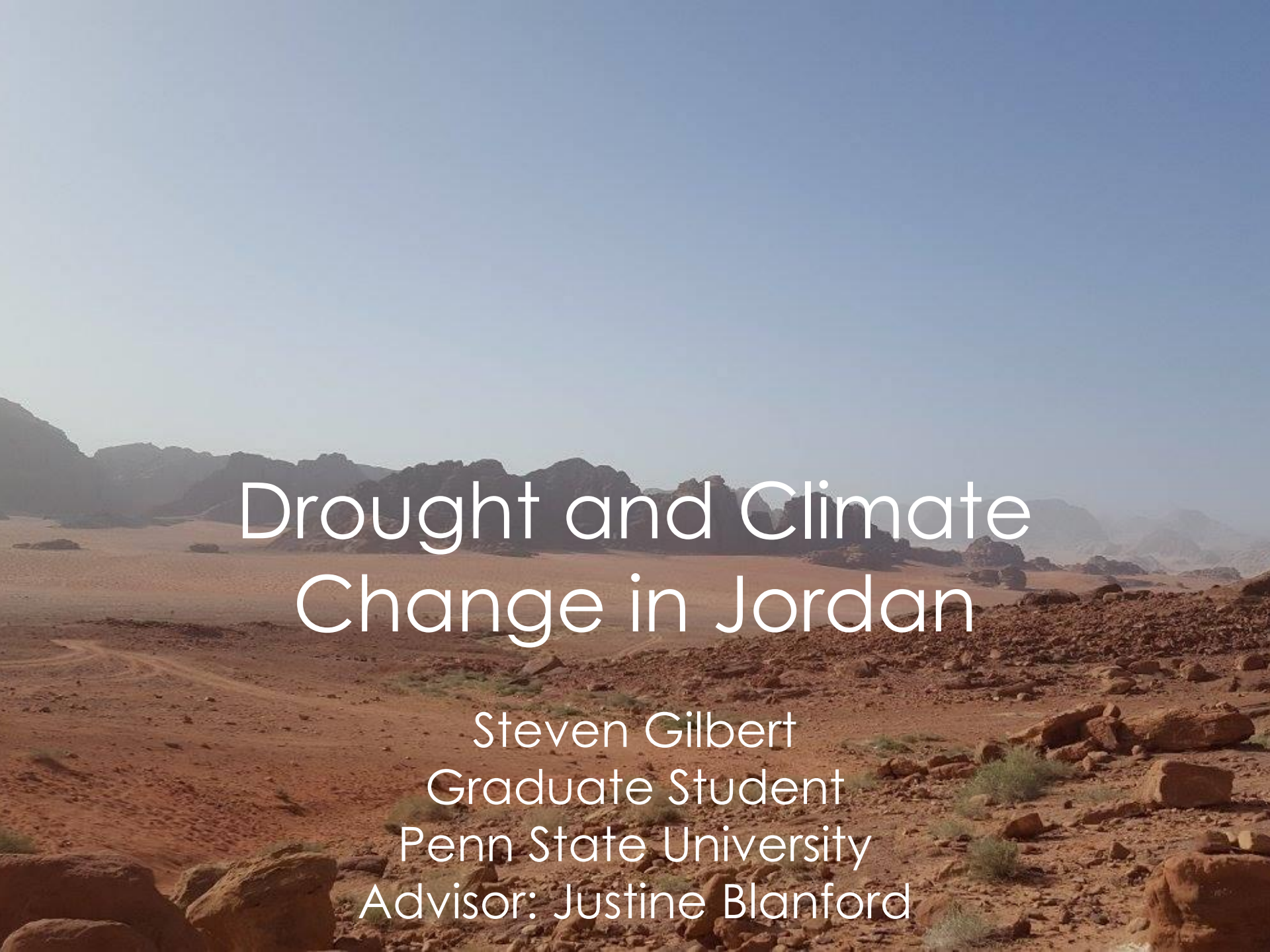


Drought and Climate Change in Jordan

Steven Gilbert
Graduate Student
Penn State University
Advisor: Justine Blanford

RESEARCH OBJECTIVE

- Examine the impact of drought on Jordan and how climate change may affect drought afflicted areas

OUTLINE

I. Context

II. Analysis and Results

III. Research Limitations

IV. Conclusions

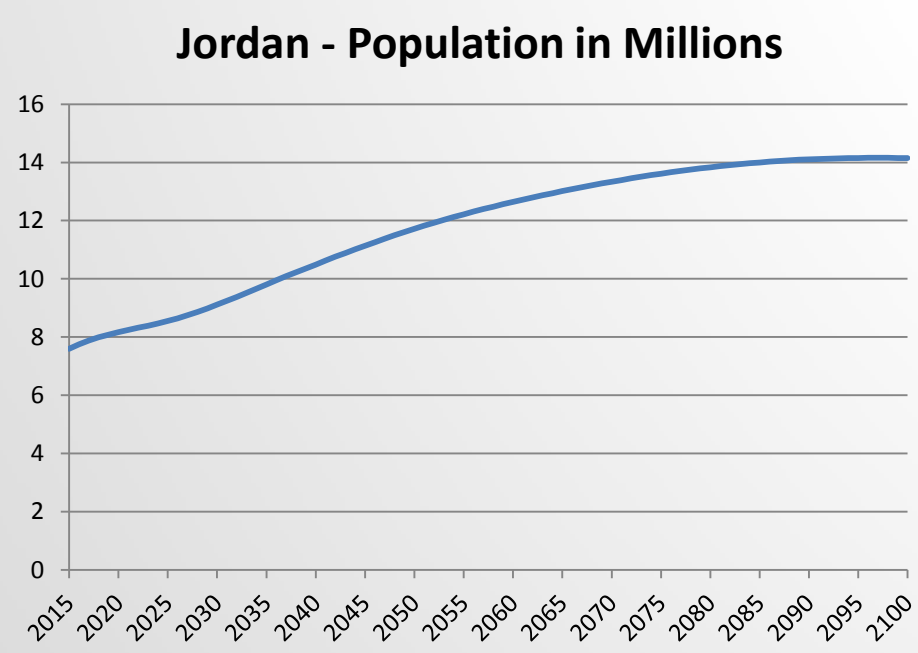
V. Further Research

JORDAN BACKGROUND

- Small arid country in heart of the Middle East
- 7.6 million people
- Upper-Middle Income country
- Key U.S. Ally
- Severe water scarcity

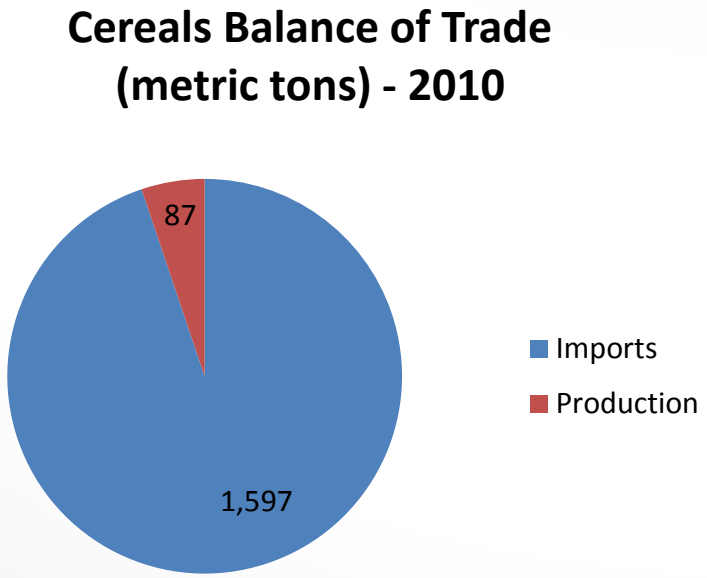
WATER INSECURITY

- Jordan has the 10th lowest per capita renewable freshwater resources in the world.



The population of Jordan is expected to increase by 85% over the next 70 years

Source: United Nations, 2015

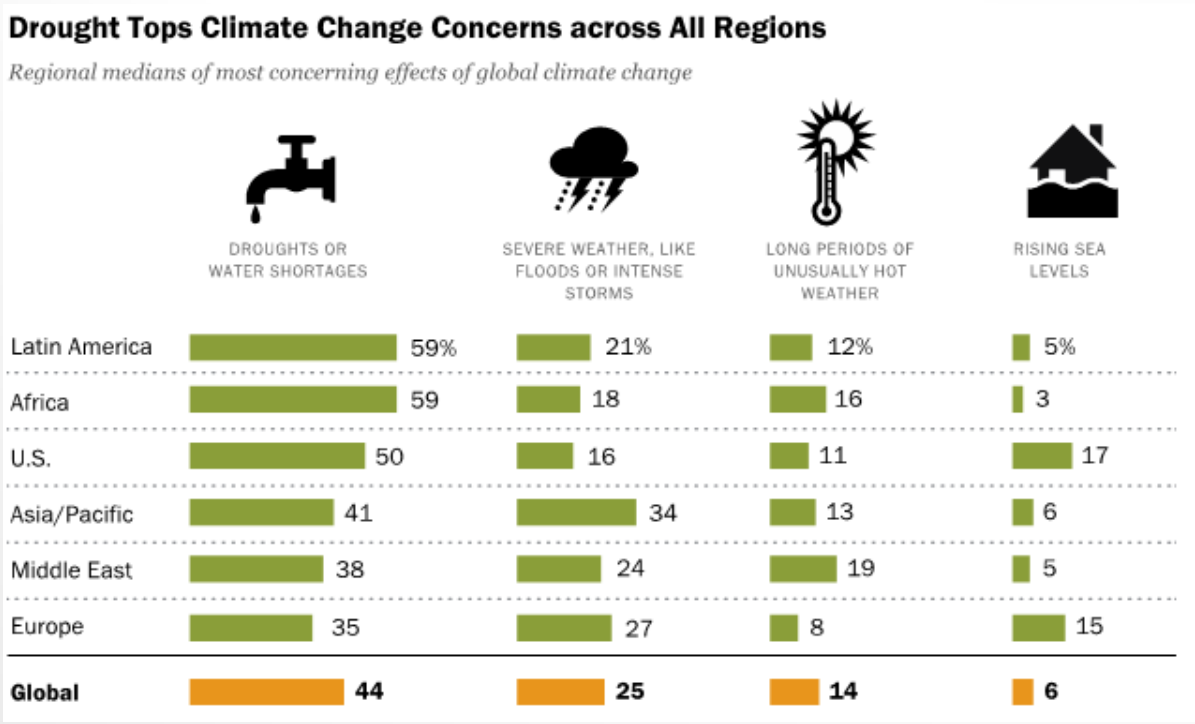


In order to meet the consumption needs of its population, Jordan imports 95% of its cereals.

Source: Arab Organization for Agricultural Development, Arab Agricultural Statistical Yearbook, 2014

CLIMATE CHANGE IMPACT IN THE MIDDLE EAST

- Climate Change Model predict the Middle East region will become hotter, drier, less predictable (IPCC, 2014).
- Climate change may already be causing extreme drought in the Middle East



Source: Stokes et al. 2015

2007-2010 REGIONAL DROUGHT

- Severe drought in 2007-2010 caused widespread water and food insecurity in Syria
- Syria forced to import wheat
- Rural-Urban Migration

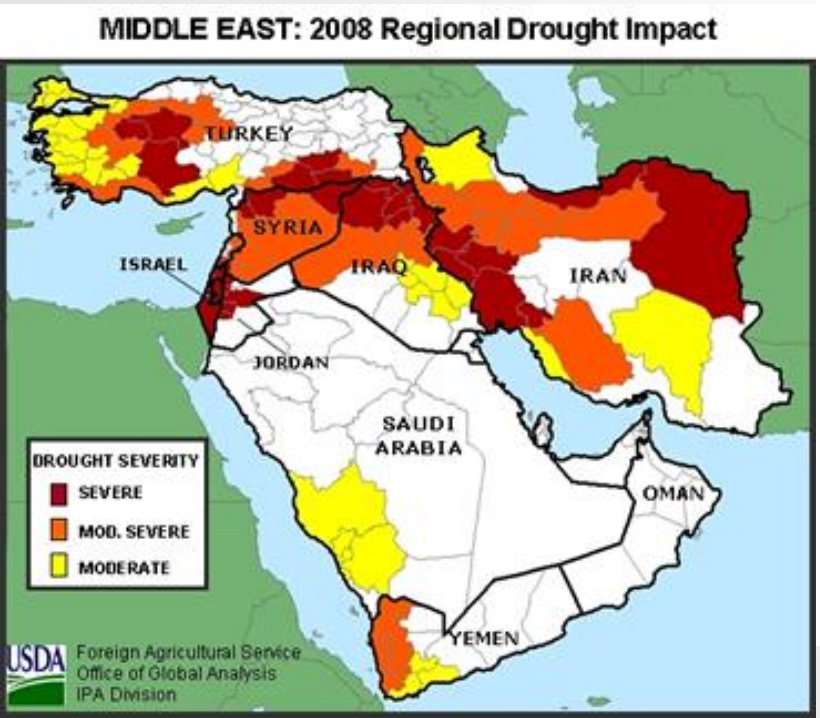
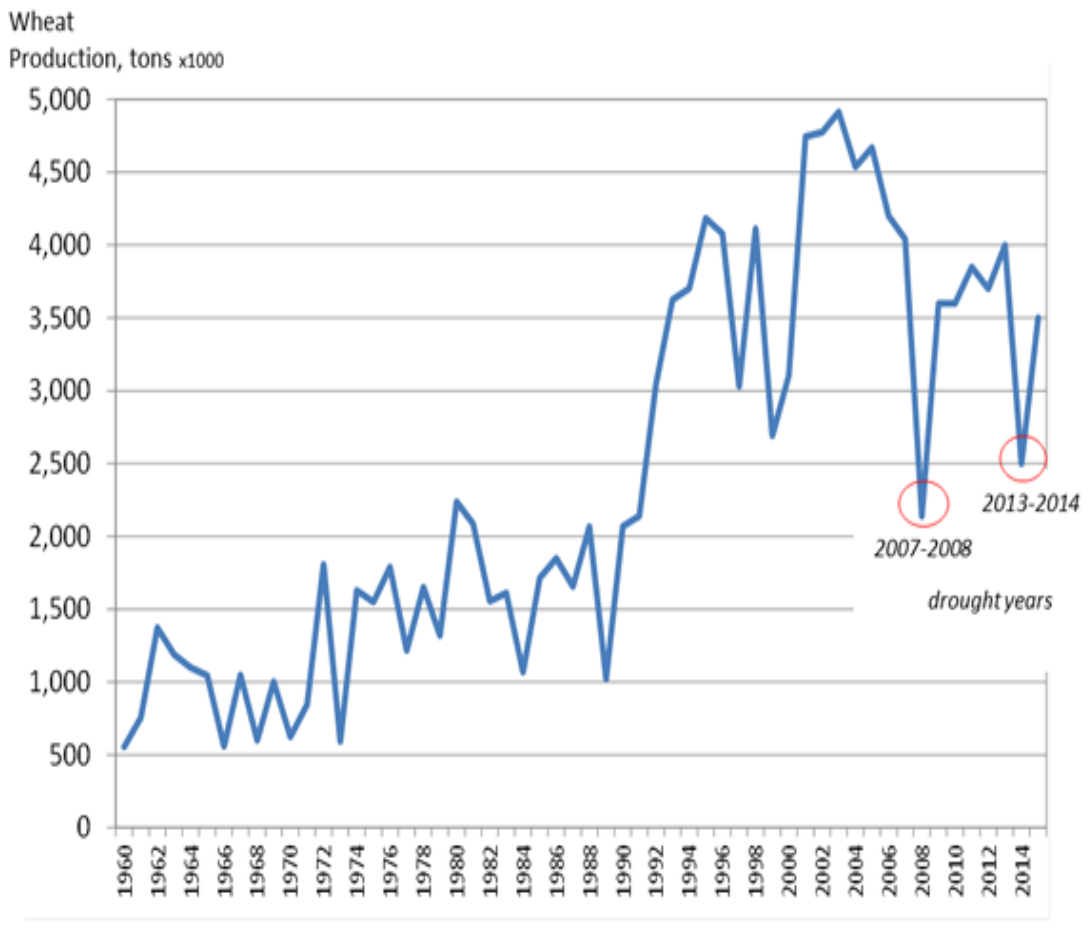


Figure 1. Syria wheat production from 1960 to 2015 (USDA Production, Supply and Demand database).



Source: United States Department of Agriculture, 2015

RESEARCH APPROACH

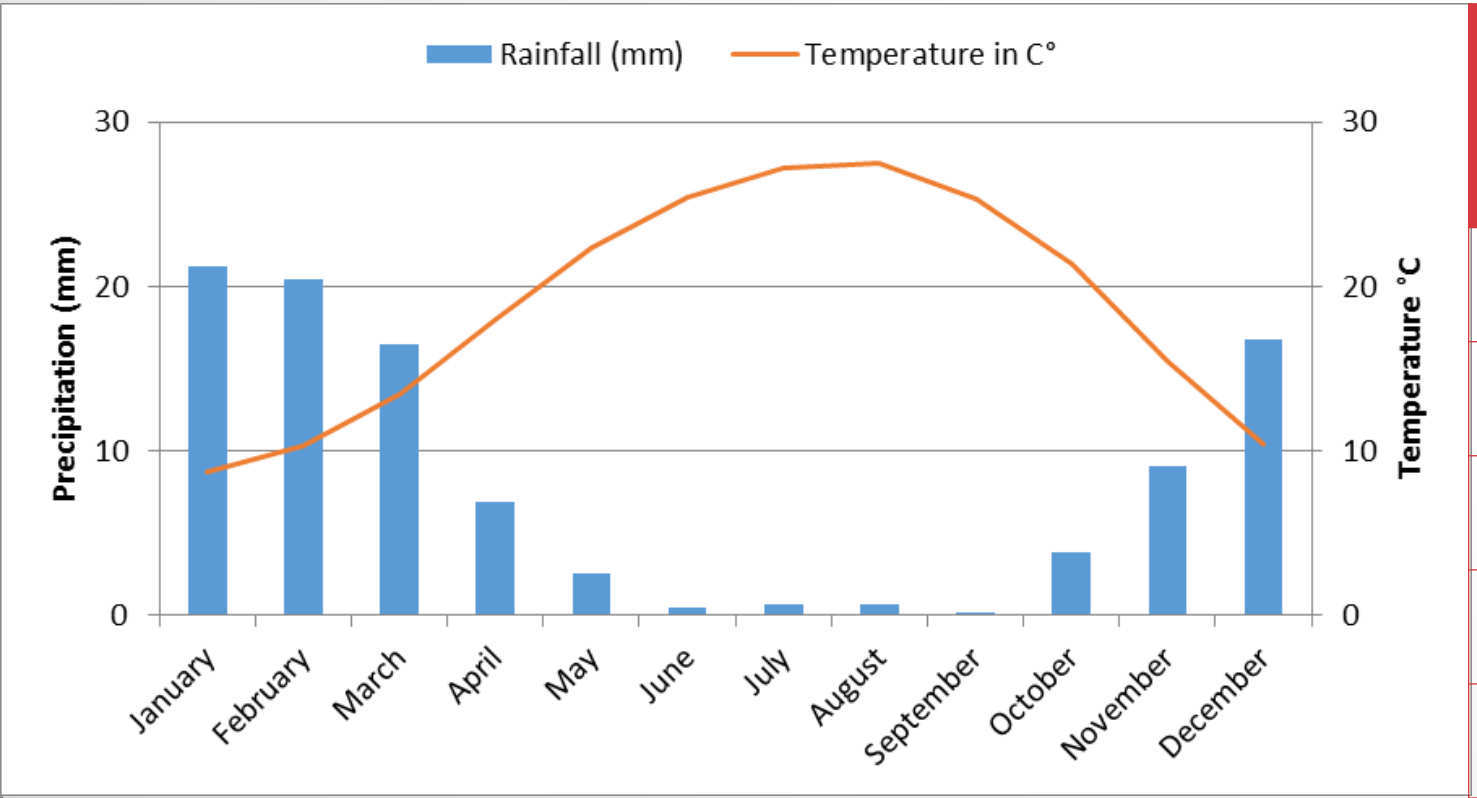
- Assessed Climate in Jordan past to present to identify drought years
- Used composite drought index to measure drought severity
- Measured population affected and impact on agricultural production.
- Identified how climate change will impact drought afflicted areas in 2050.

DATA SOURCES

Data	Timeframe	Description	Spatial Resolution	Data Source
Monthly Precipitation	1901-2012	Monthly Average precipitation data. Used data for November to April	Non-spatial	World Bank Climate Hub
Composite Drought Index	November 2008 to April 2009	Index of drought severity based on NDVI, SPI, surface temperature anomaly, and soil moisture.	.05 degree	International Center for Biosaline Agriculture
Landcover	2009	Landcover data used to identify cropland	.5km	Global Landcover Facility
Normalized Difference Vegetation Index Anomaly	November 2008 to April 2009	Input Variable for CDI, used in measuring cropland affected	.05 degree	International Center for Biosaline Agriculture
Wheat Yield, Production	2000-2014	Annual production figures for agricultural products	Non-spatial	Food and Agriculture Organization (FAO)
Barley Yield, Production	2000-2014	Annual production figures for agricultural products	Non-spatial	Food and Agriculture Organization (FAO)
Landscan	2010	Gridded Population Dataset	1km	Oak Ridge National Library
Future Climate -Monthly Precipitation - January	2040-2060	Average values from six GCMS in rcp 4.5 and 8.5 scenarios	30 seconds	WorldClim
Future Climate -Max Monthly Temperature - January	2040-2061	Average values from six GCMS in rcp 4.5 and 8.5 scenarios	30 seconds	WorldClim
Historical Average - Monthly Precipitation	1960-1990	Interpolations of observed climate data	30 seconds	WorldClim
Historical Average - Max Monthly Temperature - January	1960-1991	Interpolations of observed climate data	30 seconds	WorldClim

ASSESSMENT OF HISTORIC CLIMATE AND DROUGHT CONDITIONS

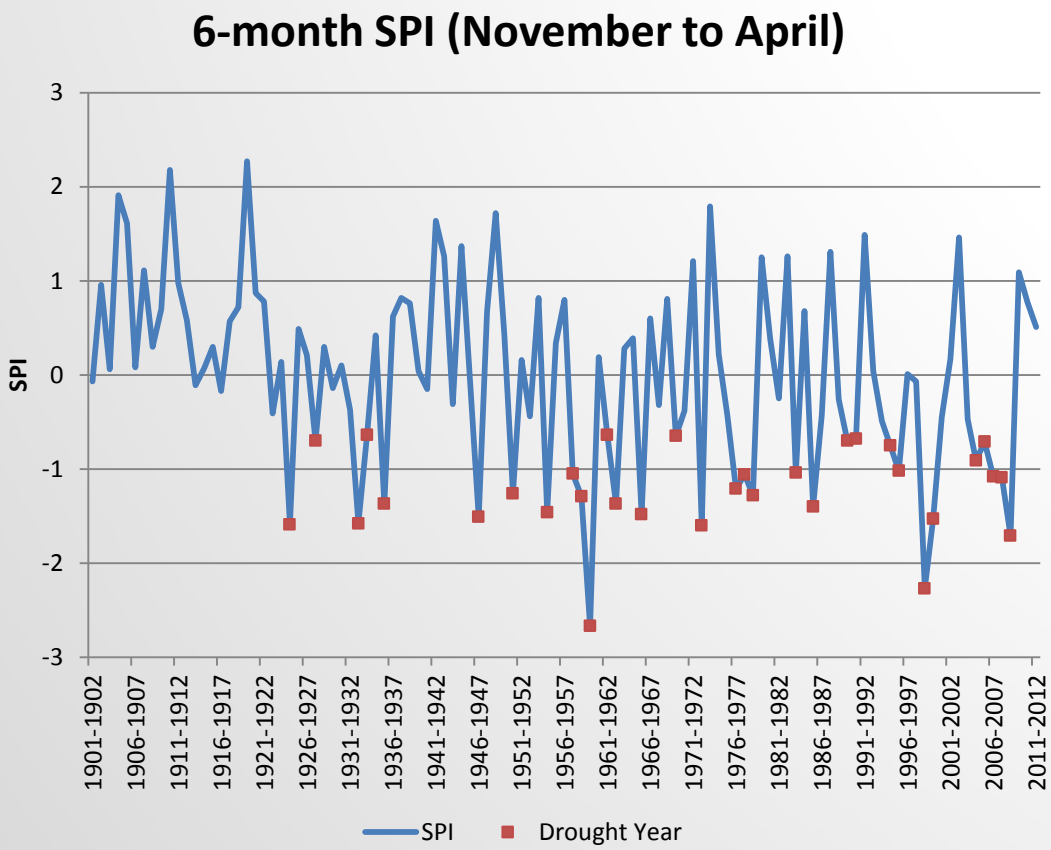
- Monthly Precipitation data from World Bank Climate Hub
- Calculated Standard Precipitation Index for winter wet months

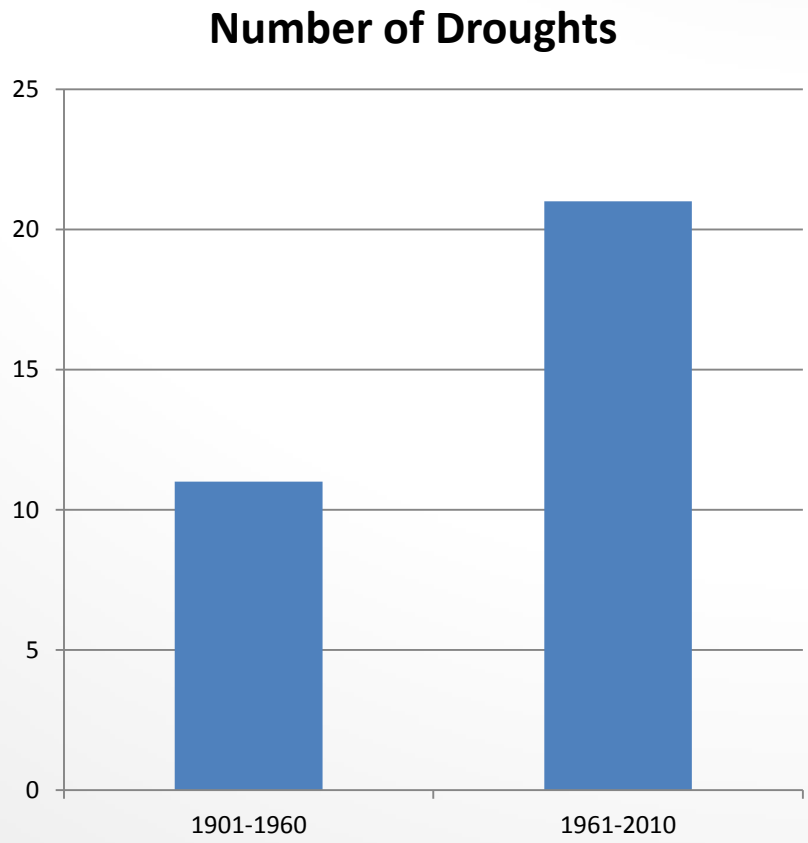


SPI Value	Drought Classification
-0.5 to -0.7	Abnormally Dry
-0.8 to -1.2	Moderate Drought
-1.3 to -1.5	Severe Drought
-1.6 to -1.9	Extreme Drought
-2.0 or less	Exceptional Drought

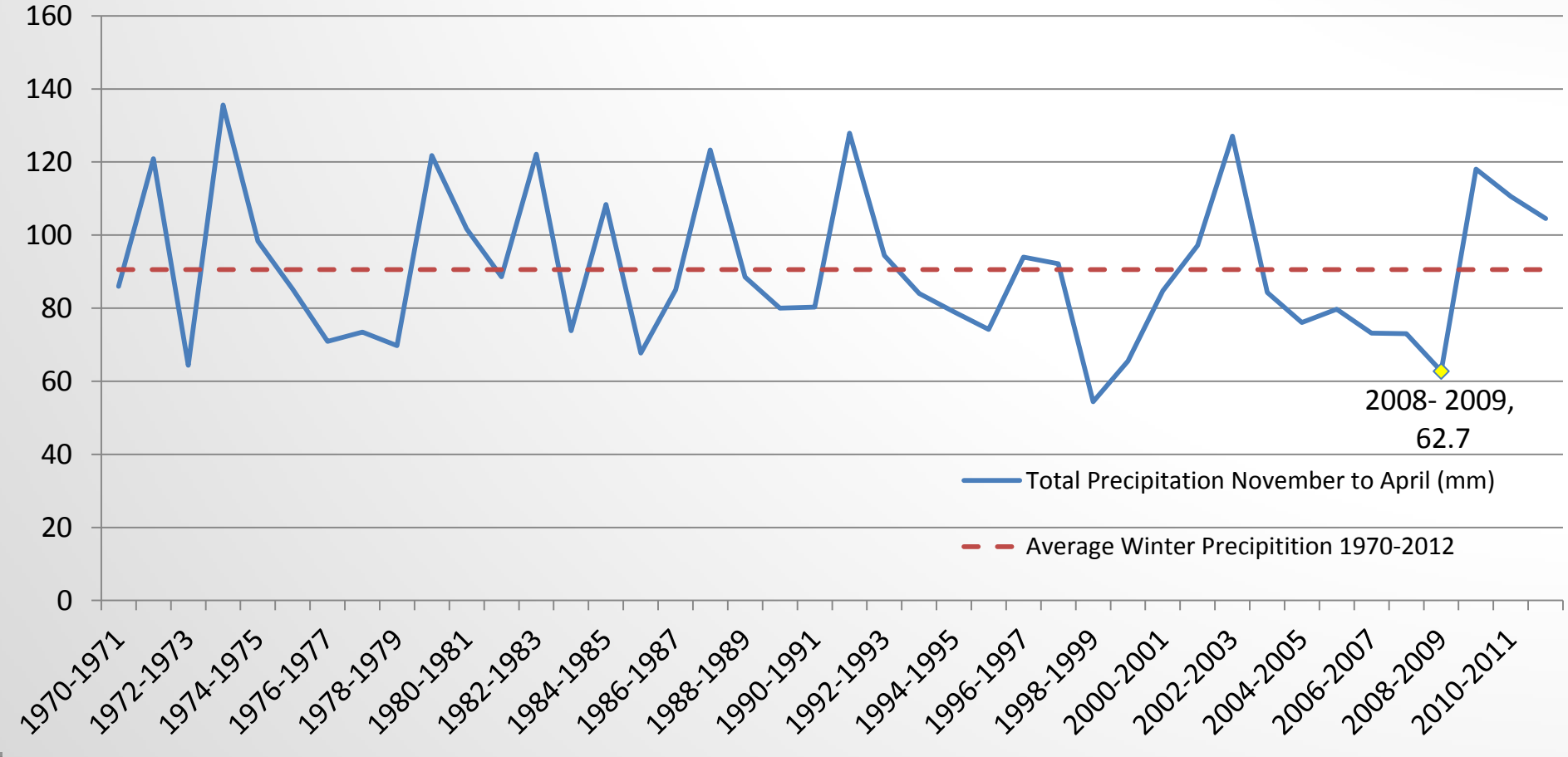
RESULTS – HISTORIC DROUGHT ANALYSIS

SPI < -0.5 = Drought years





RECENT DROUGHT 2006-2009



CASE STUDY OF 2008-2009 WINTER DROUGHT

- Composite Drought Index (CDI) used to map drought severity

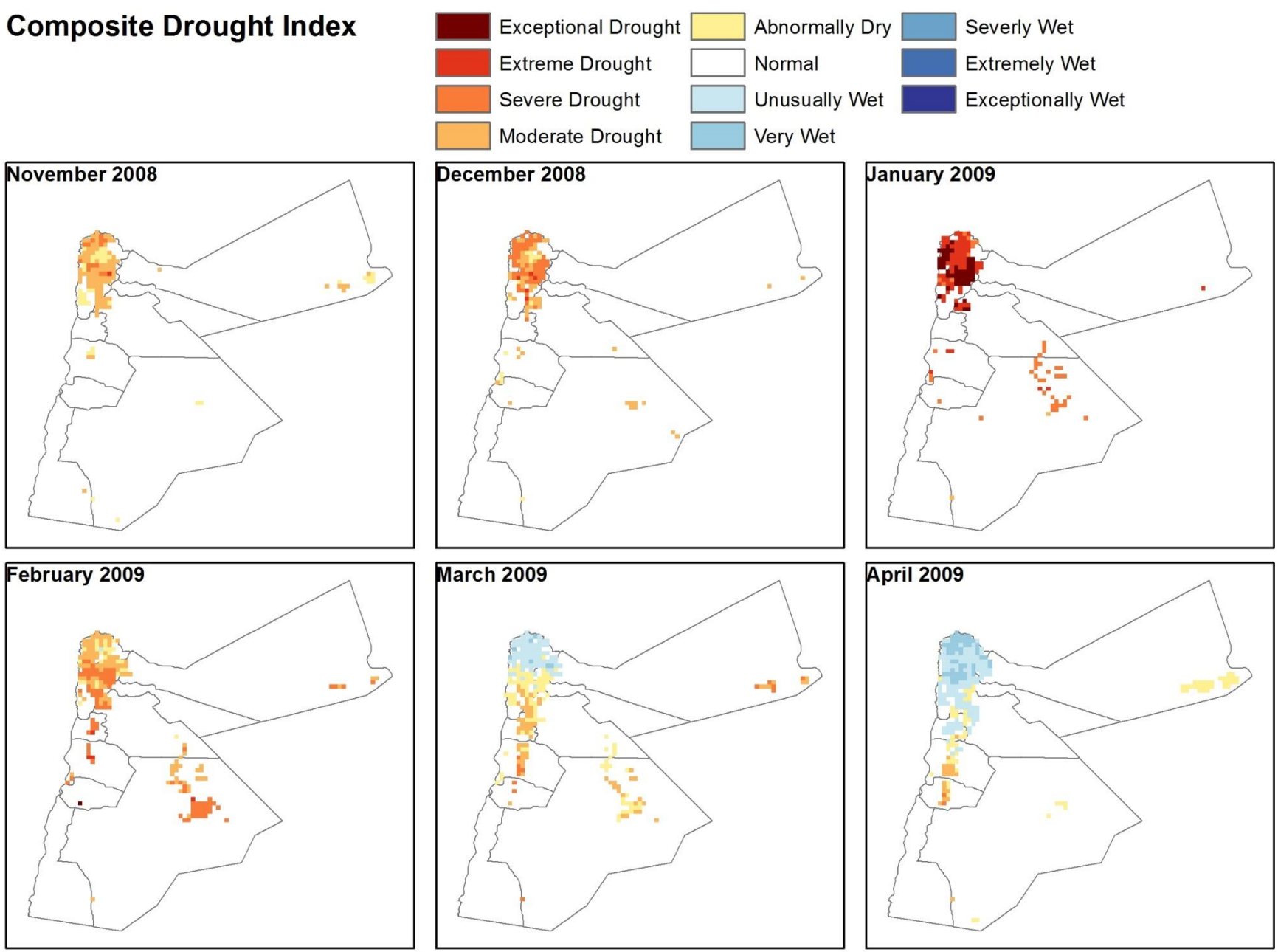
Equation:

CDI = 0.40 * SPIa + 0.2 * SMa+ 0.2 * LSTa + 0.2 * NDVIa

- Where SPIa = precipitation anomaly, SMa = soil moisture anomaly, LSTa = land surface temperature anomaly, and NDVIa = vegetation anomaly.

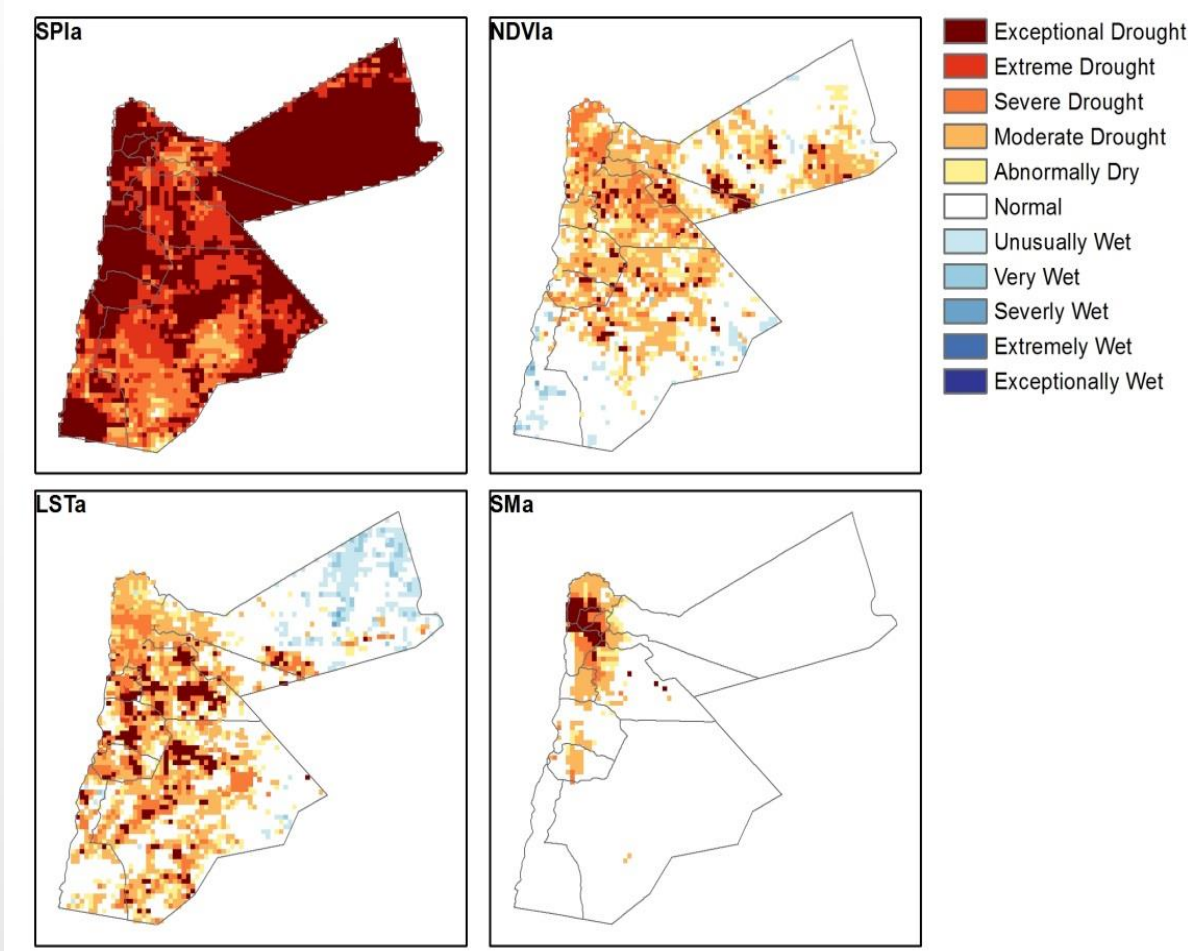
Values	Percentiles	Classification
-5	0 to 2%	Exceptional Drought
-4	2 to 5%	Extreme Drought
-3	5 to 10%	Severe Drought
-2	10 to 20%	Moderate Drought
-1	20 to 30%	Abnormally Dry
0	30 to 70%	Normal
1	70 to 80%	Unusually Wet
2	80 to 90%	Very Wet
3	90 to 95%	Severely Wet
4	95 to 98%	Extremely Wet
5	98 to 100%	Exceptionally Wet

COMPOSITE DROUGHT INDEX



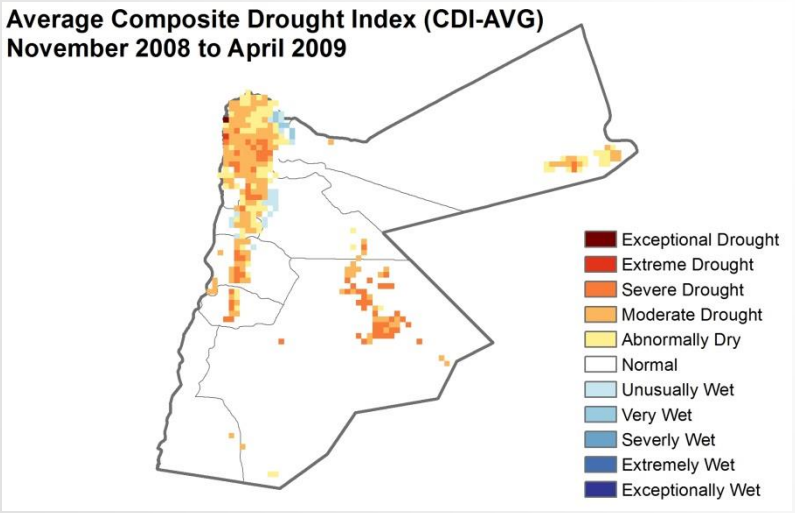
JANUARY ANOMALY DATASETS

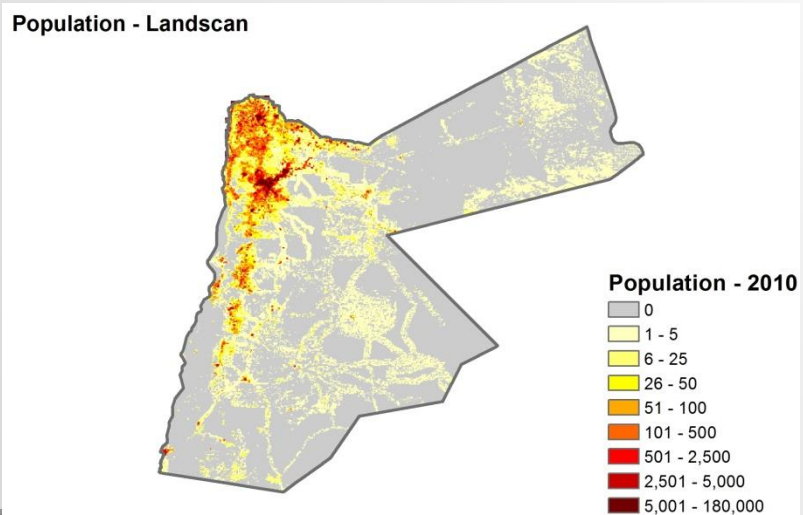
- All four anomaly datasets show drought conditions
- Precipitation Anomaly (top left) and soil moisture (bottom right) were exceptionally low in northwest Jordan

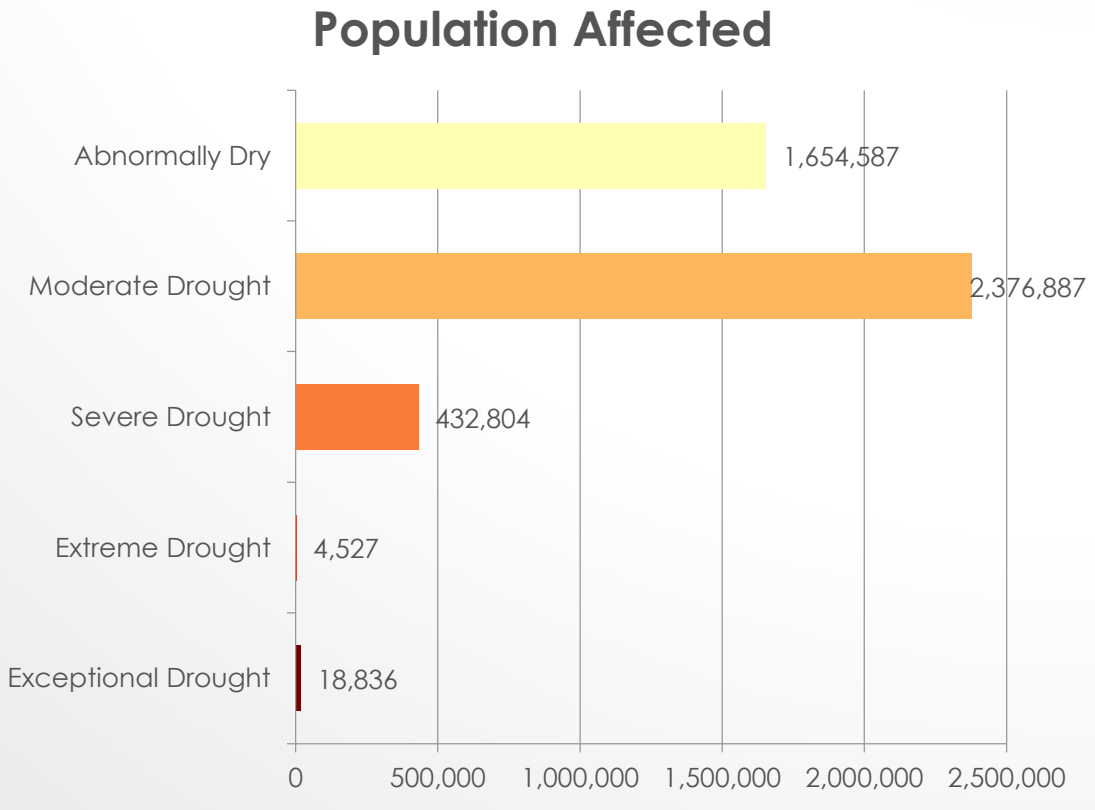


POPULATION AFFECTED

- Approximately 4.7 million people, or 73% of Jordan's population resides in areas that were impact by the drought.



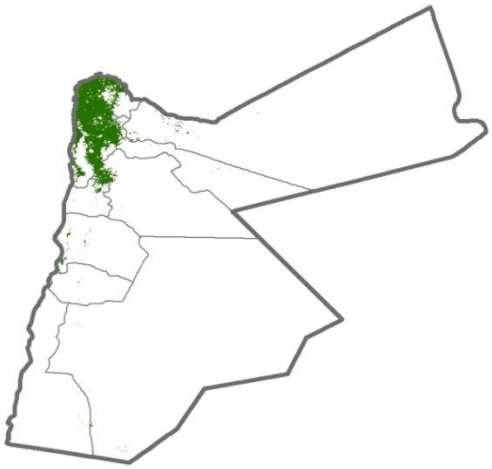




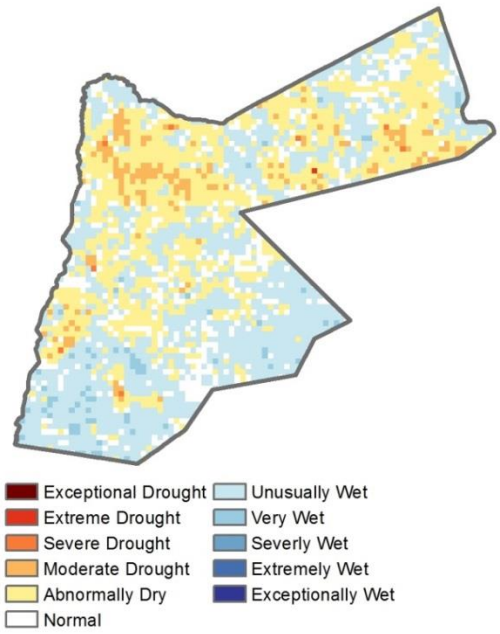
CROPLAND AFFECTED

- Cropland in Jordan is concentrated in northwest which overlaps with some of the areas affected by drought
- Approximately 52% of cropland affected

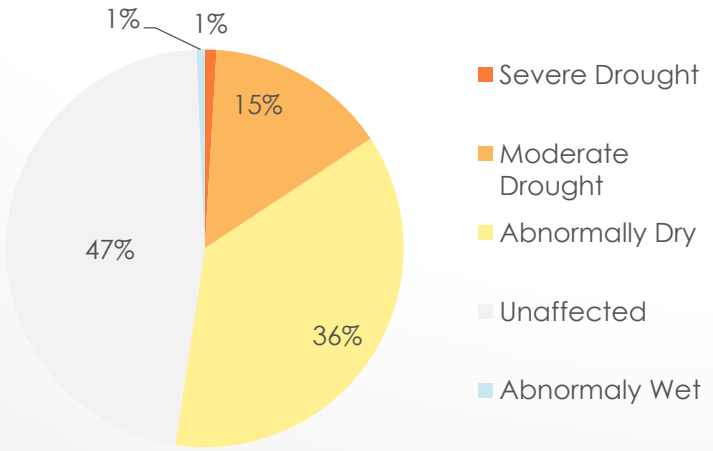
Cropland



NDVI-AVG

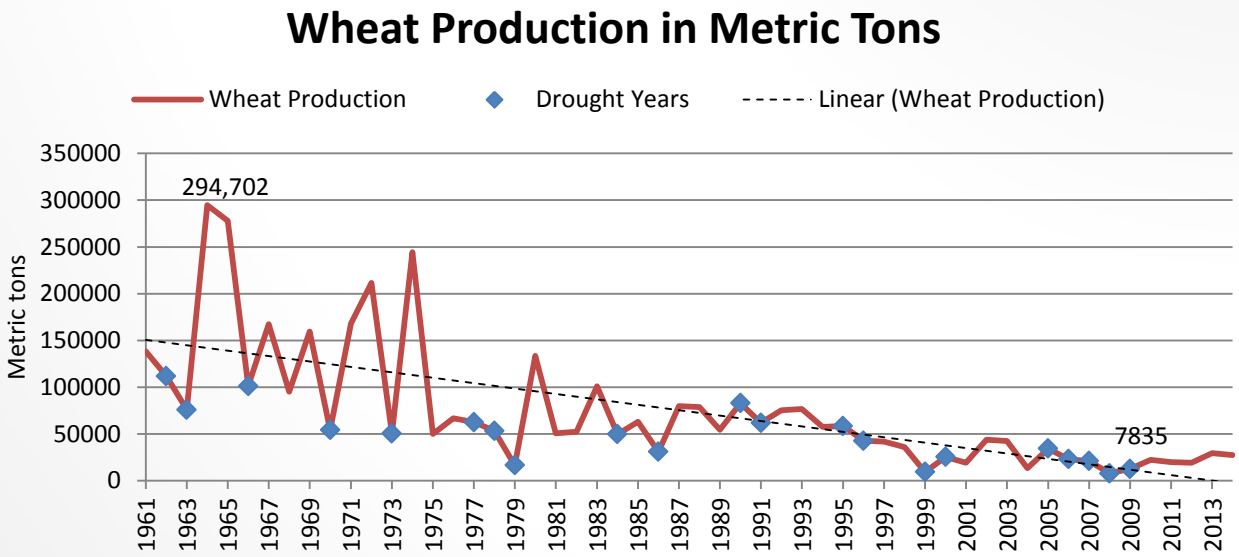


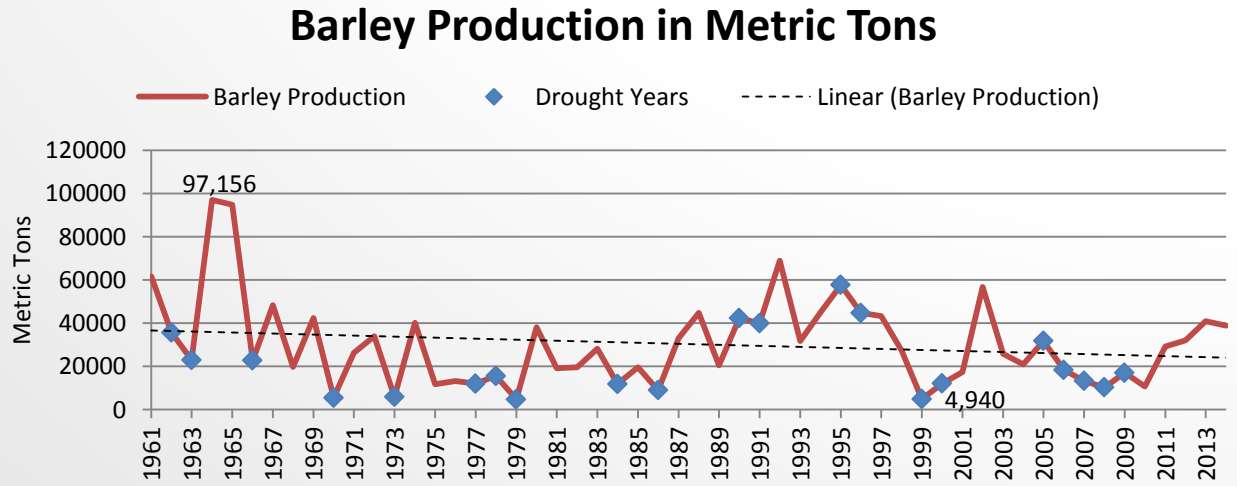
Cropland Affected



WHEAT AND BARLEY PRODUCTION

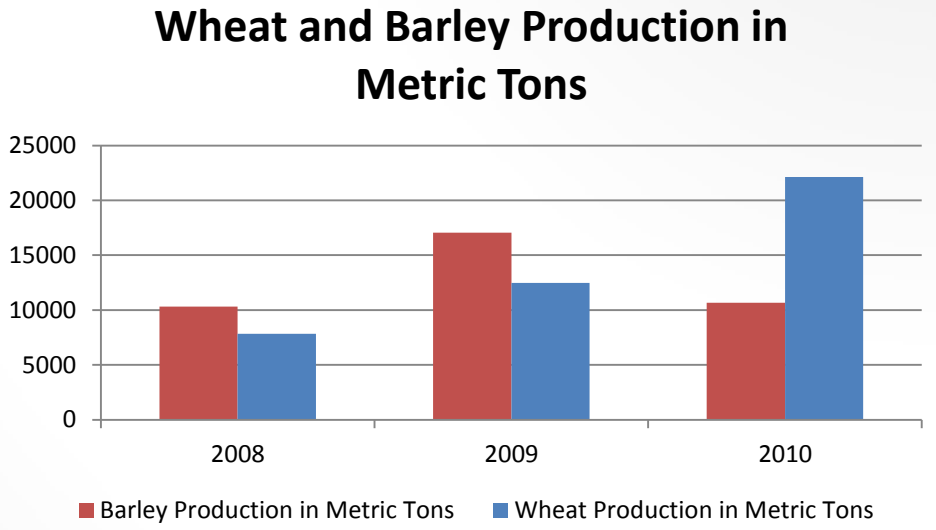
- Historical decrease in wheat and barley production
- Makes measuring the impact of drought challenging

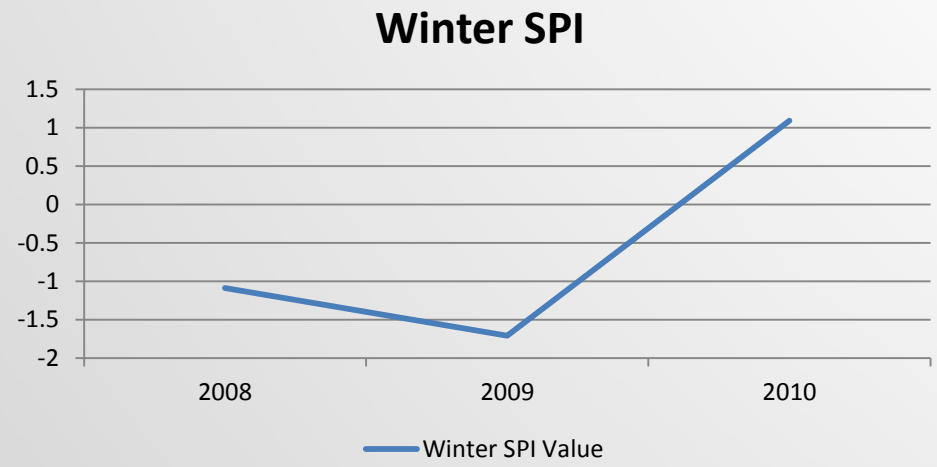


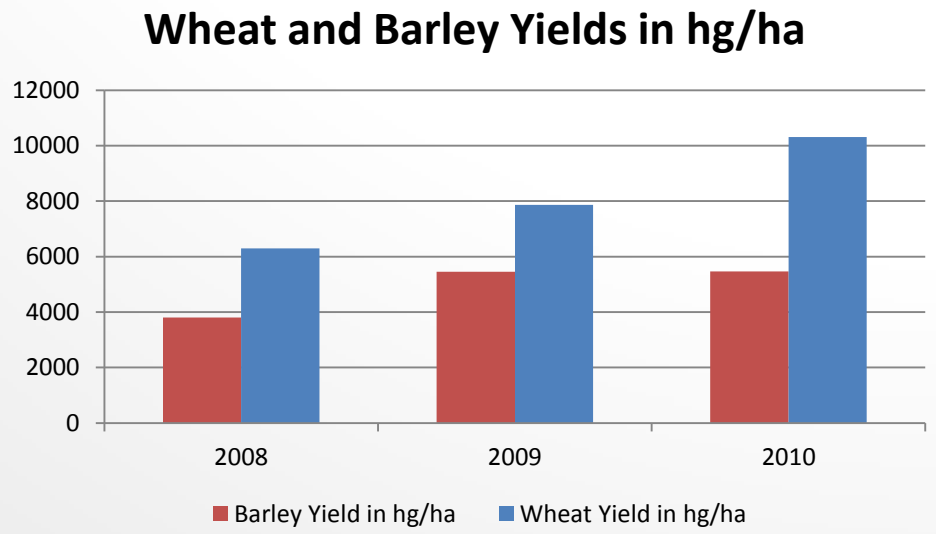


WHEAT AND BARLEY PRODUCTION

- Not a clear relationship between barley and wheat production with drought severity
- 2008-2009 winter had a lower SPI than 2007-2008, but production and yield







CLIMATE CHANGE ANALYSIS

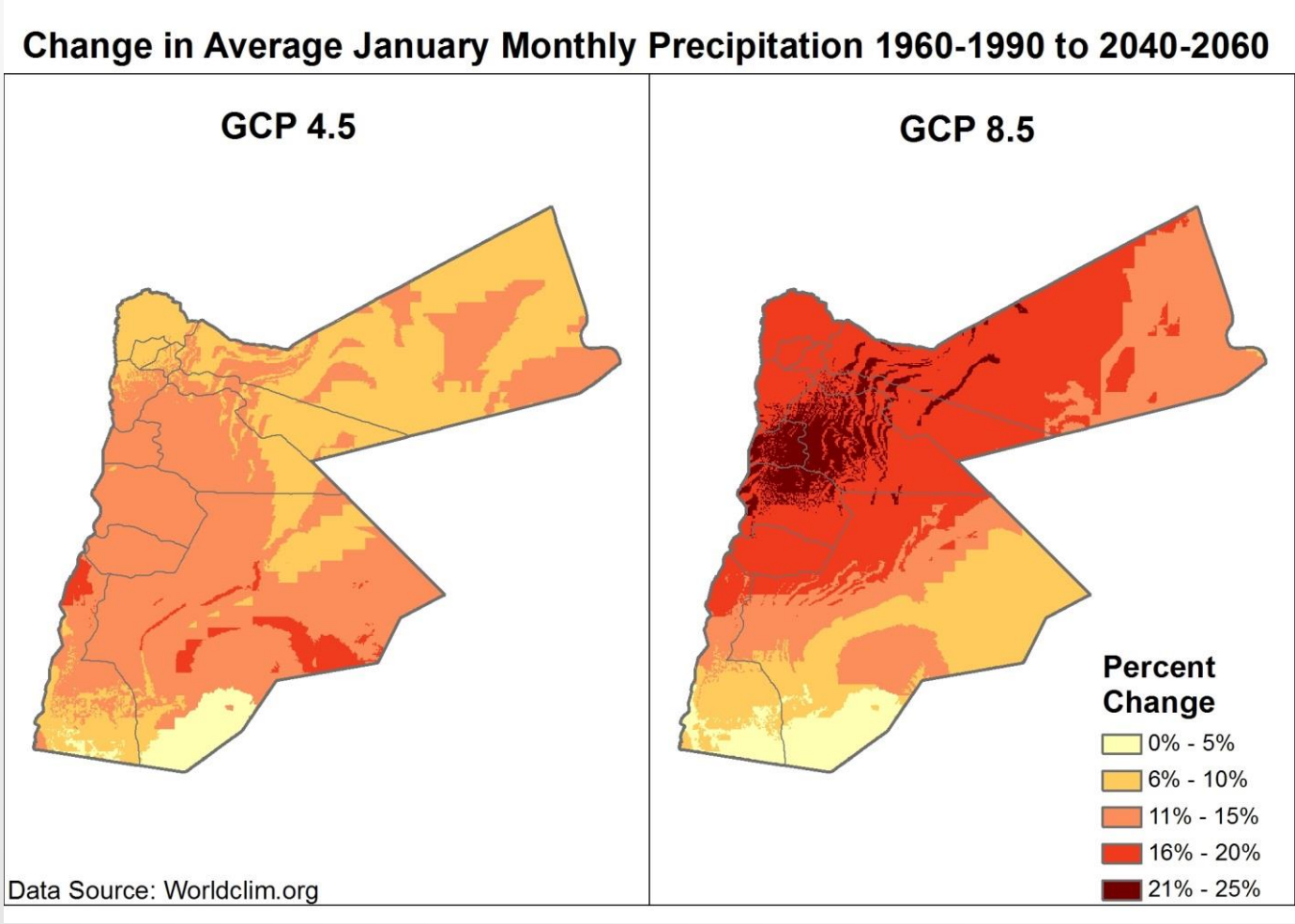
- Used publically available downscaled climate change data from World Clim
- Average of 6 Global Climate Models
- Focused on precipitation and temperature in January to identify conditions that could affect drought
- Current climate data 1960-1990 used as baseline

Model	Source
CCSM4	National Center for Atmospheric Research
CNRM-CM5	National Center for Meteorological Research
GFDL-CM3	Geophysical Fluids Dynamics Lab
HADGEM2-ES	Met Office Hadley Centre
GISS-E2-R	National Aeronautics and Space Administration - Goddard Insitute for Space Studies
MRI-CGCM3	Meteorological Research Institute

Data	Timeframe	Description	Spatial Resolution	Purpose	Data Source
Precipitation	2040-2060	Average January Precipitation	30 seconds	Measures average monthly precipitation under future climate conditions	WorldClim
Max Temperature	2040-2060	Average Max Temperature in January	30 seconds	Measures max monthly temperature under future climate conditions	WorldClim
Current Conditions	1960-1990	Current conditions data for max temperature and average precipitation	30 seconds	Used for comparison with future climate conditions	WorldClim

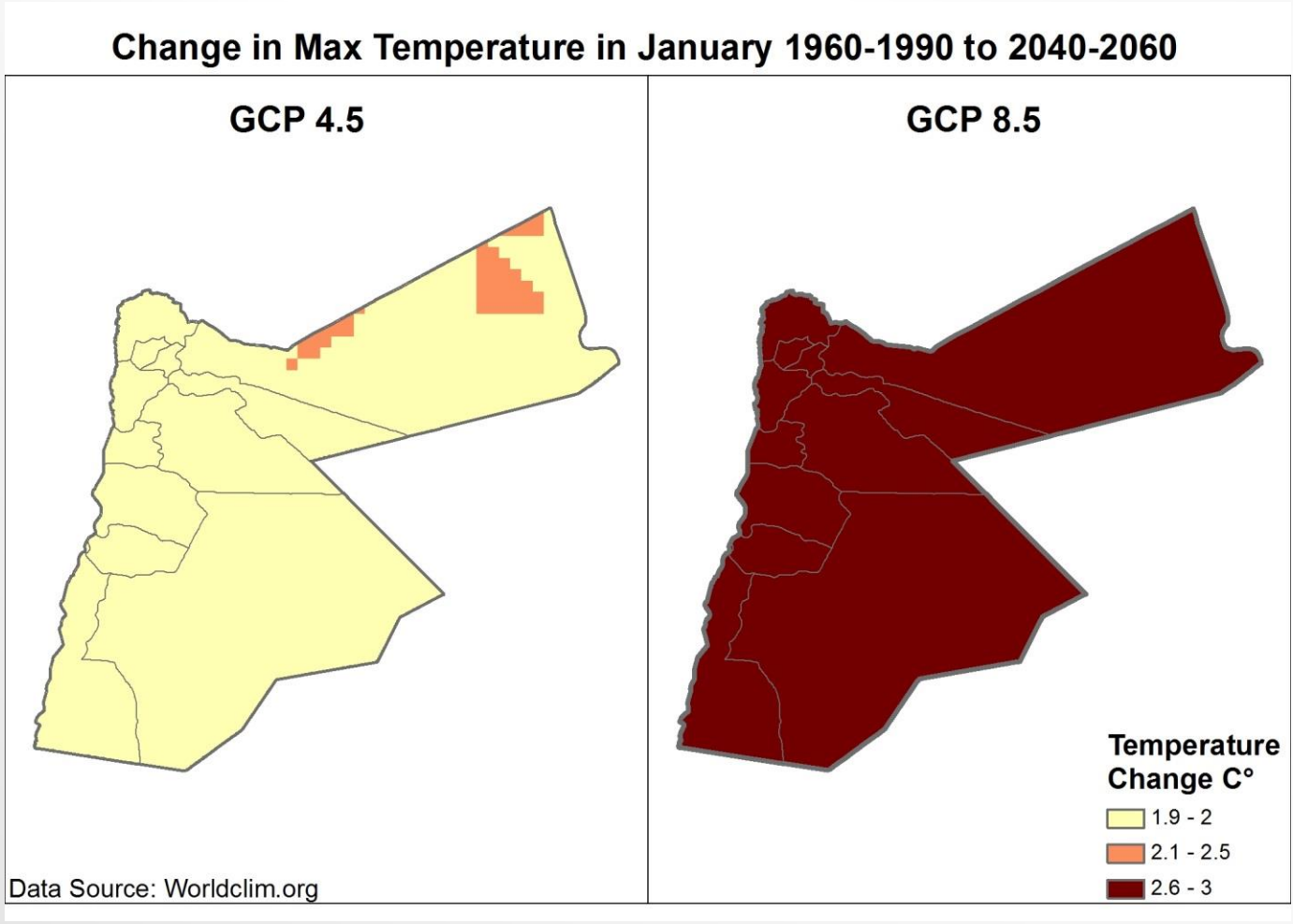
PRECIPITATION CHANGE IN JANUARY

- Under low emission scenario, can expect to see a an average decrease of 6-10% in precipitation in January.
- Under high emissions scenario, decrease will be closer to 16-20%.



MAX TEMPERATURE CHANGE IN JANUARY

- Max temperatures in January will increase by 2 to 3 degrees celcius
- Current climate average max temperature in January is 21.2 degrees
- Increase in 2 to 3 degrees is unlikely to have major effects



RESEARCH LIMITATIONS

- Composite drought index relies on satellite sensor data that is not available for long term historic analysis
- Unable to distinguish between rainfed and irrigated cropland
- Research doesn't capture the effect of drought on groundwater resources

CONCLUSIONS

- Drought frequency and severity has increased
- Climate change data suggests that this trend is likely to continue
- Drought primarily affects northwest Jordan where majority of Jordan's population and cropland are located.
- More difficult than expected to measure the relationship between drought and crop production.

FURTHER RESEARCH

- Examine why winter crop production was worse in 2008 than in 2009
- More granular analysis of cropland affected (i.e. rainfed vs irrigated, barley, wheat fields)
- Comparison study with impact in Syria

QUESTIONS?

REFERENCES

Al-Qinna, M. I., Hammouri, N. A., Obeidat, M. M., & Ahmad, F. Y. (2011). Drought analysis in Jordan under current and future climates. *Climatic Change*, *106*(3), 421–440. http://doi.org/10.1007/s10584-010-9954-y

Altz-stamm, A. (2012). *Jordan ' s Water Resource Challenges and the Prospects for Sustainability*.

Brown, O., & Crawford, A. (2009). *Rising Temperatures , Rising Tensions: Climate change and the risk of violent conflict in the Middle East*. Retrieved from https://www.iisd.org/pdf/2009/rising_temps_middle_east.pdf

Climate Change Knowledge Portal. (2016). Climate Change Knowledge Portal. Retrieved from http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisCCode=JOR

Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. S., & and F.N. Tubiello. (2007). Food, fibre and forest products. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 273–313. Retrieved from http://www.ipcc-wg2.gov/AR4/website/05.pdf

Food and Agriculture Organization. (2014). AQUASTAT. Retrieved from http://www.fao.org/nr/water/aquastat/data/query/results.html

Gillis, J. (2015). Short Answers to Hard Questions About Climate Change. Retrieved from http://www.nytimes.com/interactive/2015/11/28/science/what-is-climate-change.html?_r=1

IPCC. (2007). *A report of Working Group I of the Intergovernmental Panel on Climate Change Summary for Policymakers Summary for Policymakers*. Cambridge University Press.

IPCC. (2014a). *Climate Change 2014 Synthesis Report Summary Chapter for Policymakers*. *Ipcc*. http://doi.org/10.1017/CBO9781107415324

IPCC. (2014b). *Summary for Policymakers*. *Climate Change 2014: Impacts, Adaptation and Vulnerability - Contributions of the Working Group II to the Fifth Assessment Report*. Cambridge University Press. http://doi.org/10.1016/j.renene.2009.11.012

REFERENCES

IRIN. (2009). *Syria: Drought blamed for food scarcity*. Retrieved from http://reliefweb.int/report/syrian-arab-republic/syria-drought-blamed-food-scarcity

Jordan Ministry for Water and Irrigation, & German Technical Cooperation. (2004). The national water master plan, 97. Retrieved from http://ocid.nacse.org/rewab/docs/National_Water_Master_Plan_of_2004.pdf

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R., & Kushnir, Y. (2015). Climate change in the Fertile Crescent and implications of the recent Syrian drought. *Proceedings of the National Academy of Sciences*, *112*(11), 3241–3246. http://doi.org/10.1073/pnas.1421533112

Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature*, *529*(7584), 84–87. http://doi.org/10.1038/nature16467

Luber, G., & McGeehin, M. (2008). Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine*, *35*(5), 429–435. http://doi.org/10.1016/j.amepre.2008.08.021

Min, S.-K., Zhang, X., Zwiers, F. W., & Hegerl, G. C. (2011). Human contribution to more-intense precipitation extremes. *Nature*, *470*(7334), 378–381. http://doi.org/10.1038/nature09763

Ministry of Water & Irrigation. (2013). Jordan Water Sector Facts and Figures 2013 Opening Statement. Retrieved from http://www.mwi.gov.jo/sites/en-us/Documents/W. in Fig.E FINAL E.pdf

Olesen, J. E., & Bindi, M. (2002). Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy*, *16*(4), 239–262. http://doi.org/10.1016/S1161-0301(02)00004-7

The World Bank Group. (2015). Renewable internal freshwater resources per capita (cubic meters). Retrieved July 31, 2016, from http://data.worldbank.org/indicator/ER.H2O.INTR.PC?end=2014&locations=JO&start=2014&view=map&year_high_desc=true

REFERENCES

Stokes, B., Wike, R. & Carle, J., 2015. *Global Concern about Climate Change, Broad Support for Limiting Emissions*, Available at: http://www.pewglobal.org/2015/11/05/global-concern-about-climate-change-broad-support-for-limiting-emissions/ [Accessed September 5, 2016].

Tubiello, F. N., Soussana, J.-F., & Howden, S. M. (2007). Crop and pasture response to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(50), 19686–90. http://doi.org/10.1073/pnas.0701728104

United Nations. (2015). *World Population Prospects - Population Division - United Nations*. *World Population Prospects - 2015 Revision*. Retrieved from https://esa.un.org/unpd/wpp/

United States Department of Agriculture. (2008). *SYRIA : Wheat Production in 2008 / 09 Declines Owing to Season-Long Drought*. Retrieved from http://www.pecad.fas.usda.gov/highlights/2008/05/syria_may2008.htm

United States Department of Agriculture. (2015). *SYRIA: 2015/2016 Wheat Production Up from Last Year due to Favorable Precipitation*. Retrieved from http://www.pecad.fas.usda.gov/highlights/2015/07/Syria/Index.htm

Worland, J. (2011). Scientists Are Making Stronger Links Between Climate Change and Extreme Weather | TIME. Retrieved from http://time.com/4255428/climate-change-extreme-weather/

World Health Organization. (2016). Climate Change Adaptation to Protect Human Health: Jordan project profile. Retrieved August 8, 2016, from http://www.who.int/globalchange/projects/adaptation/en/index5.html