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Food availability in Mexico: an analysis of agricultural production over the last 35 years and its projection for 2050

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Resumen

La disponibilidad de alimentos en México: un análisis de la producción agrícola de 35 años y su proyección para 2050

En los próximos 35 años el mayor reto que enfrentará la agricultura mexicana es asegurar el abasto de alimentos para la población de nuestro país. El objetivo de este trabajo fue analizar la producción agrícola en México en los últimos 35 años y su proyección para 2050. De 1980 a 2015, la población mexicana creció 67 por ciento, para cubrir sus requerimientos alimenticios, la producción agrícola incrementó 117 por ciento a través de aumentar 67 por ciento el rendimiento de los cultivos y 23 por ciento el área cultivada. Entre 1980 y 2015 la tierra disponible per cápita disminuyo 31 por ciento, esto significa que en el futuro para aumentar la producción los agricultores deberán enfocarse a mejorar el rendimiento de los cultivos. La ganancia en rendimiento lograda en cereales, hortalizas, frutales, forrajes y cultivos industriales en el periodo analizado indica que es posible asegurar su abasto por esta vía. No obstante, debido a que en especies leguminosas y oleaginosas, la mejora del rendimiento ha sido escasa, en el corto plazo se necesitará invertir en investigación e infraestructura agrícola que ayude a mejorar su productividad. Los resultados obtenidos sugieren que la agricultura de México será capaz de producir alimentos que a futuro demande la población, sin embargo para asegurar su abasto, también será necesario mejorar su acceso y lo más importante distribuirlos con equidad.

Palabras clave: Población, alimentación, agricultura, cereales, leguminosas.

Abstract

Over the next 35 years, the greatest challenge which will face Mexican agriculture is to ensure the food supply for the population of México. The objective of this work was to analyze the agricultural production in Mexico in the last 35 years and its projection for 2050. From 1980 to 2015, the Mexican population grew by 67 por ciento, to meet their food demand, the agricultural production increased 117 por ciento through to increase 67 por ciento the crop yield and 23 por ciento the cultivated area. Between 1980 and 2015 the land available per capita decreased 31 por ciento, this means that in the future to increase the agricultural production, the farmers must focus in improving the crop yield. The gain yield achieved in cereals, vegetables, fruit, forages and industrial crops during the analyzed period indicates that in a future it is possible to ensure its supply for this way. However, since on legumes and oilseeds species the gain yields on the past has been scarce, on the short term, there will be needed to invest in research and agricultural infrastructure that will help to improve your productivity. These results suggest that farmers in Mexico will be able to produce the food that future demands the population, however to ensure its supply, there will also be necessary to improve their access and most importantly distribute them fairly.

Key words: population, food, agriculture, cereals, legumes.

Introducción

At global level, the greatest challenge that agriculture faces in the next 35 years is to secure food supply for the population, however its magnitude will be in function of the demographic growth rate, the economy, agricultural infrastructure and natural resources of each country. According to FAO (2009), in order to feed a population of 9.1 billion people, between 2007 and 2050, the volume of global agriculture production must increase 70 percent; this means, that the cultivated area must increase in 70 million hectares (1.5 billion ha at present) and the performance of cultivations, taking crops as a reference, must increase from 1.2 to 4.3 ton/ha. In the national sphere, CONAPO (2006) estimates that the population will increase 17 percent regarding the present (119.5 million inhabitants) (INEGI, 2015a); this increase will demand housing, health care, electricity, water and indeed a continuous food supply (Azuz-Adeath and Rivera-Arriaga, 2007; FAO, 2013). In Mexico, securing food supply in the coming years will be a great challenge, as even if the current cultivable are is 27.8 million ha (INEGI-SAGARPA, 2015), it is estimated that this surface might decrease owing to changes in land use to build housing. Considering this situation, to increase agricultural production, instead of opening new lands for cultivation, producers must focus on improving performance per surface unit. According to Agrios (1998), to accomplish this, all the agronomic practices that help increase performance have to be included in agriculture, among which it is included: (1) improved cultivars; (2) fertilizers; (3) irrigation; (4) pesticides to control weed, plagues and diseases; (5) crop rotation; and, (6) tillage systems. Additionally, hydroponics (Resh, 1992) and protected agriculture (Castellanos-Ramos and Borbón-Morales, 2009) must be resorted to as techniques that allow intensifying the use of arable land (Turrent-Fernández and Moreno-Dahme, 1998). In this regard the question is: what is the current state of national agriculture? A famous phrase mentions that in order to understand the present and predict the future it is necessary to know the past. On this basis, the goal of the work was to examine what has occurred to agriculture in Mexico over the last 35 years, and the current state and its perspective for the future as regards food production.

Materials and methods

In order to carry out this research, we utilized SIAP official databases (2016) and reports from the housing and population census (INEGI 2015a); the agricultural and live stocking census (INEGI-SAGARPA, 2015) and the balance of trade of agricultural products for 2015 in Mexico (INEGI, 2015b). The first indicator estimated was per capita land availability, to do so, the cultivated land was divided by the number of inhabitants. From 1980 to 2015, calculation were performed by lustrum, but from such date to 2050, calculations were made by decade. Since in Mexico about 264 vegetal species are grown (SIAP, 2016), prior to the study all these cultivations were classi-fied into eight groups that included cereals (CER), legumes (LEG), oleaginous (OLE), vegetables (HOR), fruits (FRU), forages (FOR) and aromatic and medicinal (AROyMED). In spite of being grouped, owing to their lack of food relevance ornamental species were not included in the analysis. The production volume, cultivated area and performance per surface by lustrum were calculated for each of the eight groups. Additionally, a correlation analysis was performed on the three indicators of productions above and demographic growth over time. The theoretical availability of foods was estimated dividing the volume of production of each group by the number of inhabitants for the year 2010. Then this parameter was used to estimate the projected food demand which was obtained multiplying the theoretical availability for 2010 by the number of inhabitants CONAPO (2006) estimated for 2015-2050 in the scenario of most growth. For the calculation of the increase of required performance to secure the supply of the analyzed cultivation groups in the future, it was considered that production is an exclusive function of performance; under this supposition, this parameter was calculated dividing the projected food demand for each group between its cultivated area in 2010 (SIAP, 2016). The gain in performance displayed by the eight analyzed groups over the last 35 years was obtained by means of a linear regression analysis where the depending variable (y) was the performance expressed in kg ha^{-1} and the independent variable (x) was time in years. Once the equation was generated, the value of the estimated slope (expressed in kg/ha/year) was taken annual performance gain for each cultivation group. It is worth mentioning that the in calculations it was considered that all the production is destined for meeting the national demand, in reality this does not occur as Mexico, as the rest of the world imports and exports food.

Results and discussion

Demographic growth and land availability

Over the last 35 years, Mexican population increased 79 percent, changing from 66.8 million in 1980 to 119.5 million in 2015 (table 1). In this same period, the agricultural surface grew 22 percent and the 17.99 million hectares cultivated in 1980 increased to 22.2 million in 2015. Even if the cultivated surface, the estimated per capita available land in 1980 (0.27 ha / inhab) remained unchanged up top 1985 and then decreased to become 0.18 ha / inhab in 2015; which means that per capita available land reduced 31 percent. The scenario projected for the future is more alarming, as considering that by 2050 we will be 140 million people (CONAPO, 2006). Arable land might decrease to 0.16 ha / inhab / year. Considering this projection, the question is: ware we prepared to face this challenge?

Table 1: population growth, cultivated area and per capita arable land availability in Mexico

Year	Population Million inhabitants	Arable land Million ha	Land availability Ha/inhabitant
1980	66.8	17.99	0.27
1985	74.0	20.16	0.27
1990	81.2	19.73	0.24
1995	91.2	20.94	0.23
2000	97.5	21.78	0.22
2005	103.2	21.64	0.21
2010	112.3	21.95	0.20
2015	119.5	22.2	0.18
Increase	52.7	3.96	-0.08
%	78.9	22.2	-31.0
Projected demographic growth (2)			
2020	118.2	22.2	0.18
2030	127.5	22.2	0.17
2040	135.0	22.2	0.16
2050	140.0	21.95	0.16

NB: negative values mean a diminution in the parameter.
Source: calculations made on the basis of information from INEGI (2015b), SIAP (2017) and CONAPO (2006).

Current state of agriculture

Mexico, unlike other countries, has a wide variety of soil and climate conditions that enable growing 264 vegetal species (SIAP, 2016). As a result, Mexican people's diet is based on maize, bean and chili (Román et al., 2013). Moreover, at present with 5.8 million tons of agricultural products exported to other countries, Mexico is the fourth global exporter of fruits and vegetables only surpassed by Holland, Spain and China (Financiera Rural, 2008; Macías, 2010). According to information in table 2, out of the eight vegetal groups grown in Mexico, CER, FOR and LEG 65 percent of the agricultural area; this is not surprising since from ancient times, CER and LEG are the base of diet in Mexico (Muñoz-Velázquez et al., 2009) and at present, when 2023 species are grown with alimentary ends, bean and maize cover 44 percent of the cultivation area (8.015 and 1.774 million ha, respectively). FOR account for 21 percent of the cultivation area and despite they are not directly consumed, their demand is associated to their use as food for milk, meat and egg production. As of 1980, demand for animal origin foods has increased (Martínez-Jasso and Villezca-Becerra, 2005). This is why it is not surprising that FOR cover a larger area than that destined for LEG and OLE. Ever since 1980, the LEG cultivated area has remained unchanged, even ELO has decreased. Conversely, HOR in spite of holding a relatively small surface and that is very similar to that of wheat are key to the economy since the exportation of a number of HOR is part of the economic strategy to produce incomes and employment. This strategy was set up in the 70's, when Mexico was still self-sufficient in CER production. This turned into the exportation of HOR and FRU and the importation of CER and OLE (Borlaug et al., 1982). Mexico's importation of CER and OLE makes many people think there is a food deficit, but how true is this? The answer to this question with no speculation can be obtained studying how Mexican population has grown and what its relation is with foods of vegetal origin.

Agricultural production and demographic growth

As it is noticed in table 2, from 1980 to 2015, agricultural production in Mexico increased 94 percent from 102.96 to 199.94 million tons of food. Since in this period production of vegetal foods grew at a rate higher than the population, the per capita availability of vegetal foods increased in 12% (table 3). As a result, the availability of food per person in 2015 was 177 kilos over that of 1980, being CER, HOR, FUR and FOR the ones with the most contribution.

The increase in the availability over the analyzed period was reflected in an increase in the available per capita energy, which changed from 2 750 Kcal/person/day in 1980 to 3 146 Kcal/person/day in 2009 (Moreno-Altamirano et al., 2014; Urquiza-Fernández, 2014).

Table 2: harvested surface, production volume and performance of the eight groups of the most important cultivations in Mexico over the last 35 years

Group	1980	1985	1990	1995	2000	2005	2010	2015	INCR
Production (million ton/year)									
Cereals	15.713	20.282	19.087	22.225	21.438	22.776	34.250	27.34	74.04
Legumes	1.129	1.129	1.490	1.417	1.152	0.992	1.313	1.490	32.0
Oleaginous	3.261	2.662	1.675	1.308	0.841	1.032	1.085	2.61	-19.9
Vegetables	4.720	5.529	7.376	7.960	10.681	12.371	12.802	15.565	229.8
Fruits	8.633	10.800	10.427	12.764	15.314	15.308	17.584	18.743	117.1
Forages	32.486	37.639	42.934	49.621	71.228	98.941	103.300	70.47	117.0
Industrial	37.002	36.785	43.337	47.483	45.902	55.391	53.977	63.53	71.7
Spices	0.012	0.014	0.021	0.014	0.022	0.016	0.026	0.053	337.1
Total	102.96	114.84	126.35	142.79	166.58	206.83	224.34	199.82	94.1
Cultivated area (million ha/year)									
Cereals	7.689	9.129	8.456	9.049	7.948	7.375	7.936	7.877	2.5
Legumes	1.699	1.950	2.249	2.154	1.674	1.389	1.746	1.825	8.0
Oleaginous	1.471	1.559	1.098	0.870	0.645	0.609	0.702	0.981	-33.3
Vegetables	0.387	0.426	0.516	0.498	0.623	0.659	0.604	0.667	72.3
Fruits	0.777	1.009	0.878	1.077	1.225	1.112	1.385	1.286	65.5
Forages	2.420	2.908	3.147	3.377	4.807	5.348	4.156	1.966	64.57
Industrial	1.540	1.445	1.530	1.662	1.731	1.800	1.778	1.955	26.9
Spices	0.016	0.019	0.023	0.023	0.031	0.024	0.031	0.026	61.1
Total	16.760	19.135	18.774	19.786	19.907	19.429	20.120	18.598	16.9
Performance (ton/ha)									
Cereals	2.05	2.22	2.26	2.46	2.70	3.09	3.53	3.50	70.7
Legumes	0.67	0.58	0.66	0.66	0.69	0.71	0.75	0.82	22.4
Oleaginous	2.22	1.88	1.53	1.50	1.30	1.69	1.54	2.66	19.8
Vegetables	12.20	12.96	14.29	15.99	17.15	18.76	21.20	23.35	91.4
Fruits	11.11	10.70	11.87	11.85	12.51	13.76	12.70	14.58	31.2
Forages	13.43	12.94	13.64	14.69	14.82	18.50	24.86	17.70	31.8
Industrial	24.02	25.45	28.33	28.56	26.52	30.77	30.36	32.20	34.1
Esp. & Med.	0.75	0.73	0.95	0.62	0.72	0.66	0.85	2.03	170.7
Average	6.44	6.34	7.06	7.63	8.92	11.29	11.16	10.7	66.1

Suorce: calculations made on the basis of SIAP information (2017).

Table 3: per capita food availability in Mexico (1980-2015)

Group	1980	1985	1990	1995	2000	2005	2010	2015
kg/inhabitant year								
Cereals	228.4	274.1	235.1	243.7	219.9	220.7	316.0	228.8
Legumes	16.4	15.3	18.3	15.5	11.8	9.6	12.1	12.5
Oleaginous	47.4	36.0	20.0	14.3	8.6	10.0	10.0	21.9
Vegetables	68.6	74.7	90.8	87.3	109.5	119.9	118.1	130.3
Fruits	125.5	145.9	128.4	140.0	157.1	148.3	162.2	156.8
Forages	472.2	508.6	528.7	544.1	730.5	958.7	953.0	589.8
Industrial	537.8	497.1	533.7	520.6	470.8	536.7	497.9	531.7
Spices	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.4
Total	1496	1552	1556	1566	1079	2004	2178	1672

Source: calculations made based on production volumes reported by SIAP (2017) and demographic growth reported by INEGI (2015a).

In like manner, the improvement in the availability of vegetal foods was the result of an increase in the performance pe surface unit of 66 percent and an increase in its average production area of 7 percent. Because of this, from 1980 to 2015, the cultivated area increased in 1.84 million ha and the average performance of all the cultivations in 4.3 ton/ha. This tendency is congruent with what has occurred in a number of Latin American countries, where the increase in agricultural production is attributed to the great improvement in the productivity of cultivations (FAO, 2014). The high correlation estimated between total production of vegetal foods and demographic growth ($r = 0.93$) suggests that the increase in agricultural production between 1980 and 2015 was carried out mainly to meet the demand of food (table 4). Even if this volume in the production of total vegetal foods greatly increased over the studied period, this was proportional in the eight groups; it was in CER, HOR, FRU, FOR, IND and AROyMED where the volume produced significantly increased (74, 230, 117, 72, 117 and 337, respectively).

The correlation was estimated between the production volume of CER, HOR, FRU, FOR and IND and demographic growth indicates that the increase in production was the answer from agricultural sector to cover food demand. Conversely, the LEG production increased to a lower rate than demographic growth (32 percent) and OLE even decreased 20 percent, as a result, both groups did not present any association with demographic growth ($r = 0.28$ and -0.47 for LEG and OLE, respectively). The null association between LEG production volume and demographic growth is related to the fact that in recent years the importance of LEG as a protein source has decreased; an instance of this is what occurs at present with bean. In this species, over a period of 11 years, (between 1994 and 2005) its per capita consumption decreased from 15 to 11.8 kg/person/year (Muñoz-Velázquez et al., 2009). The reduction in bean consumption is associated to changes in the diet that started in the 1980's when the economic improvement favored access to animal-origin protein (meat, milk, eggs) (Moreno-Altamirano et al., 2014; Soria and Palacios, 2014). The correlation estimated between OLE production and demographic increase is atypical, as even if at present more animal fat is consumed than vegetal, this preference does not explain on its own the negative relation estimated between OLE production and demographic growth (-0.47). Therefore, the diminution in the production of OLE from the 1980's up to the present may also be associated with the state of the cultivation of soy in Mexico. In 1994, soy production in northwestern Mexico, particularly in the states of Sonora and Sinaloa, was heavily affected by whitefly, which caused that in the following years the production of OLE almost disappeared in several agricultural zones of the country (Avilés-González et al., 2004; Ortega-Arenas, 2006). To date, the production of soy has no recovered; consequently, that OLE accounts for 16 percent of the value of food importation (INEGI, 2015b). In spite that over the studied period the production volume of AROyMED increased 337 percent, this parameter did not present a correlation with demographic growth (r = 0.48), this because even if species in this group are eaten in Mexico, a large part of its production is exported (Pérez, 2009). There is no doubt that over the last 35 years, the increase in food production in Mexico has been in function of demographic growth; however, from the agronomic standpoint the question is: what are the strategies that have allowed increasing agricultural production in Mexico?

Strategies associated to the increase in agricultural production

In Mexico as in the rest of the world, the increase in agricultural production has been the result of improving performance per surface unit, increasing the cultivated surface and the combination of both strategies (table 4). Historically, both at global and national level, the increase in agricultural production via the improvement of performance per surface unit has been key and in Mexico, the best documented case is wheat (Fischer and Edmeades, 2010). Even if the improvement of performance has helped increase the production of a number of cultivations, up to present there are some whose production is an exclusive function of their cultivated area, as their performance has remained unchanged. For example, as regards carrot, ASCA

(2000) reports that its performance has not changed since 1980 (22.3 ton/ha), therefore, its national supply has been meet increasing 500 percent its surface even if the performance potential is 64.3 ton/ha (Sosa et al., 2013). A similar case is bean, in which performance in the last 14 years has remained unchanged (FIRA, 2015), even if it is possible to obtain performances of 1.6 ton/ha, the national average is 0.8 ton/ha (Lara-Flores, 2015). Considering this situation, the question to answer is, what are the groups of cultivations in which performance has changed little?

Tabla 4: Asociación del volumen de producción (r) con el aumento poblacional, área cosechada y el rendimiento de ocho grupos de cultivos producidos en México entre 1980-2015

Grupo	Población	Área cosechada	Rendimiento
Coeficiente de correlación (r)			
Cereales	0.93*	-0.14 ns	0.94*
Leguminosas	0.28 ns	0.76*	0.34ns
Oleaginosas	-0.47ns	0.91**	0.80 **
Hortalizas	0.99**	0.95**	0.98 **
Frutales	0.98**	0.95**	0.86 *
Forrajes	0.80*	0.98 *	0.93**
Industriales	0.95**	0.92**	0.94**
AROyMED	0.48ns	0.77*	0.99*
Todos los grupos	0.93**	0.74*	0.88**

* y ** Significativo al 0.05 y 0.01 probabilidad, respectivamente, ns = no significativo.
Fuente: Los valores se estimaron con base en la información de las Tablas 2 y 3.

Performance improvement by surface unit

The association estimated between production and CER performance (r = 0.94) indicates that between 1980 and 2015, the amount of CER produced has been an exclusive function of increasing performance per surface unit; this concurs with reports for wheat in England, maize in the U.S. and rice in Japan (Favell, 2010; Fischer and Edmeades, 2010; Jaggard et al., 2010; Phillips, 2010). As an instance of how the improvement of performance has helped increase the production of CER, in figure 1 we present the changes in the cultivated area of wheat over 55 years in Mexico. As it is noticed, between 1960 and 2015, the wheat-cultivated surface reduced 5.3 percent and performance increased 320 percent from 1.62 to 5.2 ton/ha, this indicates that the increase of 317 percent has been and exclusive function of improving its performance. CER performance improvement in Mexico and particularly regarding wheat and maize is associated with the research performed by CIMMYT as of the 1950, where Norman E. Borlaug was a pioneer and because of which he earned the Nobel Prize in 1970. This has made it possible that at present in a number of zones in the country performances of wheat, maize and rice (8.0, 10.2 and 10.0 ton/ha, respectively) (Salcedo-Aceves, 2006; Figueroa-Lopez et al., 2010; Montoya-Leobardo and Armenta-Bojórquez, 2010) over the global media 2.90, 4.2.9 and 5.0, ton/ha, respectively) are obtained (FAO, 2013).

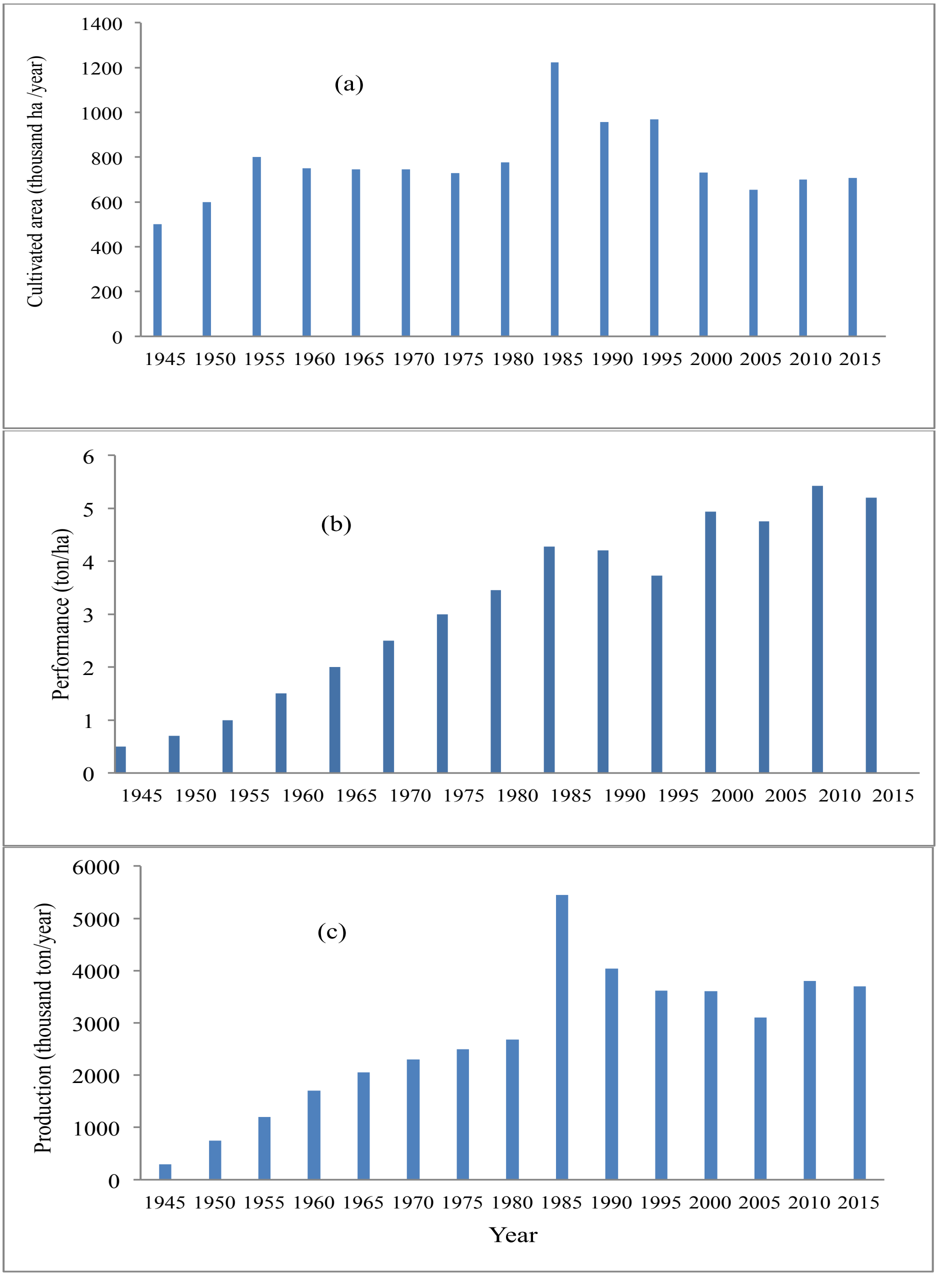
Increase in cultivated area

Unlike CER, the increase in LEG production has been exclusively linked to increase cultivated areas (r = 0.76). This fact is concerning as we find bean here, which is a pillar of Mexican diet ever since ancestral times (Celis-Vázquez et al., 2010) and nowadays, with 1.77 million ha, it accounts for 92 percent of the cultivate area in this group; 7.6 percent of the surface is used to grow vetch, fava bean, chickpea and lentil (SIAP, 2016). This fact suggests that out of all the LEG species currently cultivated in Mexico, it is been on which in the coming years resources must be destined to research and establish infrastructure to help understand better it productive potential.

Increase of performance and cultivated area

As noticed in table 4, the increase in the production volume of OLE, HOR, FRU, IND and AROYMED is the result of increasing their performance and cultivated area. For HOR and FOR, the increase in their production between 1980 and 2000 took place because their cultivated area almost doubled from 0.387 to 0.623 and from 2.42 to 4.807 million ha for HOR and FOR, respectively (table 2). However, after 2000, the cultivation area of both groups increased a bit and the increase in production was associated only to the performance improvement that changed from 17.2 to 23.4 ton/ha for HOR and from 14.82 to 17.7 ton/ha for FOR. Information regarding OLE must be taken cautiously since despite calculations suggest that the increase in production is associated to the increase of performance and cultivated area (r = 0.80 and 0.91, respectively), the high fluctuation of values of these parameters over the studied period indicate low reliability (table 2).

Figure 1: cultivated area (a), performance (b) and production volume (c) of wheat in Mexico



Source: data from 1945 to 1980 taken from Bourlag *et al*. (1982); from 1980 to 2015, SIAP information was used (2017).

Prospective agricultural production for the next 35 years

Even when it is well defined how Mexican population will grow, to date there is no projection for the total food demand that the demographic growth will bring and there is only one partial explanation for animal-origin products (Salazar-Adams et al., 2006). Considering this situation, in table 5, the food demand projected for the next 35 years is shown.

According to the calculation, for 2050, Mexico will have to produce almost 289.87 million ton/year of agricultural products. Considering there is no more arable land, the performance of cultivations must increase from 12.6ton/ha in 2010 to 15.4 ton/ha in 2050 (table 6).

Before this scenario, there is a question: is it feasible to increase production exclusively based on the improvement of performance? To answer this question, in figure 2 the gain in performance for six cultivations over the last 35 years is presented. Results suggest that for CER, HOR, FRU, FOR, IND and LEG it will be possible to meet the demand increasing performance, this statement is based on the fact that gain in performance accomplished between 1980 and 2014 for the groups above (44, 319, 97, 174, 242 and 32 kg/ha/year, respectively) is above the estimated sufficiency to secure its supply (24, 145, 87, 170, 208 and 5 kg/ha/year, respectively) (table 6).

For CER, the estimated performance is 4.6 ton/ha, this value surpasses FAO's (2009) estimations for the increment of CER in the world (4.3 ton/ha). As regards LEG, the gain in performance accomplished in the studied period was 4.8 kg/ha/year, this value is lower then the required to secure their supply up to 2015 (5.1 kg/ha/year). The low productivity of LEG in Mexico is associated to that despite there are bean-growing zones in Sinaloa and Durango, where there are performances (1.7 and 1.9 ton/ha) (López-Salinas, 2011) over the national mean (0.72 ton/ha) (SIAP, 2016), to date there are regions where productivity is lower than 0.5 ton/ha (SIAP, 2016).

Bean is seasonal crop, hence in the future to secure its supply it will be necessary to channel resources for research that allows generating technology to grow bean under this system. At present, INIFAP works to obtain cultivars that resist droughts and diseases (Anaya-López et al., 2015) and it is expected that in the short term there are varieties that allow improving its performance.

Table 5: volume projection of the expected demand of eight cultivation groups in Mexico between 2015-2050

Group	Food availability 2010 (kg/inhabitant/ year)	2014	2015	2020	2030	2040	2050
		Million tons / year					
Cereals	317.0	36.59	36.14	37.47	40.42	42.79	44.38
Legumes	12.1	1.49	1.38	1.43	1.54	1.63	1.69
Oleaginous	10.0	2.61	1.14	1.18	1.27	1.35	1.40
Vegetables	118.1	15.57	13.46	13.96	15.06	15.94	16.53
Fruits	162.2	18.74	18.49	19.17	20.68	21.90	22.71
Forages	953.0	62.08	108.64	112.64	121.51	128.66	133.42
Industrial	497.9	62.68	56.76	58.85	63.48	67.22	69.71
ARO&MED	0.2	0.05	0.02	0.02	0.03	0.03	0.03
Total	2178	199.82	236.04	244.73	263.99	279.52	289.87

Source: values estimated from information from CONAPO (2006) and SIAP (2016).

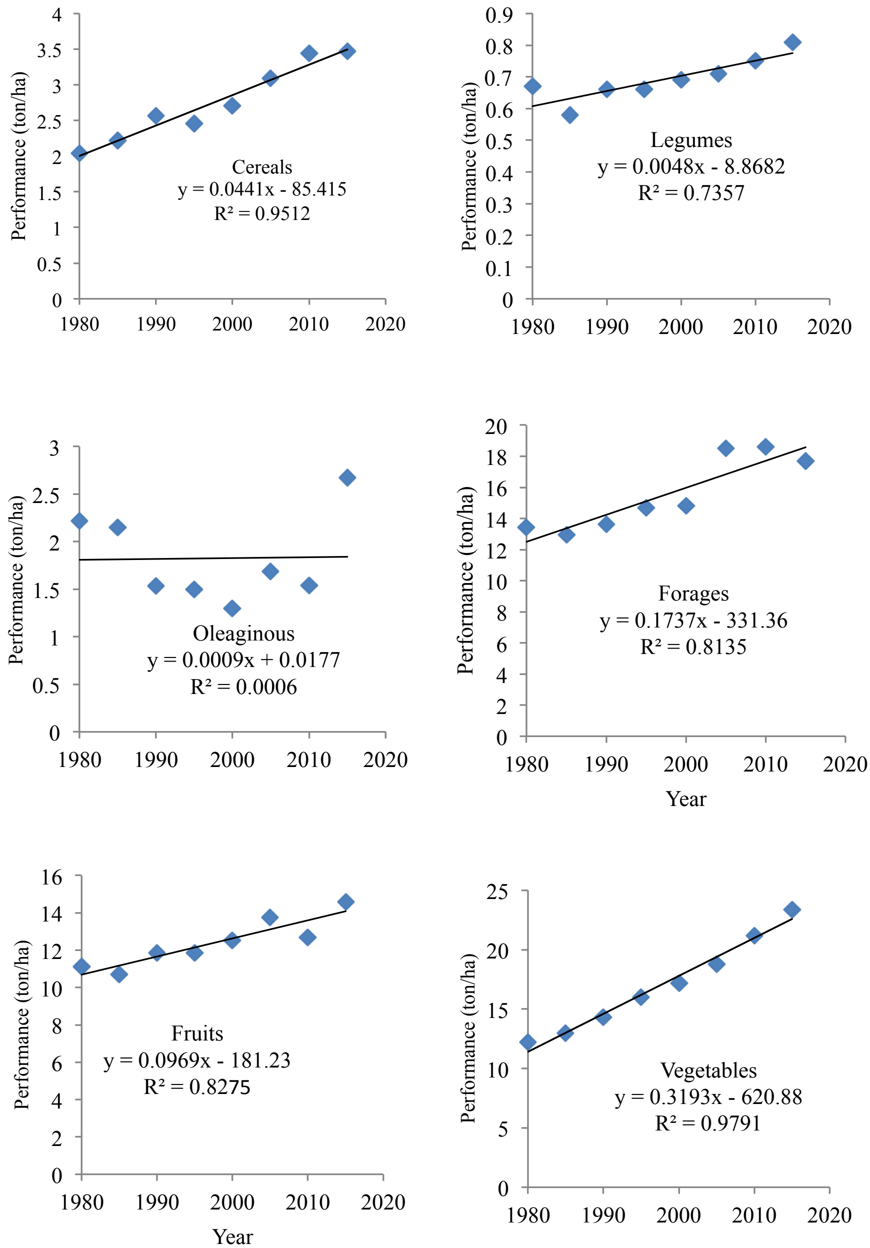
Table 6: necessary performance increase to meet the expected demand for the eight cultivations in Mexico between 2015-2050

Group	Surface (million ha)	Performance (kg/ha)					
		2015	2020	2030	2040	2050	Annual
Cereals	9.705	3.7	3.9	4.2	4.4	4.6	24.3
Leguminous	1.746	0.8	0.8	0.9	0.9	1.0	5.1
Oleaginous	0.702	1.6	1.7	1.8	1.9	2.0	10.6
Vegetables	0.604	22.3	23.1	24.9	26.4	27.4	145.3
Fruits	1.385	13.4	13.8	14.9	15.8	16.4	87.0
Forages	4.156	26.1	27.1	29.2	31.0	32.1	170.3
Industrial	1.778	31.9	33.1	35.7	37.8	39.2	208.0
ARO&MED	0.031	0.7	0.8	0.8	0.9	0.9	4.8
Total	20.106	12.6	13.0	14.1	14.9	15.4	81.9

NB: harvested agricultural area over 2010.
Source: values estimated on the basis of data from SIAP (2016) and CONAPO (2006).

For OLE, the improvement in performance (0.9 kg/ ha/year) was lower to the requirements to secure supply (10.6 kg/ha/year), this situation is already foreseen and at present there is research to generate agronomic practices to help improve the performance of some of the species of this group (cotton, safflower and sunflower); moreover the possibility of introducing new OLE is analyzed, such is the case of rapeseed (Inzunza-Ibarra et al., 2014). According to the information presented, from 1980 to date, the improvement of cultivations performance is noticeable, particularly after 2000 (table 2) when drip irrigation was introduced and protected agriculture.

Figure 2: Tendency in performance improvement (ton/ha/year) in six cultivation groups for 35 years in Mexico



Source: figure produced on data from SIAP (2016).

However, since there are still cultivations where gain in performance is low, there is uncertainty regarding if agriculture in Mexico is prepared to cover the future food demand. The demographic growth for the next 35 years has been calculated on the basis of various scenarios (CONAPO, 2006) and zones of the country (Azuz-Adeath and Rivera-Arriaga, 2007). Albeit, regarding demand and production of food, to date there are no estimations; according to Camberos-Castro (2000), this is because it is difficult to make these projections and will always have a certain degree of speculation since some suppositions have to be made such as those made in this work. Results of this analysis indicate that Mexican agriculture has the capacity and resources to cover the food demand. This statement contradicts those who argue Mexico lacks food self-sufficiency and therefore has to resort to food importation (Flores-Pérez et al., 2012; López, 2015). In this regard, food importation does not mean our country has food dependency as all the countries in the world to some extent resort to it to obtain the foods they cannot produce in a certain season or else because their production volume is lower than the demand. To measure a country's food self-sufficiency, FAO (2009) recommends using an energy balance between the foods domestically produced and those exported to other countries and those imported (FAO, 2009). This method is laborious, from here that a practical alternative is to analyze the balance of trade of food exportations and importations, a negative balance means there is a deficit in food production. In table 7, we present the balance of food importation/exportation that INEGI (2015b) reports for Mexico over 2014 and 2015. As noticed, in such years, the balance of trade of food in Mexico presented a positive balance (69.9 and 324.9 million USD, respectively).

This result is another proof that supports the statement that Mexico produces more foods than those demanded by the population and is self-sufficient from a food standpoint. It is a reality that the national production of CER and LEG is not sufficient to meet the population demand and at present maize, soy and wheat account for 44 of the total importation of foods. This fact has made some people state that in Mexico there is food deficit, which is erroneous as according to the 2015 balance of trade, only the income of HORT exportation (576.3 million USD) was 87 percent higher than the importation costs of CER (285.9 million USD). According to Borlaug et al. (1982) HORT exportation is an economic strategy that the Mexican government supported as of 1970 to generate employment and incomes, therefore, even if the 2015 balance of trade of food reports a revenue of 324.2 million USD, the cost of this is the importation of basic grains to cover the population demand.

Table 7: balance of food importation and exportation in Mexico during 2014 and 2015 (million USD)

Category	Year 2014			Year 2015		
	EXP	IMP	Balance	EXP	IMP	Balance
Animal products	120.8	177.7	-56.9	184.1	167	17.1
Bovine cattle	46.2	4.5	41.7	69.3	3.1	66.2
Milk and byproducts	0.0	71.7	-71.7	0.0	62.2	-62.2
Egg	0.0	11.2	-11.2	0.0	17.4	-17.4
Offal	0.0	17.3	-17.3	0.0	20.4	-20.4
Fish and seafood	48.3	73.0	-24.7	69.5	63.9	5.6
Frozen shrimp	26.3	0.0	26.3	45.3	0.0	45.3
Cereals	33.6	329.6	-296	15.2	301.1	-285.9
Maize	3.4	186.4	-183	4.5	165.3	-160.8
Wheat	30.2	90.2	-60	10.7	89.1	-78.4
Rice	0.0	38.4	-38.4	0.0	30.0	-30.0
Sorghum	0.0	9.6	-9.6	0.0	5.0	-5.0
Other	0.0	5.0	-5.0	0.0	11.7	-11.7
Legumes	19.7	5.0	14.7	11.2	7.0	4.2
Bean	5.5	5.0	0.5	2.7	7.0	-4.3
Chickpea	14.2	0.0	14.2	8.5	0.0	8.5
Oleaginous	0.0	257.3	-257.3	0.0	210.7	-210.7
Soy	0.0	162.1	-162.1	0.0	146.9	-146.9
Colza	0.0	72.3	-72.3	0.0	32.7	-32.7
Others	0.0	22.9	-22.9	0.0	31.1	-31.1
Industrial	26.9	57.2	-30.3	36.6	41.3	-4.7
Coffee	22.1	0.0	22.1	30.4	0.0	30.4
Tobacco	0.8	13.1	-12.3	0.9	11.4	-10.5
Cotton	4.0	44.1	-40.1	5.3	29.9	-24.6
Fruits	283.8	70.2	213.6	352	75.7	276.3
Banana	10.7	0.0	10.7	11.4	0.0	11.4
Mango	2.8	0.0	2.8	2.7	0.0	2.7
Avocado	134.6	0.0	134.6	156.4	0.0	156.4
Citric	24.7	0.0	24.7	29.9	0.0	29.9
Cantaloupe, papaya & watermelon	15.2	0.0	15.2	18.3	0.0	18.3
Fresh strawberries	37.6	0.0	37.6	49.2	0.0	49.2
Fresh and dried fruits	56.6	23.3	33.3	83.9	33.7	50.2
Grapes and raisins	1.6	13.3	-11.7	0.2	9.7	-9.5
Apples, pears and quinces	0.0	33.6	-33.6	0.0	32.3	-32.3
Vegetables	539.4	2.9	536.5	584.7	7.1	577.6
Tomato	167.7	0.0	167.7	197.2	0.0	197.2
Fresh and dried chilies and peppers	137.0	2.9	134.1	141.8	7.1	134.7
Onions and garlics	25.4	0.0	25.4	22.7	0.0	22.7
Cucumber	62.3	0.0	62.3	54.6	0.0	54.6
Other	147.0	0.0	147.0	168.4	0.0	168.4
Various	47.9	102.2	-54.3	48.6	98.3	-49.7
Other agricultural products	37.8	76.1	-38.3	40.1	77.3	-37.2
Seeds for cultivation		26.1	-26.1	0.0	21.0	-21.0
Flowers	1.9	0.0	1.9	1.6	0.0	1.6
Honey	8.2	0.0	8.2	6.9	0.0	6.9
Total	1072.1	1002.1	70.0	1232.4	908.2	324.2

EXP = Exportations; IMP = Importations.
Source: calculations made on the basis in information reported by INEGI, (2015b).

The positive balance of the balance of trade for 2014 and 2015 verifies what FAO (2014) reports regarding food availability in Mexico; this international agency states the county produces sufficient food, however the high price as a result of transporting it to the localities restricts their acquisition, even if it is available and claim that this is not a problem of lack of food but of access. In order to improve food access in Mexico, FAO (2013) states that in addition to increase production, there should be work on (1) improving the distribution network and food transportation; (2) reduce unemployment rate; (3) improve wages; and, (4) regulate the cost of the market basket. This means that regarding food security, producing foods is only a part of the equation and the other is maybe the most important is to distribute them equally. This is the greatest fail, not only in Mexico but in many other countries.

Conclusions

By 2050 in Mexico there will be only 0.18 ha of arable land to produce the food a person demands a year. Since there is no more arable land to secure national food supply toward 2050, the average performance of the eight cultivated groups must increase in 2.8 tons, from the current 12.6 ton/ha to 15.4 ton/ha. The improvements in performance over the last 30 years for CER, HOR, FRU, FOR and IND indicate that even if maintaining the cultivated surface in 2010 it will be possible to secure the supply of products from this group. For the case of LEG and OLE, research is necessary to produce technology and invest on agricultural infrastructure that allows increasing performances as a measure to secure their supply in Mexico.

Epilogue

The anthology of strawberries, a simple explanation of the food problem in Mexico

The idea of writing this article was a product of a discussion I had with a Dutch friend who visited Mexico in 2012. The debate started when he mentioned that our country lacks food self-sufficiency, I have never agreed with that, so I decided to speak my mind. As I did not have any support for my stance, cunningly I used what I called later "the anthology of strawberries" and that I improvised back then. Historically, Irapuato, Guanajuato, is deemed the national capital of strawberries; ironically, my hometown (Ticumán, Morelos) is closer to such agricultural area than my friend's (Wageningen, Netherlands), it was not until the age of 23 that for the first time I tried fresh strawberries, while he tried them as a child. Considering this, the question I made my friend was: if in Mexico there is wider *availability* of strawberries than in the Netherlands, how do you explain that you eat them since you were a boy, while I can only them now that I have a job? The answer is simple, it is called *access*. This concept from the food standpoint is associated to monetary availability an individual, family, state or country has regardless of the price. Bananas are not gown in Switzerland and in spite of this, they eat them. The United Arab Emirates do not grow vegetables and however they are eaten there. From this the question is: how do countries accomplish this? This fact is possible because the population of these countries has the purchasing power to acquire such foods at any price. Therefore, it is evident that my friend was able to eat strawberries because even if in the Netherlands their availability is lower than in Mexico, his father, a professional, earned sufficient to buy them even if expensive. While my father with a wage of a day-laborer was never able to purchase them even if they were available in the local market and were relatively cheap. The talk finished and despite my friend conceded, deep inside I knew my explanation lacked the solid support. And so, considering the food situation in Mexico is a topic of debate, I set off to look for the real answer based on solid data. As a preliminary version of this work, it was ready in 2013, I sent it to a contest organized by UABC in Mexicali, Baja California where the prize for the three first places was the publishing of the works. I did not win the contest and as I did not have money to publish it I decided to wait because of two reasons; firstly, I needed the result of the population, agricultural and livestock censuses tom complete it, since I had made calculations by lustrum; second, it was to find funding to pay for the review and publication of the work. I sent the final version to the journal Archivos Latinoamericanos de Nutrición in June 2016 and despite the interest, in the end the editor recommended publishing it a Mexican journal for its best dissemination. According to the information presented in this work, it is clear that the food problem in Mexico is not availability but access. This means that even if food is available, if a person cannot afford it, food will be out of reach, as it was my case with the strawberries. It is true that at present our country spends 301.1 and 210.7 million USD on importin CER and OLE, respectively. However, even so our agriculture accomplishes a surplus of 324.2 million USD as only incomes from fruit (352 million USD) and vegetables (584.7 million USD) exportation amply surpasses the amount destined to import basic crops (511 million USD on grains and oleaginous v. 936.7 dollars of revenue in the exportation of fruits and vegetables). These calculations were made on the basis of the balance of trade reported by INEGI for 2015. Hence, the only way they can be wrong is that the source is.

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