Climate Change risk and Agricultural Productivity in the Sahel

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The Sahel is extremely vulnerable to climate change due to its geographical location

“ The combined threat of drought, high food prises, displacement and chronic poverty is affecting millions of people in 2012 as n new food crisis emerge across the Sahel region. Food insecurity and malnutrition are recurrent in the region with more than 16 million people directly at risk this year.” **FAO**

Recurrent droughts caused important losses of agricultural production and livestock

Source : Allafrica.net

Climate in the Sahel

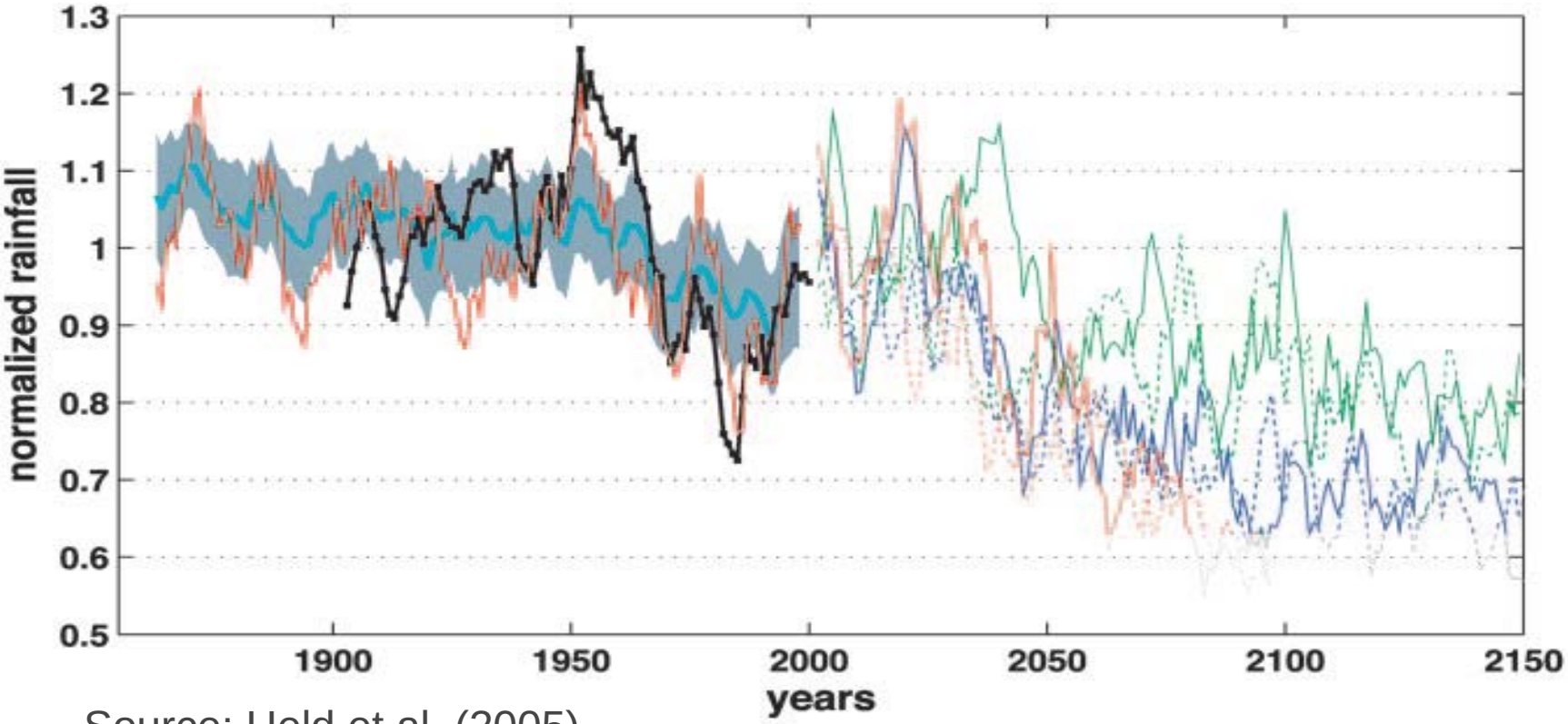
- According to many experts rainfall in the region has become less reliable and growing seasons are shorter.

- The Sahel is characterised by irregular rainfall that ranges between 200 mm and 600 mm with coefficients of variation ranging from 15 to 30 percent (Fox and Rockström, 2003;CILSS, 2004)

- Harvests of major food crops are highly uncertain due to recurrent droughts (two out of every five years).

The Observed and Projected 5-Year Mean Rainfall in Sahel

According to the IPCC, a rainfall decrease of 29-49% was observed in the 1968-1997 period compared to the 1931-60 baseline period



Source: Held et al. (2005).

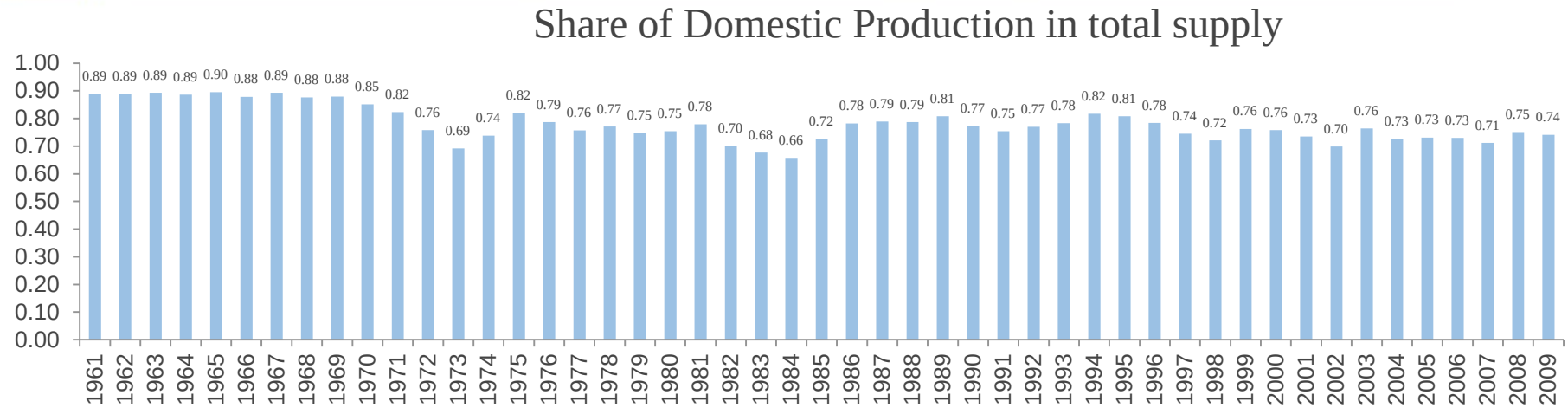
Agriculture in the Sahel : Poor performance

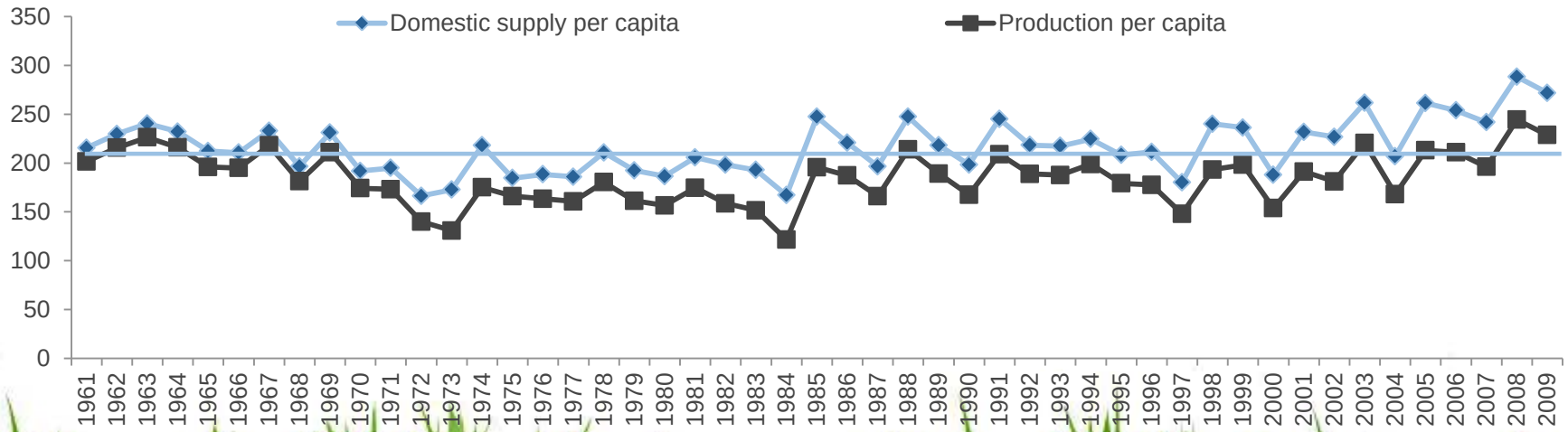
- Agriculture in the Sahelian countries is underdeveloped and almost totally dependent on rainfall.

- Agriculture is characterized by the low use of improved seeds and fertilizers, the absence of mechanization, and poor linkage to markets.

- Mendelsohn et al. (2000): 3 African countries will virtually lose their entire rainfed agriculture by 2100 and two of them are Sahelien countries: Chad and Niger

Agriculture in the Sahel: Important for food security in the Sahel





Investment in agriculture in the Sahel

- Highly risks of crop failure
- Low value of major cereal crops
- Poor road infrastructures and Poor access to market

➔ Investing in new production technologies (new seeds, fertilizers, ….) to improve productivity is not profitable

Fox and Rockström (2003): "Supplement irrigation for dry-spell mitigation of rainfed agriculture in the Sahel", *Agriculture and Water Management, 61*.

Observed average grain yields

	1998		1999		2000		1998-2000	
	Mean (kg/ha)	S.D. (kg/ha)	Mean (kg/ha)	S.D. (kg/ha)	**Mean (kg/ha)**	**S.D. (kg/ha)**	Mean (kg/ha)	S.D. (kg/ha)
Control Treatment (farmer's normal practice)	666	154	238	25	**460**	**222**	455	232
Irrigation application	961	237	388	182	**787**	**230**	712	320
Fertilise application	1470	254	647	55	**807**	**176**	975	404
Irrigation and Fertilisers	1747	215	972	87	**1489**	**123**	1403	367

Rain water use efficiency for mean grain yield per hectare (kg/mm/ha)

	1998 (571 mm)	1999 (667 mm)	2000 (418 mm)
Control Treatment (farmer's normal practice)	1.16	0.36	**1.10**
Irrigation application	1.51	0.53	**1.54**
Fertilise application	2.55	0.97	**1.93**
Irrigation and Fertilisers	2.75	1.34	**2.93**

Empirical Analysis

Objective of this work: How does drought risk affect agricultural productivity in the Sahel?

- Test the impact of weather risk on agricultural productivity
- **6 Countries** : Burkina Faso, Chad, Mali, Mauritania, Niger, and Senegal.

We proceed in 6 steps :

1. We use the Standardized Precipitation Index (SPI) to identify drought episodes over the period 1901-2000.
2. Estimate crop losses associated with drought shock relative to the nearest normal growing season. (main crops)
3. Probability distribution of crop losses
4. The Drought Risk is defined as crop losses times the probability of occurrence of drought shock
5. Estimate agricultural technical efficiency using the stochastic frontier approach
6. Test the impact of the drought risk on the agricultural technical efficiency

The impact of drought risk on farmer's decision

	States of nature	
Technologies	***Normal year***	***Dry year***
Standard technology	(low cost (C_n), normal production (Y_n))	(low cost (C_n), low production (Y_d))
Drought- resilient technology	(high cost (C_h), high production (Y_h))	(high cost (C_h), normal production (Y_n))

Drought- resilient technology : Using fertilizers + new seed varieties

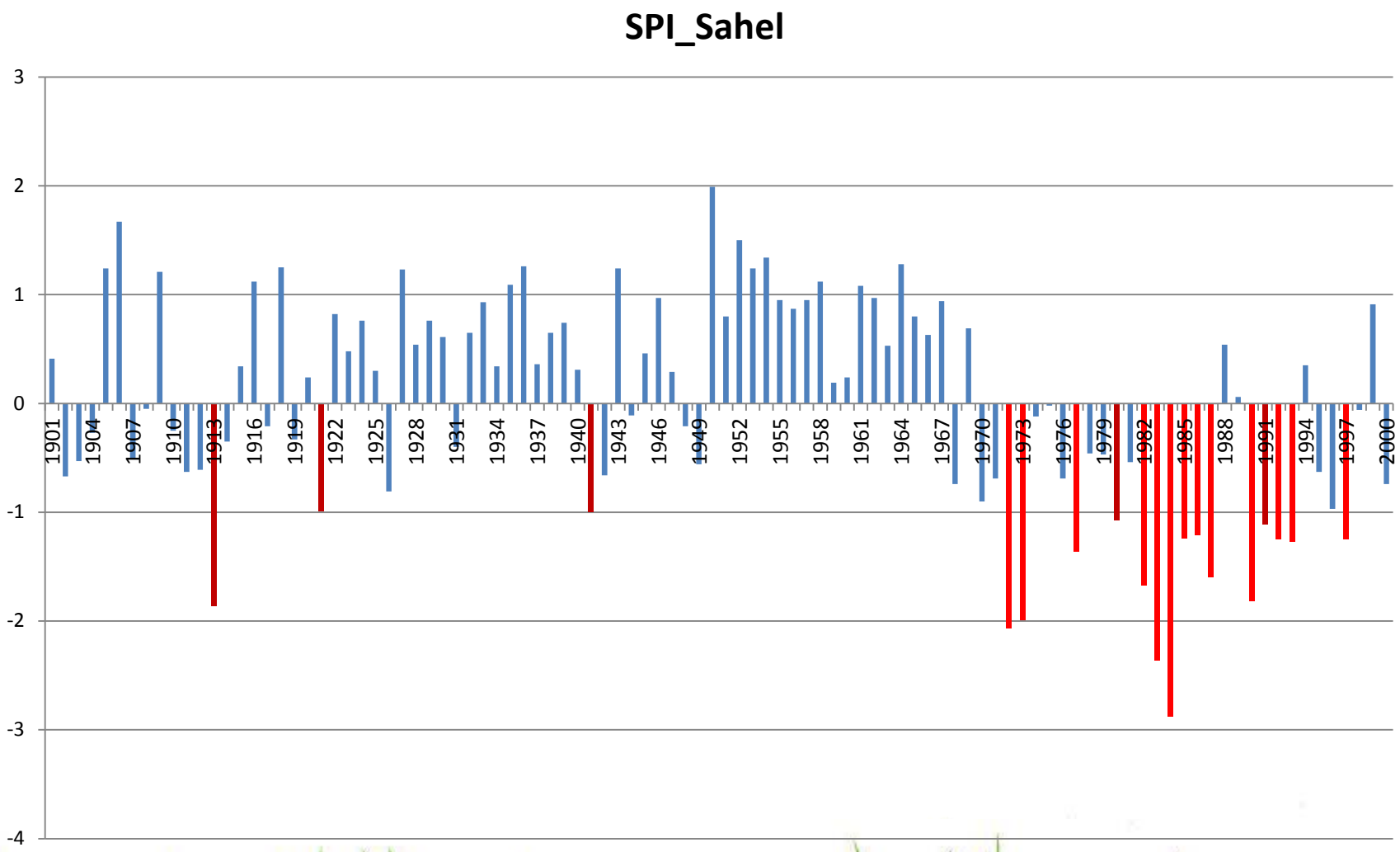
Let P denotes the probability associated with the drought shock:

- Using the standard technology : Profit (S): $P*(Y_d-C_n)+(1-P)*(Y_n-C_n)$
- Using the Drought- resilient technology : Profit (H) : $P*(Y_n-C_h)+(1-P)*(Y_h-C_h)$

The farmer prefers the Drought- resilient technology only if :

$$\mathbf{P*(Y_n - Y_d) > ((C_h-C_n) – (1-P)*(Y_h-Y_n))}$$

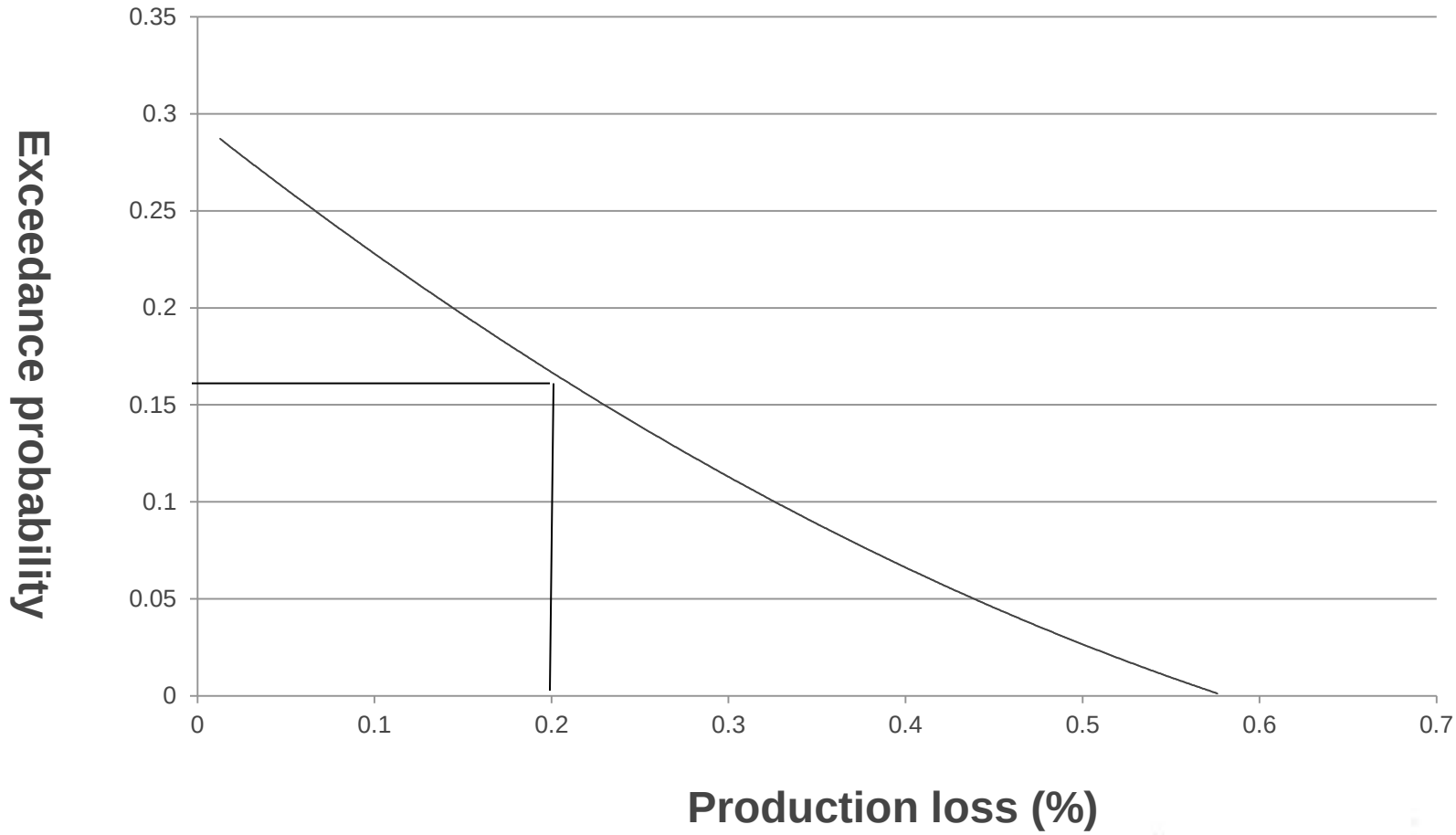
SPI for the Sahel: Growing Season (June-October)



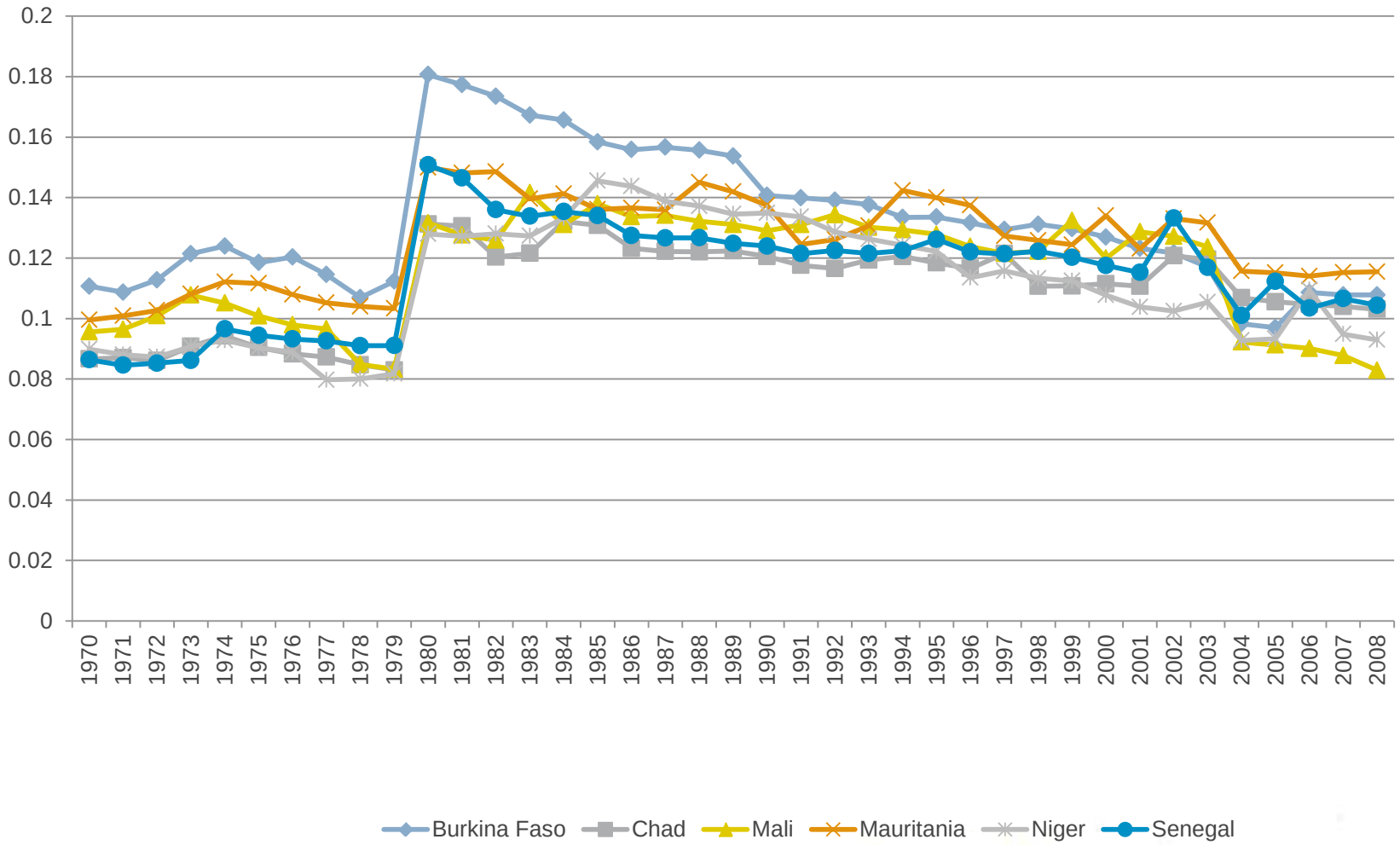
Drought Damages: Crop losses (%)

	Burkina Faso	Chad	Mali	Mauritania	Niger	Senegal
1972	26%	37%	21%	48%	31%	45%
1973	30%	30%	23%	47%	47%	25%
1977	15%	31%	31%	27%	23%	27%
1980	9%	29%	33%	28%	24%	33%
1982	9%	5%	27%	26%	33%	26%
1983	18%	26%	22%	28%	58%	39%
1984	6%	28%	35%	19%	30%	34%
1985		11%			31%	10%
1986		17%			46%	17%
1987		21%	5%		21%	8%
1990	4%	24%	33%	19%	40%	15%
1991		17%	4%	35%	51%	11%
1992		1%	34%	19%	52%	16%
1993		31%	31%	17%	42%	9%
1996		19%	3%	14%	56%	18%
1997		21%	6%	28%	35%	26%
Average	**15%**	**25%**	**25%**	**30%**	**35%**	**30%**

LEP curve for the Sahel



Technical Efficiency



Regression results

	Efficiency	Efficiency
Risk	-0.66*	-0.64*
Precipitation	0.04**	0.02*
Fertilizer Use	0.036*	0.04***
Consumer price	0.21**	0.23***
Open	0.012**	
Invest		0.04*
Risk_Open	0.06**	
Risk_Invest		0.01*
R^2	0.53	0.47

- An increase of climate risk by 1% results in a decrease in technical efficiency by 0.66%
- Openness to trade and private investment may help to weather the negative impact of climate risk on agricultural productivity

Long-run versus Short-run effects

Variables	Long-run Effects
Risk	-0.22***
Risk_2	0.21***
Precipitation	0.39***
Precipitation_2	-0.043***
Fertlizer Use	0.01***
Consumer Price	-0.01***

Countries	Short-run effects	
	Risk	Risk_2
Burkina Faso	0.07***	-0.06***
Mauritania	0.12***	-0.13***
Niger	0.05*	-0.11*

Conclusion

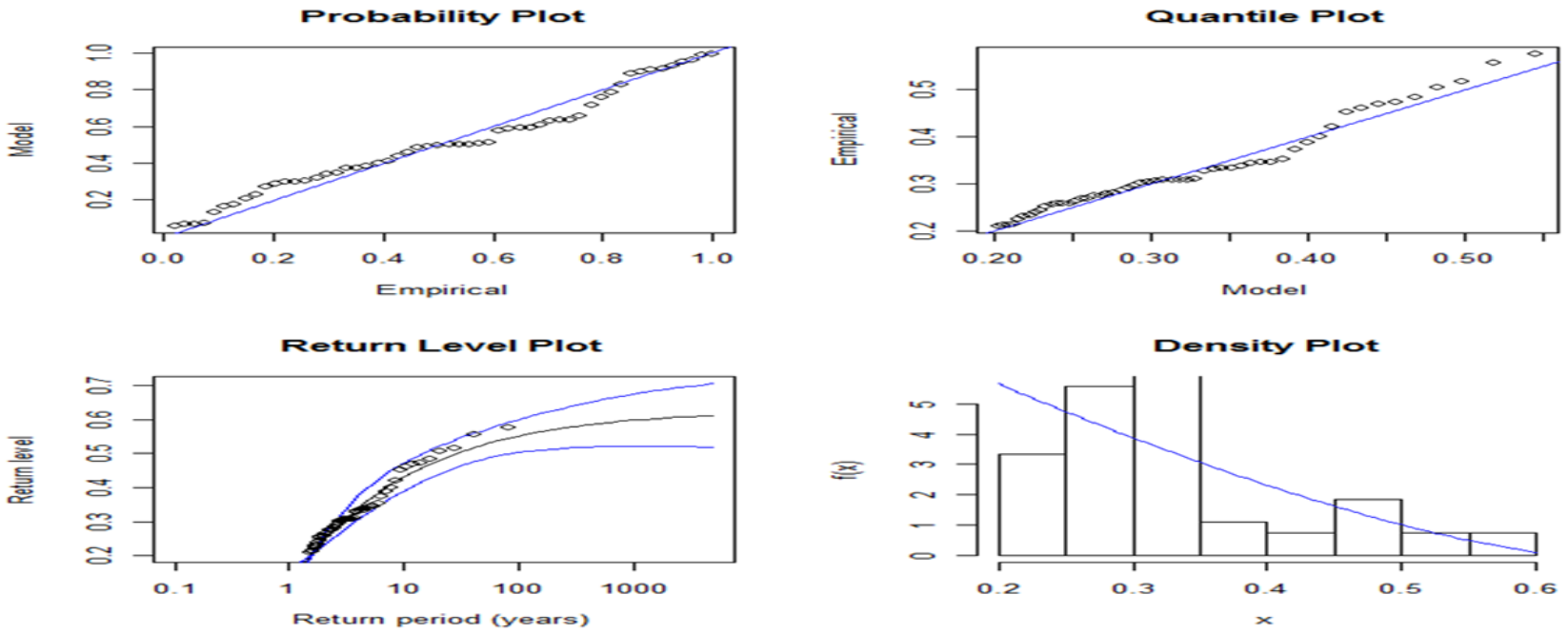
- The Sahel is extremely vulnerable to climate change
- Drought frequency, severity and damages are increasing
- Risk related to climate change has a negative impact on agricultural productivity
- Higher investment and more openness to trade reduce the impact of climate uncertainty on agricultural productivity

Diagnostic plots for GPD fit to the crop losses

Maximum likelihood estimates for excess

Threshold	σ	ξ	LR Test (P-value)
20%	0.17	-0.41	0.0078

Diagnostic plots for GEV fit to the crop losses



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