Supplementary file to **Risk-return trade-offs in diversified cropping systems under conservation agriculture: Evidence from a 14-year long-term field experiment in north-western India**

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Appendices

Appendix A: Kharif maize and rabi crops frontier

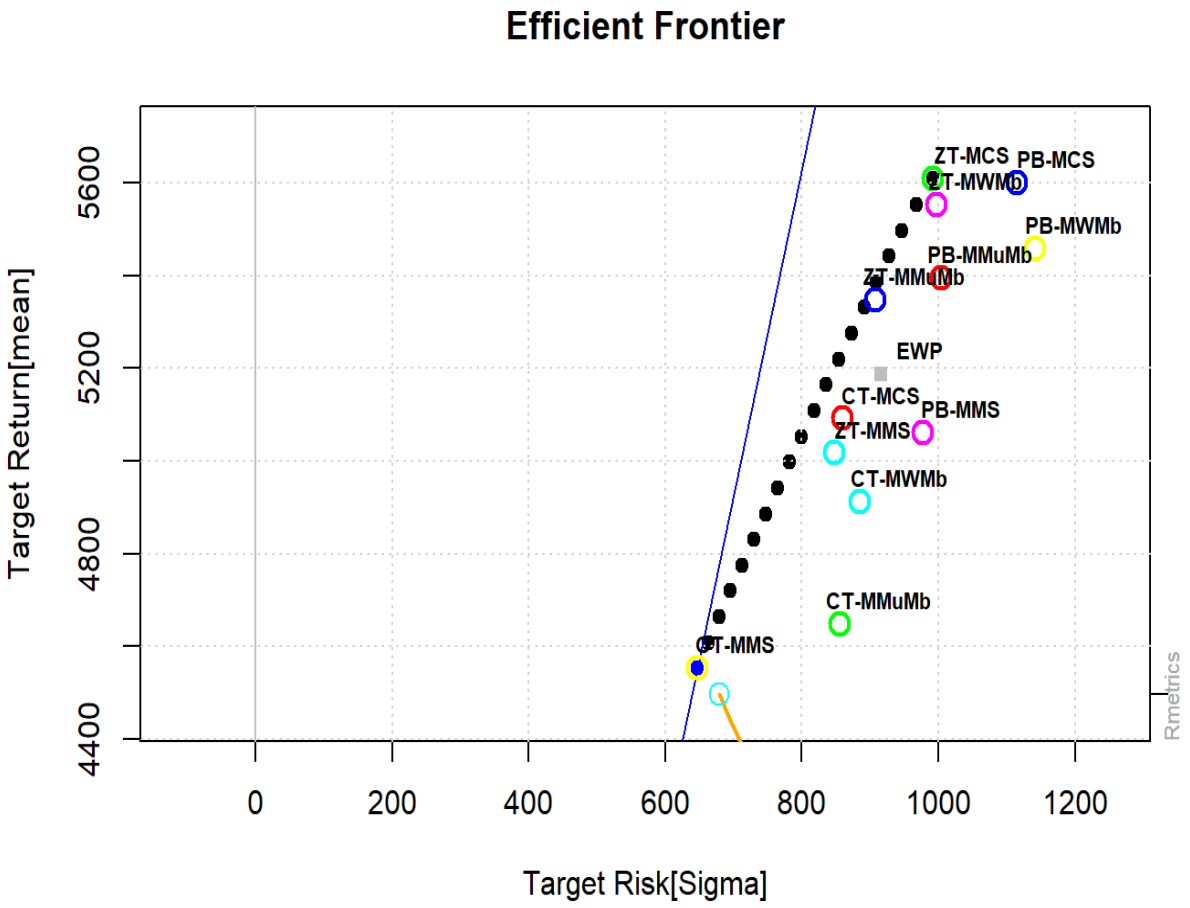

Figure A1: *Kharif* maize yield (kg ha^{-1}) fronter. Note: EWP with a square point represents the equally weighted portfolio (that is, each treatment has equal share of land). The orange line shows the lowest Sharpe ratio (return divided by target risk).

21 Table A1: Optimal weights for *kharif* maize yield frontier

Risk aversion scenarios (1=very risk averse; 20=risk neutral)	Target returns (kg ha^{-1})	Standard deviation (kg ha^{-1})	CT-MCS	CT-MMS	ZT-MCS	ZT-MMuMb
			Optimal proportions			
1	4552	647	0.00	1.00	0.00	0.00
2	4608	663	0.01	0.94	0.05	0.00
3	4663	679	0.02	0.89	0.10	0.00
4	4719	696	0.03	0.83	0.14	0.00
5	4774	713	0.02	0.77	0.17	0.03
6	4830	730	0.02	0.71	0.20	0.07
7	4886	747	0.01	0.65	0.23	0.11
8	4941	765	0.00	0.59	0.26	0.15
9	4997	782	0.00	0.53	0.28	0.18
10	5052	800	0.00	0.47	0.31	0.21
11	5108	818	0.00	0.41	0.34	0.25
12	5164	836	0.00	0.35	0.37	0.28
13	5219	854	0.00	0.29	0.40	0.31
14	5275	873	0.00	0.23	0.43	0.34
15	5330	891	0.00	0.17	0.45	0.38
16	5386	910	0.00	0.11	0.48	0.41
17	5441	928	0.00	0.05	0.51	0.44
18	5497	947	0.00	0.00	0.57	0.43
19	5553	968	0.00	0.00	0.79	0.21
20	5608	993	0.00	0.00	1.00	0.00

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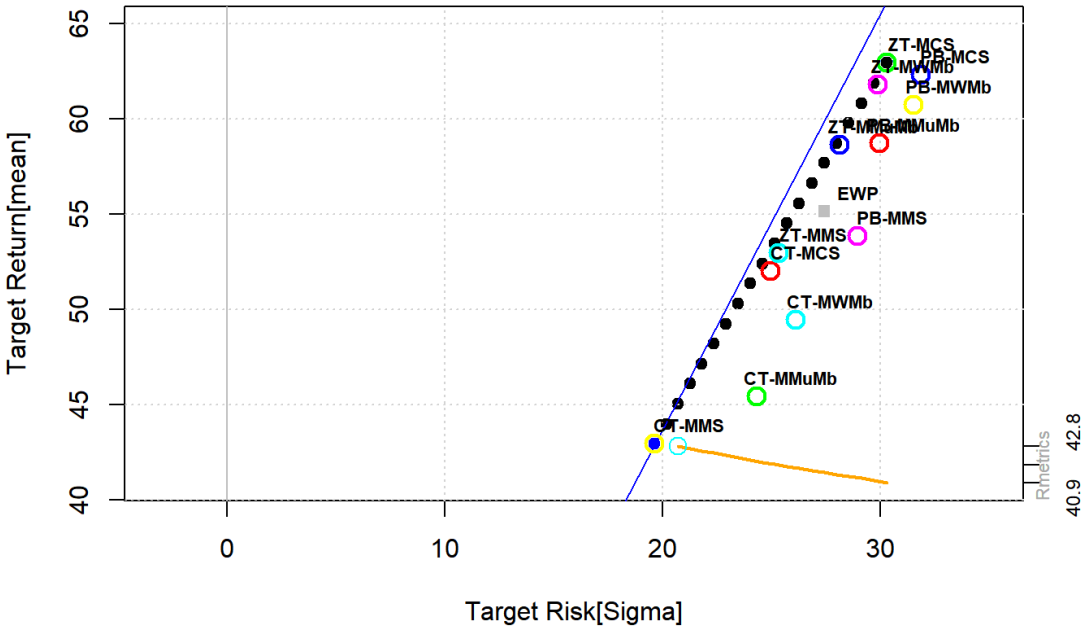

Figure A2: Possible maize net returns (000 INR ha^{-1}) portfolio of combined tillage and maize diversified systems.Note: Target returns, and target risk are in thousands of INR ha-1. EWP with a square point represents the equally weighted portfolio (that is, each treatment has equal share of land). The orange line shows the lowest sharpe ratio (return divided by target risk).

32 Table A2: Optimal hectarage weights based on *kharif* maize net returns frontiers

	Target returns	Standard deviation	CT-MMS	ZT-MCS	ZT-MMS	ZT-MMuMb	ZT-MWMb
	(000 INRha^{-1})	(000 INRha^{-1})	Optimal proportions				
1	42.92	19.63	1.00	0.00	0.00	0.00	0.00
2	43.97	20.16	0.94	0.00	0.01	0.00	0.05
3	45.02	20.70	0.89	0.00	0.00	0.00	0.11
4	46.08	21.24	0.83	0.00	0.00	0.00	0.17
5	47.13	21.79	0.78	0.08	0.00	0.00	0.14
6	48.19	22.34	0.73	0.15	0.00	0.00	0.12
7	49.24	22.90	0.68	0.23	0.00	0.00	0.09
8	50.30	23.46	0.63	0.30	0.00	0.01	0.07
9	51.35	24.01	0.57	0.35	0.00	0.04	0.04
10	52.40	24.58	0.51	0.40	0.00	0.07	0.02
11	53.46	25.14	0.45	0.45	0.00	0.10	0.00
12	54.51	25.70	0.39	0.48	0.00	0.12	0.00
13	55.57	26.27	0.34	0.51	0.00	0.15	0.00
14	56.62	26.84	0.28	0.54	0.00	0.18	0.00
15	57.68	27.41	0.22	0.57	0.00	0.21	0.00
16	58.73	27.98	0.16	0.60	0.00	0.24	0.00
17	59.78	28.55	0.10	0.63	0.00	0.26	0.00
18	60.84	29.12	0.04	0.67	0.00	0.29	0.00
19	61.89	29.70	0.00	0.76	0.00	0.24	0.00
20	62.95	30.30	0.00	1.00	0.00	0.00	0.00

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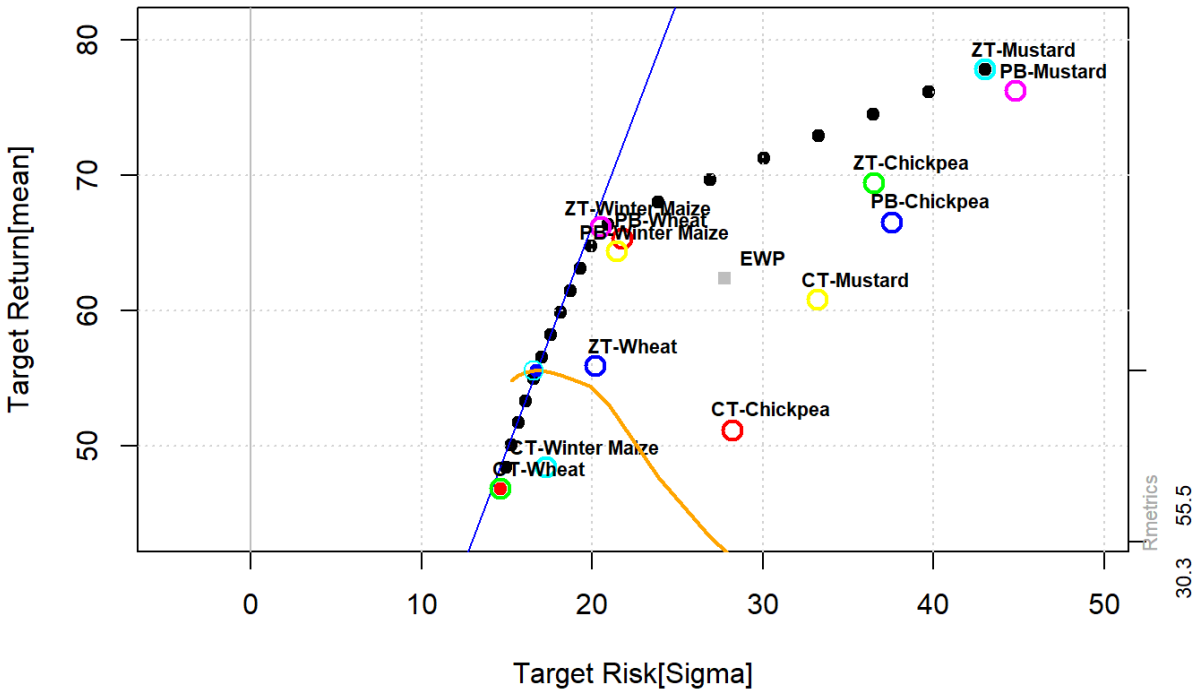

Figure A3: Net returns (000 INR ha^{-1}) frontier for *rabi* crops. Note: EWP with a square point represents the equally weighted portfolio (that is, each treatment has equal share of land). The orange line shows the lowest sharpe ratio (return divided by target risk).

41 Table A3: Optimal *rabi* crops net returns portfolio weights

Risk aversion scenarios (1=very risk averse; 20=risk neutral)	Target returns	Std.Dev	CT-Wheat	PB-Wheat	ZT-Mustard	ZT-Winter Maize
	(000 INR ha^{-1})	(000 INR ha^{-1})				
1	46.78	14.64	1	0	0	0
2	48.41	14.94	0.92	0	0	0.08
3	50.04	15.28	0.83	0	0	0.17
4	51.67	15.67	0.75	0	0	0.25
5	53.3	16.09	0.66	0	0	0.34
6	54.94	16.55	0.58	0	0	0.42
7	56.57	17.05	0.49	0	0	0.51
8	58.2	17.58	0.41	0	0	0.59
9	59.83	18.13	0.32	0	0	0.68
10	61.46	18.71	0.24	0	0	0.76
11	63.09	19.31	0.16	0	0	0.84
12	64.72	19.93	0.07	0.06	0	0.87
13	66.36	20.92	0	0	0.02	0.98
14	67.99	23.87	0	0	0.16	0.84
15	69.62	26.94	0	0	0.3	0.7
16	71.25	30.07	0	0	0.44	0.56
17	72.88	33.26	0	0	0.58	0.42
18	74.51	36.48	0	0	0.72	0.28
19	76.14	39.74	0	0	0.86	0.14
20	77.77	43.02	0	0	1	0

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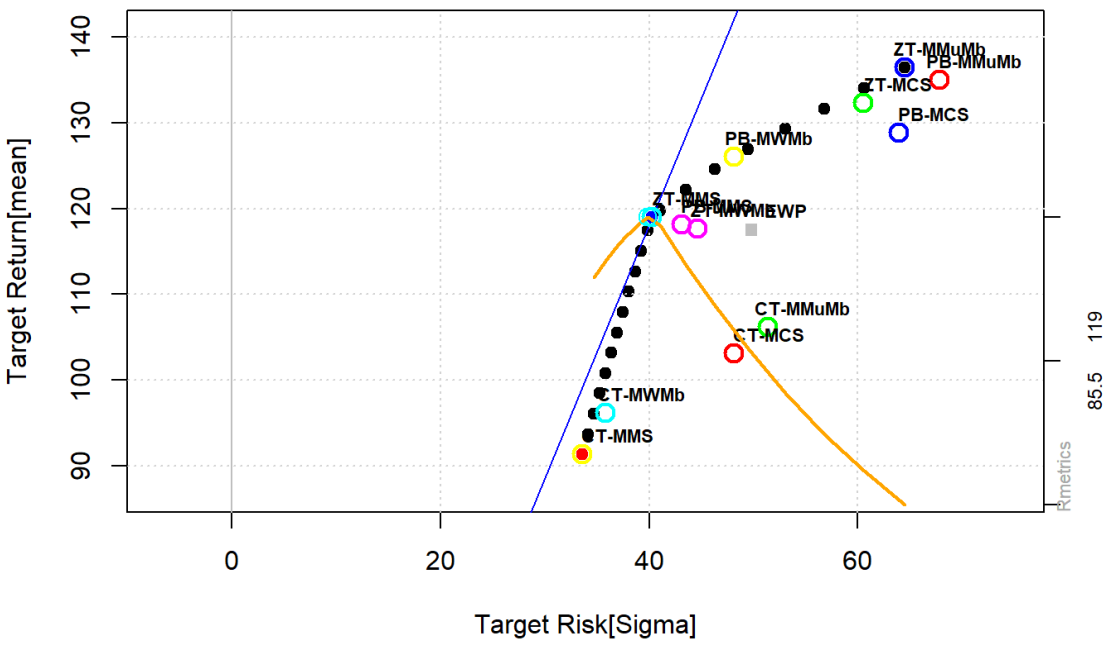

Figure A4: System net returns frontier (000 INR ha^{-1}). Note: EWP with a square point represents the equally weighted portfolio (that is, each treatment has equal share of land). The orange line shows the lowest sharpe ratio (return divided by target risk).

Table A4: System optimal weights (proportion), target return and risk (000 INR ha^{-1}).

Risk aversion scenarios (1=very risk averse; 20=risk neutral)	**Target return**	**Target risk (standard deviation)**	**CT-MMS**	**PB-MWMb**	**ZT-MMS**	**ZT-MMuMb**
			Optimal proportions			
1	91.32	33.62	1.00	0.00	0.00	0.00
2	93.69	34.15	0.91	0.00	0.09	0.00
3	96.06	34.69	0.83	0.00	0.17	0.00
4	98.44	35.23	0.74	0.00	0.26	0.00
5	100.81	35.79	0.66	0.00	0.34	0.00
6	103.18	36.35	0.57	0.00	0.43	0.00
7	105.56	36.92	0.49	0.00	0.51	0.00
8	107.93	37.50	0.40	0.00	0.60	0.00
9	110.31	38.09	0.32	0.00	0.68	0.00
10	112.68	38.68	0.23	0.00	0.77	0.00
11	115.05	39.28	0.14	0.00	0.86	0.00
12	117.43	39.88	0.06	0.00	0.94	0.00
13	119.80	41.03	0.00	0.11	0.89	0.00
14	122.17	43.54	0.00	0.45	0.55	0.00
15	124.55	46.31	0.00	0.79	0.21	0.00
16	126.92	49.48	0.00	0.91	0.00	0.09
17	129.29	53.09	0.00	0.68	0.00	0.32
18	131.67	56.81	0.00	0.46	0.00	0.54
19	134.04	60.63	0.00	0.23	0.00	0.77
20	136.41	64.51	0.00	0.00	0.00	1.00

Appendix B: Conditional value at risk (CVaR) for net returns

Table B1: *Kharif* maize returns frontier using mean-CVaR model [10%].

			Optimal weights						
Risk aversion scenarios (1=very risk averse; 20=risk neutral)	Mean (000 INR ha^{-1})	CVaR (000 INR ha^{-1})	CT-MMS	PB-MCS	PB-MMuMb	ZT-MCS	ZT-MMS	ZT-MMuMb	ZT-MWMb
1	42.92	-22.15	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2	43.97	-22.77	0.92	0.00	0.00	0.00	0.03	0.05	0.00
3	45.02	-23.19	0.86	0.00	0.00	0.00	0.02	0.12	0.00
4	46.08	-23.62	0.79	0.00	0.00	0.00	0.02	0.19	0.00
5	47.13	-24.05	0.73	0.00	0.00	0.00	0.02	0.26	0.00
6	48.19	-24.47	0.66	0.00	0.00	0.00	0.02	0.32	0.00
7	49.24	-24.90	0.59	0.00	0.00	0.00	0.01	0.39	0.00
8	50.30	-25.32	0.53	0.00	0.00	0.00	0.01	0.46	0.00
9	51.35	-25.75	0.46	0.00	0.00	0.00	0.01	0.53	0.00
10	52.40	-26.18	0.39	0.00	0.00	0.00	0.01	0.60	0.00
11	53.46	-26.60	0.33	0.00	0.00	0.00	0.00	0.67	0.00
12	54.51	-27.03	0.26	0.00	0.00	0.00	0.00	0.74	0.00
13	55.57	-27.45	0.20	0.00	0.00	0.00	0.00	0.80	0.00
14	56.62	-27.88	0.13	0.00	0.00	0.00	0.00	0.87	0.00
15	57.68	-28.30	0.06	0.00	0.00	0.00	0.00	0.94	0.00
16	58.73	-28.71	0.00	0.00	0.00	0.02	0.00	0.98	0.00
17	59.78	-29.03	0.00	0.00	0.00	0.27	0.00	0.73	0.00
18	60.84	-29.16	0.00	0.06	0.02	0.46	0.00	0.46	0.00
19	61.89	-29.06	0.00	0.17	0.00	0.60	0.00	0.21	0.02
20	62.95	-27.21	0.00	0.00	0.00	1.00	0.00	0.00	0.00

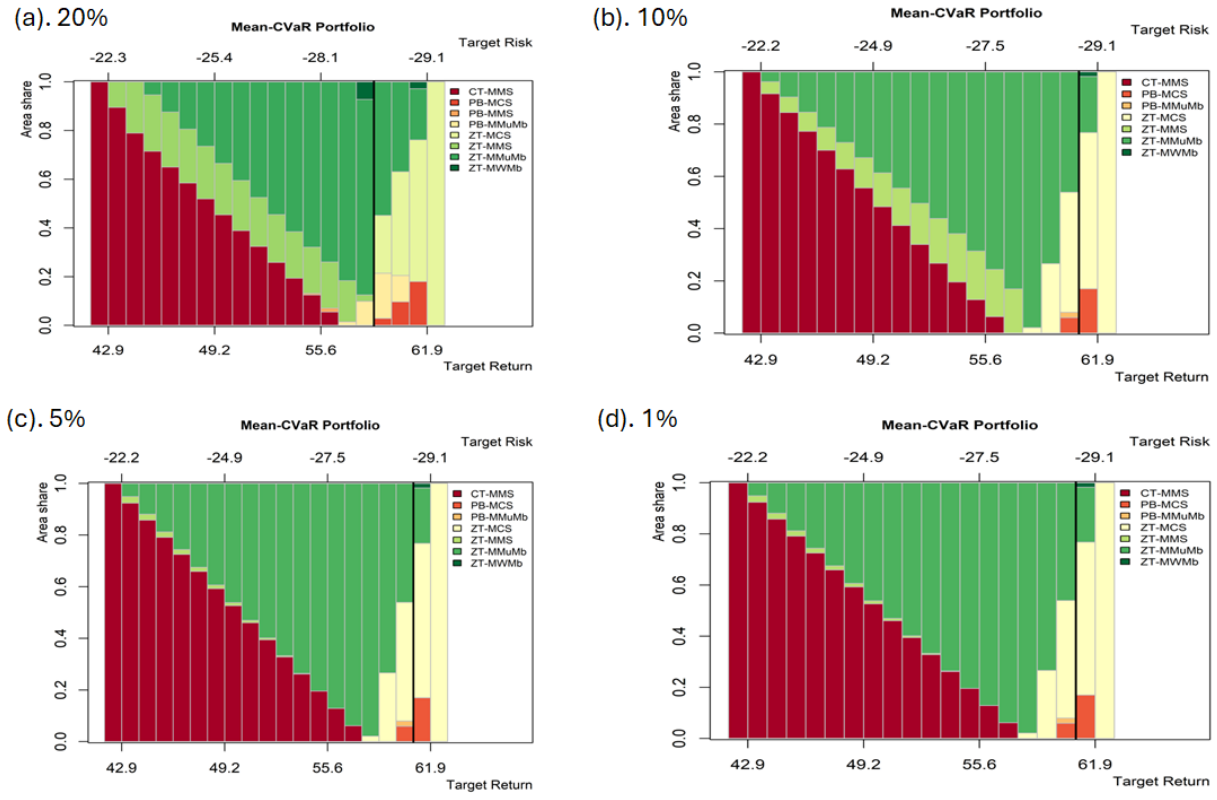

Figure B1: *Kharif* maize returns frontier optimal area allocation using mean-CVaR model at 20%, 10%, 5% and 1% levels.

Table B2: *Rabi* crops returns frontier using mean-CVaR model [10%]

			Optimal portfolio weights				
Risk aversion scenarios	Mean (000 INR ha^{-1})	CVaR (000 INR ha^{-1})	CT-Wheat	PB-Wheat	PB-Winter Maize	ZT-Mustard	ZT-Winter Maize
1	46.78	-15.91	1.00	0.00	0.00	0.00	0.00
2	48.41	-17.19	0.92	0.00	0.00	0.00	0.08
3	50.04	-18.48	0.83	0.00	0.00	0.00	0.17
4	51.67	-19.76	0.75	0.00	0.00	0.00	0.25
5	53.30	-21.05	0.66	0.00	0.00	0.00	0.34
6	54.94	-22.33	0.58	0.00	0.00	0.00	0.42
7	56.57	-23.62	0.49	0.00	0.00	0.00	0.51
8	58.20	-24.90	0.41	0.00	0.00	0.00	0.59
9	59.83	-26.19	0.32	0.00	0.00	0.00	0.68
10	61.46	-27.47	0.24	0.00	0.00	0.00	0.76
11	63.09	-28.76	0.16	0.00	0.00	0.00	0.84
12	64.72	-29.97	0.07	0.00	0.02	0.00	0.91
13	66.36	-29.81	0.00	0.09	0.00	0.03	0.88
14	67.99	-27.00	0.00	0.19	0.00	0.18	0.63
15	69.62	-24.19	0.00	0.30	0.00	0.32	0.38
16	71.25	-21.38	0.00	0.41	0.00	0.47	0.12
17	72.88	-17.78	0.00	0.39	0.00	0.61	0.00
18	74.51	-13.42	0.00	0.26	0.00	0.74	0.00
19	76.14	-9.06	0.00	0.13	0.00	0.87	0.00
20	77.77	-4.70	0.00	0.00	0.00	1.00	0.00

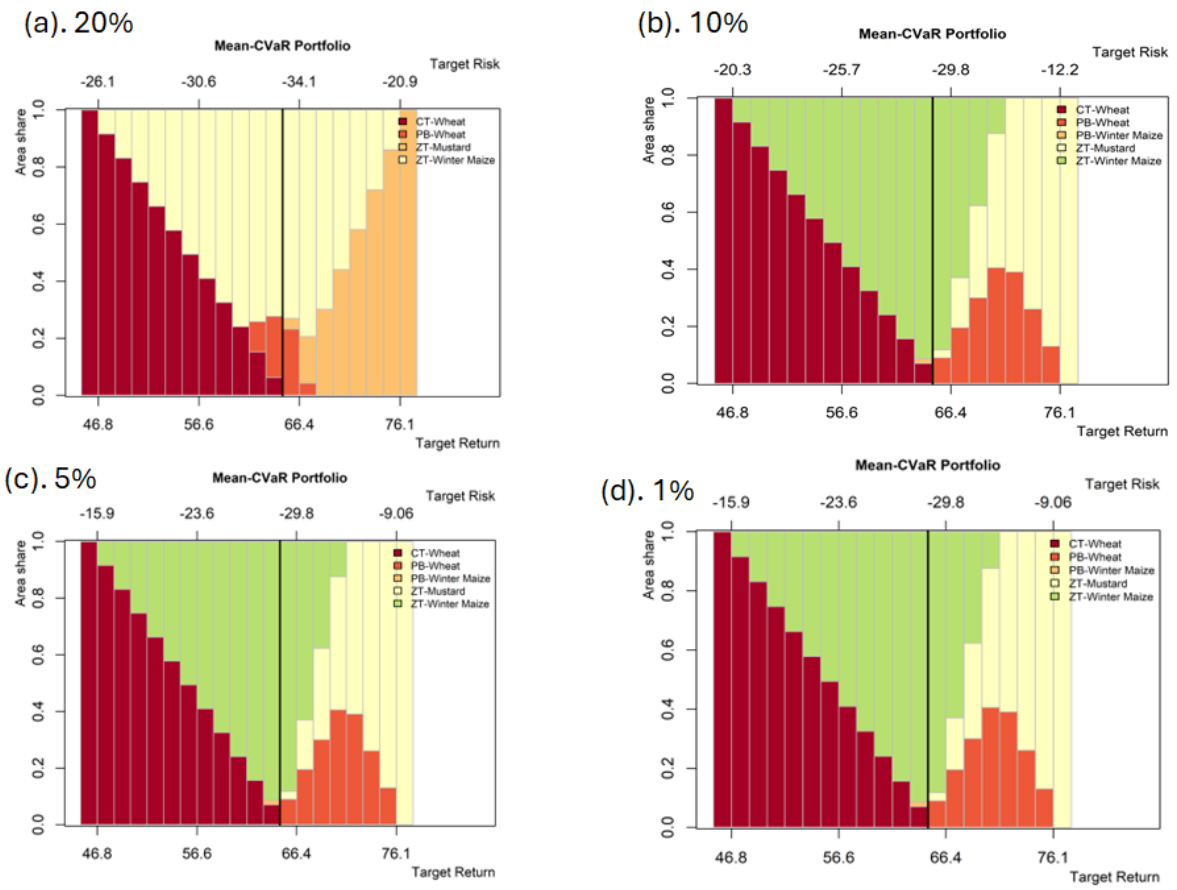

Figure B2: *Rabi* crops returns frontier optimal area allocation using mean-CVaR model at 20%, 10%, 5% and 1% levels.

74 Table B3: System returns frontier using mean-CVaR model [10%]

			Optimal portfolio weights				
Risk aversion scenarios (1=very risk averse, 20=risk neutral)	Mean (000 INR ha^{-1})	CvaR (000 INR ha^{-1})	CT-MMS	CT-MWMb	PB-MMS	PB-MWMb	ZT-MMuMb
1	91.32	-41.28	1.00	0.00	0.00	0.00	0.00
2	93.69	-44.04	0.52	0.48	0.00	0.00	0.00
3	96.06	-46.80	0.03	0.97	0.00	0.00	0.00
4	98.44	-48.15	0.00	0.90	0.10	0.00	0.00
5	100.81	-49.40	0.00	0.79	0.21	0.00	0.00
6	103.18	-50.65	0.00	0.68	0.32	0.00	0.00
7	105.56	-51.90	0.00	0.57	0.43	0.00	0.00
8	107.93	-53.16	0.00	0.47	0.53	0.00	0.00
9	110.31	-54.41	0.00	0.36	0.64	0.00	0.00
10	112.68	-55.66	0.00	0.25	0.75	0.00	0.00
11	115.05	-56.72	0.00	0.15	0.84	0.01	0.00
12	117.43	-57.22	0.00	0.06	0.88	0.07	0.00
13	119.80	-56.97	0.00	0.00	0.83	0.13	0.03
14	122.17	-55.31	0.00	0.00	0.65	0.23	0.12
15	124.55	-53.66	0.00	0.00	0.46	0.33	0.21
16	126.92	-52.00	0.00	0.00	0.28	0.42	0.30
17	129.29	-50.35	0.00	0.00	0.10	0.52	0.39
18	131.67	-46.35	0.00	0.00	0.00	0.46	0.54
19	134.04	-39.87	0.00	0.00	0.00	0.23	0.77
20	136.41	-33.38	0.00	0.00	0.00	0.00	1.00

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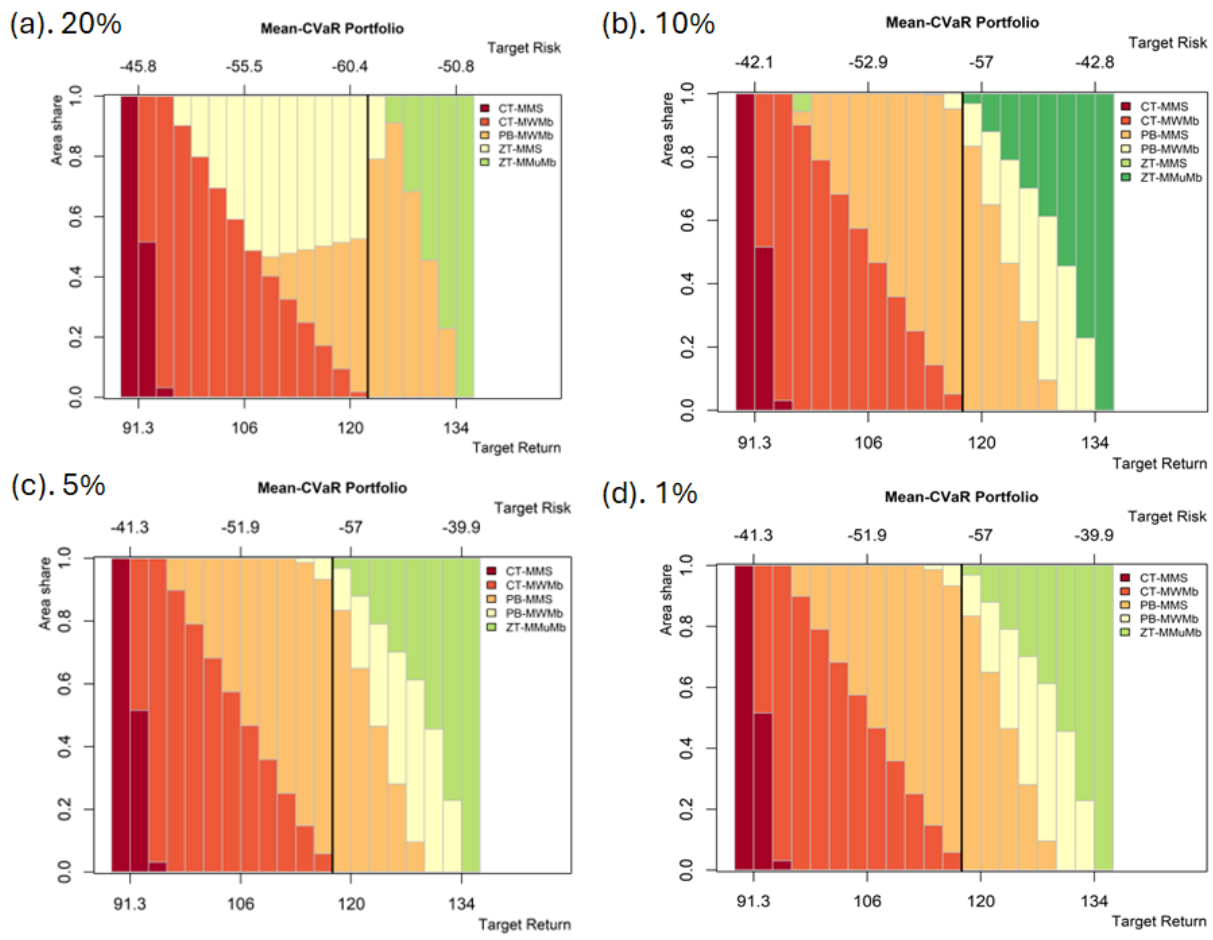

Figure B3: System returns frontier optimal area allocation using mean-CVaR model at 20%, 10%, 5% and 1% levels.

Appendix C: Summary tables

Table C1: Summary statistics of yield by treatment and seasons

		***Kharif* Yield (kg per ha)**			***Rabi* Yield (kg per ha)**		
Treatment	Tillage	*Kharif* crop	Mean	StdDev	*Rabi* crop	Mean	StdDev
CT-MCS	Conventional	Maize	5091.11	989.48	Chickpea	1737.84	392.23
CT-MMS	Conventional	Maize	4552.17	787.20	Mustard	2289.55	540.38
CT-MMuMb	Conventional	Maize	4647.51	950.18	Wheat	4181.15	726.66
CT-MWMb	Conventional	Maize	4911.92	976.01	Winter Maize	5208.54	861.80
PB-MCS	Bed planting	Maize	5598.95	1209.72	Chickpea	2043.94	525.81
PB-MMS	Bed planting	Maize	5060.79	1077.76	Mustard	2610.75	773.30
PB-MMuMb	Bed planting	Maize	5393.59	1076.12	Wheat	5093.34	946.39
PB-MWMb	Bed planting	Maize	5456.86	1239.79	Winter Maize	6150.62	899.05
ZT-MCS	Zero tillage	Maize	5608.15	1124.98	Chickpea	2130.30	487.13
ZT-MMS	Zero tillage	Maize	5016.56	1007.44	Mustard	2675.85	734.39
ZT-MMuMb	Zero tillage	Maize	5346.61	1008.08	Wheat	4546.88	897.87
ZT-MWMb	Zero tillage	Maize	5552.16	1121.89	Winter Maize	6246.63	890.00

84 Table C2: Summary statistics of yield by treatment and seasons

		***Kharif* net returns (INR per ha)**		***Kharif* net returns (INR per ha)**			***Kharif-Rabi* system net returns (INR per ha)**	
Treatment	*Kharif* crop	Mean	StdDev	*Rabi* crop	Mean	StdDev	Mean	StdDev
CT-MCS	Maize	52007.32	23301.02	Chickpea	51133.61	27549.99	103140.94	49910.75
CT-MMS	Maize	42915.94	18777.95	Mustard	60757.33	32690.70	91316.64	35050.96
CT-MMuMb	Maize	45429.74	22115.45	Wheat	46778.14	16019.49	106187.07	53835.01
CT-MWMb	Maize	49438.05	23747.54	Winter Maize	48400.70	18030.16	96216.19	38048.66
PB-MCS	Maize	62303.12	29036.62	Chickpea	66495.84	36840.74	128798.96	64692.69
PB-MMS	Maize	53858.39	25501.04	Mustard	76231.36	43843.37	118175.33	45657.51
PB-MMuMb	Maize	58738.51	27015.81	Wheat	65246.82	22981.95	134969.87	69749.89
PB-MWMb	Maize	60750.99	28770.94	Winter Maize	64316.94	21518.43	125997.80	49968.32
ZT-MCS	Maize	62947.15	27336.35	Chickpea	69349.41	35492.56	132296.56	61674.85
ZT-MMS	Maize	52935.50	23744.82	Mustard	77774.87	41884.40	119043.93	42440.26
ZT-MMuMb	Maize	58639.38	25900.84	Wheat	55876.98	21024.29	136414.25	66680.74
ZT-MWMb	Maize	61807.06	27078.70	Winter Maize	66108.42	20587.59	117684.03	46952.70

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Table C3: Shapiro Wilks test for normality

Variable	**Statistic**	**P-value**
Kharif yields	0.9649	1.29E-09
Rabi yields	0.9445	8.49E-13
Kharif net returns	0.9377	1.12E-13
Rabi net returns	0.9824	8.77E-06
System net returns	0.9641	9.26E-10