

# Etat de la santé végétale et changements globaux

Colloque Santé globale et nouveaux flux  
de risques

Serge Savary, INRAE

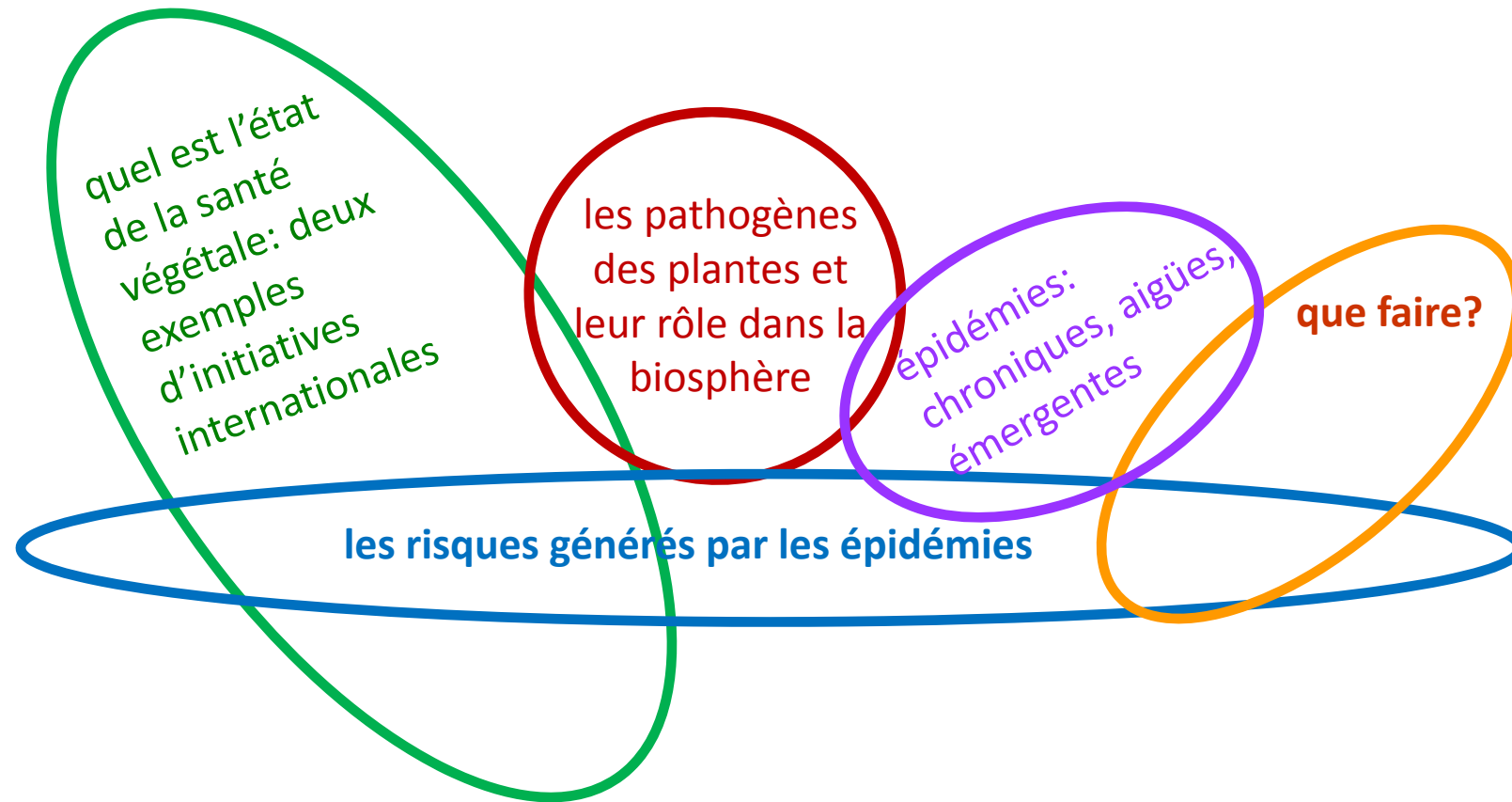
15 décembre 2020



# plan de l'exposé (principales idées)

- quel est l'état de la santé végétale: deux exemples d'initiatives internationales
- les maladies des plantes et leur rôle dans la biosphère
- épidémies: chroniques, aiguës, émergentes
- les risques générés par les épidémies
- que faire?

# plan de l'exposé (principales idées)



# état de la santé végétale

Premier exemple:

le Global Plant Health Assessment

# Evaluation mondiale de la santé des végétaux

Une évaluation internationale par des pairs de l'état de la santé des plantes dans les écorégions du monde, et des effets des maladies des plantes sur les services écosystémiques

Coordination (par ordre alphabétique):

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INTERNATIONAL YEAR OF  
**PLANT HEALTH**

2020

# Evaluation mondiale de la santé des végétaux



- une trentaine d'équipes dans le monde
- 3-4 scientifiques par équipe
- évaluations fondées sur publications
- approche inspirée du Millennium Ecosystem Assessment (2000)
- pour la santé végétale (pathogènes) seulement
- mais facteurs d'environnement (changements climatique et globaux pris en compte)

<b>System</b>
<b>Cereal systems</b>
<b>Roots &amp; Tubers</b>
<b>Banana and Plantains</b>
<b>Peri-Urban and Household Gardens</b>
<b>Forests</b>

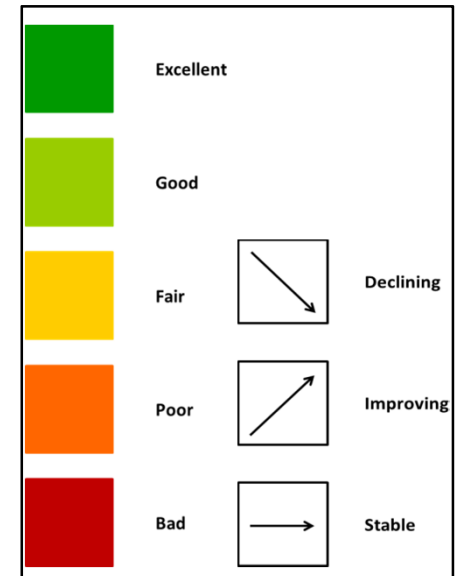
# Global Plant Health Assessment

(preliminary; work in progress – to be formally published elsewhere)

System	Plant-System	World Eco-region	Overall state of plant health	Main ecosystem services		
				Provisioning	Regulating	Culture
Cereal systems						
Roots & Tubers						
Banana and Plantains						
Peri-Urban and Household Gardens						
Forests						

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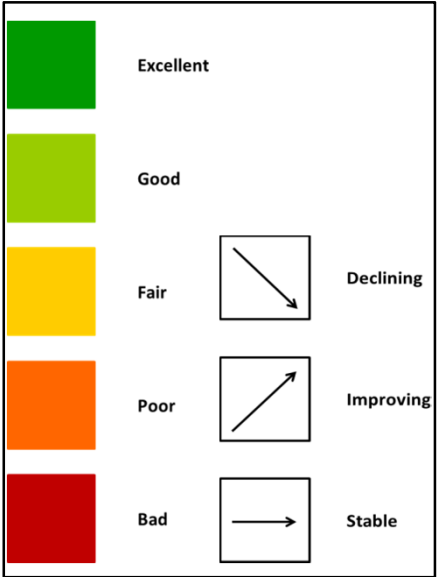














System	Plant-System	World Eco-region	Overall state of plant health	Main ecosystem services		
				Provisioning	Regulating	Culture
Cereal systems	Wheat	West Europe				
	Rice	East Asia				
	Maize	Sub-Saharan Africa				
Roots & Tubers	Potato	West Europe				
	Cassava	Sub-Saharan Africa				
Banana and Plantains	Banana and Plantains	Sub-Saharan Africa				
Peri-Urban and Household Gardens	Multiple plant species	Sub-Saharan Africa				
Forests	Multiple plant species	West Europe (Oaks)				
	Multiple plant species	Amazon				
	Multiple plant species (Myrtaceae)	Australia				

# Global Plant Health Assessment

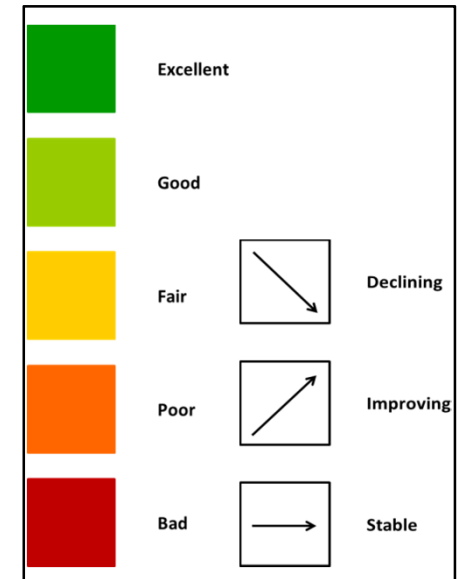
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# Global Plant Health Assessment

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System	Plant-System	World Eco-region	Overall state of plant health	Main ecosystem services		
				Provisioning	Regulating	Culture
Cereals	Maize	Sub-Saharan Africa	Good (Declining)	Good (Stable)		
			Good (Declining)	Good (Stable)		
			Poor (Improving)	Fair (Stable)		
Roots & Tubers	Potato	West Europe	Good (Declining)	Poor (Declining)		
	Cassava	Sub-Saharan Africa	Poor (Stable)	Poor (Stable)		
Banana and Plantains	Banana and Plantains	Sub-Saharan Africa	Poor (Declining)	Fair (Declining)	Poor (Improving)	Fair (Improving)
Peri-Urban and Household Gardens	Multiple plant species	Sub-Saharan Africa	Fair (Stable)	Poor (Stable)		Poor (Stable)
Forests	Multiple plant species	West Europe (Oaks)	Fair (Declining)	Excellent (Stable)	Excellent (Declining)	Excellent (Stable)
	Multiple plant species	Amazon	Fair (Stable)	Good (Stable)	Good (Declining)	
	Multiple plant species (Myrtaceae)	Australia	Fair (Stable)	Good (Stable)	Good (Stable)	Good (Stable)

Dans presque tous les cas, la santé végétale (agents pathogènes) stagne ou décline

	Excellent		
	Good		
	Fair		Declining
	Poor		Improving
	Bad		Stable

# Global Plant Health Assessment

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		Sub-Saharan Africa					
		Sub-Saharan Africa					
		Multiple plant species	Amazon				
		Multiple plant species (Myrtaceae)	Australia				

Dans beaucoup de cas, les services d' "approvisionnement" (alimentation, fibre, matériaux) stagnent ou diminuent du fait des maladies de plantes. Ceci implique des conséquences sur la sécurité alimentaire.

	Excellent		
	Good		
	Fair		Declining
	Poor		Improving
	Bad		Stable

# Global Plant Health Assessment

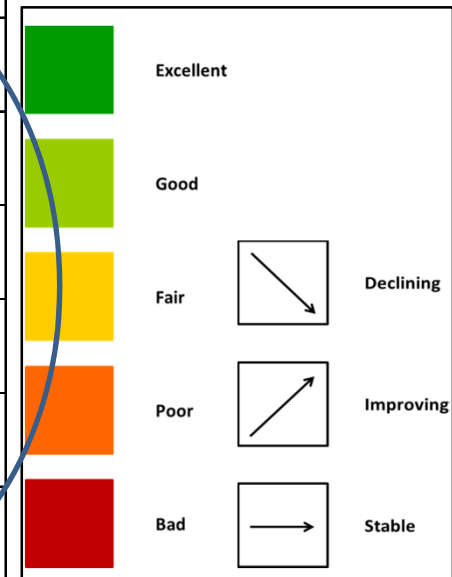
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Cereal systems	Wheat	West Europe	Good	Good		
			Good	Good		
			Fair	Fair		
Roots			Good	Improving		
			Fair	Fair		
Banana and			Improving	Fair	Improving	Improving
Peri-Urban and Household Gardens	Multiple plant species	Sub-Saharan Africa	Fair	Improving		Improving
Forests	Multiple plant species	West Europe (Oaks)	Declining	Excellent	Excellent	Excellent
	Multiple plant species	Amazon	Fair	Good	Good	
	Multiple plant species (Myrtaceae)	Australia	Fair	Good	Good	Good

Dans beaucoup de cas, les “services écosystémiques” de

- régulation des écosystèmes et
- de nature culturelle ou spirituelle

sont dans un mauvais état, déclinent, ou stagnent, du fait des agents pathogènes de plantes



# état de la santé végétale

Second exemple:

l'enquête internationale sur les pertes de récoltes causées par les pathogènes et ravageurs sur cinq productions végétales vitales pour la sécurité alimentaire

# Assessment of crop health and losses to plant pathogens and pests in world agricultural foci

Savary, S., Willocquet, L., Pethybridge, S. J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nature ecology & evolution*, 3(3), 430-439.

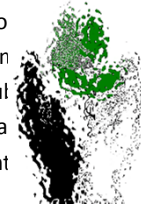


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# Assessment of crop health and losses to plant pathogens and pests in world agricultural foci

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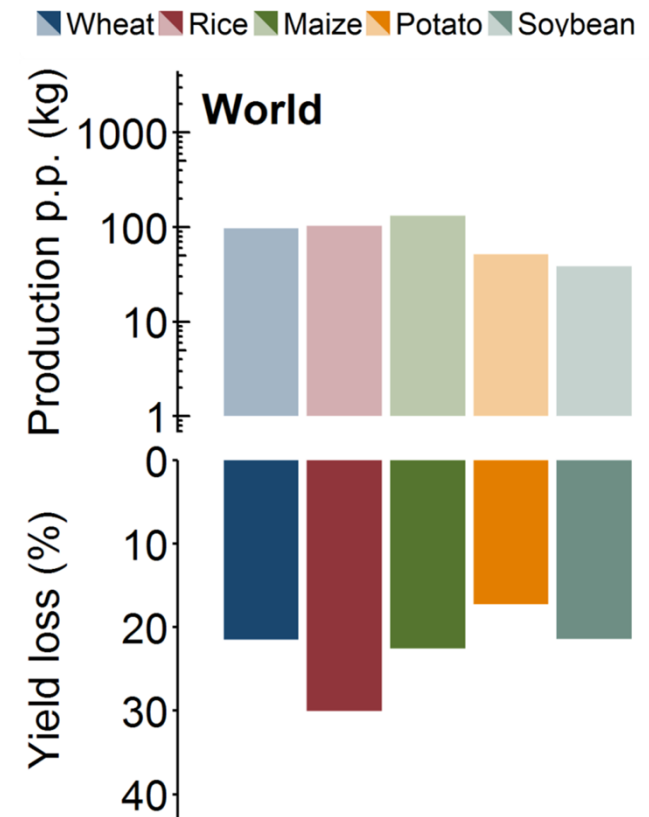
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219 contributeurs dans 67 pays

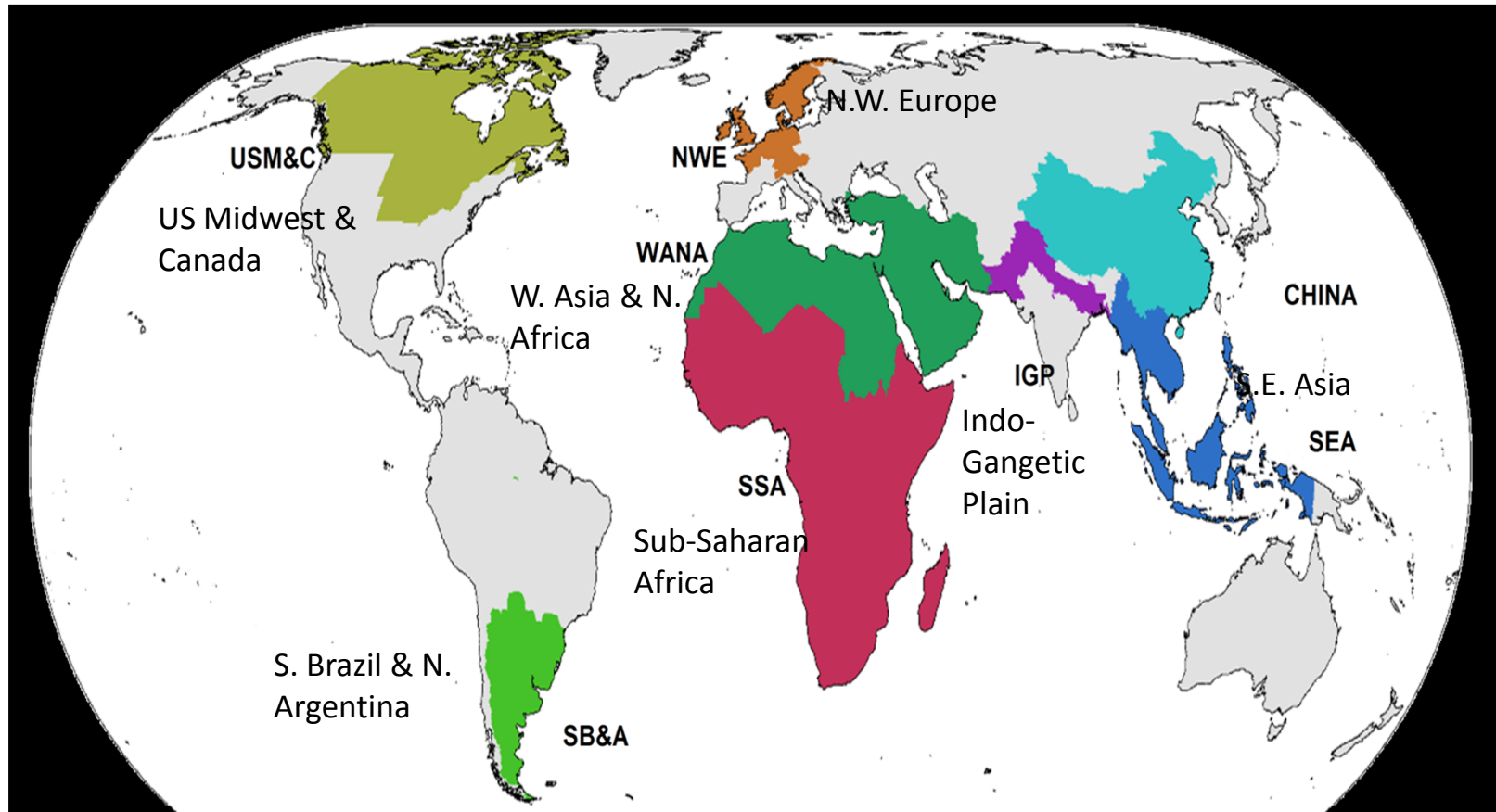
# Estimates of crop losses – globally

World	Wheat	Rice	Maize	Potato	Soybean
Losses (%)	21.5	30.0	22.5	17.2	21.4
Reports	326	247	138	154	125
P&Ps	31	26	38	17	25
Countries	35	36	20	31	16

- Top half of graph shows **production per person** (kg) per crop based on FAOSTAT production and UN population data (2010-14). Log scale!
- Bottom half of graph shows the estimated percentage yield loss per crop



# Estimates of crop losses – by food security hotspot

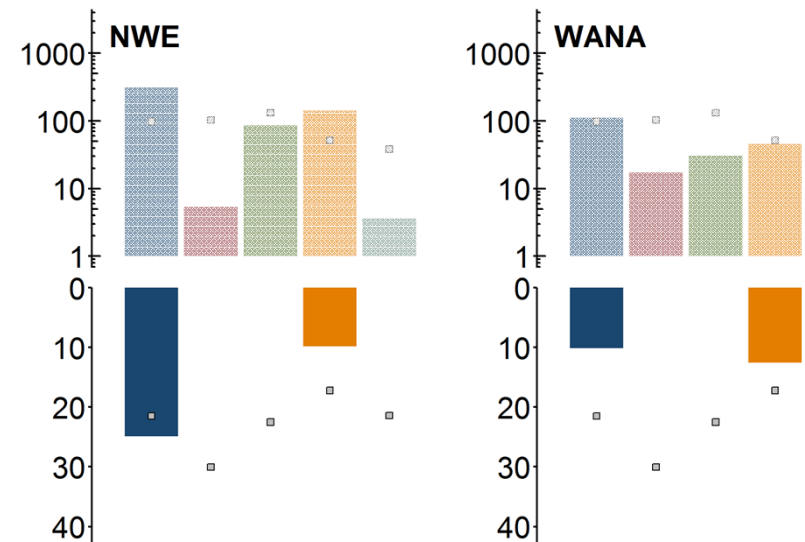


# Estimates of crop losses – NWE and WANA

Losses (%)	Wheat	Rice	Maize	Potato	Soybean
World	21.5	30.0	22.5	17.2	21.4
USM&C	17.9		21.3	8.1	25.3
SB&A	21.5		19.5		32.4
NWE	24.9			9.8	
WANA	10.1			12.6	
CHINA					
SEA					
SSA					
IGP					



Legend: Wheat (blue), Rice (red), Maize (green), Potato (orange), Soybean (grey)



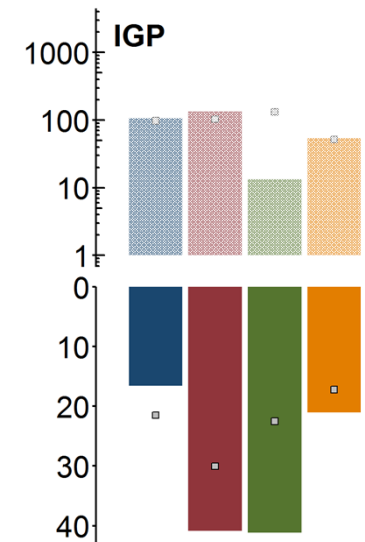
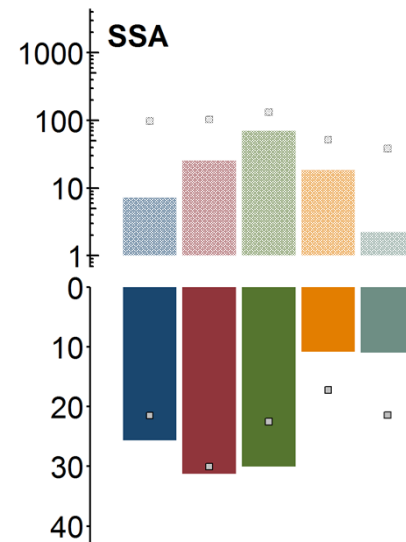
**USM&C**=US Midwest and Canada; **SB&A**=South Brazil, Paraguay, Uruguay and Argentina; **NWE**=Northwest Europe; **WANA**=West Asia and North Africa; **CHINA**=Mainland China; **SEA**=Southeast Asia; **SSA**=Sub-Saharan Africa; **IGP**=Indo-Gangetic Plains

# Estimates of crop losses – SSA and IGP

Losses (%)	Wheat	Rice	Maize	Potato	Soybean
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USM&C	17.9		21.3	8.1	25.3
SB&A	21.5		19.5		32.4
NWE	24.9			9.8	
WANA	10.1			12.6	
CHINA	28.1	32.2			
SEA		24.6			
SSA	25.7	31.3	30.1	10.8	11.0
IGP	16.6	40.9	41.1	21.0	

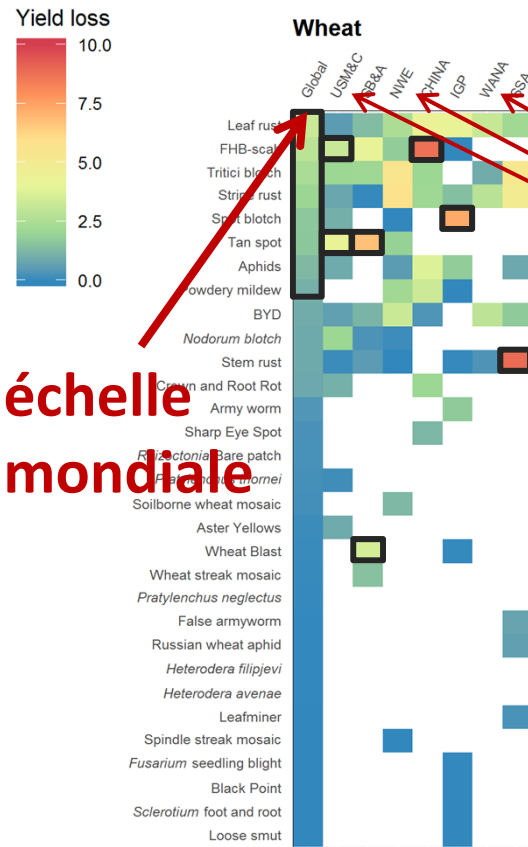


■ Wheat 
 ■ Rice 
 ■ Maize 
 ■ Potato 
 ■ Soybean



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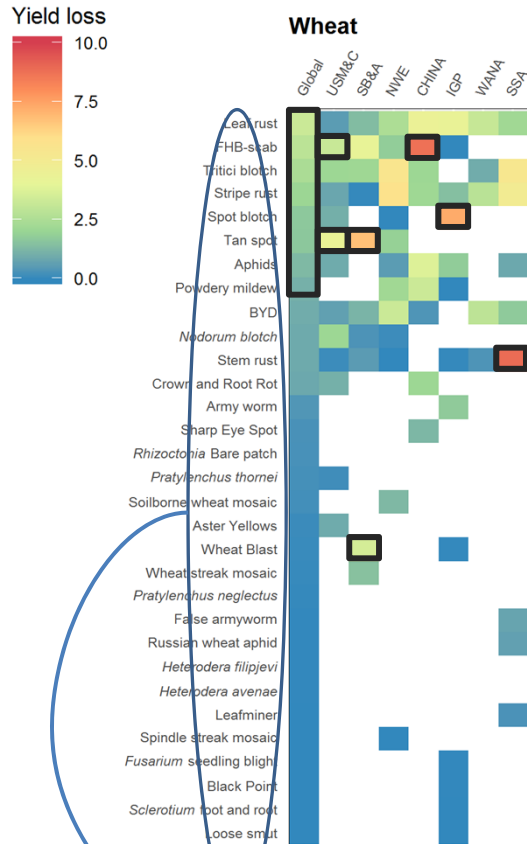
# Wheat: Losses by pathogen and pest (P&P)



échelle mondiale

différentes éco-régions du monde

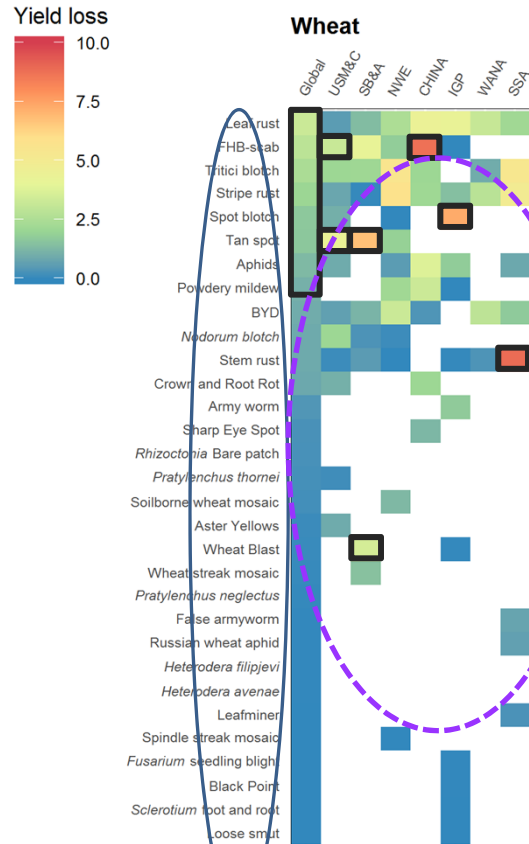
# Wheat: Losses by pathogen and pest (P&P)



liste de pathogènes et ravageurs

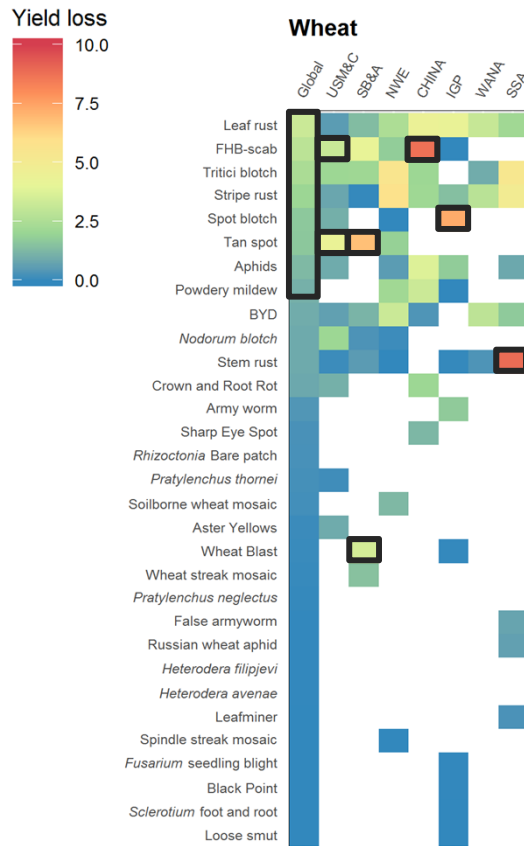


# Wheat: Losses by pathogen and pest (P&P)



pertes de récoltes par ravageur/global ou ravageur/région (gradation couleur)

# Wheat: Losses by pathogen and pest (P&P)



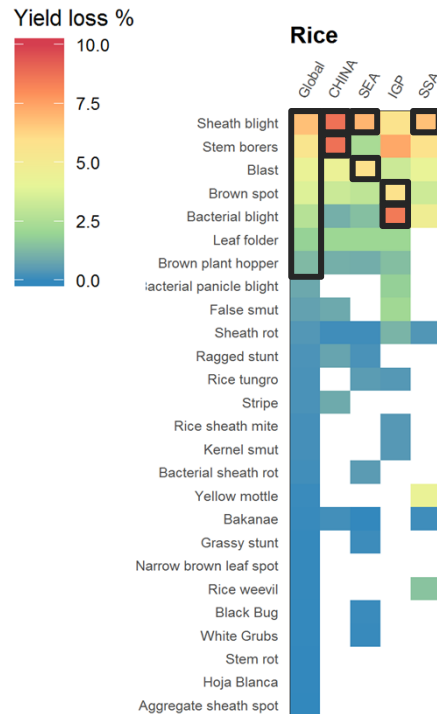
**31 P&Ps reported in wheat (based on 326 reports across 35 countries)**

Eight caused losses higher than 1% globally (leaf rust, Fusarium head blight-Scab, tritici blotch, stripe rust, spot blotch, tan spot, aphids, and powdery mildew)

**Across food security hotspots, crop losses are highest to**

- tan spot (4.3%) and FHB-scab (3.2%) in USM&C
- tan spot (6.8%) and wheat blast (3.5%) in SB&A
- FHB-scab (8.8%) in CHINA
- spot blotch (7.3%) in IGP
- stem rust (8.9%) in SSA

# Rice: Losses by pathogen and pest (P&P)



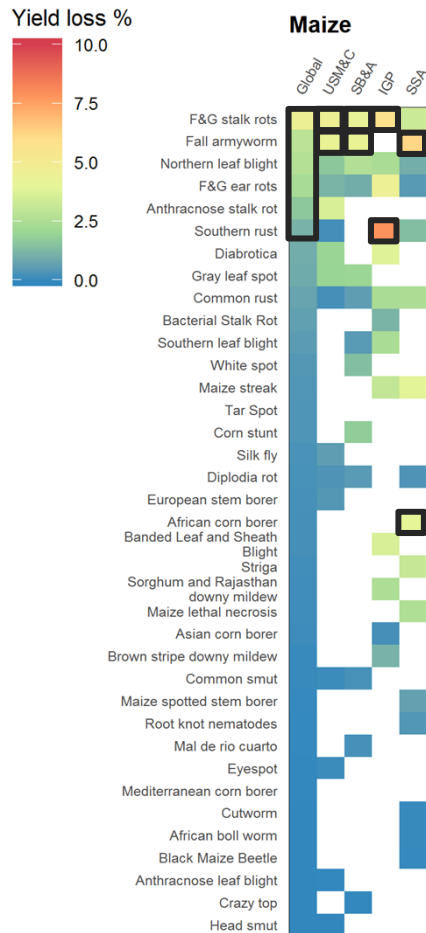
**26 P&Ps reported in rice (based on 247 reports across 36 countries)**

Seven caused losses higher than 1% globally (sheath blight, stem borers, blast, brown spot, bacterial blight, leaf folder, and brown plant hopper)

**Across food security hotspots, crop losses are highest to**

- sheath blight (8.8%) and stem borers (8.8%) in CHINA
- sheath blight (7.1%) and blast (5.9%) in SEA
- brown spot (5.9%) and bacterial blight (8.5%) in IGP
- sheath blight (6.8%) in SSA

# Maize: Losses by pathogen and pest (P&P)



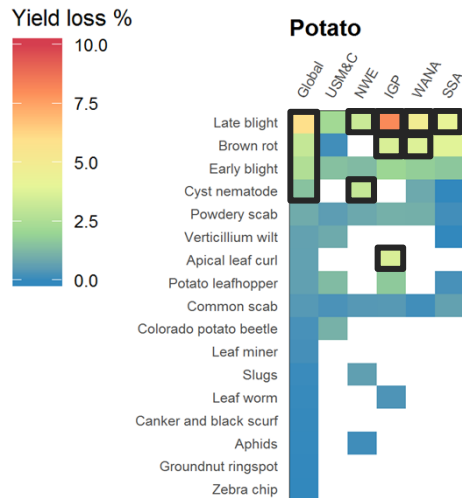
**38 P&Ps reported in maize (based on 138 reports across 20 countries)**

Six caused losses higher than 1% globally (Fusarium and Gibberella stalk rots, fall armyworm, northern leaf blight, Fusarium and Gibberella ear rots, anthracnose stalk rot, and southern rust)

**Across food security hotspots, crop losses are highest to**

- Fusarium and Gibberella (F&G) stalk rots (4.5%) and fall armyworm (4.3%) in USM&C
- fall armyworm (4.3%) and F&G stalk rots (4.2%) in SB&A
- southern rust (7.9%) and F&G stalk rots (5.8%) in IGP
- fall armyworm (6.3%) and African corn borer (4.0%) in SSA

# Potato: Losses by pathogen and pest (P&P)



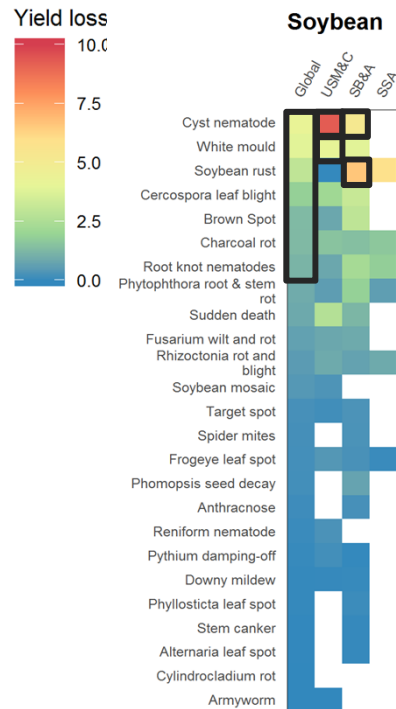
**17 P&Ps reported in potato (based on 154 reports across 31 countries)**

Four caused losses higher than 1% globally (late blight, brown rot, early blight, and cyst nematode)

**Across food security hotspots, crop losses are highest to**

- late blight (3.2%) and cyst nematode (3.1%) in NWE
- late blight (8.1%), apical leaf curl (3.7%), and brown rot (3.6%) in IGP
- late blight (4.9%) and brown rot (3.8%) in WANA
- late blight (4.2%) and brown rot (3.9%) in SSA

# Soybean: Losses by pathogen and pest (P&P)



**25 P&Ps reported in soybean (based on 125 reports across 16 countries)**

Seven caused losses higher than 1% globally (cyst nematode, white mould, soybean rust, Cercospora leaf blight, brown spot, charcoal rot, and root knot nematodes).  
higher than 1%

**Across food security hotspots, crop losses are highest to**

- cyst nematode (9.3%) and white mould (4.1%) in USM&C
- soybean rust (6.7%) and cyst nematode (5.2%) in SB&A

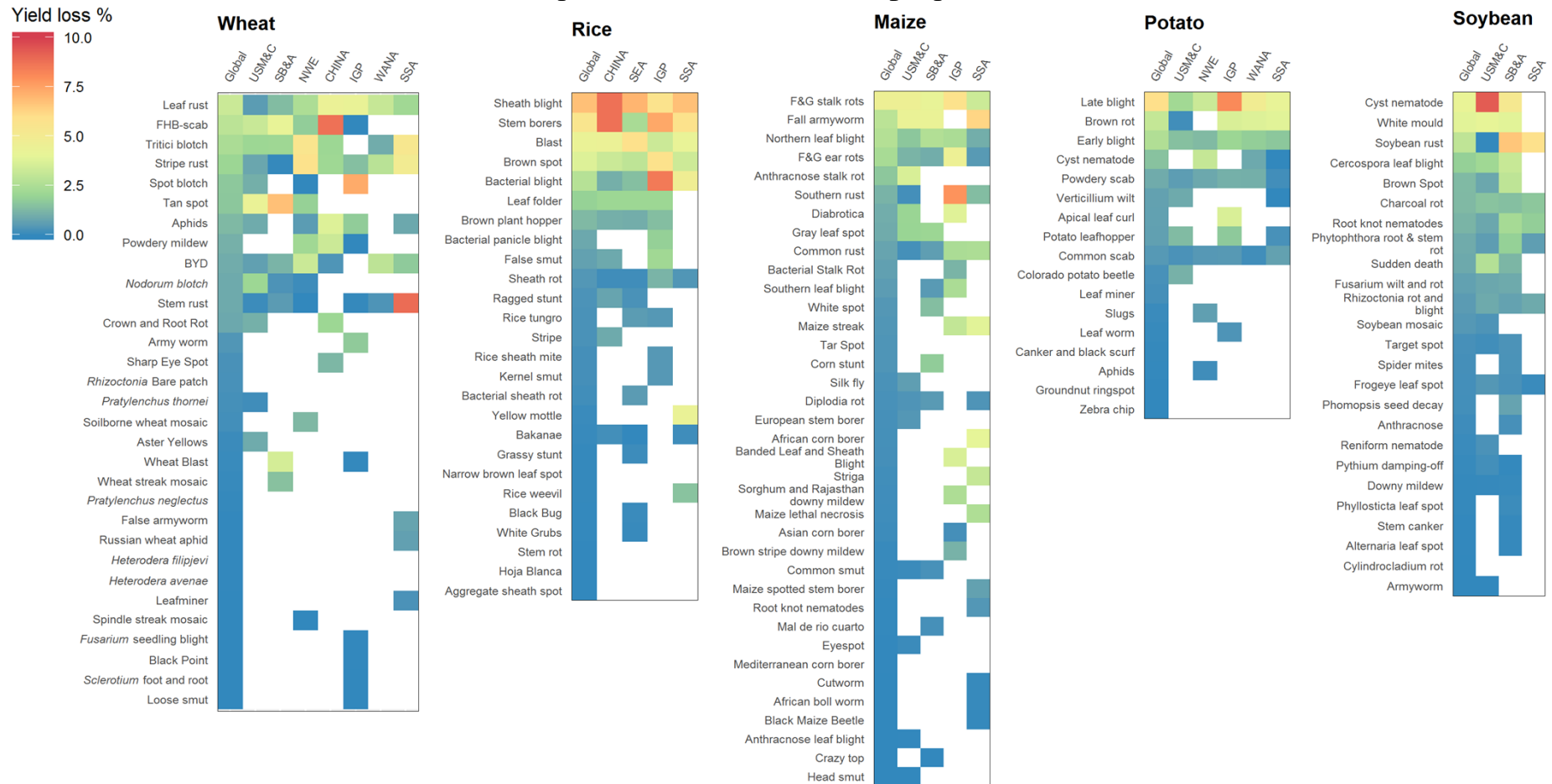
# Losses by pathogen and pest (P&P)

On five major global food crops:

- Rice
- Wheat
- Maize
- Potato
- Soybean

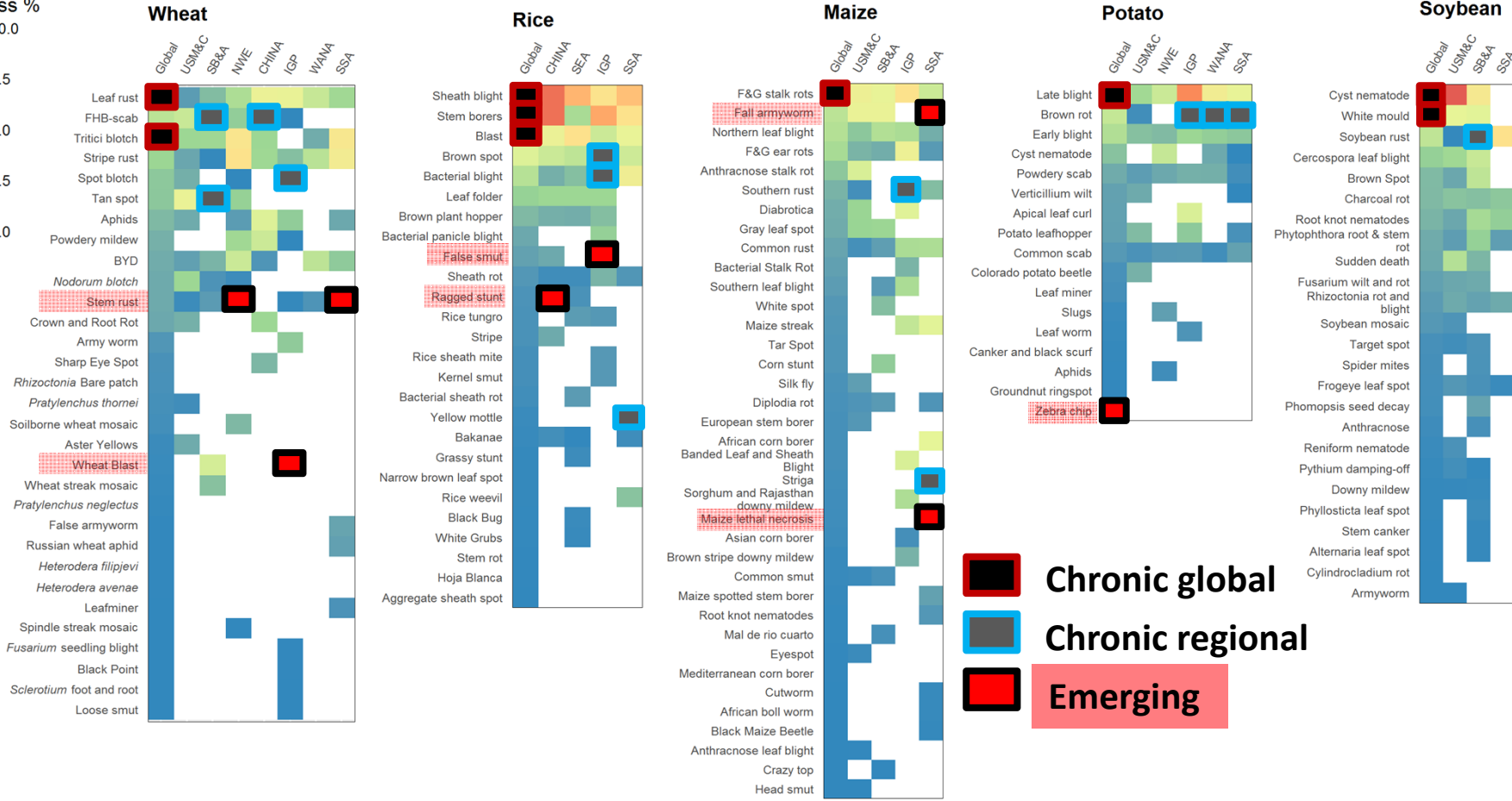
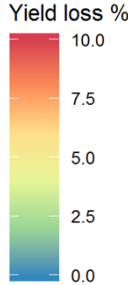
137 P&Ps were reported with a large variation in crop losses caused by specific P&Ps. The relative importance of P&Ps varied across food security hotspots.

# Estimates of crop losses – by pathogen and pest





# Chronic and emerging Pathogens & Pests



- Chronic global
- Chronic regional
- Emerging

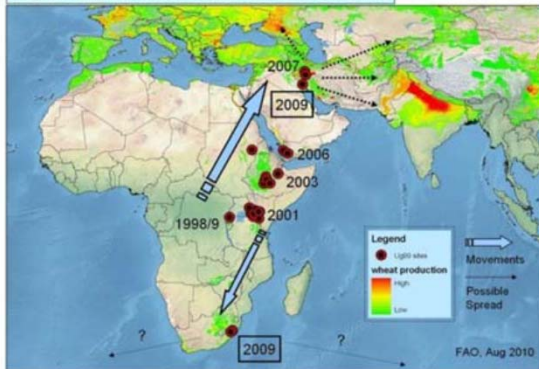
## Wheat rust and world farming

Rust in the bread basket



A crop-killing fungus is spreading out of Africa towards the world's great wheat-growing areas

THE SPREAD OF WHEAT STEM RUST UG99 LINEAGE



La rouille noire du blé est une maladie redoutée depuis très\* longtemps.

Pourquoi?

- le pathogène (*Puccinia graminis*) se multiplie très vite
- il se propage très loin
- il est, génétiquement, très souple
- il provoque une maladie des étés chauds

Mais aussi

- il provoque des pertes de récoltes très fortes
- parce qu'il affecte les cultures tard en saison
- parce qu'il accapare les résultats de la photosynthèse
- *et peut-être parce qu'il aggrave la transpiration des plantes lors des sécheresses et des étés chauds*

\*évoquée dans les anciens textes, dont la Bible

# les maladies des plantes et leur rôle dans la biosphère

vision anthropocentrique  
vision écologique

HOHEN- MESSUNGEN in verhältnißm. Wöhlerlein	ANNALEN DER REISEN IN SÜDAMERICA UND INDIEN	TOPI- GRAPHIE	HOHEN- MESSUNGEN in verhältnißm. Wöhlerlein	ANNALEN DER REISEN IN SÜDAMERICA UND INDIEN	TOPI- GRAPHIE
1769	1770	1771	1772	1773	1774
1775	1776	1777	1778	1779	1780
1781	1782	1783	1784	1785	1786
1787	1788	1789	1790	1791	1792
1793	1794	1795	1796	1797	1798
1799	1800	1801	1802	1803	1804
1805	1806	1807	1808	1809	1810
1811	1812	1813	1814	1815	1816
1817	1818	1819	1820	1821	1822
1823	1824	1825	1826	1827	1828
1829	1830	1831	1832	1833	1834
1835	1836	1837	1838	1839	1840
1841	1842	1843	1844	1845	1846
1847	1848	1849	1850	1851	1852
1853	1854	1855	1856	1857	1858
1859	1860	1861	1862	1863	1864

Geographie der Pflanzen in den Tropen-Ländern ;

Alexander von Humboldt (1769 - 1859)



**Netz des Lebens**

**web of life**

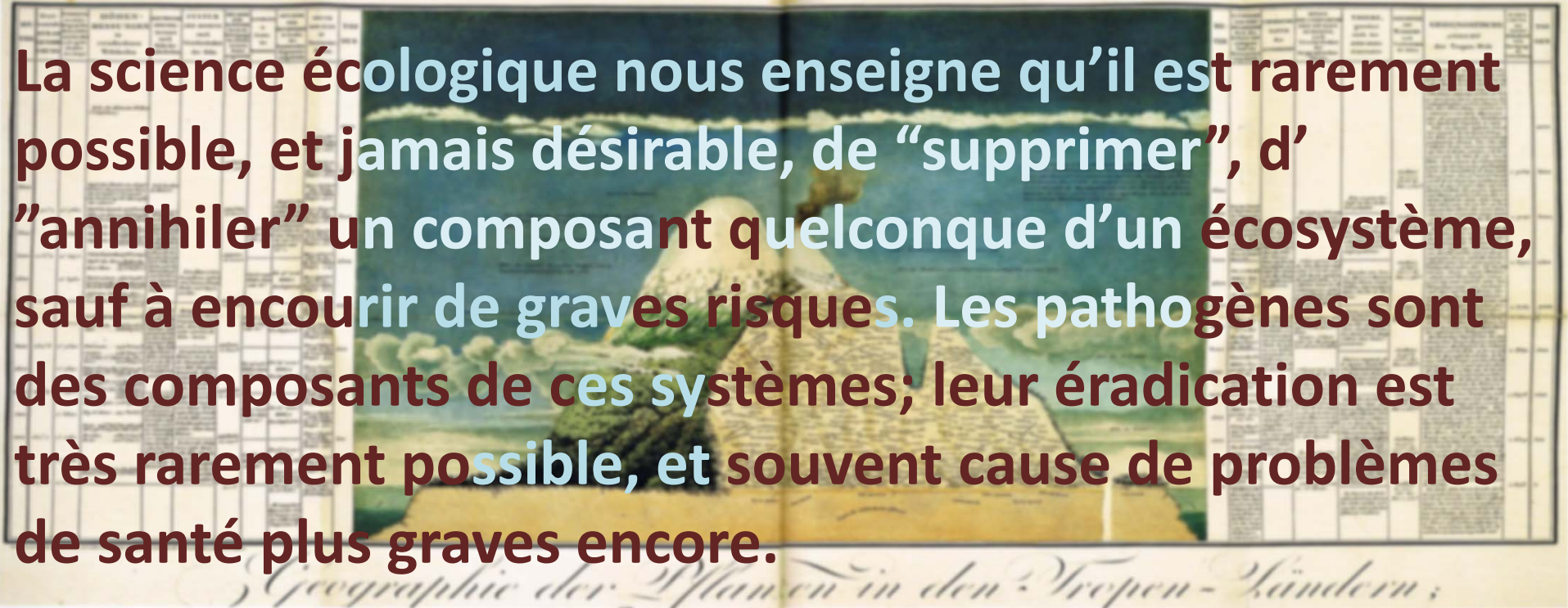
**Wechselwirkungen**

**interactions**

**Ökosystem**

**ecosystem**

*Geographie der Pflanzen in den Tropen-Ländern;*



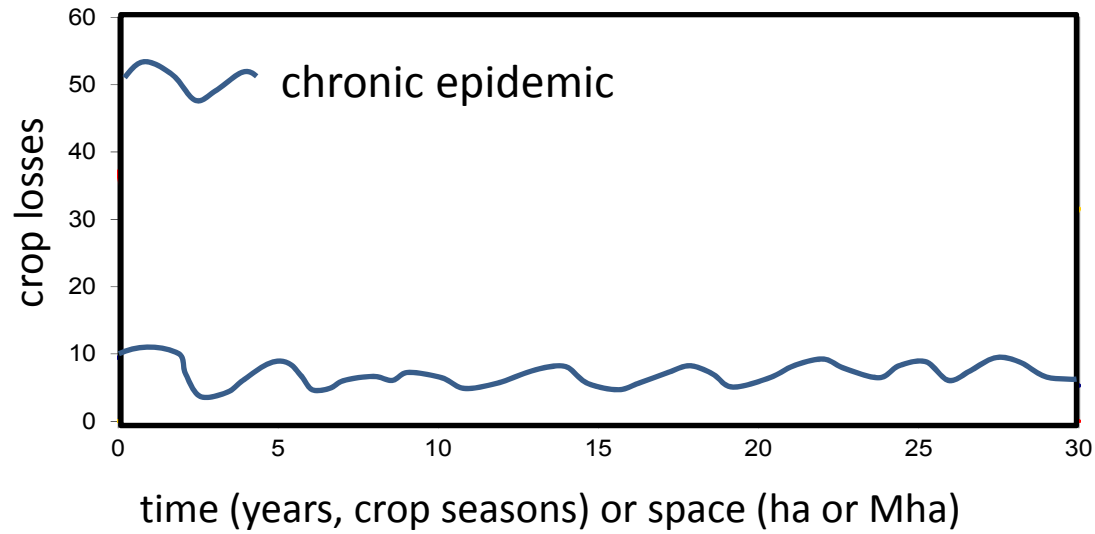
La science écologique nous enseigne qu'il est rarement possible, et jamais désirable, de "supprimer", d'"annihiler" un composant quelconque d'un écosystème, sauf à encourir de graves risques. Les pathogènes sont des composants de ces systèmes; leur éradication est très rarement possible, et souvent cause de problèmes de santé plus graves encore.

s'agissant des maladies de plantes:

gérer (acceptation), plutôt que contrôler (l'humain "maître"), et jamais éradiquer (déni)

épidémies: chroniques, aiguës,  
émergentes

# Chronic, acute, emerging losses

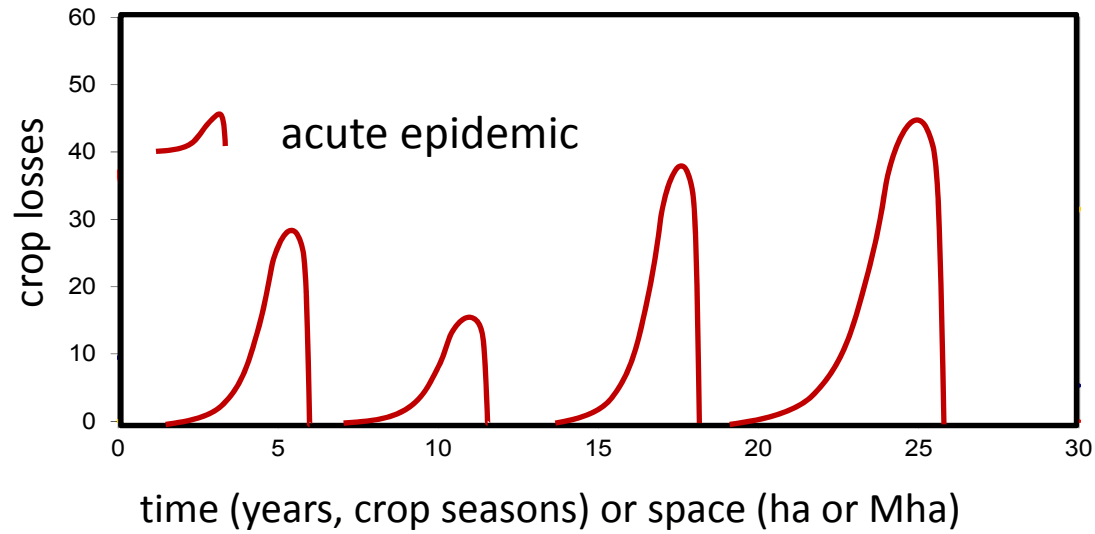


Regular over years and locations, crop loss

Rice sheath blight



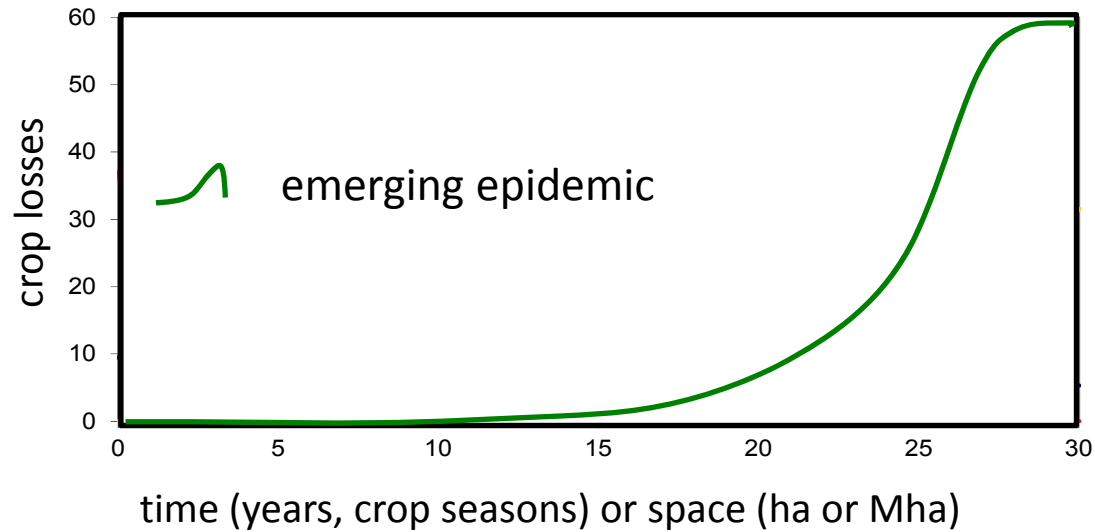
# Chronic, acute, emerging losses



Very high, local,  
sudden, crop loss

Fus Head Blight

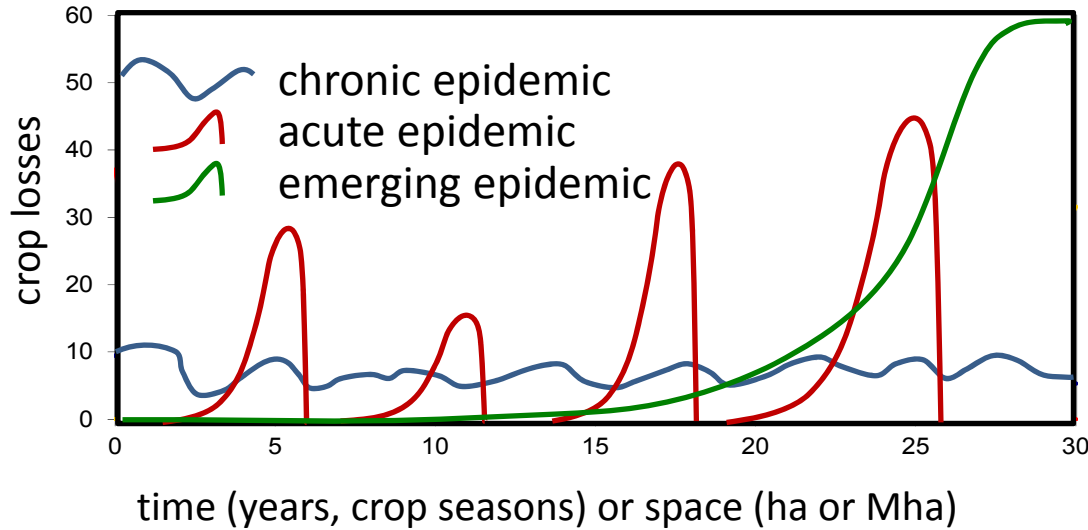
# Chronic, acute, emerging losses



Unexpected, very high,  
local, sudden, crop  
losses

Wheat blast

# Chronic, acute, emerging losses



Regular over years and locations, crop loss  
Rice sheath blight

Very high, local, sudden, crop loss  
Fus Head Blight

Unexpected, very high, local, sudden, crop losses  
Wheat blast

**Market destabilization**  
**Economic disturbance**  
**Social upheavals**

# General context of plant disease emergence

Plant disease emergences have dramatically increased recently as a result of **global change**, which includes:

**trade expansion,**

**loss of host genetic diversity,**

**change in cropping practices,**

**climate change**

# A framework for analysis of emerging epidemics: paths and processes

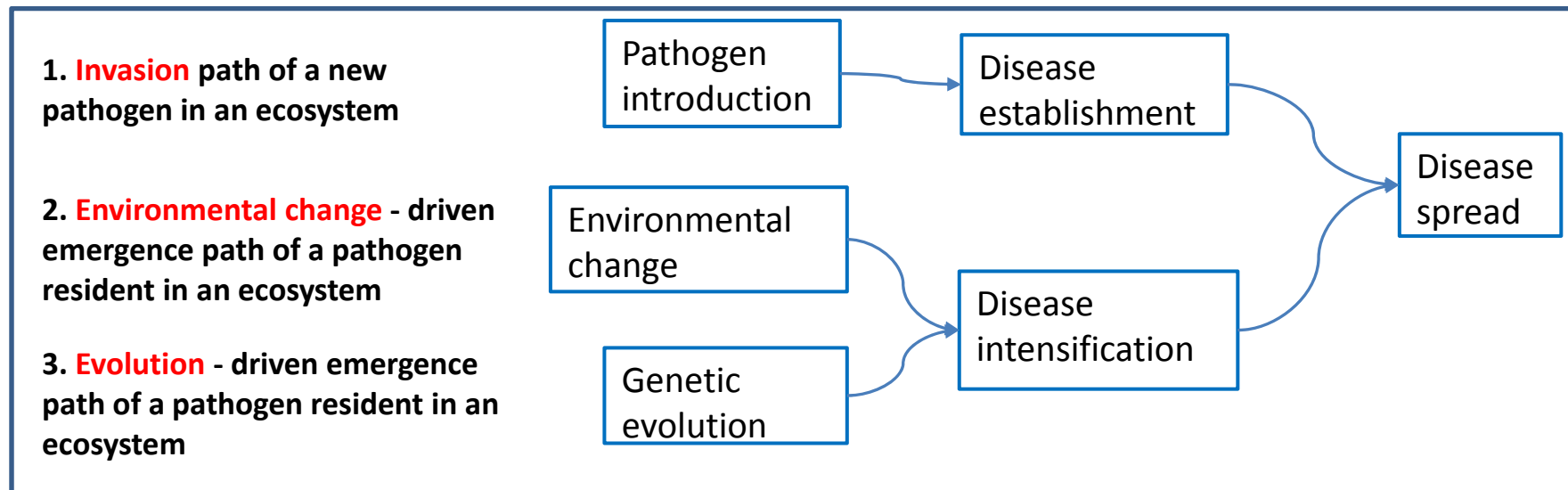
## Three paths for emergence:

1. **Invasion** path of a new pathogen in an ecosystem
2. **Environmental change** - driven emergence path of a pathogen resident in an ecosystem
3. **Evolution** - driven emergence path of a pathogen resident in an ecosystem

# A framework for analysis of emerging epidemics: paths and processes

Three paths for  
emergence:

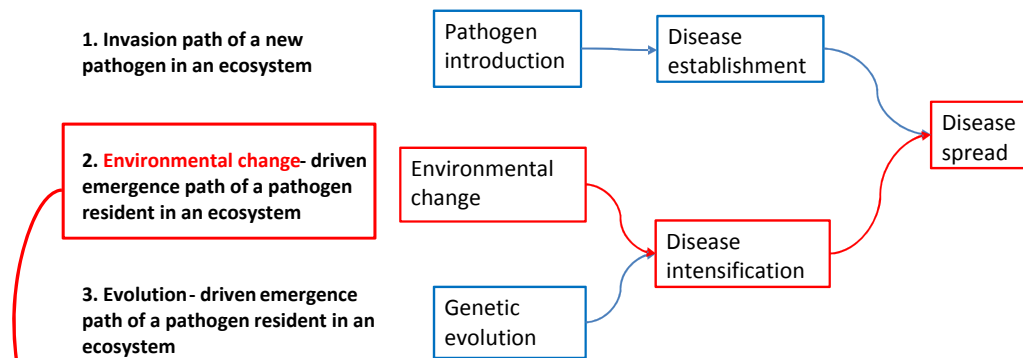
Leading to emergence  
processes:



## Recent examples of emergence of pathogens or pathogen strains

- *Puccinia graminis* f. sp. *tritici* lineages Ug99 (stem rust of wheat) first in sub-Saharan Africa and now in other continents
- *Puccinia striiformis* f. sp. *tritici* strains (yellow rust of wheat) in Europe
- *Pyricularia graminis-tritici* (wheat blast) in south Asia
- *Xylella fastidiosa* on olive in Southern Europe

# Emergence of Fusarium Head Blight on wheat in the USA mid West – 1990's

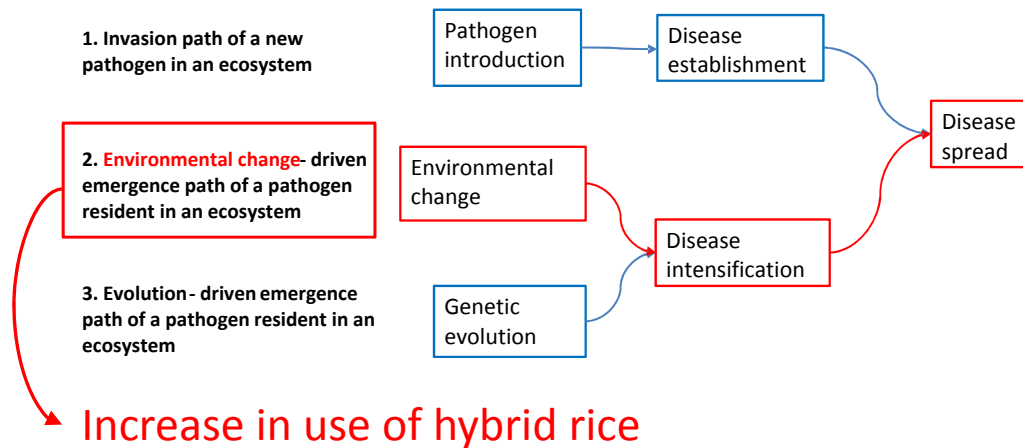


No till; increased area of the in maize-wheat rotation

Photo source: McMullen et al, 2012. Plant Dis 96: 1712-1728



# Emergence of false smut on rice in South Asia – 2000's



*Photo source: IRRI rice knowledge bank*

# Emergence of wheat blast in South Asia – 2010's

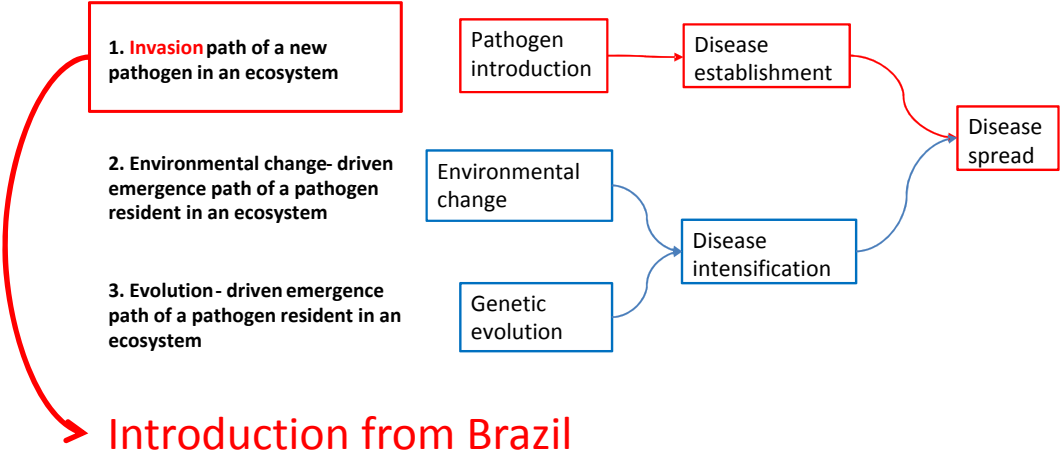
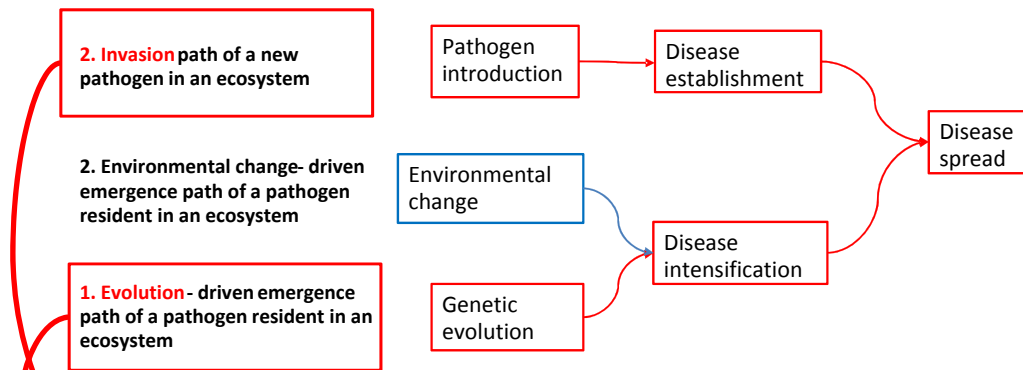
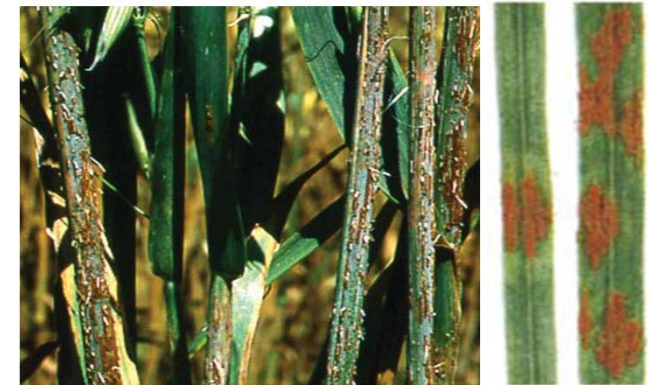


Photo source: Ceresini et al, 2019. *Mol Plant Pathol* 20:155-172

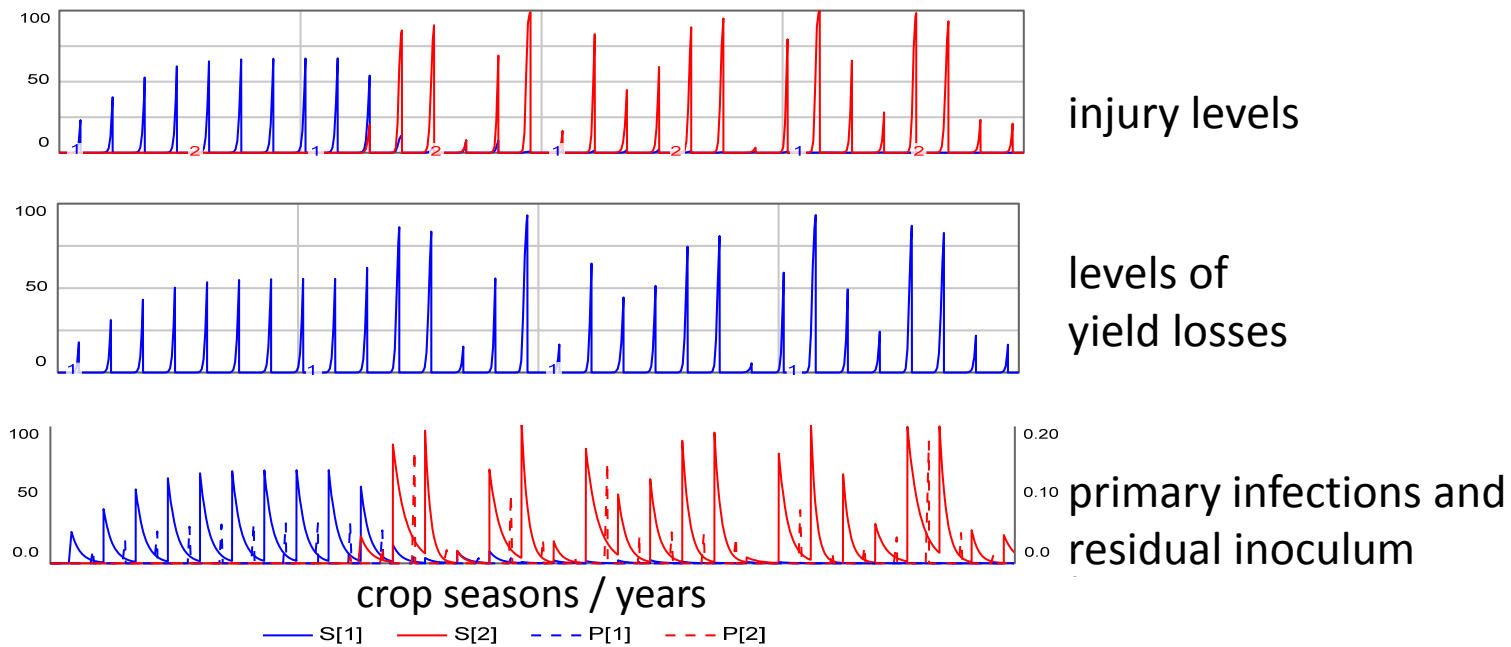
# Emergence of stem rust Ug99 lineages in Africa, and then other parts of the world - 1990's to 2010's



- 1: emergence of Ug99 new races in Uganda
- 2: introduction and spread in other parts of the world, as in Italy

Photo source: Leonard & Szabo 2005 *Mol Plant Pathol* 6: 99-111

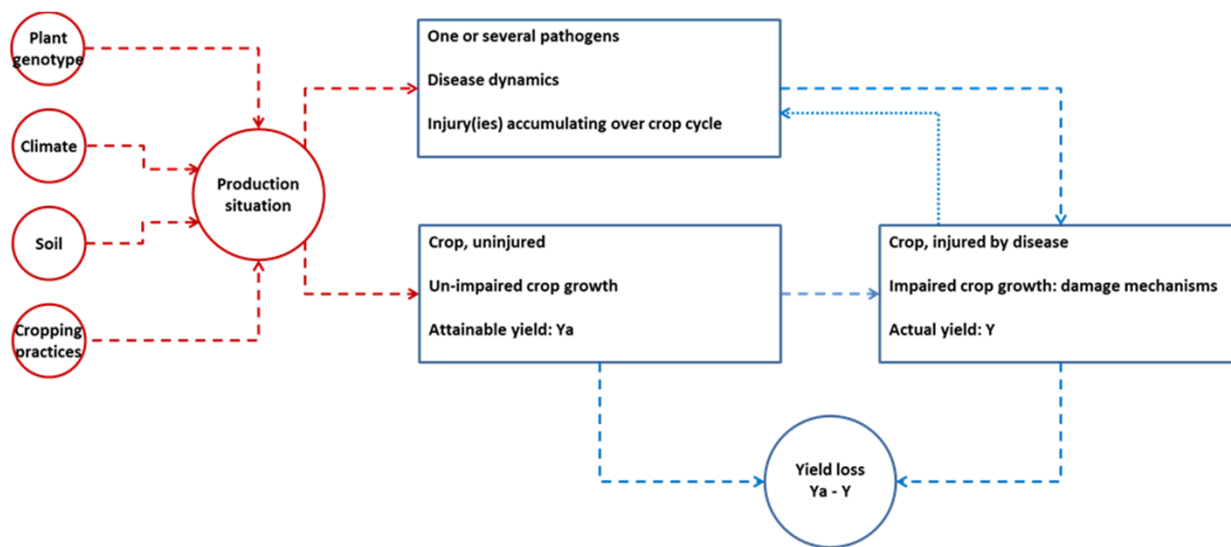
# Simulated dynamics: epidemics and yield losses, depending on pathogen survival and fitness parameters



Willcoquet, L., Savary, S.,  
B.A. McDonald, A.  
Mikaberidze, 2020. Plant  
Pathology 69:1630–1643.

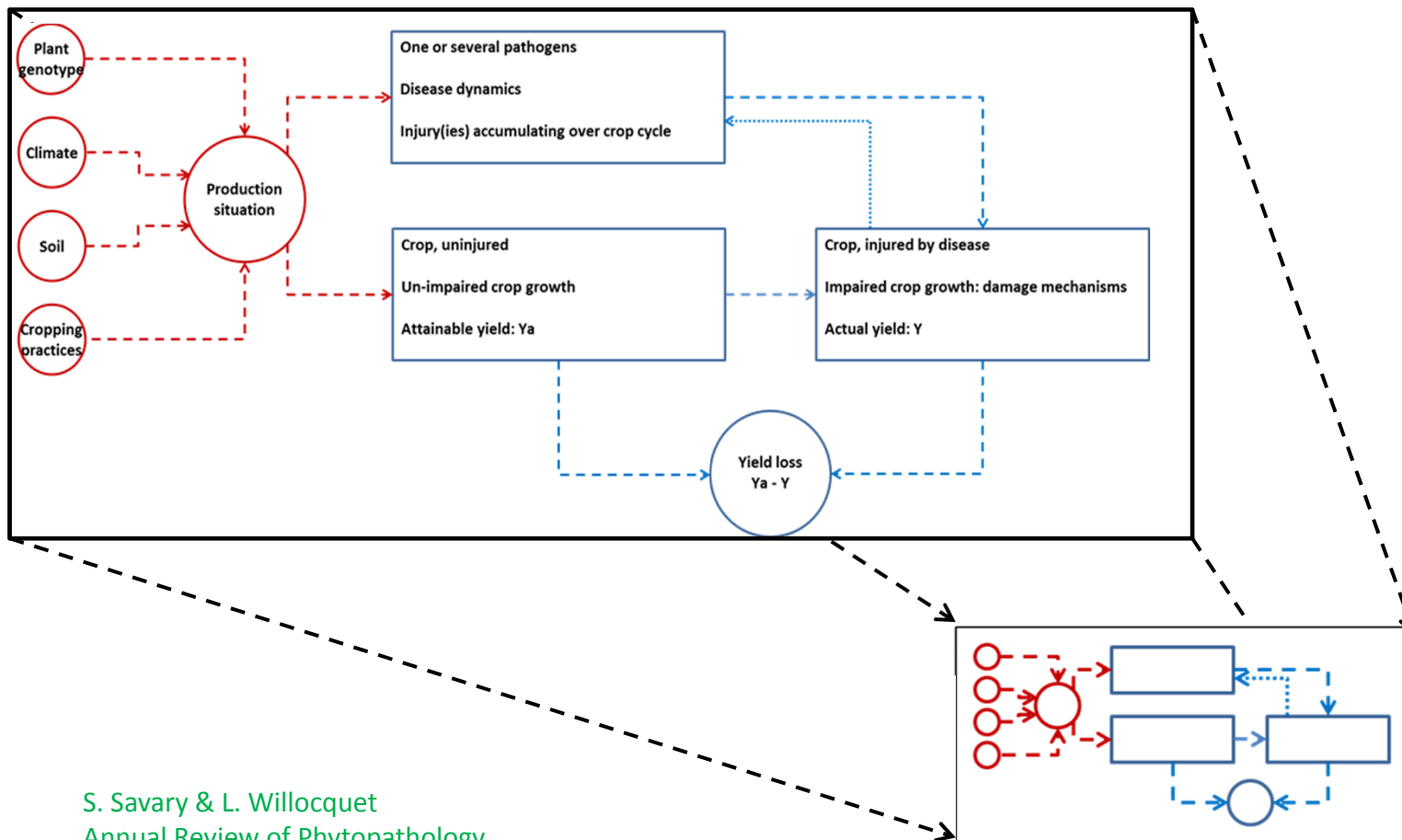
quel est l'impact des émergences sur la  
sécurité alimentaire

# Nexus of relations between production situation, crop growth, disease dynamics, and yield loss.



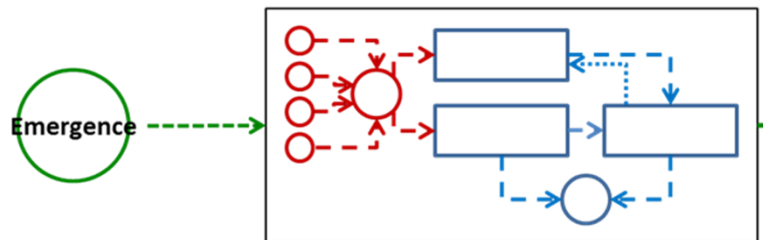
- dans un agrosystème, une **situation de production** résulte des effets conjoints des géotypes, du climat, du sol, et des pratiques agricoles;
- une situation de production détermine une **production agricole accessible**,
- dont le niveau est **réduit** par l'action des maladies et ravageurs.

S. Savary & L. Willocquet  
Annual Review of Phytopathology  
2020 58:1, 313-341



S. Savary & L. Willocquet  
 Annual Review of Phytopathology  
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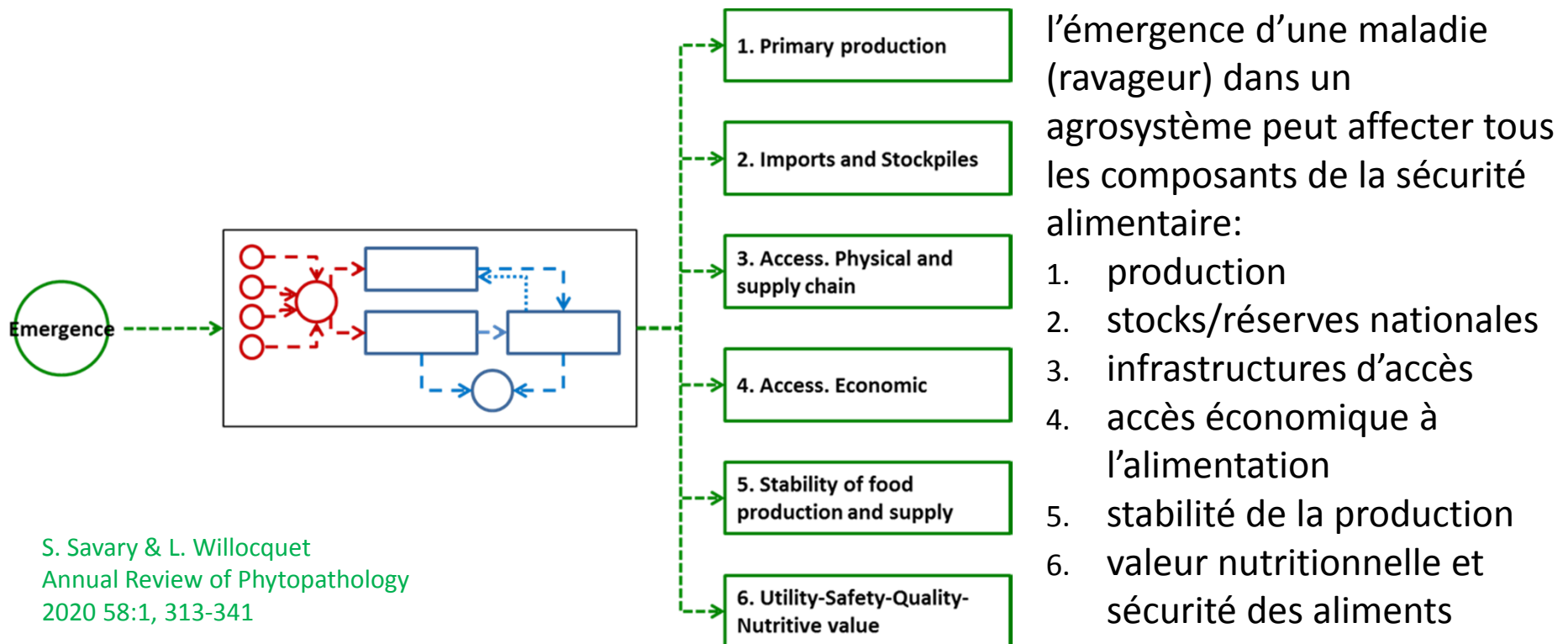
# Nexus of relations between production situation, crop growth, disease dynamics, and yield loss.



S. Savary & L. Willcoquet  
Annual Review of Phytopathology  
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# Nexus of relations between production situation, crop growth, disease dynamics, and yield loss.

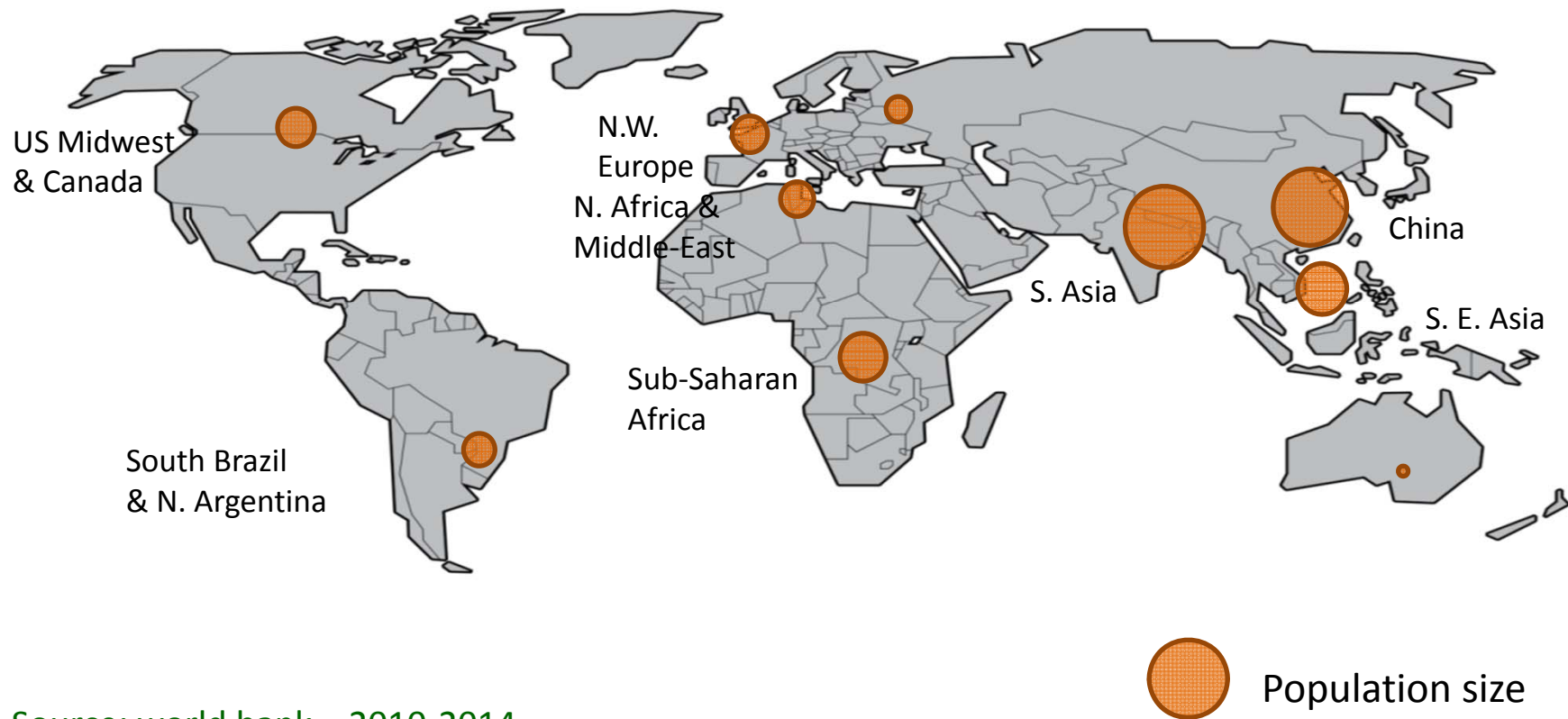


S. Savary & L. Willocquet  
Annual Review of Phytopathology  
2020 58:1, 313-341

# les risques générés par les épidémies

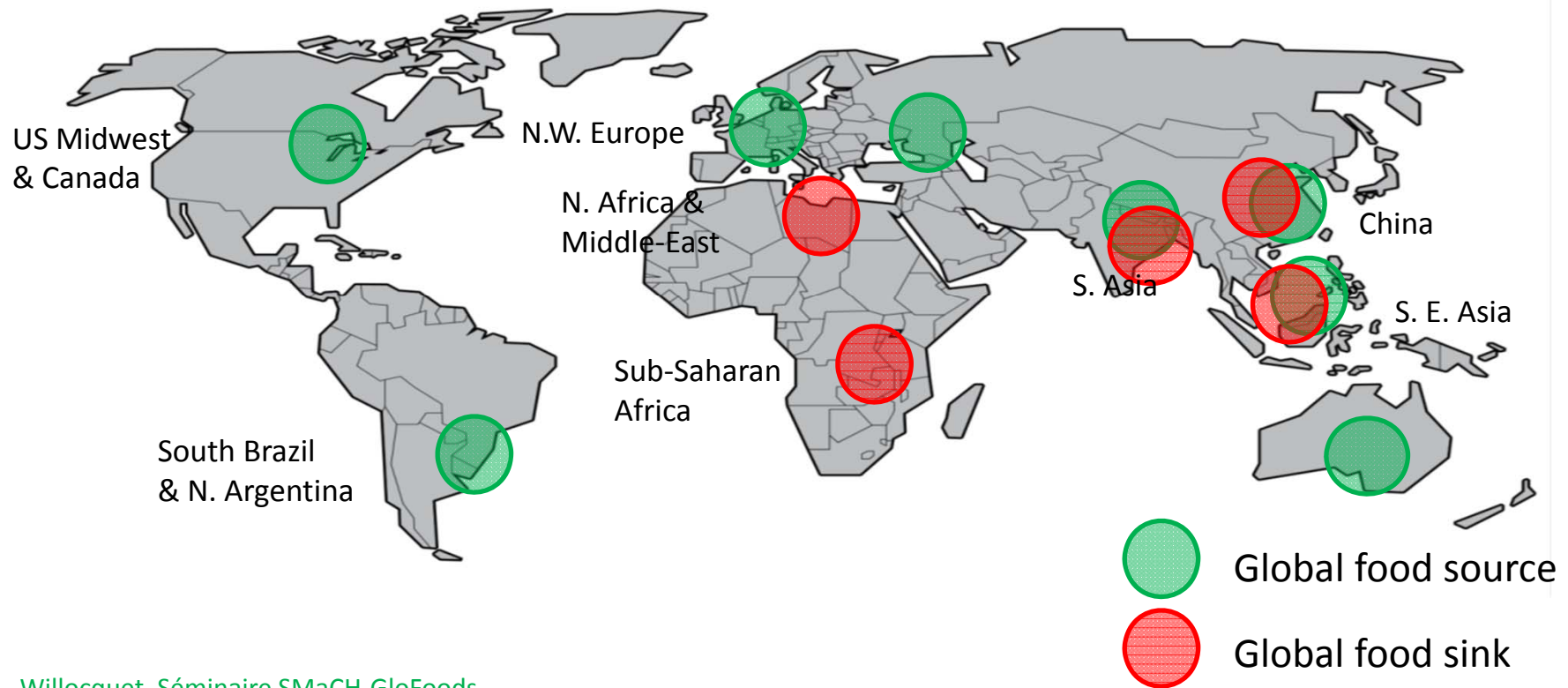
- empêchent / gênent le végétal dans son rôle dans les écosystèmes: régulations (eau, CO<sub>2</sub>, etc.); fourniture (nourriture, matériaux - pour les humains); beauté, spiritualité, des plantes
- destruction de la biodiversité
- pertes de récoltes agricoles (échelles: champ, exploitation agricole)
- dangers pour l'alimentation mondiale: les échanges agricoles mondiaux

# Global Food Security Hot Spots: population



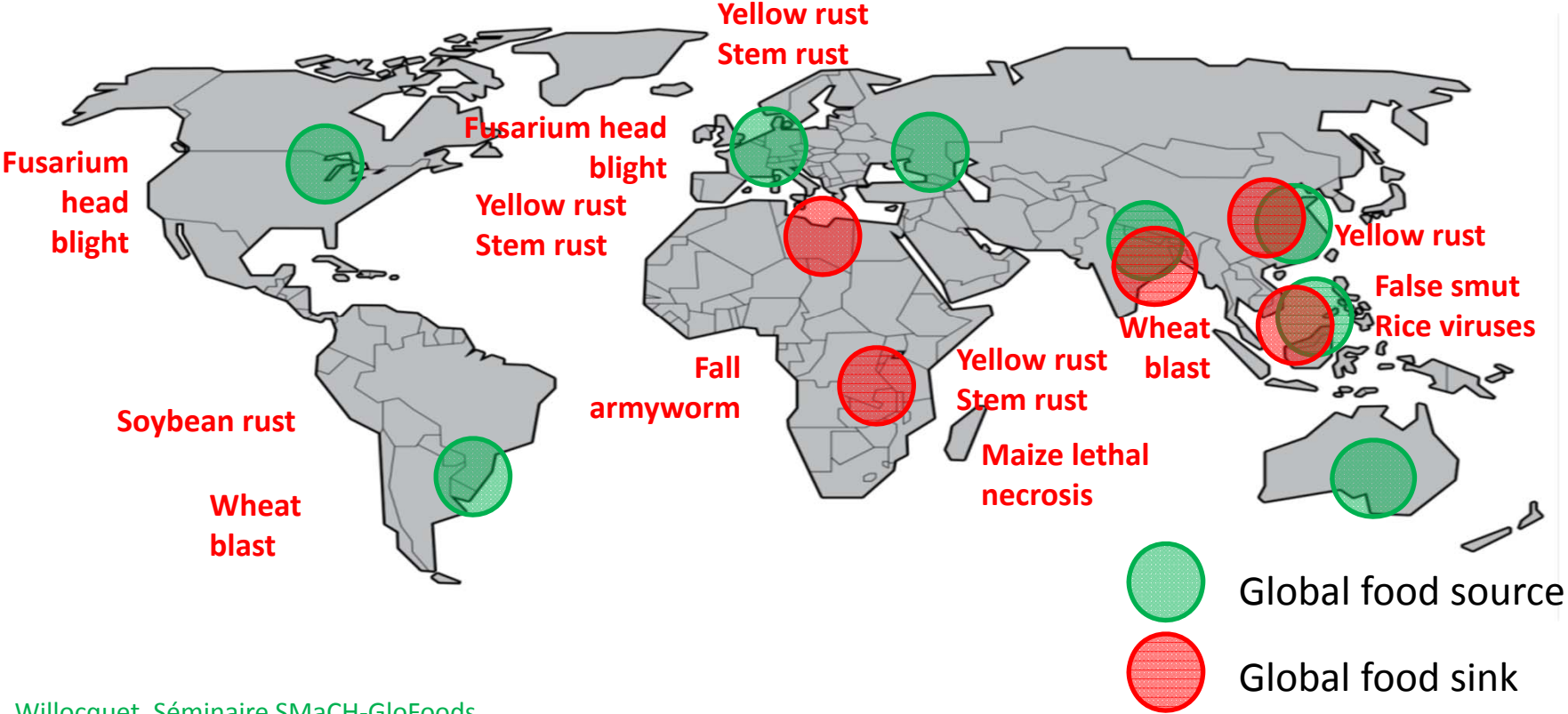
Source: world bank – 2010-2014

# Global Food Security Hot Spots



L. Willocquet, Séminaire SMaCH-GloFoods  
"Pertes de Récoltes, Paris, 2018

# Global Food Security Hot Spots: some threat diseases



L. Willocquet, Séminaire SMaCH-GloFoods  
 "Pertes de Récoltes, Paris, 2018

que faire?

la résilience  
par la diversité

# que faire?

la résilience

par la diversité - dans l'espace et le temps

- pays-continents: diversité d'espèces, de gènes dans les espèces, "rotation" des gènes (de résistance) saison après saison
- paysages: diversification agricole; réintégration d'éléments non-cultivés
- exploitation: réduire la spécialisation; favoriser la diversification
- parcelle: diversité d'espèces; rotations
- plante: rotation des gènes; cassettes de gènes de résistance

# merci



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**Editor-in-Chief, Food Security** - Journal website: [www.springer.com/life+sci/agriculture/journal/12571](http://www.springer.com/life+sci/agriculture/journal/12571)

**Honorary Professor of Plant Pathology**, GB Pant University of Agricultural Research & Technology, Pantnagar, India

Simulation Modeling in Botanical Epidemiology and Crop Loss analysis. APSnet The Plant Health Instructor:

<http://www.apsnet.org/edcenter/advanced/topics/BotanicalEpidemiology/Pages/default.aspx>

Impact of Global Crop Health on Food Security: <http://1680kcal.org>

International Summer School on Plant Disease Epidemiology: <https://sites.google.com/site/intrlsommerschoolepidemiology/home>

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