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Prediction of the availability of carbon reserves through the probabilistic random walk for the year 2015 in Colombia

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Abstract. Background: From a methodology based on probabilistic random walk, apparently random phenomena as epidemic outbreaks have been studied, achieving physic-mathematical predictions with percentages higher than 90%. Objective: to predict the availability of the carbon reservoir for the year 2015 in Colombia through probabilistic random walk. Material and methods: values reported by the DANE between 1994 and 2015 of the availability of carbon reservoirs were taken and analyzed to apply a methodology based on probabilistic random walk and give a predictive value for the year 2015. Results: it was predicted a value of 67,33 for the availability of carbon reservoirs in 2015; a success percentage of 92,24% was achieved with regards to the real value reported by the DANE for the year 2015. Conclusions: the behavior of the availability of the carbon reservoirs in Colombia obeys to a predictable probabilistic behavior based on a methodology grounded in the random walk, being useful for the decision making and public policies.

1. Introduction

Through the theory of probability, it is possible to establish the possibility that an event occurs from the analysis of all possible events [1,2]. In this context, the probabilistic model of Norbert Wiener [3] was developed, which allows us to delimit the behavior of dynamics generated from non-deterministic variations, called random walks [2,3].

Carbon is the main mineral-energy resource of Colombia, in terms of the size of its reserves [4]. Proven reserves exceed the 6,611 million tons that, according to the current production line, would reach 90 years. In Colombia in 2015, the reserves of mineral carbon were 6,158 million metric tons, showing a reduction of 1.4% compared to 2014, due to an extraction of 86 million metric tons [5].

Carbon remains a cheaper option than gas in generating electricity in different regions; however, policies aimed at reducing climate change will have an impact on the future of fossil fuels. Research on capture technology, carbon storage, efficiency of conventional plants and integration of renewable energies into electricity grids will acquire a relevant role in the global trend [6].

In the framework of the probabilistic random walk, a method was developed for the mathematical prediction of the dynamics of dengue [7] and malaria [8] in Colombia, achieving a prediction of the number of infected people for 2007 with percentages of accuracy greater than 90% in both cases. The importance of carbon in nations [9,10], the relationship between the mining-energy sector and economic progress [9,11], the energy demand of populations [10] and the limited nature of resources [12] support the realization of the present investigation; by means of which it is sought to apply said methodology,



whose utility has been demonstrated in diverse contexts [7,8]. The use of an objective and reproducible methodology in the prediction of the availability of carbon reserves in Colombia contributes to a relevant problem in the economic agenda of the countries and could be a fundamental tool in the subsequent decision making.

2. Material and methods

This paper seeks to predict the availability of carbon reserves for the year 2015 in Colombia, taking into account the dynamics registered during the years 1993 to 2014, whose records [5] were obtained from the asset account of mineral resources and of the National Administrative Department of Statistics (DANE).

2.1. Definitions

Length of an annual variation of availability of carbon reservoirs is represented by Equation (1).

$$L = \sqrt{(X_1 - X_0)^2 + (Y_1 - Y_0)^2} \quad (1)$$

Where X_0 , and Y_0 are the Cartesian coordinates of the first year; X_1 and Y_1 are the coordinates for the year to be predicted and L is the length of an annual variation.

Probability of each length (L): refers to the division between the length of the annual variation over the total number of lengths, represented by Equation (2),

$$P(L) = \frac{\text{Length of the annual variation}}{\text{Total number of lengths}} = \frac{L}{TL} \quad (2)$$

Probability of availability of carbon reserves for each year $P(N)$: represented by the annual availability of carbon reserves between the total amount of the carbon reserves through Equation (3).

$$P(N) = \frac{\text{annual availability of carbon reserves}}{\text{total amount of the carbon reserves}} \quad (3)$$

Mean square deviation: it allows to determine if it is equally probable or not that the figures obtained are presented, through Equation (4),

$$P(R_n) = \frac{\text{availability of carbon reserves for each year}}{\text{Total availability of carbon reserve}} \pm \frac{1}{2\sqrt{N}} \quad (4)$$

Predictive equation: quadratic equation (Equation (5)) that allows obtaining as a solution two values that delimit the prediction.

$$Y_1 = \frac{2Y_1 \pm \sqrt{(-2Y_1)^2 - 4\{Y_1^2 + (X_0 - X_0)^2 - [P(L)^2 \times (TL)^2]\}}}{2} \quad (5)$$

2.2. Procedure

The corresponding values of availability of carbon reserves for each year during 1993 to 2014 were taken from the DANE database [1]. With this, it can be seen that the dynamics during these years has a

behavior that can be approached by the probabilistic random walk, a methodology that was applied by Rodríguez et al. in the description of other phenomena [7,8].

Initially, the lengths of the annual variations of carbon availability are made up of Equation (1). In this, two axes are located, the Y axis, in which it locates the availability of the carbon reserve; and in the axis of X, the time that elapses are located. Because the value of the X is constant, that is to say years, values of 0 will be taken since there is no variation in the time scales.

Subsequently, the construction of the probability values of each length (L) is performed by means of Equation (2), considering each length as a probability event with which the probability values of the lengths $P(L)$ are calculated.

Then we proceed to calculate the probability of carbon reserve availability for each year $P(N)$ represented through Equation (3).

Now, it is sought to determine if the found values have the same probability of occurrence, that is, if it is an equiprobable phenomenon, for which the mean square deviation is used and according to this result, it can be established if there is a load of the probability, through Equation (4).

From the last 3 consecutive years prior to the year to predict the availability of carbon reserves, this dynamic is limited and thus it is generated the prediction for the following year. For this, we obtain the average of the previous 3 years as the probability value for the length of the period of interest to be predicted, that is, the following year, incorporating the figure obtained in Equation (1) and replacing it in Equation (5), with which two values will be obtained that define the range where the value to predict is found.

Finally, a probability space is created that takes into account the tendency to decrease or increase from the immediately previous period with respect to the availability of the carbon reserve. The usefulness of this step is that it can determine the direction towards the most probable value for prediction. With the result, we proceed to make a comparison with the real value obtained in 2015 registered by the DANE [1] and thus determine the percentage of success of the methodology.

3. Results

From the previous data, it can be concluded that the probability values and the mean square deviation (see Table 1) indicate a non-equiprobable behavior of the availability of the annual carbon reserves in Colombia, finding a loading of the probability, which will determine that a prediction is made with the three years prior to the year to be predicted (see Table 2).

It was observed that the most probable frequency of occurrence was DDD (see Table 3), whose probability value was 0.54 (see Table 4). Based on the result of Equation 5, a range is obtained over which the prediction will be made. Subsequently, the behavior of the last three years is observed with respect to increases (A) or decreases (D) and over the range, the trend of A or D can be established, on which the value to be predicted is approached through an arithmetic average. Taking into account the above, it was found that the most likely event to happen was D, so the value approached the lower range of the prediction. The value obtained was compared with the figure reported by the DANE for the year 2015, which shows a percentage of success of 92.24%.

4. Discussion

This is the first work in which a methodology developed based on the probabilistic random walk is applied to evaluate the availability of carbon reserves in Colombia for 2015, achieving a success rate of 92.24%. This methodology allows us to adequately predict the values for the following year, evidencing that it is a non-equiprobable process, showing in this way that there is a burden on the probability that underlies this phenomenon. The predictions reached with this methodology would be useful for the entities involved in the mining and energy sector to make decisions for the proper management of this mineral resource.

Previously, this methodology was able to show its predictive capacity in public health phenomena, as it has been the prediction of communicable diseases such as malaria, with which percentages of success have been achieved with respect to the actual reported value of 95.6% [8] or dengue with 90.4%

[7], even being useful for predicting noncommunicable diseases such as childhood obesity in Colombia, Mexico and the United States with percentages from 97.85% to 98% [13]. In this work, predictions outside the scope of the epidemics are achieved and their application in the field of mining and energy is found as a research tool and for decision making.

Approaches have been made from the research area of accounting in which efforts have been made to establish communication channels with which programs that cover the problems of countries [14] can be established as public policies focused on sustainable development [15] with Based on reliable data, however, there are no methodologies of a predictive nature but historical records on macroeconomic issues, with which the trend has been set over the years [16-24], making it necessary to implement methodologies that allow study and be useful in accounting.

The methodologies based on the physical and mathematical theories have allowed to describe underlying patterns of the phenomena in nature allowing to simplify the focus of the investigations that usually start from a cause-effect perspective to an acausal.

In this context of methodologies with an acausal conception, procedures have been established in different fields of medicine, usually characterization and prediction. For example, research has been conducted on adult cardiac dynamics [25] establishing normality and pathology as well as the evolution between these extremes; Likewise, arterial morphometry [26], cervical erythrocyte [27,28] have been studied, as well as predictions of peptide binding to HLA class II [29] and mortality in the intensive care unit [30].

Table 1. Values of carbon availability in Colombia. No. Number of years of annual carbon availability; L: length for the annual availability of carbon; P (L): probabilistic length of the annual availability of carbon; $\pm$ DMC: mean square deviation.

Year	No.	L	P(L)	P(N)	DMC+	DMC-	DMC+ P	DMC- P
1994	333							
1995	295	38	0.120	0.086	0.094	0.077	0.008	-0.008
1996	260	35	0.111	0.076	0.084	0.067	0.008	-0.008
1997	232	28	0.088	0.067	0.076	0.058	0.008	-0.008
1998	225	7	0.022	0.065	0.074	0.056	0.008	-0.008
1999	235	10	0.031	0.068	0.077	0.059	0.008	-0.008
2000	200	35	0.111	0.058	0.067	0.049	0.008	-0.008
2001	172	28	0.088	0.050	0.059	0.041	0.008	-0.008
2002	188	16	0.050	0.055	0.063	0.046	0.008	-0.008
2003	162	26	0.082	0.047	0.056	0.038	0.008	-0.008
2004	150	12	0.038	0.044	0.052	0.035	0.008	-0.008
2005	134	16	0.050	0.039	0.047	0.030	0.008	-0.008
2006	120	14	0.044	0.035	0.043	0.026	0.008	-0.008
2007	110	10	0.031	0.032	0.040	0.023	0.008	-0.008
2008	103	7	0.022	0.030	0.038	0.021	0.008	-0.008
2009	100	3	0.009	0.029	0.038	0.020	0.008	-0.008
2010	100	0	0	0.029	0.038	0.020	0.008	-0.008
2011	86	14	0.044	0.025	0.034	0.016	0.008	-0.008
2012	83	3	0.009	0.024	0.033	0.015	0.008	-0.008
2013	83	0	0	0.024	0.033	0.015	0.008	-0.008
2014	70	13	0.041	0.020	0.029	0.011	0.008	-0.008

Table 2. Values of the three years prior to the year to be predicted. No. Number of years of carbon availability annually; L: length for the annual availability of carbon; P (L): probabilistic length of the annual availability of carbon.

Year	No.	L	P (L)
2012	83	3	0.188
2013	83	0	0.000
2014	70	13	0.813

Table 3. Probability and frequency values of consecutive occurrence of increases (A) and decreases (D) with respect to the values of carbon availability between 1994 and 2014.

Consecutive years	Increases	Increase probability	Decreases	Decrease probability
1	2	0.117	1	0.06
2		0	2	0.24
3		0	1	0.18
7		0	1	0.41
Total	2	0.12	15	0.88

Table 4. Combination of increases (A) and decreases (D) in periods of three consecutive years of the annual availability of carbon in Colombia for the period from 1994 to 2014.

Combination	Value	Probability
DDD	7	0.54
DDA	2	0.15
DAD	2	0.15
DAA	0	0.00
ADD	2	0.15
ADA	0	0.00
AAD	0	0.00
AAA	0	0.00
Total	13	1

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