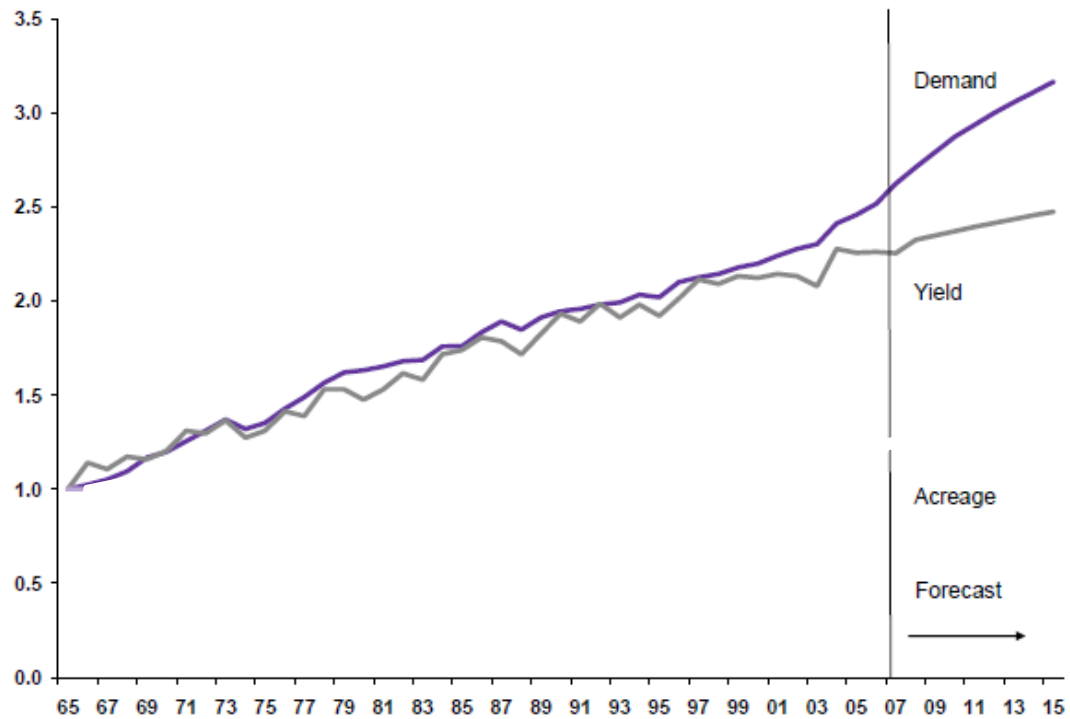


# the problem

percent growth

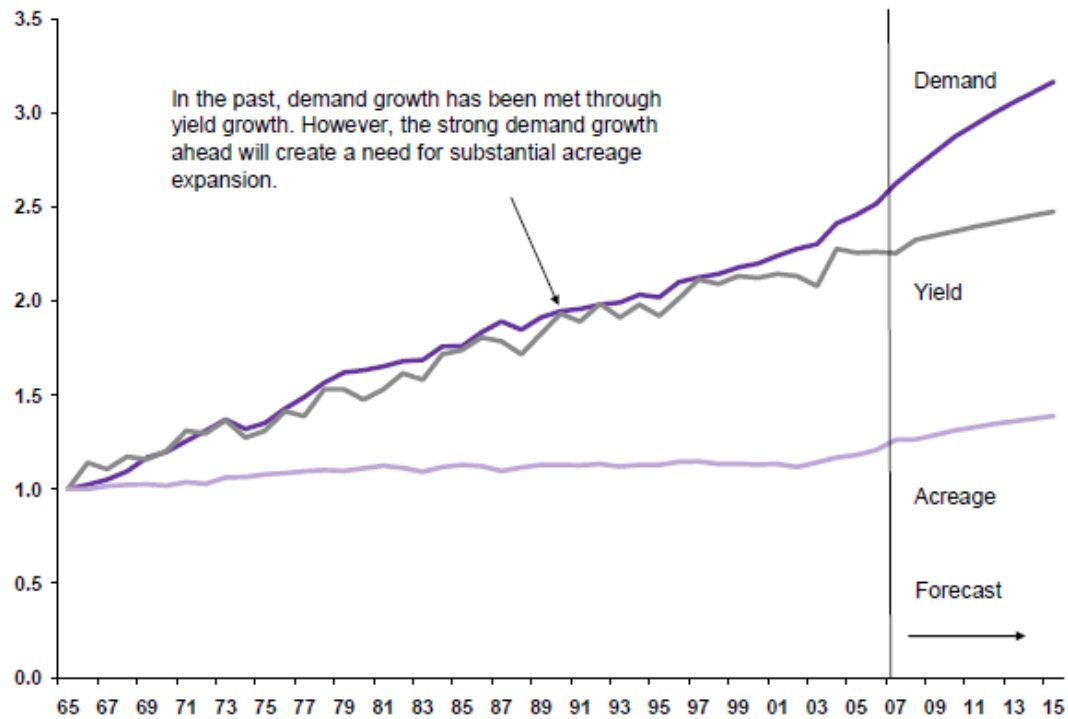


Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

# the goldman sachs perspective.....

**Exhibit 9: Tweaking of agriculture yields is no longer meeting demand growth, acreage must now be expanded**

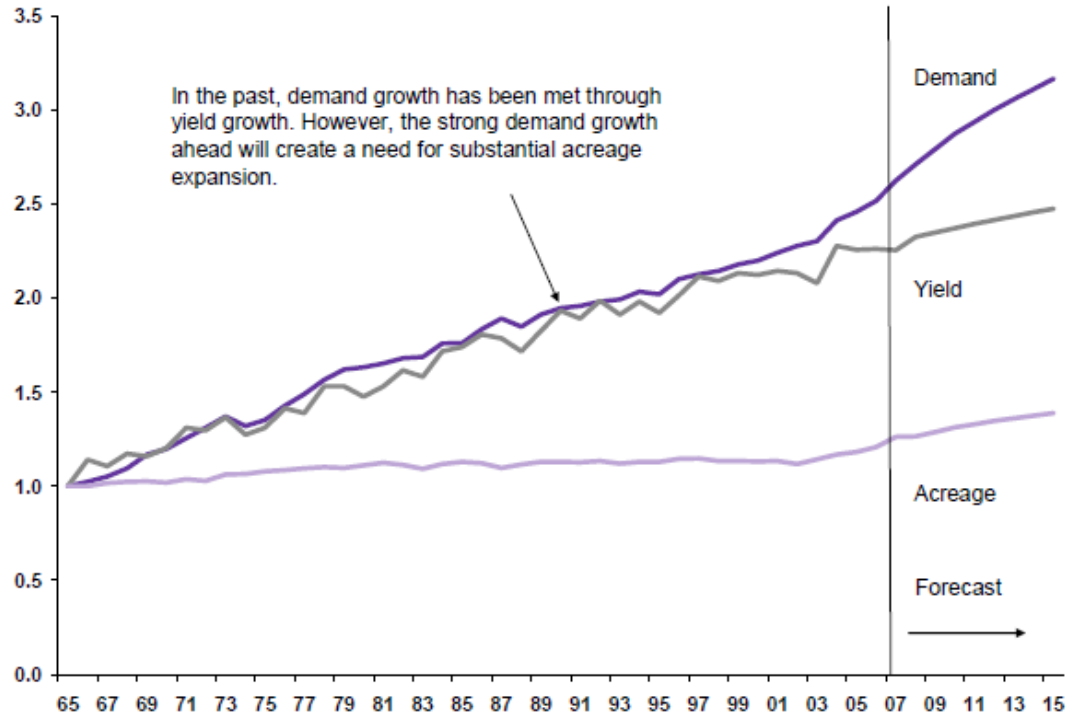
Percent growth



Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

# .....does not add up

**Exhibit 9: Tweaking of agriculture yields is no longer meeting demand growth, acreage must now be expanded**  
Percent growth



Source: US Department of Agriculture (USDA) and Goldman Sachs Commodities Research.

# sufficiency

- **demand**
  - population size
  - diet (overconsumption = consumer waste)
- **production**
- **post-production**
  - processing
  - storage
  - consumer waste

# sustainability – a definition

(Pretty 2008)

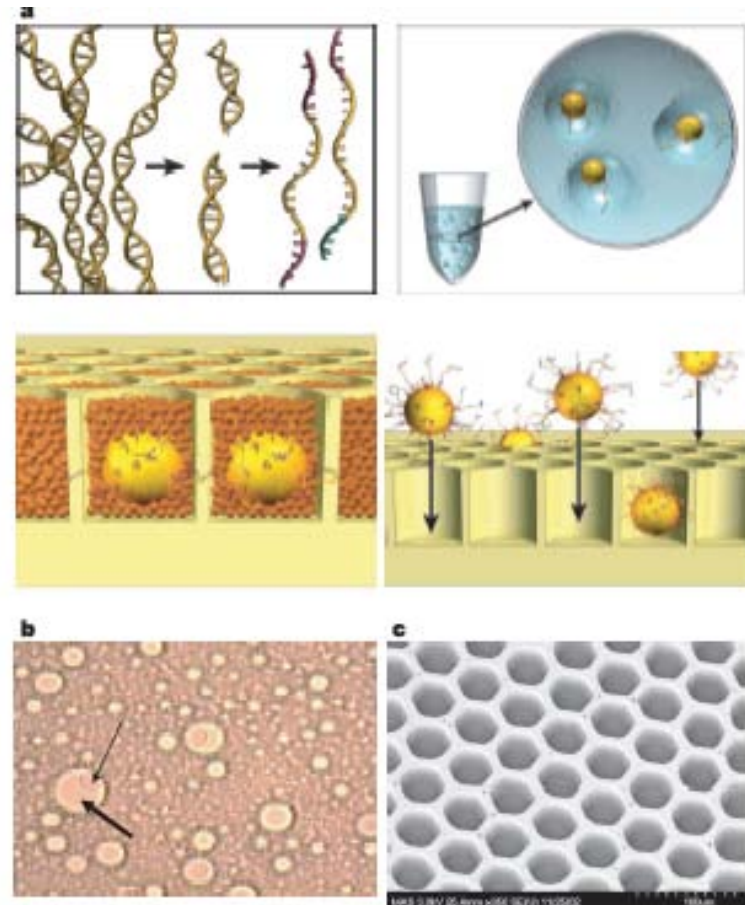
- **Persistence:** the capacity to continue to deliver desired outputs over long periods of time (human generations), thus conferring predictability;
- **Resilience:** the capacity to absorb, utilise or even benefit from perturbations (shocks and stresses), and so persist without qualitative changes in structure;
- **Autarchy:** the capacity to deliver desired outputs from inputs and resources (factors of production) acquired from within key system boundaries;
- **Benevolence:** the capacity to produce desired outputs (food, fibre, fuel, oil) while sustaining the functioning of ecosystem services and not causing depletion of natural capital (eg. minerals, biodiversity, soil, clean water).

# approaches to sustainable and sufficient production

- markets
- infrastructure
- agroecology
- integrated crop management
- agronomy
- engineering
- genetics

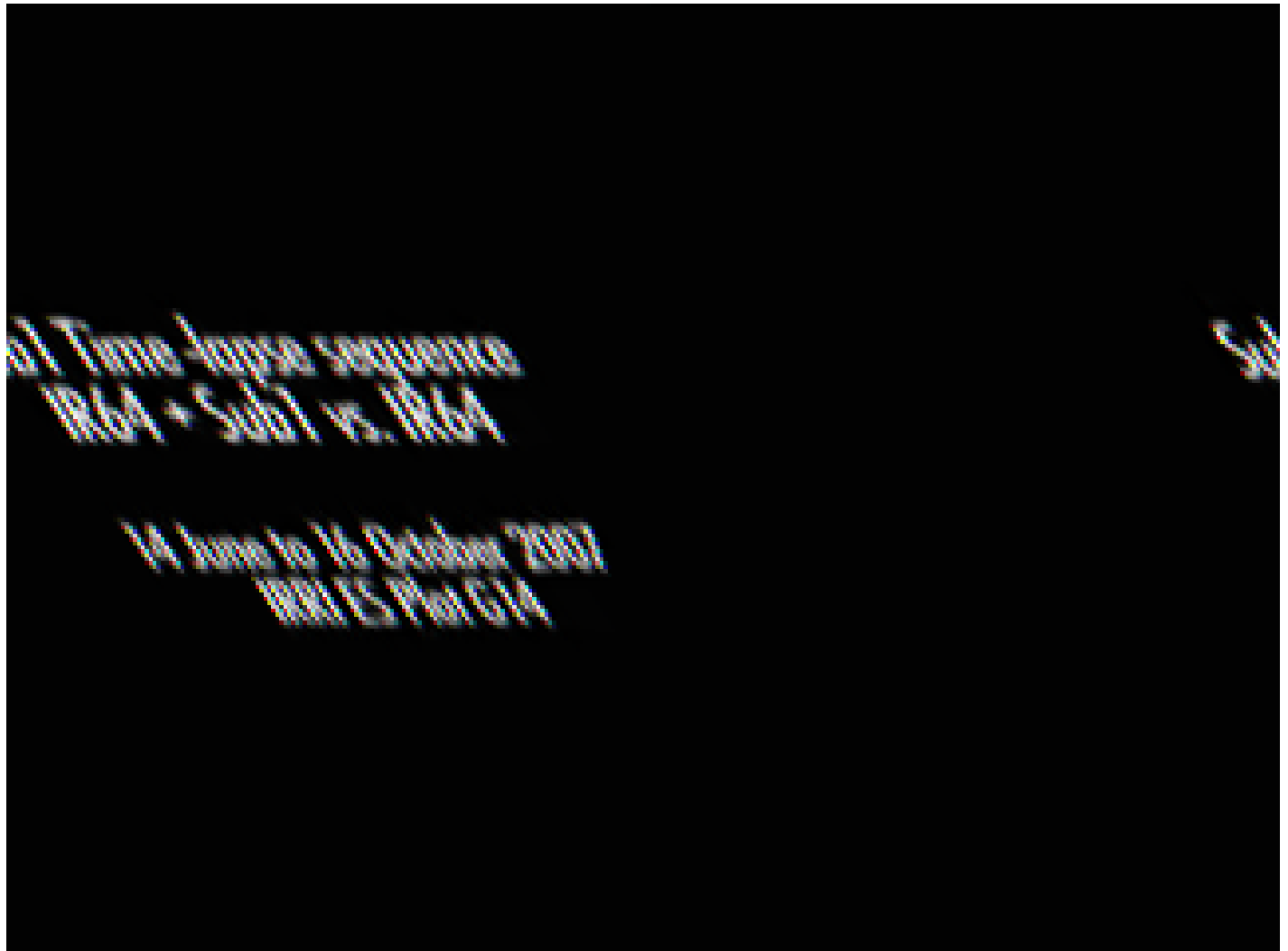
# next generation DNA sequencing

- De novo sequencing of crop and crop pathogen genomes
- Sequencing of varieties and related species
- Expression profiling
- Characterisation of non coding RNAs and epigenetic modifications

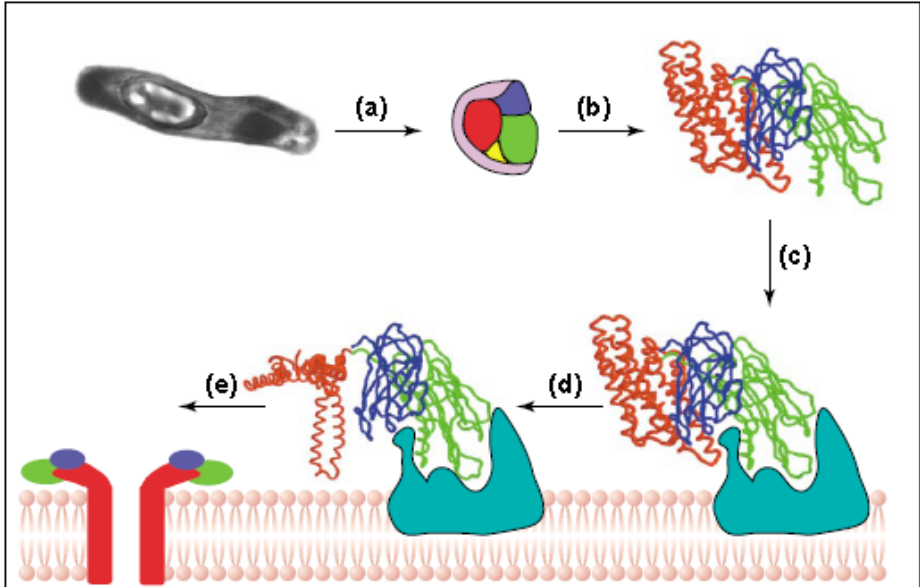


# readily accessible genome sequence facilitates gene identification and marker- assisted plant breeding

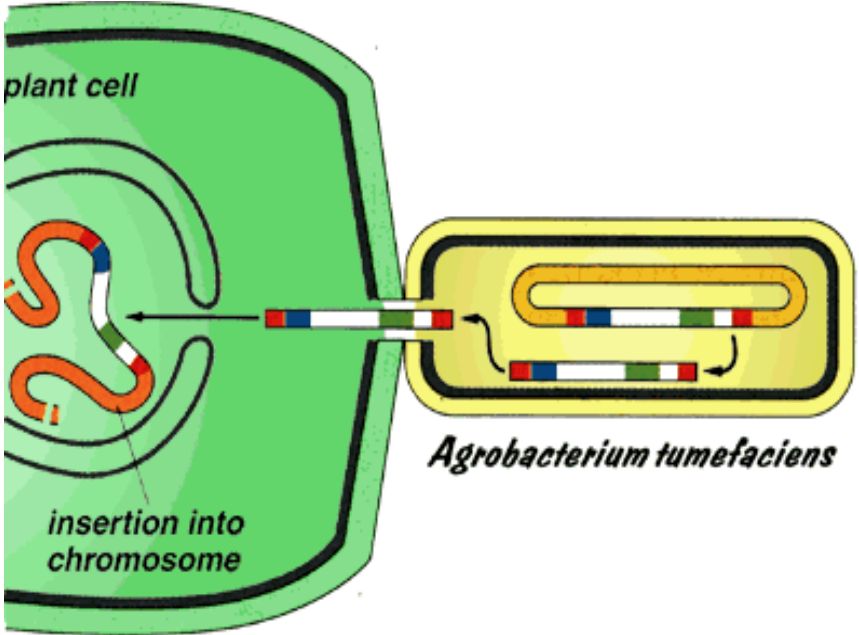
- *Sub1*



# 1<sup>st</sup> generation GM

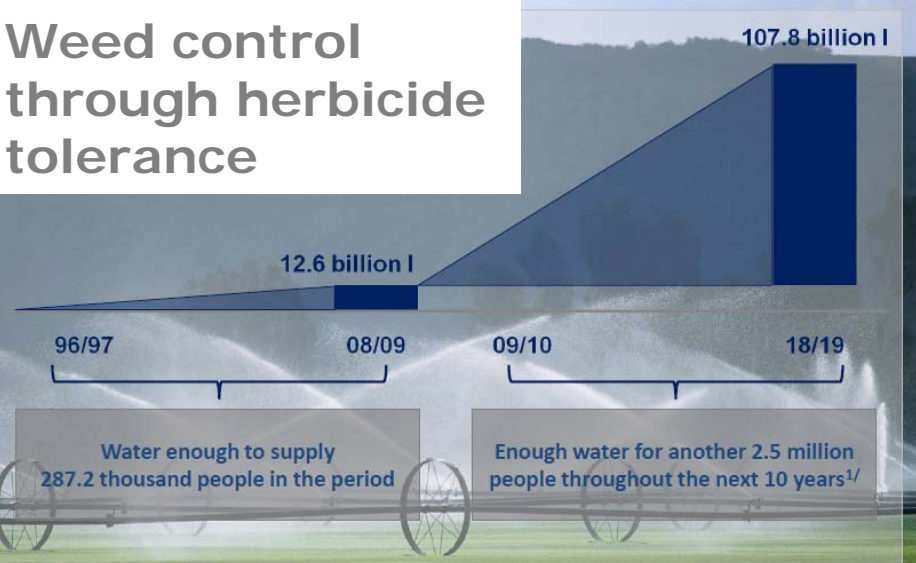


BT = insect pest resistance ENDS in Genetics



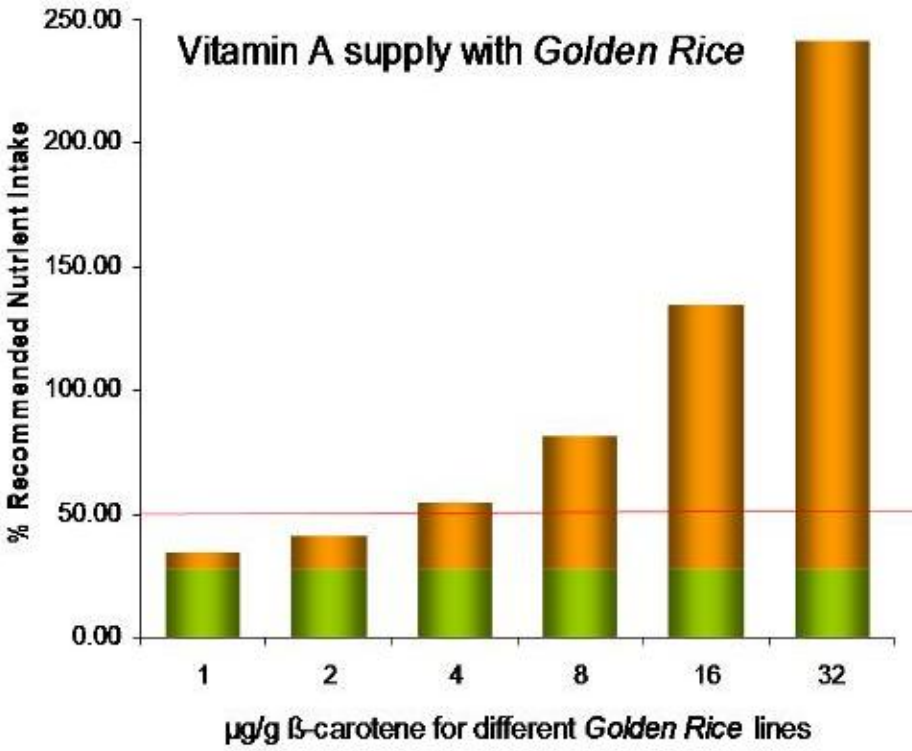
Biotech adoption in Brazil allowed a substantial reduction of water deployed on chemical spraying

Weed control through herbicide tolerance

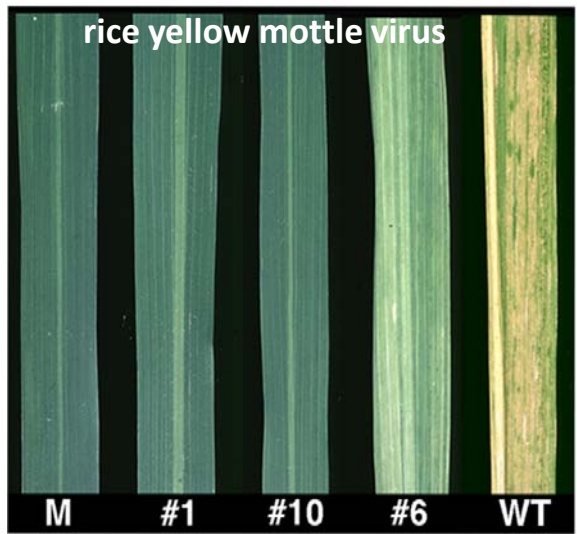
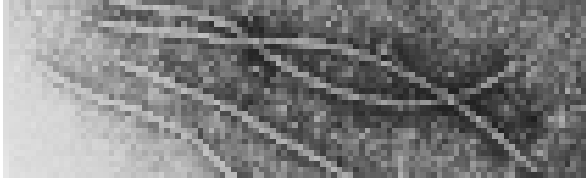


Source: CÉLERES AMBIENTAL® based on proprietary research  
<sup>1/</sup> Assuming the UN recommendation of 120 l/day/inhabitant

# 1<sup>st</sup> generation GM has not been fully exploited



Golden rice



Parasite-derived resistance

# 2<sup>nd</sup> generation GM

- isolated genes can be used in genetic manipulation – transfer of plant genes between plants - cisgenesis



**Gene RB cloned from *Solanum bulbocastanum* confers broad spectrum resistance to potato late blight**

**Junqi Song\*†, James M. Bradeen†‡, S. Kristine Naess‡, John A. Raasch§, Susan M. Wielgus\*‡, Geraldine T. Haberlach‡, Jia Liu¶, Hanhui Kuang, Sandra Austin-Phillips§, C. Robin Buell¶, John P. Helgeson‡\*\*, and Jiming Jiang\*,\*\***

[www.pnas.orgcgidoi10.1073pnas.1533501100](http://www.pnas.orgcgidoi10.1073pnas.1533501100)

**nextgen DNA sequence allows genes to be mapped easily so that GM can be used to achieve many of the targets of conventional breeding**

- **drought and stress resistance**
- **improved post harvest storage**
- **modified plant architecture**
  - **dwarf for resistance to lodging and improved harvest index**
  - **more root hairs for increased nutrient uptake**
- **modified plant metabolism (for biofuel crops or to enhance nutritional content)**
- **complex multigene** traits can also be transferred

# GM can be used to achieve targets of conventional breeding

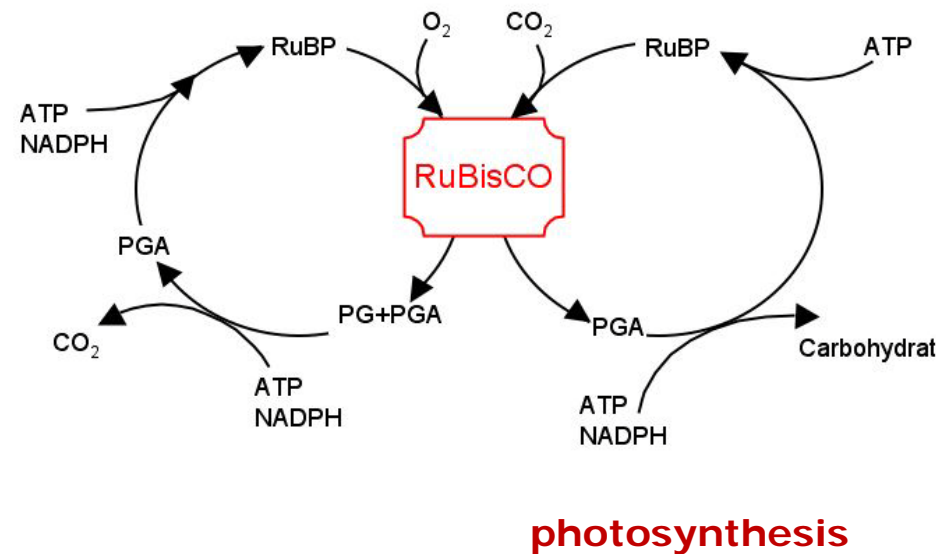
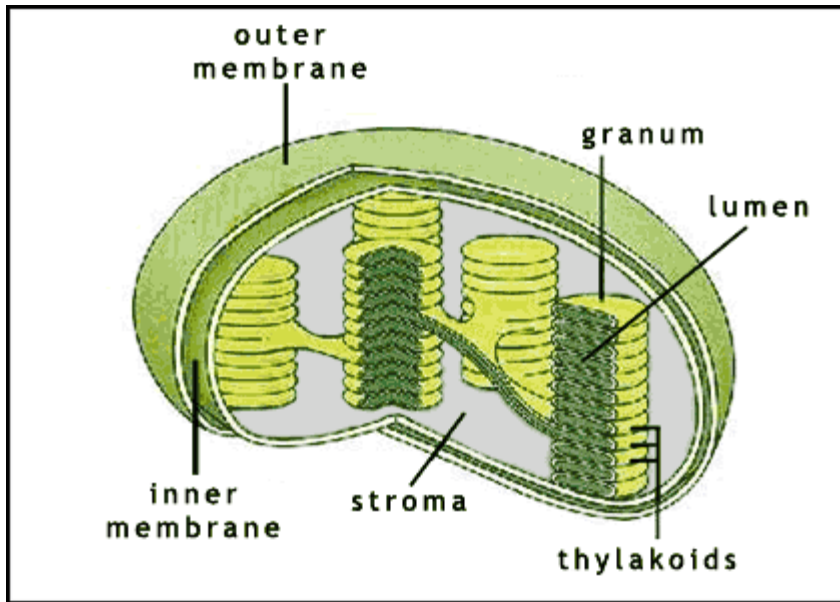
- **retaining the characteristics of original variety**
- **to generate several new varieties at once**

# 3<sup>rd</sup> generation GM

- radically altered or completely novel crops for food and fuel
- complex traits or sets of traits
- genes from plants and non plants – or both

# long term grand challenges for plant science ?

- Increasing the efficiency of photosynthesis??



# scientific grand challenges in crop production

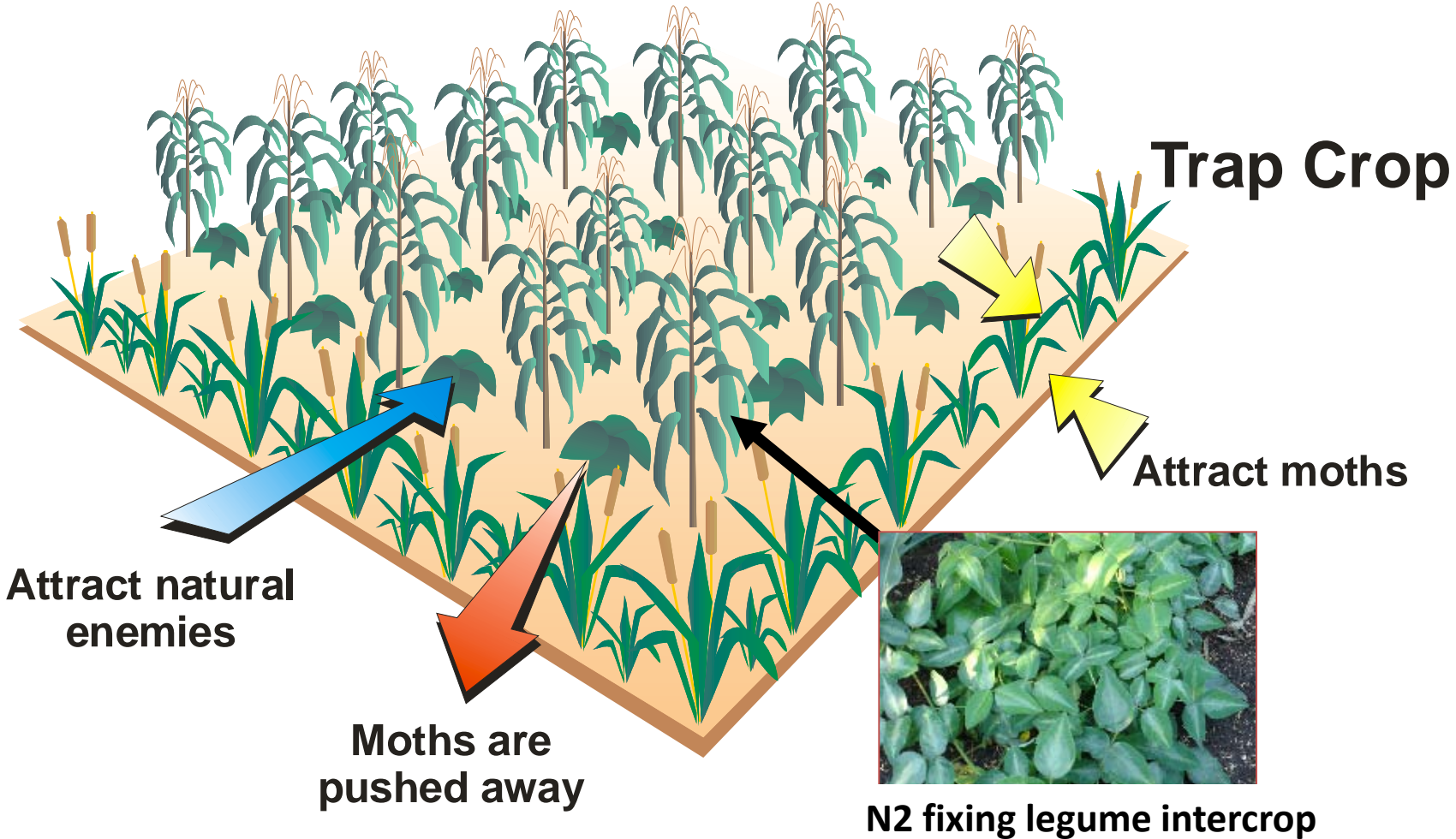
- enhanced photosynthesis
- perennial crops so that soil erosion prevented, better retention and uptake of water and nutrients from the soil, no need to rebuild root system each year
- nitrogen fixation???
- vegetative seed production (ie seed produced without pollination)
- harnessing of hybrid vigour
- new species as crops

**combining advances in  
genetics with agronomy**

# Push-pull or companion cropping

Main Crop

Trap Crop



# next generation companion cropping

- Use of GM and breeding to **adapt main and companion crop to companion cropping**
- Application of **companion cropping in developed country** agriculture to reduce inputs. Combine with 21<sup>st</sup> century maincrops with biotech enhanced traits and with improved engineering
- Requires **new IP and effective regulatory framework** for GM
- Raises important questions about **intensification and land sparing vs extensification**

# **summary – new genetics for sustainable agriculture**

- **next generation sequencing is revolutionary – gene identification and genome analysis are greatly enhanced**
- **enhanced genome analysis provides opportunities in marker assisted selection and variations on conventional breeding**
- **1<sup>st</sup> generation GM has not been fully exploited**
- **2<sup>nd</sup> generation GM achieves the targets of conventional breeding and follows from enhanced genome analysis and gene identification**
- **3<sup>rd</sup> generation GM could provide radically new crops**
- **Genetics (GM and conventional breeding) should be linked to innovation in agronomy and crop management**