Essay

Challenges and proposals to achieve food security by the year 2050

Arturo Pérez Vázquez[1]
Doris Arianna Leyva Trinidad[1§]
Fernando Carlos Gómez Merino[2]

[1]Postgraduates College-*Campus* Veracruz. Highway Xalapa-Veracruz km 88.5. Predio Tepetates, Municipality de Manlio F. Altamirano, Veracruz, México. CP. 91700. (parturo@colpos.mx). [2]Postgraduates College-*Campus* Córdoba. Highway Córdoba-Veracruz. Congregación Manuel León, Municipality de Amatlán de los Reyes km 348, Veracruz, México. CP. 94946. (fernandg@colpos.mx).

Corresponding author: leyva.doris@colpos.mx.

Abstract

This essay analyzes the global challenge of food insecurity by 2050, particularly in the face of a globally urbanized population estimated to exceed 9.1 billion inhabitants, in a context of climate change and high competition for resources such as water and land. Some proposals that could allow facing the future situation of food insecurity and generate a culture of healthy and sustainable consumption and nutrition are discussed. It is proposed that high-tech eco-intensive agriculture can be an option to overcome food needs based on sustainable high-tech management (computers, remote sensing, drones and cybernetic management), where conventional agricultural, agroecological and biotechnological practices could coexist in a harmonious relationship in order to produce more and better food with less environmental impact. It is concluded that achieving food security by the year 2050 should be a matter of national security, and for this it is necessary to be clear about this challenge and to promote research processes, technological development and innovation on food safety with a true commitment and far-reaching vision.

Keywords: climate change, high technology, intensive agriculture, world population.

Reception date: January 2018
Acceptance date: February 2018

Introduction

Food security is a matter of great importance and international alert to the increase in world population and the risks of not being able to produce enough food due to extreme events induced by climate change, land use change and the imminent reduction of water available in volume and acceptable quality for agriculture. In 1991, the United Nations Food and Agriculture Organization (FAO) predicted that by the year 2050, the population will be around 9.1 billion people. In addition, an important segment of this population will have higher incomes that will directly impact on a greater demand for food, in a society that is mostly educated and informed about issues related to nutrition and good nutrition, which will allow better rates of human development, including health.

The main cause of the current food crisis in the world is not a problem of production but of inequity in the access and distribution of food. Where food security is also related to nutrition and health. In other words, despite the global overproduction of food, the situation of hunger has worsened, with about one billion people in this condition worldwide (FAO, 2009; CINU, 2011). This forces us to design strategies that allow us to face the challenge of food security, not only in how to produce food but also how to achieve greater availability of food in a scenario of limited resources (soil, water) and climate change.

At the same time, we should think about the nutritional quality and safety of the food and develop agricultural policies to ensure sufficient supply of them for a growing population and an increase in demand. The key is not in the increase of production, but in the access to resources and in adapting new agrarian policies in which agriculture sensitive to climate and nutrition is promoted as a basic and indispensable element (Lara, 2008). In addition, a communication strategy for food security will be necessary to strengthen the practices of nutrition and healthy nutrition in the population.

On the other hand, there are 870 million people worldwide suffering from hunger, while 1.3 billion tons of food are wasted each year (FAO-FIDA-PMA, 2014). This means that between 30% and 40% of food production worldwide is lost after harvest or is wasted in stores, homes and catering (Gustavsson *et al*., 2011; FAO, 2014). The greatest waste of food (54%) occurs in the initial stages of production, handling and post-harvest storage. The rest (46%) occurs in the stages of processing, distribution and consumption of food (Parfitt *et al*., 2010).

Latin America and the Caribbean contribute 6% of food losses worldwide (FAO, 2013a, FAO, 2014), which could satisfy the food needs of thousands of people. According to the FAO (2013a), the waste of food, without counting the fish and shellfish, has a cost of 750 billion dollars. This also affects natural resources such as water, soil and biodiversity; and impacts on the sustainability of agrifood systems that negatively affect nutrition and human health (FAO, 2012).

Therefore, it is necessary to make changes along the different links of the agrifood chains to reduce the loss of food. These changes include from the producer (the farm) to the consumers (table) in the social, economic and environmental dimensions. It is necessary that consumers plan their purchases, avoid buying too much food and transport them and keep them at adequate temperatures.

In addition, when intermediaries buy the production in the field, they should not only purchase the first-class products, but also the second and third products, as long as they retain their nutritional quality and health. That is to say, it is necessary to induce intelligent strategies in the decision making of the consumer who buys products only for appearance and not for necessity, causing a lust in overconsumption of food that brings with it obesity, overweight and waste.

The challenge is to achieve agricultural security, reducing negative externalities to the environment as much as possible to achieve food security (Figure 1). In the current projections, the growing world population will have a strong pressure on food, its availability and access, as a result of higher income and greater purchasing power. This situation is especially important for countries such as China and India, which in the last two decades have gone from being countries with a predominantly poor population to countries with an eminently urban population with a better economy and greater capacity to buy food. Achieving greater food security inexorably passes through agricultural security and a socioeconomic environment of sustainable development.

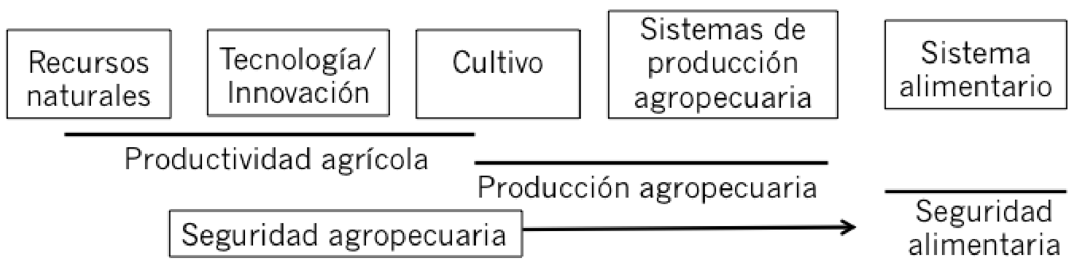

Figure 1. Elements that determine the achievement of global food security.

Another challenge to achieve food security is global climate change. This phenomenon will not only affect the level of production but also the quality of the crops due to high temperatures, drought, flooding and a higher incidence of pests and diseases (Vermeulen *et al*., 2012). One option will be to take back native or creole genetic resources to rescue the genetic diversity that confers mechanisms of tolerance or resilience to extreme climates.

The world population

Currently, the estimated population worldwide is 7 324 782 000 people (http://populationpyramid.net/es/mundo/2015). By the year 2050, the world population will reach 9 100 (FAO, 2009). This means that the world population will increase by 1 775 218 000 people. The total of this increase will occur in developing countries and approximately 70% of the population will be urban, compared to the current population (49%) and eventually greater purchasing capacity. With these projections, it is estimated that food production should increase 50% globally and 70% in developing countries, if it is desired to ensure the food of its population (Godfray *et al*., 2010).

This is a challenge, particularly when less world population lives in the countryside and more than 70% live in cities. However, increasing food production by 70% will not necessarily make it possible to respond to the food demand of a growing urban population (WSFS, 2009; FAO, 2011). This is due to the increase in the international prices of food, due to the use of food for the production of biofuels, increase in consumption in Asian countries, volatility in the world oil price that affects the price of inputs and climate change causes drought conditions and floods (WSFS, 2009).

That is, the demand for food is outstripping supply. Therefore, it is expected that the population in underdeveloped countries, 30% suffer more hunger and greater malnutrition. Therefore, to reduce the gap between demand and supply, it will be necessary to appeal to scientific research, innovation and technological development that allows producing food in a more sustainable manner.

In Mexico, the current population is around 125 million people (http://populationpyramid.net /es/mexico/2015/), which is equivalent to 1.71% of the world's population. This places Mexico in the eleventh place among the countries with the largest population worldwide (INEGI, 2015). That is to say, that by the year 2050 there will be 31 million more inhabitants, representing an additional 24.8% of the current population. If we consider that the agricultural production in the country is contracted and that it grows at an annual rate of 1.1% (period 2000-2011), it implies that it will be difficult to satisfy the food needs of the population and that year after year will depend on greater import of food (FAO, 2013b).

The challenge is not only the production of food for a population in constant growth, but how to ensure sufficient clean water, agricultural land, energy and labor, so as to reduce adverse effects on the environment and not put at risk to satisfy the basic needs of present and future generations. It is estimated that, if food were to increase by 70% by 2050, water availability would have to increase by 55% and energy by 50% (FAO, 2011; Guijarro and Sánchez, 2015), a situation that seems difficult. Although the production of food in the world may be sufficient to meet the needs of the current population, nearly one billion people are hungry and of these close to 400 million are chronically malnourished (FAO, 1991).

Then, feeding a mostly urban population with higher incomes will imply increasing food production by around 70% in developing countries (Godfray *et al*., 2010), something that is very important for countries such as Mexico, where the deterioration of Natural resources is aggravated and intensified by the effects of climate change.

Several authors emphasize that the current system of food production needs to change radically to produce more food in a sustainable way. The reports of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) (2009) and Schutter (2010) affirm that, in order to feed nine billion people by the year 2050, it will be necessary to adopt more efficient agricultural systems and recommend a fundamental change towards agroecology as a way to boost food production and, at the same time, reduce the poverty condition of the population.

The IAASTD suggests that alternative methods have great potential to maintain agricultural productivity. This is supported by Badgley *et al*. (2007) and Godfray and Garnett (2014) who point out that innovative alternative methods could produce enough food worldwide to sustain the current human population, and potentially a larger population, without increasing the cultivated area. However, Emsley (2001) and Avery (2007) have serious doubts that alternative methods can meet the food production needs of a growing world population and argue that only industrial agriculture (Green Revolution) will be able to produce enough the food for the future global population.

Conway (1997) proposes that a double green revolution is required, in the sense of a more productive agriculture with a low environmental impact. A recent example of alternative agroecological methods is the “Hunger Zero” program in Brazil, where more than 70% of the food came from family farming and, together with other actions, managed to mitigate the hunger problem in that country in an extraordinary way, going from 35% in the year 1992 to 18.1% in the year 2007 and a reduction of 10% from 2002 to 2007 (Neves do Amaral and Peduto, 2010).

Regardless of how food is produced, conventionally or agroecologically, farmers will have to produce more per unit of land, water, energy, agrochemicals and reduce the environmental impact (CO_2 emissions, biodiversity and soil). That is to say, food and nutrition security should not focus on increasing only food production but on paying attention to more sustainable ways of producing them. In other words, production systems should not be focused on productivist and profitability objectives, but on paying attention to environmental services and greater efficiency along the food chains, promoting production practices, sustainable consumption and healthy diets (FAO, 2015). This implies a change in the current model of governance in food production, and the development of efficient public policies that ensure the well-being and health of the people and the sustainability of the environment. Some proposals are the following:

Agroecological production systems

They are usually agrodiversity production systems, resilient, efficient in the use of energy, socially just, productive and based on strategies of food sovereignty (Altieri 1995, Gliessman 1998). These systems encourage local production through family farming and integrate innovation processes, a moderate rejection or rational use in the use of synthetic inputs (fertilizers, pesticides), transgenic, hormones and antibiotics in livestock production. Examples of them are:

Organic agriculture

The International Federation for Organic Agriculture Movement (IFOAM) has proposed the principles of health, ecology, care and equity of organic agriculture (IFOAM, 2012). It is one of the most important agriculture, social recognition and added value worldwide. Countries such as Australia and Argentina hold the largest area of organic production worldwide. Mexico occupies the third place worldwide by number of organic producers (170 thousand), with a cultivated area close to 400 thousand hectares, generating 400 million dollars in foreign currency and 170 thousand jobs (Gomez *et al*., 2005). This type of agriculture is based on the insertion of innovative agricultural production techniques, omitting the use of synthetic inputs and partially replicating natural cycles, through the use of friendly agricultural techniques.

Agriculture always-green

This type of agriculture developed in India, consists of the use of organic agricultural techniques, limited use of fertilizers and plant protection products. Incorporates multipurpose tree species into annual cropping systems and conservation agriculture (World Agroforestry Center, 2009). This type of agriculture is conceived as part of a complex “production ecosystem” that includes at least 20 to 30 interconnected productive activities. It has an approach based on economic science and the care of the environment, natural resources and increased food production of small farmers. Among the many benefits are the conservation of biodiversity, production of various foods, fodder, fuel, fiber and income of forest products, carbon storage and conservation of soil cover (World Agroforestry Center, 2009).

Minimum tillage agriculture

This generic term includes agricultural techniques to protect the soil, prevent erosion and other forms of degradation. The principles on which it is based are: crop rotation, plant cover, direct seeding without soil removal and reintegrating the waste into the soil. It makes efficient and effective use of natural resources through the integrated management of soil, water and biological resources, to which external inputs are added (FAO, 2015).

Sustainable intensive agriculture

This is based on agroecological principles, amplified to the point of becoming dominant in terms of agricultural practices (Godfray and Garnett, 2014). It refers to the intensive use of ecological properties applied in agroecosystems. For example, in terms of livestock, milk production in Mexico has to increase by 17% in the next 20 years to meet demand (SAGARPA, 2010). Given that livestock activity generates greenhouse gases, this activity is facing severe criticism (Oyhantçabal *et al*., 2010) and that is why it is proposed to change the conventional production system to sustainable systems, taking into account negative externalities such as accumulation of excrete, bad odors, leachates, deforestation, erosion and contamination of water tables (SAGARPA, 2010). Other proposals are the following:

Genetic improvement

Much of the innovation to ensure greater future food production will be contingent upon genetic improvement. Several countries are producing improved genetic materials from the use of native agrobiodiversity. That is, it is going to be necessary to produce genetic material with greater vigor, greater nutritional value, tolerance to diseases, extreme weather conditions (high temperature, higher concentration of CO_2, drought or high humidity) and longer shelf life. But, in addition, much of the genetic improvement will be oriented to satisfy many of the new food preferences. For example, production of specialized genetic materials and depending on market demand. It will tend to create genetic materials of short cycle, tolerant to drought and high temperatures, particularly in Mexico where vast areas will be affected by climate change (Altieri and Nicholls, 2009).

Hi-tech agriculture

In recent decades, radical changes have been experienced in the use of technological innovations in agricultural production. High-tech agriculture (Hi-Tech) will involve remote-controlled cultivation using computers, robots, video cameras, drones and others. This technology will be increasingly important, particularly in a context of modernization of the field, which will induce to grow plants and raise animals in an automated and remote way, using mobile phone or tablet. In addition, the detection of diseases will be done through PCR kits to obtain fast and efficient real-time diagnoses.

Thus, precision agriculture that includes the use of computers, sensors, global positioning systems (GPS), geographic information (SIG), remote sensing, performance monitors, and sensors to estimate and control variations in agricultural production. For example, fertigation, despite being a costly technique, has been a profitable technique, mainly in the cultivation of vegetables, since it increases the efficiency of water use and fertilizers (Biswas, 2010). However, Mexico will have limitations so that this model can be extended to the whole country, due to the costs of this technology, orographic and socioeconomic situation, but in regions that for years have shown greater proximity to high-input agriculture such as the northern states. Precision agriculture has proven not only to be more profitable but also friendly to the environment, including a reduction in the use of synthetic inputs (Norton and Swinton, 2000; Bongiovanni and Lowenberg-Deboer, 2004).

Biotechnology

According to FAO (2011), biotechnology can contribute to food security through different strategies to improve crops, livestock, forestry, agro-industry, fisheries and aquaculture. Among the strategies that have been used include plant and animal breeding to increase yields, characterization and conservation of genetic resources, diagnosis of diseases of plants and animals, development of vaccines and food safety. In terms of agricultural production, the cultivation of plant tissues, mutagenesis and the production of biofertilizers are the most widely used and accepted technologies. The International Maize and Wheat Improvement Center (CIMMYT) developed maize seeds with improved protein quality (QPM) from the introduction of genes that modify the endosperm. These seeds have 50% more tryptophan and lysine, that conventional corn seeds (Scrimshaw, 2006; Dos Santos Silva *et al*., 2012).

Another example has been the modification of plants that express antigens (edible vaccines), where rice, wheat, alfalfa, potato, pea and lettuce have been used, from the use of *Agrobacterium tumefaciens*, as a vector; which releases in the plant cells the gene that codes for the antigen of the virus or of the pathogenic bacteria and consequently generates an immune response in the individual when ingesting the vegetable (Curtis *et al*., 1994). In fact, golden rice was developed with the aim of expressing a high content of β-carotene, which is converted by the body into a vitamin (Dos Santos Silva *et al*., 2012).

A challenge that requires a coexistence approach is between the systems of organic, conventional and biotechnological agriculture due to the debate that this last issue generates in the public opinion.

These three models of agriculture differ in terms of environmental impact, dependence on synthetic inputs particularly for the control of pests, diseases, weeds and increase soil fertility and productivity (Morgan and Murdoch, 2000). However, these models must coincide in reducing externalities to the environment, human health and the quality of food. That is to say, the paradigm of agriculture must converge with a committed agriculture to solve the problem of malnutrition and the lack of future world food in a sustainable environment.

Physiology and plant science

Nowadays it is proposed as an option to model and determine physiological relationships between photosynthetically active light and dry matter production; the foliar area and the radiation interception; the temperature and the speed of growth and performance. Hence, the need to identify specific requirements of the development and growth of plants in their different phenological stages and climatic scenarios to achieve their maximum potential under field or greenhouse conditions. A key aspect is floral mapping to increase the economic value of plant material, which will help to optimize crop production and quality.

Protection and irrigation of crops

Integrated pest management (MIP) is a robust and resilient crop protection strategy that helps promote the use of organic pesticides and their automation. It is based on a combination of different tactics, trying to reduce the use of synthetic pesticides. In addition, good quality water is important for the agricultural sector (Cavoski *et al*., 2011). That is, agriculture requires quality water for acceptable and safe production. The use of recycled water is not always possible, due to the presence of several toxic substances and bacteria (Mateo-Sagasta and Burke, 2013). Therefore, technology is required to treat wastewater and reuse it, innovative systems of zero use or efficient use of water, before a scenario of restriction of this resource and therefore more expensive.

For example, in Egypt, more than 50% of their croplands are desert, and it has been shown that the use of treated wastewater can be used to irrigate trees and other crops (FAO, 2010). Therefore, wastewater treatment is a value-added option that would allow farmers to save costs for the payment of water, while taking advantage of the nutrients present in the wastewater, offering a potential "triple dividend" to urban users, producers and the environment.

Edible insects

The consumption of insects is a tradition with pre-hispanic roots in Mexico, and whose consumption occurs in other 130 countries (Ramos-Elourdy, 1989, 2009). However, there are few efforts and initiatives to establish insect breeding centers for commercial edible purposes worldwide. Miranda-Roman *et al*. (2011) propose establishing food routes around the collection, commercialization and tasting of edible insects as a culinary delight. It is estimated that 418 t of edible insects are produced and harvested annually and globally (Ramos-Elourdy, 2009). More and more restaurants in Mexico include in their menu dishes of insects, such as larvae, grasshoppers, ants and others. Recently the ONU recognized that the consumption of insects is an alternative as a source of protein and a way to mitigate climate change.

The breeding of edible insects has a high conversion of meat (protein) compared to bovine production, also recommended for the environment and for a balanced and nutritious diet. One of the advantages of insects is that they reproduce quickly, have a high content of protein, essential amino acids and minerals in an adequate balance (van Huis *et al*., 2013). Ramos-Elorduy (1998) and (2006) affirm that the most worrisome deficiency in the Mexican diet is proteins, and these are the main contribution of insects to food: while 100 g of beef contain 54 to 57% protein, 100 g of grasshoppers, for example, contain 62 to 75% protein.

Therefore, the biofactories of breeding edible insects linked to gastronomy and entomophagy can be an option of entry and greater availability of this food in shelves of supermarkets, restaurant menu and daily menu of families. A strategy to achieve a greater consumption of insects may be scientific dissemination, while rescuing the cultural root of its gastronomic use (Miranda-Roman *et al*., 2011). Thus, entomophagy can be a viable alternative to alleviate the problems of malnutrition in the world and a source of employment and income.

Use of marginal lands

Millions of people around the world depend on agriculture for their subsistence, and often develop on soils with little natural agricultural vocation (Shahid and Al-Shankiti, 2013). For example, agriculture in saline soils using adapted or tolerant plants (halophytes). Due to climate change, it is necessary to continue generating tolerant materials at the extremes of scarcity, excess water and temperature. Today, more than 1.5 billion people depend on marginal lands, in part, because many farming systems have depleted the natural fertility of the soil (UNCCD, 2014). This implies introducing new cultivars from native genotypes that are resistant or adapted to environmental and biotic stress conditions that can adequately thrive in this type of land.

That is, take advantage of native genetic diversity to generate cultivars or varieties with greater tolerance to stress due to high temperatures, drought, resistance to pests and diseases, but mainly to marginal soils (Ebert, 2014). At the same time, develop strategies to minimize the effect on agricultural productivity, and reverse the deterioration. On the contrary, producing on marginal lands will demand greater energy, selection of adapted ecotypes and use of synthetic inputs.

Therefore, a change of approach is necessary to find alternatives to food production on marginal lands and not insist on conventional crops. For example, in Chile, several vegetable species are studied, such as jojoba, castor and caper, for their production in desert lands and in Israel, farmers have implemented the crop in greenhouses.

Loss and reduction in food waste

Recent estimates indicate that one third (30 to 40%) of the food produced globally is lost and wasted in the global food system (Gustavsson *et al*., 2011). Food insecurity is a matter that motivates greater production and quality of food through sustainable forms, but at the same time it reduces the loss and waste of food. The European Union (UE), recently proposed to reduce food loss by 30% by the year 2030 (Lipinski *et al*., 2013). Along with the reduction of losses and waste of food are new ways of conserving food longer.

For example, the dehydration of fruits and vegetables with CO_2 that excludes negative aspects of conventional dehydration, resulting in a product with better quality, low cost of refrigeration, maintaining the nutritional quality and when the product is rehydrated it acquires the appearance of a fresh product. The reduction of loss of food must be procured from the initial production (farm) to the final consumption in the home, through short marketing chains. One option is the sale closer to the consumer from local markets and thereby reactivate local economies.

On the other hand, public policies must be established that motivate both the government and the private sector to develop road infrastructure, transportation, storage facilities and refrigeration, which will reduce food losses. In addition, to sensitize the population to avoid the compulsive purchase of food and provide information and knowledge that allows the actors of the agrifood chains safety and hygiene standards guaranteeing quality food. However, it is necessary to reactivate the exchange of food, locally, in order to reduce the loss of food. Also, carry out research to develop innovations that allow the elaboration of food products from the remnants.

Urban agriculture

With a world population that mostly lives in cities (UN, 2010), urban agriculture will be one of the palliatives to ensure food and reduce the ecological footprint of cities (Rees and Wackernagel, 1996). Urban and peri-urban agriculture is recognized by international institutions, citizens and local authorities of many cities in the world as a sustainable strategy, combining green spaces in and around cities that contributes to food security, well-being of people, and fresh foods for local markets, in addition to a better environment (UNDP, 1996; Mougeot, 2005, 2006; Viljoen, 2005; UN, 2012). Zezza and Tasciotti (2010) point out that urban agriculture has a positive effect on food security at the household level, in generating income and improving access to fresh food.

Urban agriculture probably does not contribute greatly to the production of food for the national market, but it can partially solve local problems of food security and provide better living conditions for people and spaces for wildlife (Pérez-Vázquez, 2001). Urban agriculture should be considered as the production of food in the confines of cities for its inhabitants, reducing their ecological footprint.

Hi-tech eco-intensive agriculture

This type of agriculture can combine the conditions expressed for sustainable intensive agriculture, also incorporating technological advances friendly to the environment. This approach to agriculture can be inclusive of technological advances such as the use of irrigation sensors, light and ventilation in greenhouses, nutrient requirements, dosing systems for nutritive solutions, which can be remotely controlled by computer or equipment. mobile telephony, the use of drones and robots.

The use of high technology in countries as shown in Australia and Brazil that can reduce production costs by more than 50%, compared to the costs achieved in Mexico (Aguilar-Rivera *et al*., 20). In addition, this agriculture applies the principles of conservation and improvement of soil quality, reduction of greenhouse gas emissions, reduction of leachates and pollution, rational and efficient use of water, and conservation of biodiversity. Therefore, this type of agriculture could have greater social benefit.

Conclusions

The planning of agriculture with criteria and principles of food sovereignty must be essential to achieve food security and improve the nutrition of the population. Experience has shown that, through specific access actions and adequate use of resources, the problems of food insecurity can be remedied. Food security can be achieved if environmentally friendly production systems, adequate policies and capacity building at different levels are established. The concrete food security is increasingly a matter of national security, particularly in a world subject to climate risks, fluctuations in international prices of food and oil, low wages, lack of employment opportunities and support to the field, forcing to families to migrate and leave their lands.

Therefore, it is necessary to promote research, technological development and innovation in the area of food safety with a true commitment and conviction, without losing sight of the challenges until 2050. Conventional agriculture, biotechnology and different forms of production agro-ecological food will have to live in a constructive, complementary and synergistic relationship in order to produce more and better foods with the least environmental impact. The use of scientific knowledge will be decisive in the taking of strategic decisions, with the purpose of making the existent more efficient and achieving food security and for this it will be necessary to promote an intensively sustainable agriculture, where the actors are integrated in a harmonious way under agri-food chain approaches and a sustainable development approach with social responsibility.

Gratefulness

The CONACYT is thanked for the support of the first author's sabbatical stay and the correspondent's doctoral grant.

Cited literature

Altieri, M. A. 1995. Agroecology: the science of sustainable agriculture. Second Edition. Westview Press, Boulder, CO. 433 p.

Altieri, M. A. y Nicholls, C. I. 2009. Cambio climático y agricultura campesina: impactos y respuestas adaptativas. In: respuestas al cambio climático. LEISA Rev. Agroecol. 24(4):5-8.

Avery, A. 2007. Organic abundance report: fatally flawed. Renewable Agric. Food Systems. 22(4):321-323.

Badgley, C. J. K.; Moghtader, E.; Quintero, E.; Zakem, M. J.; Chappell, K. R.; Avilés-Vázquez, K.; Samulon, A. and Perfecto, I. 2007. Organic agriculture and the global food supply. Renewable Agric. Food Systems. 22(2):86-108.

Biswas, B. C. 2010. Fertigation in high tech agriculture: a success story of a lady farmer. Fertilizer Marketing News. 41(10):4-8.

Bongiovanni, R. and Lowenberg-Deboer, J. 2004. Precision agriculture and sustainability. Precision Agriculture. 5(4):359-387

Cavoski, I.; Caboni, P. and Miano, T. 2011. Natural pesticides and future perspectives. In: Pesticides in the modern world - pesticides use and management. Stoytcheva, M. (Ed.). InTech. Rijeka, Croacia. 169-190 pp.

CINU (Centro de Información de las Naciones Unidas). 2011. Alimentación. CINU. http://www.cinu.org.mx/temas.htm.

Conway, G. 1997. The doubly green revolution. Food for All in the Twenty-First Century. Cornell University Press. 360 p.

Curtis, I. S.; Power, J. B.; Blackhall, N. W.; Laat, A. M. M. and Davey, M. R. 1994. Genotype-independent transformation of lettuce using Agrobacterium tumefaciens. J. Exp. Bot. 45(10):1441-1449.

Schutter, O. 2010. Report submitted by the special rapporteur on the right to food. UN General Assembly. Human Rights Council Sixteenth Session, Agenda item 3 A/HRC/16/49. United Nations. Geneva, Switzerland. 21 p.

Dos Santos Silva, D. B.; da Silva Lara, E.; Do Amaral Crispim, B.; Oliveira, V. J.; Barufatti, G. A. e Pires de Oliveira, K. M. 2012. Biotecnología aplicada a la alimentación y salud humana. Rev. Chilena Nutr. 39(3):94-98.

Ebert, W. A. 2014. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. Sustainability. 6(1):319-335.

Emsley, J. 2001. Enriching the earth: Fritz, H. and Bosch, C. and the transformation of world food. Nature. 410(6829):633-634.

FAO (Food and Agriculture Organization of the United Nations). 1991. Food, Nutrition and Agriculture - 1 - Food for the Future. http://www.fao.org/docrep/u3550t/u3550t00.htm.

FAO (Food and Agriculture Organization of the United Nations). 2009. How to feed the world in 2050. FAO. Roma. 35 p. http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/how_to_feed_the_world_in_2050.pdf.

FAO (Food and Agriculture Organization of the United Nations). 2010. The safe use of wastewater in agriculture offers multiple benefits. News Article. FAO. http://www.fao.org/news/story/en/item/44899/icode/.

FAO (Food and Agriculture Organization of the United Nations). 2011. Biotechnologies for Agricultural Development. Rome, Italy. 569 p.

FAO (Food and Agriculture Organization of the United Nations). 2012. Sustainable systems programme programa FAO-PNUMA sobre sistemas alimentarios sostenibles. FAO. Roma. 2 p. http://www.fao.org/fileadmin/templates/ags/docs/sfcp/flyer_sp_01.pdf.

FAO (Food and Agriculture Organization of the United Nations). 2013a. El desperdicio de alimentos daña al clima, el agua, la tierra y la biodiversidad. Noticias FAO. http://www.fao.org/news/story/es/item/196368/icode/.

FAO (Food and Agriculture Organization of the United Nations). 2013b. Panorama de la Seguridad Alimentaria y Nutricional en México 2012. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA). Secretaría de Desarrollo Social (SEDESOL). Instituto Nacional de Salud Pública (INSP). Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). México, D. F. 288 p.

FAO (Food and Agriculture Organization of the United Nations). 2014. The water-energy-food nexus: a new approach in support of food security and sustainable agriculture. Roma, FAO. 28 p. http://www.fao.org/nr/water/docs/fao_nexus_concept_web.pdf.

FAO (Food and Agriculture Organization of the United Nations). Fondo Internacional de Desarrollo Agrícola (FIDA) y Programa Mundial de Alimentos (PMA). 2014. El estado de la inseguridad alimentaria en el mundo 2014: fortalecimiento de un entorno favorable para la seguridad alimentaria y la nutrición. Roma, FAO. 62 p. http://www.fao.org/3/a-i4030s.pdf.

FAO (Food and Agriculture Organization of the United Nations). 2015. Agricultura de Conservación. Preguntas más frecuentes. Departamento de Agricultura y Protección del consumidor. FAO. http://www.fao.org/ag/ca/es/11.html.

Gliessman, S. R. 1998. Agroecology: ecological process in sustainable agriculture. Lewis Publishers, Washington, D.C. 347 p.

Godfray, H. C. J. and Garnett, T. 2014. Food security and sustainable intensification. Philosophical Transactions of the Royal Society B 369 (20120273):1-10.

Godfray, H. C. J.; Beddington, J. R.; Crute, I. R.; Haddad, L.; Lawrence, L.; Muir, J. F.; Pretty, J.; Robinson, S.; Thomas, S. M. and Toulmin, C. 2010. Food security: the challenge of feeding 9 billion people. Science. 327(5967):812-818.

Gómez, C. M. A.; Schwentesius, R. R. y Gómez, T. L. 2005. Agricultura orgánica en México, 10 años de experiencias y políticas para el futuro. CIESTAAM- Universidad Autónoma Chapingo (UACH). Chapingo, Estado de México. 32 p.

Guijarro, A. y Sánchez, E. 2015. El nexo agua-alimentación-energía en el marco de la agenda post 2015. Ingeniería para el desarrollo humano-ONGAWA. 17 p. http://www.manosunidas.org/sites/default/files/nexo-agua-alimentacion-nergia_ongawa_ok.pdf.

Gustavsson, J.; Cederberg, C. and Sonesson, U. 2011. Global food losses and food waste. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/fileadmin/user_upload/ags/publications/GFL_web.pdf.

IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development). 2009. Agriculture at a crossroads. In: International Assessment of Agricultural Knowledge, Science and Technology for Development (AASTD). Global report. Island Press, Washington, D.C. 608p. ISBN: 9781597265386.

IFOAM (International Federation of Organic Agriculture Movements). 2012. The IFOAM norms for organic production and processing. Germany. 132 p.

INEGI (Instituto Nacional de Estadística y Geografía). 2015. Encuesta intercensal 2015. INEGI. http://www.inegi.org.mx/.

Lipinski, B.; Hanson, C.; Lomax, J.; Kitinoja, L.; Waite, R. and Searchinger, T. 2013. Reducing food loss and waste. World Resources Institute (WRI). Working paper. 40 p.

Mateo, S. J. and Burke, J. 2013. Agriculture and water quality interactions: a global overview. SOLAW Background Thematic Report - TR08. FAO. 46 p.

Miranda, R. G. M.; Quintero, S. B.; Ramos, R. B. y Olguín, A. H. A. 2011. La recolección de insectos con fines alimenticios en la zona turística de Otumba y Teotihuacán, Estado de México. PASOS. Rev. Turismo y Patrimonio Cultural. 9(1):81-98.

Morgan, K. J. and Murdoch, J. 2000. Organic vs. conventional agriculture: Knowledge, power and innovation in the food chain. Geoforum. 31(2):159-173.

Mougeot, J. A L. 2006: Growing better cities: urban agriculture for sustainable development. International Development Research Centre (IDRC). Ottawa, ON, Canadá. 128 p.

Mougeot, J. A. L. 2005. Agropolis: the social, political and environmental dimensions of urban agriculture. International Development Research Centre (IDRC). Earthscan, London, UK. 308 p.

Neves do Amaral, W. A. and Peduto, A. 2010. Food security: the Brazilian case. Trade knowledge network (TKN). International Institute for Sustainable Development (IISD). Series on Trade and Food Security - Policy Report. 23 p.

Norton, G. and Swinton, S. 2000. Precision agriculture: global prospects and environmental implications. Inter. Association Agric. Econ. Conference, August 13-18. Berlin, Germany. 269-286 pp.

Oyhantçabal, W.; Vitale, E. y Lagarmilla, P. 2010. El cambio climático y su relación con las enfermedades animales y la producción animal. Conf. Organización Mundial de Sanidad Animal (OIE). 169-177 pp.

Pérez-Vázquez, A. 2001. The future role of allotments as component of urban agriculture in southeast of England. PhD Thesis. Imperial College Wye: University of London. Wye, Ashford, Kent. 259 p.

Pervez, B. Z. 2013. Sustainable food production: facts and figures. SciDev.Net. http://www.scidev.net/global/food-security/feature/sustainable-food-production-facts-and-figures.html.

Population Pyramid. 2015. Pirámides de población del mundo desde 1950 a 2100. Departamento de Economía y Asuntos Sociales. Naciones Unidas. http://populationpyramid.net /es/mundo/2015.

Ramos, E. J. 2009. Anthropo-entomophagy: cultures, evolution and sustainability. Entomol. Res. 39(5): 271-288. DOI:10.1111/j.1748-5967.2009.00238x.

Ramos, E. J.; Costa, N. E. M.; Ferreira dos Santos, J. Pino, M. J. M.; Landero, T. I.; Ángeles, C. S. C. and García, P. A. 2006. Estudio comparativo del valor nutritivo de varios coleópteros comestibles de México y Pachymerus nucleorum (Fabricius, 1792) (bruchidae) de Brasil. Interciencia. 31(7):512-516.

Ramos, E. J. y Pino, M. J. M. 1998. Los insectos comestibles del Estado de México y determinación de su valor nutritivo. Universidad Nacional Autónoma de México (UNAM). Anales del Instituto de Biología. 69(1):65-104.

Ramos, E. J. y Pino, M. J. M. 1989. Los insectos comestibles en el México antiguo (estudio etnoentomológico). AGT. México, D. F. 108 p.

Rees, W. E. and Wackernagei, M. 1996. Urban ecological footprints: why cities cannot be sustainable -and why they are a key to sustainability. Environ. Impact Assess Review. 16(4-6):223-248.

Shahid, S. A. and Al-Shankiti, A. 2013. Sustainable food production in marginal lands -case of GDLA member countries. Inter. Soil Water Conser. Res. 1(1):24-38.

SAGARPA (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación). 2010. Retos y oportunidades del sistema agroalimentario de México en los próximos 20 años. México, D. F. 282 p. http://www.sagarpa.gob.mx/agronegocios/Documents/pablo/ retosyoportunidades.pdf.

Scrimshaw, N. S. 2006. Quality protein maize. Food Nutr. Bulletin. 27(3):265-266.

Smit, J.; Ratta, A. and Nasr, J. 1996. Urban agriculture. Food, jobs, and sustainable cities. United Nations development program (UNDP). Publication Series for Habitat II. Vol. 1. UNDP. New York. 302 p.

UN (United Nations). 2010. Urbanization prospects. The 2009 revision. Urban and rural areas. Department of Economic and Social Affairs, Population Division. ST/ESA/SER.A/322. United Nations. New York, NY. 318 p.

UN (United Nations). 2012. Urban agriculture: improving food security and environmental health of cities. UNAPCAEM Policy Brief. Issue No. 1. 8 p. www.unapcaem.org.

UNCCD (United Nations Convention to Combat Desertification). 2014. Desertification: the invisible frontline. United Nations Convention to Combat Desertification. Bonn, Germany. 20 p.

Van, H. A.; Van Itterbeeck, J.; Klunder, H.; Mertens, E.; Halloran, A.; Muir, G. and Vantomme, P. 2013. Edible insects: future prospects for food and feed security. FAO Forestry Paper 171. Rome. 187 p.

Viljoen, A.; Bohn, K. and Howe, J. 2005. Continuous productive urban landscapes: designing urban agriculture for sustainable cities. Architectural Press. Oxford, UK. 319 p.

Vermeulen, S. J.; Campbell, B. M. and Ingram, J. S. I. 2012. Climate change and food systems. Ann. Review Env. Res. 37:195-222. https://doi.org/10.1146/annurev-environ-020411-130608.

Zezza, A. and Tasciotti, L. 2010. Urban agriculture, poverty, and food security: empirical evidence from a sample of developing countries. Food Policy. 35(4):265-273.

World Agroforestry Centre. 2009. Creating an evergreen agriculture in Africa for food security and environmental resilience. World Agroforestry Centre, Nairobi, Kenya. 24 p.

WSFS (World Summit on Food Security). 2009. Alimentar al mundo, erradicar el hambre. Cumbre sobre la Seguridad alimentaria. FAO. 21 p.