POTSDAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH

Supplementary Material – Climate Risk Analysis for Identifying and Weighing Adaptation Strategies in Ethiopia

Prepared by the Potsdam Institute for Climate Impact Research (PIK) for the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ)

Chapter 1 – Changing climate condition

The indicators analysed in this study are: the annual average mean air temperature, the annual average very hot days (maximum temperature above 35°C), the very hot nights or tropical nights per year (minimum temperature above 25°C), the annual average precipitation, the number of days with heavy precipitation (exceeding the 95th percentile calculated from EWEMBI for 2007) and very heavy precipitation per year (exceeding the 99th percentile of EWEMBI in 2007) and the precipitation and temperature in different seasons along the year considered relevant for agriculture.

Table 1: Historical temperature and projected temperature changes for Ethiopia and the four agricultural regions.

Region	Scenario	Year	Temperature [°C]	Temperature diff. [°C] with ref=2007	Temperature diff. [°C] with ref=1870
Ethiopia	Hist.	1870	22.2		
Ethiopia	Hist.+RCP2.6	2007	23.2		1
Ethiopia	Hist.+RCP8.5	2007	23.2		1
Ethiopia	RCP2.6	2030	23.8	0.6	1.6
Ethiopia	RCP2.6	2050	24.1	0.9	1.9
Ethiopia	RCP2.6	2090	24	0.8	1.8
Ethiopia	RCP8.5	2030	24	0.8	1.8
Ethiopia	RCP8.5	2050	24.8	1.6	2.6
Ethiopia	RCP8.5	2090	26.8	3.6	4.6
Amhara	Hist.	1870	19		
Amhara	Hist.+RCP2.6	2007	20.1		1.1
Amhara	Hist.+RCP8.5	2007	20		1
Amhara	RCP2.6	2030	20.7	0.6	1.7
Amhara	RCP2.6	2050	20.9	0.8	1.9
Amhara	RCP2.6	2090	20.9	0.8	1.9
Amhara	RCP8.5	2030	20.8	0.8	1.8
Amhara	RCP8.5	2050	21.8	1.8	2.8
Amhara	RCP8.5	2090	23.9	3.9	4.9
Oromia	Hist.	1870	19.5		
Oromia	Hist.+RCP2.6	2007	20.4		0.9
Oromia	Hist.+RCP8.5	2007	20.3		0.8
Oromia	RCP2.6	2030	21	0.6	1.5
Oromia	RCP2.6	2050	21.3	0.9	1.8
Oromia	RCP2.6	2090	21.2	0.8	1.7
Oromia	RCP8.5	2030	21.2	0.9	1.7
Oromia	RCP8.5	2050	22	1.7	2.5
Oromia	RCP8.5	2090	23.9	3.6	4.4
SNNP	Hist.	1870	20.4		
SNNP	Hist.+RCP2.6	2007	21.3		0.9
SNNP	Hist.+RCP8.5	2007	21.2		0.8
SNNP	RCP2.6	2030	21.9	0.6	1.5
SNNP	RCP2.6	2050	22.2	0.9	1.8
SNNP	RCP2.6	2090	22.1	0.8	1.7
SNNP	RCP8.5	2030	22.1	0.9	1.7
SNNP	RCP8.5	2050	23	1.8	2.6
SNNP	RCP8.5	2090	24.8	3.6	4.4

Tigray	Hist.	1870	22.1		
Tigray	Hist.+RCP2.6	2007	23.3		1.2
Tigray	Hist.+RCP8.5	2007	23.1		1
Tigray	RCP2.6	2030	23.8	0.5	1.7
Tigray	RCP2.6	2050	24	0.7	1.9
Tigray	RCP2.6	2090	24	0.7	1.9
Tigray	RCP8.5	2030	24	0.9	1.9
Tigray	RCP8.5	2050	24.9	1.8	2.8
Tigray	RCP8.5	2090	27	3.9	4.9

Table 2: Historical precipitation and projected precipitation for Ethiopia and the four agricultural regions.

Region	Scenario	Year	Precipitation [mm.]	Precipitation diff. [mm.] with ref=2007	Precipitation diff. [mm.] with ref=1870
Ethiopia	Hist.	1870	864		
Ethiopia	Hist.+RCP2.6	2007	868		4
Ethiopia	Hist.+RCP8.5	2007	909		45
Ethiopia	RCP2.6	2030	918	50	54
Ethiopia	RCP2.6	2050	888	20	24
Ethiopia	RCP2.6	2090	890	22	26
Ethiopia	RCP8.5	2030	913	4	49
Ethiopia	RCP8.5	2050	911	2	47
Ethiopia	RCP8.5	2090	1056	147	192
Amhara	Hist.	1870	1128		
Amhara	Hist.+RCP2.6	2007	1137		9
Amhara	Hist.+RCP8.5	2007	1141		13
Amhara	RCP2.6	2030	1146	9	18
Amhara	RCP2.6	2050	1166	29	38
Amhara	RCP2.6	2090	1152	15	24
Amhara	RCP8.5	2030	1178	37	50
Amhara	RCP8.5	2050	1169	28	41
Amhara	RCP8.5	2090	1283	142	155
Oromia	Hist.	1870	1092		
Oromia	Hist.+RCP2.6	2007	1092		0
Oromia	Hist.+RCP8.5	2007	1159		67
Oromia	RCP2.6	2030	1166	74	74
Oromia	RCP2.6	2050	1115	23	23
Oromia	RCP2.6	2090	1117	25	25
Oromia	RCP8.5	2030	1132	-27	40
Oromia	RCP8.5	2050	1134	-25	42
Oromia	RCP8.5	2090	1309	150	217
SNNP	Hist.	1870	1205		
SNNP	Hist.+RCP2.6	2007	1196		-9
SNNP	Hist.+RCP8.5	2007	1286		81
SNNP	RCP2.6	2030	1278	82	73
SNNP	RCP2.6	2050	1202	6	-3
SNNP	RCP2.6	2090	1247	51	42
SNNP	RCP8.5	2030	1262	-24	57
SNNP	RCP8.5	2050	1236	-50	31

SNNP	RCP8.5	2090	1466	180	261
Tigray	Hist.	1870	847		
Tigray	Hist.+RCP2.6	2007	835		-12
Tigray	Hist.+RCP8.5	2007	855		8
Tigray	RCP2.6	2030	867	32	20
Tigray	RCP2.6	2050	876	41	29
Tigray	RCP2.6	2090	873	38	26
Tigray	RCP8.5	2030	897	42	50
Tigray	RCP8.5	2050	910	55	63
Tigray	RCP8.5	2090	993	138	146

Table 3: Very hot days in Ethiopia and the four agricultural regions.

Region	Scenario	Year	Very hot days [No.days]	Very hot days diff. [No.days] with ref=2007	Very hot days diff. [No.days] with ref=1870
Ethiopia	Hist.	1870	37		
Ethiopia	Hist.+RCP2.6	2007	59		22
Ethiopia	Hist.+RCP8.5	2007	55		18
Ethiopia	RCP2.6	2030	71	12	34
Ethiopia	RCP2.6	2050	75	16	38
Ethiopia	RCP2.6	2090	73	14	36
Ethiopia	RCP8.5	2030	75	20	38
Ethiopia	RCP8.5	2050	98	43	61
Ethiopia	RCP8.5	2090	149	94	112
Amhara	Hist.	1870	15		
Amhara	Hist.+RCP2.6	2007	21		6
Amhara	Hist.+RCP8.5	2007	20		5
Amhara	RCP2.6	2030	24	3	9
Amhara	RCP2.6	2050	26	5	11
Amhara	RCP2.6	2090	25	4	10
Amhara	RCP8.5	2030	26	6	11
Amhara	RCP8.5	2050	36	16	21
Amhara	RCP8.5	2090	67	47	52
Oromia	Hist.	1870	5		
Oromia	Hist.+RCP2.6	2007	10		5
Oromia	Hist.+RCP8.5	2007	9		4
Oromia	RCP2.6	2030	14	4	9
Oromia	RCP2.6	2050	15	5	10
Oromia	RCP2.6	2090	14	4	9
Oromia	RCP8.5	2030	16	7	11
Oromia	RCP8.5	2050	28	19	23
Oromia	RCP8.5	2090	66	57	61
SNNP	Hist.	1870	19		
SNNP	Hist.+RCP2.6	2007	33		14
SNNP	Hist.+RCP8.5	2007	32		13
SNNP	RCP2.6	2030	40	7	21
SNNP	RCP2.6	2050	43	10	24
SNNP	RCP2.6	2090	40	7	21
SNNP	RCP8.5	2030	44	12	25

SNNP	RCP8.5	2050	60	28	41
SNNP	RCP8.5	2090	96	64	77
Tigray	Hist.	1870	35		
Tigray	Hist.+RCP2.6	2007	52		17
Tigray	Hist.+RCP8.5	2007	49		14
Tigray	RCP2.6	2030	62	10	27
Tigray	RCP2.6	2050	66	14	31
Tigray	RCP2.6	2090	65	13	30
Tigray	RCP8.5	2030	65	16	30
Tigray	RCP8.5	2050	87	38	52
Tigray	RCP8.5	2090	149	100	114

Table 4: Tropical nights in Ethiopia and the four agricultural regions.

Region	Scenario	Year	Tropical nights [No.days]	Tropical nights diff. [No.days] with ref=2007	Tropical nights diff. [No.days] with ref=1870
Ethiopia	Hist.	1870	6		
Ethiopia	Hist.+RCP2.6	2007	11		5
Ethiopia	Hist.+RCP8.5	2007	11		5
Ethiopia	RCP2.6	2030	17	6	11
Ethiopia	RCP2.6	2050	19	8	13
Ethiopia	RCP2.6	2090	18	7	12
Ethiopia	RCP8.5	2030	18	7	12
Ethiopia	RCP8.5	2050	29	18	23
Ethiopia	RCP8.5	2090	70	59	64
Amhara	Hist.	1870	0		
Amhara	Hist.+RCP2.6	2007	2		2
Amhara	Hist.+RCP8.5	2007	1		1
Amhara	RCP2.6	2030	3	1	3
Amhara	RCP2.6	2050	3	1	3
Amhara	RCP2.6	2090	3	1	3
Amhara	RCP8.5	2030	3	2	3
Amhara	RCP8.5	2050	6	5	6
Amhara	RCP8.5	2090	18	17	18
Oromia	Hist.	1870	0		
Oromia	Hist.+RCP2.6	2007	0		0
Oromia	Hist.+RCP8.5	2007	0		0
Oromia	RCP2.6	2030	1	1	1
Oromia	RCP2.6	2050	1	1	1
Oromia	RCP2.6	2090	1	1	1
Oromia	RCP8.5	2030	1	1	1
Oromia	RCP8.5	2050	2	2	2
Oromia	RCP8.5	2090	10	10	10
SNNP	Hist.	1870	1		
SNNP	Hist.+RCP2.6	2007	1		0
SNNP	Hist.+RCP8.5	2007	1		0
SNNP	RCP2.6	2030	3	2	2
SNNP	RCP2.6	2050	3	2	2
SNNP	RCP2.6	2090	3	2	2

SNNP	RCP8.5	2030	3	2	2
SNNP	RCP8.5	2050	6	5	5
SNNP	RCP8.5	2090	18	17	17
Tigray	Hist.	1870	1		
Tigray	Hist.+RCP2.6	2007	4		3
Tigray	Hist.+RCP8.5	2007	4		3
Tigray	RCP2.6	2030	6	2	5
Tigray	RCP2.6	2050	7	3	6
Tigray	RCP2.6	2090	7	3	6
Tigray	RCP8.5	2030	7	3	6
Tigray	RCP8.5	2050	14	10	13
Tigray	RCP8.5	2090	45	41	44

Table 5: Heavy precipitation in Ethiopia and the four agricultural regions.

Region	**Scenario**	**Year**	**No. of days with heavy pr. [No.days]**	**Diff in no. of days with heavy pr. with ref=2007**	**Diff in no. of days with heavy pr. with ref=1870**
Ethiopia	Hist.	1870	7		
Ethiopia	Hist.+RCP2.6	2007	7		0
Ethiopia	Hist.+RCP8.5	2007	8		1
Ethiopia	RCP2.6	2030	9	2	2
Ethiopia	RCP2.6	2050	8	1	1
Ethiopia	RCP2.6	2090	8	1	1
Ethiopia	RCP8.5	2030	9	1	2
Ethiopia	RCP8.5	2050	9	1	2
Ethiopia	RCP8.5	2090	12	4	5
Amhara	Hist.	1870	7		
Amhara	Hist.+RCP2.6	2007	8		1
Amhara	Hist.+RCP8.5	2007	8		1
Amhara	RCP2.6	2030	8	0	1
Amhara	RCP2.6	2050	9	1	2
Amhara	RCP2.6	2090	9	1	2
Amhara	RCP8.5	2030	9	1	2
Amhara	RCP8.5	2050	10	2	3
Amhara	RCP8.5	2090	12	4	5
Oromia	Hist.	1870	9		
Oromia	Hist.+RCP2.6	2007	10		1
Oromia	Hist.+RCP8.5	2007	11		2
Oromia	RCP2.6	2030	12	2	3
Oromia	RCP2.6	2050	10	0	1
Oromia	RCP2.6	2090	11	1	2
Oromia	RCP8.5	2030	11	0	2
Oromia	RCP8.5	2050	12	1	3
Oromia	RCP8.5	2090	16	5	7
SNNP	Hist.	1870	11		
SNNP	Hist.+RCP2.6	2007	11		0
SNNP	Hist.+RCP8.5	2007	13		2
SNNP	RCP2.6	2030	13	2	2
SNNP	RCP2.6	2050	12	1	1

SNNP	RCP2.6	2090	12	1	1
SNNP	RCP8.5	2030	13	0	2
SNNP	RCP8.5	2050	13	0	2
SNNP	RCP8.5	2090	18	5	7
Tigray	Hist.	1870	6		
Tigray	Hist.+RCP2.6	2007	6		0
Tigray	Hist.+RCP8.5	2007	7		1
Tigray	RCP2.6	2030	7	1	1
Tigray	RCP2.6	2050	8	2	2
Tigray	RCP2.6	2090	8	2	2
Tigray	RCP8.5	2030	8	1	2
Tigray	RCP8.5	2050	9	2	3
Tigray	RCP8.5	2090	11	4	5

Table 6: Very heavy precipitation in Ethiopia and the four agricultural regions.

Region	Scenario	Year	No. of days with very heavy pr. [No.days]	Diff in no. of days with very heavy pr. with ref=2007	Diff in no. of days with very heavy pr. with ref=1870
Ethiopia	Hist.	1870	1		
Ethiopia	Hist.+RCP2.6	2007	1		0
Ethiopia	Hist.+RCP8.5	2007	1		0
Ethiopia	RCP2.6	2030	2	1	1
Ethiopia	RCP2.6	2050	2	1	1
Ethiopia	RCP2.6	2090	2	1	1
Ethiopia	RCP8.5	2030	2	1	1
Ethiopia	RCP8.5	2050	2	1	1
Ethiopia	RCP8.5	2090	3	2	2
Amhara	Hist.	1870	1		
Amhara	Hist.+RCP2.6	2007	1		0
Amhara	Hist.+RCP8.5	2007	1		0
Amhara	RCP2.6	2030	1	0	0
Amhara	RCP2.6	2050	2	1	1
Amhara	RCP2.6	2090	1	0	0
Amhara	RCP8.5	2030	1	0	0
Amhara	RCP8.5	2050	2	1	1
Amhara	RCP8.5	2090	3	2	2
Oromia	Hist.	1870	1		
Oromia	Hist.+RCP2.6	2007	2		1
Oromia	Hist.+RCP8.5	2007	2		1
Oromia	RCP2.6	2030	2	0	1
Oromia	RCP2.6	2050	2	0	1
Oromia	RCP2.6	2090	2	0	1
Oromia	RCP8.5	2030	2	0	1
Oromia	RCP8.5	2050	3	1	2
Oromia	RCP8.5	2090	5	3	4
SNNP	Hist.	1870	2		
SNNP	Hist.+RCP2.6	2007	2		0
SNNP	Hist.+RCP8.5	2007	2		0
SNNP	RCP2.6	2030	3	1	1

SNNP	RCP2.6	2050	2	0	0
SNNP	RCP2.6	2090	2	0	0
SNNP	RCP8.5	2030	3	1	1
SNNP	RCP8.5	2050	3	1	1
SNNP	RCP8.5	2090	4	2	2
Tigray	Hist.	1870	1		
Tigray	Hist.+RCP2.6	2007	1		0
Tigray	Hist.+RCP8.5	2007	1		0
Tigray	RCP2.6	2030	1	0	0
Tigray	RCP2.6	2050	1	0	0
Tigray	RCP2.6	2090	2	1	1
Tigray	RCP8.5	2030	2	1	1
Tigray	RCP8.5	2050	2	1	1
Tigray	RCP8.5	2090	3	2	2

Table 7: Anomalies in annual precipitation over Ethiopia, averaged for 20 years (running average) over 2017-2099

Scen/Model	GFDL-ESM2M	HadGEM2-ES	MIROC5	Ensemble mean
RCP2.6	812	907	883	845
RCP8.5	905	911	910	871

Precipitation (in mm.) over 2007 for the historical period for each model and the models mean.

Regional Summary

Region	RCP2.6	RCP8.5
Amhara	• Temperature is projected to increase from 0.6°C in 2030 to 0.8°C by 2050 and 2090. • The number of very hot days and tropical nights per year are projected to moderately rise. • Precipitation is projected to increase by 3% (29 mm.) by 2050. • The number of precipitation extreme events will increase.	• Temperature is projected to increase from 0.8°C in 2030, 1.8°C in 2050 to 3.9°C by 2090. • The very hot days per year are projected to rise from 6 in 2030 until 47 by 2090, tropical nights will also increase, but to a lesser extent. • Precipitation is projected to increase by 2% (28 mm.) in 2050 and 12% (142 mm.) by 2090. • The frequency of heavy precipitation is projected to increase from 14 days per decade in 2030 to 44 days by 2090, with very heavy precipitation events also increasing.
Oromia	• Temperature is projected to increase from 0.6°C in 2030 to 0.9°C by 2050. • Tropical nights are no concern in Oromia under RCP2.6, with very hot days only showing moderate increase by 2030 and 2050 (4 days and 5 days per year, respectively).	• Temperature is projected to increase from 0.9°C in 2030 to 3.6°C by 2090. • The very hot days per year are projected to rise from 7 in 2030 until 57 by 2090, with the frequency of tropical nights also rising, but with a lower magnitude.

	• Precipitation is projected to increase by 7% (74 mm.) by 2030. • The frequency of precipitation extreme events will increase.	• Precipitation is projected to decrease by 2% (27 mm) in 2030 and to increase by 13% (150 mm) by 2090. • Heavy and very heavy precipitation events are projected to occur much more often by the end of century, with 48 and 23 days per decade by 2090, respectively.
SNNP	• Temperature is projected to increase from 0.6°C in 2030 to 0.9°C by 2050. • The very hot days per year are projected to rise from 7 in 2030 and 2050 until 10 by 2090. • Tropical nights per year are projected to rise by 2 in every period. • Precipitation is projected to increase by 7% (82 mm.) by 2030. • The frequency of extreme precipitation events will rise.	• Temperature is projected to increase from 0.9°C in 2030 to 3.6°C by 2090. • The very hot days per year are projected to rise from 12 in 2030 to 64 by 2090. • The very hot nights per year are projected to rise from 2 by 2030 up to 17 by 2090. • Precipitation is projected to decrease by 4% (50 mm) by the year 2050 and to increase by 14% (180 mm) by 2090. • The frequency of heavy precipitation is projected to increase from 2 days per decade in 2030 to 51 days by 2090, with 24 days projected for very heavy precipitation.
Tigray	• Temperature is projected to increase from 0.5°C in 2030 to 0.7°C by 2050. • The very hot days per year are projected to rise from 10 in 2030 up to 14 by 2050. • The very hot nights per year are projected to rise from 2 to 3 by 2090. • Precipitation is projected to increase by 5% (41 mm) by 2050 and 2090. • The frequency of heavy precipitation is projected to increase from 7 to 14 days per decade by 2090.	• Temperature is projected to increase from 0.9°C in 2030 to 3.9°C by 2090. • The very hot days per year are projected to rise from 16 in 2030 up to 100 by 2090. • Tropical nights per year are projected to rise from 3 by 2030 until 41 by 2090. • Precipitation is projected to increase from 5% (42 mm) in 2030 until 16% (138 mm) by 2090. • The frequency of heavy precipitation is projected to increase from 11 days per decade in 2030 to 39 days by 2090.

Chapter 2 – Changing water availability for agricultural production

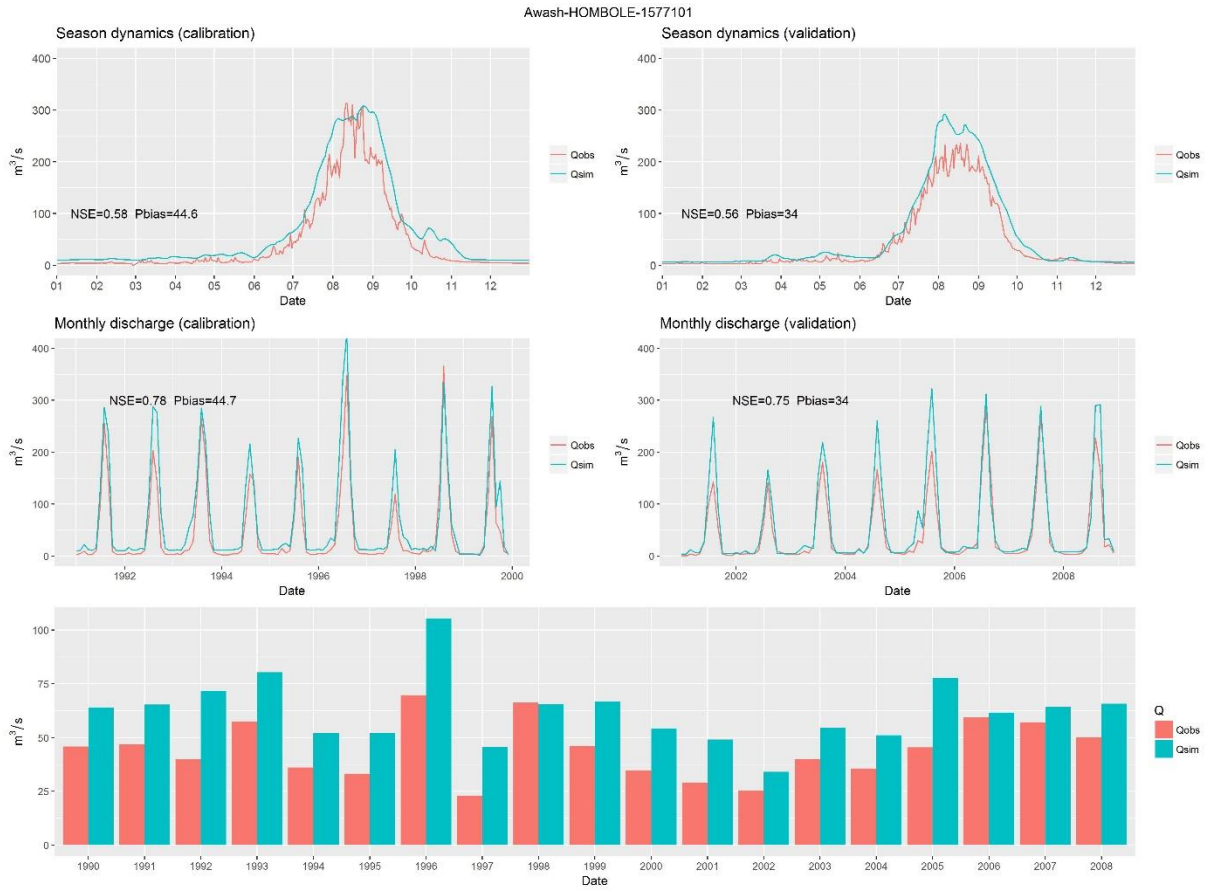

Figure 1 Calibration and validation results of the river discharge at the Hombole gauge (Awash basin)

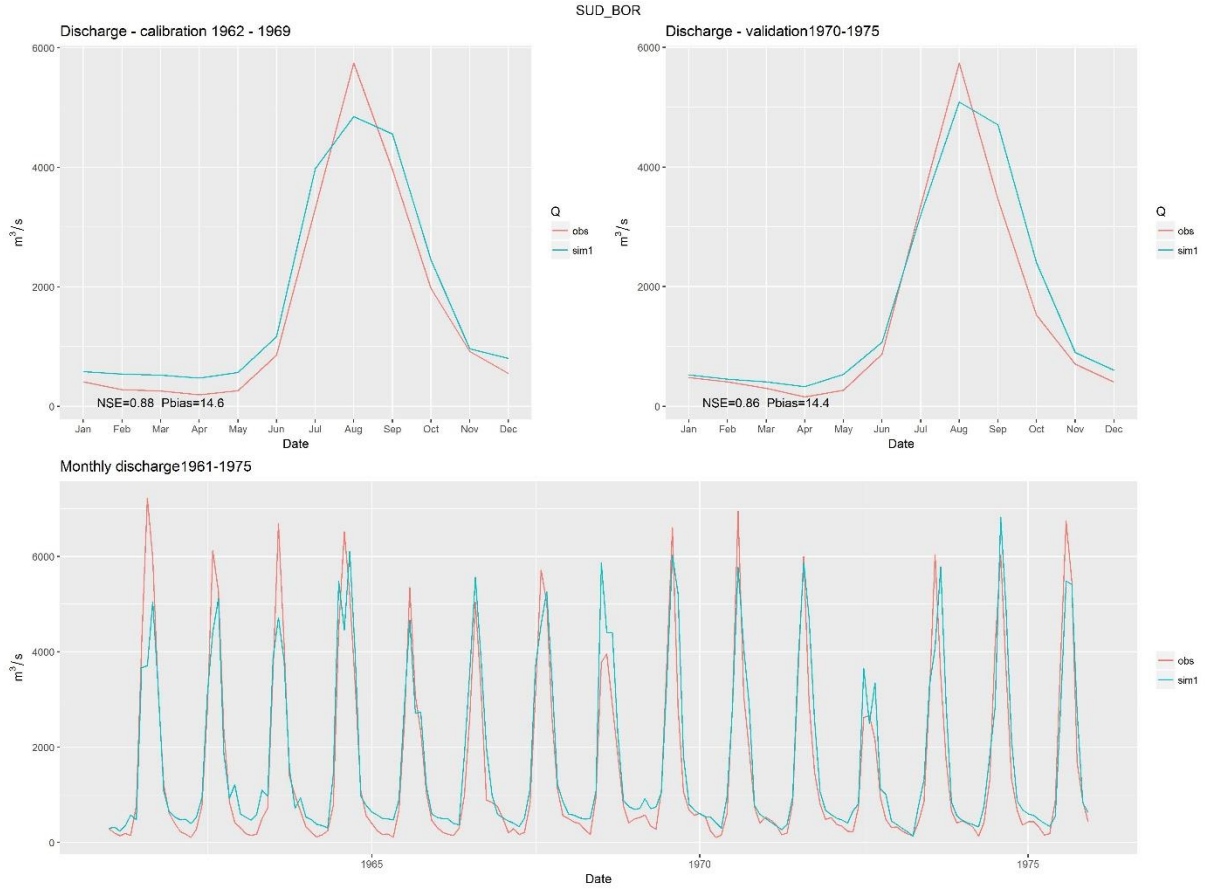

Figure 2 Calibration and validation results of the river discharge at the Sudan border gauge (Blue Nile basin)

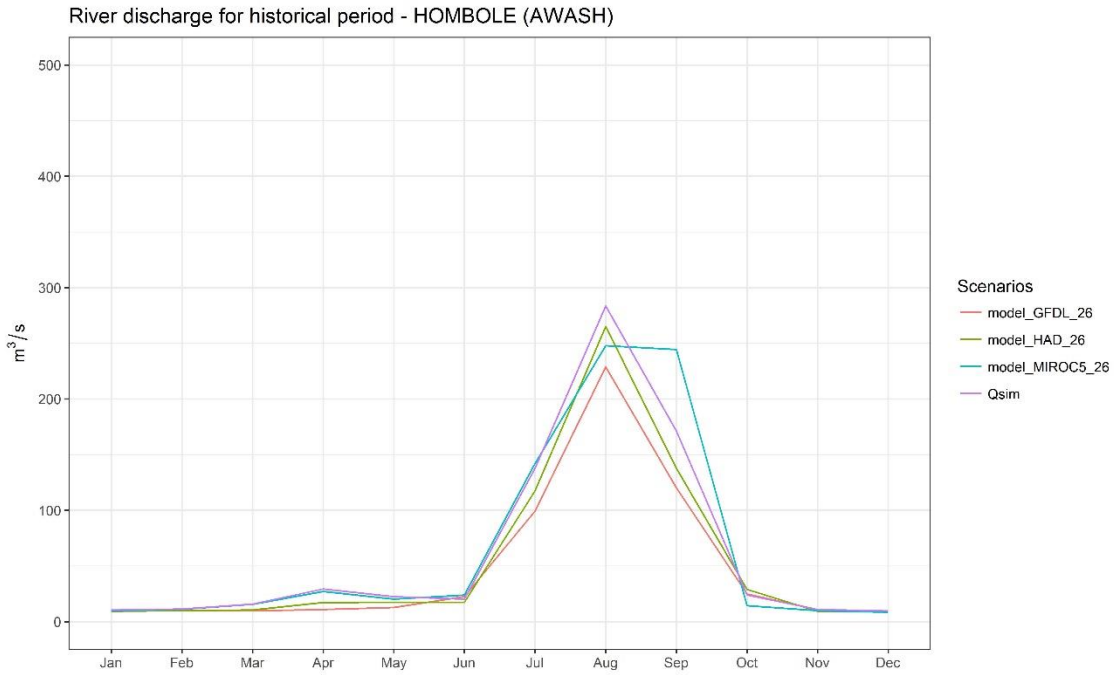

Figure 3 Long term mean seasonal discharge driven by different climate models and WFDEI for the historical period (Hombole, Awash basin)

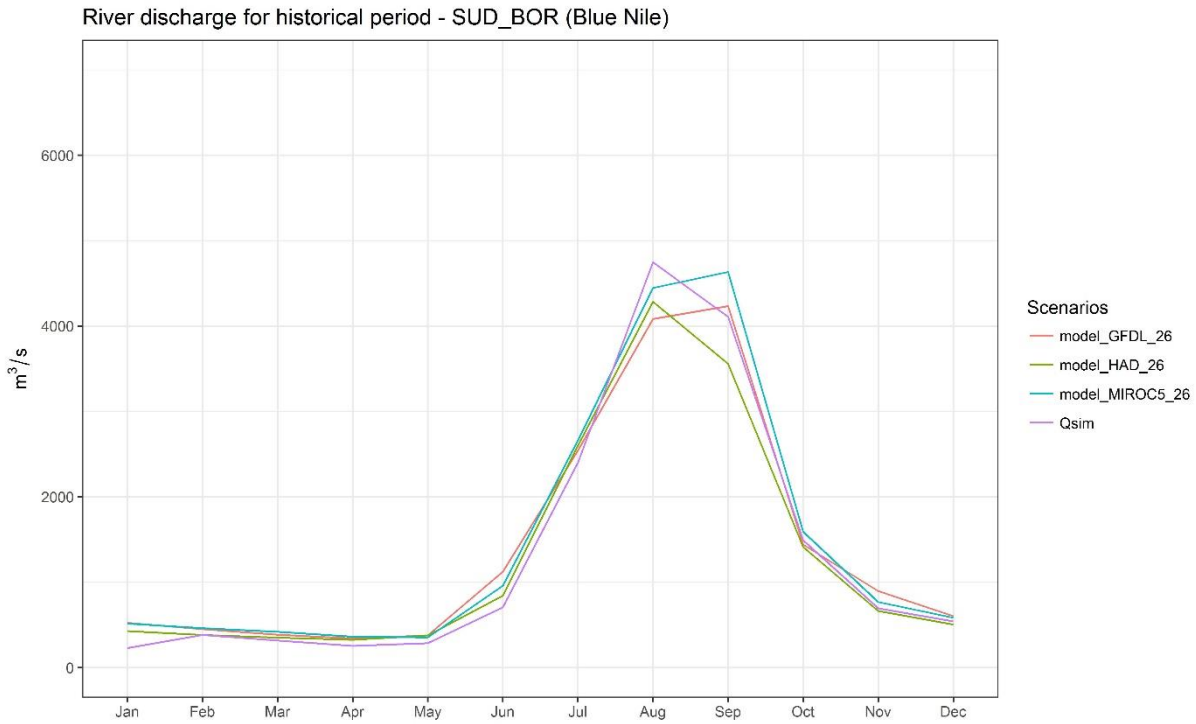

Figure 4 Long term mean seasonal discharge driven by different climate models and ERA40 for the historical period (Sudan border, Blue Nile basin)

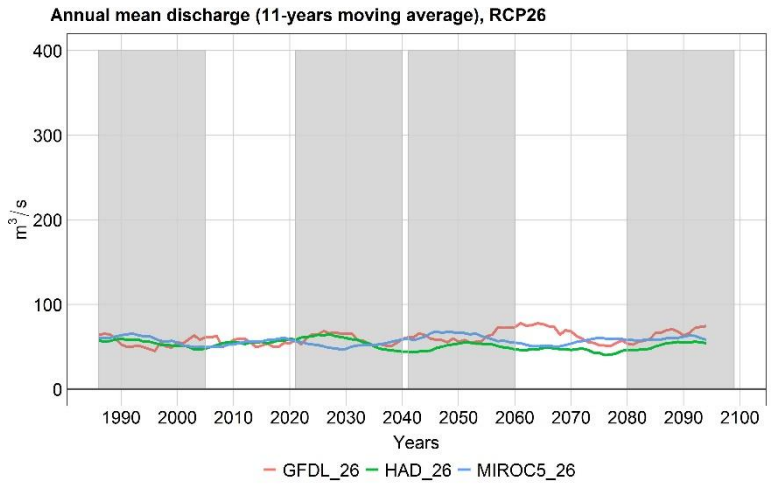

Figure 5 Annual mean discharge at the Hombole gauge (11-years moving average) under RCP 2.6

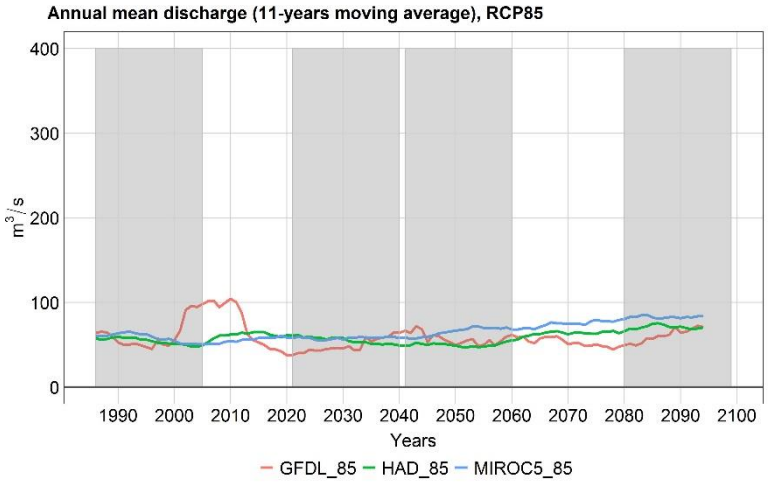

Figure 6 Annual mean discharge at the Hombole gauge (11-years moving average) under RCP 8.5

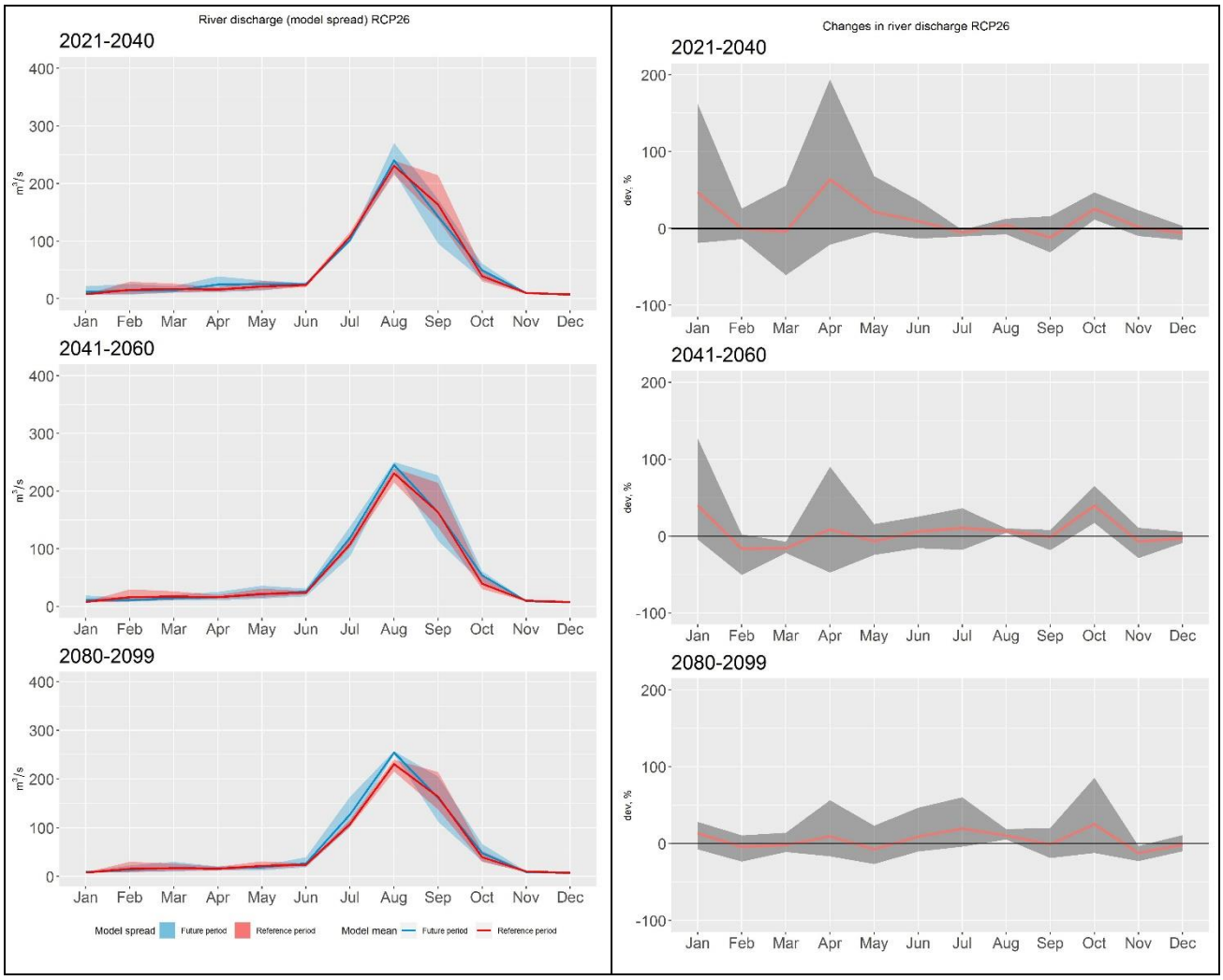

Figure 7 Absolut (left) and relative (right) mean monthly discharge changes of the river discharge at the Hombole gauge (Awash basin) for three future periods compared to reference period under RCP 2.6

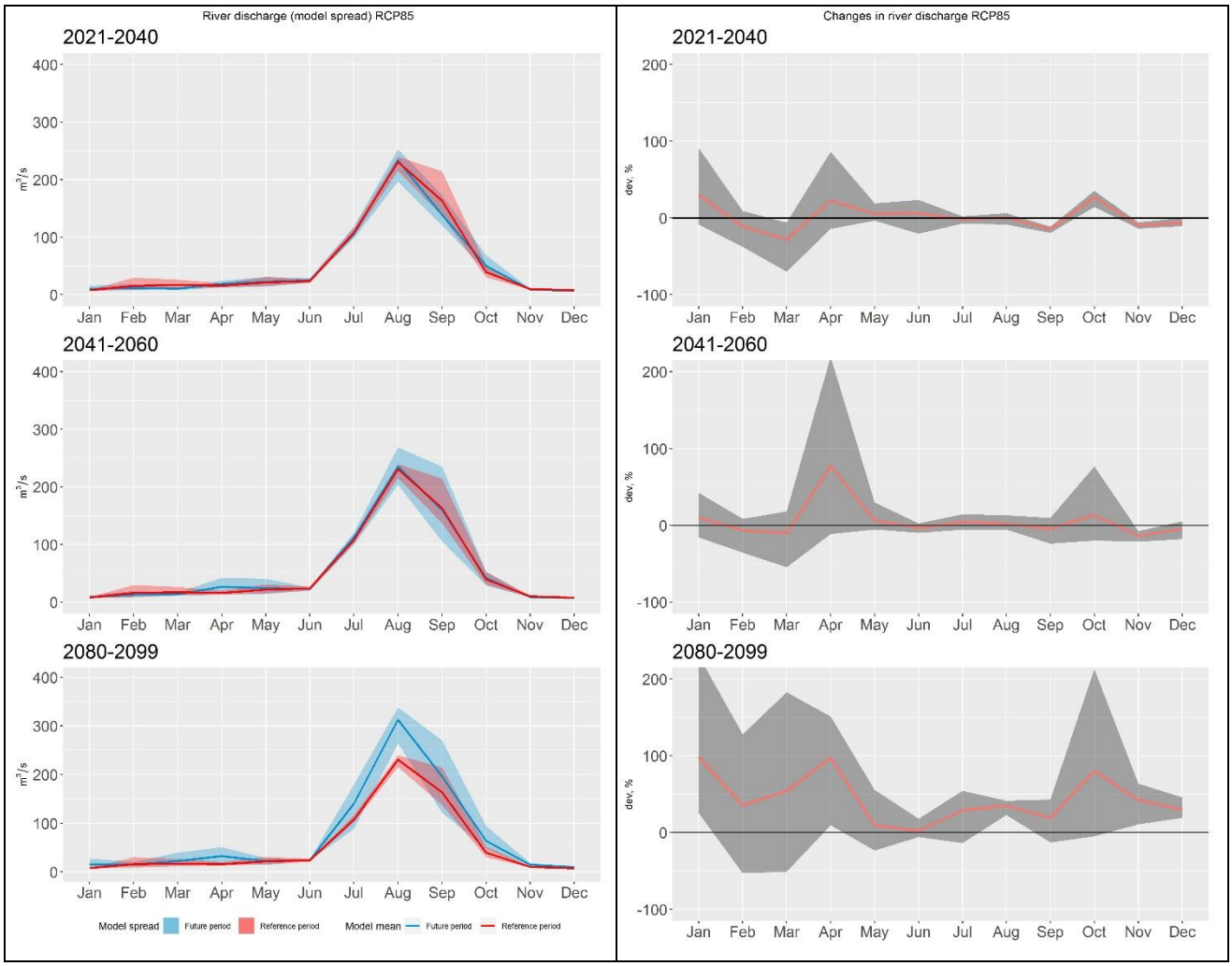

Figure 8 Absolut (left) and relative (right) mean monthly discharge changes of the river discharge at the Hombole gauge (Awash basin) for three future periods compared to reference period under RCP 8.5

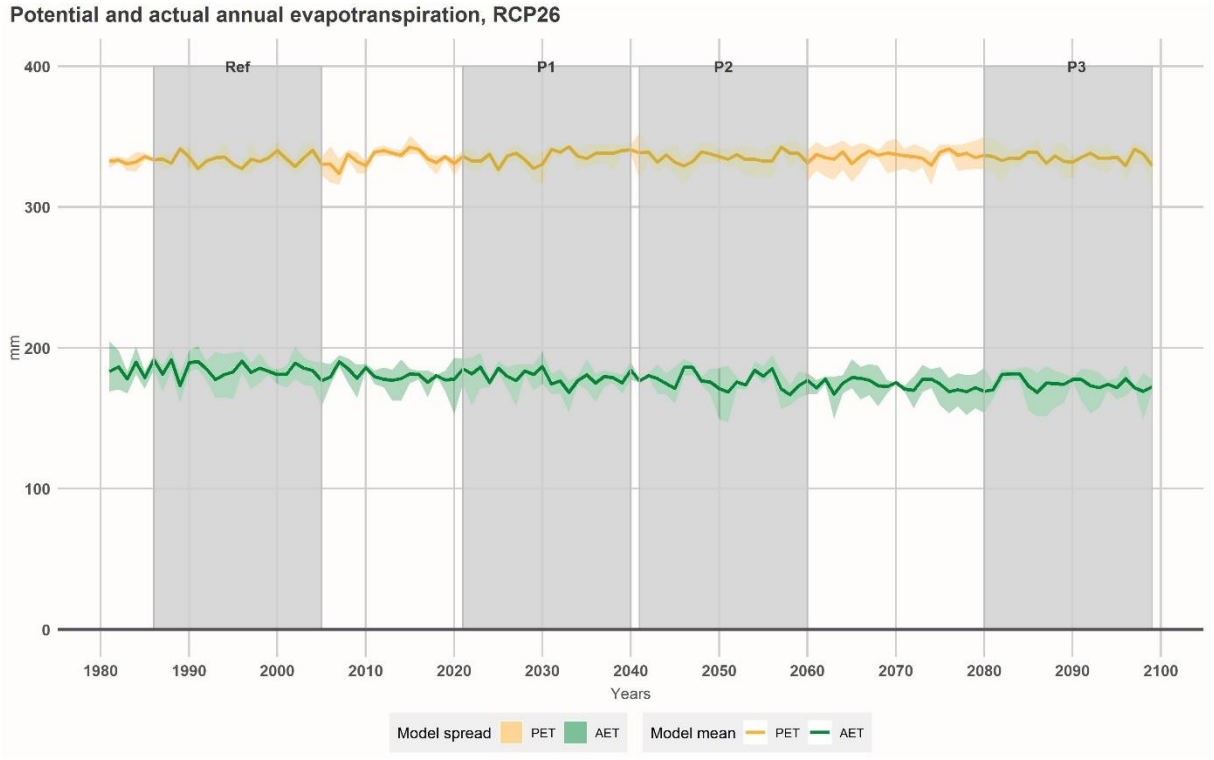

Figure 9 The multi-model mean of annual potential and actual evapotranspiration under RCP 2.6 to the end of the century

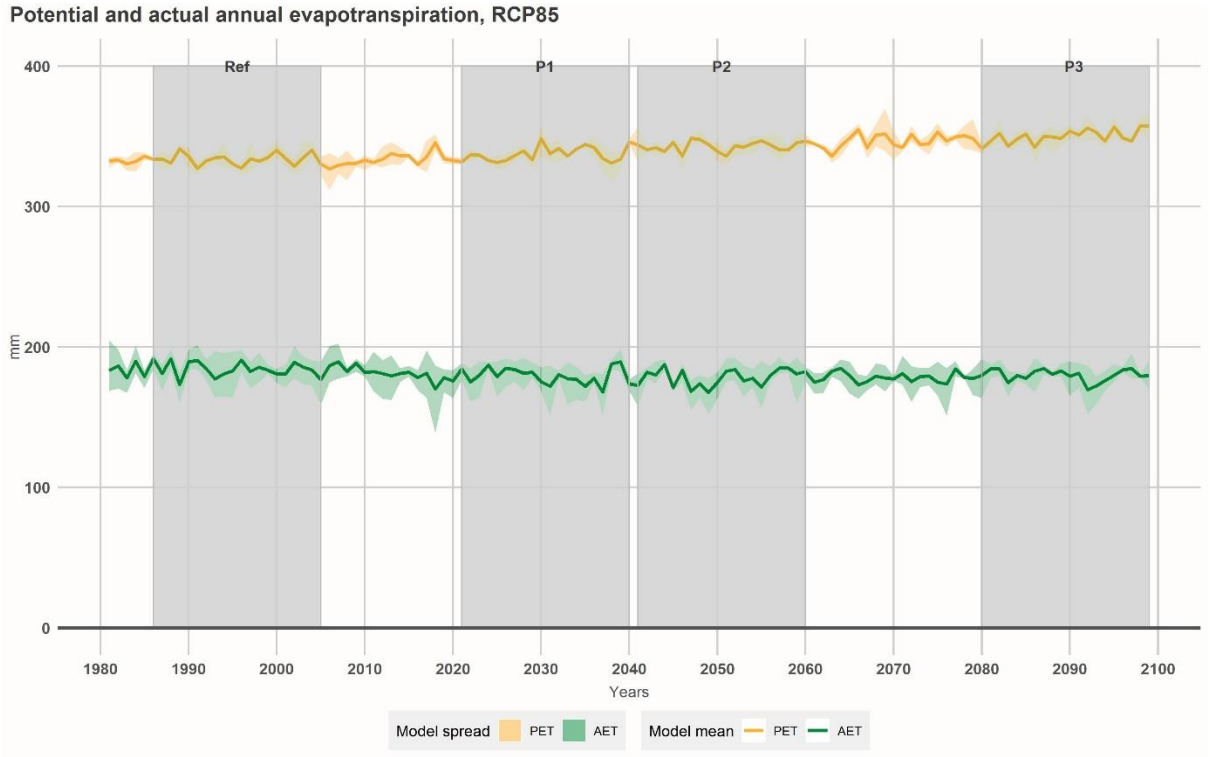

Figure 10 The multi-model mean of annual potential and actual evapotranspiration under RCP 8.5 to the end of the century

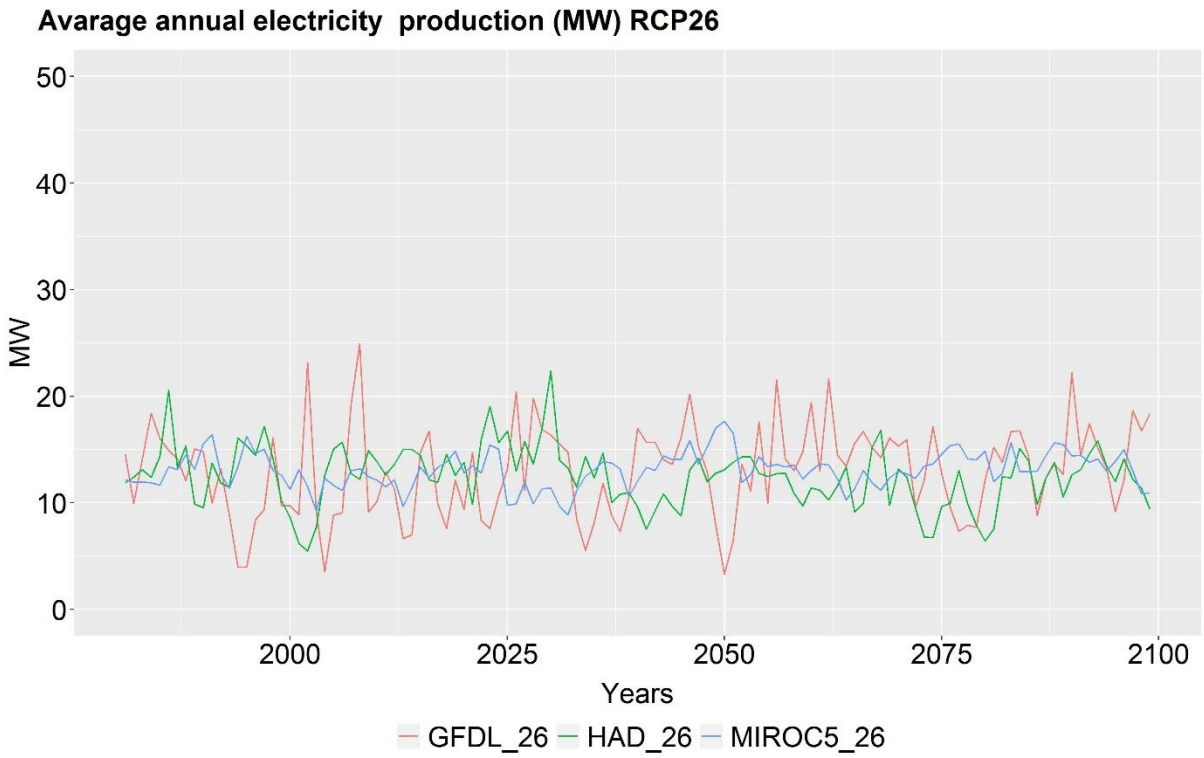

Figure 11 Annual average electricity production of the Koka (Awash 1) HPP under RCP 2.6 to the end of the century

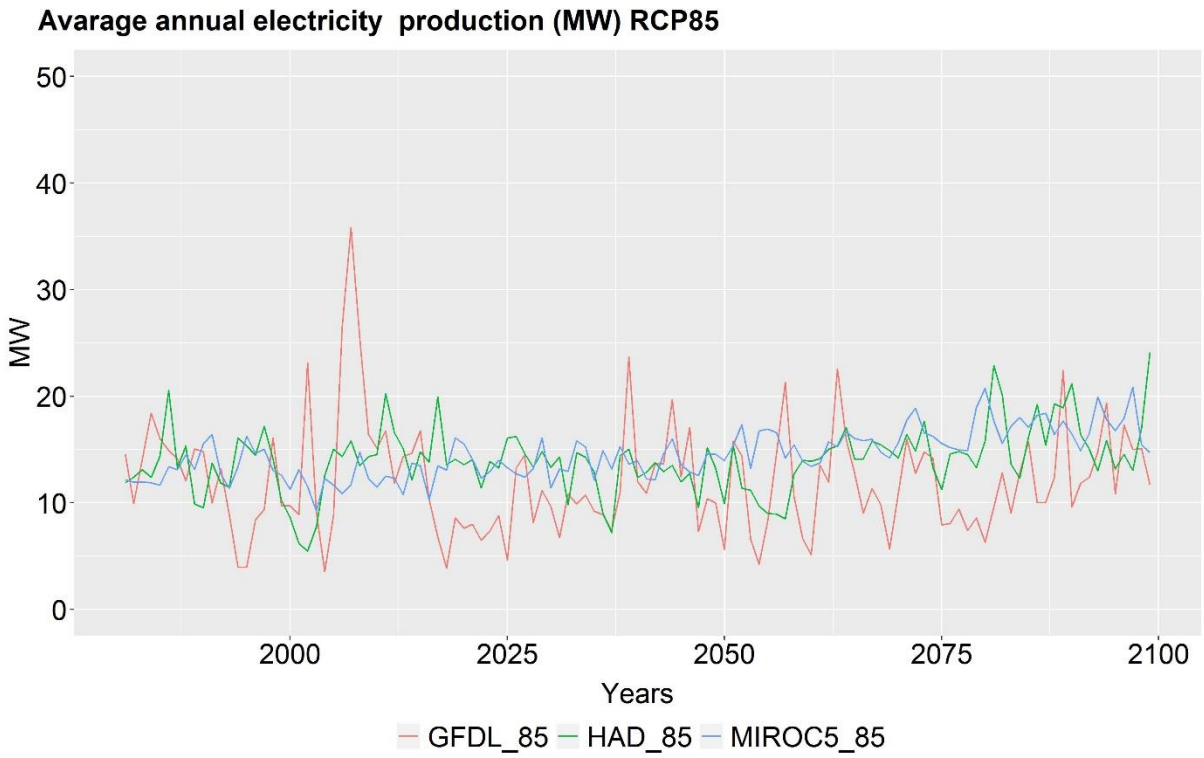

Figure 12 Annual average electricity production of the Koka (Awash 1) HPP under RCP 8.5 to the end of the century

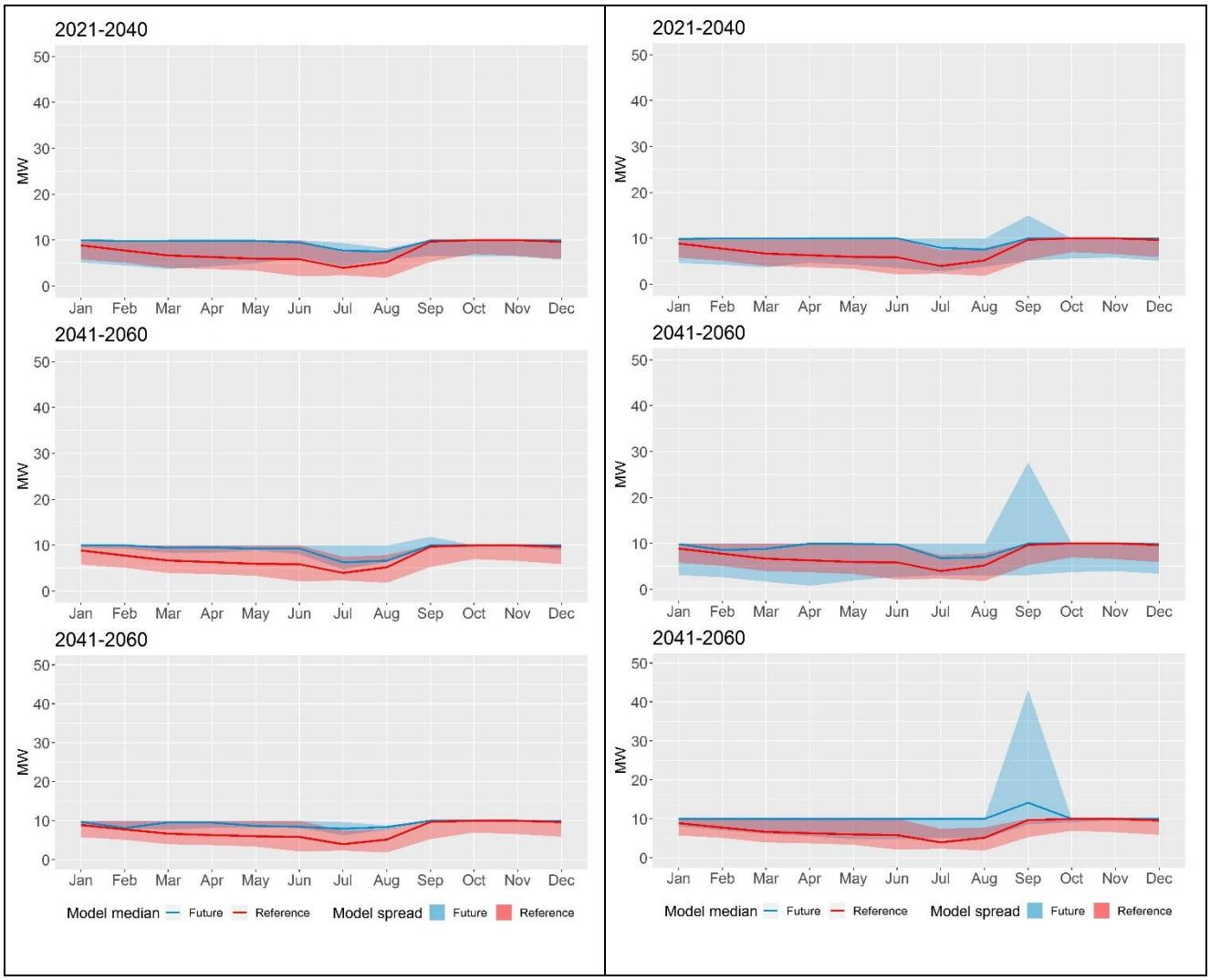

Figure 13 Q10 of the monthly electricity production (MW) of the Koka (Awash 1) HPP for three future periods compared to the reference period under RCP 2.6 (left) and RCP 8.5 (right).

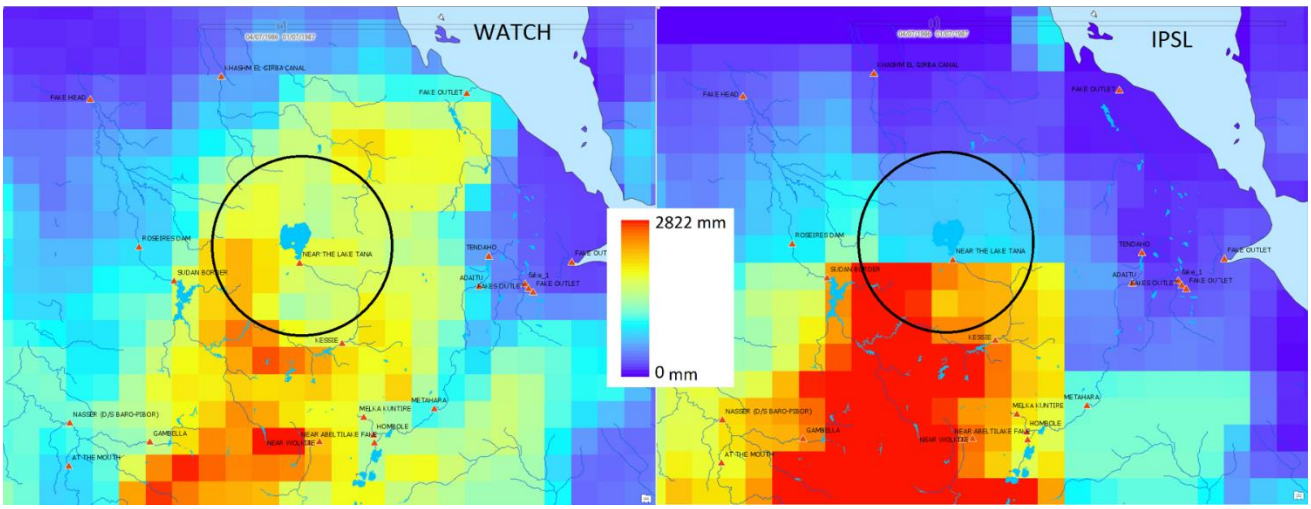

Figure 14 Annual sum precipitation in 1986 according to WATCH (left) and IPSL model (right)

Chapter 3 – Climate impacts on crop production

Table 8: Impact of climate change on suitability for multiple crops in each agro-ecological region. Percentage of area that is suitable for producing the number of crops in each AEZ. Difference to the current status indicates the impact of climate change.

AEZ	Crops	None	One	Two	Three	Four
Drought prone	Current	0.0	0.0	0.0	0.0	0.0
	RCP26	28.3	23.0	23.5	15.3	9.9
	RCP85	36.2	20.9	15.4	17.0	10.5
Humid lowland moisture reliable	Current	8.5	16.4	29.4	40.7	5.1
	RCP26	15.3	24.9	41.8	9.0	9.0
	RCP85	18.6	35.6	37.3	6.8	1.7
Moisture reliable – Cereals	Current	1.1	1.4	19.5	13.1	64.9
	RCP26	1.5	15.9	10.0	14.3	58.3
	RCP85	2.7	16.5	10.1	20.0	50.7
Moisture reliable – Enset	Current	0.4	5.5	10.7	41.5	41.9
	RCP26	0.8	1.6	24.9	43.5	29.2
	RCP85	3.2	8.7	21.7	36.0	30.4
Pastoralist	Current	63.2	24.0	12.8	0.0	0.0
	RCP26	88.6	8.1	1.5	0.1	0.0
	RCP85	90.6	6.0	1.0	0.1	0.1

Table 9: Impact of climate change on suitability for multiple crops in each administrative region.

Region	Crops	None	One	Two	Three	Four
Amhara	Current	0.0	6.6	16.8	22.5	54.0
	RCP26	2.2	19.3	17.7	23.6	37.2
	RCP85	6.3	16.8	12.5	25.4	38.9
Oromia	Current	6.0	12.5	27.1	14.5	39.9
	RCP26	16.7	14.3	16.0	11.3	41.7
	RCP85	19.5	14.9	10.3	17.7	37.6
SNNP	Current	4.6	11.4	14.5	36.7	32.7
	RCP26	8.0	3.1	28.1	37.3	23.5
	RCP85	10.8	14.2	22.5	28.4	24.1
Tigray	Current	0.7	28.5	55.6	12.6	2.6
	RCP26	5.3	55.6	30.5	7.3	1.3
	RCP85	21.2	51.0	17.2	8.6	2.0

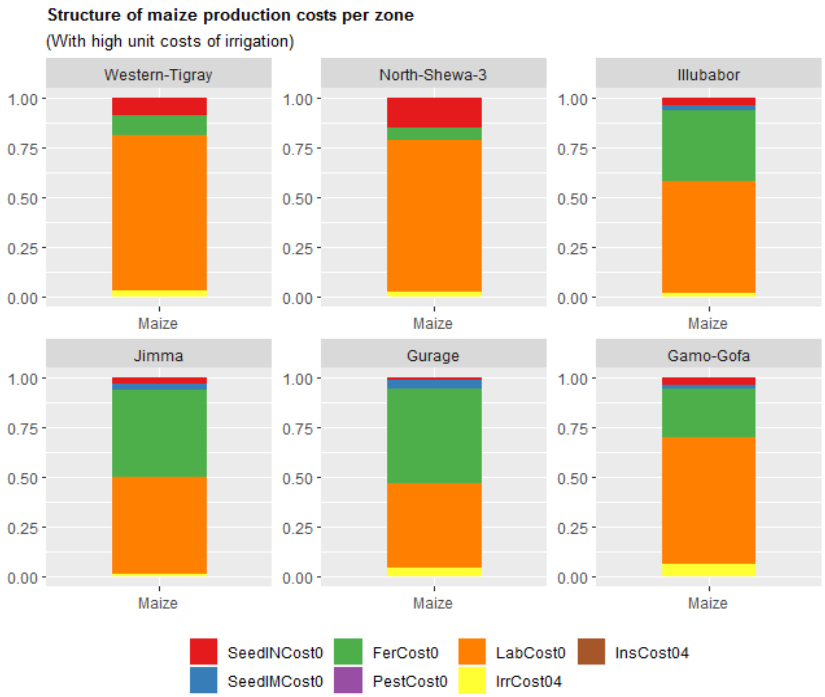

Figure 15: Structure of maize production costs in different zones. Note: Production costs excludes land and capital costs. Insurance costs (premiums) are zero in the benchmark case. SeedINCost0 (indigenous seed cost), SeedIMCost0 (improved seed costs), FerCost0 (Chemical fertilizer costs), PestCost0 (pesticide costs), LabCost0 (labor costs), IrrCost04 (irrigation costs with high unit cost assumed), and InsCost04 (insurance costs with high premium assumed).

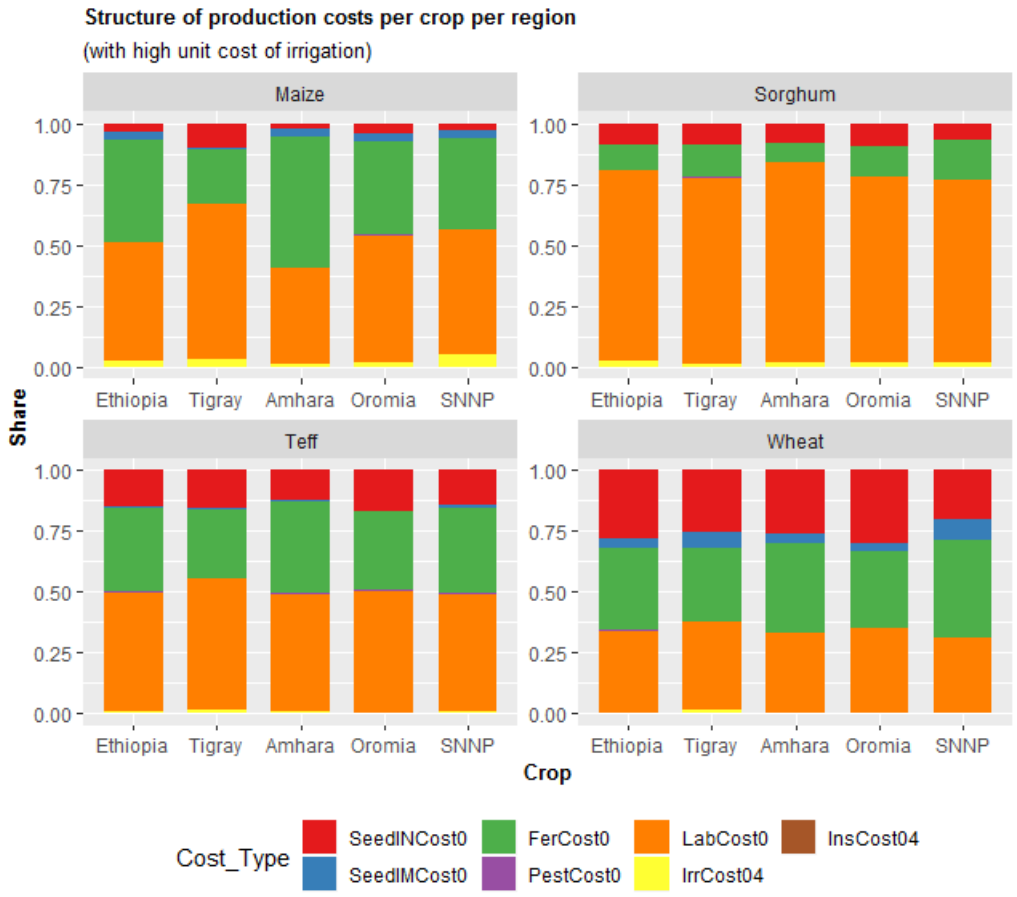

Figure 16: Production cost structure per crop per region.

Notes: SeedINCost0 (indigenous seed cost), SeedIMCost0 (improved seed costs), FerCost0 (Chemical fertilizer costs), PestCost0 (pesticide costs), LabCost0 (labor costs), IrrCost04 (irrigation costs with high unit cost assumed), and InsCost04 (insurance costs with high premium assumed). Remember that the insurance costs in the base cost structure are zero as no area is assumed to be insured because of the non-exist market for agricultural insurance.

Supplementary Information for the Economic Analysis

1. Main Equations

Average yield of crop

$$Y_a = \beta_r . Y_r + \beta_w . Y_w \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where;

$$\beta_r + \beta_w = 1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$Y_w = Y_r . (1 + Y_m) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Y_m is incremental yield due to irrigation relative to rain-fed farming system. Which we assumed to be 20%. The share of irrigated land is derived from the above equation. We assumed that climate change impacts are reflected on rain-fed yields only. Average yield is

targeted by adaptation policy. Below are the equations used to derive the irrigation demand to meet a specific adaptation policy targets.

Irrigation: Demand

$$Y_a = \beta_r . Y_r + \beta_w . Y_w$$

$$Y_a = (1 - \beta_w) . Y_r + \beta_w . Y_w$$

$$Y_a = Y_r - Y_r . \beta_w + \beta_w . Y_w$$

$$Y_a - Y_r = \beta_w . Y_w - Y_r . \beta_w$$

$$(Y_a - Y_r) = \beta_w . (Y_w - Y_r)$$

$$\beta_w = \frac{Y_a - Y_r}{Y_w - Y_r}$$

$$\beta_w^s = \frac{Y_a^s - Y_r^s}{Y_r^0 . (1 + \overline{Y_m}) - Y_r^s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4a)$$

($if\ we\ assume\ irrigated\ yields\ are\ not\ affected\ by\ climate\ change$)

$$\beta_w^s = \frac{Y_a^s - Y_r^s}{Y_r^s . \overline{Y_m}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4b)$$

($if\ we\ assume\ irrigated\ yields\ are\ also\ affected\ by\ climate\ change$)

We assumed the former, i.e., irrigated yields are not affected by climate change. In other words, irrigated areas will maintain the present level of irrigated yields despite climate change.

Irrigation: Costs

$$\text{IrrCost}^s = c . A_w = c . \beta_w{}^s . A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where ***c*** unit cost of irrigation per ha. From this one can calculate incremental costs of irrigation as adaptation to climate change.

$$\text{IrrCost}^{AD} = c . \beta_w{}^{IRR} . A - c . \beta_w{}^0 . A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Insurance: Premiums

$$\text{InsCost}^s = r . A_{INS} = r . \delta_w{}^s . A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where ***r*** is premium per ha.

Insurance: Sum insured

$$\text{SumInsured}^s = \frac{\text{InsCost}^s}{\gamma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where $\boldsymbol{\gamma}$ is the rate of premium.

Insurance: Claims

$$\text{InsClaim}^s = A_{INS}.(Y_a^0 - Y_a^s).P = \delta_w{}^s.A.(Y_a^0 - Y_a^s).P \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where ***P*** product price.

2. Materials

Table 10 summarizes the benchmark data sources used for the economic analysis which include average (of 2014-2016 *meher* cropping seasons) area harvested, yields, share of cropland under farm management practices (irrigation, chemical fertilizer, pesticides, indigenous seeds and improved seeds) and input intensity per ha of cropland (indigenous seed, improved seed, and chemical fertilizers) and retail prices of crops (2014/15).

Table 10: Summary of data sources used for the economic analysis.

Variable	**Main sources/reference**
Area harvested	CSA (2014, 2015, 2016)
Observed yields	CSA (2014, 2015, 2016)
Labor costs	ILOSTAT (2017)
Fertilizer costs	CSA (2014, 2015, 2016); Rashid et al. (2013); IFDC (2012)
Irrigation costs	CSA (2014, 2015, 2016); Gebregziabher et al. (2013)
Insurance premiums	Belay (2011); CSA (2014, 2015, 2016)
Pesticide costs	Makombe et al. (2007)
Product prices	CSA (2015)
Projected yield changes	APSIM model
Projected area suitability changes	Suitability Model

Table 11: Benchmark information on the selected crops (average of 2014-2016).

Geographic Area	Crop	Area ('000 Ha)	Yield (tons/Ha)	Irrigated Area (%)	Price (USD/ton)
Ethiopia	Teff	2967	1.60	0.32	709
Ethiopia	Wheat	1675	2.58	0.35	484
Ethiopia	Maize	2121	3.50	1.50	327
Ethiopia	Sorghum	1857	2.41	0.86	439
Tigray	Teff	172	1.34	0.87	732
Tigray	Wheat	106	1.85	1.32	482
Tigray	Maize	64	2.41	1.35	368
Tigray	Sorghum	239	2.71	0.48	429
Amhara	Teff	1125	1.63	0.35	679
Amhara	Wheat	543	2.29	0.19	507
Amhara	Maize	517	3.62	0.95	346
Amhara	Sorghum	657	2.23	0.50	456
Oromia	Teff	1413	1.65	0.19	707
Oromia	Wheat	882	2.87	0.24	450
Oromia	Maize	1133	3.61	0.99	315
Oromia	Sorghum	740	2.53	0.63	439
SNNP	Teff	232	1.36	0.52	678
SNNP	Wheat	133	2.51	0.10	477

SNNP	Maize	319	3.22	3.12	278
SNNP	Sorghum	107	2.13	0.59	353
Western-Tigray	Maize	5	3.24	1.35	343
North-Shewa	Maize	7	2.83	0.95	335
Illubabor	Maize	100	3.83	0.99	269
Gamo-Gofa	Maize	54	3.31	3.12	300

Source: Authors' compilation from various reports by Central Statistics Agency of Ethiopia (CSA).

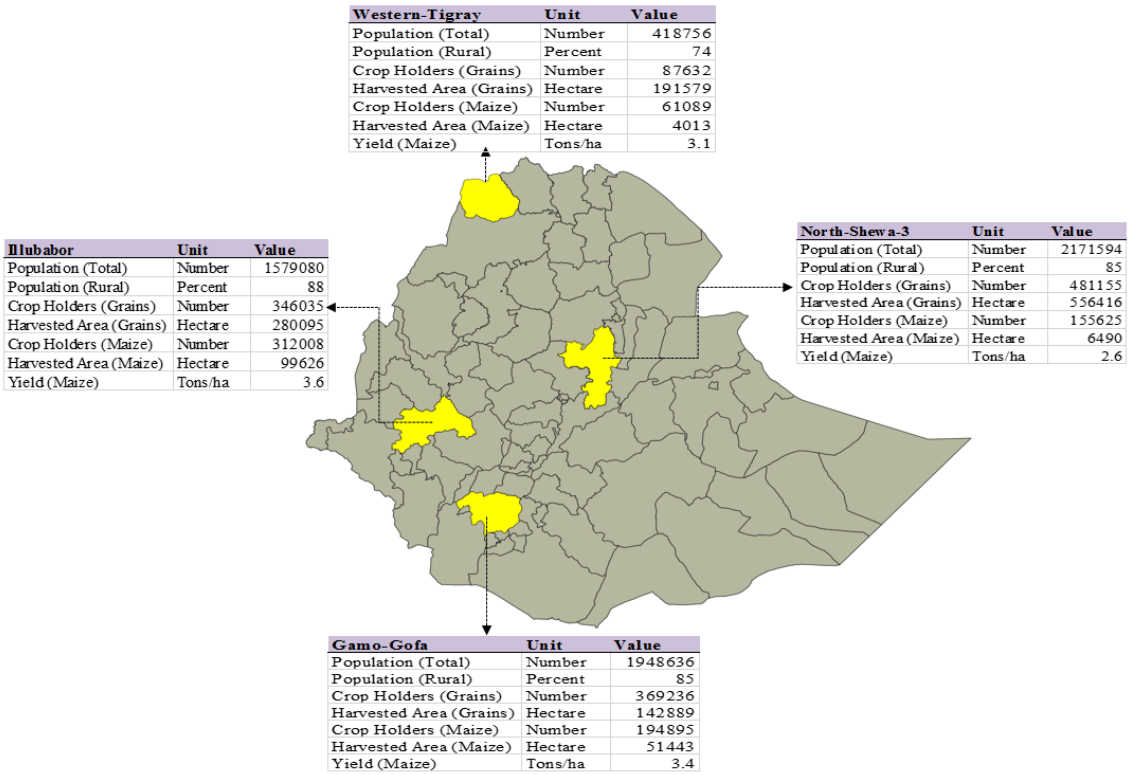

Figure 17: The four zones for economic analysis: Illubabor, Western-Tigray, North-Shewa-3 and Gamo-Gofa.

3. Results and Discussions

Irrigation as adaption to maize yield changes

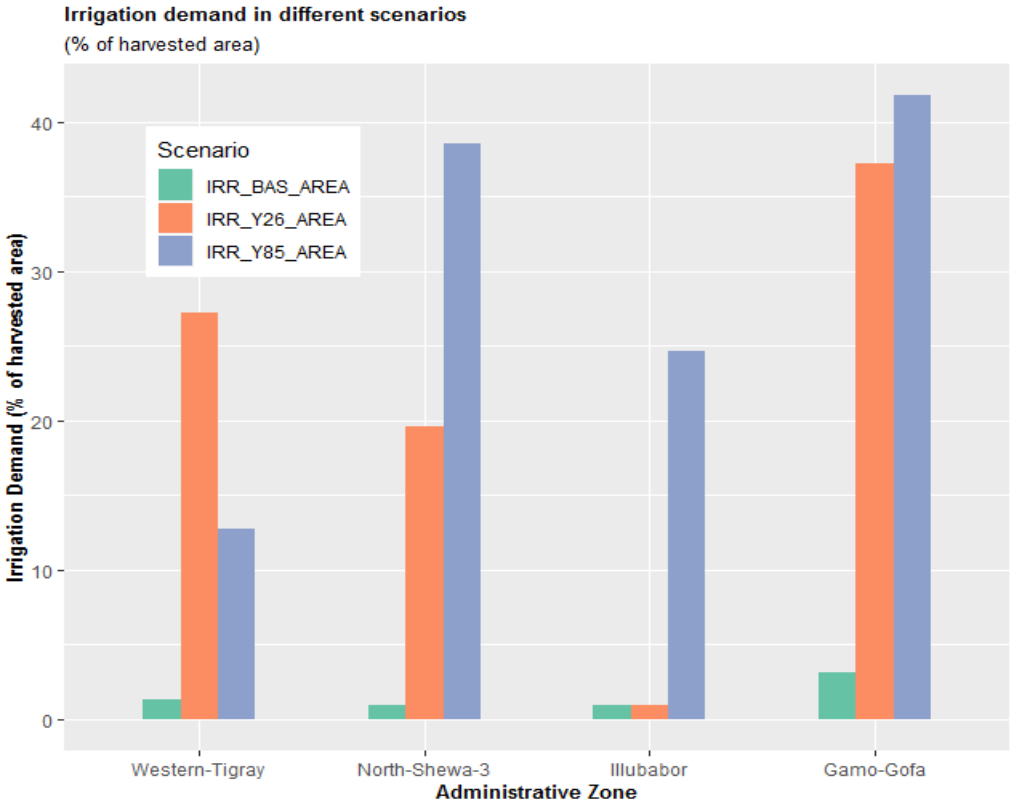

Figure 18: Irrigation demand under different scenarios.

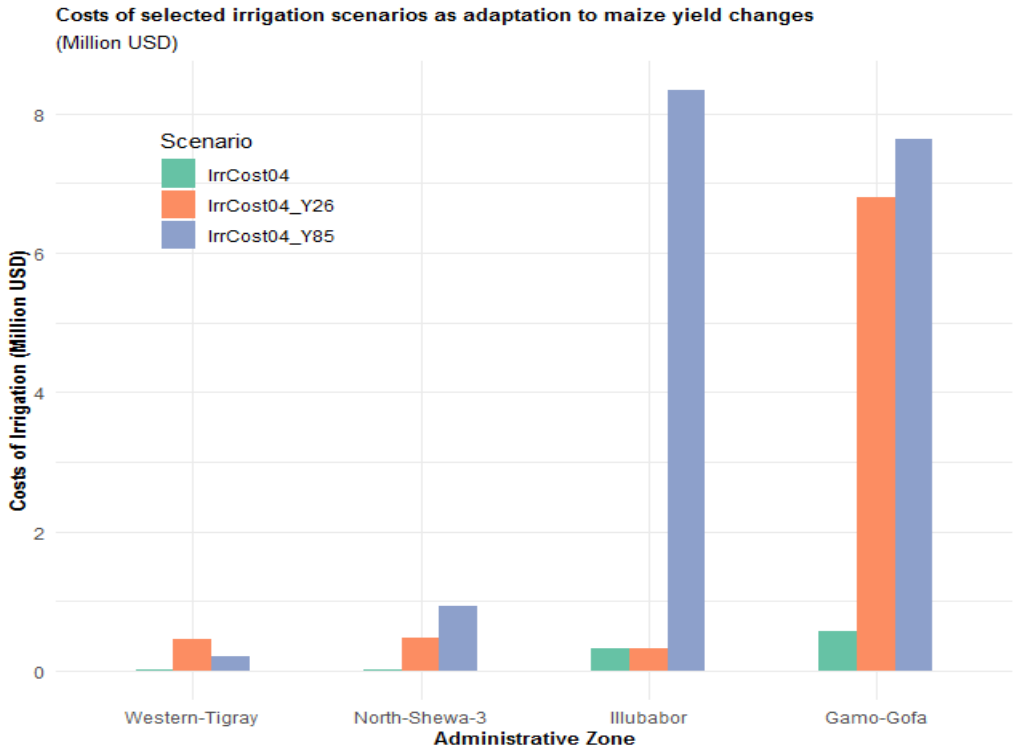

Figure 19: Costs of selected irrigation scenarios.

The figure shows that total costs of irrigation increases relative to our previous policy target which was to offset about 75% of the impacts. This is natural and expected.

In general, the policy target changes did not change the overall evaluation outcomes. The combination of unit cost and climate change scenarios under which we regard as irrigation as effective and viable measure of adaptation remain intact compared with the cases with reversing 75% of climate change-induced yield changes presented in the main body of this study. This can be taken as our conclusions are robust to policy targets.

Chapter 5 – Selection of adaptation measures

Table 12: List of interviewees

	Group	Date	Location
1	Research	01.03.2019	Addis Ababa
2	Research	01.03.2019	Addis Ababa
3	Research	01.03.2019	Addis Ababa
4	Practitioner	04.03.2019	Addis Ababa
5	Research	04.03.2019	Addis Ababa
6	Practitioner (2)	04.03.2019	Addis Ababa
7	Practitioner	04.03.2019	Addis Ababa
8	Practitioner (2)	05.03.2019	Addis Ababa
9	Practitioner	05.03.2019	Addis Ababa
10	Practitioner (3)	06.03.2019	Addis Ababa
11	Research	06.03.2019	Addis Ababa
12	Research	06.03.2019	Addis Ababa
13	Practitioner	06.03.2019	Addis Ababa
14	Research	07.03.2019	Addis Ababa
15	Practitioner (2)	07.03.2019	Addis Ababa
16	Practitioner	08.03.2019	Addis Ababa
17	Farmer	09.03.2019	Wukro, Tigray
18	Farmer	09.03.2019	Wukro, Tigray
19	Farmer	09.03.2019	Wukro, Tigray
20	Farmer	09.03.2019	Wukro, Tigray
21	Farmer	09.03.2019	Wukro, Tigray
22	Farmer	09.03.2019	Wukro, Tigray
23	Research	09.03.2019	Wukro, Tigray
24	Practitioner	11.03.2019	Addis Ababa
25	Practitioner	11.03.2019	Addis Ababa
26	Research	13.03.2019	Addis Ababa
27	Research	13.03.2019	Addis Ababa

Consolidated list of all measures proposed during the stakeholder workshop, the survey and the interviews:

- Off-farm activities: e.g. petty trade, cottage industries etc., job creation,
- Additional income generating activities: bee-keeping, goat/shoat fattening, fattening small ruminants, poultry, cash crops, high value horticulture
- Developing farmers' skills: Provision of training on basic construction, training on marketing and value chains,
- Migration (labour mobility)
- Pest management
- Natural resource management: Wetland management, Watershed management (Integrated Watershed Management), Water Resources Management (including underground water resources), Grazing Land Management, Landscape based restoration, Integrated rangeland management, Forest Management

- Natural soil fertility enhancement mechanisms
- Implementation of Nutrition Sensitive Agriculture
- Community Managed Disaster Risk Reduction (CMDRR)
- Promotion of sustainable organic agriculture technologies
- Establishing saving and credit associations and rural enterprises
- Drought- and disease resistant crop varieties and livestock breed

Chapter 8 – Insurance

Insurance as coping mechanism to suitability changes

As mentioned earlier, crop insurance is not yet common in Ethiopia. Therefore, we assume a policy target for area-suitability changes is to insure the share of cropland, which become less suitable under climate change.

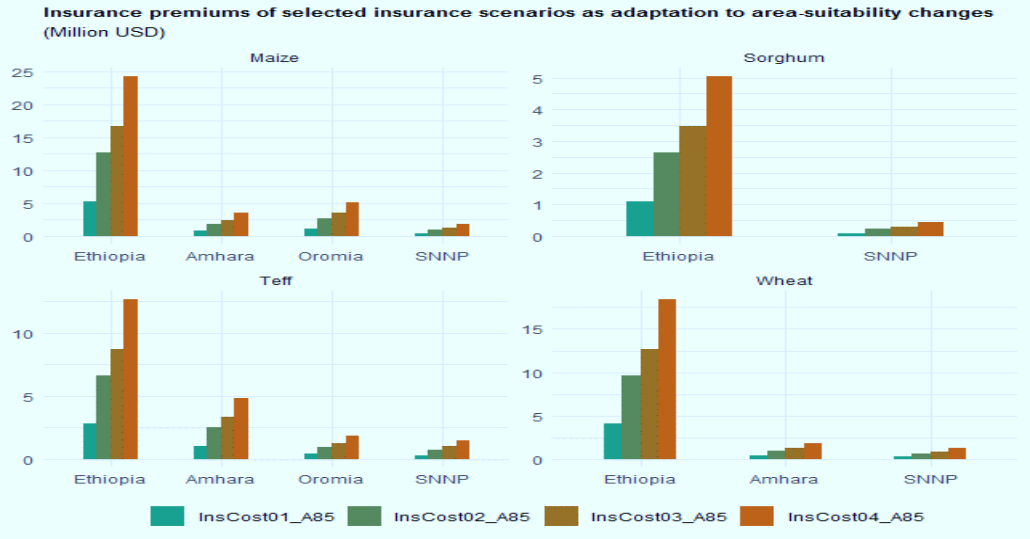

Figure 20: Insurance premiums of selected insurance scenarios to area-suitability change impacts.

As in the case of irrigation, we assume no insurance contract is taken for crops where favorable changes are expected, according to the suitability models discussed in Chapter 3 of the study.

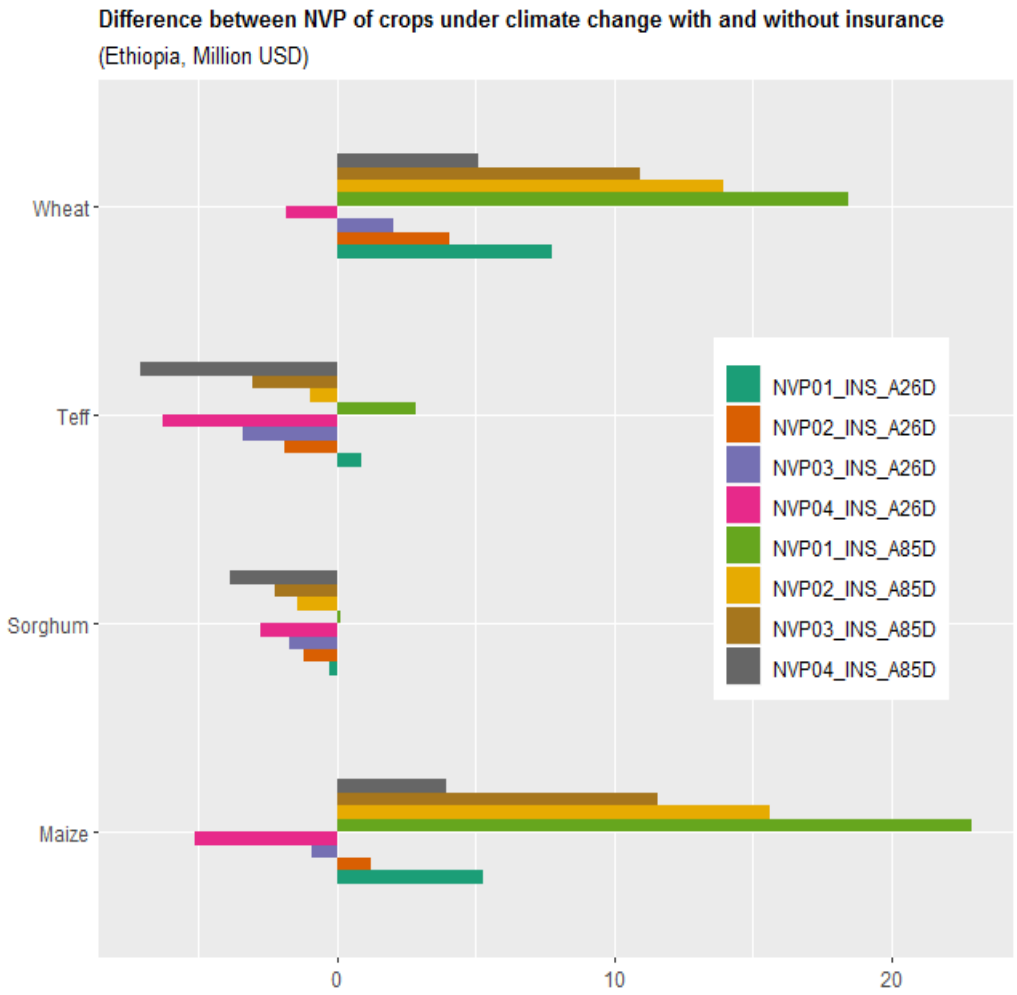

Figure 21: Difference between NVP of crops under climate change with and without insurance for Ethiopia

Unlike the case with irrigation, our results indicate that the net benefits of insurance would be viable measure if and only if the insurance premiums are low and the expected impacts of climate change are very high. In terms of crops, the expected net benefits are high for maize and wheat in many cases. Otherwise, it is better, the results suggest, to absorb the economic effects of climate change. The contrast between results for irrigation and insurance are partly explained by the benchmark scenarios. Currently, crop insurances are not part of costs in agricultural accounting as they do not exist. Therefore, the irrigation scenario adds no insurance premiums to deduct from the gross value of production. In contrast, even if the share is very small, irrigation costs contribute to the total benchmark costs of production thus included in the insurance scenario as well.

Chapter 9 – Improved crop management

Table 13: Effect of moving the season and organic carbon on crop suitability by agro-ecological region.

Crop	Measure	Climate	Drought prone	Humid lowland moisture reliable	Moisture reliable - Cereals	Moisture reliable - Enset	Pastoralist
Maize	4 Weeks	Current	-0.9	-5.1	-2.9	-2.8	1.6
		RCP26	-1.2	-14.1	-0.9	-12.3	-5.6
		RCP85	-2.2	-11.9	3.0	-6.7	2.8
	20%OC	Current	2.7	4.5	2.7	2.4	2.3
		RCP26	1.2	3.4	2.8	1.6	2.7
		RCP85	11.2	2.3	7.8	3.2	7.4
	4 Wks + 20%OC	Current	1.4	0.6	2.2	-4.0	1.1
		RCP26	0.4	-2.8	0.1	-4.0	4.8
		RCP85	9.34	-2.82	5.17	-2.77	8.91
Sorghum	4 Weeks	Current	0.7	-5.6	0.4	0.4	-1.2
		RCP26	0.0	-7.3	0.7	-1.6	-2.0
		RCP85	1.2	-10.7	2.7	-3.2	-1.0
	20%OC	Current	4.4	0.0	0.7	2.8	0.7
		RCP26	3.7	1.1	0.0	2.4	1.9
		RCP85	5.0	4.0	3.0	0.8	3.2
	4 Wks + 20%OC	Current	1.7	-4.0	0.2	0.4	-0.8
		RCP26	-2.9	2.8	-2.1	-2.0	-0.6
		RCP85	1.6	-3.4	2.8	-2.8	-0.3
Teff	4 Weeks	Current	-1.4	-4.0	-0.4	-0.4	-0.3
		RCP26	-1.2	-4.5	0.8	-0.4	0.0
		RCP85	2.0	-6.2	4.6	0.0	-0.6
	20%OC	Current	0.6	1.7	5.7	-0.4	0.9
		RCP26	2.0	7.9	6.1	0.0	0.2
		RCP85	4.9	4.0	9.4	0.0	-0.5
	4 Wks + 20%OC	Current	-0.6	6.8	1.6	-0.8	-0.2
		RCP26	3.9	4.5	2.8	-0.4	-12.5
		RCP85	3.4	-3.4	5.7	-0.4	-0.6
Wheat	4 Weeks	Current	-1.3	-2.8	-0.8	-3.1	0.1
		RCP26	-0.8	-1.1	-0.9	-3.9	-0.5
		RCP85	-0.2	2.3	0.7	-15.4	-0.8
	20%OC	Current	0.0	2.8	0.8	6.3	0.3
		RCP26	1.8	4.0	1.5	3.1	0.6
		RCP85	2.0	2.3	1.2	0.4	0.5
	4 Wks + 20%OC	Current	-1.1	-1.1	-0.5	3.1	0.1
		RCP26	-0.7	-0.6	-0.7	0.4	0.2
		RCP85	-0.3	2.3	0.8	-16.5	-0.5

Table 14: Effect of moving the season and organic carbon on crop suitability by region.

Crop	Measure		SNNP	Tigray	Amhara	Oromia
Maize	4 Weeks	Current	-4	-7	-2.8	-3.0
		RCP26	-6	-17	-3.9	-1.6
		RCP85	01	-9	-0.9	-0.2
	20%OC	Current	12	78	1.1	1.6
		RCP26	1.5	5.3	1.1	1.6
		RCP85	5.2	6.0	4.8	1.8
	4 Wks + 20%OC	Current	-1.9	-8.6	10.9	-2.3
		RCP26	-5.9	-13.9	-1.3	-0.7
		RCP85	1.5	-4.6	0.4	0.3
Sorghum	4 Weeks	Current	-1.2	-6.6	-1.5	-1.5
		RCP26	-3.4	-25.2	-8.5	-4.9
		RCP85	-2.2	-21.2	-14.2	-4.5
	20%OC	Current	0.3	0.7	4.2	0.2
		RCP26	3.1	-7.9	2.8	0.1
		RCP85	6.2	-6.6	-1.8	0.7
	4 Wks + 20%OC	Current	-0.6	-8.6	-1.3	-1.1
		RCP26	-6.8	-18.5	-8.8	-5.6
		RCP85	-0.9	-19.2	-11.4	-3.8
Teff	4 Weeks	Current	2.2	-1.3	-1.1	-1.5
		RCP26	1.2	-4.6	-2.2	-2.0
		RCP85	-0.3	-6.0	-1.8	-7.3
	20%OC	Current	2.5	4.0	-0.4	1.7
		RCP26	3.4	10.6	1.3	0.9
		RCP85	6.8	19.9	1.3	0.9
	4 Wks + 20%OC	Current	1.9	7.3	9.8	-4.3
		RCP26	-2.2	2.0	-2.4	-2.7
		RCP85	3.4	6.0	-1.1	-6.4
Wheat	4 Weeks	Current	-5.5	-12.6	1.1	-1.7
		RCP26	-8.0	-15.2	-0.6	-3.0
		RCP85	-12.0	-15.9	-0.2	-1.9
	20%OC	Current	8.6	-4.6	0.0	0.9
		RCP26	1.8	2.0	0.6	0.4
		RCP85	0.3	4.6	1.3	0.0
	4 Wks + 20%OC	Current	-2.2	-11.3	1.1	-1.5
		RCP26	-8.0	-15.2	-0.6	-3.0
		RCP85	-14.2	-9.9	0.2	-1.7

Micro-economic cost-benefit analyses

Chapter 6: Irrigation CBA

Table 15: Screenshot of the CBA output template for the action scenario switch from rainfed to irrigated maize production under future climate change conditions

				Internal Rate of Return (IRR):			20,89%	Net Present Value (NPV):			22.319
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-9518	1974	-7544			0	1,00	-9518	1974	-7544	-7544
2021	-952	2088	1136			1	0,94	-898	1970	1072	-6472
2022	-952	2163	1212			2	0,89	-847	1925	1078	-5393
2023	-952	2279	1327			3	0,84	-799	1913	1114	-4279
2024	-952	2354	1402			4	0,79	-754	1864	1111	-3169
2025	-952	2440	1488			5	0,75	-711	1823	1112	-2057
2026	-952	2527	1575			6	0,70	-671	1782	1111	-946
2027	-952	2637	1685			7	0,67	-633	1754	1121	174
2028	-952	2743	1791			8	0,63	-597	1721	1124	1298
2029	-952	2865	1913			9	0,59	-563	1696	1132	2431
2030	-952	2953	2001			10	0,56	-531	1649	1117	3548
2031	-952	3041	2090			11	0,53	-501	1602	1101	4649
2032	-952	3146	2194			12	0,50	-473	1563	1090	5739
2033	-952	3234	2282			13	0,47	-446	1516	1070	6809
2034	-952	3360	2408			14	0,44	-421	1486	1065	7874
2035	-952	3489	2537			15	0,42	-397	1456	1059	8933
2036	-952	3586	2635			16	0,39	-375	1412	1037	9970
2037	-952	3711	2759			17	0,37	-353	1378	1025	10995
2038	-952	3829	2877			18	0,35	-333	1341	1008	12003
2039	-952	3912	2960			19	0,33	-315	1293	978	12981
2040	-952	4012	3060			20	0,31	-297	1251	954	13935
2041	-952	4139	3188			21	0,29	-280	1218	938	14873
2042	-952	4263	3311			22	0,28	-264	1183	919	15792
2043	-952	4391	3439			23	0,26	-249	1150	900	16692
2044	-952	4513	3561			24	0,25	-235	1115	879	17571
2045	-952	4611	3659			25	0,23	-222	1074	853	18424
2046	-952	4701	3750			26	0,22	-209	1033	824	19248
2047	-952	4831	3879			27	0,21	-197	1002	804	20053
2048	-952	4940	3989			28	0,20	-186	966	780	20833
2049	-952	5048	4096			29	0,18	-176	932	756	21589
2050	-952	5148	4196			30	0,17	-166	896	731	22319

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Table 16: Screenshot of the CBA output template for the no-regret scenario switch from rainfed to irrigated maize production under current change conditions

				Internal Rate of Return (IRR):	21,05%			Net Present Value (NPV):	23.123		
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-9518	1974	-7544			0	1,00	-9518	1974	-7544	-7544
2021	-952	2068	1117			1	0,94	-898	1951	1053	-6490
2022	-952	2164	1213			2	0,89	-847	1926	1079	-5411
2023	-952	2262	1310			3	0,84	-799	1899	1100	-4311
2024	-952	2360	1409			4	0,79	-754	1870	1116	-3196
2025	-952	2461	1509			5	0,75	-711	1839	1127	-2068
2026	-952	2562	1610			6	0,70	-671	1806	1135	-933
2027	-952	2665	1713			7	0,67	-633	1772	1139	206
2028	-952	2769	1818			8	0,63	-597	1738	1140	1347
2029	-952	2875	1923			9	0,59	-563	1702	1138	2485
2030	-952	2982	2031			10	0,56	-531	1665	1134	3619
2031	-952	3091	2140			11	0,53	-501	1628	1127	4746
2032	-952	3202	2250			12	0,50	-473	1591	1118	5864
2033	-952	3314	2362			13	0,47	-446	1554	1107	6972
2034	-952	3427	2475			14	0,44	-421	1516	1095	8067
2035	-952	3542	2590			15	0,42	-397	1478	1081	9147
2036	-952	3659	2707			16	0,39	-375	1440	1066	10213
2037	-952	3777	2825			17	0,37	-353	1403	1049	11262
2038	-952	3897	2945			18	0,35	-333	1365	1032	12294
2039	-952	4018	3067			19	0,33	-315	1328	1014	13307
2040	-952	4142	3190			20	0,31	-297	1291	995	14302
2041	-952	4267	3315			21	0,29	-280	1255	975	15277
2042	-952	4394	3442			22	0,28	-264	1219	955	16232
2043	-952	4522	3570			23	0,26	-249	1184	935	17167
2044	-952	4653	3701			24	0,25	-235	1149	914	18081
2045	-952	4785	3833			25	0,23	-222	1115	893	18974
2046	-952	4919	3967			26	0,22	-209	1081	872	19846
2047	-952	5055	4103			27	0,21	-197	1048	851	20697
2048	-952	5193	4241			28	0,20	-186	1016	830	21527
2049	-952	5332	4381			29	0,18	-176	984	808	22335
2050	-952	5474	4522			30	0,17	-166	953	787	23123

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Table 17: Screenshot of the CBA output template for the action scenario crop switch from maize to sorghum under future climate change conditions

				Internal Rate of Return (IRR):			11,06%	Net Present Value (NPV):			11.771
Undiscounted Flows				Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-3482	900	-2582			0	1,00	-3482	900	-2582	-2582
2021	-4425	2239	-2187			1	0,94	-4175	2112	-2063	-4645
2022	-3928	2511	-1417			2	0,89	-3496	2235	-1261	-5905
2023	-1327	1622	295			3	0,84	-1114	1362	248	-5657
2024	-3273	2517	-756			4	0,79	-2593	1994	-599	-6256
2025	-4891	3751	-1139			5	0,75	-3655	2803	-851	-7108
2026	-4404	4315	-89			6	0,70	-3105	3042	-63	-7171
2027	-5138	4318	-820			7	0,67	-3417	2872	-545	-7716
2028	-5651	5623	-28			8	0,63	-3546	3528	-17	-7733
2029	-5565	5922	357			9	0,59	-3294	3505	211	-7522
2030	-5072	5259	187			10	0,56	-2832	2937	105	-7417
2031	-5387	5892	505			11	0,53	-2838	3104	266	-7151
2032	-6050	6599	549			12	0,50	-3007	3279	273	-6879
2033	-5340	6403	1064			13	0,47	-2503	3002	499	-6380
2034	-4892	6262	1370			14	0,44	-2164	2770	606	-5774
2035	-5404	6489	1085			15	0,42	-2255	2708	453	-5321
2036	-5816	7986	2169			16	0,39	-2289	3143	854	-4467
2037	-4963	7063	2100			17	0,37	-1843	2623	780	-3687
2038	-6033	8662	2630			18	0,35	-2113	3035	921	-2766
2039	-6628	9496	2868			19	0,33	-2191	3138	948	-1818
2040	-6807	9832	3025			20	0,31	-2122	3066	943	-875
2041	-6559	10103	3544			21	0,29	-1930	2972	1042	167
2042	-6469	11358	4888			22	0,28	-1795	3152	1357	1524
2043	-6926	11627	4701			23	0,26	-1813	3044	1231	2755
2044	-7358	11223	3865			24	0,25	-1817	2772	955	3709
2045	-6752	12283	5531			25	0,23	-1573	2862	1289	4998
2046	-7593	13278	5685			26	0,22	-1669	2919	1250	6248
2047	-7206	14177	6971			27	0,21	-1494	2940	1446	7693
2048	-7519	15050	7532			28	0,20	-1471	2944	1473	9167
2049	-5925	13437	7512			29	0,18	-1094	2480	1386	10553
2050	-9602	16597	6996			30	0,17	-1672	2890	1218	11771

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Table 18: Screenshot of the CBA output template for the no-regret scenario crop switch from maize to sorghum under current climate change conditions

				Internal Rate of Return (IRR):	9,31%			Net Present Value (NPV):	6.908		
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-3482	900	-2582			0	1,00	-3482	900	-2582	-2582
2021	-3263	1350	-1912			1	0,94	-3078	1274	-1804	-4386
2022	-3047	1885	-1162			2	0,89	-2711	1677	-1034	-5420
2023	-3292	2278	-1014			3	0,84	-2764	1913	-852	-6272
2024	-3542	2681	-860			4	0,79	-2805	2124	-682	-6953
2025	-3795	3094	-701			5	0,75	-2835	2312	-523	-7477
2026	-4051	3517	-534			6	0,70	-2856	2479	-377	-7853
2027	-4311	3949	-361			7	0,67	-2867	2627	-240	-8094
2028	-4574	4392	-182			8	0,63	-2870	2756	-114	-8208
2029	-4842	4846	5			9	0,59	-2866	2868	3	-8205
2030	-5113	5311	198			10	0,56	-2855	2966	111	-8094
2031	-5387	5787	399			11	0,53	-2838	3048	210	-7884
2032	-5666	6274	608			12	0,50	-2816	3118	302	-7582
2033	-5949	6773	824			13	0,47	-2789	3175	387	-7195
2034	-6235	7284	1049			14	0,44	-2758	3222	464	-6731
2035	-6526	7807	1281			15	0,42	-2723	3258	535	-6197
2036	-6820	8343	1523			16	0,39	-2685	3284	599	-5597
2037	-7119	8891	1773			17	0,37	-2644	3302	658	-4939
2038	-7422	9453	2031			18	0,35	-2600	3312	712	-4227
2039	-7729	10028	2300			19	0,33	-2554	3314	760	-3467
2040	-8040	10617	2577			20	0,31	-2507	3311	804	-2664
2041	-8356	11220	2865			21	0,29	-2458	3301	843	-1821
2042	-8676	11838	3162			22	0,28	-2408	3285	877	-944
2043	-9001	12471	3470			23	0,26	-2356	3265	908	-35
2044	-9330	13118	3788			24	0,25	-2304	3240	936	900
2045	-9664	13781	4118			25	0,23	-2252	3211	959	1860
2046	-10002	14461	4458			26	0,22	-2199	3179	980	2840
2047	-10346	15156	4810			27	0,21	-2145	3143	998	3837
2048	-10694	15868	5174			28	0,20	-2092	3104	1012	4850
2049	-11047	16597	5551			29	0,18	-2039	3063	1024	5874
2050	-11404	17344	5940			30	0,17	-1986	3020	1034	6908

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Table 19: Screenshot of the CBA output template for the action scenario switch from maize monoculture to maize agroforestry under future climate change conditions

				Internal Rate of Return (IRR):	42,65%			Net Present Value (NPV):	123.273		
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-6764	-130	-6893			0	1,00	-6764	-130	-6893	-6893
2021	-1691	222	-1469			1	0,94	-1595	210	-1386	-8279
2022	-1691	2369	678			2	0,89	-1505	2108	603	-7676
2023	-1691	4630	2940			3	0,84	-1420	3888	2468	-5208
2024	-1691	6800	5109			4	0,79	-1339	5386	4047	-1161
2025	-1691	9010	7319			5	0,75	-1264	6732	5469	4308
2026	-1691	11236	9545			6	0,70	-1192	7921	6729	11037
2027	-1691	11659	9968			7	0,67	-1125	7754	6629	17667
2028	-1691	11965	10274			8	0,63	-1061	7507	6446	24113
2029	-1691	12315	10624			9	0,59	-1001	7289	6288	30401
2030	-1691	12568	10877			10	0,56	-944	7018	6073	36475
2031	-1691	12823	11132			11	0,53	-891	6755	5864	42339
2032	-1691	13124	11433			12	0,50	-840	6522	5682	48020
2033	-1691	13378	11687			13	0,47	-793	6272	5479	53500
2034	-1691	13738	12047			14	0,44	-748	6076	5329	58828
2035	-1691	14111	12420			15	0,42	-706	5888	5182	64011
2036	-1691	14391	12700			16	0,39	-666	5665	4999	69010
2037	-1691	14750	13059			17	0,37	-628	5477	4849	73859
2038	-1691	15088	13397			18	0,35	-592	5286	4693	78553
2039	-1691	15327	13636			19	0,33	-559	5066	4507	83060
2040	-1691	15614	13923			20	0,31	-527	4869	4341	87401
2041	-1691	15982	14291			21	0,29	-497	4701	4204	91605
2042	-1691	16338	14647			22	0,28	-469	4534	4065	95669
2043	-1691	16705	15014			23	0,26	-443	4373	3931	99600
2044	-1691	17056	15365			24	0,25	-418	4212	3795	103395
2045	-1691	17338	15647			25	0,23	-394	4040	3646	107041
2046	-1691	17598	15907			26	0,22	-372	3868	3497	110537
2047	-1691	17972	16281			27	0,21	-351	3727	3376	113913
2048	-1691	18286	16595			28	0,20	-331	3577	3246	117160
2049	-1691	18595	16904			29	0,18	-312	3432	3120	120280
2050	-1691	18882	17191			30	0,17	-294	3288	2993	123273

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Table 20: Screenshot of the CBA output template for the no-regret scenario switch from maize monoculture to maize agroforestry under current climate conditions

				Internal Rate of Return (IRR):			42,66%	Net Present Value (NPV):			125.590
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-6764	-130	-6893			0	1,00	-6764	-130	-6893	-6893
2021	-1691	173	-1518			1	0,94	-1595	163	-1432	-8325
2022	-1691	2371	680			2	0,89	-1505	2111	606	-7720
2023	-1691	4586	2895			3	0,84	-1420	3851	2431	-5289
2024	-1691	6818	5127			4	0,79	-1339	5401	4061	-1227
2025	-1691	9067	7376			5	0,75	-1264	6776	5512	4285
2026	-1691	11334	9643			6	0,70	-1192	7990	6798	11083
2027	-1691	11740	10049			7	0,67	-1125	7808	6683	17766
2028	-1691	12040	10349			8	0,63	-1061	7554	6493	24259
2029	-1691	12345	10654			9	0,59	-1001	7307	6306	30565
2030	-1691	12653	10963			10	0,56	-944	7066	6121	36686
2031	-1691	12966	11276			11	0,53	-891	6831	5940	42626
2032	-1691	13284	11593			12	0,50	-840	6602	5761	48388
2033	-1691	13606	11915			13	0,47	-793	6379	5586	53974
2034	-1691	13932	12241			14	0,44	-748	6162	5414	59388
2035	-1691	14263	12572			15	0,42	-706	5951	5246	64634
2036	-1691	14599	12908			16	0,39	-666	5747	5081	69715
2037	-1691	14939	13248			17	0,37	-628	5548	4920	74635
2038	-1691	15284	13593			18	0,35	-592	5355	4762	79397
2039	-1691	15634	13943			19	0,33	-559	5167	4608	84005
2040	-1691	15989	14298			20	0,31	-527	4985	4458	88464
2041	-1691	16348	14657			21	0,29	-497	4809	4312	92775
2042	-1691	16713	15022			22	0,28	-469	4638	4169	96944
2043	-1691	17083	15392			23	0,26	-443	4472	4030	100973
2044	-1691	17458	15767			24	0,25	-418	4312	3894	104868
2045	-1691	17838	16148			25	0,23	-394	4156	3762	108630
2046	-1691	18224	16533			26	0,22	-372	4006	3634	112264
2047	-1691	18615	16924			27	0,21	-351	3860	3510	115774
2048	-1691	19012	17321			28	0,20	-331	3719	3388	119162
2049	-1691	19414	17723			29	0,18	-312	3583	3271	122433
2050	-1691	19821	18130			30	0,17	-294	3451	3157	125590

Source: Own figure. (LCU = Local Currency Unit, here Ethiopian Birr)

Chapter 9: Napier grass CBA

Table 21: Screenshot of the "khat vs. napier grass production" CBA output template for the year 2050 and Ethiopia.

								Benefit-Cost Ratio:			2,273
				Internal Rate of Return (IRR):			50%	Net Present Value (NPV):			77.911
	Undiscounted Flows			Discount factors				Discounted flows			
	Cost	Benefit	Net Cash flow	Discount rate	Base year	Year index	Discount factor	Cost	Benefit	Net	Cumulative
Year	LCU	LCU	LCU	6,00%	2020			LCU	LCU	LCU	LCU
2020	-14155	0	-14155			0	1,00	-14155	0	-14155	-14155
2021	-3419	10637	7218			1	0,94	-3225	10035	6809	-7346
2022	-3419	10584	7165			2	0,89	-3043	9419	6376	-969
2023	-3419	10531	7112			3	0,84	-2871	8842	5971	5002
2024	-3419	10478	7059			4	0,79	-2708	8300	5591	10593
2025	-3419	10426	7007			5	0,75	-2555	7791	5236	15829
2026	-3419	10373	6954			6	0,70	-2410	7313	4903	20731
2027	-3419	10322	6903			7	0,67	-2274	6864	4591	25322
2028	-3419	10270	6851			8	0,63	-2145	6443	4298	29620
2029	-3419	10219	6800			9	0,59	-2024	6048	4025	33645
2030	-3419	10168	6749			10	0,56	-1909	5677	3768	37413
2031	-3419	10117	6698			11	0,53	-1801	5329	3528	40941
2032	-3419	10066	6647			12	0,50	-1699	5003	3303	44245
2033	-3419	10016	6597			13	0,47	-1603	4696	3093	47338
2034	-3419	9966	6547			14	0,44	-1512	4408	2896	50233
2035	-3419	9916	6497			15	0,42	-1427	4138	2711	52944
2036	-3419	9866	6447			16	0,39	-1346	3884	2538	55482
2037	-3419	9817	6398			17	0,37	-1270	3646	2376	57858
2038	-3419	9768	6349			18	0,35	-1198	3422	2224	60082
2039	-3419	9719	6300			19	0,33	-1130	3212	2082	62165
2040	-3419	9670	6251			20	0,31	-1066	3015	1949	64114
2041	-3419	9622	6203			21	0,29	-1006	2830	1825	65938
2042	-3419	9574	6155			22	0,28	-949	2657	1708	67646
2043	-3419	9526	6107			23	0,26	-895	2494	1599	69245
2044	-3419	9478	6059			24	0,25	-844	2341	1497	70742
2045	-3419	9431	6012			25	0,23	-797	2197	1401	72143
2046	-3419	9384	5965			26	0,22	-752	2063	1311	73454
2047	-3419	9337	5918			27	0,21	-709	1936	1227	74681
2048	-3419	9290	5871			28	0,20	-669	1817	1149	75830
2049	-3419	9244	5825			29	0,18	-631	1706	1075	76905
2050	-3419	9198	5779			30	0,17	-595	1601	1006	77911

Source: Own figure.