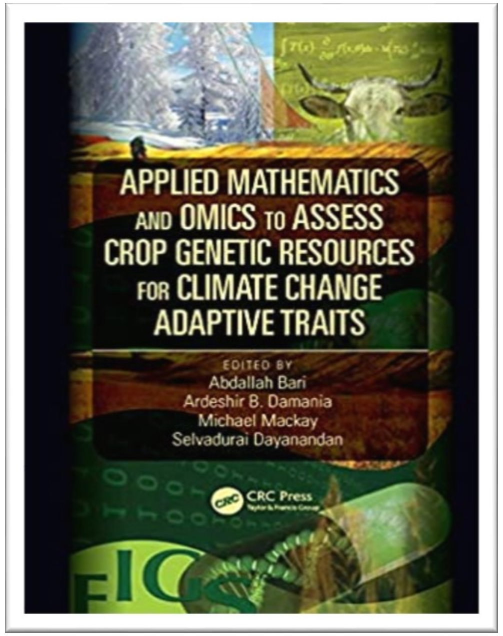
Machine Learning Speeding Up the Development of Portfolio of New Crop Varieties to Adapt to and Mitigate Climate Change



NeurIPS | 2021

OperAI

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HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

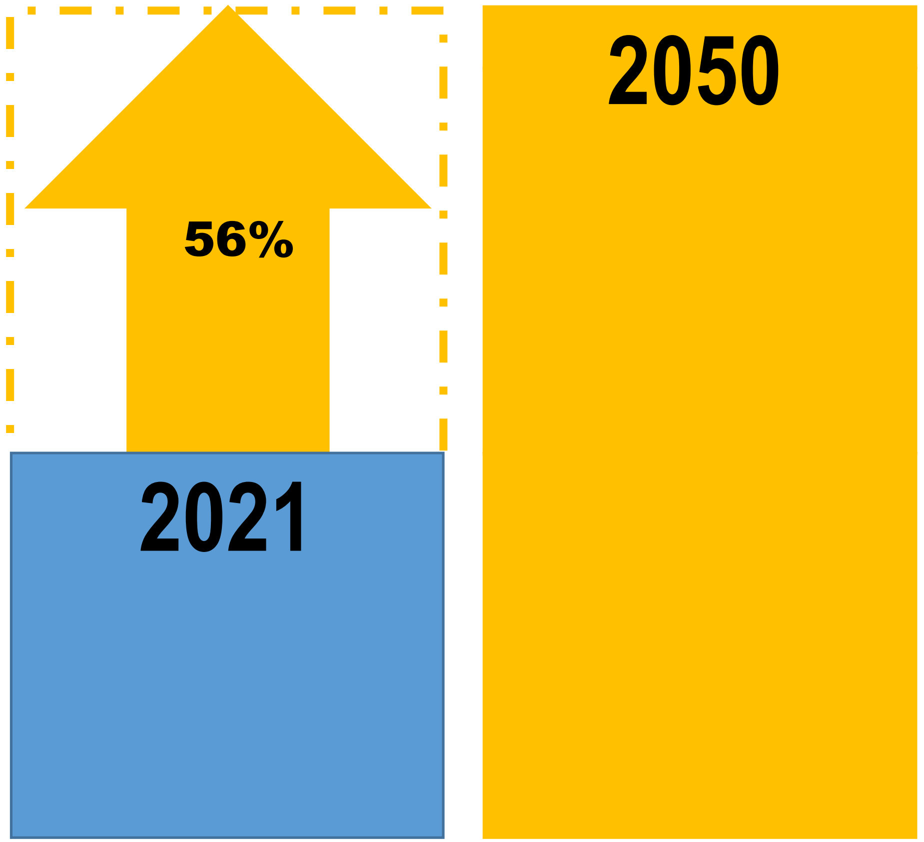
UNIVERSITY OF OULU

World Vegetable Center

The agriculture sector’ s dual challenge

- **Produce more food to close the gap of 56%** between the amount of food available today and that required by 2050.

- **Adapting and mitigating climate change.**



WRI, 2021

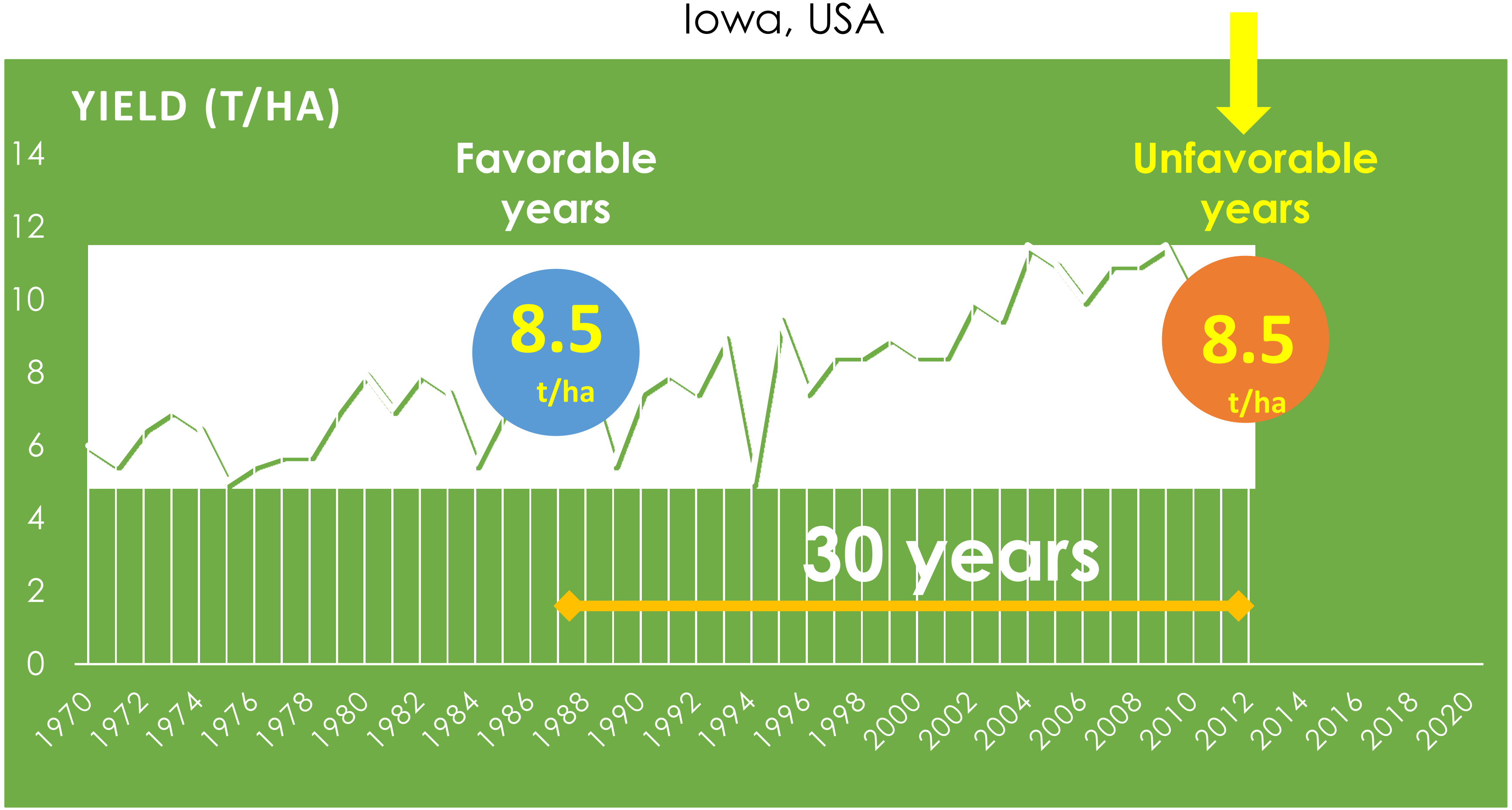
Why the need for speed?

Increase the **rate of genetic improvement**

Maize yield
Iowa, USA

The severe drought year of
2012

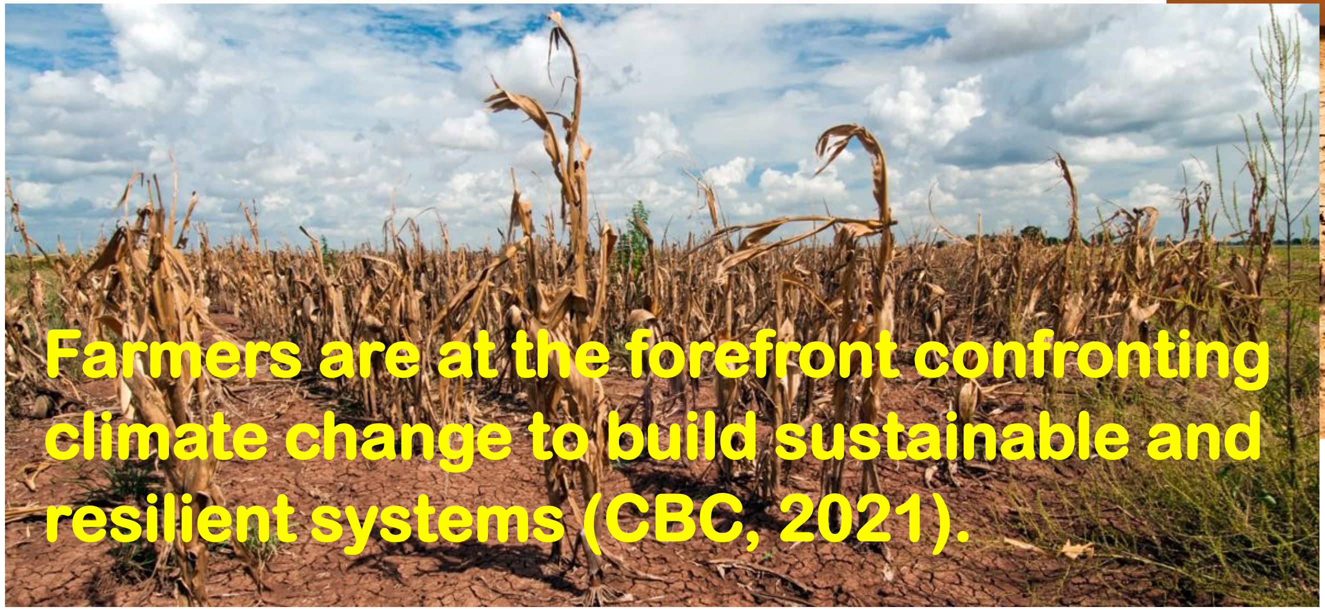
The worst drought in more than half a century in USA.



Climate change

Heat and drought spells are becoming recurrent scenarios

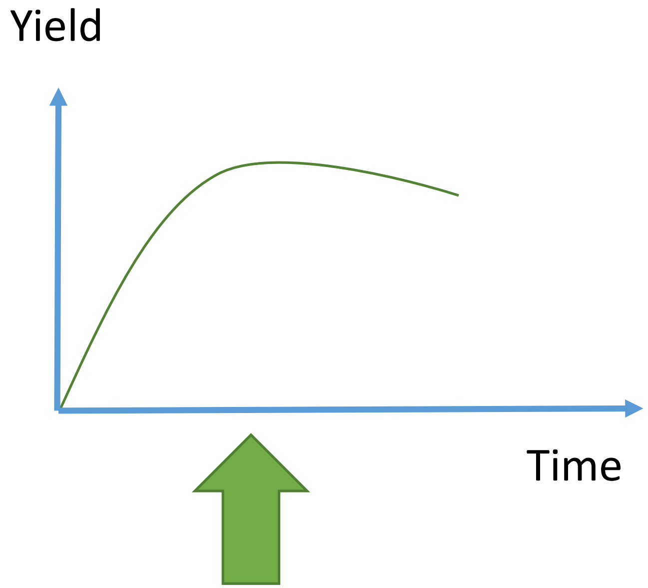
Keith Randall, Texas A&M University



Union of Concerned Scientists
https://www.ucsusa.org/resources/drought-and-climate-change

Speeding up the Development of New Crop Varieties to Adapt to/ Mitigate Climate Change

The Optimal Timing to allow to factor-in time in the development process in the face of **uncertainty.**

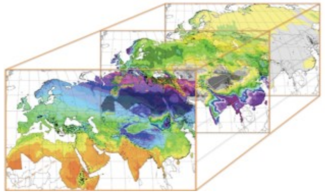


Anderssen RS, Edwards MP (2012) **Mathematical modelling** in the science and technology of plant breeding. Int. J. Numer. Anal. Model. Series B 3:242–258

Koo, Bonwoo and B.D. Wright. 2000. "The **Optimal Timing of Evaluation of Gene bank Accessions** and the Effects of Biotechnology." American Journal of Agricultural Economics 82(4): 797–811.

Modeling to speed up the search for traits

Geo-referencing
Climate Surface Data
Data Alignment



Environment (X)

ML Modeling

Evaluation (in-silico)

Trait (Y)

Evaluation (Field)

Samples
(Genotype/Variety)

Modeling techniques – Inverse Problem

Inverse problem to **mimic evolutionary processes**.

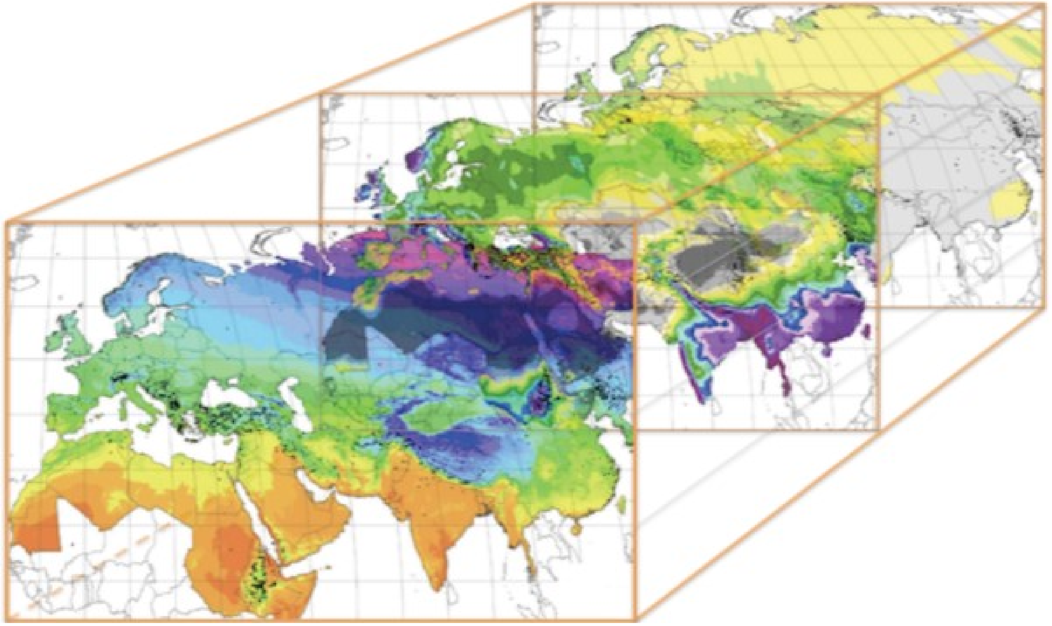
- **Bayes-Laplace inverse models** dealing with uncertainty.

- **Neural Networks models** to mimic plant improvement' s reasoning/rational procedures.

novel traits

Environmental data - Surface climate data

Generation of surface climate data (more than 36 surfaces/variables)
Use of DEM – improve precision



Environment
(tmin, tmax, prec..)

Climate data (X variables)

site_code	…..	ari02	…..
ETH-S893		**0.246**	
ETH-S1222		**0.344**	
NS_339		**0.552**	
ETH-S1153		**0.390**	
NS_415		**0.419**	
NS_424		**0.380**	
ETH64:55		**0.344**	
NS_525		**0.352**	
NS_526		**0.354**	
NS_559		**0.397**	

Data Preparation – Normalisation (NN)

Data Alignment – Plant Growth Simulation

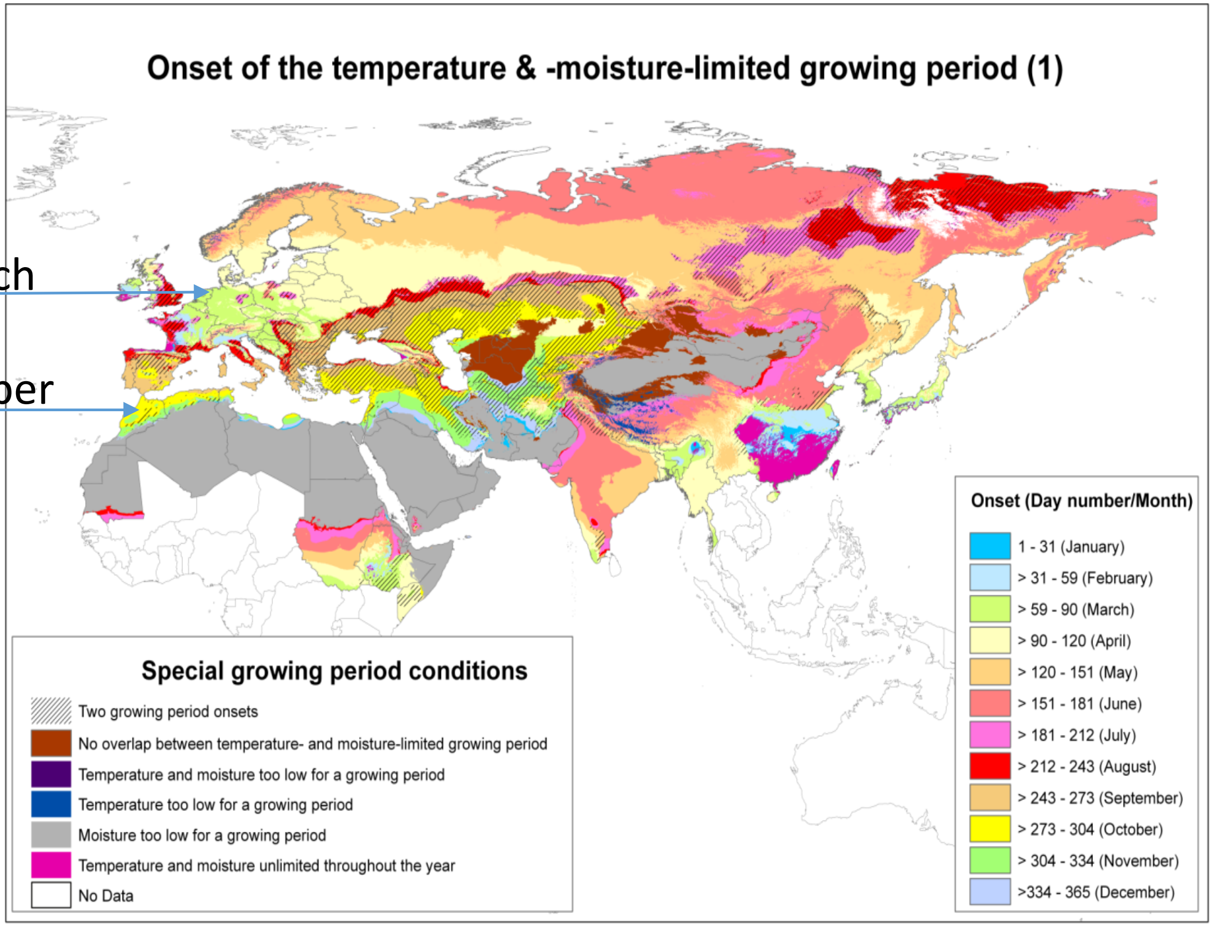
Sowing date generation

(spatial variation)

Phase adjustments

March

October



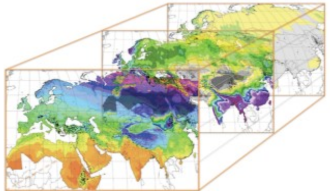
Based on the estimation of the duration of the period during the year in which neither moisture nor temperature are limiting to plants.

Trait data sets – Plant
Genotype / Variety (Field)

- Phenology data (time - Days to flowering…)
- Physiological data (Canopy temperature…)
- Morphological data (Shape and Structure…)

Modeling to speed up the search for traits

Geo-referencing
Climate Surface Data
Data Alignment



ML Modeling

Evaluation (in-silico)

Environment (X)

Trait (Y)

Evaluation (Field)

Samples
(Genotype/Variety)

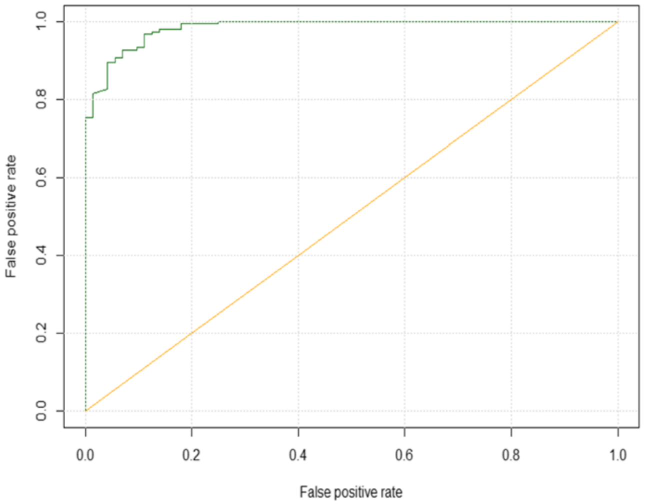
Results/Outcome

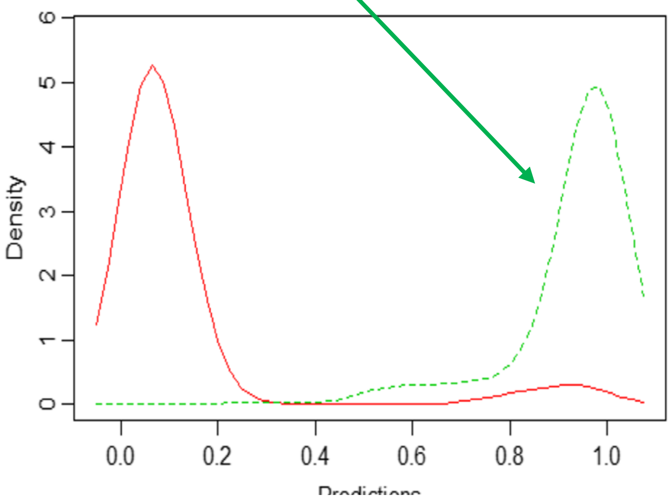
- Adaptive traits for heat and drought were identified with high accuracy (AUC) when compared to heuristic approaches
- Field *a posteriori* evaluation was carried out to ascertain and confirm the results
- These traits then incorporated into plant improvement programs

Subset	Test set		
Statistic	AUC	%Correct	Kappa
Mean	0.88	0.88	0.77
SD	0.04	0.04	0.08
CI 95%	±0.02	±0.02	±0.05

Adaptive traits identified & incorporated

Drought traits identified





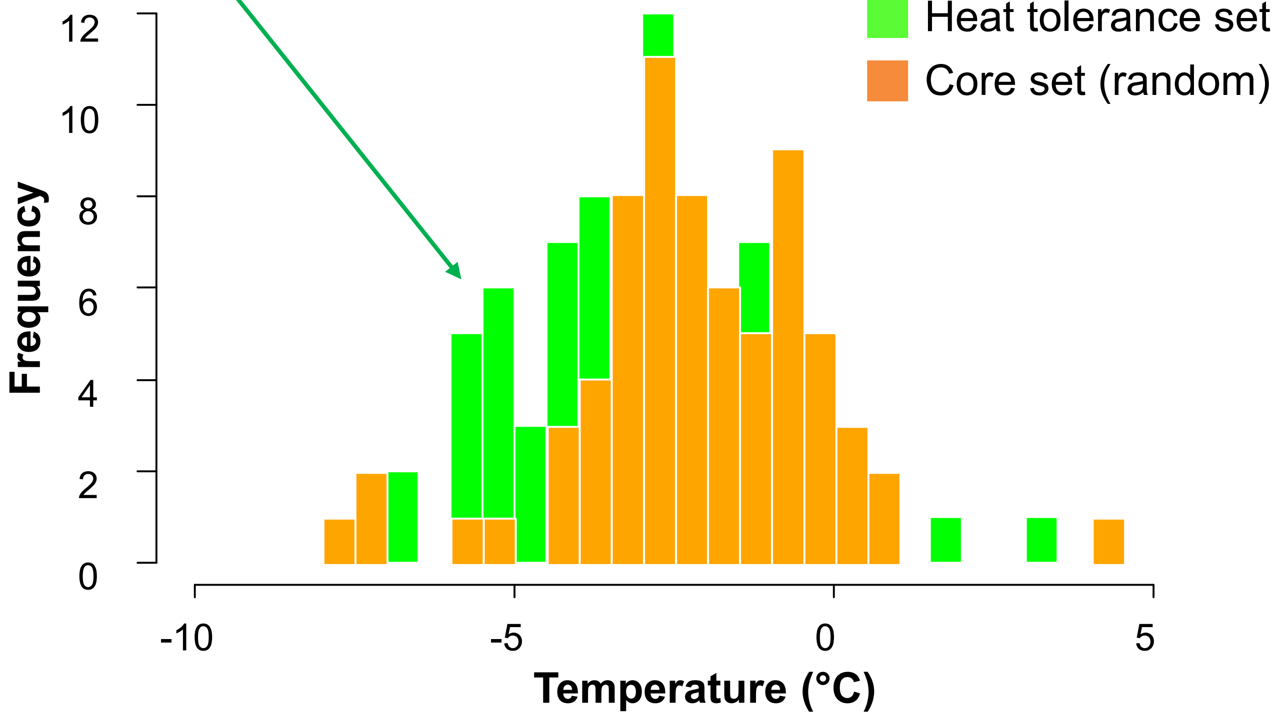
Screening for drought tolerance in faba bean (earliness in right found among accessions) - Helsinki

Khazaei, University of Helsinki

Adaptive Traits identified

Incorporated into crop improvement

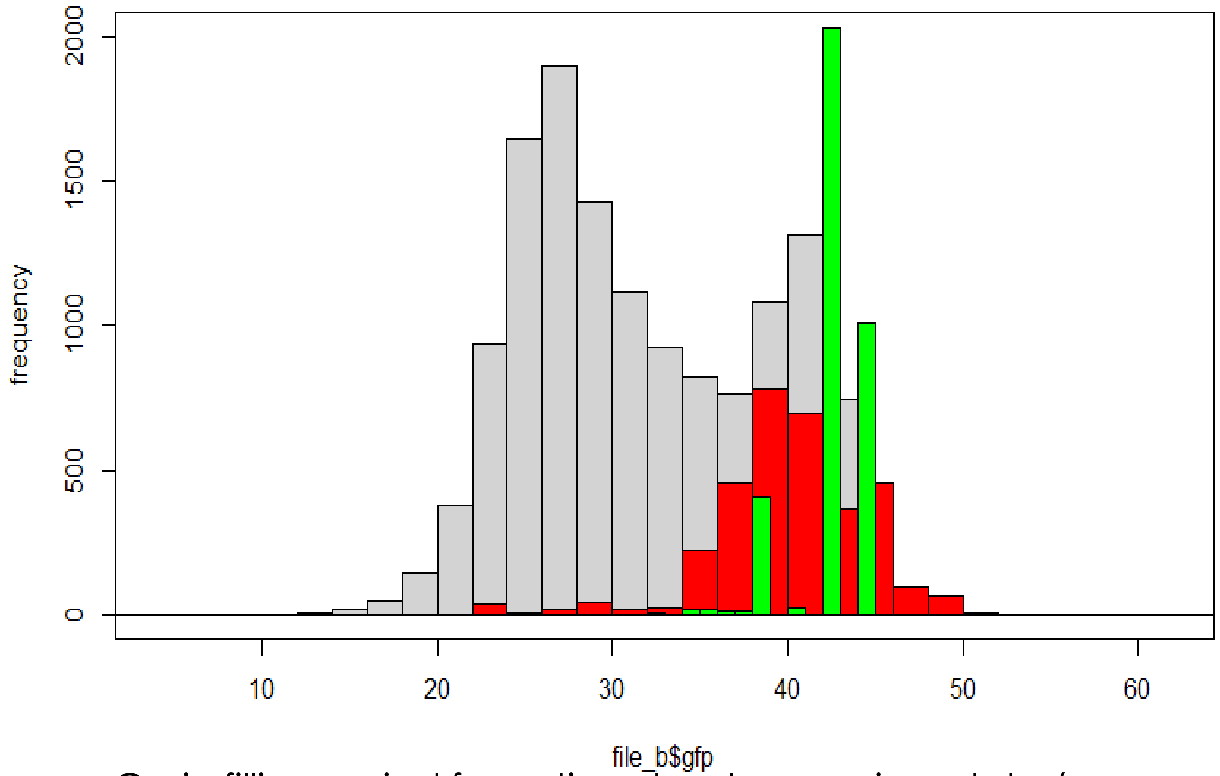
Heat traits identified



Jilal, INRA Morocco

Genetic Resources – Untapped

Heat tolerance – genetic resources of wheat



Grain filling period for entire wheat accessions data (grey colour bars) and the subsets prior to evaluation (green bars) and after evaluation (red bars).

University of Minnesota (2019)

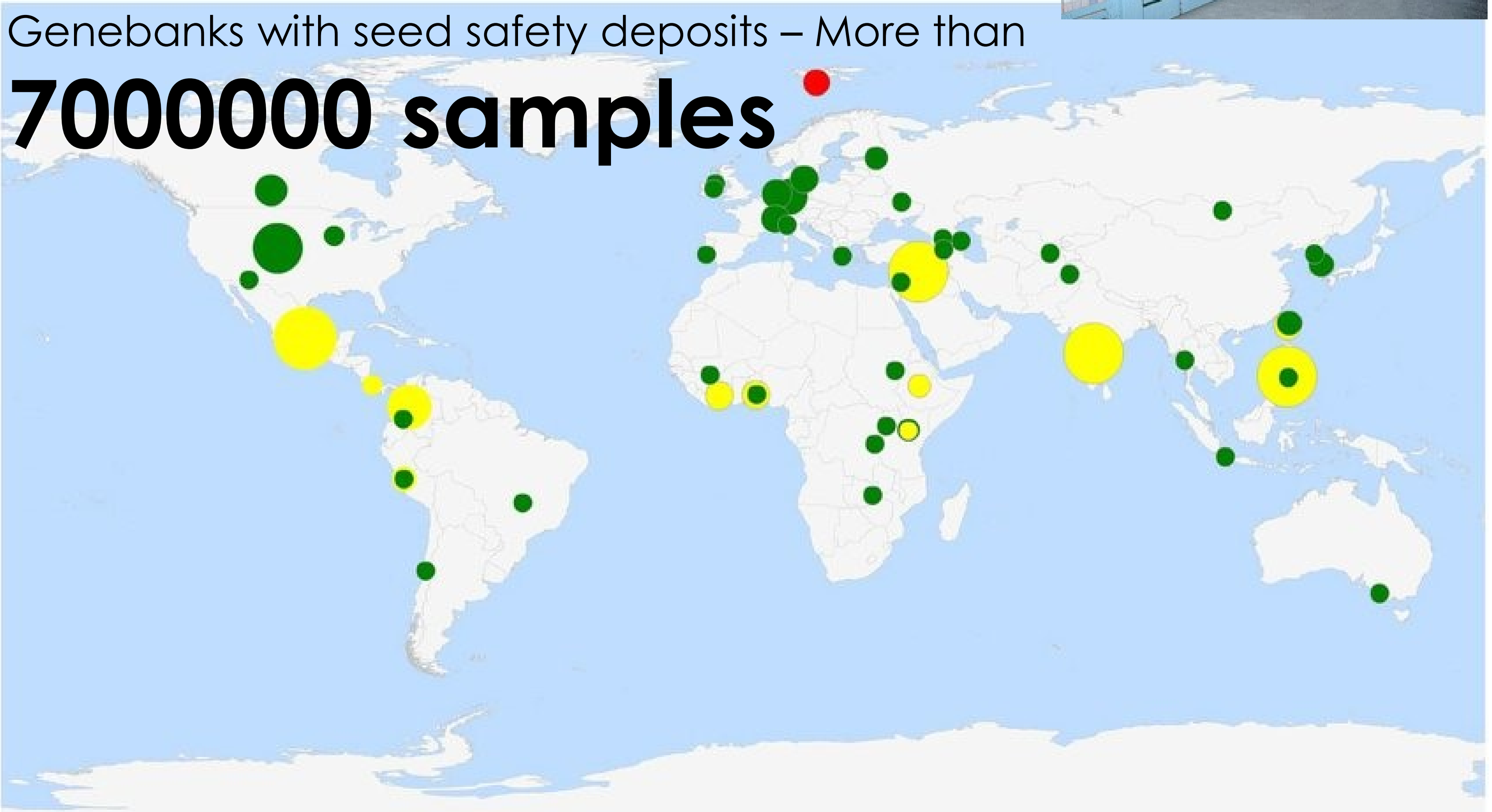
Genetic Resources – Untapped

"These resources stand between us and starvation on a scale we cannot imagine. In a very real sense, the future of the human race rides on these irreplaceable materials."

Jack Harlan

Genebanks with seed safety deposits – More than

7000000 samples



The size of the circle is proportional to the number of samples – Major Genebanks

doi:10.1371/journal.pone.0064146.g002

ML can help

- **Speed up adaptation to current and future CC stresses.**
- **Increase genetic gain (genetic resources rational utilization).**
- **Provide new crop varieties for different framing needs and different food systems.**

Published: 11 November 2015

In silico evaluation of plant genetic resources to search for traits for adaptation to climate change

Abdallah Bari, Hamid Khazaei, Frederick L. Stoddard, Kenneth Street, Mikko J. Sillanpää, Yogen P. Chaubey, Selvadurai Dayanandan, Dag T. F. Endresen, Eddy De Pauw & Ardeshir B. Damania

Climatic Change **134**, 667–680 (2016) | Cite this article

Abstract

Plant genetic resources display patterns resulting from ecological and co-evolutionary processes. Such patterns are instrumental in tracing the origin and diversity of crops and locating adaptive traits. With climate change and the anticipated increase in demand for food, new crop varieties will be needed to perform under unprecedented climatic conditions. In the present study, we explored genetic resources patterns to locate traits of adaptation to drought and to maximize the utilization of plant genetic resources lacking *ex ante* evaluation for emerging climate conditions. This approach is based on the use of mathematical models to predict traits as response variables driven by stochastic ecological and co-evolutionary processes. The high congruence of metrics between model predictions and empirical trait evaluations confirms *in silico* evaluation as an effective tool to manage large numbers of crop accessions lacking ex ante evaluation. This outcome will assist in developing cultivars adaptable to various climatic conditions and in the ultimate use of genetic resources to sustain agricultural productivity under conditions of climate change.

Bari A., H. Khazaei, F.L. Stoddard, K. Street, M.J. Sillanpää, Y.P. Chaubey, S. Dayanandan, D.F. Endresen, E. De Pauw, A.B. Damania (2016). In silico evaluation of plant genetic resources to search for traits for adaptation to climate change. Climatic Change 134(4): 667-680. http://dx.doi.org/10.1007/s10584-015-1541-9

https://link.springer.com/article/10.1007/s10584-015-1541-9

Thank you

Bari A., Ouabbou H., Jilal A., Stoddard F.L., Sillanpää K. M.J., Khazaei H.

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