The Future Direction and Opportunities of Horticultural Research

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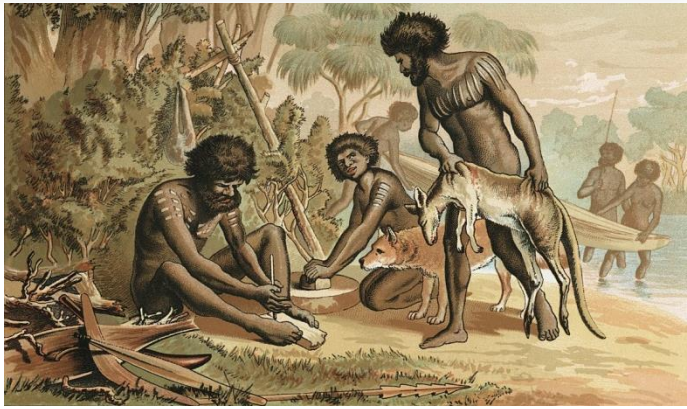
INTRODUCTION

Horticulture: *hortus* (garden) and *cultura* (culture).

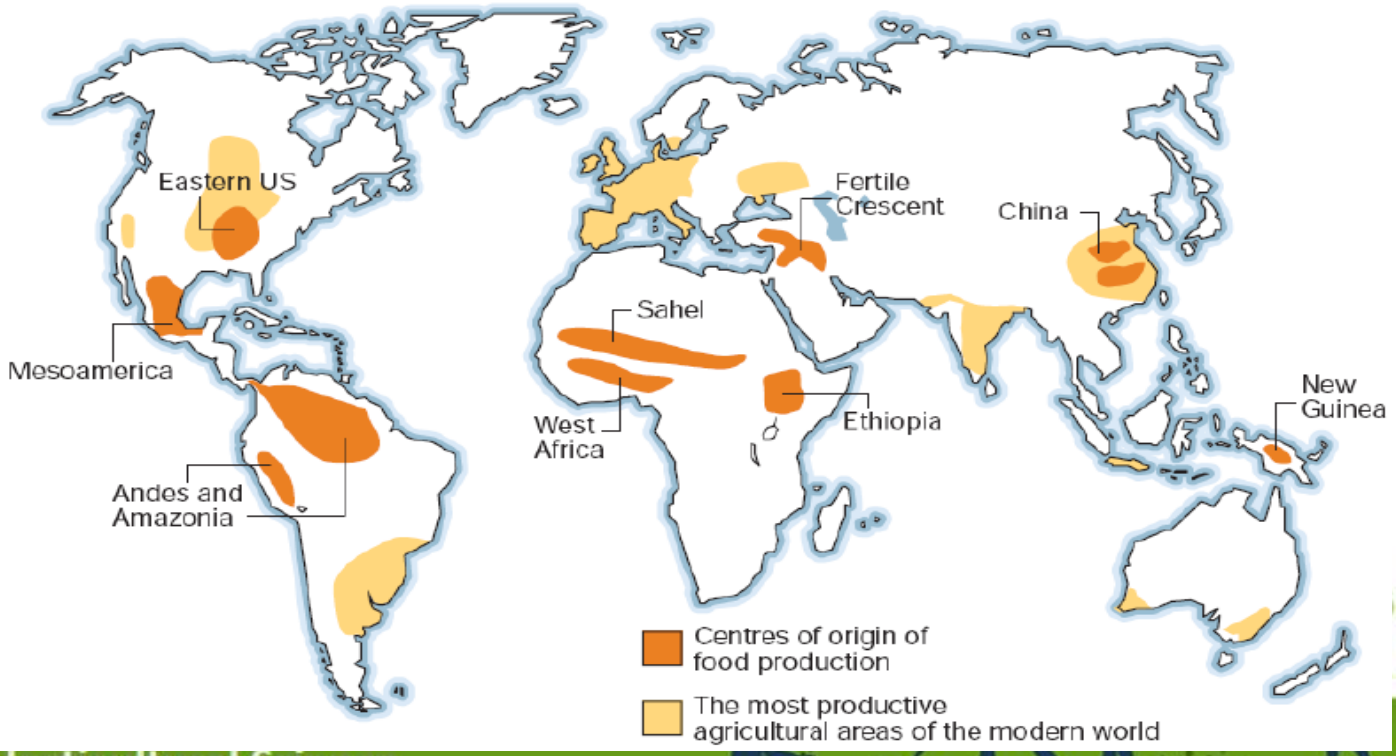
Horticulture is the art and science of the culture of plants such as fruits, nuts, berries, vegetables, ornamentals and medicinal and aromatic plants for food, beauty, utility, comfort, health and therapy.

HISTORY

- closely linked with the history of agriculture going back 10000 years ago.
- Humans were hunter-gatherers, relying on wild animals and initiated a revolution by shifting agriculture instead of scavenging, collecting, and hunting (Janicke, 2007).



The emergence of agriculture was in seven to nine major centers, mainly in the river valleys of the Tigris-Euphrates, Indus and Nile, and in China, Mesoamerica, and East and West Africa.

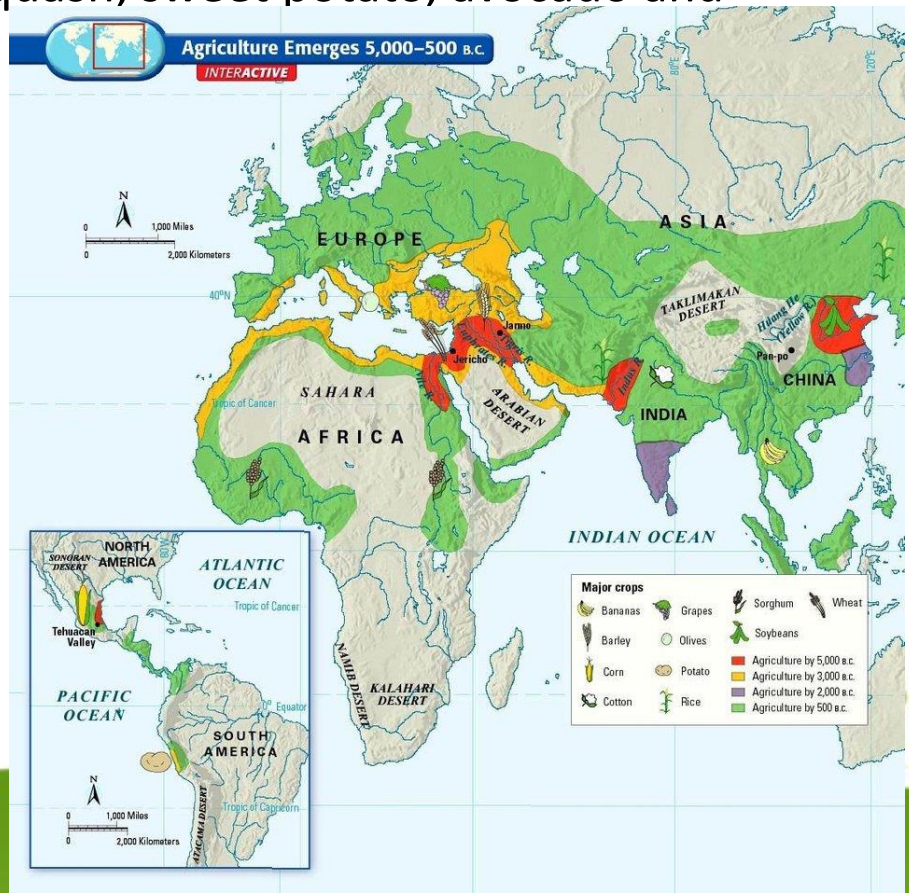


ISHS

3000 BCE (Von Baeyer, 2014)

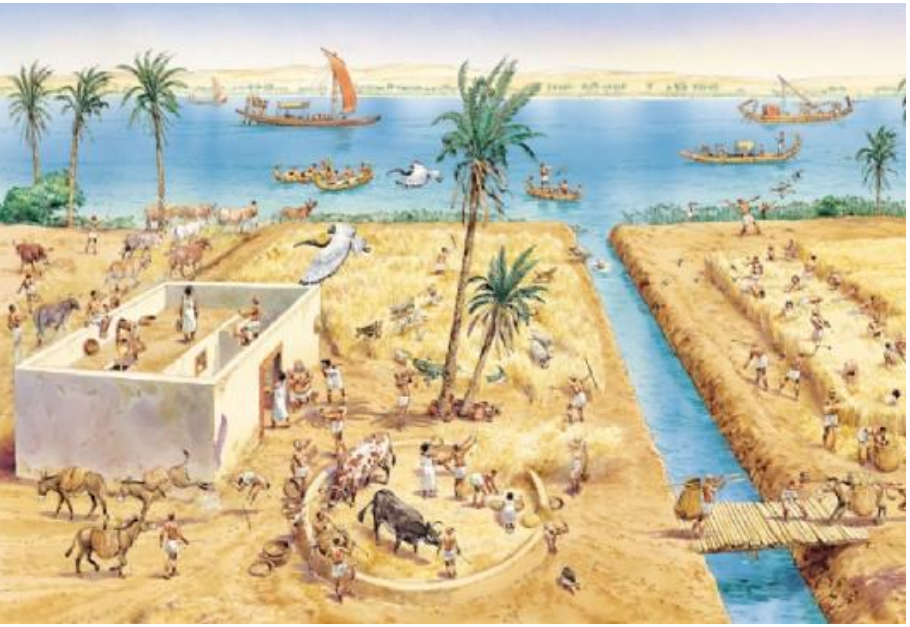
Asia: food crops such as turnip, onion, carrot, lettuce, apple, pear, quince, banana, peach, citrus and almonds
Mediterranean: cabbage, cauliflower and broccoli
Mesoamerica: corn, beans, tomato, cacao, squash, sweet potato, avocado and potatoes.

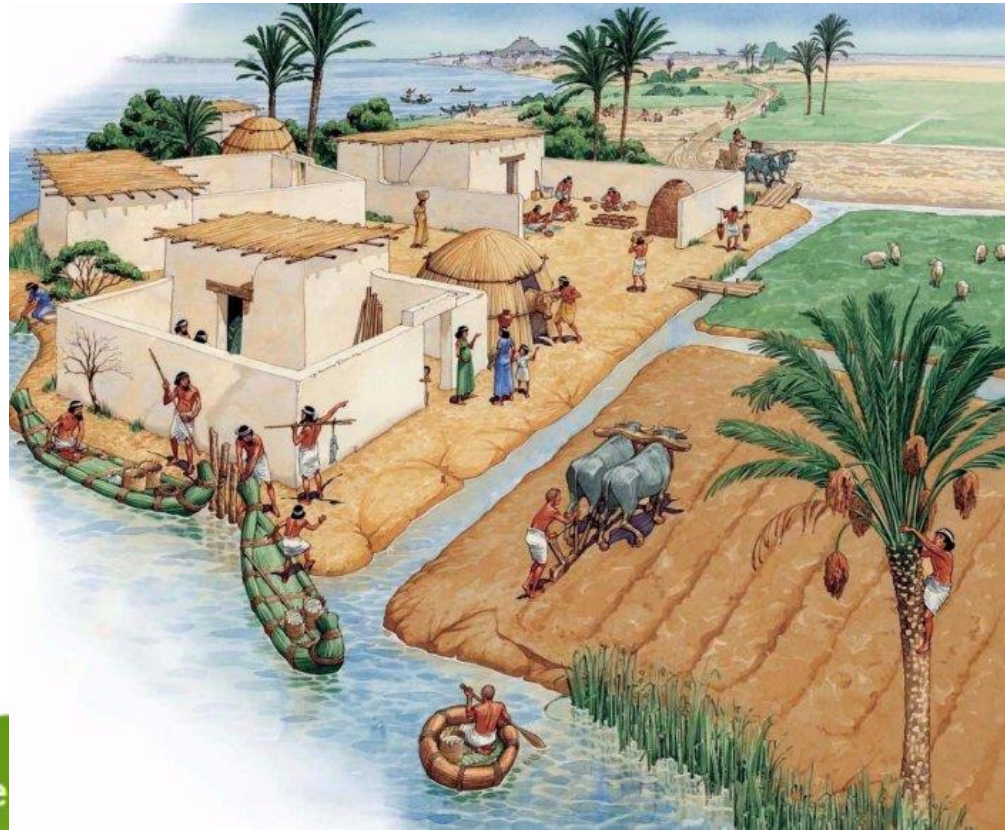
6000-4000 BCE: grapewine is the first plant manipulated (Huxley, 1978)



The writings of a tablet dating from the 7th century BCE in Babylon (Sumerian civilization) listed the vegetables and herbs of the gardens of Babylonian.

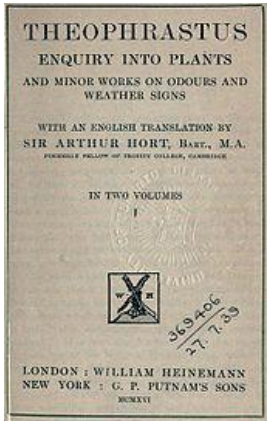
- Egyptians used technologies such as irrigation which were most probably invented by Sumerians, incorporating with a network of canals, dikes, sluices, basins, etc. A wide range of foodstuffs (garlic, onion, radish, lettuce, parsley, different beans and lentils, melons and gourds, dates, figs, grapes and later the pomegranate, olive, apple, peach and pear), herbs, spices and medicinal plants were cultivated by Egytians.

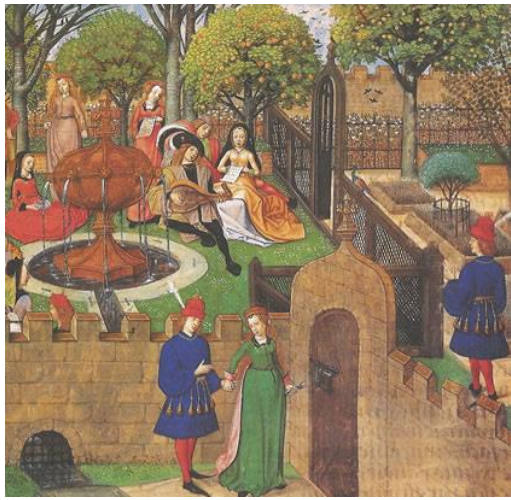




- The centers of horticultural development were found in South America (Aztec, Maya & Inca) for the years between 8000 and 2000 BCE and China and Japan at least until the 10th century.

- Greek civilization by 1600 BCE influenced Romans (7th century BCE up into the 5th century CE) who inherited the information about grafting, budding, rotation with legumes, etc.


THEOPHRASTUS
ENQUIRY INTO PLANTS
AND MINOR WORKS ON ODOURS AND WEATHER SIGNS
WITH AN ENGLISH TRANSLATION BY
SIR ARTHUR HORT, BART., M.A.
IN TWO VOLUMES
LONDON : WILLIAM HEINEMANN
NEW YORK : G. P. PUTNAM'S SONS

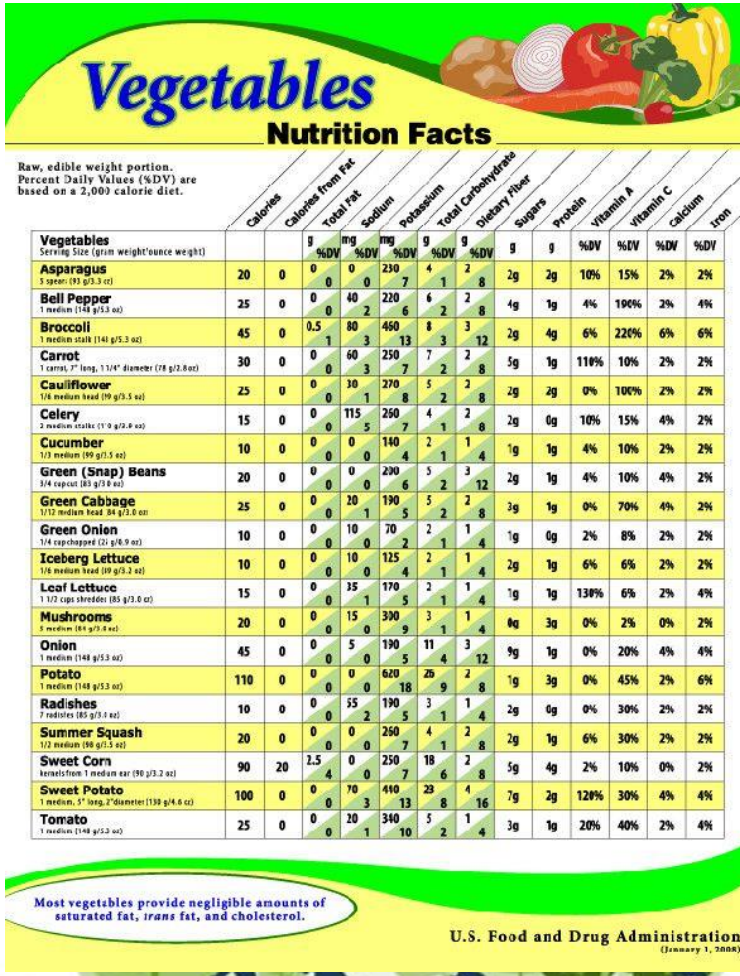


- Agriculture and horticulture continued to evolve until the Middle Ages when horticulture was formally recognised as a discipline distinct from agriculture (Von Baeyer, 2014).

RECENT PRODUCTION HISTORY OF HORTICULTURE

- Horticulture has gained more importance due to
  - recognition of health related effects of horticultural products in our diet,
  - their importance for a healthy human nutrition and well being,
  - in combating the problem of hidden hunger in developing countries.

Also, an important source of employment and provider of industrial raw materials !



Vegetables

Nutrition Facts

Raw, edible weight portion. Percent Daily Values (%DV) are based on a 2,000 calorie diet.

Vegetables (Serving Size (gram weight/ounce weight))	Calories	Calories from Fat	Total Fat g	%DV	Sodium mg	%DV	Potassium mg	%DV	Total Carbohydrate g	%DV	Dietary Fiber g	%DV	Sugars g	Protein g	Vitamin A %DV	Vitamin C %DV	Calcium %DV	Iron %DV
Asparagus (5 spear; (93 g/3.3 oz))	20	0	0	0%	0	0%	230	7%	4	1%	2	8%	2g	2g	10%	15%	2%	2%
Bell Pepper (1 medium (148 g/5.3 oz))	25	0	0	0%	40	2%	220	6%	6	2%	2	8%	4g	1g	4%	190%	2%	4%
Broccoli (1 medium stalk (141 g/5.3 oz))	45	0	0.5	1%	80	3%	460	13%	8	3%	3	12%	2g	4g	6%	220%	6%	6%
Carrot (1 carrot, 7" long, 1 1/4" diameter (78 g/2.8 oz))	30	0	0	0%	60	3%	250	7%	7	2%	2	8%	5g	1g	110%	10%	2%	2%
Cauliflower (1/6 medium head (99 g/3.5 oz))	25	0	0	0%	30	1%	270	8%	5	2%	2	8%	2g	2g	0%	100%	2%	2%
Celery (2 medium stalks (1' 0 g/2.9 oz))	15	0	0	0%	115	5%	260	7%	4	1%	2	8%	2g	0g	10%	15%	4%	2%
Cucumber (1/3 medium (99 g/3.5 oz))	10	0	0	0%	0	0%	140	4%	2	1%	1	4%	1g	1g	4%	10%	2%	2%
Green (Snap) Beans (3/4 cup cut (83 g/3 0 oz))	20	0	0	0%	0	0%	200	6%	5	2%	3	12%	2g	1g	4%	10%	4%	2%
Green Cabbage (1/12 medium head 84 g/3.0 oz)	25	0	0	0%	20	1%	190	5%	5	2%	2	8%	3g	1g	0%	70%	4%	2%
Green Onion (1/4 cup chopped (2i g/6.9 oz)	10	0	0	0%	10	0%	70	2%	2	1%	1	4%	1g	0g	2%	8%	2%	2%
Iceberg Lettuce (1/6 medium head (89 g/3.2 oz)	10	0	0	0%	10	0%	125	4%	2	1%	1	4%	2g	1g	6%	6%	2%	2%
Leaf Lettuce (1 1/2 cups shredded (85 g/3.0 oz)	15	0	0	0%	35	1%	170	5%	2	1%	1	4%	1g	1g	130%	6%	2%	4%
Mushrooms (5 medium (84 g/3.4 oz)	20	0	0	0%	15	0%	300	9%	3	1%	1	4%	0g	3g	0%	2%	0%	2%
Onion (1 medium (148 g/5.3 oz)	45	0	0	0%	5	0%	190	5%	11	4%	3	12%	9g	1g	0%	20%	4%	4%
Potato (1 medium (148 g/5.3 oz)	110	0	0	0%	0	0%	620	18%	26	9%	2	8%	1g	3g	0%	45%	2%	6%
Radishes (7 radishes (85 g/3.1 oz)	10	0	0	0%	55	2%	190	5%	3	1%	1	4%	2g	0g	0%	30%	2%	2%
Summer Squash (1/2 medium (98 g/3.5 oz)	20	0	0	0%	0	0%	260	7%	4	1%	2	8%	2g	1g	6%	30%	2%	2%
Sweet Corn (kernels from 1 medium ear (90 g/3.2 oz)	90	20	2.5	4%	0	0%	250	7%	18	6%	2	8%	5g	4g	2%	10%	0%	2%
Sweet Potato (1 medium, 5" long, 2" diameter (130 g/4.6 oz)	100	0	0	0%	70	3%	440	13%	23	8%	4	16%	7g	2g	120%	30%	4%	4%
Tomato (1 medium (148 g/5.3 oz)	25	0	0	0%	20	1%	340	10%	5	2%	1	4%	3g	1g	20%	40%	2%	4%

Most vegetables provide negligible amounts of saturated fat, *trans* fat, and cholesterol.

U.S. Food and Drug Administration

RECENT PRODUCTION HISTORY OF HORTICULTURE

- Horticultural production became particularly important for income generation and food production in developing and emerging economies.

RECENT PRODUCTION HISTORY OF HORTICULTURE

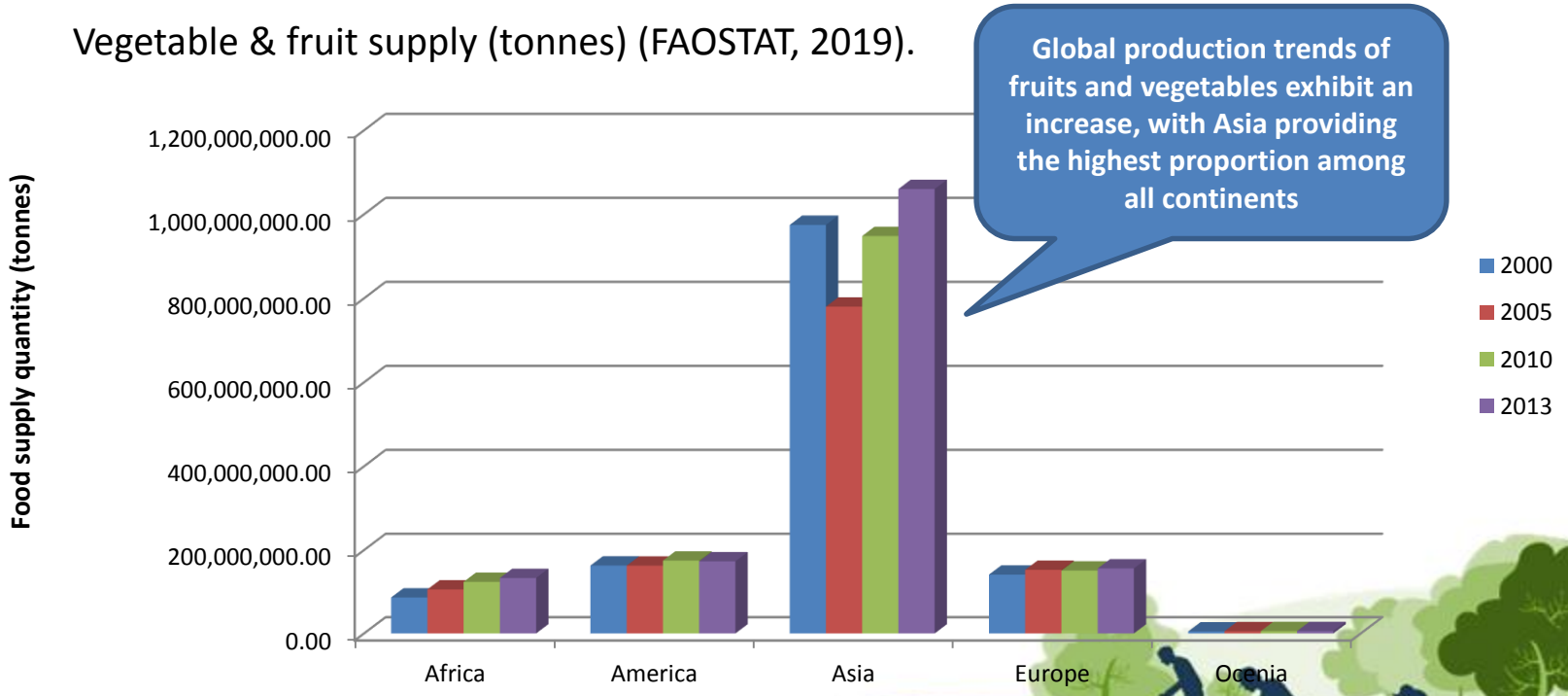
- In 1950s comparatively more resources have been assigned to the improvement of staple grains than to improving horticultural crops.
- Between 1960 and 2000, the land resources needed for horticultural crop production have more than doubled worldwide and continued to increase.

Vegetable and fruit supply (tonnes)

(FAOSTAT data, 2019)

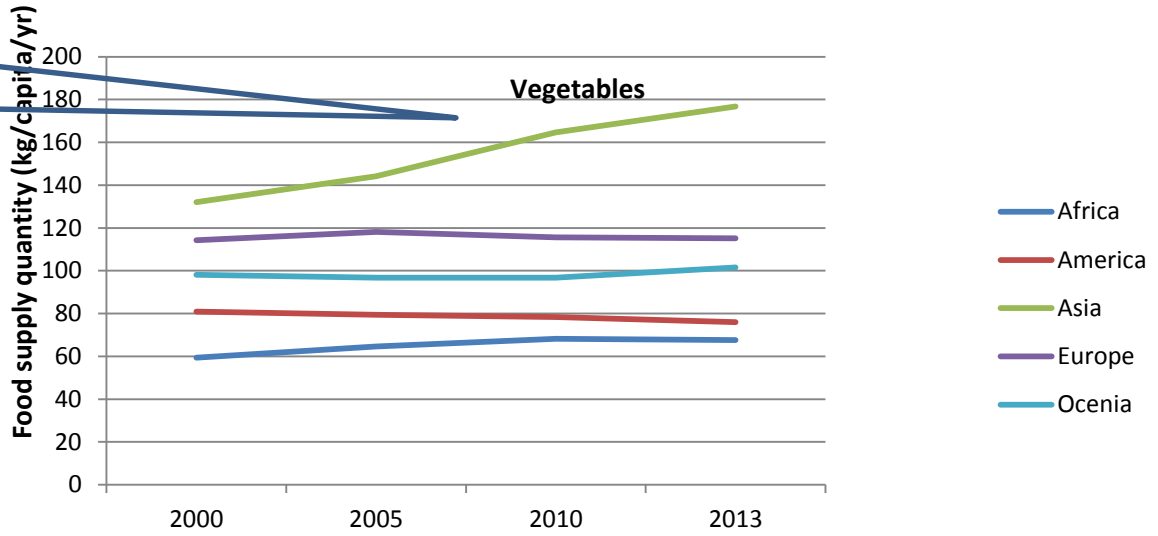
Among fruits, nuts, berries, vegetables, ornamentals and medicinal and aromatic plants and other food crop sectors, the fruit and vegetable sector compares favourably in terms of employment and income generation (Joosten et al. 2015). Therefore, fruits and vegetables are of priority importance in our reflection of future directions and opportunities.

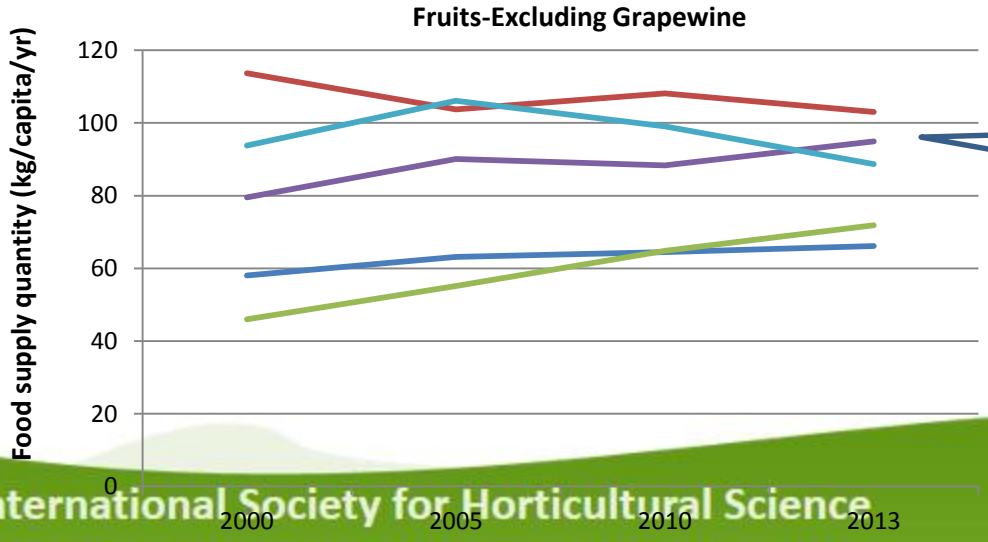
Vegetable & fruit supply (tonnes) (FAOSTAT, 2019).



Vegetable & fruit consumption per capita (FAOSTAT data, 2019)

with regard to per capita supply of vegetables, Asia took the lead

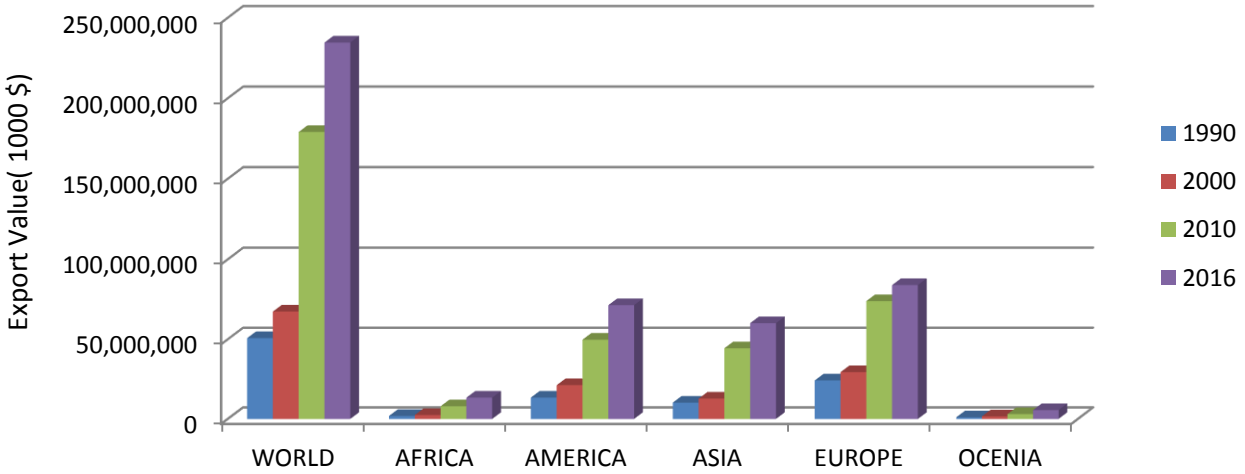




with regard to fruits, America, Africa and Europe delivered more per capita than Asia

Trends & Challanges

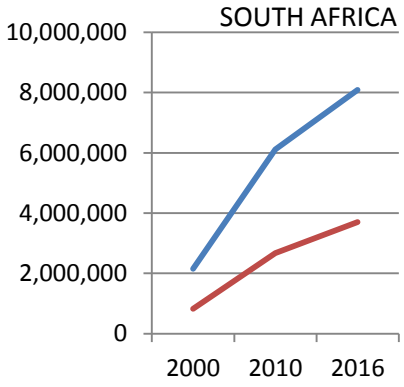
- The World population is projected to reach 9 billion by 2050 which will translate into increased food requirement of at least 70% (Marondedze et al., 2018). The relevance of fruits and vegetables with regard to export value, rural development, employement and welfare to society are at large important and have continously increased.

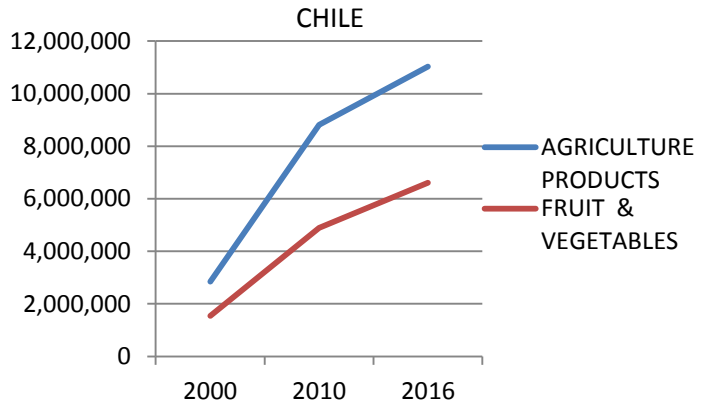


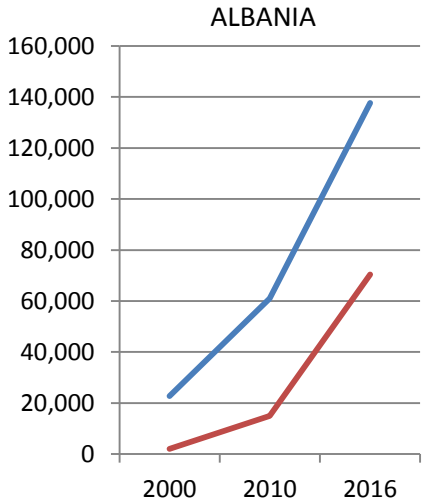
Export value of fruits and vegetables.

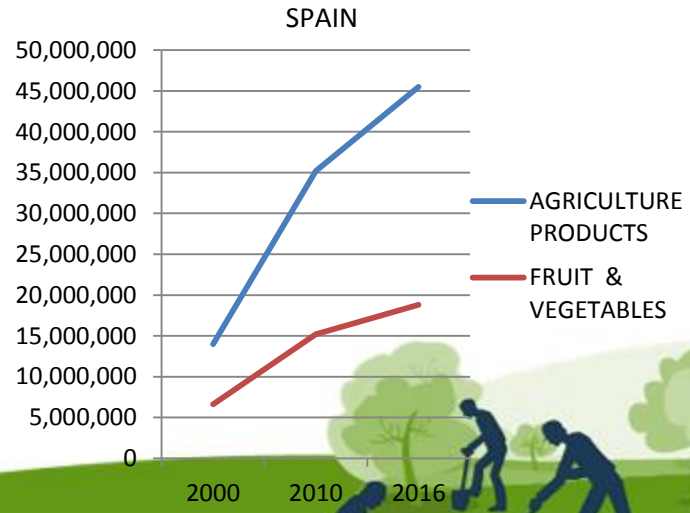
Share of export value of fruits and vegetables in agricultural products in different countries (x1000 $)

(Source: FAOSTAT, 2016)









Challanges

- Globalization and Trade policy
- Urban horticulture
- Increased Demand for Food
- Avoiding food waste
- Pressing need for more efficient use of natural resources
- The need for a drastical reduction of the dependance on synthetic inputs
- Soil fertility & biodiversity loss
- Progressive climate change

Globalization and trade policy

- Globalization and increasing demand to safe and high quality products has affected fresh fruit and vegetable marketing (Nicola and Fontana, 2010) resulting in changes in food supply chain (i.e. tracebility, record keeping, standarts, etc.) and enhancement of production systems.
- Consumer preferences, need to product diversity, advances in technology from farm to fork, easy accesibility of markets and increased levels of international investment have played an important role in changes of marketing in wholesale and retail markets worldwide providing consumers horticultural crops year-round (Wu-Huang, 2004).

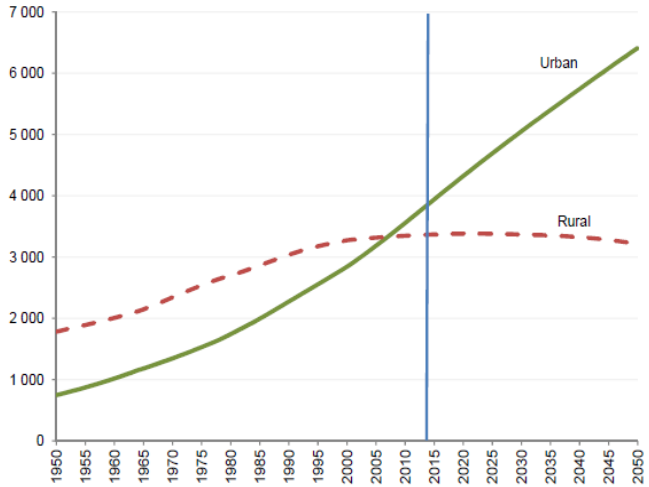
Globalization and trade policy

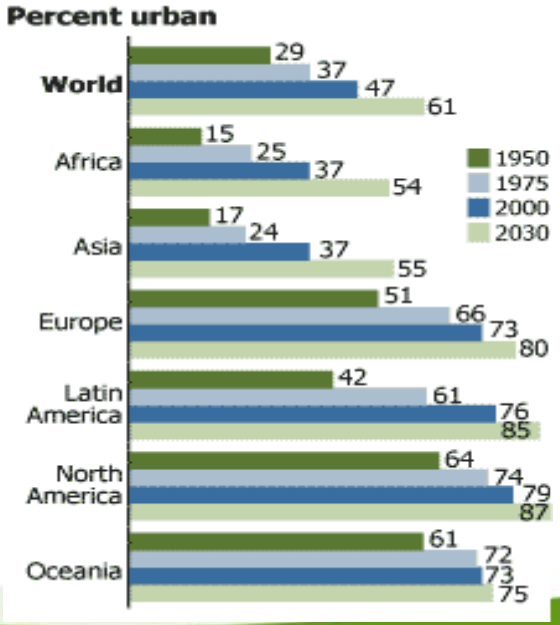
- As a result of changes in supply chain of horticultural products, super/hipermarkets replaced with small markets and/or fruit-veg sellers since they provide horticultural crops (i.e. fruits, vegetables, flowers) the year-round and a certain number of international retailers consolidating the buying power are well known all over the over world with their brand names.

Name of company	Country of origin	Retail revenue (USD M)(2016)	Growth rate (%) (2016)
Wal-Mart Stores, Inc.	US	485,873	0.8%
Costco Wholesale Corp.	US	118,719	2.2%
The Kroger Co.	US	115,337	5.0%
Schwarz Group	Germany	99,256	5.3%
Walgreens Boots Alliance, Inc.	US	97,058	8.3%
Amazon.com, Inc.	US	94,665	19.4%
The Home Depot, Inc.	US	94,595	6.9%
Aldi Group	Germany	84,923*	4.8%
Carrefour S.A.	France	84,131	-0.4%
CVS Health Corporation	US	81,100	12.6%

Urban Horticulture

- Urbanization is the shifting of population from rural to urban areas. It is projected that about 66% of the population of the world will be urbanized by 2050 (*World Urbanization Prospects, 2014*). Also it's predicted that more than half the world's population will be living in urban areas within the next few years.





Urbanization has some several positive effects of urbanization such as increased employment, modernization, easy accesibility, however it's detrimental effects on the environment (i.e increase of energy consumption, overpopulation) have key importance to start to think for sustainable urbanization.

Increased demand for food

- It's projected that global population will reach 11.2 billion even more by 2100 that will increase the food demand. Additionally global diet has shown changes due to differences in demands as a result of shifting demographics.

Global and regional per capita food consumption (kcal per capita per day)

Region	1964 - 1966	1974 - 1976	1984 - 1986	1997 - 1999	2015	2030
World	2358	2435	2655	2803	2940	3050
Developing countries	2054	2152	2450	2681	2850	2980
Near East and North Africa	2290	2591	2953	3006	3090	3170
Sub-Saharan Africa	2058	2079	2057	2195	2360	2540
Latin America Caribbean	2393	2546	2689	2824	2980	3140
East Asia	1957	2105	2559	2921	3060	3190
South Asia	2017	1986	2205	2403	2700	2900
Industrialized countries	2947	3065	3206	3380	3440	3500
Transition countries	3222	3385	3379	2906	3060	3180

Avoiding food waste

- According to US Environmental Protection Agency, 37.6 million tons of food was wasted in 2015 in US. Also a survey conducted in Britain has shown that over 30% of all food purchased is wasted.
- Although some processes for waste utilization are used in developed countries, they may not be adopted easily due to the economical reasons. Therefore there is a need to develop cost effective technologies in order to convert those wastes into value added products (Garg, 2014).

Pressing need for more efficient use of natural resources

- Global material use is expected to double to 190 billion tonnes (from 92 billion), by 2060 with an increase of 110% resulting in a reduction in forests and habitats over 10 and 20%, respectively and an increase in greenhouse gas emmissions by 43%. Rapid growth in extraction of materials is the main reason of climate change and biodiversity loss (Global Resources Outlook 2019).

- Resources such as land, water, labour, energy and some inputs namely fertilizers and pesticides are used intensively in horticulture crop production. However, excessive use of such resources has a potential of negative impact on the environment (Wainwright et al., 2014).

The need for a drastical reduction of the dependance on synthetic inputs

- Global pesticide market is projected to grow from around $ 75 billion in 2017 to $ 90 billion by 2023 (Mathews, 2018). Global insecticides, herbicides, and fungicides & bactericides use had increased during 1990 to 2007 and declined since 2007.

Pesticide use (kg/ha)

Year	Insecti.	Herbi.	Fungi. & Bacteri.	Rodenti	Other Pst. nes	Total
1990	0,2743	0,4178	0,2558	0,0118	0,0264	1,0736
1995	0,2526	0,4085	0,2354	0,0117	0,9773	1,9807
2000	0,2819	0,5313	0,3310	0,0111	1,1785	2,4606
2005	0,3204	0,6275	0,3330	0,0105	1,2730	2,6618
2010	0,2648	0,7265	0,3527	0,0013	1,4736	2,8554
2014	0,2015	0,6740	0,3240	0,0001	1,4458	2,7353

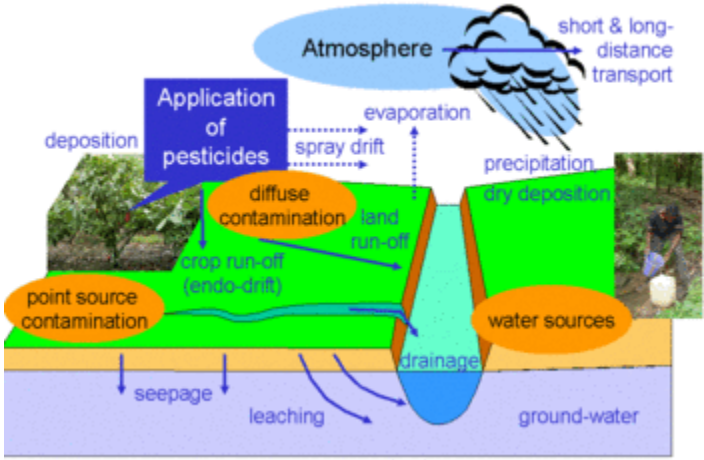
The need for a drastical reduction of the dependance on synthetic inputs

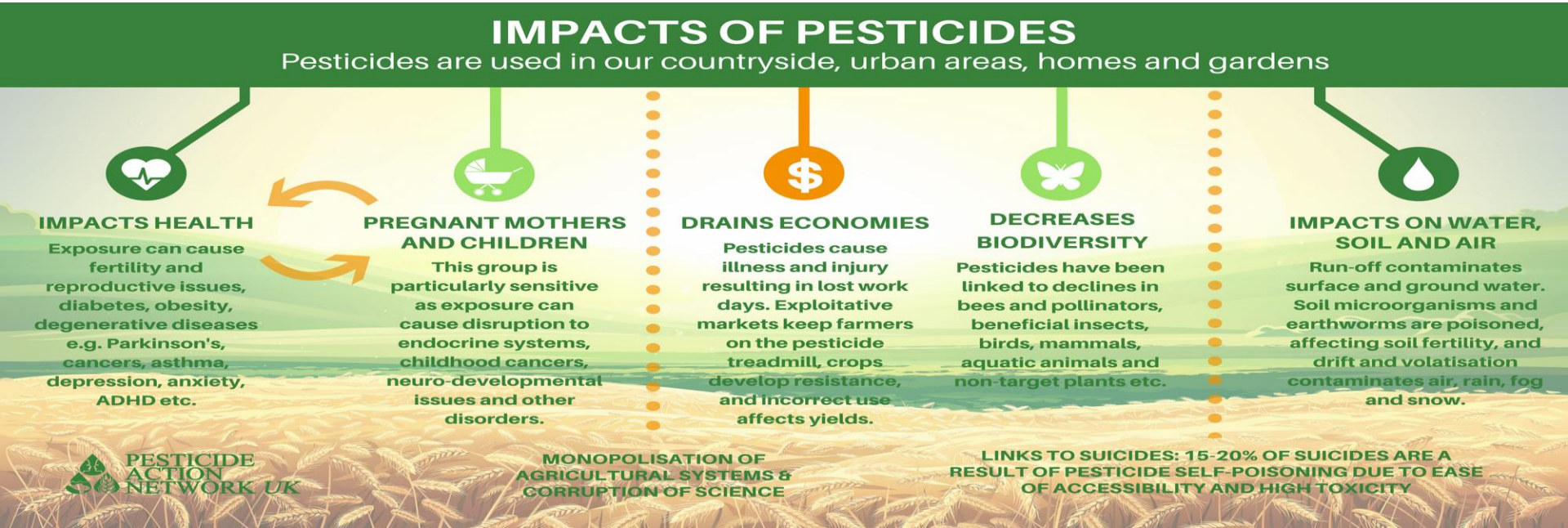
Global pesticide use (tonnes)

YEAR	Insecti.	Herbi.	Fungi. & Bacteri	Roden.	Other Pst. Nes	Total
2018	187.884,45	723.704,91	397.947,56	0	2.000.199,84	3.496.854,77
2020	152.692,87	723.704,91	392.256,98	0	2.047.714,20	3.471.780,00

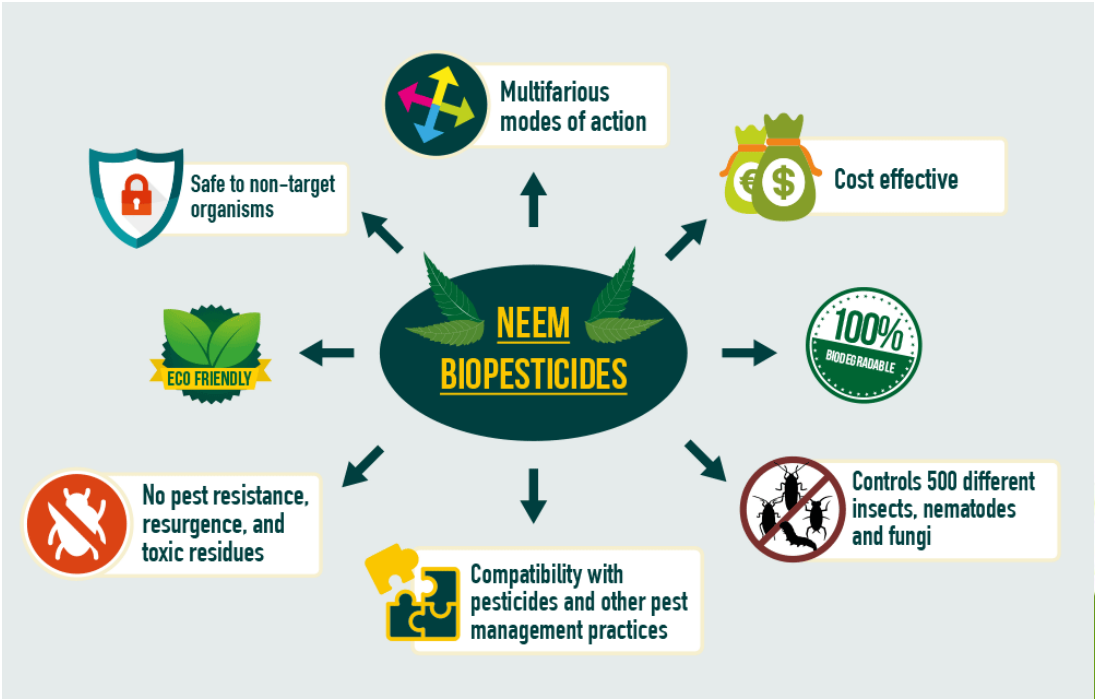
Rank	Country	Annual Pesticide Consumption (millions of kilograms)
1	China	1,806
2	United States	386
3	Argentina	265
4	Thailand	87
5	Brazil	76
6	Italy	63
7	France	62
8	Canada	54
9	Japan	52
10	India	40

- While pesticides have invalubly conribute to increasing productivity and assuring marketable high quality produce, in recent years negative and detrimental effects of pesticides on humans and on the ecosystem have become evident and attracted attention.
- There are risks associated with pesticide application that result in environmental and human health problems be it for those having direct contact with the pesticides (Tsimbiri et al., 2015) or negative long term effects of pesticide residues in the ecosystem, drinking water and horticultural produce.





- There is an increasing interest for the use of biopesticides in recent years. Biopesticides are natural materials derived from animals, plants, and bacteria, as well as certain minerals used for pest control.
- Currently, biopesticides have a small share of the pesticide market with a value of about $3 billion worldwide, accounting for just 5% of the total crop protection market. However 10% increase has estimated for each year. A better understanding of the microbiome in the soil and on plant and produce and of plant – pest and plant – pathogen interactions must eventually turn into a better management of the horticultural value chain without pesticides.



ISHS

- The amount of fertilizers used globally is estimated above 200.5 million tonnes in 2018. There is an increase of 25% between the years of 2008 and 2018. The consumption worldwide will grow by 1.8% per year and it's projected that nitrogen, phosphate and potash use will incresae 1.4, 2.2 and 2.6% through 2018.
- However, synthetic fertilizers are expensive, their production is energy intensive and nutrient losses into ground water endanger the ecosystem.
- Excessive fertilization (over fertilization) causes serious environmental degradation resulting in lower crop yields. Excessive N application increases the nitrate level the soil resulting in pollution in groundwater and atmosphere (Rahman and Zhang, 2018). This is why a more efficient use of nutrients is needed in horticultural crop production. It is beneficial in economical terms for horticulture and ecological terms for society.

Soil fertility & biodiversity

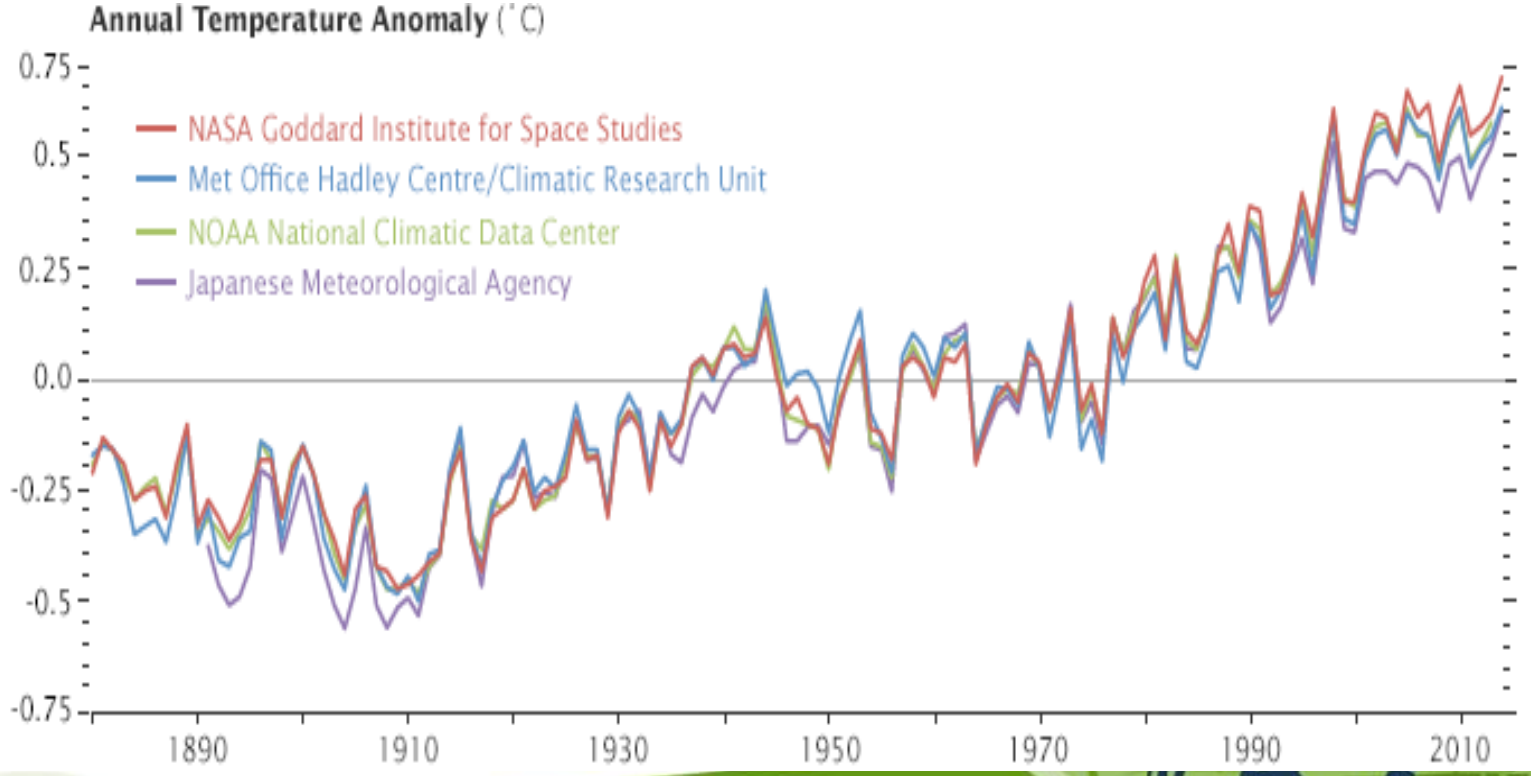
- Soil fertility is the fundament of most of horticultural production. Taking care of soil fertility deserves our utmost attention in order to not deny future generations to produce food with soil-based agriculture and horticulture.
- This demands to appreciate soil not only as a source of nutrients and anchoring opportunity for plants that can be endlessly exploited, but as a rich complex systems of including living components, that can be destabilised and impoverished easily if not managed properly.
- Industrialised horticulture risks to destabilise the soil system. Appropriate soil management concepts are needed for avoiding this.
- Production systems characterised by a high biodiversity are more resilient and have a better buffering capacity with regard to climate change incidents.
- However, global biodiversity loss is alarming. It was found that, due to human impact on the environment in the past half-century, the Earth's biodiversity has suffered a catastrophic decline unprecedented in human history.

Soil fertility & biodiversity

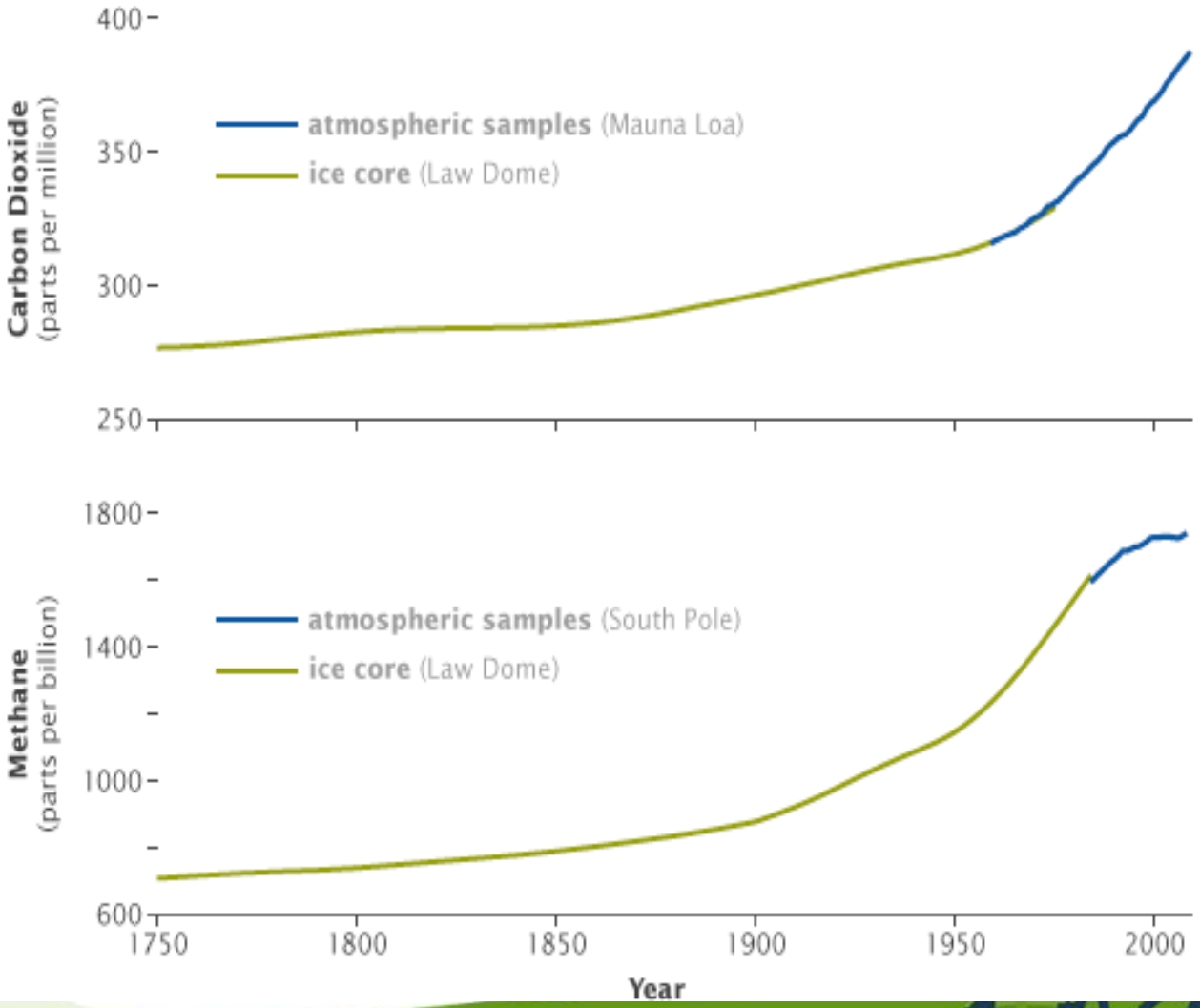
- Future horticultural production systems must strengthen and enhance biodiversity. Crop management techniques exist already, that would contribute to an increase biodiversity in the system.
- For instance, apple production systems were enriched with wild flower inter-row section, showed a positive effect on pest control and the soil fertility.

Progressive Climate Change

- Climate change has constantly happened since centuries.



Progressive Climate Change



- The effect of climate change on horticultural crops (e.g. ealier flowering and harvesting times in the Northern hemisphere, combined with an increased risk for frost, desiccation and hail damage) is significantly increasing production risks and investment for risk protection, while also in some areas, new production opportunities might arise.
- Innovative technological and efficient solutions are needed to solve the problems and for seizing the opportunities. Production techniques are needed for mitigating the impact of climate change on horticulture, while changing production systems must allow for easen adaptation of horticulture to climate change (e.g. new cultivars, resistant varieties, efficient water and nutrient management, plant architecture (Malhotra, 2017)

Digitization

- Horticulture 4.0, as a part of revolution Agriculture 4.0, will involve the use of technology such as sensors, robots, machines and information technology etc. for sustainable supply chain (De Clercg, 2018).

- The use of smart technologies is an opportunity, crucial and increasing in order to enhance horticultural crop productivity. Different e-learning modules, web applications, mobile apps and other tools encourage the introduction of smart horticulture (Roy et al., 2019).
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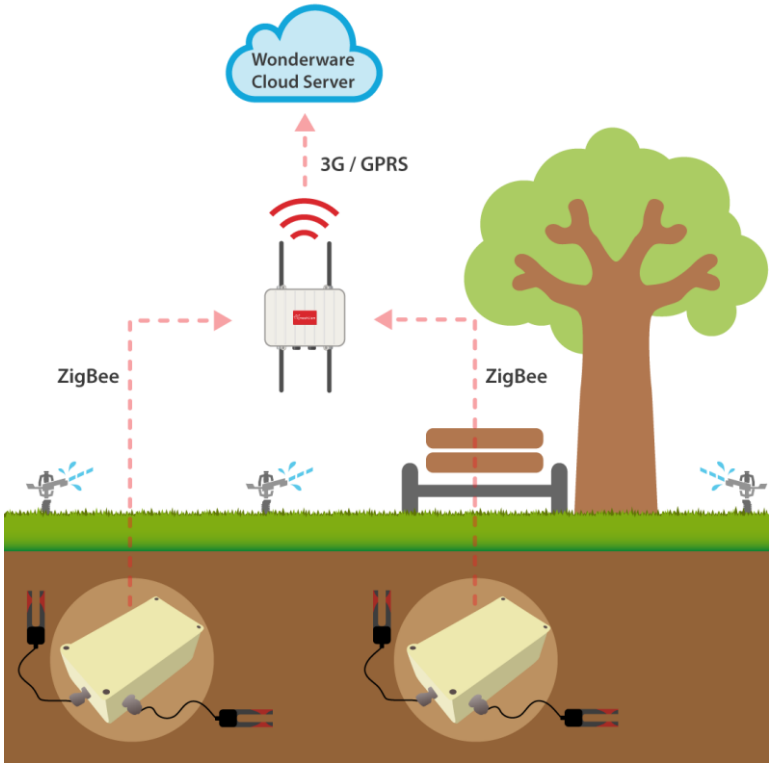
- Even if these technologies seem to offer great opportunities for improving productivity, we must remain critical with a holistic view, verifying whether the envisaged introduction improves sustainability and if not, propose sustainable alternatives for the introduction of new technologies, avoiding the negative effects and taking advantage of sustainable components of new technologies.



Sustainable Development Goals

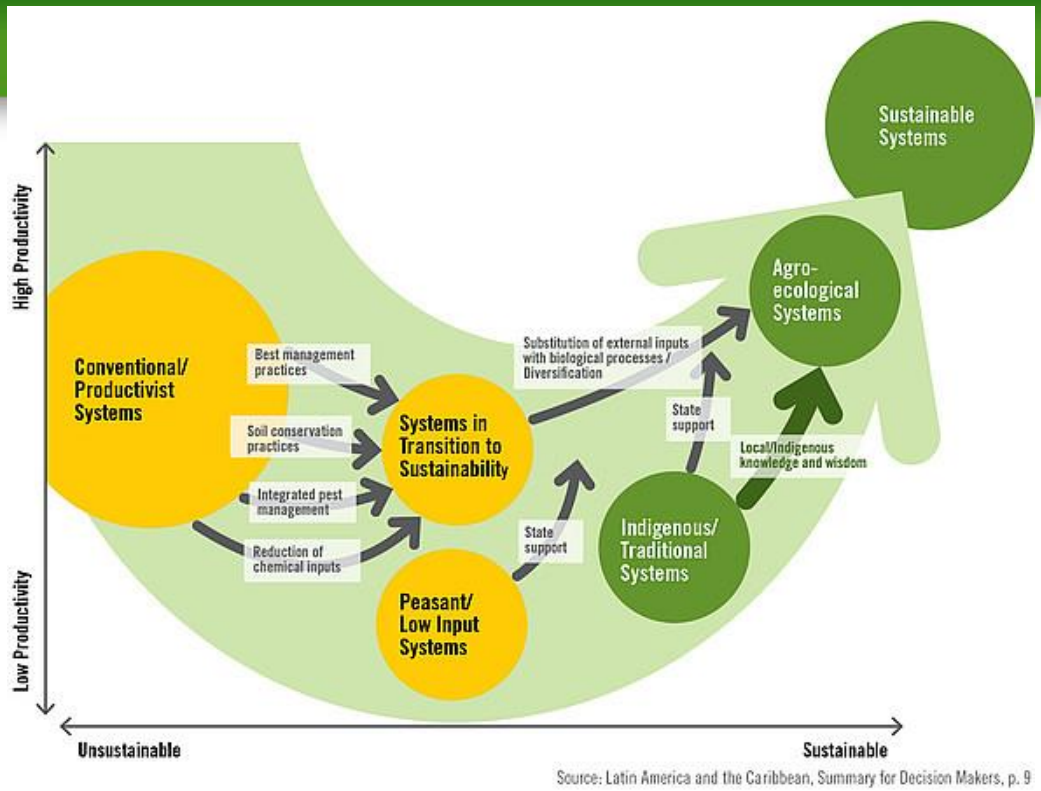
- In the past, modern plant breeding and new cultivation techniques have undoubtedly contributed significantly to food security and market adapted food quality.
- These challenges however, make evident that approach how we produce and with which we tend to improve production methods must change disruptively in order to not destroy the fundament of food production and to be able to provide sufficient and safe products.

The ultimate need for a transformation and the UN SDGs

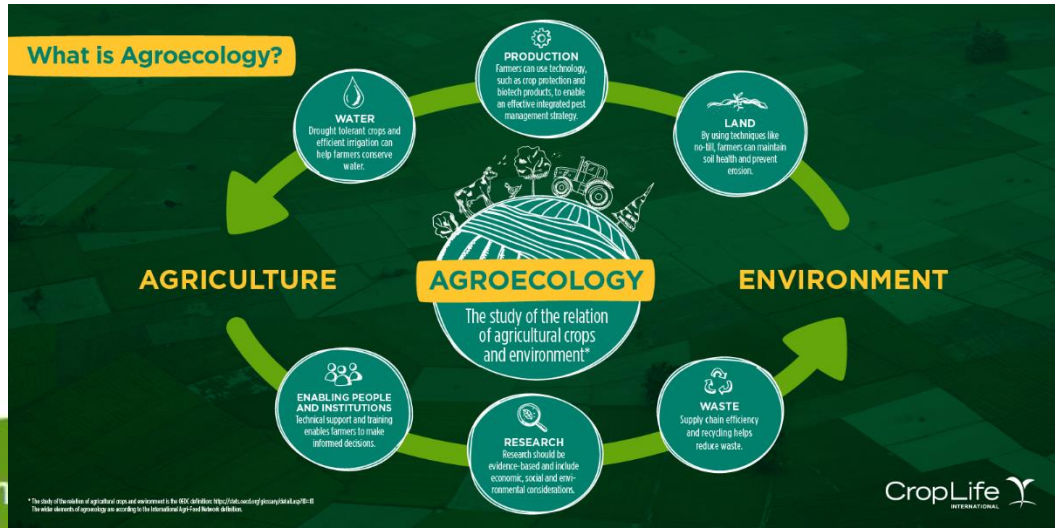
- The United Nations designed on the basis of the Millennium Development Goals (MDGs) the Sustainable Development Goals (SDG), which entered into force on 1 January 2016 for a period of 15 years.
- The 17 SDGs are the heart of agenda 2030 for a sustainable development, which was approved by the UN on September 25-27, 2015 and is a plan of action for people, planet and prosperty .
- The SDG apply to all nations and to all sectors of society. Many of the SDG are highly relevant to horticulture.

Agroecology is a scientific discipline since decades, but it has become in recent years also a synonym for a movement that synthesizes and applies knowledge of agronomy, ecology, sociology, ethnobotany and other related sciences with a holistic and strong ethical component .

Agroecology is thought to better achieve sustainable agroecosystems than former concepts. It is a concept, that strongly relies a systems approach, and more, than in the past, stresses the requirements of an inter- and transdisciplinary thinking. However, this is easier says than done.



Source: Latin America and the Caribbean, Summary for Decision Makers, p. 9



What responds best to the mentioned challenges?

- An Integrated Production 2.0, Organic Farming 3.0 or another production system?
- Resilient production systems, that have the capacity of responding flexibly to unexpected climate hazards and a changing context require a conceptual framework that is flexible enough to adapt to changing realities while keeping on track with the holistic view of agroecology.

- A recently published agroecology based concept for orienting policy intenventions seems to offer the flexibility needed (Eyhorn et al., 2019). Horticultural value chains seem an excellent field for testing who universally this interesting concept would be applied, also for orienting research and development interventions.

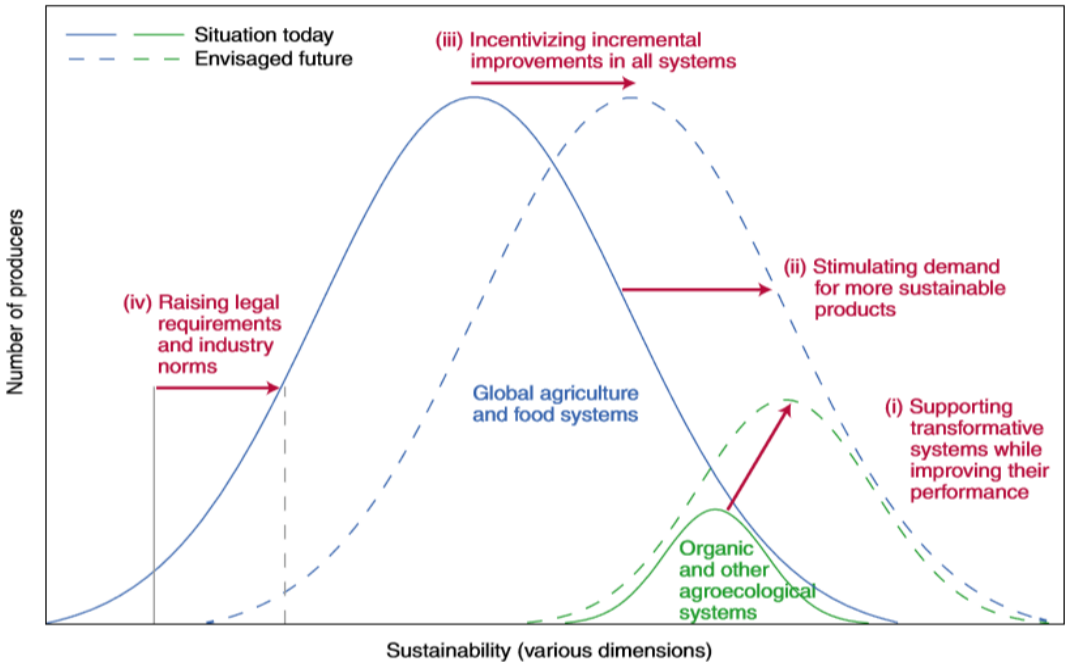


Fig. 1 | Policy interventions (red arrows) to drive sustainability in agriculture and food systems.

THE ROLE OF HORTICULTURAL RESEARCH

- Science is defined as the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment. Over the past 150 years science has been a driver of success of modern societies and in particular of agriculture. Research became the tool for achieving the scientific understanding of problem contexts and for problem solving (Bertschinger and Weber, 2019).
- In the past, the general tendency was to study on the problem of a defined space or discipline due to its practicality and easy management. This was an efficient way on addressing distict issues requiring expertise on a topic. However this has changed due to a need to broader perspectives to provide a better view in order to optimize the food and agricultural/horticultural system.
- Today, we have complex problems and challanges which would not be solved using conventional approach resulting in a reqirement for rational systemetic process to understand and to solve. Therefore we will need large research groups to carry multidisciplinary research in the future.

- In the next decade, the major goals either for horticulture or agricultural in general is expected to
  - **(1) improve the efficiency of production systems,**
  - **(2) increase the sustainability and resource use efficiency &**
  - **(3) increase the resiliency of horticultural cultural systems in order to to cover the demands of future societies** (Science Breakthroughs to Advance Food and Agricultural Research by 2030, 2019).
- The breakthroughs needed must solve the mentioned challenges of horticultural production.

- Research, development and innovation are the fundament for making this breakthrough possible.

- New Technologies in genetics and genom researches,
- Implementation of artificial intelligence and data intense management,
- Big data,
- Microbiomes,

- A different comprehensive research approach is needed than until now. Particularly because horticultural value chains tend to require more technical skills and more intensive care as compared to other crop value chains, a strong inter- and transdisciplinary impetus is needed. The agroecology concept seems particularly suitable to go along those lines, for further developing and transforming horticultural research in educating and orienting research and devlopment, the private sector and public policy makers. Horticulture should take a decisive role in such cropping systems innovation in leading agriculture onto this direction.

The role of ISHS

- ISHS, as a huge scientific network, has a key focus on facilitating cooperation and knowledge transfer in all branches of horticultural science on a global scale. The meetings (i.e., symposia, workshops, and congresses), publications, scientific structure and all other communication tools are a good platform to share, exchange and transfer knowledge on horticulture and to identify the needs (industry, consumers). ISHS then organize worldwide research and training capacities to provide innovative solutions.

Scientific Programme:

- **each year ~45 meetings**
- **www.ishs.org/calendar**

- ISHS must take an active role by increasing networking and connecting people, improving communication with members, developing efficient strategies to network with industry, continuing to link with international organizations, national societies, and societies in horticulture related fields, encouraging higher participation and submissions to our scientific meetings and publications, strengthening the regional relations in order to discuss and disseminate of the development and use of emerging technologies and systems.

- Actively draw on the to competences of ISHS members and ISHS commissions, particularly the recently created ISHS-Commission on Agroecology, for facilitating the making of the breakthroughs needed!

Conclusion

- The ISHS must also take an active role in addressing the UN SDGs, make clear, what horticultural research already does and can and will do in the future for contributing to the SDGs and support its members in going along those lines.
- It is essential that we share ourknowledge, competence and workforce to solve problems. We must unite and create large impact research groups and units, sharing multidisciplinary teams, to solve specific problems.

ISHS

Thank you for your attention

www.ishs.org