Weather index-based insurance in a cash crop regulated sector: an ex ante evaluation for cotton growers in Cameroon

A. Leblois, P. Quirion and B. Sultan

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- How should the supply scheme be implemented ? Are agro-ecological zones (AEZ) really playing a role in the meteo/yield relationship ?
- What is the gain of such insurance compared to a perfect (basis risk free) area-yield insurance ? How much prices affects income variation, (compared to the weather) ?

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- Heavy losses ($>$ growing period investments) or side-selling are also significant risks.

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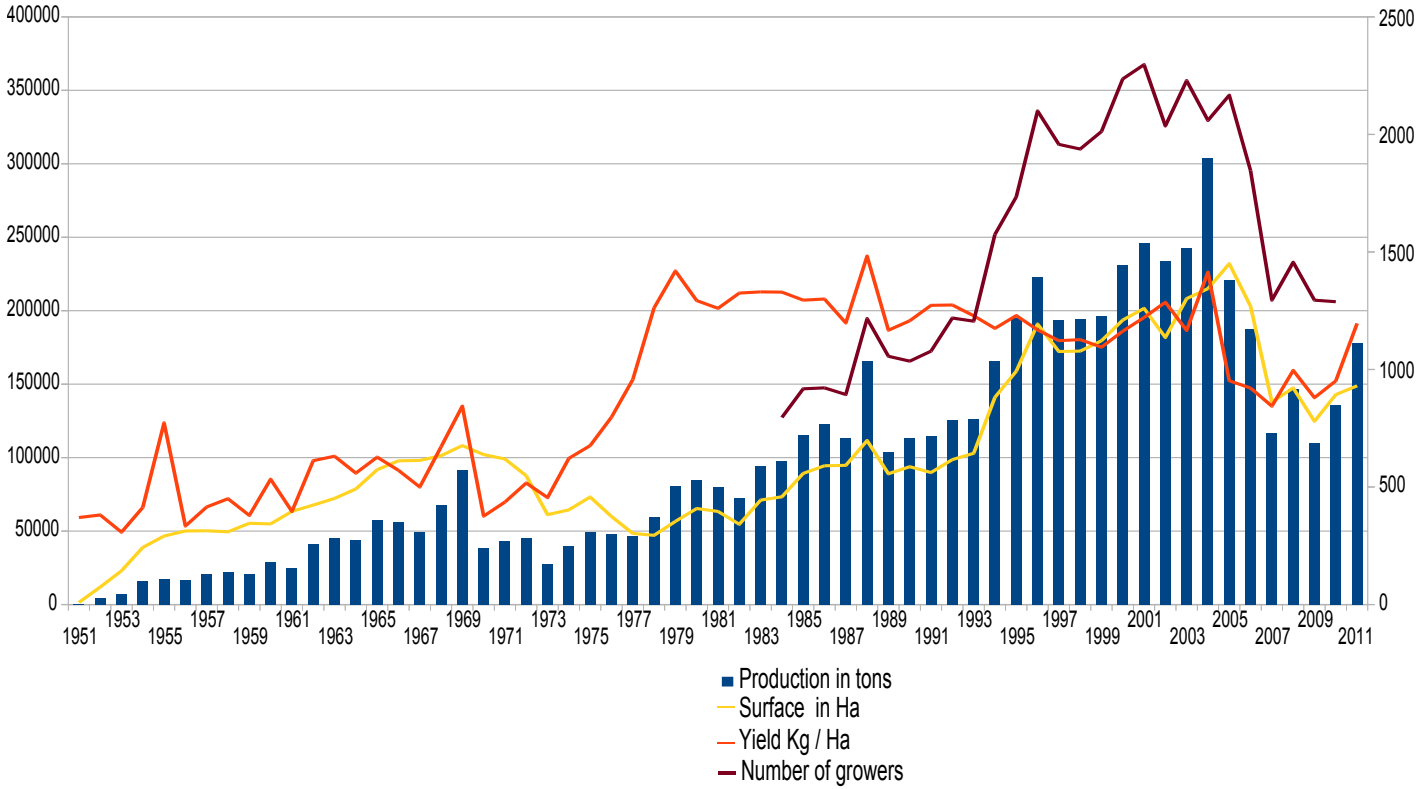

Figure: Evolution of the Cameroonese cotton sector 1951-2010.

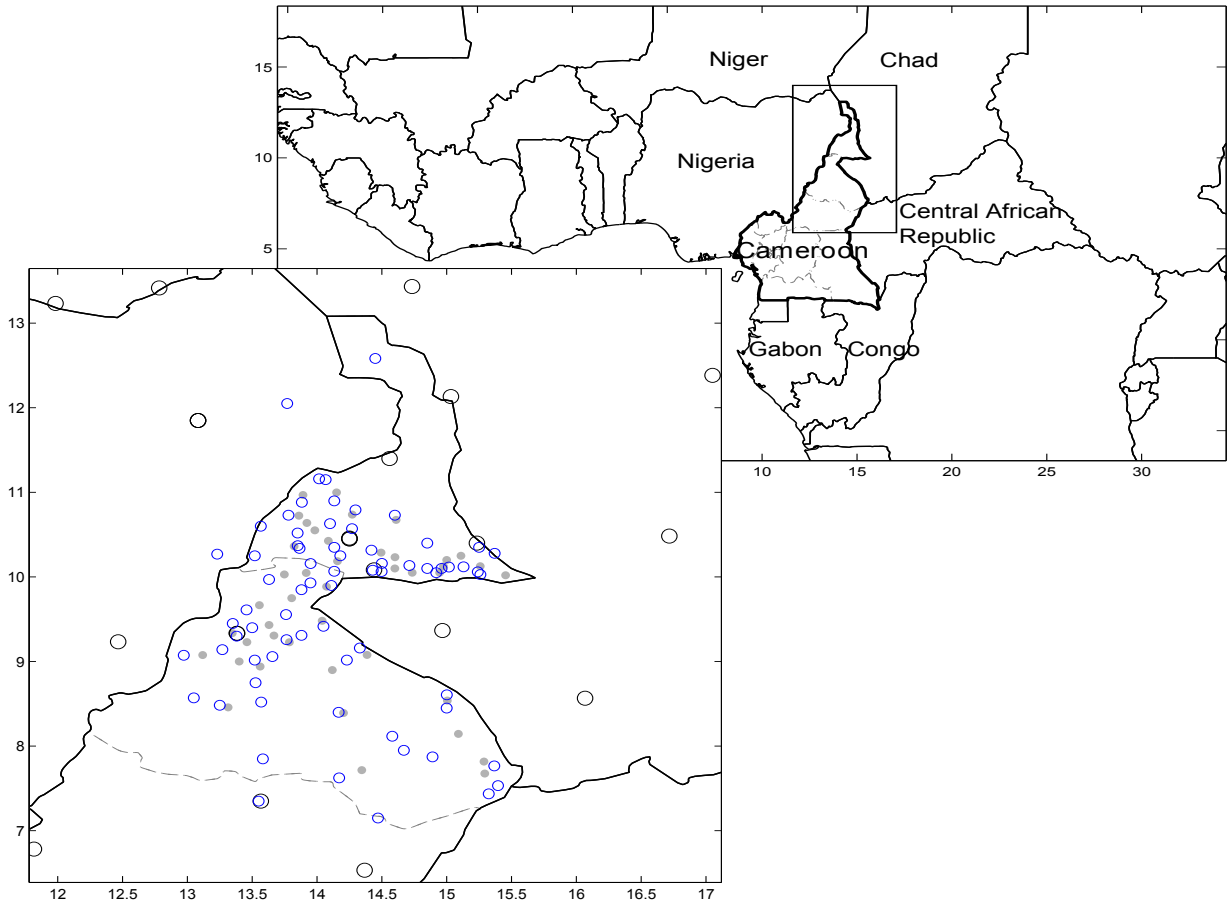

Figure: Meteorological (large circles) and rainfall stations (blue circles) network provide daily rainfall data and remote sensing vegetation indicator (NDVI) matched to administrative sectors (grey dots) yields. Sources: SODECOTON and GHCN

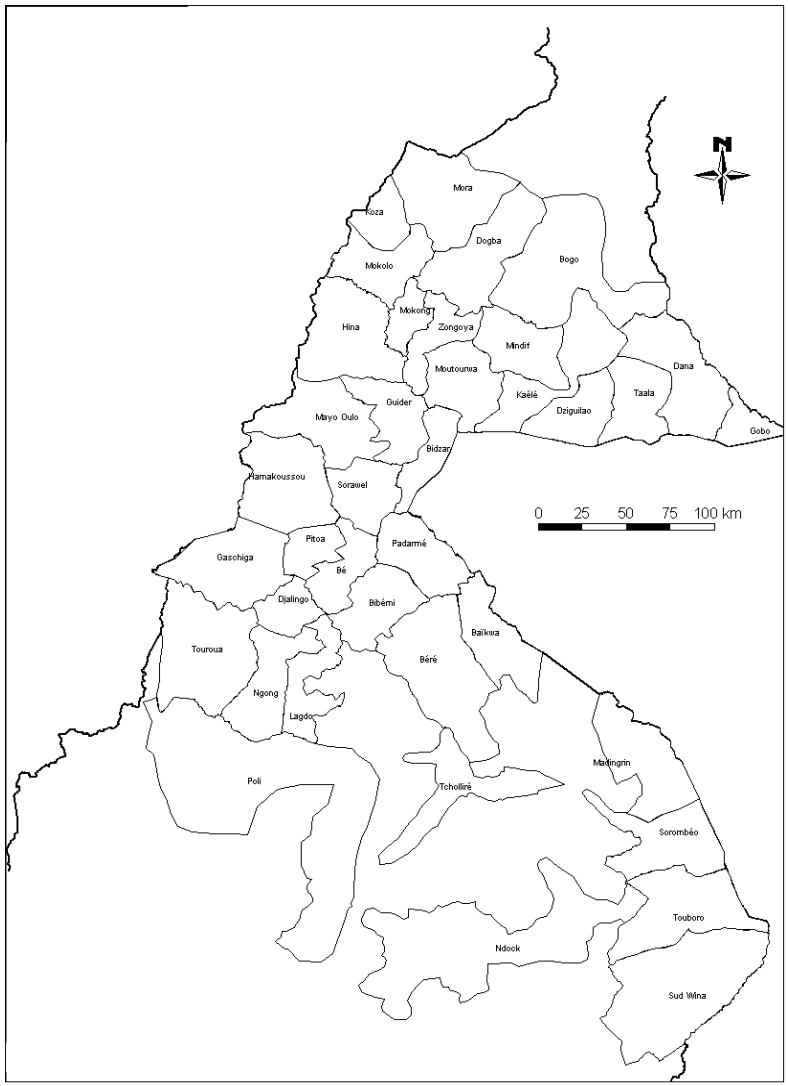

Figure: Sodecoton admistrative cutting: the sectors.

Cotton, rainfall, temp. and remote sensing

- **Daily rainfall** allow us to consider cumulative rainfall (CR) over the season and to simulate a growing cycle schedule ($\Rightarrow$ length of the rainy season, growing phases CR...)

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- Comparison of rainfall and **remote sensing** indices
- **Temperature** is the major channel identified for climate change impacts (reproduction issues, growing cycle reduction).

Hypothesis

3 (EUT) objective functions:

$$U_{ssd}(\tilde{y}) = E(\tilde{y}) - \phi \times \sum_{i=1}^{N} \Big(\max\left(E(y) - y_i, 0\right) \Big), \qquad \tilde{y} = \{y_1, ..., y_N\} \tag{1}$$

$$U_{crra}(\tilde{y}) = \frac{(y_i + W_i)^{(1-\rho)}}{(1-\rho)}, \qquad \tilde{y} = \{y_1, ..., y_N\} \tag{2}$$

$$U_{cara}(\tilde{y}) = 1 - \exp\big(- \psi \times (y_i + W_i)\big), \qquad \tilde{y} = \{y_1, ..., y_N\} \tag{3}$$

The insurance contract parameters are optimized maximizing utility of insured income:

$$Y_{ins} = Y - P\big(S^*, M^*, \lambda^*, x\big) + I\big(S^*, M^*, \lambda^*, x\big) \tag{4}$$

The premium includes a loading factor: 10% of total indemnification for the insurer

(in order to cover administration and risk costs) and a transaction cost for each indemnification (1% of average yield).

Initial wealth

- Use Sodecoton surveys (3 rounds)

Table: cotton growing income as a share of on-farm income of cotton producers during the 2003-2010 period

Cotton share of income (%)	Mean	Std. Dev.	Min.	Max.	N
2003	46.5	21.6	0	100	1562
2006	38.3	20.5	0	100	943
2008*	57	30.3	0	100	939
2009*	35.1	23.9	0	100	1111
2010	24.9	25	0	100	1449

Source: Sodecoton's surveys and author's calculations.

Risk aversion

- Use a field survey (Nov-Dec, 2011): implement lotteries.

Table: Lotteries options

	I		II			
Number of BB (prob. of a bad outcome)	RB	BB	RB	BB	Difference of expected gain	risk aversion (CRRA) of agents switching from I to II
No risky option chosen						> 1.7681
5/10	50	350	150	250	0	]1.1643,1.7681]
6/10	50	350	150	250	20	]0.7236,1.1643]
7/10	50	350	150	250	40	]0.3512,0.7236]
8/10	50	350	150	250	60	]0,0.3512]
9/10	50	350	150	250	80	≤ 0

Risk aversion parameter (CRRA)

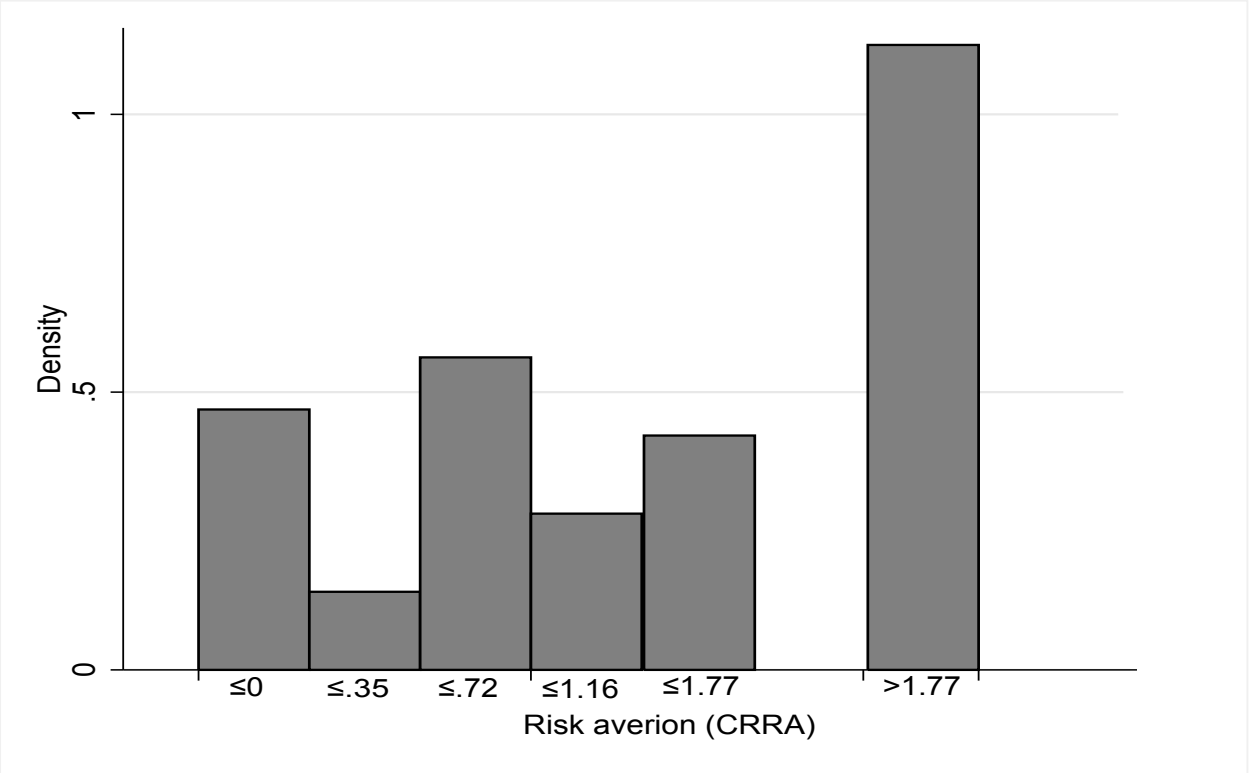


Figure: Distribution of risk aversion parameter density.

	SSD			CRRA			CARA			
	$\phi=1$	$\phi=2$	$\phi=3$	$\rho=1$	$\rho=2$	$\rho=3$	$\psi=1/W$	$\psi=2/W$	$\psi=3/W$	N
$Length_{sim}$	13.18%	13.18%	13.18%	.00%	.00%	.00%	.00%	.00%	.00%	479
$Length_{obs}$	28.79%	31.19%	31.75%	.00%	12.14%	15.85%	17.14%	20.03%	19.92%	247
Sowing $date_{obs}$	33.93%	33.93%	33.93%	.00%	20.89%	21.20%	22.94%	22.85%	22.39%	247
Annual cumulative rainfall (CR)	7.15%	7.15%	8.47%	.00%	.00%	.00%	.00%	.00%	.00%	479
CR_{sim}	1.16%	5.44%	5.44%	.00%	.72%	.66%	.83%	.66%	.47%	479
$CR_{sim\ gdd}$	2.09%	5.85%	5.85%	.00%	1.17%	1.24%	1.39%	1.03%	.71%	479
CR_{obs}	18.70%	21.31%	21.31%	.00%	1.45%	1.38%	1.53%	5.02%	5.27%	247
Sum NDVI	12.64%	13.34%	13.34%	.00%	.00%	.00%	.00%	.00%	.00%	479
% of area where cotton emerged at June the 30	22.20%	22.20%	22.20%	13.67%	23.80%	23.74%	24.29%	26.29%	28.74%	252

Figure: Share of the maximum risk premium reduction among different indices and samples (1991-2004).

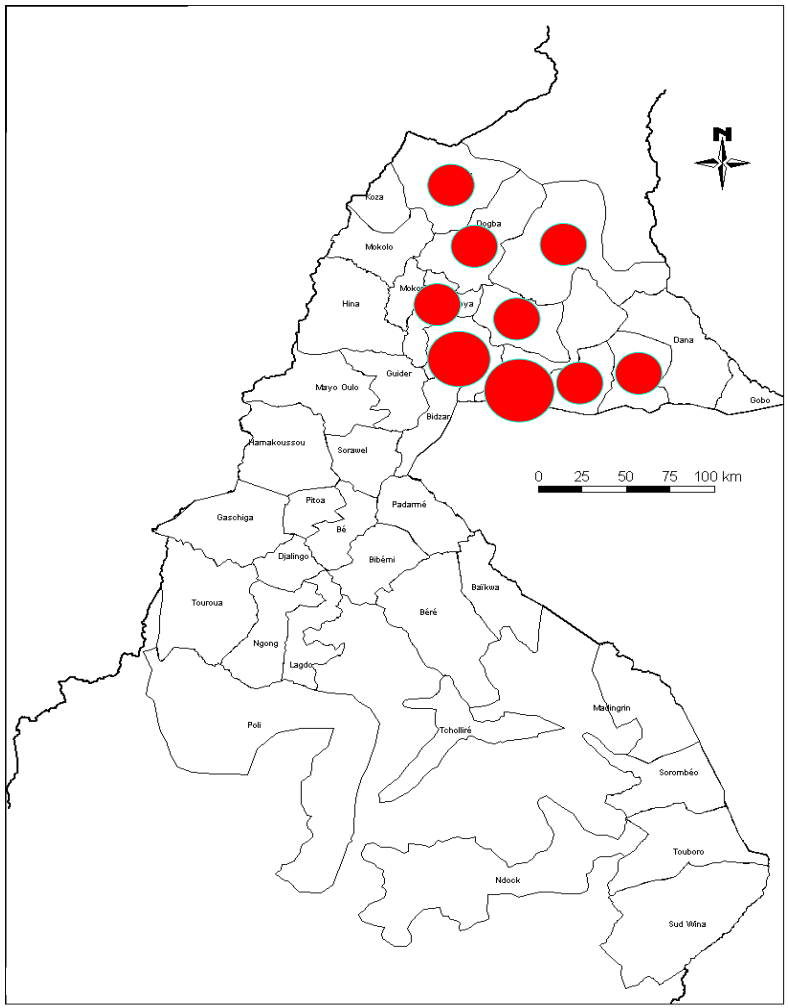


Figure: Indemnification (red bubbles) of a contract against late sowing.

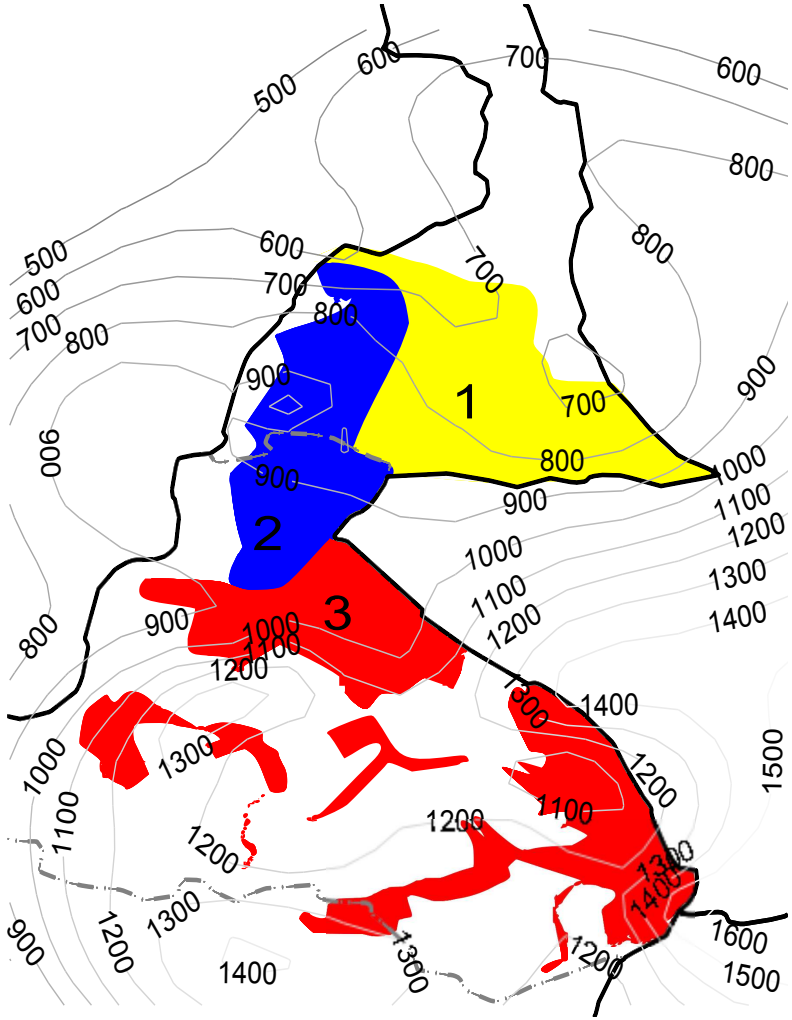


Figure: Agroecological zones (North West: 1, North East: 2 and South: 3) and isohyets (in mm).

Table: Agro-ecological areas summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
North-East					
Yield	959.459	243.07	352	2241	302
Annual cumulative rainfall (mm)	803.37	158.587	412	1244	302
CR_{sim}	717.61	151.848	355.9	1128.8	302
$CR_{sim\ gdd}$	659.908	144.493	319	1044.1	302
Sum NDVI	5222.26	479.148	3914.5	6546.17	248
$Length_{obs}$	111.185	13.158	84	141	146
CR_{obs}	612.321	128.466	299	973	146
North-West					
Yield	1225.828	290.505	594	1981	299
Annual cumulative rainfall (mm)	946.338	164.52	540	1575	299
CR_{sim}	817.08	158.386	340	1247	299
$CR_{sim\ gdd}$	733.089	148.195	267	1087	299
Sum NDVI	6226.557	842.911	4311.75	8489.08	237
$Length_{obs}$	118.773	15.276	80	173	172
CR_{obs}	716.437	165.82	279	1114	172
South					
Yield	1291.348	319.317	593	2352	248
Annual cumulative rainfall (mm)	1131.375	233.86	541	1790	248
CR_{sim}	959.296	208.322	340	1538	248
$CR_{sim\ gdd}$	846.451	194.217	267	1419	248
Sum NDVI	8267.915	1568.815	5953.41	12817.25	190
$Length_{obs}$	128.27	13.235	96	161	148
CR_{obs}	915.504	222.21	319	1439	148

Producer prices

	SSD			CRRA			CARA			
	$\phi=1$	$\phi=2$	$\phi=3$	$\rho=1$	$\rho=2$	$\rho=3$	$\psi=1/W$	$\psi=2/W$	$\psi=3/W$	N
Calibrated on the first AEZ sample (AEZ=1, North)										
$CR_{sim\ gdd}$	7.59%	9.92%	9.92%	.00%	1.48%	2.09%	.00%	1.59%	2.40%	174
CR_{obs}	23.70%	23.37%	23.37%	.00%	2.11%	2.12%	.00%	2.37%	2.39%	86
Sum NDVI	6.22%	6.14%	6.14%	.00%	4.97%	4.88%	.00%	5.16%	5.11%	174
$CR\ Phase4_{sim\ gdd}$	17.33%	21.29%	21.42%	.00%	5.63%	5.44%	.00%	5.78%	5.63%	174
$CR\ Phase5_{sim\ gdd}$	30.93%	30.50%	30.50%	.00%	4.52%	4.34%	.00%	4.74%	4.61%	174
$Length_{obs}$	21.18%	20.89%	20.89%	.00%	12.77%	20.81%	.00%	13.67%	22.48%	86
% of area where cotton emerged at June the 30	50.31%	49.61%	49.61%	32.67%	39.88%	42.17%	34.26%	40.63%	42.76%	87
Sowing $date_{obs}$	4.55%	4.48%	4.48%	.00%	2.04%	2.07%	.00%	2.49%	2.45%	86
Calibrated on the second AEZ sample (AEZ=2, Center)										
CR_{obs}	11.62%	11.62%	11.62%	.00%	5.85%	6.18%	.00%	6.57%	6.73%	90
Sum NDVI	24.84%	24.84%	24.84%	.00%	3.68%	10.63%	.00%	4.20%	10.41%	173
$CR\ Phase5_{sim\ gdd}$	28.12%	28.86%	28.86%	.00%	11.09%	15.64%	.00%	17.85%	17.21%	173
$Length_{obs}$	13.92%	13.92%	13.92%	.00%	5.85%	6.17%	.00%	6.57%	6.73%	90
% of area where cotton emerged at June the 30	18.99%	18.99%	18.99%	21.25%	14.89%	15.28%	21.88%	15.09%	15.22%	94
Calibrated on the third AEZ sample (AEZ=3, South)										
$Length_{sim\ gdd}$	5.51%	5.51%	5.51%	2.18%	2.01%	1.82%	2.43%	2.27%	2.11%	132
$Length_{obs}$	9.53%	11.42%	11.42%	.00%	.00%	2.15%	.00%	.00%	2.52%	71

Figure: Share of the maximum risk premium reduction among different indices and samples (1991-2004) among different agro-ecological zones (AEZ).

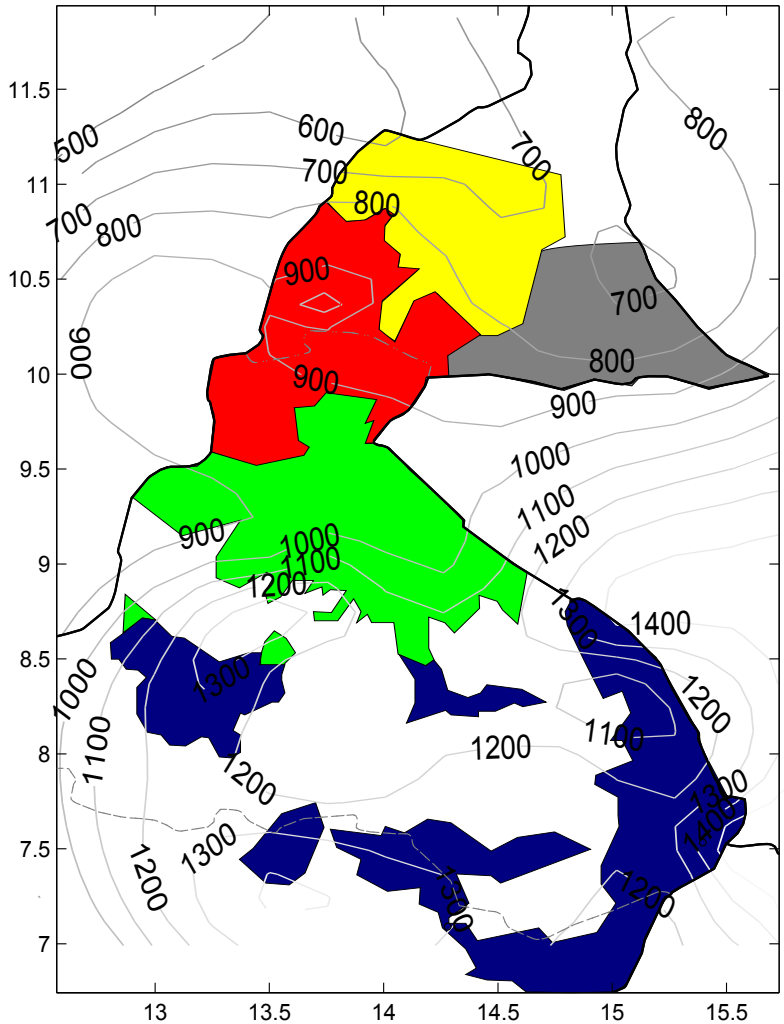


Figure: Zoning based on meteorological (annual cumulative rainfall) classification (different areas are called North: 1, North West: 2, North

Table: Rainfall zoning summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
North					
Yield	985.385	244.393	352	1746	149
Annual cumulative rainfall (mm)	785.39	147.413	412	1174.2	149
Length_{obs}	113.065	13.239	84	140	77
Sum NDVI	5050.988	617.441	3914.5	8653.110	121
North West					
Yield	943.494	238.774	513	2241	141
Annual cumulative rainfall (mm)	821.930	162.83	464	1244	141
Length_{obs}	109.985	12.679	86	141	65
Sum NDVI	5439.067	454.6	4424.14	6546.17	116
North East					
Yield	1279.068	298.864	725	2352	207
Annual cumulative rainfall (mm)	965.877	185.685	541	1575	207
Length_{obs}	123.016	15.478	86	173	127
Sum NDVI	6772.352	591.613	5629.56	8489.08	165
Center					
Yield	1262.766	337.617	557.38	2189	197
Annual cumulative rainfall (mm)	1151.99	238.341	505.8	1790	197
Length_{obs}	129.28	14.035	92	157	100
Sum NDVI	8323.054	1935.995	4765.33	12817.25	154
South					
Yield	1181.59	279.553	594	1981	155
Annual cumulative rainfall (mm)	944.257	164.959	540	1575	155
Length_{obs}	115.876	13.523	80	143	97
$\text{CR}_{sim\ gdd}$	743.288	139.236	364.3	1087	155
Sum NDVI	5885.955	664.364	4311.75	7587.360	119

Producer prices

	SSD			CRRA			CARA			
	$\phi = 1$	$\phi = 2$	$\phi = 3$	$\rho = 1$	$\rho = 2$	$\rho = 3$	$\psi = 1/W$	$\psi = 2/W$	$\psi = 3/W$	N
Calibrated on the first rainfall zone sample										
$CR_{sim\ gdd}$	42.42%	42.42%	42.42%	.00%	9.81%	10.61%	.00%	9.65%	11.26%	84
CR_{obs}	59.59%	59.59%	59.59%	.00%	.00%	6.60%	.00%	.00%	4.79%	41
$Sum\ NDVI$	27.50%	27.50%	27.50%	.00%	.00%	.00%	.00%	.00%	.00%	84
$CR\ Phase3_{sim\ gdd}$	44.34%	44.34%	44.34%	.00%	.00%	10.60%	.00%	.00%	9.94%	84
$CR\ Phase5_{sim\ gdd}$	45.12%	45.47%	46.60%	11.44%	18.60%	17.27%	13.95%	18.53%	17.94%	84
$Length_{obs}$	78.03%	80.98%	80.98%	.00%	18.85%	18.39%	.00%	19.29%	20.60%	41
$\%\ of\ area\ where\ cotton\ emerged\ at\ June\ the\ 30$	97.42%	97.42%	97.42%	.00%	70.36%	72.13%	.00%	67.39%	70.83%	41
Calibrated on the second rainfall zone sample										
$Sum\ NDVI$	9.80%	9.80%	9.80%	.00%	.00%	.00%	.00%	.00%	.00%	80
$CR\ Phase4_{sim\ gdd}$	32.89%	32.89%	32.89%	.00%	5.36%	5.13%	5.71%	5.71%	5.46%	80
$CR\ Phase5_{sim\ gdd}$	40.04%	40.23%	40.23%	.00%	17.73%	16.87%	18.80%	18.80%	17.58%	80
$\%\ of\ area\ where\ cotton\ emerged\ at\ June\ the\ 30$	58.45%	58.45%	58.45%	98.41%	48.38%	47.07%	51.10%	51.10%	48.52%	42
Calibrated on the third rainfall zone sample										
$CR\ Phase2_{sim\ gdd}$	13.02%	13.61%	13.61%	.00%	2.65%	2.46%	.00%	2.82%	2.69%	125
$CR\ Phase4_{sim\ gdd}$	13.65%	13.65%	13.65%	.00%	2.65%	2.45%	.00%	2.83%	2.68%	125
Calibrated on the fourth rainfall zone sample										
CR_{obs}	28.18%	30.81%	30.81%	.00%	23.36%	24.44%	.00%	27.07%	26.53%	47
$\%\ of\ area\ where\ cotton\ emerged\ at\ June\ the\ 30$	39.72%	39.72%	41.46%	7.70%	19.88%	26.36%	8.73%	22.67%	28.83%	51
Sowing $date_{obs}$	35.97%	37.59%	37.59%	17.84%	17.80%	24.59%	19.74%	27.07%	27.01%	47
Emergence $date_{obs}$	34.41%	34.41%	34.41%	.00%	23.08%	23.86%	.00%	26.40%	26.03%	47
$Length_{obs}$	43.20%	43.20%	43.20%	10.19%	18.50%	24.26%	11.21%	26.49%	26.63%	47
Mean temp. in July	37.14%	37.14%	37.14%	.00%	14.36%	16.48%	.00%	12.29%	14.19%	105
Calibrated on the fifth rainfall zone sample										
CR_{sim}	13.20%	13.20%	13.57%	.00%	5.72%	5.71%	.00%	6.30%	6.18%	85
$CR_{sim\ gdd}$	18.44%	19.01%	19.01%	.00%	6.56%	6.27%	.00%	6.82%	6.52%	85
CR_{obs}	22.01%	22.01%	22.01%	8.16%	6.21%	5.92%	8.44%	6.34%	6.02%	49
$Sum\ NDVI$	42.49%	42.49%	42.49%	.00%	22.40%	24.29%	.00%	21.28%	22.75%	85
$\%\ of\ area\ where\ cotton\ emerged\ at\ June\ the\ 30$	43.99%	43.99%	43.99%	46.30%	31.66%	31.79%	46.37%	31.69%	31.40%	49
$CR\ Phase3_{sim\ gdd}$	13.63%	13.63%	32.12%	15.24%	7.24%	6.60%	15.40%	8.93%	7.73%	85
$CR\ Phase4_{sim\ gdd}$	30.05%	30.06%	30.07%	11.87%	8.46%	8.11%	12.00%	8.60%	8.15%	85
Mean temp. in July	26.56%	26.56%	26.56%	18.16%	14.69%	14.27%	17.90%	14.70%	14.10%	85

Figure: Share of the maximum risk premium reduction among different indices and samples (1991-2004) among different rainfall zones.

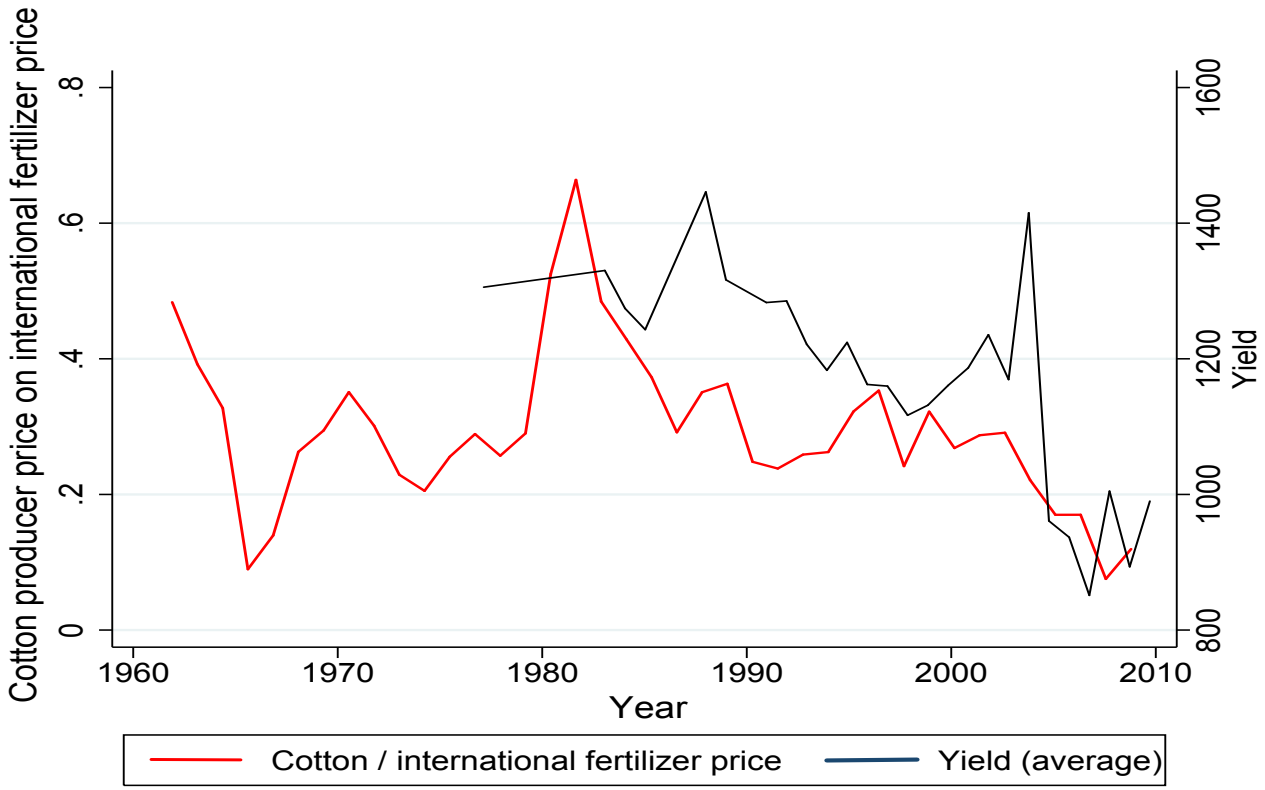
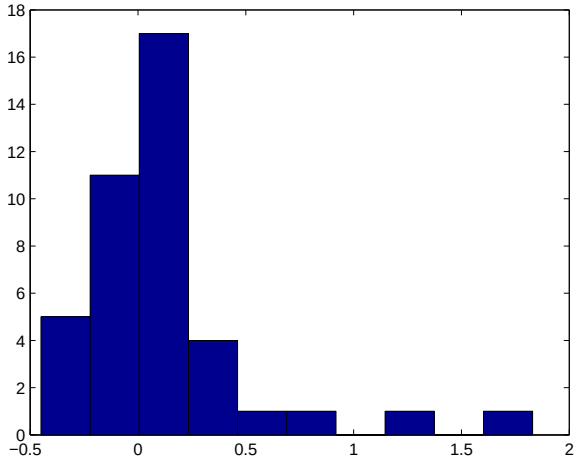
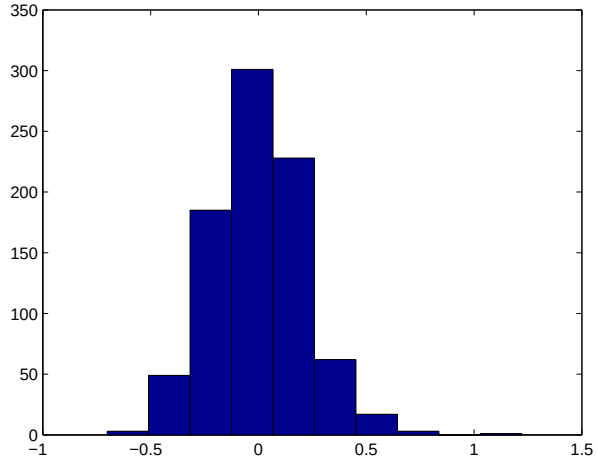
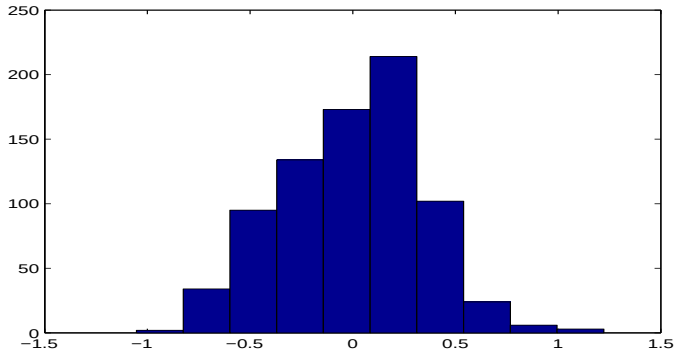


Figure: Yield and cotton producer prices in Cameroon (USD$ per kg) on fertilizer price (USD$ per kg). Sources: Sodecoton, Baffes (2007), Kaminsky (2011) and World Bank Commodity Price Data.





Distribution of sector-specific price and yield variations.



Distribution of sector-specific cotton margin variations.

Concluding remarques

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Cotton cultivars use through time

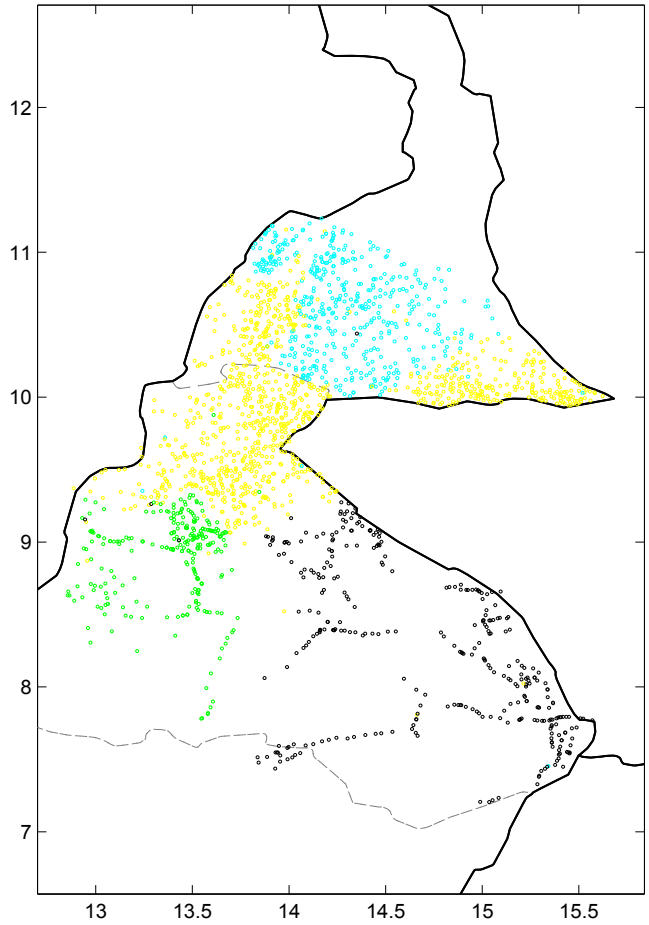
Table: Cotton cultivars average spatial and temporal allocation

▶

Cultivars (Province)	1^{st} **flower date** (Days after emergence)	1^{st} **boll date** (Days after emergence)	**Period of use**
Nord			
Allen commun	61	114	untill 1976
444-2			untill 1976
Allen 333	59	111	1959-197?
BJA 592	61	114	1965-197?
IRCO 5028	61	111	untill 1987
IRMA 1243	53	102	1987 - 1998
IRMA 1239	52	101	2000-2007
IRMA A 1239	52	101	2000-2007
L 457	52	104	2008-onwards
Extrême-Nord			
IRMA L 142-9	59	109	until 1984
IRMA 96+97	55	115	1985 - 1991
IRMA BLT	51	99	1999-2002
IRMA BLT-PF	56	116	2000 - 2006
IRMA D 742	51	95	2003-2006
IRMA L 484	51	105	2007 - onwards

Sources: Dessauw (2008) and Levrat (2010).

Cultivars



Producer prices

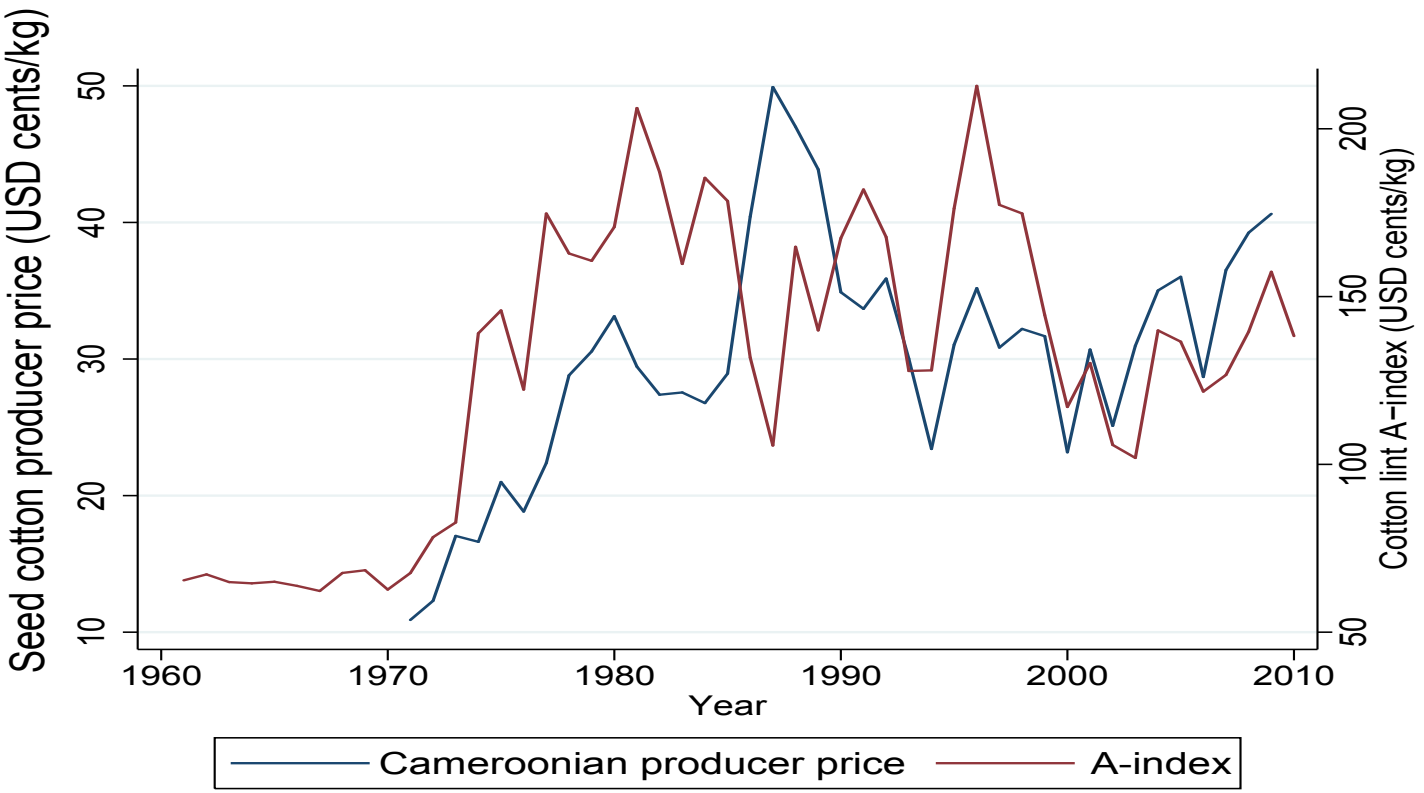


Figure: Raw seed-cotton Cameroonian producer and international lint (A-index) prices

Loteries

Table: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
rho	1.095	0.711	0	1.942	64
Among which:					
rho (Dogba)	1.18	0.475	0.639	1.655	10
rho (Mo'o)	1.2	0.827	0	1.942	10
rho (Djarengol-Kodek)	1.242	0.689	0	1.768	11
rho (Bidzar)	1.179	0.884	0	1.768	9
rho (Pitoa)	0.637	0.471	0	1.768	12
rho (Djalingo)	1.198	0.803	0	1.768	12

Loteries

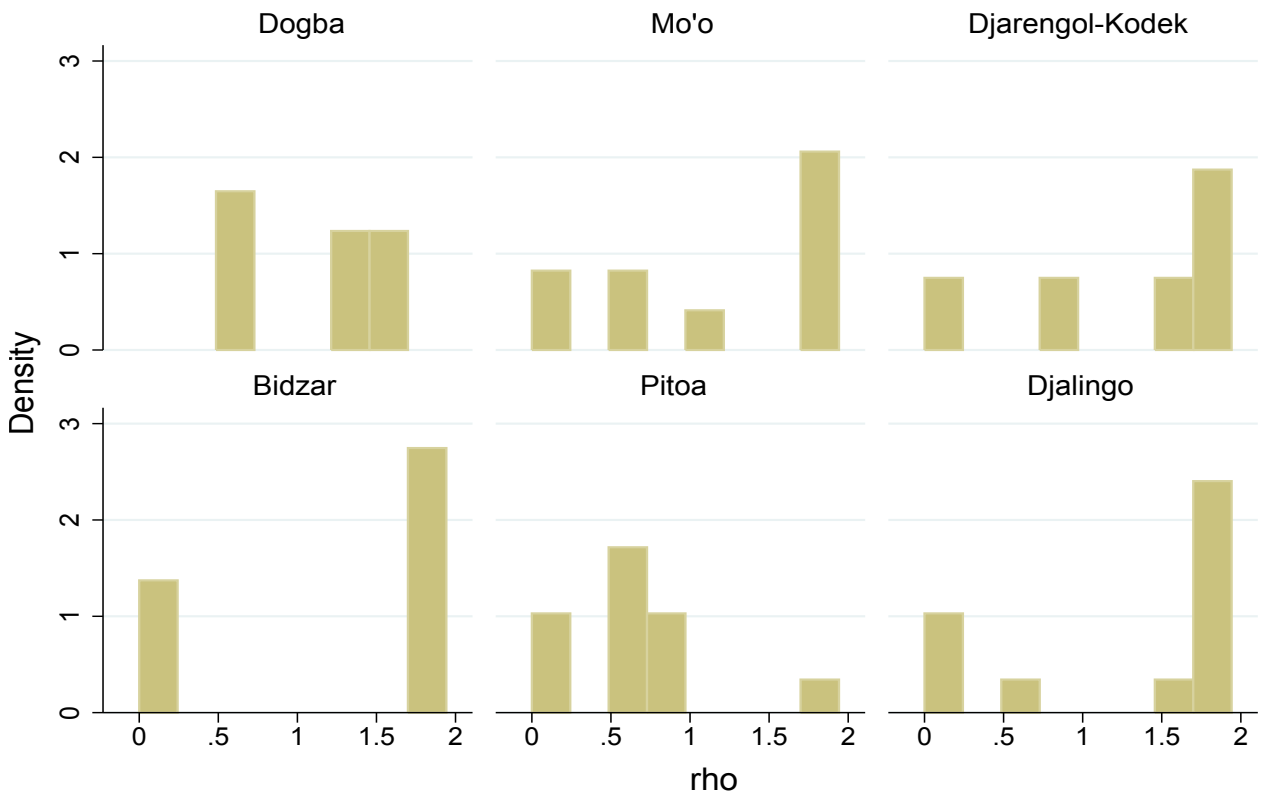


Figure: Distribution of risk aversion parameter density.

Figure: Evolution of Cameroun national seed cotton yield and production according to different sources.