Education, research and partnerships in Agri-Food in a global and connected world

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Overview

In recent years, governments around the world have again realized that food and nutrition security is one of the most pressing issues facing global society today and even more so in the coming decades. This awareness crystallized during and after the food prices crisis in 2008. Raising agricultural productivity in a sustainable way is the main challenge, especially in those regions where food security is at stake today. The question is this: how, given environmental constraints, limited resources, depleting aquifers in several regions and a changing climate, can we build a global food system fit to feed more than nine billion people by 2050, and possibly up to 11 billion in 2100? Even today, with all that has been achieved, one in nine people are undernourished.

Though the obstacles to improving agricultural productivity may vary according to context, the approach that must be taken is global. Each individual innovation represents only an incremental improvement, but in combination with others and in the right context, they can become transformative. Agricultural production exists within a complex environment, encompassing science, society, industry and government. Therefore interdisciplinary, landscape-scale initiatives must be developed, and applied in partnership with all the actors involved.

As well as the availability of food, it is also necessary to have a balanced and regionally-appropriate focus on the other two elements of food and nutrition security: access and utilization. This makes it all the more important to work within the framework of agri-food systems to solve these important societal problems. I will mainly discuss the first component in relation to agronomic research. However, scientists have to work together to focus on and ensure the use of proper production tools for specific environments and contexts (in relation to access with logistics scientists and socio-economists), also considering the contribution of suitable crop nutrient content and composition to healthy diets.

The task of enhancing food availability involves several components. Of course, a major component is enhanced productivity. That is a core part of the work of agronomists. But other aspects should not be forgotten: such as non-land use, the avoidance of losses and waste (now 30 percent) and the development of alternative protein sources. Besides that, systems approaches are needed to embed the work in frameworks at higher scales: the bio-based economy and ecosystem services (e.g. water supply). These are what we call landscape approaches and as a result our work takes place at different scales: from gene to landscape. For an overview see Kropff et al. (2013).

In order to create agricultural innovation systems capable of having a transformative impact on agriculture at a global scale, research must become an integral part of the innovation processes, connecting all relevant stakeholders in co-innovation processes. This increasingly takes place within public private partnerships (PPPs). Within these processes, education plays a crucial role in training the leaders, designers, managers and policy makers of the future based on the needs of industry and cutting-edge of research.

Sustainably enhancing productivity

Yield gap and sustainable intensification

If the world population is set to grow, it stands to reason that more food must be produced, while it is also clear that this must be done while making better use of the resources available. Below the macro scale, agri-food systems in different areas in the world face very different challenges to be overcome. Even climate change, often discussed in global terms, is expected to have highly variable effects from one locality to the next. Yet by analyzing this situation, it is possible to see that the way forward for agricultural research is universal across all contexts, and best approached from a global perspective.

For those areas of Africa, Asia and Latin America that have not fully participated in the green revolution, there is still an opportunity to close existing yield gaps, i.e. the difference between actual yields and those that we know are possible: the yield potential that is determined by the variety, radiation and temperature. Yield gaps exist in most countries, ranging from almost negligible in the Netherlands to 90 percent in many African environments.

The yield potential of a variety in a specific environment is well defined, and can be calculated with good accuracy using eco-physiological simulation models. In the concept designed by CT de Wit in the 1980s, water and nutrients are yield-reducing factors, so that the so-called attainable yields (water and/or nutrient limited) can be calculated using the proper water and nutrient balance models. This is difficult to parameterize using detailed inputs from the local agro-ecological environment. On top of that we have yield reducing factors: pests, diseases and weeds. With models scenarios can be simulated to arrive at the actual yield. This understanding is based on the backbone of genotype, environment and management (G x E x M). If we understand the factors causing the so-called yield gap, improved management can help to increase yields. As improved management options have to be carefully developed and disseminated in each context, this process is known as sustainable intensification, making use of precision techniques as far as possible, both in low-yielding systems and high yielding systems (see review in van Ittersum et al., 2002).

When we look at the statistics and calculated genetic gains, it is surprising that annual yield increases have been pretty similar across regions and constant over time since the green revolution; some 70 kg of grain per hectare each year. Many hurdles must be overcome to increase productivity, such as the access to appropriate knowledge, improved seed with the desired qualities, markets and agricultural inputs by small-scale farmers in varying ecological and socio-economic environments, along with the need to improve national infrastructure and research capacities. It is also crucial to understand why farmers adopt new technologies at different rates and experience varying levels of success, while special care must be taken to include disadvantaged groups, women and youth.

For the major food exporters such as Australia that form the backbone of the global food system, yields tend to be much closer to what is possible to achieve with current knowledge and technologies. In irrigated areas we can seek the potential yield, while in rainfed or water-constrained areas it is the attainable yield that must be sought. There are some amazing examples of what can be achieved. Irrigated rice yields in the Yanco area go up to 15 t/ha compared to 7 and 10 t/ha in tropical wet and dry seasons. Just as a result of temperature and radiation. In the Netherlands, farmers harvest up to 12 t/ha of wheat, when it had long been assumed that yield potential was 10 t/ha. This is similar to the best farm yields that are already achieved here, in Tasmania.

At the global scale however, there has been a general stagnation of yields that has proven difficult to address, as yields approach the maximum potential, or the maximum attainable yield in rainfed areas. Globally, we also find challenges common to most environments that force us to take new directions and ensure that agricultural production is made sustainable. These include overcoming the unsustainable use of dwindling water supplies, managing the increased pressure from urbanization and environmental degradation of arable land.

In most continents yields of the main cereal crops have grown at rates of 70kg/ha/yr since the introduction of the semi-dwarf varieties in the 1960's. However, in Africa, yields have not shown these green revolution rates but remained more or less stable at 10% of the potential yield with the possible exception of rice where a recent analysis of FAO statistics revealed a small discontinuity in rice yield increases also in the order of 70 kg/ha/yr. However, for other crops we are still waiting for that moment where the conditions are in place for yields to begin the steep rise that we know is possible. This is a major challenge for agricultural research today that must be supported by investment in better governance systems and institutions for technology adoption.

In countries with smaller yield gaps, we see yield increases flattening off. That indicates that the breeders are not raising the yield potential and most farmers have maximized or hopefully optimized their practices. Science will have to venture into new areas of research in order to sustainably increase productivity.

Today, there is vast investment worldwide in photosynthesis research to enhance yield potential, through reduced respiration, better light capture or different pigments. There is even work underway to introduce C4 photosynthesis in C3 species.

However, leaps forward in agricultural science will not be enough to jumpstart a new era of progress: they must be coupled with policy-level changes, a reimagining of the relationship between agricultural research and industry, and further investment in human resources.

System-level approaches
The complexity of food systems means that innovations must be sought at all levels of food production, from the seed, to the farm, ecological, market, policy and research levels. This also means uniting many different scientific disciplines, and pursuing system-level approaches involving many different kinds of actors, in order to transform the capacity of agricultural systems to sustainably intensify production, while making it more market-oriented by linking consumer preferences to breeding activities. In this way, breeding becomes a systems activity, focused not on individual traits but on finding the right combinations of traits for each variety according to context and environment.

Farming systems are complex and subject to change; it is necessary to possess an understanding of dynamics at the landscape level in order for researchers and policymakers to stimulate positive changes in different regions. Several models have been developed for optimization studies and scenario studies at the regional level. The approaches developed by van Ittersum et al. (2008) make use of models that operate at different levels of integration: the crop level, the cropping system level, the landscape level and the regional/national level. Using multiple goal analyses, it is possible to analyze the effect of changes in farming systems for different decision parameters such as subsidies, labor costs, farm size etc. It would be of great benefit for policymakers and scientists to collaborate based on the insight from such models.

Scientists at both Wageningen and CIMMYT are working and at times collaborating on approaches for complex adaptive systems. In addition to thinking about dynamics of farming systems at different levels, an important development in farm systems thinking also takes into account the temporal level. Systems theories such as those developed by Scheffer on critical transitions and tipping points can be used to understand behaviors in natural systems (Scheffer, 2009). One collaboration between Wageningen and CIMMYT is exploring the factors, synergies and tradeoffs that determine the trajectories of important indicators of sustainable intensification in three different agro-ecosystems around the world, also using a participatory, goal-oriented approach (the ATTIC project, see below).

Gender studies is another critically important component of socioeconomics to help understand behaviors within farming systems. Groundbreaking work is underway within the CGIAR, with CIMMYT playing a key role, to develop tools to integrate gender understandings in the research and design process, examining the factors governing women's agency within agricultural innovation using an opportunity structure framework such as that developed by the World Bank (for example see Boudet et al., 2013). This global study, known as Gennovate, will involve interviews and focus groups with farmers in approximately 100 countries.

An urgent example of the need to adopt a systems-level approach is the prospect of climate change. The challenge to reliably realize yield gains of more than 1.5 percent per annum is heightened by expected temperature increases in most producing areas coupled with more erratic weather conditions; more floods heatwaves and droughts. The risks are especially high in the tropical and sub-tropical regions that are home to most of the world's undernourished, and where future population increases will be greatest. However, this is also a particular challenge for Australia that has amongst the most variable climates in the world.

This means that climate change poses a whole-system challenge at all scales, from the farmer deciding on the optimal crop management strategy to the stress and uncertainty placed on regional food systems. New agricultural technologies and practices must be developed in order to mitigate the negative impacts on productivity, but resilient agricultural systems must also be designed to be more adaptable at a systemic level. This is the triple win of enhanced food security, mitigation and adaptation.

There is international recognition that not only must the germplasm and deployment pipeline take account of the systemic changes wrought by climate change, but that agronomists should also adopt a climate smart agriculture (CSA) approach. Many agronomists see continuity with established practices such as precision farming that also lie at the core of CSA, however climate smart agriculture is a system-level approach that offers important perspectives, introduces an added degree of foresight and emphasizes important avenues for research.

An interesting example is one of my studies showing that good rice management practices, ensuring that the sink is suitable for the grain filling period, strongly reduces emissions of methane, a strong contributor to climate change (van der Gon et al., 2002). On the other hand, a recent inquiry from scientists at CIMMYT into the true extent of soil carbon capture potential of zero-tillage conservation agriculture practices has generated some debate (Powlson et al., 2014).

Agri-food transformations for impact

Previous agricultural transformations, such as the green revolution, have ensured a growth of agricultural production that matched population growth. But we are still left a world in which billions of people suffer health problems due to insufficient food, inadequate nutrition or poor diet. Measures must therefore also be taken to ensure equality of access to food, and the resilience of the global food system to shocks such as those that caused the food crisis of 2006-2007. Losses throughout the supply chain in the developing world, and waste in the developed world, are considered to account for a third of food production (FAO, 2013). If it were a country, the carbon footprint of this wasted production would only be inferior to that of the U.S. and China. Measures must also be taken to address the nutritional quality of food, and the impact of changing diets on the footprint of agriculture and human health. Finally, it must be understood that agriculture, from Africa to Australia, is a business, and must be profitable and attractive for those involved.

Therefore, it is important to include the concept of agri-food systems in our understanding of agriculture as a set of complex systems working at many levels. On the one hand, we can work at the level of DNA, to that of the plant, field, ecology or landscape; on the other hand, we must consider the social dimension. Agriculture is a social practice carried out for society, from the individual, to the household, community and societal levels. Encompassing the space between agronomy and society are the agri-food sector and the policy environment. So each innovation has both an agronomic and a socioeconomic dimension, and in this innovation process it is important to work in public-private partnerships.

For example, in many African countries, agricultural development will not develop in earnest without the stimulation of a vibrant private seed sector. Elsewhere, the challenge may be to link the public and the private sector more strongly to ensure the regular deployment of new varieties, or introduce policies to facilitate international seed sharing. Such public-private partnerships are operational in Australia, while in the Netherlands they are embedded within the government's 'top sector' approach. At CIMMYT, we are in the process of intensifying our work on PPPs, for example in the international maize improvement consortia for Asia and Latin America.

More investment in research and development into agri-food systems worldwide is needed, especially for the poorest of the poor in developing countries where the needs are highest. The only way to achieve this using the relatively limited resources currently available for agricultural research in developing countries is to work within strong partnerships from the local to the international level, ensuring that research is relevant and that the innovations created are put to good use in the right context.

Wageningen and CIMMYT: Working in networks to achieve food security

International, interdisciplinary approaches

The strategies of both Wageningen UR and the International Maize and Wheat Improvement Center (CIMMYT) are both based on the same core concepts: scientific excellence, the need for disciplinary depth, interdisciplinary and whole-system approaches, collaboration with different partners at all levels (transdisciplinary) and the importance of working across different contexts to maximize the value and coherence of research efforts.

Wageningen is a world-leading center of excellence for academic education and research in life sciences. Wageningen works within a 'golden triangle' of government, research institution and private sector partners to create the solutions to societal problems. It has a strong international outlook, with programs and projects in over a hundred countries, and an equally international studentship and growing international faculty. It gains strength through good relations with local and national government, private sector and NGO partners, regional and international research partners, and cooperation with developing countries who can gain from knowledge exchange and capacity-building. Wageningen focuses on science for impact on science society and business (Kropff and Kalwij, 2007).

To put this integrated approach into practice, Wageningen focuses its work on a domain defined by 3 components: Society and well-being; Food, feed and bio-based production; Natural resources and the living environment. Several themes have been selected for extra investment in new developments such as synthetic biology, bio-based economy, and complex adaptive systems. Education programs focus on B.Sc., M.Sc. and Ph.D. programs as well as international capacity-building, especially in developing countries.

CIMMYT is a leading international center for research and development of maize- and wheat-based farming systems, with research covering germplasm collection, breeding and sustainable intensification, to social sciences, gender studies, foresight and economic impact analysis. Through its collaboration with research institutions, national agricultural bodies, non-government organizations, the private sector and farmers' groups, CIMMYT leads in global innovation networks for the production, dissemination and application of agricultural innovations. Through partnerships impact is realized. Through its status as one of the 15 research centers in the CGIAR and leader of the Agri-food CGIAR Research Programs (CRPs) MAIZE and WHEAT (338 and 219 partners, respectively), CIMMYT brings together this deep-rooted network to form part of a coordinated global research agenda.

For instance, germplasm from CIMMYT's Genebank is sent to nearly all areas of the world (500,000 packages per year), creating a global platform for breeding and knowledge exchange. 50 percent of the maize and wheat sown in the developing world is derived from CIMMYT germplasm. CIMMYT has 23 offices in 13 countries, projects in 38 countries, and has a workforce of 1200 hailing from over 50 countries.

Australia is one of CIMMYT's largest financial supporters. In addition to the impact in CIMMYT's target countries, a key outcome of Australia's investment in CIMMYT is the contribution of our research and development outputs to Australian farming and the Australian economy. 98 percent of all wheat grown in Australia is derived from CIMMYT wheat varieties. Hartog, a CIMMYT introduction, was grown on more than 60 percent of Australia's wheat area in the late '80s and early '90s. This represents a major contribution to increased productivity on Australian grain farms. Australian economists have estimated that CIMMYT's wheat varieties have increased the value of outputs from the Australian wheat industry by at least AU$750 million (Brennan and Quade, 2004).

Working within agri-food system networks
The CGIAR strategy for 2016-2030 creates eight agri-food CRPs, of which CIMMYT leads MAIZE and WHEAT. Recognizing a need for integrated approach, these CRPs are cross-cut by a further four global integrating programs: Nutrition and Health; Climate Change; Water, Land Soils & Ecosystems; and Policies, Institutions and Markets. In addition to orienting global research and development networks towards agri-food systems, this structure also creates greater interaction to maximize relevance, impact and efficacy.

Wageningen works within a top-sector approach set by the government of the Netherlands, working on the sectors of water and agri-food. These two top sectors (of a total of nine) are chosen not only because they are important for society in the Netherlands, but also because they areas in which Dutch research institutions and the private sector excel and collaborate to create products and innovations of global value. This three-way 'golden triangle' of knowledge institutes, the government and the private sector acts to ensure that innovations are produced and put in use to transform agri-food systems.

As the agri-food sector is essential in all countries and can be the engine of the economy in developed and developing countries, such recognition of this sector by society is important. In Australia that recognition has always been obvious, but could be further strengthened via a more explicit focus on and support for innovation platforms and public-private partnerships (PPPs) that link public and private providers with farmers and agri-food businesses. Similar approaches are also considered for emerging and developing economies.

Global partnerships for food security
Together, Wageningen and CIMMYT provide a good example of the nexus between education, research and global partnerships. One such example is the Agro-ecosystem diversity, trajectories and trade-offs for intensification of cereal-based systems (ATTIC) project. Combining expertize from both Wageningen and CIMMYT, the project employs PhD projects in Africa, Asia and Latin America to pilot new approaches to research and development that are able to account for the dynamics of socio-ecological systems. Applied within the context of CIMMYT's global innovation network, the space for innovation created by such collaborations can have a transformative impact. Both institutions are strengthened as a result, as are those with whom they work.

Australia's interaction with CIMMYT, an organization with an explicit focus on 'yield gap' countries, also exemplifies the benefits of working in global partnerships. As mentioned above, Australia's investments in CIMMYT has a high rate of return, considering that CIMMYT wheat varieties have added AU$750 million to the value of Australian wheat industry outputs. Through the partnerships leveraged by CIMMYT, Australian institutes are supporting important research into drought- and disease-tolerant varieties in Africa and Asia that will lead to further innovations at home.

Many Australian universities are providing their expertize to a project, funded by the Australian Centre for International Agricultural Research (ACIAR), to transform the Eastern Gangetic Plains, covering parts of Bangladesh, India and Nepal, into an important food-producing region. Such a transformation requires the improvement of markets, access to agricultural knowledge and services, better use of water resources and the widespread adoption of more productive and sustainable farming practices. It is important to consider the policy environment and the innovations that could be adopted by public institutions to create the conditions for success. In this case, CIMMYT is playing a coordinating role between a network of research institutions, agricultural NGOs, public institutions and the private sector. Another project with CIMMYT, supported by ACIAR, takes a similar approach to intensify maize-legume systems in eastern and southern Africa.

These global collaborations between CIMMYT, Australian institutions and other partners are key to generating multi-disciplinary and multi-sector innovations that are essential to the improvement of regional food security.

The role of education, capacity building and partnerships
In the nexus of research and collaboration in a global and interconnected world, education plays a vital role. Capacity-building and training are prioritized at CIMMYT for three reasons: firstly, they add value to the organization and the research community; secondly, they derive more value from the research produced by the organization; and finally, they generate the expertise and capacities that make innovation successful, and therefore sustainable.

Each year, CIMMYT provides 50,000 days of training to farmers, technicians and students in 21 countries, while there are 10,000 researchers and professionals worldwide known to be alumni of CIMMYT training programs. The topics of capacity-building include breeding for scientists, seed production and registration support for small- to-medium-sized seed enterprises or direct support to extension workers and farmers. In this way, CIMMYT builds capacities at all levels.

For Wageningen, education and capacity building are core activities next to research. Academic education is directly linked to academic research following the Humboldt model set for universities some 100 years ago. Research at Wageningen not only addresses fundamental scientific questions, but takes the form of applied research with an immediate impact for clients in the government, private sector, non-governmental and research sectors. As such, the research themes pursued are responsive not only to trends in global research, but also the needs of partners from different sectors around the world. Because education is so closely linked to research at Wageningen, the students and professionals it creates are able to make valuable contributions to solving the problems facing society today.

New communications technologies offer new avenues to further increase the impact of research institutions. CIMMYT is developing electronic decision support tools for farmers that can be delivered by extension workers or directly through mobile phones. This is being linked to new remote sensing technologies to give small-scale farmers access to the kind of knowledge used by commercial farmers in the developed world.

In Wageningen we developed the philosophy of an education ecosystem with connected components and coherence. Campus education, from undergraduate to doctorate levels, is at the heart of this ecosystem. This year the first distance learning programs will start with M.Sc. programs, with distance learning courses also being used for incoming M.Sc. students. The latest development is the use of MOOCs. Wageningen launched its first online course in 1998, and now has a strategy to integrate campus and virtual education to create an international education ecosystem using massive open online courses (MOOCs). The first two MOOCs started with 40,000 students, many from the U.S., Canada and Australia. Ph.D. research and education is organized in Wageningen Graduate Schools and courses are organized with international partners.

The global university sector must play an ever-greater role in providing vitality to agricultural innovation systems. This can be achieved by providing more exchange program opportunities for students at the undergraduate and postgraduate levels, and Ph.D. projects involving supervision from partner universities and research centers such as CIMMYT. Further value can be added with partnerships in graduate schools and large international programs with a focus on impact in areas of research such as photosynthesis, big data or genomics. The research pursued at universities can represent the high end of scientific advancement, whether in pioneering new systems approaches or new genomic techniques, and partnerships with other institutions add to the value of education for students.

Concluding remarks

According to all predictions, the world must take a great step forward to meet the challenges of raising productivity, reducing resource use, adapting to climate change and creating a fairer and healthier food system. For agricultural research to step up to the challenges facing the world today, it is necessary for agricultural research and education institutes to work in global partnerships, across disciplines and contexts to harness the power of agricultural innovation to transform agri-food systems. This requires the creation and use of strong partnerships between all the stakeholders involved in agriculture, building capacities where they are most needed and creating future generations of well-trained agricultural researchers and professionals. In this global nexus of research and global partnerships, stronger investment in education must play a central role. Agronomy is clearly a central discipline in the global food water and energy nexus!

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