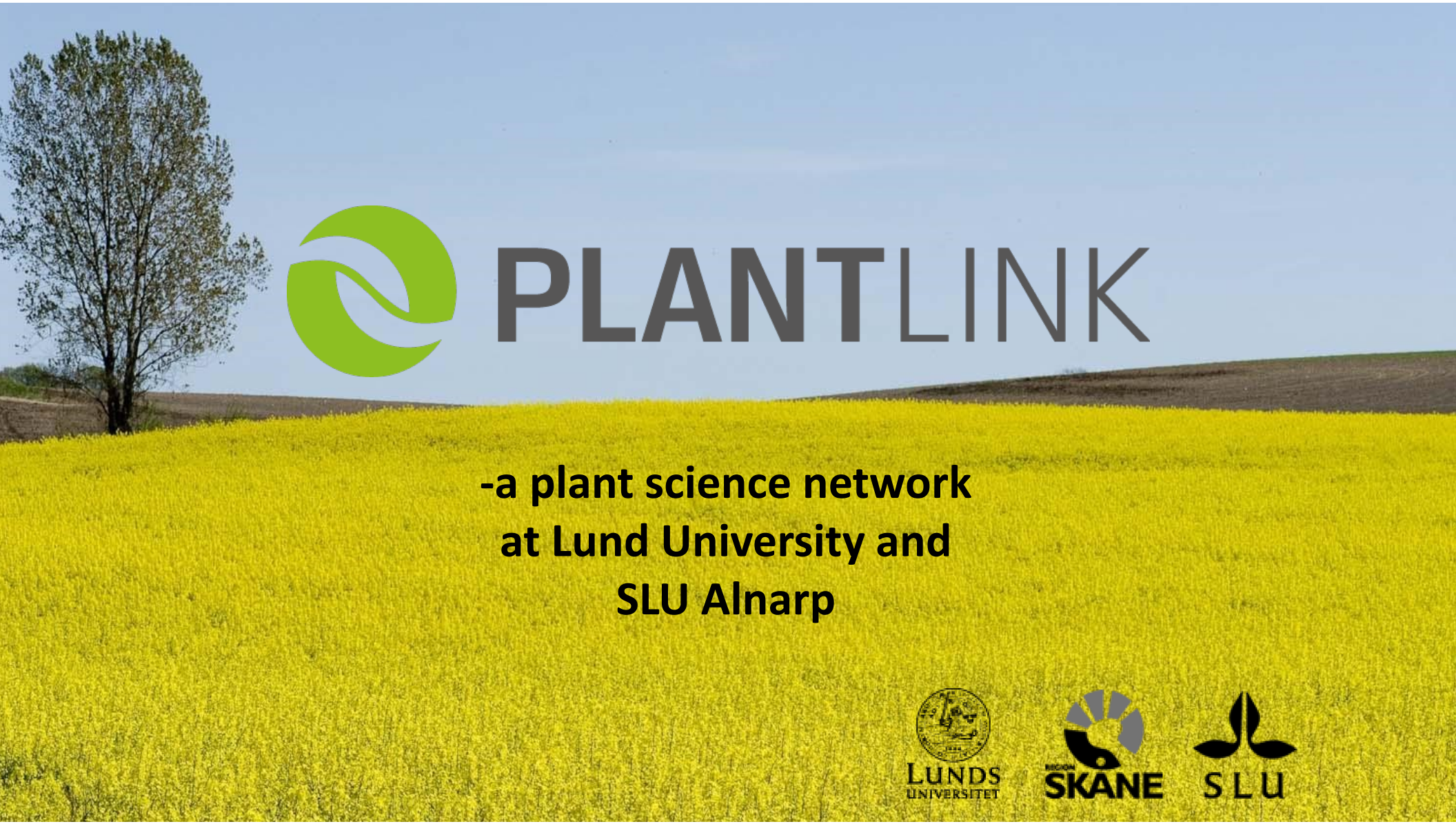
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

What can Plant Health and Breeding do for Food Science?

Erik Alexandersson, Department of Plant Protection Biology, SLU Alnarp

NordPlant

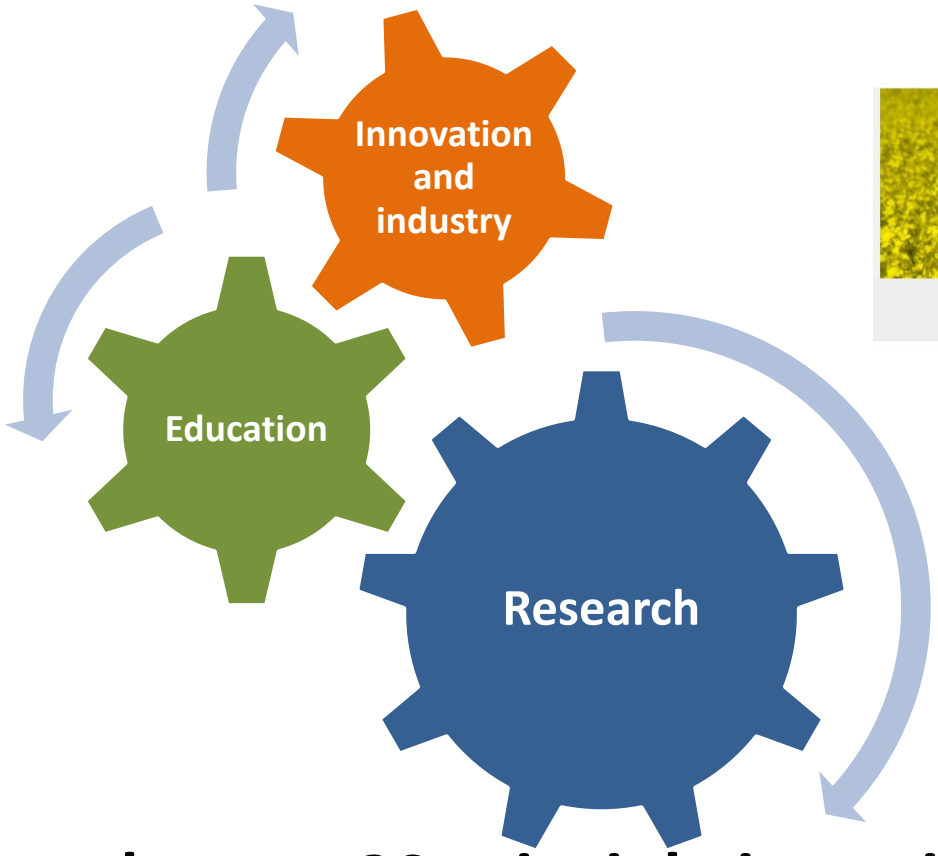
PLANTLINK

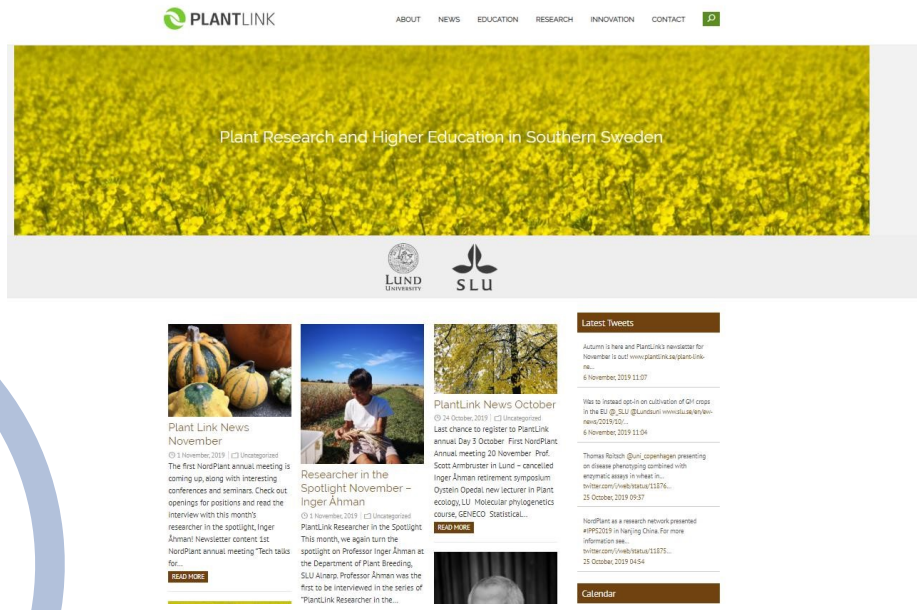

PLANTLINK
-a plant science network
at Lund University and
SLU Alnarp
LUNDS UNIVERSITET
SKÅNE
SLU

PLANTLINK - vision

To create an internationally leading environment for plant research and education

PLANTLINK - our three pillars



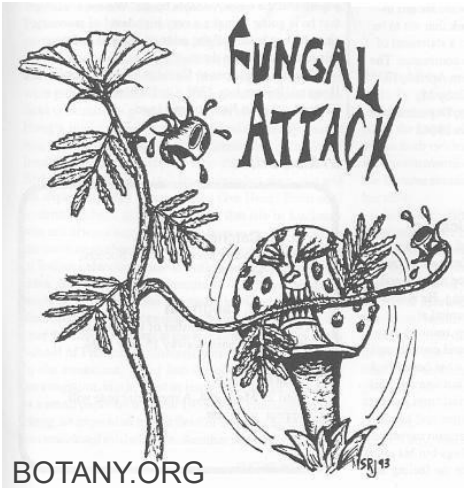


www.plantlink.se

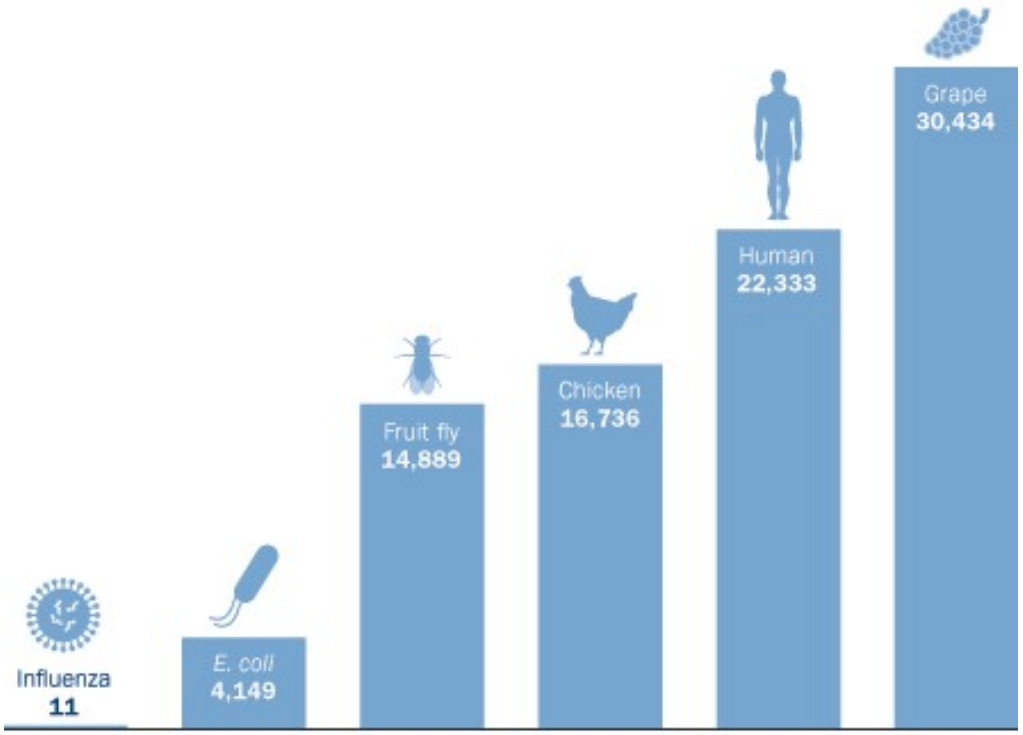
PlantLink gathers ca 30 principle investigators at LU and SLU Alnarp

Plants are amazing!

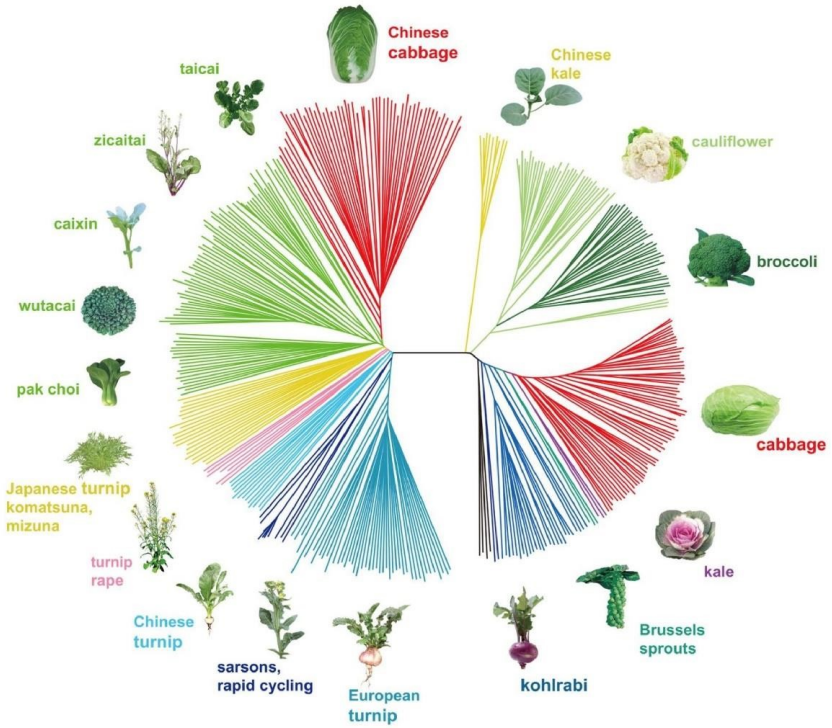
Plants have to survive all kinds of conditions…



…therefore they have a lot of genes…



…leading to a lot of variation…



Due to the triplication of the genetic material of the ancestors of our cabbage, farmers on two continents were able to select a wide range of cabbage varieties from two different cabbage ancestral species (left Brassica rapa, right Brassica oleracea). Both Asian and European farmers independently selected heading cabbages and tuber forming turnips or kohlrabies

Feng Cheng, et al., Nature Genetics 2016

…that we can select for

- Yield, yield and yield
- Disease resistance
- Drought and heat tolerance -> future climates

…CO2 efficiency

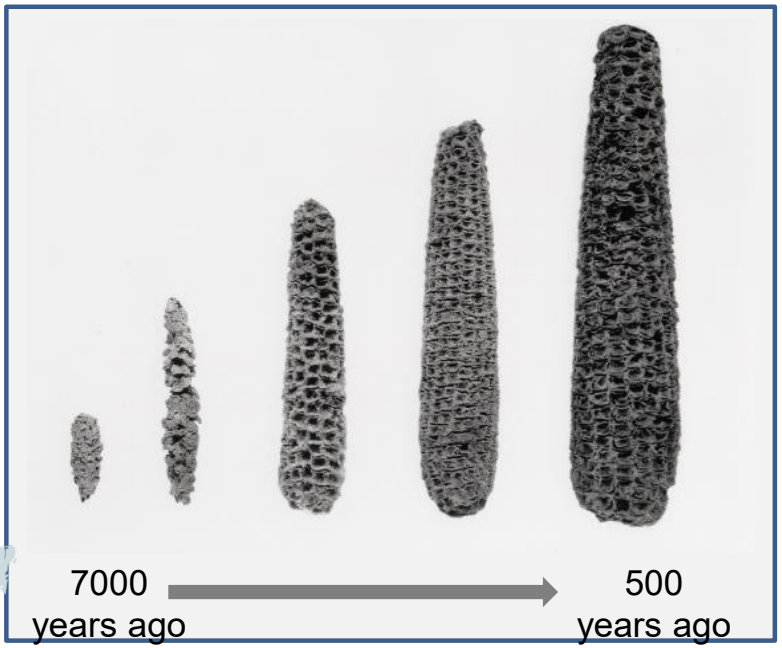
- Nutrition

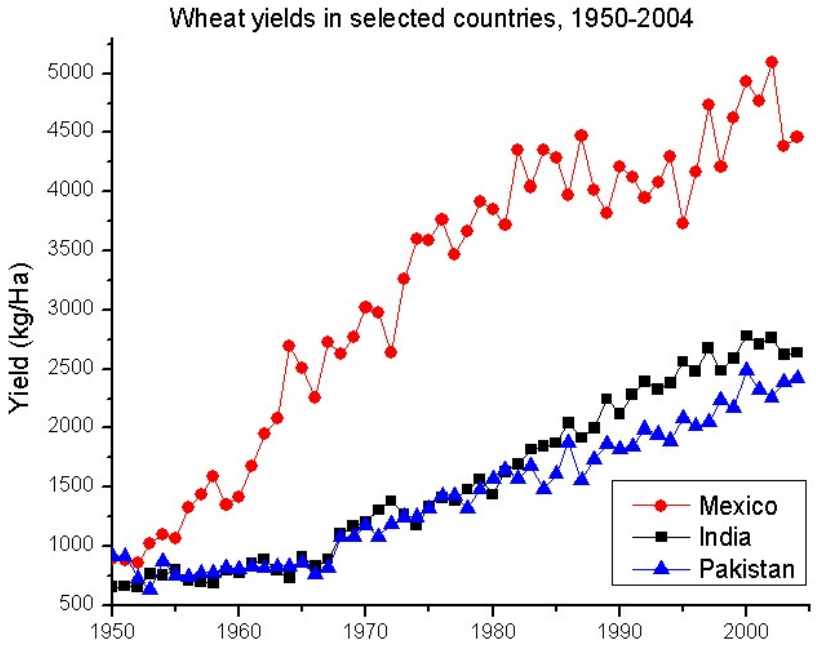
-> with climate change this has to be done **fast** keeping **multiple traits**!

-> precision breeding and precision agriculture!

During maize domestication cob size increased

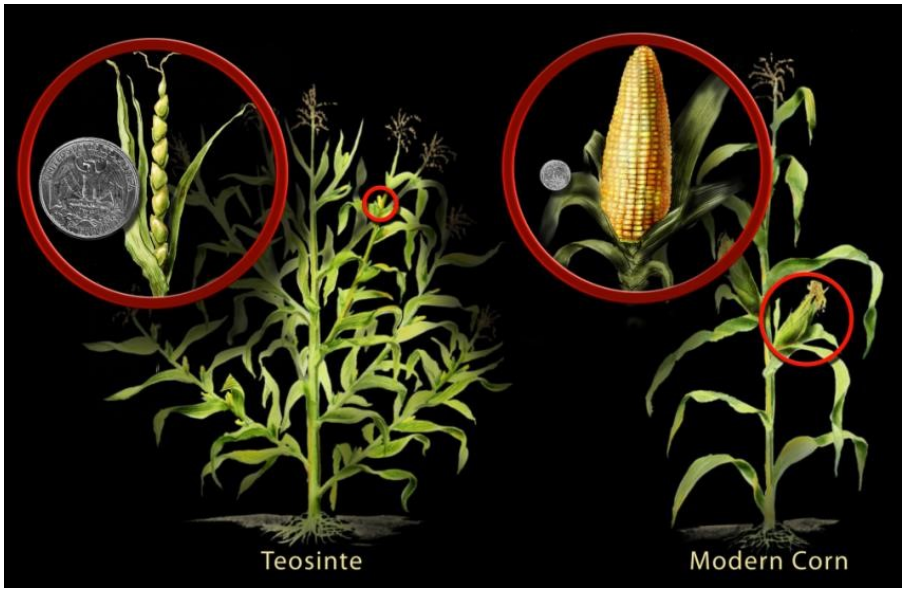
Cobs from archeological sites in the Valley of Tehuacan, Mexico





The myth of natural food

The food we eat comes from plants already extensively modified from their original form. **Even heritage varieties** are extensively genetically modified.



Credit: Nicolle Rager Fuller, National Science Foundation

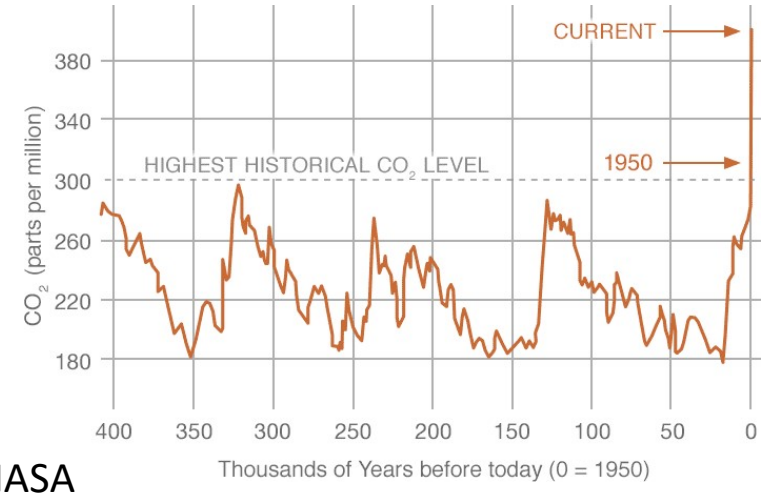
Agriculture – needs, losses and sustainability

- Agriculture is responsible for ~25% of CO_2 emissions
- Current global population is approaching 8 billion
  - As high as 10 billion by 2050!
- Crop losses to pests and pathogens are ~30%

→ Lowering losses to biotic/abiotic stresses and stabilising yields of nutritious crops for climate change mitigation AND improving food security

Climate change will effect food production

- Climate change threatens yields in Potato Park, a farming association near Cuzco, Peru



NASA

JIM RICHARDSON/*NATIONAL GEOGRAPHIC*

Effect on production

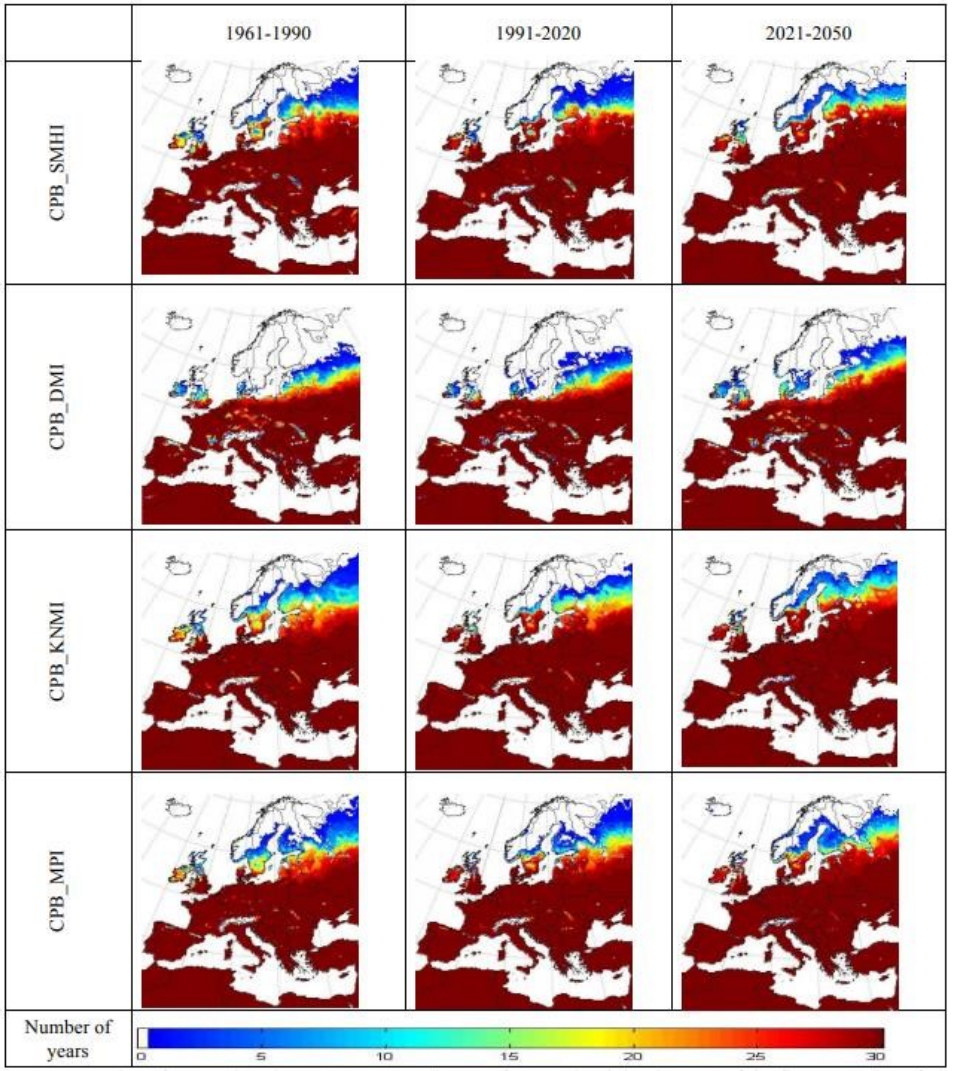
Så har Skåne förvandlats av torkan – ”liknar Afrika”

Expressen 9 Aug 2018

→ potato starch production down 20% even if irrigated!

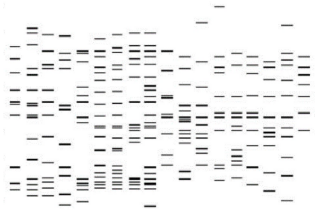
Invasive species

Simulations: Number of years when the temperature requirement for completed development of the first generation of Colorado potato beetle are fulfilled

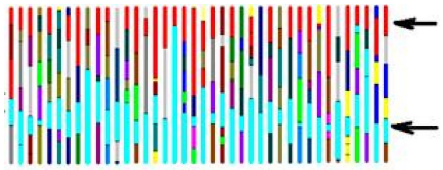


Pulatov, B., Hall, K., Linderson, M. L., & Jönsson, A. M. (2014). Effect of climate change on the potential spread of the Colorado potato beetle in Scandinavia: an ensemble approach. *Climate Research*, *62*(1), 15-24.

Precision breeding - Precision agriculture

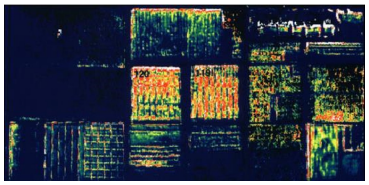


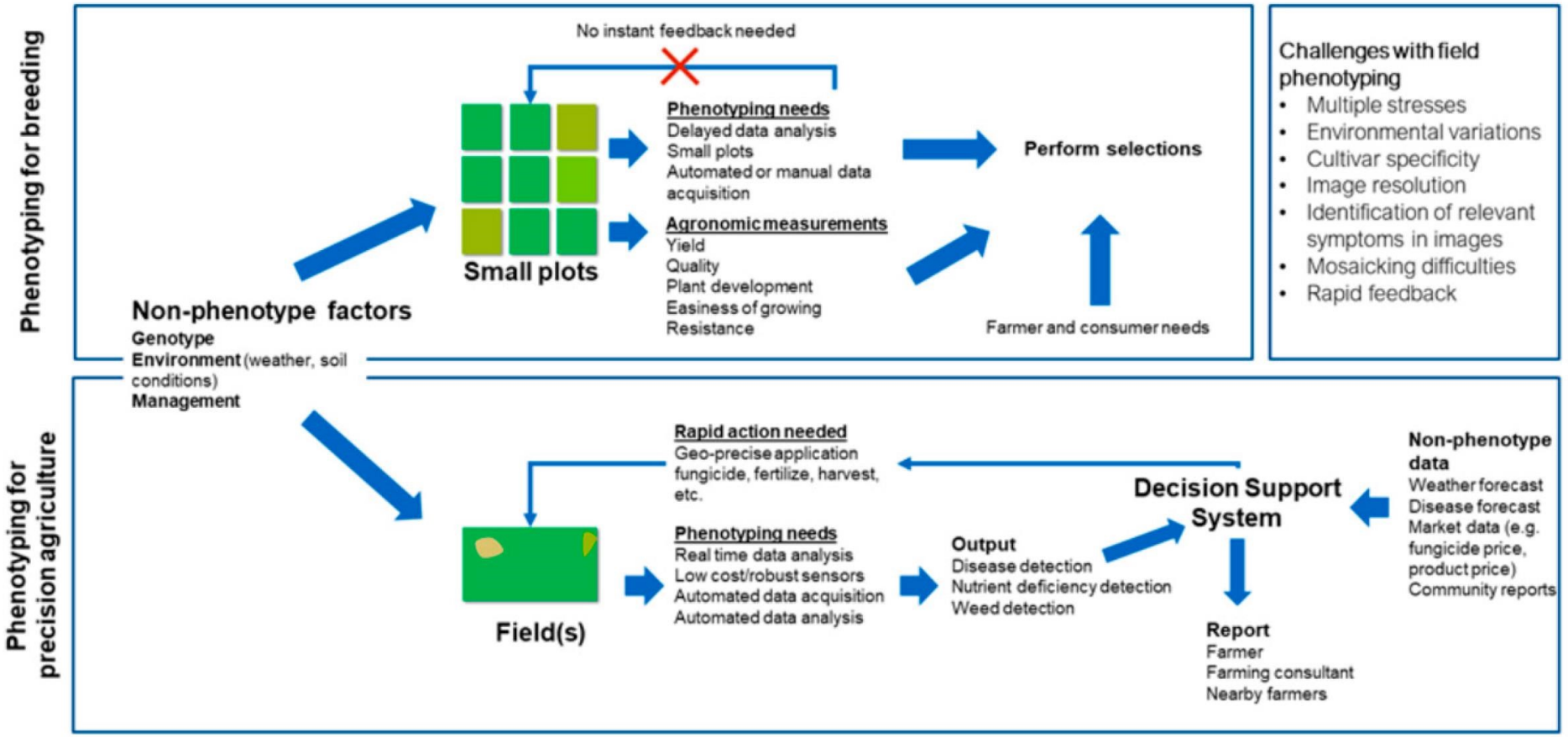
Association analysis



Gene/marker discovery

Modern breeding techniques





Chawade, A., van Ham, J., Blomquist, H., Bagge, O., Alexandersson, E., & Ortiz, R. (2019). High-Throughput Field-Phenotyping Tools for Plant Breeding and Precision Agriculture. Agronomy, 9(5), 258.

PHENOMICS

The study of how the genetic makeup of an organism determines in appearance, function and performance.

It involves the gathering of high-dimensional phenotypic data at multiple levels of organization.

BUT, the ”phenotyping bottleneck”

Modified from PhenomicsNL platform, Wageningen University.

Modern phenotyping relies on

- **Non-destructive** measurements to follow a trait over time;
- **High-throughput** measurements for the screening of many genotypes at similar conditions.
- Multidisciplinary team with expertise in:
  - Sensor development, automation and usage;
  - -omics in its broad sense;
  - Plant ecology, physiology, pathology, and interactions with other organisms;
  - (Bio)informatics, computational power and statistics.

Plant phenotyping research trends

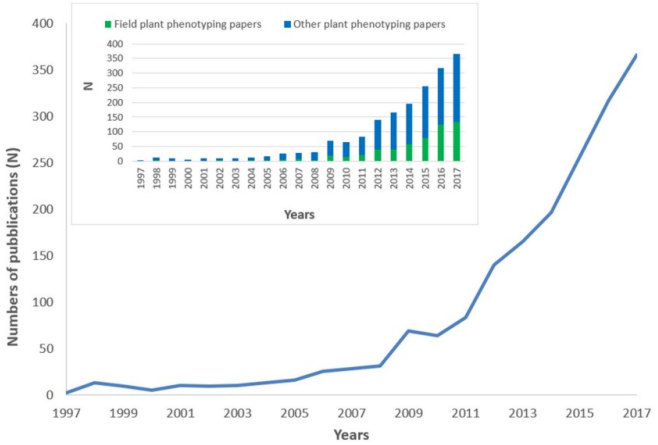


FIGURE 1 | Trend in plant phenotyping publications from 1997 to 2017. The histogram on the top-left side of the figure represents the number of field plant phenotyping papers with respect to other plant phenotyping papers. 2017 publications were underestimated being not yet all inserted in the Scopus database.

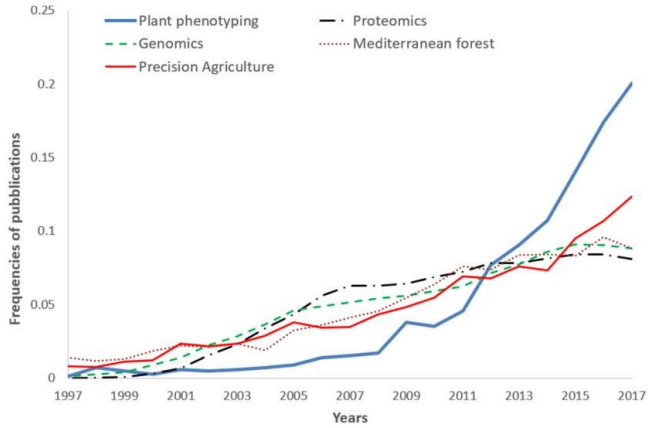


FIGURE 2 | Frequencies of plant phenotyping publications from 1997 to 2017 compared with other subjects: Genomics, Proteomics, Mediterranean forest (Nardi et al., 2016), and Precision agriculture (Pallottino et al., 2018). 2017 publications were underestimated being not yet all inserted in the Scopus database.

Costa C., Schurr U., Loreto F., Menesatti P. and Carpentier S. (2019). Plant Phenotyping Research Trends, a Science Mapping Approach. *Front. Plant Sci.* 9:1933. doi: 10.3389/fpls.2018.01933

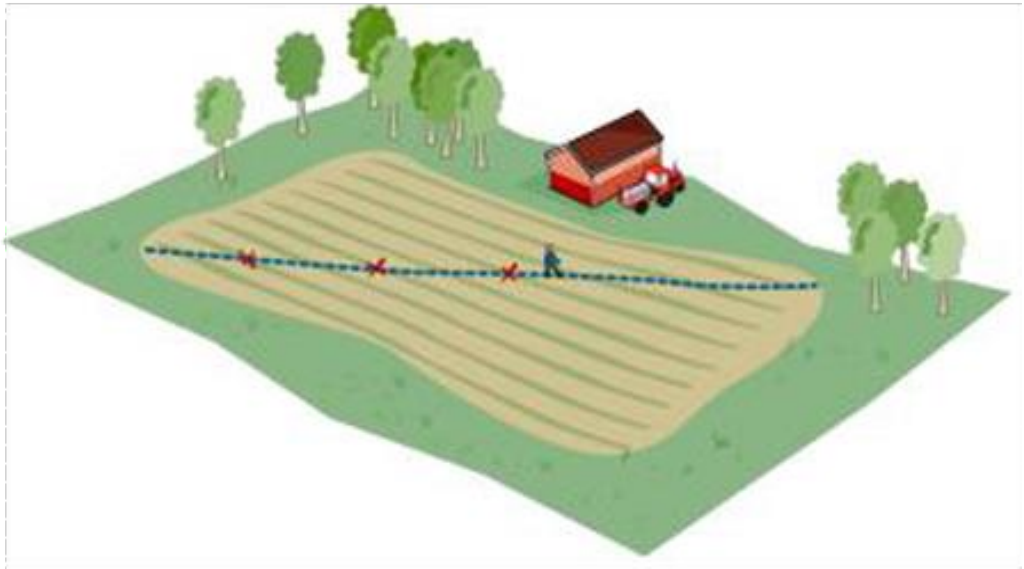
Late blight progression during 2014

2014-07-01

2014-07-21

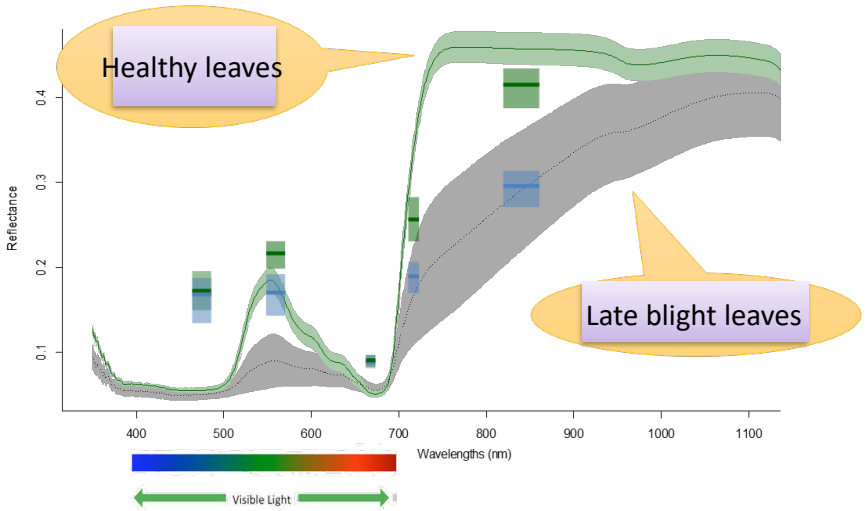
2014-08-06

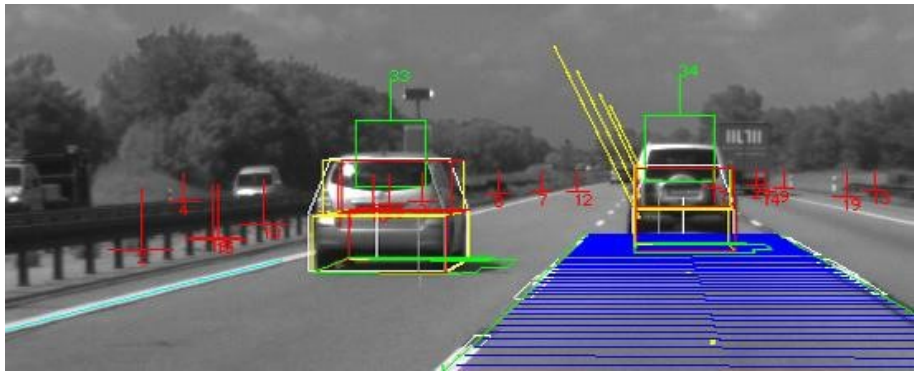
Early detection and monitoring - EnBlightMe!



Explorian 8, RX-100 Sony,
Rededge (Micasense)

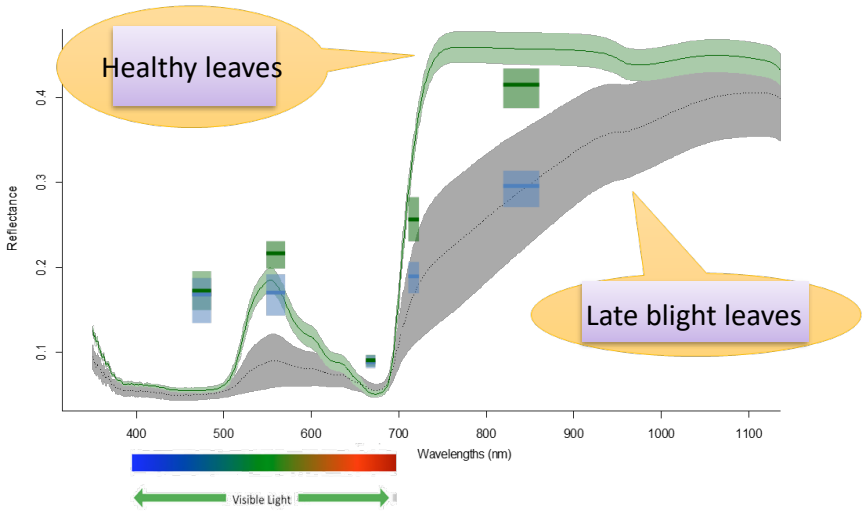
Reflectance vs computer vision for late blight detection



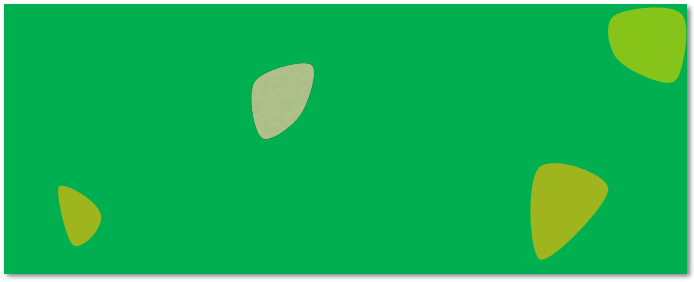


GitHub: Computer Vision

Reflectance vs computer vision for late blight detection



Approach for app



1) Georeferenced (multi-spectral) images

2) GUI

3) Data storage

4) Preprocessing

5a) Feature recognition using machine learning

5b) Spectral indices

6) Late blight likelihood in specific location

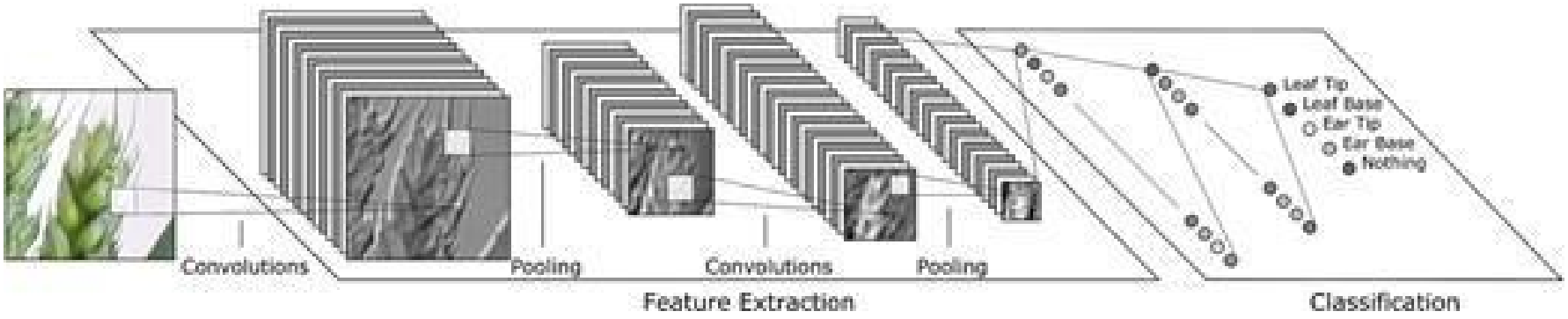
Information on nearby outbreaks

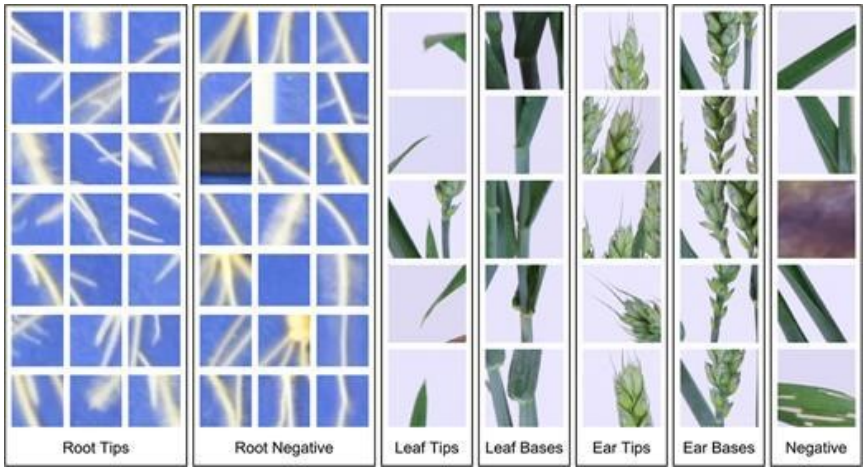
Outbreak model based on weather prediction

VINNOVA

IBM

Plant morphology by machine learning for breeding





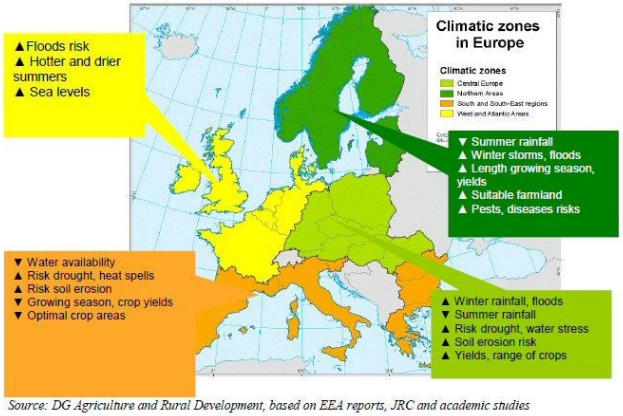
Pound et al *GigaScience*, Volume 6, Issue 10, 1 October 2017

NordPlant

NordPlant - A Climate and Plant Phenomics Hub for Sustainable Agriculture and Forest Production in Future Nordic Climates

Nordic climates

Climate change – Possible impacts on EU agriculture



Source: DG Agriculture and Rural Development, based on EEA reports, JRC and academic studies

- Long days – short seasons
- Lack of breeding
- Relatively small farms

NordForsk supported university hub

With cofunding ca 32+16 MNOK (€4.8M) up to six years

NaPPI, Helsinki Finland

Biotron, Alnarp Sweden

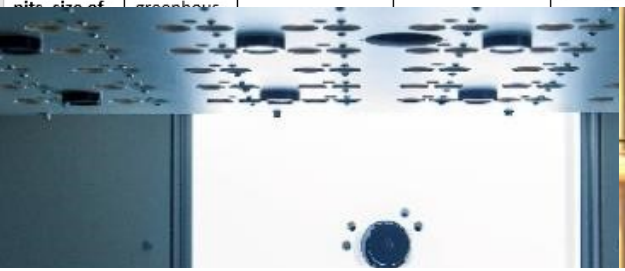
PhenoLab, Taastrup Denmark

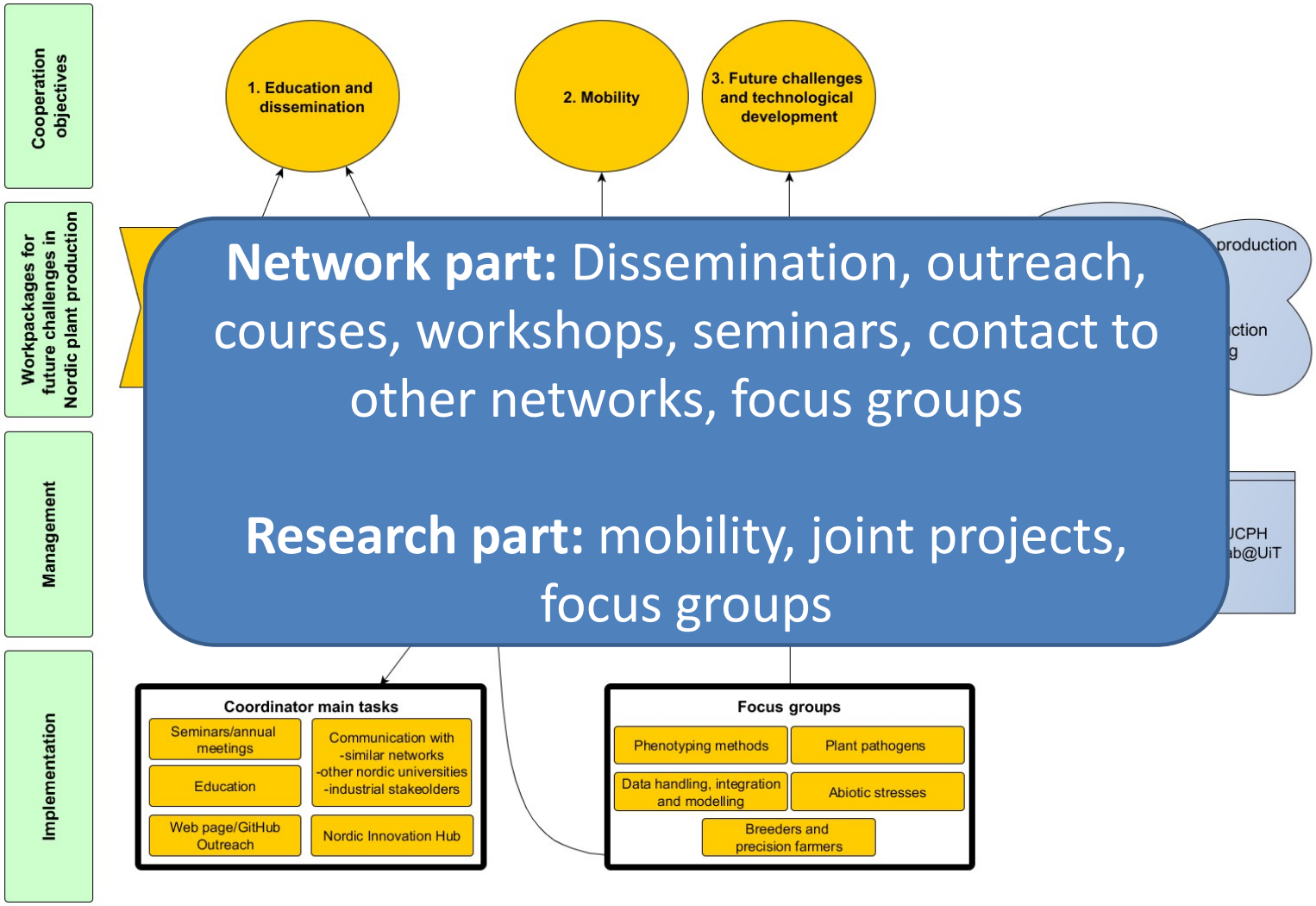
ClimaLab, Tromsø Norway

Survey of 14 Nordic Plant Growth Facilities for phenotyping and controlled climates

Alexandersson et al 2018 (Agricultural and Food Science 27: 7-16)

Name of facility	PhenoDyn: Drought spotter and Planteye	Frederiksberg facilities at University of Copenhagen	Phenolab Taasterup at University of Copenhagen	Greenhouse Taasterup, University of Copenhagen	RERAF - Risø Environmental Risk Assessment facility	Controlled Environment Facility for Plant Research	The Centre for Plant Research in Controlled Climate (SKP)	Climate laboratory Holt	The biotron at SLU Alnarp
Host institution	Food Science, Aarhus University	PLEN, University of Copenhagen	PLEN, University of Copenhagen	PLEN, University of Copenhagen	Inst for Env engineering, Technical University of Denmark	Department of Biosciences, University of Oslo	Norwegian University of Life Sciences (NMBU)	UiT The Arctic University of Norway	LTV faculty, SLU Alnarp
Type of facility	Phenotyping and controlled environment	Controlled environment in greenhouses	Phenotyping and controlled environment	Greenhouse with controlled climate	Controlled environment	Controlled environment	Controlled environment, test fields	Controlled environment And test fields	Controlled environment
Year constructed	2012-2015	1972-1984-1996	2015	2013	1993, upgraded 2003	1973	1995-2017	1978	2016
Type and number of chambers/units, size of	6 climate chambers, 6 full scale	15 chambers	117 fixtures/plants	12 compartments ($50m^2$)	6 identical chambers are	16 artifical environments ($10m^2$). 6 conditioned natural daylight (CND; $30m^2$). 4 small	22 freezing chambers (0.6-6.3m^2); 15 cooling chambers (6.3-8.8m^2); 62 greenhouse rooms (12-40m^2) 16 phytotron rooms ($12m^2$); 60 growth chambers (0.3-9m^2)	6 day light chamber (10,5m^2); 3 x 2 dark rooms (3,6m^2); 2 S3 rooms, (3,6m^2); 3 Cold rooms, (9,5m^2)	12 Climatized rooms (CR; 11.5m^2) 4 Climatized daylight




Cooperation objectives
Workpackages for future challenges in Nordic plant production
Management
Implementation
1. Education and dissemination
2. Mobility
3. Future challenges and technological development
Network part: Dissemination, outreach, courses, workshops, seminars, contact to other networks, focus groups
Research part: mobility, joint projects, focus groups
production
ction
UCPH
ab@UiT
Coordinator main tasks
Seminars/annual meetings
Communication with -similar networks -other nordic universities -industrial stakeolders
Education
Web page/GitHub Outreach
Nordic Innovation Hub
Focus groups
Phenotyping methods
Plant pathogens
Data handling, integration and modelling
Abiotic stresses
Breeders and precision farmers

Focus groups

1. Phenotyping methods in field, greenhouse, and cell physiology (UHEL)
2. Data handling and integration related to phenotyping and modelling by integrated climate and phenomics data (UCPH/LU)
3. Emerging and increasing plant pathogens and pests in the Nordic countries (SLU)
4. Abiotic stress relevant for future climate change in the Nordic countries (UiT)
5. *Demands of breeders and precision farmers (UCPH)*

Workshop on phenotyping standards and data handling held in Lund 29-30 April, 2019

- Célia Michotey and Anne-Françoise Adam-Blondon from INRA Versailles
- Introduced phenotyping standards. The participants had the opportunity to use the standards to describe a dataset that they had brought to the workshop

www.nordplant.org

NordPlant Annual Day, 20 November 2019 Ecology Building in Lund, Sweden

“Tech talks for plant phenotyping in the Nordic countries”

Llorenç Cabrera-Bosquet INRA, Stefan Paulus University of Göttingen, Stefan Jansson Umeå Plant Science Center, Uno Wennergren (AgTech 2030, Linköping), Kristiina Himanen (UHEL) and more…

Tech corners: AgroVäst, Cgrain, Heliospectra, Lunicore, SenseFarm, Solvi, Valoya, Videometer and Vultus

NordPlant

Drought of 2018

- Biotron SLU Alnarp and NaPPI University of Helsinki to test drought tolerance of potato lines
- Measured morphological traits, physiological traits and yield
- Considerable difference in the effect of drought on different potato lines

Cuticular wax of European blueberry

- Collaboration between University of Tromsö and SLU Alnarp
- Blueberrys are nutritionally interesting (polyphenols) – ”The Nordic Diet”
- Large project to compare blueberries from different latitudes using field and controlled environments

Priyanka Trivedi studies the cuticular wax protecting the berry fruits against water loss, pathogen attack and UV radiation

-> climate and nutrients

New breeding techniques: Cassava with improved beta-carotene by gene editing

James Hutton Inst

Priscilla Olayide

Problem! Combine high starch and high b-cartotene
-improved mechanistic understanding of biosynthesis and CRISPR/cas9

IITA
Research to Nourish Africa

What can Plant Health and Breeding do for Food Science? [by phenotyping and modern breeding]

- Keywords: phenotyping bottleneck; precision breeding/farming
- Food security in future climates
  - Accelerating breeding
  - Optimising plant health
- More nutritious food
  - Improved growth systems
  - Re-wilding
  - Minor crops
- Reduce pesticide use
  - Improved monitoring

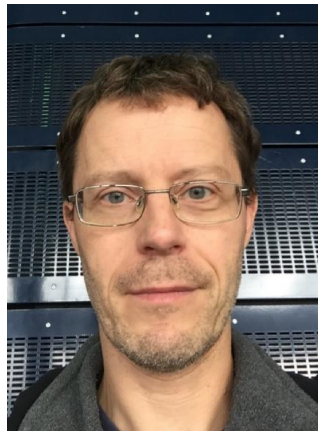
PLANTLINK

NordPlant

Tina D'Hertefeldt, Deputy Director

Varma Saripella, Bioinformatician

Erik Alexandersson, Coordinator



Svante Resjö, Administrative coordinator

Representative	Deputy representative	University
Jari Valkonen	Kristiina Himanen	UHEL
Erik Andreasson	Rodomiro Ortiz	SLU
Thomas Roitsch (chair)	Alexander Schulz	UCPH
Laura Jaakola	Kirsten Krause	UiT
Lars Eklundh	Anna Maria Jönsson	LU

Acknowledgements

Junfeng Gao


Murilo Sandroni

EnBlightMe! team









Erland Liljeroth, Erik Alexandersson (SLU, Alnarp)
Kristin Piikki, Mats Söderström (SLU Skara)
Oscar Bagge, Hanna Blomquist, Mats Persson (IBM)
Martin Holmberg (SLU)
Peter Antkowiak (University of Freiburg)
Daniel Barwén (Malmö Yrkeshögskola)
Joost van Ham (Lund University)

A Vinnova funded project

We are looking for interactions, collaboration and input!

NordPlant

PLANTLINK

THANK YOU FOR LISTENING!