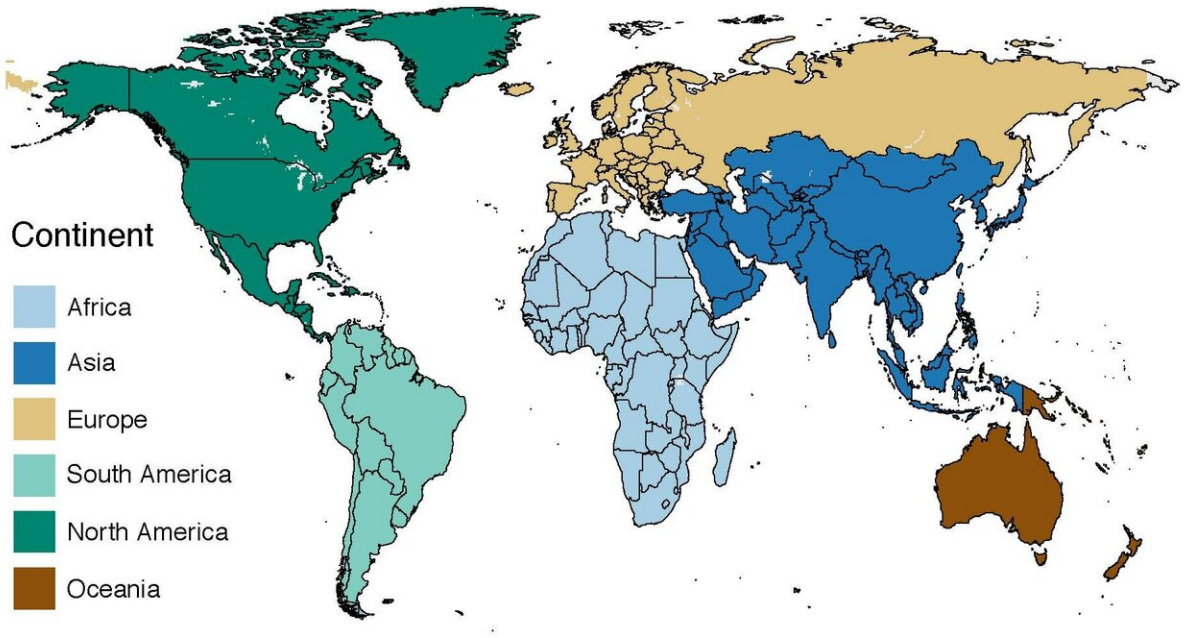
Climate extremes explain 18%-43% of global crop yield variations

May 3 2019



Continental regions for staple crops. Credit: Supplied by author

Researchers from Australia, Germany and the US have quantified the effect of climate extremes, such as droughts or heatwaves, on the yield variability of staple crops around the world.

Overall, year-to-year changes in climate factors during the growing season of maize, rice, soy and spring wheat accounted for 20%-49% of

yield fluctuations, according to research published in *Environmental Research Letters*.

Climate extremes, such as hot and cold temperature extremes, drought and heavy precipitation, by themselves accounted for 18%-43% of these interannual variations in crop yield.

To get to the bottom of the impacts of climate extremes on agricultural yields, the researchers used a global agricultural database at high spatial resolution, and near-global coverage climate and climate extremes datasets. They applied a machine-learning algorithm, Random Forests, to tease out which climate factors played the greatest role in influencing crop yields.

"Interestingly, we found that the most important climate factors for yield anomalies were related to temperature, not precipitation, as one could expect, with the average growing season temperature and temperature extremes playing a dominant role in predicting crop yields," said lead author Dr. Elisabeth Vogel from the Centre of Excellence for Climate Extremes and Climate & Energy College at the University of Melbourne.

Table 1: Indicators ranking global and regional production by relevance for total crop production and sensitivity to climate fluctuations. Indicators i-iv: i) share of a region's crop production relative to global production in 1990-2008 (%), ii) mean variability of regional production (SD of anomalies relative to mean production, in %), iii) the extent to which production anomalies are associated with yield anomalies (R^2 of regression between production anomalies calculated from yield anomalies vs. actual production anomalies), iv) the explained fraction of variance of yield anomalies, predicted by climate conditions (a – all climate factors, b – contribution of extreme events). Indicators A and B are the aggregate of indicators i, ii, iii and iv a / iv b (calculated as geometric mean). Numbers in bold highlight the six largest values in each column for all continent-crop combinations (without global values).

Crop	Continent	i) Share of global production [%]	ii) rel. SD of production anomalies [%]	iii) R^2 - Production anomalies related to yield anomalies [%]	iv a) R^2 - full statistical model (extreme events + mean conditions) [%]	iv b) R^2 - contribution of climate extremes only [%]	Indicator A (i, ii, iii and iv a) Production and total climate conditions [-]	Indicator B (i, ii, iii and iv b) Production and climate extremes [-]
maize	global	100	4	72	49	43	35.0	33.8
soybeans		100	4	24	20	20	20.9	20.9
rice		100	2	60	28	27	24.2	23.9
spring wheat		100	10	88	46	18	44.4	34.8
maize	Africa	7	7	69	**55**	**16**	20.5	15.1
	Asia	**26**	5	71	**45**	**38**	25.4	**24.4**
	Europe	13	11	**80**	**47**	**19**	**27.0**	21.6
	South America	9	9	66	25	15	18.7	16.6
	North America	**45**	8	**82**	**47**	**38**	**34.8**	**33.1**
	Oceania	0	**25**	5	10	6	3.2	2.8
soybeans	Africa	1	8	50	30	-1	9.1	-
	Asia	14	6	26	12	12	12.8	12.8
	Europe	2	**14**	19	6	2	7.5	5.6
	South America	**39**	6	47	28	**16**	23.7	20.4
	North America	**45**	8	72	15	15	24.8	**24.8**
	Oceania	0	**39**	46	1	0	2.9	1.0
rice	Africa	2	5	59	3	3	6.3	6.3
	Asia	**91**	2	62	28	**26**	23.9	**23.5**
	Europe	1	4	64	6	6	6.2	6.2
	South America	4	8	36	5	4	8.3	8.0
	North America	2	6	27	3	-4	5.9	-
	Oceania	0	**27**	25	17	6	6.7	5.1
spring wheat	Africa	2	10	21	1	1	4.2	4.1
	Asia	20	12	**89**	**40**	11	**30.2**	22.1
	Europe	21	**20**	**90**	28	8	**32.4**	**23.7**
	South America	0	7	37	0	-3	2.2	-
	North America	**40**	11	**82**	29	**17**	**32.0**	**28.1**
	Oceania	16	**25**	**95**	**67**	7	**39.9**	22.5

Indicators ranking global and regional production by relevance for total crop production and sensitivity to climate fluctuations. Credit: Provided by author

The research also revealed global hotspots—areas that produce a large proportion of the world's crop production, yet are most susceptible to climate variability and extremes.

"We found that most of these hotspots—regions that are critical for overall production and at the same time strongly influenced by climate variability and climate extremes—appear to be in industrialised crop production regions, such as North America and Europe."

For climate extremes specifically, the researchers identified North

America for soy and spring wheat production, Europe for spring wheat and Asia for rice and maize production as hotspots.

But, as the researchers point out, global markets are not the only concern. Outside of these major regions, in regions where communities are highly dependent on agriculture for their livelihoods, the failure of these staple crops can be devastating.

Wheat crop ready to be harvested. Credit: Melissa Askew (Unsplash)

"In our study, we found that maize yields in Africa showed one of the strongest relationships with growing season climate variability. In fact, it was the second highest explained variance for crop yields of any crop/continent combination, suggesting that it is highly dependent on climate conditions," Dr. Vogel said.

"While Africa's share of global maize production may be small, the largest part of that production goes to human consumption—compared to just 3% in North America—making it critical for food security in the region."

"With climate change predicted to change the variability of climate and increasing the likelihood and severity of climate extremes in most regions, our research highlights the importance of adapting food production to these changes," Dr. Vogel said.

"Increasing the resilience to climate extremes requires a concerted effort at local, regional and international levels to reduce negative impacts for farmers and communities depending on agriculture for their living."

More information: Elisabeth Vogel et al, The effects of climate extremes on global agricultural yields, *Environmental Research Letters* (2019). DOI: 10.1088/1748-9326/ab154b

Provided by University of New South Wales