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# IMPORTANCE OF THE FOREST SECTOR IN THE POTENTIAL OF ATTRACTING PEOPLE

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**ABSTRACT**

Importance of the forest sector in the potential of attracting people. In this work, a modification of Newton's gravitational model was performed to determine the attraction potential of people in cities. It was proposed to add weights, defined by variables that make up the agricultural sector, which allowed us to identify the importance of each sector segment. Through the proposed modeling, it was identified that the Nominal Value of Forest Production presented the greatest potential for attracting people in the municipalities of the Second Parana plateau region. The data and modeling framework presented are useful for defining strategies, especially for investments in the agricultural sector, as well as for describing the economic growth of a region in terms of its productive structure and identification of regional growth components.



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## INTRODUCTION

The greater the centrality of a place, the larger its surroundings, that is, the greater the complexity of the service offered, the larger the area served by this center. The importance of central places is greater the broader their supply of goods and services. Therefore, it is the distribution and reach of central goods and services that will structure the hierarchical network of cities. Cruz (2000) points out "the predominant descriptive idea in the Central Place Theory is that central cities constitute nodes of a large network of cities and an "invisible hand" will make the most important centers hierarchically superior". The author argues that spatial hierarchy would be a resultant and not a cause. According to Silva (2011) "central place" are the spaces (establishment, settlement, region, city, among others) that economic agents seek to complete their demands for goods and services, these spaces are elevated hierarchically because of their geographical position and variety of goods and services offered to nearby locations. For the author, these variables determine their degree of centrality. Von Thünen (1966), in order to explain the locational pattern of German agriculture, demonstrated that this arose from the combination of physical productivity of land with distance to markets and transportation costs, which determined the rings of agricultural specialization around cities. The author developed a theory called thünenrings, which are the circumferences around the city, each delimiting the area of cultivation of a product. As a result, product prices would be influenced according to their distances from the center. Weber (1929) developed an important study on company location, in which cost minimization was analyzed as a decision variable. The author suggested three factors that would determine the location of the industrial enterprise: transportation cost; labor costs; the advantages associated with agglomeration, that is, the so-called crowding economies. In Weberian Theory, the company looks for location that minimizes wage costs or the transportation costs of raw materials and finished products in different situations. Likewise, the Central Place Theory is based on the principle of centrality, the space being organized around a main urban core, called the central place. The complementary region, or surroundings, has a codependency relationship with the main nucleus, as this is the *locus* provider of goods and services. This model seeks to demonstrate that a city system, that is, a long-distance network characterized in a hierarchy of central places, arises from defined socio-spatial relationships based on size, functions, and long-distance distances. Subsequently, the works of Lösch (1957) were

developed, indicating that economic activities would be at the center of market areas, which were assumed uniform in geographical space. The model combined scale and transportation costs. Lösch (1957) sought to describe how a company produces an industrial good at a certain average cost, reaching the most distant consumer, until the transportation cost and the cost of production are equal to the price of the product. Extending the problem of industrial location to the entire economic system suggests a general spatial equilibrium, which remains current. Finally, among the classics of location theory, it is necessary to emphasize Isard's contribution (1956; 1975). Disagreeing with the interpretation given by neoclassical economic theories to the spatial dimension, the author created what is now called Regional Science. Isard's criticism referred to the fact that the spatial dimension was not considered by the classics, which were based on the assumption that there should be an equalization of the production factor prices, due to the perfect competition regime, and the perfect factor mobility, with which transport costs were disregarded. Isard (1975), in his articles and texts, has always presented and developed techniques and methods of regional analysis from information bases already disseminated in developed countries, notably the USA, such as national accounts systems, population censuses, economic censuses, input-output matrices, among others, but was explicitly concerned with indications and instructions for the construction of such bases. Isard (1956) synthesized the theoretical-methodological production of this line by integrating Von Thünen's model with microeconomics (profit maximization and cost minimization). Through the concept of transportation inputs, it was possible to equate the locational question, pointing out the effect of distance on spatial interactions. Your work *Location and space-economy* (1956) provoked the emergence of regional science, which aimed to improve the spatial and regional structure of different social sciences, especially economics, by establishing a more adequate general theory of location and economic space. Later, inspired by the famous Law of Universal Gravitation, elaborated by the English physicist and mathematician Isaac Newton in 1687, Isard (1975) observes that the same principle can be employed in demarcating the area of influence of a geographically located economic pole. The gravitational model proposed by Isard (1975) "allows the definition of a pole interaction area sketch, close to the idea of market area, taking into account the power of attraction determined positively by the intensity of economic exchanges and negatively by distance economically reflected in the transport cost per unit of the product transported".

According to Isard (1975), "as with gravitational phenomena in physics, we are not able to explain the spatial interaction phenomena of the journey to work and the relationship in the social world. We can only speculate on the "why" of them.
For Almeida, Araújo and Rodrigues (2009), economic development is different depending on the geographical location and the distances of the major consumer centers. The study assumes how economic activities are distributed in geographical space. For Oliveira (2004), the models of the new economic geography do not bring major contributions or innovations from a theoretical point of view in relation to theories elaborated by regional and urban scientists, but rather in the form of modeling the sources that provide the economic basis to explain the distribution of activities in space. Thus, the present study aimed to investigate the regional economic dynamics by means of passenger flows in inter-municipal collective transport in the cities of the Parana Second Plateau region and to estimate the potential for attracting people through the gravitational model observing agricultural activities.

## MATERIAL AND METHODS

**Data Source:** This research was developed in the region of Second Parana Plateau, state of Paraná, Brazil. The cities of Telemaco Borba, Ortigueira, Sapopema, Curiúva, Figueira, São Jeronimo da Serra, Imbaú, Reserva, Tibagi and Ventania were considered. The main reason for the choice of this region is that the economy of the region presents itself in a diversified way, highlighting the timber sector, assuming that the municipality of Telêmaco Borba was initially driven by the activity of pulp and paper process wood, located there, and later the Forest Activity was disseminated to the neighboring municipalities. In view of this context, it is worth mentioning Myrdal's brief quotation (1957), "from an initial agglomeration, a region in which economies of scale and technological development existed would attract new resources that would reinforce its expansion." In the application of the model proposed by Isard (1975), the distances between the studied municipalities, their respective populations and the flows of passengers in the year 2010 in intermunicipal collective transport were used. The mass of the gravitational model in the present study corresponds to the variable population ($_{Pi}$). The socioeconomic data come from the censuses conducted in 1991, 2000 and 2010 by the Brazilian Institute of Geography and Statistics (IBGE). To compose the original Gravitational Model, the values of the distance (dij, in kilometers) between the municipalities were provided by the Department of Roads and Drive of the State of Paraná [1](DER / PR, 2010).

The number of trips made by public transport between the municipalities of the region in 2010 was obtained through data observed by DER / PR (2010). Among the 90 possibilities of flows, 43 were obtained, since the rest did not occur, due to the lack of regular and direct lines of intermunicipal collective transportation among some municipalities. It was observed that on the sample was 309,079 displacements in the year 2010.
The study has the characteristics of being exploratory, with a quantitative approach from secondary data. For the application of the model proposed by Isard (1975), the distances between the municipalities, their respective populations and the flows of passengers observed in the intermunicipal collective transport were used. Thus, according to Newton's proposals, the force of attraction (F) value is directly proportional to the masses of the two bodies and is inversely proportional to the square of the distance between them. The forces appear in pairs, that is, if one body attracts another, it is also attracted by the first. In the present study, the constant (G) represents a correction factor between the mass units and the distance that separates it. With all the variables and constants obtained through these mathematical procedures, the model developed by Isard (1975) was applied to obtain a new flow estimated by the gravitational model of the displacements of the people through intermunicipal collective transportation. As such, it is expressed by:

$$I_{ij} = G \frac{P_i * P_j}{(d_{ij})^b} \quad \text{.....(1)}$$

[11]Departamento de Estradas e Rodagem do Estado do Paraná (DER/PR)

In what: $_{Iij}$ = Estimated flow; G = correction factor; Pi = Population of i; Pj = Population of j; dij= distance between i and j; b = exponential coefficient

In order to determine or estimate the Potential of Attraction ($_{Vi}$) of the municipalities of the Second Plateau of Paranaense, the Principle of Superposition was observed. This means that when two or more waves propagate simultaneously in the same medium and instant and in the same direction, it is said that there is a superposition of waves. The resulting wave is equal to the algebraic sum of the waves that each would produce individually. This principle can be applied to obtain a resulting scalar magnitude. Thus, considering passenger flows in inter-municipal collective transport, such as waves, the greater the volume and intensity of these flows to the same municipality, the greater its potential attraction (Vi). According to Schneider *et al*. (2016), two interpretations can be given to the concept of attraction potential ($_{Vi}$). On the one hand, it is a measure of their influence or impact on point *i*, and the set of masses distributed in space (including the mass of *i* itself). On the other hand, it is a measure of accessibility of point *i* to the set of masses distributed in the space under study. In this way, the greater the intensity at point *i*, when compared to the other points, the greater its attraction potential (Vi). In this context, the interaction (or flow) between points *i* and *j* estimated by the presented model can be calculated in order to obtain the interaction between *i* and all points *j*, which represents the attraction potential (Vi) of point *i*. It should be noted that the attraction potential (Vi) of point *i* is equal to its own mass ($_{Pi}$), plus the masses of the remaining points, each corrected by its distance to i, multiplied by a constant (G). As described, the interaction between *i* and *j* is expressed by:

$$V_i = 1 + (I_{i1} + I_{i2} + I_{i3} + \cdots + I_{in}) \quad \text{.....(2)}$$

In what: $_{Vi}$ = Potential of Attraction of the municipality *i* ; Ii1 = Estimated flow from municipality 1 to *i* ; Ii2 = Estimated flow from municipality 2 to *i* ; Ii3 = Estimated flow from municipality 3 to *i* ; Iin = Estimated flow of the municipality *n* for *i*.

In the composition of mass values ($P_i w_i$), proposed by Isard (1975), it was decided to add the variable ($w_i$) in values relative to the analyzed set. This gives the new value for the variable called weighting factor ($w_i$).

The new mass ($P_i w_i$) was obtained using the expression:

$$P_i w_i = P_i * (1 + w_i / w_T) \quad \text{.....(3)}$$

Where: $P_i w_i$ = Mass value with weighting factor; $P_i$ = Population of city "i"; $w_i$ = Weighting factor; $w_T$ = Σ of Weighting Factor.

The value of the new mass ($P_i w_i$) is presented in the same dimensional unit (unitary) when compared with the values of the original model proposed by Isard (1975), where ($w_i$) was presented in absolute values. As a weighting factor ($w_i$) the Nominal Value of Forest Production (gravitational model "1"), the Nominal Value of Agricultural Production (gravitational model "2") and the Nominal Value of Livestock Production (gravitational model "3") were used.

From this expression, the attraction potential ($V_i$) of the municipality can be described by:

$$V_i = G * P_i w_i + G * \frac{P_i w_i * P_1 w_1}{(d_{i1})^b} + G * \frac{P_i w_i * P_2 w_2}{(d_{i2})^b} + \cdots + G * \frac{P_i w_i * P_n w_n}{(d_{in})^b} \quad \text{.....(4)}$$

On what: $V_i$ = Municipality Attraction Potential " *i* "; G = Correction Factor; $P_i w_i$ = Weighting Factor of " *i* "; $P_1 w_1$ = Weighting factor of municipality 1; $P_2 w_2$ = Weighting factor of municipality 2; $P_{no} w_{no}$ = Weighting factor of municipality n; $d_{i1}$ = Distance between municipality " *i* "And the municipality "1"; $d_{i2}$ = Distance between municipality " *i* " And municipality "2"; $d_{in}$ = Distance between municipality " *i* " And the municipality " *no* "; b = $b_1$.

## RESULTS AND DISCUSSION

The observed flows ($I_{ij}$) presented a total of 309,079 people (T) who used intercity transport in 2010. The total value of the new mass, the population of the region, is 199,288 people (P). When observing the gravitational model "1", the values added to the new mass ($P_i w_i$) are presented in Table 1. When the regression of the variables in question is made, having as dependent variable (Log $I_{ij} / T_{ij}$) and the independent variable (Log $d_{ij}$), the equation obtained was:

$$\text{Log}(I_{ij} / T_{ij}) = 5.2356 - 3.2635 \text{ Log}(d_{ij}) \quad \text{.....(5)}$$

The model presented a coefficient of determination ($R^2$) equal to 0.76 and a high F value of 132.30, being significant at the 95% probability level. The standard error of the estimate ($S_{xy}$ %) was 20%. Thus, it can be stated that the new model, with the weighting factor ($w_i$), the Nominal Value of Forest Activity, combining the Population variable ($P_i$), forms a new mass ($P_i w_i$) which, when related to the distance between them, better explains the variations in flows between municipalities. The estimated flows (*Iij*)in intermunicipal collective transport should occur in less quantity than was observed for the equilibrium between the two sides of the equation to occur. The correction factor provided an increase in the value of the quantity of the quotient between the size of the masses and the distance that separates them so that the mathematical equality occurred in the gravitational model.

The gravitational model can then be written as follows:

$$I_{ij} = 1{,}33 \frac{P_i w_i * P_j w_j}{(d_{ij})^{3{,}26}} \quad \text{.....(6)}$$

With respect to the attraction potential (Vi), that is, the attractiveness of each municipality in the region can be represented by the equation:

$$V_i = 1{,}33 * P_i w_i + 1{,}33 * \frac{P_i w_i * P_1 w_1}{(d_{i1})^{3{,}26}} + 1{,}33 * \frac{P_i w_i * P_2 w_2}{(d_{i2})^{3{,}26}} + .. + 1{,}33 * \frac{P_i w_i * P_n w_n}{(d_{in})^{3{,}26}} \quad \text{.....(7)}$$

The municipality with the highest attraction potential ( $V_i$ ) of people was Telemaco Borba (139,120; 42.77%), followed by the municipality of Reserva (38,416; 11.81%). The municipality of Ortigueira had the third best potential with 32,745, representing 10.07%. The least attractive municipalities were Tibagi (29,515; 9.07%), Curiúva (20,847; 6.41%), Imbaú (15,464; 4.75%), São Jerônimo da Serra (15,263; 4.69%), Ventania ( 13,505; 4.15%), Figueira (11,337; 3.49%), Sapopema (9,069; 2.79%).

**Table 1. Weighting factor ($p_i w_i$) population *versus* nominal value of forestry**

| MUNICIPALS | $P_i$ | Forest Activity (R $) * | ($w_i / w_T$) | ($P_i w_i$) |
|---|---|---|---|---|
| Telêmaco Borba | 69,872 | 239,034,910 | 0.49 | 103,908 |
| Imbaú | 11,274 | 11,825,816 | 0.02 | 11,546 |
| Reserva | 25,172 | 68,619,235 | 0,14 | 28,692 |
| Ortigueira, | 23,380 | 22,604,480 | 0.05 | 24,457 |
| Tibagi | 19,344 | 68,486,100 | 0,14 | 22,044 |
| Curiúva | 13,923 | 58,044,390 | 0.12 | 15,570 |
| Ventania | 9,957 | 6,388,920 | 0.01 | 10,087 |
| Figueira | 8,293 | 10,312,806 | 0.02 | 8,467 |
| Sapopema | 6,736 | 2,677,182 | 0.01 | 6,773 |
| São Jerônimo da Serra | 11,337 | 2,711,724 | 0.01 | 11,400 |
| TOTAL | 199,288 | 490,705,563 | 1 | |

* Nominal Amount (R $ 1.00)

**Table 2. Weighting factor ($p_i w_i$) population *versus* nominal value of agricultural activity**

| **MUNICIPALS** | **$P_i$** | **Agricultural Activity (R $)** * | **($w_i / w_T$)** | **($P_i w_i$)** |
|---|---|---|---|---|
| Telêmaco Borba | 69,872 | 1,936,431 | 0.002 | 69,993 |
| Imbaú | 11,274 | 13,265,266 | 0.012 | 11,408 |
| Reserva | 25,172 | 267,191,203 | 0.241 | 31,227 |
| Ortigueira, | 23,380 | 120,146,870 | 0.108 | 25,909 |
| Tibagi | 19,344 | 444,731,953 | 0.400 | 27,090 |
| Curiúva | 13,923 | 43,859,234 | 0.039 | 14,472 |
| Ventania | 9,957 | 117,285,073 | 0.106 | 11,008 |
| Figueira | 8,293 | 12,561,581 | 0.011 | 8,386 |
| Sapopema | 6,736 | 7,907,354 | 0.007 | 6,783 |
| São Jerônimo da Serra | 11,337 | 81,723,526 | 0.074 | 12,171 |
| TOTAL | 199,288 | 1,110,608,496 | 1 | |

* Nominal Amount (R $ 1.00)

The Nominal Value of Forest Activity, as a weighting factor ($w_i$) provided an increase in attraction potential ($V_i$) of people when compared to the original model. The factor represented 48%, increasing the centrality of Telemaco Borba. This characteristic is associated with the demand for forestry products from the installed companies, resulting from the Forest Based Local Productive Arrangement, mainly the pulp and paper industry. According to Schneider (2019), investments in commercial forest planting provided facilities and benefits from the Local Productive Arrangement (LPA) installed in the central municipality, generating a large rural-urban migration from 1991 to 2000, providing greater potential for attracting people. According to Clemente (1994), the existing production links between regions indicate that the internal supply of each region depends on other regions and, at the same time, the influences, showing that if in each region part of the demand is supplied with the production from other regions, aggregate demands are interdependent.

Given this inference, it is observed that the region of the Second Plateau Paranaense is interdependent, because the supply of forest raw material is regional. The largest concentration is in Telêmaco Borba and in the nearest municipalities, that is, in the shortest distance from the central place, that is, where is the largest concentration of companies related to the forest activity, and the main regional economic activity is due to the industrial activities. developed in the municipality and consequently in the region. In recent years, the radius of the forest around the central place has increased, causing an increase in the area of influence of the municipality of Telêmaco Borba. According to Schneider *et al*. (2018) one of the advantages of agglomeration for companies in the same industry includes gravitation around sources of raw material and / or facilities of non-transportable resources. These synergies depart from the central place (Telêmaco Borba) to the nearest municipalities and, to a lesser extent, to the municipalities further from the center.

The closest ones benefit from the advantages produced by the LPA, especially in terms of the distance from the raw material to the beneficiation site, when compared to the more distant municipalities. According to the authors, this increase in regional demand for forests comes from the increase in the production of forest-based derivatives, due to the expansion of the national and international market. Telemaco Borba, with the pulp and paper industry and the LPA, represents the largest forest consuming center in the region. When observing the gravitational model "2", the values added to the new mass ($P_i w_i$) are presented in Table 2. When the regression of the variables in question is made, having as dependent variable ($\text{Log } I_{ij} / T_{ij}$) and the independent variable ($\text{Log } d_{ij}$), the equation obtained was:

$$\text{Log } (I_{ij} / T_{ij}) = 4.8922 - 3.0305 \text{ Log } (d_{ij}) \quad \text{.....(8)}$$

The model presented a coefficient of determination ($R^2$) equal to 0.69 and a high F value of 93.32, being significant at the 95% probability level. The standard error of the estimate ($S_{xy}$ %) was 20%. The new model, with the weighting factor ($w_i$), the Nominal Value of Agricultural Activity, combining the Population variable ($P_i$), forms a new mass ($P_i w_i$) which, when related to the distance between them, diminishes the explanatory power of variations in flows between municipalities. The estimated flows ($I_{ij}$) in intermunicipal collective transport should occur in less quantity than was observed for the equilibrium between the two sides of the equation to occur. The correction factor provided an increase in the value of the quantity of the quotient between the size of the masses and the distance that separates them so that the mathematical equality occurred in the gravitational model.
The gravitational model can then be written as follows:

$$I_{ij} = 0{,}60 \frac{P_i w_i * P_j w_j}{(d_{ij})^{3{,}03}} \quad \text{.....(9)}$$

**Table 3. Weighting factor ($p_i w_i$) population *versus* nominal value of livestock activity**

| MUNICIPALS | $P_i$ | Livestock Activity (R $) * | ($w_i / w_T$) | ($P_i w_i$) |
|---|---|---|---|---|
| Telêmaco Borba | 69,872 | 4,751,595 | 0.02 | 71,023 |
| Imbaú | 11,274 | 4,049,105 | 0.01 | 11,432 |
| Reserva | 25,172 | 35.093.564 | 0.12 | 28,234 |
| Ortigueira, | 23,380 | 62,454,398 | 0.22 | 28,442 |
| Tibagi | 19,344 | 82,410,511 | 0.29 | 24,871 |
| Curiúva | 13,923 | 35,656,668 | 0.12 | 15,644 |
| Ventania | 9,957 | 11,192,257 | 0.04 | 10,343 |
| Figueira | 8,293 | 5,665,135 | 0.02 | 8,455 |
| Sapopema | 6,736 | 28,082,281 | 0.10 | 7,391 |
| São Jerônimo da Serra | 11,337 | 19,062,001 | 0.07 | 12,086 |
| TOTAL | 199,288 | 288,417,520 | 1 | |

* Nominal Amount (R $ 1.00)

With respect to the attraction potential (Vi), that is, the attractiveness of each municipality in the region can be represented by the equation:

$$V_i = 0{,}60 * P_i w_i + 0{,}60 * \frac{P_i w_i * P_1 w_1}{(d_{i1})^{3{,}03}} + 0{,}60 * \frac{P_i w_i * P_2 w_2}{(d_{i2})^{3{,}03}} + .. + 0{,}60 * \frac{P_i w_i * P_n w_n}{(d_{in})^{3{,}03}} \quad \text{.....(10)}$$

The municipality with the highest attraction potential ($V_i$) of people was Telêmaco Borba (42,502; 32,04%), followed by the municipality of Reserva (18,963; 14,29%). The municipality of Tibagi had the third best potential with 16,451, representing 12.40%. The least attractive municipalities were Ortigueira (15,733; 11,86%), Curiúva (8,789; 6,63%), São Jerônimo da Serra (7,391; 5,57%), Imbaú (6,932; 5,23%), Ventania ( 6.685; 5.04%), Figueira (5.093; 3.84%), Sapopema (4.120; 3.11%). The Nominal Value of Agricultural Activity, as a weighting factor ($w_i$), is concentrated in the municipalities of Tibagi (40%) and Reserva (24%) causing a better distribution of the attraction potential ($V_i$) of people between the municipalities of the region. Agricultural activity attracts fewer people compared to the potential of forest activity. This phenomenon can be explained by the greater use of people in forestry when compared to agricultural activity, due to agricultural mechanization, which, with the implementation of new technologies, generated a lower demand for labor for this activity. This characteristic is related to the main agricultural activity (forestry) of the municipality of Telêmaco Borba, and developed agricultural activity is incipient when compared to the other municipalities of the region of Second Parana Plateau. Unlike the forest activity developed in the municipality, with large forest massifs and a high level of mastery of this activity.

According to Schneider *et al*. (2018), the characteristic of the movements of production factors may represent an increase in the area of influence of the central place due to the need for some scarce production factor. In this case, the land factor production, scarce in the municipality of Telêmaco Borba, provided new investments in the acquisition and planting of new areas for forest production, due to the increased demand for this raw material in the central place. Given this inference, it is observed that in the neighboring municipalities to the central place decreased investments in agricultural and livestock activities, providing greater competition of the factor land for the development of forest activities and detriment of a decrease in other agricultural activities. When observing the gravitational model "3", the values added to the new mass ($P_i w_i$) are presented in Table 3.

When the regression of the variables in question is made, having as dependent variable (Log $I_{ij} / T_{ij}$) and the independent variable (Log $d_{ij}$),

$$\text{Log}(I_{ij} / T_{ij}) = 4.8747 - 3.0225 \text{ Log}(d_{ij}) \quad \text{.....(11)}$$

The model presented a coefficient of determination ($R^2$) equal to 0.71 and a high F value of 101.12, being significant at the 95% probability level. The standard error of the estimate ($S_{xy}$ %) was 20%.

The new model, with the weighting factor ($w_i$), the Nominal Value of Livestock Activity, combining the Population variable ($P_i$), forms a new mass ($P_i w_i$) which, when related to the distance between them, diminishes the explanatory power of variations in flows between municipalities. The estimated flows ($I_{ij}$) in intermunicipal collective transport should occur in less quantity than was observed for the equilibrium between the two sides of the equation to occur. The correction factor provided an increase in the value of the quantity of the quotient between the size of the masses and the distance that separates them so that the mathematical equality occurred in the gravitational model. The gravitational model can then be written as follows:

$$I_{ij} = 0{,}58 \frac{P_i w_i * P_j w_j}{(d_{ij})^{3{,}02}} \quad \text{.....(12)}$$

With respect to the attraction potential (Vi), that is, the attractiveness of each municipality in the region can be represented by the equation:

$$V_i = 0{,}58 * P_i w_i + 0{,}58 * \frac{P_i w_i * P_1 w_1}{(d_{i1})^{3{,}02}} + 0{,}58 * \frac{P_i w_i * P_2 w_2}{(d_{i2})^{3{,}02}} + \cdots + 0{,}58 * \frac{P_i w_i * P_n w_n}{(d_{in})^{3{,}02}} \quad \text{.....(13)}$$

The municipality with the highest attraction potential ($V_i$) of people was Telêmaco Borba (41,425; 32,59%), followed by the municipality of Ortigueira (16,590; 13,05%). The municipality of Reserva had the third best potential with 16,469, representing 12.96%. The least attractive municipalities were Tibagi (14,507; 11,41%), Curiúva (9,125; 7,18%), São Jerônimo da Serra (7,050; 5,55%), Imbaú (6,672; 5,25%), Ventania (6.033; 4.75%), Figueira (4.933; 3.88%), Sapopema (4.312; 3.39%). The difference between the behavior of attraction potential ($V_i$) of people from livestock and agricultural activity is shown only in the hierarchy of municipalities, and Ortigueira assumes the second largest potential. It is noteworthy that the livestock activity developed in the municipality represents the second largest proportional value (22%) of the region.

There was a lower centrality of the attraction potential ($V_i$) of people in the municipalities of the Second Parana Plateau region due to a better proportional distribution of the weighting factor ($w_i$), added to the original model. This characteristic is linked to revenues from livestock activities developed in the municipalities of the region. According to Schneider *et al*. (2018), the addition of the weighting factor (wi) to the original gravitational model provided a better fit in relation to the gravitational model. The variable population by itself does not fully explain people's behavior regarding the use of public transport between cities. In its study it was demonstrated that the regional industrial activity provided a greater potential of attraction when compared with the other economic activities developed in the region of the Second Parana Plateau. According to the authors, the model developed by Newton is static and closed, thus showing limitations in the explanation of each city in attracting people. Thus, their study demonstrated the importance of establishing correction and weighting factors to obtain a better explanation of the results found. For Schneider (2019), the "land" production factor became scarce, generating greater competitiveness among the activities developed in the region under study, and the forestry activity stood out due to the facilities generated by the LPA installed there, directing the use of this factor. For activities related to the forest and its particularities thus generating a greater potential for attracting people.

**Final Considerations**

The addition of the weighting factor ($w_i$), to the original gravitational model, provided a better fit in relation to the evaluated statistics. The greater the centrality of the weighting factor ($w_i$), the greater the attraction potential ($V_i$) of people from the central place. The municipality that provided the greatest attraction potential ($V_i$) of people was Telêmaco Borba, being considered the central place of the region under study. Among the weighting factors ($w_i$) that makes up the variables of the agricultural sector, the Nominal Value of Forest Production provides the greatest potential for attraction ($V_i$) of people in the municipalities of the Second Parana Plateau region. This is a fact that can be explained by the local productive arrangement (LPA) located there because of the primary activity of the forest sector. Thus, it is observed that the main regional activity generates a greater potential for attracting people. From this study it was demonstrated that the data and the modeling structure presented is useful for the definition of strategies, especially regarding investments in the agricultural sector, mainly in the forestry activity, as well as to describe the economic growth of a region in terms of its productive structure and identification regional growth components.

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