Target Population Environments and Pest Distribution Modelling: An Approach towards Pest Prioritization and Preparedness

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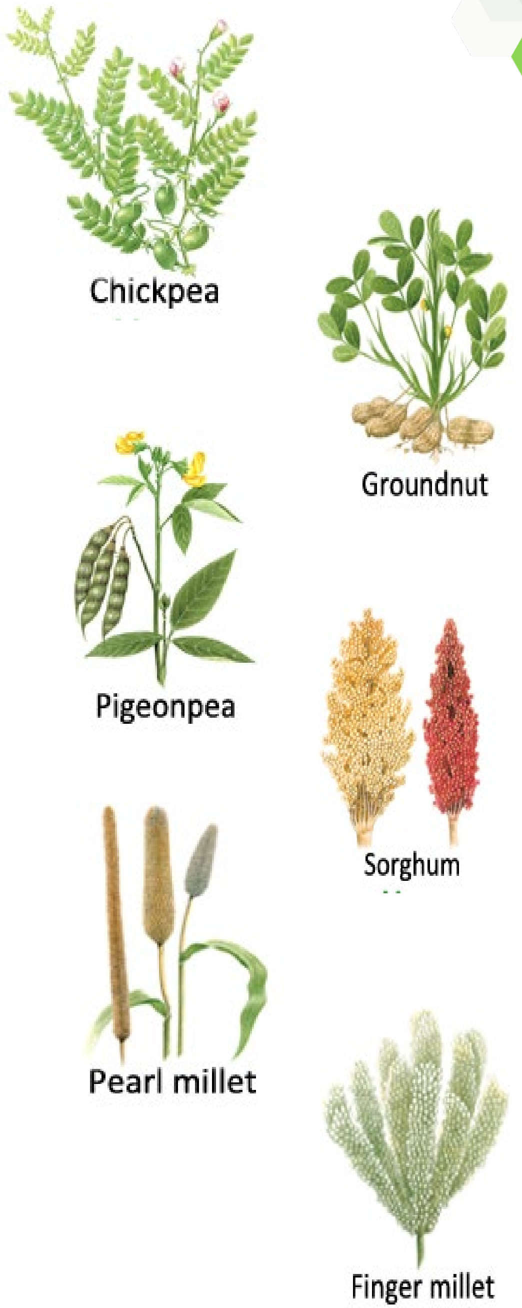
Annual Meeting of the International Pest Risk Research Group,
3-6 September 2019, Poznan, Poland

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

ICRISAT locations in the Semi-Arid Tropics



ICRISAT Works

- Breeding for Crop Improvement
- Genomics and Trait discovery
- Innovative systems for Dryland
- Integrated Crop Management
- Market and Agribusiness
- Gender studies and Smart food
- Digital & climate smart agriculture

Integrated Crop Management

- ✓ Host plant resistance (HPR)
- ✓ Diagnostics and surveillance
- ✓ Pest population dynamics and Multi-location testing
- ✓ Virulence analysis and Patho-genomics
- ✓ Biological Control
- ✓ Mycotoxins
- ✓ Climate change & emerging diseases

Understanding the Context

- Failure of genotypes/variety against pest and diseases under field conditions
- Evolution of new race/strains in pathogens
- **Minor pest are becoming major pests**
- **Transboundary pest & diseases**
- **Climate vulnerabilities & shock events**
- Inadequate knowledge on pest among farmers
- **Lack of preparedness and climate change adaptation strategies**

Current estimates of climate change indicate an increase in global mean annual temperatures of 1.5°C by 2030-52 and 3°C by 2100.

Variability in rainfall pattern is expected to be high.

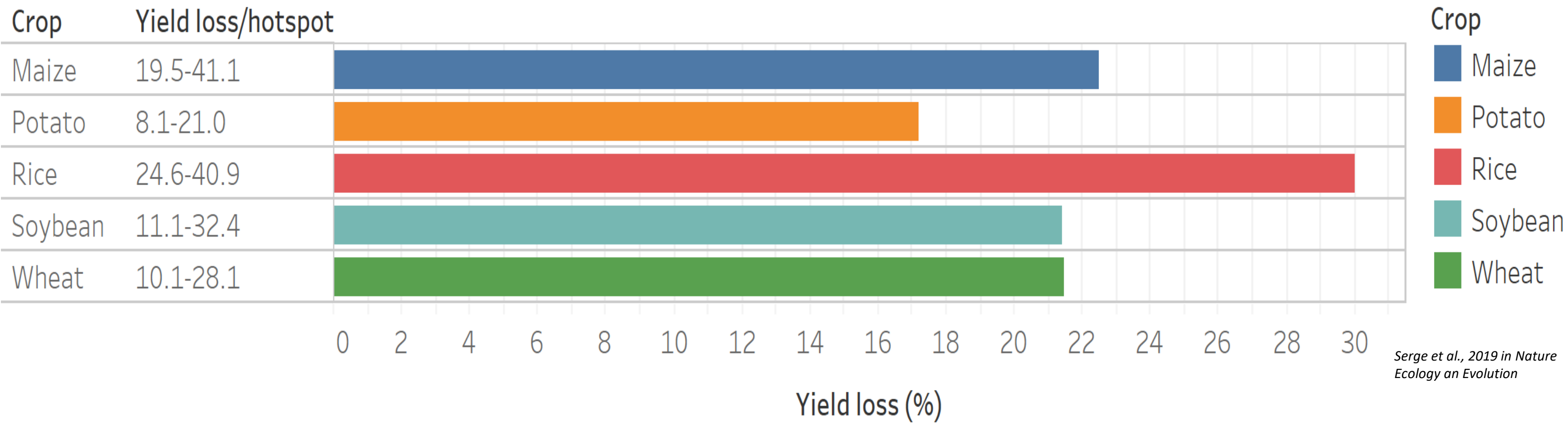
(CO_2 and O_3) would result in increase in global precipitation of 2 ± 0.5°C per 1°C warming.

Impact of Climate Change on Agricultural Pests and Diseases

Climate change and transboundary agricultural pests and diseases (P&D) amount to an estimated 1/6th of farm produce losses globally each year.

(https://ccafs.cgiar.org/)

Overall losses in attainable yield due to P&D are far greater in Asia and Africa impacting smallholder farmers' ability to feed their families.



Serge et al., 2019 in Nature Ecology an Evolution

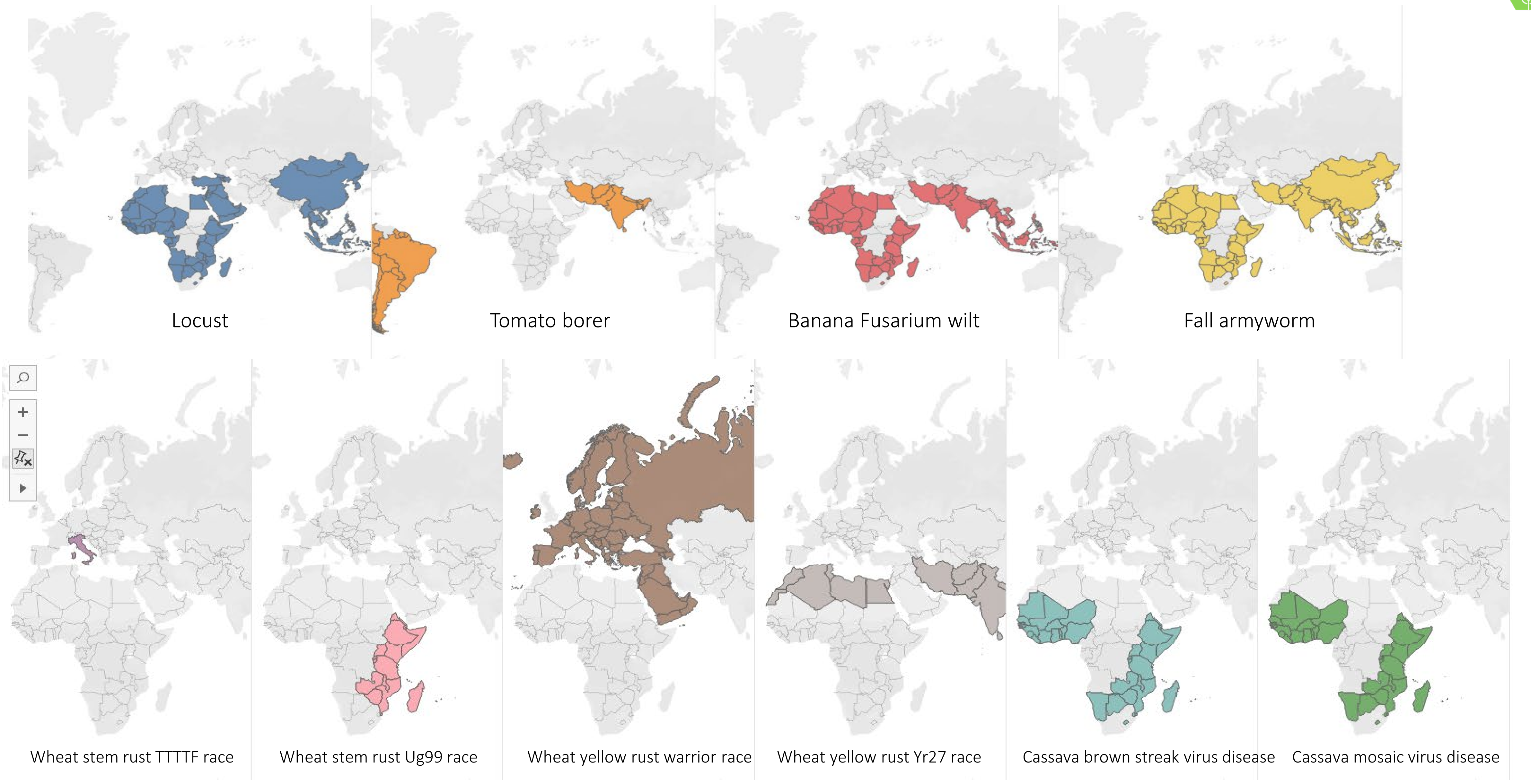
" Worldwide major yield losses by P&D are estimated to be 21.5% in wheat; 30. 0% in rice; 22.6% in maize; 17.2 % in potato and 21.4% in soybean annually "

"Africa has the highest percentage of crop losses due to climate change (49 %) followed by Asia (47 %), Soviet Union (former) and Latin America (41 % both)"

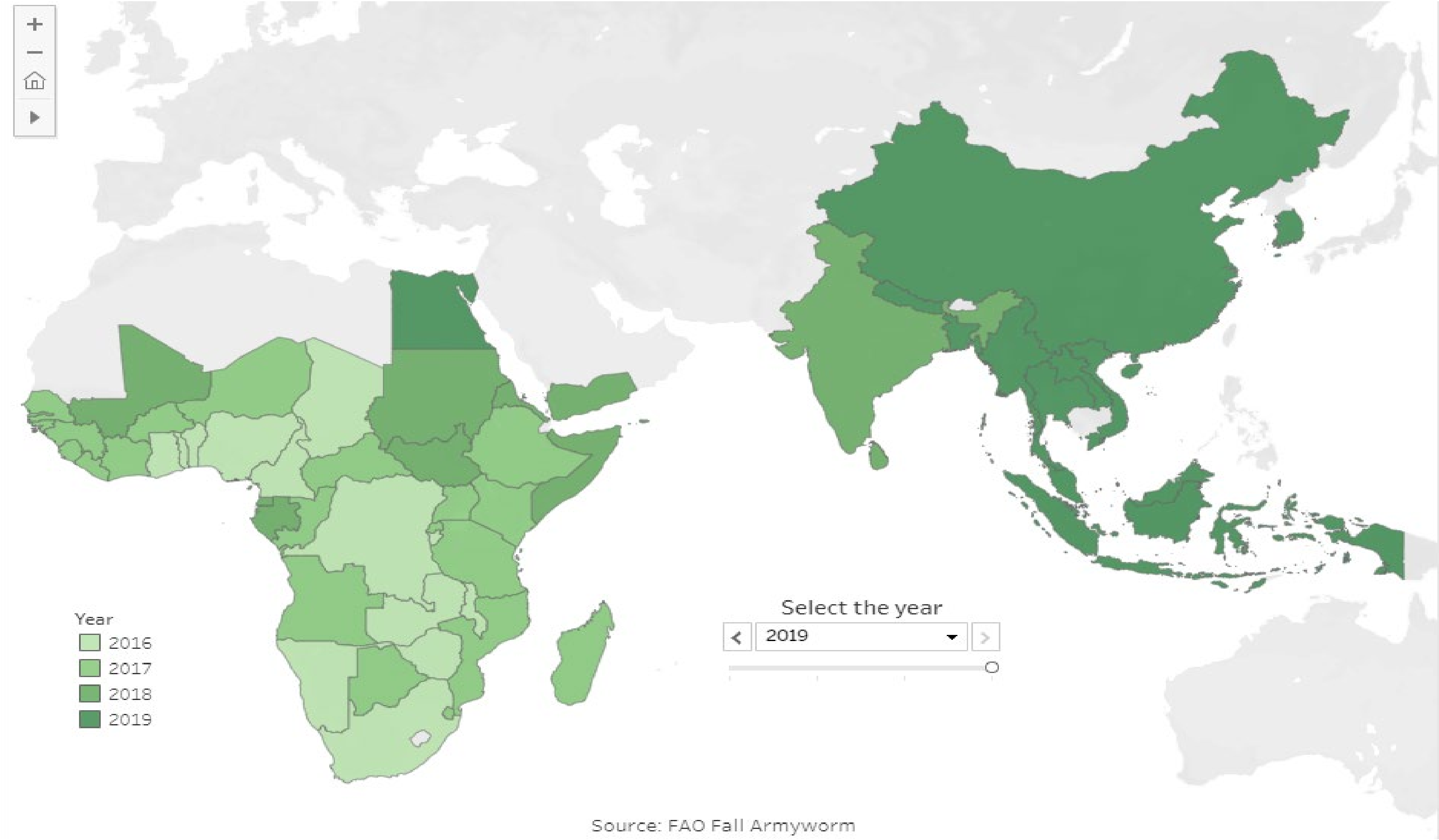
What are consequences of climate change on agricultural crop pests and diseases?

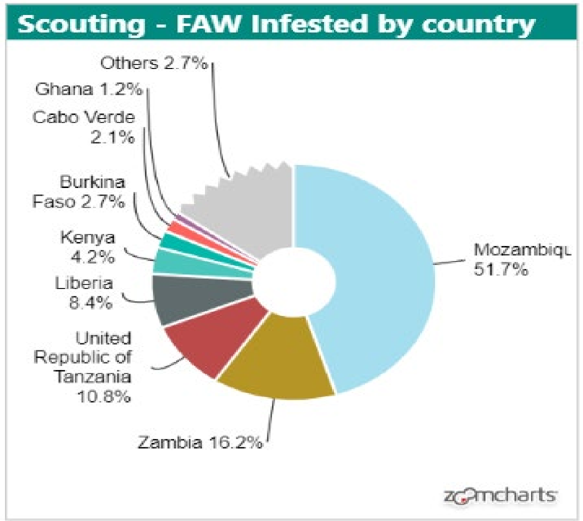
- Rapid geographical expansion of existing Pests and Diseases
- Disruption of biological synchrony and Promotion of minor pests to primary pests
- Increased damage potentials of new invasive alien species
- Changes in population dynamics and host plant resistance
- Accelerated pest development leading to more pest cycles per season
- Pesticide resistance and ecological imbalance

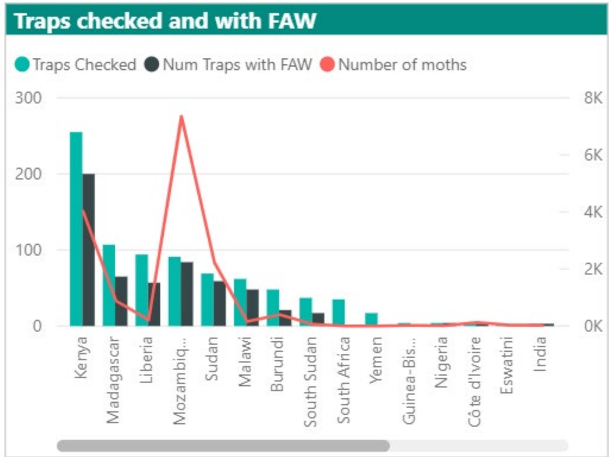
Emerging Transboundary Pest and Diseases



Epidemics of fall armyworm (FAW)







Center of Excellence on Climate Change Research for Plant Protection (CoE-CCRPP)

The Center of Excellence on Climate Change Research for Plant Protection (CoE-CCRPP) is a joint initiative of Department of Science and Technology (DST) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Its focus is to develop a framework and create facilities for climate change adaptation strategies for Pests and Diseases.

The Consortium Approach

The multilateral research institutes working group articulated to increase the impacts of climate change on agriculture in an inclusive manner with key audience (adaptation funding entities, planners, policymakers and practitioners) at national and regional level (NARS, ARIs and CGIAR).

Our Holistic Approach on pests & diseases science

Pest distribution and simulation for identifying risk areas

- Establishment of appropriate databases for weather & P&D
- Spatial and temporal distribution of P&D under future climatic scenarios
- Identify P&D hot spots/ alarm zones to map risk areas
- Develop and validate weather-based P&D forecasting systems
- Scaling up of forecasting models to other pathosystems

Developing adaptation strategies to minimize crop losses

- Analysis of key climatic drivers leading to potential outbreak of P&D
- Study population dynamics of P&D under simulated conditions
- Impact of altered climatic variables on HPR/ gene expression
- Develop crop-pest interaction deterministic models for P&D based on population biology and dynamics

Developing weather- based plant protection advisory tools

- Develop web/mobile based location-specific weather-based plant protection advisory
- Dissemination of advisory for extension functionaries as well as farmers
- Linking the decision support system with appropriate control measures

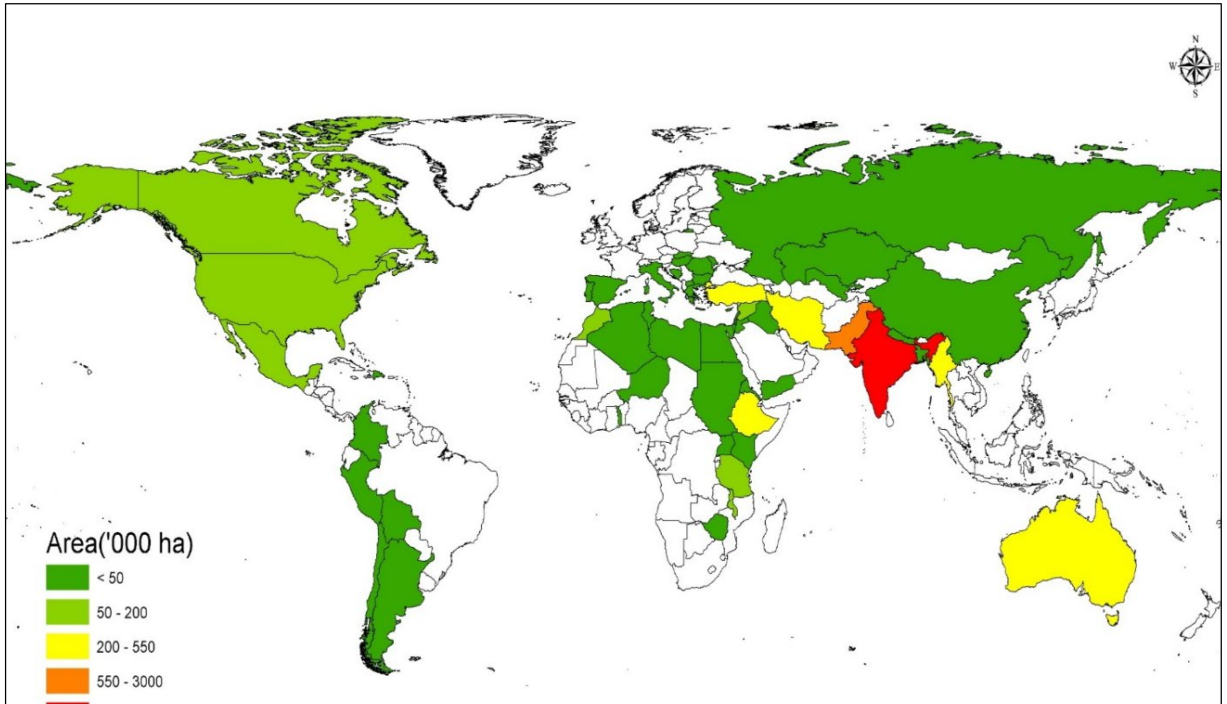
Capacity building

- Training/ education on climate change adaptation and climate-smart pest management
- Strengthen NARS in transforming agriculture for climate resilience
- Community of practices for P&D management
- Student exchange- promotion of climate change adaptation

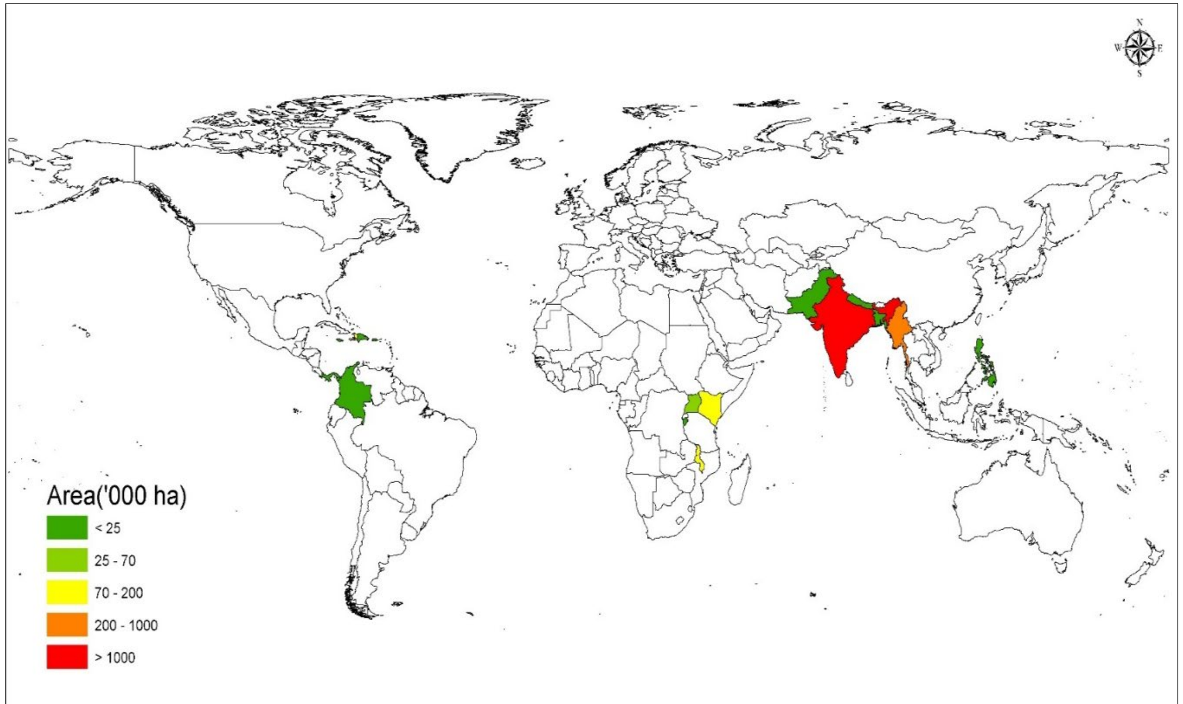
Target insect pests and diseases	Crop	Critical crop growth stage	Critical weather	Responsible Institute*
Dry root rot (*Rhizoctonia bataticola*)	Chickpea	Flowering to podding	High temperature >30°C and soil moisture stress	ICRISAT
Pod borer (Helicoverpa armigera)		Vegetatative to podding	Maximum temperature >27- 28°C	
Phytophthora blight (*Phytophthora cajani*)	Pigeonpea	Seedling to flowering	High rainfall leading to temporary flooding, high humidity	
Pod borer (*Maruca vitrata*)		Flowering to podding	Rainfall coupled with high humidity with temperature >25°C	
Blast (*Magnaporthe oryzae*)	Peal millet and Rice	All growth stages infect all aerial parts of plant	Cool temperature and high moisture coupled with cloudy overcast weather and dew.	ICRISAT & IIRR
Plant hoppers (*Nilaparvata lugens, Sogatella furcifera*)	Rice	All growth stages	Cold and dry or hot and wet	IIRR
Sheath blight (*Rhizoctonia solani*)		Vegetative to flowering	Maximum temperature ~ 34˚C/minimum temperature ~26˚C and high relative humidity (more than 90%).	
Mungbean Yellow Mosaic Virus (MYMV) White fly (*Bemecia tabaci*)	Mungbean	Vegetative stage	Critical weather window is 29-33 SMW & maximum temperature alone had direct influence on disease	PAU
Pink bollworm (*Pectinophora gossypiella*)	Cotton	Flowering to boll development	Maximum temperature 33- 34°C during 40th SMW, minimum temperature <17°C in 44th SMW, humidity <70%	UAS
Diamond back moth (DBM) (*Plutella xylostella*)	Crucifers	Flowering to podding	High temperature coupled with moisture stress	TNAU
Aphids (*Aphis craccivora*)		Seedling to vegetative	dry hot weather (~27°C)	

*ICRISAT: International Crops Research Institute for the Semi-Arid Tropics, Patancheru; IIRR: Indian Institute of Rice Research, Hyderabad; PAU: Punjab Agriculture University, Ludhiana; UAS: University of Agriculture Sciences, Raichur; TNAU: Tamil Nadu Agricultural University, Coimbatore.

Chickpea & Pigeonpea



Chickpea



Pigeonpea

Chickpea Pest and diseases in India & Africa

- ❑ Fusarium wilt (*Fusarium oxysporum f. sp ciceris*)
- ❑ Collar rot (*Sclerotium rolfsii*)
- ❑ Dry root rot (*Rhizoctonia bataticola*)
- ❑ *Ascochyta blight* (*Ascochyta rabiei*)
- ❑ *Botrytis grey* mould (*Botrytis cinerea*)
- ❑ Pod borer (*Helicoverpa armigera*)
- ❑ Beet armyworm (*Spodoptera exigua)*
- ❑ Bruchids, (*Callosobruchus spp)*

Question?

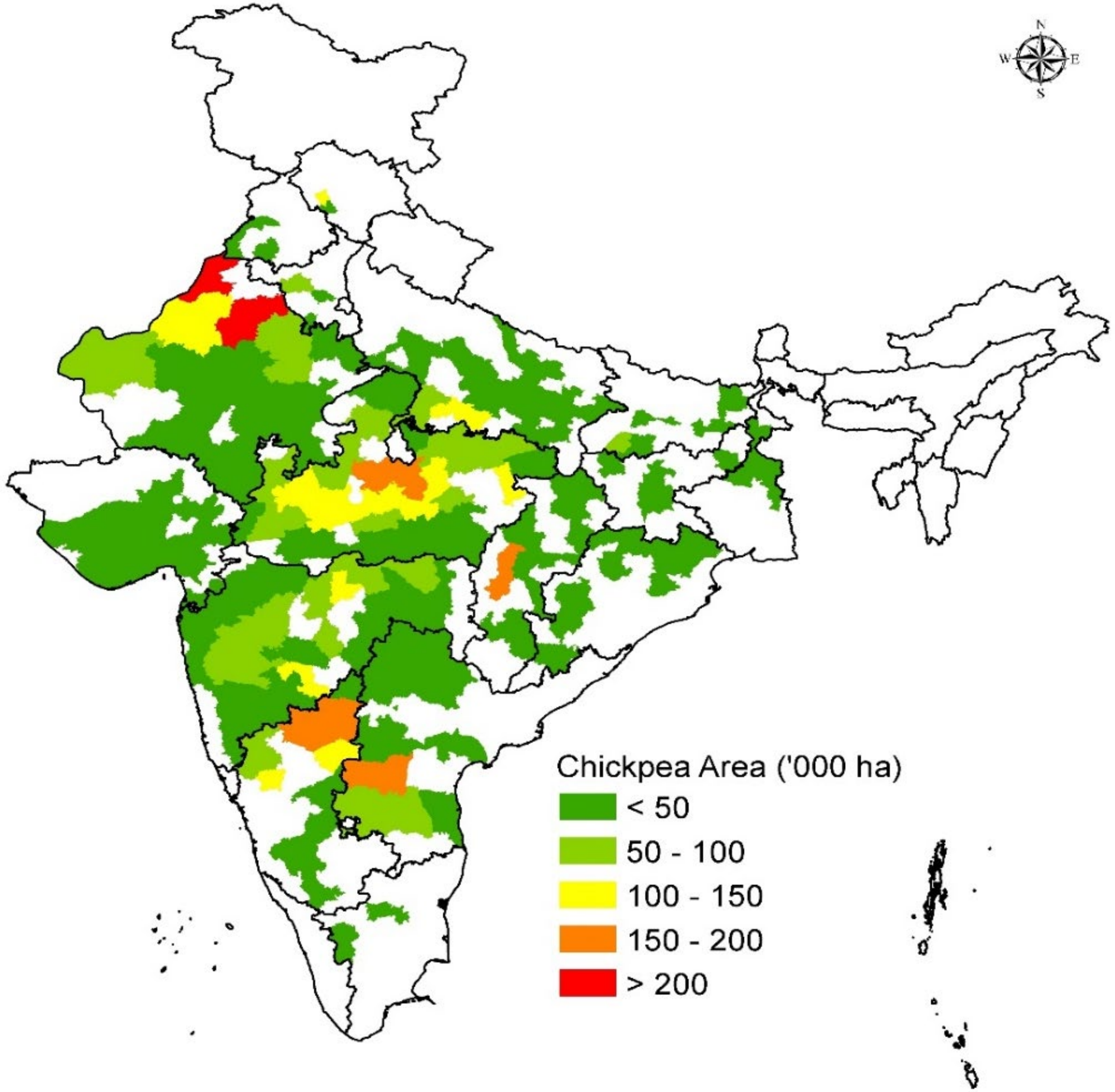
What are resistance breeding program and decision making abilities real-time pest management?





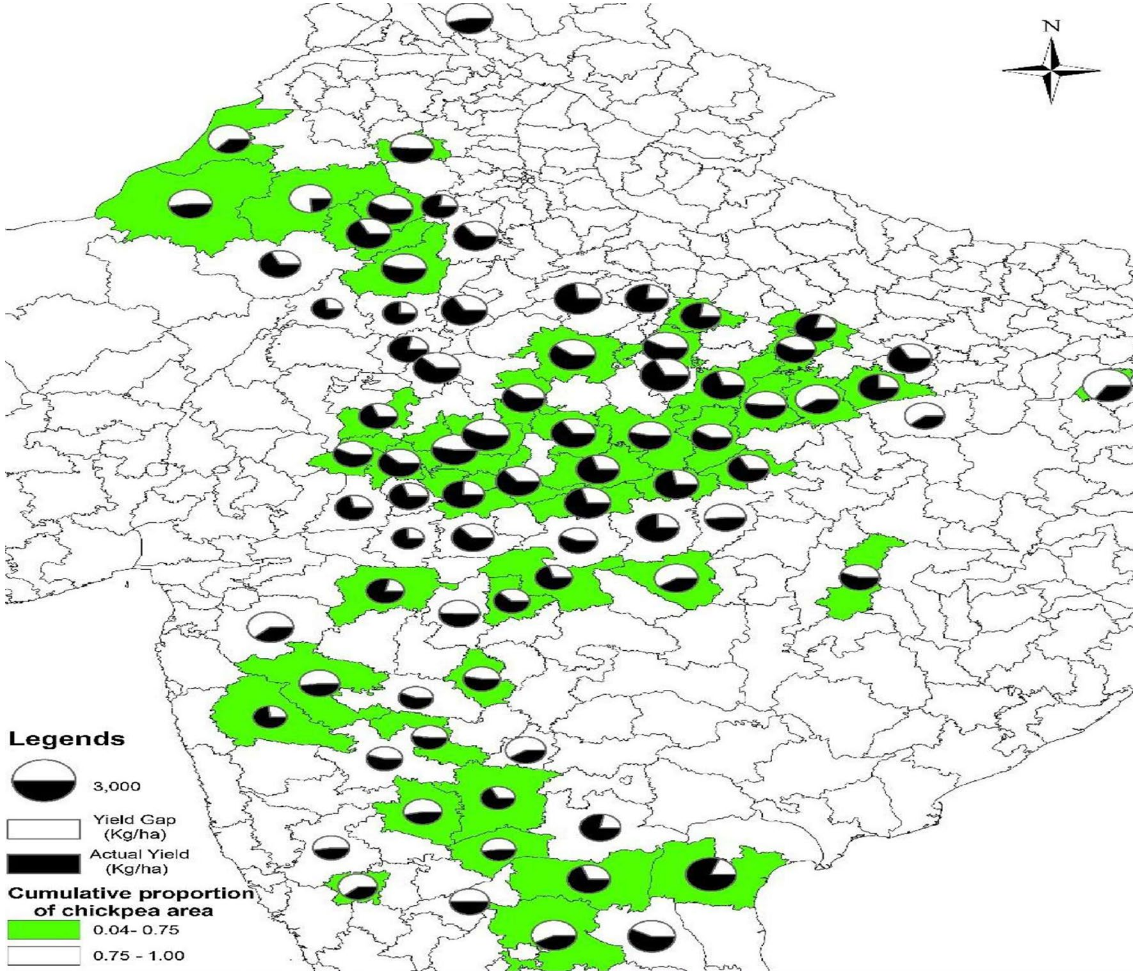
Chickpea status of India

- Collected the time series data of district wise chickpea production and productivity data (2000-15)
- Chickpea Area= 7487.43 (000ha)
- Chickpea production= 6350.601 (000tones)
- 82 districts cover the 85% of area and 83.4 % of total production



Simulation and yield gap analysis

- **SSM-ilegume-chickpea models** (Models captures genotype and bio-gio-physical factors of environment)
- The time series data of district wise chickpea production and productivity data
- Available and syntactic weather (MarkSim and AgMERRA) were used to simulate the models
- Soil data were compiled from the national Bureau of Soil survey and land use Planning and International soil reference and information center

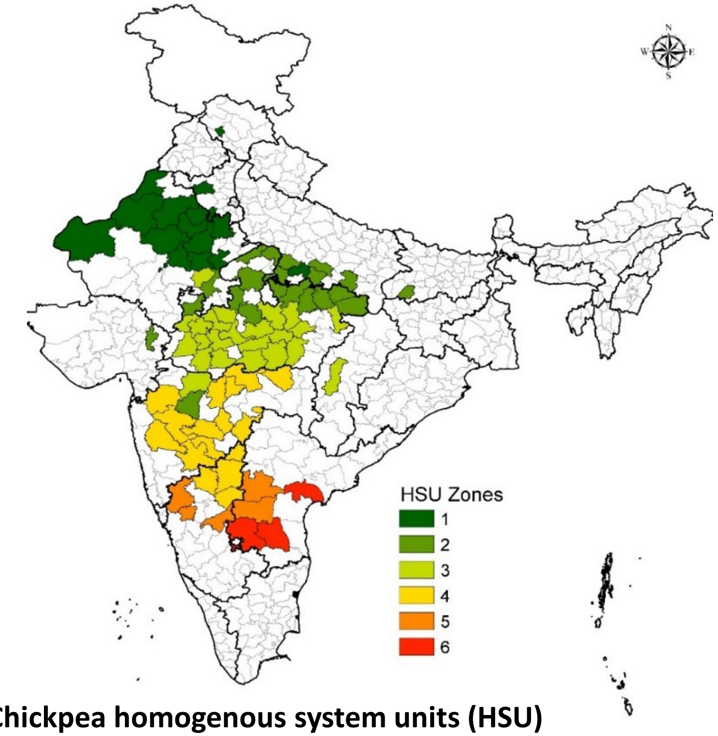


Simulations and Yield gap analysis

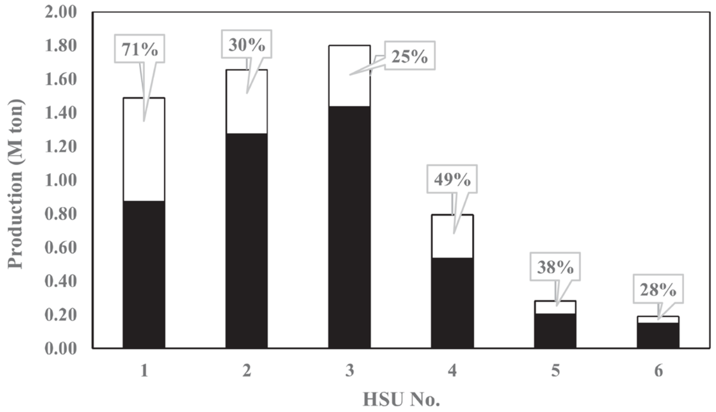
- Potential yield
- Water limited potential yield
- Partially-irrigated yield potential

Identification of Homogeneous Systems Units (HSU) across production environment

- Based on **Bio-geo-physical properties** (Latitude, temperature rainfall, evaporations soil WHC and depth, actual yield, crop characters, irrigation scenarios and *etc.*) and **management strategies**.
- We Identified **“6” Homogenous System Units**
- Model predicts that India has the ability to produce 40% more chickpea
- North- western and central mega environments was too crude to represent effective breeding targets



Chickpea homogenous system units (HSU)



Bar chart shows the average of chickpea production from 2000-15 (dark parts) and the percentage of production increase needed to achieve 85% of (white parts) with in each of the identified HSU

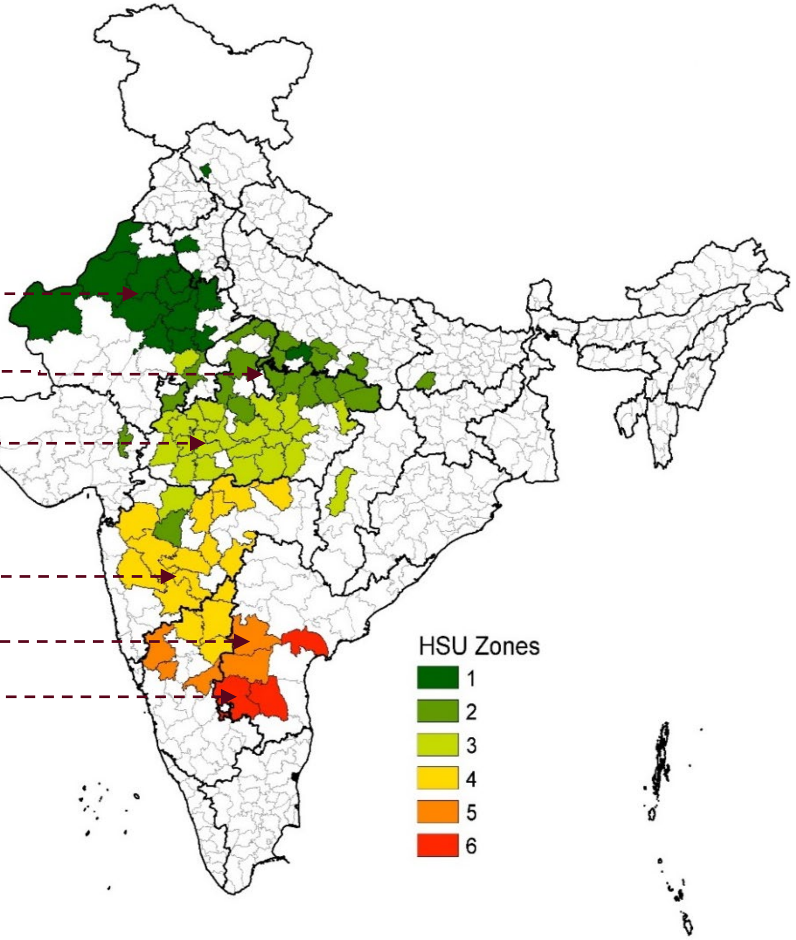
Chickpea pest and disease layering on target population environments (TPEs)

1) Ascochyta blight
2) Fusarium wilt
3) Helicoverpa pod borer

1) Dry root rot
2) Collar rot
3) Fusarium wilt
4) Helicoverpa pod borer

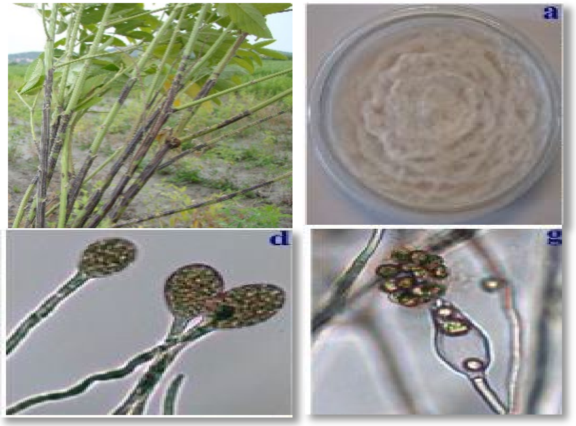
1) Fusarium wilt
2) Dry root rot
3) Rust
4) Helicoverpa pod borer
5) Beet armyworm

1) Fusarium wilt
2) Rust
3) Helicoverpa pod borer
4) Beet armyworm



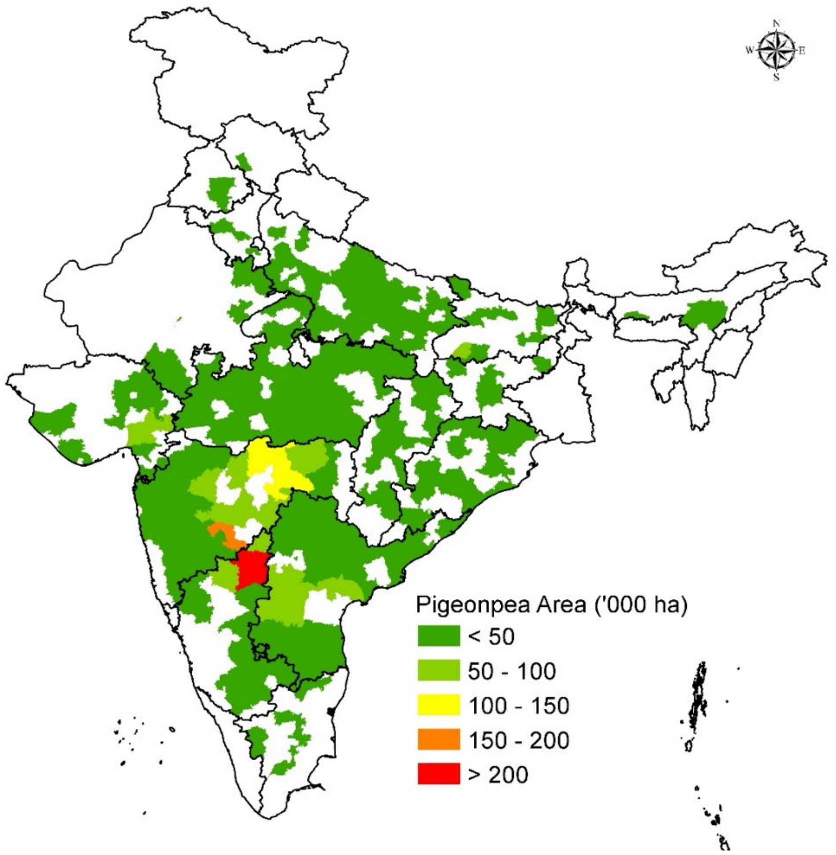
Pigeonpea pest and diseases in India & Africa

- Fusarium wilt *(Fusarium udum Butler*)
- *Phytophthora* blight (*Phytophthora drechsleri Tucker f.* sp. *Cajani*)
- Sterility mosaic disease (Pigeonpea sterility mosaic virus)
- *Helicoverpa* pod borer (*Helicoverpa armigera*)
- *Maruca* pod borer (*Maruca vitrata*)
- Pod Fly (*Melanagromyza obtusa*)
- Pigeonpea plume moth (*Exelastis atomosa Wals.*)

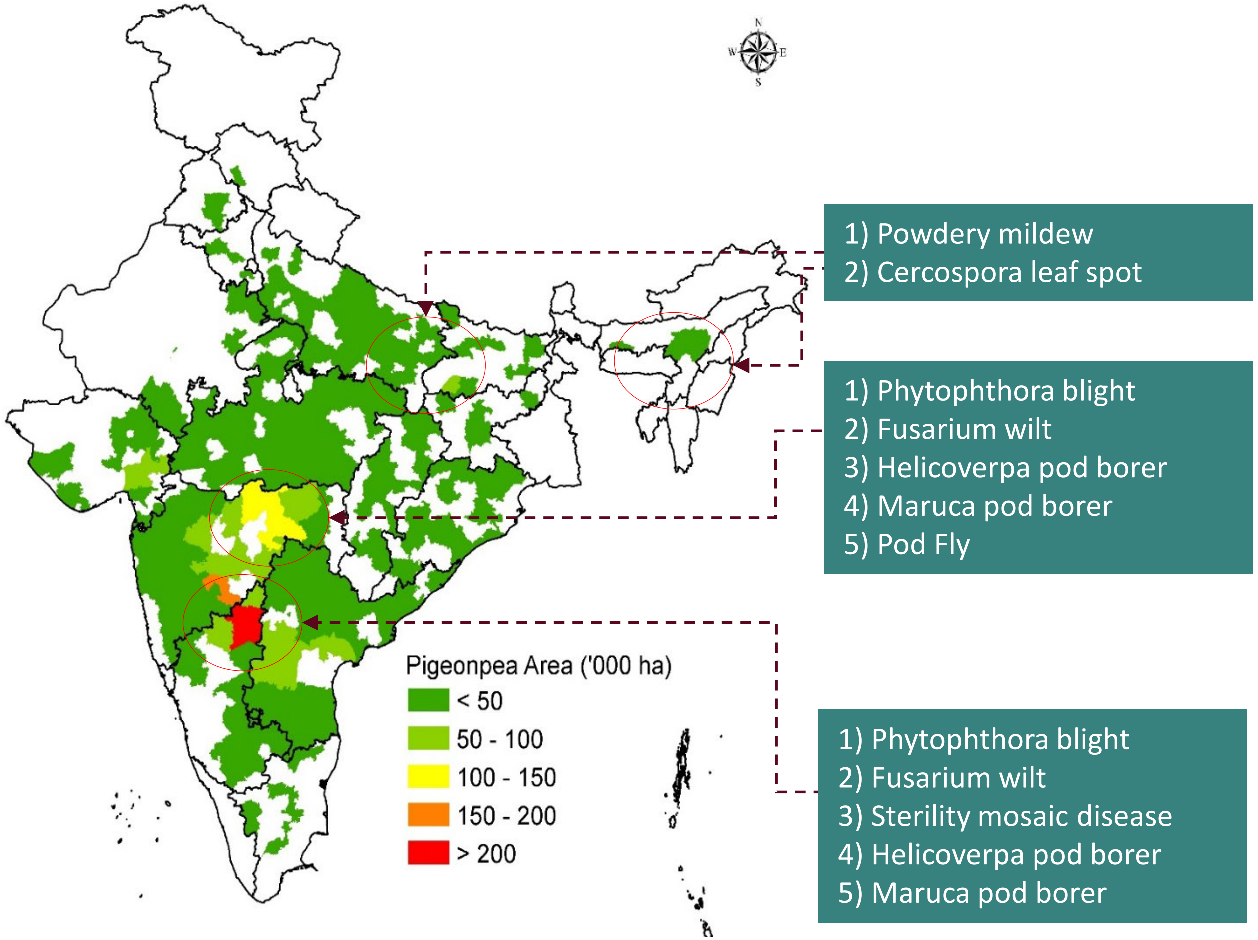


Pigeonpea status of India

- Collected the time series data of district wise chickpea production and productivity data (2000-15)
- Pigeonpea area= 3575.79 (000ha)
- Pigeonpea production= 2466.76 (000tones)
- 51 districts cover the 85% of area and 74.4 % of total production

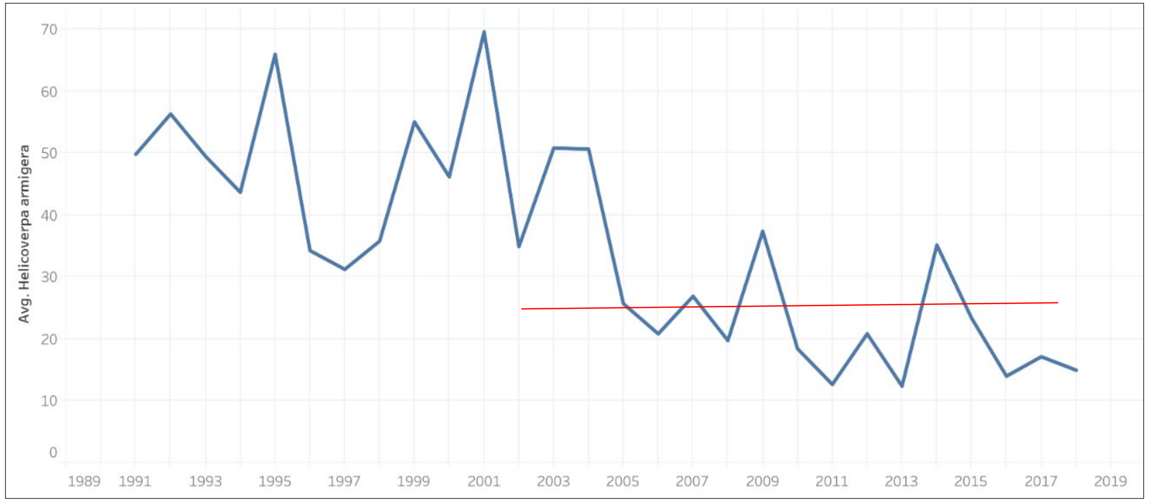


Pest and disease layering on target population environments (TPEs) and monitoring

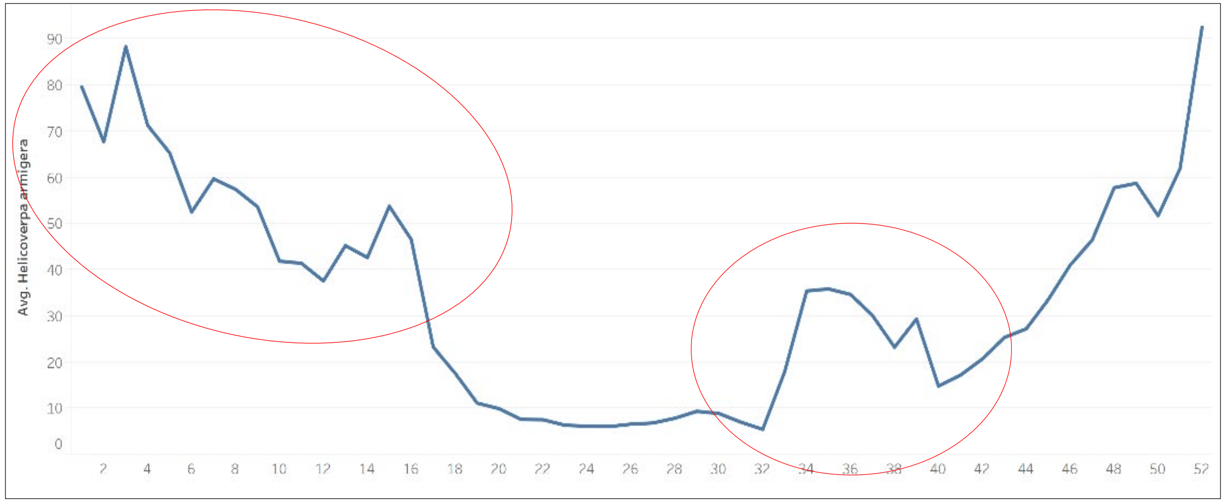


ICRISAT historical *Helicoverpa armigera* insect population pattern (Pheromone trap & surveillance data)

Pheromone trap (No. Insect/week)

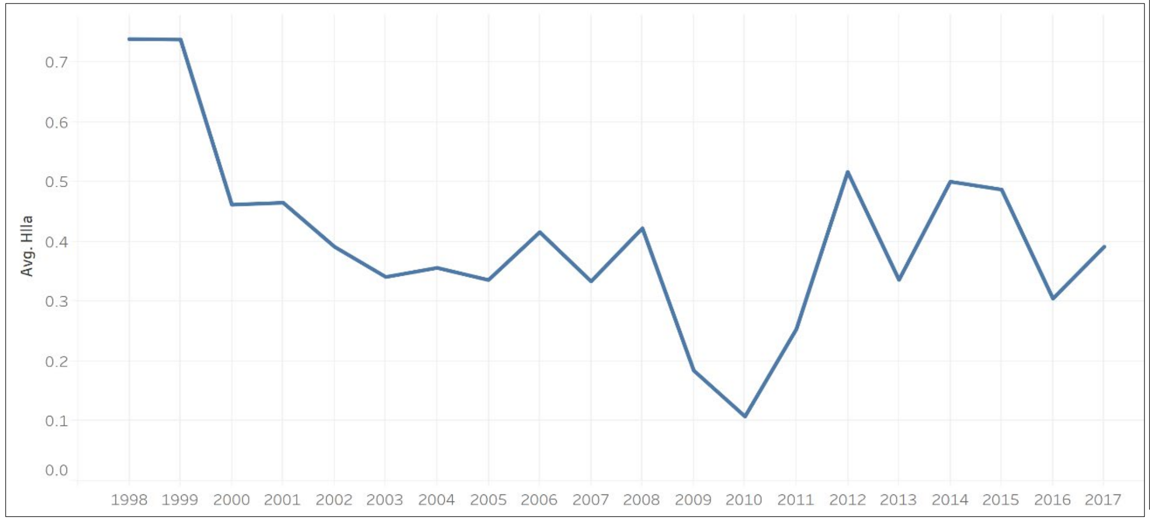


Year

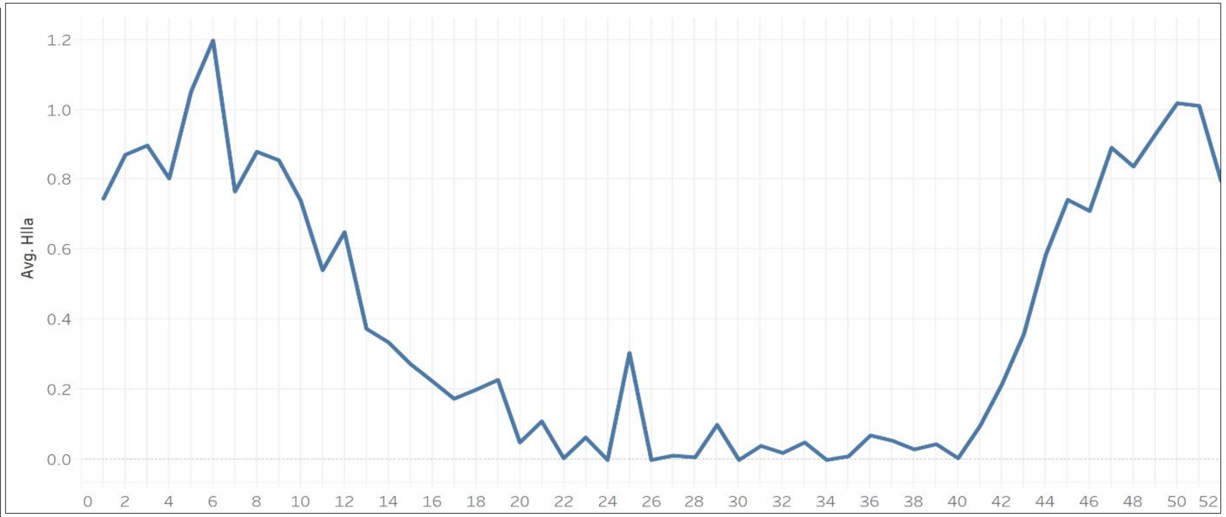


week

Helicoverpa field incidences



Year

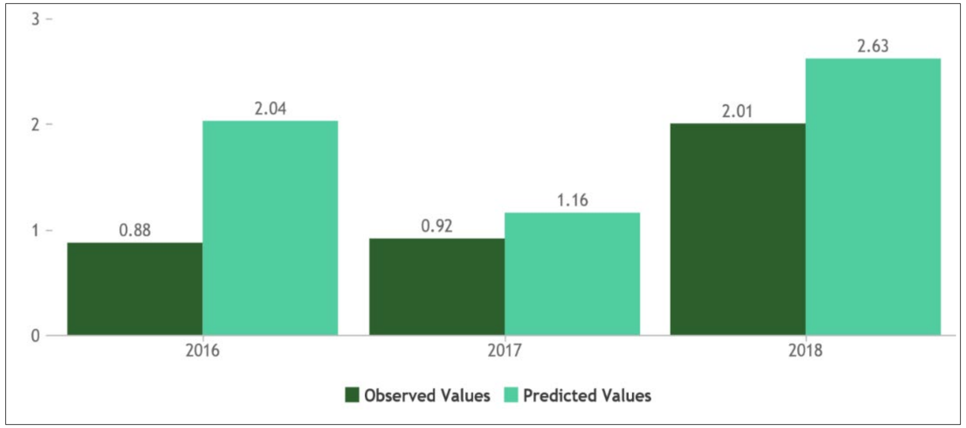


week

Development of weather based forewarning model for Chickpea *Helicoverpa armigera*

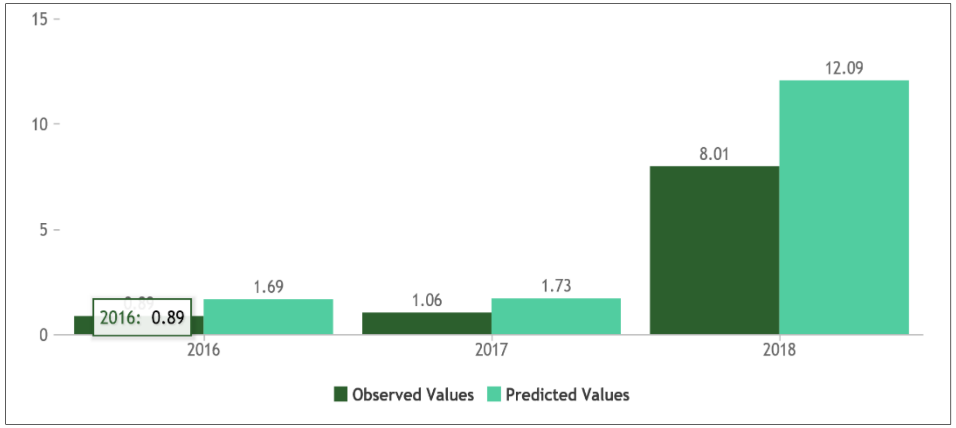
Models for maximum population of Helicoverpa along with coefficient of determination

Pest	Data used	Model	R^2
Pigeon pea	25 to 33 SMW	$Y=-1853.60 - 0.19^* Z_{120} + 38.34 Z_{11} + 0.55 Z_{131} + 0.052 Z_{251}$	0.7501
Pigeon pea/ Chickpea	45 to 3 SMW	$Y=-978.72 + 0.149 Z_{130} + 0.63 Z_{131} + 0.17 Z_{141} + 2.23 Z_{251}$	0.6896



Models for maximum population of Helicoverpa (Egg and Larva) along with coefficient of determination on chickpea

Pest	Data used	Model	R^2
Chickpea (Egg)	40 to 49 SMW	$Y=0.196+ 0.00095^* Z_{361}+ 0.0007^* Z_{121}$	0.6672
Chickpea (Larva)	40 to 49 SMW	$Y= -11.035+ 0.001^* Z_{461}+ 0.151^* Z_{11}+ 0.005^* Z_{30}$	0.7532



Observed and predicted maximum population of Chickpea Pod borer at Egg & Larval stages at ICRISAT

Future steps

- ✓ Target population environments (TPEs) for mandate crops
- ✓ Generate strategic knowledge on pest distribution modellingand pest vulnerability
- ✓ Pest prioritization and real-time pest forecasting
- ✓ Preparedness and risk assessment for minor pests and transboundary pests
- ✓ Capacity building and collaboration/partnerships

1 NO POVERTY

2 ZERO HUNGER

13 CLIMATE ACTION

17 PARTNERSHIPS FOR THE GOALS

Thank You

सत्यमेव जयते
Department of Science and Technology (DST)
DST

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ICRISAT is a member of the CGIAR System Organization