Crop Adaptation in a Changing Climate and Biotechnology's Role: Drought Tolerant Varieties

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United States
Department
of Agriculure

Agricultural
Research Service

Climate Change
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Technical Bulletin 1935

USDA

Climate Change and Agriculture in the United States: Effects and Adaptation

USDA

United States
Department of
Agriculture

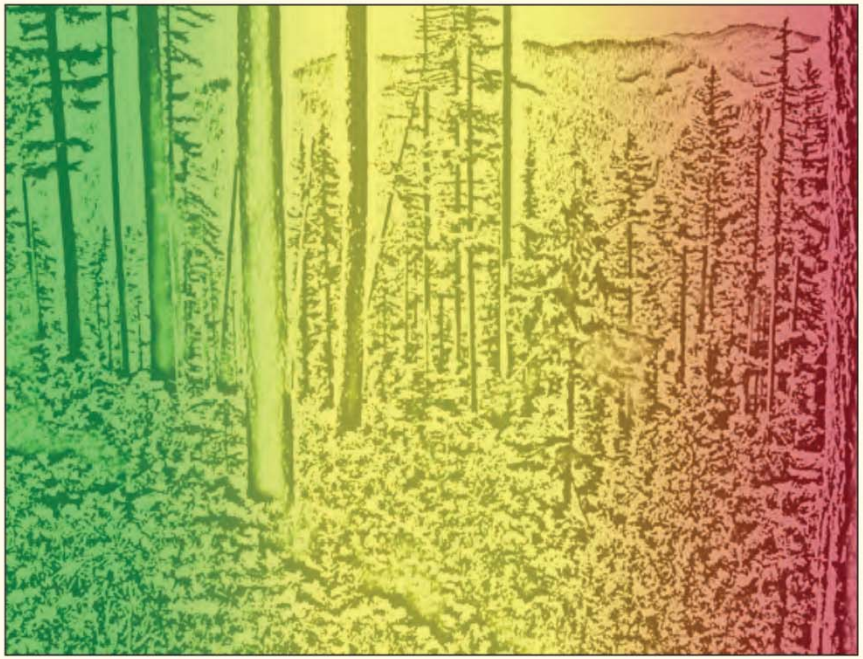
Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-870

December 2012

Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector



http://www.usda.gov/oce/climate_change/effects.htm

Climate Change Impacts on Ag

Which factors that influence agriculture could be affected by climate change?

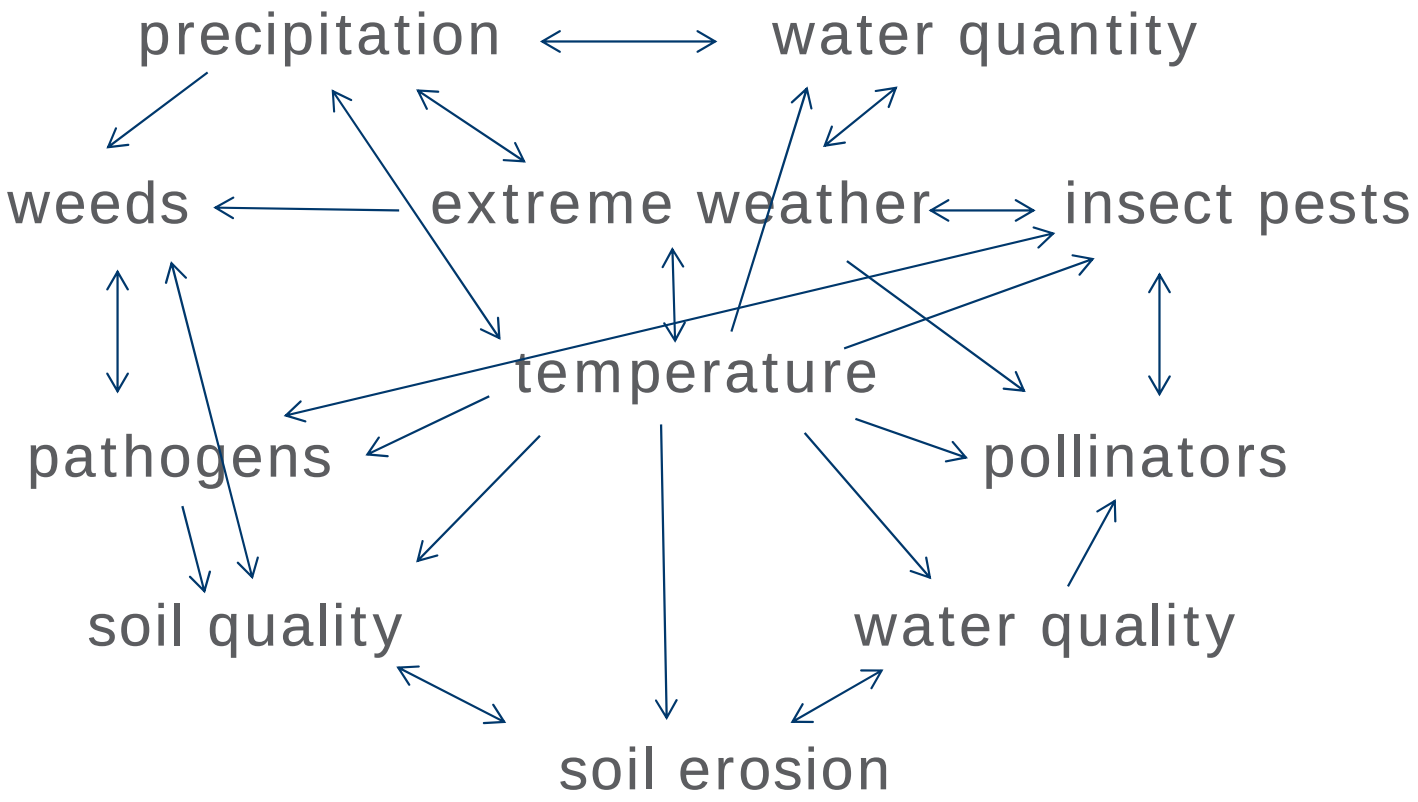
- Temperature
- Precipitation
- Insect pests
- Pathogens
- Pollinators
- Weeds
- Soil quality/erosion
- Water quality/quantity
- Extreme weather events

Climate Change Impacts on Ag

How will changing climate affect these factors?

- Temperature – increase 1°C – 3°C by 2050
- Precipitation - variable
- Insect pests – variable, uncertain
- Pathogens – variable, uncertain
- Pollinators – variable, uncertain
- Weeds – variable, uncertain
- Soil quality/erosion - variable
- Water quality - variable
- Extreme weather– More, but when? where? what kind?

Climate Change Impacts on Ag



Climate Change Impacts on Ag

- Extremely complex
- Highly variable
- Great uncertainty

Biotechnology's Role

What can biotechnology do to help?

- mitigation
- adaptation

Mitigation - Biotechnology's Role

Biotech crops have already helped in mitigation

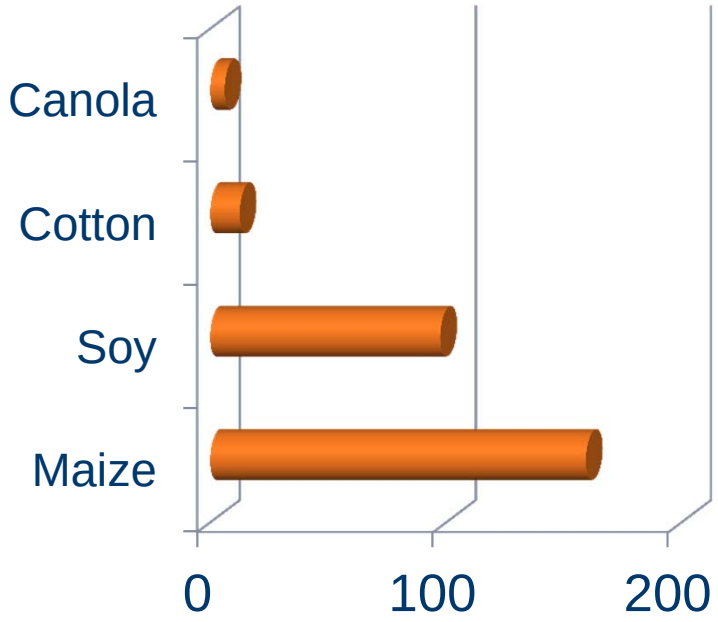
- Maintaining forested lands
- Decreasing consumption of fossil fuels
- Furthering conservation tillage

All affect amount of carbon dioxide

Mitigation - Biotechnology's Role

Maintaining land in forests while increasing yields

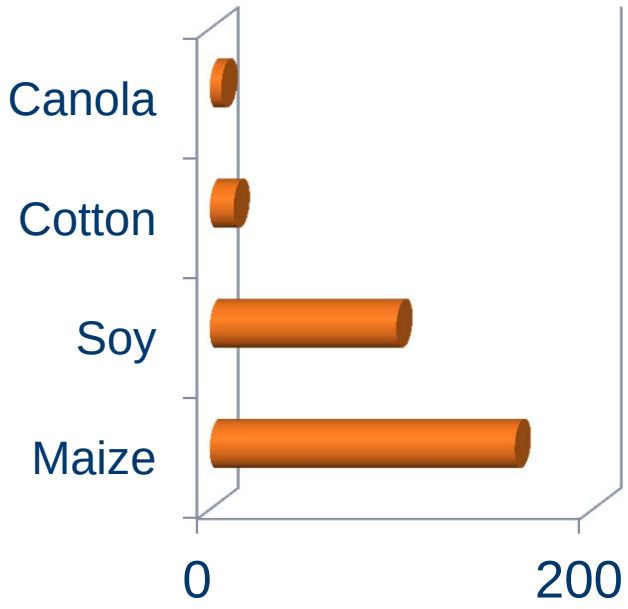
300 million more tons - 1996-2010



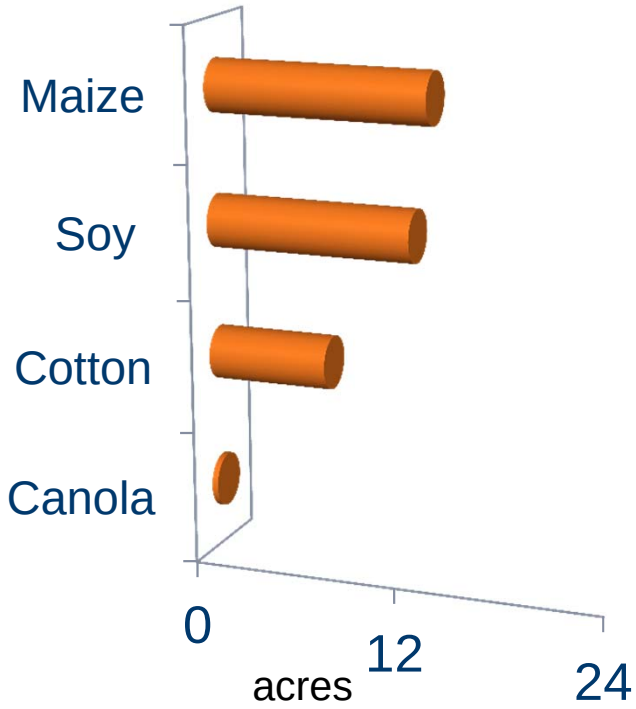
Mitigation - Biotechnology's Role

Maintaining land in forests while increasing yields

300 million more tons



Without biotech ~32 million more acres



Mitigation - Biotechnology's Role

From 1996 – 2010 decreased global fuel use

- by 1.2 billion gallons
- fewer applications - insecticides and herbicides
- less soil cultivation

Barfoot, P., Brookes, G. "GM Crops: Socio-Economic and Environmental Impacts 1996-2010", PG Economics LTD. UK (2012)

Mitigation - Biotechnology's Role

Less soil cultivation for weed control

- Adoption of biotech herbicide tolerant crops increased no-till by 69%
- More carbon stays in the soil

Facilitating conversation Farming Practices and Enhancing Environmental Sustainability with Ag Biotech, CTIC, 2004

Mitigation - Biotechnology's Role

Decreased fuel use + Carbon retained in soil (**2010**)

=

Removing 8.6 million cars from the road that year

Barfoot, P., Brookes, G. "GM Crops: Socio-Economic and Environmental Impacts 1996-2010", PG Economics LTD. UK (2012)

Adaptation to Changing Climate

Biotechnology Industry Organization

Adaptation - Biotechnology's Role

Adapting to possible changes

- Insect pests
- Pollinators
- Pathogens
- Weeds
- Soil quality/erosion
- Water quality
- Water quantity

Biotech (GE) crops have proven they can help

Adaptation - Biotechnology's Role

Biotechnology is a collection of research tools

- Identify useful genes in existing crop varieties
- Find new genes
- Understand plant biology
- Develop new "biotechnologies"

These uses of biotechnology are especially important for complex traits like drought tolerance.

Drought Tolerant Varieties

Biotech tools for identifying useful genes

- “molecular breeding”
- “gene mapping”
- “marker assisted breeding”
- “high throughput phenotyping”

Ex: Optimum® AQUAmax™ from DuPont Pioneer
Drought tolerant – not GE, but “biotech-dependent”

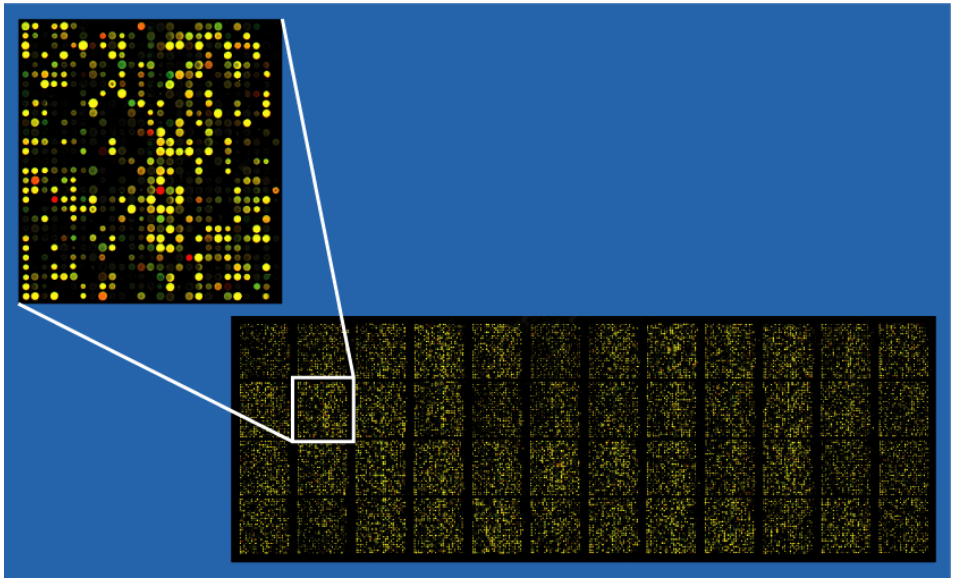
Adaptations in the Move from Sea to Land

Moss

Resurrection Fern

The “Lazarus” Effect

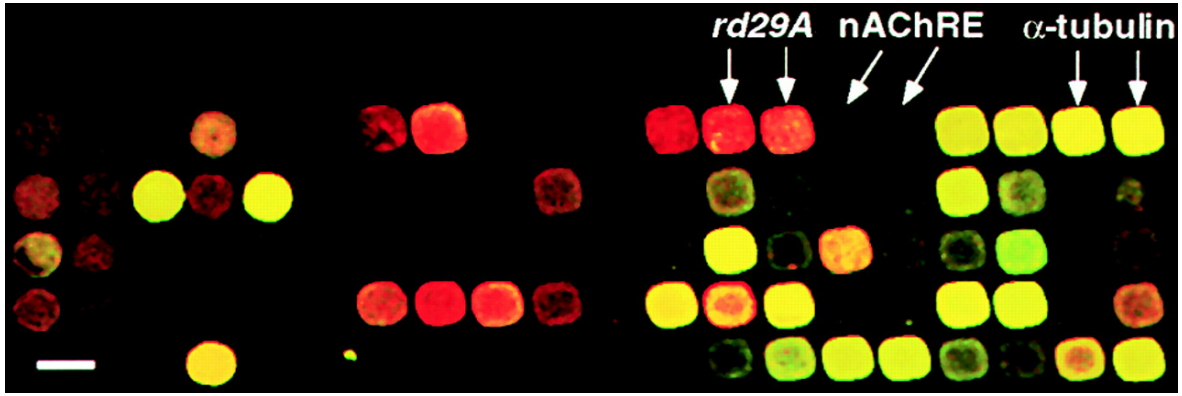
Microarray – Gene Expression



Systems Biology

- Proteomics
- Transcriptomics
- Metabolomics

Arabidopsis
Plant genomics



Response of genes to mild and severe drought stress as discovered through microarrays

Clone ID	Annotation	Class	Mild			Severe		
			1	2	3	1	2	3
14D07	Putative Dehydrin	LEA Group 2	0	+	0	0	0	0
NXCI_002_C10	Putative Dehydrin	LEA Group 2	0	0	+	0	0	0
NXCI_006_H04	Embyonic abunndant protein (white spruce)	LEA Group ?	0	0	+	0	0	0
PC23D04	LEA76 homolog	LEA Group 3	0	0	0	0	+	0
ST01E01	Putative LEA	LEA Group 3	0	0	0	0	+	+
PC14C08	LEA76 homolog	LEA Group 3	0	0	0	0	0	+
PC14G04	LEA76 homolog	LEA Group 3	-	0	-	+	+	+
PC05A11	LEA76 homolog	LEA Group 3	0	0	-	+	+	0
PC08E04	LEA76 homolog	LEA Group 3	0	0	-	+	0	+
39A03	DNA J-like protein	DNA J	0	+	0	-	0	0
40F04	Low molecular weight heat shock protein	sHSP	+	0	-	0	0	0
NXNV_132_E06	DNA J homolog	DNA J	+	0	0	0	0	0
NXSI_116_B04	Heat Shock Protein 82	HSP 90	0	+	0	0	0	0
NXSI_117_C08	DNA K type molecular chaperone hsc 70	HSP 70	0	+	0	-	0	0
NXNV_149_E10	Putative Heat Shock Protein 90	HSP 90	0	0	0	0	+	0
NXCI_022_G01	Heat Shock 70 Kda protein, mitochonrial	HSP 70	0	0	0	+	+	0
NXNV_	Heat Shock Protein, 82K, precursor	HSP 90	0	0	0	+	0	0
13C12	Putative peptidyl-prolyl cis-trans isomerase	Ppiase	0	0	0	+	0	0
38H03	Peptidyl proline isomerase	Ppiase	0	+	0	0	0	0
39H08	Peptidyl prolyl cis-trans isomerase	Ppiase	0	+	0	0	0	0

BASF Plant Science

Cutting-edge platform technologies for gene discovery

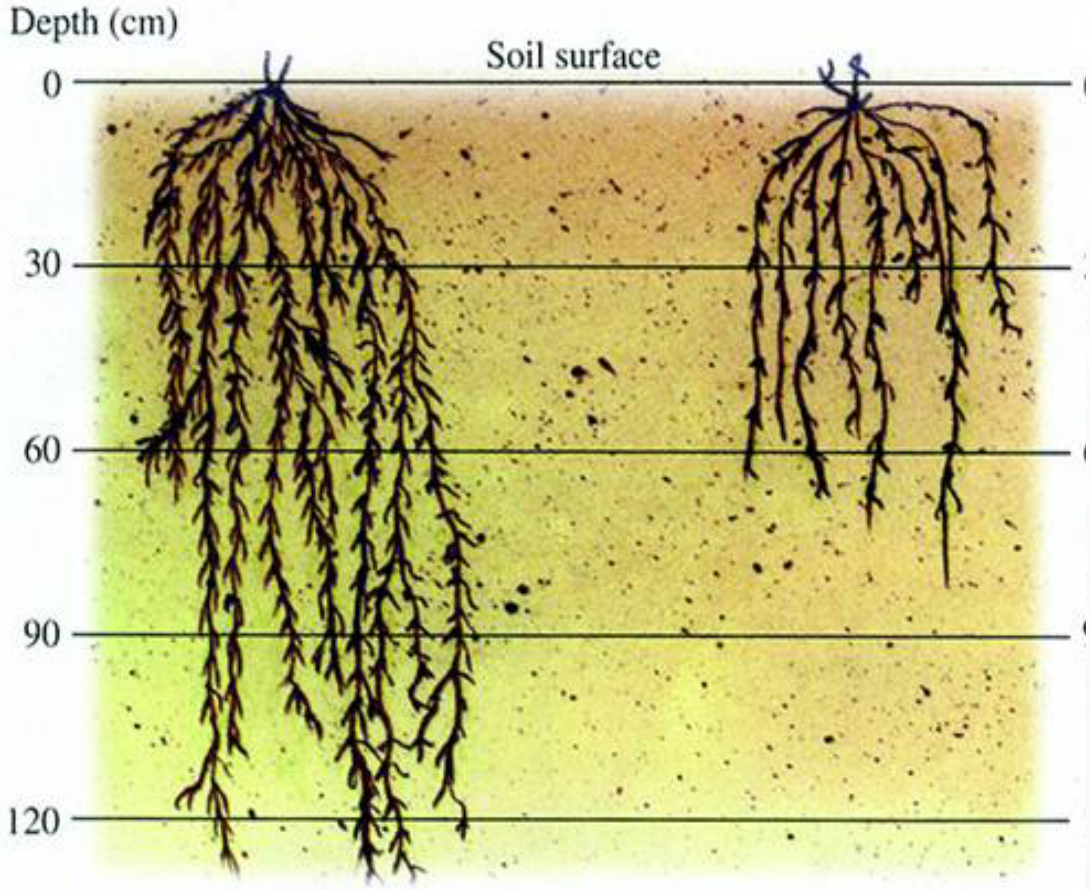
Partnership agreements with other large companies

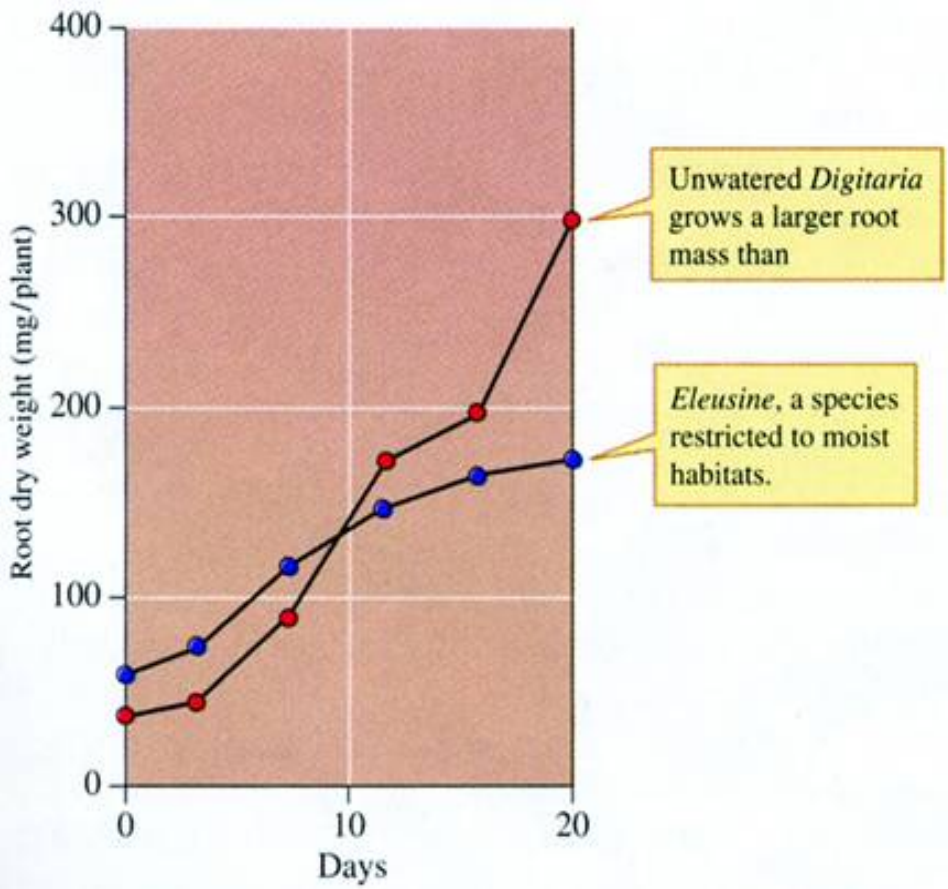





Drought Tolerant Varieties

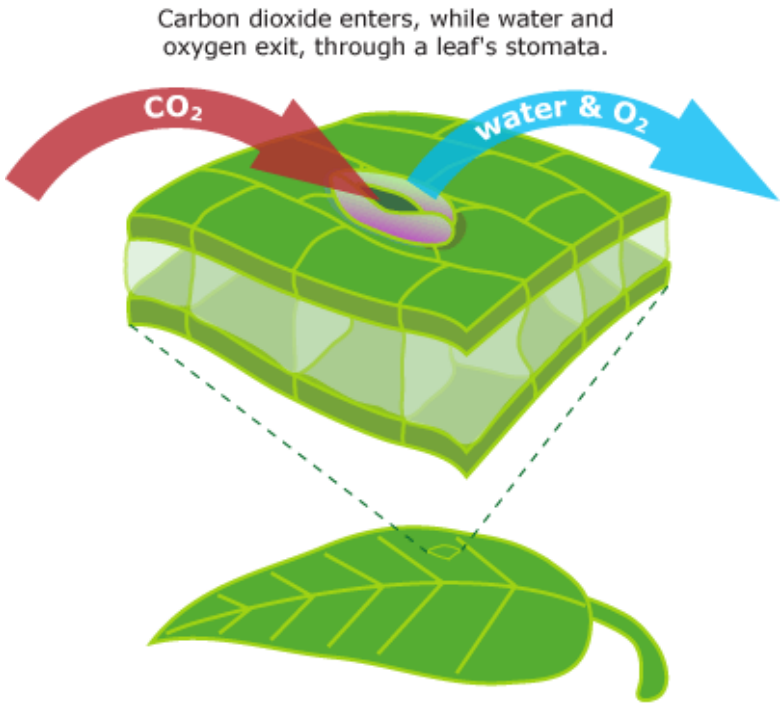
Understanding Plant Biology

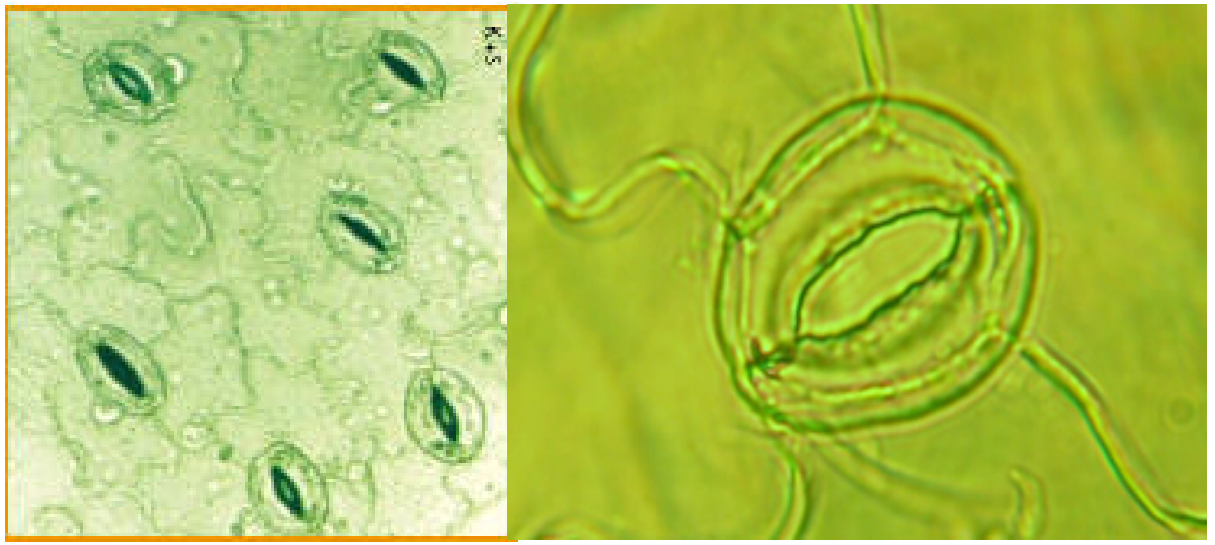




Drought Tolerant Varieties

Understanding Plant Biology





Stomata

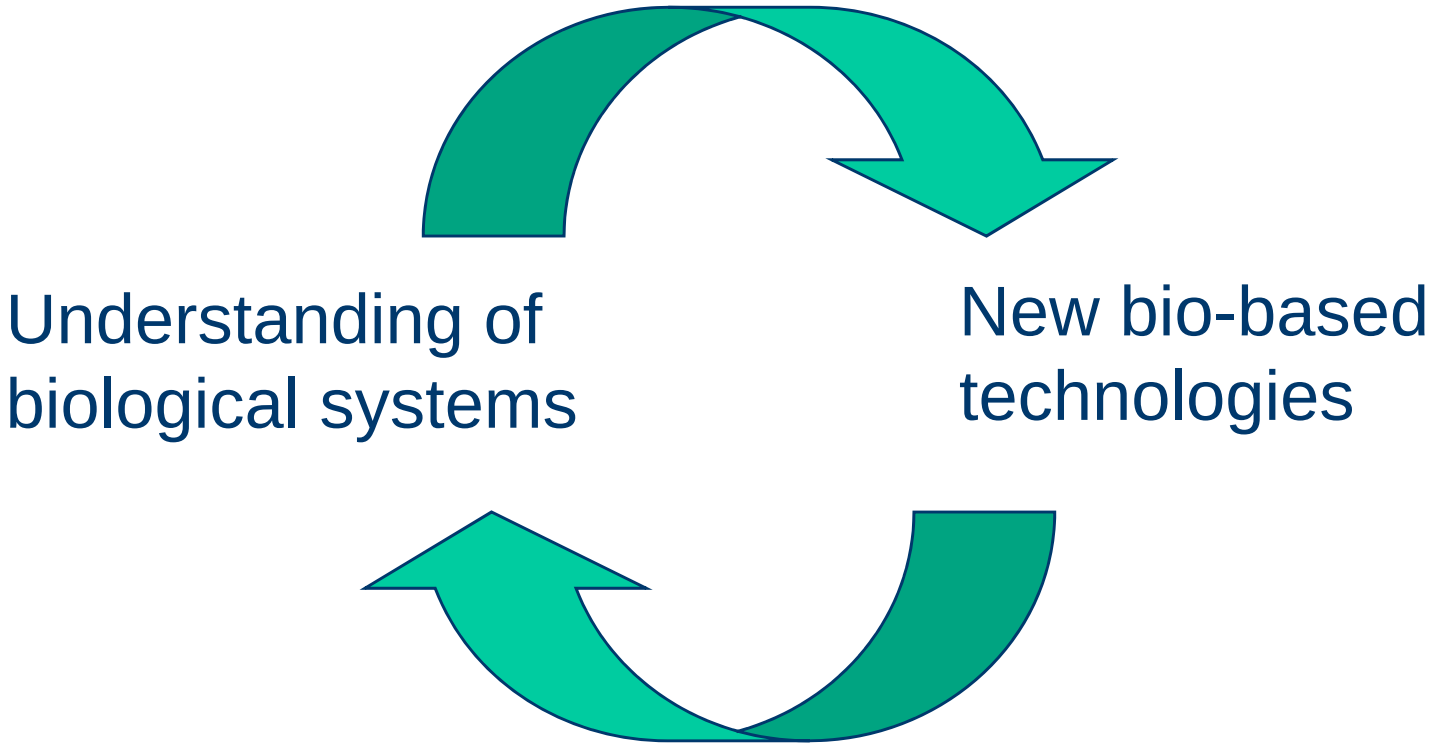
Drought Tolerant Varieties

Understanding Plant Physiology/Biochemistry

-Plant hormone – ABA
-Plant enzyme – farnesyltransferase
-Plant protection proteins
-Transcription factors – *DREB1* and *DREB 2*

Bayer Crop Science
Exclusive license with Performance Plants, Inc. for its proprietary Heat and Drought Tolerance Technology™

Mendel Biotechnology
Platform “enabling” technologies - Plant gene regulatory networks

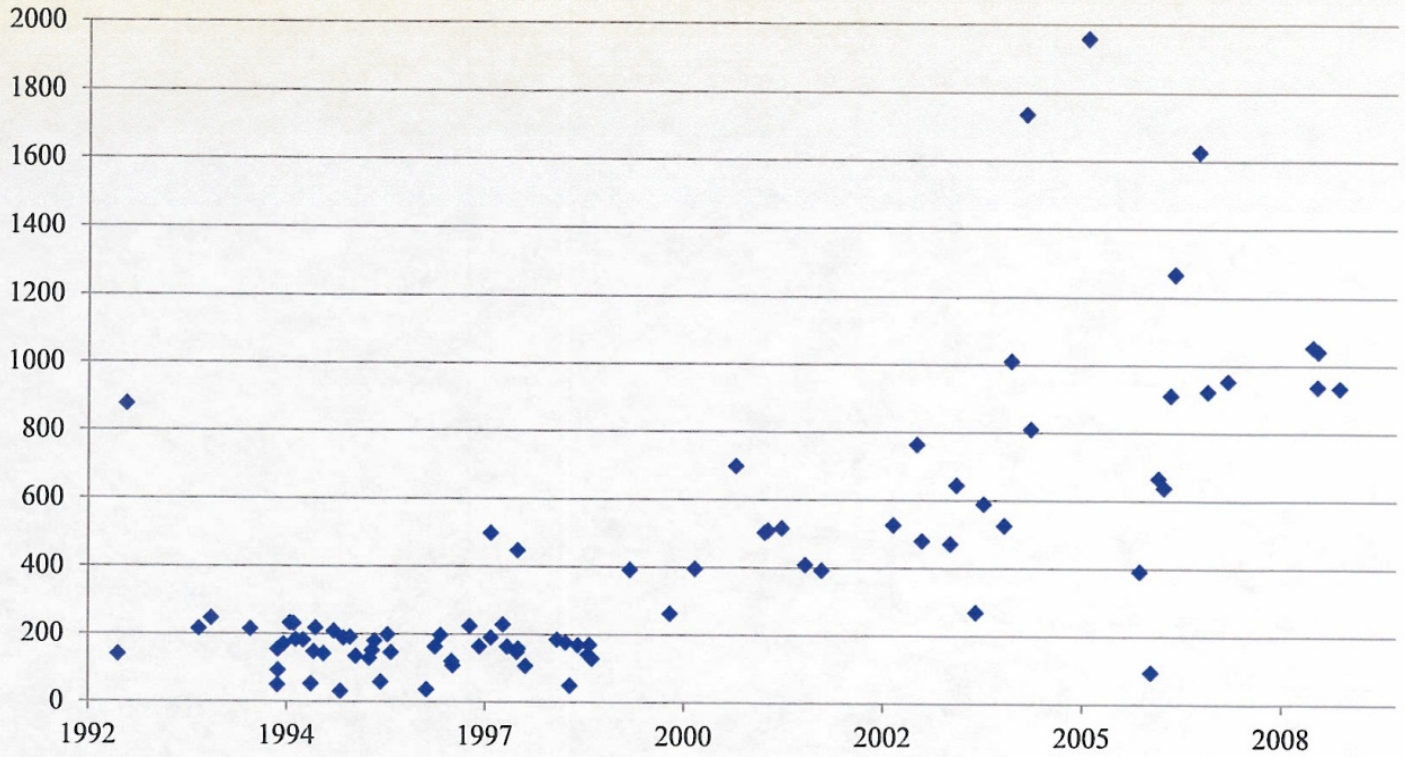

Understanding of biological systems
New bio-based technologies

New Bio-based Technologies

- Zinc finger technologies
- Transcription activator like effector (TALE)
- Oligonucleotide-directed mutagenesis
- RNA-mediated DNA methylation
- RNA interference (RNAi)

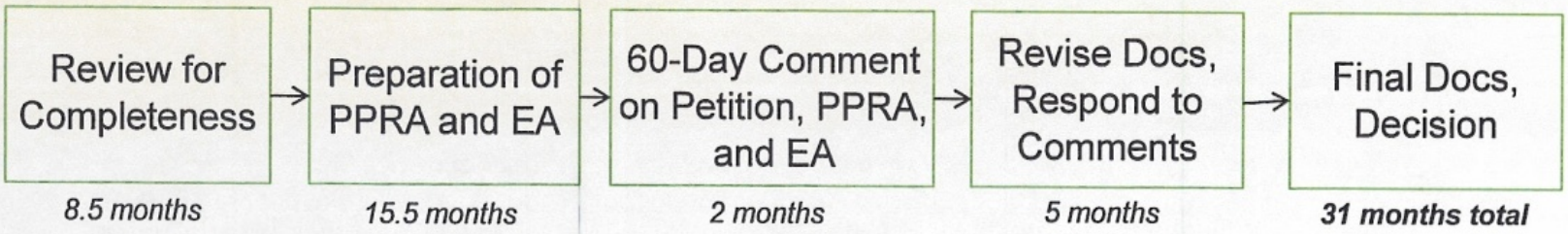
Dow AS – Zinc finger technologies

Time to Final Decision
(days from submission)

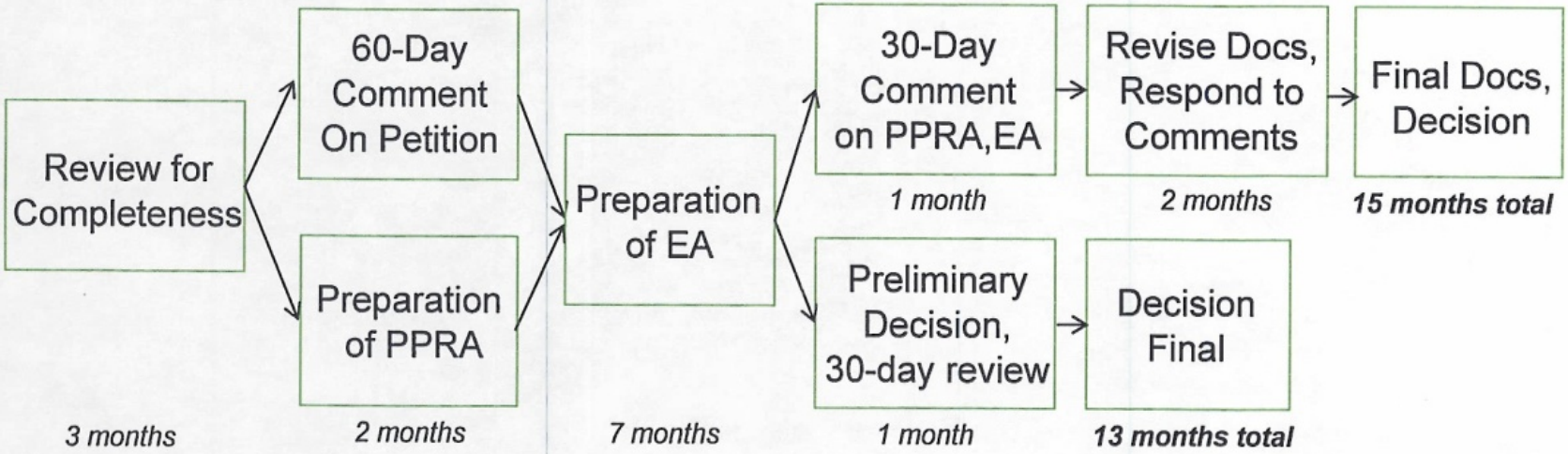


Old and New Compared

Previous Process



Improved Process



USDA United States Department of Agriculture
Animal and Plant Health Inspection Service

Biotechnology Regulatory Services

Results to Date

Process Step	# of Petitions	Actual, Days	Previous, Days[1]	Days Saved
Initial petition review	5	28	205	-177
Petitioner response	5	23	107	-84
Final petition review	7	41	39	2
All review steps	5	64	324	-260
Draft PPRA	6	73	143	-70
Draft NEPA document	--	TBD	213	TBD

[1]Average since 2005

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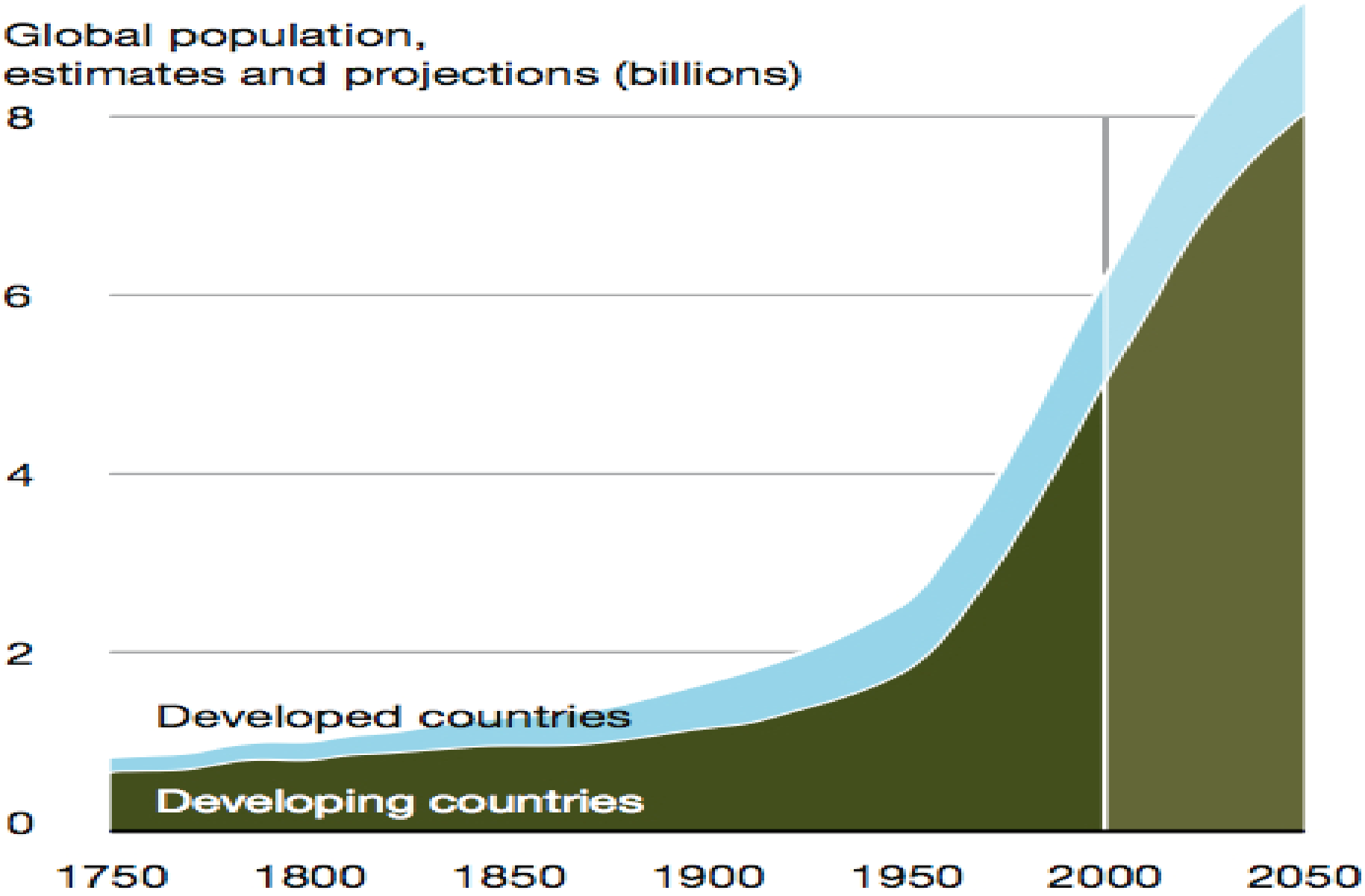
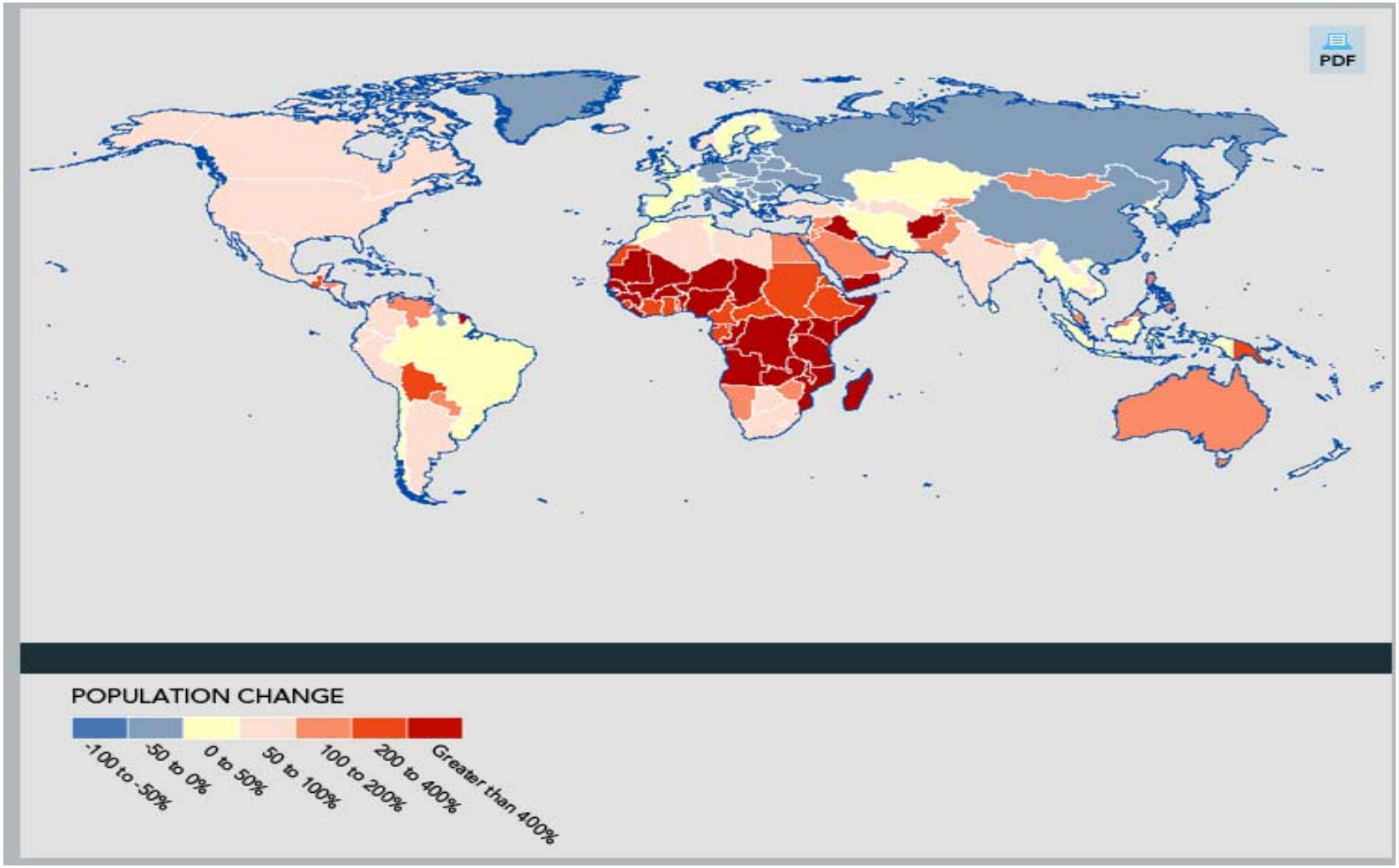

Global population,
estimates and projections (billions)
8
6
4
2
0
Developed countries
Developing countries
1750
1800
1850
1900
1950
2000
2050

Projected Population Change 1990-2090

Population Action International



Mapping the Impacts of Climate Change

Select below

Extreme Weather

Direct Risks

Overall Vulnerability

Sea Level Rise

Direct Risks

Overall Vulnerability

Agricultural Productivity Loss

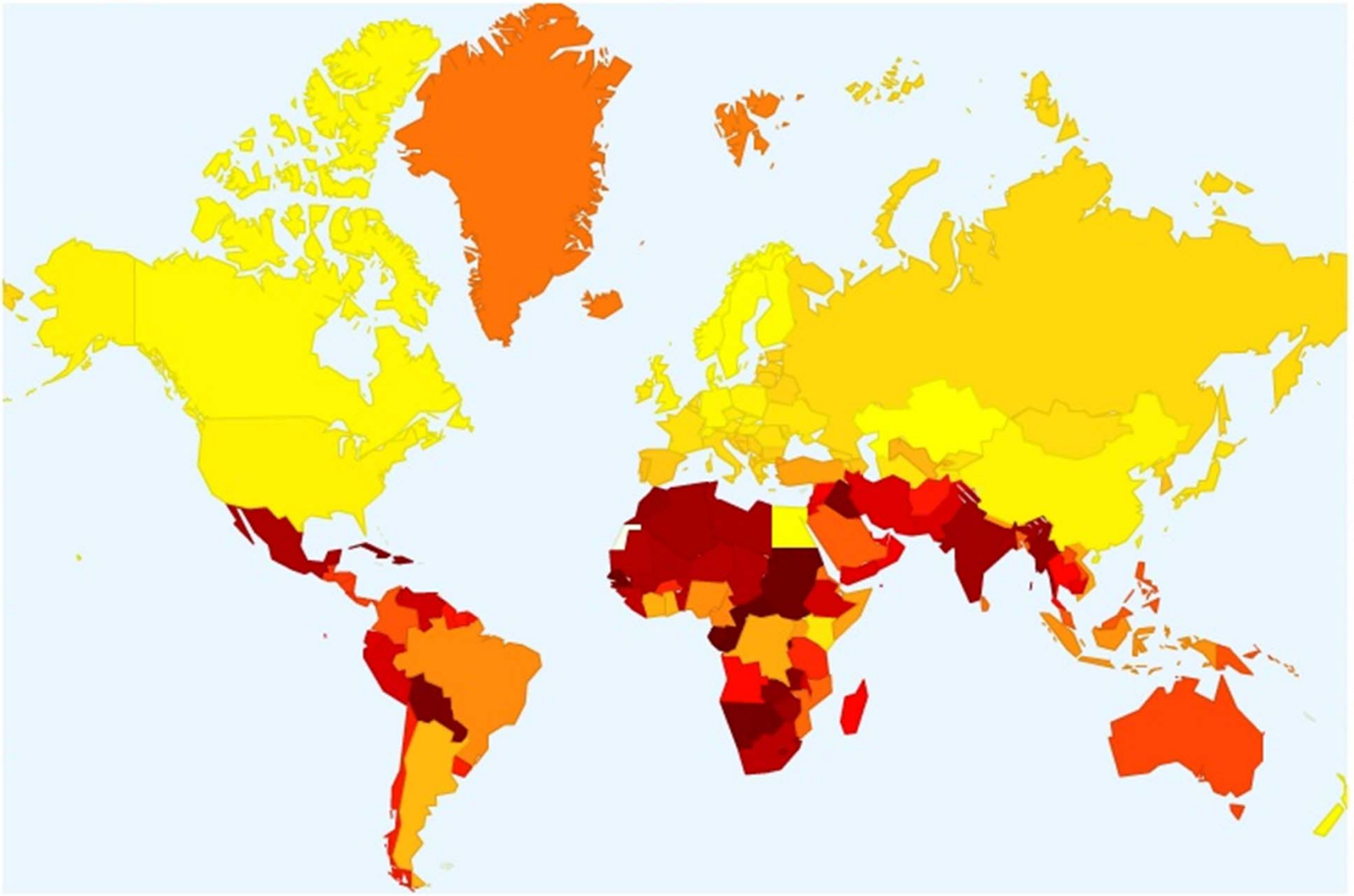
Direct Risks

Overall Vulnerability

Overall

Direct Risks

Overall Vulnerability



Rank 1 — 169

Agricultural Productivity Loss Direct Risks:
Physical Climate Impacts