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Padrões de empreendedorismo "verde" intensivo em conhecimento: Uma análise do programa PIPE no Estado de São Paulo no Brasil

Patterns of knowledge-intensive "Green" entrepreneurship: An analysis of the PIPE program in the State of São Paulo, Brazil

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Resumo
A recente industrialização prejudicou o meio ambiente, causando aquecimento global, emissões e contaminação. Isso estimulou o interesse por soluções verdes e sua integração nas estratégias de negócios, com o empreendedorismo e a inovação verdes emergindo como soluções. Esta pesquisa, dentro dos campos do empreendedorismo e sustentabilidade, utiliza dados do programa PIPE da FAPESP em São Paulo para identificar padrões ambientais em projetos intensivos em conhecimento. Emprega uma abordagem qualitativo-quantitativa, analisando 1.844 projetos através de agrupamento hierárquico. O estudo examina o EIC Verde como um tipo distinto, explorando seu papel nas transições sustentáveis dentro do Ecossistema Empreendedor. Destaca a liderança de certos ecossistemas, a ausência de abordagens empreendedoras em alguns ODS, e o tratamento variado de questões sociais e ambientais.
Palavras-chaves: Empreendedorismo intensivo em conhecimento, Empreendedorismo Verde, Ecossistema de Empreendedorismo, EIC Verde, Brasil

Abstract
Recent industrialization has harmed the environment, causing global warming, emissions, and contamination. This has spurred interest in green solutions and integrating them into business strategies, with green entrepreneurship and innovation emerging as solutions. This research, within entrepreneurship and sustainability, uses PIPE program data from FAPESP in São Paulo to identify environmental patterns in knowledge-intensive projects. It employs a qualitative-quantitative approach, analyzing 1,844 projects using hierarchical clustering. The study examines Green KIE as a distinct type, exploring its role in sustainable transitions within the Entrepreneurial Ecosystem. It highlights the leadership of certain ecosystems, the absence of entrepreneurial approaches in some SDG, and the varied handling of social and environmental issues.
Keywords: *Knowledge-Intensive Entrepreneurship, Green Entrepreneurship, Entrepreneurial Ecosystem, Green KIE, Brazil.*

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1. Introduction

The rapid pace of industrialization in recent years has negatively impacted the environment, manifesting in issues like global warming, gas emissions, toxic pollution, and soil contamination (Geng et al., 2017; Peng & Lin, 2008). Currently, this issue is an integral aspect of organizational performance. In response, the increasing visibility of green entrepreneurship and sustainable innovation is recognized as a viable strategy to mitigate these impacts, encouraging technologies that promote ecological sustainability (Muangmee et al., 2021; Nawaz, 2021; Li et al., 2021; Demirel et al., 2017).

Entrepreneurship converts knowledge into growth (Ács & Varga, 2005; Machado et al., 2023), identifying opportunities that lead to future product and service creation, considering how it will be achieved, who will undertake it, and the consequences (Shane & Venkataraman, 2000; Queirós & Oliveira, 2021; Sousa et al., 2020; Xie et al., 2022). In this context, interest in environmental entrepreneurship has emerged, recognizing sustainability as essential in addressing environmental degradation while also enhancing economic value (Allen & Malin, 2008; Jiang et al., 2018). Green entrepreneurship is recognized for achieving environmental performance within businesses, crucial in transforming business models to reduce waste and address unsustainable resource use (Xie et al., 2022; Sreenivasan et al., 2023).

Sustainable Development emerged between the late 1960s and early 1970s, prompting a reassessment of economic growth. The Brundtland Report later highlighted it as a guiding principle for addressing environmental and humanitarian issues (United Nations World Commission on Environment and Development, 1987). With this sustainable path, the Millennium Development Goals arose, serving as a guiding force for addressing various issues over 15 years and as a framework for policy priority development (Caprani, 2016; Huang et al., 2023). In 2015, the UN defined 17 goals to continue the work initiated by the WCED and MDGs, aiming to enhance global conditions by 2030, with a plan to promote sustainability worldwide (Salvia et al., 2019; Dhahri et al., 2021).

Green Entrepreneurship operates within a knowledge context. Knowledge-Intensive Entrepreneurship (KIE) is recognized as the most crucial type of entrepreneurship in the modern economy, serving as a fundamental source of macroeconomic competitiveness and innovative capabilities impacting sustainable development (Fischer et al., 2018). This emerging concept lacks extensive literature and is an evolving process. This research addresses a gap by examining Green Knowledge-Intensive Entrepreneurship (Green KIE), an emerging area within knowledge-intensive ventures focused on environmental impact. The study seeks to answer: What are the patterns of knowledge-intensive entrepreneurial projects with environmental focus in São Paulo, Brazil? Aiming to clarify and expand the Green KIE concept, this research explores its origins, proposes a formal definition, and distinguishes it from traditional KIE. Through cluster analysis, the study identifies distinct Green KIE patterns, providing insights into its unique attributes and alignment with sustainable development.

To understand this new KIE type, this article examines PIPE (Innovative Research in Small Enterprises), a FAPESP (São Paulo Research Foundation) program supporting scientific or technological research in small and mid-sized companies in São Paulo, Brazil (IBGE, 2016). Data from approved PIPE projects were consolidated into a dataset. An analysis was conducted to explore relationships between each project and "green" thinking within a sustainable context, per the Green KIE definition. This study offers an opportunity to further understanding in entrepreneurship studies (Fischer et al., 2022). Understanding this concept and its ecosystem enables the definition of key dimensions, revealing necessary conditions for this entrepreneurship type to thrive. With this foundation, practical analysis can uncover more details, aiding decision-makers in recognizing its influence on a region's economic, social, and environmental growth and promoting green policies and management guidelines for companies in this area.

2. Literature Review

Knowledge Intensive Entrepreneurship

Knowledge-Intensive Entrepreneurship (KIE) is derived from the scientific and technological assets in small companies across diverse sectors, focusing on innovation capabilities (Malerba & McKelvey, 2020). KIE acts as a fundamental source of macroeconomic competitiveness and innovative capabilities, influencing local employment, and emphasizing its relevance for city planning and policy (Fischer et al., 2018). In the modern knowledge economy, KIE is recognized as the most crucial type of entrepreneurship (Malerba & McKelvey, 2020).

According to Malerba e McKelvey (2020), "KIE ventures are new, innovative firms with significant knowledge intensity, embedded in innovation systems, exploiting innovative opportunities in diverse, evolving sectors and contexts." Each characteristic within the involved system defines the Entrepreneurial Ecosystem (EE). The concept of EE originates from the biological ecosystem concept (Audretsch et al., 2021), initially defined as an interactive system of living organisms and biotic components within their physical, abiotic environment (Cavallo et al., 2018). The EE approach links entrepreneurial activity to its contextual features, recognizing it is insufficient to consider only individual entrepreneurs' behaviors; it requires key roles from numerous agents and institutions to nurture entrepreneurial endeavors (Stam & Van de Ven, 2019). The EE is regarded as a network of interconnected business actors, organizations, institutions, and entrepreneurship processes that collectively connect, mediate, and govern performance in the entrepreneurial environment (Alves et al., 2019; Fischer et al., 2022; Rocha & Audretsch, 2022; Spigel, 2017; Stam & Van de Ven, 2019). Expanding innovation relies on collaborative arrangements among ecosystem actors (Rossi et al., 2022).

Entrepreneurs and ecosystem elements rely on each other to sustain the entrepreneurial ecosystem (Stam & Van de Ven, 2019). The EE approach shifts from traditional entrepreneurship policy to fostering an entrepreneurial economy (Stam, 2015). Entrepreneurs lead innovation and community change, disrupting structures and creating new paths, influenced by other ecosystem actors (Wurth et al., 2021; Stam, 2015). Entrepreneurs drive regional growth and socio-economic benefits (Ács et al., 2017), explaining the growing interest in EEs in policy, research, and practice (Wurth et al., 2021; Theodoraki et al., 2022). By sharing knowledge, entrepreneurs foster networks of investors, advisors, and mentors, strengthening the ecosystem's startup culture and access to financing (Spigel, 2017).

A "Green" perspective on KIE

Sustainable entrepreneurs enhance resource efficiency, mitigate environmental risks, and uphold social and cultural quality, aiding policymakers in achieving sustainable development goals. Their activities stimulate institutional, social, and legal market changes, generating economic, social, and environmental value (Gholamrezai et al., 2021; Suriyankietkaew et al., 2022).

Sustainable Development is a pivotal concept in entrepreneurship policy, practice, and theory (Hall et al., 2010), benefiting society and positively impacting the natural environment (Gast et al., 2017; Cojoianu et al., 2020). Green management is considered the most crucial strategic decision in both developed and emerging markets (Li et al., 2021), marking sustainable entrepreneurship as a significant recent concept. This process considers new technologies, making green entrepreneurial activity a specific KIE type (Fischer et al., 2022).

KIE garners significant attention from academics and policymakers (Audretsch et al., 2020). Transitioning from KIE to Green KIE involves several aspects. Primarily, sustainable transitions, defined by geographical processes influenced by political and local environmental knowledge, demonstrate green entrepreneurship's localized nature (Hansen & Coenen, 2015). Secondly, green entrepreneurship introduces solutions to urban areas, connecting locations to sustainable transitions from a bottom-up approach (Mullins, 2017). Additional aspects include entrepreneurs' contributions, implementing green buildings, smart city tools, transportation networks, smart grids, and AI applied to water management, reducing environmental impacts (Gebhardt, 2019).

The source of green entrepreneurship opportunities lies in novel ideas and knowledge from universities, firms, and research organizations. This KIE type extends beyond general knowledge, characterized by the double externality issue, creating positive impacts during innovation and diffusion stages while reducing environmental harm compared to conventional technologies, advancing innovation-based economies, and offering opportunities in developing markets (Cojoianu et al., 2020; Kuckertz et al., 2020). This dual intention is policy-relevant, as environmental regulation encourages firms to innovate through green technologies (Colombelli & Quatraro, 2019).

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New green ventures gain positive influence from diverse, heterogeneous knowledge sources and increased green knowledge. Regions with strong pro-environmental norms yield greener entrepreneurship (Cojoianu et al., 2020).

3. Methodological approach

The methodological framework outlines the methods, procedures, and assumptions related to the topic (Tasca et al., 2010). This article is descriptive in its purpose and objectives (Gil, 2002). The research utilizes secondary data, drawing from a FAPESP database, and employs a Qualitative-Quantitative problem approach. This involves systematic, empirical, and critical processes, collecting and analyzing both quantitative and qualitative data, integrating and discussing them jointly to make inferences and gain a better understanding of the studied phenomenon (Sampieri et al., 2014). The study aims for applied results. The technical procedures are bibliographic, as the theoretical aspects are derived from scientific publications (Tasca et al., 2010), and a Case Study, which seeks answers concerning the causes of a specific phenomenon through database analysis using cluster analysis methodology (Gil, 2002).

Inclusion criteria

For this research, 1844 projects across major areas—agrotech, biology, health, exact sciences, humanities, social sciences, engineering, interdisciplinary, and linguistics—were analyzed. All these areas are part of the PIPE program; however, "linguistics" was excluded as it lacked an environmental focus in some projects. Only "Approved" projects from the program data were selected, and only one project phase was chosen, as a project in the PIPE program may have phases I, II, or III. The unit of analysis is the project, allowing the same company to appear multiple times. The time frame spans 1998-2020, offering a representative data set. The analysis revealed 456 Green Entrepreneurship initiatives, representing 24.69% of total projects. Engineering is the most represented area at 43%, followed by agrotech at 23%. No projects related to the Covid-19 era were included up to the research's selected date. This research focuses on each project's entrepreneurship aspect, excluding the year from the analysis.

To begin the analytics process, using the selected database, the first step involved organizing the database information according to Bardin's 2012 guidelines. An initial validation ensured projects weren't duplicated, using a unique project-associated code. This validated data was crucial for assessing each project's impact on the PIPE program. With this database cleaning, codification determined if initiatives fit within Green Entrepreneurship, following the environmental orientation of business activities (Fischer et al., 2022). Each initiative was individually assessed for green entrepreneurship potential, based on project names and summaries, reviewing for market opportunities in greentech products or services (Trapp & Kanbach, 2021), and considering environmental orientation as key to green entrepreneurial ventures (Cohen & Winn, 2007).

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For the encoding process the following words were considered inside the title and in the abstract: "Green", "Entrepreneu*", "Eco-friendly", "Bio*", "Smart", "Renewable", "Sustainab*", "Agriculture", "Agro", "Environment*", "Innov*". After this, the following Areas were considered: "Agronomy", "Food Science and Technology", "Ecology", "Agricultural Engineering", "Sanitary Engineering", "Forest Resources and Forestry Engineering", "Zoology" as a priority inside the codification process for the relation with the general area, and in the end an analysis of the summary with the same words used in the title process was conducted. After these, a binary coding was attributed to the database. When the project considers green entrepreneurship within its approach, the coding is 1 and when it is not, it is 0. In this way, 456 initiatives were initially found within the concept of green entrepreneurship.

After the coding process, we proceeded to the categorization process. This categorization was framed into the Sustainable Development Goals (SDG), to consider into the analysis because it stimulates action in the critical and important areas for humanity and the planet and recent studies identify that they have energizing effects guiding organizational policy and action (Bebbington & Unerman, 2018).

In 2015, the United Nations defined 17 goals to continue with the work defined in the writing "Our Common Future", goals for achieving a better situation for the world by 2030, establishing an action plan to seek sustainability in all countries (Salvia et al., 2019). These 17 goals are grouped in 4 dimensions: Social problems (SDG 1, 2, 3, 4, 5), Environment (SDG 6, 7, 11, 12, 13, 14, 15), Economics (SDG 8, 9, 10) and Institutional (SDG 16, 17), and every dimension with their group of objectives (Estratégia ODS, 2023).

For this research were selected all the SDG inside the group of environment: 6, 7, 11, 12, 13, 14, 15 because this group of SDG talk about the reversing deforestation, protecting forests and biodiversity, combating desertification, sustainable use of oceans and marine resources to adopting effective measures against climate change. It was selected an SDG 2, from the social dimension and SDG 9 from the economic dimension because the objective 9 addresses the use and depletion of natural resources, waste production, energy consumption, among other in relation with the environment, and the objective 2 with focus in zero hunger, because are several projects inside the PIPE program that present proposals with the aim of making sustainable agriculture and bioeconomy.

The objectives inside the institutional dimension, 16 and 17 were not selected because they are more focused on the behavior of the institutions (government, private sector and civil society), to achieve sustainable development. This could surely be part of future research, to understand how through the connection of stakeholders the objectives can be met.

This is how a total of 9 objectives were selected for the investigation. The selected objectives are presented below, in Table 1.

Table 1. Selected Objectives for research

No.	Name	Description
2	Zero Hunger	End poverty in all its forms everywhere.
6	Clean water and sanitation	Ensure availability and sustainable management of water and sanitation for all.
7	Affordable and clean energy	Ensure access to affordable, reliable, sustainable and modern energy for all.
9	Industry, innovation and infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
11	Sustainable cities and communities	Make cities and human settlements inclusive, safe, resilient and sustainable.
12	Responsible consumption and production	Ensure sustainable consumption and production patterns.
13	Climate action	Take urgent action to combat climate change and its impacts.
14	Life below water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
15	Life on land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Source: The authors (2024).

For this part, the name and summary of each project was initially considered, reading each item, understanding if each one fit within one or more objectives according to the description and its indicators. Some words were considered for this analysis according to the meaning of each objective. For this, words were defined within the projects with an environmental scope. All words are specified in Table 2 within each objective.

Table 2. Words considered in each objective for the analysis

No.	Name	Description
2	Zero Hunger	“Agro”, “Agricultural”, “Food”, “Bio”, “Eco”, “Tech”, “Population”
6	Clean water and sanitation	“Sustainable”, “Water”, “Sanitation”, “Scarcity”, “Hydraulic”, “Potable”
7	Affordable and clean energy	“Sustainable”, “Energy”, “Clean”, “Renewable”, “Regeneration”, “Wind”
9	Industry, innovation and infrastructure	“Infrastructure”, “Industrial*”, “Innovation”, “Business”, “Efficiency”, “Systems”, “Process”, “Development”, “Technology”, “Improvement”

11	Sustainable cities and communities	"City", "Cities", "Safe", "Resilient", "Sustainable", "Smart", "Development"
12	Responsible consumption and production	"Sustainable", "Consumption", "Production", "Technology", "Business", "Product", "Service"
13	Climate action	"Damage", "Flora", "Fauna", "Environment*", "Global warming", "Effects", "Pollut*", "Climate", "Ecological", "Biodiversity"
14	Life below water	"Sustainab*", "Oceans", "Seas", "Marine", "Resources", "Sustainable development", "Life", "Bio"
15	Life on land	"Sustainab*", "Resources", "Sustainable development", "Life", "Bio", "Terrestrial ecosystems", "Forests", "Desertification", "Land", "Biodiversity"

Source: The authors (2024).

With the codification and categorization process it was possible to understand in the initial context that 24,69% of the total projects consider green entrepreneurship in a general way, approximately a quarter of the total. The relevant SDG inside the projects were the 9, Industry, innovation and infrastructure with 24,80% of the total, very similar to the result for codification for green entrepreneurship. This goal has a key role in introducing and promoting new technologies, this helps to facilitate international trade and enables the efficient use of resources. The next goal is the 12, Responsible consumption and production with 8,72% of the total projects, this goal is about doing more and better with less, increasing resource efficiency and promoting sustainable lifestyles, and the next goal is the 2, Zero hunger with 7,15% of the total projects, this goal is about swift actions to provide food and humanitarian relief to the most at-risk regions. This last objective makes sense considering that in the database a large number of projects related to bioeconomy are found.

Analytical Procedures

Aligned with the main objective to identify patterns in the dataset for an innovative program in São Paulo, Brazil, the statistical procedure of Cluster Analysis is employed. This multivariate technique groups objects based on shared characteristics, classifying them according to their relationships with others (Hair Jr. et al., 2009), sorting observations into similar sets or groups (Ketchen & Shook, 1996).

The focus of hierarchical agglomerative clustering is comparing objects based on statistical variables representing each object's characteristics. This makes defining the variables a critical step in the analysis (Hair Jr. et al., 2009). Seven variables were defined for this research. Derived from the PIPE program (Innovative Research in Small Enterprises) managed by the São Paulo Research Foundation (FAPESP), this dataset provides a consistent source of knowledge-intensive entrepreneurship in the Brazilian context (Alves et al., 2021). Each project was classified within every variable.

The first variable is Project, considering each project in the database from 1 to 1844. The next variable is City, encompassing 150 cities in São Paulo, Brazil, numbered from 1 to 150. Another variable, Projects Related to SDG, aligns with projects targeting environmental challenges via the Sustainable Development Goals, encouraging rethinking unsustainable development (Dhahri et al., 2021). This is a binary variable, 1 if related to SDG, otherwise 0. Quantity of SDG ranges from 1 to 5, reflecting the number of SDG linked to each project, based on project descriptions.

The SDG Dimension assigns 1 for Socioeconomic Challenge or 2 for Environment. Although the UN defines four SDG dimensions (social, environment, economic, and institutional) (Estratégia ODS, 2023), this research considers only three: social, environment, and economic. For social dimension projects, a new dimension was defined: Socioeconomic Challenges, encompassing social and economic aspects.

The Leading Ecosystem variable is binary, 1 if the project is in cities leading the Green Entrepreneurship Ecosystem, otherwise 0. This reflects that although the database considers 150 cities, 65% of projects are in five key cities: São Paulo, São Carlos, Campinas, Piracicaba, and São José dos Campos, identified as Green Entrepreneurship Ecosystems.

The last variable, KAG, the Knowledge Area Group, identifies the project's development area. The original PIPE program database considered nine areas (exact sciences, engineering, agricultural, biological, health, human, applied social, interdisciplinary, linguistics, and arts) with each project associated with one. Areas with similarities were grouped into four large categories: 1 for Exact Sciences + Engineering. 2 for Agricultural + Biological. 3 for Health. 4 for Human + Applied Social + Interdisciplinary. Linguistics and arts, with only five projects, were excluded due to their lack of environmental focus. Thus, eight areas were unified into four main categories. The overview of variables is in Table 3.

Table 3. Quantity of projects in the Knowledge Area Group

Variable	**Description**
Project	Number of projects, from 1 to 1844. The database has 1844 projects.
City	City where the project is presented. From 1 to 150. The PIPE program has 150 cities.
Project related to SDG	Binary variable. 1 if the project is related to the SDG, else 0.
Quantity of SDG	Variable from 1 to 5. Quantity of SDG that are related in every project.
SDG Dimension	Two dimensions for the database. 1 for Socioeconomic Challenge, 2 for Environment.

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Leading Ecosystem	Binary variable. 1 if the project is inside cities that are leading the Green Entrepreneurship Ecosystem, else 0.
KAG	Knowledge Area Group. Area in which the project is developed. 1 for Exact Sciences + Engineering. 2 for Agricultural + Biological. 3 for Health. 4 for Human + Applied Social + Interdisciplinary.

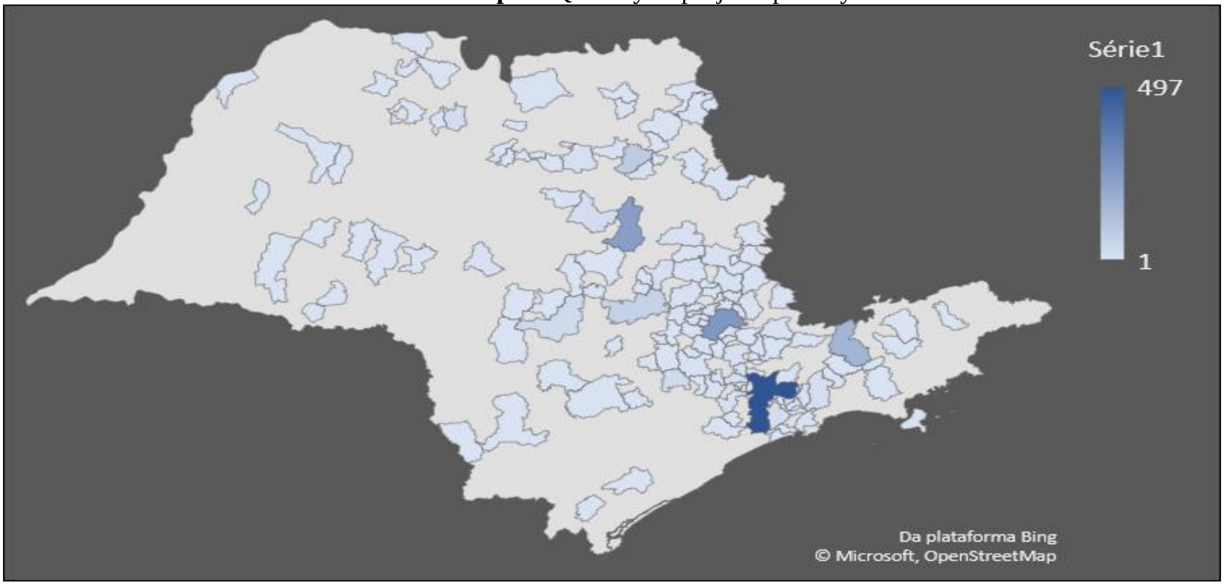
Source: The authors (2024).

4. Empirical Analysis

Sample description

Regarding the data, the variables were defined from the PIPE program with the following characteristics. The complete database comprises 1844 projects within the PIPE program, each developed in a city in the State of São Paulo, Brazil. The database includes 150 cities, with São Paulo having the highest number of projects at 497. Graph 1 illustrates the project density in each city across the state.

Graph1. Quantity of projects per city



Source: The authors (2024).

From the 1,844 projects in the database, 615 are related to SDG. Among these projects, there are 100 cities involved, but 61.79% are concentrated in just five cities: São Paulo (24.23%), São Carlos (13.66%), Campinas (11.06%), Piracicaba (6.67%), and São José dos Campos (6.18%). These cities are the most representative within the PIPE projects considering Sustainable Development Goals and are thus defined as the Green Entrepreneurship Ecosystem leaders.

Each project may relate to more than one objective. Among the 615 projects, 38% are linked to one SDG, 46% to two SDG, and 17% to three or more SDG. Details are provided in Table 4 below.

Table 4. Quantity of SDG related in every project

Quantity of SDG	Projects related	% Percentage	%Accumulated Perc
1	232	37,72%	37,72%
2	280	45,53%	83,3%
3	92	14,96%	98,2%
4	8	1,30%	99,5%
5	3	0,49%	100%

Source: The authors (2024).

The projects that are related to the SDG, 33% of the total projects of the program, are well defined within 1 or 2 goals. The table 4 shows how 512 projects have this characteristic.

This investigation contemplates 2 dimensions: Environment (SDG 6, 7, 11, 12, 13, 14, 15) and Socioeconomic Challenges (SDG 2, 9). The social and economics were joined generating a dimension of Socioeconomic Challenges for the quantity of projects in the social part.

Table 5 shows the 2 dimensions for the SDG in this research. The research considers 9 SDG. The group most representative is the "Socioeconomic Challenges" with the SDG 9: Industry, innovation and infrastructure and with the SDG 2: Zero hunger, with a 54% participation. The next group is "Environment" with 46%. For this classification, the summaries of the projects were reviewed again to validate which group was best suited.

Table 5. SDG in dimension group

Number of dimension	Dimenions	SDG	Quantity of projects	% Percentage
1	Socioeconomic Challenges	2, 9	330	54%
2	Environment	6, 7, 11, 12, 13, 14, 15	285	46%

Source: The authors (2024).

Each project is within an area, but for the analysis 4 Knowledge Area Groups were defined: Exact Sciences + Engineering, Agricultural + Biological, Health and Human + Applied Social + Interdisciplinary. Participation in the projects is found in Table 6. This grouping was carried out considering affinity between the areas.

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Table 6. Quantity of projects in the Knowledge Area Group

Number of KAG	Knowledge Area Group (KAG)	Quantity of projects	% Percentage	% Accumulated Percentage
1	Exact Sciences + Engineering	314	51,1%	51,1%
2	Agricultural + Biological	232	37,7%	88,8%
3	Health	22	3,6%	92,4%
4	Human + Applied Social + Interdisciplinary	47	7,6%	100%

Source: The authors (2024).

Table 6 indicates that half of the projects are within Exact Sciences + Engineering (314 projects), with 157 projects aligned with dimension 1, socioeconomic challenges, and 157 in dimension 2, environment. The next largest group, comprising 37.7% participation, is Agricultural + Biological (232 projects), where 139 align with dimension 1 and 93 with dimension 2. Together, these two areas account for 88% of the total projects related to the goals.

Understanding these groups highlights the stronger presence within two areas; 88% of projects are in the exact sciences, engineering, agricultural, and biological groups. These areas represent the largest trend among PIPE projects. A potential future discussion could explore why these trends exist (differential points within the ecosystem motivating these projects) and what might be lacking to foster greater participation in the other two areas with fewer projects.

As previously noted, 615 projects in this database relate to the SDG. The number of submitted projects has evolved, increasing from 1998 to 2020. In Graph 2, dark gray denotes non-SDG-related projects, while light gray indicates SDG-related projects, together representing the total PIPE projects. The line depicts the percentage of SDG-related projects out of the total per year, with 2010 being most significant, achieving approximately 50% of the total.

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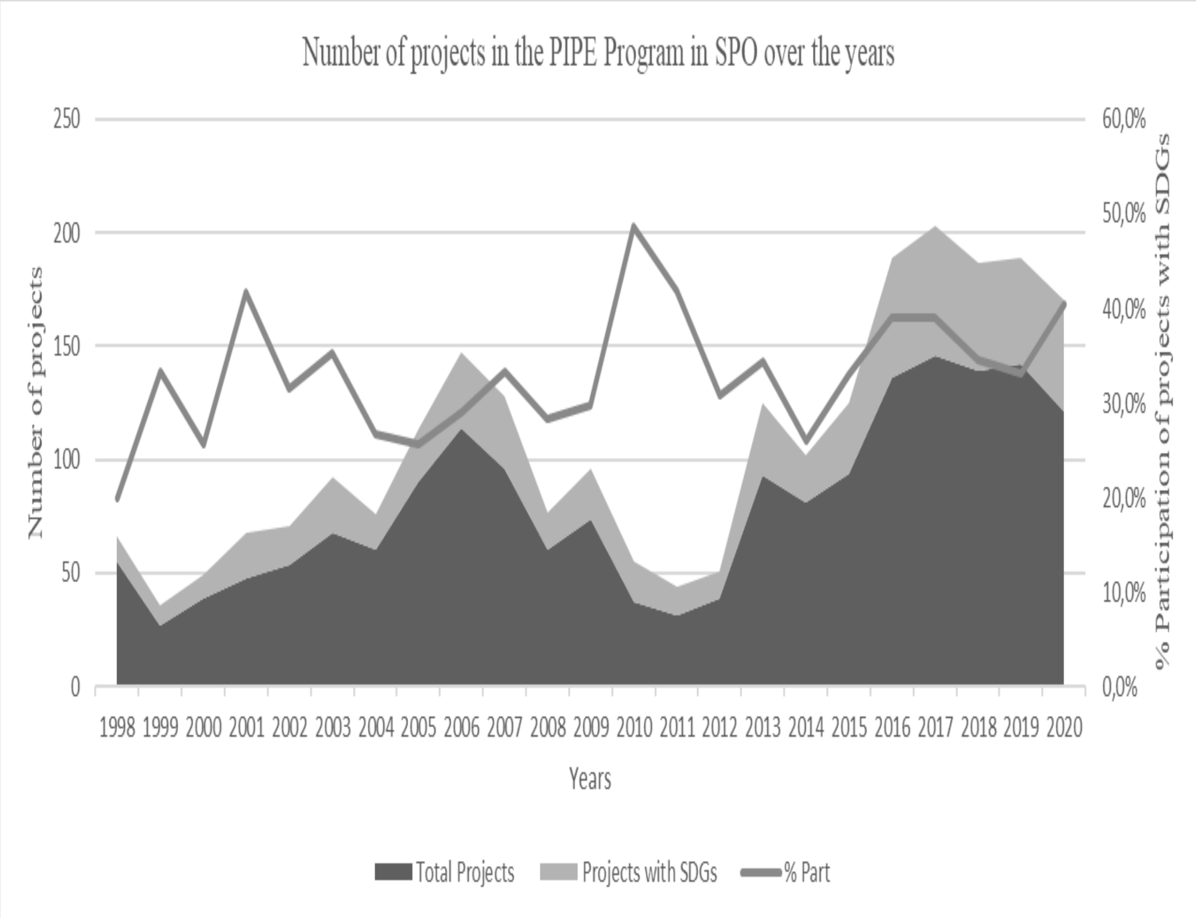
Graph 2. Number of projects in the PIPE program in São Paulo over the yea



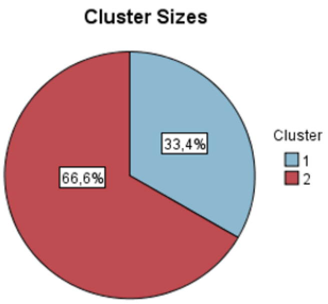
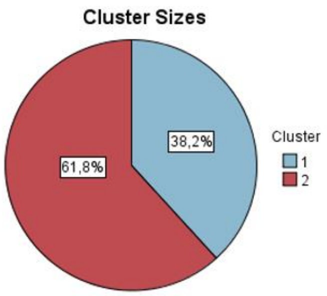
Source: The authors (2024).

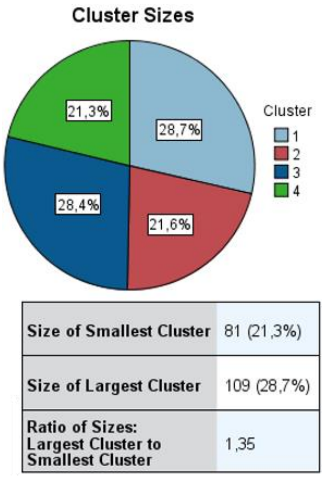
Cluster Analysis

Cluster Analysis is a multivariate technique that classifies objects, grouping similar objects based on selected characteristics (Hair Jr. et al., 2009). This research employed a two-step cluster analysis approach. Two-step cluster analysis was chosen for this study as it is the only type in SPSS (Statistical Software) that forms clusters using both categorical and continuous data (Rundle-Thiele et al., 2015).

The two-step cluster analysis retains complete information for researchers, offering a comprehensive explanation for decision-making purposes (Tkaczynski et al., 2015). It is also applicable to relatively large datasets (n = 1844 in this study), reducing processing time compared to conventional cluster analyses (Hsu et al., 2015). The cluster analysis results are presented in Table 7.

Table 7. Summary of the study's cluster analysis

Cluster Name	Summary of analysis	Graph	Results of Analysis
General Cluster Analysis	Initial clustering using all available variables (SDG Dimension, Quantity of SDG, Project related to SDG, KAG, CityName, Leading Ecosystem). The data was segmented into two clusters.	 Size of Smallest Cluster: 615 (33,4%) Size of Largest Cluster: 1224 (66,6%) Ratio of Sizes: Largest Cluster to Smallest Cluster: 1,99	This first partial result shows the definition of the clusters from the SDG, doesn't show relevant information, only the separation of the sample in relation to the SDG. The most important variables in this cluster analysis were: SDG Dimension, Quantity of SDG, Project related to SDG. **Cluster 1:** 33.4% of the projects. 615 projects related to SDG, considering 1-5 SDG, in some SDG dimension (Socioeconomic Challenges or Environment). **Cluster 2:** 66.6% of the projects. 1224 projects not related to SDG, no relation with SDG or their dimensions.
SDG Cluster Analysis	Refined clustering focusing on projects related to SDG. Five variables were used, excluding ***Project related to SDG*** - only SDG = 1(binary variable). The data was segmented into two clusters.	 Size of Smallest Cluster: 235 (38,2%) Size of Largest Cluster: 380 (61,8%) Ratio of Sizes: Largest Cluster to Smallest Cluster: 1,62	In the SDG Cluster Analysis, the representative variable inside the analysis is "Leading ecosystem", a variable that is placed as a relevant separator of the projects related to SDG. The most important variables in this cluster analysis were: Leading Ecosystem and CityName **Cluster 1:** 38.2% of the projects. Projects not inside the Leading Ecosystem, 235 projects related to SDG, concentrated in seven cities: Ribeirão Preto, Sorocaba, Botucatu, Valinhos, Santana de Parnaíba, Mogi das Cruzes, and Indaiatuba. **Cluster 2:** 61.8% of the projects. Projects inside the Leading Ecosystem (São Paulo, São Carlos, Campinas, Piracicaba, and São José dos Campos), 380 projects related to SDG. São Paulo and São Carlos emerge as central clusters

			with the majority concentration of projects.
Leading Ecosystem Cluster Analysis	Further analysis of projects related to SDG within the leading ecosystem. Four variables were used: KAG, Quantity of SDG, SDG Dimension, and CityName. The data was segmented into four clusters.		The most important variables in this cluster analysis were: KAG and Quantity of SDG. **Cluster 1:** 28.7% of the projects. **Cluster 2:** 28.4% of the projects. **Cluster 3:** 21.6% of the projects. **Cluster 4:** 21.3% of the projects. **Most Frequent Categories: KAG**: Exact Sciences + Engineering, **Quantity of SDG**: 2, **SDG Dimension**: Environment, **CityName:** São Paulo. **Project Distribution by KAG**: Exact Sciences + Engineering: 225 projects (59%), Agricultural + Biological: 111 projects (29%), Health: 11 projects (3%), Human + Applied Social + Interdisciplinary: 33 projects (9%).

Source: The authors (2024).

5. Discussion

The research has explored Green Entrepreneurship as a new type of entrepreneurship (Lotfi et al., 2018), tracing its evolution from the emergence of sustainable development and recognizing it as influential in entrepreneurship policy, practice, and theory (Hall et al., 2010). The concept of Knowledge-Intensive Entrepreneurship (KIE) has also been examined, identifying it as a phenomenon originating from the scientific and technological assets available in small companies across various sectors. This understanding assesses how KIE enhances innovation expansion through interactions among various actors within the entrepreneurial ecosystem, focusing on innovation capabilities (Malerba & McKelvey, 2020).

The transition from KIE to Green KIE marks an essential evolution in entrepreneurial endeavors. Initially, KIE leveraged scientific and technological knowledge to drive innovation and competitiveness across sectors. However, with growing global awareness of environmental issues, there has been a shift towards incorporating environmentally conscious practices within entrepreneurship. Green KIE represents a fusion where the knowledge-intensive approach is harnessed for economic gains and to create sustainable solutions, highlighting entrepreneurial ecosystems' adaptability to societal and environmental challenges.

Furthermore, various geographical contexts were studied to conduct a comprehensive analysis of ecosystem dimensions. First, understanding the role of leading ecosystems in triggering sustainable transitions: the PIPE database considers 151 cities from 1998 to 2021, but just five cities account for 380 projects, representing 61.7%. This group was termed "The Leading Ecosystem." The question is: What do these cities possess that others don't? They have robust technology transfer regulations, leadership, financing access, talent, and strong entrepreneurship initiatives, with knowledge hubs like incubators and technology parks connecting universities, entrepreneurs, and the community, reducing entry barriers (Fischer et al., 2022).

This aligns with Spigel (2017), who discusses the advantages of entrepreneurial ecosystems in spreading entrepreneurship as a startup culture and access to financing. Entrepreneurial ecosystems unite different actors, including investment capital, universities, and active economic policies, creating environments supportive of innovation-based ventures. It's a combination of social, economic, political, and cultural elements within a region to support startup growth and encourage nascent entrepreneurs in developing high-risk ventures (Spigel, 2017; Rocha & Audretsch, 2022).

With data analysis findings aligned with the literature review, the importance of leading ecosystems in triggering sustainable transitions is evident (Fischer et al., 2022). It's not enough to focus solely on projects as units; validating the ecosystem in which the idea is developed is crucial, as ideas within leading ecosystems can be developed more easily. The PIPE program, promoting research to boost competitiveness and environmental development (Fapesp, 2023), suggests the need for policies fostering such ideas, as green entrepreneurship connects locations to sustainable transitions through a bottom-up approach (Mullins, 2017).

Second, for the PIPE program, considering SDG as a principal part of projects isn't a submission requirement, but some projects always related to SDG, with a 20% participation in 1998, growing to 40% in 2020. The research considered nine objectives: 2 Zero Hunger, 6 Clean Water and Sanitation, 7 Affordable and Clean Energy, 9 Industry, Innovation and Infrastructure, 11 Sustainable Cities and Communities, 12 Responsible Consumption and Production, 13 Climate Action, 14 Life Below Water, 15 Life on Land.

General results indicate that not all SDG hold the same relevance within projects, showing a lack of entrepreneurial approaches to specific SDG. In different clustering iterations, "Quantity of SDG" and "SDG Dimension" didn't define clusters, indicating concentration in specific SDG and little diversity. The PIPE program receives diverse initiatives, aiming to solve environmental problems (Fapesp, 2023), aligning with Green KIE's goal of generating economic, social, and environmental values (Gholamrezai et al., 2021; Suriyankietkaew et al., 2022). Disparities in SDG subsets create inequalities in outcomes, highlighting the need for targeted approaches to achieve program objectives.

The sustainable development goals were crafted to achieve a better world with shared prosperity, peace, and climate-focused partnership, rooted in gender equality and rights for all (Mahida et al., 2021). These objectives don't carry different relevance in meeting 2030 goals. Ideally, projects would cover various objectives to ensure diversity. Future research could explore why goal 9: Industry, Innovation and Infrastructure, encompasses 25% of projects in São Paulo.

Third, knowledge is generated in places like universities, firms, and research organizations (Cojoianu et al., 2020), playing a key role in KIE, a fundamental source of macroeconomic competitiveness and innovation with local employment impacts, critical for city planning and policy (Fischer et al., 2018). In today's knowledge economy, it's recognized as the most crucial entrepreneurship type (Malerba & McKelvey, 2020).

Four areas were defined for this research, indicating the project's development area. The analysis reveals knowledge area heterogeneity in addressing societal/environmental issues. The database includes 615 SDG-related projects across four areas. The minority concentration in groups 3, Health, and 4, Human + Applied Social + Interdisciplinary at 11.2%, versus the majority in group 1, Exact Sciences + Engineering, and group 2, Agricultural + Biological at 88.8% of SDG-related projects, suggests specific business orientation bias.

The PIPE program has significant potential to promote diverse-knowledge projects while nurturing a collaborative business network, creating an entrepreneurial-friendly environment, especially with defined technology transfer regulations, as noted by Guerrero and Urbano (2019). Strategically aligning project calls with a business consortium's recognition of issues' complexity could spur innovation. Future research might investigate strengthening health, human, applied, and interdisciplinary projects in São Paulo's ecosystem.

Lastly, the entrepreneurial ecosystem approach signifies a shift from traditional entrepreneurship policy to policies supporting a thriving entrepreneurial economy (Stam, 2015) because environmental regulations spur companies to innovate in green technologies (Colombelli & Quatraro, 2019).

With this perspective, the PIPE program becomes increasingly compelling for developing KIE promotion policies aligning with SDG. This enhances comprehension of underlying principles and enables precise direction for initiatives facilitating sustainable transitions.

6. Concluding remarks

This research aimed to identify patterns in knowledge-intensive entrepreneurial projects with an environmental focus in São Paulo, Brazil. It explored the new concept of Green KIE, recognizing it as a specific KIE type (Fischer et al., 2022), and understanding that this kind of entrepreneurship induces institutional, social, and legal marketplace changes while generating economic, social, and environmental values (Gholamrezai et al., 2021; Suriyankietkaew et al., 2022).

Understanding the transition from KIE to Green KIE involves sustainable transitions, geographical processes influenced by factors like the political environment and local knowledge, indicating that green entrepreneurship is highly localized and place-dependent

(Hansen & Coenen, 2015). Green entrepreneurship introduces new solutions for urban areas, connecting locations to sustainable transitions via a bottom-up approach (Mullins, 2017).

This KIE type extends beyond general knowledge, characterized by the double externality issue, as it positively impacts both the innovation and diffusion stages, reducing environmental harm compared to conventional technologies (Cojoianu et al., 2020).

Guided by literature, an analysis of the PIPE database was conducted to identify patterns in knowledge-intensive green entrepreneurship projects. Through cluster analysis, alignment opportunities with the Sustainable Development Goals (SDG) were uncovered. While SDG alignment isn't required for submissions, it's central to PIPE's mission, suggesting potential for policies promoting diverse projects across various SDG.

The analysis highlighted the low participation of certain knowledge areas in the projects. To address this, promoting projects presented by business networks as an entity, encompassing diverse knowledge areas, could be beneficial. This approach considers the complexity of challenges posed by the SDG. Encouraging collaboration between clusters enhances the potential for leveraging knowledge and nurturing ecosystem creation.

It's important to acknowledge the limitations of the findings. While the study provided valuable insights by examining a PIPE program database in São Paulo, it's constrained by a limited set of variables, offering only a partial view of Green KIE and the Entrepreneurship Ecosystem.

Therefore, further investigations in this field are imperative to enhance the understanding of green entrepreneurial ecosystems. It would be interesting to study. Why do some areas of knowledge have a greater impact? How are the projects developed in the EE, among a group of stakeholders or for only one unit? To achieve a more comprehensive perspective, complementary methodologies are warranted to illuminate how ecosystems can more effectively foster environmentally-sustainable entrepreneurship.

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