Farm of the Future

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Abstract

The evolution of the farms in the next 30 years will be impressive. There are several external drivers that will have a very strong influence on the farm of the future, such as: the increase of food demand for growing world population and for growing individual food consumption, the need to increase productivity and efficiency of production on current crop land and to cultivate new land, the availability of new technologies for farm tools, the pervasive presence of information and data. The farming activities will also have to be increasingly sustainable for the environment.

Farmers will interact more and more with global crop and food markets, which will increasingly drive farm medium to long term strategy, while they will be strengthening links and connections with local farm communities and groups, leveraging on local and regional networks for energy production and sharing, logistic optimization, information and services.

1. Introduction

The world today is facing extraordinary challenges; amongst the major ones, we surely have to include the need to feed all the world inhabitants, more than 9 billion people foreseen in 2050. And the need to preserve the environment and the life on the planet.

Agriculture is the key tool, the main enabler for feeding the planet and re-balancing the use and regeneration of resources.

Many studies and reports confirm and estimate the main global trends and the key needs. Even if the future is always uncertain, there are phenomena that are already happening and clearly show the inevitable direction of their evolution. There is no escape to the future, and a portion of it is enough understandable and of clear concern. We cannot just wait and see, because acting now is the only option to be there tomorrow.

2. Top Drivers

2.1. The World Population Increase

The world population is already over 7 billion today, and it's expected to grow up to over 9 billion in 2050. It's about 30% increase in 35 years (**Fig. 1**).

Average global life expectancy is increasing, while fertility rates show a limited decrease, mainly in high-fertility countries.

All these people will be there tomorrow, and they will all need to eat.

2.2. Food Availability

The first issue to solve is food availability to everyone: today almost 800 million people are chronically undernourished, one in nine of the world's population. This number is slowly decreasing over the years, but we must go to zero undernourishment at a much higher speed. FAO stated: "Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition" *[2]*.

The second significant trend is the increase of the amount of available protein per person, and of the share of livestock products in protein supply, due to an increase of the per capita income. Then a proportionally higher increase of vegetal products needed to grow animal proteins (7 to 10 times).

All that means agriculture has to find ways to overcome economic constraints and to dramatically increase productivity and efficiency. World agricultural production would need to expand by some 50 percent from now to 2050.
The increase of population will drive 70% of the increase in the world agricultural production, while the remaining 30% will be caused by the per capita income growth (meat consumption and other shifts in diets) *[3]*.

2.3. Sustainability of Growth

Climate changes will be a major challenge to the development of agriculture, forcing farmers to find robust and sustainable ways of increasing production and productivity of their land. Not only they have to face increased weather-related risks, water scarcity and land degradation, but at the same time they must invest in crops and farming practices that minimize the impact on the environment, to prevent further issues and invest on long-term environmental benefits (fertile land, water, energy).

Many countries that produce large amounts of food—including India, China, Australia, Spain and the United States—have reached or are close to reaching their water resource limits *[5]*

Land degradation costs an estimated US$40 billion annually worldwide, without taking into account hidden costs of increased fertilizer use, loss of biodiversity and loss of unique landscapes.

The consequences of land degradation are reduced land productivity, socio-economic problems, including uncertainty in food security, migration, limited development and damage to ecosystems. Degraded land is costly to reclaim and, if severely degraded, may no longer provide a range of ecosystem functions and services, with a loss of the goods and many other potential environmental, social, economic and non-material benefits that are critical for society and development. *[6]*

If the agriculture output has to grow so much in the next decades, the only option is to make it fully sustainable, for the environment and for the economy.

3. The multi-factor sustainable farm

To understand how agriculture and, in particular, the farm, will evolve in the next decades, it may be helpful to summarize the scenario like in **Fig 3**.

Under the tremendous pressure of the key global drivers, agriculture will have to dramatically increase its total vegetal and animal output.

Facing that challenge, the farms, all the farms, small or big, will have to imagine and design new ways to use the key factors offered to them: land, water, energy and technology.
And, while using and managing the factors, the farm must become increasingly sustainable, 360 degrees. Sustainability will become a condition for surviving.

3.1. Land

For sure land and water have always been key factors for farms, but the traditional farmer's attention on how to make best use of them is no more enough: from now on it will be necessary to conceive ways and implement actions to invest in those factors for their future availability and expansion.
With the same cultivated land as today, there will be not "enough future".
Therefore strong actions are required to find new land to cultivate and to preserve the fertile land already available today:

- New land suitable for agricultural use theoretically available in the world can be estimated around 1 billion ha, of which about 90% is concentrated in Sub-Saharan Africa and Latin America. There is virtually no spare land available for agricultural expansion in Southern Asia, the Western Asia and Northern Africa. *[3]*. A big portion of the theoretically available land will need strong efforts to be actually "put in service" and some of it will be good only for some crops.
- Farm concentration and cultivation practices evolution will also allow for more usable land and the extension of irrigation systems will improve the usability of existing land for more varieties of crops.
- Conversely, soil degradation leads to the reduction of good available land, at least reducing the variety of crops that can be cultivated in the area or the crop yield. Therefore regeneration of soil fertility and maintenance of biodiversity must become common practices in future farms.
- Improving plant characteristics and increasing plant vigor will make double cropping or triple cropping possible, on the good production ground, equivalent to have more land.
- By 2050, 66% of the world's population is projected to be urban: this means that over 6 billion people living in urban areas will need fresh fruits, vegetables, meats and other staples which create increasingly complex logistics and interesting urban agricultural practices, particularly for the high value crops like vegetables and fruits that can be successfully grown in greenhouse environments. So another way to add new land is to develop urban "vertical farms", using various building surfaces or dedicated buildings, suitable for growing some edible crops, like vegetables or fruits, with minimum amount of soil, irrigation with closed loop water system, in some cases with artificial light for continuous or semi-continuous plant growth.

3.2. Water

Only 0.003% of the planet's water is what is called "fresh water resources", about 45000 cubic km, water that theoretically can be used for drinking, hygiene, agriculture and industry. In fact, only about 10000 cubic km are economically available for human use.
Agriculture is by far the biggest user of water, accounting for almost 70 percent of all withdrawals, and up to 95 percent in developing countries.
The water needed for crops amounts to 1000-3000 cubic meters per ton of cereal harvested. Put another way, it takes 1 - 3 tons of water to grown 1 kg of cereal *[7]*.

It appears very clear that new water management strategies are needed to guarantee future agricultural output increase.

Rain-fed land, currently about 80% of available arable land, will continue to be subject to weather variations, probably worsening with the effects of climate changes. Actions will be needed to facilitate drainage of excess water or compensate drought periods with supplemental irrigation.

For irrigated land (20% of arable land, constantly growing, **Fig. 4**), freshwater availability is a very critical issue, as water used by activities other than agriculture and water pollution are increasing. Farms will have to use very wisely the water they have access to, limiting the water needed by specific cultivations, re-using water in closed loop systems, contributing to water purification, etc. The closed loop irrigation systems, with feedback from the plant health and soil conditions, will be imperative. It will help with the water usage along with plant breeding and selections for drought resistance.
"Farmers who switch from surface irrigation to localized irrigation can cut their water use by 30 to 60 percent" *[7]*.

Another possibility for some lands is irrigation with desalinated saltwater (saltwater is 97% of all planet's water). Desalinization requires a lot of energy, but in certain regions it may become the only alternative to regain usable land. And the energy can be derived from renewable sources at increasingly affordable costs.

"Using and managing the world's water efficiently is everybody's business, from government officials to small-scale farmers" *[7]*.

3.3. Energy

Energy is a key survival and development factor for the world, and in particular for agriculture.

The future farm will need continuously available energy to function; the decrease of energy used by more and more efficient farm machines and processes may not be able to totally offset the increase of energy consumption required by the increased farm production (more machines, more logistics, more irrigation, etc.).

So the two "options" future farms will have are:

- Save energy
- Produce energy

And they are not really options: they are both probably necessary actions for the farm.

Energy saving has no alternative. The quantity of energy economically available to the farm will simply not be enough to support all the farm activities. And an inefficient use of energy would rapidly lead to limit the needed increase of productivity, to increase CO2 emissions, to push the demand of energy and its marginal cost.

The search for efficiency must be continuous and smart, in all farming operations, with: energy efficient equipment, precise and very limited use of fertilizers and pesticides, accurate planting and seeding, limited tillage, very accurate field and crop mapping and monitoring. In most of the cases the use of closed-loop systems will be a must, with actions directly related to actual and specific plant conditions and needs.

Energy production by farms, today still very limited even if growing rapidly, will be a very valuable action, and a quite feasible one.

The energy produced in the farm may have several positive characteristics:

- It normally comes from renewable sources (sun, wind, waste, biomass), with very low CO2 emissions
- Can be generated with limited investments (small scale plants and equipment)
- Does not require wide area distribution (local production and use)
- Can be accumulated using energy vectors (pressurized gas, biofuels)
- Energy in excess can be offered and sold to others (e.g. feeding the grid)
- Some process by-products can be used as fertilizers
- The energy production and cost is more controlled by the farm and can be balanced and optimized inside the overall farm economy
- Possible issues of energy availability from the grid are mitigated by a distributed production and sharing model.

Not all farms can and need to produce energy; in a local area a group of farms can pool and share costs and benefits for a small-medium size energy plant.

Energy production in the farms will require social investments on awareness, training, supporting regulations, financing tools, technology and service offering, etc.

Sustainable and cheaper availability of energy to the farm may resolve key issues (like water pumping and purification, intense and advanced mechanization) and really boost the agriculture output increase.

3.4. Technology

Having seen the challenges and the scale of the other factors (land, water, and energy), technology must provide a lot of "answers" to support the development of future farms.

And the technology, widely speaking, has already well demonstrated to be a key positive factor for the development of agriculture:

- Agricultural mechanization has been, and continues to be, a positive revolution in farming operations all over the world, allowing a major increase of farm productivity. Without machines, tractors, tillage equipment, seeders, harvesters, there is no game. Human labor in agriculture must shift everywhere from direct manual work to power-assisted work and then to "brain work", directing the machines according to knowledge and information.
- Plant hybridization has always been a very powerful boost to farm productivity, providing continuously improved plant varieties with characteristics adapted to the demanding conditions of land, water, weather, diseases and weeds. Now genetic engineering is going beyond known limits, manipulating the DNA (genetic material) of plant cells to change hereditary traits and produce new biological products.
- Bio-chemical engineering helped developing very effective fertilizers, fungicides and pesticides, allowing for precise targeting and selective actions on land and crops.
- Biological engineering studies allow the application of improved farming techniques to optimize outputs and support higher yields.

- Information and communication technology is driving another deep revolution in agriculture. The availability of a huge variety of data and information and the connectivity among equipment, farms and farm service providers, is unbelievably expanding farmer's ability to control their actions and processes with high precision and high automation. This is more than boosting again productivity, it's a big change in nature of the modern and future farms, where farm operations are very integrated into a much wider system, including fleets of equipment, groups of farms, energy supply networks, logistic systems, info and service providers, seed and chemical suppliers, crop buyers, communities of users, finance and insurance sources, global market players.

  The "connected farm" is becoming the new model, progressively applicable to all farms, small and big, because no future farm will have the possibility to work or even exist isolated. Also the small and family farms, including the ones in the developing countries, will find the "network" their new and necessary environment.

- The combination of advanced equipment and information-communication technology will be the new, most powerful engine for the future farm. Increasingly automated, high precision and very selective machines, unmanned vehicles, drones and micro-drones, new sensors and vision systems, high capacity microprocessors, all will assist the farmers in daily operations and play a major role in farm integration and development.

Sophisticated technology and innovation will contribute more in the next 35 years than in any time in the past.

4. Conclusions

The farm of the future will surely be new and different from today. There will be a continuous evolution, step by step, but at an increasing speed, touching all the countries and continents.

The drivers are so big and so strong that will inevitably cause a complete change in the agriculture scenario world-wide. All the necessary increase in production and productivity will not just come from better farming practices; an intimate revolutionary change will pervade agriculture and its main players, the farmers.

Of course there is not just one model, one path to the future, even if the target is clear. Several think tanks are contributing to imagine and planning the journey. Two good examples, from two different perspectives, are indicated here.

The first vision comes from the FAO, United Nation's Food and Agriculture Organization, in the **Table 2**.

Clearly FAO indicates high-level policy pathways, but with very precise identification of key instruments, like:

- farmers central role,
- scientific research needed to re-think scenarios and actions,
- training and support,
- role of public economic and innovation policies,
- importance of communities and collaboration.

And the concept of "acceleration" is strongly present as an absolute need.

A different player is Rabobank, a large financial institution, global leader in Food & Agribusiness financing and in sustainability-oriented banking.

According to the Rabobank Duisemberg Lecture report *[9]*, the challenge for global F&A is how to plan for significant future growth in today's difficult operating environment. Justin Sherrard the report author said, "Innovation can provide a bridge between global F&A's near-term challenges and the longer-term opportunities, by leading to new ways to profit through the current period of uncertainty and slow growth, while positioning the sector to increase food availability and improve access for future populations."
While innovation may be the key ingredient, leadership will be the single most important tool for putting these big ideas into practice. The future of global F&A requires leaders with the confidence to invest in the future by thinking big and embracing change. "It also requires leaders who recognize that global F&A's future depends on innovation that delivers significant gains in resource efficiency to ensure a more sustainable future. Such leaders can catalyse necessary change across global F&A".

Naturally, the Rabobank approach is much more "project oriented", but also here it is possible to recognize some familiar concepts: increase and secure farms output, productivity, importance of ICT, new use of water, key role of connection, trade and logistics (**Figure 5**).

Another relevant contribute from Rabobank comes from the recent "Five priorities in global food agenda for 2015" (**Table 3**).

- Multi-level cooperation within supply chain,
- existing knowledge sharing,
- investments in innovation,
- war to losses,
- education,

are all elements of a clear vision and also concrete operative lines, which can become real action plans for farmers, industry managers, banks, international organizations, governments and politicians.

A very clear recommendation to all the players, and in particular to the farmers, surfaces from these vision reports: don't wait for future issues to come, but plan and act in advance, define 5-10 years plans and then execute the plans, deliver plan results and start new plans, leveraging on new awareness, new information and new technologies already available today.
Actions, to be effective, will have to be taken by farms in a united and coordinated way, not isolated. Only collaboration, coordination, network operations will produce sensible and sustainable results.

A paradigm shift, a major change in thought-pattern will happen, with the need for the farm to re-think the use and the regeneration of its key factors: land, water, energy, with the help of new technology.

Sustainability will be necessary, not just desirable; it will be the new global mission of agriculture: feed the world, preserve the planet.

References

[1] **UN**, World population prospects. The 2015 Revision, New York, 2015

[2] **FAO**, The State of Food Insecurity in the World, Rome, 2015

[3] **FAO**, World Agriculture Towards 2030/2050, Rome, 2012

[4] **International Grains Council**, Five year global supply and demand projections, London, 2014

[5] **WWF**, Threats: water scarcity, 2014

[6] **FAO**, – LADA project, 2010

[7] **FAO**, Water at a Glance, 2014

[8] **FAO**, The State of Food and Agriculture, 2014

[9] **Rabobank**, The Rabobank Duisenberg Lecture, Washington, DC, 2014

[10] **Rabobank**, Five priorities in global food agenda for 2015, Utrecht, 2015

[11] **USDA**, Sustainable Agriculture: Definitions and Terms, by Mary V. Gold. AFSIC, 2007

[12] **FAO**, – Aquastat, Rome, 2015

Figure 1 - World population trends.

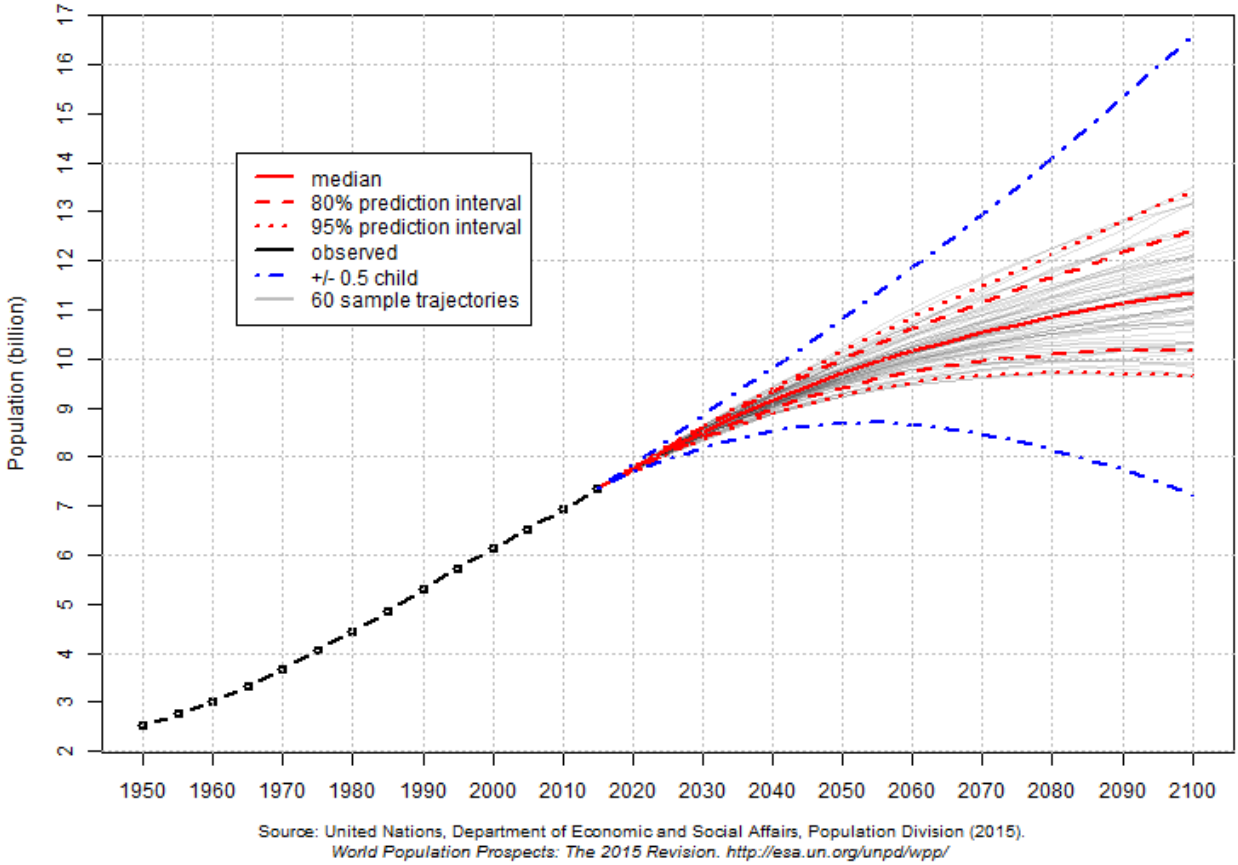

Figure 2 - Total grains: world supply and demand. *Source: [4]*

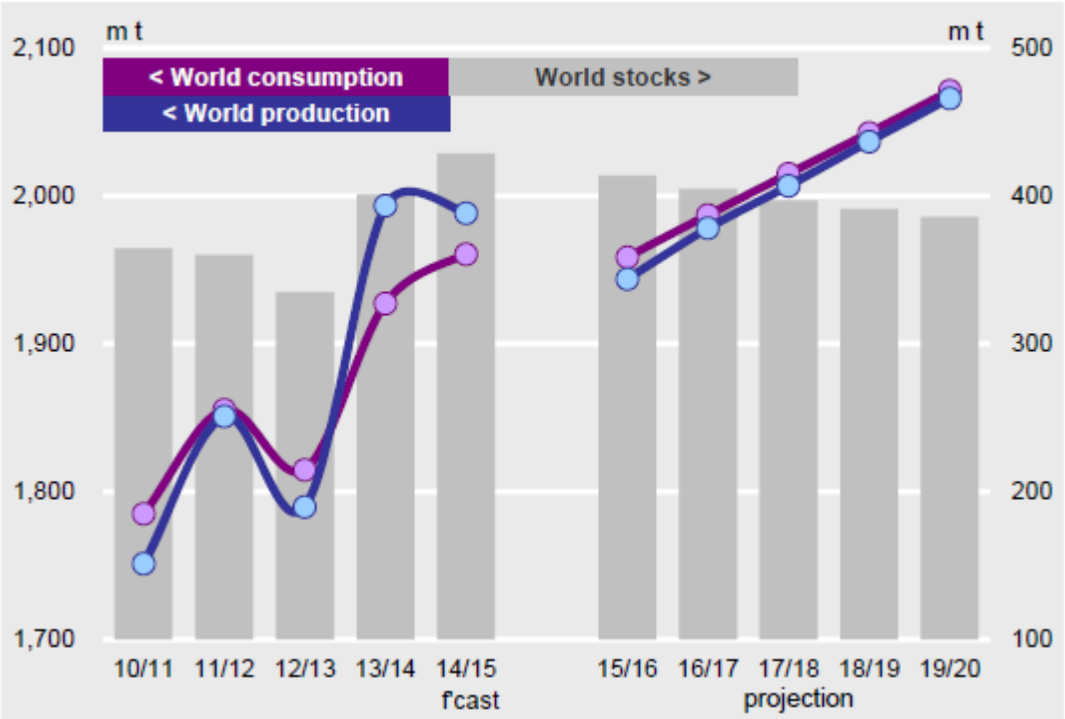

Figure 3 - The multi-factor sustainable farm.

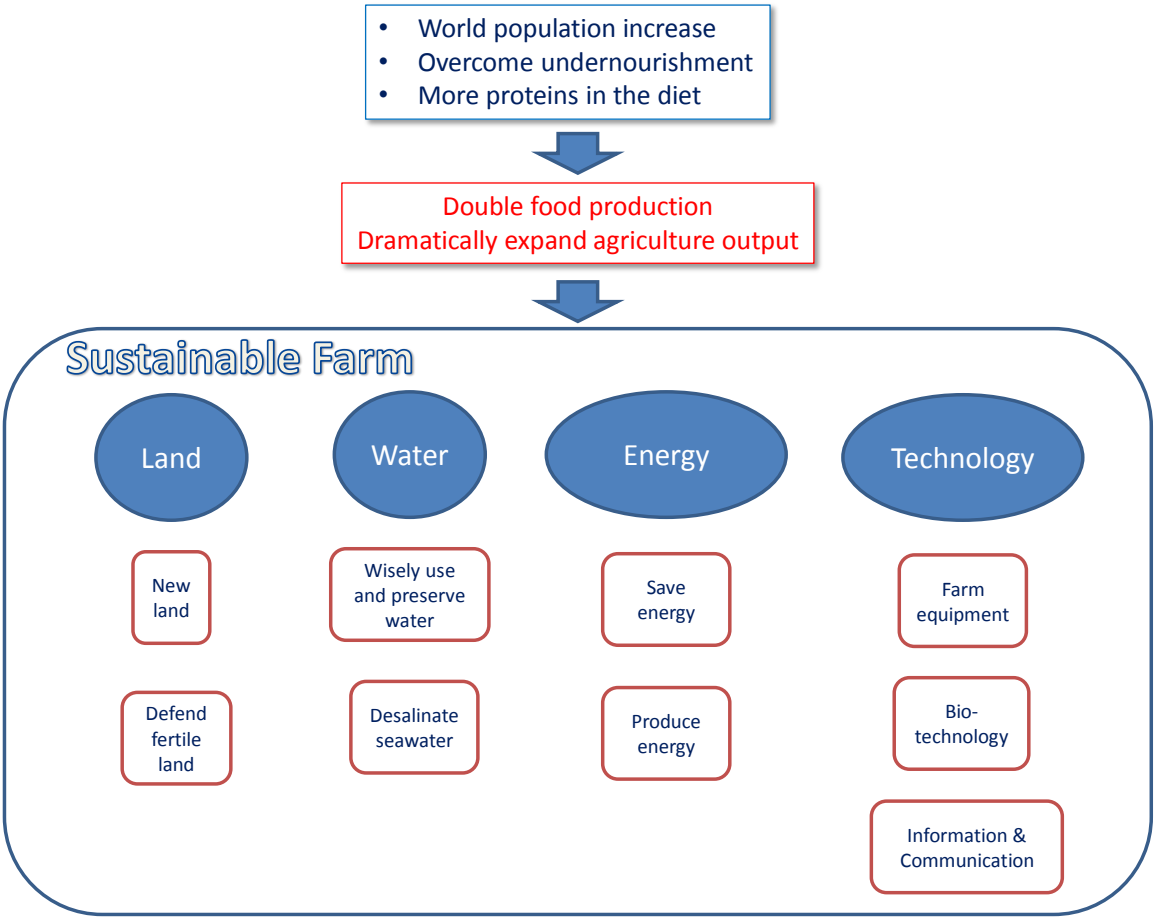

Figure 4 - Part of cultivated area under irrigation. *Source: [12]*

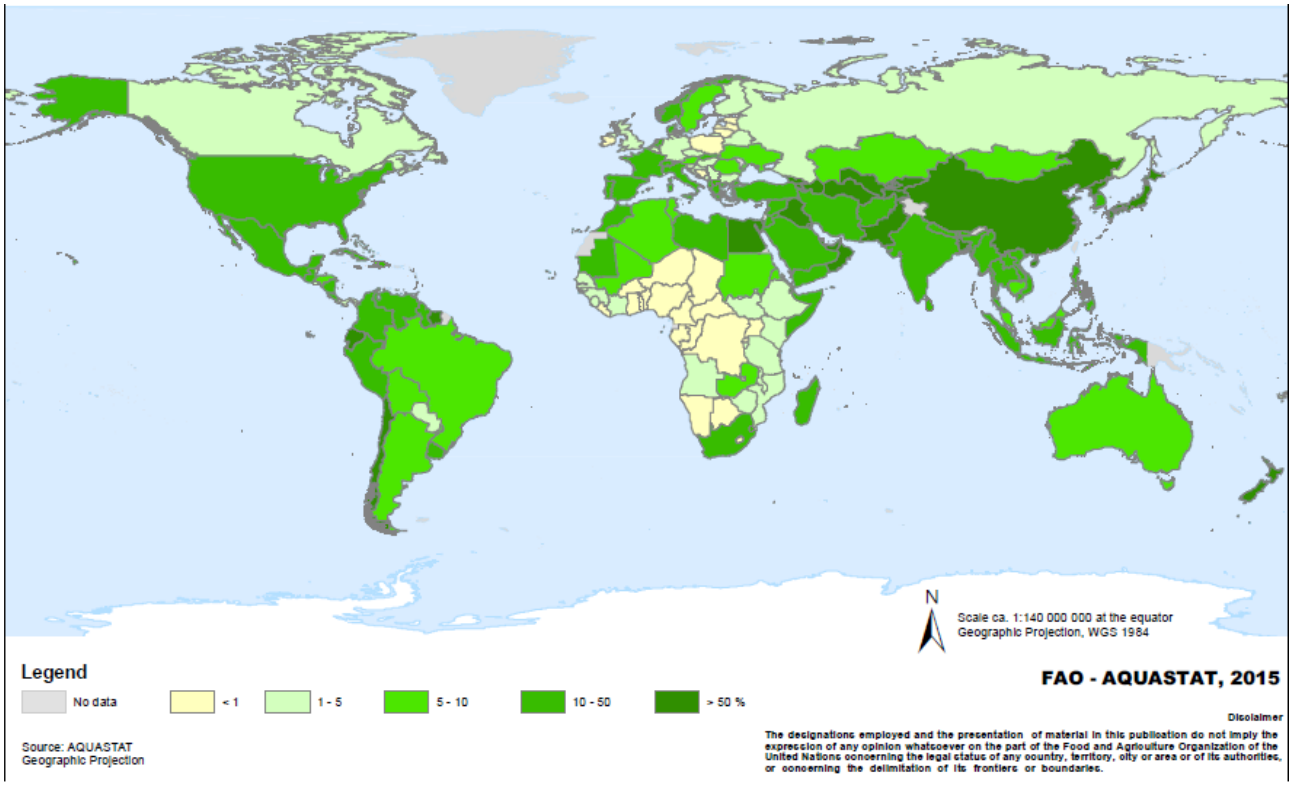

Figure 5 - 10 Big Ideas to Boost Global Food Availability. *Source: [9]*

Table 1 - Population of the world and major areas, 2015, 2030, 2050 and 2100, according to the medium-variant projection. *Source: [1]*

Major area	*Population (millions)*			
	2015	*2030*	*2050*	*2100*
World	7 349	8 501	9 725	11 213
Africa	1 186	1 679	2 478	4 387
Asia	4 393	4 923	5 267	4 889
Europe	738	734	707	646
Latin America and the Caribbean	634	721	784	721
Northern America	358	396	433	500
Oceania	39	47	57	71

Table 2 – FAO: Pathways and instruments for sustainable productivity growth in agriculture. *Source: [8]*

Pathway	**Types of instruments**
Developing, adapting and applying new technologies and practices	• Farmer-led improvements in technologies and practices • Formal scientific research and development • Combining farmer-led improvements and formal scientific research and development
Accelerating and increasing adoption of existing technologies and practices	• Addressing economic constraints to adoption of technologies and practices • Extension and advisory services (public and private) • Promotion of innovation capacity • Individual (education, training) • Collective (including producer organizations and cooperatives) • Enabling environment for innovation (including linkages and networks)

Table 3 – Rabobank: Five priorities for global food agenda in 2015. *Source: [10]*

Priority #1: Greater cooperation between the various levels of the chains	The food supply chain starts with suppliers of inputs to farmers and ends on the consumer's plate. A combination of cooperation, information exchange and new distribution models should lead to more stability. This would involve vertical cooperation between the various levels of the chain, along with horizontal partnership for example between farmers.
Priority #2: Using existing knowledge more effectively	By working together the various supply chain partners can also make better use of existing knowledge. Rabobank will be launching a digital information network in Australia this year, to be followed by other countries in due course.
Priority #3: Greater investment in research and development	New production methods are required to increase output while using fewer raw materials. This calls for substantial investments in research, development and knowledge. We need investors who are willing to get on board who can look beyond the short term and who have patience.
Priority #4: Reducing losses in the supply chain	With better systems in place and through improved planning and scheduling, food waste can be prevented. Also, food and food production deserve respect: we wouldn't throw out other things that have monetary or emotional value, so why wouldn't we have those same qualms when it comes to food?
Priority #5: Improving education on agriculture and food	We need to create more awareness among people of a whole slew of issues related to agriculture and food: reducing food waste, improving people's diets, increasing agricultural output and forging close relationships between customers and farmers.