Evaluation of the rational use of agricultural space for better human occupation

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Abstract

Changes in microclimates in urbanized areas are due to direct human interference, such as the replacement of wooded areas by paving and construction in inadequate locations. For the study of environments, climatic variables interpreted in isolation have little informative content because its exist in set. Considering the expansion of urban areas over the rural environment, the characterization of anthropized environments has been an important tool for feeding urban projects that, in order to be sustainable, have used comfort indexes in your evaluations. Another resource currently used are decision support systems, such as those that use fuzzy logic, as they assist in the observation of conflicting situations such as those involving environmental issues. Thus, in this research, the human discomfort index (HDI) was used to assess 6 different microclimates and to verify the degree of interference of rural anthropization in human thermal comfort and with the observed information build a mathematical model based on fuzzy logic, relating climatic variables and microenvironments, in which the response variable were levels of human well-being. In the end, it was possible to conclude that the urbanization process in rural areas influences the microclimate and quality of the environments, reflecting human thermal comfort. In addition, the Fuzzy model constructed estimated the observed scenarios in a coherent manner, serving to assist in the management of agricultural environments and decision making.

Keywords: Anthropization; environmental comfort; fuzzy logic; expert system.

1. Introduction

The vegetation directly influences the local climatic elements known as microclimate, being considered a natural method to reduce the incidence of solar radiation, resulting in benefits such as lowering the temperature, maintaining air humidity, wind and rain (FERREIRA; HERRMANN, 2016).

According to De Freitas; Costa (2018), the climatic changes caused by the urbanization process of a rural area start by altering the surface, where a green area is replaced by buildings, causing a greater heat production of the urbanized area itself, changing the composition of the atmosphere of that urban area. microclimate, causing the production of gases previously not produced in that location.

The increase in temperature in urbanized areas, mainly in the microclimate, happens due to the direct interference of man, such as replacement of wooded areas by different coated areas, constructions in inadequate locations, movement of motor vehicles, in addition to the verticalization of buildings, intensifying heating and air cooling (MARTELLI; SANTOS JR., 2015).

The urbanization process is usually conceptualized as the increase of the urban population in relation to the rural population, and in this sense urbanization only occurs when the percentage of increase in the urban population is higher than that of the rural population (SILVA *et al.,* 2014). However, according to Li *et al*. (2018) there has been a conceptualized process as rural urbanization, resulting from urban housing problems, urban-rural inequality that cause differences in the quality of life, excessive development of those who live on the land, loss of agricultural areas if not used and increase in values and energy consumption in urban areas.

According to Oliveira et al. (2006), the climatic variables available in isolation are information with little informative content, given the existence of the binomial temperature / relative humidity of the air, influence of the wind, pockets of heat and cold, among others. According to Buriol et al. (2015), in average terms, the conditions of discomfort due to low temperatures occurred in the morning, around 6 am, and by high temperatures, in the afternoon (3 pm).

According to the IPCC (2014), in a climate change scenario, where it is predicted that the number of extreme events of high temperatures and intense rains will increase, strategies to make vegetation compatible in densely built areas become even more important.

From the ambience, well-being is defined as the feeling of comfort having several levels, stress is a syndrome that affects physiological, productive and reproductive reactions and behavior, which in turn, can be described as the unique act, or a series of joint activities, resulting from some environmental stimulus (SANTOS, 2018).

The thermal comfort of a person in a given environment is defined as the result of a satisfactory combination in that environment, of the average radiant temperature, relative humidity, temperature and relative air speed, with the activity developed (metabolism) and the thermal insulation of the clothing at levels qualified as comfortable (DISCOLI et al., 2014).

According to Wiebusch et al. (2017), the correct assessment of well-being, in order to offer adequate comfort environments, requires investments in research, common in the area of Applied Ambience.

The assessment of anthropized environments has been an important tool for the feedback of urban projects, both in the building scale and in the environmental conservationist (SILVA; FREITAS, 2016). Researchers have proposed various indices encompassing varying climatic to assist in environmental assessment, including highlighting the Human Discomfort Index (HDI) that relates the air temperature varying temperature and dew point , described by Ono and Kawamura (1991) and the Human Well-Being Index (HWBI) that allows measuring well-being and was presented by YANAGI JUNIOR et al. (2012) .

Decision support systems have emerged with the intention of assisting in the observation of conflicting situations and more sustainable management of environmental issues. However, most simulations use incomplete databases or even unknown information, generating answers that are not always reliable (MA et al., 2018). It is to resolve this issue that the use of decision support systems based on fuzzy logic in the assessment of environmental issues is increasingly common.

According to Conde (2019), environmental management is composed of a set of managerial and operational practices that aim to improve sustainable environmental performance, however due to the uncertainty of the observed variables an alternative is the use of fuzzy logic as a management tool to observe different compositions of scenarios , because as a specialist system, it generates models with results that provide a greater degree of certainty for intervention.

Based on the above, the objective of this research was to evaluate the environmental conditions that represent different types of occupation in an urbanized rural area, comparing microclimates, and to represent the studied scenario in the form of a mathematical model based on fuzzy logic.

2. Material and Methods

The experiment followed two stages of execution:

• Field Experiment: In this stage, field data were collected in 10 different microenvironments, the human discomfort index (HDI) was calculated and the information was evaluated according to the literature;

• Construction of a mathematical model: Using information from the literature and knowledge of the specialist, a model was built with fuzzy logic, relating climatic variables and microenvironments, in which the response variable was levels of human well-being.

2.1. Field Experiment

The experimental part of the research was carried out with data collected at the Federal University of Grande Dourados (UFGD) and Embrapa Agropecuária Oeste, INMET station, municipality of Dourados - MS, Brazil.

10 days of data were collected and considered in the summer with similar climatic characteristics, between Dec / 2019 and Jan / 2020.

Temperature (T) and relative humidity (RH) were recorded, and the collection at UFGD took place with an automatic data acquisition system that recorded the hourly averages from 6:00 am to 6:00 pm. In INMET, T and RH information was made available on the official website of the climate agency.

With the values of T and RH, the HDI was calculated using Equation 1 described by Ono and Kawamura (1991).

$$HDI = 0{,}99T_a + 0{,}36T_d + 41{,}5 \quad (1)$$

Where:

T_a = air temperature, in ºC;

T_d = dew temperature, in ºC.

Being T_d calculated by Equation 2:

$$T_d = \frac{b*\alpha(T_a,RH)}{a-\alpha(T_a,RH)} \quad (2)$$

$$\alpha(T_a,RH) = \frac{a*T_a}{b+T_a} + \ln(RH) \quad (3)$$

Where:

a = 17.27

b = 237.7

Ta = air temperature, in ºC;

RH = relative humidity divided by 100 (one hundred).

The classification of comfort levels in each microenvironment using the HDI took place according to Table 1, adapted from Santos and Melo (2010).

Table 1. Intervals and respective effects on the application of the HDI.

HDI RANGE	IT IS MADE
HDI> 80	Heat Stress
75 <HDI <80	Uncomfortable Heat
60 <HDI <75	Comfortable
55 <HDI <60	Uncomfortable Cold
HDI <55	Cold Stress

Source: Adapted from Santos and Melo (2010).

The T and RH sensors were positioned at 1.5 m from the ground to reflect the reality of the climate microenvironment of interest in locations shown in Figure 1.

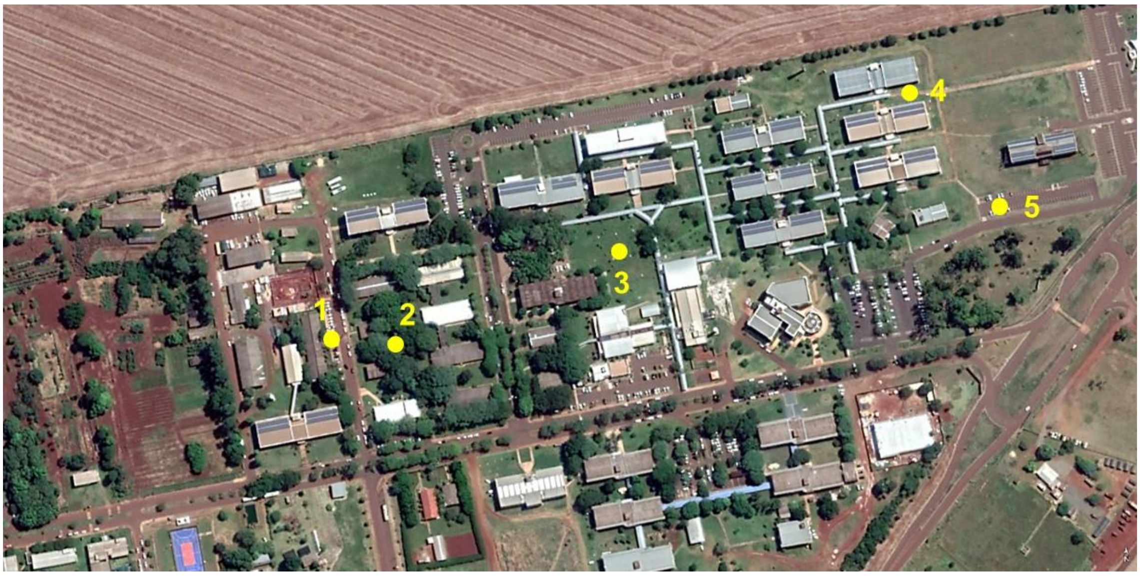

Figure 1. Climatic data collection points at UFGD.
Source: Google Earth-MAPAS (2020)

Microenvironments are characterized as follows:

- **point 1:** area without shading and concrete floor;
- **point 2:** area with trees and grassy floor.
- **point 3:** area without shading and grassy floor.
- **point 4:** area between two buildings and grass floor;

- **point 5:** area without shading and asphalt floor.
- **point 6:** INMET meteorological station, 15km away, grassy ground and without lateral obstacles.

The HDI averages were subjected to analysis of variance and Tukey average test ($p \leq 0.05$) with the Sisvar® software (FERREIRA, 2019) to compare the different microenvironments. The experiment was carried out in a factorial scheme (6 x 13), with 6 microenvironments and 13 observation times, in randomized block design, with 10 experimental days (repetitions).

With the characterization of the types of occupation of areas in UFGD and INMET for field situations it was possible to verify the interaction of the HDI, use of areas and levels of well-being, making it possible to build a fuzzy model with these three variables so that it could be used in numerous simulations in addition to those observed in the field.

2.2. Construction of a mathematical model

To build the Fuzzy model, the MATLAB® software was used. The type of occupation of the area and the human discomfort index (HDI) were entered as input variables. From the interaction resulting from the inputs, the system estimated the human well-being index (HWBI) as the output.

Mamdani's inference method and its respective degrees of relevance were used, through the minimum operator, superimposing the rules through the maximum operator. For defuzzification the Area Centroid method was used, considering all possibilities of exit, resulting in a base of activated rules.

The first input variable was the type of occupation of the area in different microenvironments. This linguistic variable followed the conclusions of DOS SANTOS et al. (2011) who, when assessing the comfort levels provided by different types of environments, found that asphalt cover and waterproofed areas are less comfortable than points covered by vegetation. On the other hand, places between buildings, even with plant floors, present intermediate environments, as they have difficulty in ventilation and retain heat. And the best environments are those with tree coverings, which provide ventilation and natural shading. Table 2 presents this membership function.

Table 2. Relevance functions for the type of occupation of the area.

Value	OCCUPATION
[0.70 0.80 1 1]	Wooded
[0.45 0.55 0.70 0.80]	Edified
[0.20 0.30 0.45 0.55]	Lawn
[0 0 0.20 0.30]	Paved

As in a thermal environment, temperature variations are directly related to the relative humidity of the air, and these are represented in the human discomfort index (HDI), this was the second input variable in the set. The HDI membership function with its ranges of values were represented as in Table 3:

Table 3. Relevance Functions for the HDI.

Value	IT IS MADE
[78 82 100 100]	Heat Stress
[73 77 78 82]	Uncomfortable Heat
[58 62 73 77]	Comfortable
[53 57 58 62]	Uncomfortable Cold
[00 00 53 57]	Cold Stress

Source: Adapted from Santos and Melo (2010).

And finally, the output variable, Human Well-Being Index (HWBI), presented by YANAGI JUNIOR *et al.* (2012) allowed the indication of the level of well-being in the analyzed microenvironments. Its set was established in a domain of [0.1], as shown in Table 4.

Table 4. Relevance functions for HWBI.

Value	IT IS MADE
[0.75 1 1]	Very good
[0.50 0.75 1]	Good
[0.25 0.50 0.75]	Average
[0 0.25 0.50]	Bad
[0 0 0.25]	Too bad

For the construction of the mathematical model, the input and output variables were related by means of fuzzy rules, in the form of linguistic sentences based on the literature and assistance from experts.

3. Results and Discussion

Through statistical analysis it was found that for the HDI, there was a significant difference between treatments because F was greater than Critical and P less than 0.05. Thus, he continued up to the test Tukey test at 5% significance where it was identified that the only treatments that showed no significant difference between them was 3 (green) and INMET. This can be explained by the fact that these two regions are similar, grassy and exposed to the sun, without any kind of shading. The other areas, on the other hand, represent different microclimates and therefore differences between them.

According to Nunes (2002), the alteration of the so-called primary nature in second nature, or transformed nature, intensified from the urbanization process, preceded by an intense industrialization and demographic growth, which culminated in the so-called urbanized rural area that provides the appearance of microclimates distinct even if close.

Analyzing Figure 2, it appears that the mean HDI values have similar behaviors, but express different physiological reactions in thermal comfort throughout the day. Considering the HDI comfort bands proposed by Santos and Melo (2010), it is possible to observe that the arboreal environment is the only one that does not reach the region of thermal stress although it is uncomfortable after 11 am. Locations with waterproofed pavement (concrete and asphalt) are the most aggressive results, and already enter the heat stress zone after 9 am, staying there all day.

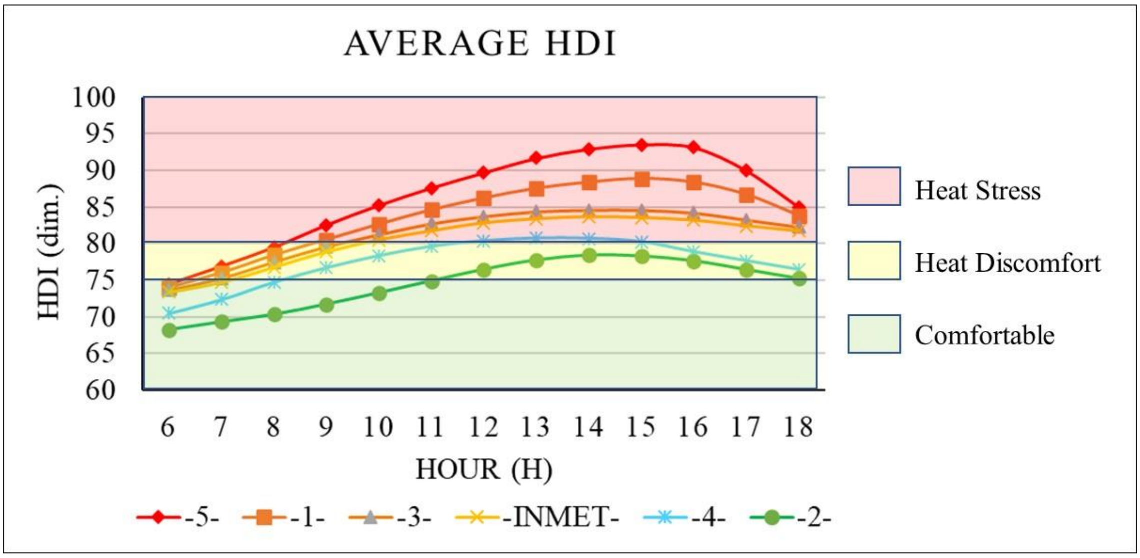

Figure 2. Average hourly HDI of the area. Source: The Authors.

The best result for the wooded region is confirmed by LIVESLEY *et al*. (2016) when stating that, if properly planned in favor of environmental quality, a vegetation system using trees significantly reduces heat islands through shading and evapotranspiration. And De Souza *et al*. (2019) found a reduction of 37.37% in the levels of exposure to thermal stress with the planning of tree planting in a region, with thermal comfort being the first characteristic noticed by users.

And the results verified in the waterproofed regions are corroborated by Barros and Lombardo (2016) when they stated that the increase in temperature in the cities is caused by the absence of trees, a high number of buildings and mainly by the areas with concrete and asphalt pavement.

Figure 3 shows the 3D graphic resulting from the fuzzy modeling constructed by inserting information from the literature (HDI and IBEH) and field observations (occupation of areas). Looking at Figure 3, it appears that there is a consistent relationship between HDI and area occupation. In places with high HDI (> 80) the comfort level (IBEH) is improved as it moves away from the paved region (0) and moves towards the wooded region (1). The best situation is represented with comfortable HDI (70) and occupation contributing from the building with partial shading (> 0.6) to the best of them, wooded, with very good IBEH (> 0.75).

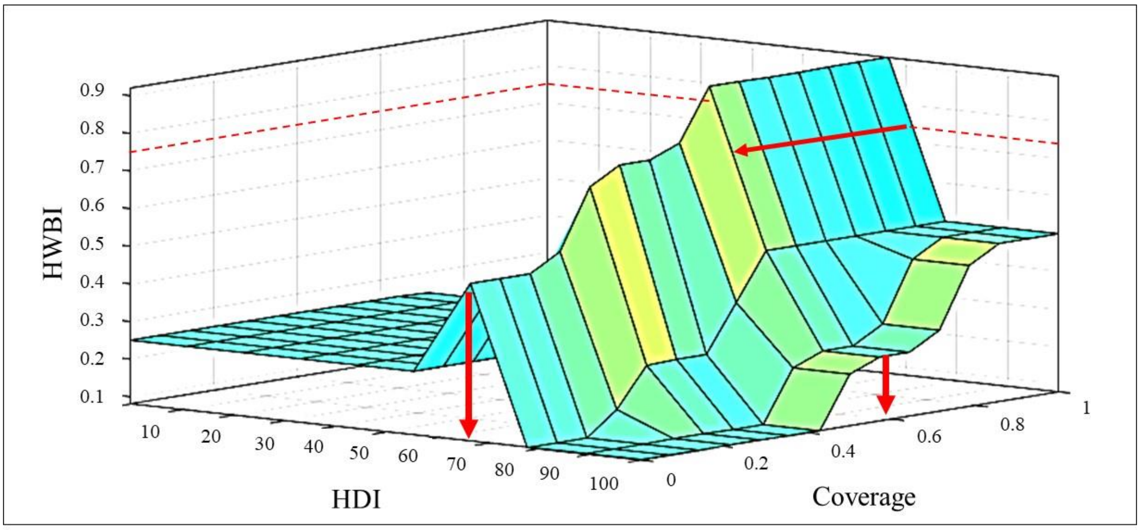

Figure 3. Surface generated by the Fuzzy System. Source: The Authors.

With the use of Fuzzy Logic, it is possible to make precise inference through imprecise linguistic concepts and with a certain degree of ambiguity, such as those observed in the field, in a similar way to what human beings do in the real world. The modeling Fuzzy well-built shows the inaccuracies that humans treat with great skill in real life, but they are usually difficult to represent in traditional sets (AMORIM *et al.,* 2016). As in this research, Lopes et al. (2016) also USER plow Logic Fuzzy to study environments. They evaluated the risk of contamination of a water system with the Fuzzy Logic having as input variables Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO). At the end of the research, they emphasized the importance of having a solid method like this for environmental analysis.
It can be seen in Figure 3 as described by De Paula and Souza (2007) when stating that the Logic Fuzzy can be used as a tool for managing uncertain situations, such as environmental ones, as it is contained in the category of non-algebraic map analyzes cumulative or logical analyzes, together with Boolean simultaneity, generating products such as maps integrated to different situations, instead of merged maps such as those resulting from the algebra of geoprocessed maps.

4. Conclusions

The study pointed out the impact of urbanization in rural areas and demonstrated the importance of the microclimate in the quality of environments where, evaluating the HDI, it was noted that the wooded area has the best characteristics to provide human thermal comfort and a region without vegetation cover with asphalt waterproofing. offers great thermal discomfort. The use of the precision ambience proved to be efficient in the assessment of environments and qualitative measurement of different forms of occupation of areas in urbanized rural regions. And the Fuzzy model built estimated the observed scenarios in a coherent way, showing the importance of this type of modeling for the management of agricultural environments and decision making.

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