Data analytics applied to the analysis of petroleum production in Brazil

Análise de dados aplicada à análise da produção de petróleo no Brasil

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Alessandra Brito Leal
Graduanda em Engenharia de Exploração e Produção de Petróleo Pela Universidade Federal do Pará.
Universidade Federal do Pará, Faculdade de Engenharia - UFPA.
Rua Raimundo Santana Cruz, s/n, São Tomé, Salinópolis – PA, Brasil.
E-mail: eng.alessandraleal@gmail.com

Thiago Rafael da Silva Moura
Doutor em Física Pela Universidade Federal do Rio Grande do Norte.
Universidade Federal do Pará, Faculdade de Física - UFPA.
Rua Raimundo Santana Cruz, s/n, São Tomé, Salinópolis – PA, Brasil
Marabá – PA.
E-mail: trsmoura@yahoo.com.br

ABSTRACT
We mine the set of data provided by the ANP (Agência Nacional do Petróleo e Gás - National Oil and Gas Agency), of petroleum production and distribution in Brazilian territory. We use modern data science techniques to collect, analyze, treat and model hydrocarbon production data from all production units operating in the period from February 2009 to 2020. We highlight the high production of hydrocarbons in the Brazilian territory related to the performance of Petrobras, responsible for about 95% of Brazilian production. We report the discovery of an apparent paradox: the Tupi field presents the highest daily production, however it is not the largest national producer, a position that belongs to the Marlim field, yet we present the data analytics techniques that we use to solve this paradox.

Keywords: Data Science, Business Intelligence, Petroleum Production.

RESUMO
Mineramos o conjunto de dados fornecidos pela ANP (Agência Nacional do Petróleo e Gás), da produção e distribuição de petróleo em território brasileiro. Utilizamos técnicas modernas de ciências de dados para coletar, analisar, tratar e modelar os dados de produção de hidrocarbonetos de todas as unidades de produção atuantes no período de 2009 até 2020. Destacamos a elevada produção de hidrocarbonetos no território brasileiro relacionada à atuação da Petrobras, responsável por cerca de 95% da produção brasileira. Reportamos a descoberta de um aparente paradoxo: o campo campo de Búzios apresenta a maior produção diária, no entanto não é o maior produtor nacional, posição que cabe ao campo de Tupi, ainda, apresentamos as técnicas de analíticas de dados que utilizamos para solucionar este paradoxo.

Palavras-chave: Ciência de Dados, *Business Intelligence*, Produção de petróleo.

1 INTRODUCTION

Big Data is an emerging phenomenon associated with data production characterized by the volume, speed, variety, veracity and value of the data. Nevertheless, Big Data is a phenomenon associated with large volumes of data, produced quickly in a variety of formats and stored in a large amount of equipment, enabling the aggregation of veracity and value to the data [1] [2] [3] [4]. The genesis of this phenomenon is in the cheapness, in the miniaturization and in the increase of the capacity to produce and store data; associated with visualization, internet, cloud computing, etc. [5]. In 2020, an average of 1.7MB of data was created per person per second. In the past two years, 90% of the world's data data has been created, 2.5 quintillion bytes are produced every day, 95 million photos and videos are shared every day on Instagram, every day 306.4 billion emails are 500 million tweets are sent. By 2025, it is expected that approximately 3,463 exabytes will be produced per day [6] [7] [8]. Approximately fifty percent of current data is structured, implying that it can be stored in a relational database made up of rows and columns. The other fraction of data is unstructured, existing in the form of emails, blogs, logs, videos and social media. This data is stored and / or delivered on / by electronic devices, accompanied by the growth in supply and demand, such as tablets, notebooks, mobile phones. Associated with this phenomenon is the accelerated growth of social networks, defining the interaction of people through the network [2] [9]. In summary, Big data is the phenomenon characterized by the following variables: the volume, speed, variety, truthfulness and value of information assets that require an unusual form of processing. The appropriate techniques for dealing with Big Data are in Data Science that discovers insight, optimizes the process and improves decision making [9]. Data science tools can help with insight, optimization and decision making in financial scoring, textual analysis, human mobility, Dark Web, academic performance and behavior patterns, including these other new scientific, technological and rules-related challenges business [10] - [16].

Companies from various branches of business have invested heavily in data science systems to work with Big Dada, including: ORACLE, My SQL, Postgre SQL, Teradata, Sybase, Hadoop, Microsoft SQL Server, IBM Netezza, etc. These systems are called tools for business intelligence. Business intelligence tools are software that collect and process a large amount of data from a variety of media and content [17]-[18]. Changes in the volume, speed, variety, veracity and value of the data require new ways of handling the data; new ways of handling data imply new ways of managing knowledge; gaining more attention from

research, non-governmental, business and government institutions, including cooperation between international institutions [19]-[27].

Following the perspective of intelligent data and information management, for the development of business rule proposals and decision making for petroleum production in Brazilian territory, we propose to analyze the data provided by ANP (Agência Nacional do Petróleo e Gás - National Agency of Oil and Gas) [27]. The data produced by ANP has sufficient characteristics to be addressed by Big Data techniques, they show growth, speed, variety, truthfulness and value. We use Power BI software to dynamically analyze, treat, model and visualize data, creating Dashboards to present oil production data in Brazil [28].

Our work follows the following schedule. First, for the reader unfamiliar with data analytics techniques, we provide an overview and qualitative view of the Power BI software, presenting the main modules of the program and the data science techniques used to implement them. Second, we present our results, highlighting all offshore petroleum production and the main onshore fields in the period from February 2009 to July 2020. We highlight production by operator, the most productive wells and fields. Finally, we report the Pré-sal seminal role for petroleum production in the national territory.

2 MATERIAL AND METHODS

Microsoft Power BI is a service software for business analysis. Microsoft provides some ways to use Power BI: Power BI Desktop, Power BI Service and Power BI premium. Power BI Desktop is an application for desktops and notebooks; while the Power BI Service is a cloud service used through the web browser; and Power BI Premium is aimed at large companies that want to run the Power BI report server locally, ensuring a larger and more stable data flow, usually running on dedicated hardware [28]-[29]. In our work we use Power BI Services and Power BI Desktop.

2.1 POWER BI DESKTOP

Power BI Desktop is the Windows version of the program. This version allows connection to local and online data sources; has a high relationship detection function for the loaded data; allows the construction of reports and functions [30].

The oil production database was imported and processed in Power BI Desktop, and then the Dashboard was created.

2.2 POWER BI SERVICE

The Power BI service is a free platform, based on the cloud service used through the web browser. It has the ability to connect to hundreds of data sources, share reports, as well as a question box so you can raise questions about the data [31].

The results of this work will be disseminated from the Power BI Service, so that it will be possible to enjoy the benefits of this platform.

2.3 POWER BI INTERFACE

Power BI has three main navigation panels: Data: this panel gives access to the data set that will be connected to Power BI (ORACLE, My SQL, Postgre SQL, Teradata, Sybase, Hadoop, Microsoft SQL Server etc.), here it occurs data processing. The base of data treated in this work was imported from Excel. Model: it is the panel that allows the establishment of the relationships between the data that was uploaded to Power BI. In this way, numerous relationships were created from tables that have similar information. Report: it is the part of the program where data visualization (in the form of graphs, tables and cards) was allowed after the import, treatment and relationship steps.

2.4 DASHBOARD CREATION

A dashboard (or report in Portuguese) is a graphical interface that provides quick views of key performance indicators relevant to a specific business objective or process. It is possible to display a web page linked to a database that allows the report to be updated constantly. In this work, the dashboard can be updated monthly according to the new disclosures of oil production data by the ANP. However, in order to be able to visualize the data, the results of this work have information from 2009 until July 2020.

2.4.1. Data Processing

We collect the oil production data provided by the ANP and import it into Power BI. To handle this data, we use the Power Query Editor interface (this interface is separate from Power BI). The function language M is the basis of Power Query, derived from the term data mashup, i.e., obtaining and combining data [30] - [32].

There are more than 600 functions in the M language that, when combined, provide a comprehensive variation for obtaining, processing and joining data. Its main concept is in the automation of this whole process, being necessary to connect only once with the data source and to treat it so that the next updates follow the same pattern [31].

We import the data into Power Query Editor to be manipulated, transformed, enriched, merged and added, only to be applied in Power BI.

2.4.2 Relationship and Data Modeling

The concept of data modeling is a logical process of relationships between different data, highlighting their possible connections to meet and respond to business needs [32]. From that, we relate the data according to the purposes we want to present.

Some tables that we list in Power BI have detailed operations data, called the Fact Table (like the Production History by Platform table). They store oil, gas and water production data that will be calculated from measurements (sum, average, etc.) and summarized in scalar values. To view the calculated information, we filter the data using the filter tool contained in the Power BI Visuals.

Other tables will have descriptive and unique data, called Characteristic Tables, which describe why, when, where, who, what and how the events in the Fact Tables were recorded. They are able to group several facts into specific attributes, categorizing them and enabling filters through these similar descriptions among several records in the Fact Table. In addition to this attribute, they are essential to make the "connection" between Fact Tables, describing common information among them, through the similar record relationship. The Characteristic Tables have few lines (between 20 to 30 lines) in the database (tables of onshore, offshore production, distribution by basin, etc.).

We visualize the data, creating two types of tables: a Fact and a Characteristic one, working through primary key and and a foreign key, i.e., communicating the relationship channel between the data in the two tables. The key that connects the other tables is the UEPs, this is a filtered column of the database, containing all platforms that produced oil from 2009 to July 2020. Following this protocol, it was possible to perform the calculations and perform the necessary procedures to display the results.

2.4.3 Calculations

To perform calculations in Power BI, we will use the so-called DAX functions, which is an expression language used to perform calculations and queries about our data models. DAX is an acronym for Data Analysis Expressions [30] - [33].

As the data was organized in such a way as to generate results with the least possible calculations, it was only necessary to merge columns, create sum and average measures, in

addition to adding new time columns from the calendar database, in order to obtain the results and create the dashboard.

2.5 VISUALS USED IN CREATING THE DASHBOARD

There are several ways to view the data, such as cards, matrices, graphs, maps, etc. Each of them is appropriate for a type of statistical data. To facilitate the interpretation of the information contained in the countless data, it was necessary to choose the appropriate look and thus present the data.

In order to define the most suitable (visual) type of graph, one must first define what is important to show from the database being analyzed, for example, presenting a distribution, comparison, composition or relationship between the production data of hydrocarbons.

In Power BI, it is possible to view the information that the database has quickly and intelligently. This was executable through the tool known as “Visual”, from the choice of Visual (matrix, graphs, maps etc.) suitable for the information to be presented, it was possible to create a complete and interactive Dashboard [30] - [33].

In addition to the conventional visualization forms, Power BI is also capable of presenting more than one information in the same graph, transforming the graph's legend into another visual, this procedure is known as a tooltip and was also explored in this work.

3 RESULTS AND DISCUSSION

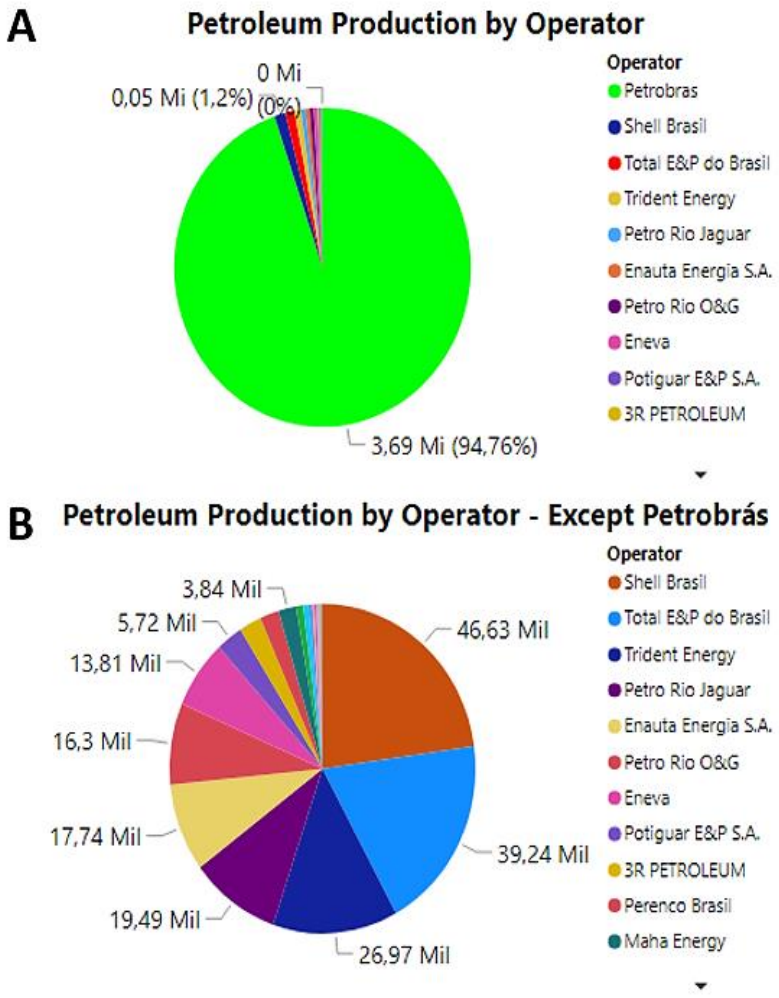
We analyze, model and relate the petroleum production data, generating graphs and tables to visualize the data. Our results have information taken from the daily production data per well, field and installation (UEPs). The data mined covers the period from February 2009 to July 2020. The values are subject to correction and do not correspond to the total national production, since it covers practically all offshore production and the main onshore fields, but presents the variables characteristic of the dynamics Big Data: volume, speed, variety, truthfulness and value. Nevertheless, we report the results of our work, presenting the production and distribution of petroleum, from mining, treatment and application of data analysis techniques to the ANP database.

Figure 1 shows the typical daily petroleum production, distributed by operator. On the left side of the image (figure 1A) it is clear that Petrobras is the largest petroleum producer with 3.68 million boe/d (barrels of oil equivalent per day), equivalent to 94.7% of national production.

In figure 1B, to visualize the production of the other operators, we remove Petrobras. It is noticed that the second largest operator in Brazil (until July 2020) is Shell with 46.63 thousand boe/d. Next, we have TOTAL with a production of 39.24 thousand boe/d.

Adding the daily production of oil produced we have 3.9 million boe/d data compatible with those shown by the National Oil and Gas Agency on its official website.

Figure 1 - Petroleum Production by Operator with Petrobras and without Petrobras (July/2020).



In figure 2, we show the petroleum production by Basin. The basin that produces the most is Santos, the second largest producer is the Campos basin, basins in the Brazilian Pré-Sal, from where a large part of the hydrocarbons produced in Brazil are explored. Then there are the Solimões, Potiguar and Recôncavo basins. It is well known that a large part of oil production comes from states located on the Brazilian coast.

Figure 2 - Petroleum production by basin in (boe/d).

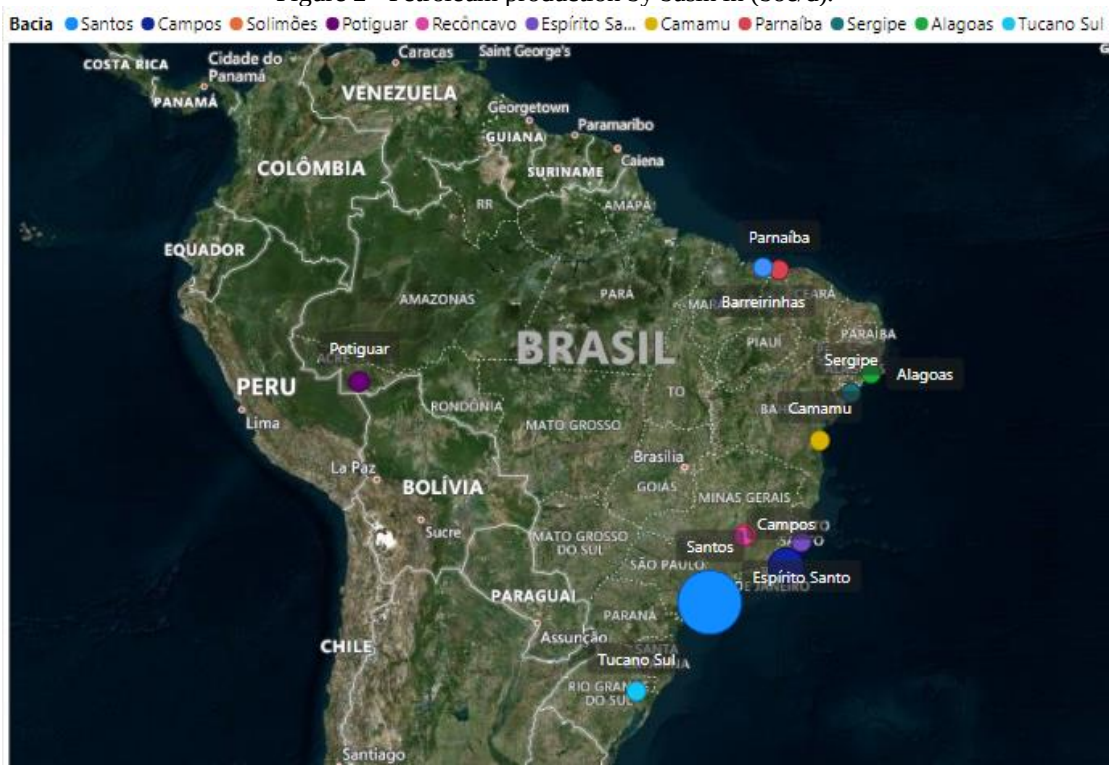


Figure 3A highlights production at sea, the wells with the highest petroleum production per day. For the Búzios field, the 7-BUZ-12-RJS well with 55.7 thousand bbl/d stands out as the largest producer. This production is much higher when compared to the largest well on the Brazilian onshore that produces only 1.692 bbl/d (well 7-TIE-1D-BA). The second largest offshore producer is well 7-BUZ-24D-RJS with 53.7 thousand bbl/d also located in Campo de Búzios.

Highlighted in figure 3B, note that the wells that most produce natural gas in Mm^3/d are those in the Búzios Field: 7-BUZ-31D-RJS, 7-BUZ-24D-RJS and 7-BUZ-12-RJS with 2,121 , 2,038 and 1,971 Mm^3/d; respectively. The production of offshore natural gas is very superior when compared to onshore production, since the largest onshore gas producing well produced only 623.19 Mm^3/d.

All 30 offshore wells, which have the highest daily production of petroleum and gas, figure 3, are in the Santos Basin in the Pré-Sal.

Figure 3 - Thirty offshore wells with higher production of petroleum.

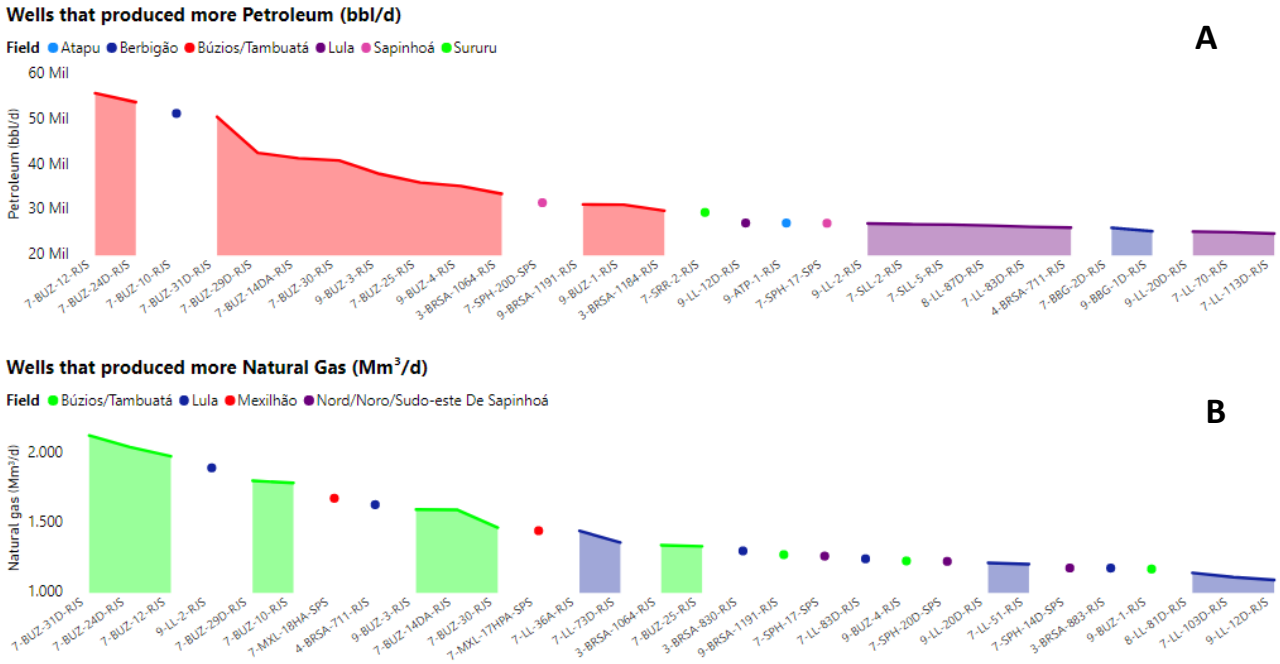


Figure 4 - Historical average production and accumulated petroleum production.

CAMPO	Inicio da Produção	Média Histórica de produção
LULA	29/12/2010	167,20
MARLIM	17/03/1991	88,57
SAPINHOÁ	05/01/2013	67,44
RONCADOR	25/01/1999	64,83
JUBARTE	12/12/2002	56,90
MARLIM SUL	30/04/1994	50,48
BÚZIOS	10/03/2015	40,40
ALBACORA	24/10/1987	27,91
BARRACUDA	29/09/1997	26,86
PEREGRINO	09/04/2011	22,48
MARLIM LESTE	09/04/2000	20,96
SUL DE LULA	01/01/2019	18,20
ALBACORA LESTE	01/06/1998	17,05
PAMPO	06/08/1998	15,56
BAÚNA	19/02/2012	15,43
CARATINGA	24/11/1997	13,58
TARTARUGA VERDE	06/07/2014	13,23
LAPA	19/12/2016	12,50
MARIMBÁ	30/04/1985	11,42
NAMORADO	30/06/1979	10,38

Figure 4 shows the historical average production of petroleum fields. The highest average field is that of Marlim and this field has the highest cumulative production. This field has been producing since 1991 (30 years of production). Because of the time producing Marlim has a large amount of accumulated oil, as highlighted in figure 5.

Looking at figure 4, clearly the second field with the highest average production is the Lula field (currently called Tupi). this is because Lula is the Pré-sal field that produces the most petroleum in barrels of oil equivalent per day, with about 10 years of production. The Tupi field started to become productive only in 2010.

Figure 5 - Accumulated hydrocarbon production per field since the start of production.

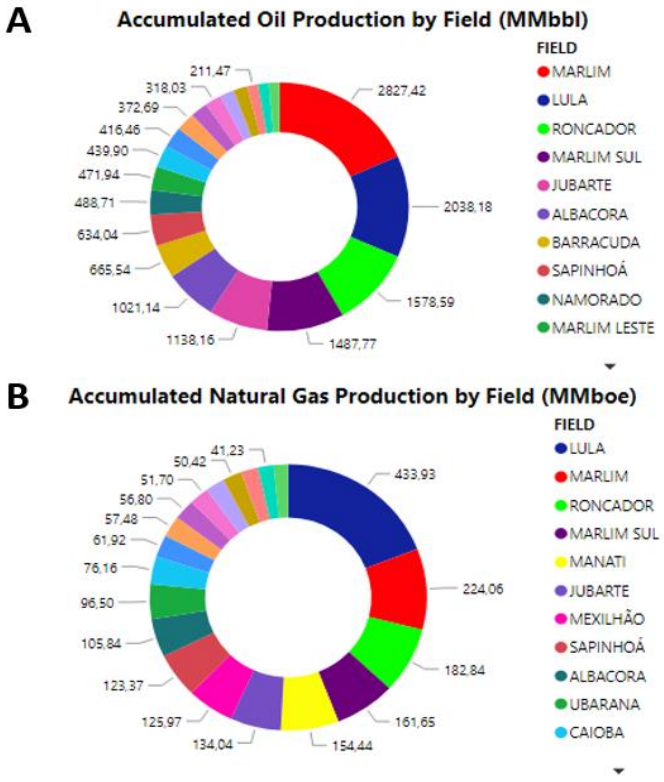


Figure 5 shows the accumulated petroleum production from the moment each field was considered a producer. In figure 5A, the field that has the highest accumulated oil production is Marlim, with approximately 2.83 billion barrels accumulated, this field has been in operation since March 1991. Presenting a vertiginously different production in relation to the Carmópolis onshore field, with an oil production of 396 million barrels.

The second largest offshore oil producing field is Tupi, with 2.04 billion barrels accumulated since the beginning of its production in December 2010. The third largest accumulated oil producer is the Roncador field with 1.58 billion barrels.

In figure 5B, we have the accumulated production of gas per field, since the beginning of production. The field that produced the most gas was Tupi with 433.93 MMboe. Producing since 1991, the second largest producer of natural gas is the Marlim field with 224.06 Mmboe. Then, since 1999, we have the Roncador field, producing 182.84 MMboe of natural gas.

When comparing offshore and Brazilian onshore gas production, we report that the field that produced the most onshore was that of Rio Urucu with approximately 267 million barrels accumulated, this field began to produce since July 1988. Although the Rio Urucu field is more mature in relation to the offshore fields, it produced less natural gas, its production is in the order of millions, while in the sea the production order is in the billions.

Analyzing the Brazilian Pré-Sal data provided by the ANP, found on the official website of the ANP [28]. We identified the field that has the highest daily petroleum production.

Figure 6 shows the hydrocarbon producing fields in the Brazilian Pré-Sal. The field with the highest daily production is Tupi, with more than 1 million barrels produced per day. Tupi, too, is the largest producer of natural gas with more than 45 million m³/d.

The second largest petroleum producer is the Búzios field with 614.9 thousand bbl/d and a natural gas production of 23.8 million m³/d.

Figure 6 - Volume of hydrocarbons produced in Brazilian Pré-Sal fields.

Campo	Petróleo (bbl/d)	Gás natural (Mm^3/d)	Produção Total (boe/d)
Lula	1.049.265,17	45.581,98	1.335.967,15
Búzios	614.903,38	23.877,33	765.087,26
Nord/Noro/Sudo-este De Sapinhoá	122.388,81	5.187,77	155.018,87
Jubarte	121.080,18	4.450,07	149.070,26
Nordeste De Sapinhoá	101.993,76	4.829,30	132.369,12
Berbigão	51.008,69	675,18	55.255,45
Lapa	32.303,83	1.103,10	39.242,09
Sururu	29.299,00	925,28	35.118,86
Anc_Norte_Atapu	26.941,59	994,87	33.199,11
Mero	10.081,91	688,10	14.409,96
Albacora	8.158,59	245,86	9.704,99
Barracuda/Caratinga	6.751,34	166,95	7.801,43
Anc_Brava/Marlim/Voador	4.502,74	138,19	5.371,91
Marlim Leste	978,46	17,39	1.087,84
Nordeste/Noroeste De Sapinhoa	0,58	0,02	0,70
Total	**2.179.658,03**	**88.881,37**	**2.738.704,99**

Figure 7 shows the proportion of petroleum field production in the Pré-Sal. In it we observe that the Tupi and Búzios fields hold most of the daily oil production, adding up to more than 75% of the production in the Pré-Sal. Tupi emerges as responsible for almost half of the total production, holding 48.78% of all the production.

Figure 7 - Proportion of oil and natural gas production by field in the Pré-Sal.

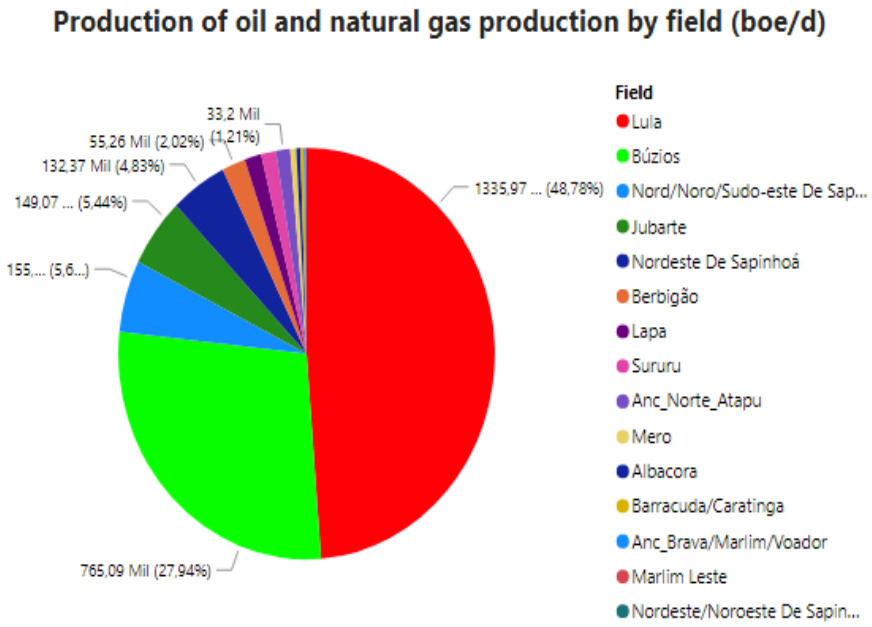


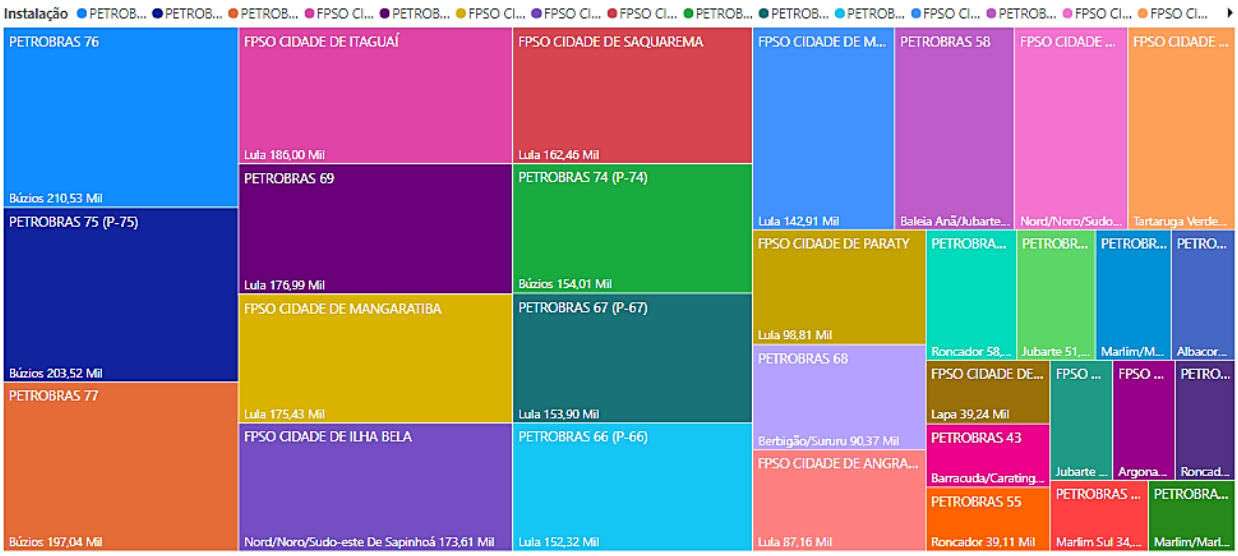
Figure 8 - Wells that most produce hydrocarbons in the Pré-Sal in boe/d.

In figure 8, we show our results in the tree graph, where you can see which wells produce the most petroleum per day. The quadrilateral sizes are associated, comparatively, with each other, proportionally relating production and tanning in the graph, i.e., the larger the area in the tree graph, the greater the daily oil production. Therefore, we observe that the largest producing wells are in the Búzios field. Surprisingly, in relation to production per field, Búzios is not the field that produces the most, its wells produce a large amount of hydrocarbons per day, i.e., Búzios has wells that produce more per day. However, Tupi is

the largest producing field in Brazil. This phenomenon is explained when we look at figures 7 and 8 respectively. We note, looking at figure 7, that the largest producer proportionally, comparing the production of the petroleum fields in the Pré-Sal, is the Tupi field. While, looking at figure 8, we note that the wells with the highest daily production are in Búzios, but this fact does not make the Búzios field the largest producer, proportionally and comparatively to all the Pré-Sal fields, espetially compared with the Tupi fields.

Figure 9, for completeness, shows the 30 stationary production units (UEPs) that produce the most petroleum per day. More than 50% of the UEPs that produce the most are from Petrobras, the largest daily production unit is in the Búzios field (P-76) producing approximately 210 thousand boe/d (oil and gas production).

Figure 9 - Top 30 Installations with the highest petroleum production per day in boe/d.



A table containing more than 601 kbytes of data was made available by the ANP. This table shows the production of oil, natural gas and water from all platforms from February 2009 to August 2020. As the ANP report is monthly, (that is, every month the companies that are inspected by the ANP, send the report of how much was produced) this table has 11 years of information on national production. From it, figure 10, we see the platforms that were producing in a specific year and how much was produced by these production units.

Figure 10 - Visualization of the production history table imported into Power BI .

4 CONCLUSION

We observed oil, natural gas and water production data from all platforms made available by ANP, from February 2009 to August 2020. We built our data analytics model using Microsoft Power BI software.

According to the hydrocarbon production data analyzed, it is possible to conclude that Petrobras has a large share of national production, 94% of the total petroleum produced in relation to companies operating in Brazil. In addition, the basin that produces the most hydrocarbons per day is Santos, followed by Campos, the Brazilian Pré-Sal basins where Petrobras acts as the largest producer.

We observed that most of the Brazilian production comes from the sea. Located in the Santos basin, the field that contributes most to production is that of Lula (currently Tupi), producing more than 1 million barrels of oil per day and 45 million m³/d of natural gas. Also, in the Santos basin, the 30 most productive oil wells are located.

Analyzing offshore production, we note that the largest volume of accumulated oil (all petroleum produced over the productive life of the field) in the country comes from fields located at sea, such as the Marlim field, which has 2.83 billion barrels accumulated; distinguishing itself from the onshore fields, with the Carmópolis field, producing around 396 million barrels.

In the period from 2009 to 2020, looking at the hydrocarbon production history of all the production units in operation, we found data on how much petroleum was produced per day in previous years and compare it with current production. The results of the analyzes made in this work are consistent with those presented by the ANP.

Our analyzes allowed us to solve the apparent paradox between the fields with the highest daily production and the largest national production. We observed that the largest producing wells are in the Búzios field. Surprisingly, even having the wells with the highest daily production, Búzios is not the most productive field in Brazil.

The largest daily national producer is the Tupi field and the largest cumulative national producer. This phenomenon is explained when we observe the production proportionally and comparatively the production of the oil fields in the Pré-Sal. When the production of Marlim is purchased the total production of the Pré-Sal, the accumulated percentage production of Marlim is less than the production of the Tupi field. Allowing the solution of this apparent paradox between the largest daily producer (Tupi field) and the largest national cumulative producer (Marlim field).

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