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GEOGRAPHIC VISUALIZATION AS A PLANNING SUPPORT TOOL TO IMPROVE PUBLIC PARTICIPATION IN NEW URBAN DEVELOPMENT DECISION MAKING PROCESSES: GEODESIGNING POTENCIAL HOUSING AREAS AT THE IRON QUADRANGLE IN MINAS GERAIS, BRAZIL

A Visualização Cartográfica como Instrumento de Apoio à Participação no Processo de Planejamento da Expansão Urbana: Geodesign do Potencial para Habitação no Quadrilátero Ferrífero em Minas Gerais, Brasil

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ABSTRACT

Planning for the new urban development areas has always been a very contentious issue in local planning in Brazil, as it concentrates important interest conflicts from a diversity of involved stakeholders. Thematic cartography and multiple criteria analytical methods have been widely used as Planning Support Systems, especially with regards to the evaluation of carrying capacity of the territory to guide the location of these areas. However, data and technical information communication to communities is still a barrier to the extension of participatory decision making processes, which has enhanced the importance of geovisualization tools. This paper discusses the results of a simulated collaborative planning process at an academic workshop when Geodesign framework (STEINITZ, 2012) and geovisualization resources have been used to provide simultaneous information sharing, knowledge leveraging and establishment of preconditions for defining areas for urban growth. The outcomes showed the broad analytical and communication possibilities provided by the applied methods, which can be replicated in similar situations, involving non technical individuals with no specific knowledge for traditional cartography reading skills.

Keywords: Geovisualization, Geodesign, Multiple Criteria Analysis, Urban Development, Iron Quadrangle.

RESUMO

O planejamento da expansão urbana tem sido um dos temas mais controversos nos processos de planejamento municipal, concentrando importantes conflitos de interesses dos diversos agentes envolvidos. A cartografia temática e os métodos de análise multicritérios têm sido amplamente utilizados como Sistemas de Apoio ao Planejamento, particularmente no que se refere à analise da capacidade de suporte para orientar a localização das áreas de expansão urbana. No entanto, a comunicação dos dados e informações técnicas à população ainda é um entrave à ampliação dos processos participativos de tomada de decisão, aumentando a importância das ferramentas de geovisualização. Este trabalho discute os resultados da simulação de um processo de planejamento colaborativo realizado no âmbito de um *workshop* acadêmico cujo objetivo foi a utilização do *framework* de *Geodesign* (STEINITZ, 2012) e recursos de geovisualização para o compartilhamento simultâneo de informações, nivelamento do conhecimento do território e de pressupostos para a definição de áreas de expansão urbana. Os resultados demonstram as amplas possibilidades analíticas e de comunicação propiciadas pelos métodos utilizados, podendo os mesmos serem replicados em situações análogas, envolvendo atores sem conhecimentos técnicos específicos para a leitura da cartografia temática tradicional.

Palavras-chave: Geovisualização, Geodesign, Análise Multicritérios, Expansão Urbana, Quadrilátero Ferrífero.

1. FOREWORD

Planning methods based on inter-relations among environmental features, economic activities and cultural aspects related to local communities have a long lasting tradition in planning since the first efforts by Patrick Geddes, expressed by his Valley Section at the beginning of the 20th century. The analysis of this relationship through the use of overlaying thematic maps also date far back. Warren H. Manning used this method in 1912 for putting together a development and conservation plan for Billerica, Massachusetts. In 1969, Ian McHarg published his seminal text Design with Nature that expands the use of overlaying maps through collaborative planning among different specialists, being responsible for setting forth concepts and procedures that were later the basis for the development of Geographic Information Systems. GIS has made the combination of the two logic processes involving planning possible: identification of driving variables (analytical process) and composition of those variables (synthesis process), by the use geographic information and database technologies.

With the introduction of computer added systems, multiple criteria analytical applications increased to a large extent and important studies have been developed, setting up the conceptual basis and the methodological possibilities, aiming at decision making process efficacy as well as its legitimacy and effectiveness. (EASTMAN *et al*, 1993; MALCZEWSKI, 1999, 2015; JANKOWSKI & NYERGEs, 2001, among others).

In Brazil, these efforts are also very closely related to participatory urban planning and democratic city management principles, which have been established by Federal Law 10.267/2001, also known as the City Statute. The related planning instruments, also put in place by this same legislation, must be translated within Municipal Master Plans that are legally considered the basic instrument to set forth urban development and growth policies at the local level. Besides, Article 42.b, which has been added to this same act in 2012 (Federal Law 10.267/2001) introduced the requirement of specific studies that certify the existence of appropriate conditions for the expansion of urban development zones in municipalities.

Nevertheless, recent studies such as the one by Santos Junior and Montandon (2011) show that, although widely carried out by a great number of Brazilian municipalities, not all Master Plans are effectively resulting from social compromise towards territorial management, leading to, among other issues, the clear need to improve existing participation channels. This way, involvement and facilitation strategies to improve stakeholder's participation in planning decision-making processes such as Geodesign have acquired a central position both in urban planning theory as well as in practice, also in countries of the Global South.

According to Steinitz (2012) Geodesign is a methodology that provides a design framework and supporting technology to leverage geographic information, resulting in designs that more closely follow natural systems. It is, in fact, an invented word to describe a planning method based on communication strategies aimed at sharing knowledge, assumptions and language to achieve an effective collaborative decision making process.

Within the Geodesign framework, design professionals, geographic scientists, information technicians and local stakeholders are supposed to work together to answer key questions about the problem area, relating data, knowledge and values through planning models and planning phases as shown in the following (Figure 1).

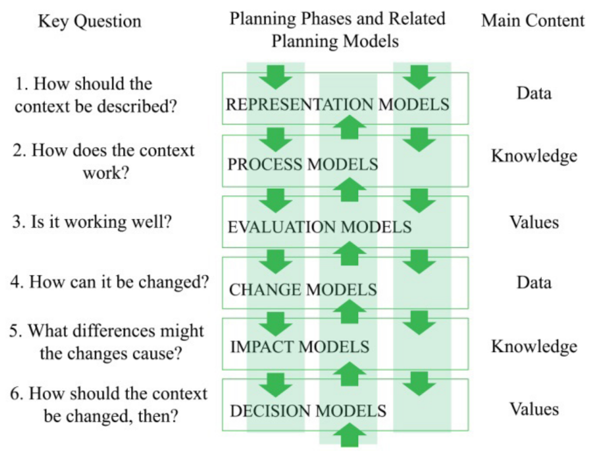

Fig. 1 - Geodesign framework steps for a collaborative planning decision-making process. Source: Adapted from Steintz (2012).

According to this method, the decision model drives the whole process, so that, regardless the shortage of data and time, a proposed intervention with a reasonable degree of consensus is supposed to come out at the end of the line.

The achievement of an informed decision through collaboration depends, however, on collective knowledge building and for that purpose many different tools and methods have been developed as Planning Support Systems (PSS), in which the use of spatial data visualization has played an important role and produced promising benefits to participatory planning.

Masala, Pensa and Lami (2013) emphasize the use of geovisualization in order to stimulate communication and discussion among actors involved in the decision making process and as a means for allowing the planning process to be more effective towards the promotion of more sustainable urban development policies.

Geodesign methodology restates planning as a multidisciplinary activity and relates itself to one of the basic principles synthesized by Geddes (1915) in his famous quote "survey before plan". Besides, it adds another essential aspect to it that is the integrated and collaborative component, with the use of geomatics to broaden stakeholders participation in planning decision-making processes through geovisualization resources and simultaneous information sharing to leverage knowledge about the territory and improve accessibility and efficacy in participatory planning strategies.

The following experience uses geovisualization tools within a Geodesign framework to improve participation and collaboration in a simulated decision-making process involving different stakeholders for the definition of future urban development areas in the Quadrilátero Ferrífero or the Iron Quadrangle region in the State of Minas Gerais, Brazil.

The Iron Quadrangle is a region of Minas Gerais State that shows conflicts between urban development, mineral extraction, steel related industrial uses, historic heritage, environmental and landscape protection. The region comprises approximately 7.000 km2 and counts on a very complex urban network that includes 22 cities highlighting southern development axis of Belo Horizonte Metropolitan Region and important regional centers such as Conselheiro Lafaiete to the south and Itabira to the East (Figure 2). It is also characterized by great urban concentration – about 3,2 million inhabitants (MINAS GERAIS, 2009) – and by its strategic position for both economic development and environmental preservation due to the presence of worldwide significant iron ore deposits and also important water resources, conservation units and protected historic sites.

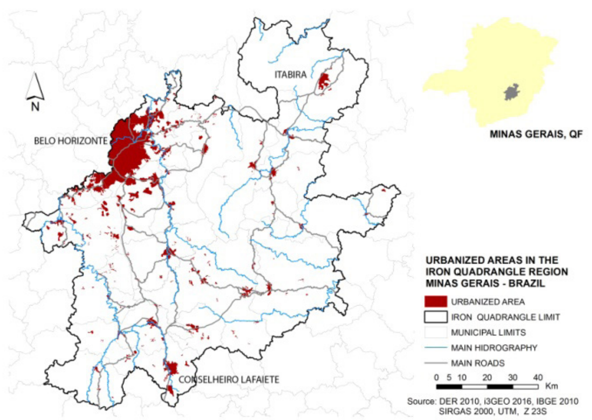

Fig. 2 - Iron Quadrangle Region.

2. THE ISSUE OF URBAN GROWTH IN BRAZIL AND THE RELATED CONFLICTS IN THE IRON QUADRANGLE PLANNING PROCESS

Urban development in Brazil occurs mostly by private initiatives or by private projects under public financing, very often in the absence of a previous detailed structure plan to guide the process of urban development. The public sector is legally in charge, however, of deciding where and how urban growth should take place by the use of master plans, zoning ordinances and other urban control instruments.

Due to prevailing private interests as opposed to collective and environmental concerns, and also as a result of low planning and management capacity of municipalities, which are legally in charge of urban control, urban development, very frequently, occurs in unsuitable areas and under incomplete and unsustainable patterns.

Conflicts involving land use issues have been approached by many authors including Singer (1982), Rolnik (1999, 2015), Villaça (2001) and Costa *et al.* (2006). Costa analyses the metropolitan urban growth to the South of Belo Horizonte which is shaped by the contentious coexistence of high income gated communities, mining fields and informal settlements. These conflicts pose very complex planning challenges that municipalities are not prepared to properly deal with. Although they are empowered to legislate and control land use since the 1988 National Constitution, in which Article 182 establishes the minimum scope for Master Plans, they are usually not technically qualified nor politically organized to face private hegemonic interests.

Besides, most of theses issues, being environmental in nature or due to real estate market dynamics, are not limited by administrative jurisdictions, requiring a regional understanding and an integrated treatment that surpasses municipal boundaries.

Three most common types of urban development patterns in Brazil – and in the Iron Quadrangle as well – were chosen to picture urban growth processes in the study area both for its significance in terms of quantity as well as for the nature of socioeconomic problems and environmental impacts they provoke.

The first and more common comprises illegal residential settlements which are mostly private, located in peripheral urban expansion areas or even rural zones, where land prices are low and basic urban infrastructure, facilities and services insufficient or inexistent. Not complying with land use and subdivision regulations, they are very often located in improper sites such as steep slopes, flood hazard areas, or conservation units, which are also reasons for price depreciation in formal real estate market (Figure 3)

Fig. 3 - Illegal residential settlements in Brazilian peripheral urban expansion areas. Source: http://racismoambiental.net.br. Access on Nov. 14th. 2016

The second relates to low income state subsidized housing projects which are also located far from central well-equipped urban areas, but having, in general, all basic urban utilities (water supply, sewer systems and paved roads) and lacking social facilities, commerce and services, as well as job and leisure opportunities (Figure 4).

Fig. 4 - Low income state subsidized housing projects in Brazil. Source: http://portalpbh.pbh.gov.br. Access on Nov. 14th. 2016.

The third one is composed of high income suburban subdivisions, also known as gated communities, which are low density single housing suburban neighborhoods, usually all residential, being therefore also dependent of private vehicles and of central city areas for jobs, commerce and services. (Figure 5)

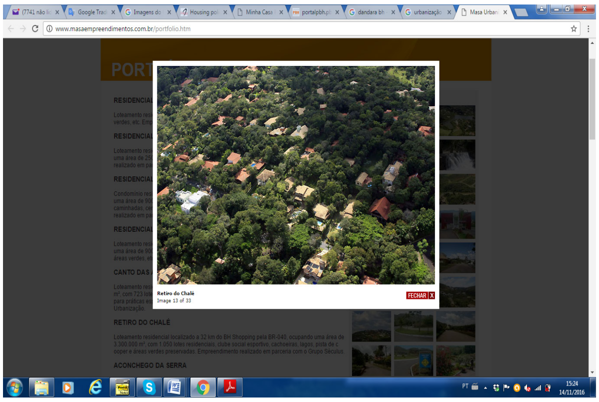

Fig. 5 - High income gated community in Brazil. Source: http://www.masaempreendimentos.com.br. Access on Nov. 14th. 2016.

The three together form a pattern of irrational urban sprawl not only for its extension, its environmental impacts and unplanned carrying capacity but also for its discontinuity, making it very difficult and expensive for local municipalities to catch up with infrastructure and public service demands.

It is important to highlight, however, that these urban development types occur simultaneously and somehow mixed, with a high degree of dependence to each other, also presenting slight variations to the given density patterns, very often subjected to socio spatial segregation processes. Even though socioeconomic status has not been a criterion for choosing the density intervals, access to urban land and infrastructure basically by market oriented constraints, result a strong relationship between density patterns and income levels.

Considering mining activities are not limited by municipal boundaries and the that long term strategic planning have been historically developed only by mining companies, with no participation of other stakeholders being from civil society or from local municipalities, the UFMG GIS Laboratory carried out the First International Geodesign Workshop Alternative Futures for the Iron Quadrangle in Minas Gerais, Brazil with the presence and guidance of Professor Carl Steinitz from Harvard University. The main goal of this workshop was the experiment of using the Geodesign framework to promote a participatory planning forum, involving civil society representatives, faculty members, planners and government officials, to discuss and design alternative future land use scenarios for the Iron Quadrangle.

The workshop was carried out during three days and counted on 30 participants, being five public officials, seven members from the private sector (mining companies, real state market and development companies, three members from environmental NGOs and two from Cultural Heritage Protection institutions. Besides there were 13 faculty members and students. For the simulation purposes, the absence of local residents was partially fulfilled by faculty and students representing different interest groups.

The event was organized according to 10 thematic axis: potential urban development areas split into two density types: high and low, existing dynamics for urban growth, existing mining resources, roads and transportation infrastructure needs, geomorphologic hazard areas, water supply resource vulnerability, nature-based tourism potential, environmental conservation areas, cultural/ heritage values and visual axis protection. This paper focuses the housing system only.

For the purposes of this academic exercise, two housing density categories were selected as more likely to occur for future planned urban expansion in the region. The density typologies are also related to land use patterns, the necessary urban infrastructure (roads and utilities) and potential environmental impacts related to each development pattern. Although urban development in Brazil is characterized by informal processes, this study consider urban control and public policies by local government for the definition of urban growth zones (as opposed to rural ones) as well as urban upgrading and regularization programs.

Based on studies on urban development densities in Brazil (ACIOLY & DAVIDSON, 1998; MASCARÓ, 1989; PONT & HAUPT, 2010) as well as on analysis of recent urban space production in the study region (COSTA *et al*, 2006; CONTI, SOSA & ANDRADE, 2016;

CONTI, 2013), we characterized two typologies as follow.

One refers to a more scattered and low density pattern, having average densities between 25 and 50 inhab./ha. It relates to high income and large parcel residential subdivisions, which are identified by literature as gated communities, a fast growing tendency in metropolitan areas in Brazil.

The other has a more compact pattern and relates to medium-low and low income housing projects which are usually subsidized by the public sector, having average densities between 100 and 150 inhab./ha. It is important to highlight that this study is not concerned with the different urban living conditions and socioeconomic consequences of each of these development types to the production of urban space. The only purpose here is the identification of urban development trends with regards to the environmental carrying capacity of the study area.

The following experience tries to explore possibilities of expanding the range of analysis to a regional scale, and of facilitating community participation through visualization of shared knowledge and information in a context of little data, high complexity, rapid growth and short time form long range decision within a scenario of high uncertainty.

3. CARTOGRAPHIC ANALYSIS AND COMMUNICATION AND ITS POSSIBLE USES FOR PLANNING URBAN GROWTH

Within the context of information technology development, new instruments for spatial analysis, evaluation and representation have become essential tools for territorial planning and management. Among examples of new technologies applied to cartography, GIS mapping and geovisualization stand out for their availability, usability and accessibility, resulting an important breakthrough for information sharing in planning processes (MASALA & PENSA, 2016).

Representing a given territory is the first step to get to know it. With regards to urban and regional planning, geovisualization can also be understood as a tool to broaden the possibilities of community participation in decision-making processes. As a means to enhance spatial understanding, it allows for higher alignment and leverage of information among different stakeholders within a participatory planning process. It is, then, essential to provide voice to those so far excluded from planning decisions due to the absence of technical knowledge or for not feeling able to contribute.

Van Den Brink *et. al*. (2007) proposed a synthesis comparing different typologies of participation based on the works of Arnstein (1969), Edelenbos and Mannikhof (1998 and 2001) and a few governmental guidelines for participatory planning, including the European Commission's (2002). They range from manipulative passive processes to more interactive and collaborative planning experiences, depending on the degree of stakeholders' involvement in the decision making process.

Different levels of participation consequently relate to different requirements for the use of digital media as a planning support tool. Streich (2004) proposed three increasing degrees, from information supply and consultation, somehow applied in Brazil in participatory local Master Plans and public hearings, to active participation, involving co-producing and co-deciding planning strategies which also relates to a growing number of actors eager to influence the contents of plans.

The prevailing methods in participatory planning in Brazil follow two basic steps. The first consists of technical inventories and analysis made by specialists resulting comprehensive reports that often contain thematic maps. The second relates to the discussion of the technical understanding of the study area's main issues with society through participatory workshops and public hearings, with the help of the cartographic material, which has been produced. The discussion process, however, is often deficient and does not achieve expected goals as far as effectively involving and communicating with the general public.

Peets and Leach (2000) had already highlighted the growing reticence among citizens and NGOs to use institutional participatory instruments also due to bottlenecks arising from the use of technical language and sectorial approaches to describe a growing complexity of planning issues.

Aiming at more inclusive and interactive participatory processes, geo-visualization approaches seem to increase opportunities for citizen participation in spatial planning as an essential tool to create collaborative environments for co-producing planning strategies and decision making processes, which is also the main goal of Geodesign.

Considering the short period of time available for this experiment, it's been decided all data collection and base mapping development would have to be prepared in advance, leaving enough time for simulating the decision making process. This way, the representation, process and evaluation maps were made by faculty members and students involved in the workshop.

Even though the adopted methodology is dynamic, using digital maps and not printed material, allowing for constant adjustments on screen, it is understood that, in real planning situations, all stakeholders should participate in all phases from the beginning, being also able to choose variables and decide on criteria and values.

The process of building up the base and evaluation maps used in the workshop is described in the next section followed by the collaborative decision making process. The description of the mapping process allows the understanding of the previous stage to the workshop and enables the replication of the methods by new works.

3.1 Producing the initial base map, defining variable drivers and partial synthesis maps

Based on the conceptual references already mentioned, the first attempt has been focused on understanding the way urban development has occurred in the study area, its logic and the main urban expansion typologies that characterize it. Given that analysis, the key drivers and/or constraints for urban growth were identified to allow for the evaluation of potential developable areas, supported by collaborative planning scenarios carried out during the Workshop.

For the first step, a set of criteria was selected to assess the developable areas for the most common urban development types present in the study area. Maps of Potential Areas for High and for Low Density Urban Development were then produced.

According to Steinitz (2012), one way of defining evaluation criteria is by the use of benchmark studies made by specialists, and by the combination of different information sources. This way, the first challenge to overcome has been the interpretation of the available bibliography into types of urban development according to density patterns (inhabitants/hectares).

The next step involved the choice of data and variables to be used to ensure consistency to results, having in mind that less complex data and more simple models are key elements in Geodesign to make communication among stakeholders more effective. The objective here was the identification of the main development drivers for each typology.

For the High Density type, proximity to existing urban infrastructure (mostly sanitation and public education and health facilities) was considered most relevant. The presence of sewer systems was selected as the indicator for urban infrastructure since it is the last one to be implemented. Many illegal settlements and favelas have water supply and electricity systems long before they get to have sewers.

Maps locating health and education public facilities and areas covered by sewer systems were prepared (Figure 6 and Figure 7). Public facilities were represented by points and buffers corresponding to their influence radius according different walking distances for each type of school (500 meter radius for elementary and 750 for high school) and health centers (500 to 1000 meters). Next, all influence radius were overlaid, resulting a scale of public service provision from very good, to medium, medium low and low, being considered "very good" areas having schools and health center within a 500 meter radius and "low" the ones with schools and/or health centers in more distant radius (up to 1000 meters) (Figure 8).

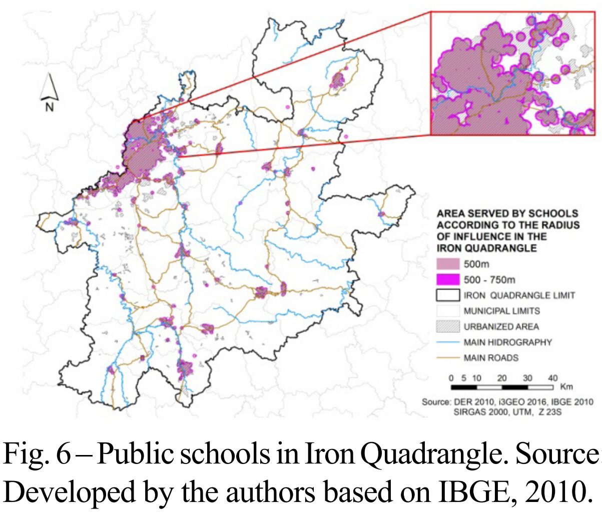

Fig. 6 – Public schools in Iron Quadrangle. Source: Developed by the authors based on IBGE, 2010.

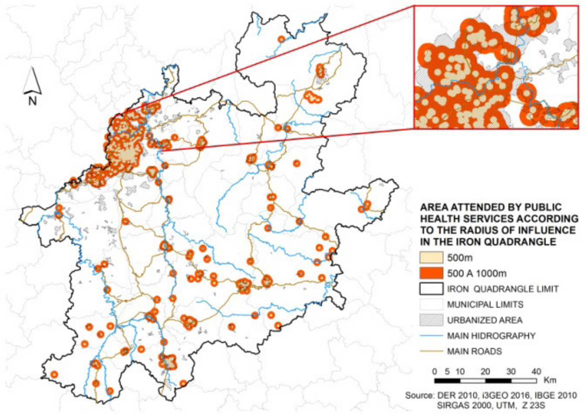

Fig. 7 – Map of public health centers in the Iron Quadrangle. Source: Developed by the authors based on IBGE Census data, 2010

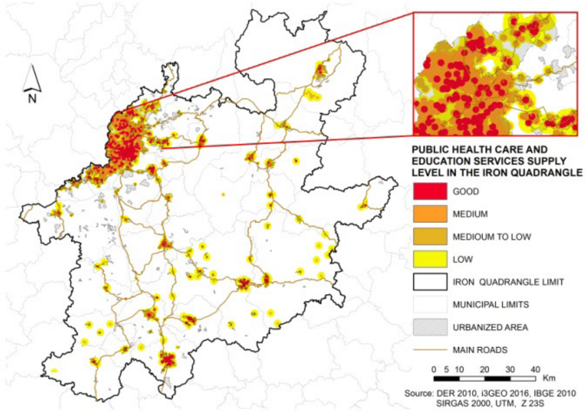

Fig. 8 – Maps of public education and health facilities in the Iron Quadrangle. Source: Developed by the authors based on IBGE Census data, 2010.

Sewer system network coverage was mapped based on IBGE Census data (2010), using the percentage of dwellers served per census district. Two classes of service provision were then arbitrated: less than 85%, considered "inadequate", and from 86 to 100% considered "adequate". Besides these classes within census district boundaries, a 300-meter buffer was added for the "adequate" areas, considering the possibility of easy network extension in face of new development demands. This led to a five-class map being "high" the areas with adequate services, "medium" the ones within 300 meter radius form the first, "low" the ones with inadequate service outside the 300 meter radius and the forth with no sewer service. As a result, the following maps were developed (Figure 9).

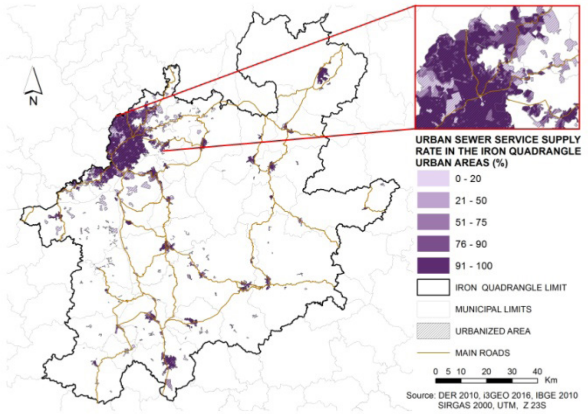

Fig. 9. Sewer system network coverage by census district in the Iron Quadrangle, MG. Source: Developed by the authors based on IBGE Census data, 2010.

After public health and education facilities and sewers network maps were produced it was necessary to compile the results and generate a scale for these infrastructure and service delivery levels combined. A synthesis map was produced from overlaying the two previous maps (Figure 8 and Figure 9) and using a value matrix applied to each theme and then combined to produce a new map with the resulting values. This matrix has been built with sewage infrastructure values placed vertically (column) and health and education services horizontally (line) (Figure 10). Then a number was assigned to each value in a way that they would never sum up to the same value. Then, each value was crossed summed up to resulting values that were interpreted and grouped to produce a map of public education and health service ratios and sewer system coverage all combined (Figure 11).

HEALTH CARE AND SCHOOLS / SEWAGE	good (1)	medium (2)	medium to low (3)	low (4)
0-20 (10)	11	12	13	14
21-50 (11)	12	13	14	15
51-75 (12)	13	14	15	16
76-90 (13)	14	15	16	17
91-100 (14)	15	16	17	18

Fig. 10 - Matrix of combination.

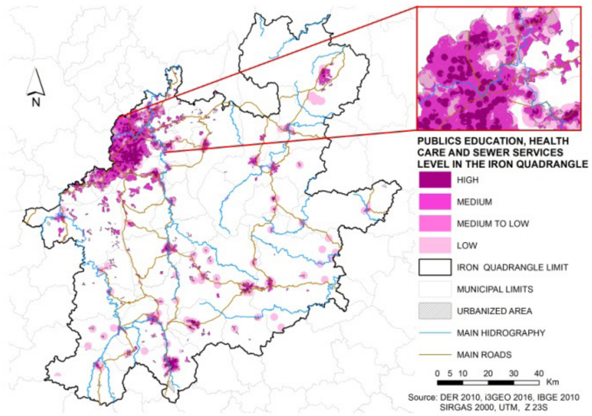

Fig. 11 - Public education and health service ratios and sewer system coverage in the Iron Quadrangle, MG.

With regards to the *Low Density* type, the road system was considered as the main infrastructure to constraint development for its car dependency and due to the fact that infrastructure, including sewer systems, being either septic or gravity, is provided by the private developer.

The map that presents buffers around the roads shows the influence areas of main regional and urban roads in the study area. This map was made by setting up a 1km-buffer for regional roads measured from road axis and 3km-buffer for urban areas limits as direct influence areas for this kind of infrastructure (Figure 12).

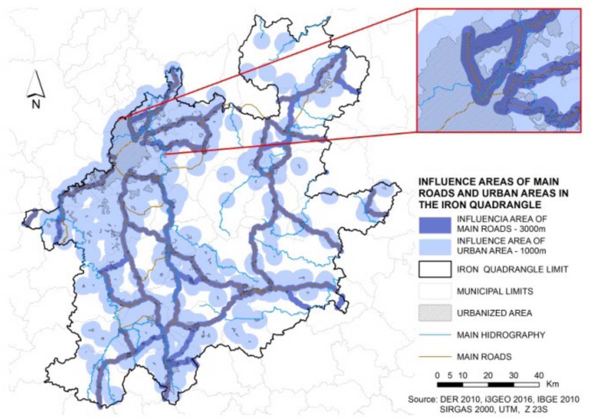

Fig. 12 – Influence areas of main regional and urban roads in the Iron Quadrangle, MG.

Another aspect, which has been considered inductive of new development areas, was the proximity to other existing urban areas, avoiding the process of "leap-frog development". This includes, existing urban areas and new development projects with an influence radium defined around them, as well as areas within official municipal urban zones that remain undeveloped. According to these criteria, a map of urban areas and urban expansion areas was developed showing the consolidated existing urban areas and areas within municipal legal urban zone limits as defined by IBGE that remain undeveloped (urban expansion areas) (Figure 13).

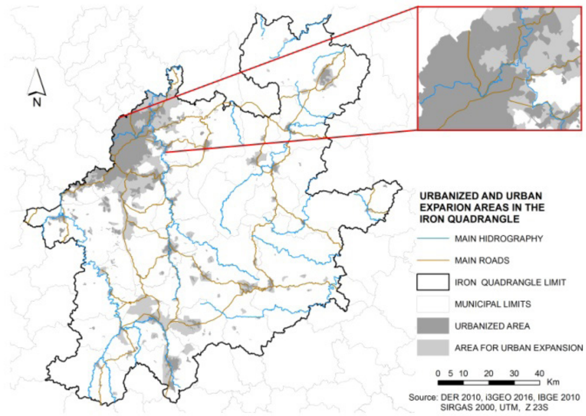

Fig. 13 - Urban and urban expansion areas in the Iron Quadrangle, MG. Source: IBGE, 2010.

To control the relationship among these areas of possible urban expansion and the actual growth due to new urban development projects, another map was produced (Figure 14), showing.

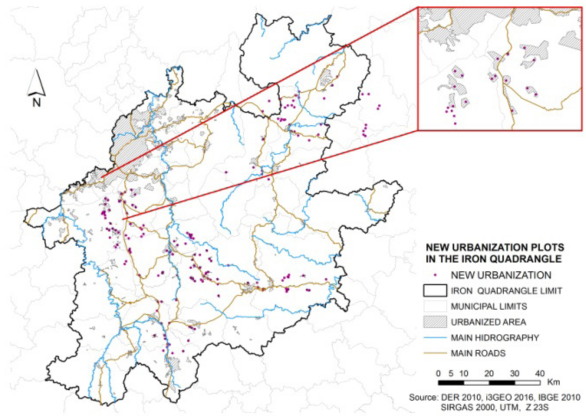

Fig. 14 - New urbanization in the Iron Quadrangle, MG. Source: Conti, A; Martinez. 2016 (Io. Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

Recent residential development projects and their influence areas, indicating the existence of some kind of real estate dynamism around them.

Departing from the location of new development projects (points), it was possible to produce a density index (Kernel), using a

5.000 meter radius and a five-class map (natural breaks), and the choice of the two highest ones to represent two levels of real estate dynamism: the core area and its influence area (Figure 15).

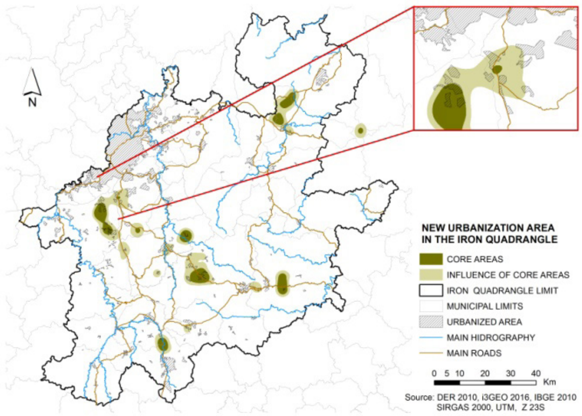

Fig. 15 - Real estate dynamic core areas and their influence areas in the Iron Quadrangle, MG. Source: Conti, A; Martinez. 2016 (Io. Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

3.2 Building up evaluation maps

For building up evaluation maps the multicriteria analysis methodology was adopted. This methodology has been one of the most used spatial model for territorial analysis at different scales when the goal is the selection of potential areas for specific purposes. Its use is very widespread because it is based on a systemic approach that decomposes a problem into parts, which are represented by a set of variables that combined are supposed to represent reality. However, this fragmentation is only accepted if the analysis links the elements to the context in which they are since the role of a variable in a system is not absolute, but relative to the reality portrayed.

This way, the result of a multi-criteria analysis is always an interpretation of a combination of the main variables involved. According to Bohnam-Carter (1994) this translation of a given reality can be "data-driven" (such as data mining to identify trends) or "knowledge-driven" (by gathering expert's opinions through methods such as Delphi or AHP)., When the "data-driven" approach is adopted, the combination of variables establishes the suitability of an area for a given potential. When the "knowledge-driven" approached is chosen, it is important to maximize consensus among specialists. Besides, the integration of data by multi-criteria may be led by Combinatorial Analysis or by the adoption of different weights of evidence for each variable. The main concerns to these methods refer to the allocation of weights as approached by the Analytic Hierarchy Process (SAATY, 1980) or Delphi (LINSTONE & TUROFF, 2002) methods. Their main fragility is precisely the variability of responses due to differences in weights that relate, in fact, to different opinions and perceptions with regards to a given reality. However, to confront this apparent weakness of the method, sensitivity analysis studies may be used to reduce uncertainties in the responses - SASE - Sensitivity Analysis to Suitability Evaluation (LIGMANN-ZIELINSKA, JANKOWSKI & WATKINS, 2012; MOURA, 2016).

In this specific case study, the Multicriteria Analysis was based on a Combinatorial Analysis of Variables without hierarchizing the relative importance of each one. That is, the combined variables were all considered having equivalent importance. However, the selection of variables to be considered by each thematic analysis was based on the opinion of experts, who have previous knowledge about the area and the about the investigated phenomena..

The two maps showing areas prone to urban development were prepared: one for high-density residential typology and another for the low-density one. For the identification of potential areas for future high-density development, the following variables were mapped:

- Proximity to existing urban developed areas;
- Proximity to existing sewer infrastructure networks;
- Proximity to existing public health and education facilities.
- For the low-density ones, the following variables were mapped:
- Proximity to existing urban development areas;
- Proximity to existing urban and regional main roads;
- Proximity to existing public health and education facilities.

Then, both maps were collated and

analyzed against a series of development constraints, mainly environmental ones, within a regional context such as conservation zones.

The selection of variables in this study was just enough to provide consistency to the analysis, which was very successful in testing geovisualization strategies in communication and evaluating its role in collaborative planning process. This way, the chosen variables do not fulfill all possible constraints and potentialities in the region. Other specialists and workshop participants elsewhere in any planning process could come up with other variables. It is, though, very important to keep in mind that the larger the number of variables, the higher the challenges for communicating them to participants. As presented by Steinitz (2012), more complex models require a higher effort by specialists to make communication simple, being always necessary to prioritize data to be used in evaluation maps.

Evaluation maps are a synthesis of a previous judgment made by specialists on a certain issue, in this case being the potential areas for future urban growth. The evaluation criteria for this judgment shall put together all favorable or unfavorable features with regards to an initial question, and then they will be expressed according to their potentiality, vulnerability and attractiveness with regards to the given question. Thus, they are not universal but built up based on previous knowledge of each study area (STEINTZ, 2012).

The resulting synthesis evaluation maps are presented as the following.

As a way of simplifying data communication and understanding, a traffic light chromatic scale was used: green relating to areas with high development potential (go) and red to areas with higher constraints (don't go), resulting the following categories for the High- Density Evaluation Map (Fig. 16):

- RED - Low development potential, including environmentally constrained areas, areas far from existing urban areas, those far from exiting public health and education facilities and from sewer networks. This category also encompasses existing consolidated urban areas, which are not considered for new urban development expansion areas.
- YELLOW - Medium to low development potential, including those areas located not as far from existing urban areas but still far from existing public health and education facilities as well as from sewer networks.
- LIGHT-GREEN – Medium development potential, which embraces areas which are close to existing urban areas but still far from existing public health and education facilities and from sewer networks. This category includes undeveloped areas located in the middle of existing developed ones, being somehow subjected to urban development pressures and having a tendency for conurbation. Urban development in these areas requires high investments in infrastructure and public service facilities.
- MEDIUM-GREEN – Medium to high development potential, including those areas located near existing urban areas, public health and education facilities and sewer networks. This category includes areas surrounding existing development areas which are highly dynamic. They require average investments in infrastructure and social facilities to be developed.
- DARK-GREEN – High development potential, embracing those areas which are located close to existing developed areas, having easy access to a large number of public health and education facilities as well as to sewer networks already put in place. This category includes those vacant and under-used areas located within the legal urban zone, already served with urban infrastructure and services.

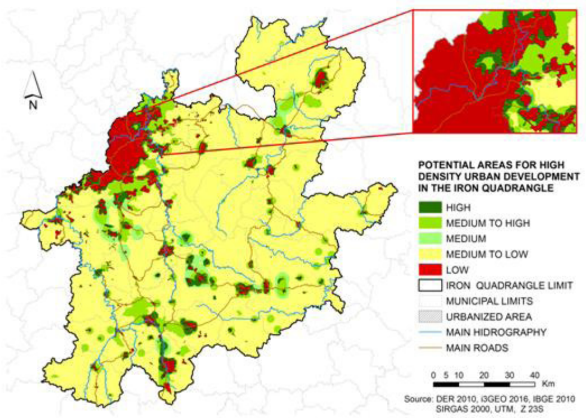

Fig. 16 - Potential areas for high density urban development.

For the Low-Density Evaluation Map, the following categories were considered (Fig. 17):

- RED – Low potential for development, including environmental protected areas and those located far from main regional roads. This category also encompasses existing consolidated urban areas, which are not considered for new urban development expansion areas.
- YELLOW - Medium to low development potential, including those areas located close to existing urban areas but still far from main regional roads..
- LIGHT-GREEN – Medium development potential, which encompasses those areas which are close to existing urban areas, including those located in the midst of existing developed areas or somehow subjected to real estate pressures, however far from main regional accesses.
- MEDIUM-GREEN – Medium to high potential for development, including areas located close to main regional accesses and subjected to a high real estate dynamics,
- DARK-GREEN – High potential for development, including those areas which are subjected to high real estate dynamics and are at the same time located close to existing urban developments and regional road accesses.

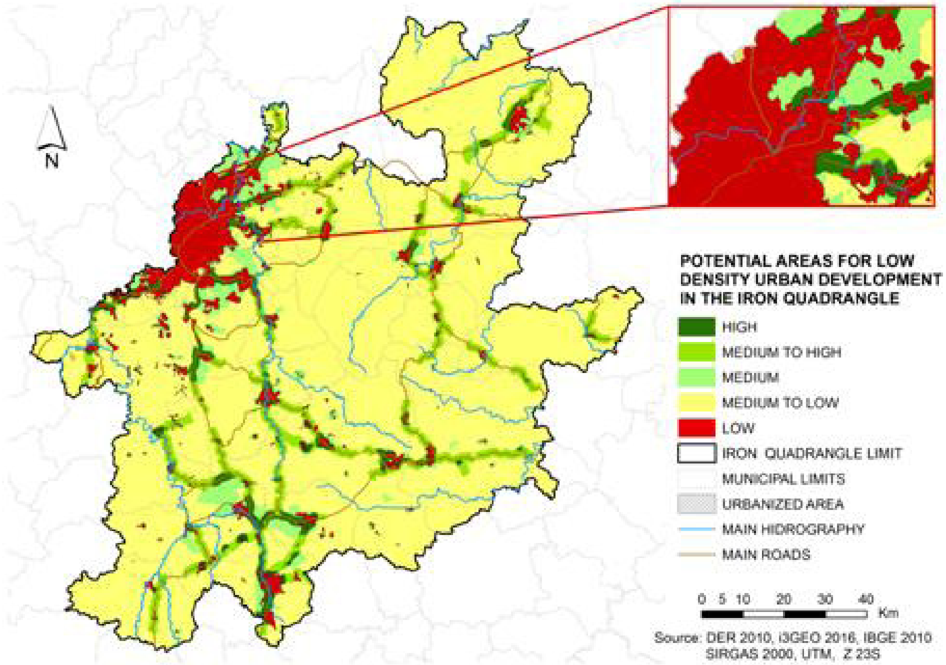

Fig. 17 - Potential areas for low density urban development.

3.3 The decision-making process on alternative future scenarios

Visualization is as a cognitive action, a human ability to develop mental representations which allow, as highlighted by MacEachren *et al*. (1992) the identification of patterns, and creation or imposition of order". The use of traffic light colors in the workshop synthesis maps - red (low), orange and yellow (medium-low and medium) and green (medium high to high) to represent different potential areas for urban development as well as the grouping of the characteristics of each area together into the same visual language were essential for a successful communication with workshop participants. This way, we could see that the technical interpretation that had been developed from the cross-check of thematic data with the use of multiple criteria analysis has become much more accessible to workshop participants than with conventional planning cartography representations.

The same geovisualization method was used to develop evaluation synthesis maps related to the other thematic axis approached in the workshop. The participants were divided into three interest groups representing the people of the place and their social concerns, the environmentalists and their environmental protection priorities and the entrepreneurs and their market motivations. This way, the interest groups were reorganized in new groups formed by representatives of the three social sectors. The new groups developed simultaneous analysis based on visual interpretation of evaluation maps and each group could propose changes in the diagrams made by the other groups in real time using a Geodesign platform developed by Professor Steinitz and his team. Therefore, in a collaborative way, participants could propose land use diagrams over the maps for the each of the ten systems, with great potential to generate consensus-based design. (Figure 18)

Meanwhile, for each diagrams generated by a groups, an impact assessment was simultaneously being produced, providing an immediate feedback of the proposed designs and allowing each participant to redesign his/her previous diagram, as a whole or partially, depending on its impact assessment within a given theme (Figure 19).

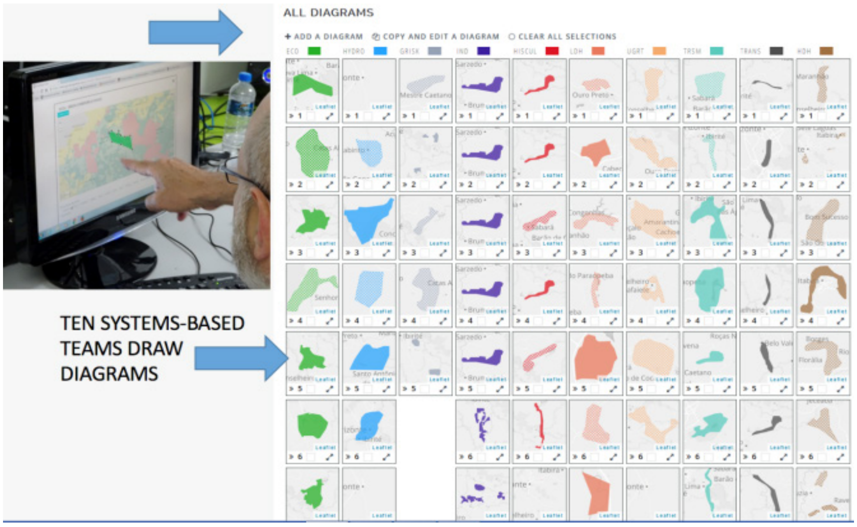

Fig. 18 - Diagrams generated by groups in the *Geodesign Hub*.
Source: Geoproea, 2016 (I Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

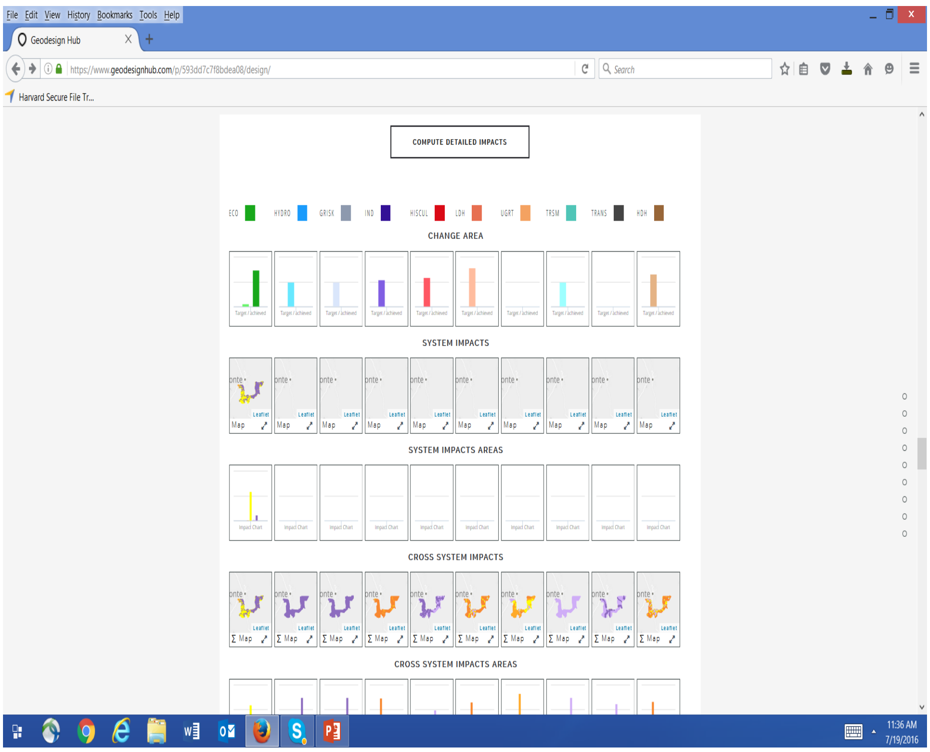

Fig. 19 - Impact assessment - *Geodesign Hub*.
Source: Geoproea, 2016 (I Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

4. OUTCOMES: OPINION AND DECISION MAKING SUPPORT SYSTEM

At the final session of the workshop, through the combination of all diagrams proposed by the different interest groups, concerning potential areas for low and high-density development, a high degree of consensus was achieved in defining where urban growth should occur. The geovisualization of these diagrams over a satellite image increased territorial understanding to the decision-making process.

The overlaying of proposed diagrams for different land uses (i.e. new environmental conservation areas, iron ore mining fields, new residential development projects, new roads, etc.) were simultaneously seen by all participants through the platform (*Geodesign Hub*) and had their performances evaluated according to given constraints and targets (territorial interest conflicts, expected costs and dimensions for a certain use extension). The immediate access to the performance of each proposed design favored discussion and building up consensus around a compromised choice. Once each interest group had its own design set up, and once a final design has been collectively agreed upon among all three groups, a final plan containing projects and policies could be visualized at the Geodesign hub platform in which maps and diagrams are bidimentionally represented and may as well be exported to other platforms.

Geovisualization of urban development processes at the regional level was also of great value for the decision-making process on locating future urban growth in the study area. The consideration of geographic analytical units, which are not limited by political or administrative boundaries but by biophysical characteristics (hill tops, watersheds, biophysical spatial units) and human activities that comprise a region (urban sprawl, mining, road systems) was also very useful for understanding development trends within an urban network as well as its interwoven impacts. This simplified understanding was due, to a large extent, to the use of geotecnologies.

This workshop also counted on the use of tridimensional visualization schemes provided by *Vale Mining Company Virtual Reality System*, as well as the support of *ArcGis* and *Rhino 3D* software. The use of these planning support systems led to a much better visualization and a higher precision on designing diagrams. Also the use of zooming devices to change scales and the overlaid satellite image provided more interactivity in recognizing the territory, and turned out to be great facilitating tools to help participants visualize the concrete impacts of their proposals within scenarios with a great deal of abstraction and uncertainty

However, the interface of data and mapped outputs could also be easily adapted for free open access applications and platforms such as *Google Earth* which makes this experience easily replicable.

Finally, it is important to mention that the overlay of proposed diagrams and evaluation maps of potential areas for future urban development showed a high degree of consistency and coherency between the collective design and the technical constraints analysis (Figure 20, Figure 21 and Figure 22).

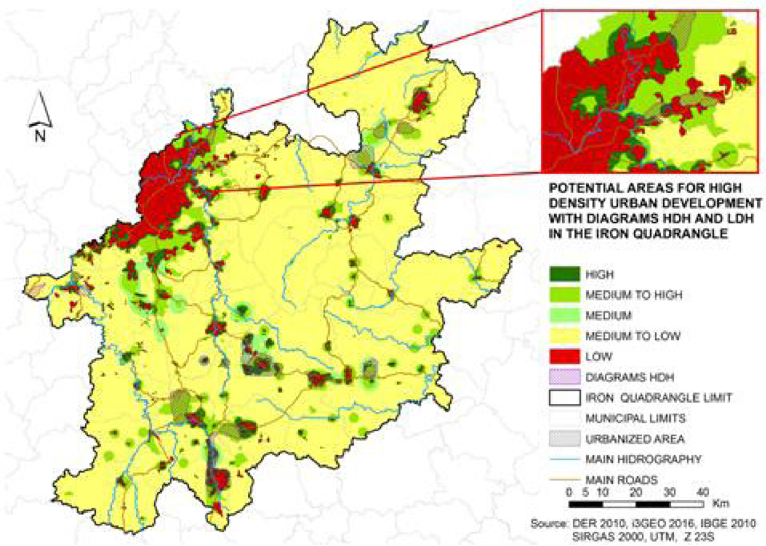

Fig. 20 - Potential areas for high density with diagrams.
Source: Geoproea, 2016 (I Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

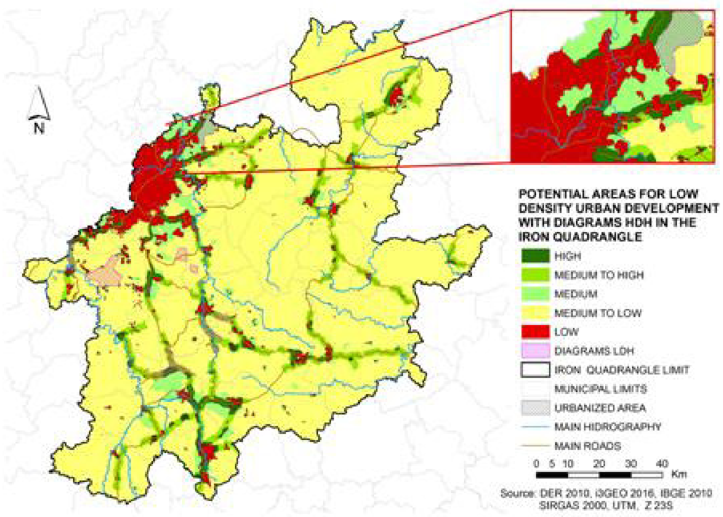

Fig. 21 - Potential areas for low density with diagrams.
Source: Geoproea, 2016 (Io. Workshop Internacional Futuros Alternativos para o Quadrilátero

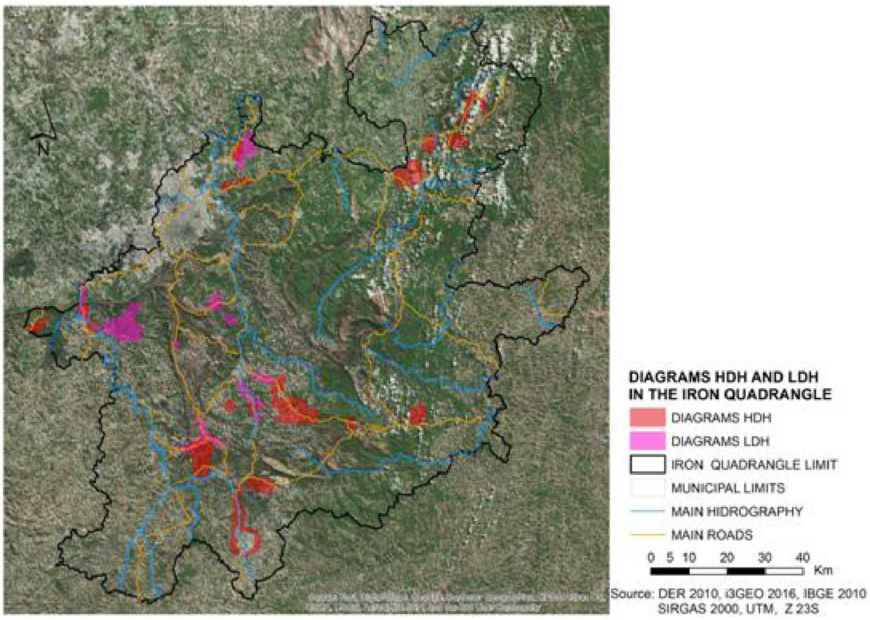

Fig. 22 - Overlapping high and low densities diagrams on satellite image.
Source: Geoproea, 2016 (I Workshop Internacional Futuros Alternativos para o Quadrilátero Ferrífero).

5. FINAL REMARKS

The Geodesign Workshop case presented in this paper has demonstrated the use of planning support systems and geovisualization tools for simultaneous information sharing and increased participation of different stakeholders in regional planning processes. The methodology and the tools that were used made it possible for the collective and fast construction of simultaneous different scenarios that could be compared and evaluated by groups of different stakeholders, resulting highly coherent and consensus designs. It showed that the use of geovisualization of planning data representing different stakeholder's values and concerns aiming at maximizing consensus on alternative future designs increases to a great extent the possibilities of shared agreements.

The use of the traditional participatory planning approach based on a two phase process: a previous "technical analysis of collected data and mapping of pre-selected variables followed by a "community analysis" by a group of stakeholders the workshop's experience proved to be much more limited as a collaborative planning experience than the Geodsign framework allows for. On the other hand, the use of geovisualization strategies allowed for more participation and co-decision making possibilities, instrumenting the Geodesign framework for a multiple phase collaborative planning, also involving local stakeholders (people of the place) that future experiments shall include.

The applied method used defensible and replicable criteria (XAVIER-DA-SILVA, 2001) which means it has been possible to argue on justifying variable choices, values and rules, being furthermore, possible to replicate this experiment. It is above all possible to review variables, values and rules, as well as the relationship between them. The choice for free access data and open software also makes the use of this methodology replicable in different planning and scale situations.

This way, geovisualization creates a base for common dialogue and collaboration among different stakeholders. Based on this dialogue platform, it is possible to develop critical opinions, assessments and reflexions on relevant issues to the community, which highlights the method's didactic feature and its powerful use for enhancing citizen's participation in planning.

ACKNOWLEDGEMENTS

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