Climatic variations in tea growing regions & Vulnerability of tea plantations to climate change

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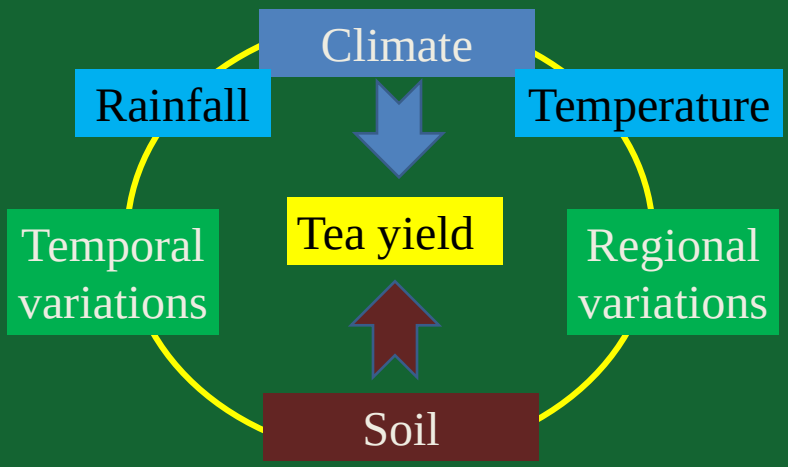
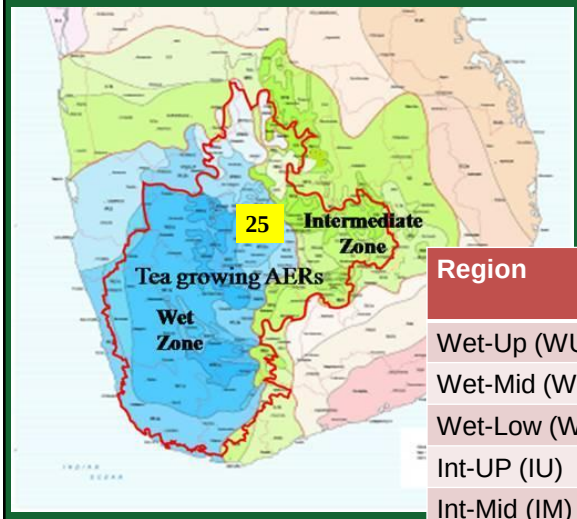
Climate & Tea yield



Agro-Ecological Regions (AER)



46 AERs demarcated based on rainfall and elevation

Region	Rainfall (mm/yr)	Elevation (m)
Wet-Up (WU)	>2500	>900
Wet-Mid (WM)	>2500	300-900
Wet-Low (WL)	>2500	<300
Int-UP (IU)	1750-2500	>900
Int-Mid (IM)	1750-2500	300-900

Agro-Ecological Regions (AER)...

AER	Locations
WU1	Watawala, Ambaganuw Korale,
WU 2a	Talawakelle, Hatton, N Eliya (West), Kothmale (East)
WU 2b	Bogawanthalawa, Kothmale (South), Udapalatha
WU 3	N Eliya (East)
WM 1a	Deniyaya, Maliboda, Kenilworth, Kotapola (North), Kalawana (South)
WM 1b	Rakwana, Kalawana (North)
WM 2a	Nawalapitiya, Gampola, Kothmale (West)
WM 2b	Peradeniya, Hemmathagama, Udunuwara, Yatinuwara, Aranayake
WM 3a	Tumpane, Mawanella (East), Hataraliyadda
WM3b	Kandy, Pathadumbara, Akurana, Harispattuwa, Pujapitiya, Panwila, Rattota (Mid), Ambagamuwakorale
WL 1a	Avissawella, Eheliyagoda, Ratnapura (West), Pelawatta, Nagoda, Akuressa (Noth) Pitabeddara, Niyagama, Tawalama, Elpitiya, Bulathsinhala, Ruwanwella, Dehiovita
WL1b	Matugama, Dodangoda, Bandaragama
WL 2a	Kalutara, Galle, Akuressa, Mulatiyana, Aturaliya, Yakkalamulla, Imaduwa, Akmeemana, Baddegama, Ambalangoda,
IU 1	Medadumbara (North), Panvila (North), Udadumbara (West)
IU 2	Ragala, Padiyapelella,Walapane, Hanguranketha (South), Passara (East)
IU 3a	Bandarawela (South), Haputale (East)
IU 3b	Imbulpe (Noth), Haputale (South), Haldummulla (North)
IU 3c	Ella, Haliela, Passara (South)
IU 3d	Rahangala, Welimada (West)
IU 3e	Welimada, Uva-paranagama (South), Haputale (North), Bandarawela (West)
IM 1a	Badulla, Hanguranketha (East), Walapane (North & East), Haliela (South), Passara (West)
IM 2a	Kolonne-korale, Weligapola (West), middle parts of Balangoda & Imbulpe, Haldummulla (Mid)
IM 2b	Imbulpe (East), Balangoda and Weligapola, Badalkumbura, Southern and western parts of Haldummulla Rattota (West), Middle parts of Ukuwela and Kundasale, Pathahewaheta (North)
IM 3a	Hangureanketha (North), Kundasale (South), Meda-dumbara (South)
IM 3c	Hanguranketha

Data collection & analysis

Collected data for 50 years: 1961-2010

1961-1990: Base period

1991-2010: Recent two decades

Rainfall

Developed monthly Rainfall surfaces for the Island & established rainfall for each AER

Maximum and Minimum Temperature :

Used available data in the Met Department representing main tea growing regions

Data collection & analysis….

Trend analysis of RF based on 4 monsoons

1st Inter-monsoon: *March-April*

South-west monsoon: *May-September*

2nd Inter-monsoon: *October-November*

North-east monsoon: *December-February*

Established *vulnerability indices* based on available data (Climate and soil)

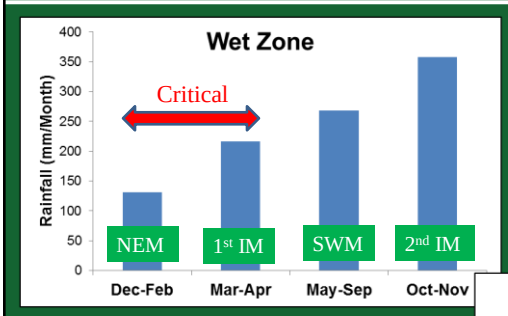
Identified vulnerable regions based on the indices

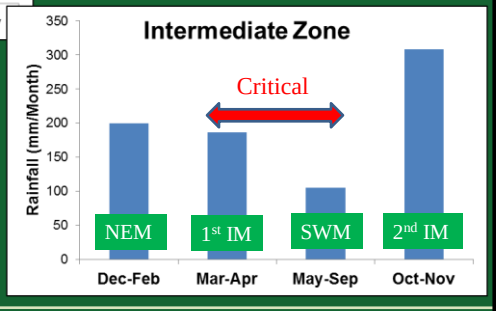
Identification of Vulnerable regions to CC

AER potentially vulnerable to Climate Change:

- *High temperatures (above optimum; 22°C)*
- *Low RF regions: Annual RF<2000mm/yr*
- *High rainfall variability (CV)*
- *Low RF during Critical Periods (<100mm/mo.)*
  - *CP-Wet Zone: Dec-April*
  - *CP-Int. Zone: March-Sept*
- *Significant negative trend of Annual RF*
- *Low RF during the recent two decades (CP)*
- *Poor soil conditions*

Monthly Rainfall during monsoons





Mean Temperatures

AER	Minimum Temp. ^{o}C	Maximum Temp. ^{o}C	Mean Temp. ^{o}C
WU 2a -Talawakelle	13.1	23.4	18.2
WU 3 – N'Eliya	11.5	20.1	15.8
IU 3c - Bandarawela	15.6	24.8	20.2
IM 1a - Badulla	18.4	28.7	23.5
WM3b - Katugastota	20.2	28.9	24.5
WL 1a - Ratnapura	22.9	32.0	27.4
WL 2a – Galle	24.1	29.2	26.6

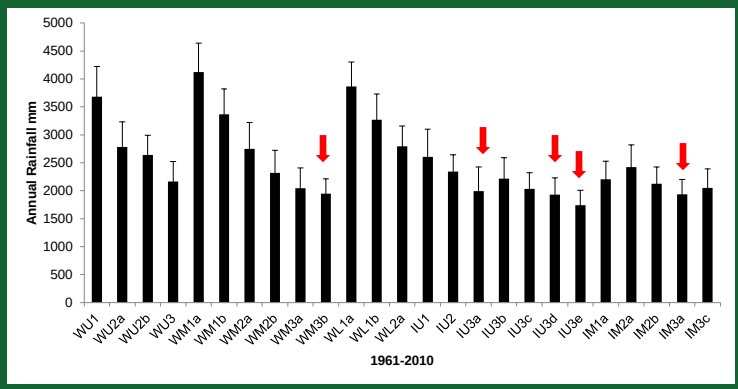
Wide variation of temperatures among AERs
Mean temperatures in Mid & Low country regions >22^{o}C

Variation of temperature: ^{o}C/yr

Location	Annual	NEM	1st inter-monsoon	SWM	2nd inter-monsoon
Badulla (Max)	0.028*	0.028*	0.040*	0.027*	0.020*
Badulla (Min)	0.010*	0.010	0.006	0.013*	0.010*
Bandarawela (Max)	0.020*	0.015*	0.017*	0.026*	0.013*
Bandarawela (Min)	0.026*	0.021*	0.029*	0.029*	0.025*
Galle (Max)	0.024*	0.029*	0.028*	0.018*	0.026*
Galle (Min)	0.020*	0.022*	0.023*	0.017*	0.024*
Katugastota (Max)	0.015*	0.017*	0.016	0.015*	0.010*
Katugastota (Min)	0.013*	0.011	0.014*	0.013*	0.014*
Nuwara Eliya (Max)	-0.001	-0.002	-0.013	0.005	-0.003
Nuwara Eliya (Min)	0.023*	0.026*	0.033*	0.018*	0.026*

Monthly temperature increased by around 0.5-2^{o}C during the last 50 years

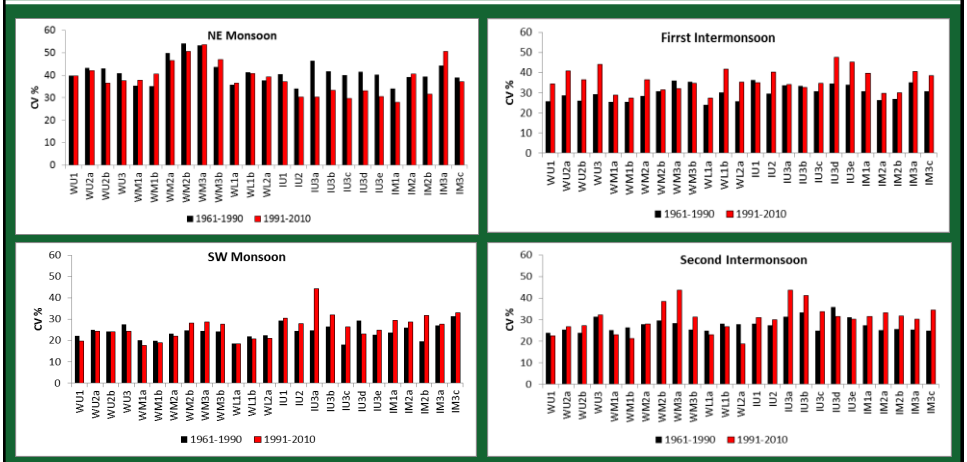
Mean Annual Rainfall (1961-2010)



Rainfall markedly vary among AERs

Lowest RF (<2000mm) in WM3b, IU3a, IU3d, IU3e, IM3a

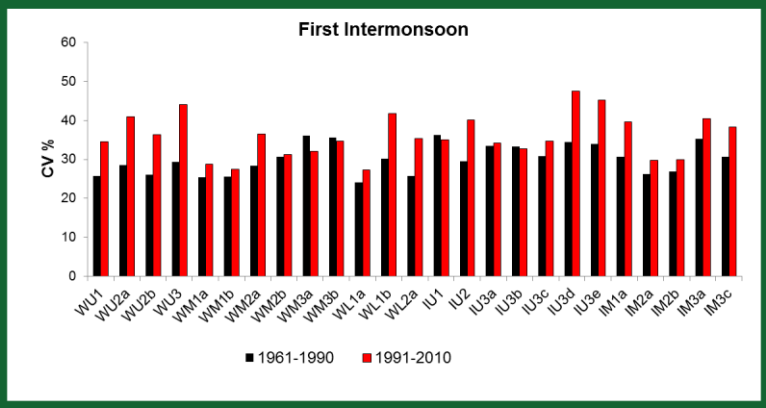
Change of Rainfall Variability (CV)



Variability (CV) of NEM RF is high

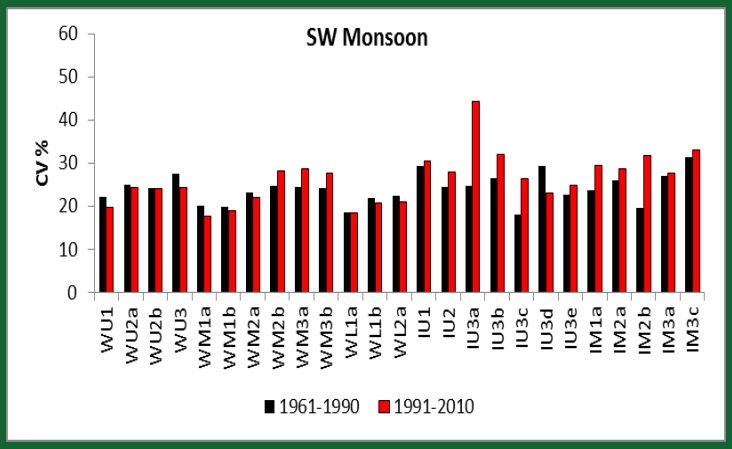
Inter-monsoon variability increased in the past two decades

Rainfall Variability...



Highest increase (>10%) in RF variability (CV):
WU2a, WU2b,WU3,WM2a,WL1b, IU2, IU3d, IU3e

Rainfall Variability...



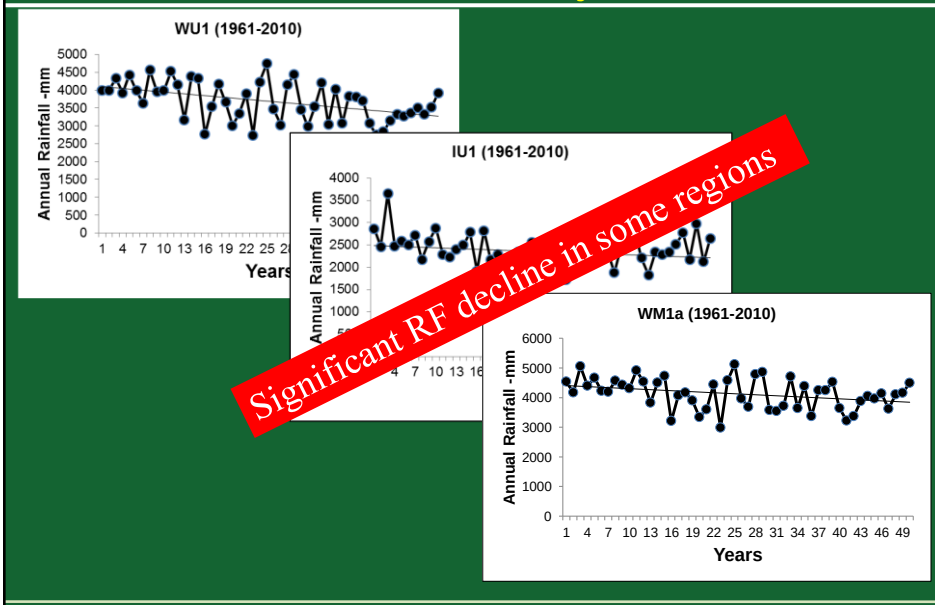
Highest increase (>10%) in RF variability (CV):
IU3a, IM2b

Mean monthly RF for different periods

AER	NEM	1st Inter - monsoon	SWM	2nd Inter-monsoon
WU1	130	249	397	398
WU 2a	112	174	294	297
WU 2b	127	212	233	323
WU 3	123	153	188	262
WM 1a	163	299	423	460
WM 1b	172	277	294	387
WM 2a	103	189	270	339
WM 2b	91	183	194	329
WM 3a	89	181	149	331
WM3b	146	143	123	303
WL 1a	173	303	365	454
WL 1b	139	244	305	413
WL 2a	137	201	251	347
IU 1	311	172	129	361
IU 2	274	167	106	313
IU 3a	146	223	90	325
IU 3b	159	265	104	343
IU 3c	186	187	99	298
IU 3d	158	153	117	259
IU 3e	166	145	87	243
IM 1a	289	156	75	302
IM 2a	157	256	138	336
IM 2b	177	233	83	339
IM 3a	151	135	125	288
IM 3c	211	139	104	289

Low RF during Critical period (<100mm/month) :
WM2b, WM3a, IU3a, IU3c, IU3e, IM1a, IM2b

Variation of Annual RF-mm/yr



Variation of Annual RF mm/yr ....

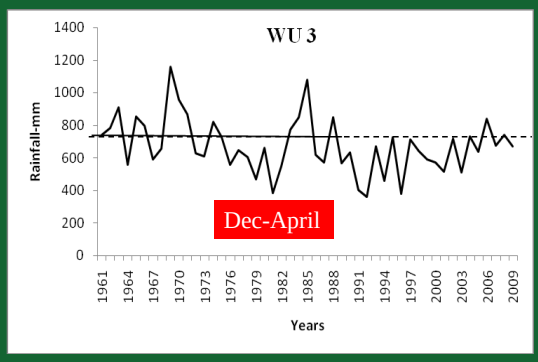
AER	Annual	NEM	1IM	SWM	2IM
WU1	-16.6*	-1.63	-0.1	-14.0*	-1.2
WU 2a	-4.49	-0.1	-0.5	-3.91	0.31
WU 2b	-6.94*	-0.1	0.0	-6.6*	-1.0
WU 3	-7.77*	-1.63	-1.2	-3.58	-1.1
WM 1a	-10.31*	-1.3	0.3	-8.23*	-0.9
WM 1b	-8.09	-0.27	-0.6	-7.03*	-0.6
WM 2a	-13.1*	-0.64	-0.1	-11.6*	-1.95
WM 2b	-10.9*	-0.8	0.2	-7.32*	-2.13
WM 3a	-11.8*	-1	-1.41	-6.93*	-1.7
WM3b	-4.8	-0.7	0.8	-4.21*	-0.6
WL 1a	-6.72	-0.1	-1.1	-6.22*	0.5
WL1b	-7.68	-0.14	-0.87	-6.9*	-0.1
WL 2a	-5.8	-0.8	-0.4	-4.76	-0.6
IU 1	-18.9*	-4.63	-1.72	-7.87*	-2.04
IU 2	-3.87	-1.3	0.1	-0.9	0.1
IU 3a	4.45	-0.1	1.8	0.7	2.94
IU 3b	-3.87	-0.6	0.1	-1.51	-0.9
IU 3c	0	-0.7	-0.0	-0.5	1.6
IU 3d	-6.52*	-2.95	-1.32	-0.07	-0.5
IU 3e	-3.41	-1.6	-0.06	0.5	0.3
IM 1a	-3.87	-1.4	0.02	-0.2	0.9
IM 2a	0	-0.6	2.45	-2.4	1.31
IM 2b	0	-0.3	1.71	-1.2	1.2
IM 3a	-6.91*	-1.4	0.7	-4.39*	-1.89
IM 3c	-10.2*	-3.27	-0.8	-4.43*	-1.6

Significant Negative trend:

WU1, WU2b, WU3, WM1a, WM2a, WM2b, WM3a, IU1, IU3d, IM3a, IM3c

Change of RF during the recent decades

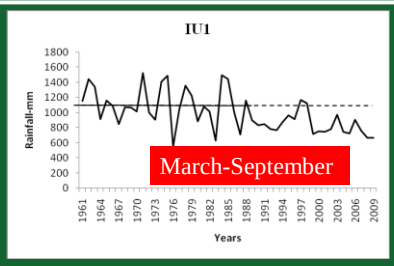
Rainfall of Critical months of the Wet zone (December-April)

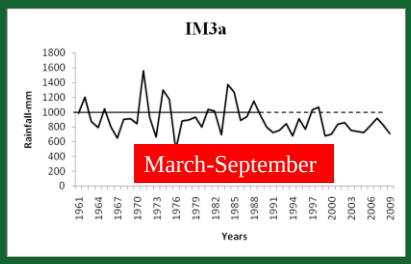


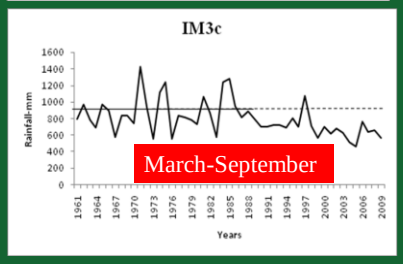
Significant decline in the past 2 decades- WU3

Change of RF during the recent decades...

Rainfall of Critical months of the Int. zone (March-September)







Significant decline in the past 2 decades- IU1, IM3a, IM3c

Vulnerability Indices - *RF of Wet Zone*

	RF Total	RF <100mm *Critical period*	RF trend *Annual*	Low RF *Critical period*	RF Variability	Score -No. of *	Vulnerability
WU1			*			1	
WU 2a					*	1	
WU 2b			*		*	2	*
WU 3			*	*	*	3	**
WM 1a			*			1	
WM 1b							
WM 2a			*		*	2	*
WM 2b		*	*			2	*
WM 3a		*	*			2	*
WM3b	*					1	
WL 1a							
WL1b					*	1	
WL 2a							

* *Vulnerable*

WU2b, WM2a, WM2b, WM3a

** *Highly Vul.*

WU3

Vulnerability Indices – *RF of Int. Zone*

	RF Total	RF<100mm *Critical period*	RF *Trend* Annual	Low RF *Critical period*	RF Variability	Score-No. of *	Vulnerability
IU 1	-	-	*	*	-	2	*
IU 2					*	1	
IU 3a	*	*			*	3	**
IU 3b							
IU 3c		*				1	
IU 3d	*		*		*	3	**
IU 3e	*	*			*	3	**
IM 1a		*				1	
IM 2a							
IM 2b		*			*	2	*
IM 3a	*		*	*		3	**
IM 3c			*	*		2	*

** Vulnerable*

IU1, IU3d, IM2b, IM3c

*** Highly Vul.*

IU3a, IU3e, IM3a

Vulnerability Indices: *Temperatures*

AER	Minimum Temp. °C	Maximum Temp. °C	Mean Temp. °C
WU 2a -Talawakelle	13.1	23.4	18.2
WU 3 – N'Eliya	11.5	20.1	15.8
IU 3c - Bandarawela	15.6	24.8	20.2
IM 1a - Badulla	18.4	28.7	23.5 *
WM3b - Katugastota	20.2	28.9	24.5 *
WL 1a - Ratnapura	22.9	32.0	27.4 **
WL 2a – Galle	24.1	29.2	26.6 **

Up country - *Not Vulnerable*
Mid country – *Vulnerable **
Low country- *Highly Vulnerable* **

Soil conditions

Soil properties	WL	WM	WU	IM	IU
Depth-cm	79.5	83.5	95.0	80.8	84.0
Gravel %	39.5	40.5	13.5	35.4	28.2
Sand %	51.3	62.6	40.0	53.6	48.6
Bulk Density	1.2	1.2	1.08	1.18	0.86
OC %	1.37	2.30	4.40	2.17	2.60

Amarathunga, SLD-2000

Vulnerability Indices: *Soil*

Soil properties	WL	WM	WU	IM	IU
Depth-cm	*	*	-	*	*
Gravel %	**	**	-	**	*
Sand %	*	*	-	*	*
Bulk Density	*	*	-	*	-
OC %	**	*	-	*	*
Score (No.*)	7	6	-	6	4
Vulnerability	**	**	-	**	*

** Vulnerable* IU *** Highly Vul.* WL, WM, IM

Overall Vulnerability - *Wet Zone*

	Rainfall	Temperature	Soil	Score-No of *	Overall Index
WU1					
WU 2a					
WU 2b	*			1	
WU 3	**			2	
WM 1a		*	**	3	*
WM 1b		*	**	3	*
WM 2a	*	*	**	4	**
WM 2b	*	*	**	4	**
WM 3a	*	*	**	4	**
WM3b		*	**	3	*
WL 1a		**	**	4	**
WL1b		**	**	4	**
WL 2a		**	**	4	**

** Vulnerable*

WM1a, WM1b, WM3b

*** Highly Vul.*

WM2a, WM2b, WM3a, WL1a, WL1b, WL2a

Overall Vulnerability - *Int. Zone*

	Rainfall changes	Temperature rise	Soil conditions	Score-No of *	Overall Index
IU 1	*		*	2	
IU 2			-		
IU 3a	**		*	3	*
IU 3b			-		
IU 3c			-		
IU 3d	**		*	3	*
IU 3e	**		*	3	*
IM 1a		*	**	3	*
IM 2a		*	**	3	*
IM 2b	*	*	**	4	**
IM 3a	**	*	**	5	**
IM 3c	*	*	**	4	**

** Vulnerable*

IU3a, IU3d, IU3e, IM1a, IM2a

*** Highly Vul.*

IM2b, IM3a, IM3c

Conclusions

Inter-monsoon RF variability has increased in the recent 2 decades

Annual RF & especially SWM (May-Sept) have significantly declined in the Wet zone & some Intermediate zone AERs during the last 50 years

Monthly temperatures increased by around 0.5-2^{o}C during the last 50 years

Conclusions....

WL1a, WL1b, WL2a, WM2a, WM2b, WM3a, IM2b, IM3a and IM3c are highly vulnerable to CC

WM1a, WM1b, WM3b, IM1a, IM2a, IU3a, IU3d and IU3e are also vulnerable to CC

Tea growers should adopt appropriate measures to minimize adverse impacts of CC on tea yield and quality.

Thank you

Highly Vulnerable regions...

AER	Locations
WL 1a	Avissawella, Eheliyagoda, Ratnapura (West), Pelawatta, Nagoda, Akuressa (North) Pitabeddara, Niyagama, Tawalama, Elpitiya, Bulathsinhala, Ruwanwella, Dehiovita
WL1b	Matugama, Dodangoda, Bandaragama
WL 2a	Kalutara, Galle, Akuressa, Mulatiyana, Aturaliya, Yakkalamulla, Imaduwa, Akmeemana, Baddegama, Ambalangoda,
WM 2a	Nawalapitiya, Gampola, Kothmale (West)
WM 2b	Peradeniya, Hemmathagama, Udunuwara, Yatinuwara, Aranayake
WM 3a	Tumpane, Mawanella (East), Hataraliyadda
IM 2b	Imbulpe (East), Balangoda and Weligapola, Badalkumbura, Southern and western parts of Haldummulla, Rattota (West), Middle parts of Ukuwela and Kundasale, Pathahewaheta (North)
IM 3a	Hangureanketha (North), Kundasale (South), Meda-dumbara (South)
IM 3c	Hanguranketha

Vulnerable regions...

AER	Locations
WM 1a	Deniyaya, Maliboda, Kenilworth, Kotapola (North), Kalawana (South)
WM 1b	Rakwana, Kalawana (North)
WM3b	Kandy, Pathadumbara, Akurana, Harispattuwa, Pujapitiya, Panwila, Rattota (Mid), Ambagamuwakorale
IU 3a	Bandarawela (South), Haputale (East)
IU 3d	Rahangala, Welimada (West)
IU 3e	Welimada, Uwa-paranagama (South), Haputale (Noth), Bandarawela (West)
IM 1a	Badulla, Hanguranketha (East), Walapane (Noth & East), Haliela (South), Passara (West)
IM 2a	Kolonne-korale, Weligapola (West), middle parts of Balangoda & Imbulpe, Haldummulla (Mid)