

## REAL OPTIONS FINANCIAL ANALYSIS FOR THE APPLICATION OF SOLID RAIN: THE CASE OF AVOCADO IN MICHOACÁN

Laura Vera-Herrera, José de J. Brambila-Paz\*, J. Alberto García-Salazar, J. Alfredo Carrillo-Salazar

<sup>1</sup>Colegio de Postgraduados. Carretera Federal México-Texcoco, km 36.5 Montecillo, Texcoco, Estado de México. 56230.

\*Corresponding author: jbrambilaa@colpos.mx

### ABSTRACT

The objective of this study was to perform a financial analysis of the use of solid rain (*potassium polyacrylate*) with the real options method, to deal with price volatility and water scarcity for avocado production (*Persea americana* Mill.) in the state of Michoacán. The analysis is based on field data for extensive farming and a financial evaluation to decide the most convenient, economic, social and environmentally sustainable option for the project. The results from the study indicate that the incorporation of the polymer increased the efficiency in water use by 50%, decreased costs by 65%, and increased agricultural productivity by 30%. The cash flow (CF) at present value of the project with the option of investing in this technology is \$3,261,608.13 and without the option it is \$3,000,200.00. The Net Present Value (NPV) changes to \$1,726,526.50, which elevates the value of the project by \$57,326.50, so that the hypothesis of financial viability of the project is proven. The study concludes that it is possible to increase the profitability in the cultivation of avocado with the use of solid rain, in order to deal with water scarcity and price volatility in the study period.

**Keywords:** Efficiency in water use, polymer, sustainable, financial and technical viability.

### INTRODUCTION

In recent decades, it has been very noticeable how societies have radically changed thanks to the huge steps that have been made by technology and innovations in productive systems, advances that have contributed with improvements in productivity, more efficient use of resources, and an increase in food security (FAO, 2017).

However, there is a long road to travel in order to fulfill one of the greatest objectives set out by the Food and Agriculture Organization of the United Nations (FAO), since its foundation more than 70 years ago, and it is that food and agriculture contribute to improving the living conditions of all people (PNUD, 2017).

Thus, the themes that ought to be addressed integrally and systematically point to improving agricultural productivity in a sustainable way, to cover the growing demand and to guarantee a sustainable basis of natural resources, in face of the increase in competition over them (FAO, 2017).

The advances in productive systems observed in recent years can be compromised by a series of structural elements, such as the unsustainable use of natural resources, the losses and waste of foods, and the prevalence of natural disasters, among others (FAO, 2013).

The strong demand for water from agriculture, industry and urban zones is exhausting water resources. Water extraction for agriculture represents 70% of the total extraction

**Citation:** Vera-Herrera L, Brambila-Paz JJ, García-Salazar JA, Carrillo-Salazar JA. 2022. Real options financial analysis for the application of solid rain: the case of avocado in Michoacán. *Agricultura, Sociedad y Desarrollo*. <https://doi.org/10.22231/asyd.v19i1.995>

**Editor in Chief:**  
Dr. Benito Ramírez Valverde

Received: June 28, 2019.  
Approved: January 25, 2021.

**Estimated publication date:**  
September 14, 2022.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



of this resource (ONU, 2015). Industry, cities and agriculture are the main sectors that compete over the water supply; its scarcity is a phenomenon that is not only natural but also caused by the action of human beings since it is distributed irregularly, wasted, contaminated and managed in an unsustainable way (PNUD, 2006).

In agricultural and livestock production activities, the producer is incapable of predicting with certainty what will be the result obtained. Although there is a relatively stable relationship between inputs and other resources involved in the production and the product expected, the configuration of these in different years, environments or productive plans can generate rather dissimilar results (The World Bank, 2005).

On the other hand, the volatility of food prices, understood as significant and frequent changes in the direction and magnitude of food prices. Although it is a normal characteristic of agricultural markets that function correctly, when prices are magnified and become unpredictable, that is, volatile, they produce negative effects in food security, which especially affects the most vulnerable groups: family subsistence agriculture and the urban and rural population of low income, which witness their purchasing power decreasing drastically and inequalities growing, making their decisions about how and what to produce become subjected to higher risk (FAO, 2017).

This phenomenon also affects governments, because they can come to face situations that are highly inflationary with unexpected fiscal and budgetary repercussions that generate high social tension. Since the year 2007 global markets have experienced dramatic fluctuations in the prices of basic products. The prices of foods in the summer 2008 reached levels that had not been seen for 30 years, then they collapsed in the following winter and increased rapidly in the next months; today food prices are at very high levels and it is estimated that their volatility will continue (ONU, 2015).

Higher levels of volatility cause lower agricultural profitability and, associated to this, lower production levels which at the same time make the demand for inputs decrease (Robinson 1987; Torero, 2010).

The main objective of this study was to perform a real options financial analysis of the use of a polymer applied to the soil known as solid rain (*potassium polyacrylate*), which acts as a moisture retainer, suggesting with this an option of sustainable irrigation in the avocado crop (*Persea americana* Mill.) in the state of Michoacán, accentuating the possibility of dealing with water scarcity and price volatility in the market.

Also, to measure the importance of this methodology in the valuation of investment projects with technical data of trials made in the field and complementing them with a financial assessment, which allows completing a solid study and making decisions for the most convenient alternatives, in an economic, social and environmentally sustainable manner.

In this way, the intention is to give greater certainty to the producer or the investor, based on knowing the real options value inherent to the project and to what degree different scenarios can determine the growth or the success of a project under rainfed and irrigation conditions for agriculture, as well as in zones with unexploited arable potential due to lack of water.

The general hypothesis of the study suggests that the implementation of solid rain (*potassium polyacrylate*) is viable from the financial point of view, as an alternative for sustainable

irrigation of the avocado crop (*Persea americana* Mill.) in the state of Michoacán, to deal with price volatility and water scarcity in the zone. Derived from this, making the use of resources efficient can translate into a decrease in production costs and an increase in agricultural productivity, thus generating a higher cost-benefit.

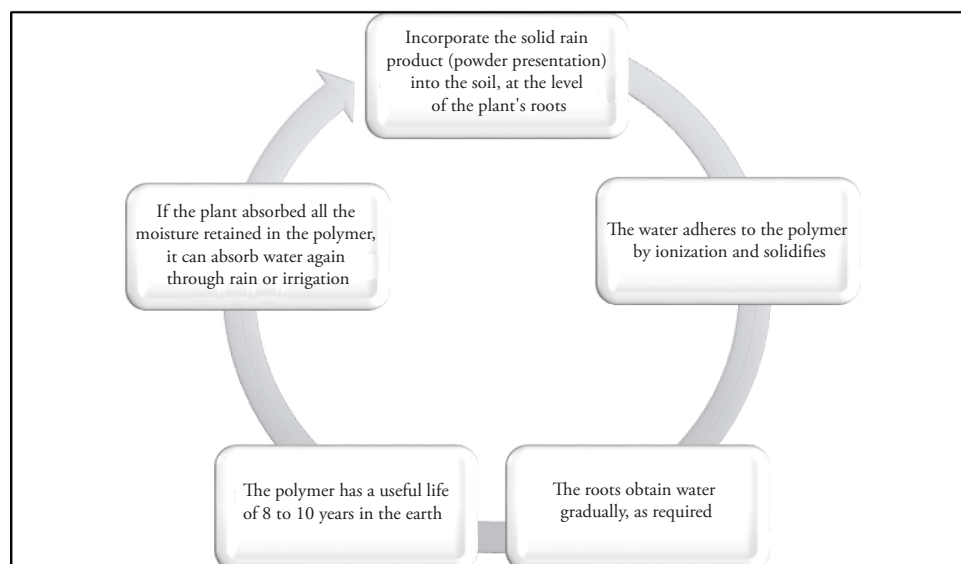
Solid rain is a potassium-based polymer (*potassium acrylate*), that is biodegradable, insoluble, innocuous and non-toxic; it is granulated powder similar to sugar, which expands when it comes into contact with water, becomes gel and is capable of absorbing 200 to 350 times its weight in distilled water, retaining moisture in the root of the plantation to maintain it hydrated without the need for irrigation or rain, storing the liquid for weeks, and reducing the frequencies of irrigation because the water is absorbed by the plants' roots in 95%, through osmosis, and with a useful life of 8 to 10 years, generating costs savings of up to 65% (DROP-FEN SA DE CV, 2018).

It can be used for any type of plants, crops, trees, gardens, pots, hydroponics, plants, etc.; the technique is also useful for reforestation, gardens, golf fields, or to fight fires. The plants will take up the moisture according to their needs, ensuring a stable and healthy growth, reducing the frequencies of irrigation up to 90%. It is a polymer that retains water and which can be available in time of drought; with its use, the pH, salts and soil nutrients are not modified (DROP-FEN SA DE CV, 2019).

Figure 1 illustrates the polymer's operation and form of use.

### Mexico, current situation and profitability of the avocado crop

Avocado is one of the most successful products of the country's agrifood exports, and its demand in 26 countries represents a consumption of 1.7 million tons. Mexico contributes



Source: prepared by authors with information provided by DROP-FEN SA DE CV, 2019.

**Figure 1.** Operation of solid rain® (potassium polyacrylate).

45.95% of the global exports and participates with 4.39% in the agricultural National GDP, with 8.84% in the production of fruits and a *per capita* annual consumption of 8 kg according to data obtained from the document of National Agricultural Planning 2017-2030, of the Ministry of Agriculture, Livestock Production, Rural Development, Fishing and Food (*Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación*, SAGARPA, 2017).

As Tables 1 and 2 show, Mexico is the first avocado producer at the global level, with 2,029,886.00 t in 2017, with Michoacán as the state with highest participation with a volume of 1,565,896.00 t which is more than 70% at the national level, with a trade balance of more than 1 million ton in production volume and \$ 2.958 billion US dollars (SIAP -SAGARPA, 2018).

### MATERIALS AND METHODS

To achieve the objectives set out, the study was developed in three basic stages. First, compilation of information in the field, in the care of the company DROP-FEN SA DE CV, which is a developer of technology called Lluvia Sólida® (*potassium polyacrylate*) that has contributed to this research in a timely manner, with a series of data regarding the use of the polymer for avocado farming in the state of Michoacán, data collected directly from the trials performed in the farmland throughout its productive process and corroborated with producers involved directly in this activity.

The data were compiled in the municipality of Ario de Rosales, located 95 km southwest of Morelia, capital of the state of Michoacán. Data included the amount of water required in traditional avocado farming, with or without applying the polymer, operation time of the irrigation system translated into the economic expenses generated, as well as water stress provoked in the plant with the resulting abortion or not of flowering and, finally, the fruit weight obtained.

**Table 1.** Top 10 in volume of avocado production in Mexico, years 2012 to 2017.

Place	Satate	Volume (t)		Variation (%) 2012-2017
		2012	2017	
	National total	1,316,104.00	2,029,886.00	54.20
1	Michoacán	1,117,338.00	1,565,896.00	40.10
2	Jalisco	40,846.00	169,688.00	315.00
3	Estado de México	28,766.00	108,768.00	278.00
4	Nayarit	29,178.00	49,246.00	68.80
5	Morelos	35,542.00	34,846.00	-10.00
6	Guerrero	14,784.00	23,586.00	59.50
7	Puebla	12,015.00	16,842.00	40.20
8	Chiapas	6,148.00	12,009.00	95.30
9	Yucatán	11,431.00	10,772.00	-9.40
10	Oaxaca	4,164.00	9,097.00	118.00
	Rest	15,892.00	29,137.00	83.30

Source: prepared by the authors with data from the Food and Agricultural Atlas 2012-2018, SAGARPA, SIAP, 2018.

**Table 2.** Estimates for avocado production and export in Mexico, 2012-2017.

	2012-2017 Foreign Trade Avocado		
	Imports	Exports	Trade balance
Volume (t)	1,099.0	1,003,002	1,001,903
Value (millions of USD)	2.9	2,961	2,958

Source: prepared by the authors with data from the Food and Agricultural Atlas 2012-2018, SAGARPA, SIAP, 2018.

The second stage consisted in a traditional financial analysis for a project of avocado production of 10 ha, with a current production volume of 14.3 t/ha; a mean rural price of \$23,076.92 MXN/ton was considered (SIAP; SAGARPA, 2018).

The discount rate, which refers to the yield index used to discount future cash flows from their current value, was 15%, considering a real interest rate of 5% and a risk of 10%. The Development Bank uses discount rates that range from 12% to 16% (BANXICO, 2019). Official data series of the nominal prices of avocado var. HASS PRIMERA (MX pesos (\$), box with 12 kg) were used (SNIIM, 2000-2017), the national consumer price index (NCPI) with base second fortnight of July 2018 National, by expenditure object, general index, annual inflation (INEGI, 2000-2017), in addition to documental and statistic information about the productive process of avocado (SIAP; SIACON, 2000-2017).

The Net Present Value (NPV) is calculated based on this information, an investment criterion used since the 1950s, which consists in updating the costs and benefits of a project or investment to understand how much is going to be earned or lost with this investment, in addition to economic indicators of Benefit-Cost Analysis (BCA) and Internal Rate of Return (IRR). For the example, the following is considered:

$$NPV = -I + \sum_{i=1}^t \frac{FC_i}{(1+r)^i} \quad (1)$$

where  $I$ : initial investment in year 0=-\$1,120,000.00;  $FC_i$ : cash flow for the moment  $i$ =\$3,000,200.00, representing the income minus operation costs of each period of the project's useful life;  $r$ : discount rate (interest rate plus risk)=15%;  $t$ : time of duration of the project 4 years.

NPV = \$1,880,200.00.

BCA = 3.6.

IRR = 42%.

Once these values were available, the purpose was to obtain the total NPV, which is composed of the sum of the traditional NPV plus the net present value of the real options, of the operative flexibility.  $NPV_{total} = NPV_{traditional} + \text{real option value}$  (Brambila, 2011).

It should be pointed out that the case of a negative traditional NPV can happen,

considering the fact of rejecting it. If the NPV is positive, there should be investment, and if it is negative, it should be rejected. However, with a real option value so large that it could counteract the negative effect and thus the values added, the result is a positive total NPV and finally opting to accept the project (Mascareñas, 2005).

In the third stage of the application of the real options methodology, diverse circumstances were considered around the project that are originated in a panorama of constant changes, that is, a dynamic risk analysis. To estimate the value of the real option, the continuous movement rate of the project's real prices (TMP) is calculated, which is obtained from the natural logarithm of 1 plus the discrete rate  $(1+r)$ .

$$TMP = \ln\left(\frac{P_{t+1}}{P_t}\right) \tag{2}$$

where  $\ln$ : natural logarithm;  $P_{t+1}$ : time period+1;  $P_t$ : time period.

The use of some statistical instruments was incorporated, such as: arithmetic mean ( $\bar{x}$ ), variance ( $\Gamma^2$ ) and normal distribution ( $Z$ ). The period of the data is from year 2000 to year 2017.

The arithmetic mean ( $\bar{x}$ ) is the expected average of a series of data in a period, which is obtained using the following formula when each  $x_i$  has the same probability of occurrence (Stevenson, 1981). It is interpreted as an indicator of the growth trend of profitability.

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n (x_i) \tag{3}$$

where  $x_i$ : value of the variable in period  $i$ ;  $n$ : total number of periods.

Growth trend of profitability MEAN ( $\bar{x}$ ) 0.047595	
---	--

The variance ( $\Gamma^2$ ) is the second moment of the dispersion of a set of data (Fisher, 1925). It is interpreted as the indicator of the price volatility.

$$\Gamma^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \tag{4}$$

where  $\Gamma^2$ : variance;  $x_i$ : value of the variable in period  $i$ ;  $\bar{x}$ : mean;  $n$ : total number of periods.

Volatility VARIANCE ( $\Gamma^2$ ) 0.082124	
---	--

The standard deviation with natural logarithms ( $\Gamma$ ) refers to the statistical mean which measures when the values are dispersed around their average. It is interpreted as the risk indicator of the prices, and results from the square root of the variance.

$$\frac{\text{Risk}}{\text{STANDARD DEVIATION } (\Gamma)} = 0.286573$$

The normal distribution is a probability distribution of continuous variable that describes the data that are grouped around a central value; thus, any process where there are only random causes for variation follows a normal distribution law. This condition appears frequently in natural phenomena (from this that it is called “normal”) and its graphic representation is the normal distribution curve, also called Gaussian bell curve in honor of C. Friedrich Gauss (1855).

In this analysis the assumption is that the Central Limit Theorem is operating (Walpole, 1992); if  $\bar{x}$  is the mean of a random sample of size  $n$  that is taken from a population with mean  $m$  and finite variance ( $\Gamma^2$ ), then the limit shape of the distribution will be:

$$Z = \frac{\bar{x} - \mu}{\Gamma / \sqrt{n}} \tag{5}$$

If  $n$  tends to increase, then the distribution tends to be the standard normal  $Z \sim (0,1)$  mean 0, variance 1. This allows us to have a relationship between the standard deviation and the probability of occurrence of specific values.

The application of these instruments in our study case, as well as the incorporation of risk, allowed us to obtain as a result the behavior for the first year of the project.

When the prices increase and the project is going well=up	$(u) = \ell$	$= \ell^{0.282563}$	$= 1.33186$
When the prices decrease and the project is not going well=down	$(d) = \ell^{-}$	$= \ell^{-0.282563}$	$= 0.75083$

Where  $\ell$ : number  $e$  or Euler value  $\approx 2.718281828$ . One constant, base of natural logarithms.

As part of the analysis, we emphasize the calculation of the NPV, which consists in bringing all the cash flows to the present moment discounting them at a specific interest rate. The NPV will express a measure of profitability of the project in net absolute terms, that is, in number of monetary units. Calculating the NPV of different investments we will understand with which of them we will obtain greater profit, so it is used for the valuation of different investment options.

$$NPV = -I_0 + \sum_{t=1}^n \frac{F_t}{(1+k)^t} = -I_0 + \frac{F_1}{(1+k)} + \frac{F_2}{(1+k)^2} + \dots + \frac{F_n}{(1+k)^n} \tag{6}$$

where  $F_t$  are the cash flows in each period  $t$ ;  $I_0$  is the investment performed at the initial moment ( $t = 0$ );  $n$  is the number of periods of time;  $k$  is the type of discount or type of interest demanded from the investment.

Therefore, considering a real interest rate free of risk, such as the real yield rate of a government bond, with a value of  $r = 5\%$  (0.05) and taking into account a cash flow discounting 15% of \$3,000,200.00, highlighting that it is at present value ( $V_0$ ), that is, it does not include the initial investment; such a value will begin to move in time resulting in the values: value of increasing up =  $mV_0$  and value of decreasing down =  $dV_0$ . Likewise, the probability of occurrence of each case,  $p$  and  $1 - p$ ;  $1 + r$  is discounted from the result, being equal to the initial present value ( $V_0$ ), taking the probability as weight. Clearing the probability  $p$  in each case, the following is obtained:

$$V_0 = \frac{p\mu V_0 + (1 - p)dV_0}{1 + r} \quad (7)$$

Probability of increasing =  $p = 0.5149$ .

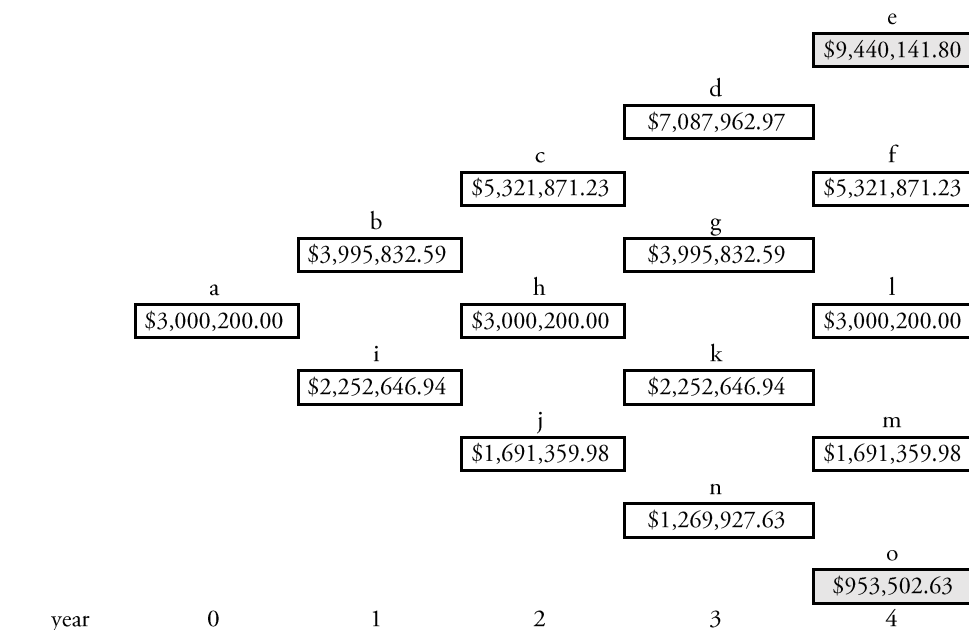
Probability of decreasing =  $1 - p = 0.4851$ .

Replicating this procedure to the entire project in its 4 years of duration to illustrate the possibilities in which it can fall, nodes are created for that purpose, and in each one the prior value is multiplied by  $\mu$  or  $d$ . Thus, for year 4 the cash flow can have a value of \$9,440,141.80 or \$953,502.63, on average the cash flow is \$3,000,200.00 although the dispersion is very wide. The present value of each node is obtained without applying any option, only considering the price volatility, which in this case is the standard deviation, which can be seen in Figure 2.

Thus, the probability of reaching each node from year 4 is calculated, allowing to graph these values and noticing that the distribution curve approximates a normal curve; with more years considered, it becomes more similar to the normal curve.

$$\beta(n / T, p) = \binom{T}{n} p^n (1 - p)^{T-n} \quad (8)$$

where, for our example, the data are  $n$ : number of nodes in the year in question, counting from top to bottom to end in  $n=0$ ; for example, for year 4 there are 5 nodes ( $n = 4, 3, 2, 1, 0$ );  $t$ : total of 4-year periods (statistically the number of trials);  $p$ : 0.3888 (probability of having a good result with the project);  $1 - p$ : 0.6112 (probability of having a bad result with the project).



Source: prepared by authors.

**Figure 2.** Present value of the project with risk or price volatility.

Value	Probability
\$9,440,141.80	7.03%
\$5,321,871.23	26.49%
\$3,000,200.00	37.43%
\$1,691,359.98	23.51%
\$953,502.63	5.54%
	100%

As Table 3 shows, the sum of probabilities is 1, since there are all the possibilities where the project can be in year 4. The distribution curve approximates a normal curve (Copeland, 2003). Until this part, the analysis conducted considers the volatility or risk in the cash flow and the calculation of the probability of reaching any node, which allows observing that the project can have a bad result since the first years of management and without the possibility of doing something, which is why the most ideal option is to change it, which is a real option. There can be several options for the project such as diversifying their product portfolio, seeking new machinery technologies, inputs, resources, decreasing the productive capacity selling assets or abandoning the project.

For the example, it will be assumed that in year 2, if things go wrong, we reach the node (V<sub>j</sub>) = \$1,691,359.98, so that the real option that would result for the project would be to invest in incorporating *potassium polyacrylate* in the productive process of avocado; that is, a differentiation of the product since the second year, as shown in Figure 3.

According to the technical file of Solid Rain® (*potassium polyacrylate*) and with the trials conducted in the field for various extensive crops such as trees and grasses, there is willingness

**Table 3.** Probability of reaching each of the nodes.

					Probability	Value
$\beta(4/4, (0.5149)) =$ De a e, n= 4	$4*3*2*1/4*3*2*1$	$(0.5149)^4$	$(0.4851)^0$	0.0703	7.03%	\$9,440,141.80
$\beta(3/4, (0.5149)) =$ De a f, n= 3	$4*3*2*1/1*3*2*1$	$(0.5149)^3$	$(0.4851)^1$	0.2649	26.49%	\$5,321,871.23
$\beta(2/4, (0.5149)) =$ De a l, n= 2	$4*3*2*1/2*1*2*1$	$(0.5149)^2$	$(0.4851)^2$	0.3743	37.43%	\$3,000,200.00
$\beta(1/4, (0.5149)) =$ De a m, n= 1	$4*3*2*1/3*2*1*1$	$(0.5149)^1$	$(0.4851)^3$	0.2351	23.51%	\$1,691,359.98
$\beta(0/4, (0.5149)) =$ De a o, n= 0	$4*3*2*1/4*3*2*1$	$(0.5149)^0$	$(0.4851)^4$	0.0554	5.54%	\$953,502.63
				Addition	1.0000	100.00%

Source: prepared by authors.

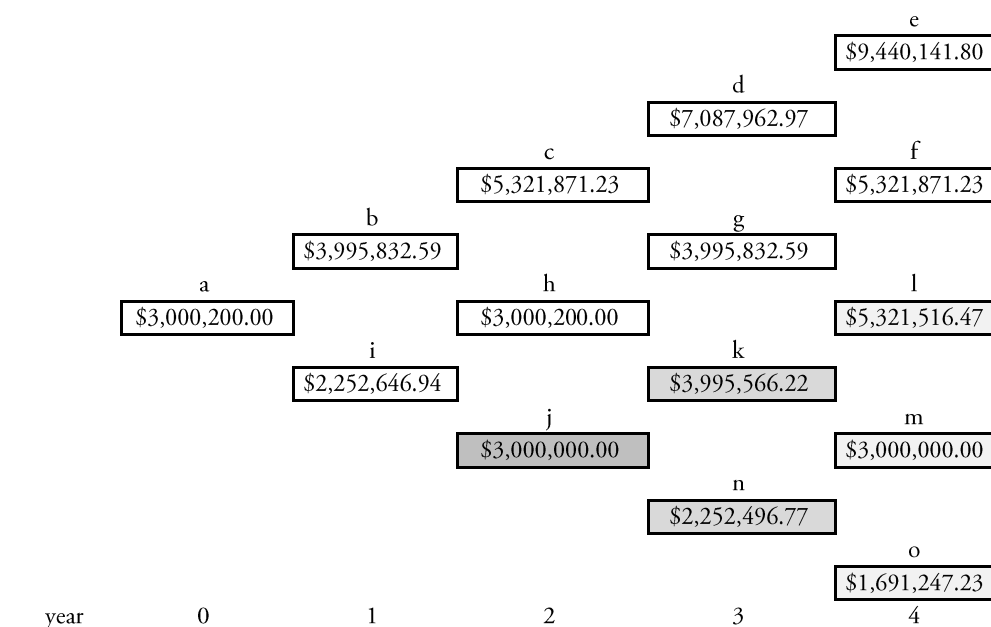
to perform an investment of \$225,000.00 MX pesos (cost of the input) for its application in the 10 ha that are object of this study. With this alternative, it is expected for the project to generate a cash flow of \$3,000,000.00 MX pesos, from that year, and the binomial tree is formed since year 2. The focus of attention will be the nodes: j, k, l, m, n, o.

The probability of being in Vj in the second year is  $(0.4851)^2 = p = (0.4851) (0.4851) = 0.2353$ .

The decision of differentiating the product has a probability of 24% = 0.235, adopting the technology.

The decision of NOT differentiating the product has a probability of 76% = 0.764, not adopting the technology.

Therefore, the value of each node that overlaps is calculated again, and the general rule will be to choose the highest value (with or without differentiation) and where there is overlap



Source: prepared by authors.

**Figure 3.** Binomial tree with investment from year 2.

that is weighted by the probability of occurrence of the differentiation (Brambila, 2011). Taking into account that for our example we decided to differentiate in Vj. That is, to reach the node Ve, it is decided not to differentiate, but for Vo, we did opt to differentiate since MAX (\$1,691,247.23, \$953,502.63). The calculation of the other nodes is shown in Figure 4.

	Value “if”	Value “not”	Weighing	Selected value
Vo	\$1,691,247.23	\$953,502.63	\$1,127,111.50	\$1,691,247.23
Vi	\$5,321,516.47	\$3,000,200.00	\$3,546,461.03	\$3,546,461.03
Vm	\$3,000,000.00	\$1,691,359.98	\$1,999,314.13	\$1,999,314.13

To calculate the values of the 3rd, 2nd and 1st year, it is done from the back to the front and discounted by  $(1+r)$ .

The value of Vj is not \$3,000,000.00 as had been assumed, because the decision to differentiate is not a certainty, but rather only a probability (Brambila, 2011).

$$\begin{aligned}
 V_d &= \$7,087,962.97 \\
 V_g &= \$4,248,206.15 \\
 V_k &= \$2,662,797.34 \\
 V_n &= \$1,761,781.25 \\
 V_e &= \$5,438,468.26 \\
 V_h &= \$3,313,448.95 \\
 V_j &= \$2,119,726.44 \\
 V_b &= \$4,197,730.91 \\
 V_i &= \$2,604,163.76 \\
 V_a &= \$3,261,608.13
 \end{aligned}$$

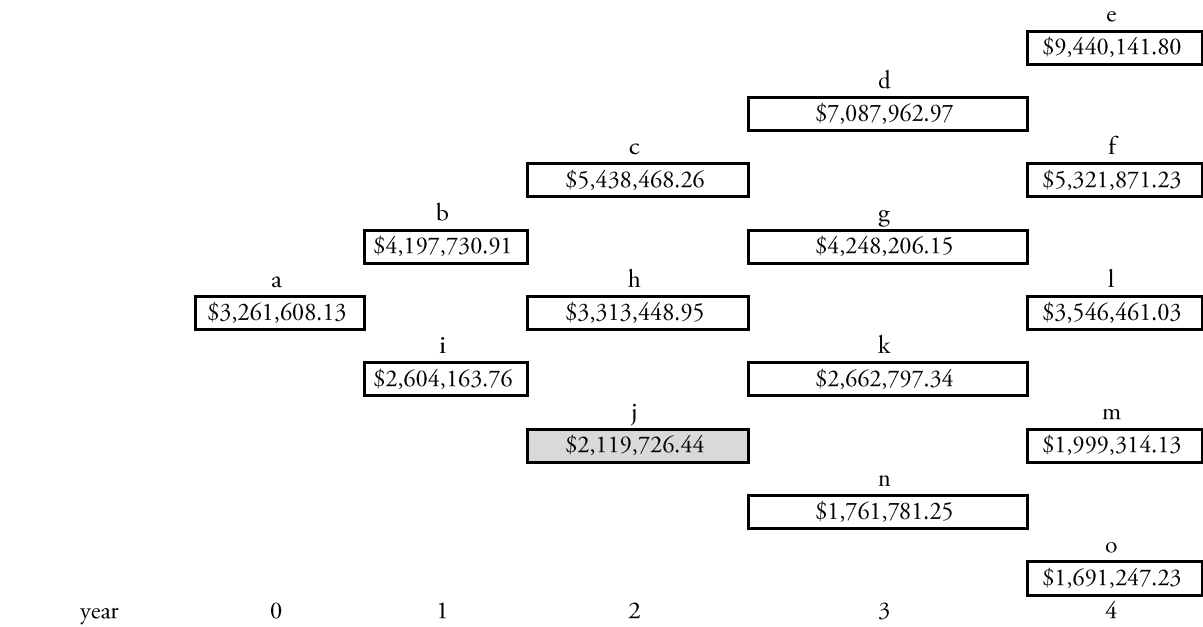
Thus, the cash flow, at present value of the project with the option of investing is: \$3,261,608.13 and without the option it is \$3,000,200.00. The option of investing in the year 2 is worth \$261,408.13 today. The Net Present Value is now \$1,937,526.50, which elevates the value of the project in \$57,326.50.

### Real option to purchase (call), for expansion

Until the year 1973, the models by which the options were valued were very simple until Myron Sholes, Robert C. Merton, and Fisher Black appeared; they published a new methodology to analyze this type of financial products. Known as the Black-Scholes-Merton model, this study gives a theoretical value to the options “Put” as the European options “Call” that use actions that do not pay dividends as an underlying asset (Merton, 1973).

The key argument on which this model is based is that investors can, without taking any type of risk, compensate the “long” positions (purchase) with “short” positions (sale) of the action, constantly adjusting the coverage radius each time it was necessary. This model received the Nobel Prize in Economics in 1997.

The starting assumptions of the model are the following: there are no transaction costs or taxes, the interest rate that is free of risk is constant for all the expiration dates, the action does not pay dividends, and the volatility remains constant. Short sale is allowed, there are no opportunities of arbitrage without risk, and it is assumed that the distribution of



Source: prepared by authors.

**Figure 4.** New binomial tree, with the investment option of \$225,000.00 MX pesos of year 2.

probability of the returns is a normal distribution. The real options that the manager of a project can have are: differ or postpone the investment, broaden, reduce, abandon, follow, change (Mun, 2002).

If the project underway has excellent results, the manager or producer can decide to expand, acquire companies that formerly competed with it, or else, improve its competitiveness by increasing its scale, which is known as an option to purchase. Thus, through the Black-Scholes and Merton model, it will be assumed that there is an option to purchase (call) and there is the right to purchase on the 4th year at \$ 2,000,000.00, derived from the previous analysis, where the production costs have suffered a decrease allowing with this an expansion in the production surface from 10 ha to 20 ha.

The formulas and the option value, stemming from the assumption that the distribution of the values is normal:

$$C = SN(d_1) - K_e^{-rt} N(d_2) \tag{9}$$

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{r^2}{2}\right)t}{\Gamma\sqrt{t}} \tag{10}$$

$$d_2 = d_1 - r\sqrt{t} \tag{11}$$

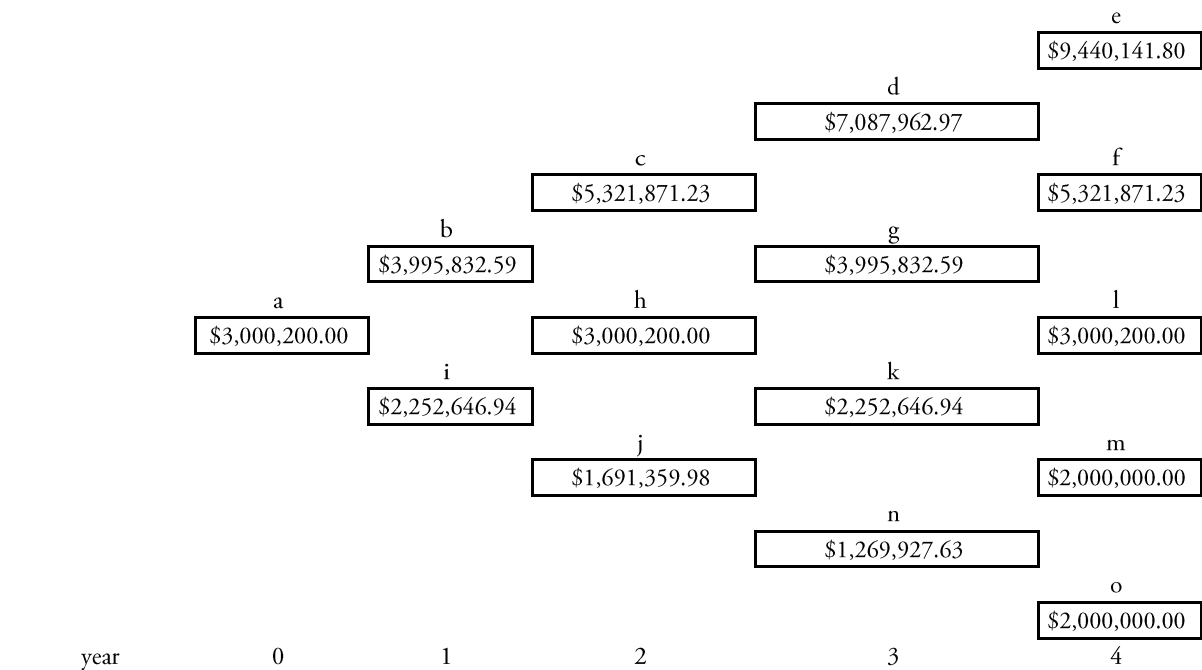
where  $C = \$1,545,330.50$ . Value of the real option to purchase (call);  $S = \$3,000,200.00$ . (Initial value) the present value of the cash flow;  $K = \$2,000,000.00$ . Purchasing power in the fourth year;  $r = 0.048790164$ . Continuous risk free rate;  $t = 4$ . Prefixed time to exert the option (if it is convenient);  $\Gamma = 0.2865730$ . Standard deviation of the data of the continuous movement rate from the real prices or incomes;  $N(d_1) = 0.9090$ . Probability to be searched for in the table of values  $Z$ . ( $d_1 = 1.3346$ );  $N(d_2) = 0.7182$ . Probability to be searched for in the table of values  $Z$ . ( $d_2 = 0.5777$ ).

The “Call” value is  $\$1,545,330.50$ , which means that in order to have the purchasing right of the project in the fourth year for  $\$2,000,000.00$ , the amount of  $\$1,545,330.50$  must be paid today, which would be very profitable for whoever has the right if the project in the fourth year has a value of  $\$9,440,141.80$ . If the value of the project in the fourth year is  $\$953,502.63$ , it is not worth it to opt for the purchasing option and the  $\$1,545,330.50$  will not be lost. This practice would have a base of  $\$1,545,330.50$ , although the profit is open. See Figure 5.

To complement the Black-Scholes and Merton model, the contrary case is done, that of sale (put).

$$P = \$190,535.45.$$

$$S = \$3,000,200.00. \text{ Cash flow at present value.}$$



Source: prepared by authors.

**Figure 5.** New binomial tree with the option to purchase (call), for expansion, in year 4.

$K = \$2,000,000.00$ . Able to sell in the 4th year.  
 $r = 0.0487902$ . Continuous risk free rate.  
 $t = 4$ . Prefixed time to exert option.  
 $\Gamma = 0.2865730$ . Standard deviation.  
 $N(-d_1) = 0.0910$ . Probability of searching for in table of values Z.  
 $N(-d_2) = 0.2818$ . Probability of searching for in table of values Z.

Verification operation, to verify that the calculations are correct:  $C - P = S - Ke^{-rt}$

$$\$1,354,795.05 = \$1,354,795.05$$

### RESULTS AND DISCUSSION

According to the financial analysis and based on the information gathered for this study, the following parameters have been considered regarding avocado farming in the state of Michoacán; in an initial scenario the average yield in an avocado orchard of the zone was determined to be 11 t/ha and according to the trials conducted, with the application of the polymer, an increase of close to 30% was obtained, that is, 14.3 t/ha, indicating in addition that the weight of the fruit increased from 315 g to 400 g.

Table 4 shows relevant information regarding the impact of the use of this technology in terms of liters of water required weekly in the plantation, operation time of the irrigation system, percentage of abortion in flower, weight of the fruit, savings in fertilizer, and production per tree.

These results are in agreement with other studies conducted, as in the case of XunLiu *et al.* (2015), who examined the effect of *potassium polyacrylate* (K-PAM) on the water content of the soil and the physiological changes of the bermuda grass (*Cynodon dactylon*) in greenhouses. The results that were obtained showed that the incorporation of K-PAM increased the water content in the soil and the survival rate of the grass. The analysis of

**Table 4.** Effect of the application of solid rain polymer\* (potassium polyacrylate) in avocado.

Without polymer application	With polymer application
For traditional avocado planting, without solid rain: 80 liters of water per week were required. The operating time of the irrigation system was 5 hours a day using a diesel pump, generating a cost of \$45,000.00. Water stress in the plant caused 60% of flower abortion. The weight per avocado was approximately 315 g. The production per tree was 300 kg.	In contrast, for the traditional planting of avocado with Solid Rain, dose: 600 g 40 liters of water per week were required (37 days without irrigation). The operating time of the irrigation system was 2.5 hours per day using a diesel pump, generating a cost of \$15,000.00 and savings of 65%. 80% of the flower remained on the tree, and only 20% aborted. The weight per avocado was approximately 400 g. Fertilizer savings of 30%. The production per tree was 550 kg.

Source: prepared by authors with information provided by DROP-FEN SA DE CV, 2019.

physiological parameters showed that the treatment with K-PAM resulted in a decrease in the cell membrane damage through the modulation of the contents of leaked electrolytes (EL) and malondialdehyde (MDA) in the grass. The plants cultivated with K-PAM accumulated a larger amount of proteins and proline under stress conditions, indicating that the application of K-PAM increased effectively the water content in the soil and improved the growth of bermuda grass under stress conditions from drought.

A positive value  $NPV > 0 = \$1,880,200.00$  suggests that there should be an investment in the project; according to the decision criteria, it is established that the updated value of charges and future payments for the investment, at the discount rate chosen, will generate benefits.

However, this indicator does not consider the price volatility and other circumstances from the ones exposed in the project, which is why it is necessary to complement this methodology to add value to the project by taking into account a certain “operational flexibility” and being able to deal with the different scenarios that could come up and signify a risk (Brambila Paz, 2011).

With a mean rural price of \$ 23,076.00 MX/t, which, in contrast with the costs, generates a profit of \$ 165,769.23 annually / ha; thus, the initial investment in year 0 is \$1,120,000.00, with a cash flow of \$3,000,200.00, at a discount rate of 15% and with an evaluation period for the project of 4 years, there is a cash flow at present value of the project without the real option of investing to adopt the technology which is \$ 3,000,200.00 and with the option of doing it, it is \$3,261,608.13.

The option of investing in year 2 is worth \$261,408.13 today. The Net Present Value (NPV) is now \$1,937,526.50, which elevates the value of the project in \$57,326.50.

The results shown about this financial analysis are compatible with other studies conducted. In the case of Thomas *et al.* (2008), comparing evaluations of projects from public institutions and using the same methods, the authors concluded that the real options method revealed values between 25 and 500% higher than the same projects evaluated by the traditional NPV method, depending on the project under study.

On the other hand, Da Silva *et al.* (2004) applied the real options theory (with the Black-Scholes model and also the binomial model) in the evaluation of a product for internet in ASP technology (Application Service Providers) and they compared the values with the results obtained with the use of the Net Present Value.

The authors show that despite the negative result when the NPV reveals at the beginning and when incorporating some options included in the project, it became viable.

Chávez O., (2004) concludes, in his study about alternative methods of project evaluation that the evaluation of projects traditionally through Net Present Value and real options does not exclude, and on the contrary, it allows using the most adequate financial criteria and complementing them with the information that will decrease its uncertainty and risk. In this way, the real options methodology, specifically with the Black-Scholes and Merton model (Nobel of Economy, 1997) allows making an economic-financial analysis of the implementation of a project. This is done under different scenarios, for example, when dealing with the volatility of market prices, an increase in input price, and changes in the

production volumes and periods of time, which can affect directly the cash flow that is generated along a specific horizon and thus can define different alternatives (options) in relation to the project.

### CONCLUSIONS AND RECOMMENDATIONS

When it comes to the most outstanding findings of this study, there is that having carried out an assessment of the project in a traditional way, the panorama shown with the real options methodology turns out to be much higher, since that is where it can be appreciated clearly, if price volatility is taken into account, such as how the cash flow can increase to \$9,440,141.80 or fall to \$953,502.63, due to the presence of such a broad dispersion.

Among the great advantages of the real options financial analysis, there is that it is possible to incorporate all the scenarios in the analysis, such as the probabilities of success or failure, and to return to the stage in which the producer or investor decides to invest or not in the project, showing more completely the different options that there would be in the different phases for the project: differ or postpone the investment, broaden, reduce, abandon, continue or change.

In this case in particular, the real option available for the project is to invest in incorporating the polymer as input in the productive process of avocado, starting in the second year of the project.

The hypothesis set out at the beginning is proven, since the viability is shown from the financial point of view, of the use of solid rain (*potassium polyacrylate*) as an alternative for sustainable irrigation in avocado farming (*Persea americana* Mill.) in the state of Michoacán, since, according to the data presented, the use of the polymer increased the efficiency in water use in 50%, which translates into a decrease in costs of up to 65%, and an increase in agricultural productivity in 30%, thus generating greater benefits for the producer and the investor.

In an initial scenario the average yield in an avocado orchard in the zone, it was determined to be 11 t/ha and according to the trials conducted, with the application of the polymer, an increase of close to 30% was obtained; that is, 14.3 t/ha, also indicating that the weight of the fruit increased from 315 g to 400 g.

When it comes to cost reduction, there are savings of up to 65% in monetary terms, derived from less time of functioning of the irrigation system using a diesel pump, a reduction in liters of water required weekly, from 80 to 40, as well as savings in fertilizer of 30%; in addition, the water stress in the plant provoked 60% of the abortion in flower, compared to the use of the polymer, where 80% of the flower remained in the tree, which meant 20% of abortion.

In the future, the price level of foods will depend on the response that production systems give to the growing demand in a context of climate change and limited resources, as well as how much the agricultural trade manages to act as adaptation mechanism facing this changing context that demands guaranteeing a sustainable basis of natural resources, since with the recent and continuous expansion, agricultural lands and water resources are becoming exhausted.

Having said this, any increase in agricultural production will have to be based primarily on the conservation and efficient use of natural resources; there is now a permanent challenge generated by the need to find an optimal balance to satisfy the growing social demands. As future extension of this research, it could be suggested as the basis of study for an impact evaluation in public organizations, as for example, in the management of public policies that make possible the adoption of this technology by small and large scale farmers, incentivizing for there to be an increase in productivity, primarily in rainfed zones where water scarcity causes ravages and abandonment of lands. In this sense, the real options methodology is based on solid financial theory, which can considerably increase its degree of complexity, based on the research line used and the approach or analysis that is required.

## REFERENCES

### Fuentes Bibliográficas

- Black F, Scholes M. 1972. The valuation of Options Contracts and a Test of Market Efficiency. *Journal of Finance*. p: 399-418.
- Black F, Scholes M. 1973. The pricing of options and corporate liabilities. *Journal of Political Economy*. p: 637-654.
- Brambila JJ. 2006. *En el umbral de una agricultura nueva*. (1ra. Edición). Universidad Autónoma Chapingo, México.
- Brambila JJ. 2011. *Bioeconomía: Instrumentos para su análisis económico*. (1ra. Edición). Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, México. p: 183-296.
- Brambila JJ, Martínez MÁ, Rojas MM, Pérez V. 2013. La bioeconomía, las biorefinerías y las opciones reales: el caso del bioetanol y el azúcar. *Agrociencia*. Vol. 27, número 3. México.
- Cantú M, Garduño H. 2004. *Administración de derechos del agua: de regularización a eje de la gestión de los recursos hidráulicos*.
- Chávez JE. 2004. *Evaluación de proyectos planificación estratégica*. Universidad Francisco Marroquín, Guatemala.
- Copeland TE, Antikarov V. 2003. *Real options: a practitioner's guide*. New York: Thomson/Texere.
- Cortés AFI. 2004. El agua en México y su perspectiva científica y tecnológica, en *El agua en México: una vista desde la academia*, B. Jiménez Cisneros. Academia Mexicana de Ciencias. México.
- Fisher RA. 1970. *Statistical methods for research workers*. 14. Aufl., Oliver and Boyd. XIII, (362). Edinburgh, London.
- Garza LE. 2013. *Fundamentos e Instrumentación de la Economía basada en el Conocimiento*. (1ra. edición). Colegio de Postgraduados, Campus Montecillo, México.
- Hernández SR, Fernández CC, Baptista LP. 2003. *Metodología de la investigación*. (3ra. ed). México. Mc Graw-Hill.
- Jiménez B, J Alcocer. (coords). *El agua en México Vista Desde la Academia*. México: Academia Mexicana de Ciencias. pp: 271-288.
- Mascareñas J. 2005. La valoración de un proyecto de inversión biotecnológico como una opción real compuesta. *Monografías de Juan Mascareñas sobre Finanzas Corporativas*, número 34.
- Merton RC. 1973. Theory of rational option pricing. *Bell Journal of Economics and Management Science* (4). (p. 141-183).
- Mun J. 2002. *Real options analysis: Tools and Techniques for valuing strategic investments and decisions*. John Wiley and Sons. New York
- Norton GW, Davis JS. 1981. Evaluating returns to agricultural research: A review. *American Journal of Agricultural Economics* 63 (4). (685-699).
- Robinson LJ, Bary P J. 1987. *The Competitive firm's response to risk*. New York, Macmillan Publishing Company.
- Rubenstein M. 1998. Edgeworth Binomial Trees. *Journal of Derivatives* 5(3). p: 20-27.
- Stevenson W. 1981. *Estadística para Administración y Economía*. Ed. Harla S.A de C.V. México.
- Torero M. 2010. *Agricultural Price Volatility: Prospects, Challenges and Possible Solutions*. Presentación en

Seminario Agricultural price volatility: prospects, challenges and possible solutions. España.  
Walpole RE, Myers RH. 1992. Probabilidad y estadística. (4ta. ed.). EUA. McGraw-Hill.

#### Fuentes de Sitios Web

- BANCO MUNDIAL. 2019. Datos sobre las cuentas nacionales del Banco Mundial y archivos de datos sobre cuentas nacionales de la OCDE. Recuperado de: <https://datos.bancomundial.org/indicador/ny.gdp.mktp.cd>
- BANXICO. 2019. El Sistema Financiero Nacional. Recuperado de: <http://www.anterior.banxico.org.mx/divulgacion/sistema-financiero/sistema-financiero.html>
- CEPAL. 2014. Comisión Económica para América Latina y el Caribe. **World Economic Situation and Prospects, 2014**. Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/74616/9\\_Perspectivasagosto2015.pdf](https://www.gob.mx/cms/uploads/attachment/file/74616/9_Perspectivasagosto2015.pdf)
- CEPAL. 2015. Comisión Económica para América Latina y el Caribe. Sobre la base de Naciones Unidas, **World Economic Situation and Prospects, Update as of mid-2015**, Nueva York, 2015; Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/74616/9\\_Perspectivasagosto2015.pdf](https://www.gob.mx/cms/uploads/attachment/file/74616/9_Perspectivasagosto2015.pdf)
- CONAGUA. 2008. Estadísticas del agua en México, Ed. 2008. Recuperado de: <http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/EAM2014.pdf>
- CONAGUA. 2011. Estadísticas del agua en México, Ed. 2011. Recuperado de: <http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/EAM2014.pdf>
- CONAGUA. 2014. Estadísticas del agua en México, Ed. 2014. Recuperado de: <http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/EAM2014.pdf>
- CONOCER. 2018. Norma Técnica de Competencia Laboral EC0020 Formulación del diseño de proyectos de inversión del sector rural. México. Recuperado de: <https://www.gob.mx/cms/uploads/attachment/file/136671>.
- FAO. 2013. La agricultura mundial en la perspectiva del año 2050. Recuperado de: [http://www.fao.org/fileadmin/templates/wsfs/docs/Issues\\_papers/Issues\\_papers\\_SP/La\\_agricultura\\_mundial.pdf](http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/Issues_papers_SP/La_agricultura_mundial.pdf)
- FAO. 2017. El futuro de la alimentación y la agricultura tendencias y desafío. Recuperado de: <http://www.fao.org/3/a-i6881s.pdf>
- FAO. 2017. Trabajo estratégico de la FAO para REDUCIR LA POBREZA RURAL. Recuperado de: [www.fao.org/3/a-i6835s.pdf](http://www.fao.org/3/a-i6835s.pdf)
- FAO. 2018. Estudios de perspectivas mundiales, datos basados en ONU. Recuperado de: <https://esa.un.org/unpd/wpp>
- FND. 2018. Financiera Nacional de Desarrollo. Recuperado de: <http://www.financierarural.gob.mx/informacionsectorrural/Panoramas/Panorama%20Papa%20%28abr%202014%29.pdf>
- Grupo Banco Mundial. (2014). Promedio detallado de precipitaciones, Recuperado de: <https://datos.bancomundial.org/indicador/AG.LND.PRCP.MM>.
- INEGI. 2009. VIII Censo Agropecuario y Forestal, 2009. Recuperado de: [www.inegi.gob.mx](http://www.inegi.gob.mx).
- INEGI. (2019). Inflación Anual. Recuperado de: <https://www.inegi.org.mx/app/indicesdeprecios/Estructura.aspx?idEstructura=112001300030andT=%C3%8Dndices%20de%20Precios%20al%20ConsumidorandST=Inflaci%C3%B3n%20Mensual>
- INFOASERCA. 2008. Escenarios futuros del cambio climático en México. Claridades Agropecuarias, marzo, Número 175, DF, México. Recuperado de: [www.infoaseca.gob.mx](http://www.infoaseca.gob.mx)
- ONU. 1992. Convención Marco de las Naciones Unidas sobre el Cambio Climático. Recuperado de: <https://www.gob.mx/semarnat/acciones-y-programas/convencion-marco-de-las-naciones-unidas-sobre-el-cambio-climatico-y-su-protocolo-de-kioto-cmnucc?idiom=es>
- ONU. 2015. World Population Prospects: revisions. Recuperado de: <https://esa.un.org/unpd/wpp>.
- PNUD. 2006. Programa de las Naciones Unidas para el Desarrollo. Avances, brechas y lineamientos estratégicos para América Latina y el Caribe. Recuperado de: <https://www.undp.org/content/undp/es/home.html>
- PNUD. 2017. Programa de las Naciones Unidas para el Desarrollo. La sostenibilidad del desarrollo a 20 años de la Cumbre para la Tierra: Avances, brechas y lineamientos estratégicos para América Latina y el Caribe. Recuperado de: <https://www.undp.org/content/undp/es/home.html>
- SAGARPA. 2017. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación 2017. Planeación Agrícola Nacional 2017-2030. Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/255627/Planeaci\\_n\\_Agr cola\\_Nacional\\_2017-2030\\_-\\_parte\\_uno.pdf](https://www.gob.mx/cms/uploads/attachment/file/255627/Planeaci_n_Agr cola_Nacional_2017-2030_-_parte_uno.pdf)
- SAGARPA. 2017. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación 2017. Planeación Agrícola Nacional 2017-2030. Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/255627/Planeaci\\_n\\_Agr cola\\_Nacional\\_2017-2030\\_-\\_parte\\_uno.pdf](https://www.gob.mx/cms/uploads/attachment/file/255627/Planeaci_n_Agr cola_Nacional_2017-2030_-_parte_uno.pdf)

- ación Agrícola Nacional 2017-2030. Segunda parte. Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/255625/Planeaci\\_n\\_Agr cola\\_Nacional\\_2017-2030-\\_parte\\_dos.pdf](https://www.gob.mx/cms/uploads/attachment/file/255625/Planeaci_n_Agr cola_Nacional_2017-2030-_parte_dos.pdf)
- SAGARPA. 2017. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación 2017. Planeación Agrícola Nacional 2017-2030. Tercera parte. Recuperado de: [https://www.gob.mx/cms/uploads/attachment/file/255626/Planeaci\\_n\\_Agr cola\\_Nacional\\_2017-2030-\\_parte\\_tres.pdf](https://www.gob.mx/cms/uploads/attachment/file/255626/Planeaci_n_Agr cola_Nacional_2017-2030-_parte_tres.pdf)
- SAGARPA - SIAP. 2018. Atlas Agroalimentario 2012-2018: la transformación productiva del campo mexicano. Recuperado de: [https://nube.siap.gob.mx/gobmx\\_publicaciones\\_siap/pag/2018/Atlas-Agroalimentario-2018](https://nube.siap.gob.mx/gobmx_publicaciones_siap/pag/2018/Atlas-Agroalimentario-2018)
- SIACON. 2017. Sistema de Información Agroalimentaria de Consulta. Recuperado de: <https://www.gob.mx/siap/prensa/sistema-de-informacion-agroalimentaria-de-consulta-siacon>
- SIAP. 2019. Servicio de Información Agroalimentaria y Pesquera. Recuperado de: [http://infosiap.siap.gob.mx:8080/agricola\\_siap\\_gobmx/ResumenDelegacion.do](http://infosiap.siap.gob.mx:8080/agricola_siap_gobmx/ResumenDelegacion.do)
- SIAVI. 2019. Sistema de Información Arancelaria Vía Internet. Secretaría de Economía. Clasificación Arancelaria: 0804.40.01 Aguacates (paltas). Recuperado de: <http://www.economia-snci.gob.mx/>
- SNCI. 2019. Sistema de Información Comercial Vía Internet. Recuperado de: <http://www.economia-snci.gob.mx/>
- SNIIM. 2017. Sistema Nacional de Información de Mercados. Recuperado de: <http://www.economia-sniim.gob.mx/nuevo/>
- Técnicas de trading. 2017. Las opciones financieras. Recuperado de: <https://www.tecnicasdetrading.com/2010/05/las-opciones-financieras.html>
- The World Bank. 2005. The world bank annual report. Recuperado de: <https://www.worldbank.org>
- UNHCR ACNUR. 2019. La Agencia de la ONU para los refugiados, comité español. Escasez de agua en el mundo: causas y consecuencias. Recuperado de: <https://eacnur.org/blog/escasez-de-agua-en-el-mundo-causas-y-consecuencias/>