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Anticipated Impact of Climate Change on Rangeland Productivity in Central South Africa by the Mid-21st Century

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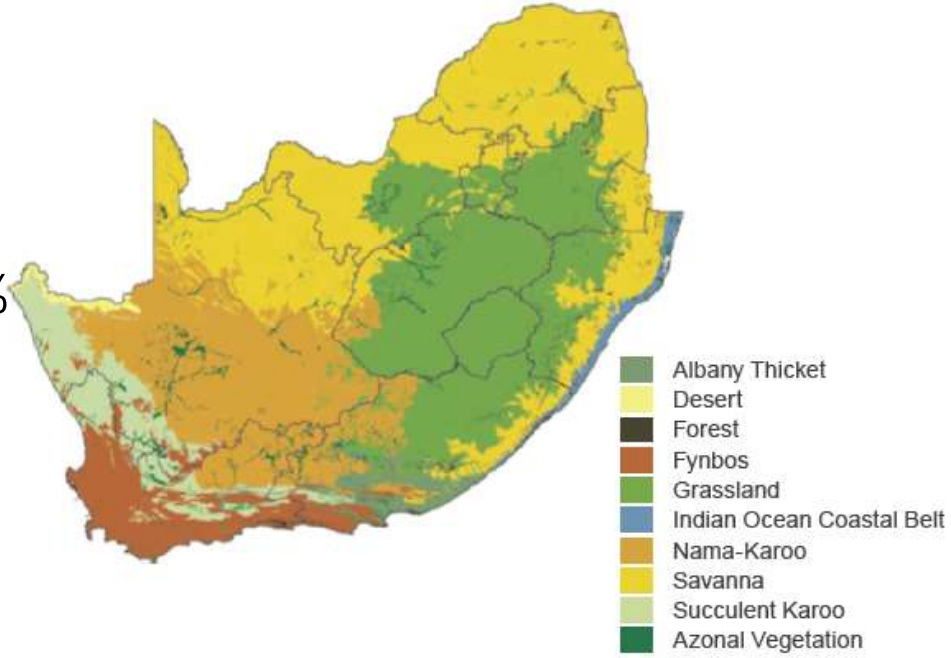
Introduction: Grasslands



- 69% of SA suitable for grazing, 30% covered by pastoral grasslands
- Provides various natural resources for man
  - Only real potential for food production is as a feed source for animal production
- Amount of cover depends on rainfall and degree of grazing
- Veld is farmer's most precious resource
  - If in a good condition = cheapest food source
- Environmental influences from outside (drought) can be dealt with in simulation models
- Models can be used as artificial "labs" where the interactions are investigated

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Introduction: Biophysical Production Models

- The integration of mathematical equations and algorithms which describe the interaction of the biotic and abiotic components of the grassland ecosystem
- Modelling is thus a process of organising, synthesising, conceptualising and integrating in a realistic description of the prototypes
- Provides an aid which can be used by researchers or by managers
- Examples of grassland models:
  - Integrated Farm System Model (IFSM)
  - GRASIM
  - Simulation of Production and Utilisation of Rangelands (SPUR)
  - Crop Environment Resource Synthesis (CERES)
  - PUTU 11/VELD

Research Questions and Objectives

Study will address the following questions:

- Can biophysical models accurately simulate historical rangeland production?
- Will rangeland production differ significantly under future climate scenarios?

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Objective 1: To assess the historical rangeland production over the study area. (1980/81 – 2009/10)

Specific objectives:

- Verify PUTU VELD against historical data [done to some extent by Booysen (1983) and Fouché (1992)]
- Simulate rangeland production using PUTU VELD and observed climate data for the historical period (1980/81 – 2009/10)
- Evaluate the simulated rangeland production for the historical period

Results not shown

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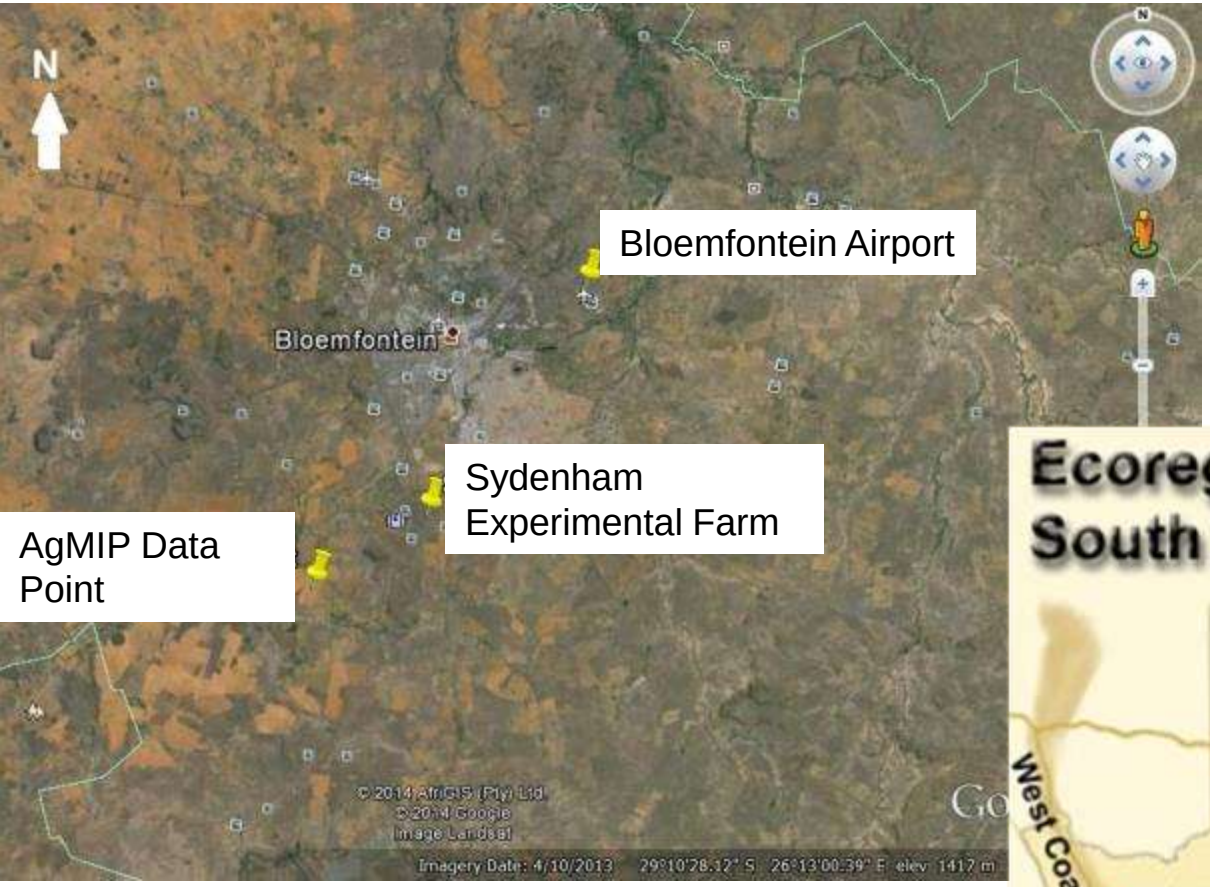
GCM data for base period
PUTU VELD
Simulated RP for base period
Historical simulated RP
GCM data for future period
• 5 climate models, 2 RCP values
PUTU VELD
Simulated RP for future period
Analyze

Methodology: Study Area



Methodology: Study Area

(1980 – 2010)

- Average monthly rainfall: 5.9 mm (July) – 101.7 mm (Feb)
- Average annual total rainfall: 569.7 mm
- Highest average monthly max temperature: 30.8 °C (Jan)
- Lowest average monthly min temperature: -2.2 °C (Jul)
- Average monthly sunshine hours: 8.2 (June) – 10.1 (Dec)
- Prevailing wind directions: North West to North East
- Dry *Themeda-Cymbopogon* veld
- Soil forms: Mispah, Milkwood, Swartlands, Sterkspruit, Arcadia, Valsrivier, Hutton
- Terrain is undulating to flat

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Methodology: Data sources

- Historical
  - BFN Airport data for 1980/81 – 2009/10 (base period) from SAWS
  - Daily rainfall, min and max temperatures, sunshine hours
  - Evapotranspiration data calculated by using the Hargreaves-Semani method
  - Observed rangeland production from Sydenham Experimental farm used for verification of base period

- Future Global Climate Model (GCM) (obtained from Climate System Analysis Group, UCT (AgMIP)
  - 5 Models: CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5, MPI-ESM-MR
  - 2 RCPs: 4.5 and 8.5
  - Base period: 1980/81 – 2009/10
  - 3 future periods: 2010/11 – 2039/40, 2040/41 – 2069/70, 2070/71 – 2099/2100
  - Evapotranspiration data calculated using the Hargreaves-Semani method
  - Solar radiation convert from $MJ.m^{-2}.d^{-1}$ to sunshine hours (*Excel* program Wton)

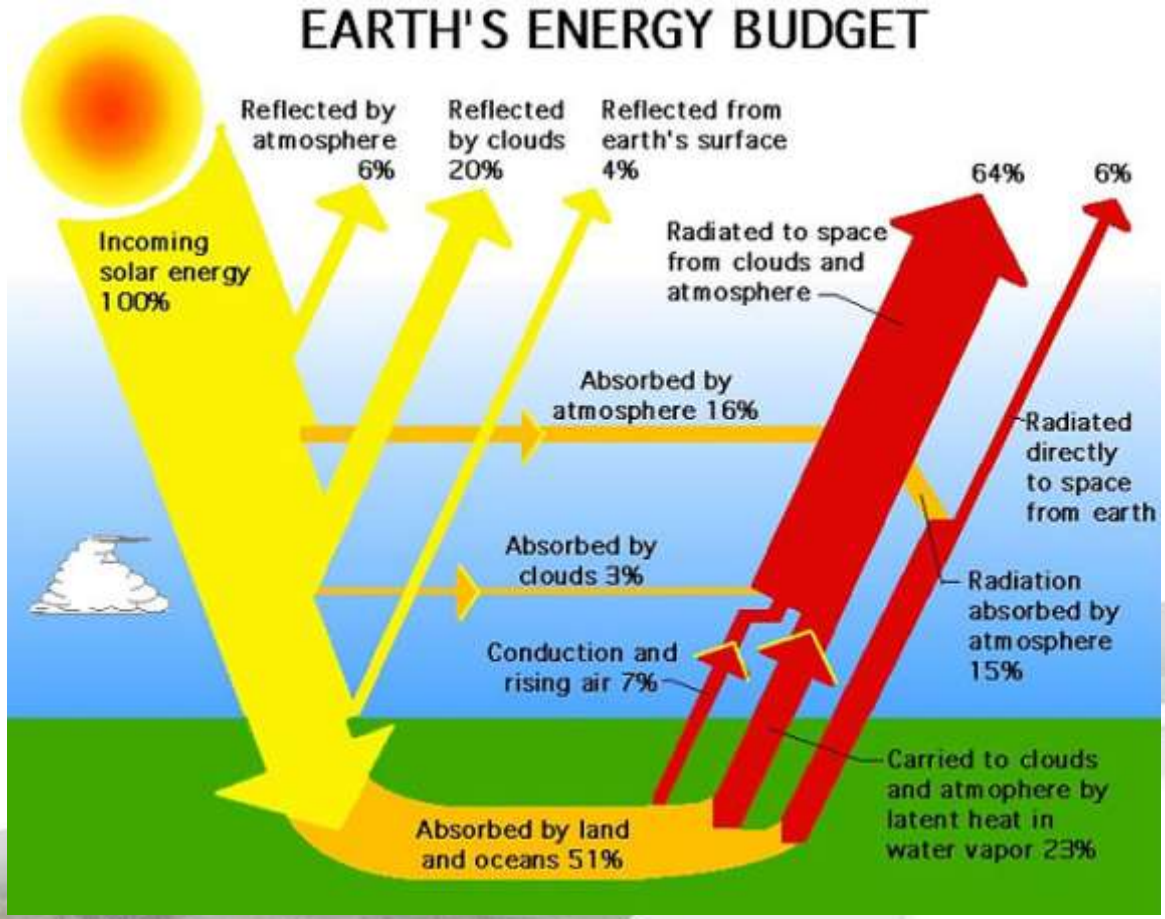
Representative Concentration Pathways

- The RCP is the latest generation of scenarios that provide input to climate models
- AR3 and AR4 used SRES (Special Report on Emissions and Scenarios)
  - e.g. B2, A2, B1, etc.
- AR5 developed RCPs, e.g. 2.6, 6.5, 4.5 and 8.5
- They are time and space dependant trajectories of concentrations of greenhouse gases and pollutants resulting from human activities, including changes in land use
- Provide a quantitative description of concentrations of the climate change pollutants in the atmosphere over time, as well as their radiative forcing in 2100

Radiative forcing

- The difference in the balance of energy that enters the atmosphere and the amount that is returned to space compared to the pre-industrial (1750) situation.

- As the radiative forcing increases, the global temperature rises. Unit: $W.m^{-2}$



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RCPs Comparison

	RCP 4.5	RCP 8.5
Emissions	Intermediate	High
Policy changes	Yes	No
Development	USA (Pacific Northwest National Laboratory)	Austria (International Institute for Applied System Analysis)
SRES scenario	B1	A1F1
	Decreasing use of croplands and grasslands due to yield increases and dietary changes	Increase use of croplands and grasslands which is driven by an increase in population
	Stable methane emissions	Rapid increase in methane emissions
		3x today's CO_2 emissions by 2100

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Methodology: PUTU VELD Model

- Dynamic, deterministic model, also is physically and biologically orientated. Improved version of the PUTU 2 model
- Simulates growth and development of climax grasses
- Meteorological simulation is kept but the single layered soil profile is amended to a two layered version
- PUTU 2 worked for a single plant basis, PUTU VELD calculates the production per unit area as well as taking into account the basal cover

- Model was rewritten in FORTRAN 95 from quick Basic
- Slightly modified to run smoother
- Description of model written by Booysen was translated from Afrikaans to English

Daily total rainfall (mm)

Daily minimum temperature (°C)

Daily maximum temperature (°C)

Daily ET (mm)

Sunshine duration (h)

PUTU VELD

Biomass production ($kg.ha^{-1}$) reached on a certain date

Maximum biomass production ($kg.ha^{-1}$) (from here can calculate LSU)

Number of moisture stress days

Reserves ($kg.ha^{-1}$) on 1 July

Residual production on 1 July
Maximum cumulative available yield

Growth pattern of accumulated dry matter

Assumptions

- Uniform grass cover
- No fire
- No grazing
- No bush encroachment
- Grass species composition does not change
- Climate models are accurate and RCP is a good approach for the evaluation of greenhouse gases

Results

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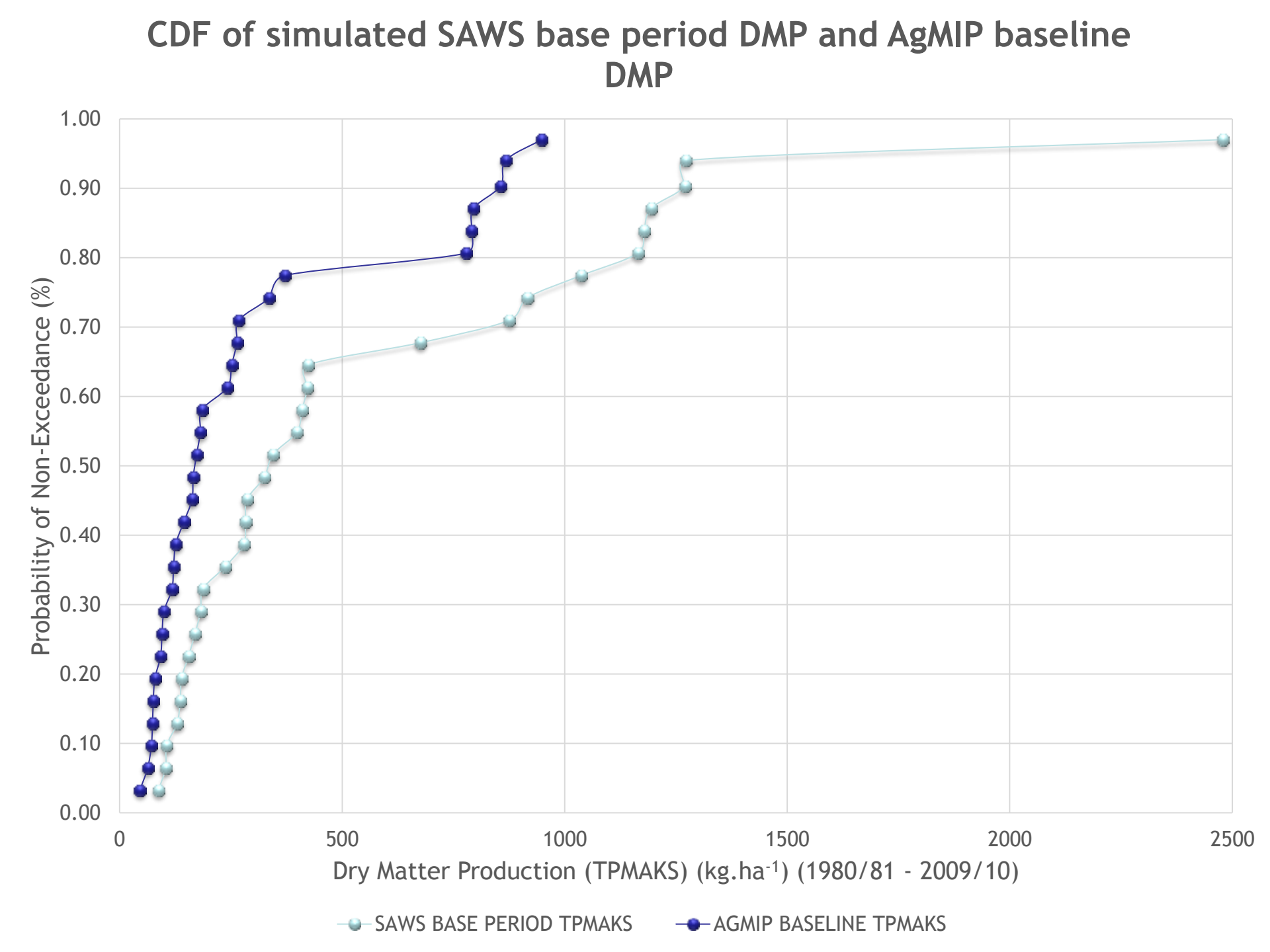
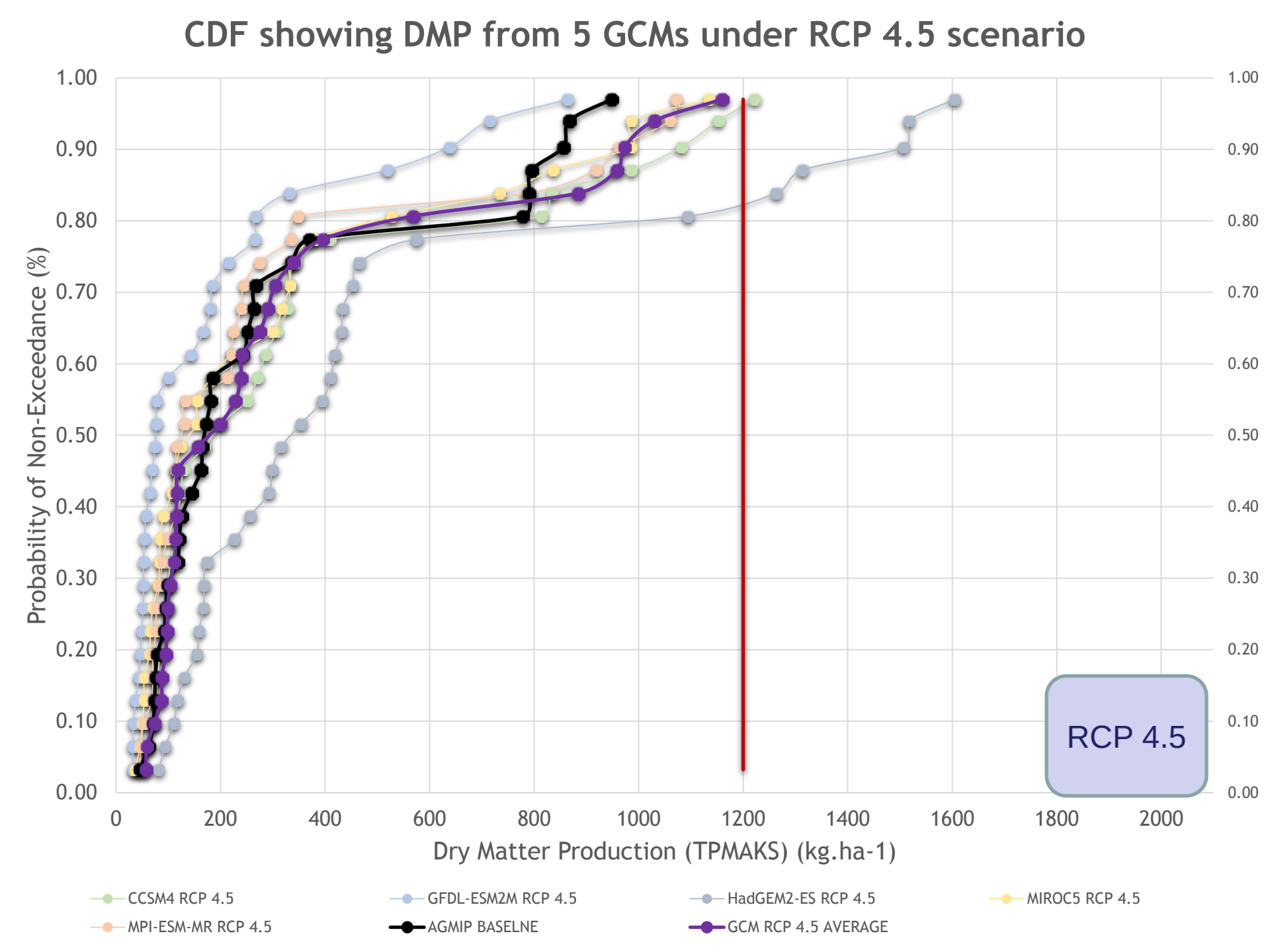
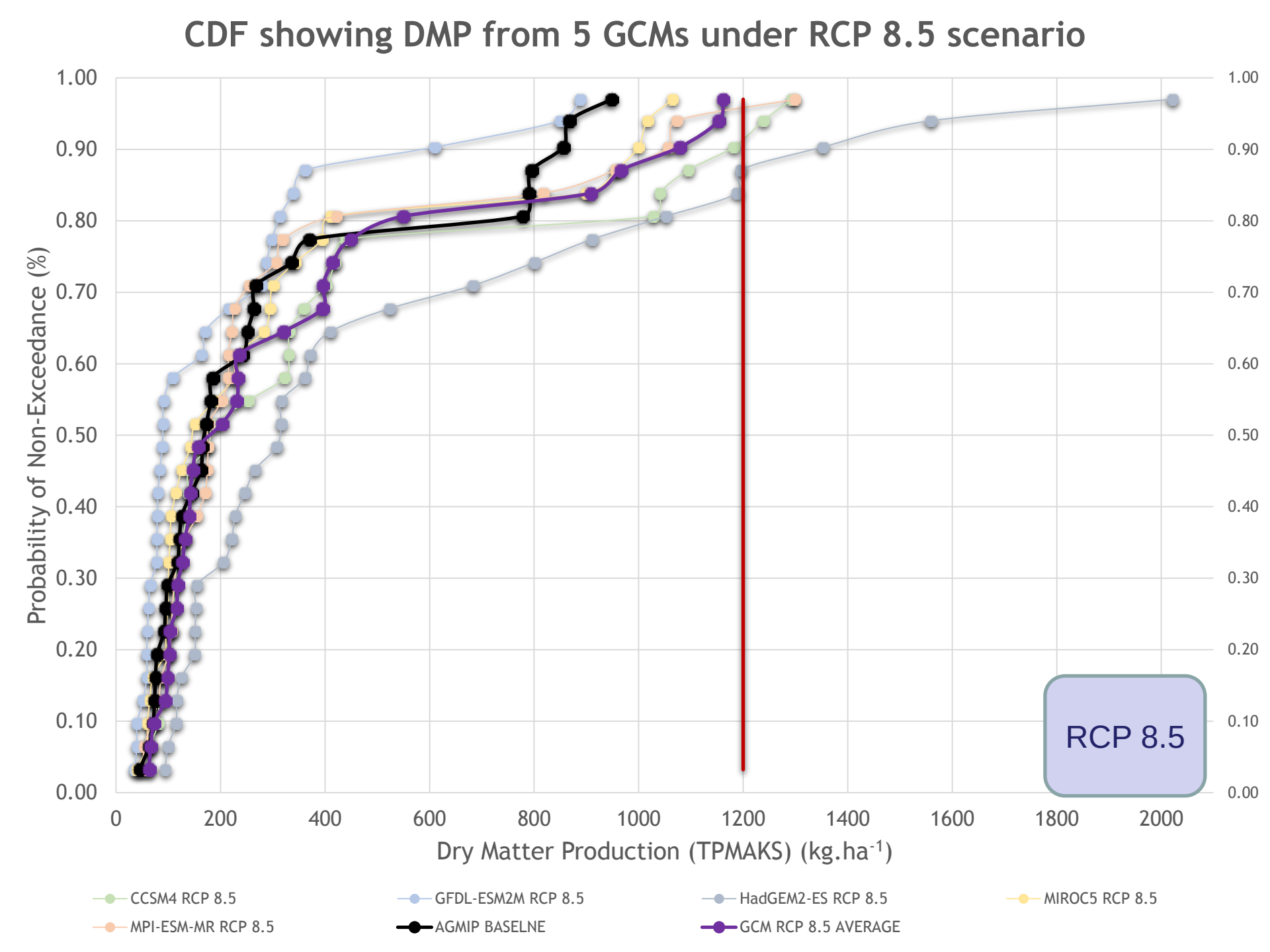
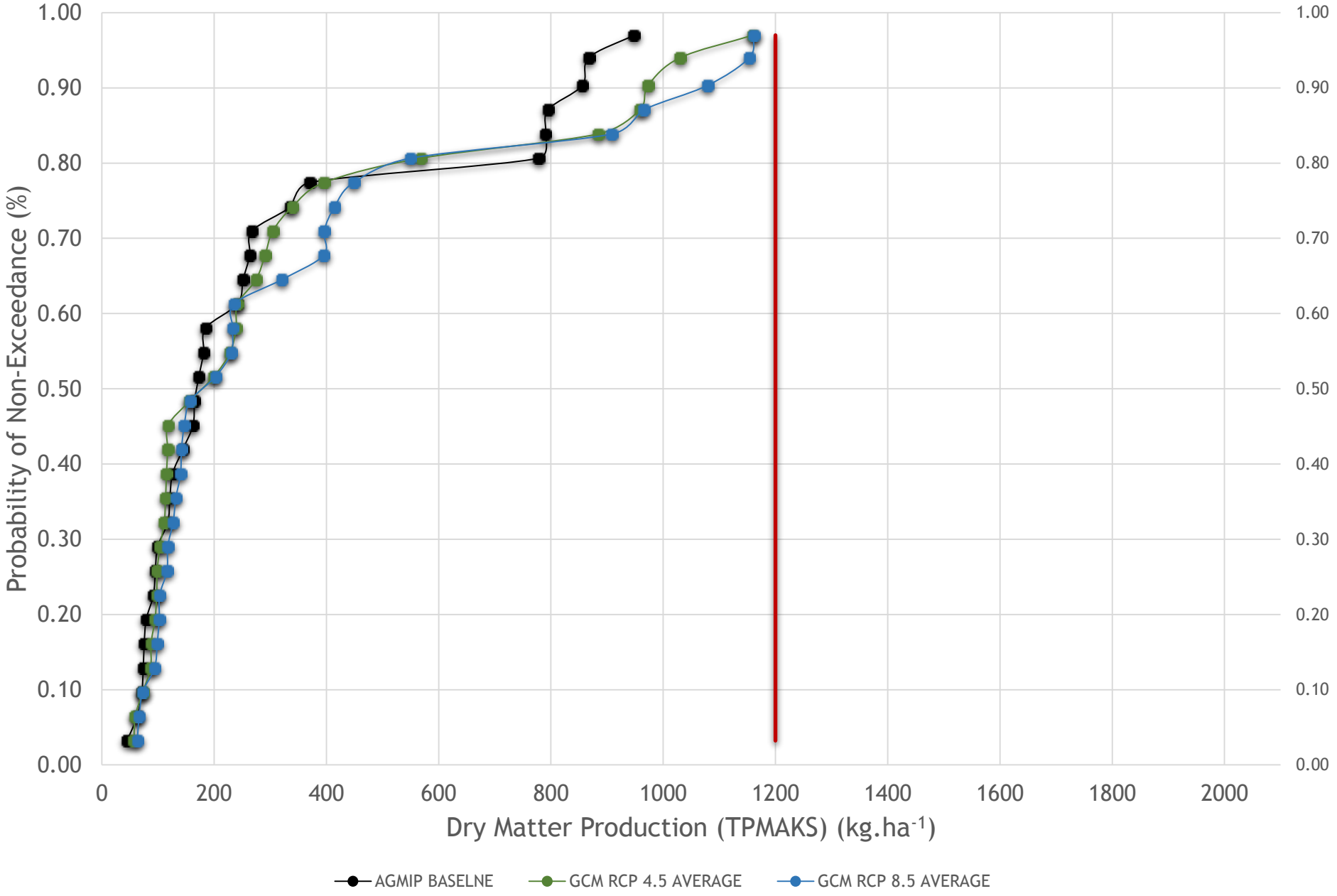
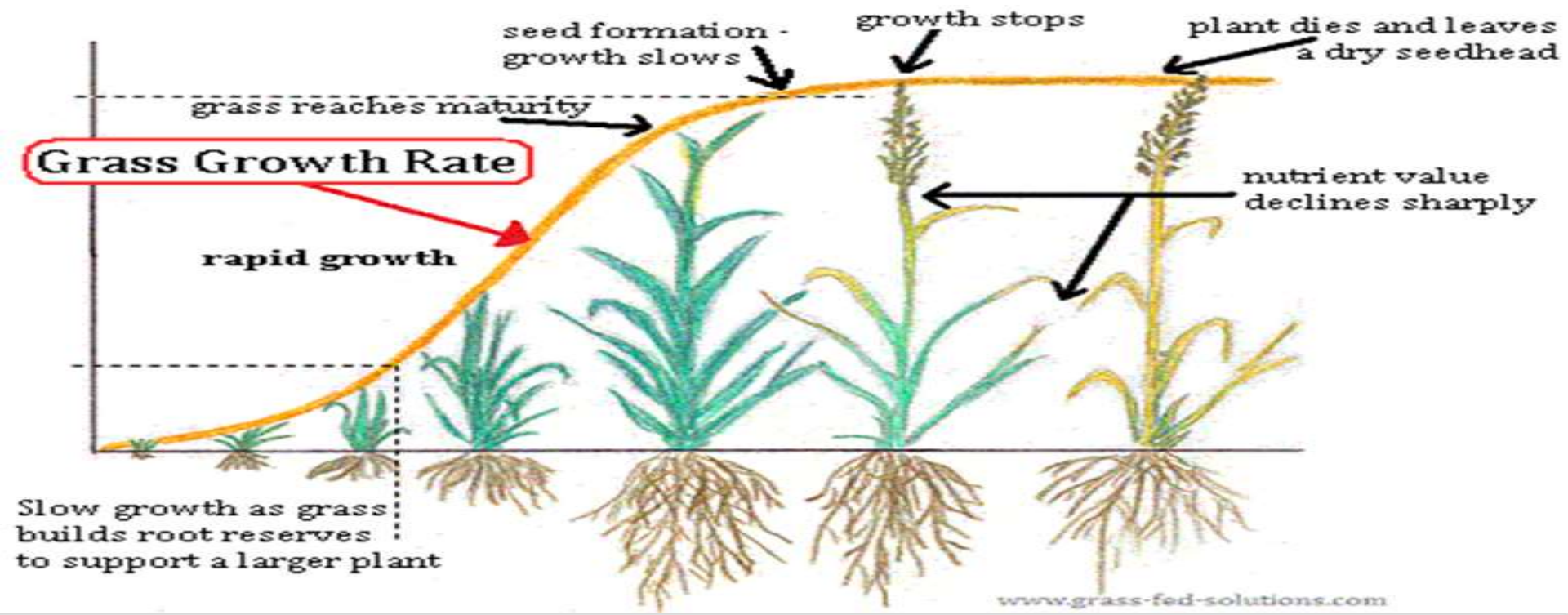

CDF of simulated SAWS base period DMP and AgMIP baseline DMP
Probability of Non-Exceedance (%)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
500
1000
1500
2000
2500
Dry Matter Production (TPMAKS) (kg.ha-1) (1980/81 - 2009/10)
SAWS BASE PERIOD TPMAKS
AGMIP BASELINE TPMAKS

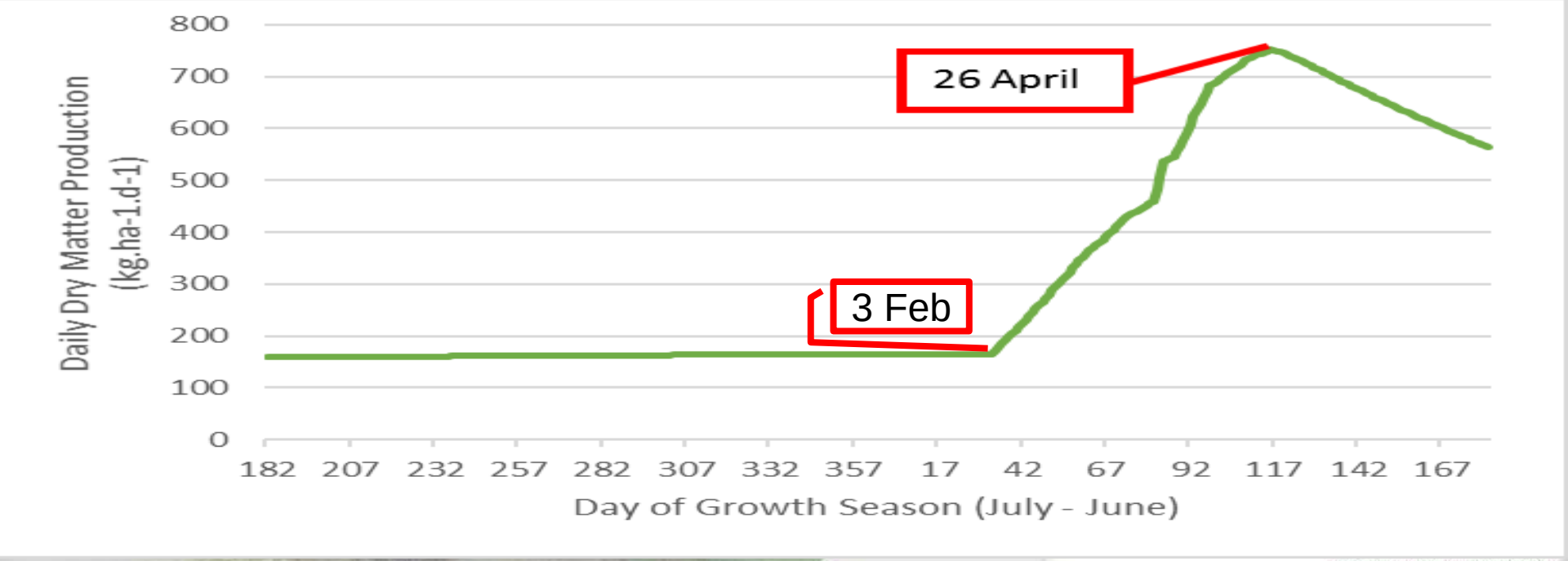

CDF showing DMP from 5 GCMs under RCP 4.5 scenario
Probability of Non-Exceedance (%)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Dry Matter Production (TPMAKS) (kg.ha-1)
RCP 4.5
CCSM4 RCP 4.5
GFDL-ESM2M RCP 4.5
HadGEM2-ES RCP 4.5
MIROC5 RCP 4.5
MPI-ESM-MR RCP 4.5
AGMIP BASELNE
GCM RCP 4.5 AVERAGE

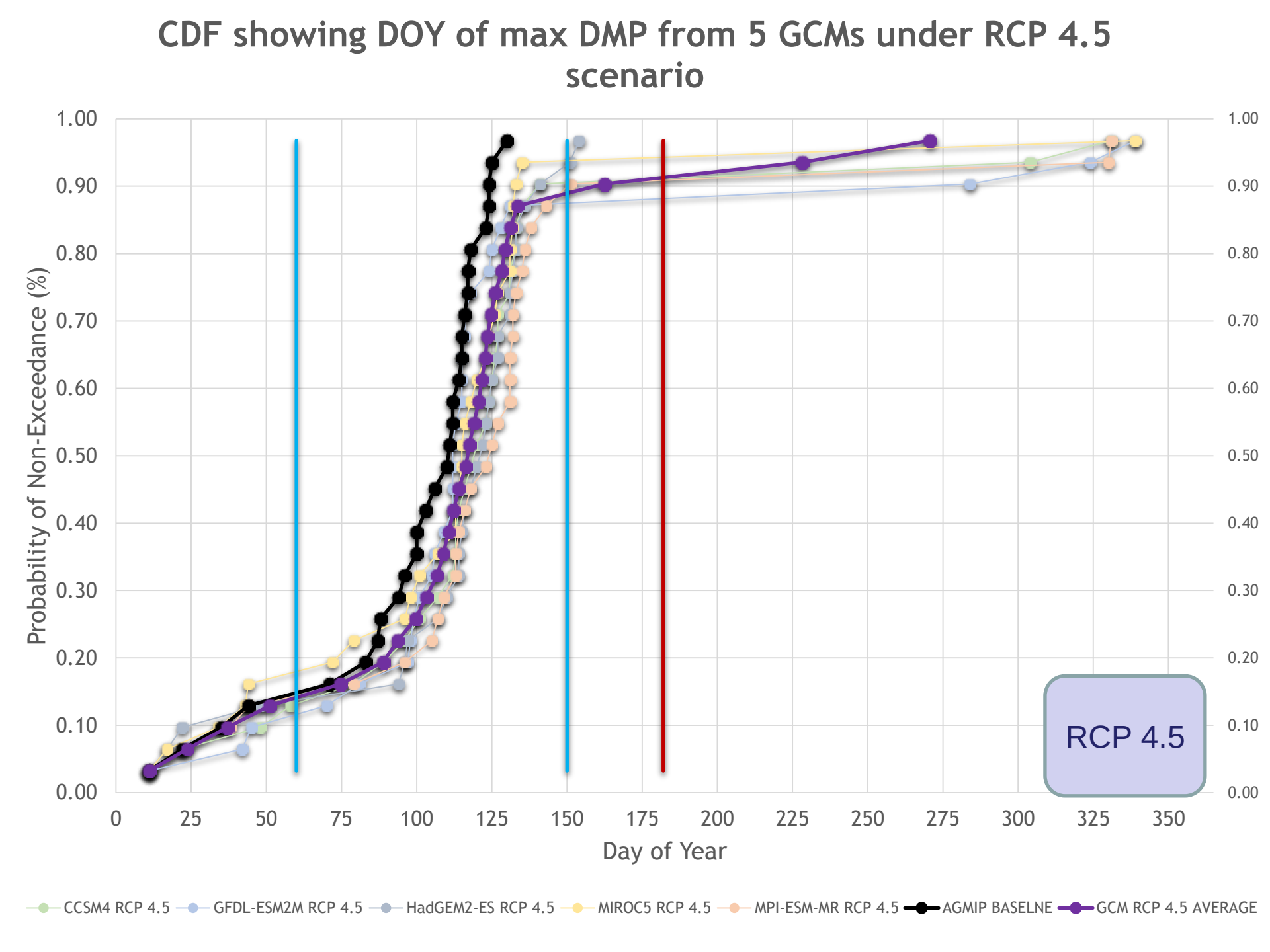

CDF showing DMP from 5 GCMs under RCP 8.5 scenario
Probability of Non-Exceedance (%)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Dry Matter Production (TPMAKS) (kg.ha-1)
RCP 8.5
CCSM4 RCP 8.5
GFDL-ESM2M RCP 8.5
HadGEM2-ES RCP 8.5
MIROC5 RCP 8.5
MPI-ESM-MR RCP 8.5
AGMIP BASELNE
GCM RCP 8.5 AVERAGE

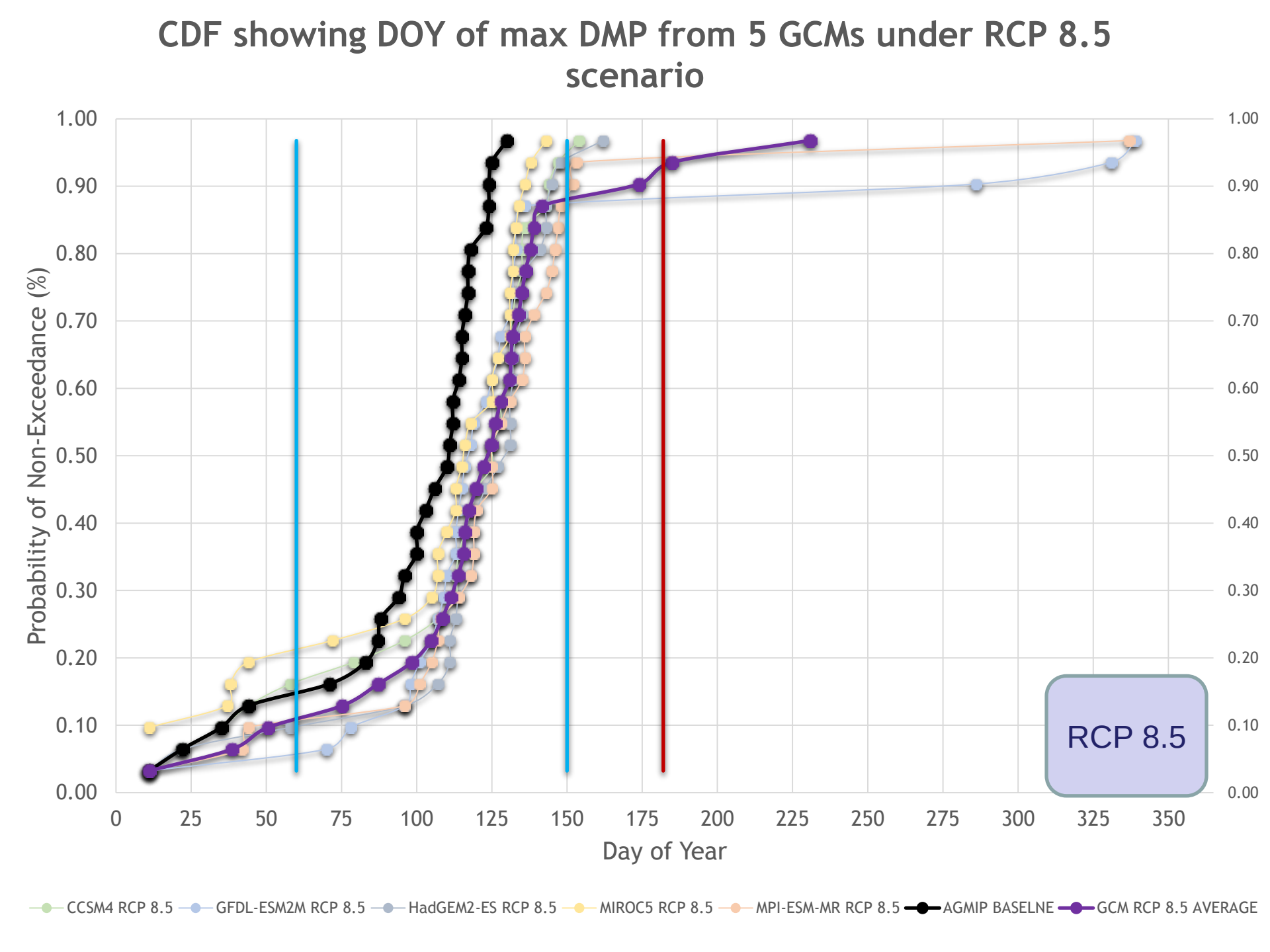
CDF showing the average DMP from 5 GCMs under RCP 4.5 and 8.5 scenarios



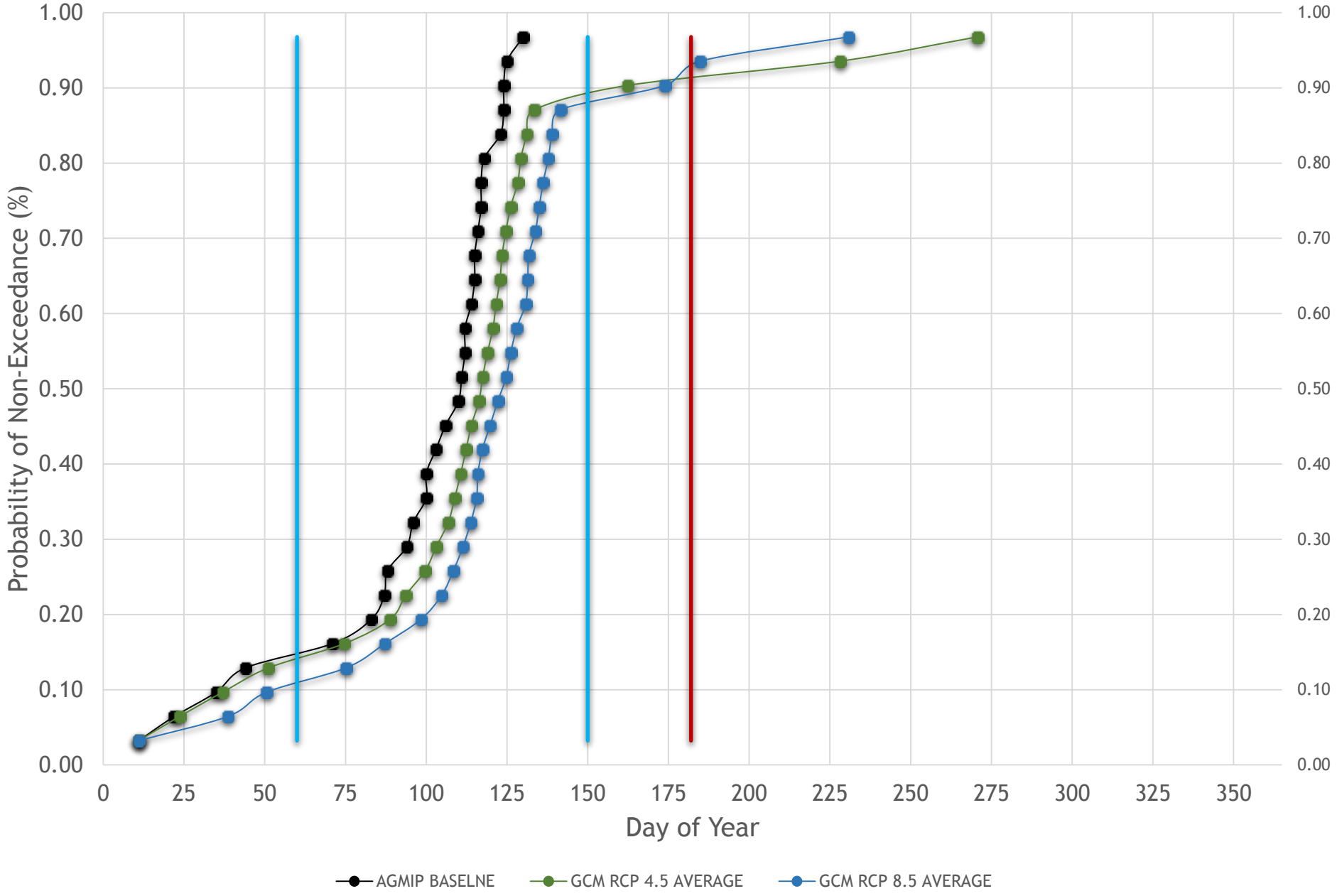

seed formation - growth slows
growth stops
plant dies and leaves a dry seedhead
grass reaches maturity
Grass Growth Rate
rapid growth
nutrient value declines sharply
Slow growth as grass builds root reserves to support a larger plant
www.grass-fed-solutions.com


Daily Dry Matter Production (kg.ha-1.d-1)
800
700
600
500
400
300
200
100
0
26 April
3 Feb
182 207 232 257 282 307 332 357 17 42 67 92 117 142 167
Day of Growth Season (July - June)

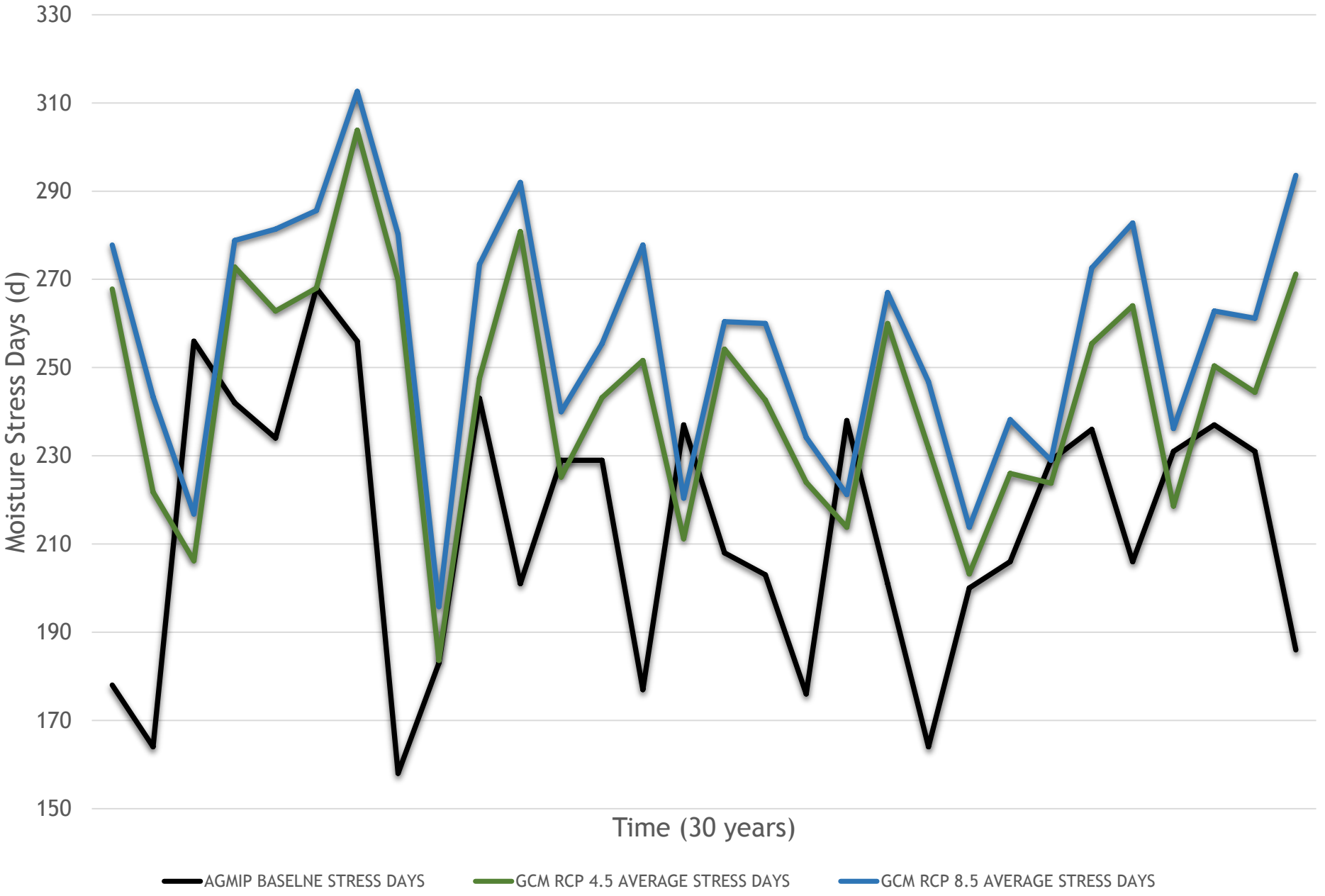

CDF showing DOY of max DMP from 5 GCMs under RCP 4.5 scenario
Probability of Non-Exceedance (%)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Day of Year
RCP 4.5
CCSM4 RCP 4.5
GFDL-ESM2M RCP 4.5
HadGEM2-ES RCP 4.5
MIROC5 RCP 4.5
MPI-ESM-MR RCP 4.5
AGMIP BASELNE
GCM RCP 4.5 AVERAGE


CDF showing DOY of max DMP from 5 GCMs under RCP 8.5 scenario
Probability of Non-Exceedance (%)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
Day of Year
RCP 8.5
CCSM4 RCP 8.5
GFDL-ESM2M RCP 8.5
HadGEM2-ES RCP 8.5
MIROC5 RCP 8.5
MPI-ESM-MR RCP 8.5
AGMIP BASELNE
GCM RCP 8.5 AVERAGE

CDF showing average DOY of max DMP from 5 GCMs under RCP 4.5 and 8.5 scenarios



Comparison between average Moisture Stress Days for RCP 4.5 and 8.5 and AgMIP baseline



Conclusions and Recommendations

Dry Matter Production	Average RCP 8.5 slightly more than average RCP 4.5 and baseline. Positive.
Day of year for max production	Marked differences between average RCP 8.5, 4.5 and baseline. RCP 8.5 on average later in the active period. Positive.
Moisture Stress Days	Significant differences between average RCP 8.5, 4.5 and baseline. Increase from baseline – RCP 4.5 – RCP 8.5. Negative.

- Forecast for 5 years rather than more, get better picture of near future. Make contingency plans. Revise.
- MESA project for SADC. Carrying capacity. More grass species and soil forms.

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Thank you

AgMIP

The Agricultural
Model Intercomparison
and Improvement Project

ARC - PDP

Professional Development Program

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