Food and Nutritional Security in Peru

Winayhuayna, Inca ruins of agricultural center, Machu Picchu, Peru © Shutterstock

Peru

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Although **Peru** has made great strides in the past 20 years regarding the rational use of fishery, land and water resources, environmental conservation, genetic reserve and mitigating the negative impact of climate change, it has not sufficed to **guarantee the food security, health and quality of life of today's inhabitants and future generations**

Summary

Peru is one of the countries with the greatest diversity of ecosystems and species. It is home to 84 of the 117 life zones recognized in the world, included in a wide range of climates, geoforms and types of vegetation. It is an agricultural and livestock country par excellence, contributing 80% of the food consumed by its population, meaning that it needs to import the remaining 20%. It has a capacity to develop agricultural crops above 4000 masl and is internationally recognized for its production of "superfoods" such as quinoa, kiwicha, cañihua, maca, yacón, Inca nut, anchovy, camu camu, purple maize and soursop. Peru is among the top ten food exporters, meaning that is on the way to becoming the world's pantry.

Although the availability of resources is wide and varied, a significant percentage of the population is exposed to food insecurity, particularly as a result of climate change and natural disasters. The state promotes agricultural, livestock and aquaculture development through the enactment of laws and economic investment for the promotion of human resource research and training for the technological generation and innovation, agricultural production and export. It also promotes the rational use of fishery, land and water resources, conservation of the environment and genetic reserves and mitigation of the negative impact of climate change. Although over the past 20 years, the country has had many achievements, these are still insufficient to guarantee the food security, health and quality of life of its inhabitants and future generations.

1. The Characteristics of Peru

a. A land of contrasts

The third largest country in South America with an area of 1'285,215.60 square kilometers, straddling the steep, rugged Andes and culminating at 6,768 meters above sea level, Peru enjoys an exceptional situation since it is part of the Pacific watershed, with 3,080 km of marine coast and the Amazon basin, offering a myriad of landscapes, resulting from the impressive climatic and biological diversity created by slopes of over 6,000 meters. With 96 (Pulgar Vidal, 2014: 225) of the world's 104 life zones, 12 climate zones[1] and eight natural regions, Peru is one of the ten countries in the world with greatest mega-diversity. It depends on and uses most of its biodiversity. The population uses approximately 5,000 of the country's 25,000 plant species (10% of the world total), of which at least 30% are endemic, for a variety of purposes: food (782); medicine (1,400);

1. According to Köppen.

decoration (1,608), timber and construction (618); fodder (483) and dyes and coloring (134) (MINAM, 2008). The seven food baskets also reflect the abundance and diversity of local food resources, the current possibilities of using them and the centuries-old wisdom of the indigenous peoples (**Box 1**).

Farmers in ancient Peru domesticated 25 species of edible roots and tubers. These crops can be of global significance such as the potato (*Solanum tuberosum*), olluco (*ullucus*), oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*), Peruvian parsnip (*Arracacia xanthorrhiza*), daisy (*Smallanthus sonchifolius*), Mauka (*Mirabilis expansa*), arrowroot (*Canna edulis*), Andean yam bean (*Pachyrhizus ahipa*) and maca (*Lepidium meyenii*). These crops have a high tolerance to pests and diseases and nutritional efficiency,

Box 1. The Seven Food Baskets (Javier Pulgar Vidal, 2014)

The contents of the "basket" differ at each level; but together, they meet all the biological needs of the population and reflect both the efforts to successfully acclimate the species needed and to tame the slope and ensure water availability.

- **La Chala (0-500 m).** Animal protein predominates in the La Chala food basket (fish and seafood: anchovy, bonito, sardine, mackerel, mackerel, tuna, sea bass, sole) as well as sweet potato, various types of bean, corn, squash, cabbage, lettuce, cauliflower, spinach, cucumber, leek, peas, caigua, vainita, tomato, onion and fruits such as grapes, fig, banana, guava and plums.
- **La Yunga (500 a 2,300 m).** This basket mainly contains poultry, guinea pig, eggs and various fruits: avocado, custard apple, lucuma, passion fruit, papaya, tumbo, plums, palillo, cactus pear, pitahaya; introduced citrus fruits (orange, lime, sweet and sour lemon, cider, kumquat and grapefruit); sweet potato, canna, beans; and condiments such as various kinds of chili and an aromatic herb known as chincho.
- **La Quechua (2,300 a 3,500 m).** This basket consists mainly of guinea pig meat and poultry, trout and dry-salted fish; maize, potatoes, parsnips, pumpkin, shupe, beans, numia, pashullo, all kinds of vegetables, herbs, a variety of seasonings and typical and acclimatized fruit.
- **La Suni or Jalca (3,500 a 4,000 m).** The basket comprises guinea pig meat, llama jerky, dried fish; quinoa, cañigua, tarhui, potato varieties, oca, mashua, olluco, various vegetables; condiments such as shill-shill which is similar to Guacatay, anise and pachamuña. The fruit basket is rounded out by Layan fruits, burro-shillanco and blackberry.
- **La Puna (4,000 a 4,800 m).** The local food basket consists of dried meat and the fresh meat of camelidae, sheep, pig, cattle and wild or domestic guinea pigs; lagoon or stream fish; bitter potatoes turned into chuño, non-bitter potatoes, maca, watercress, cushuro, potaca, huagoro fruits and occasionally non-bitter potato berries.
- **La Janca (4,800 a 6,768 m).** This food basket is mainly found at the lower levels.
- **La Rupa-Rupa (400 a 1,000 m).** The diet of humans living in the high jungle is dominated by forest meat, as well as beef, mutton, goat's meat, pork, guinea pig meat, poultry and river fish. It also features pituca, cassava, chuncho bean, a type of bean known as frejol de palo, millet, maize, cocoa and peanuts; condiments such as annatto, turmeric, palillo de palito, various peppers, vanilla, and tea, matico, pucherí and sharamasho infusions.
- **La Omagua or Selva Baja (80 a 400 m).** This area has a food basket consisting of bush meat, Amazonian cattle, water buffalo, sheep without wool, common goose and guinea fowl; river fish, river and land turtles; cassava, pituca, bananas, yams, cantaloupe, watermelon, native fruit and cultivated vegetables.

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Table 1. Agricultural area by natural region in hectares, 2012

Natural region	Total	%	Agricultural	Non agricultural
Coast	4 441 453,92	11,5	1 686 778	2 754 376
Mountains	22 269 270,66	57,5	3 296 008	18 973 263
Rain forest	12 032 040,10	31,1	2 142 222	9 889 818
Total	38 742 464,68	100,0	7 125 008	31 617 457

Source: INEI. IV Censo Nacional Agropecuario 2012

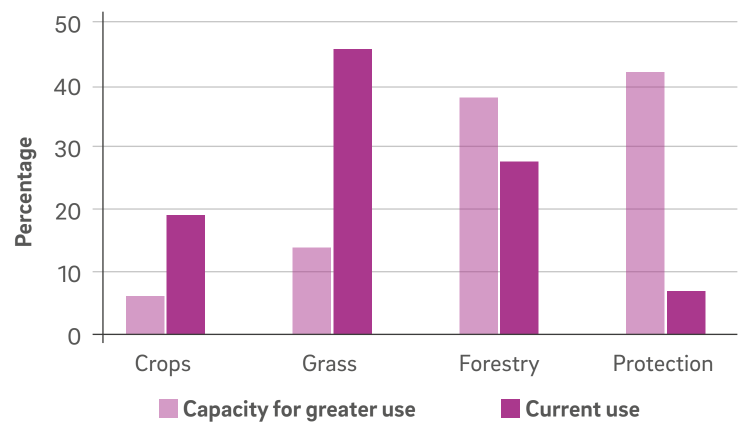
because of their degree of adaptation to extreme environments (CONDESAN, 1997). Pulses include the lupin (*Lupinus mutabilis*) while grains include quinoa (*Chenopodium quinoa*) and amaranth (*Amaranthus caudatus*), both with a great nutritional value (Repo-Carrasco-Valencia, 2014).

This impressive biodiversity is distributed very unequally throughout three geographical regions as follows; the desert coast, dotted with fertile oases (11% of the territory, 52% of the population); the sierra with its enormous latitudinal and altitudinal complexity (30% of the territory, 36% of the population) and the extensive tropical forest with its contrasting diversity (59% of the territory, 12% of the population). The impressive diversity of the Peruvian sea is vastly undervalued. A total of 750 fish, 872 mollusk, 412 crustacean, 45 echinoderm and 240 algae species have been identified, together with turtles, cetaceans and mammals, of which only a small fraction are commercially exploited (MINAGRI, 2017).

Despite having such a vast territory and being one of the centers of origin of cultivated plants (Brack, 2004), Peru's agricultural potential is reduced to 5.9% of the country's total area, most of it suitable for seasonal crops (3.8%) and the remainder for permanent crops (2.1%), with protected lands accounting for 42% of the national territory. **Table 1** shows that the coast is the region with the lowest amount of farmland and pastures. Demographic pressure and other circumstances forced populations to indiscriminately use soil beyond its capabilities (**Figure 1**), causing severe desertification and land degradation that compromise 26.76% of the total national territory (34'384,796 ha) (MINAM, 2014: 151).

This overwhelming diversity, combined with the multiple constraints of a land of contrasts, explains why, since ancient times, Peruvians have

Figure 1. Greater land use capacity and current use (%), 2015



Source: INEI, Anuario de Estadísticas Ambientales, 2015, and ONERN, 1985

sought and found solutions to evaluate the environmental supply and reverse the problems of desertification and degradation of plant cover, building galleries, canals and pipelines, controlling erosion (water, wind, thermal) through ridges, waru-waru and extensive platforms currently being restored (**Table 2**). Also, at present, the area under irrigation represents 2.6 million ha (36.2%) of a total of 7.1 million ha, while 4.5 million are rainfed (63.8%) (INEI, 2012).

b. Continuous, uneven population growth

With a total population of 31,488,625 on July 11, 2016, Peru has moderate annual population growth of 1.5% (1993-2007), low average density of 24.60 inhab/square kilometers and a large urban population (76.7%), 41% of which is concentrated in the metropolitan capital of Lima (9'901,107 inhabitants). Population dynamics are characterized by a double asymmetry by natural region and occupation (urban/rural), together

Table 2. Conservation status and current use of platforms in the provinces of southern Peru in hectares, 2012

Province	Total	Well conserved		Moderately well conserved			Destroyed		
		PU	TU	PU	TU	WAU	PU	TU	WAU
Total	**256955**	**13565**	**11025**	**31005**	**76160**	**105**	**400**	**84305**	**40390**
Apurímac	22620	-	-	25	6260	-	-	15430	905
Arequipa	48345	3260	6775	10195	11855	-	-	6120	10140
Cusco	23675	875	430	4395	2990	105	90	13610	1180
Ica	3345	-	-	160	915	-	310	960	1000
Lima	79380	3055	945	4950	28315	-	-	28405	13710
Moquegua	19390	4965	450	4500	2830	-	-	910	5735
Puno	46720	-	2425	-	20895	-	-	17715	5685
Tacna	13480	1410	-	6780	2100	-	-	1155	2035

Key: PU=Permanent use, TU= Temporary use, WAU= without agricultural use. Source: MINAGRI (INEI, 2015).

with a large indigenous population (25% of the national total) that is culturally and ethnically diverse, with 70.1% living in the mountains, 25.8% on the coast and 4.1% in the forest.

The demographic dynamic is characterized by a drop in the Overall Fertility Rate (from 2.6 children/woman in the 2005-2010 five-year period to 2.22 children/woman at present) and the child mortality rate (from 21,00/1,000 live births for the 2005-2010 five-year period to 16,60/1,000 live births) and an increase in life expectancy at birth (73,12 for the 2005-2010 five-year period to 75,07 at present) (INEI, 2016).

The agricultural sector accounts for 25% of the Economically Active Population (EAP) nationwide and in 2014, it accounted for 5.3% of the national Gross Domestic Product (GDP). With the exception of Lima, approximately 40% of the economically active population is engaged in agriculture (in the mountains, this figures rises to 55%) and represents between 20% and 50% of the regional GDP (Zegarra and Tuesta, 2009; Dragonfly, 2010; MINAM, 2016). The 2012 census recorded 2,260,973 farmers in Peru, 63.9% of these in the highlands, 20.3% on the coast and 15.8% in the forest (INEI, 2015).

c. Food insecurity, poverty and vulnerability

In 2010, MIDIS conducted a first detailed measurement of food insecurity in terms of availability, accessibility, food utilization and stability (time), noting that 47.5% of the total population is at risk of food insecurity, the most severely affected regions being Huancavelica, Huánuco, the Amazon and Puno (**Map 1**).

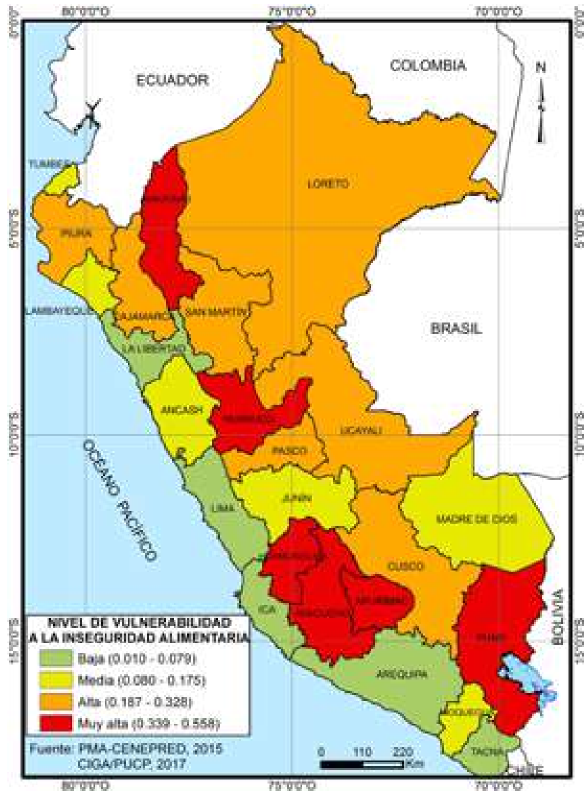
In 2015, 459 districts nationwide- in other words, 3.7 million people (INEI, 2014)– were exposed to Extreme Vulnerability to Food Insecurity in the event of natural phenomena (VIAFFNN). A total of 460 districts (with 3.4 million people) have a 37% probability of experiencing VIAFFNN with regard to food and nutrition insecurity. The most vulnerable provinces are Puno, Huancavelica, Ayacucho, Apurimac, the Amazon and Huánuco (**Map 2**).

In 1994, 49.6% of Peruvian households were unable to cover their basic consumption basket, and by 1997, this percentage had dropped to 44.3% (Vásquez, 1999). In 2001, a process of recovery and economic growth began (4.2% from 2001 to 2005) (Mendoza, 2006), reaching 7.2% in the 2006-2010 period (MEF, 2010; 2011).

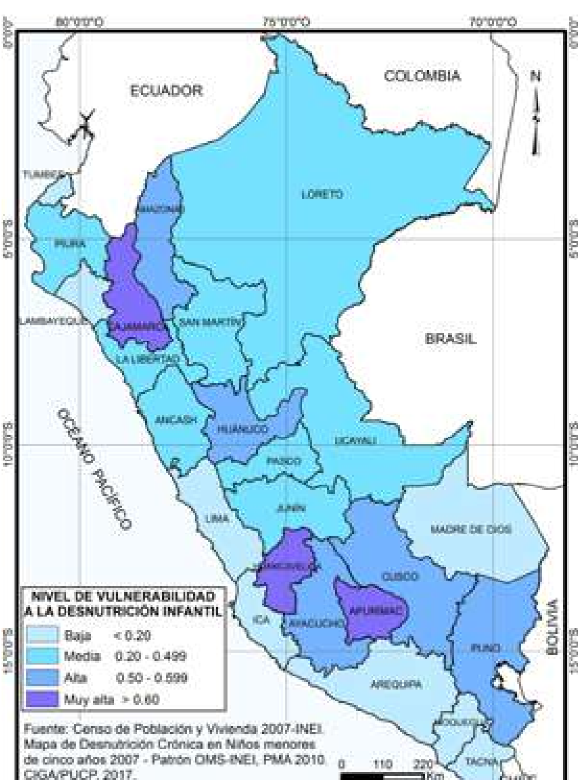
However, a very high rate of chronic child malnutrition due to inadequate food intake and disease can be observed, mainly in the highland regions (Huancavelica, Apurimac and Cajamarca) (**Map 3**), coinciding with the INEI poverty map where the three regions mentioned always lead the poverty or vulnerability rankings (MIDIS, 2012). Likewise, of the 2,087 Amazonian indigenous peoples (RM 321-2014-MC), 1,749 (85%) experience high and very high VIAFFNN, with towns in the Loreto, Amazon and Ucayali regions being the most severely affected (**Map 4**).

Map 1. Vulnerability to food insecurity

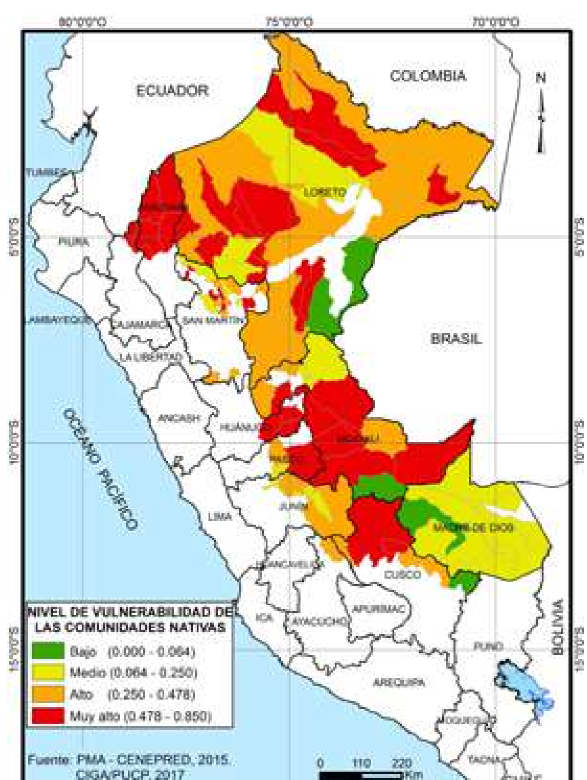
Map 2. Level of vulnerability to food insecurity



Map 3. Vulnerability to child malnutrition



Map 4. Vulnerability of native communities



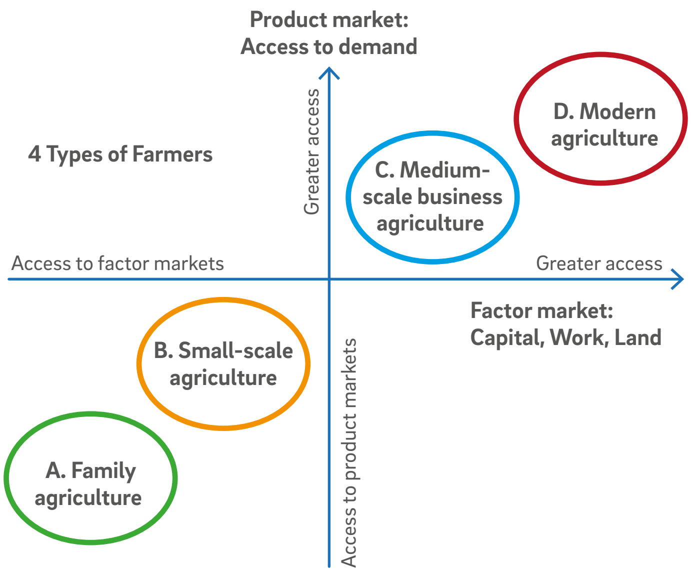
d. Types of agriculture

The Ministry of Agriculture and Irrigation (MINAGRI) defines four types of agriculture in Peru: family farming (formerly known as subsistence farming); small-scale agriculture; medium-sized corporate agriculture and modern agriculture, depending on the degree of access to demand, capital, labor and land (**Figure 2**). Most farmers are legal (99.4%) persons, with only 0.6% registered as legal entities. This figure corresponds to the characteristics of agricultural units and their fragmentation, in contrast with production by large companies. Agriculture in Peru is characterized by its low organizational capacity. Whereas in 1994 only 3% of farmers were associated, by 2012, this figure had increased to a mere 5% (MINAGRI/COMSAN, 2013). Other problems include both the lack of property deeds and the management of climate factors and pests that can affect crops and changes in the type of agriculture.

Since the 1990s, a greater impetus has been placed on the development of two types of agriculture. The first is agriculture with an export potential that still needs more state support to create technology and reach the investment levels required for the development of amaranth, cañihua, tarwi, tara, heart of palm, inchi sacha, yacon, camu camu and maca. The second is non-traditional export agriculture that uses high technology and has high investment levels because of its access to credit, enabling it to develop crops such as asparagus, paprika, citrus, artichoke, mango among others, occupying about 100 thousand ha at present, with an upward tendency (Rendón Schneir, 2010). This type of agriculture leverages the competitive advantages in fruit growing and horticulture, but is practiced by a smaller percentage of farmers. Consequently, the current agrarian structure provides an overall picture of an uneasy coexistence between two types of economies: a commercial one, mobilizing large amounts of capital, export-oriented and generating rural employment, and one based on family, small or medium production, managed by domestic units and creating agricultural self-employment (Ten, 2014: 26) units. However, the link among the number of cultivated hectares, access to irrigation and chronic malnutrition rates remains (**Table 3**).

In response to this situation, in recent years, the Peruvian government chose to promote the development of family farming in order to increase crop areas and improve the quality of life

Figure 2. Types of agriculture in Peru



Source: MINAGRI, 2013: 3.

Table 3. Link between chronic malnutrition rate, hectares of cultivated land and land with irrigation technology

Provinces with CM rates	N° of Provinces	CM%	Land for cultivation (ha)	Land under irrigation (ha)
<10%	16	7.1	5.8	5.0
10-<20%	48	15.2	6.6	2.8
20-<30%	63	25.5	3.6	1.4
≥30%	64	35.0	2.9	0.7

CM: Chronic malnutrition. Adapted from Pintado 2012, based on data from the IV Agricultural Census (2012) and MINSA malnutrition rates (2014).

Figura 3. Characteristics and types of family agriculture

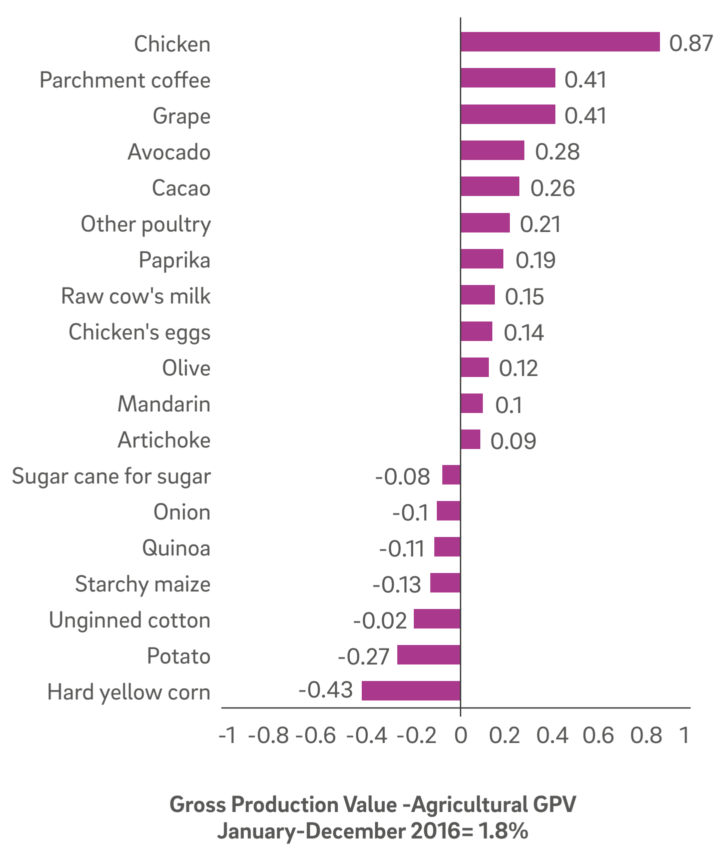
Source: Compiled by Nicole Bernex

of families who depend on this type of farming characterized by limited land resources, the important role of women, reciprocity and the community dimension. It has also acknowledged the fact that family farming is the backbone of rural communities by encouraging families' attachment to the land, the preservation of ancestral knowledge and traditions and the care of the plants and animals in each region. Although family farming accounts for 97% of all livestock farms, it has different degrees of development, meaning that it can be classified into three major types (**Figure 3**).

Agricultural production

As a result of various state programs and innovations, agricultural production overall has shown slow but steady growth. Thus, in the January-December 2016 period, agricultural production grew by 1.8% in comparison with the same period in 2015, due to the increased production of certain products that were particularly important (grape, parchment coffee, cacao, avocado, paprika, olive, tangerine, artichoke and chicken, eggs and raw cow's milk) (**Figure 4**) (MINAGRI 2016). The 1.4% decrease in the agricultural subsector (maize, potato, onion, quinoa, sugar cane) is overshadowed by the 4.3% increase in production in the livestock

Figure 4. Main products that contributed to the growth of the Agricultural Sector: January-December 2016 (percentage points)



Platforms in Moray, Cuzco. Photo: Wendy Gonzales.

subsector. Production of coastal crops usually predominates and, by the end of 2016, sugar cane production had reached 10,211,900 t; potatoes, 4,712,400 t; alfalfa, 6,635,100 t; rice, 3,137,000 t; banana, 2,072,100 t; yellow corn, 1,438,600 t; and cassava 1,230,000 t, to mention just some of the wide range of plant foods produced by Peru (MIN-AGRI, 2016).

Agriculture over 4,000 meters above sea level

Peru's proximity to the equator means that its populations can live above 4,000 meters above sea level (masl). These areas with difficult weather conditions have managed to grow plants such as bitter potato, oca, olluco, mashua, maca, kañiwa and quinoa, known as extremophile plants.

Some species are tolerant to low temperatures and are highly adapted to extreme environmental conditions, such as maca (Lepidium meyenii Walp.), characterized by its high protein and

Platforms in Machu Picchu, Cuzco. Photo: Wendy Gonzales.

Box 2. Maca: a Crop or a Miracle of the Peruvian Andes?

Lepidium meyenii (maca) is a cruciferous (Brassicaceae) vegetable cultivated exclusively at between 4,000 and 4,500 meters above sea level (masl) in the Peruvian Central Andes. Maca is traditionally used because of its nutritional and allegedly medicinal properties.

Maca occurs in different varieties depending on its external color. Maca is used mainly after its hypocotyls have naturally dried and is consumed mainly in juice, showing the mixture of different colors of the hypocotyls. Experimental scientific evidence has shown the effects of maca on nutrition, fertility, osteoporosis, memory and mood. Black maca has a better effect on sperm production, memory and fatigue whereas red maca reverses prostate hyperplasia in rats and mice and osteoporosis in female rats and has immunomodulatory effects.

Subjects in Carhuamayo (4,100 masl) who do not consume maca decrease their HRQL score as their age increases, while those consuming maca have a high HRQL score at 40 years of age, which they maintain up to the age of 75. It seems as if these people do not age (Figure 1) (Gonzales, 2010). A double trial controlled by placebo showed that extracts of red maca or black maca increase people's HRQL score (Figure 2) (Gonzales-Arimborgo et al., 2016).


Woman farmer in Pasco at a height of 4,200 m
Photo: Wendy Gonzales

Although maca was declared in danger of extinction in 1982 (National Research Council, 1989), its sustainability has increased significantly since the 1990s. The government of Peru has made an enormous effort to increase its cultivation and promote the product in foreign markets. Since 2001, the number of international publications by Peruvian scientists on maca in peer-reviewed journals has increased together with interest in the properties of maca in international markets. Since 2005, it has been considered a Peruvian flagship product. The main problem with maca, which has been documented since the time of the Spaniards' conquest of Peru, is related to intellectual property rights. Policies must be developed to increase support for research on medicinal plants and develop strategies to patent results obtained from research on Peruvian medicinal plants.

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energy content. In 1982, it was declared an endangered species and now, thanks to scientific research, it has become a food of worldwide interest, because of its numerous biological properties (**Box 2**) (Gonzales et al., 2014).

Other species cultivated at a high altitude include the bitter potato, where its transformation into chuño (a natural lyophilisate) has been one of the most important achievements of the Andean people, since it enables it to be preserved for years. Frost- and drought-tolerant crops include kañiwa (*Chenopodium pallidicaule* Aellen), characterized by its protein content with a high biological value (15.7-18.8%), carbohydrates (63.4%), vegetable oils (7.6%), unsaturated fats, iron, calcium and dietary fiber (Apaza, 2010). Quinoa (*Chenopodium quinoa*) is a strategic crop because of its nutritional quality, since it contains phenylalanine, threonine and tryptophan, with broad genetic variability, adaptability and low production costs (FAO/PROINPA, 2011).

Animal Agriculture

The sierra is suitable for pasture land despite its limitations (such as temperature, soil erosion and degradation and water shortage) coupled with overgrazing and mismanagement (burning). Like the coast, it has an enormous potential for livestock production, with the areas planted with alfalfa, chala maize, feed barley, fodder oats, elephant grass, signalgrass and ryegrass expanding annually. This increases livestock

Maca farmer in Junín (4100 m).

Maca hypocotyl. Photos: Wendy Gonzales.

Maca selection in Pasco (4200 m). Photo: Wendy Gonzales.

Maca shrub in Pasco. Photo: Wendy Gonzales.

Livestock in the mountains. Photo: Wendy Gonzales.

Table 4. Population of cattle, sheep, pigs and poultry (in thousands), by natural region

Region	Cattle	Sheep	Pigs	Poultry
Total	**5,156.0**	**9,523.2**	**2,224.3**	**121'394,062**
Coast	612.9	482.5	853.0	104'329,347
Mountains	3,774.3	8972.2	1,135.8	6'321,891
Rain forest	768.8	68.5	235.5	10'742,824

Source: IV Censo Nacional Agropecuario 2012.

production and although cattle, sheep and pigs predominate in the mountains and birds on the coast, the regions with the largest share of beef production are Cajamarca (15, 8%), Huánuco (10.1%), Puno (7.5%), Metro (6.9%), Lima provinces (5.0%), the Amazon (4.9%) and Junín (4, 6%). Raw cow's milk production is steadily increasing, particularly in the regions of Cajamarca (18.8%), Aréquipa (18.8), Lima Province (13.4%) and Metropolitan Lima (4.5%). There has also been a significant rise in the production of chicken eggs around major urban centers, the regions with the highest production being Ica (39.1%), La Libertad (17.5%), Lima Province (16.3%) and Metropolitan Lima (10.7%), showing a clear orientation toward an urban market, away from the poorest areas such as high-Andean and forest areas (**Table 4**).

e. The challenge of agricultural self-sufficiency

Since the beginning of the 20th century, the challenge of Peruvian agriculture has been to meet internal demand, hence the ongoing effort to modernize agricultural infrastructure and the quest for technological and research innovations. Since the forest has very little agricultural land, it is less able to ensure food sufficiency and its inhabitants have the highest malnutrition rates, which is also due to their high poverty rates (Anticona and San Sebastián, 2014) and parasitosis (Casapía et al., 2007), together with limited access to health services and education (Anticona and San Sebastián, 2014). This pattern can also be observed in several high Andean areas (Cabada et al., 2015). Factors such as economic growth and nutritional intervention policies, however, have reduced food shortages in the poorest areas of the country (Huicho et al., 2016).

Although agriculture contributes 80% of the food, import dependence is approximately 20% for poultry and livestock feed inputs (such as yellow corn and soybean) and bread and pasta production (Villar-Castillo, 2008). In 2016, according to MINAGRI, Peru imported 90% of the wheat required and virtually 100% of the soybean oil and 65% of the hard yellow maize consumed in the country. Over the past 10 years, imports of agricultural products have tripled. This implies growing food dependency, which must be reversed in the future to ensure food and nutritional security. Global food-demand trends, the development of the biofuel sector and land degradation pose major threats to national food security.

f. More food exports/imports and markets

According to MINAGRI, Peru is among the top ten countries providing food to the world, with approximately 2.3 million farmers being affected by the low productivity of traditional agriculture. Many Peruvian foods have attracted worldwide interest. A case in point is the potato, which is native to Peru (Spooner et al., 2005). Due to the different climates in which it develops, it is possible to find cold-resistant genotypes (Condori et al., 2014). Main export products include asparagus, coffee, mango, olives, fresh grapes, fresh avocado, artichokes, dried peppers, beans, mandarin, ginger, beans, onion, fresh peas, quinoa, maca and blueberries, which have enormous nutritional value and numerous health benefits (**Table 5**).

The world's interest in Peruvian food is such that every five years the value of agricultural exports from Peru doubles, and by 2021, it is expected to exceed $10 billion USD (MINAGRI/COMSAN, 2013). Agricultural exports totaled

$4.849 billion USD between January and November 2016. The main export destinations are the US and the Netherlands, Spain, Germany and the UK. **Figure 5** shows that maca is Peru's most widely exported nutraceutical product.

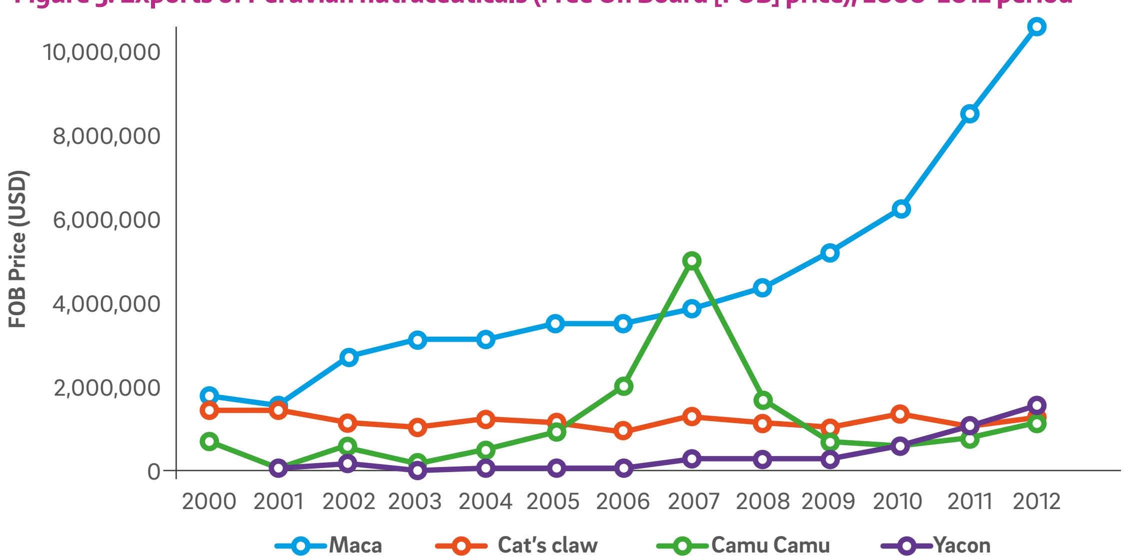
g. Potential sources of instability in food and nutrition security

Numerous factors can affect the stability of the food security actions that a country undertakes. These include the vulnerability of food production to climate change and changes in the international prices of food imports such as oil, soybeans, yellow corn, wheat and derivatives, which are part of the basic food basket (MINAGRI/COMSAN, 2013). Peru is one of the most vulnerable countries to the impacts of climate change, with risks to the sustainability of national development (MINAM, 2014: 33). Research has shown how climate change affected several societies during the

Table 5. Beneficial health effects of certain Andean-Amazonian crops

Crop	Beneficial effects
Quinoa *Chenopodium quinoa*	Metabolic, cardiovascular, and gastrointestinal health (Abderrahim et al., 2015, Graf et al., 2015).
Camu camu *Myrciaria dubia*	Antioxidant, anti-inflammatory and antimicrobial properties. High vitamin C content (Arellano-Acuña et al., 2016).
Yacon *Smallanthus sonchifolius*	Hypoglycemic and probiotic properties due to its high fructooligosaccharide content (Caetano et al., 2016).
Sacha inchi *Plukenetia volubilis*	Its oil has a high linolenic acid (omega 3) content, whose endogenous transformation permits the transformation into DHA, which has enormous biological importance (Gonzales et al., 2014a).
Aguaymanto *Physalis peruviana*	High provitamin A and ascorbic acid content, some B complex vitamins (thiamine, niacin and vitamin B12). It is also renowned for its high raw protein, phosphorus and iron content (Fischer et al., 2013).
Purple corn *Zea mays*	Antioxidant properties, beneficial for cardiovascular diseases (hypertension), cholesterol reduction, and combating diabetes (Guillén-Sánchez et al., 2014).

Figure 5. Exports of Peruvian nutraceuticals (Free On Board [FOB] price), 2000-2012 period



pre-Hispanic era. An important example was its impact on Caral, the oldest civilization of America, which developed along the north-central coast of Peru, in Supe Valley, between 2,800 and 1,900 BCE (Sandweiss et al., 2009). The inhabitants of Vichama, in Huaura Valley, adjoining Supe, left reliefs of 34 modeled figures for posterity, showing the ravages caused by famine on people's bodies (R Shady, personal communication).

In recent decades, as a result of climate change, the El Niño and La Niña phenomena has been both more frequent and severe, causing heavy rain and flooding on the north coast (Hernández-Vásquez et al., 2016A) and droughts in the south. By 2025, climate change could contribute to a 70% increase in the number of people experiencing enormous difficulty in accessing clean water sources; in 2050, 50 million people could be at risk of not having a sufficient supply of water for human consumption, hydro-energy or agriculture as a result of the deglaciation of the Andes (MINAGRI, 2013). Accordingly in 2012, with the support of FAO, MINAGRI drew up the National Plan for Risk Management and Adaptation to Climate Change for the Agricultural Sector for the 2012-2021 period (PLANGRACC-A).

h. Main challenges of agriculture

In response to increasingly frequent and severe episodes of rainfall, floods, frosts and droughts, MINAGRI, in conjunction with other sectors, launched the PLANGRACC-A, which prioritizes five strategic axes, directing and coordinating national and regional projects and/or programs concerning Disaster Risk Management (DRM) and Adaptation to Climate Change (ACC) for the agricultural sector (MINAGRI, 2012):

1. Research and information for DRM and ACC.
2. Emergency preparedness for and response to weather events.
3. Prevention and risk reduction considering climatic events.
4. Development planning in DRM and ACC.
5. Improving local capacities in DRM and ACC.

Due to the presence and magnitude of the El Niño and La Niña phenomena, there is a significant risk of agricultural losses and rising food insecurity during periods of rain or drought. Since 2015, the revitalization of the National Emergency Operations Center (COEN) has made it possible to more efficiently monitor disaster risks and act more quickly nationwide. At the same time, with the support of several institutions (European Union, DIPECHO Project, Welt Hunger Hilfe, Diakonie, Soluciones Prácticas and PREDES, among others), many Early Warning Systems (EWS) have been developed at the local and regional level.

2. Institutional context

a. National Agricultural Research System

The Ministry of Agriculture and Irrigation (MINAGRI), the agency responsible for setting the national agricultural policy, is in charge of the Agricultural Research System. It comprises entities such as the National Water Authority (ANA), responsible for national water resource management, the Agricultural Health Service (SENASA), an authority on agricultural health, seeds and organic production and the National Institute for Agrarian Innovation (INIA), in charge of incorporating technological change as a growth strategy for farming in a permanent, sustainable manner. Together with these institutions that undertake regional studies and research, the Research Institute of the Peruvian Amazon (IIAP), assigned to the Ministry of Environment (MINAM) in 2010, has a research system revolving around six major programs that contributes to sustainable management and biodiversity conservation, as well as knowledge of the Amazonian economy and social diversity.

Peru has many strengths through its programs such as AGROIDEAS, the Compensation Program for Competitiveness, a MINAGRI unit created in 2009, which provides resources to support business management, partnerships and the adoption of technology for small and medium producers' sustainable businesses to consolidate their market share.

Another strength is the incentive to promote Peru's main organic crops, such as coffee, cocoa, bananas, quinoa, maca and wild chestnuts.

There are over 100 certified products although they are only commercialized on a small scale.

Sierra Exportadora, established in 2006, contributes to economic growth in the Andean region through social and productive inclusion. It promotes exports, improving quality, volume and processes with a greater added value, in an open economy with a market perspective (*Sierra Exportadora*, 2013). As a result of Law 30495, it was transformed into the "*Mountain and Forest Export*" Program. By 2016, the program had trained 27,732 small farmers in the country's rural areas to enable them to obtain the quality products demanded by the global market.

The past 15 years have seen significant attempts to update science, technology and agricultural innovation institutions in order to provide them with a technological innovation approach. The creation of the INCAGRO program, the chain approach in agricultural promotion, the renewal of INIA, the Centers for Technological Innovation (CITE) and the Research Institute of Peruvian Amazonia (IIAP) constitute significant advances in the public sector. Among the main institutes in the private sector are the Peruvian Cotton Institute (IPA), the Peruvian Institute of Pulses, the Peruvian Institute of Natural Plants, the Peruvian Institute of Asparagus and Vegetables (IPEH), intergovernmental organizations such as the World Bank and the Food and Agriculture Organization (FAO), as well as agencies such as the Swiss Cooperation and German Technical Cooperation (GIZ) (Rendón Schneir, 2010; Libélula, 2011).

In Peru, the International Potato Center (CIP) has a genetic bank of varieties of potato, sweet potato and other Andean tubers. An important example of international collaboration is the work to determine the nearly 40,000 genes in the genome of the potato, the world's fourth most important food crop after soybeans, rice and corn. Scientists from 14 countries including Peru are currently working together to achieve this. They have set up a unique cooperation mechanism among countries in Latin America and the Caribbean, and Spain, which promotes family farming innovation, competitiveness and food security.

Peru has a number of geoservers in the Geographic Information System located in various ministries and institutes such as MINAGRI, MINAM, ANA, and MINSA that are available to the public at www.google.es/maps

One of the policy guidelines of MINAGRI's General Directorate of Agricultural Information (DGIA) is to strengthen and decentralize the National Agricultural Information System (SINFA) to support economic agents in making decisions on production and trade issues. SINFA contains agricultural and agro-industrial statistics on supplies and prices, agroclimatic issues, foreign trade and inputs.

b. Universities and Research Institutes

In Peru, there are several institutions dedicated to agricultural research, and socionutritional and health impact. These include, among others, the La Molina Agrarian University (Lima), the Daniel Alcides Carrión National University (Pasco), the National University of the Altiplano (Puno), the National University of the Amazon (Iquitos), the Pontifical Catholic University of Peru (Lima), the Ricardo Palma University (Lima) and the Cayetano Heredia Peruvian University (Lima), each dedicated to a specific task while maintaining interdisciplinarity.

In addition to the aforementioned CIP, INIA, IIAP in the forest and the Peruvian Sea Institute (IMARPE), a Ministry of Production agency oriented toward scientific research, the study and knowledge of the Peruvian sea and its resources, advises the state on decision-making regarding the rational use of fishery resources and the conservation of the marine environment.

Agrarian policy significantly changed during the first half of 2000, introducing the value chain approach and emphasizing technological innovation as a means of improving competitiveness (Rendón Schneir, 2010). However, although there are capacities with a critical mass at the country's universities and research institutes, a vision of multidisciplinary work among the science of agricultural crops, the science of postharvest, the functional activity of the product to be consumed by humans and marketing has yet to be achieved. Nevertheless, the La Molina Agrarian University has several research institutes: the Institute for Agroindustrial Development (INDDA); the Institute for Biotechnology (IBT); the Institute for Sustainable Small-Scale Production (IPPS); the Regional Development Institute of the Costa (IRD) and the Regional Institute for Forest Development (IRD).

The National University of San Marcos contains the Antonio Raimondi Institute of Biological Sciences Research (ICBAR), whose function is to produce scientific knowledge on biodiversity, biotechnology, ecology, health, biological resource management and the environment. The Natural History Museum has branches in IVITA-Pucallpa and IVITA-Iquitos. The Ricardo Palma University houses the Institute of Science and Technology (ICT), which studies biodiversity using classical taxonomy and molecular genetics. The Natural History Museum is dedicated to the knowledge and conservation of biological diversity as a key aspect that must be developed in our country. At the Pontifical Catholic University of Peru, the Institute of Natural Sciences, Planning and Renewable Energy (INTE) is an institute for research, academic training and the socioenvironmental and ecological promotion of biodiversity, territory and renewable energies. The Center for Research in Applied Geography (CIGA-PUCP) has several research groups on water, energy and food security, sustainable cities and rural development. Cayetano Heredia University houses the Institute of Tropical Medicine, the Institute of Height and the Laboratories of Marine Sciences where analyses of interstitial water are conducted on marine sediments, phytoplankton, sediments (organic matter) in coastal marine areas, siliceous remains in sediment, benthic foraminifera and oceanographic data.

Although Peru is one of the most economically developed countries in Latin America (OECD, 2016), the challenge for the future is to add value to its products. This requires skilled labor, which in turn is reflected in the increase in agricultural exports by large companies, particularly on the coast.

The problem is exacerbated in rural zones and subsistence farming, where farmers have less training. The creation of agricultural institutes near farming areas, particularly in the mountains and forests of Peru, will contribute to the training of skilled labor.

c. Relative contributions of the public and private sectors

Although state entities such as CONCYTEC, FONDECYT and INNOVATE PERU promote investment in Research and Technological Development (&D), public and private participation is still low.

In 2016, Peru invested 5 billion soles ($1.5 billion USD) in research and development, representing 0.2% of Peru's GDP. Only 24.6% of this amount was assigned to research in agricultural sciences. These aspects are indicative of the fact that a great deal of research remains to be done on the production and improvement of the nutritional content of native agricultural and aquacultural products from the coast, highlands and forest. Despite all this investment, it is still insufficient because there is much to study, many puzzles to solve and many species that have yet to be registered in Peru. National inventories of flora and fauna from the coast, highlands and forest must be drawn up to have a basis of taxonomic identification and undertake molecular studies of genomics, proteomics and metabomics. Moreover, scientific production on biodiversity is carried out at several national and private universities, such as UNMSM, UALM, UPCH, PUCP, URP and UFV.

d. Outlook for the future

Since 2013, there has been a significant increase in the budget for R&D from the National Council for Science, Technology and Technological Innovation (CONCYTEC).

In 2016, the System of Support for Research was incorporated, whereby companies can deduct up to 175% in income tax for their contribution to Research, Technological Development and Innovation (R-D-I). CONCYTEC designs the National Programs for Environmental Science and Technology and the Valuation of Biodiversity, which prioritize the research areas to be strengthened, as well as those in the area of "Climate variability and climate change," which is aligned with the Agenda for Environmental Research (MINAM, 2016). It is also important to protect and preserve human diversity with our ethnic groups, whose genome has scarcely been studied, and to promote respect for indigenous peoples. It is hoped that these efforts will improve food security in the coming years. More investment is required for the protection, conservation and management of biodiversity to ensure the conservation of genetic diversity, ecosystems and species.

It is important to place greater emphasis on biodiversity studies at centers of excellence such as universities and institutes. These institutions have produced key publications and scientific articles in scientific journals with enormous amounts of information on biodiversity, the basis of food security.

3. Resources and Characteristics of Ecosystems

a. Water resources and challenges for the next 50 years

Peru's average annual volume of water of 1,768,172 Million Cubic Meters (MCM) makes it one of the world's 20 richest countries in water. Its average annual runoff, representing nearly 5% of global runoff, makes it the country with the greatest freshwater availability per capita in Latin America. In other words, every Peruvian has 64,000 cubic meters of water per year. However, the natural distribution of this vital resource is asymmetric: 97.7% on the Atlantic slope (Amazon basin); 1.8% on the Pacific slope (53 basins), and 0.5% in Titicaca. These constraints are caused by the fact that the population is distributed in an inversely asymmetrical way to resources: 70% of the population is concentrated where 1.8% of the available surface water is located and 26% where 97.7% of water is found (Bernex, 2010; ANA, 2012).

There is also an imbalance in the distribution of water between productive sectors and the user population: the agricultural sector accounts for 86.8% of water use nationwide, followed by the population, which utilizes 11.2%, mining, which absorbs 1.4% and industry, which employs 0.6% (ANA, 2013).

b. Soil resources and challenges for the next 50 years

Soil suitable for agriculture is the country's scarcest resource (7% of the country), as well as that most threatened by deterioration processes, especially salinization on the coast, gradual erosion in the mountains and loss of fertility in Amazonia. A total of 8 million ha have been classified as severely eroded and 31 million as moderately eroded (MINAGRI, 2017). Despite these severe constraints, efforts have been made to recover degraded soils on the coast and in the highlands and forest to ensure food security. Even if the current scenario indicates a reduction in lands planted for human consumption and an increase in those for the production of manufactured goods (MINAGRI/CONSAM, 2013), it is essential to achieve integrated soil management in order to obtain agriculture resistant to climate change using a food and nutritional security approach (IICA, 2016; CEPES, 2011).

c. Energy challenges

The growing economic, social and environmental pressure on water, energy and food systems increases and highlights the various interdependencies and conflicts among these sectors, reminding one that the modernization of irrigation can save water while at the same time increasing energy consumption and threatening the sustainability of aquifers. Biofuel production can reduce oil dependence yet affects food production, making it more expensive. Likewise, lowered energy prices can increase agricultural production as well as leading to the overexploitation of aquifers (Jouralev, 2016). While it is true that in Peru, electricity production recorded sustained growth at an annual rate of 6.5% over the past decade (MINAM, 2016), at times of water shortage, it competes with the human population's use (INEI, 2015), even though energy production by thermal power plants increased by 12% and contributed 50% of all electricity production. Moreover, nationwide generating capacity increased by an average annual rate of 7% from 6,200 MW in 2005 to 12.251 MW in 2015. Regarding unconventional Renewable Energy Resources, 96 MW of solar power, 240 MW of wind power and 80 MW of thermal energy have been installed (MINAM, 2016). Nevertheless, there is an enormous disparity between backward rural zones and urban areas. Peru has large natural gas reserves constituting a major source of thermal energy. It is estimated that in 2013, they totaled 875,733 million barrels (INEI, 2015), with a proven reserve of 16 Trillion Cubic Feet (TCF), guaranteeing a 15-year supply for national consumption and export.

d. Conflicts and challenges of biodiversity

Together with Chile, Peru is the only country in the region with extensive, extremely arid -hyperarid- areas (81,000 square kilometers) receiving only 2% of the country's rainfall (MINAM, 2016). According to lNEl (2013), the five main reasons why agricultural land is not worked were (a) lack of water (48.9%), (b) lack of credit (24.1%), (c) lack of labor (11.3%), (d) erosion, salinity and poor drainage (5%), and (e) lack of seed (4.2%) (lNEl, 2012), which affect the coast, mountains and forest.

Although Peru has an extensive coastline and abundant maritime resources, industrial and artisanal overfishing is a constant. This particularly affects anchovies, the most economically important marine resource. In 2014, the Supreme Decree No. 005-2012-PRODUCE reorganized anchovy fishing and established new fishing areas, which led to a 41.9% reduction in the catch quota in comparison with 2013 (INEI, 2015). Another species controlled by the ban is the river shrimp. The Peruvian Sea Institute has undertaken wide-ranging studies to protect the populations of seagrass meadows that are mega-diverse ecosystems.

The national economy relies heavily on biodiversity, both in relation to agricultural production (65.0%), fishing (99.0%), cattle (95.0%) and forestry (99.0%) (INEI, 2015). Although Peru is one of the world centers of genetic reserves of wild species and biodiversity, a diversity that is unlikely to disappear in the short term, a depletion of genetic diversity due to human actions has been observed. It is therefore essential to draw up inventories and preserve the wild relatives of cultivated plant species, which represent reservoirs of genetic resources that promote food security (Tapia, 1993).

Peru is a land of forests. A total of 57.3% of its territory is covered by this resource and by 2014 there were only 16.8 million ha of permanent production forests, 4.3 million ha of which are under management plans (MINAGRI, 2015). However, between 2001 and 2014 1,653,255 ha of Amazon forest were lost in Peru, with a record average of 118,089 ha/year (Forest Program, 2015). Eighty-five percent of deforestation occurs because of the change in land use to family farming and small-scale farming, and although reforestation programs have been generated, the process is slow. By 2014, only 8,990 ha (INEI, 2015) had been replanted.

e. Potential impacts of climate change

Not only do the effects of climate change impact biophysical resources (water, soil, glaciers, vegetation) (CONSAM, 2013), they also entail concrete losses for the agricultural sector (decreased potato production on the coast and mountains, loss of agricultural land and soil salinization, reservoir silting and the destruction of productive infrastructure). High temperatures also lead to low meat and milk production, and the migration of marine and coastal fish (MINAM, 2016).

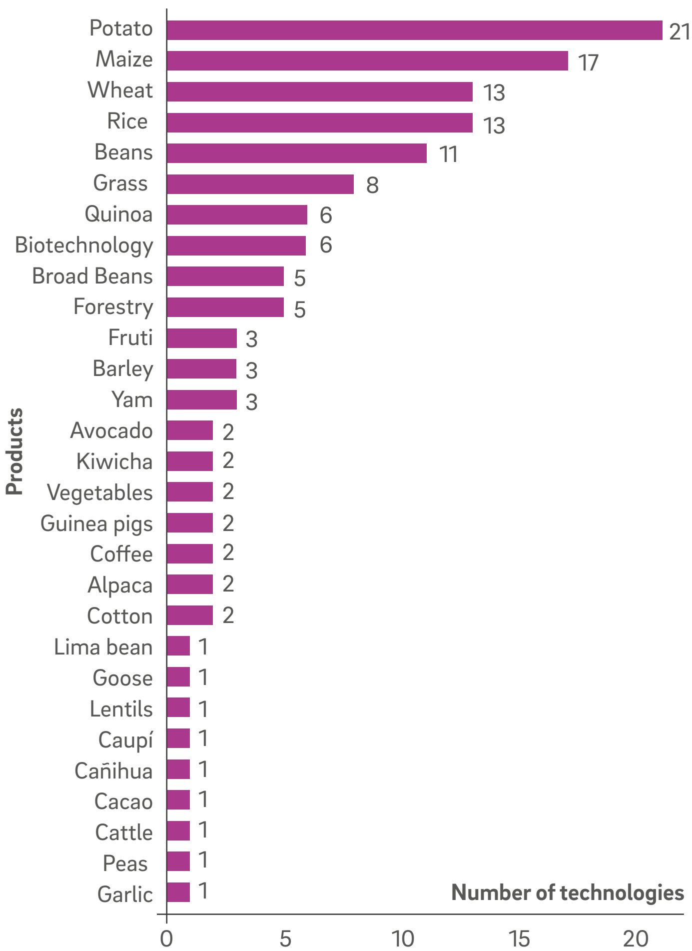
f. Building resilience to extreme events

In 2015, drawing up a map of Vulnerability to Food Insecurity, due to the recurrence of natural phenomena, identified areas where the population finds it harder to obtain food under these circumstances. Thus, of a total of 36,606 population centers with 50 or more persons each, approximately 25,700 (70%), in other words, a population of 4.35 million, are in predominantly rural areas with high or very high vulnerability to food insecurity (PMA and CENEPRED, 2015). The Central Government thereby hopes to improve intervention strategies through programs and projects that will reduce vulnerability, promote food security and nutrition and, at the same time teach citizens to deal with the various contingencies caused by these phenomena by creating interventions that boost the resilience of communities and ecosystems to current climate variability. Over the past six years, over 330 mitigation/adaptation-to-climate-change programs and project actions have been implemented (MINAM, 2016). However, rains and flooding in the north and center of the country in early 2017 showed that these systems remain fragile.

g. Outlook for the future

Peru's main challenge is to achieve sustainable development for people, the planet and prosperity (Agenda 2030) and to promote the adoption of a resilience-to-climate-change approach (MINAM, 2016). The investment gap to achieve these goals is enormous. The current scenario justifies the urgent need to design programs to identify, describe and characterize biodiversity as soon as possible so that appropriate conservation and mitigation measures can be implemented. It is essential to emphasize the importance of using modern techniques in the study model of integrative taxonomy, including the study of the evolutionary processes associated with areas with greater diversity and endemism and the effects of climate change on Peruvian biodiversity (Von May et al., 2012).

Figure 6. INIA. Technologies released by product during the 1991-2011 period



Source: Compiled by Nicole Bernex.

4. Technology and Innovation

According to the assessment of the Technology Transfer Index (ranging from +2 to -2), countries with the greatest technology transfer are those in East Asia (+0.8), followed by industrialized countries (+0.4). Conversely, Latin American countries, including Peru (-0.3), have a technology transfer deficit (CONSAM, 2013) that must be reversed.

a. Role of biotechnology

Worldwide, nearly two billion people lack food security. By 2050, the demand for food will have increased by 70% (FAO, 2009). Biotechnology has been used since ancient times. A clear example is the preparation of Chicha de Jora (Peruvian Corn Beer), the recipe for which was handed down from generation to generation without people's realizing it was a biotechnological process. The year 1960 saw the Green Revolution, characterized by an increase in the productivity of varieties of staple crops and the introduction of methods for analyzing genetic sequences and the identification of genetic markers. The use of recombinant DNA makes it possible to identify, select and modify DNA sequences to accomplish specific genetic characteristics (WHO, 2005).

In Peru, academic institutions, together with the International Center for Tropical Agriculture (CIAT) and international organizations, developed a type of weevil-resistant bean (*Zabrotes subfasciatus Boheman* and *Acanthoscelides obtectus Say*), and tubers such as sweet potato resistant to the nematode *Meloidogyne incognita*, with higher nutritional content in two native varieties. Progress has been made in the production of maize with twice the concentration of lysine and tryptophan, together with improvements in the production and nutritional value of rice under different water availability conditions (UNALM/AGROBANCO, 2014: 8-11).

INIA develops and transfers quinoa seeds tolerant to adverse climatic factors, with higher performance and improved grain quality, which are suitable for agroindustrial processing and resistant to diseases and pests. It has also developed the production of genetic garlic, potato and virus-free vine seeds, improving their potential yield (MINAGRI/INIA, 2009; 2012a; 2014b). It works on the agricultural innovation of plant genetic resources, Andean crops, fruit, vegetables, maize, avocado, roots and tubers (MINAGRI/INIA. 2012a).

Among its technology transfer activities, INIA has released 137 technologies, 106 of which correspond to improved cultivars, 23 to management technologies, six to biotechnology protocols and two to genetic compounds (**Figure 6**) (MINAGRI/INIA, 2012a).

INIA undertakes animal husbandry activities such as embryo transfer, *in vitro* fertilization, insemination, animal health, and the genetic improvement of tropical cattle, High Andean cattle, camelids and guinea pigs (MINAGRI/INIA, 2011a; 2011b; 2012b). Despite this, building new biotechnological capacities remains an urgent pending issue for the country.

SENASA is the authority responsible for the control and management of pests and diseases in the most economically important crops and livestock. It ensures the safety of food for human consumption and domestic or foreign production (SENASA, 2016).

Intervention strategies, begun in 2006, have enabled Peru to have fruit fly-free zones and be 100% free of Foot and Mouth Disease (FMD) without vaccination, producing savings in the cultivation and breeding processes. There are over 1,000 identified pests and diseases that should not enter Peru. Of this total, 947 are plant pests such as the Guatemalan potato moth, which, if allowed to enter, would affect more than 400,000 ha of crops, damaging up to 80% of production (SENASA, 2014; 2017).

The application of biological control has reduced losses in agricultural production as a result of pests in crops such as sugar cane, citrus fruit, bananas, coffee and various fruits and vegetables by using biological control (SENASA, 2014).

IMARPE analyzes the composition and abundance of zooplankton associated with water bodies, in order to extend the patterns and variability of their distribution and abundance, thereby providing food for other trophic levels. It monitors the presence of biological zooplankton indicators associated with the water mass.

b. Outlook for new agricultural products

In Peru, INIA is the main agency dedicated to the development of new plant varieties resistant to adverse factors and with higher yield. Another important institution in the research of new plant varieties is the La Molina Agrarian University, which has developed nationally important varieties. As mentioned earlier, it has research laboratories in different institutions.

The International Potato Center collaborates with INIA, the La Molina National Agrarian University and other universities to undertake research to obtain new varieties of agricultural interest.

c. Opportunities and obstacles to the management of new technologies (e.g., irrigation and water or fertilizer management)

Peru generally uses imported fertilizers. In 1993, it imported 303,807 t and in 2013, it imported 905,198 t, with urea being the most commonly used fertilizer in 2013 (365,085 t). The organic fertilizers it uses include worm humus, chicken manure and island guano. Peru produced 19,700 tons of island guano in 2012 and 23,604 t in 2013. In 2012, of the total of 2,213,500 agricultural units, 833,600 used chemical insecticides, 118,800 non chemical or biological insecticides, 521,200 herbicides and 600,000 fungicides (INEI, 2015).

There is a water transfer system that provides water for certain areas for the benefit of agriculture, although it is a source of conflict among populations. Peru has 14 water dams on the north coast, most of which are used for agriculture. Where there is no storage infrastructure, groundwater is exploited, as in the valleys of Ica-Villacurí, Caplina, Chilca, Motupe and Asia (ANA, 2012).

d. Development of aquaculture/ marine resources

Fishing activity can involve both extraction and transformation. There are two types of fishing: artisanal, for direct consumption, and industrial, which transforms products into preserves and fishmeal. Both pose a threat to the sector's sustainability due to overfishing.

In 2013, 5,949,000 metric tons of hydrobiological resources were caught, 23.9% more than in 2012. Anchovy accounted for 79.9%, while the remaining species included horse mackerel, mahi mahi, mackerel and bonito (INEI, 2015).

Trout, from the family of salmonids, is raised at fish farms in the Peruvian highlands and is an important protein source for High Andean populations. It is found in Ayacucho, Huanuco, Pasco, Lima, Aréquipa and the Amazon. In Lake Titicaca, the introduction of silver smelt from Argentina and rainbow trout has had a negative impact on native species. In the forest, there are fish farms that breed paiche (*Arapaima gigas* Cuvier), an emblematic fish from the Amazon measuring an average of 2.5 m and weighing 250 kg.

Mechanisms have been set in place to preserve species for the mass consumer market such as anchovy, hake and shrimp, among others.

5. Increased efficiency of food systems

a. Outlook for increased technology-based agricultural production

In 2010 and 2011, less than 1% of the country's farmers received information on the existence and importance of the use of new agricultural technologies. Moreover, the percentage of farmers nationwide who received technical assistance on the proper use of agricultural input was 3.8% between 2008 and 2010 and 2.6% between 2009 and 2011 (MINAGRI/COMSAN, 2013). This obviously delays the optimization of agricultural processes designed to increase productivity.

Limited access to financing by small and medium farmers and artisanal fishermen constitutes an obstacle to increasing the efficiency of food production (MINAGRI/COMSAN, 2013). The only type of agriculture that has increased its production through the use of modern technologies is run by business groups located on the coast.

b. Infrastructure needs (e.g., transport systems)

The national road network comprises a total of 156,792 km, an increase of over 78,000 km since 2000. Railways, however, are less extensive and have been reduced over the years. In the Amazon region, most of the population uses river transport for its various activities (MINAM, 2016).

According to Webb (2012), the road network over the past 50 years has increased by 372%. The highway construction boom began in 2000. However, it is not yet an efficient, integrated system that meets all the requirements. In 2012, the five provinces with greatest road length are Cusco, Puno, Arequipa, Ancash and Cajamarca. Conversely, the province with least road length is Loreto, the largest province in Peru (MINAGRI/CONSAM, 2013).

c. How to ensure food use with minimal losses

By 2015, it is estimated that 2.3 million people in Peru were food insecure. According to the FAO, food wastage amounts to seven million t per year. Peru has committed to halving food waste per capita by 2030, particularly at the retail and consumer level. It is estimated that Peru annually loses more than 500 million soles (US $151.5 million) in food at supermarkets.

To minimize food loss, the civil society created the Food Bank of Peru (BAP) in 2014. The BAP receives foods from private companies that cannot be marketed for various reasons yet are still useful. They are delivered to places such as schools, shelters and soup kitchens. On August 2, 2016, the law promoting food donation was passed.

d. Conflicts between food production and energy and fiber production

One reason why the area planted with crops for direct human consumption has not increased in line with demand has been the expansion of other crops (asparagus, sugar cane, peppers, paprika, grapes, coffee and cocoa) for agroindustry and agro-exports. This causes problems in the continued growth of crops for direct feeding (MINAGRI/CONSAM, 2013). There is also an obvious risk of affecting food security in the event that farmland is used for agrofuel production rather than crops for human consumption. To prevent this situation, FAO promoted the Bioenergy and Food Security Project (BEFS), which analyzed the way the development of bioenergy can become a tool for increasing productivity in the agricultural sector without compromising food security (García, 2010).

6. Health Considerations

Food has implications for health, either directly through its components or indirectly, since it carries chemicals and/or microorganisms that may damage health.

a. Foodborne diseases

Food can indirectly affect people's health. The use of pesticides to preserve agricultural crops and irrigation with sewage or contaminated water can influence the health of those who consume these foods.

Pesticides

Many plant foods are treated with pesticides in order to maintain crops and increase their yield. These pesticides are impregnated in food and may be consumed by people or livestock, which are then used for human consumption, or may contaminate water and expose the human population to risk. Organophosphorus pesticide applicators in Majes (Aréquipa) were found to have lower-quality seminal fluid, which constitutes an occupational health problem (Yucra et al., 2006). Acaricide, fungicide and herbicide exports increased between 2007 and 2013 (INEI, 2015), significantly increasing health risks, since protective measures have not improved.

Heavy metals

Since Peru is a mining country, part of the population is exposed to contamination by heavy metals. Water is the main vehicle, in that it is used both for crop irrigation and postharvest processing, washing vegetables prior to their sale at consumer markets or consumption by livestock, which are then consumed by humans.

There are areas such as southern Peru where metals such as arsenic (As) are naturally present in river water or underground aquifers (geogenic origin) (George et al., 2014). Although arsenic pollution is associated with health problems, there is no research to suggest that the speciation of arsenic in southern Peru is associated with diseases prevalent in the area (Schlebusch et al., 2015).

Parasites

Parasitosis is still a problem in Peru, particularly in the mountains, forest and marginal areas of the urban coast. The presence of parasites has been reported in the consumption of contaminated food, such as fasciolasis in alfalfa juice (Mark et al., 2006). Liver fluke infections are common in High Andean regions (Cajamarca and Cusco) (Rinaldi et al., 2012; Cabada et al., 2014), in both humans and cattle (Cabada et al., 2014). In general, children with moderate to severe infections with helminths suffer from chronic malnutrition (Gyorkos et al., 2011), hence the importance of deworming programs for children in highly endemic areas.

Pork tapeworm infections require health interventions in both humans and livestock. Vaccinating and treating sick livestock in endemic areas has proven to prevent the transmission of infection (García et al., 2016).

Mycotoxins

Mycotoxins are produced by fungi and can infest food. The presence of mycotoxins such as ochratoxins has been associated with gallbladder cancer. These mycotoxins are present in grains and in the Andes region, they have been found in red peppers (Ikoma et al., 2015).

b. Overconsumption

In Peru, as in other countries, the improvement of the economy and the implementation of programs to reduce child malnutrition have increased childhood overweight and obesity rates. This is exacerbated by the extensive advertising of high calorie foods such as sugary soft drinks and fast food, decreased physical activity, fewer hours of sleep and inactivity associated with the number of hours in front of the television or computer (Poskitt, 2009). Similarly, the increase in household expenditure, based on recent economic growth, has driven up the consumption of foods of animal origin (Humphries et al., 2014).

Childhood overweight and obesity are predominant on the Peruvian coast and in urban areas. A spatial analysis found a higher prevalence of overweight in 199 districts (126 urban and 73 rural) and of obesity in 184 districts (136 urban and 48 rural) (Hernández-Vásquez et al., 2016). The risk of obesity is also high in adult populations in urban areas and higher in migrants from rural to urban zones (Antiporta et al., 2016). Peru has a 61.86 prevalence rate of overweight/malnutrition (Méndez et al., 2005). Feeding programs have helped reduce malnutrition in Peru since 2005 (Pérez-Lu et. et al., 2016). However, these programs should specifically target people in need, since adult women who participate in these programs are at an increased risk of overweight and obesity if they live in households without poverty indicators (Chaparro et al., 2014; Carrillo-Larco et al., 2016).

c. Expected changes in consumption patterns (and implications for food imports)

According to the FAO, approximately 7,000 of the world's plants have been domesticated for food purposes, but food security is based on 30 crops that provide 95% of the calories in a person's diet. Wheat, rice and maize provide more than 50% of the calories consumed by Peruvians (Salaverry, 2012).

Pattern of food consumption on the Peruvian coast

In ancient Peru, the coast was interspersed with valleys with extensive hills, where large herds of camelids were bred and wildlife proliferated. This area was devastated by the introduction of sheep and goats, coupled with overgrazing, which created arid soils and the growth of low, sparse vegetation (Antúnez de Mayolo, 1981). The ancient inhabitants' diet was more than balanced by the consumption of marine species such as fish, shellfish and sea lions.

This eating pattern subsequently evolved, with increasing dependence on imported food such as wheat, sugar, vegetable oil and dairy products, and the progressive decline of products of vegetal and indigenous origin (FAO, 2000). At the same time, food resulting from social policies was incorporated (World Bank, 2007). Franchises were opened, leading to an increase in fast food consumption from 12% in 2001 to 35% in 2015 (Arbaiza, 2014) and a greater tendency to eat outside the home (Arbaiza, 2014; PAHO, 2015).

Five traditional products have been identified in the family budget: milk; bread; chicken; egg and rice (IEP, 2010), coupled with non-traditional food (olives, mango, sugar cane, paprika, avocado, hard yellow maize, coffee and asparagus) (MINAGRI, 2014; 2015). Currently, consumption is mostly based on carbohydrate, fat and lower fiber intake with a slightly lower average intake of vegetables (INEI, 2014; 2015a).

Consumption pattern in the Peruvian highlands

The Andean people enjoyed a wide variety of foods domesticated thousands of years ago, such as quinoa (*Chenopodium quinoa*), one of the first plants with crops in an extremely effective terrace system, which currently does not equal the area under cultivation in ancient Peru (Salaverry, 2012). The food pattern was vegetarian, based on maize, quinoa, kañiwa, beans, potatoes and mashua, occasionally supplemented by fish from lakes and rivers, hunting birds and camelids such as llamas and alpaca. They processed camelids' meat as jerky (dried, salted meat) (Cieza de León, 1995), eating up to four meals a day.

The Peruvian Andes currently practices eating habits associated with the production and consumption of local animals, such as alpaca meat and beef, dried meat and animal offal. The consumption of Andean foods such as olluco and quinoa predominates during the harvest season, in a variety of traditional dishes, including potato, maize and Andeanized crops (bean, barley) as additional ingredients (Tapia, 2000; 2007). Food consumption patterns in the urban highlands have been modified by the increasing introduction of non-native foods.

Before 2000, 46% of households had access to one or more food-aid programs (INEI, 2000). This probably explains the progressive decline of local products, which, together with the entry of fast food franchises in the 1990s (Arbaiza, 2014) modified eating patterns (MINSA, 2006).

Consumption pattern in the Peruvian forest

Little is known about current consumption patterns in the forest. Native communities base their diet on cassava (95.1%) and bananas (98%), supplemented by the consumption of rice, eggs, worms, fish (carachama) and certain vegetables, with considerable consumption of carbohydrates. The bulk of the food budget is spent on fish, poultry and rice (Huaman and Valladares, 2006). Caloric deficiency in the forest is 23.1% as opposed to 33% in Lima. Poor fat intake in the forest is lower (53.7%) than on the coast (74.2%) and urban highlands (71.8%). A total of 33.1% of the country's inhabitants have poor animal protein intake and have vitamin A and iron deficiency (MOH/INS/CENAN, 2012).

Caloric intake has risen from 1,980 kcal in 1983 (Parillón et al., 1983) to 2,100 in 2016. Current diets consist mainly of carbohydrates coupled with fried foods and industrial meat byproducts (Caballero and Gonzales, 2016a). There is a growing tendency to eat outside the home, accounting for 32.4% of food spending, slightly less than in coastal and highland areas (INEI, 2014).

Direct effect of food on health

By contributing primary metabolites such as carbohydrates, lipids, proteins, vitamins and minerals, food has a direct effect on human beings' growth, development and health. Deficient food intake produces chronic malnutrition, iron deficiency and anemia, together with a deficiency of other micronutrients such as iodine, vitamin A and folic acid.

Mountain and forest populations are sensitive to iodine deficiency and have shown a high rate of endemic goiter for years. The Ministry of Health's programs have eradicated iodine deficiency and endemic goiter through salt iodization (Pretell et al., 2017).

In the case of folic acid, although the World Health Organization (WHO) recommends consuming 2.6 mg/kg of fortified wheat flour, Peruvian law recommends less than half this (1.2 mg/kg). This generates a neural tube defect rate of 18.4/10,000 (Ricks et al., 2012), which would be reduced by a change in the Peruvian legislation.

Anemia in children <6 years in Peru is regarded as a moderate public health problem and as a slight public health problem in expectant mothers (Mújica-Coopman et al., 2015). A study of 7,513 infants <6 months of age from 25 regions of Peru reported a prevalence of 10.2% for anemia (Gómez-Guizado and Munares-García, 2014), whereas in adults, there is a 17.1% prevalence of mild anemia, a 5.7% prevalence of moderate anemia and a 0.5% prevalence of severe anemia (Tarqui-Mamani et al., 2015).

Various studies report greater anemia rates at high altitudes than in coastal or forest areas, possibly because in the former, the cutoff point for defining anemia is corrected since hemoglobin increases at higher altitudes. Some studies suggest that hemoglobin should not be corrected in higher areas (Gonzales et al., 2014b).

Vitamin A deficiency (<20 μg/dl) is a public health problem with 11.7% prevalence in children, which increases in children under 5 months and in those living in rural areas and the forest (Pajuelo et al., 2015).

Various governments have implemented a range of maternal and child health policies. Although there is still room for improvement, Peru ranks first among 75 low- and middle-income countries in reducing neonatal mortality, and second in reducing mortality in children under 5. The decrease in the prevalence of chronic malnutrition and equity in the use of health care and health outcomes have significantly improved (Cotlear and Vermeersch, 2016).

In the 2000-2011 period, chronic malnutrition was reduced from 31.6% to 19.6%, acute malnutrition from 1.1% to 0.4% and anemia from 50.4% to 30.7% (Sobrino et al., 2014). However, chronic malnutrition is three times higher in rural than urban areas, affecting extremely poor children under 5 to a greater extent (MOH/INS/CENAN, 2015; Urke et al., 2014) and indigenous populations more than non-indigenous ones (56.2 vs. 21.9%) (Díaz et al., 2015).

Peru has seen changes in the population's nutritional status, with improvements in birth weight, resulting in an increase in normal weight in newborns from 74.6% between 2004 and 2006 to 92.5% in 2015, a situation that it is similar on the coast, highlands and jungle (**Table 6**). Furthermore, 14.9% of infants suffer from chronic malnutrition, while 7.3% are overweight, and 1.52% suffers from obesity (Apaza, 2014; Hernández, 2016; 2016b). A total of 32.4% of young people are overweight and 12.6% obese. In adults, the situation is more critical, since 46.1% are overweight and 23.8% obese (MINSA/INS/CENAN, 2015).

7. Political considerations

Reports published in late 2013 show that state subsidies for major projects have failed to achieve a significant impact on domestic agriculture, despite investments in irrigation mega-projects on the coast, privatized since 1990. The income earned by the state from the sale of new lands and other goods and services barely covered 7% of the public investment in these projects, meaning that the remaining 93% was provided by a state subsidy.

The agro-export sector would be the main taxpayer in the agricultural sector. However, the impact of taxation of this sector from 1998 to 2012 never exceeded 0.73% of the total collected in the country, which, in combination with the sugar subsector, barely reached 1%. This marginal contribution to Peruvian tax collection fails to reflect the importance of agriculture in GDP (Eguren, 2014).

Since 2000, in an attempt to meet the Millennium Development Goals, Peru implemented a number of social policy instruments for reducing poverty and achieving water, food and nutrition security. Thus, in 2012, the population's food and nutritional security was declared to be of national interest and a public need. Accordingly, the permanent Multisectoral Commission on Food Security and Nutrition attached to MINAGRI (Supreme Decree No. 102-2012-PCM) was created. Aware that the central problem is that the population does not permanently satisfy its nutritional requirements, the Commission undertook a diagnosis to recognize the causes and effects of this situation (MINAGRI, 2013). **Figure 7** shows the central government's concern and continuing effort in this direction.

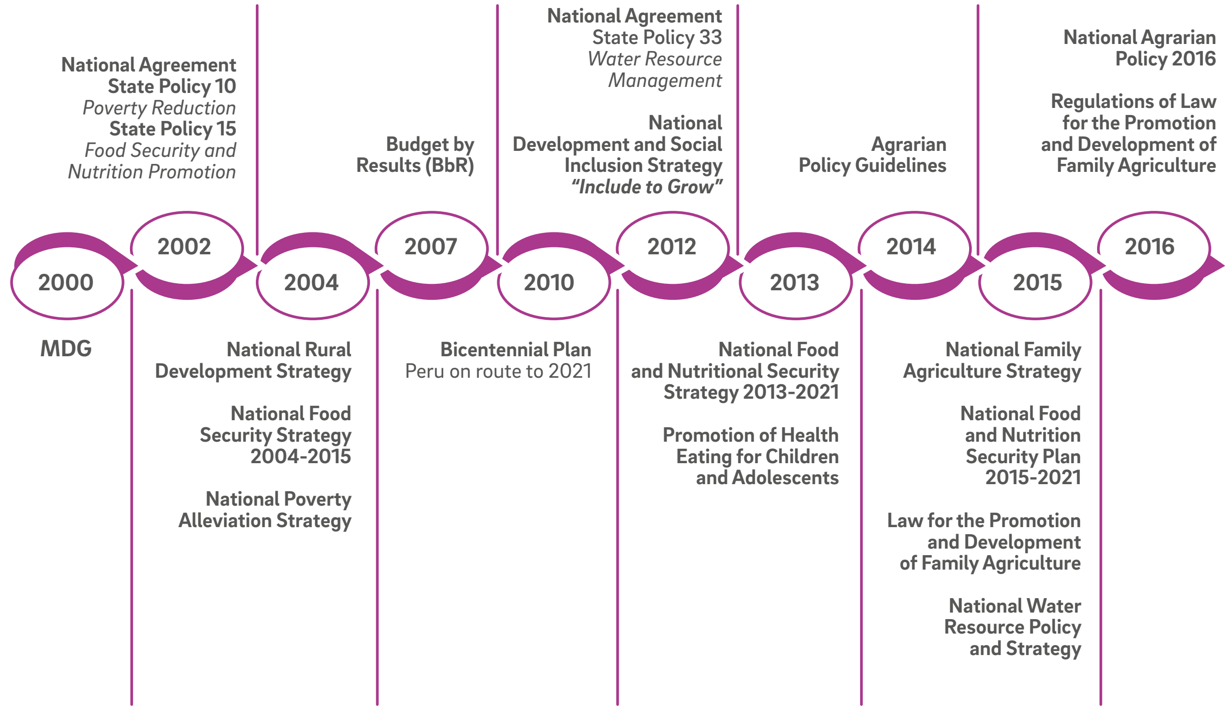
Meanwhile, realizing the challenges posed by food and nutrition security and in order to mitigate the degradation of biodiversity and the negative impact of climate change, Peru has incorporated the issue of risk management

Table 6. Percentage of births with adequate birth weight (≥2.5 Kg), by geographical area. 2004-2015

Years	Peru	Lima	Rest of coast	Mountains	Rain forest	Urban	Rural
2004-2006**a**	74.6	92.2	81.3	65.9	62.6	87.7	87.7
2007-2008**b**	79.5	92.7	83.8	72.5	74.2	89	89
2009**c**	83.2	93.9	89.3	77.2	73.0	89.8	89.8
2010**d**	82.8	92.5	88.1	77.6	73.1	89.6	89.6
2011**e**	84.9	93	89.4	80.7	75.0	91.1	91.1
2012**f**	86.2	93.1	89.9	81.2	81.8	90.7	77.7
2013**g**	85.9	92.8	88.6	81.5	79.0	90.4	76.3
2014**h**	87.6	94.4	90.3	84.1	78.6	91.9	77.3
2015**i**	92.5	93.2	93.1	91.3	92.0	92.7	91.9

Source: aINEI. ENDES. 2004-2006. bINEI. ENDES. 2007-2008. cINEI. ENDES. 2009. dINEI. ENDES. 2010. eINEI. ENDES. 2011. fINEI. ENDES. 2012. gINEI. ENDES. 2013. hINEI. ENDES. 2014. iINEI. ENDES. 2015.

Figure 7. Time line of Social Policy Instruments



Source: Compiled by Nicole Bernex.

through the passage of the National Disaster Risk Management Law. The following plans are currently being implemented:

- National Action Plan for the Conservation of Coastal and Marine Biodiversity in Peru (RM N° 039-2006-PCM).
- National Plan for Prevention and Attention to Disasters (DS No. 001-A-2004-DE/SG), comprising six strategies related to estimation, prevention, reduction, development planning, institution building, disaster prevention and emergency response.
- National Environmental Action Plan 2010-2021 (PLANAA) (DS N° 014-2011-MINAM). Contains the main goals to be achieved in the next ten years and will contribute to conservation, sustainable use of natural resources, improving environmental quality and the population's quality of life.
- Action Plan for Climate Change Adaptation and Mitigation (RM N° 238-2010-MINAM). At the level of regional governments, it suggests incorporating and institutionalizing the DRM and CCA approach in planning processes for the preparation of studies and the mapping of regional vulnerability and watersheds to cope with the effects of climate change.
- Bicentennial National Plan (DS N° 054-2011-PCM). It considers two strategic guidelines: "Encourage the adoption of mitigation strategies and ACC by the three levels of government, based on studies and scientific research with a preventive approach" and "Encourage vulnerability reduction and disaster risk within the framework of sustainable development and adaptation to mitigate negative effects and take advantage of the opportunities generated by the positive impacts of FEN".

For a decade, Peru's public sector institutions have engaged in a cross-sectoral effort to facilitate intersectoral and complementary integrated management processes. They facilitated the development of policies for technological innovation, human resource training and the promotion of healthy food consumption.

Policies that encourage technological innovation
The 29811 Law, enacted in 2011, which declared a ten-year moratorium on the admission and production of modified live organisms into national territory p put the debate on genetically modified seeds on the agenda. This law was not the first to limit the use of transgenic seeds. Since 2007, most regional governments in Peru have declared their region "GMO-free". This was done by the governments of Áncash, Aráquipa, Ayacucho, Cajamarca, Cusco, Huancavelica, Huanuco, Junín, Lambayeque, Lima Metropolitana, Lima Region, Loreto, Madre de Dios, Puno and San Martín.

In Peru, policies have been implemented to improve the social indicators of poverty, education and health. Educational and inclusion policies have reduced illiteracy rates and promoted women's participation in the country's government and productive activities. Many gaps remain in education, however, including the transfer of new agricultural technologies and training people to use them.

Law 30021 for the Promotion of Healthy Eating for Children and Adolescents (2013) and its Guidelines (2015) seeks to reduce and eliminate the diseases associated with overweight, obesity and chronic non-communicable diseases.

Other laws, such as the Consumer Protection and Defense Code (Law 29571), enshrine the right to consume safe food and establish the obligation to include labels, showing the composition and trans fat content of foods and indicating whether they contain genetically modified components. The Food Safety Law (DL No. 1062, 2008) ensures the hygiene of food for human consumption throughout the food chain.

Peru also has assistance programs such as the National School Meal Program (Qali Warma), which has provided food service for children at the initial and elementary level of public educational institutions throughout the country since 2013. The National Glass of Milk Program (PVL) covers the child population aged 0-6 and pregnant and breastfeeding women with a daily allowance from the State. Other programs, such as the National Additional Cradle and Together Program, contribute to food security.

Its location, morphology, enormous biodiversity, diversity of climates, soils and sociodiversity create large relative advantages for the country, enabling the production of an extraordinary variety of food, which has benefitted the food industry. Since 2000, Peru has achieved a cumulative growth of 116% in its GDP, making it an attractive market for domestic and foreign investment. Agricultural production rose from 1.4% in 2014 to 3.5% in 2016 and the fishing sector grew from 17.2% in 2015 to 18.1% in 2016 (MRE, 2015). However, there are also growing risks. Free Trade Agreements (FTAs) have increased the risks of chronic diseases due to the increased availability of processed foods. During the period of pre- and post-FTA ratification in Peru, soft drink production increased by 122%. The consumption of carbonated sugar-sweetened beverages increased (Baker et al., 2016), affecting the population's health. The challenge for Peru in the short and medium term is to reduce its dependence on imported products, develop innovative products and position itself competitively in unexplored market niches. Thus, several small- and medium-sized Peruvian companies are developing so-called "*superfoods*" with a high nutritional value (quinoa, amaranth, kañihua, maca, purple maize, yacon, camu camu, aguaymanto, carob, cocoa and Sacha inchi).

VIII. Final remarks

Peru is one of the world centers of genetic reserves of species and biodiversity, meaning that it has a great capacity for food production. The country has undergone social and economic changes that have contributed to increasing life expectancy and decreasing birth and death rates. At the same time, it has seen an increase in chronic non-communicable diseases as a cause of death and of eating patterns having been modified. The current diet involves high consumption of carbohydrates, saturated and trans fats, with a low intake of omega-3 polyunsaturated fatty acids, vegetables, fruits, legumes, fish and dairy products. The infant population has high rates of obesity and chronic malnutrition.

a. Some potential national agricultural scenarios for agricultural production in the next fifty years

In Peru, food availability has grown steadily in recent years. This improves the supply of calories and protein for its inhabitants. According to MINAGRI, in 2007, every Peruvian had 403 kg of primary foods and 176 kg of foods derived from cereals, milk, oils and fats, reflecting an average increase of 3% per year, whereby each inhabitant obtained 3,043 kcal (COMSAN, 2013). This scenario could be improved however, since problems associated with an increased reliance on food imports, climate change, low access to water and overexploitation of land can affect food and nutrition security.

b. High-priority actions to achieve agricultural sustainability

Efforts must be made to promote producer associations; develop technological institutes near to agricultural areas; provide technology training to producers to optimize their production; continue to develop climate change adaptation and mitigation programs; strengthen legislation on the development of modern biotechnology; and develop stronger legislation for the protection of biodiversity and reforestation.

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