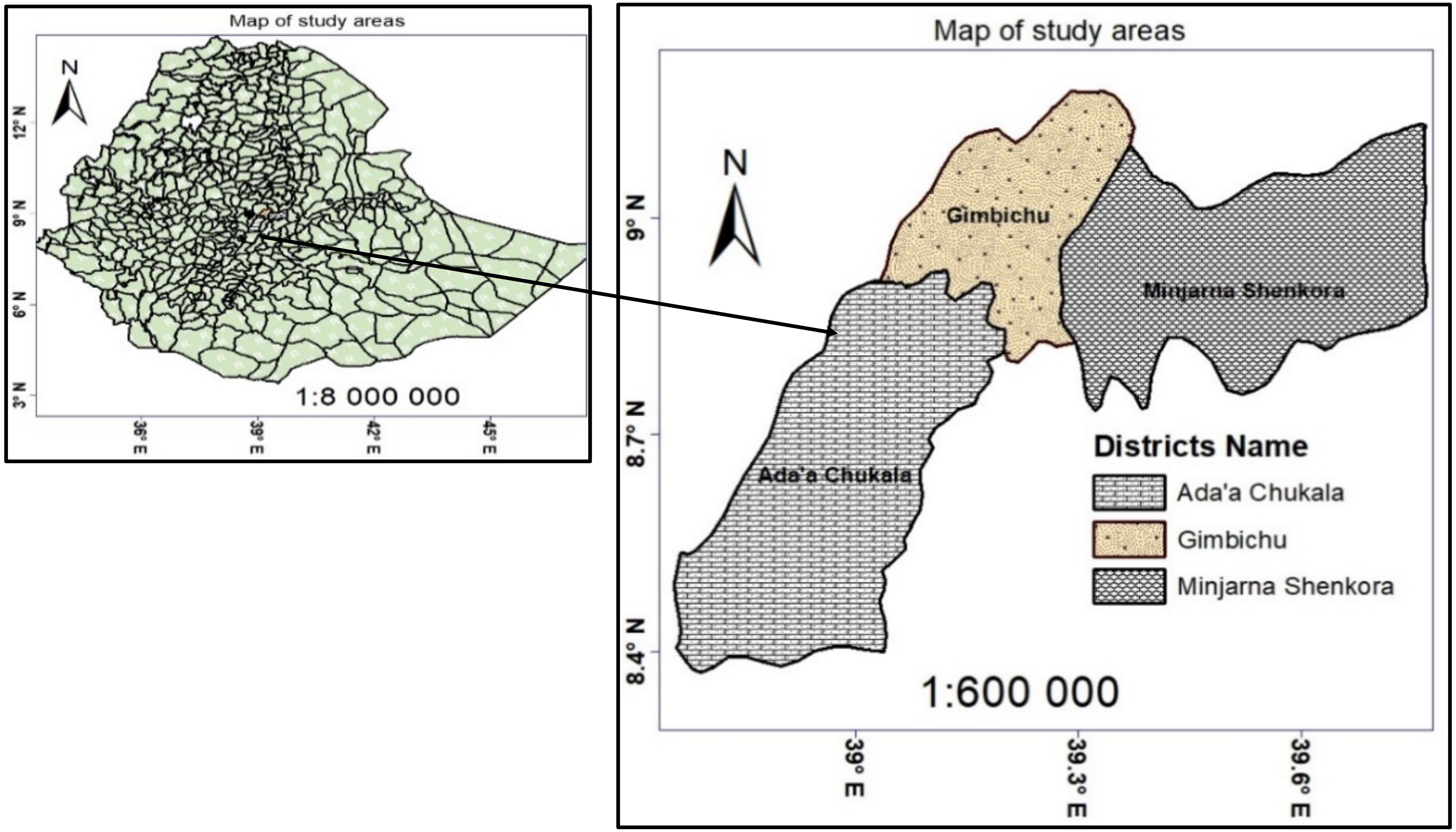
- The elevated of $CO_{2,}$ increases photosynthesis, thereby increasing the carbohydrate pools of leaves and stems, and finally to grain yield ***(Attri and Rathore, 2003).***
- A doubling of ambient CO_2 cause an approximate 40% decrease in stomatal space, which may reduce transpiration by 23–46% ***(Cure and Acock, 1986; Morison, 1987).*** and increase yield and plant productivity up to 30-60% ***(Mulholland et al., 1997).***
- These results suggest that an increase in temperature may offset the benefits of increasing CO_2 concentration on crop yield.
- The ultimate effect of increasing CO_2 concentrations and related climate change on crops strongly depends on the current environmental conditions ***(Ludwig and Asseng, 2006).***

Chickpea production in Ethiopia

- In Ethiopia, chickpea is grown with residual moisture *(Bejiga and Tullu, 1982).*
- As result, the chickpea growth is mostly vulnerable for water stress *(Wolde-meskel et al. 2018).*
- Terminal drought accounts for up to 50% yield losses in chickpea across the globe *(Pang et al. 2017).*
- Low and high temperatures also account 15–20% of chickpea yield lost *(Nene et al., 2012).*
- The national average yield of chickpea in Ethiopia under farmers condition is less than 1.5 ton/ha *(CSA (2009)*
- However, if the improved management strategies are implemented, its potential productivity is more than 3 ton/ha in Ethiopia (Kihara, 2013)
- Adjusting planting date is a means of resilient to climate variability *(Attri and Rathore, 2003),* and used as effective adaptation option to climate change impacts. Cuculeanu et al. (2002) and Masanganise et al. (2012)
- The aim of this study was to determine the climate change and its impact on chickpea yield, and to explore effective crop management options that optimize chickpea yield

Study areas

Fig 1. Study areas



➢ **Locations**: Three chickpea potential crowing areas i.e. Debre Zeit site (Adaa districts, Oromia, Ethiopia), Cheffe donsa site (Gimbichu districts, Oromia, Ethiopia), Minjar Shenkora (Minjar district, Amhara, Ethiopia)

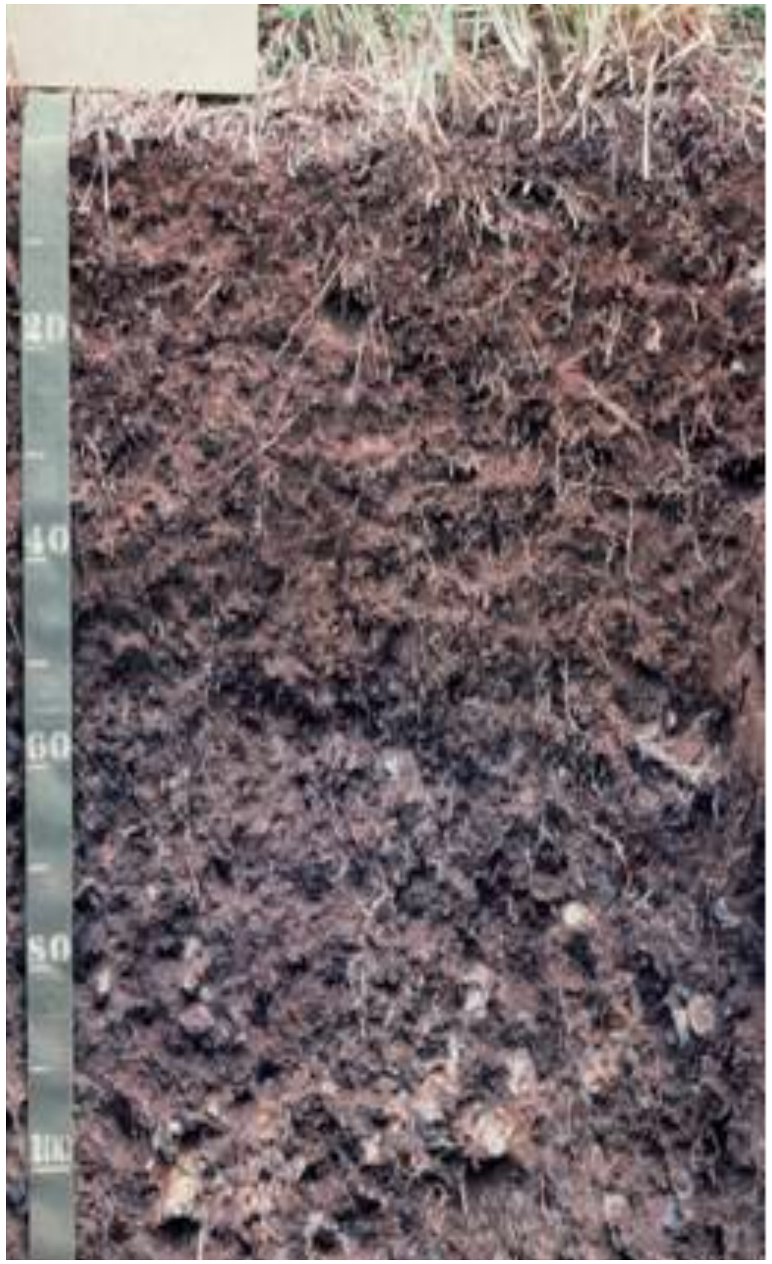
Methods and Materials…

Data generation

Chickpea crop data collection

Meteorological data collection

Soil data collection

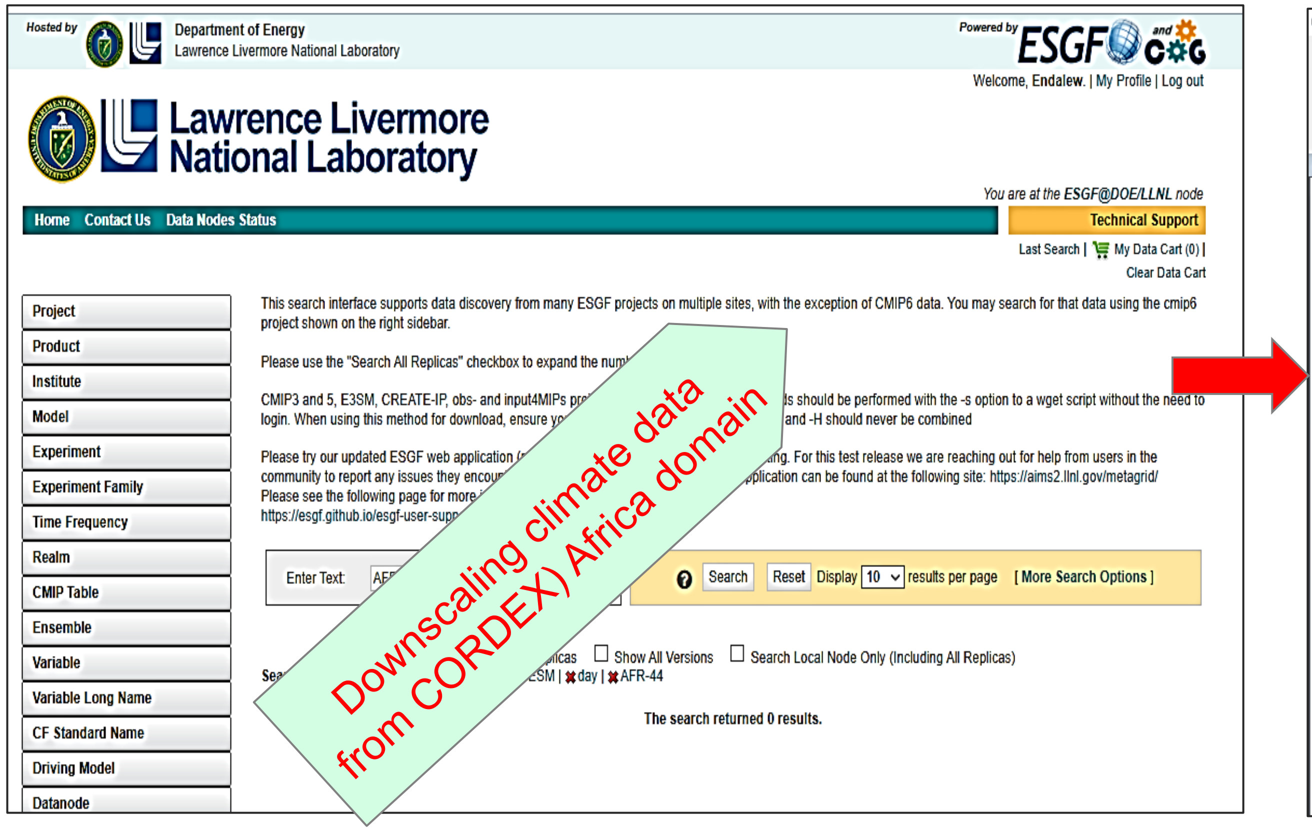


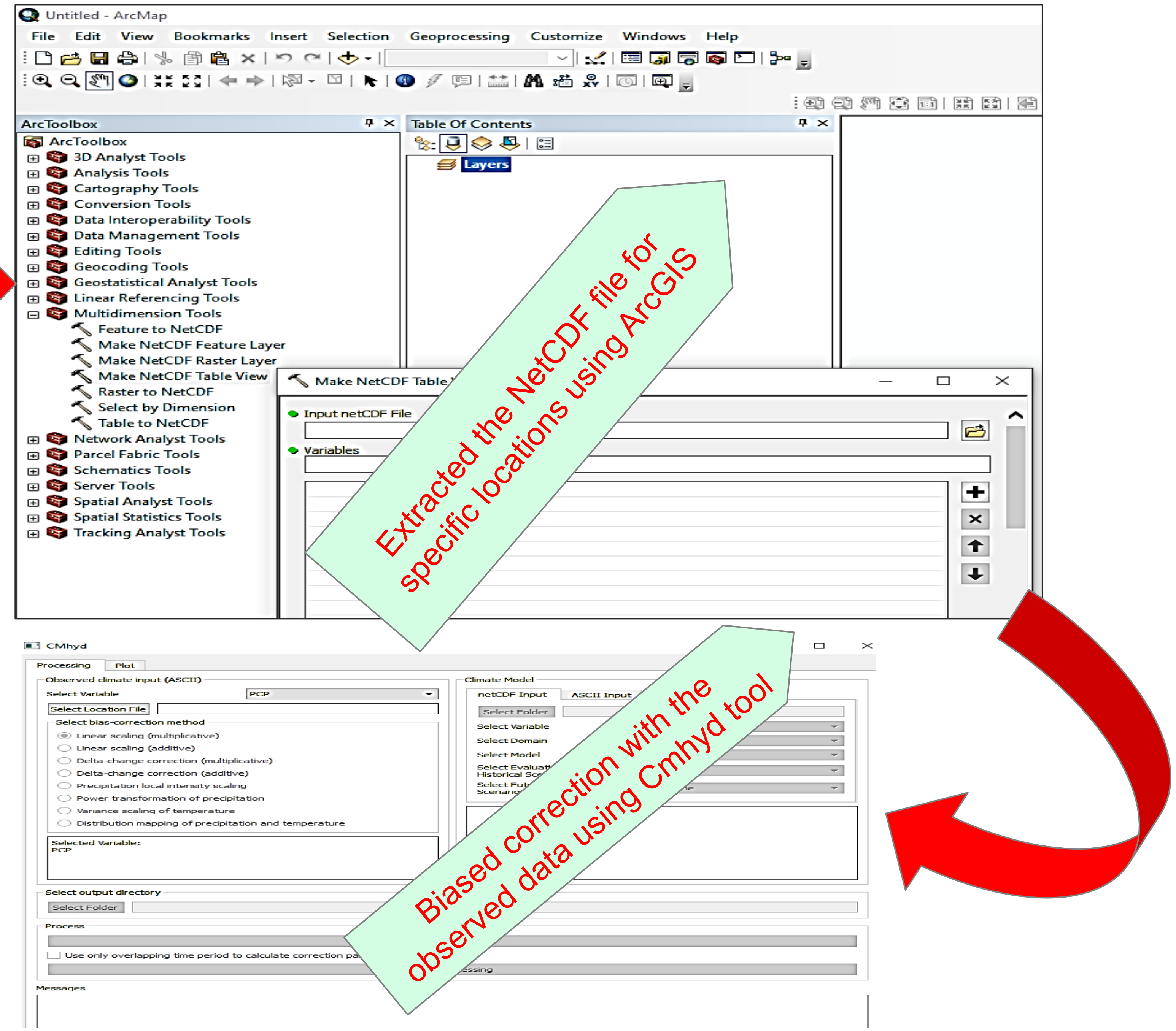
	Soil depth (cm)			
Parameters	0 - 30	30 - 90	90 - 140	140 - 200
Clay				
Silt				
Sand				
LL				
DUL				
Bulk density (g/cm3)				
Organic carbon (%)				
Total N (%)				
pH				
CEC (meq/100g soil)				

Methods and Materials…

Climate projection

Fig. 3. Future climate Data generation process





- Baseline (1971-2000) and future weather data (2010-2039) are downscaled from Coordinated Regional Downscaling Experiment (CORDEX) Africa domain *(Taylor et al., 2012)* under RCP4.5 emission scenario.

Global and Regional Climate models

Table 1. Availability and accessibility of GCMs and RCMs for CORDEX Africa domain

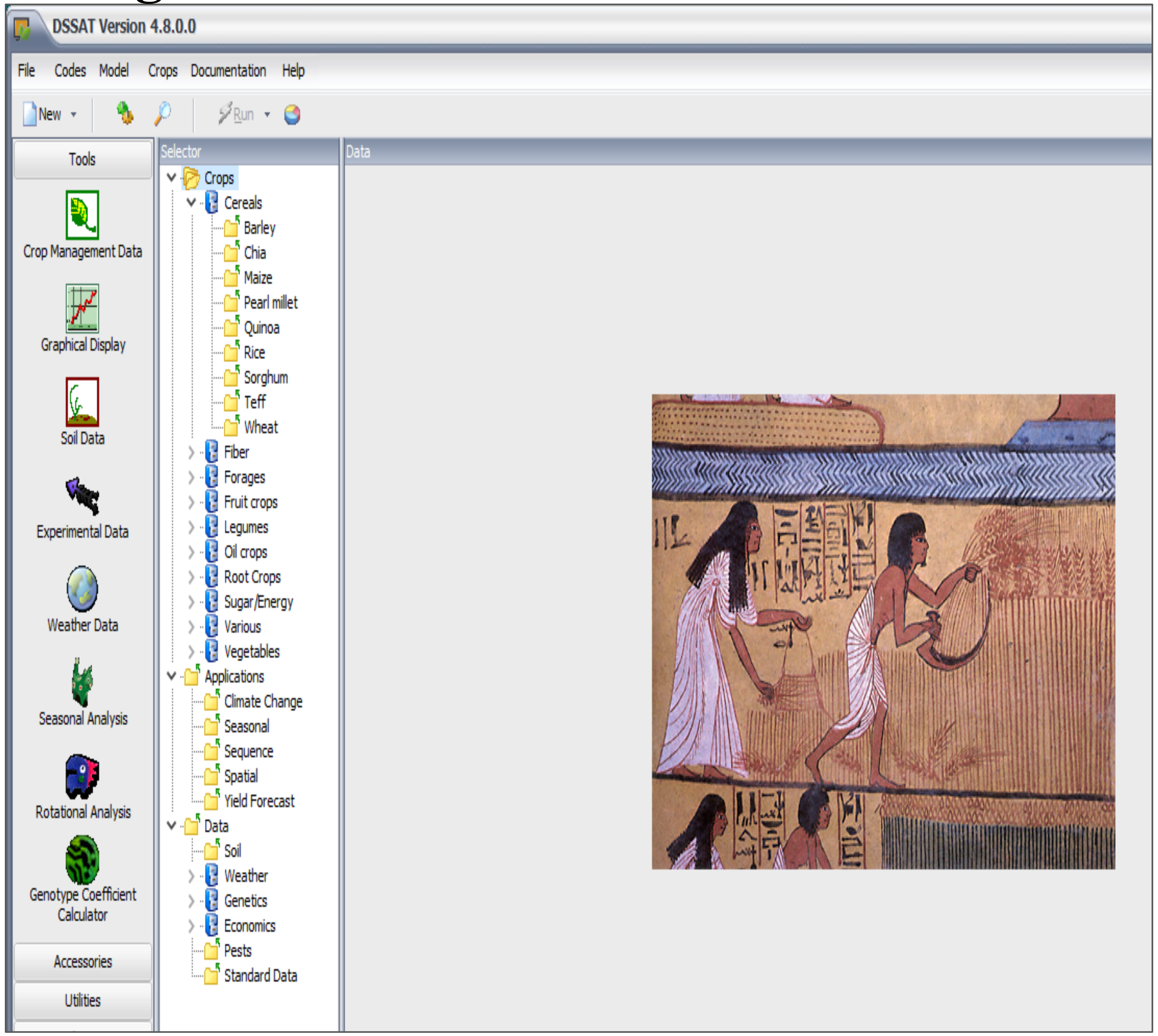
GCMs	RCMs	Accessing portal	Modelers	Availability for RCP4.5	Availability for RCP8.5	Availability for baseline
CNRM-CM5	RCA4	ESGF	G. Nikulin	Available	Available	Available
GFDL-ESM2M	RCA4	ESGF	G. Nikulin	Available	Available	Available
ICHEC-EC-EARTH	RCA4	ESGF	G. Nikulin	Available	Available	Available
MIROC-MIROC5	RCA4	ESGF	G. Nikulin	Available	Available	Available
MPI-ESM-LR r1	RCA4	ESGF	G. Nikulin	Available	Available	Available
NORESM1-M	RCA4	ESGF	G. Nikulin	Available	Available	Available

Method….

The Decision Support System for Agrotechnology Transfer (DSSAT version 4.75)

- DSSAT crop model was employed in calibration, evaluation and exploring the potential crop management options from planting time, fertilizer rate, tillage depth and irrigation.
- The advisory services will be evaluating whether they are costly or not using DSSAT crop model. *(Buccola and Subaei 1984; Fawcett and Thornton et al., 1989)*

Fig. 4 DSSAT Shell



Crop management strategies set up

Table 2 Agronomic practices for future climate condition

Crop management options	Debre Zeit site	Cheffe donsa site	Minjar Shenkora site
Tillage depth (cm)	5	5	5
	10	10	10
	15	15	15
Fertilizer rate (kg ha^{-1})	0	0	0
	23	23	23
	46	46	46
Planting time	15-Aug	20-Aug	01-Aug
	25-Aug	30-Aug	10-Aug
	05-Sep	10-Sep	15-Aug
Irrigation	Auto irrigation	Auto irrigation	Auto irrigation
	Without irrigation	Without irrigation	Without irrigation

Result

Calibration and evaluation

Table 3. Comparison of simulated and observed of physiology and yield components of chickpea

Model activities	Variable Name	Observed	Simulated	R^2 (%)	d-stat (%)	RMSE
Calibration	Anthesis day	52	53	0.70	0.71	3.76
	Canopy height (m)	0.39	0.56	0.71	0.41	0.18
	Mat Yield (kg/ha)	2033	2330	0.88	0.59	440.7
	Maturity day	116	117	0.76	0.73	5.99
Evaluation	Anthesis day	49	51	0.73	0.61	3.16
	Canopy height (m)	0.40	0.52	0.75	0.51	0.28
	Mat Yield (kg/ha)	2213	2210	0.84	0.50	520.7
	Maturity day	111	113	0.76	0.71	4.99

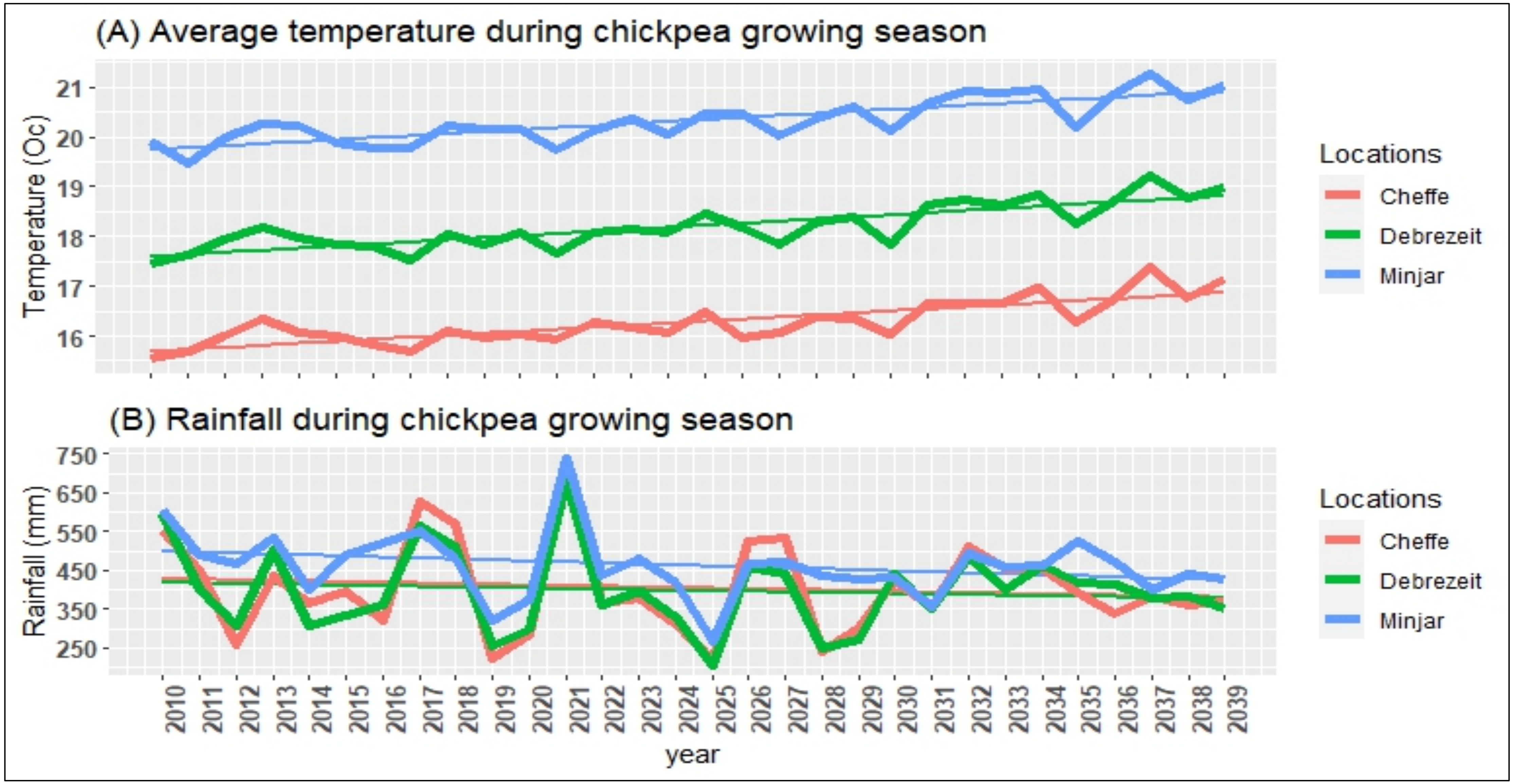
Table 4. Genetic coefficients of chickpea crop (Ejere variety)

CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR	THRSH	SDPRO	SDLIP
9	-0.143	35	10	11	31	68	1	200	10	0.8	0.182	25	1.2	18	85	0.216	0.048

Results….

Trends of future climate

Fig. 5. Average temperature (A) and rainfall (B) for 2010 to 2039

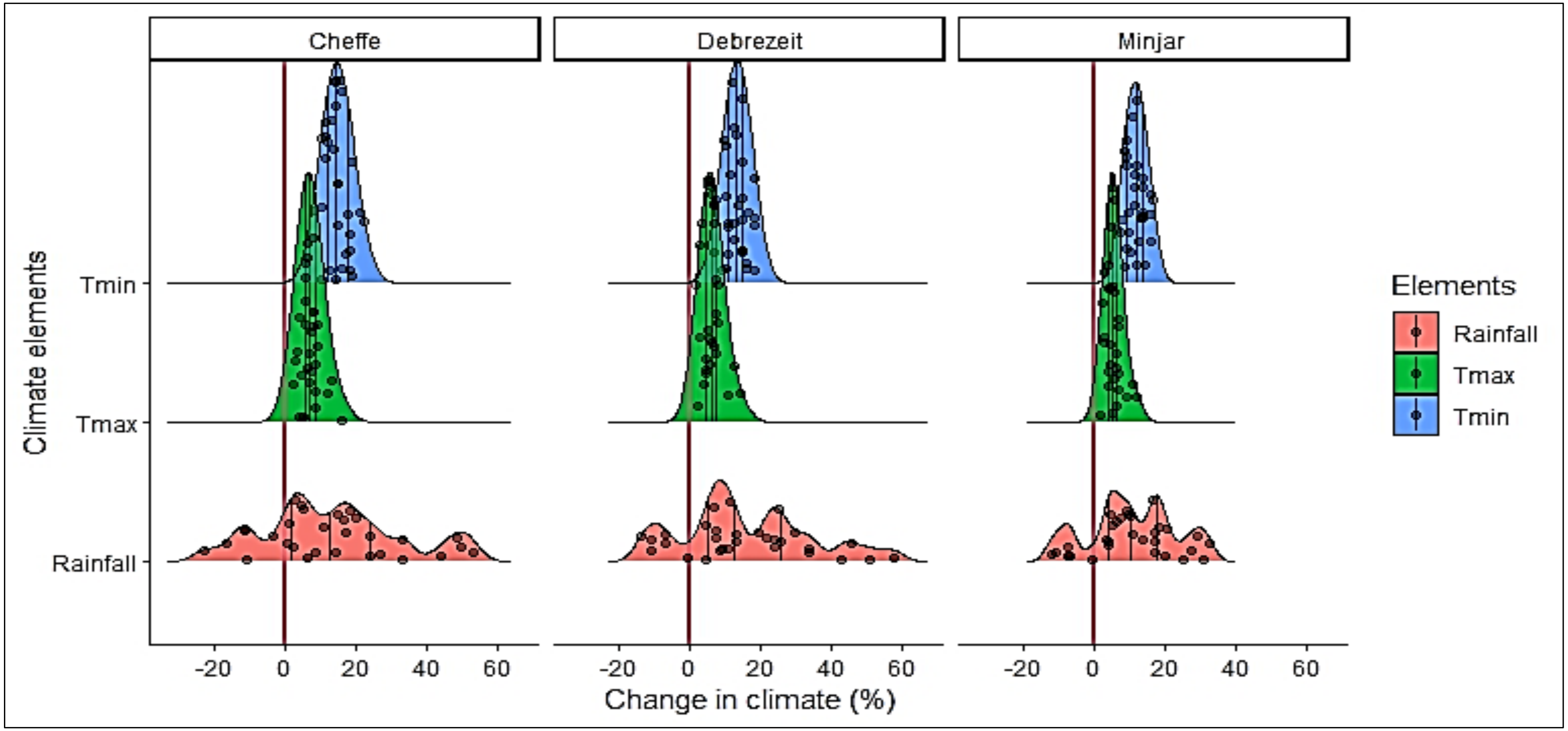


- ➢ The average daily air temperature (Fig. 5A) showed an increasing trend,
- ➢ while the total rainfall (Fig. 5B) showed decreasing trend across each year.

Results….

Climate change in the study areas

Fig. 6 . Climate change during the main rainy season at the end of 2040s

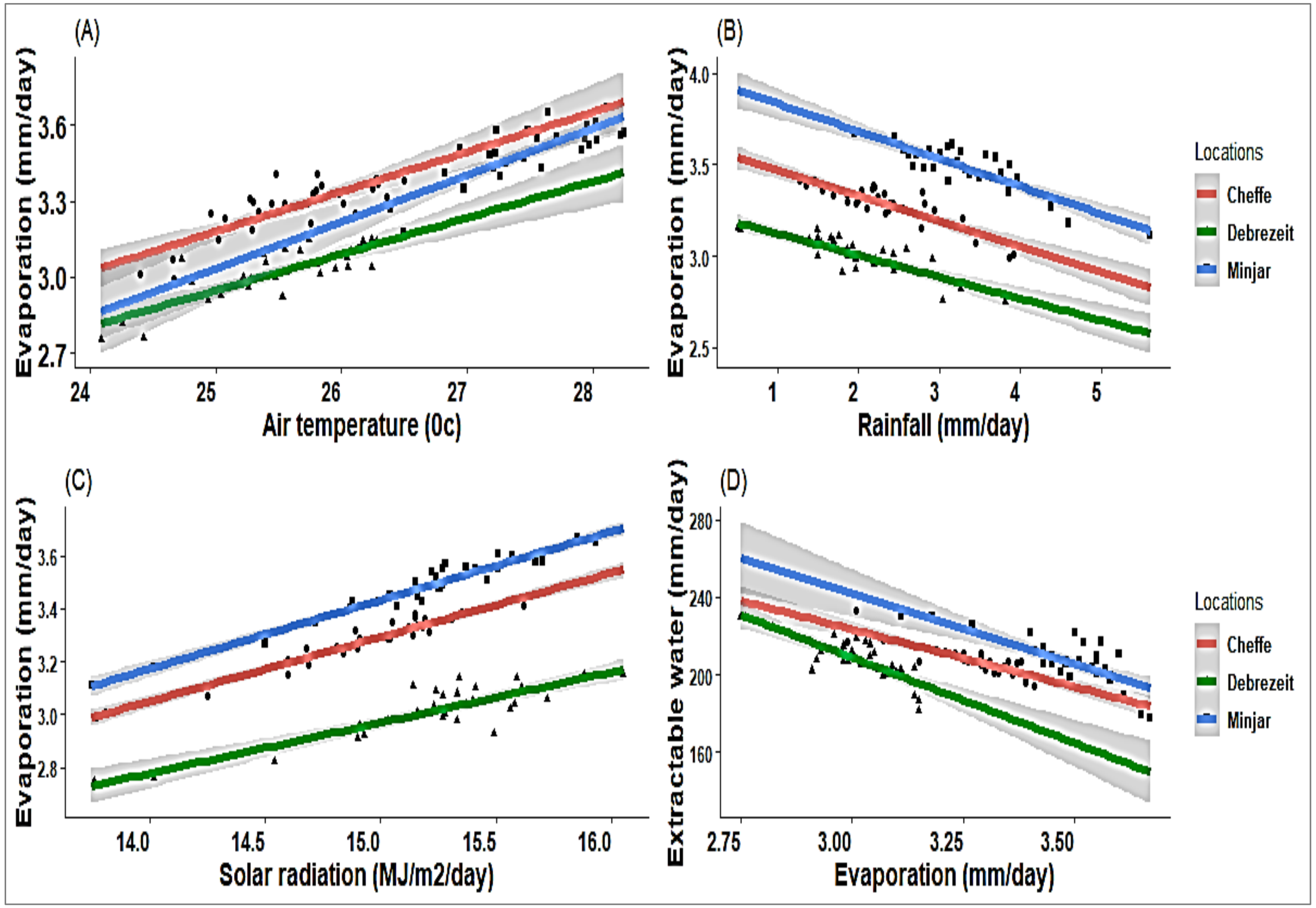


- ➢ The future rainfall will be most likely highly variable (-21 to 58%) (Fig. 6)
- ➢ The maximum and minimum temperature showed strong positive change (0 to 20%) (Fig. 6)

Results….

Climate effects

Fig. 7. Effects of future climate on evapotranspiration

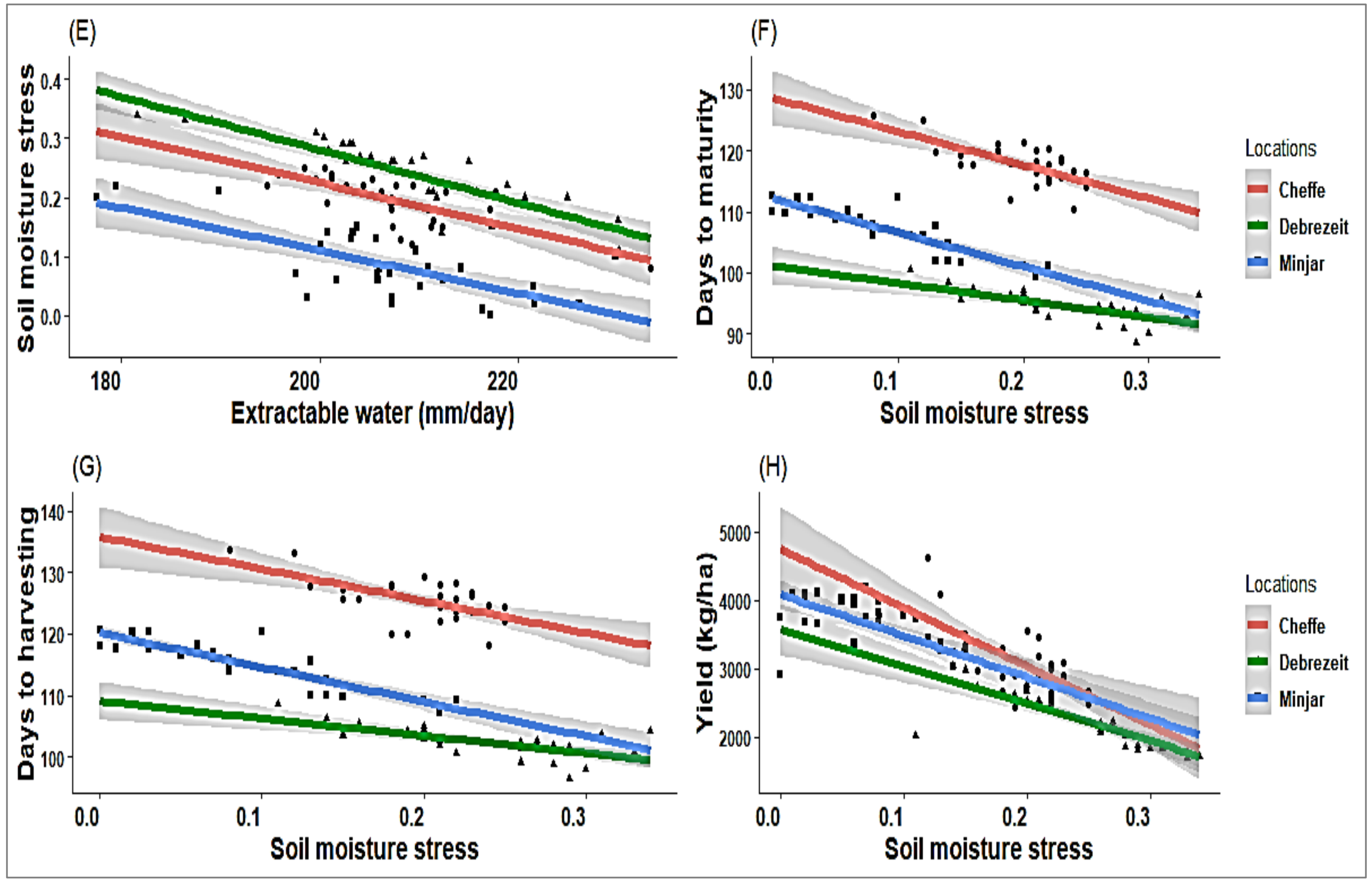


- Evapotranspiration (ETo) is increased in response to
  - Increased air temperature (Fig. 7A).
  - Decline of rainfall (Fig. 7B).
  - Increasing of solar radiation (Fig. 7C).
- The increasing of evapotranspiration also leads to the depletion of extractable soil water (Fig. 7D).

Results….

Soil water stress effects

Fig. 8. Effects of water stress to chickpea yield and phenology



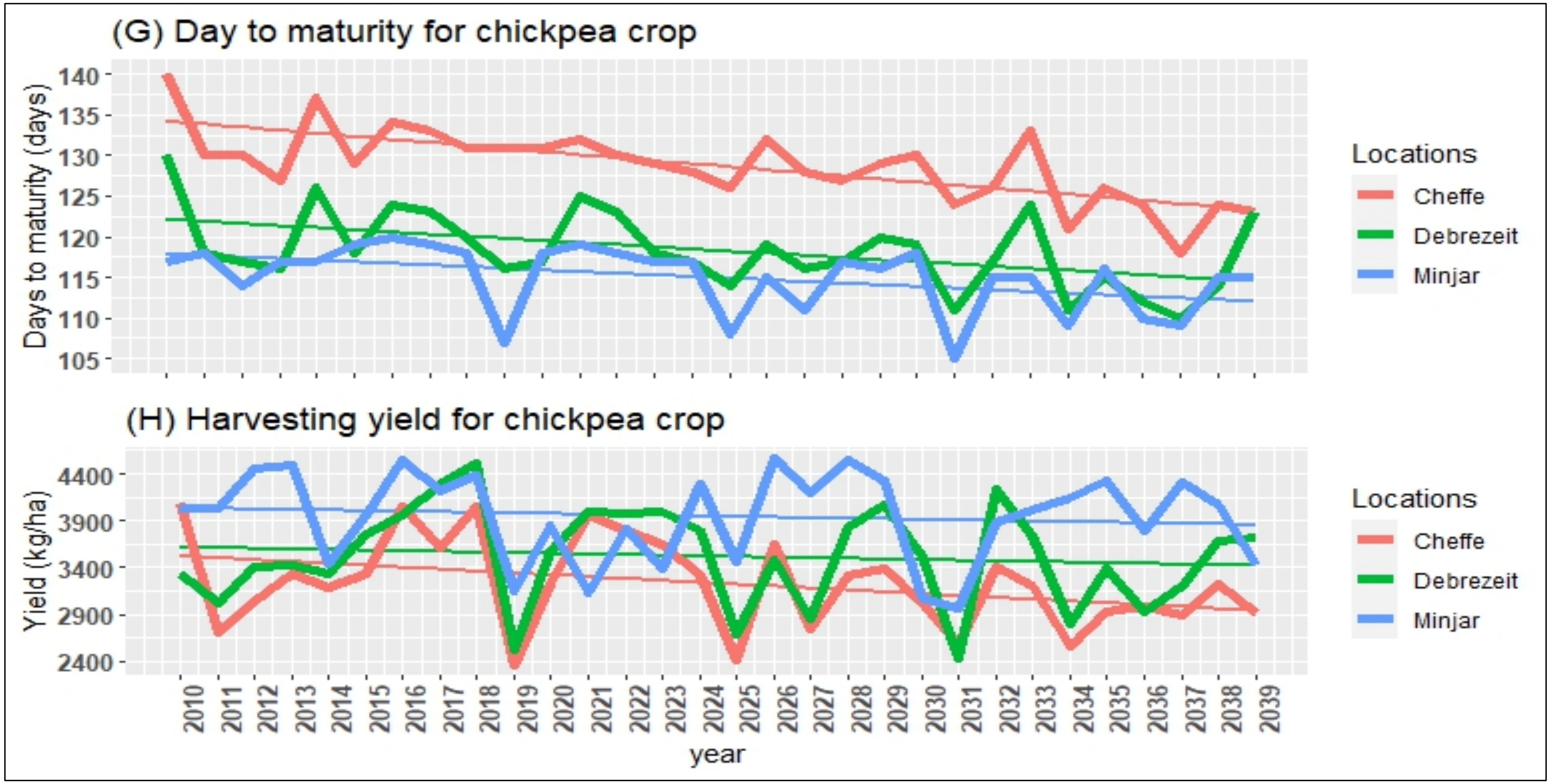
- The continues depletion of extractable soil water led to increase the soil water stress (Fig. 8E).
- The increasing of soil water stress cause for
  - Declining of days to flowering (Fig. 8F),
  - Declining of days to maturity (Fig. 8G) and
  - Declining of chickpea yield (Fig. 8H).

- The variation of precipitation and air temperature lead to the variation of soil moisture, and finally leads to reduction of chickpea phenology and yield in the future

Results….

Trends of chickpea phenology and yield

Fig. 9. Days to maturity (G) and chickpea yield (H) for 2010 to 2039

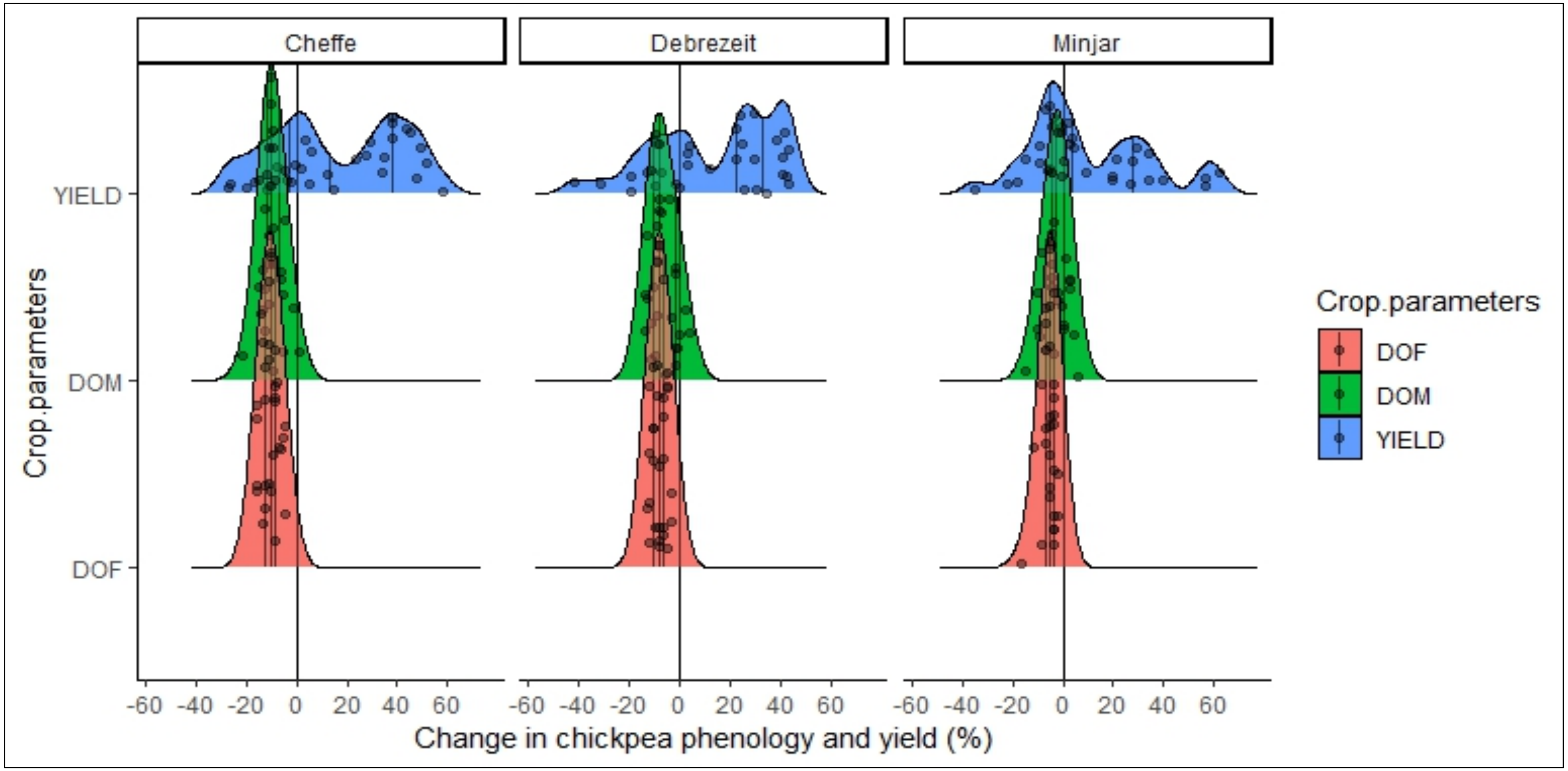


- The days to maturity (Fig. 9G) and the grain yield of chickpea showed in decreasing trend over the three locations (Fig. 9H).

Results….

Future chickpea yield and phenology

Fig. 10 . Chickpea phenology and yield at the end of 2040s

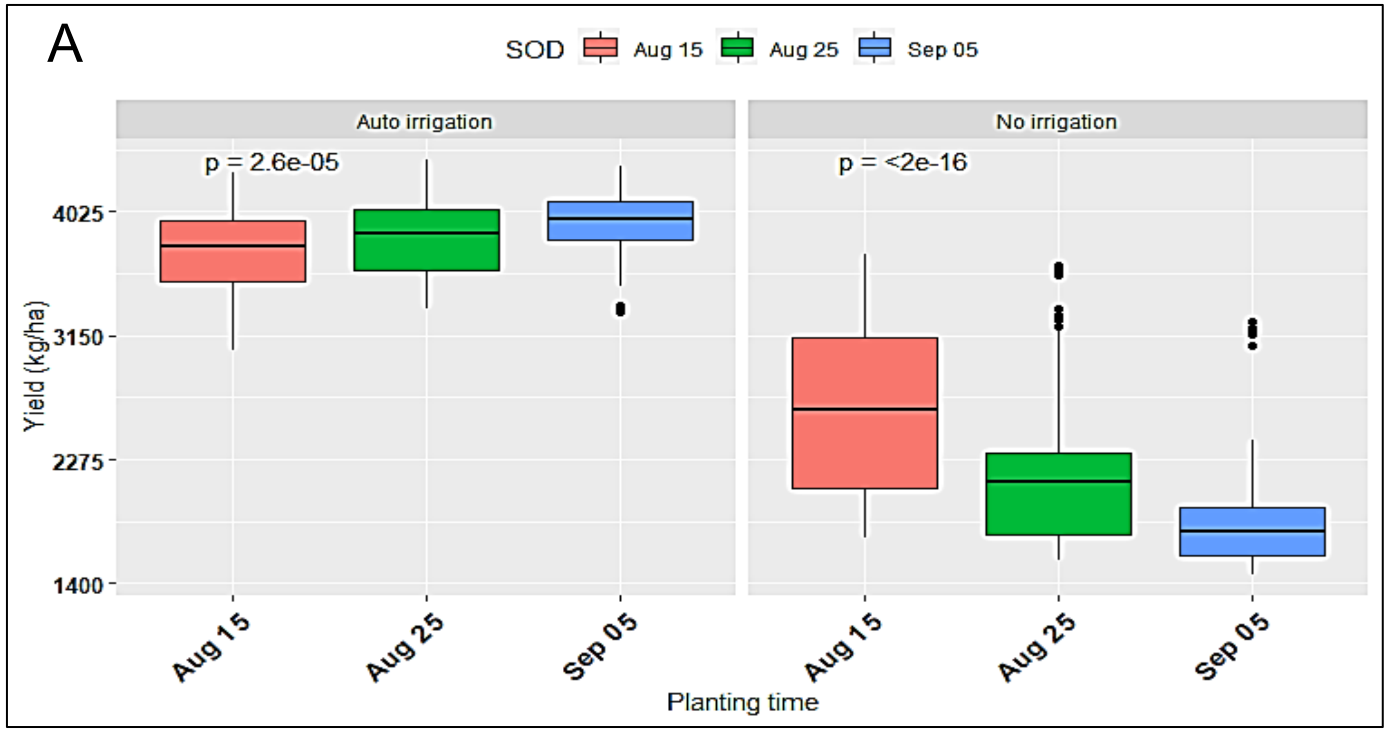


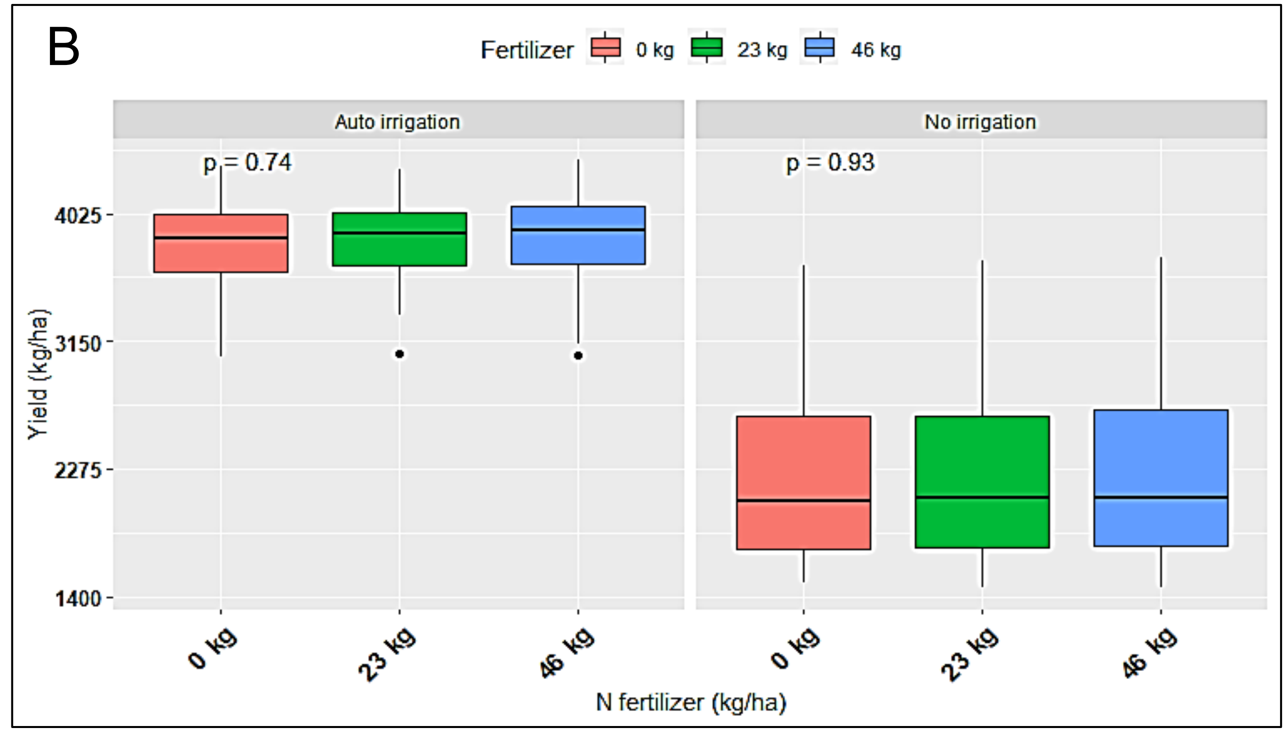
- Future chickpea yield showed negative and positive change (most likely highly variable, -40 to 60%) (Fig. 10).
- The chickpea crop phenology showed strong negative change (shortening of growing season, -22 to 0%) (Fig. 10).

Results….

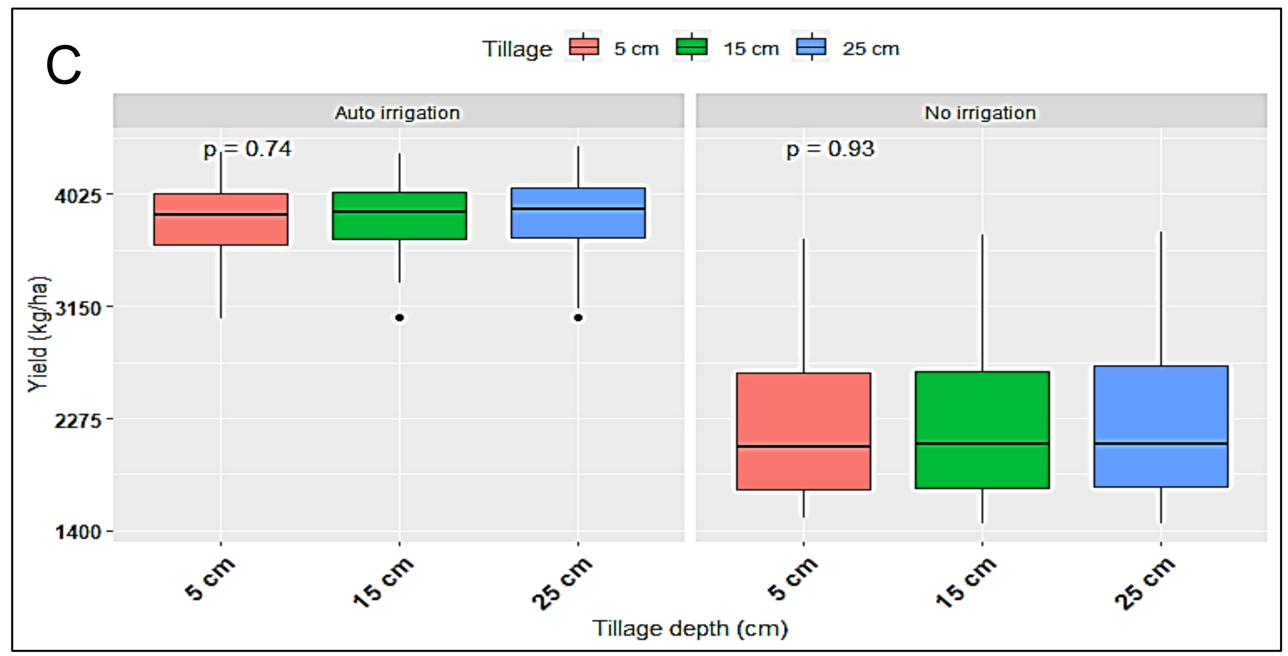
Crop management strategies

Fig. 11. Effects of sowing date, fertilizer rate and tillage





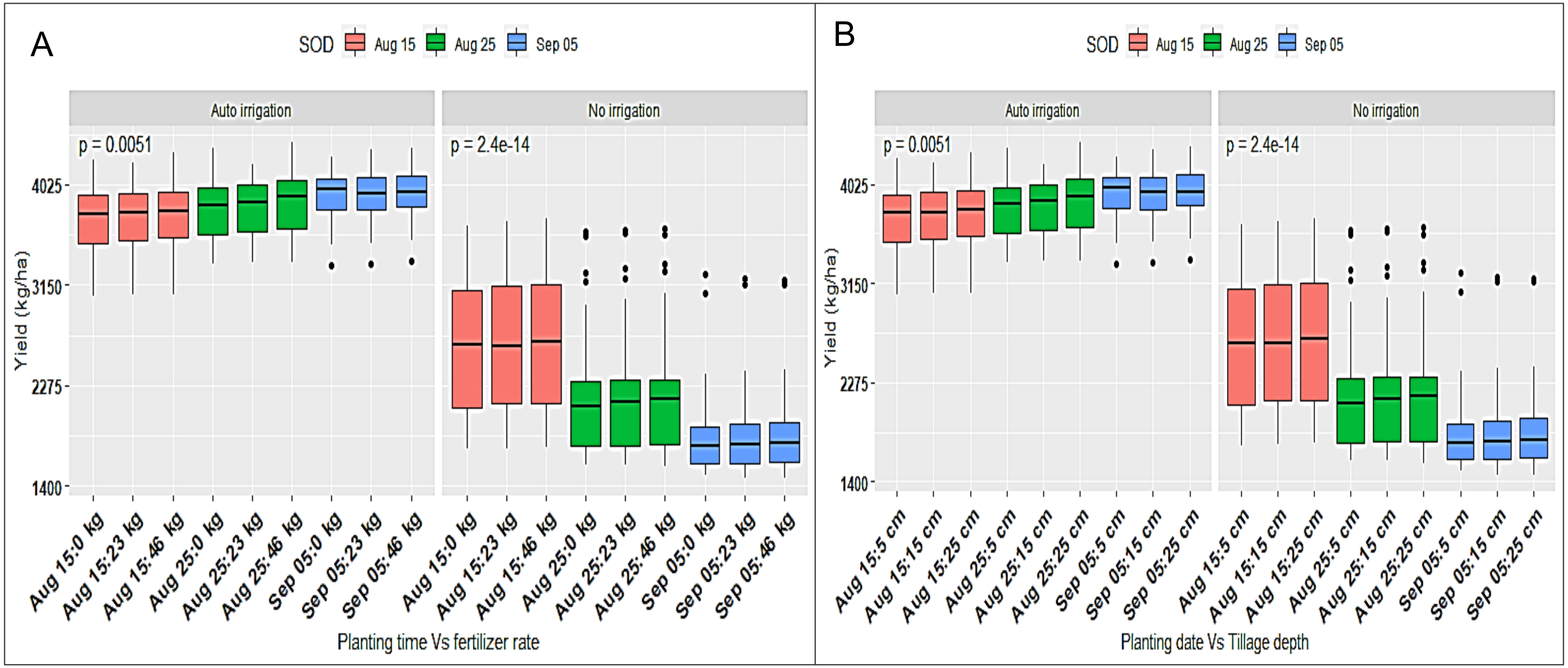
- Planting time had good response to yield for none irrigation system, but not much response for irrigation system (Fig. 11A)
- Adding nitrogen had no much response to yield in both with and without irrigation (Fig. 11B)
- Using different tillage depth had no response for chickpea yield in both with and without irrigation (Fig. 11C)



Results….

Crop management strategies…..

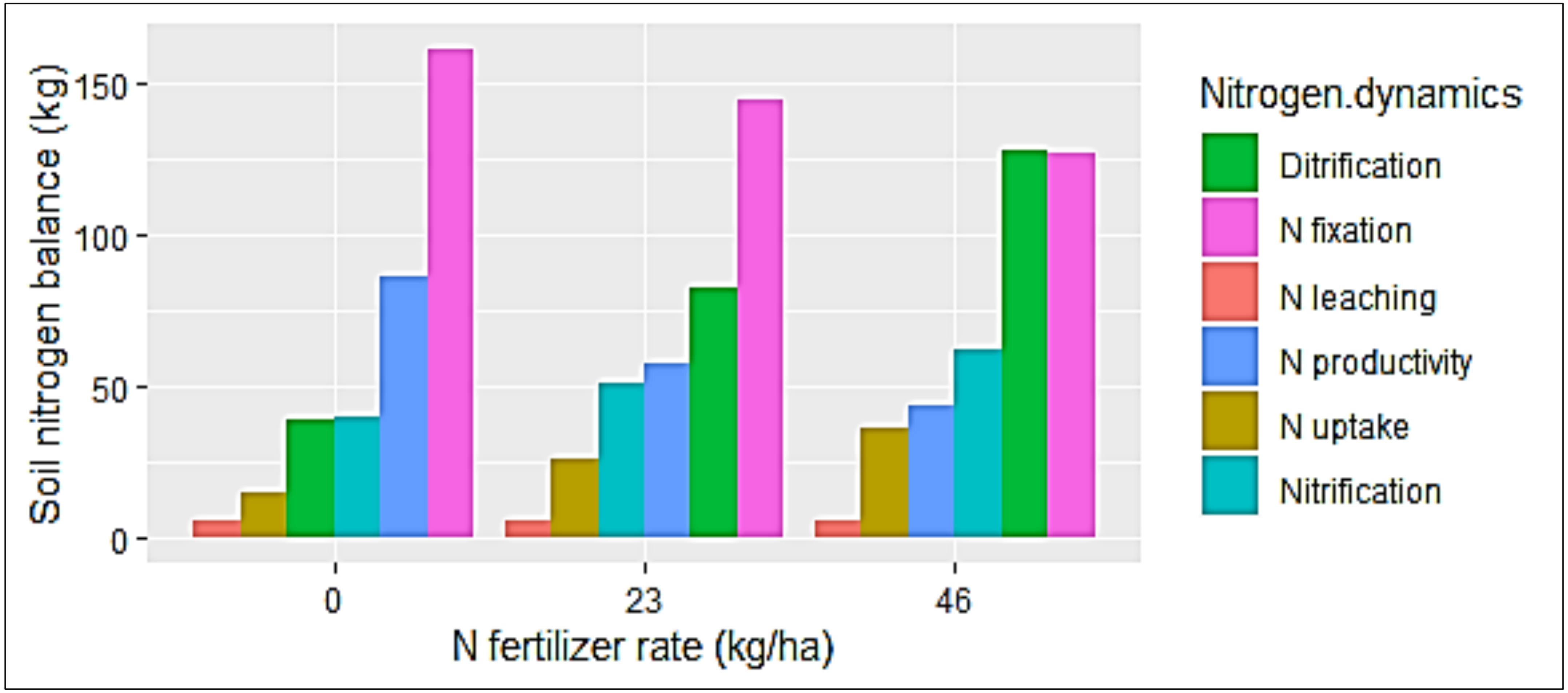
Fig. 12. Interaction effects of sowing date, fertilizer rate and tillage



- The sowing date coupled with fertilizer rate (Fig. 12A) or sowing date coupled with tillage practices (Fig. 12B) did not change the none response of both the fertilizer rate and tillage application for chickpea production

Results…. Effect of N fertilizer application for chickpea crop

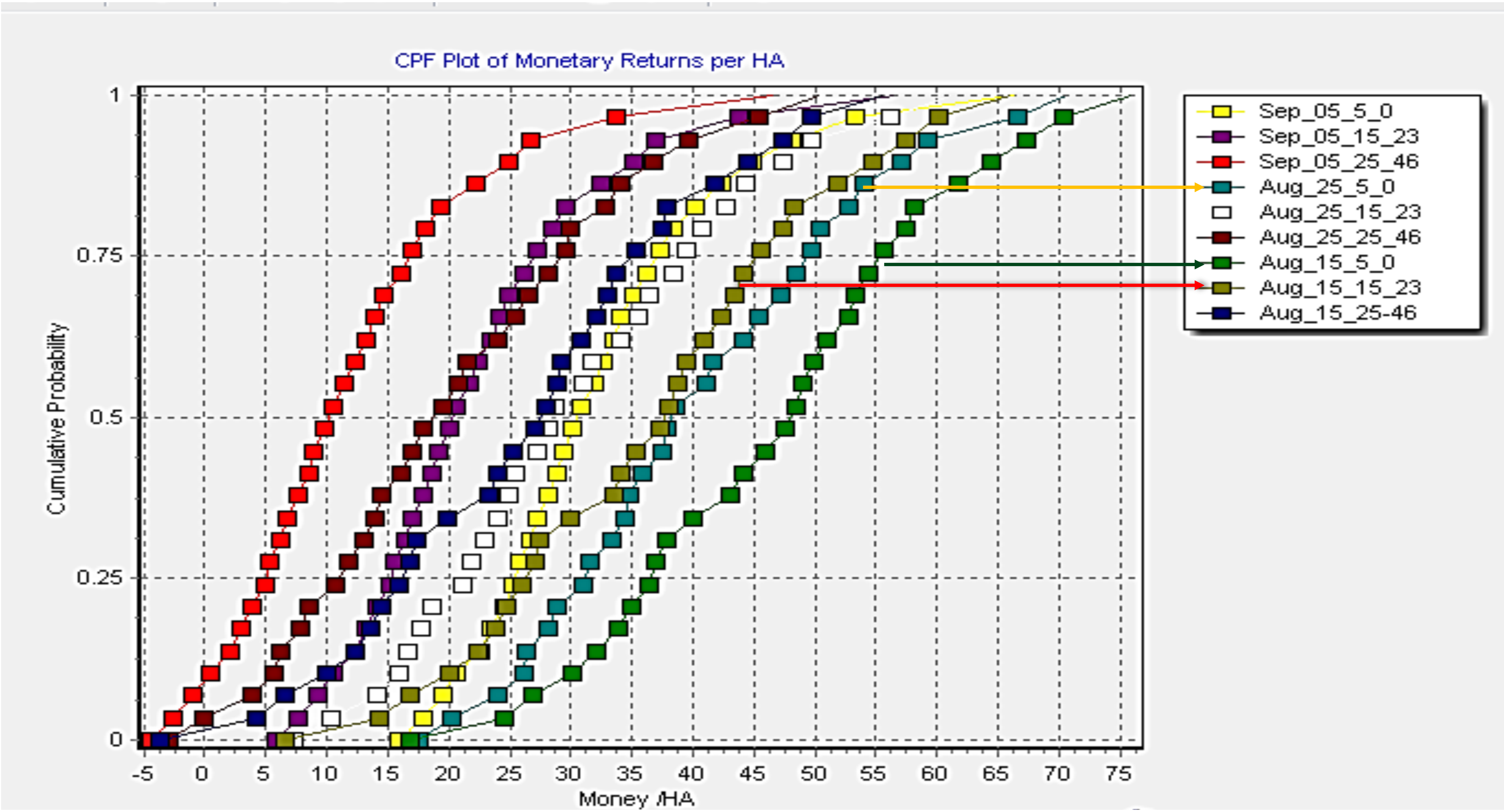
Fig. 13. Soil N balance for chickpea crop



- Adding more nitrogen lead to
  - Decrease N productivity (Fig 13)
  - Decrease N fixation
  - Increase denitrification
  - Decrease Nitrogen use efficiency

Results….

Economic analyses at debrezeit site



Conclusion and recommendation

- Sowing date at different time interval shows great response to chickpea yield.
- Early planting time with no irrigation system had a good response to chickpea yield
- Mid-August to early September is ideal planting time for chickpea in major chickpea growing areas of Ethiopia (Bejiga and Tullu, 1982)
- If planting is extended until the last week of September, it may have 100% yield lost (Bejiga and Tullu., 1982)
- Early planting enhances early seedling establishment whereas late planting may expose dry period (Araya et al., 2010b).
- Early planting of chickpea also has an advantage for climate change impacts (Morton, 2007)
- Lijalem et al. (2020) suggested that sowing for chickpea crop is should make balance avoiding severe waterlogging from early planting and terminal drought from late planting.

Conclusion and recommendation……

- Applying different nitrogen fertilizer rate and tillage practice had no much response for chickpea yield optimization under changing climate.
- Chickpea is non-responsive to nitrogen application (Eshete and Beniwal, 1987).
- Chickpea does not need any kind of nutrient application (Furtherly, Chala et al. (2018) and Wolde-meskel et al., 2018).
- Chickpea can fix 60–80%of its N requirements under favorable conditions (Wolde-meskel et al., 2018)
- However, Lijalem et al. (2020) disagreed with none applicable of nutrient for chickpea crop
- Asrat et al. (2016) reported that N application improved agronomic performances of chickpea on Vertisols at Debre Zeit site.
- Erkossa and Teklewold (2009) also more emphasized the benefits of fertilizer application on chickpea

AICCRA project, "Accelerating the Impacts of CEAJR Climate Research for Africa"

1. Introductory Training Course: Community of Practice Decision Support Modeling Tools for Ethiopia (DSMT-E)
2. DSSAT International Advanced Training Program DSSAT 2022

Thank you!