The ecological footprint of João Monlevade city, Brazil – Conventional Method

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Abstract. The Ecological Footprint (EF) is a measure of the burden imposed by a population on nature. It represents the soil area required to sustain resource consumption and waste generation levels, expressed in units of a hectare per person. This work aims to calculate and evaluate the EF of a small city in Brazil, João Monlevade (JM) - Minas Gerais (MG). For the calculation, the conventional method proposed by Wackernagel and Rees in the '90s was used. It is based on the sum of the footprint of variables calculated from the annual average of consumption items, dividing the total consumption by the population size, subtracted from the biocapacity. JM's biocapacity and EF are 0.048, and 0.643 ha / inhabit., respectively. Therefore, local consumption exceeds the support capacity of the natural environment, making it necessary to have an adequate environmental municipality planning. The most significant footprint was related to CO₂ emission from burning fossil fuels, 0.47 ha / inhab., indicating the need to implement mitigation measures. It is concluded that the calculation of the municipality's EF points out more sustainable ways for a better population life quality. However, the calculation requires improvement, with the definition of other relevant indicators and data careful analysis.

Keywords: Ecological Footprint. Sustainability. Environmental Indicator. Environmental impact.

1. Introduction

Consumerism, population growth and the progressive cities expansion, are sustained by the appropriation of the resources in areas, many times greater than their own. This means that the support capacity and the ecosystems natural renewal cannot keep up with the unrestrained occupation of spaces and the urbanization growth. (CARLETTO E OLIVEIRA, 2017).

Sustainable Development (SD) in a given community must integrate social, economic and environmental aspects, relying on tools that materialize these expected effects (CIDREIRA-NETO E RODRIGUES, 2017).

In this sense, sustainability indicators can motivate solutions and lead to decision-making for public policy formulation (TEIXEIRA, 2012). Therefore, it is necessary to identify the negative and positive aspects to expand the topic discussion, and to improve the population lives, seeking to insert into the daily lives of city citizens basic principles of sustainability (MASSOLLI, MASS E VILELLA, 2018).
Besides, it is necessary to know the individual's consumption patterns and to point out the environmental damage associated with unsustainable practices, to show their community (SILVA et al., 2016; CARLETTO E OLIVEIRA, 2017). In this context, the ecological footprint (EF) stands out because, it easily shows if the consumption of a given population is supported by it (GONZALEZ E ANDRADE, 2015).

João Monlevade originated in the early 19th century, being a pioneer in steelmaking Minas Gerais states, Brazil. Since its emancipation, it has significantly progressed, becoming one of the most important mining towns (IBGE, 2010; GUIMARÃES, 2010). However, progress has also brought harmful consequences to the environment, being necessary to carry out environmental planning.

Thus, this study aims to perform and evaluate the EF calculation for the municipality of João Monlevade-MG, Brazil.

2. Methodology

The municipality of João Monlevade is located in the Middle Piracicaba, southeast of the state of Minas Gerais (Brazil), in the Itabira microregion (Figure 1), between the geographic coordinates of 19° 48' 36" S of latitude and 43° 10' 26" W longitude with a territorial unit of approximately 99,158 Km² and an estimated population of 73,610 inhabitants (IBGE, 2010). The steel industry is its main economic activity (GUIMARÃES, 2010).

**Figure 1. João Monlevade City Location Map**

The reference method applied to obtain EF was that of Wackernagel and Ress (1996), which calculates the average biocapacity in footprints on the planetary scale, adapting it to the local level. Variables defined for the calculation were based on the reference method and, among other studies, by the justifications presented by Lisbon and Barros (2010, p. 3):

**Green and built area:** it is obtained from the analysis of the use and occupation map of the municipality, made available by the planning secretariat of JM city hall.
**Food consumption:** sales checked-in a supermarket in the city centre - data regarding the main consumed foods were requested: rice, beans and beef, in Kg/year, besides the leading butchers. For data conversion on food amount in kilograms (kg) to hectares (ha), the proportion methodology established by Embrapa was used (2005).

**Energy consumption:** obtained from the Atlas Solarimétrico of Minas Gerais, a study carried out by the State Energy Company SA (CEMIG, 2012). First, an energy consumption average of Itabira's microregion in 2010 was made. Later, the total consumption was divided by inhabitants number. This value was multiplied by the whole city population to obtain the value of the population's electricity consumption. Subsequently, the average energy consumption of the municipality in 24 hours was then defined, and the amount of energy produced by the hydroelectric plant closest to João Monlevade was obtained. The daily energy consumption divided by the amount of energy produced by the plant estimated the area used for the production of the energy consumed in JM, in ha.

**Water consumption:** consumption and annual rainfall in the city were used. From these data, the area, in ha, that would be necessary to collect annual water in the city for its own supply was calculated, dividing the water consumption (m³) by the pluviometric index (mm), with the necessary conversions, and dividing the value obtained by the JM population.

**CO₂ emissions from burning fossil fuels:** based on João Monlevade's vehicle fleet, according to IBGE (2010). The average annual fuel consumption of a car, which is 822.1 litters/year was based on the assumption that burning 1 litre of fuel releases 2.3 kg of CO₂ into the atmosphere, and that each hectare of green area absorbs 1.8 t of CO₂.

**Waste generation:** "garbage" average production, in Kg/year, according to data from the city's landfill, provided by the JM Municipality. Based on the assumption that each 3 kg of waste emits 1 kg of CO₂, and taking into account that each hectare absorbs 1.8 tons of CO₂.

The EF index total value was calculated on the footprint of the other variables (\( \sum P \)), subtracted from biocapacity (Equation 1).

\[
EF = \sum P - \text{Biocapacity} \tag{1}
\]

Biocapacity represents what the local ecosystem is capable of providing, that is, natural resources also called biological capacity (LISBOA E BARROS, 2010). The variables footprints were obtained by the average consumption and capacity items, dividing the total consumption by the size of the municipality's population, with results expressed in global hectares unit per inhabitants (ha/hab) (GLOBAL FOOTPRINT NETWORK, 2006).

3. **Results and Discussions**

In the João Monlevade city, the green area constitutes a total of 3520 ha, formed by the preservation zones. The built area is 6192 hectares, which can be characterized as urbanized predominant. According to Massolli, Mass and Vilella (2018 p. 48) "it is important that we know the conditions of the green areas within the municipalities, since these areas fulfil relevant environmental services, and can also serve as recreation areas for the population."

Considering the total of 73610 inhabitants (inhab.), the biocapacity and footprint of the built area are 0.048 and 0.084 hectares per inhabitants (ha/inhab.), respectively. The global biocapacity is 1.7 ha/inhab., considering a total of approximately 7 billion inhabitants (ONUBRASIL, 2011), and has been decreasing, either by increasing the population or by the degradation of soils and seas (FAVA e VIALLI, 2009).
João Monlevade's biocapacity value is below the global measure. This may be explained by the increasing urbanization in the 20s, coinciding with the arrival of a steel company, which brought the population growth, unplanned population distribution, devastating much of the original vegetation, the Atlantic Forest.

Thus, the total food consumption per year is 560564.5 kg, that is, 4268.8 ha for food production, which results in a footprint of 0.058 ha/inhab. (Table 1).

| FOOD          | SOURCE             | QUANTITY (kg/year) | AREA (ha) |
|---------------|--------------------|--------------------|-----------|
| Rice          |                    | 205614,0           | 3,62      |
| Bean          |                    | 88474,5            | 1,56      |
|               | Comil Supermark    | 78007,0            | 1248,1    |
|               | Zebu Butchery      | 67200,0            | 1075,2    |
|               | Werly Butchery     | 53769,0            | 860,3     |
| Beef          | Carneirinho Butchery | 67500,0         | 1080      |
| TOTAL         |                    | 560564,5           | 4268,8    |
| EF (ha/inhab.)|                    |                    | 0,058     |

Source: own research data

Agricultural activities usually cause significant impacts on biodiversity, and, most often, are configured in degraded areas, increasing energy demand and emissions of gases causing the greenhouse (GHG) (LAMIM-GUDEDE e OLIVEIRA-VILELA, 2011). For Santos, Leonardos and Mota (2013 p. 51) "the EF serves to demonstrate the quantitative pressure of food consumption on the environment, but it is insufficient as an indicator of food security because it is not appropriate for more qualitative analyses".

João Monlevade's energy consumption is 6.7407 MWh/inhab., the populations are 496183.539 MWh, and in the 24-hour period, it was 56.642 MW. Based on daily energy consumption, the area used for producing the energy consumed in the municipality is 3607.77 ha. When considering the whole population, the energy consumption footprint is 0.049 ha/inhab.

The values obtained for water consumption and annual rainfall in João Monlevade were 9460800 m³/year and 1372 mm, respectively. To meet the water demand of 9460800 m³, an area of 70.03 ha would be required, which is equivalent to a water consumption footprint of 0.00095 ha/inhab. Although it seems sustainable, the World Wide Fund for Nature - WWF (2007) recommends savings in water use, as the population has spent an average 25% more natural resources than its renewal capacity, depleting natural capital faster.

The JM vehicle fleet has 32864 cars (Table 2), according to o IBGE (2010). The annual average fuel consumption per vehicle is 822.1 liters/year. Burning 1 litre of fuel releases 2.3 kg of CO₂, emitting approximately 62140.24t of CO₂ per year. Each hectare of green area absorbs 1.8t of CO₂. The green space needed to absorb all the CO₂ emitted would be 34522.36 ha, which generates an ecological footprint of 0.47 ha/inhab.

| VEHICLE         | QUANTITY |
|-----------------|----------|
| Automobiles     | 21471    |
| Trucks          | 1180     |
| Lorries         | 321      |
| Pickup Trucks   | 3518     |
| Trucks          | 681      |
In one year, JM produces an average of 11,747,760 kg of waste, and each 3 kg emits 1 kg of CO$_2$. Therefore, an average of 3,915,920 kg of CO$_2$ is issued from these. Taking into account that each hectare absorbs 1.8 tons of CO$_2$, 2,175.511 ha would be needed to absorb the CO$_2$ emitted by the waste production, which generates a waste footprint of 0.0296 ha/inhab.

Studies carried out by Cartaxo et al. (2019), and Santos (2019) corroborate the present research, with results that also presented an ecological surplus for waste generation, which may reflect the rates of Urban Solid Waste (MSW) generation and the population size. Thus, it can be seen that the footprint is dependent on this factor.

The EF index for the municipality of João Monlevade was 0.643 ha/inhab. Figure 2 illustrates, proportionally, the footprint per variable, according to the consumption categories in ha.tor.

![Figure 2. Ecological footprint per variable]

Source: own research data

It is possible to determine that João Monlevade has an ecological deficit for the built area, food consumption, electricity and CO$_2$ emissions due to the burning of fossil fuels since the value of local biocapacity is less than these variables footprints. According to Almeida et al. (2010) for the consumption of the variable, so that the ecosystem's regeneration capacity is respected, the municipality needs to present a bioproduction area equivalent to or higher than the area found.

It is essential to highlight that the most significant value for the ecological footprint was related to the CO$_2$ emissions by burning fossil fuels. Therefore, reducing the use of internal combustion engines is essential to diminish harmful gases emissions. In addition, increasing the green area through afforestation and/or reforestation supports the absorption of the residual values.

In the case of João Monlevade, 9915.8 ha / 73610 inhab., which is equal to 0.13 ha/inhab., there is a deficit of approximately 0.5 ha/inhab., meaning that nature's demands are greater than the support capacity (SANTOS, XAVIER E PEIXOTO, 2008).

The footprint of 0.643 ha inhab., indicates that the JM population requires approximately 473314.8 ha of natural areas to supply their demands. It happens that the local area consists of only 9915.8 ha, leaving a deficit of 37397.9 ha, which constitutes the area that this population needs to meet their demands, besides what it is available.

The analysis of this ecological deficit is a relevant indicator for the environmental perspective stage in which the municipality is. It suggests a starting point for decision making and creation of local policy,
aiming beyond the environmental aspect itself, to improve social and economic elements, which should also be considered (FURTADO, JÚNIOR E HRDLICKA, 2008).

Using services or benefits, consuming them beyond limits is the path to what is called overshoot, as nature will no longer be able to regenerate (WACKERNAGEL E REES, 1996). In 1999, the global ecological footprint was 2.29 ha / inhab., while biocapacity was 1.90 ha/inhab., which resulted in an overshoot of 20% (WWF, 2002). For João Monlevade, this index value is less than the ecologically productive portion of the city, and generates an overshoot above 100% and, therefore, the consumption exceeds the biocapacity value.

Massolli, Mass and Vilella (2018 p. 48) consider that "the Ecological Footprint analysis can help public policies of governments and city halls that are interested in assessing urban environmental quality. The public authorities are responsible for urban management, but society's participation in decisions is necessary".

Unlike most researchers, Maduro-abreu et al. (2009) criticize and highlight limitations concerning EF. However, they recognize the educational nature and popularity that the method reached, and this, in a way, can assist in promoting awareness. Borges, Brito and Nunes (2018 p. 172) conclude that studies referring to urban EF still need to move forward and should have more care with the way it proposes to collect data, considering the objective of giving a score on the city.

The calculation of João Monlevade's EF can become an important management tool, which points the way to a more sustainable municipality, with a better quality of life for its citizens. But it is a process step, which must be followed by a broad discussion with local actors, with the development of mitigation strategies to reduce the footprint, needing to be improved by defining other relevant variables.

4. Conclusions

This work aimed to calculate the Ecological Footprint of a small city in Brazil, named João Monlevade, trying to identify which specific factors interfere in the result of this environmental indicator. According to the biocapacity and the EF of JM city, local consumption exceeds the support capacity of the natural environment, and appropriate environmental planning is necessary. The highest value was related to CO2 emissions from burning fossil fuels.

The calculation of the municipality's PE becomes a vital management tool, pointing out the most sustainable paths. However, it must be improved by the definition of other relevant variables.

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