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UMBU TREE (*Spondias tuberosa* Arr. Cam. – Anacardiaceae): FROM EXTRACTIVE TO PLANTED CULTURE IN BRAZIL

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Submitted: *07/08/2024*
Accepted: *03/09/2024*

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Abstract: Umbu tree (*Spondias tuberosa* Arr. Cam.) is a botanical species native to the Caatinga that plays a significant cultural and economic role in Northeast Brazil. The aims of this study was to evaluate the trend in umbu fruit production over a period of 21 years and to discuss the cultivation of the species, associated with its socioeconomic and environmental advantages in the semiarid region of Northeast Brazil. Data on extractive production and the monetary value of umbu fruit were obtained from the official platform of the Brazilian Institute of Geography and Statistics. Silvicultural aspects of cultivation, management, and its market was obtained from specialized literature. Descriptive statistics of the data set and a trend analysis through regression model fitting were performed using JMP® software. A downward trend in umbu tree fruit was estimated for most states, except for Alagoas, Paraíba, and Rio Grande do Norte. Alagoas was the only one with the best average variation (74.6%) in production and price (US$ 0.83) per kg of production via extractivism. The cultivating through plantations for commercial fruit umbu production is an alternative to overcome the declining trend in extractivism, ensuring continuation of family income and environmental protection of umbu tree populations in their natural habitats.

Keywords: umbu, extinction, conservation, commercial cultivation, productive yield.

1. Introduction

Among the native botanical species of Brazil, 20% are found in the Northeast Region (GOMES-DA-SILVA et al. 2022), an area characterized by a semi-arid climate with predominance of Caatinga vegetation. Some native species stand out due to their fruits, which are highly appreciated for their distinctive and different citrus or sweet flavours. This has led to an increase in commercial demand for these fruits in recent years, based on market trends, such as Caatinga passion fruit (*Passiflora cincinnata* Mast. - Passifloraceae), cambuí (*Myrciaria tene*lla (DC.) O. Berg - Myrtaceae), mangaba (*Hancornia speciosa* Gomes - Apocynaceae), juá (*Ziziphus joazeiro* Mart - Rhamnaceae), araticum (*Annona* spp. - Annonaceae), jatobá (*Hymenaeae spp.* - Fabaceae), murici (*Byrsonima* spp. - Malpighiaceae), licuri (*Syagrys coronata* Mart. - Arecaceae), quixaba (*Sideroxylon obtusifolium* (Humb. Ex Roem. & Schult.) T. D. Penn. - Sapotaceae), and umbu (*Spondias tuberosa* Arr. Cam - Anacardiaceae). Consequently, these products have become a greater source of income and food security for low-income families in these areas (DRUMOND et al. 2000; SANTOS et al. 2012; TEIXEIRA; PIRES, 2017; GAMA et al. 2017; BIASOTO et al. 2021; CAMACAM; MESSIAS, 2022).

Umbu (*Spondias tuberosa*) is a native tree species endemic to Brazil, naturally occurring in the Caatinga (*stricto sensu*) and Carrasco areas in the states of Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, Maranhão, and Sergipe, as well as in the northern regions of Minas Gerais and Espírito Santo (BRASIL, 2024). This plant represents one of the 18 species of fruit-bearing trees in the Anacardiaceae family native to tropical America, Asia, and Madagascar, belonging to the type genus of the subfamily Spondioideae (*Spondia* L.), which holds significant economic and cultural value for local populations (MITCHELL; DALY, 2015).

Specifically, regarding the umbu tree, whose fruits are known as umbu (or imbu), a name with indigenous origin (y-mb-u meaning 'tree that gives drink') (SLOWFOOD, 2022), this tree holds significant social, cultural, and economic importance for the populations of the Northeast Brasil, generating a source of income contributing to the reduction of inequalities, due to its various uses as food by local communities, further contributing to good health and well-being (SLOWFOOD, 2022).

The edible part of the fruit is the pericarp, consisting of a succulent, slightly acidic pulp (edible) that can be consumed directly (fresh), or used in the preparation of different foods such as juice, refreshments, ice cream, compote, jams, coconut candies, and the famous "umbuzada" (a chilled drink made by blending or squeezing and straining umbu with milk), but also due to the use of the plant's roots as sources of water by locals and travellers, especially during drought periods. This latter use comprises cultural stories about muleteers, travellers, and various other historical figures of the North-eastern Caatinga, including the consumption of the umbu tree potato as a water source (FOLEGATTI et al. 2003; DRUMOND et al. 2016; NEVES, 2023).

The fruit of the umbu tree, like many native fruit species in the Caatinga, is obtained through extractivism practiced by residents of rural communities. Non-timber forest extractivism, predominantly carried out by rural communities in Brazil, holds great social, economic, and environmental significance, primarily on small properties, providing employment and contributing to household income (MENDES 1990, CAVALCANTI et al. 1999, FIEDLER et al. 2008, BARRETO; CASTRO, 2010).

http://dx.doi.org/10.5380/rsa.v20i2.96452

In order to achieve greater productive yields, in an environmentally responsible manner, the extraction of umbu fruit should be supported by organized management practices outlined by protocols, technical guidelines, and based on species knowledge, especially regarding its reproduction (BARRETO; CASTRO, 2010; LINS NETO et al. 2010). However, recurring environmental degradation in the Caatinga biome due to constant deforestation, wildfires, the indiscriminate collection of fruits in large quantities without maintaining the natural germplasm bank, as well as the foraging of fruits and plants by goats and sheep, hindering species regeneration, are the main factors threatening the species. This has led to a reduction in natural umbu tree populations, compromising genetic diversity due to habitat destruction and loss of genetic variability, particularly in areas commonly used by residents known as "fundo-de-pasto" or “bottom pastures” (FERRARO JÚNIOR; BURZTYN, 2008, QUEIROZ 2011; MITCHELL; DALY, 2015; FERRARO JÚNIOR et al. 2017; SLOWFOOD, 2022; CONCEIÇÃO; RAMOS, 2023).

Another threat to the species is predatory extractivism, involving the recurrent practice of removing the tuber (xylopodium) from adult trees in natural umbu tree populations, resulting in the death of the reproductively active adult tree. This is used for water consumption, the production of coconut candies and sweets (traditional cuisine), and flour by the Kariri indigenous people. This issue could be minimised through recommendations for good management practices of umbu extractivism (BARRETO; CASTRO, 2010; BARBATURU, 2014; CONCEIÇÃO; RAMOS, 2023).

Although it has not been officially recognized by government agencies, it is possible to assert that the species is already threatened with extinction (SLOWFOOD, 2022; MERTENS et al. 2017), as according to some researchers, it is the combination of these threats previously mentioned that may have already pushed the species to the brink of extinction. This is compounded by the absence of compensatory public policies that could promote the replanting of the species, repopulating areas where natural populations have been reduced or eliminated.

Therefore, these interventions on natural umbu tree populations could potentially affect fruit production in the medium and long term, as extractive activities have been performed continually without concern for species conservation. Moreover, the adoption of commercial cultivation systems with the species through rational planting, either pure or adopting agroforestry systems, in addition to generating decent work and economic growth for rural producers, could also be a more economically viable alternative, with possibilities of ensuring the preservation of natural species’ populations without affecting economic activity (MICCOLIS et al. 2019; SANTOS et al. 2021), while also encouraging responsible consumption and production.

In the context of loss, the performance of umbu fruit extractivism, considering temporal data sequences of production, can be understood through time series analyses, allowing for predictions about the future of extractive fruit production.

Therefore, this study aimed to evaluate the trend in umbu fruit production over a period of 21 years, its current monetary production value, and to discuss the advantages of adopting the commercial cultivation of the species associated with its socio-economic and environmental benefits in the semiarid region of Northeast Brazil.

2. Materials e Methods

2.1. Characterization of the Environment and Study Object

The semi-arid region in Northeast Brazil encompasses an area of 1,128,697 km², which is equivalent to 72.7% of the total territory of the Brazilian Northeast region, which covers a total area of 1,552,175.42 km². The local population comprises just over 26,647,700 inhabitants divided between urban (62%) and rural (38%) areas (BRASIL, 2019; 2021a; 2021b; 2022a; 2023a). In 60.09% of the municipalities in the Semiarid region, the Human Development Index (HDI) ranges from very low to low (BRASIL, 2021c).

The Phytogeographic Domain of the Caatinga, which presents significant environmental heterogeneity and floristic diversity (MORO et al. 2016), occupies approximately 76% of the territory in the semi-arid region of Northeast Brazil (BRASIL, 2021d). The average annual precipitation in the semi-arid region is around 800 mm, ranging from 1,000 mm on the east coast to around 500 mm inland. In some inland areas, rainfall values approach 1,500 mm, in areas coinciding with higher relief. The high availability of solar radiation, combined with the irregularity of the rainfall regime, results in evaporation rates ranging from 1,200 to 3,200 $mm.year^{-1}$. Average annual temperatures are quite high, ranging from 24 to 28ºC in most of the semi-arid area. The relative humidity in this region is 55%, increasing as it moves away from the central region, reaching around 75-80% transitioning to the east coast and 65-70% near the western limit (MOURA et al. 2019).

The umbu tree is a native plant species of the Caatinga and is widely distributed in semi-arid regions of Northeast Brazil. Trees of this species are xerophytic, deciduous, and adapted to soils with low fertility and low humidity, notably sandy soils. They are small in terms of size, ranging from 5-7m in height, with a short trunk that is highly branched and twisted. The canopies are wide with lengths ranging from 9-12.5m. The fruits, known as umbu, imbu, or ambu, are of significant commercial interest. They are drupes, and can be glabrous or slightly hairy, with a spherical or rounded shape varying from 2 to 5 cm in diameter and from 10-40g to 96g in weight. On average, they consist of 22% peel, 68% pulp, and 10% pit. The size of the seed varies considerably, affecting the amount of pulp per fruit, and the different appearance of the peel confirms the genetic diversity of this species. Fruits from cultivated plants, specifically the umbu-giant variety, can weigh an average of 70g, reaching values of 100g to over 120g (MENDES, 1990; LIMA; SILVA, 2016; LIMA et al. 2018; NEVES, 2023). The umbu tree has a robust root system, composed of a large network of tubers (xylopodium) capable of storing liquids and enduring the entire dry season and drought (MENDES, 1990; SLOWFOOD, 2022), which makes this species well-adapted to local environmental conditions.

http://dx.doi.org/10.5380/rsa.v20i2.96452

2.2. Data Acquisition and Analysis

The data regarding umbu fruit production in the states of the Northeast region were obtained from the official platform of the Brazilian Institute of Geography and Statistics / Production of Vegetal Extraction and Forestry - IBGE/PEVS (BRASIL, 2022b), considering production data recorded over the past 21 years (2002-2022). Additionally, volume and monetary value data for the latest production cycle (2022) of umbu fruit extractivism were obtained from the same official IBGE/PEVS platform.

We performed descriptive statistical analyses of the data obtained for umbu fruit production (and monetary value of production). This analysis included an examination of production evolution, considering the initial value (2002) compared to the final value (2022) of the historical series, as well as an analysis of the average percentage variation for all production values throughout the entire historical series analysed. The average percentage variation was calculated using Equation 1:

$$\bar{a} = \frac{\sum_{m=0}^{n}\left(ni - \frac{nf}{ni}\right) * 100}{k} \qquad (1)$$

where: ā = average percentage variation; ni = production values considered from the previous year; nf = production values considered from the subsequent year; k = total number of values (from 2002 to 2022); with production values ranging from m (2002) to n (2022).

For the data obtained from the time series from 2002 to 2022, a trend analysis was performed, which can show how a particular phenomenon behaves through a curve in relation to the time series, assessing changes and trends that have developed over time, given the complexity of curve relationships (CHAOLONG et al. 2012). The trend behaviour in the series can be estimated through various mathematical models, where the ideal model is that which best fits the available dataset (FAVARINI, 2018).

Two models were tested: first-order linear and second-order polynomial (quadratic). The additive regression model (first-order) was tested to find the curve (regression equation) that best fits the data, describing the relationship between the dependent variable Y (umbu fruit extractivism production) and the independent variable X corresponding to the study period (KLEINBAUM, 1988). The second-order polynomial model (quadratic) was tested since data fitted short-term predictions, either alone or in combination with seasonal components, and demonstrated a higher possibility of providing the best fits for estimated trend curves (WEST; HARRISON, 1997). The model used (second-order polynomial for one variable) is represented by the hierarchical generic equation, based on Montgomery et al. (2021):

The regression coefficients β0 and β1, for the first-order linear model and β0, β1, and β2 for the quadratic model, were found according to the hierarchical generic equation of Equations 2 and 3.

$$y[x] = \beta 0 + \beta 1x + \varepsilon, \qquad (2)$$

$$y[x] = \beta 0 + \beta 1x + \beta 2x^2 + \varepsilon, \qquad (3)$$

where: y[x] = expected value; β2 = quadratic effect parameter; β1 = linear effect parameter; β0 = average parameter of y when x = 0, if the data interval includes x = 0. Otherwise, β0 has no practical interpretation; ε = random error component.

The regression model for trend analysis was chosen based on its high confidence power from a statistical point of view and for presenting maximum ease of formulation and interpretation (KLEINBAUM, 1988). A trend was considered significant if the estimated model showed an adjustment with $p < 0.05$. The statistical analyses and preparation of scatter plots were achieved using JMP® software version 17.2.0 (JMP, 2023), and the results were presented in self-explanatory graphs and tables.

A technical-scientific analysis regarding the economic and silvicultural aspects of planting and commercial cultivation of umbu trees for fruit production was conducted based on a literature review of available specialized literature.

3. Results and Discussion

The volume of umbu fruit extracted over the past 21 years (2002 – 2022) in the producing states of the Northeast region of Brazil exhibited highly variable evolutionary behaviour. The coefficients (R^2) reveal the precision with which the estimated values correspond to the actual values in the dataset, where the most strongly adjusted coefficients were found in the quadratic model (second-order polynomial) for all analysed North-eastern states (Table 1).

Table 1 – Coefficient of determination (R^2) of the linear and quadratic (second-order polynomial) models tested for trend analysis ($p<0.05$), and best-fit parameter values ($\beta0$, $\beta1$, $\beta2$) for the quadratic model of umbu (*Spondias tuberosa* Arr. Cam - Anacardiaceae) production from 2002 to 2022 in the states of the Northeast region of Brazil.

States	Models	
	Linear	Quadratic
Alagoas	$R^2=0.44$ ($p=0.0009$)	$R^2=0.52$ ($p=0.0012$)
Bahia	$R^2=0.79$ ($p=0.0001$)	$R^2=0.82$ ($p=0.0001$)
Ceará	$R^2=0.45$ ($p=0.0008$)	$R^2=0.46$ ($p=0.0033$)
Paraíba	$R^2=0.37$ ($p=0.0032$)	$R^2=0.71$ ($p=0.0001$)
Pernambuco	$R^2=0.48$ ($p=0.0004$)	$R^2=0.82$ ($p=0.0001$)
Piauí	$R^2=0.03$ ($p=0.4592$)	$R^2=0.51$ ($p=0.0015$)
Rio G. do Norte	$R^2=0.50$ ($p=0.0003$)	$R^2=0.91$ ($p=0.0001$)
	Quadratic model (polynomial second order)	
States	Parameters	Trend
Alagoas	$\beta_2 = 1.2794882$; $\beta_1 = 16.681818$; $\beta_0 = -33490.11$	Upward
Bahia	$\beta_2 = -6.2640792$; $\beta_1 = -159.5039$; $\beta_0 = 328175.81$	Downward
Ceará	$\beta_2 = -0.036435$; $\beta_1 = -1.2233766$; $\beta_0 = 2492.2935$	Downward
Paraíba	$\beta_2 = 7.4682309$; $\beta_1 = 42.235065$; $\beta_0 = -84982.45$	Upward
Pernambuco	$\beta_2 = 1.9376059$; $\beta_1 = 12.544156$; $\beta_0 = 25622.177$	Downward
Piauí	$\beta_2 = 0.3061209$; $\beta_1 = -0.4051948$; $\beta_0 = 898.64619$	Downward
Rio Grande do Norte	$\beta_2 = 2.2238402$; $\beta_1 = 13.38961$; $\beta_0 = -26740.06$	Upward

The trend lines show changes in umbu fruit production through extraction, varying periodically over the analysed period, exhibiting increasing regularities based on the 5% error significance in the states of Rio Grande do Norte, Paraíba, and Alagoas. Conversely, there are downward trends in umbu fruit production in the states of Bahia, Pernambuco, Piauí, and Ceará. Regarding the states of Ceará and Piauí, the notable R^2 adjustments of 0.46 and 0.51, respectively, reflect significant data fluctuations. The distribution of production data in Piauí, with frequent peaks and troughs, inconsistent with a constant rate, could also suggest a non-trending but stable curve.

Upon further analysis of the states showing downward trends in umbu production, except for Piauí, it was possible to identify that these states represent regions with a strong tradition of umbu use and larger populations in both the Northeast region, comprising 58.9% of the total population (Bahia=26.4%; Pernambuco=16.6%; Ceará=15.9%), and the semi-arid region, concentrating 66.3% of the total population (Bahia=29.1%; Ceará=22.1%; Pernambuco=15.1%) (BRASIL, 2017; 2021b). This may be associated with the downward trend in extractive production, as umbu becomes a significant source of income, attracting numerous families and potentially reaching a production exhaustion limit due to higher fruit exploitation in these states with larger populations compared to others.

In Ceará, where the curve is adjusted for a downward trend, data segments show different trends, with half of the series showing an upward trend (from the beginning to the year 2010) followed by a sharp decrease in data disposition until 2018. Overall, production fluctuates cyclically over the period, exhibiting varying intensity and repeating mostly on a biennial basis. According to Chaolong et al. (2012), evaluating changes and trend development over time does not guarantee that a specific pattern indicating the time series curve will be found.

It is possible that this production behaviour in the state of Ceará is associated with some phenological effect due to seasonal soil and climatic factors, which are regulatory parameters of plant phenology, especially when combined with constant anthropogenic interference (MEDINA, 2007; JARDIM et al. 2023). These factors, in the umbu tree populations in the harvesting regions of this analysed state, may have influenced the occurrence of oscillations in production, generating values in a regular succession of peaks and troughs, demanding a more intense management approach in terms of extractivism activities in these environments. This temporal variation, as emphasized by Wang et al. (2008), signifies changes in trend analysis and may also express abnormalities of fluctuating values above the normal range.

No records of umbu extractivism production were found for the states of Maranhão and Sergipe. The trend curve behaviours analysed for umbu fruit production data over the studied period for the involved states in the Northeast are shown in Figure 1.

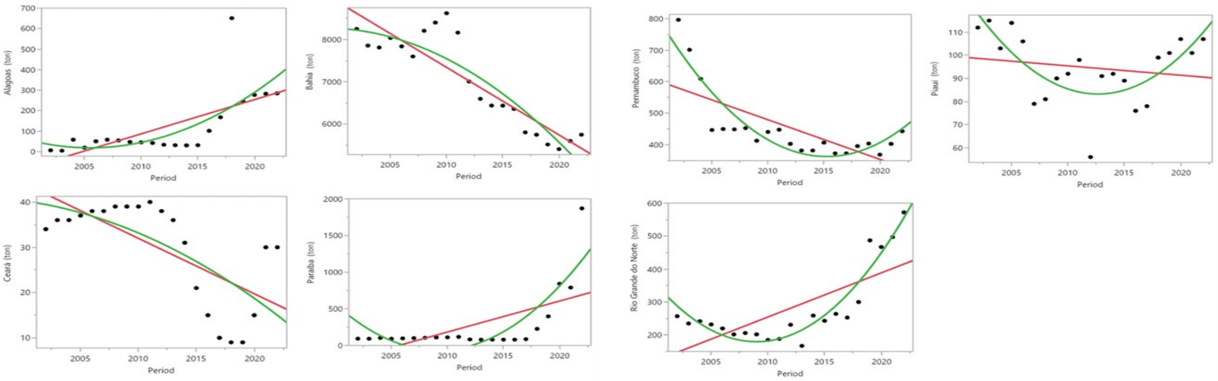

Figure 1 – Data dispersal, trend curves of linear fit (red) and polynomial fit curves degree=2 (green) of observed values over the past 21 years (2002-2022) regarding umbu production through the extractivism of umbu trees (*Spondias tuberosa* Arr. Cam - Anacardiaceae) in the Northeast of Brazil.

Umbu production through umbu tree extractivism shows a highly irregular behaviour among North-eastern states over the past 21 years, from 2002 to 2022. Regarding the production value at the beginning and end of the analysed series, there is significant evolution for states with upward trends, unlike states with downward trends (Table 2).

Table 2 – Descriptive statistics and average percentage variation over the last 21 years (2002-2022) of umbu production from umbuzeiro extraction (*Spondias tuberosa* Arr. Cam - Anacardiaceae) in Northeast Brazil.

States	Max.	Min.	Mdn.	Avg.	SD (±)	CV	Proportion 2002/2022	Average variation
			(t)					
Bahia	8,624	5,413	7,010	7,024.29	1,115.87	15.89%	-30.28%	-0.5% (±7.0%)
Alagoas	651	5	51	120.62	154.67	128.23%	3,971.43%	74.6% (±247.2%)
Ceará	40	9	36	29.53	11.22	38.00%	-11.76%	2.5% (±29.7%)
Paraíba	1,870	79	100	268.33	428.47	159.68%	1,910.75%	18.8% (±56.6%)
Pernambuco	796	369	413	454.38	111.37	24.51%	-44.35%	-2.2% (±8.9%)
Piauí	115	56	98	94.619	14.72	15.56%	-4.46%	1.0% (±20.0%)
Rio Grande do Norte	572	167	242	281.38	116.94	41.56%	122.57%	3.2% (±24.1%)

Where: Max = maximum value; Min = minimum value; Mdn = median value; Avg. = average value; SD (±) = standard deviation of the mean; (t) = ton/tonne; CV = coefficient of variation; Average variation in percentage over the entire analysed historical series.

Regarding the production value at the beginning and end of the analysed time series, Alagoas showed a 3,971.43% increase, going from 7 tons (2002) to 285 tons (2022), along with an average variation over the 21-year production period of 74.6% (±247.2%). Paraíba, with a 1,910.75% increase, jumping from 93 tons (2002) to 1,870 tons (2022), had the second highest average variation of 18.8% (±56.6%). Rising from 93 tons in 2002 to 572 tons in 2022, Rio Grande do Norte also showed significant growth (122.57%) between the initial and final periods of the considered series, and although presenting a smaller average variation, it was still positive at 3.2% (±24.1%).

While in Bahia, despite accounting for the largest volume of umbu production in the entire Northeast throughout the historical series, with an average annual production of 7,024.3 (±1,114.87) tons, it exhibited a 30.28% decrease between the beginning and end of the series, dropping from 8,252 tons (2012) to 5,753 tons (2022), with a decreasing average variation of -0.5% (±7.0%), reflecting its consistently downward trend.

Similarly, the downward trends in the states of Pernambuco and Ceará, and the undefined trend in Piauí, reflect the decreases in the production rate between the beginning and end of the analysed series. Pernambuco showed a decrease of 44.35%, going from 796 tons in 2002 to 443 tons in 2022, with a negative average variation of -2.2% (±8.9%).

Despite presenting insignificant values in umbu extractive production, Ceará and Piauí still experienced declines in production when comparing the initial and final values of the analysed time series. Production in Ceará decreased by 11.76%, going from 34 (2002) to 30 (2022), maintaining a positive average variation of 2.5% (±29.7%). Piauí presented a negative balance of 4.46%, dropping from 112 (2002) to 107 (2022), despite a positive variation of 1.0% (±20.0%) over the entire analysed series of umbu extractive production.

According to Conceição and Ramos (2023), one of the factors contributing to the decrease in production, in addition to deforestation, wildfires, phenological effects, or low regeneration of the species, is also due to the constant and uncontrolled growth of extractivism. The significant production amount in tons during the analysed period, attest to the impact of constant and uncontrolled extractivism, which can lead to the environmental loss of the species by interfering with its local regeneration. Additionally, the density of natural umbu populations in the Caatinga, ranging from 9 ind.ha^{-1} to 0.3 ind.ha^{-1}, with an average value of 2.92 (±2.73) ind.ha-1 (MERTENS et al. 2017), may have direct implications for the decrease in fruit production, probably due to anthropogenic pressures. Another important aspect is the high industrial demand (for jellies, sweets, pulps, ice creams), which involves boiling the fruit and killing the seed, thus destroying the necessary germplasm bank for the maintenance of the species.

Considering the current value of production in 2022 (the last umbu fruit extractive production campaign in the Northeast region of Brazil available from IBGE), it can be observed in Table 3 that a quantity of just over nine thousand tons was generated, corresponding to a monetary value of over 14.1 million reais (US$ 2.82 million). Bahia accounted for more than 60% of this total production, followed by Paraíba with approximately 20%. In terms of production relative to monetary value, Alagoas and Ceará, despite low production, presented the maximum and minimum values, respectively, compared to the regional average. Bahia and Rio Grande do Norte were the only ones with values relatively close to the regional average.

Table 3 – Distribution of the amount produced and the monetary value of umbu fruit production through extractivism of umbu trees (*Spondias tuberosa* Arr. Cam - Anacardiaceae) in the year 2022 across the states of the Northeast region of Brazil.

States	Amount		Production value*		(US$.kg^{-1})*
	(t)		(Thousand US$)		
Bahia	5,753.00	63.5%	1,876.00	66.3%	0.33
Paraíba	1,87	20.6%	356.20	12.6%	0.19
Rio Grande do Norte	572	6.3%	136.80	4.8%	0.24
Pernambuco	443	4.9%	173.60	6.1%	0.39
Alagoas	285	3.1%	237.80	8.4%	0.83
Piauí	107	1.2%	45.60	1.6%	0.43
Ceará	30	0.3%	4.20	0.1%	0.14
Nordeste	9,06	100.0%	2,830.20	100.0%	0.31
Average	1,006.70		314.47		0.28
SD (±)	1,873.90		598.30		0.26

Where: (t) = ton/tonne; (US$.t^{-1}) = relative value of the quantity produced by the production value; SD (±) = standard deviation of the mean. (*) = Values converted from Brazilian currency (reais) to North American currency (dollars), considering the exchange rate of R$ / US$ 5.00 in 10/26/2023 (Brasil 2023b).

In terms of monetary value in the Brazil, the average production value found of US$ 0.30 per kg can generate a theoretical value of US$ 15.00 with direct sale of the product in natura after harvesting a 50 kg sack (US$ 0.30 x 50 kg), for example. However, it is still very common to sell the product in natura after harvesting at very low prices, ranging from US$ 4.00 to US$ 7.00, and sometimes as low as US$ 1.00, for the same 50 kg sack (CONCEIÇÃO; RAMOS, 2023). In such cases, the producer often ends up with less than US$ 0.20 per kg of their production (MAYNART, 2019), although much higher values are obtained through direct sales at markets and in streets of the North-eastern state capitals during the harvest season, such as Salvador, where one kilogram (900g) of the fruit in natura can cost between US$ 0.40 e 0.60 (MAYNART, 2019; FRANCO, 2020). Additionally, when transformed into jam, sweets, etc., this same 50 kg sack generates a net revenue of up to US$ 26.00, according to Conceição and Ramos (2023). This suggests that diversification is a viable alternative for adding value to the product, thus obtaining better economic returns.

Similarly, expanding horizons and market specificities, since direct sales at open-air markets or to intermediaries have been the main means of marketing fruits obtained from the extractivism of native species in the Caatinga in natura form, as observed by Santos et al. (2012), Gama et al. (2017), and Conceição and Ramos (2023). Not to mention that the total volume of native fruits marketed in natura has been small compared to other commercial fruits (WATANABE; OLIVEIRA, 2014).

As such, authors like Santos et al. (2012) and Camacam and Messias (2022) emphasize that many of the fruits found in the Caatinga, despite their economic potential, are only appreciated by the local population. Possibly related to this, according to these authors, is the lack of knowledge among producers, industry, and the populations of major urban centres about native fruits and their nutritional potential.

Another potential alternative that can contribute to increased family income, has been the production and sale of pickles made from xylopodia obtained from cultivated seedlings (CAVALCANTI et al. 2007). This not only adds value but also helps mitigate threats to trees from natural populations when their xylopodia are removed.

In terms of production, a naturally occurring umbu tree from the Caatinga reaches an annual production of 300 kg of fruits, according to Barreto and Castro (2010), considering an adult plant producing 15 thousand fruits weighing 20 g per fruit, on average. For cultivated umbu trees, on the other hand, with the giant-umbu variety weighing an average of 70 g per fruit (NEVES, 2023), the annual fruit production can be around 1,050 kg, considering the same 15 thousand fruits (70g x 15 thousand = 1,050 kg) produced per plant. This shows that fruits from cultivated umbu trees represent a real gain that is three times higher than the production from the extractivism of naturally occurring umbu trees found in the Caatinga. This can be even higher, considering that the giant-umbu variety can yield fruits weighing from 100 to over 120 grams on average, according to Neves (2023).

In terms of productivity, the annual harvest of cultivated umbu trees with a spacing of 10 m x 10 m, considering the value of 1,050 kg per tree per year, is approximately 105 tons per hectare (100 plants x 1,050 kg). On the other hand, the productivity from extractivism with naturally occurring umbu trees in the Caatinga with an average density, ranging from 6 to 8 plants per hectare, as mentioned by Barreto and Castro (2010), is between 1.8 tons and 2.4 tons, which is 300 kg x 6 trees and 300 kg x 8 trees, respectively. This clearly shows that the productivity of cultivated umbu trees (giant-umbu variety) generates significantly higher economic gains than the productivity achieved through extractivism.

The productive approach to umbu cultivation allows us to understand that the expected socioeconomic results become more predictable and advantageous, with more favourable conditions for planning and controlling activities, enabling more informed decision-making. Consequently, at the end of the production chain, this reflects in the possibility of greater profitability with better economic gains through productivity effects, planned logistical and production costs, where extractivism with low productivity and decreasing and uncertain trends over time cannot guarantee future possibilities of real gains.

To achieve this, high-yield commercial planting requires the implementation of appropriate techniques, starting with the selection of the best available genetic materials, for example the giant-umbu variety, from which vegetative propagation is carried out by the grafting method (with a slit opening in the rootstock), as this technique offers the best advantages for the full development of the plant such as nutritional efficiency and rapid growth. And without the risk of tipping over when mature, since the method promotes the development of xylopods in the rootstock, which does not occur in other methods of vegetative propagation, such as cutting (ARAÚJO et al. 2016; FIOR; NEVES, 2023; GUIMARÃES et al. 2023). Additionally, it enables fruiting from the fifth year of age on average, surpassing seed propagation and regenerants, which take more than 10 years to fruit.

Therefore, in addition to the benefit of umbu tree cultivation enabling productivity and higher profitability by adopting new production and fruit processing technologies and by marketing production in different market niches, as noted by Folegatti et al. (2003), Lima et al. (2018), and Camacam and Messias (2022), umbu tree cultivation also contributes to keeping the species protected from the risk of extinction (MITCHELL; DALY, 2015).

Furthermore, this and other silvicultural information about implantation (pure or intercropped plantations in agroforestry systems), management, fertilization, pruning, pest control; vegetative propagation procedures (especially grafting) of umbu trees; and aspects of quality, markets, and marketing of umbu fruits, can be easily found in books and articles published by different authors, for example, Araújo et al. (2000), Batista et al. (2015), Fonseca (2015), Drumond et al. (2016), Donato et al. (2019), Gonçalves et al. (2019), Miccolis et al. (2019), and Neves (2023).

On another note, in addition to representing a multipurpose species, providing food (fruits), wood, and fodder for domestic animals (SAMPAIO et al. 2006), for example, umbu trees play an important ecological role in their natural habitats, through interactions with a wide associated biodiversity, maintaining and conserving floral visitors such as wasps, butterflies, ants, flies, and bees (BARRETO; CASTRO, 2007; NADIA et al. 2007; ALMEIDA et al. 2011), and through interactions with other animals, such as the white-lipped peccary (*Mazama gouazoubira* Fischer, 1814), the agouti (*Dasyprocta* cf. *prymnolopha* Wagler, 1831), the collared peccary (*Tayassu tajacu* Linnaeus, 1758), the crab-eating fox (*Dusicyon thous* Linnaeus, 1766), and the six-banded armadillo (*Euphractus sexcinctus* Linnaeus, 1758), which act as natural dispersers of umbu fruits and seeds (CAVALCANTI et al. 2009).

It is important to note that although different insect species can pollinate umbu trees, as observed by Almeida et al. (2011), bees are the main pollinators of this species (MITCHELL; DALY, 2015), especially stingless native bees (Meliponini) such as *Trigona* spp., *Frieseomelitta doederleini* (Friese, 1900), *Frieseomelitta languida Moure*, 1990, *Frieseomelitta meadewaldoi* (Cockerell, 1915) [identified as *Frieseomelitta francoi* (Moure, 1946)], in addition to social wasps (family Vespidae) such as *Polistes canadenses* (Linnaeus 1758) and *Polybia sericea* as potential pollinators for the umbu species (BARRETO et al. 2006; BARRETO; CASTRO, 2010; KILL et al. 2016). This is another important gain-to-gain association, as using stingless bees for directed pollination of umbu trees can increase fruit production, in addition to generating financial gain through honey production by bees, resulting in more income for the producer.

The absence of wild animals as natural seed dispersers of this botanical species and the significant presence of goats and sheep foraging on fruits and young seedlings (since the leaves have a pleasant taste even for humans) can compromise the natural regeneration of umbu trees in the Caatinga, the establishment of new seedlings, constituting an additional reason for great concern related to the conservation of this plant species (CAVALCANTI et al. 2009).

Therefore, the restoration of species populations through replanting or natural regeneration management in disturbed areas, whether in permanent preservation areas (PPAs), pasturelands, or legal reserves (LRs); the establishment of conservation units (CUs) in Caatinga remnants and the constant presence of regulatory agencies, along with the implementation of environmental education campaigns aimed at rural communities, can contribute to the protection of natural populations and their associated biodiversity. This also makes umbu tree populations in these areas an active in situ arboreal germplasm bank (BAGA). Nonetheless, while preserving this genetic resource, it is important to ensure the economic activity of rural community residents through the production of umbu fruits by implementing commercial plantations with superior genetic material (for maximum use of productive capacity) and employing appropriate techniques, thus ensuring productive success with real gains in terms of production volume and final product quality. This also includes intercropping with other crops, increasing beekeeping, and other sustainable activities. Therefore, we can conclude that umbu fruit extractivism can be improved by following specific management practices, which are systematized based on the knowledge of experienced extractivists and research conducted in various regions, as pointed out by Barreto and Castro (2010).

4. Conclusion

The extractivist production of umbu fruits (*Spondias tuberosa* Arr. Cam - Anacardiaceae) in the Northeast region of Brazil showed upward trends in the states of Alagoas, Paraíba, and Rio Grande do Norte, with a downward trend in Bahia, Pernambuco, and Ceará, and uncertainties in the state of Piauí.

Cultivating umbu trees through cultivated plantations for high-yield fruit production is a viable economic option that contributes to overcoming the downward trend in extractivist production and ensures employment and family income. Additionally, it promotes environmental protection for umbu tree populations in their natural habitats, which should be conserved for maintaining *in situ* germplasm and use by local communities, provided they are well managed when necessary.

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