Global Burden of Crop Loss

Measuring and understanding the global burden of crop loss: data requirements and opportunities on yields, pest presence, and economic burden of the hazards.

Agricultural Development and Climate Change Unit´s II Experts Meeting on Agricultural Statistics

ECLAC, Mexico City, 10th September 2024

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Who we are

CABI is an international not-for-profit organization that improves people's lives by providing information and applying scientific expertise to solve problems in agriculture and the environment

What we do

We help farmers grow more and lose less of what they produce, combating threats to agriculture and the environment from pests and diseases and improving access to scientific knowledge

How we work

Our **49 Member Countries** guide and influence our core areas of work and by working closely with our donors and partners, individuals and organizations, countries and regions, together, we aim to solve problems and build sustainable livelihoods

Our member countries


Afghanistan


Anguilla


Australia


Bahamas


Bangladesh


Barbados


Bermuda


Botswana


British Virgin Islands


Brunei Darussalam


Burundi


Canada


Chile


China


Colombia


Cote d'Ivoire


DPR Korea


Ethiopia


Gambia


Ghana


Grenada


Guyana


India


Jamaica


Kenya


Malawi


Malaysia


Mauritius


Montserrat


Myanmar


Nigeria


Pakistan


Papua New Guinea


Philippines


Rwanda


Sierra Leone


Solomon Islands


South Africa


Sri Lanka


St Helena*

Switzerland

Tanzania

The Netherlands

Trinidad & Tobago

Uganda

United Kingdom

Vietnam

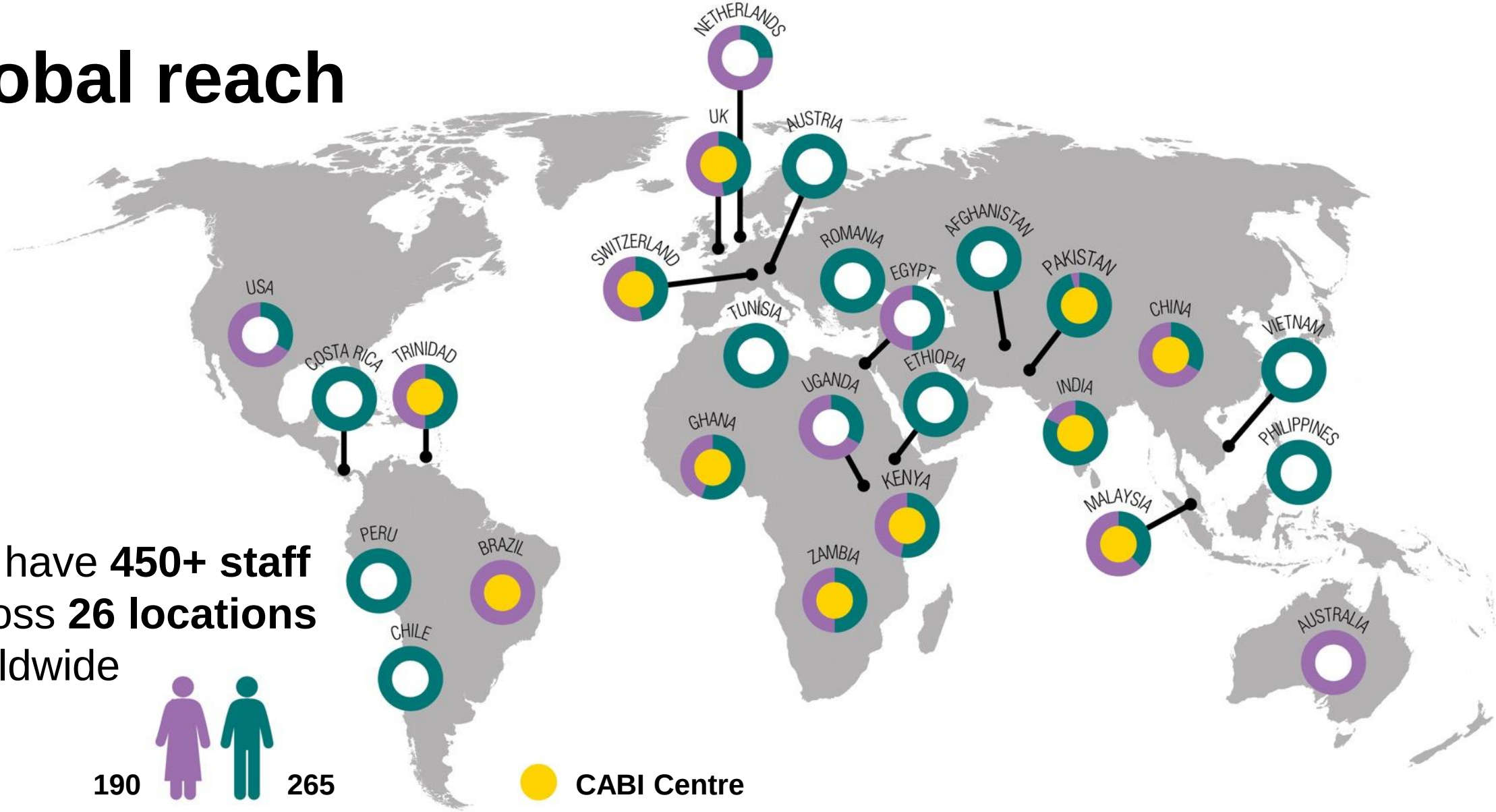
Zambia

Zimbabwe

Working in partnership

We partner with others to help the world achieve the **Sustainable Development Goals** (SDGs) and our strategy supports the delivery of the following SDGs:

Global reach



We have **450+ staff** across **26 locations** worldwide

190 **265**

CABI Centre

Our areas of focus

Food & nutrition security

Climate change & biodiversity

Gender & youth

Economic development

Our areas of expertise

Crop health

Development communication and extension

Digital development

Invasive species

Publishing

Value chains and trade

Quantifying and communicating loss of crops and onward impact caused by abiotic and biotic factors (including invasive species)

The growing challenge of crop loss

Keeping pace with the growing demand for food, under increasing impacts from climate change, is one of the defining challenges of our time.

High levels of crop loss makes this even harder. According to a widely cited FAO figure, around **20-40%** of the world's crops are lost to pests alone.

$25.8 billion

Is spent annually on agricultural research and development*.

If we don’t measure crop loss well, then how do we know if this investment is working or we are spending it in the right ways?

*Cost of expenditure on crop production based on public and private sector estimates from the following sources. Fuglie, K. (2016) ‘The growing role of the private sector in agricultural research and development world-wide’, Global Food Security. 10 pp29-38 Donor Tracker (2021) 'Agriculture'. Available at https://donortracker.org/sector/agriculture

Global Burden of Crop Loss

The Global Burden of Crop Loss (**GBCL**) initiative aims to provide rigorous, authoritative evidence on **impacts**, **causes**, and **risk factors** of crop loss.

Evidence-based estimates of crop loss and its attribution to different causes will help **direct funding**, **policy**, and **research** efforts to reduce crop loss at the farm level.

Our mission

Our mission is to support global food security by providing actionable estimates of crop losses, fostering informed decision making at local, national, and global levels – ultimately resulting in lower losses and more resilient food systems.

Theory of Change

Impacts

Improved food security and resilience for farmers globally

Long-term outcomes

Data-driven resource allocation
National and regional strategies aim to reduce losses
Funding directed towards filling knowledge gaps

Intermediate outcomes

Stakeholders aware of where and why losses are happening and the magnitude of losses

Outputs

Global crop specific burden estimates produced broken down by: yield loss, causes/attribution, economic burden (revenue, cost of control)

Inputs

Datasets
Methods, skills and expertise
Collaboration

Learning from human and animal health systems

The Global Burden of Disease in Human Health provides comprehensive, authoritative data on the impact of hundreds of health problems and risk factors and has transformed the health agenda over the past 30 years.

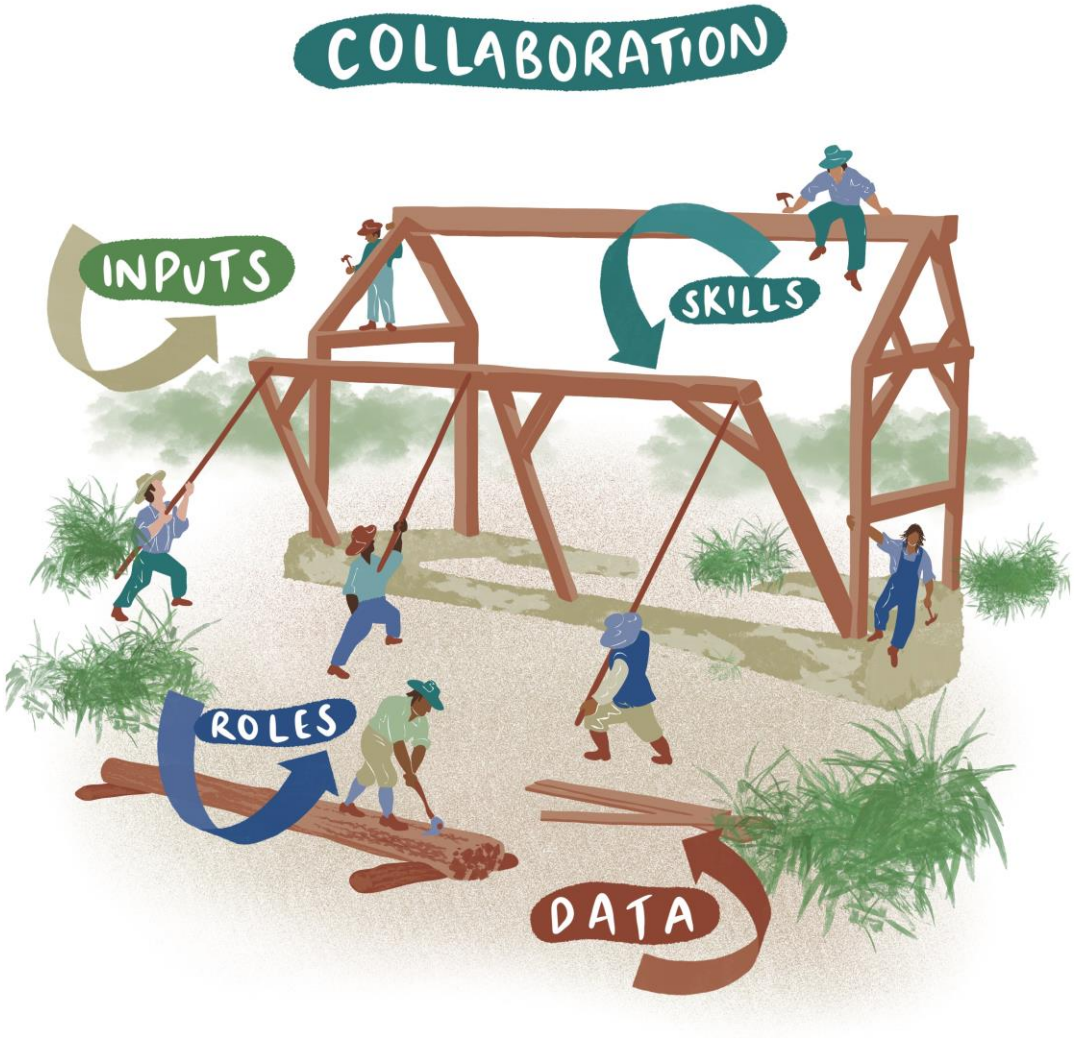
The Global Burden of Disease initiative is led by the Institute for Health Metrics and Evaluation (IHME).

GBADs

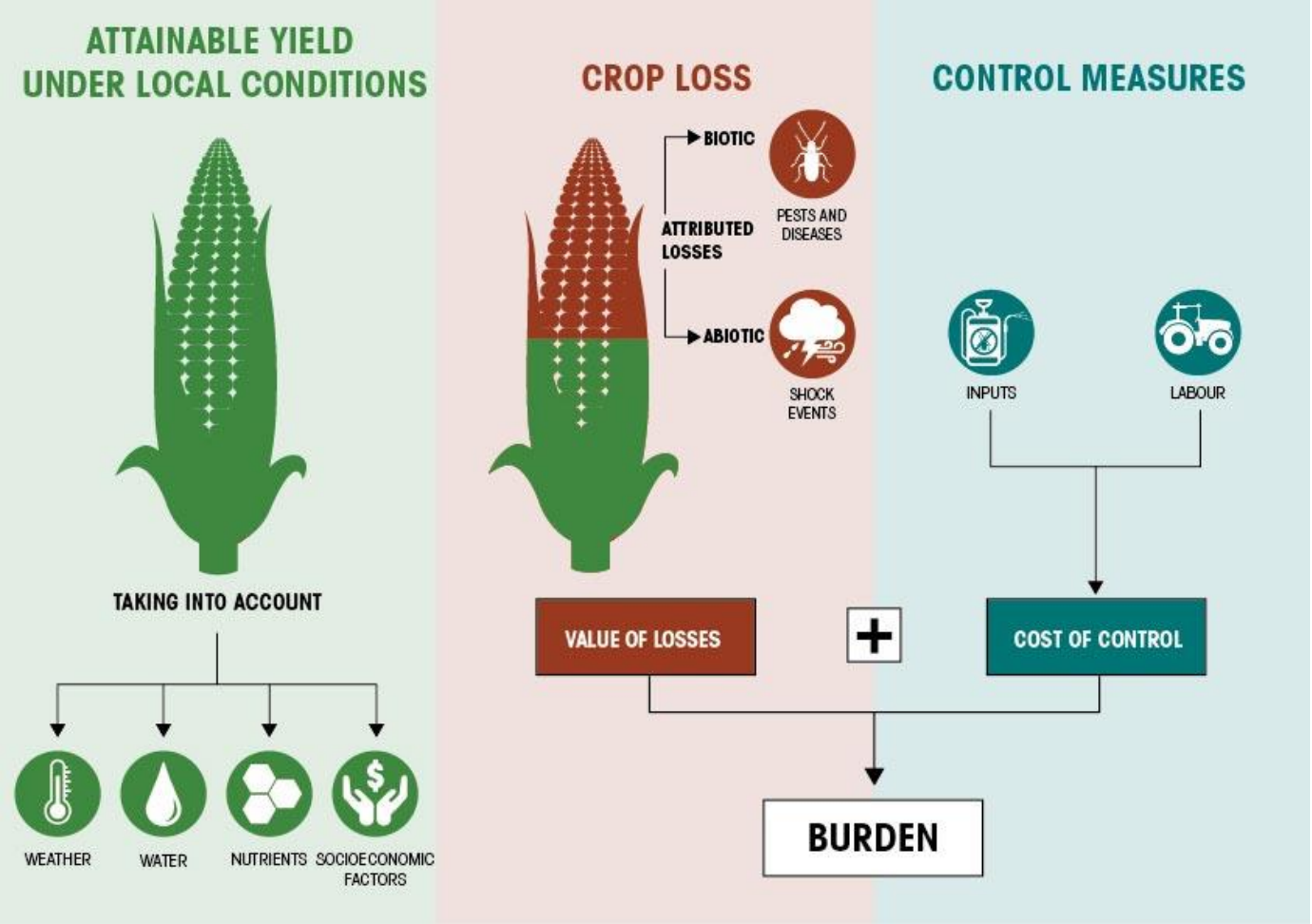
The Global Burden of Animal Diseases (GBADs) will produce estimates on the economic impacts of pathogens and animal diseases based on their effect on the mortality and productivity in animals (Rushton *et al.,* 2021).

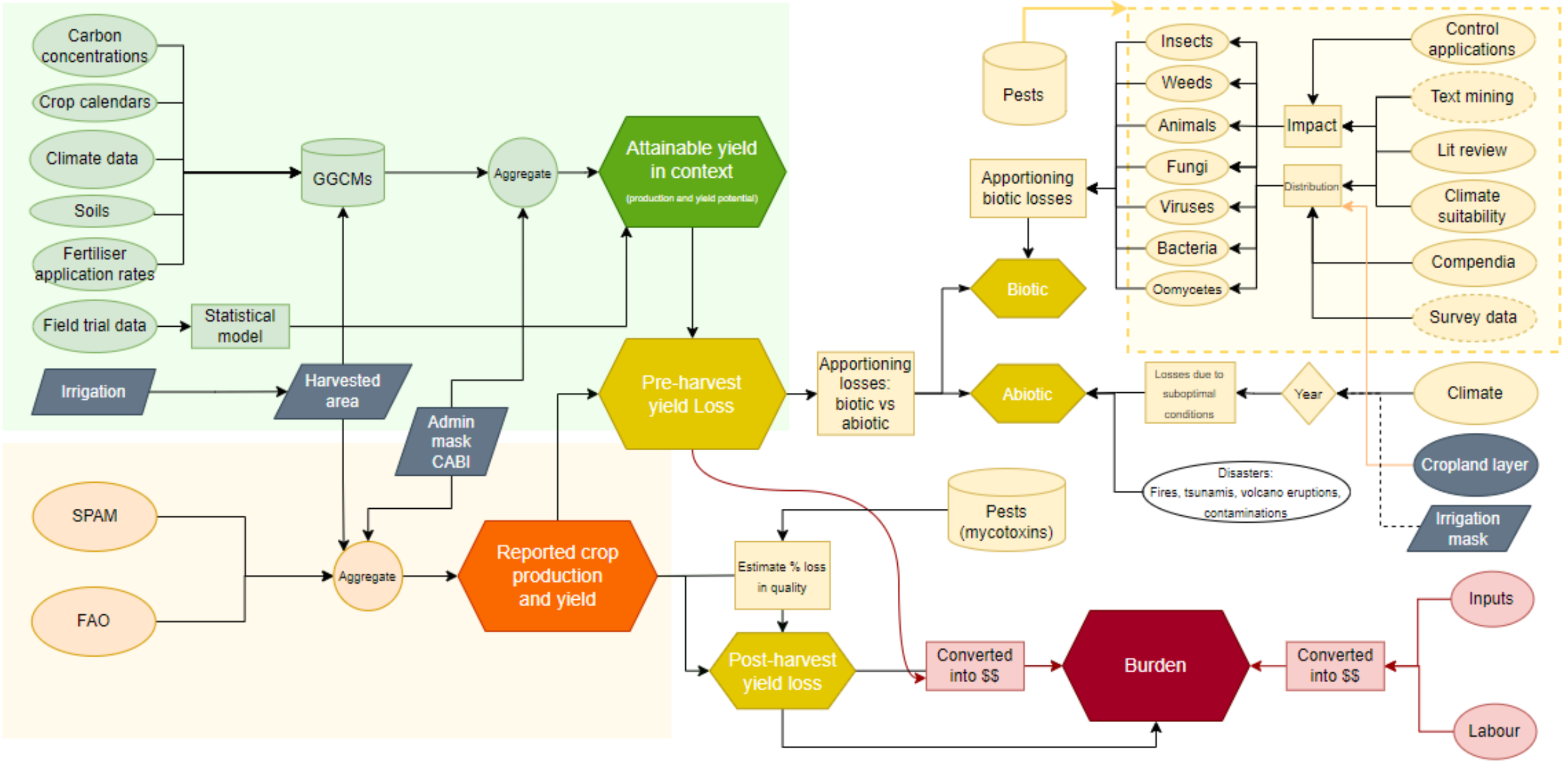
GBADs is led by the University of Liverpool

Our partners



Theoretical framework




Carbon concentrations
Crop calendars
Climate data
Soils
Fertiliser application rates
Field trial data
Statistical model
Irrigation
Harvested area
GGCMs
Aggregate
Attainable yield in context
(production and yield potential)
Admin mask CABI
Pre-harvest yield Loss
Pests
Insects
Weeds
Animals
Fungi
Viruses
Bacteria
Oomycetes
Impact
Distribution
Control applications
Text mining
Lit review
Climate suitability
Compendia
Survey data
Apportioning biotic losses
Biotic
Apportioning losses: biotic vs abiotic
Abiotic
Losses due to suboptimal conditions
Year
Climate
Cropland layer
Irrigation mask
Disasters: Fires, tsunamis, volcano eruptions, contaminations
SPAM
FAO
Aggregate
Reported crop production and yield
Pests (mycotoxins)
Estimate % loss in quality
Post-harvest yield loss
Converted into $$
Burden
Converted into $$
Inputs
Labour

Global burden of wheat loss

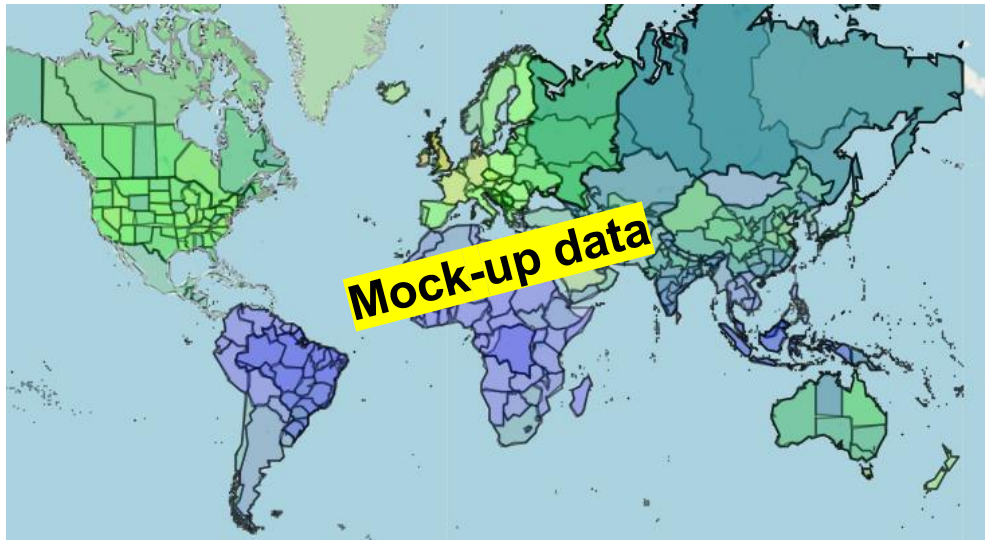
Crop
Wheat

Year
2015

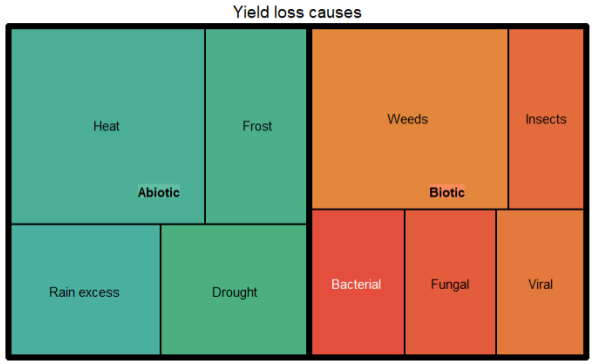
Country/region
Global

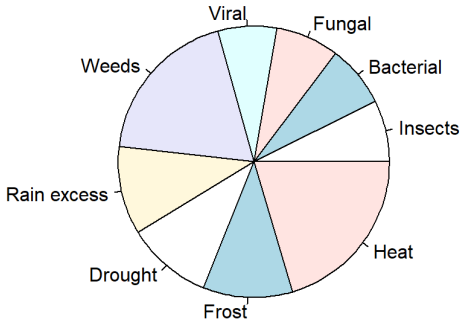
Loss type
Biotic and abiotic

Loss group
All



Loss %





The Global Burden of Crop loss for wheat for 2015 is $48 billion

Representing 23% loss of yield potential (0.06% of global GDP)

Attainable yield: **973.25** mln tonnes

Actual yield: **778.6** mln tonnes

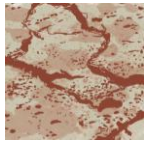
Economic burden estimate: **$48 billion**

Export data

Explore crop loss causes in wheat:

Fungi (16%)

Weeds (11%)



Drought (8%)

Latest research on wheat loss:

Forecasting the global extent of invasion of the cereal pest Spodoptera frugiperda, the fall armyworm

A preliminary assessment of the extent and potential impacts of alien plant invasions in the Serengeti-Mara ecosystem, East Africa

Effects of Abiotic Stress on Respiratory Carbon Loss of Two Maize (Zea mays L.) Inbred Lines and Their Hybrid During Silking and Grain-Filling

Yield losses in maize (Zea mays) infested with parthenium weed (Parthenium hysterophorus L.)


PROTECTING FOOD SECURITY
DEVELOPMENT OF VARITIES, PRODUCTS + SYSTEMS
LAND USE DECISIONS
SMART AGRICULTURE
BETTER INVESTMENTS + CHOICES
SUPPORTING FARMER LIVELIHOODS
BETTER DECISIONS
BETTER DATA

Yields – data requirements

How much is grown? What is attainable?

- Field yield observations
- Field trials
- Crop production statistics
- Fertilizer and pesticide inputs data
- Satellite observations

Modelling yields

Maize yield data

FIELD OBSERVATIONS

- **Global field** trial data reporting maize yields downloaded (~ 230000 unique observations) which included different experiments and field observations Source: CG ***Gardian***, **Figshare**, **Zenodo** and **Harvard Dataverse, Dimensions** data repositories.
- **Processing:** The downloaded data were all collated in single Excel file with uniform unit for yield (t/ha). Coordinates were obtained for the points missing them using ggmap R package and Google Maps. Other information such as fertiliser rates, irrigation, pests and weeds, and agriculture system were extracted from data files or literature.

GRIDDED PREDICTIONS

- AgMIP version 3 10 global gridded maize prediction models downloaded and processed to represent multi-model ensemble mean globally
- AgMIP grid used for in-house INLA model predictions

Covariates

- Global **crop calendars** for maize: since maize growing season vary across maize growing area, cell specific crop calendar downloaded from Goethe University Website, processed, and added to each point in both trial and prediction dataset.
- **Soil** PH, SOC, and soil classes from Harmonized World Soil Dataset.
- **Cropping season average and monthly temperature, total precipitation in the growing season** extracted from ERA-5.
- Standardised Precipitation-Evaporation Index (**SPEI**) from The Global SPEI database.
- **Agroecological zone** from Gaez-FAO
- Percentage of **irrigated lands** from Geothe University Website
- Elevation
- **Socio-economic data** (GDP, percent of labour employed in agriculture, percent of mechanised agriculture etc) - Worldbank
- All those covariates were downloaded as a raster file, processed, and added to both trial and prediction datasets.

Modelling

- **Spatio-temporal model with R-INLA**
- **Generalised Additive Models (GAM)**
- **(Spatial) Random Forest**
- Approaches to identify the most influential covariates tested (stepwise regression, AIC etc)
- Routines to remove collinearity (Pearson R, Variance Inflation Factor)
- Log transpormation of coraviates, normalization of covariates where needed
- Model parametirisation, choice of distribution of the response
- Fitting and evaluating the models
- Export trial data with predicted values as CSV file for internal validation.
- Convert and prediction data with predicted values to raster for mapping and external validation.

Validation

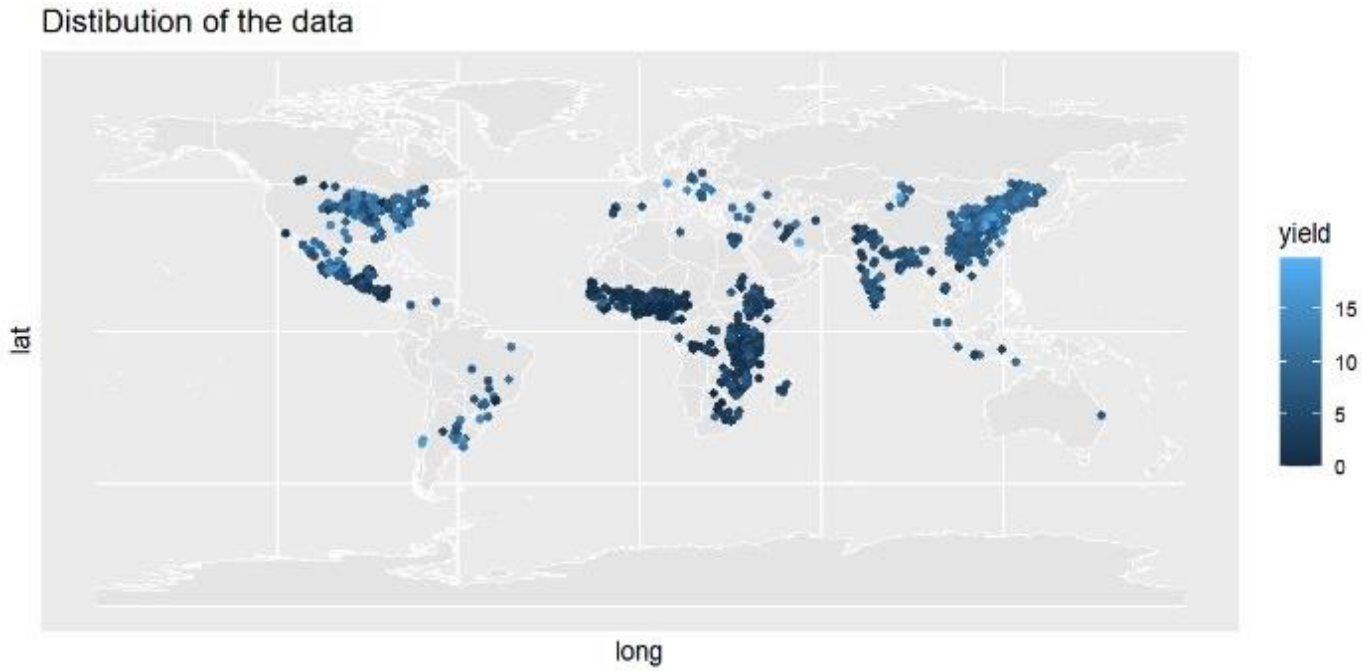
Internal:
Includes validation in trial dataset such as plotting predicted vs observed yields, estimating R2, explained deviance and residuals, computing variograms and visualizing the spatial distribution of observed, predicted yields and residuals.

External:
Compared predicted raster to other data products and models such as FAO, AgMip, Spam, GYGA and Gaez by generating scatter plots, maps and estimating the difference at grided and country leaves using rgbcl package.

Maize data collection

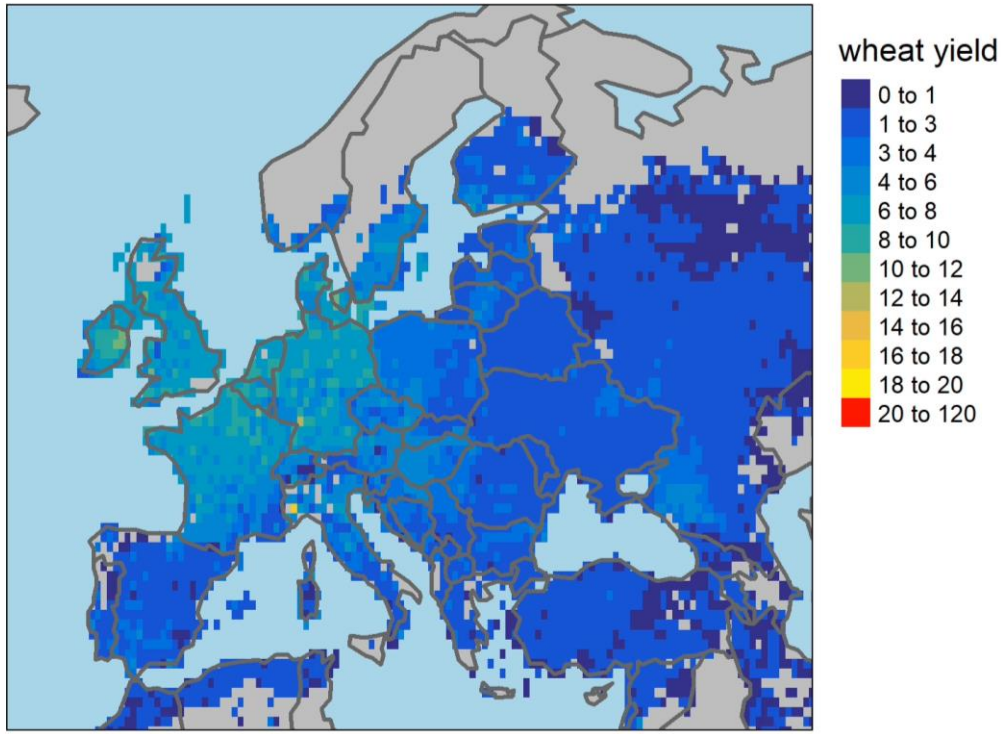
No	Variable	Stats / Values	Freqs (% of Valid)	Graph	Valid	Missing
1	continent [character]	1. Africa 2. Asia 3. Central America 4. Europe 5. North America 6. Oceania 7. South America	155895 (66.7%) 17080 (7.3%) 192 (0.1%) 825 (0.4%) 49793 (21.3%) 44 (0.0%) 9865 (4.2%)		233694 (100.0%)	0 (0.0%)

No	Variable	Stats / Values	Freqs (% of Valid)	Graph	Valid	Missing
2	country [character]	1. NIGERIA 2. KENYA 3. USA 4. TANZANIA 5. CHINA 6. MEXICO 7. ETHIOPIA 8. BRAZIL 9. GHANA 10. MALAWI [73 others]	49823 (21.3%) 47682 (20.4%) 34754 (14.9%) 11678 (5.0%) 10554 (4.5%) 7495 (3.2%) 6529 (2.8%) 6472 (2.8%) 5941 (2.5%) 4795 (2.1%) 47971 (20.5%)		233694 (100.0%)	0 (0.0%)
	year [numeric]	Mean (sd) : 2008.6 (11.3) min ≤ med ≤ max: 1959 ≤ 2013 ≤ 2022 IQR (CV) : 11 (0)	64 distinct values		233694 (100.0%)	0 (0.0%)
	yield [numeric]	Mean (sd) : 4.8 (3.2) min ≤ med ≤ max: 0 ≤ 4 ≤ 29.6 IQR (CV) : 3.8 (0.7)	48963 distinct values		233694 (100.0%)	0 (0.0%)

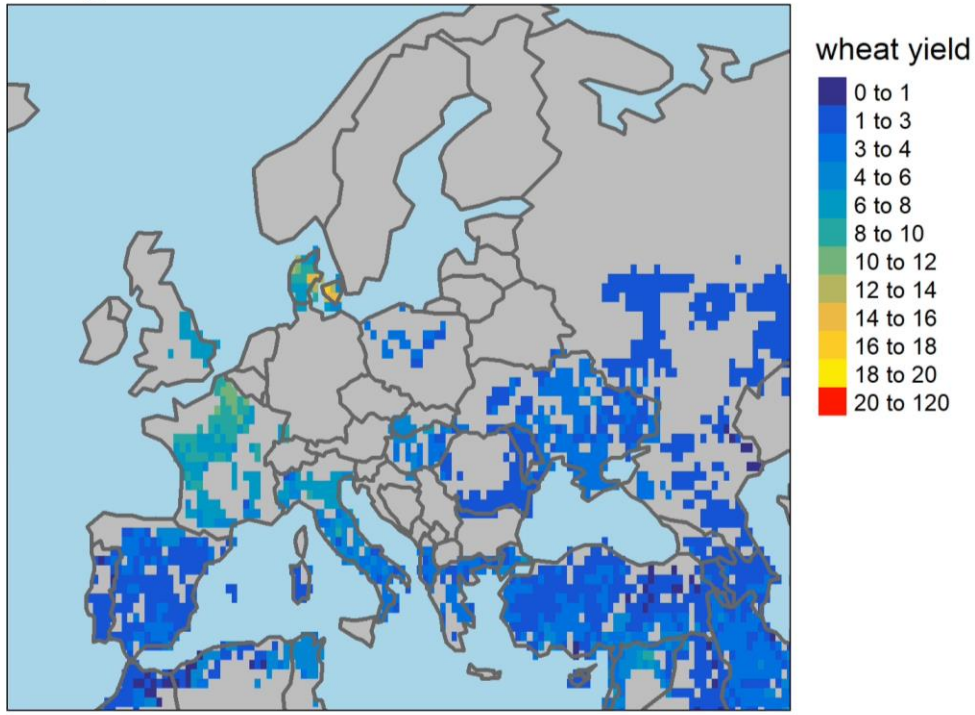


Attainable yield multi-model mean timeseries

Rainfed scenario: 1902



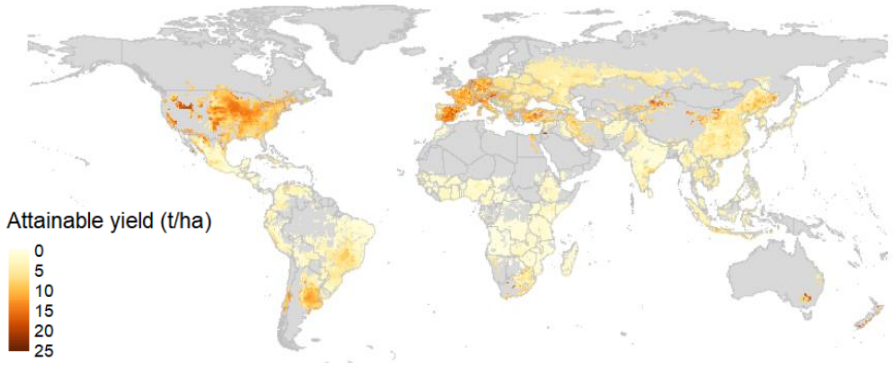
Irrigated scenario: 1902

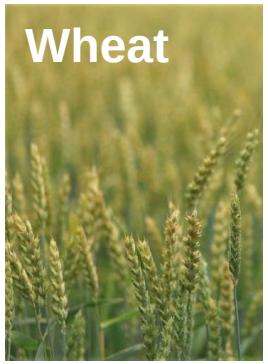


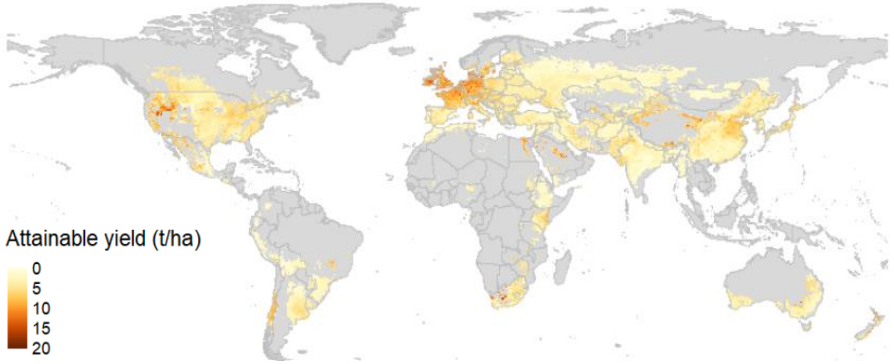
Global and regional losses in maize and wheat

Modelled attainable yield

AgMIP multi-model ensemble mean – rainfed and irrigation composite scenario. The attainable yield assumes national recommendations for N applications and is estimated based on maximum attained yields over 20 years timeframe.

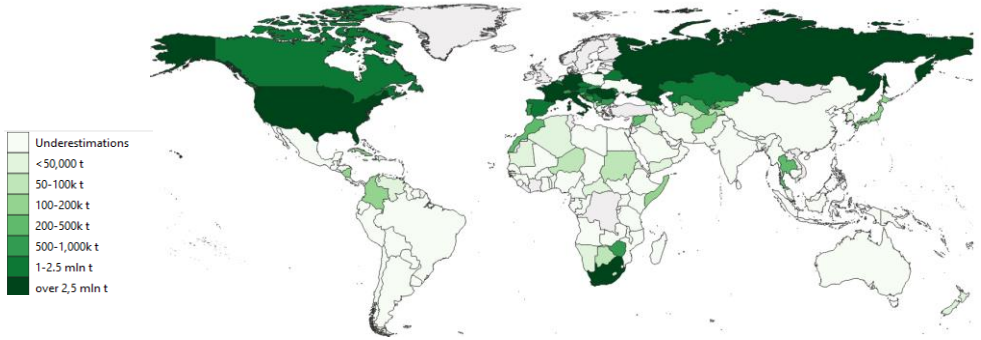


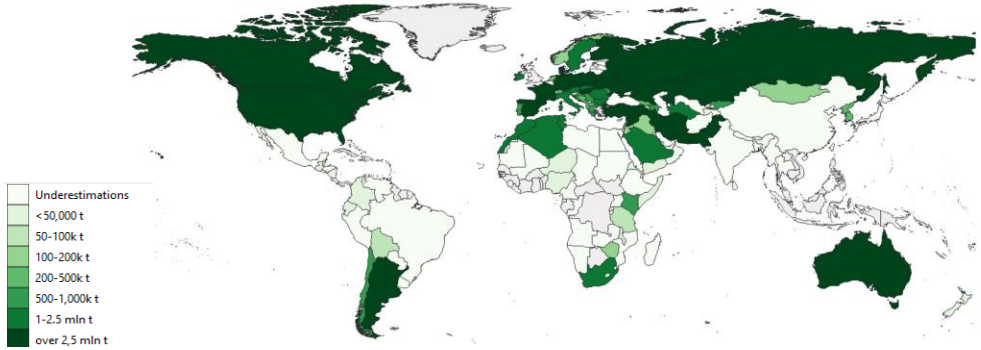




Aggregated production losses in 2015

As estimated for 2015 based on 20-year maximum multi-model mean predictions from AgMIP and compared against FAO 2015 national level crop production statistics. For a number of countries, the attainable yields are underestimated. We are working on developing new spatio-temporal models underpinned by comprehensive field observation data to improve these estimates and couple with re-calibrated crop models.





Agricultural pests – data requirements

Where are pests present? What is their impact?

Distribution

Impact

Frequency

Impact on yield studies results: published data and literature reviews

Field observations

Climate suitability models

Country-wide pest surveys

Pest distribution, incidence

Control and management

Our current key data sources

Biotic pressure and key pest identification

Pest distribution

- CABI Crop Protection Compendia
- CABI Pest Distribution Database
- CABI Plantwise+ Plant Clinics data
- Field trials
- Survey data retrieved from literature and published datasets
- Climate suitability models

Frequency of occurrence

- Field trials
- CABI Knowledge Bank data (from CABI Plantwise+ Plant Clinics)
- CAB Abstracts
- Climate suitability models

Impact on yield

- **CABI Plantwise+ Plant Clinics** data
- **CABI historical pest impact surveys**
- Field trials and pest surveys
- Literature review (manual and automated)

Leveraging CABI's expertise

JUNO Transforming Evidence for Agriculture, Food and Climate

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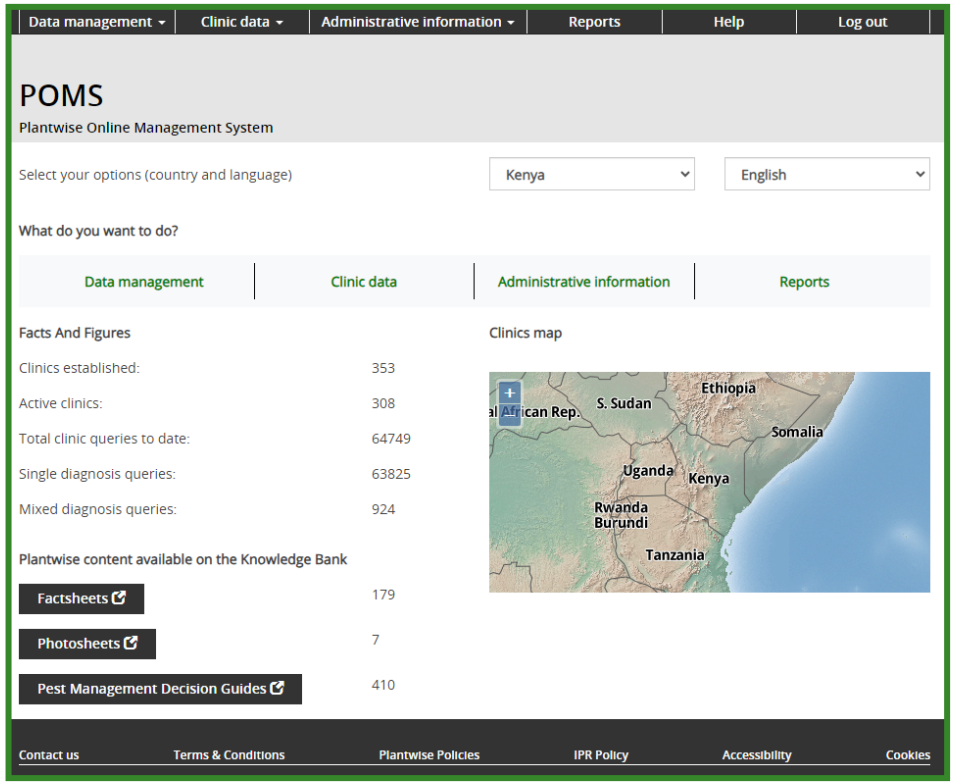
Plantwise Clinic Data

Farmers visit a plant clinic with a pest/disease/weed problem and a trained extension worker (‘Plant Doctor’) records details about the farm, crop, symptoms, makes a diagnosis as to the problem and provides management recommendations to the farmer. Data is recorded in ‘POMS’ in the Plantwise Knowledge Bank

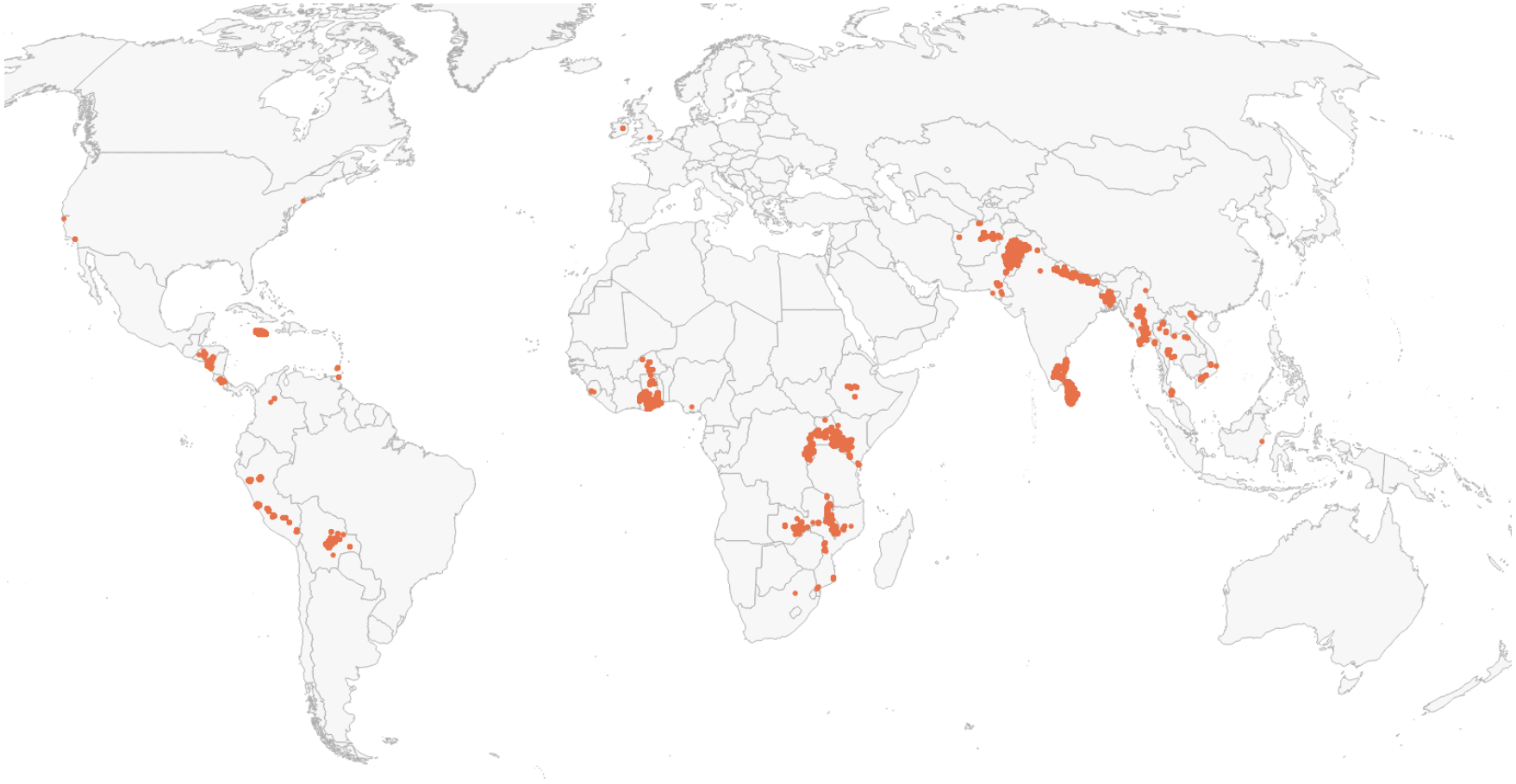
No. records – Global: 800,000
No. records – Africa: 190,000
No. records – Kenya: 64,000

Ranging from 2012 to present but with different start dates for each country and with large gaps in COVID years



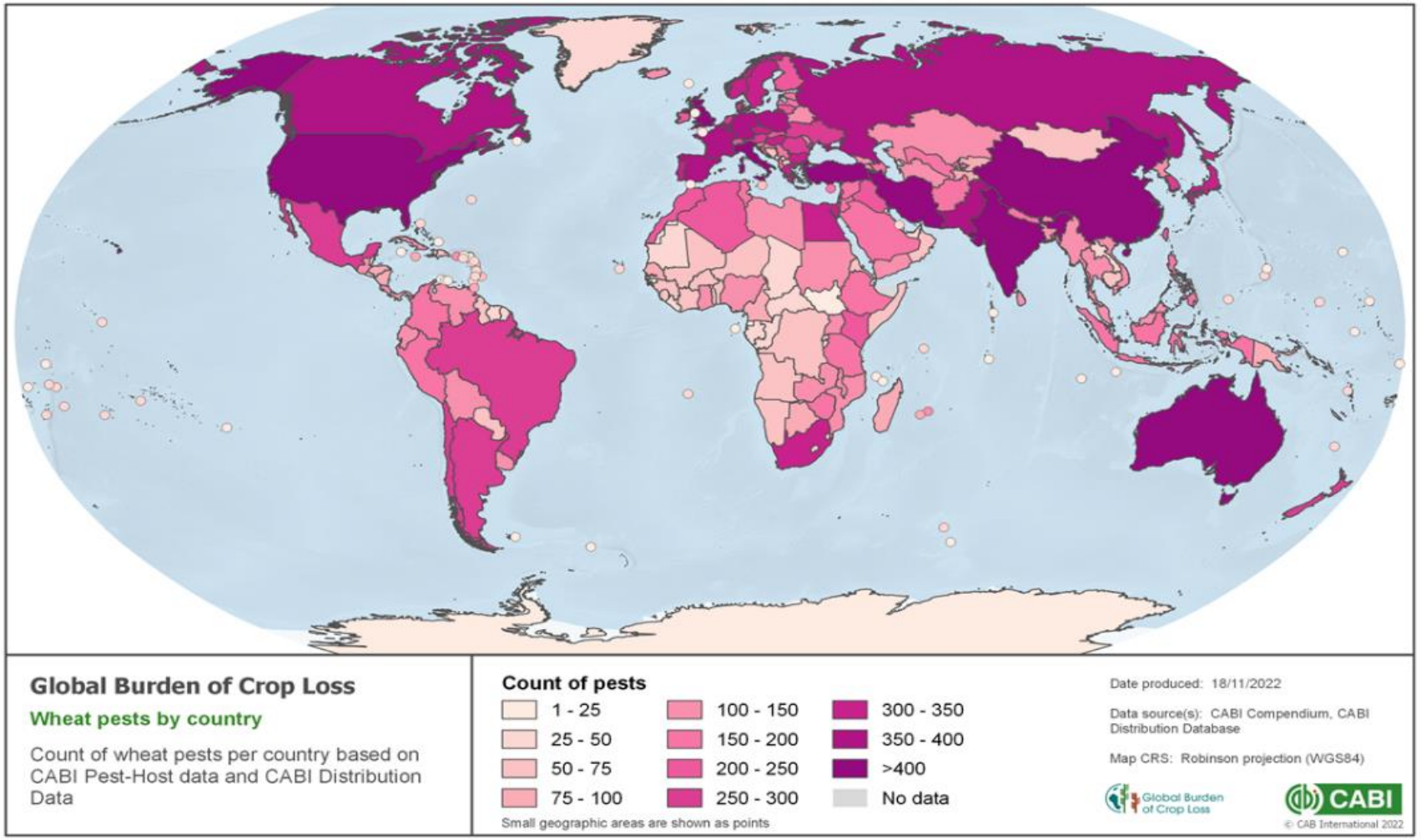
POMS – Plantwise Online Management System

Plantwise Clinic Data



Plant clinics - Global

CABI Crop Protection Compendium data



Abiotic impacts
and agricultural issues associated with climate change

Climate Change

- Increase in global temperature
- Increase in extreme weather events
- Changing seasonal pattern of weather

Effects on Agriculture

- Unpredictable growing conditions
- Changes to distribution of pests
- Ecosystem level effects- increase pest outbreaks

Effects to farmers

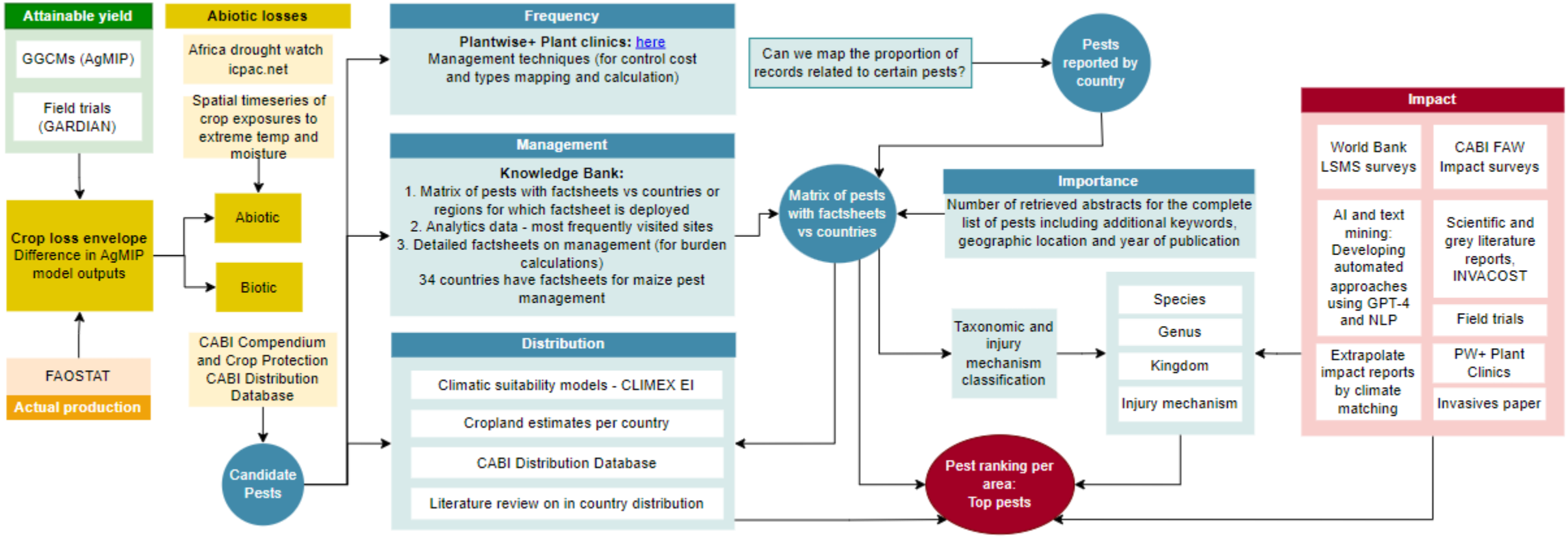
- Historical practises may no longer be effective
- Potential yield losses
- Increased costs
- Loss and damage to assets

Economic Burden

- Pesticide application rates by crop and country
- Labour cost
- Crop replacement cost
- Irrigation cost

- Environmental externalities: GHG emissions, pollution, freshwater use

Apportioning biotic losses - Kenya

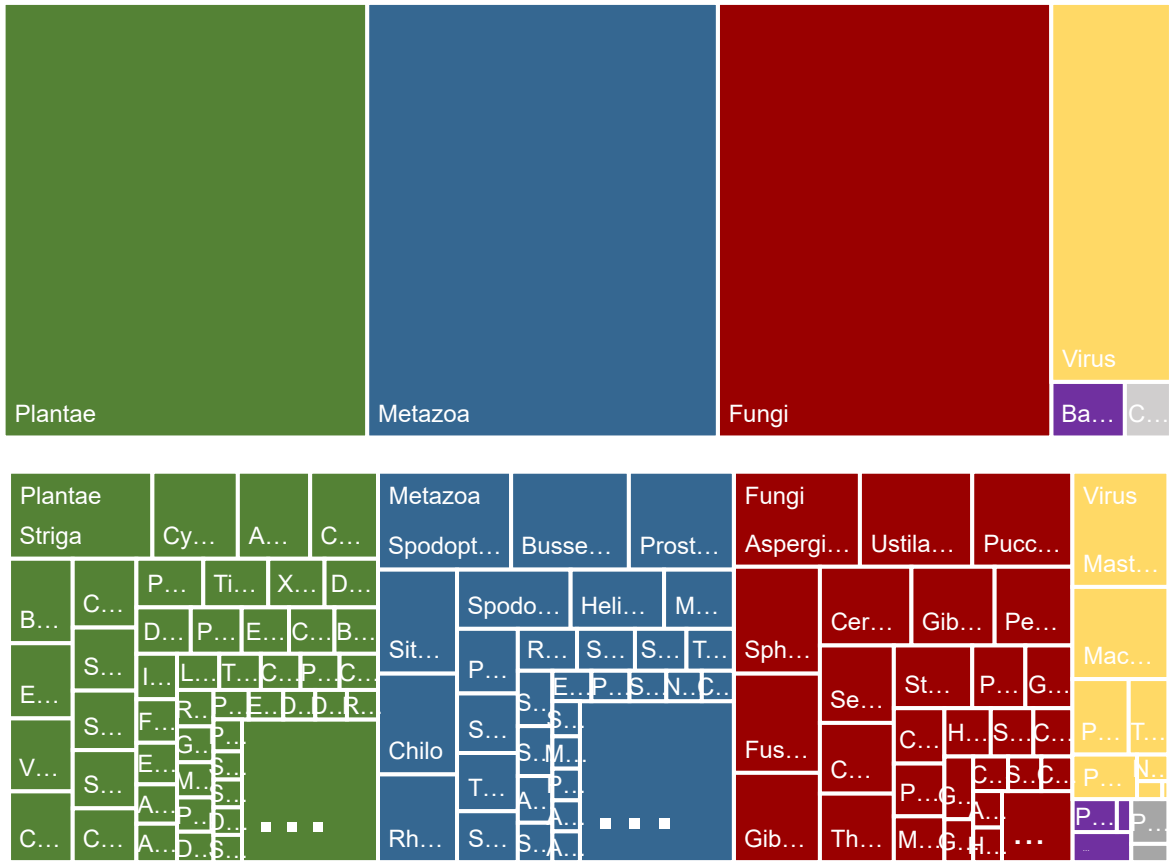


Estimates of maize yield losses in Kenya and key biotic constraints

Attainable yield and loss estimates

Attainable production 2010 2015	4,230,077 t 4,419,416 t
Actual production FAO 2010 2015	3,464,598 t 3,825,092 t
Total loss envelope 2010 2015	765,479 t 594,324 t

Key biotic factors – by group and genus



Our current 3-year project plan

Foreign, Commonwealth & Development Office

WORK PACKAGES

1. Global country-level economic burden estimates for five crops
2. Robust **data management plan** and **data infrastructure** capable of storing a large quantity of heterogenous and relational data to drive models.
3. **Business model & sustainability plan**, including governance and financial considerations, to ensure the long-term viability of GBCL.
4. **Dissemination & uptake** via open access papers, interactive dashboard and policy engagement.

DELIVERABLES

1. From 2024 to 2026 the Global Burden of Crop Loss (GBCL) will deliver an authoritative, data driven service providing trusted metrics on the magnitude, drivers, and burden of crop loss across geographies and crops, at a global scale.
2. GBCL will deliver economic burden estimates for three major global crops and two significant tropical crops to generate actionable insights.
3. Closely work with key end-users and stakeholders to improve uptake of information and change behaviours to improve how resources are allocated to combat food insecurity.
4. Prioritising sustainability and innovative business models and approaches will guarantee sustained impact and the long-term viability of the initiative for lasting global impact.

Work Package 1: Burden Estimates

Global – main cereal crops


Wheat


Maize


Rice

Regional – tropical crops


Cassava


Banana

Deliverables

- Attainable yield estimates
- Crop loss envelope estimates
- Attribution of crop loss to abiotic/biotic factors
- Economic burden estimates

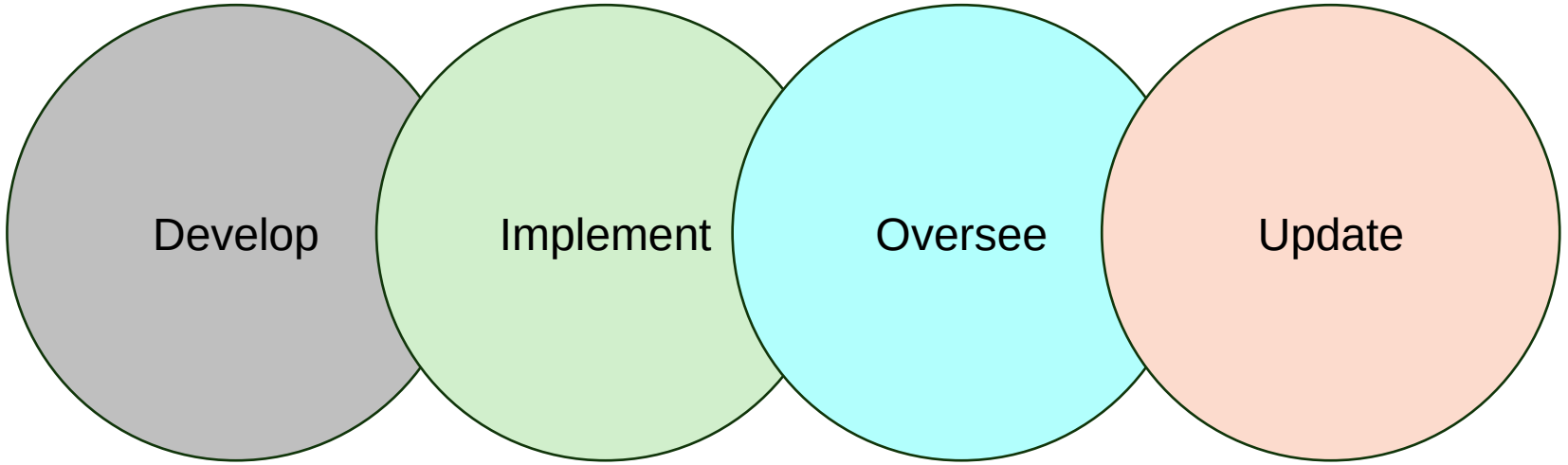
Case studies countries

Deliverables
Three use cases presented where we use granular country level data to **develop methodological approaches** to detailed attribution of losses focusing on biotic factors

Likely case countries:
Ghana – cassava and maize
Colombia - banana

Objective 2 – Data Management

Reliable data infrastructure is available to support data processing, data sharing and burden estimate calculation in line with the FAIR data principles

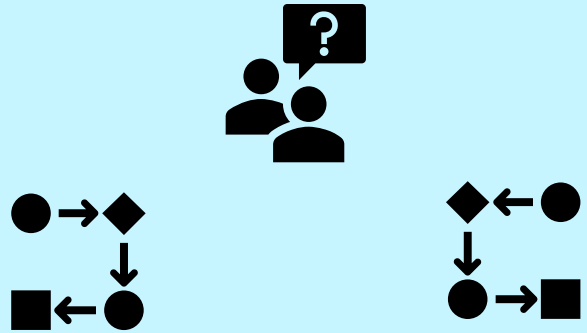


Objective 3 – Sustainability Plan

Business model & sustainability plan, including governance and financial considerations, to ensure the long-term viability of GBCL.

Use Insights

Business Model / Sustainability Plan



Governance Structure

Objective 4 – Dissemination & Uptake

Interactive Dashboard

Policy Documents

Communications Plan

Open Access Paper

CABI is an international intergovernmental organisation, and we gratefully acknowledge the core financial support from our member countries (and lead agencies) including:

Bill & Melinda Gates foundation

The Alan Turing Institute AI UK

UKaid from the British people

Foreign & Commonwealth Office

Ministry of Agriculture and Rural Affairs, People's Republic of China

Australian Government Australian Centre for International Agricultural Research

Agriculture and Agri-Food Canada

Ministry of Foreign Affairs of the Netherlands

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Agency for Development and Cooperation SDC