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APPENDICES

APPENDIX 01: - Available Climate Models and Climate Extremes over South Asia

Table A1-1 Climate Models and Their Resolutions

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
1: BCC-CM1, 2005	Beijing Climate Center, China	top = 25 hPa T63 (1.9° x 1.9°) L16 Dong et al., 2000; CSMD, 2005; Xu et al., 2005	1.9° x 1.9° L30 depth, free surface Jin et al., 1999	no rheology or leads Xu et al., 2005	heat, momentum Yu and Zhang, 2000; CSMD, 2005	layers, canopy, routing CSMD, 2005
2: BCCR-BCM2.0, 2005	Bjerknes Centre for Climate Research, Norway	top = 10 hPa T63 (1.9° x 1.9°) L31 Déqué et al., 1994	0.5°–1.5° x 1.5° L35 density, free surface Bleck et al., 1992	rheology, leads Hibler, 1979; Harder, 1996	no adjustments Furevik et al., 2003	Layers, canopy, routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
3: CCSM3, 2005	National Center for Atmospheric Research, USA	top = 2.2 hPa T85 (1.4° x 1.4°) L26 Collins et al., 2004	0.3°–1° x 1° L40 depth, free surface Smith and Gent, 2002	rheology, leads Briegleb et al., 2004	no adjustments Collins et al., 2006	layers, canopy, routing Oleson et al., 2004; Branstetter, 2001
4: CGCM3.1(T47), 2005	Canadian Centre for Climate Modelling and Analysis, Canada	top = 1 hPa T47 (~2.8° x 2.8°) L31 McFarlane et al., 1992; Flato, 2005	1.9° x 1.9° L29 depth, rigid lid Pacanowski et al., 1993	rheology, leads Hibler, 1979; Flato and Hibler, 1992	heat, freshwater Flato, 2005	layers, canopy, routing Verseghy et al., 1993
5: CGCM3.1(T63), 2005		top = 1 hPa T63 (~1.9° x 1.9°) L31 McFarlane et al., 1992; Flato 2005	0.9° x 1.4° L29 depth, rigid lid Flato and Boer, 2001; Kim et al., 2002	rheology, leads Hibler, 1979; Flato and Hibler, 1992	heat, freshwater Flato, 2005	layers, canopy, routing Verseghy et al., 1993
6: CNRM-CM3, 2004	Météo-France/Centre National de Recherches Météorologiques, France	top = 0.05 hPa T63 (~1.9° x 1.9°) L45 Déqué et al., 1994	0.5°–2° x 2° L31 depth, rigid lid Madec et al., 1998	rheology, leads Hunke-Dukowicz, 1997; Salas-Mélia, 2002	no adjustments Terray et al., 1998	layers, canopy,routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
7: CSIRO-MK3.0, 2001	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia	top = 4.5 hPa T63 (~1.9° x 1.9°) L18 Gordon et al., 2002	0.8° x 1.9° L31 depth, rigid lid Gordon et al., 2002	rheology, leads O'Farrell, 1998	no adjustments Gordon et al., 2002	layers, canopy Gordon et al., 2002
8: ECHAM5/MPI-OM, 2005	Max Planck Institute for Meteorology, Germany	top = 10 hPa T63 (~1.9° x 1.9°) L31 Roeckner et al., 2003	1.5° x 1.5° L40 depth, free surface Marsland et al., 2003	rheology, leads Hibler, 1979; Semtner, 1976	no adjustments Jungclaus et al., 2005	bucket, canopy, routing Hagemann, 2002; Hagemann and Dümenil-Gates, 2001
9: ECHO-G, 1999	Meteorological Institute of the University of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	top = 10 hPa T30 (~3.9° x 3.9°) L19 Roeckner et al., 1996	0.5°–2.8° x 2.8° L20 depth, free surface Wolff et al., 1997	rheology, leads Wolff et al., 1997	heat, freshwater Min et al., 2005	bucket, canopy, routing Roeckner et al., 1996; Dümenil and Todini, 1992

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
10: FGOALS-g1.0, 2004	National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/Institute of Atmospheric Physics, China	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Wang et al., 2004	1.0° x 1.0° L16 eta, free surface Jin et al., 1999; Liu et al., 2004	rheology, leads Briegleb et al., 2004	no adjustments Yu et al., 2002, 2004	layers, canopy, routing Bonan et al., 2002
11: GFDL-CM2.0, 2005	U.S. Department of Commerce/ National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory (GFDL), USA	top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004	0.3°–1.0° x 1.0° depth, free surface Gnanadesikan et al., 2004	rheology, leads Winton, 2000; Delworth et al., 2006	no adjustments Delworth et al., 2006	bucket, canopy, routing Milly and Shmakin, 2002; GFDL GAMDT, 2004
12: GFDL-CM2.1, 2005		top = 3 hPa 2.0° x 2.5° L24 GFDL GAMDT, 2004 with semi-Lagrangian transports	0.3°–1.0° x 1.0° depth, free surface Gnanadesikan et al., 2004	rheology, leads Winton, 2000; Delworth et al., 2006	no adjustments Delworth et al., 2006	bucket, canopy, routing Milly and Shmakin, 2002; GFDL GAMDT, 2004
13: GISS-AOM, 2004	National Aeronautics and Space Administration (NASA)/ Goddard Institute for Space Studies (GISS), USA	top = 10 hPa 3° x 4° L12 Russell et al., 1995; Russell, 2005	3° x 4° L16 mass/area, free surface Russell et al., 1995; Russell, 2005	rheology, leads Flato and Hibler, 1992; Russell, 2005	no adjustments Russell, 2005	layers, canopy, routing Abramopoulos et al., 1988; Miller et al., 1994
14: GISS-EH, 2004		top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006	2° x 2° L16 density, free surface Bleck, 2002	rheology, leads Liu et al., 2003; Schmidt et al., 2004	no adjustments Schmidt et al., 2006	layers, canopy, routing Friend and Kiang, 2005
15: GISS-ER, 2004	NASA/GISS, USA	top = 0.1 hPa 4° x 5° L20 Schmidt et al., 2006	4° x 5° L13 mass/area, free surface Russell et al., 1995	rheology, leads Liu et al., 2003; Schmidt et al., 2004	no adjustments Schmidt et al., 2006	layers, canopy, routing Friend and Kiang, 2005
16: INM-CM3.0, 2004	Institute for Numerical Mathematics, Russia	top = 10 hPa 4° x 5° L21 Alekseev et al., 1998; Galin et al., 2003	2° x 2.5° L33 sigma, rigid lid Diansky et al., 2002	no rheology or leads Diansky et al., 2002	regional freshwater Diansky and Volodin, 2002; Volodin and Diansky, 2004	layers, canopy, no routing Alekseev et al., 1998; Volodin and Lykosoff, 1998
17: IPSL-CM4, 2005	Institut Pierre Simon Laplace, France	top = 4 hPa 2.5° x 3.75° L19 Hourdin et al., 2006	2° x 2° L31 depth, free surface Madec et al., 1998	rheology, leads Fichefet and Morales Maqueda, 1997; Goosse and Fichefet, 1999	no adjustments Marti et al., 2005	layers, canopy, routing Krinner et al., 2005
18: MIROC3.2(hires), 2004	Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	top = 40 km T106 (~1.1° x 1.1°) L56 K-1 Developers, 2004	0.2° x 0.3° L47 sigma/depth, free surface K-1 Developers, 2004	rheology, leads K-1 Developers, 2004	no adjustments K-1 Developers, 2004	layers, canopy, routing K-1 Developers, 2004; Oki and Sud, 1998
19: MIROC3.2(medres), 2004		top = 30 km T42 (~2.8° x 2.8°) L20 K-1 Developers, 2004	0.5°–1.4° x 1.4° L43 sigma/depth, free surface K-1 Developers, 2004	rheology, leads K-1 Developers, 2004	no adjustments K-1 Developers, 2004	layers, canopy, routing K-1 Developers, 2004; Oki and Sud, 1998

Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution[a] References	Ocean Resolution[b] Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
20: MRI-CGCM2.3.2, 2003	Meteorological Research Institute, Japan	top = 0.4 hPa T42 (~2.8° x 2.8°) L30 Shibata et al., 1999	0.5°–2.0° x 2.5° L23 depth, rigid lid Yukimoto et al., 2001	free drift, leads Mellor and Kantha, 1989	heat, freshwater, momentum (12°S–12°N) Yukimoto et al., 2001; Yukimoto and Noda, 2003	layers, canopy, routing Sellers et al., 1986; Sato et al., 1989
21: PCM, 1998	National Center for Atmospheric Research, USA	top = 2.2 hPa T42 (~2.8° x 2.8°) L26 Kiehl et al., 1998	0.5°–0.7° x 1.1° L40 depth, free surface Maltrud et al., 1998	rheology, leads Hunke and Dukowicz 1997, 2003; Zhang et al., 1999	no adjustments Washington et al., 2000	layers, canopy, no routing Bonan, 1998
22: UKMO-HadCM3, 1997	Hadley Centre for Climate Prediction and Research/Met Office, UK	top = 5 hPa 2.5° x 3.75° L19 Pope et al., 2000	1.25° x 1.25° L20 depth, rigid lid Gordon et al., 2000	free drift, leads Cattle and Crossley, 1995	no adjustments Gordon et al., 2000	layers, canopy, routing Cox et al., 1999
23: UKMO-HadGEM1, 2004		top = 39.2 km ~1.3° x 1.9° L38 Martin et al., 2004	0.3°–1.0° x 1.0° L40 depth, free surface Roberts, 2004	rheology, leads Hunke and Dukowicz, 1997; Semtner, 1976; Lipscomb, 2001	no adjustments Johns et al., 2006	layers, canopy, routing Essery et al., 2001; Oki and Sud, 1998

Table A1-2 Extreme Climate Indices used for Extreme Analysis over South Asia

Code	Indicator Name	Definition	Units
FD0	Frost days	Annual count when TN (daily minimum temperature < 25°C	Days
SU25	Summer Days	Annual count when TN (daily maximum temperature > 25°C	Days
TR20	Tropical Nights	Annual count when TN (daily minimum temperature > 20°C	Days
GSL	Growing season length	Annual count between first span of at least 6 days with TG > 5°C and first span after 1st July of 6 days with TG < 5°C, where TG is daily mean temperature	Days
TXx	Max Tmax	Annual maximum value of daily maximum temperature	°C
TNx	Max Tmin	Annual maximum of daily minimum temperature	°C
TXn	Min Tmax	Annual minimum value of daily maximum temperature	°C
TNn	Min Tmin	Annual minimum value of daily minimum temperature	°C
TN10p	Cool nights	Percentage of days when TN < 10th percentile	Days
TX10p	Cool days	Percentage of days when TX < 10th percentile	Days
TN90p	Warm nights	Percentage of days when TN > 90th percentile	Days
TX90p	Warm days	Percentage of days when TX > 90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN < 10th percentile	Days
DTR	Diurnal temperature range	Annual mean difference between TX and TN	°C
ETR	Extreme temperature range	Annual difference between highest TX and lowest TN	°C
R10	Number of heavy precipitation days	Annual count of days when rainfall ≥ 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when rainfall ≥ 20mm	Days
RX1day	Maximum 1-day precipitation amount	Annual maximum 1-day precipitation	mm
RX5day	Maximum 1-day precipitation amount	Annual maximum consecutive 1-day precipitation	mm
R95p	Very wet days	Annual total PRCP when daily rainfall > 95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when daily rainfall > 99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (daily rainfall ≥ 1mm)	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as daily rainfall ≥ 1mm) in the year	mm/day
R95PT	Annual contribution from very wet days	(R95p/PRCPTOT) x 100%	%
CDD	Consecutive dry days	Maximum number of consecutive days with rainfall < 1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with rainfall ≥ 1mm	Days

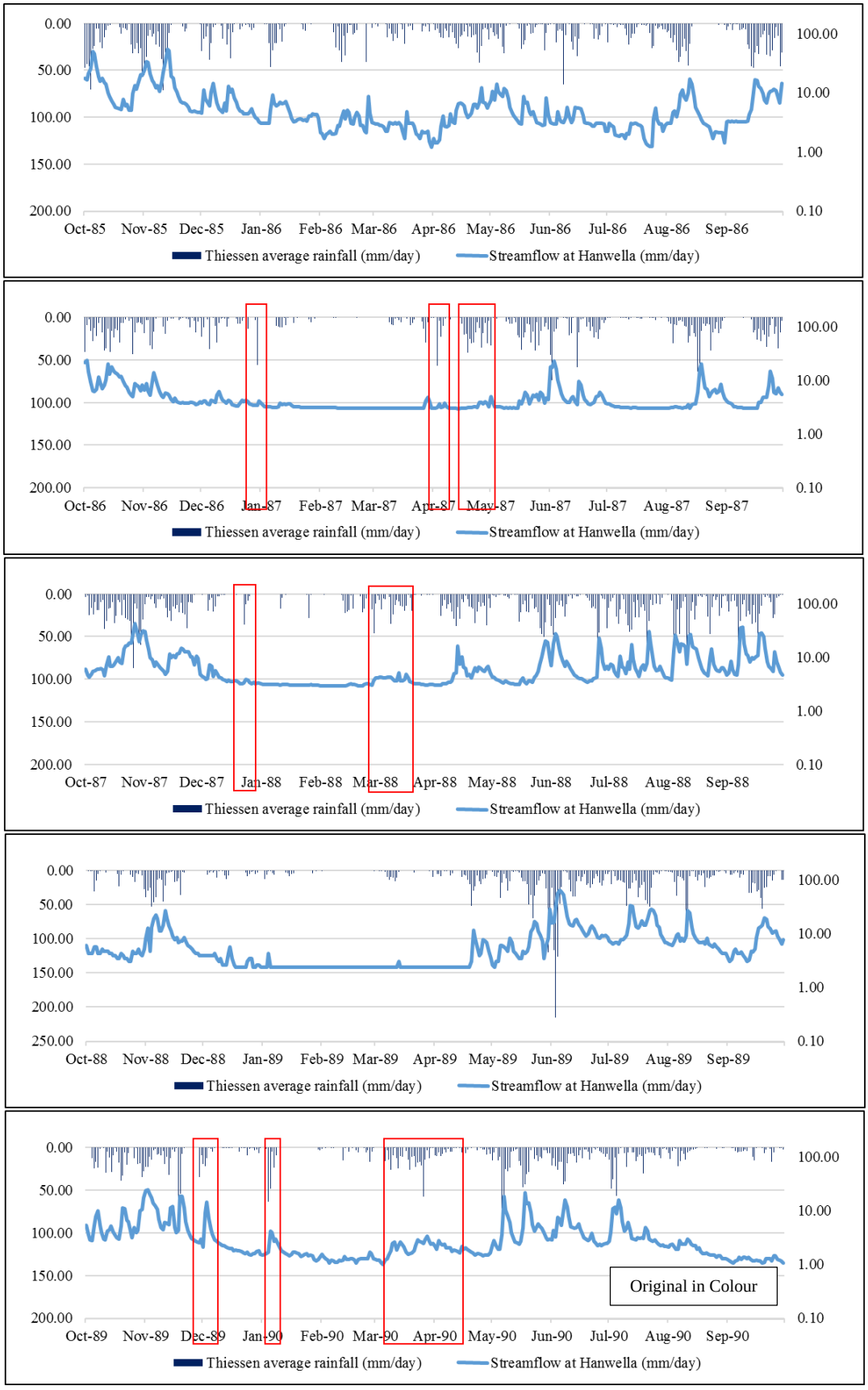
Table A1-3 Trends of Temperature Indices for Specific Regions over South Asia (Asterisks * denote significant trends at 95% level)

Index	Overall	Sri Lanka	Tropical Region (excluding Sri Lanka)	Greater Himalayan Region	Eastern Himalayan Region	Thar/ Rajasthan desert region
CSDI	-0.17*	-0.08*	-0.16*	0.11	-0.38	-0.33*
WSDI	.010	0.42*	0.05	0.14	0.41*	0.09
DTR	-0.00	-0.01	-0.01	0.08*	0.02*	-0.02
ETR	0.01	-0.03	0.01	0.09	-0.08	0.05
SU25	0.20*	0.19	0.11	0.40	1.10*	0.39*
TN10p	-0.19*	-0.25*	-0.20*	0.15*	-0.29*	-0.29*
TN90p	0.12*	0.33*	0.11	-0.13	0.14	0.17*
TNn	0.01	0.04*	0.00	-0.01	0.02	0.05*
TNx	-0.01	0.01*	0.00	-0.01*	0.02	0.02
TR20	0.04	0.26	0.10	-0.43*	0.70*	0.17
TX10p	-0.14*	-0.24*	-0.14*	-0.03	-0.22*	-0.02
TX90p	0.16*	0.44*	0.14*	0.17*	0.41*	0.10
TXn	-0.02*	0.02	-0.01	-0.03	-0.04*	-0.01
TXx	0.01	0.04*	0.00	0.08	0.06*	0.05*

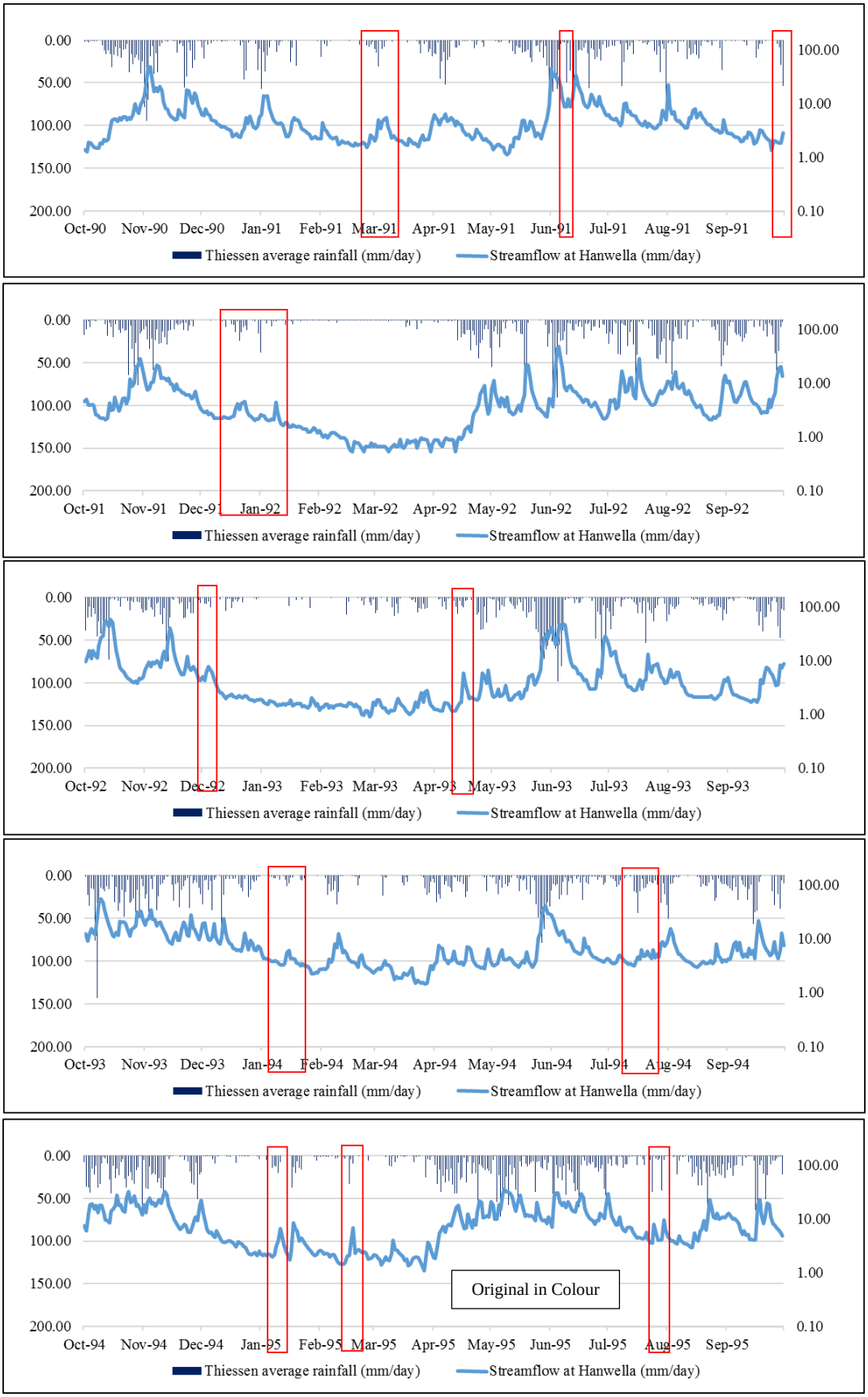
Table A1-3 Trends of Precipitation Indices for Specific Regions over South Asia (Asterisks * denote significant trends at 95% level)

Index	Overall	Sri Lanka	Tropical Region (excluding Sri Lanka)	Greater Himalayan Region	Eastern Himalayan Region	Thar/ Rajasthan desert region
CDD	-0.52*	0.23*	-0.60*	-0.09	-0.25	-0.67*
CWD	.01	-0.03	-0.00	0.01	0.01	-0.02
PRCPTOT	2.97*	-3.82	4.27*	6.05*	1.05	0.13
R10mm	0.09*	-0.12	0.10*	0.18*	0.04	0.01
R20mm	0.05*	-0.04	0.07*	0.10*	0.01	0.00
R95p	0.63	-0.66	1.02	2.06	-0.16	0.69
R99p	0.20	-0.60	0.34	1.09*	-0.31	0.09
RX1day	0.08	0.02	0.25*	0.34	-0.12	0.08
RX5day	0.07	-0.23	0.35	0.96	-0.28	0.04
SDII	-0.02*	0.02*	-0.02	0.02	-0.01	0.01

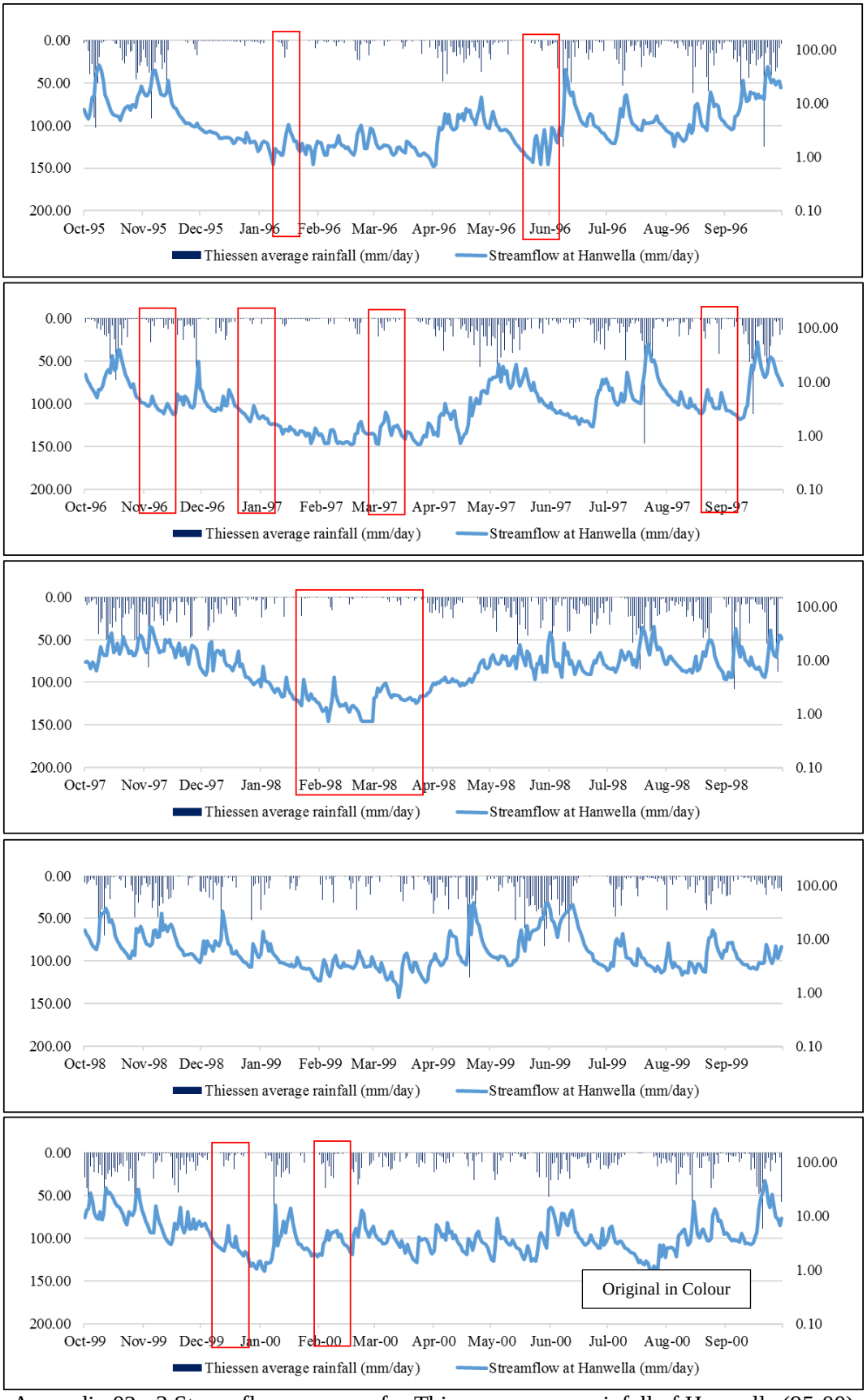
APPENDIX 02: - Thiessen Weighted Rainfall and Streamflow Comparison (Visual Checking – Hanwella Watersheds)



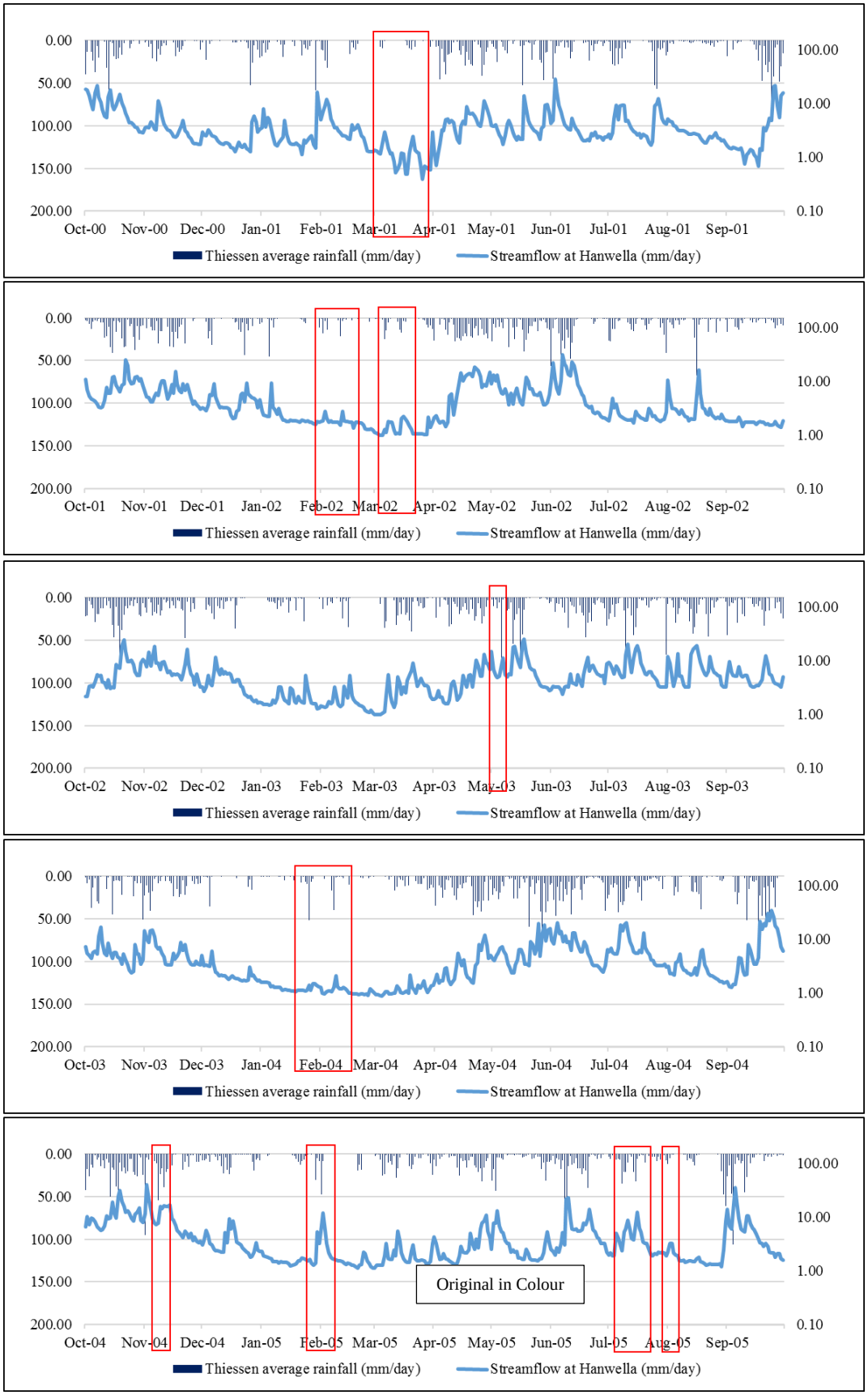
Appendix 02 - 1 Streamflow response for Thiessen average rainfall of Hanwella (85-90)



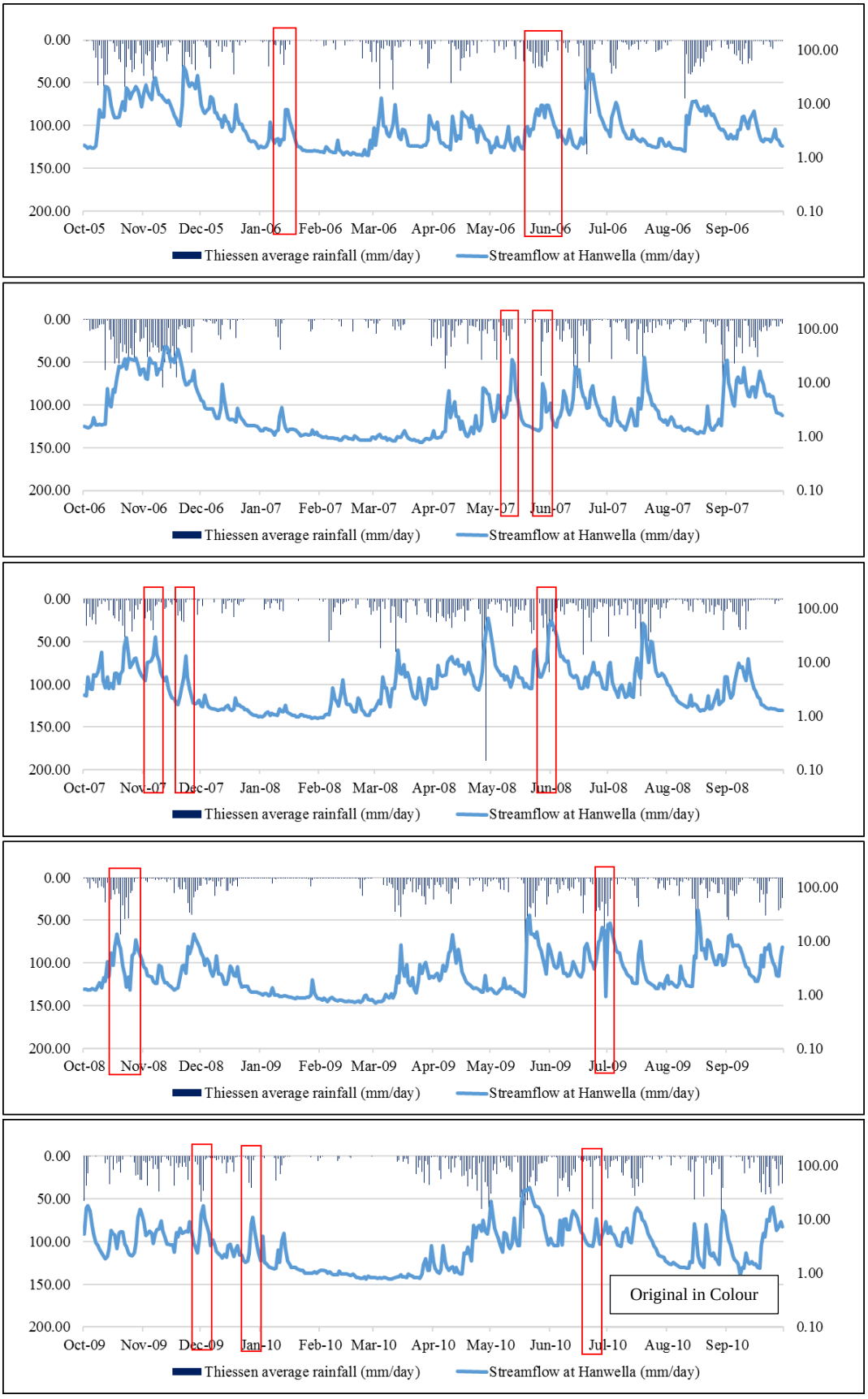
Appendix 02 – 2 Streamflow response for Thiessen average rainfall of Hanwella (90-95)



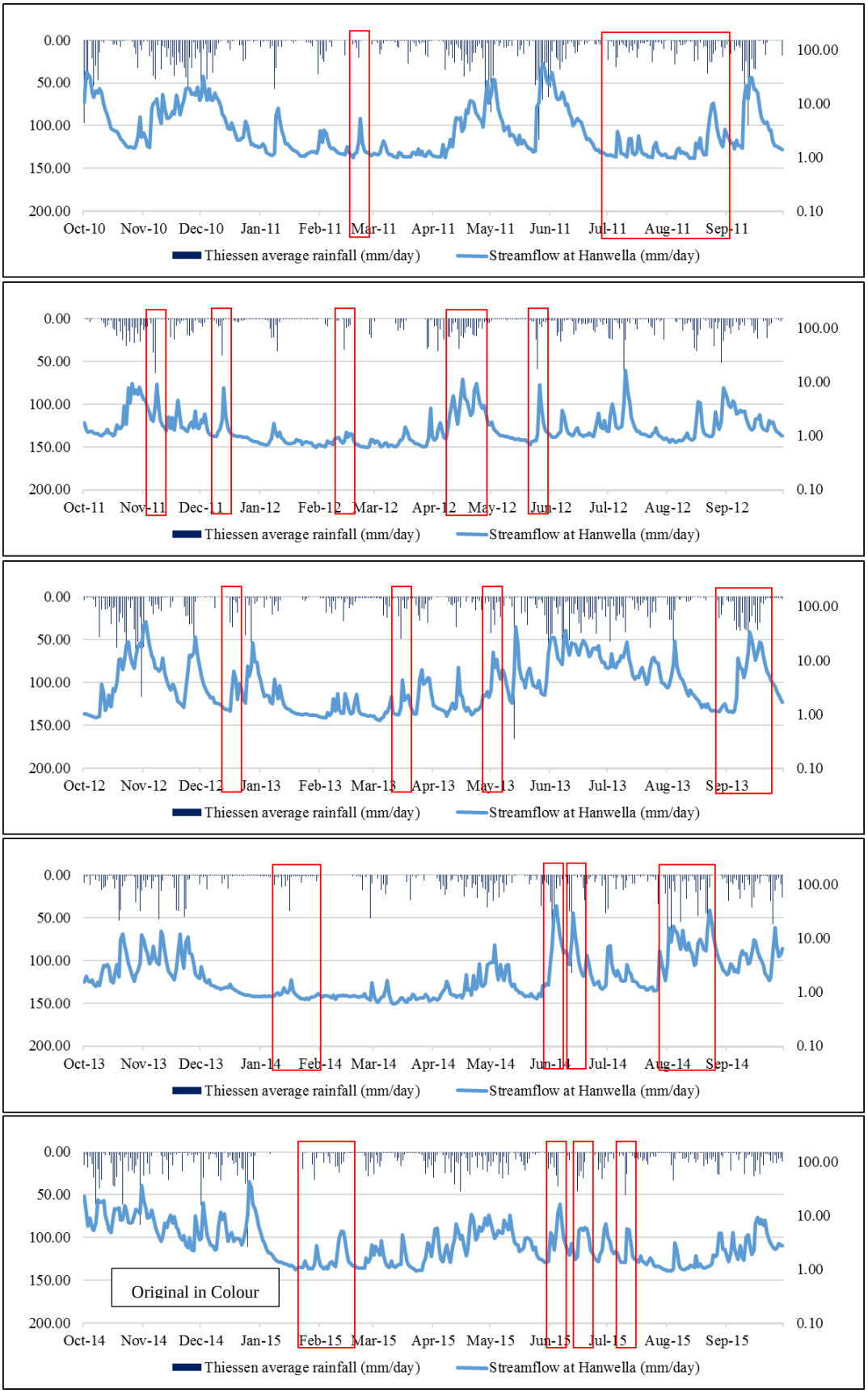
Appendix 02 - 3 Streamflow response for Thiessen average rainfall of Hanwella (95-00)



Appendix 02 - 4 Streamflow response for Thiessen average rainfall of Hanwella (00-05)

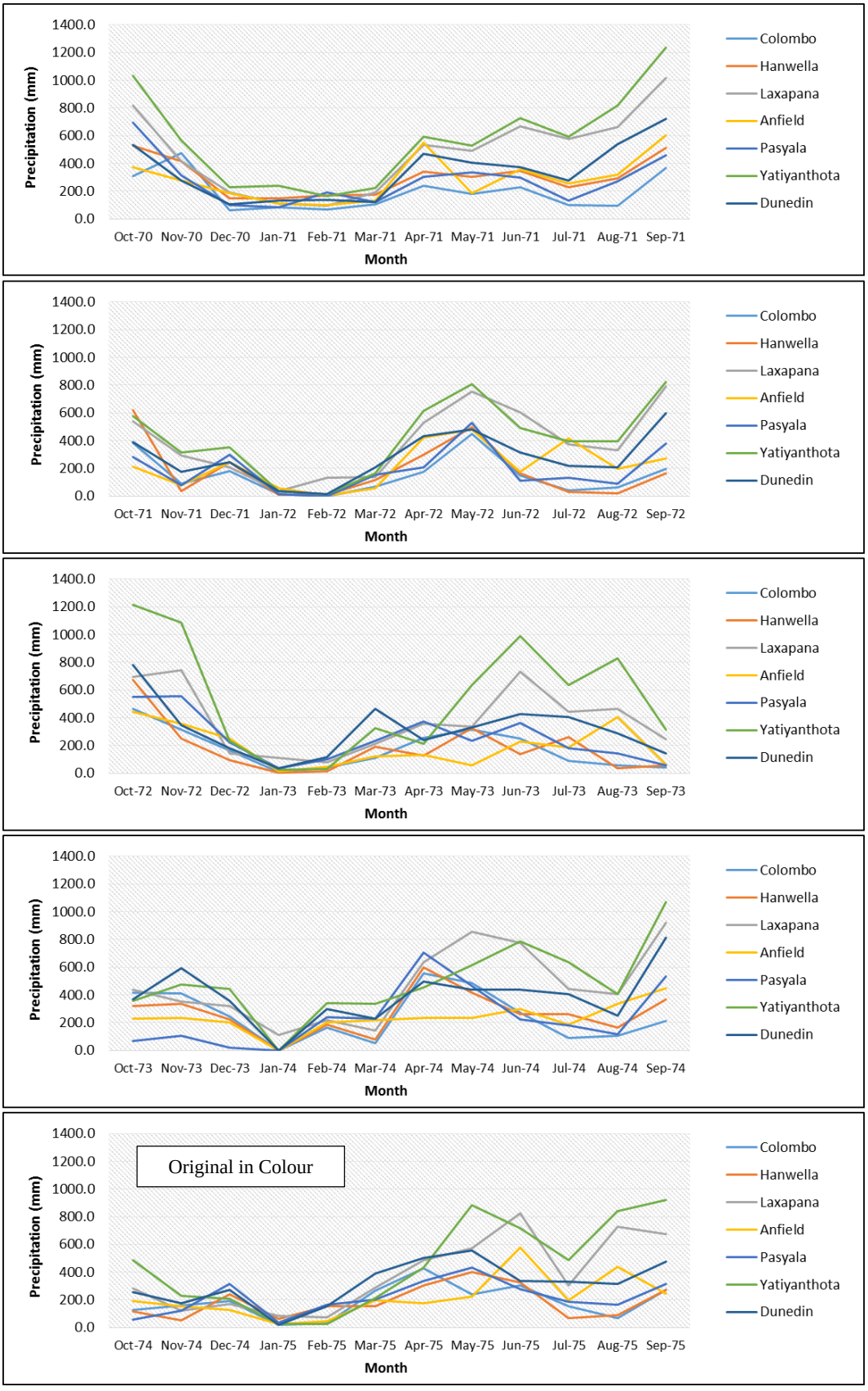


Appendix 02 - 5 Streamflow response for Thiessen average rainfall of Hanwella (05-10)

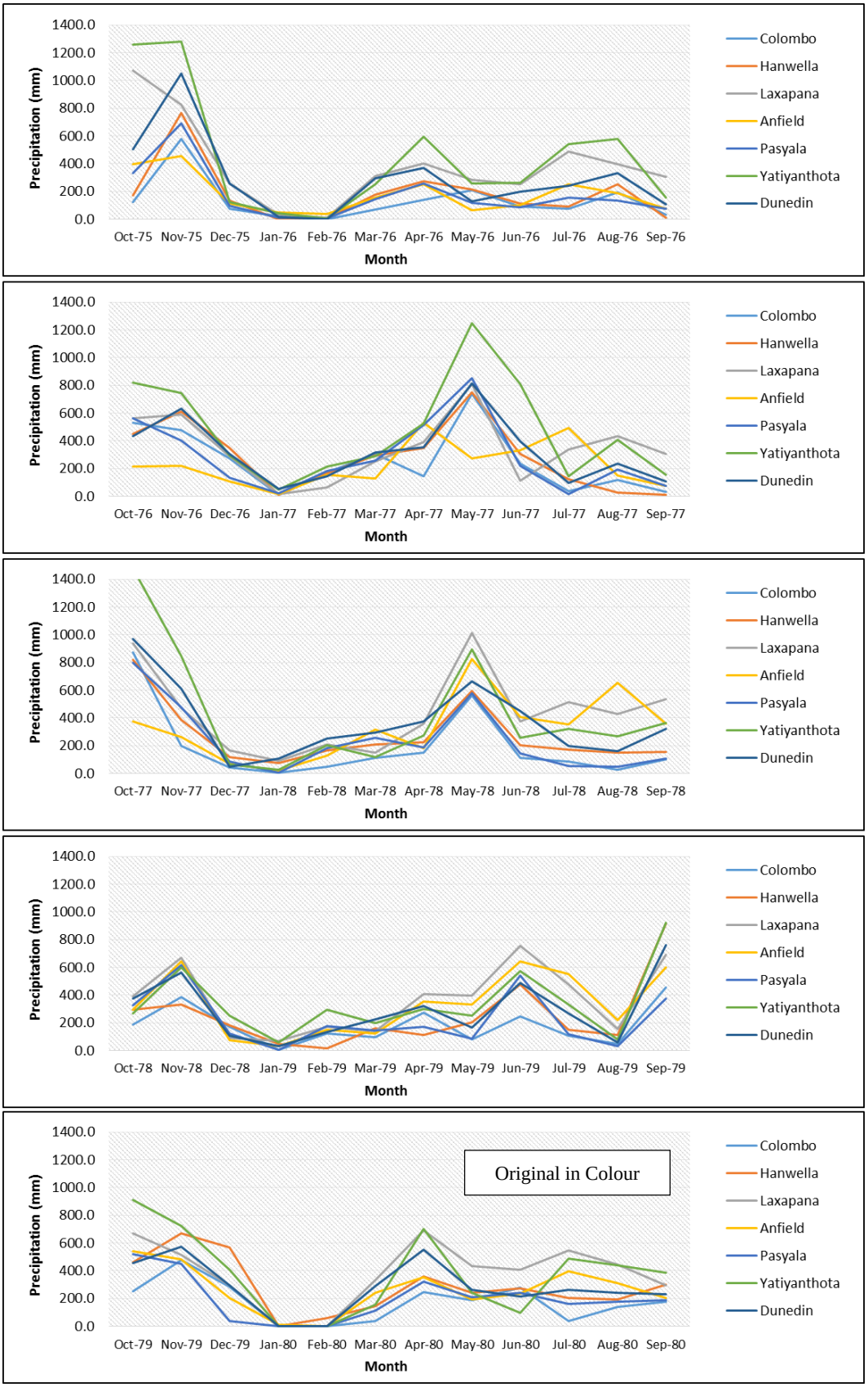


Appendix 02 - 6 Streamflow response for Thiessen average rainfall of Hanwella (10-15)

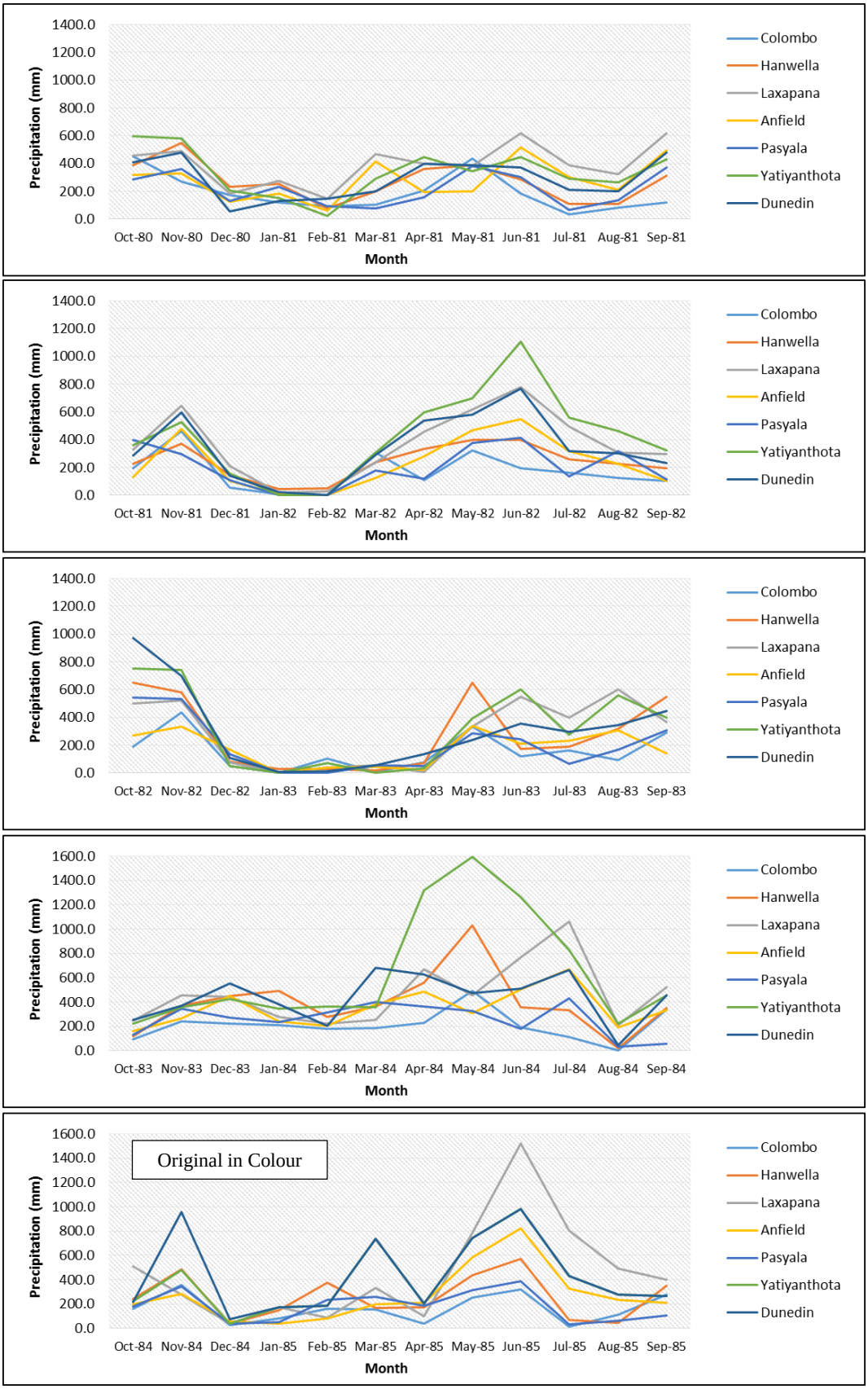
APPENDIX 03: - Monthly Rainfall Comparison (1970-2015)



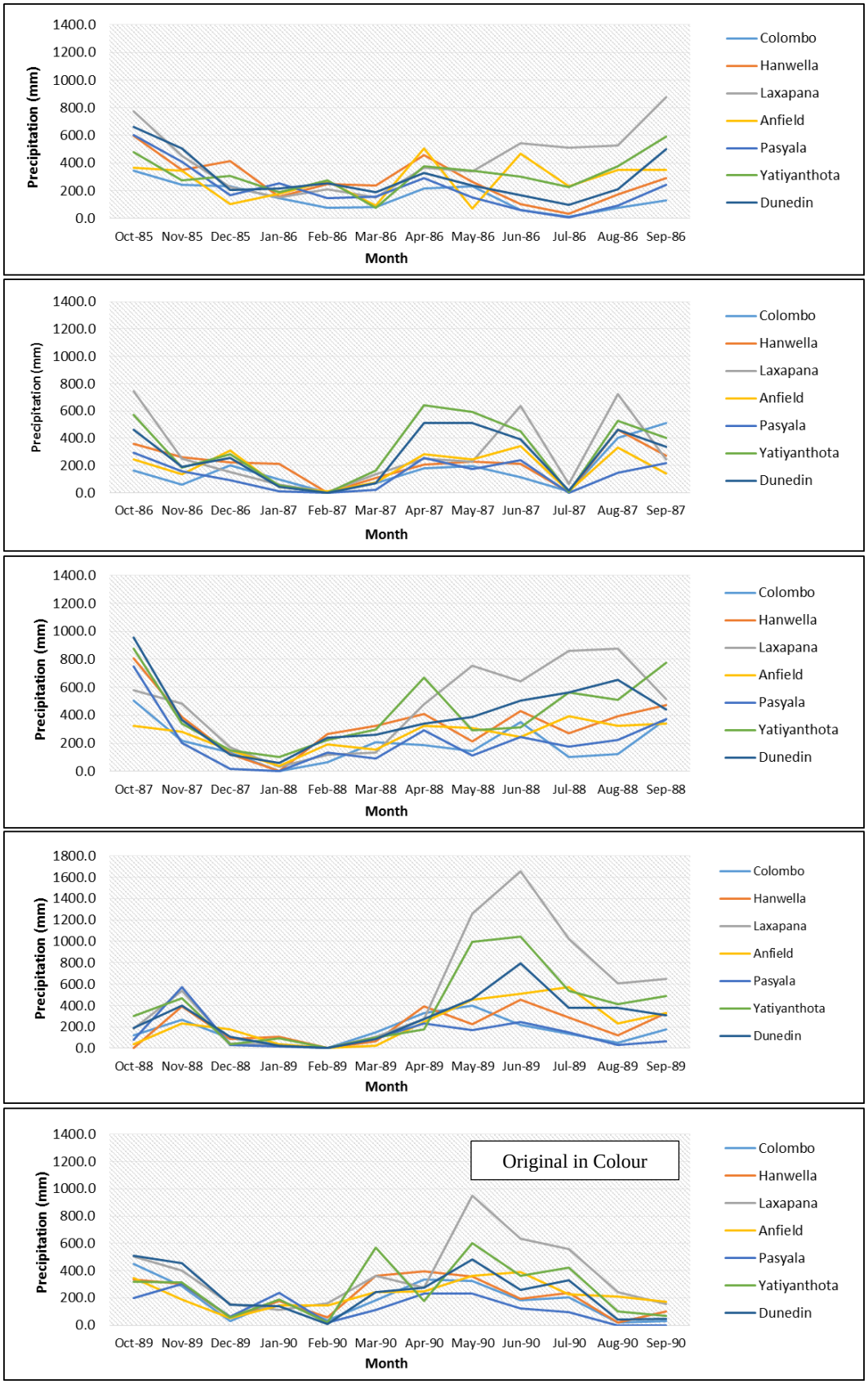
Appendix 03 - 1 Monthly cumulative precipitation variation from 1970-1975



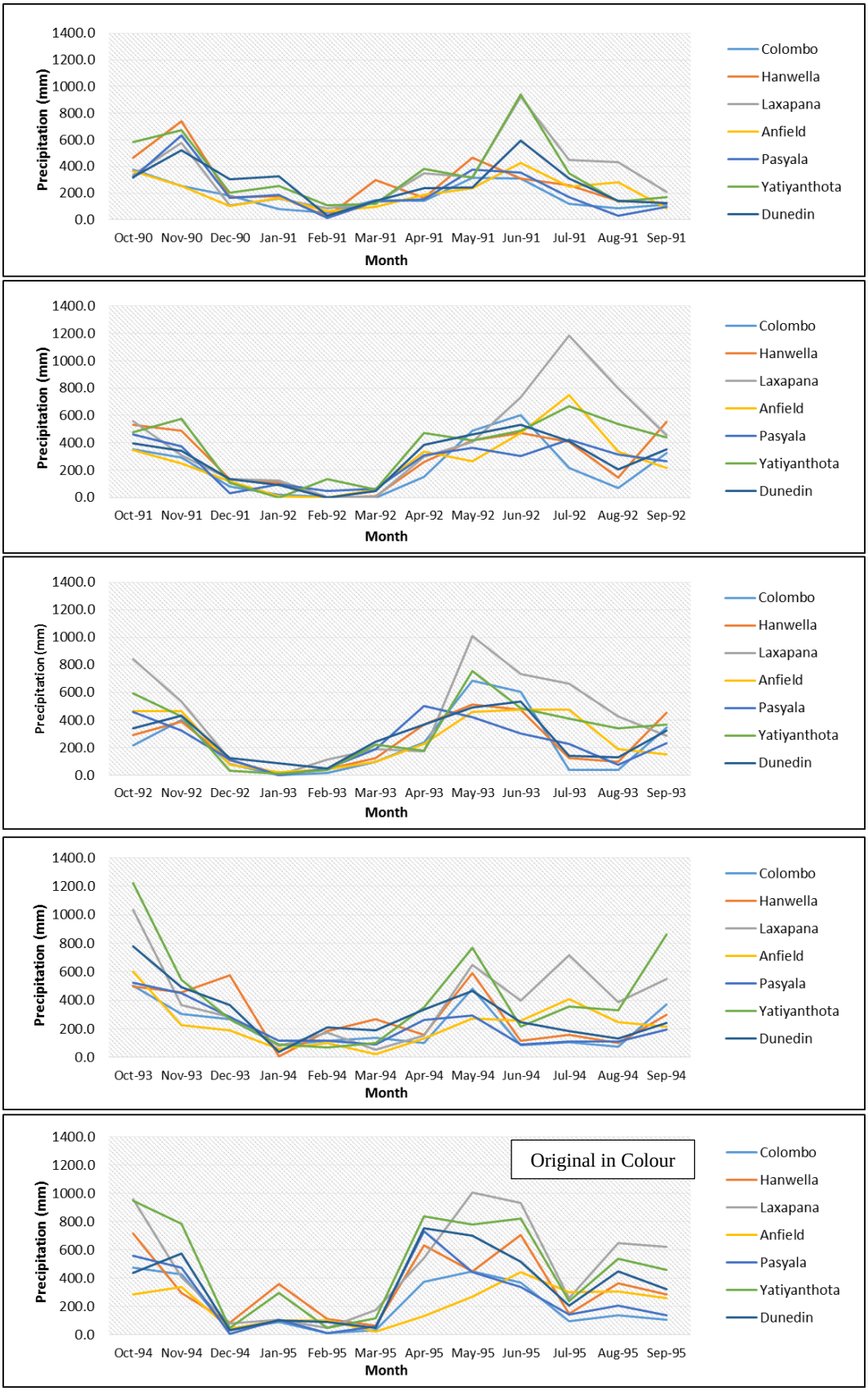
Appendix 03 - 2 Monthly cumulative precipitation variation from 1975-1980



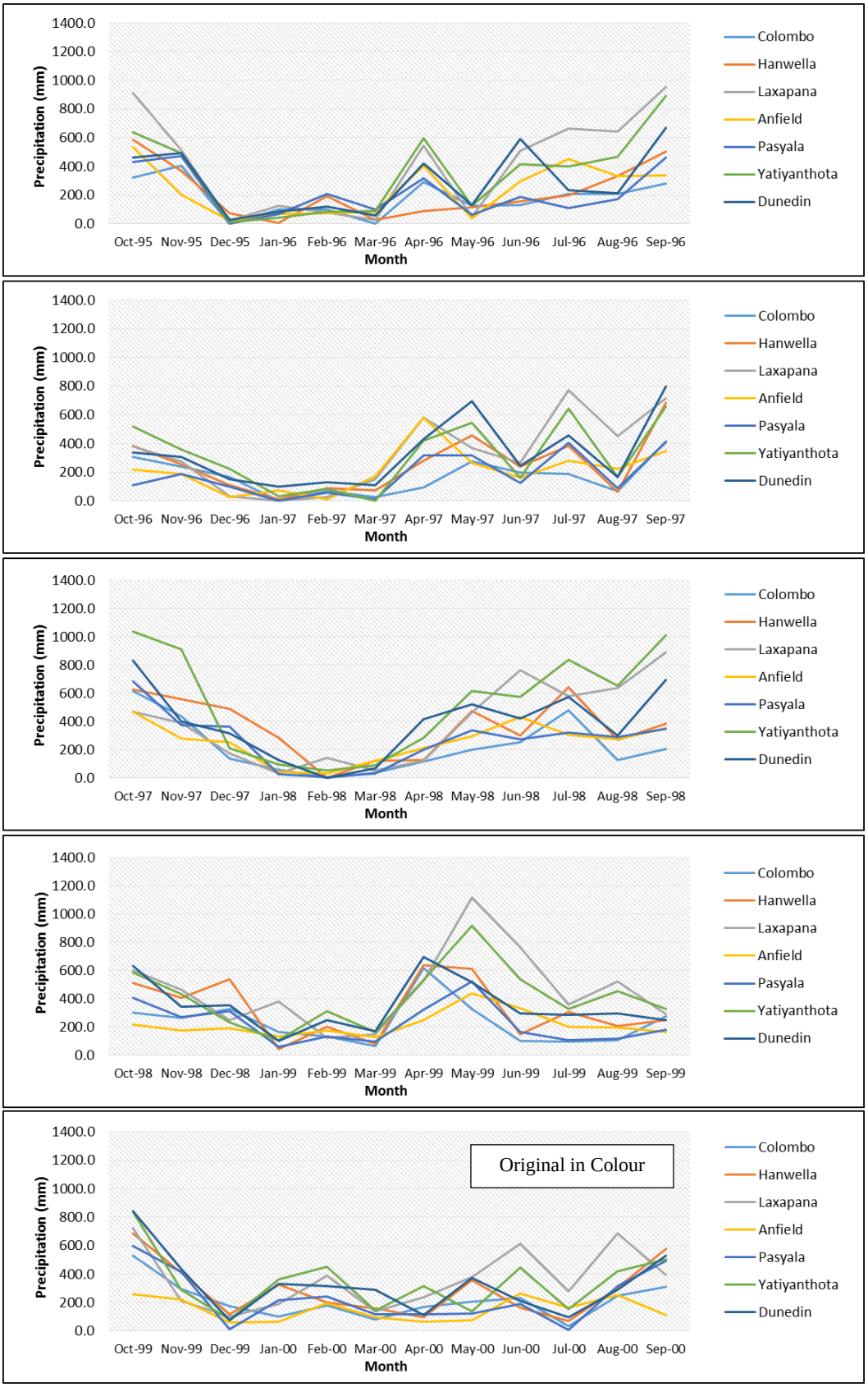
Appendix 03 - 3 Monthly cumulative precipitation variation from 1980-1985



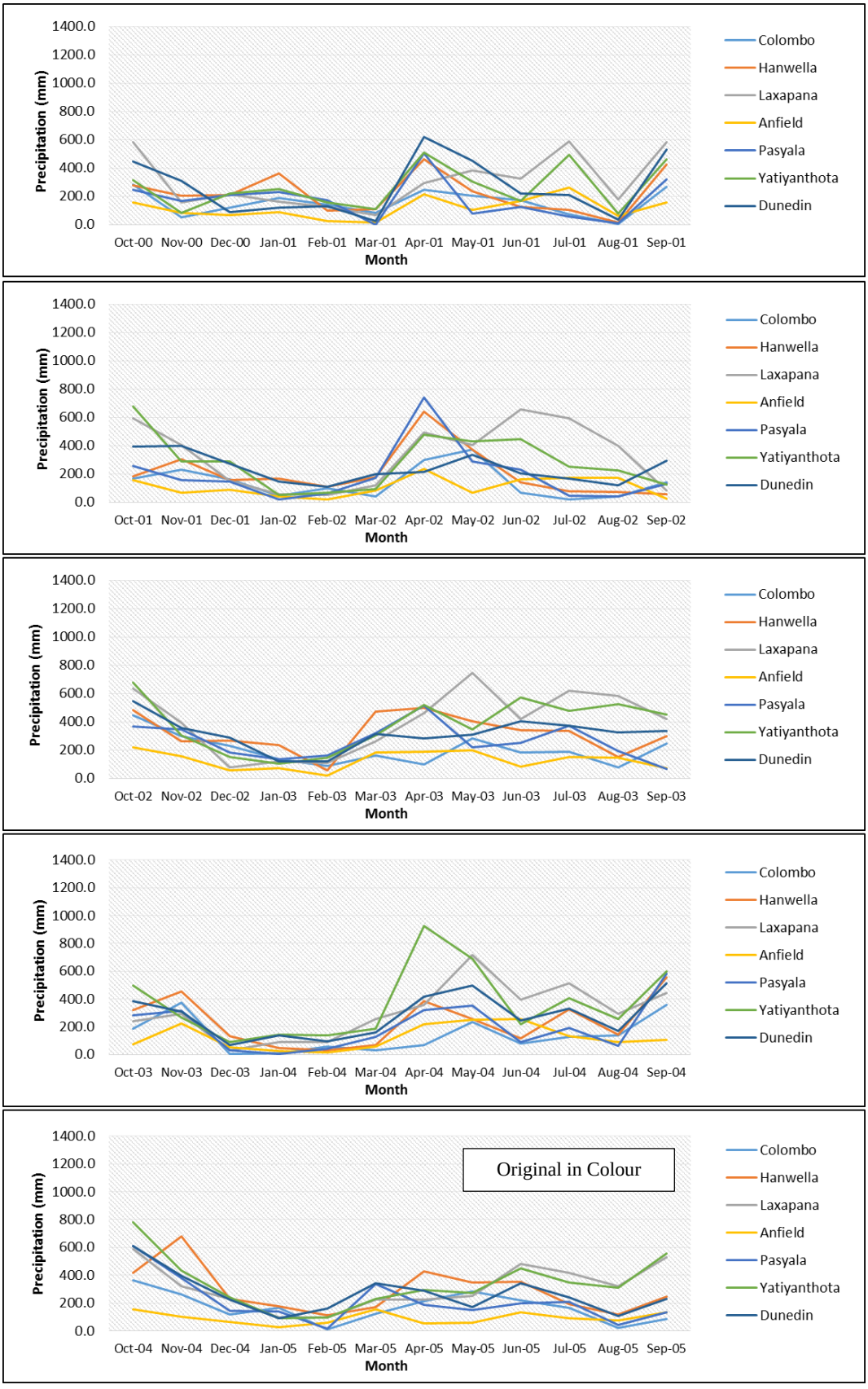
Appendix 03 - 4 Monthly cumulative precipitation variation from 1985-1990



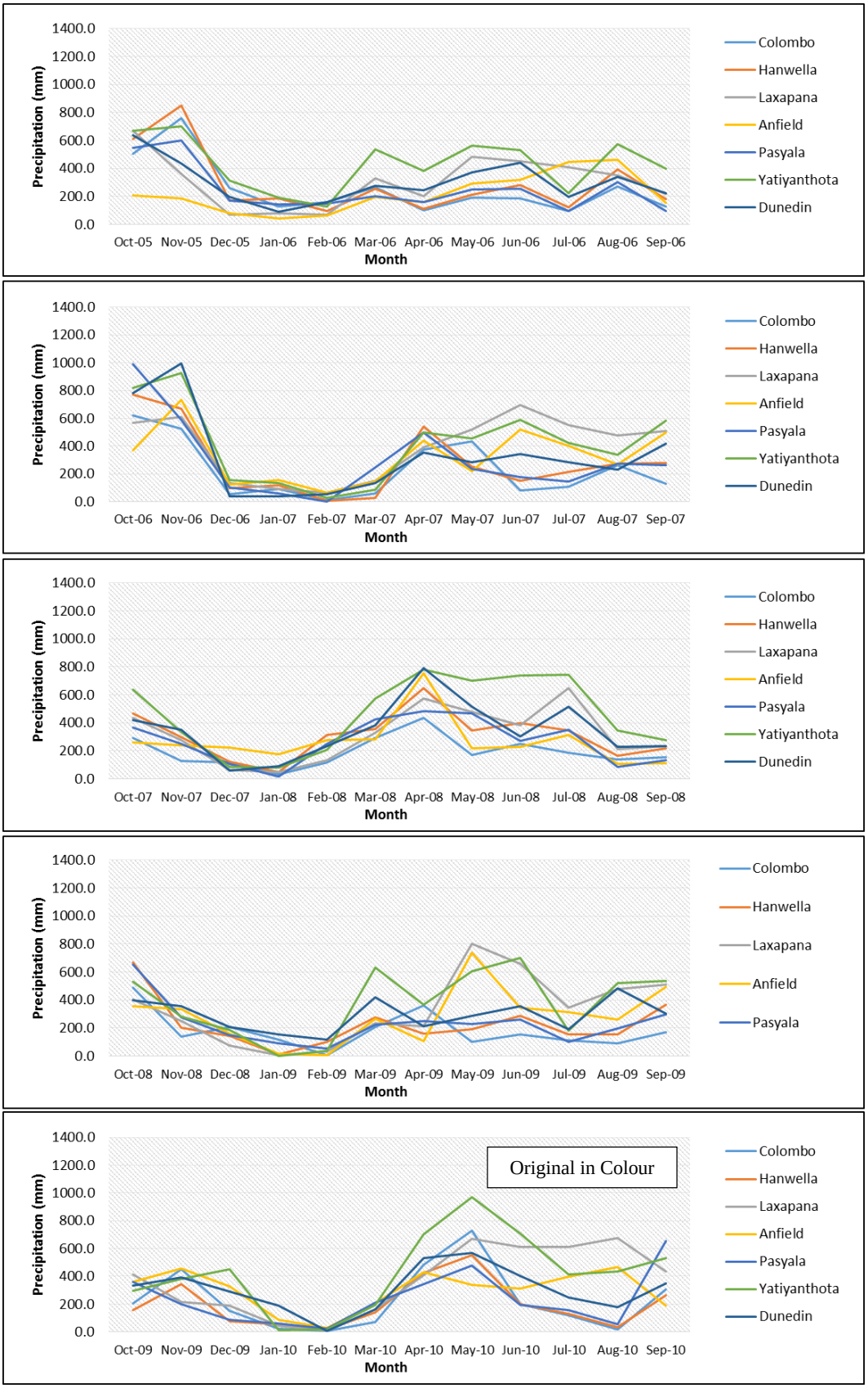
Appendix 03 - 5 Monthly cumulative precipitation variation from 1990-1995



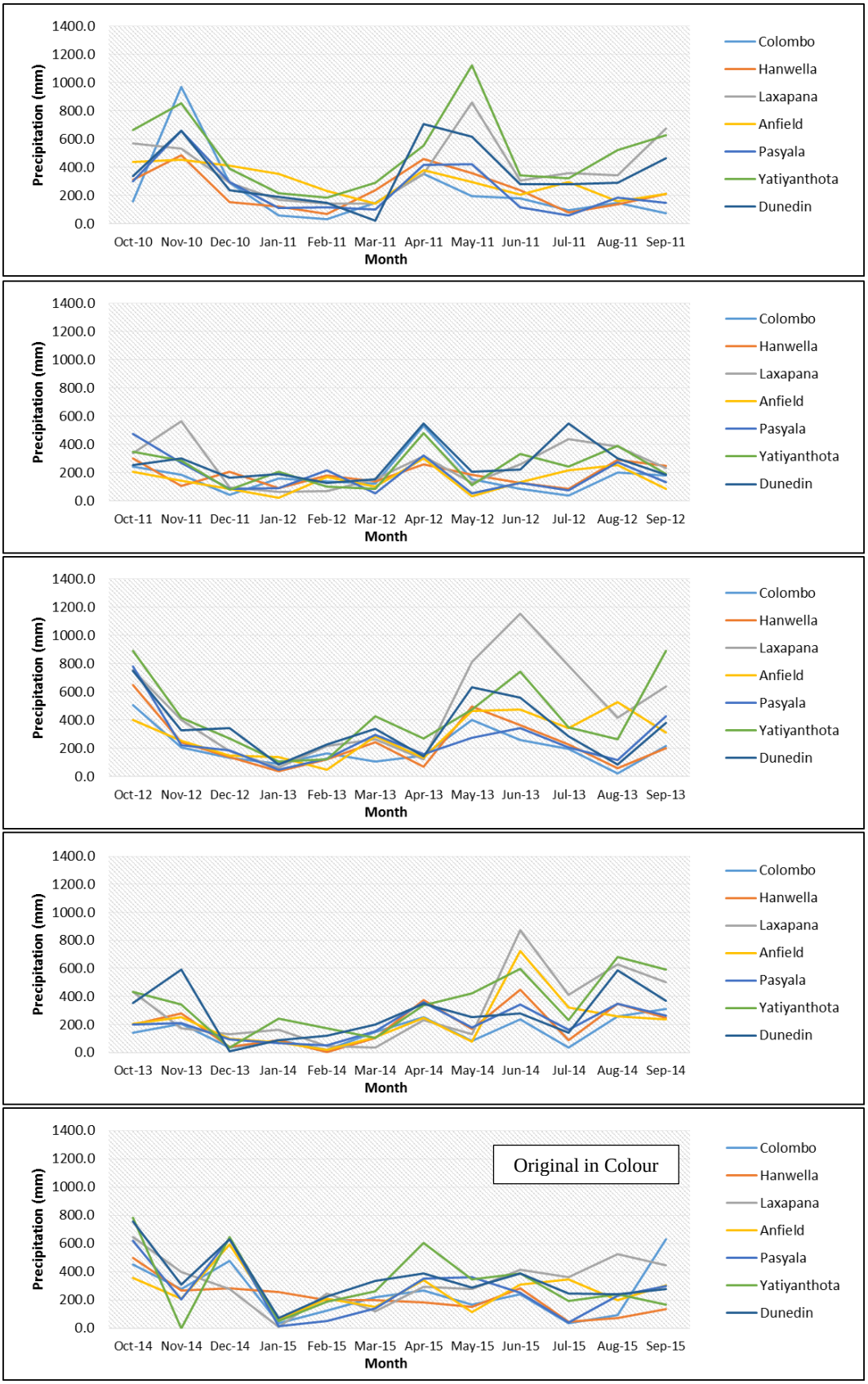
Appendix 03 – 6 Monthly cumulative precipitation variation from 1995-2000



Appendix 03 - 7 Monthly cumulative precipitation variation from 2000-2005

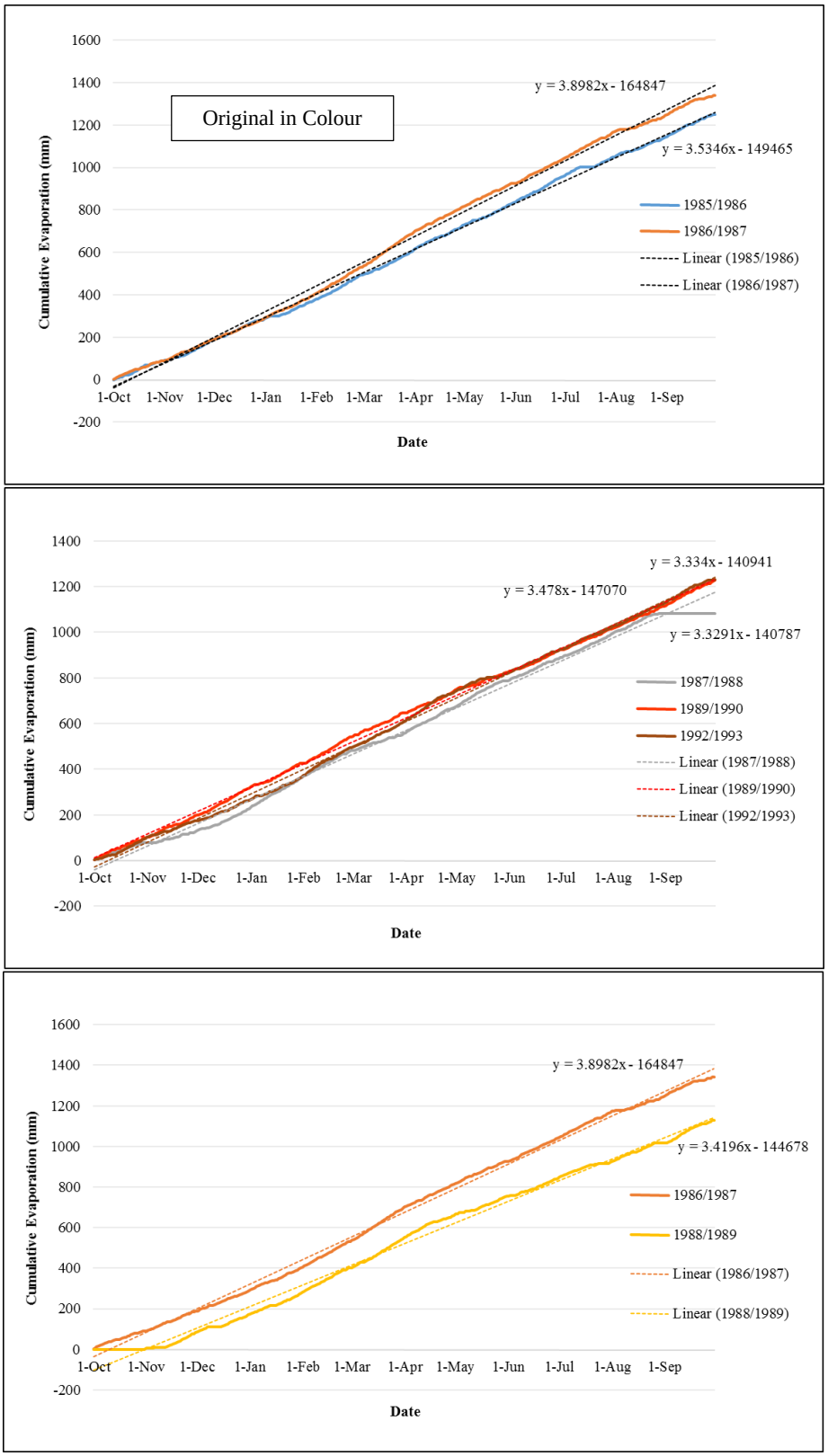


Appendix 03 - 8 Monthly cumulative precipitation variation from 2005-2010

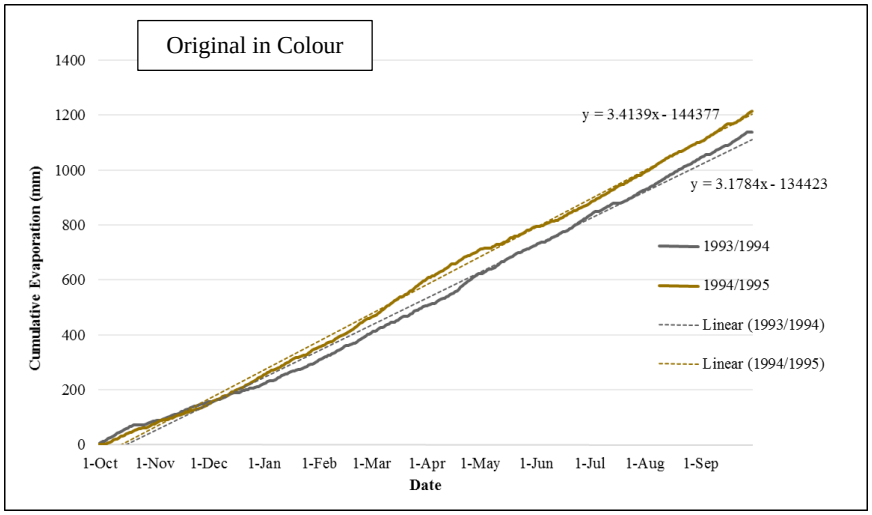


Appendix 03 - 9 Monthly cumulative precipitation variation from 2010-2015

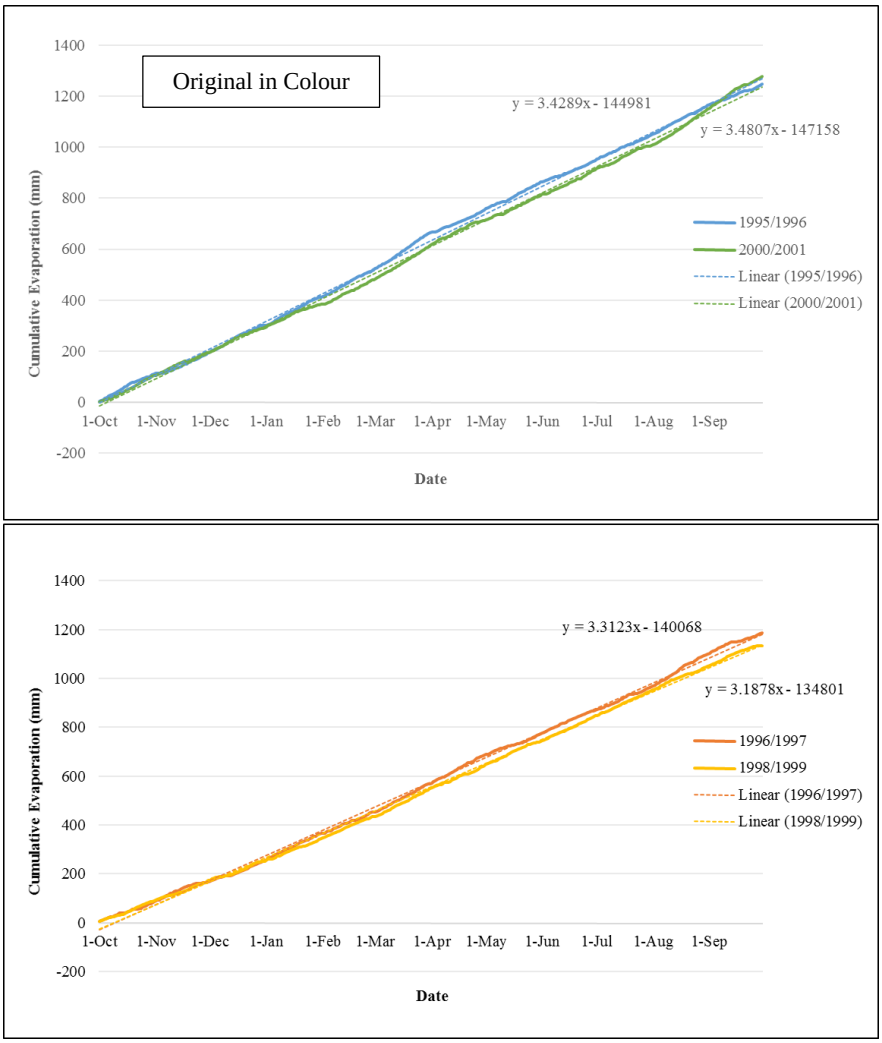
APPENDIX 04: - Replacing of Missing Values of Evaporation (Colombo)



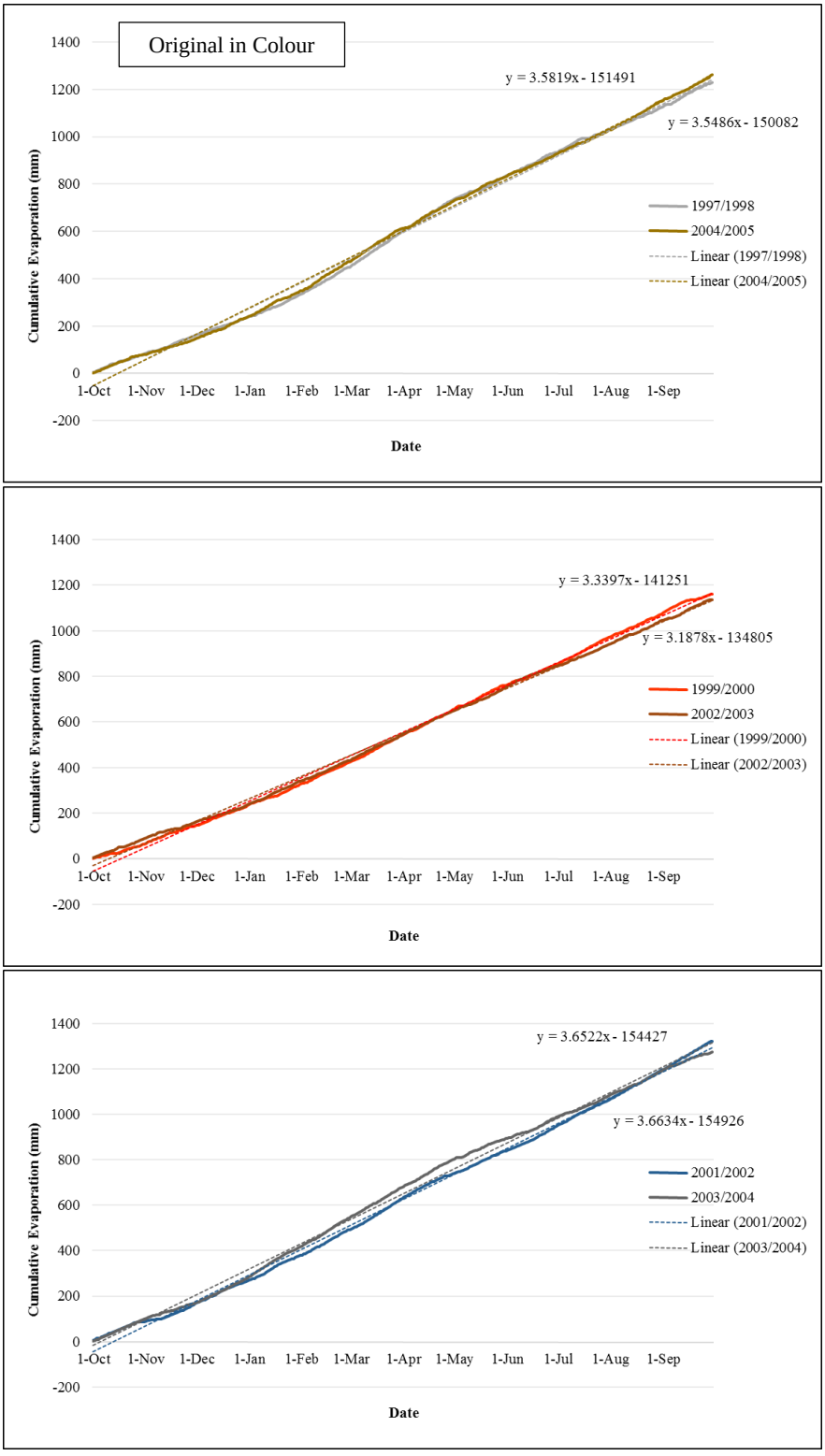
Appendix 04 - 1 Replacing missing data of evaporation of Colombo Meteorology observation from 1985-1992



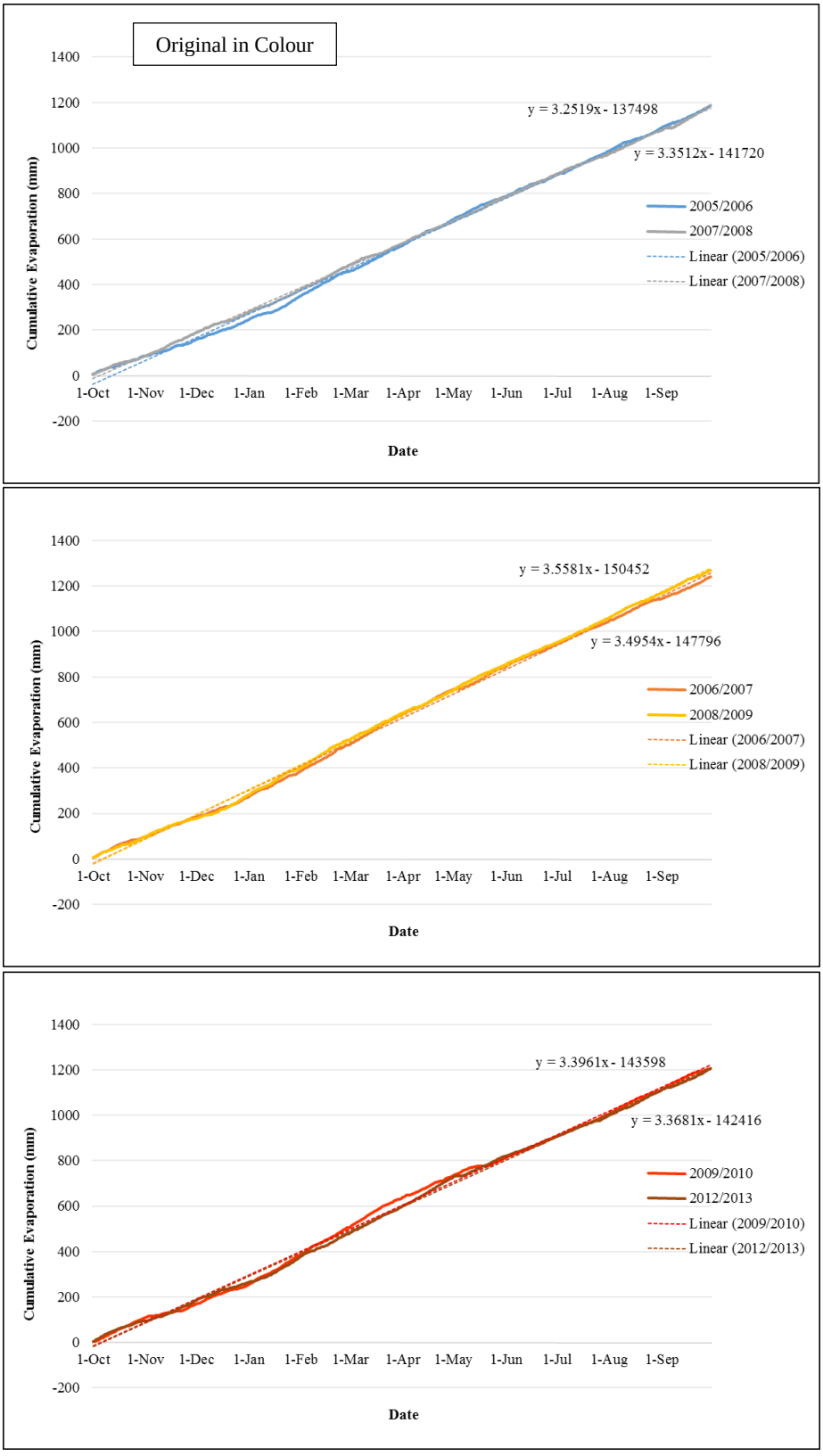
Appendix 04 - 2 Replacing missing data of evaporation of Colombo Meteorology observation from 1993-1995



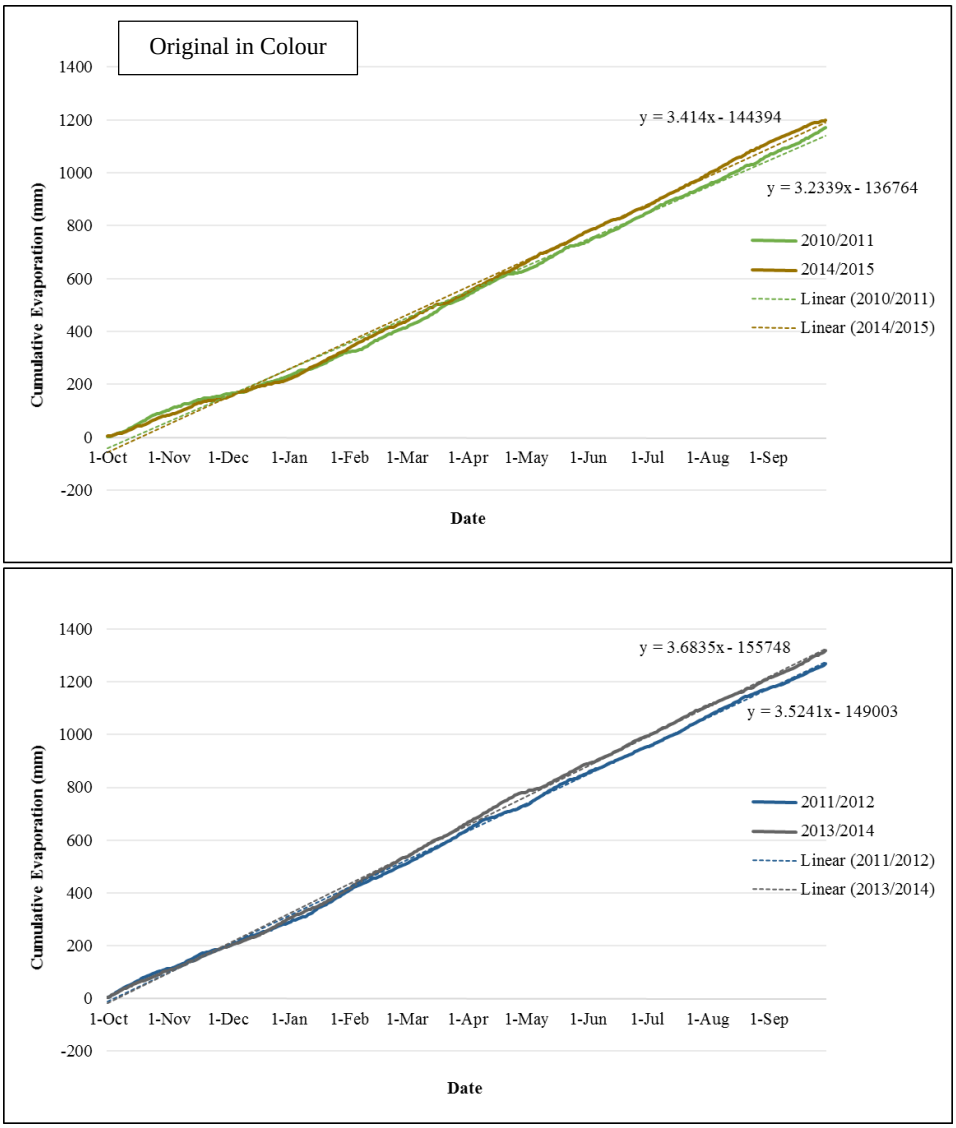
Appendix 04 - 3 Replacing missing data of evaporation of Colombo Meteorology observation from 1995/1996, 2000/2001, 1996/1997 & 1998/1999



Appendix 04 - 4 Replacing missing data of evaporation of Colombo Meteorology observation from 1997/1998 & 2004/2005, 1999/2000 & 2002/2003, 2001/2002 & 2003/2004

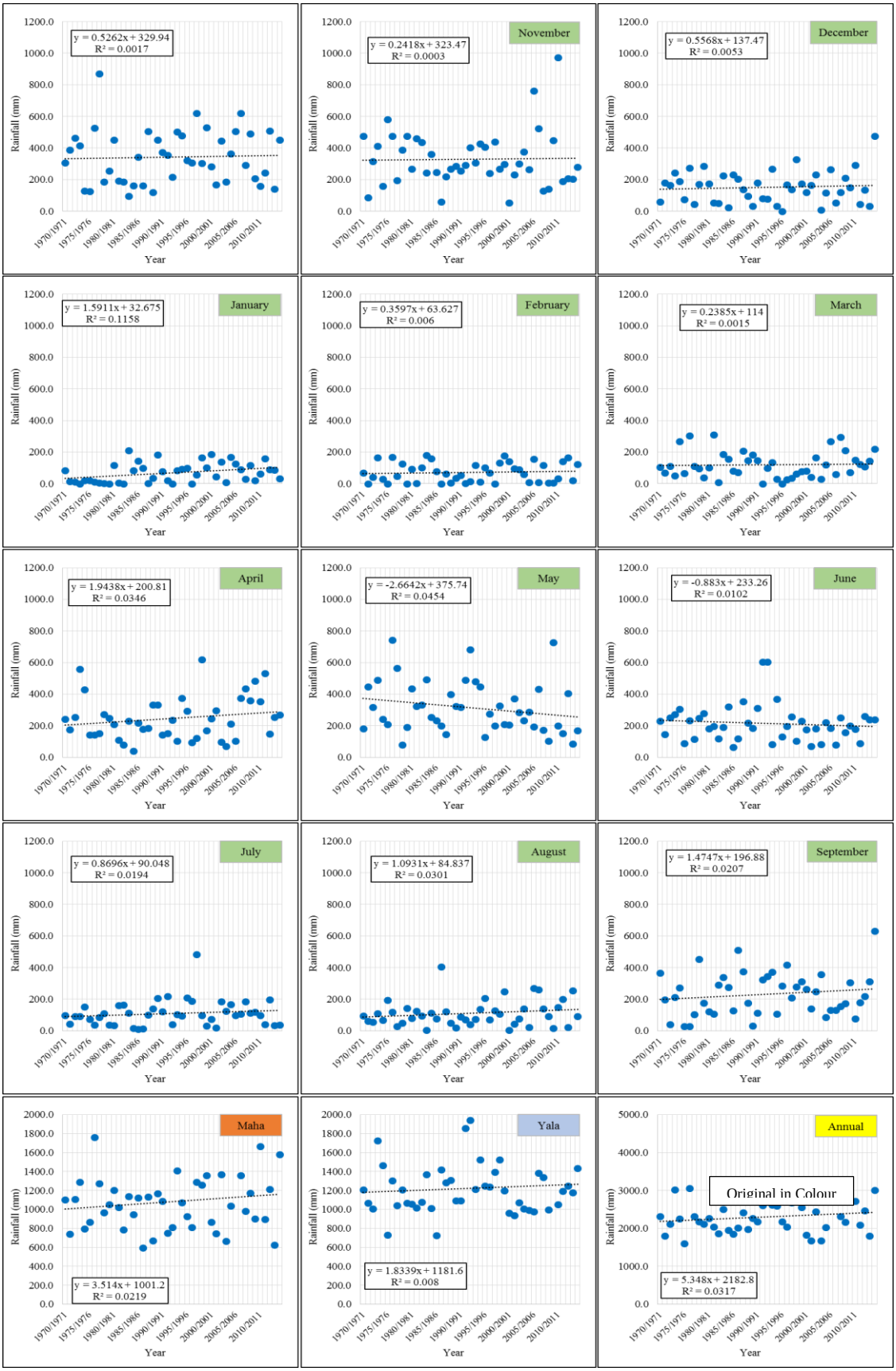


Appendix 04 - 5 Replacing missing data of evaporation of Colombo Meteorology observation from 2005/2006 & 2007/2008, 2006/2007 & 2008/2009, 2009/2010 & 2012/2013

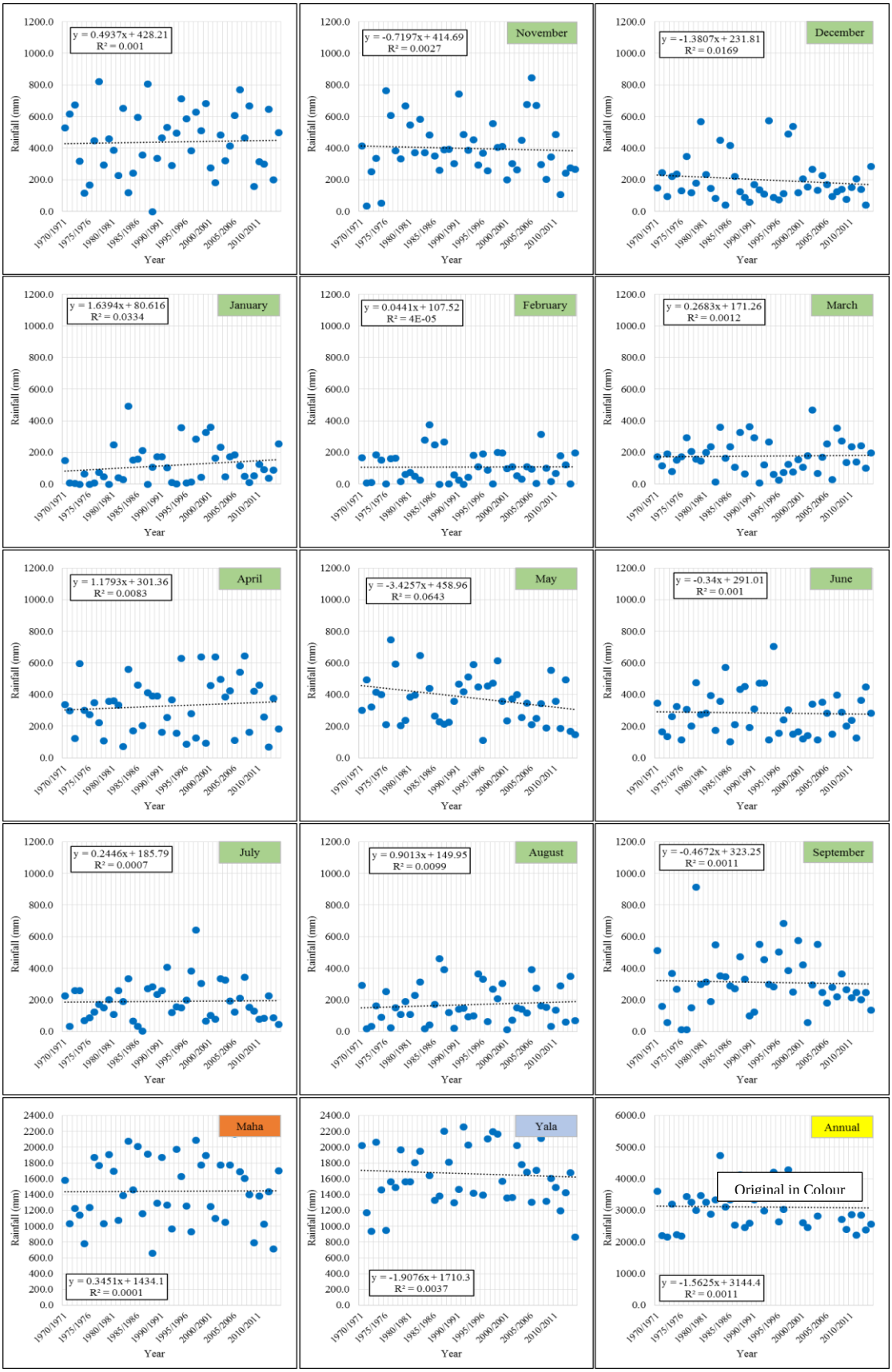


Appendix 04 - 6 Replacing missing data of evaporation of Colombo Meteorology observation from 2010/2011 & 2014/2015, 2011/2012 & 2013/2014

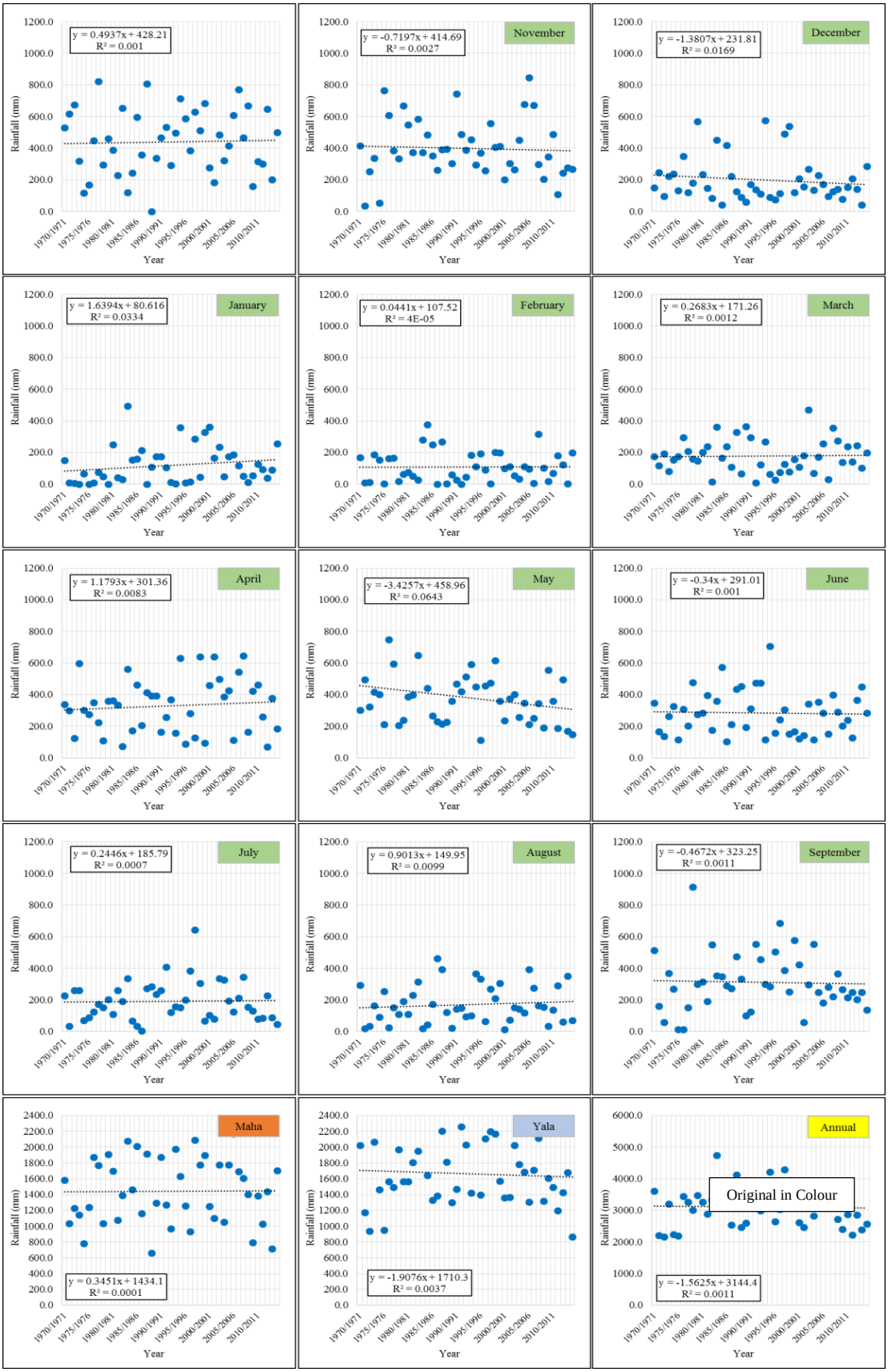
APPENDIX 05: - Trend Analysis of Point Rainfall



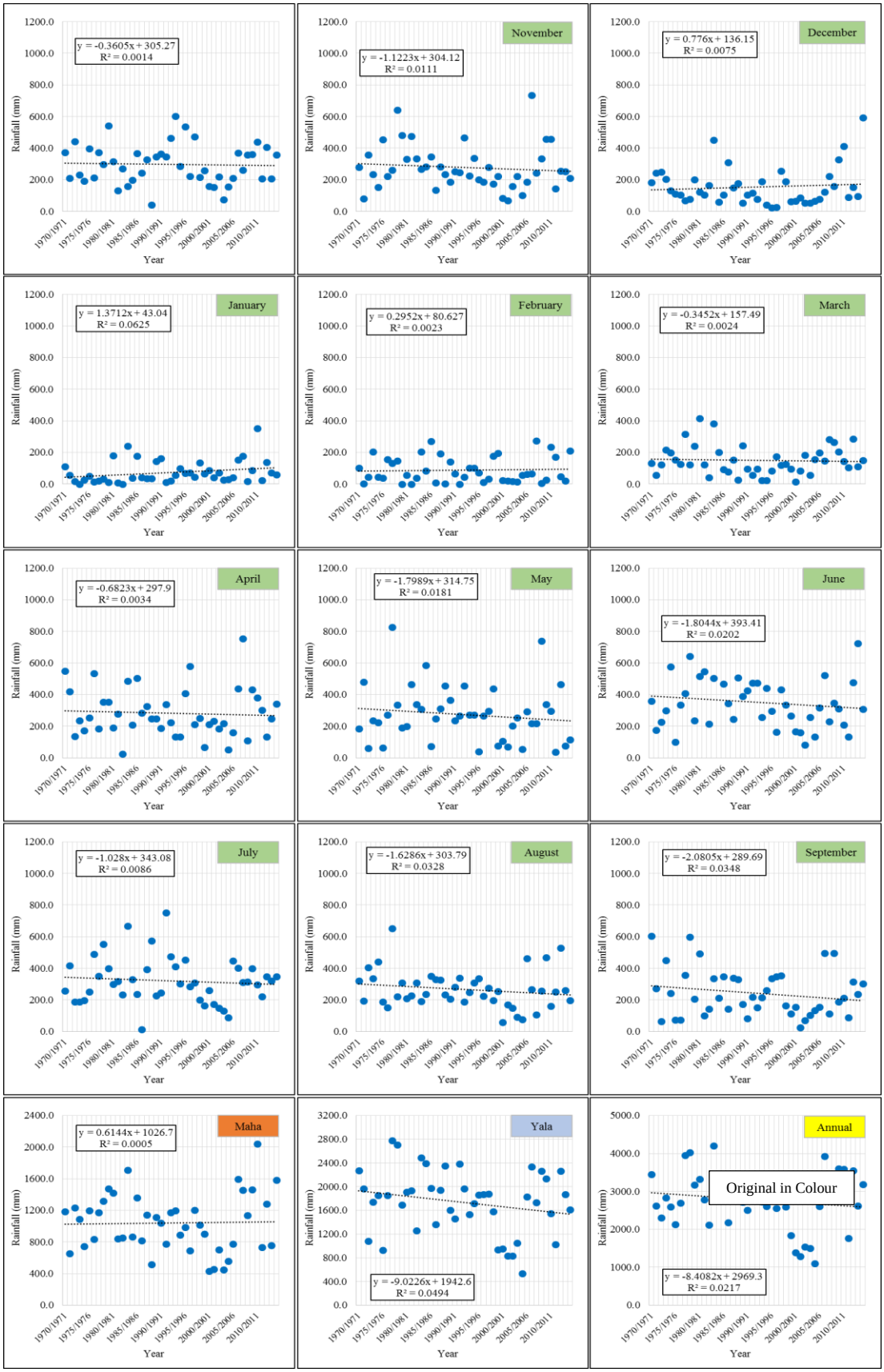
Appendix 05 - 1 Trends of Rainfall at Colombo (1970-2015)



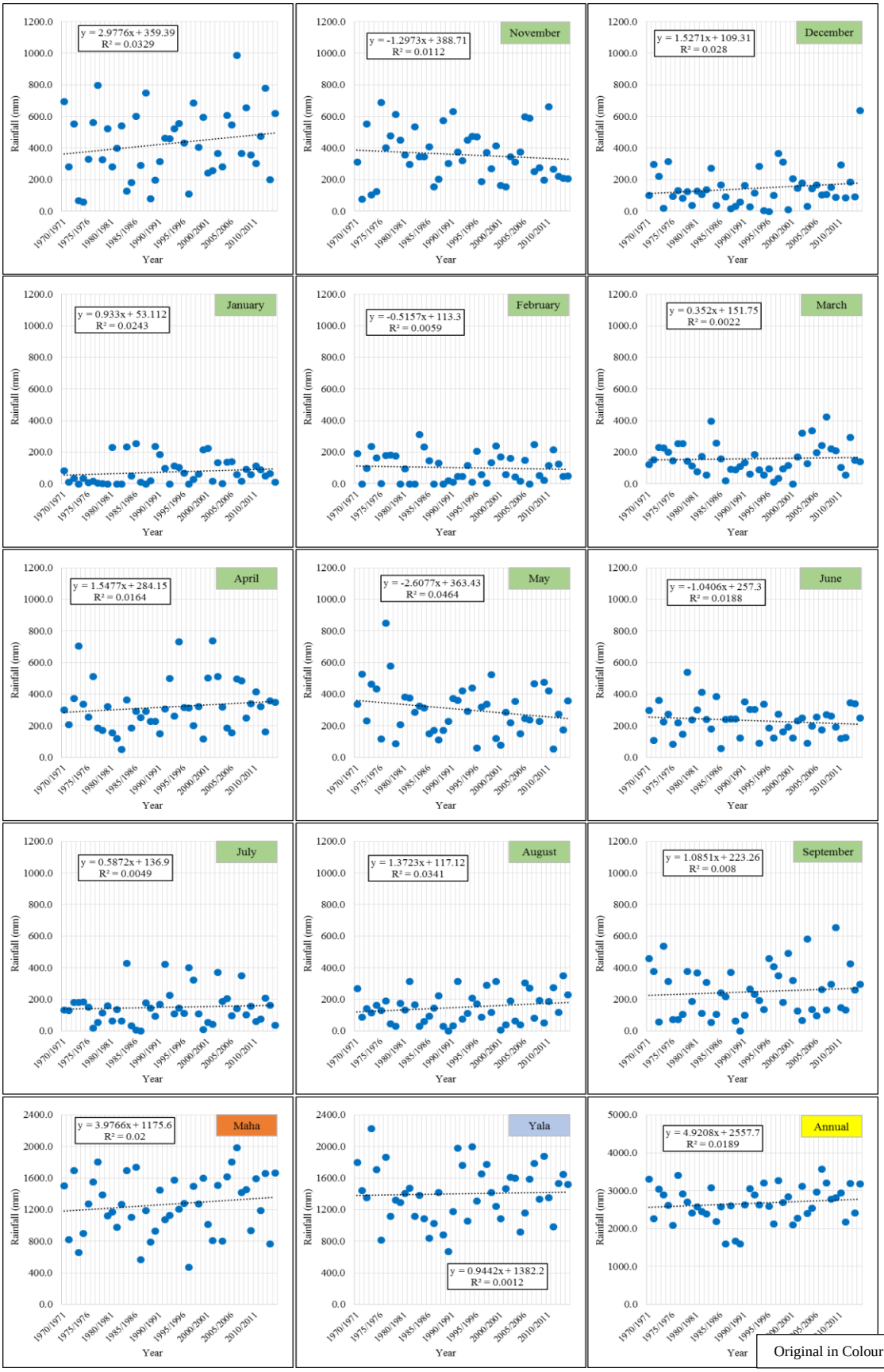
Appendix 05 - 2 Trends of Rainfall at Hanwella (1970-2015)



Appendix 05 - 3 Trends of Rainfall at Laxapana (1970-2015)

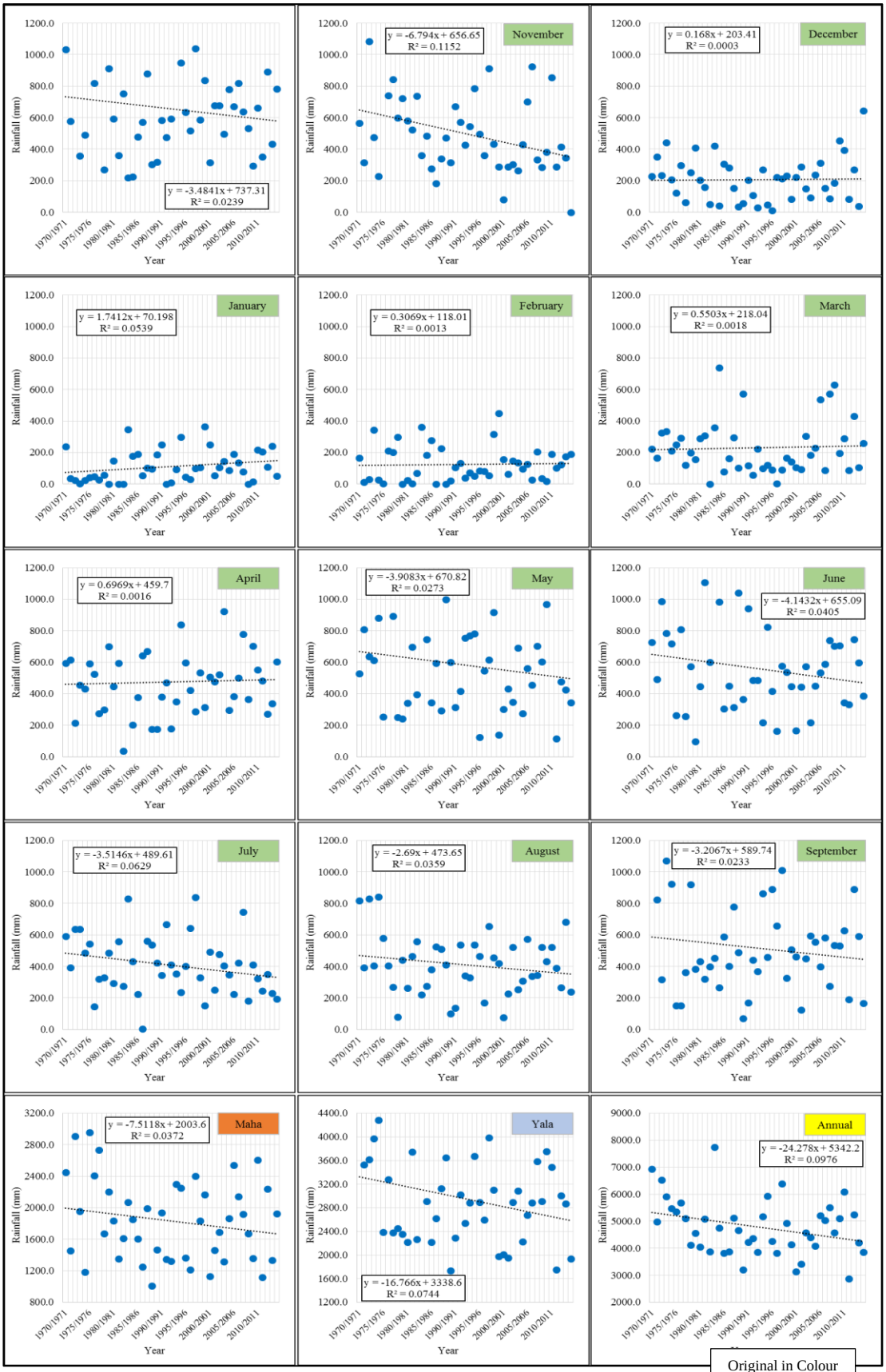


Appendix 05 - 4 Trends in Rainfall at Annfield (1970-2015)



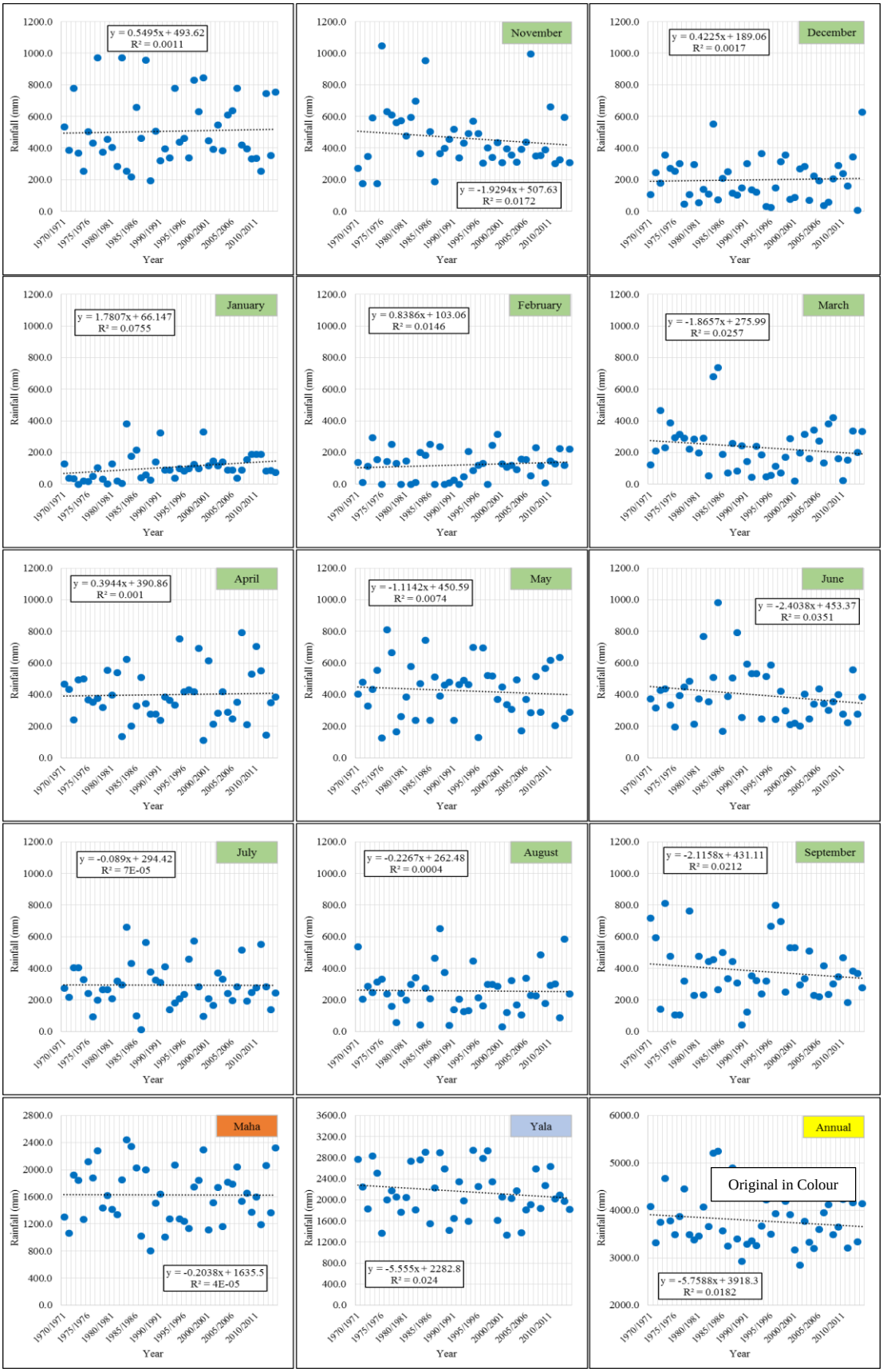
Original in Colour

Appendix 05 – 5 Trends in Rainfall at Pasyala (1970-2015)



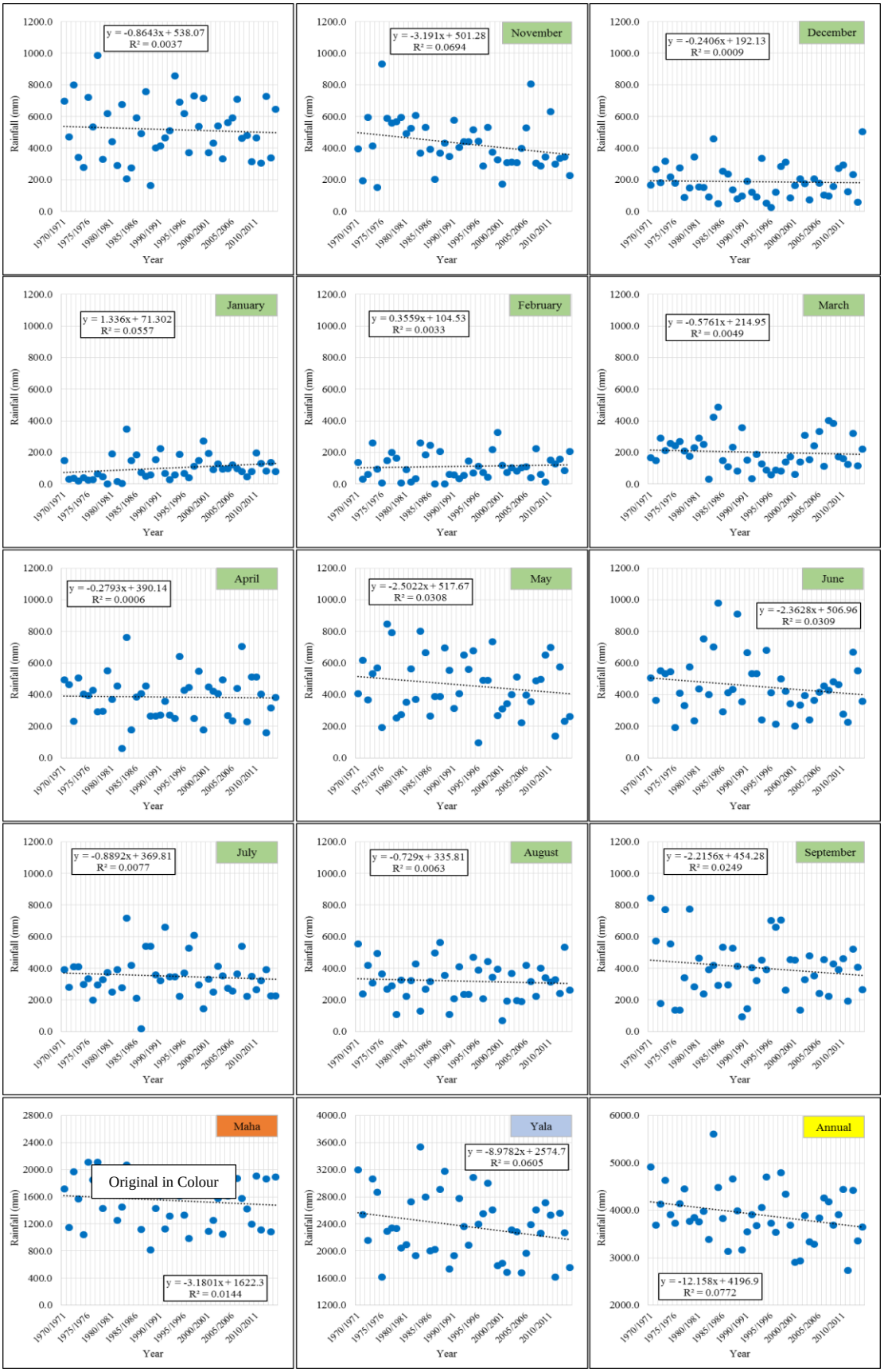
Original in Colour

Appendix 05 - 6 Trends in Rainfall at Yatiyanthota-Wewalthalawa (1970-2015)



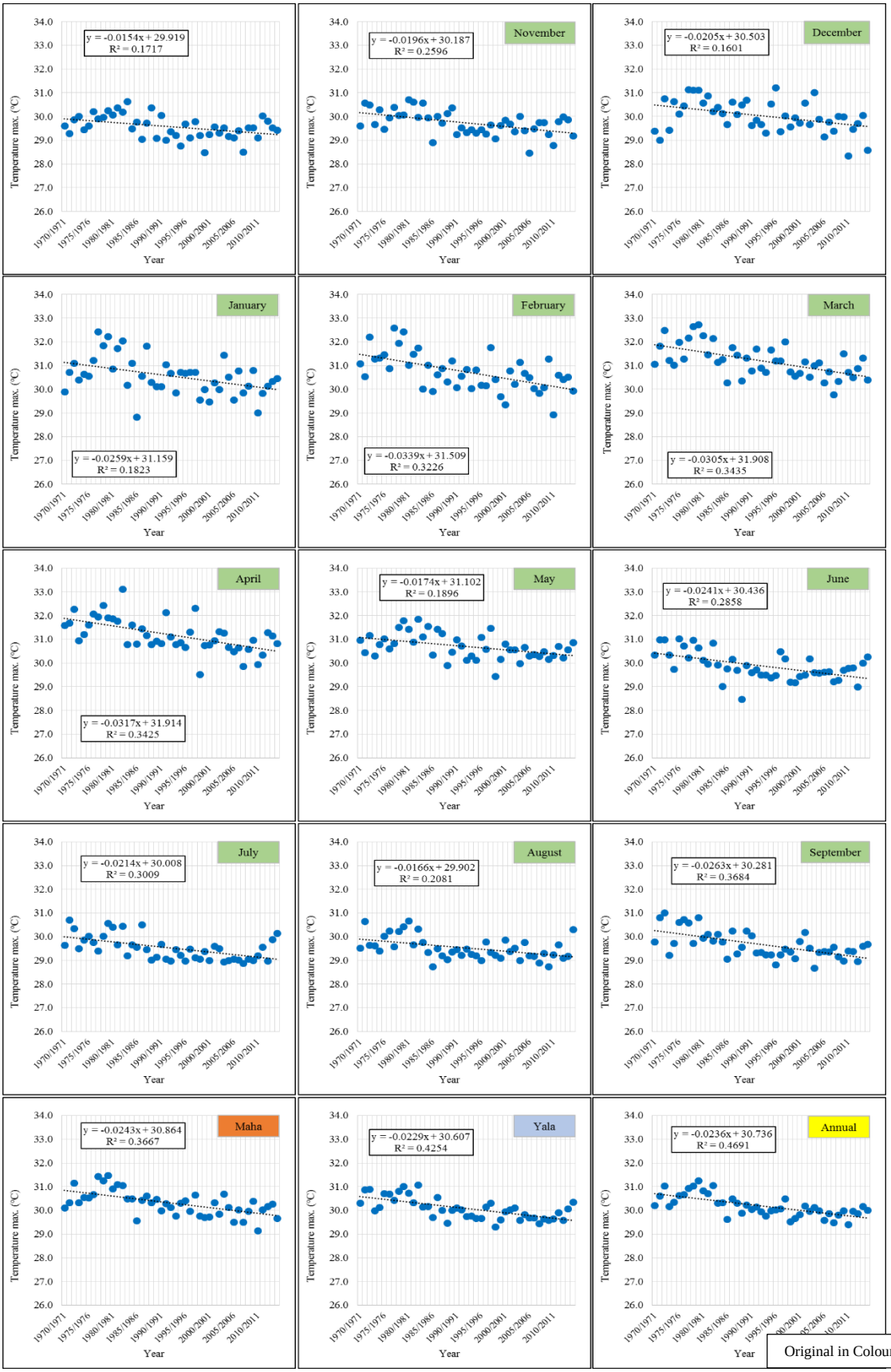
Appendix 05 - 7 Trends in Rainfall at Dunedin-Chesterford (1970-2015)

APPENDIX 06: - Trend Analysis of Catchment Rainfall

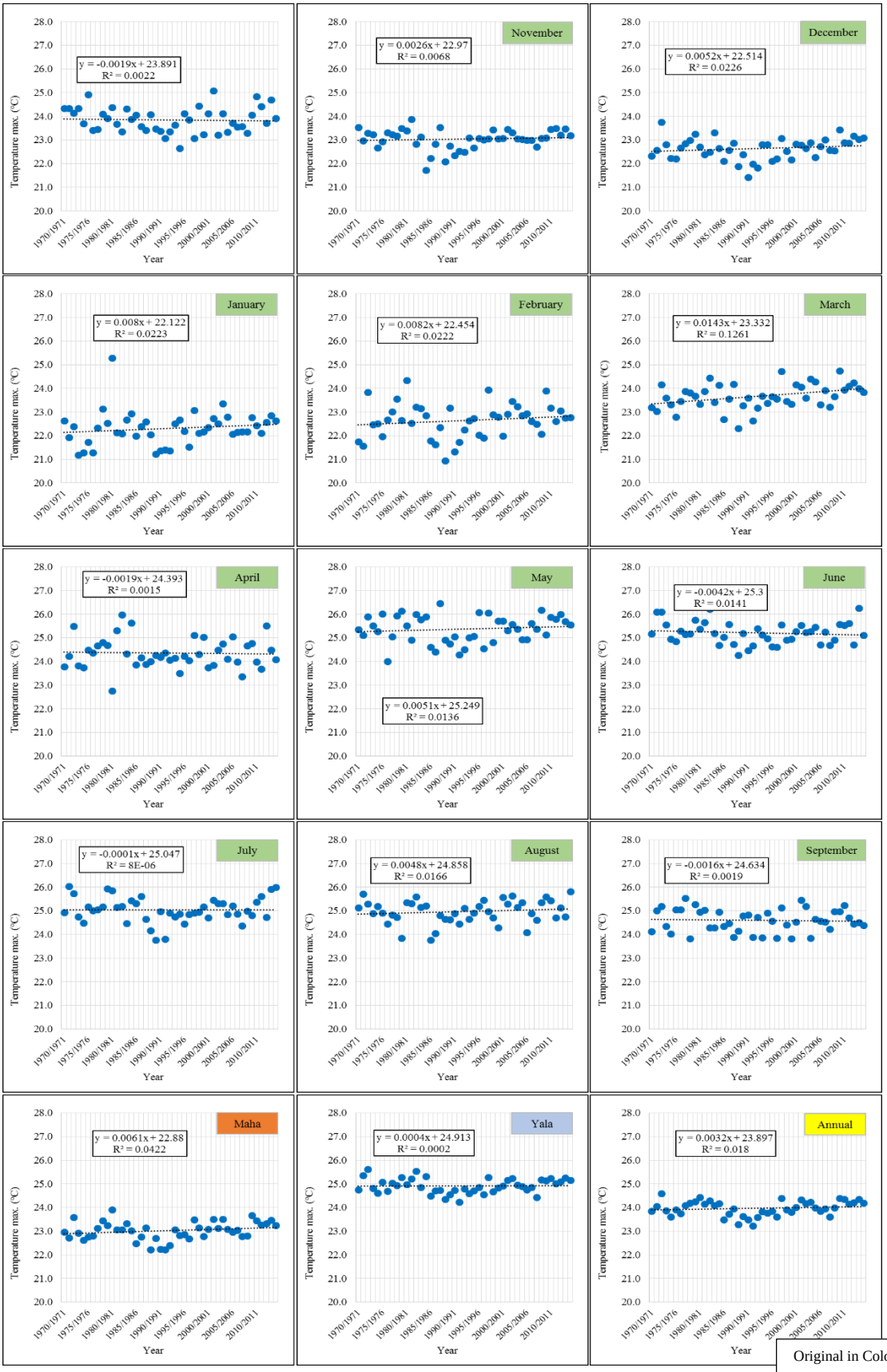


Appendix 06 - 1 Trends in Catchment Rainfall at Hanwella Watershed (1970-2015)

APPENDIX 07: - Trends Analysis of Point Temperature

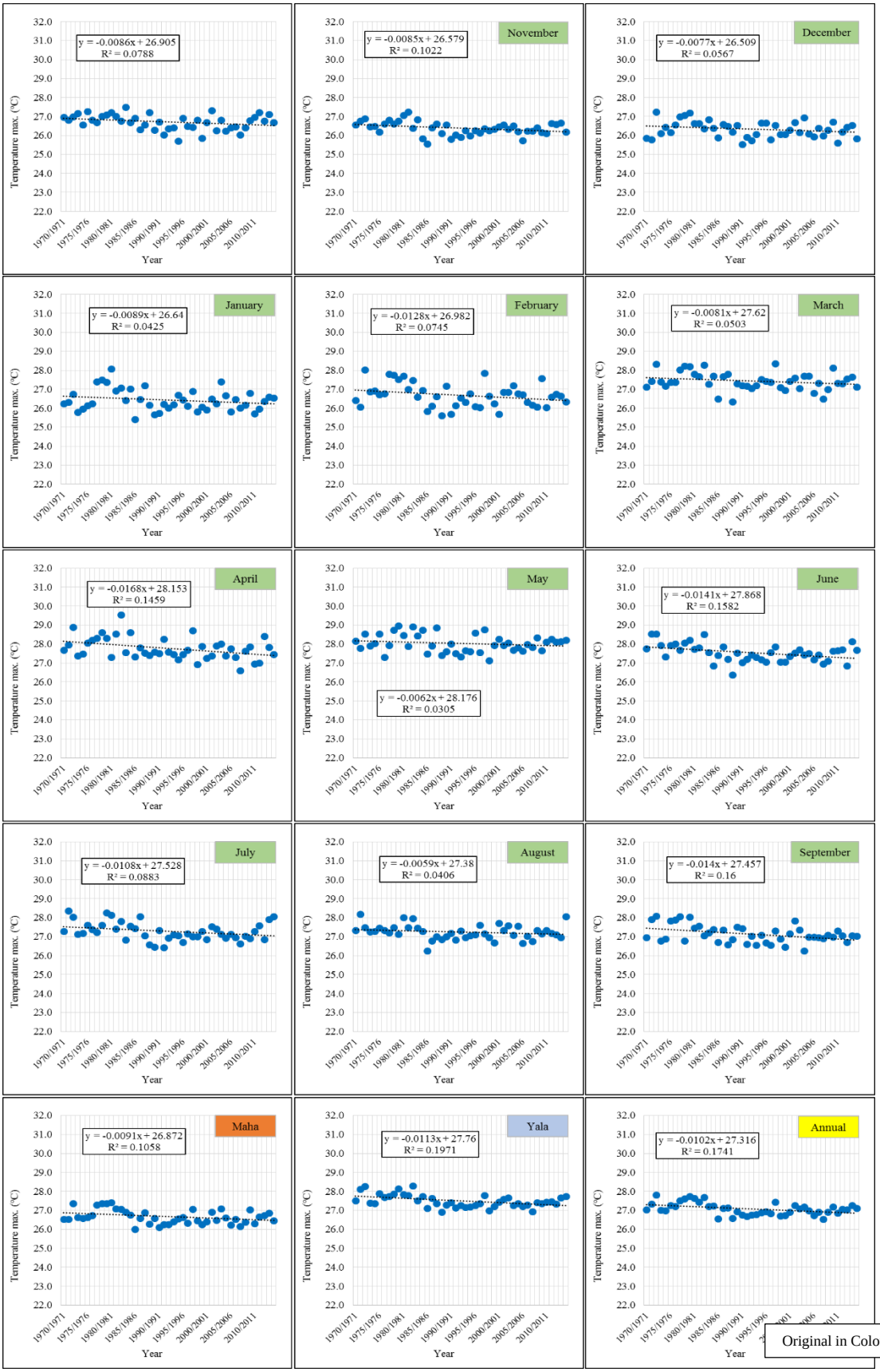


Appendix 07 - 1 Trends of Colombo T_{max} (1970-2015)

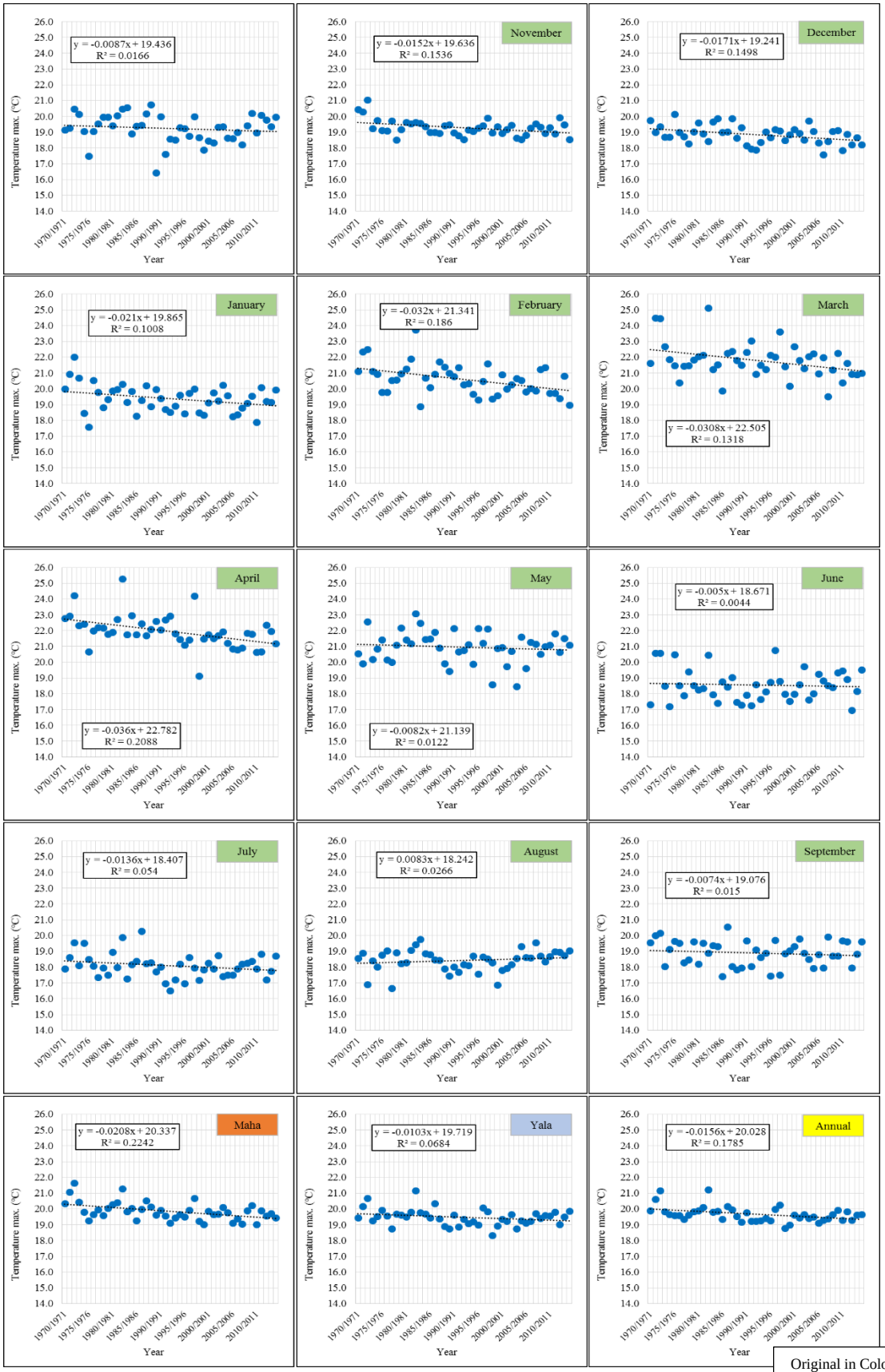


Original in Colour

Appendix 07 - 2 Trends of Colombo T_{min} (1970-2015)

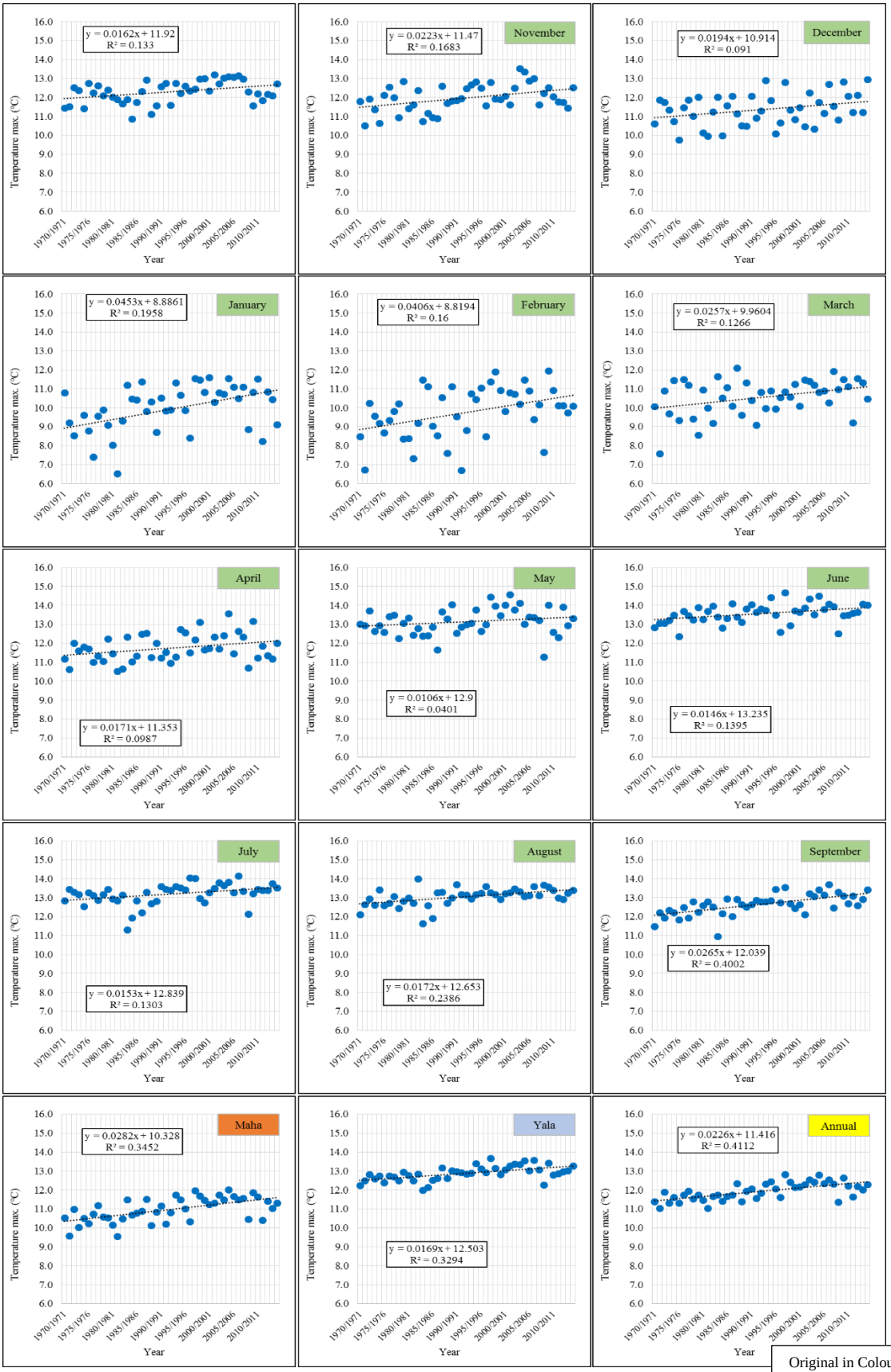


Appendix 07 - 3 Trends of Colombo T_{avg} (1970-2015)



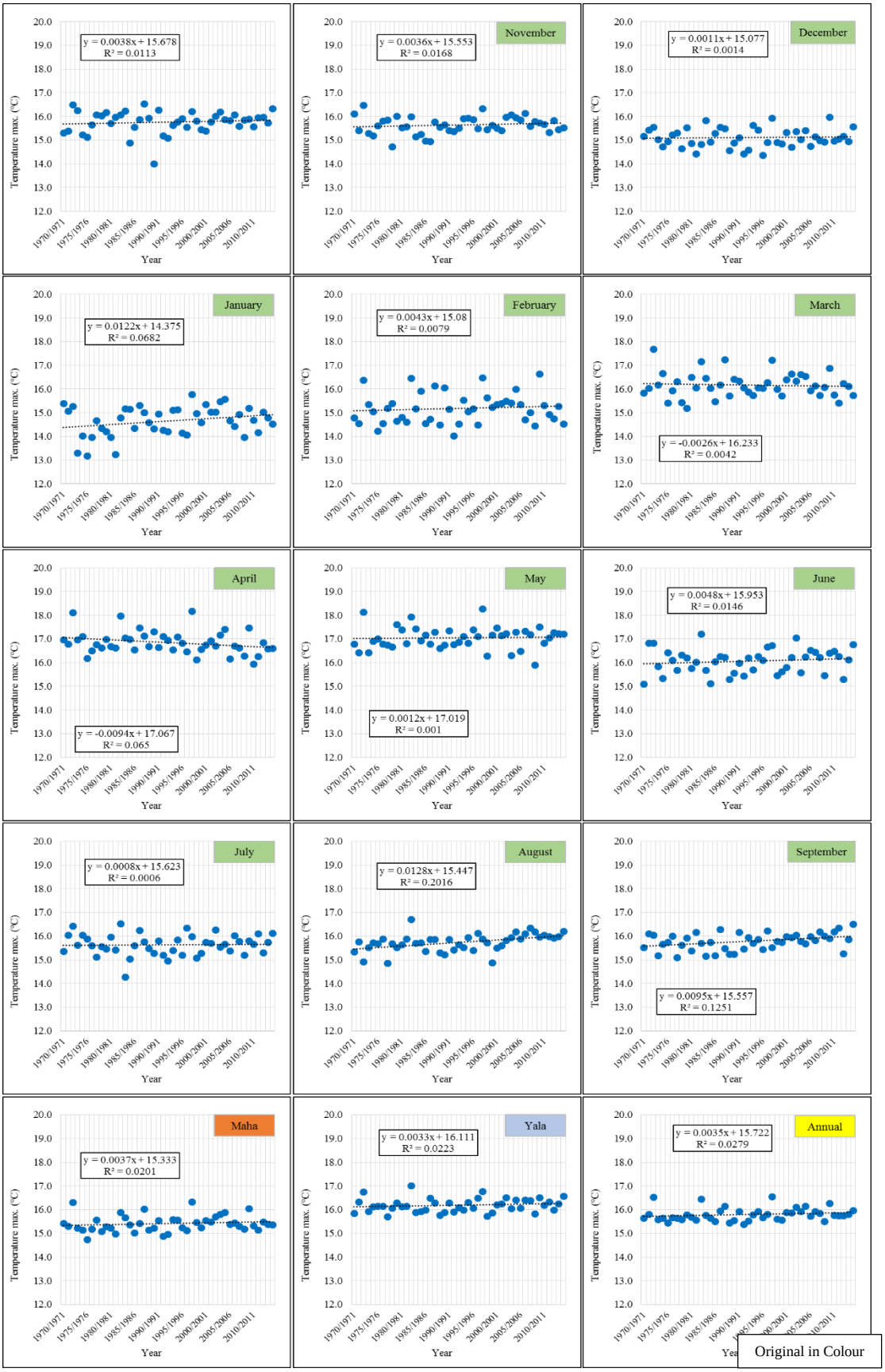
Original in Colour

Appendix 07 - 4 Trends of Nuwara-Eliya T_{max} (1970-2015)



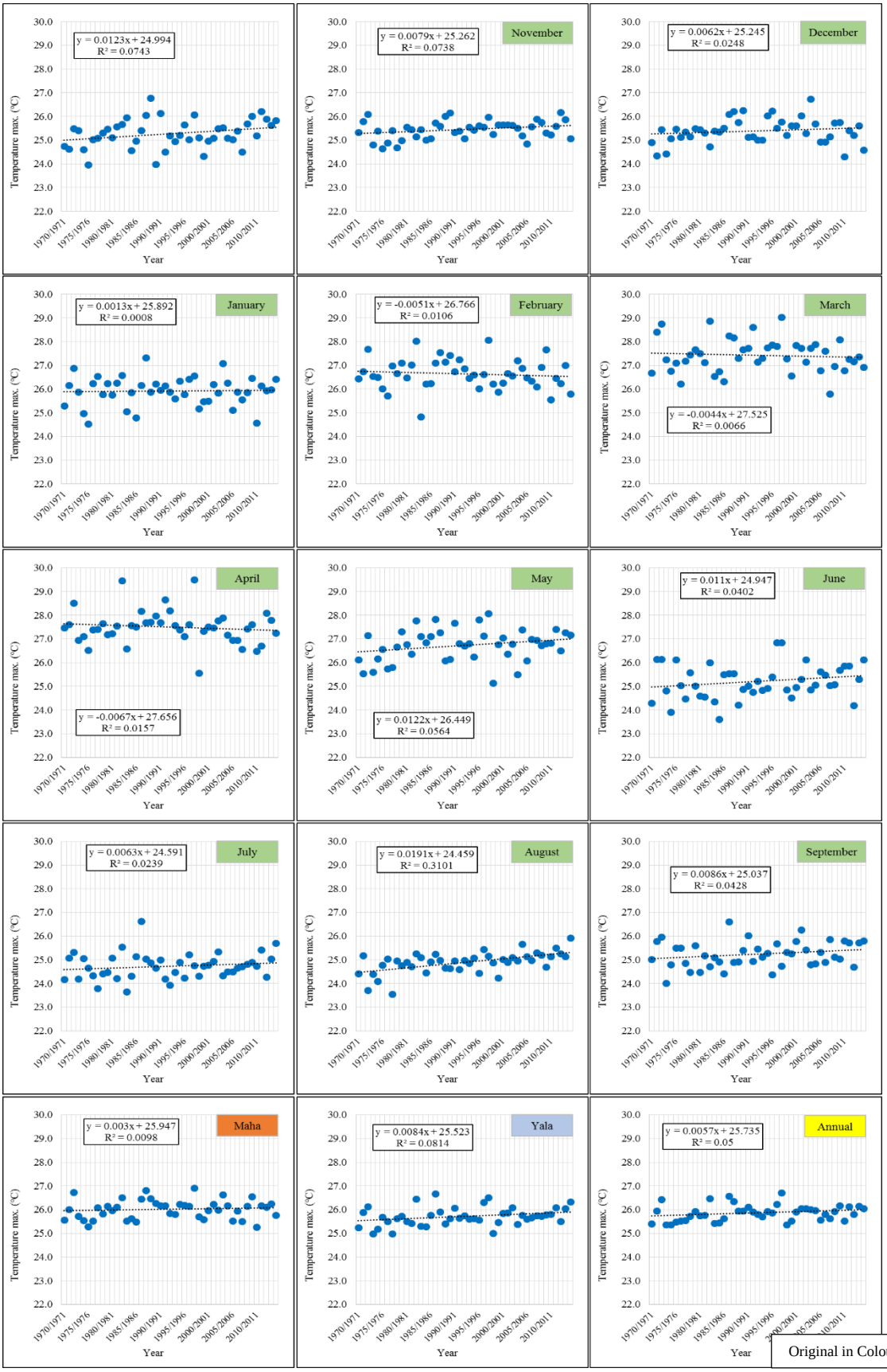
Original in Colour

Appendix 07 - 5 Trends of Nuwara-Eliya T_{min} (1970-2015)



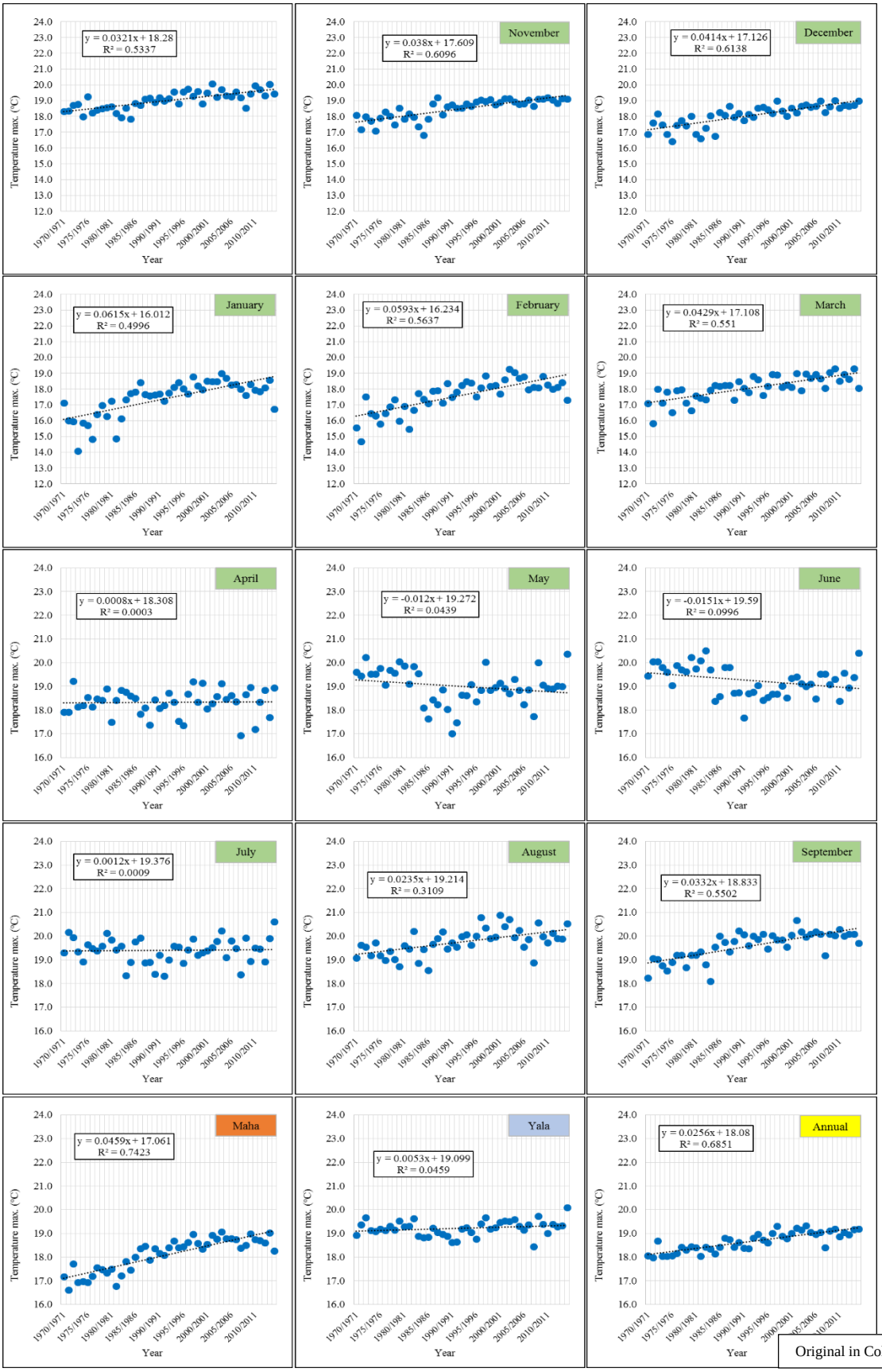
Original in Colour

Appendix 07 - 6 Trends of Nuwara-Eliya T_{avg} (1970-2015)



Original in Colour

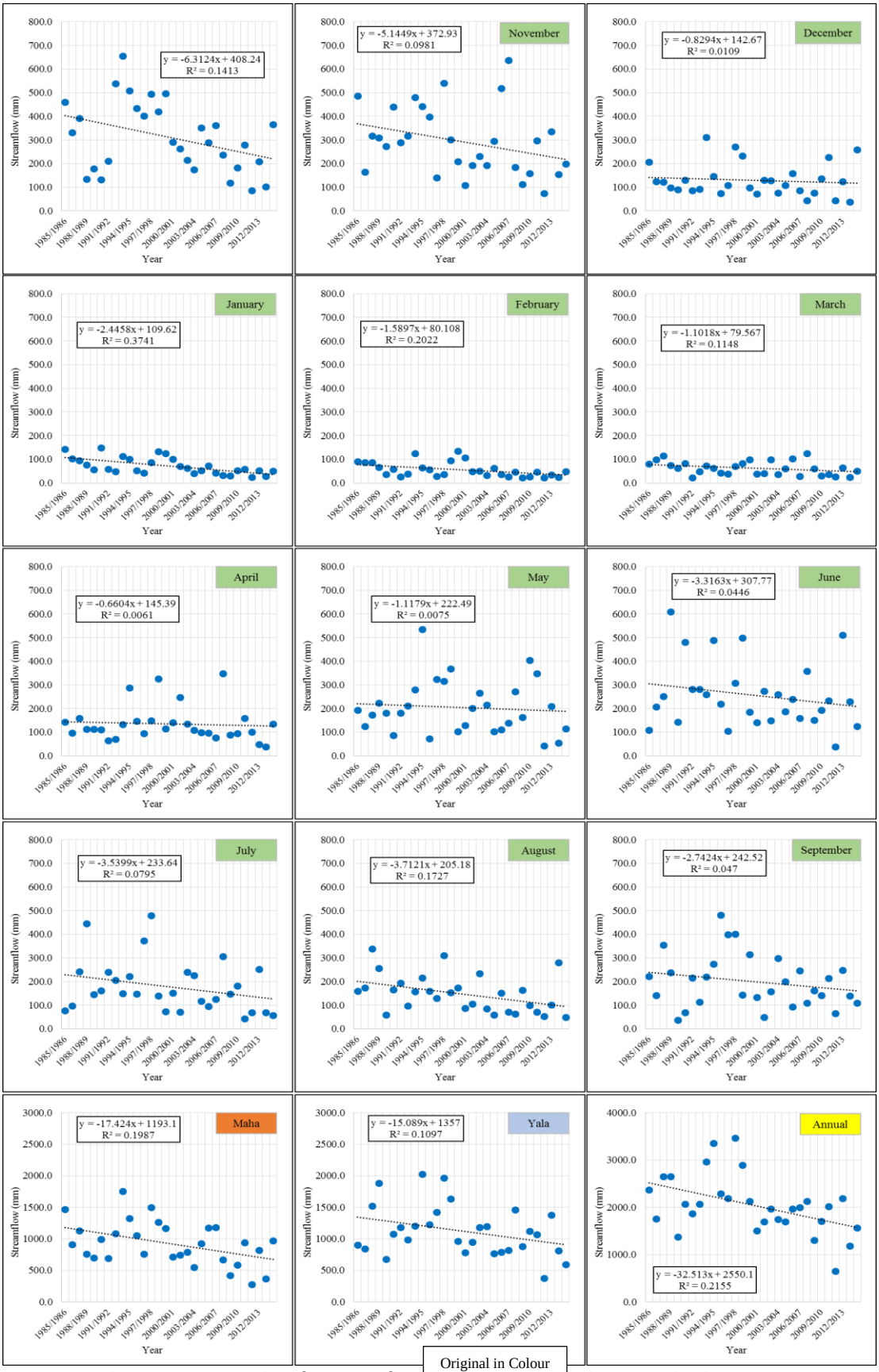
Appendix 07 - 7 Trends of River Basin T_{max} (1970-2015)



Original in Colour

Appendix 07 - 8 Trends of River Basin T_{min} (1970-2015)

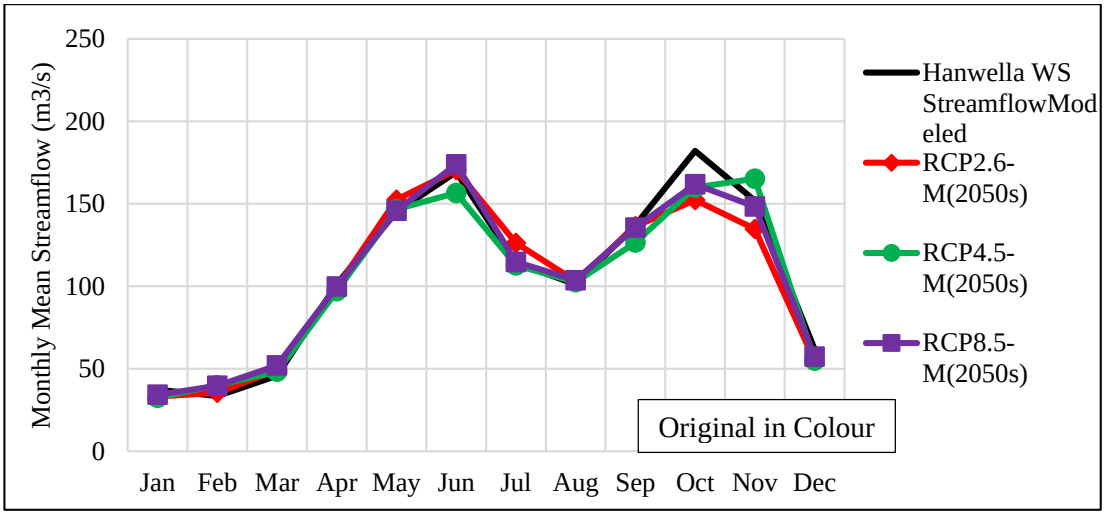
APPENDIX 08: - Trends Analysis of Streamflow (Hanwella Sub-watershed)



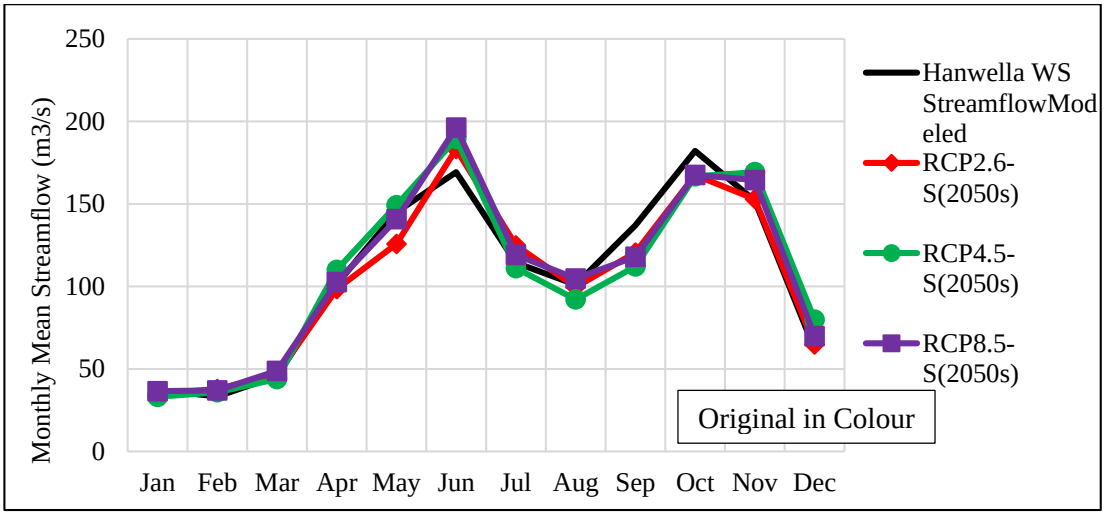
Original in Colour

Appendix 08 - 1 Trends of Streamflow at Hanwella sub watershed (1985-2015)

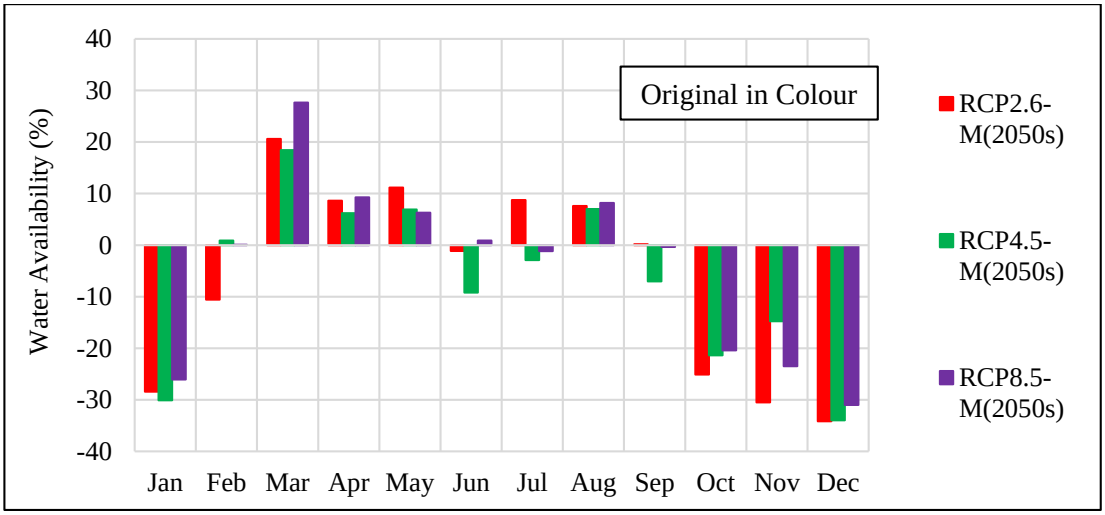
APPENDIX 09: - Future Streamflow Variations



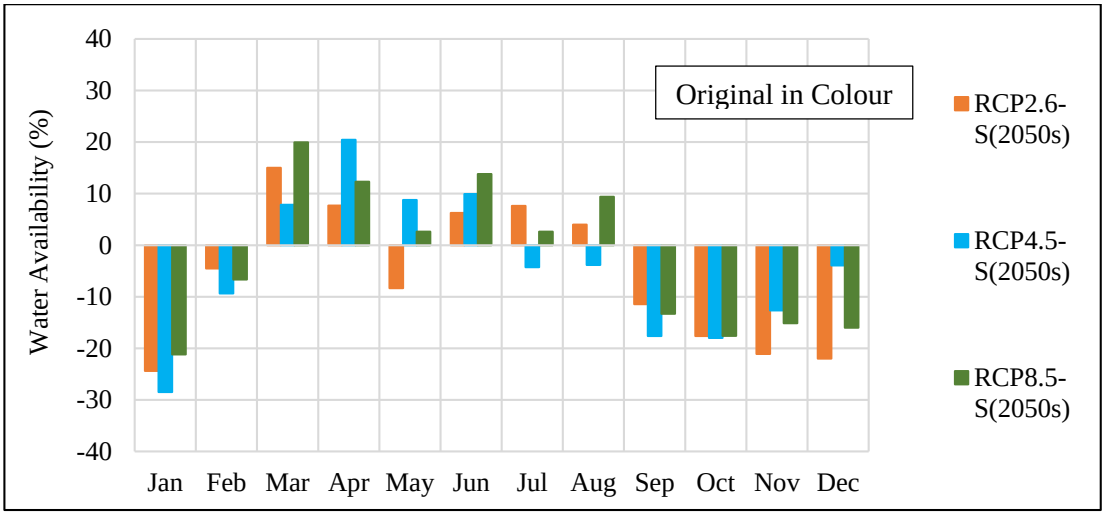
Appendix 09 - 1 Future Streamflow Variation of Hanwella Sub-watershed in 2050s for SDSM_M



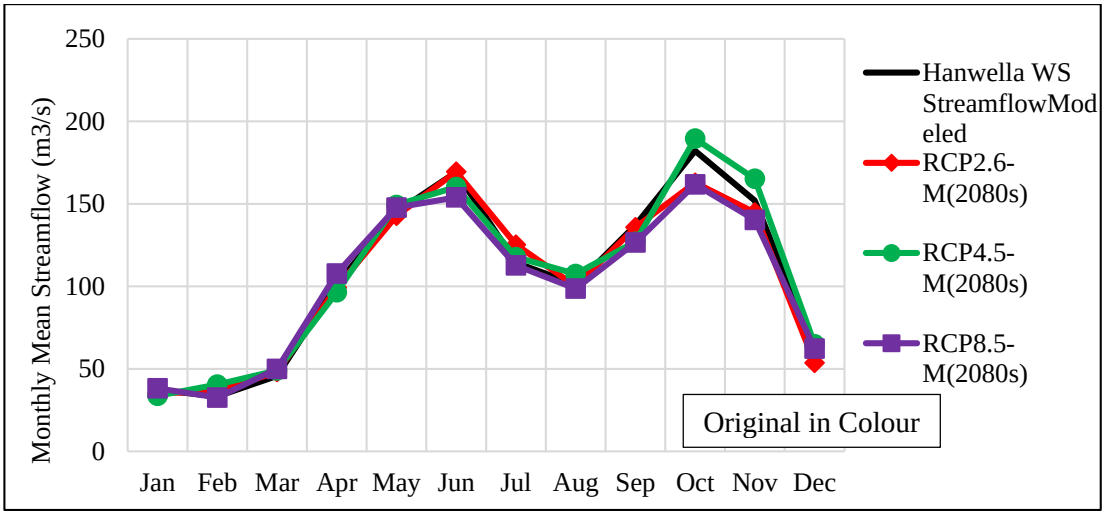
Appendix 09 - 2 Future Streamflow Variation of Hanwella Sub-watershed in 2050s for SDSM_S



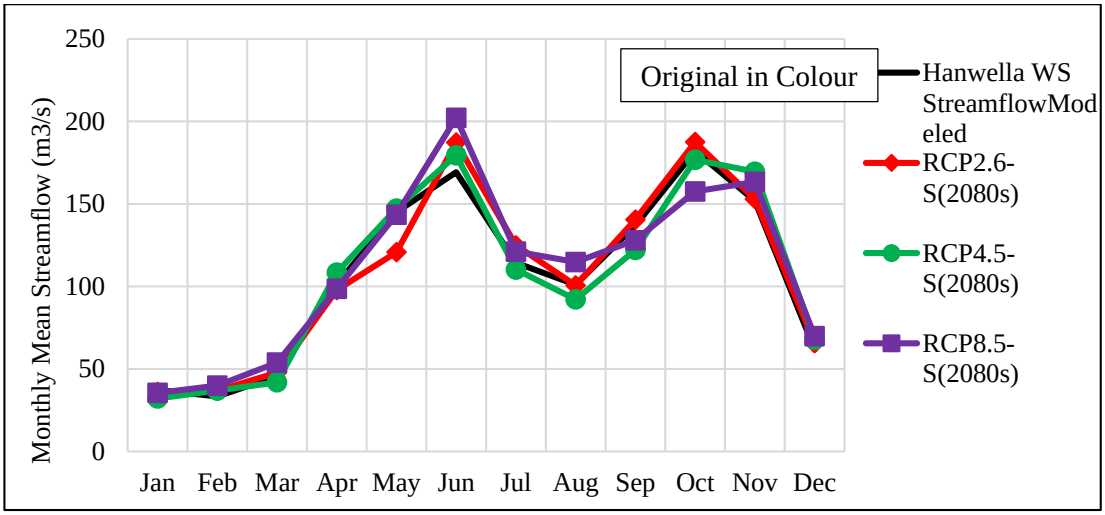
Appendix 09 - 3 Future Streamflow Availability in Hanwella Sub-watershed in 2050s for SDSM_M



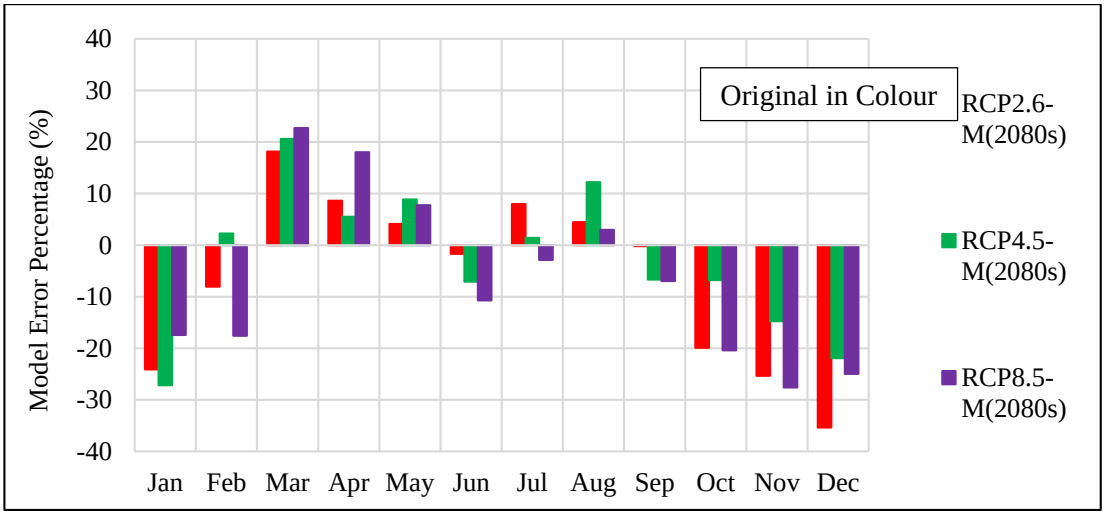
Appendix 09 - 4 Future Streamflow Availability in Hanwella Sub-watershed in 2050s for SDSM_S



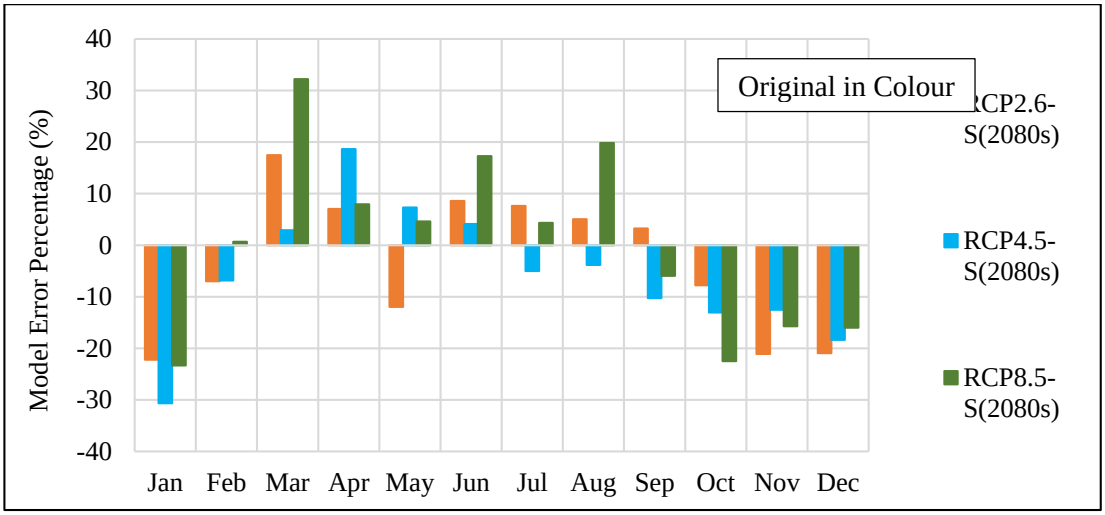
Appendix 09 - 5 Future Streamflow Variation of Hanwella Sub-watershed in 2080s for SDSM_M



Appendix 09 - 6 Future Streamflow Variation of Hanwella Sub-watershed in 2080s for SDSM_S



Appendix 09 - 7 Future Streamflow Availability in Hanwella Sub-watershed in 2080s for SDSM_M



Appendix 09 - 8 Future Streamflow Availability in Hanwella Sub-watershed in 2080s for SDSM_S