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Social and environmental impacts of the adoption of a variety of table grape in the region of vale do São Francisco–Brazil

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Abstract. The aim of this article is to explore and analyse the socio-environmental implications associated with the cultivation of the "BRS-Vitoria" table grape variety. Focusing on its adoption by farmers in the Vale do Submedio São Francisco region in Brazil, this study delves into the diverse impacts and changes brought about since its introduction, encompassing both the social and environmental dimensions of agricultural practices in the area. This study was guided by the framework of technological change theory in order to comprehend the adoption of new technology and its ramifications for sustainable development under the technology adopters' perspective. To achieve this, we employ the AMBITEC-Agro Methodology, a comprehensive tool developed by the Brazilian Agricultural Research Corporation (Embrapa). Our findings reveal that the adoption of the BRS Vitoria grape variety has significantly enhanced the income of farmers, surpassing that of previous varieties. Furthermore, its cultivation has yielded environmental advantages, primarily due to its reduced reliance on chemical inputs. The database for this study was constructed from 29 interviews, which, while insightful, may not fully capture the entire spectrum of farmers' perspectives. The study could spur further research into developing other crop varieties that are both economically beneficial and environmentally sustainable, following the model of BRS Vitoria.

1. Introduction

Sustainable agriculture faces challenges like water scarcity, land degradation, and reliance on chemicals, heightened by the need for food security in growing populations. While there's no single definition of agricultural sustainability, it broadly involves using environmental resources efficiently and sustainably. Understanding the drivers of sustainability, including demographic and socio-economic factors, is crucial, and there is a pressing need to develop detailed, pragmatic and responsive methods for effectively assessing sustainability.[1]

Assessing sustainability presents significant challenges due to the multifaceted nature of the concept, the constraints inherent in methodologies that rely primarily on quantitative data, and the critical role played by the user interface of these tools in the evaluation process. The available frameworks for evaluating agricultural sustainability are based on distinct interpretations of sustainability and designed to suit a range of end-users and specific situations. Achieving the "best" framework is complex and subjective, as different frameworks are based on different sustainability definitions, target diverse end-users, and are built for specific contexts.

The literature brings several tools and methods developed for this purpose, including indicator lists, environmental assessments, indexes, linear programming tools, and trade-off models. The use of indicator lists is especially common. Indicators, defined as quantitative measures for assessing policy or management strategy performance, are central to sustainability assessments. However, there are challenges like unclear selection processes, failure to consider agriculture's multi-functionality, integration issues, and gaps in knowledge application. [2]

Despite its typical bottlenecks, such as complexity and aggregation, value judgments, cultural context and holistic approach, Indicators are widely used to understand how changes can affect the society, the environment and the economy. The plethora of tools that can help to understand

and to monitor complex system, though often confusing, can also be useful for anticipation of sustainability-related phenomena and, hence, for decision-making by a variety of actors. [3]

The scrutiny of technological outcomes by agricultural research institutions worldwide has escalated in significance. These entities bear the vital duty of providing society with transparent and accurate assessments regarding the efficacy of their endeavours. Such accountability is paramount to guarantee that the advancements and innovations they introduce are not only effective but also yield positive and far-reaching benefits for the wider community, by guiding research towards areas with high potential payoffs, reducing uncertainties and increasing positive impacts. [4]

In this sense, the application of Nelson and Winter's theory of evolutionary technical change highlights the critical role of specialized skills in promoting change and innovation in the productive sector. The theory highlights the importance of flexible adaptation rather than strict optimization in response to environmental variability and market dynamics. In this context, routines and practices need to adapt to changing conditions, making the organization's “memory” effective. For the purposes of innovation, this is crucial, as the introduction of new techniques and processes requires careful integration with existing practices. [5]

Embrapa, Brazil's federal agricultural research institution, encompasses a network of 43 thematic research centres spread across the nation. As a publicly funded organization, it has been a pioneer in Latin America in developing methodologies for evaluating the technologies it develops. This aspect of Embrapa's work has received recognition at an international level. For the past twenty years, the institution has consistently published annual Social Reports [6]. These reports detail the societal benefits that arise from public investment in Embrapa, particularly in terms of developing new technologies for the agricultural sector. The documentation of these outcomes provides a clear picture of how public funds are utilized in fostering agricultural innovation and contributing to societal advancement.

Among its research centres, Embrapa Uva e Vinho specializes in research related to table grapes, among other topics. A significant part of its work involves the development of new table grape varieties. This initiative serves as an alternative to varieties created by private companies from the northern hemisphere, which require payment of royalties by farmers. By focusing on the development of its own varieties, Embrapa Uva e Vinho not only contributes to the diversification of grape options available to farmers but also reduces dependency on externally developed, royalty-bound varieties [7]. This approach supports local agricultural practices and provides economic benefits to Brazilian grape growers by offering cost-effective, regionally adapted grape varieties.

Since 2018, Embrapa has been conducting an assessment of the socio-environmental impacts resulting from the adoption of its table grape variety, BRS Vitoria [8], [9], [10], [11]. This variety, which was released for commercial use to farmers in 2012, has seen widespread adoption in Northeast Brazil, particularly in the Vale do Submédio São Francisco region.

The objective of this article is to examine and understand the socio-environmental impacts linked to the cultivation of the "BRS-Vitoria" table grape variety. With a specific focus on its adoption by farmers in the Vale do Submédio São Francisco region of Brazil, the study investigates the various effects and transformations that have occurred since the variety's introduction. This analysis covers both social and environmental aspects of agricultural practices in the region, based on the adopters' view of the implications of growing BRS-Vitoria.

2. Literature review

2.1. The Northeast irrigated grape farming and BRS Vitoria

Irrigated fruit farming in the São Francisco Valley, particularly in the municipalities of Petrolina and Juazeiro presents a diverse range of fruit and vegetable production. The region, which was once economically underdeveloped and impoverished, has transformed into a major hub for high-value fruit production, primarily for export. Irrigated agriculture in this region has evolved to contemporary techniques since the 1970s, significantly influenced by the Brazilian Federal Government's initiatives. The development of irrigated fruit cultivation has spurred growth in other sectors. Other than that improving the skill sets of farms and the role of a conducive environment in fostering human capital development. This includes factors like living standards, formal education, and a culture of innovation and entrepreneurship [12].

The success of fruit production in this region, overall table grape, attributed to the use of irrigation and advanced technologies, allows for year-round production and supplying both domestic and international markets, especially the European Union and the United States. Advances in genetics and plant breeding have led to the introduction of new cultivars, developed by Embrapa and other breeding companies, replacing traditional varieties and doubling average yields to 50 tons per hectare with two annual harvests. These newer cultivars require less management, use fewer growth regulators, and offer improved quality and flavors. This shift has not only consolidated domestic consumption of seedless grapes but also reduced imports, notably from Chile. This increased production did not result in a proportional expansion of cultivated areas; instead, land-saving technologies such as higher plant density and efficient training systems were employed [13].

Developed by the Brazilian Agricultural Research Corporation (Embrapa), BRS-Vitoria is a table grape variety characterized by its black-skinned berries and vigorous growth profile. This cultivar exhibits adaptability across diverse climatic conditions, with notable efficiency in vineyard establishment during the first year, especially in tropical regions. It yields approximately 25-30 tons of grapes per hectare per cycle.

In practices involving up to three cycles, the yield is estimated to be between 16 to 24 tons per hectare per cycle. The BRS Vitoria variety is recognized for its balanced sugar-acid profile, yielding a raspberry flavor with minimal astringency. Additionally, it demonstrates tolerance to downy mildew, a prevalent grape disease. Post-harvest assessments indicate minimal berry loss and stable sugar-acid balance, suggesting potential for consumer acceptance and viability in export markets [14], [15].

2.2. Impact assessment

Since the early 2000s, Embrapa has shifted its impact assessment methodology from a solely economic focus to a comprehensive, multidimensional approach which includes the assessment of environmental, social, knowledge, training, and political-institutional impacts of agricultural technologies. Embrapa has developed creating models for assessing environmental and social impacts influenced by the International Food Policy Research Institute, allowing for a more holistic evaluation of Embrapa's projects, encompassing economic, social, environmental, and other impacts. This integrated process results in detailed reports that are crucial for strategic decision-making and management at Embrapa, and the methodology is designed to be flexible, catering to the unique aspects of each developed technology [16].

Embrapa employs, amongst others, the Ambitec-Agro system of socio-environmental performance indicators for assessing the impacts of agricultural innovations. This adaptable system caters to various technologies and different rural, environmental, and socio-economic contexts, and it encourages active participation from technology users for practical knowledge integration. It integrates concepts such as 'life cycle' analysis and environmental vulnerability into its impact assessments, expanding its scope to cover biotechnologies, nanotechnologies, and broader sustainability analyses. This impact assessment system, crucial to Embrapa's technological management, informs its Social Balance report and supports sustainable strategies. It offers a practical, cost-effective, multi-criteria assessment approach, utilizing matrices for indicator weighting and involving extensive fieldwork, data analysis, and reporting to minimize negative impacts and enhance positive outcomes [17] . This methodology (Ambitec-Agro) was the one adopted in the present study and further details about its operational aspects are detailed in section 3 of this paper.

3. Methodology

3.1. The study area

The present study seeks to understand the socio-environmental impacts of adopting the table grape cultivar "BRS-Vitória", developed by Embrapa, by producers in the Vale do Submédio São Francisco region, in 29 irrigated land farms in the years 2018, 2019, 2021 and 2022 (Figure 1). The municipalities are located in the sub-middle region of the São Francisco Valley, in Petrolina, Pernambuco, and Juazeiro, Bahia.

3.2. Research methods and techniques

The methodology used to gather and analyze data was Ambitec-Agro [17], and 29 producers, technicians, and managers of rural properties located in the said region were interviewed, between October and November of the years 2018, 2019, 2021, and 2022.

The Ambitec-Agro methodology is based on a system that consists of a set of electronic spreadsheets in which researchers, when interviewing producers, technicians, or managers of agricultural companies, record notes assigned to different indicators in the face of such interviews when comparing the adopted table grape variety (BRS-Vitoria) with a variety previously implanted in their areas. These notes express their perception in relation to improvement (positive notes), worsening (negative notes), or no change (zero value) compared to the previously used technological asset.

The evaluation criteria are predefined by the system and are composed of a specific set of indicators, which in turn are related to the topics under analysis. Each note is assigned based on specific weights, depending on the potential and nature of the impact associated with each indicator, in terms of its potential, namely: "punctual", i.e., on the property; "local" occurring on the property as a whole, or in the "surroundings" of the property (neighbors, rural neighborhoods, districts, or municipality), or "not applicable", if the indicator is not relevant.

The notes assigned by the interviewees, which can be -3 (significant negative change), -1 (small negative change), 0 (no noticeable change), +1 (small positive change), +3 (significant positive change), are then summed, considering the corresponding weights, with the aim of calculating an index for each criterion. This index can vary between -15 to +15, reflecting the evaluation of the socio-environmental impact related to each criterion.

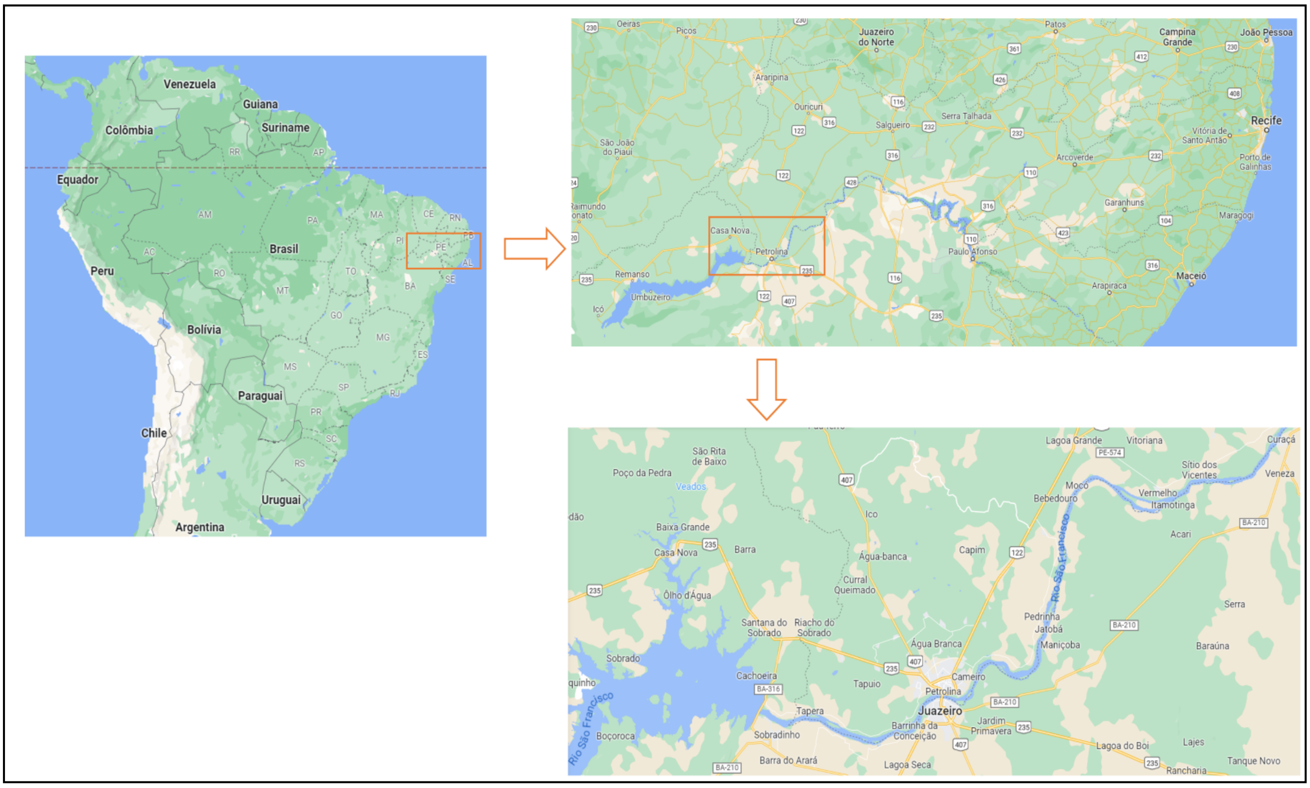

Figure 1. Map of the region assessed.

Table 1. Example of notes assigned by a hypothetical interviewee to the component indicators of the Criterion "Change in Land Use" (hypothetical values). Source: extracted from the Ambitec-Agro system.

TECHNOLOGY EFFICIENCY	What socio-environmental changes have been observed in direct land use variables?						
Direct Land Use Change			Productivity per unit of área (land sparing effect)	Fire Prevention	Carbon Stock	Productive Biodiversity	Weighting Factor
Weighting Factors (k)			0,25	0,25	0,25	0,25	1
Scale of occurrence=	Not applicable	(mark with an X)					
	Punctual	*1*					
	Local	*2*					
	Surroundings	*3*	3	0	0	0	
Impact coefficient = (change coefficients * weighting factors)			3,75	0	0	0	**3,75**

For example, Table 1 above, extracted from the Ambitec-Agro System, displays (hypothetical) data regarding the Criterion "Change in Land Use", which is constituted by the indicators: "Productivity per area", "Fire Prevention", "Carbon Stock", and "Productive Biodiversity". In this illustrative example, the sum of the indicators, multiplied by their respective weights (weighting factors), for this criterion totals +7.50. Such a value is called the Impact Coefficient. Next, the Criteria (27 in total), are classified, according to their nature, into "Aggregated Indicators of Technology Impact", as shown in the (hypothetical – not real data) example in Table 2.

Once the coefficients are consolidated, the calculation of the values for the Integrated Indices (Table 3) is carried out based on the importance of each criterion, which was previously estimated/defined by the researchers in consultation with Embrapa's professionals who hold expertise on the said technology.

From the integrated indices, the Impact Indices for the dimensions of sustainability: Environmental, Economic, and Social, as well as the General Impact Index for the technology (Table 4) are then mathematically estimated. The average of such indices, for the group of interviewees, along with a broader economic and institutional analysis, helps to compose the information that integrates, amongst other technologies developed by Embrapa's Research Centres, the "Embrapa annual Social Balance" (or Social Report).

Table 2. Technology Impact Coefficients (hypothetical values). Source: adapted from the Ambitec-Agro system.

TECHNOLOGICAL EFFICIENCY	
Change in direct land use	3,75
Change in indirect land use	-3,75
Water consumption	0,00
Use of agricultural inputs	9,00
Use of veterinary inputs and raw materials	0,00
Energy consumption	0,00
Own generation, utilization, reuse and autonomy	-1,50
ENVIRONMENTAL QUALITY	
Emissions to the atmosphere	0,00
Soil quality	0,00
Water quality	0,00
Biodiversity conservation and environmental restoration	0,00
RESPECT TO CONSUMER	
Product quality	3,50
Social capital	0,00
Animal welfare and health	0,00
JOBS / OCCUPATION	
Capacity building	0,00
Qualification and job offer	-0,90
Quality of employment and occupation	0,00
Equity among genders, generations and ethnicities	-1,25
INCOME	
Income generation	9,00
Value of rural property	0,25
HEALTH	
Occupational safety and health	0,00
Food security	11,00
MANAGEMENT / ADMINISTRATION	
Dedication and profile of the manager	0,00
Marketing condition	0,00
Residues disposal	0,00
Management of chemical inputs	0,00
Institutional relationships	0,00

Table 3. Integrated Indices calculated by Ambitec-Agro (hypothetical values). Source: adapted from the Ambitec-Agro system.

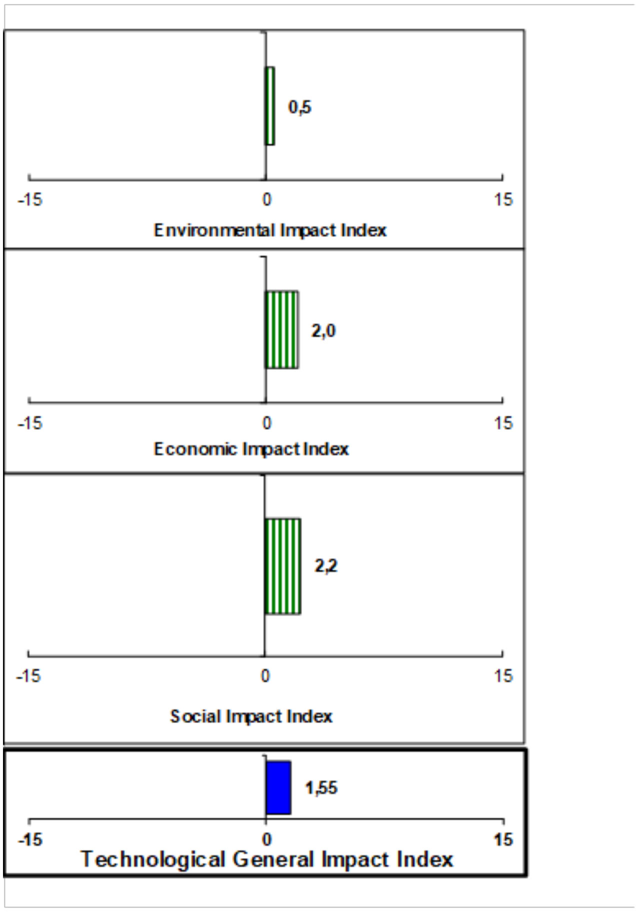

Table 4. Example of totalization of Impact Indices generated by Ambitec-Agro (hypothetical values).

Activity impact criteria	Criteria importance	Performance coefficients
Change in direct land use	0,05	3,8
Change in indirect land use	0,05	-3,8
Water consumption	0,05	0,0
Use of agricultural inputs	0,05	9,0
Use of veterinary inputs and raw materials	0,05	0,0
Energy consumption	0,05	0,0
Own generation, utilization, reuse and autonomy	0,025	-1,5
Emissions to the atmosphere	0,02	0,0
Soil quality	0,05	0,0
Water quality	0,05	0,0
Biodiversity conservation and environmental restoration	0,05	0,0
Product quality	0,05	3,5
Social capital	0,02	0,0
Animal welfare and health	0,02	0,0
Capacity building	0,02	0,0
Qualification and job offer	0,02	-0,9
Quality of employment and occupation	0,05	0,0
Equity among genders, generations and ethnicities	0,02	-1,3
Income generation	0,05	9,0
Value of rural property	0,02	0,3
Occupational safety and health	0,025	0,0
Food Security	0,05	11,0
Dedication and profile of the manager	0,05	0,0
Marketing condition	0,05	0,0
Residues disposal	0,02	0,0
Management of chemical inputs	0,02	0,0
Institutional relationships	0,02	0,0

Once the Ambitec-Agro methodology is presented in general terms, based on the information collected from 29 interviews, a descriptive statistical analysis was carried out considering data frequency, with an estimation of the mean, mode, and standard deviation of the data set obtained, which is presented in item 5 – Results and Discussion.

4. Results and Discussion

4.1. Descriptive Statistics

Table 5 brings the set of data collected regarding the 27 criteria classified under seven integrated indices, consolidated from the notes assigned by the respondents to the component indicators of the said criteria, after due weighting according to the impact potential of each indicator from the perspective of the interviewees.

From the aforementioned database, measures of central tendency were established, namely: the mode, the mean, and the respective standard deviation. Given that these are opinion research data from BRS Vitória grape producers in the São Francisco Valley, based on 27 (twenty-seven) criteria under seven integrated indices (which measured the environmental, economic, social impacts, and technological reception), the measures used confer a degree of reliability for the treatment of the collected data.

The mode indicates the weighted value for each criterion that showed the highest occurrence in interviews with producers, which is characterized as the main measure of central tendency to diagnose the majority perception of producers. The mean, in turn, indicates the weighted value when verifying the whole and its division by the number of producers interviewed, therefore, it is not the measure that best diagnoses the perception of the producers. The standard deviation will indicate the variability between the weighted values by the interviewees in relation to each criterion defined by the researcher.

The integrated indices were analyzed from data which reflects the perspectives or views the producers have of the criteria, according to the central tendency measures listed above (Table 6).

By analyzing the integrated indices and their respective criteria, it is observed that income and health were the indices that had the greatest impact on the producers' perception, especially income generation and food security (with the highest mode among all analyzed criteria). The criteria "Use of veterinary inputs and raw materials" and "Animal welfare and health" do not apply to these arms, as there are no animal production activities taking place on their premises.

Regarding technological efficiency, the change in direct land use showed the most significant positive perception, while, on the other hand, the change in indirect land use was perceived negatively, according to the respondents. In terms of environmental quality, only the criterion seen as causing a positive impact with the introduction of BRS Vitória was a reduction on Atmospheric gas emissions, with the other criteria being irrelevant to the respondents. Similarly, when addressing the integrated index related to work and employment, there were no significant positive impact, according to the estimated data.

In the integrated index related to consumer respect, the quality of the product was the criterion that showed the greatest significance in the producers' perception. In this sense, respect for the consumer is associated with the criteria verified regarding management and administration, which indicated that institutional relationships and commercialization conditions were the criteria best evaluated by the respondents.

4.2. Descriptive Statistics

It must be considered that descriptive statistics, although help to infer a series of important understandings about the studied object, does not allow evaluating the relationship between criteria, such as correlation coefficients, which are important to try to understand if one variable relates to another, for instance: would the criterion "Change in Land Use" relate to the criterion "Generation of Income"?

Therefore, we performed a correlation analysis considering all variables against each other, in pairs, by applying the Spearman's rank correlation, using the PASW software (former IBM's SPSS) in order to obtain elements or subsidies for a better interpretation of the impact that the BRS-Vitória variety provides, in its various dimensions and criteria, to its adopters in the Vale do Submédio São Francisco region.

We have ranked the correlation coefficients (Table 7) and have selected the ones higher than 0,7 (by numerical approximation), negative and positive, in our discussion, as these, in our view, may illustrate the most important relations between the indexes. Regression analysis between selected variables would allow for a better understanding of the nature and dimension of cause-and-effect relationships between them. With such correlations and regressions at hand, one could choose those that make the most sense together, not only in terms of statistical significance but mainly in logical terms that represent the reality of the sustainability conditions of the properties adopting the technology.

Based on these criteria, we could, for instance, verify, among the most important variables, the influence of one variable over another and, finally, on their final behaviour.

From Table 7, it can be observed that the first three correlations pertain to environmental aspects. Naturally, it is expected that the reduction in energy consumption and atmospheric emissions have a proportional relationship with each other and with the index that consolidates the environmental aspects of the analysis.

Table 5. Values calculated by the Ambitec-Agro System for the impact criteria from 29 interviews (V1 to V29).

	2018				2019						2021									2022									
CRITERIA AND INTEGRATED INDICES	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**	**V21**	**V22**	**V23**	**V24**	**V25**	**V26**	**V27**	**V28**	**V29**
TECHNOLOGICAL EFFICIENCY																													
Change in direct land use	3,75	3,75	3,75	3,75	3,75	5,00	2,50	2,50	3,75	5,00	7,50	5,00	2,50	5,00	5,00	1,25	5,00	5,00	7,50	-2,50	0,00	2,50	2,50	2,50	2,50	0,00	5,00	5,00	7,50
Change in indirect land use	-3,75	0,00	0,00	-1,25	0,00	-1,25	-1,25	-3,75	-3,75	-3,75	-2,50	-2,50	-1,25	2,50	-1,25	-3,75	-3,75	-6,25	-2,50	1,25	-1,25	-1,25	3,75	-1,25	0,00	-1,25	0,00	-1,25	0,00
Water consumption	0,00	0,00	0,00	-1,00	0,00	1,00	1,00	-1,00	-1,00	0,00	3,00	0,00	0,00	0,00	0,00	3,00	0,00	2,00	-1,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00	-3,00
Use of agricultural inputs	9,00	3,50	9,00	5,50	6,00	12,00	10,50	10,50	10,00	11,50	0,00	0,00	3,00	4,50	4,50	0,50	-1,50	0,00	6,00	0,50	-3,50	3,50	-2,00	-2,00	-1,50	-0,50	2,00	-2,00	1,00
Use of veterinary inputs and raw materials	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Energy consumption	0,00	2,00	2,00	2,00	0,00	4,50	1,50	4,50	1,50	4,50	0,00	0,00	6,00	6,00	6,00	6,00	0,00	0,00	2,00	2,00	2,00	6,00	0,00	-2,00	2,00	2,00	2,00	-2,00	2,00
Own generation, utilization, reuse and autonomy	-1,50	0,00	0,75	0,00	0,00	0,75	0,75	0,00	0,00	0,75	4,25	2,00	3,75	3,00	2,00	2,00	2,00	2,00	2,75	2,25	4,50	2,00	-2,25	0,75	2,25	-0,50	0,75	2,00	0,75
ENVIRONMENTAL QUALITY																													
Emissions to the atmosphere	0,00	4,00	4,00	4,00	0,00	0,00	2,00	6,00	0,00	6,00	0,00	0,00	12,00	12,00	12,00	12,00	0,00	12,00	4,00	4,00	4,00	4,00	0,00	-4,00	4,00	4,00	4,00	-4,00	4,00
Soil quality	0,00	0,00	1,25	0,00	0,00	0,00	0,00	1,25	1,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,25	1,25	1,25	0,00	1,25	1,25	1,25	1,25	-1,25	1,25
Water quality	0,00	0,00	-1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Biodiversity conservation and environmental restoration	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
RESPECT TO CONSUMER																													
Product quality	3,50	3,50	8,50	6,00	2,50	2,75	6,00	4,00	6,00	0,50	0,25	-0,50	6,50	2,75	0,00	8,00	-2,25	-2,25	-6,00	-1,50	11,25	9,00	6,75	2,75	4,25	0,75	1,50	1,50	1,00
Social capital	0,00	0,00	0,00	0,75	0,00	1,75	0,75	1,00	1,00	1,50	6,00	7,50	4,00	0,00	1,50	2,50	1,00	3,00	3,75	1,00	2,25	4,50	3,00	2,50	1,75	1,00	3,00	1,50	4,50
Animal welfare and health	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
JOBS / OCCUPATION																													
Capacity building	0,00	0,00	0,00	1,75	0,00	0,50	0,50	-0,50	-1,50	-0,50	4,25	4,25	4,00	-1,00	2,25	3,00	0,00	0,00	1,75	5,00	3,00	1,00	10,00	6,00	2,75	1,75	0,00	3,00	10,00
Qualification and job offer	-0,90	0,00	0,00	-1,50	0,00	0,00	1,00	-2,00	-1,75	-4,50	1,25	-2,50	-0,50	0,00	2,00	-3,50	4,25	-0,75	-2,00	2,25	1,50	3,50	4,75	0,50	1,75	3,25	0,50	0,50	1,75
Quality of employment and occupation	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,25	0,00	0,25	0,50	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	0,75	1,00	0,25	0,50	0,50	1,00	1,50
Equity among genders, generations and ethnicities	-1,25	-1,25	0,63	0,00	0,00	0,00	3,13	1,25	1,88	0,00	8,13	15,00	4,38	-1,88	3,13	6,25	5,00	10,63	3,75	1,25	5,00	1,88	3,13	8,13	6,88	6,25	3,75	3,75	8,13
INCOME																													
Income generation	9,00	10,00	7,00	9,00	12,00	12,00	13,00	13,00	12,00	13,00	15,00	15,00	4,00	4,00	9,00	8,00	5,00	10,00	8,00	1,00	5,00	5,00	-2,00	7,00	5,00	3,00	7,00	9,00	1,00
Value of rural property	0,25	0,25	-2,25	0,00	6,75	1,75	4,75	0,00	-1,00	4,50	0,25	0,25	1,00	-1,00	-0,50	2,75	0,00	1,75	5,50	-1,75	0,25	2,75	2,75	4,75	2,25	2,75	0,25	0,25	2,75
HEALTH																													
Occupational safety and health	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Food security	11,00	12,00	7,00	15,00	15,00	15,00	15,00	6,00	11,00	15,00	6,50	8,00	5,00	8,00	4,00	12,00	10,50	6,50	15,00	1,50	9,00	12,00	7,50	9,00	9,00	6,00	12,00	8,00	7,50
MANAGEMENT / ADMINISTRATION																													
Dedication and profile of the manager	0,00	0,00	1,25	1,25	-6,00	4,50	15,00	-1,25	-0,50	2,50	6,50	10,00	2,50	0,75	2,50	3,00	0,00	2,25	2,50	4,50	7,50	6,25	5,75	4,75	8,00	-0,50	4,25	4,50	7,50
Marketing condition	0,00	-0,75	2,25	2,50	3,00	6,75	12,75	3,00	3,50	8,25	13,50	11,25	4,50	0,00	7,50	8,25	6,00	2,75	12,00	3,00	3,75	3,50	6,75	6,75	8,25	3,75	6,00	7,25	9,00
Residues disposal	0,00	0,00	2,00	2,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Management of chemical inputs	0,00	0,00	1,00	-1,25	0,00	0,00	1,00	0,00	0,00	0,00	0,00	2,25	2,25	0,00	0,00	0,75	0,00	0,75	0,00	9,50	9,75	6,00	13,50	11,00	11,00	5,00	11,00	9,50	13,50
Institutional relationships	0,00	0,00	0,00	-1,25	7,50	7,50	12,50	6,25	5,00	10,00	15,00	15,00	12,50	1,25	15,00	15,00	15,00	10,00	11,25	2,50	0,00	0,00	7,50	12,50	12,50	0,00	10,00	10,00	8,75
ENVIRONMENTAL IMPACT INDEX	0,50	1,20	1,60	1,10	0,70	1,80	1,30	1,80	0,90	2,00	0,90	0,30	2,50	3,00	2,70	2,10	0,10	1,70	1,60	0,70	0,60	1,40	0,10	-0,70	0,80	0,40	1,10	-0,70	1,20
ECONOMIC IMPACT INDEX	2,00	2,40	1,30	2,30	4,70	3,50	5,00	3,10	2,80	3,80	5,50	5,90	2,30	0,50	3,00	3,40	2,40	4,20	3,80	0,90	2,50	2,70	2,50	4,90	3,30	2,90	2,40	3,30	3,60
SOCIAL IMPACT INDEX	2,20	2,30	2,50	3,50	3,10	4,30	6,00	2,10	3,10	4,10	4,10	4,70	3,50	1,80	2,50	5,00	3,00	2,20	4,00	1,50	4,10	4,60	4,60	4,40	4,80	1,70	4,80	3,80	4,40
TECHNOLOGICAL IMPACT GENERAL INDEX	1,55	1,76	2,18	2,23	2,10	3,36	4,33	2,18	2,26	3,18	3,30	3,20	2,54	1,98	2,62	3,14	1,51	1,81	2,80	0,93	2,23	2,76	2,17	2,18	2,71	1,07	2,59	1,88	2,90

Table 6. Descriptive Statistics from the data generated by the Ambitec-Agro system for 29 adopters of the BRS-Vitória table grape variety in the Vale do Submédio São Francisco. Source: Source: prepared by the authors based on data from Embrapa (2023).

CRITERIA AND INTEGRATED INDICES	MODE	AVERAGE	STANDARD DEVIATION
TECHNOLOGICAL EFFICIENCY			
CHANGE IN DIRECT LAND USE	5	3,66	2,2393
CHANGE IN INDIRECT LAND USE	-1,25	-1,42	2,0789
WATER CONSUMPTION	0	-0,83	1,8721
USE OF AGRICULTURAL INPUTS	0	3,45	4,7233
USE OF VETERINARY INPUTS AND RAW MATERIALS	0	0	0
ENERGY CONSUMPTION	2	2,16	2,3796
OWN GENERATION, UTILIZATION, REUSE AND AUTONOMY	0,75	1,30	1,5746
ENVIRONMENTAL QUALITY			
EMISSIONS TO THE ATMOSPHERE	4	3,79	4,5777
SOIL QUALITY	0	0,43	0,6908
WATER QUALITY	0	-0,03	0,1857
BIODIVERSITY CONSERVATION AND ENVIRONMENTAL RESTORATION	0	0	0
RESPECT TO CONSUMERS			
PRODUCT QUALITY	6	3,00	3,8782
SOCIAL CAPITAL	0	2,10	1,8714
ANIMAL WELFARE AND HEALTH	0	0	0
JOBS / OCCUPATION			
CAPACITY BUILDING	0	2,11	2,9144
QUALIFICATION AND JOB OFFER	0	0,31	2,1972
QUALITY OF EMPLOYMENT AND OCCUPATION	0	0,23	0,3892
EQUITY AMONG GENDERS, GENERATIONS AND ETHNICITIES	0	3,69	3,8980
INCOME			
INCOME GENERATION	9	7,90	4,3371
VALUE OF RURAL PROPERTY	0,25	1,45	2,2454
HEALTH			
OCCUPATIONAL SAFETY AND HEALTH	0	0	0
FOOD SECURITY	15	9,62	3,7337
MANAGEMENT / ADMINISTRATION			
DEDICATION AND PROFILE OF THE MANAGER	3,42	2,5	4,0461
MARKETING CONDITION	5,69	3	3,7729
RESIDUES DISPOSAL	0,14	0	0,5158
MANAGEMENT OF CHEMICAL INPUTS	3,67	0	4,9561
INSTITUTIONAL RELATIONSHIPS	7,63	0	5,6925

Table 7. Description of correlated variables and their respective coefficients. Source: prepared by the authors based on data from Embrapa (2023).

CORRELATED VARIABLES	CORRELATION COEFFICIENT
Atmospheric Emissions and Environmental Impact Index	0,81
Energy Consumption and Environmental Impact Index	0,79
Energy Consumption and Atmospheric Emissions	0,77
Commercialization Conditions and Institutional Relationship	0,76
Person in Charge's Dedication and Profile and Social Impact Index	0,75
Social Impact Index and General Technologic Impact Index	0,75
Commercialization Conditions and General Technologic Impact Index	0,72
Emancipating Opportunity and Equitable Reward Between Gender and Social Capital	0,72
Commercialization Conditions and Social Impact Index	0,70
Economic Impact Index and Commercialization Conditions	0,69
Person in Charge's Dedication and Profile and Capacitacion	0,68
Agricultural Inputs Use and Emancipating Opportunity and Equitable Reward Between Gender	-0,68
Water Quality and Waste Disposal	-0,69

The other positive correlations reflect socio-economic aspects. Generally, aspects such as professional dedication, gender issues, training, and other variables related to the development of people and social relations are linked to better commercial conditions, which is reflected in both the social impact index and the economic impact index. It is important to note the high correlation between the commercial conditions and the overall index of the technology, indicating that such a variable is of great weight when evaluating sustainable development from a holistic perspective.

Regarding negative correlations, it is noted that the increased use of agricultural inputs is inversely proportional to conditions of opportunity, emancipation, equity, and gender. In the São Francisco Valley region, the vast majority of people working in harvesting are women, and management positions have been increasingly occupied by females, which may indicate a greater concern on the part of the managers due to the empathy they have with the harvesters, who are the workers most exposed to pesticide residues.

The other case of negative correlation occurred in relation to water quality versus waste disposal. In this case, it should be noted that the Ambitec-Agro system adopts the concept of increasing waste for the second variable, and not the strategy for waste elimination, which explains the inversely proportional correlation between these variables.

5. Conclusions

Technological advancements in table grape, such as the introduction of new cultivars like BRS Vitória, have complex and wide-ranging effects. These impacts span various domains, including agricultural practices, economic outcomes, and environmental sustainability. The introduction of new technology doesn't just alter farming techniques; it also influences the economic viability of farms, environmental outcomes, and social aspects like employment and consumer perceptions. This relates to the theory of technical change as skills are not static – they evolve as new technologies, methods and challenges emerge. This evolution is sequential and interconnected meaning that proficiency in one aspect leads to advancement in others, a cause-effect relation which is only perceived by a long-term monitoring and assessment of this ongoing process. By continuously learning from and adapting to the impacts of new technologies, farm managers, policymakers, and mainly research institutions can ensure that innovations truly benefit the sector and the communities it supports.

From the quantitative analyses, it is possible to observe that there was an increase in the income of the producers as a positive balance in the insertion of BRS Vitória cultivars in the Vale do Submédio São Francisco. From an environmental point of view, although the technology does not necessarily imply less use of agricultural inputs, it results in a more rational use of pesticides with the adoption of products with a lower degree of toxicity. Socially, the cultivar boosted the number of jobs in the region since it can provide up to 3 harvests per year, compared to a single annual harvest of the traditional predecessor cultivars. The correlations between the main variables were consistent with these findings.

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