PSS in informal urban settlements: results of five years of implementation in Belo Horizonte, Brazil

Gerson José de Mattos Freire, Fernanda Borges de Moraes, Lucas Saliba Santos, Sheyla Aguilar Santana, Andrea Scalon Afonso, Vera Lúcia Voll and Marcílio Felício Pereira

Abstract

The deprived settlements permeate the Brazilian urban fabric, representing a challenge for urban planning. In fact, one out of five inhabitants of Belo Horizonte lives in a slum. In 2009 the municipality of Belo Horizonte made a diagnose of the consolidated deprived settlements to predict the outcomes of interventions known as Programa Vila Viva. It consists in integrated actions of urbanization, social development and property regularization, enabling public managers to consolidate policies of social inclusion. Methodology made use of territorial multi-criteria analysis and map algebra to discuss possible scenarios. Results were converted in a Planning Support System. The present work seeks to check out the results of the previous system and to measure how great the power of irradiance of actions on benefited settlements was.

G. J. M. Freire (Corresponding author) • F. B. Moraes • L. S. Santos •S.A. Santana
Programa de Pós-Graduação em Arquitetura e Urbanismo Escola de Arquitetura, Universidade Federal de Minas Gerais, Belo Horizonte, Brasil
Email: gmfreire@aluvial.com.br
F. B. Moraes Email: fernanda.borges.moraes@gmail.com
L. S. Santos Email: lucassaliba.arq@gmail.com
S.A. Santana Email: shesantana@hotmail.com
A. S. Afonso Companhia Urbanizadora e de Habitação de Belo Horizonte - Urbel Email: andrea.scalon@pbh.gov.br
V. L . Voll Fundação João Pinheiro Email: vera.l.voll@gmail.com
M. F. Pereira Aluvial Engenharia e Meio Ambiente Email: mfpereira@aluvial.com.br

1. Introduction

Cities require an increased dose of intelligence in their management. According to the UN Population Division (2014), in the current days, globally, more people live in urban areas than in rural areas: 54 per cent of the world's population residing in urban areas in 2014. In 1950, 30 per cent of the world's population was ur-ban, and by 2050, 66 per cent of the world's population is projected to be urban.

In Brazil, where the density per square kilometer in persons of land increased from 6.4 in 1950 to 20.3 in 2000, the United Nations believes this number will be 27.6 in 2050, with 93% of the population residing in urban areas.

The consolidated informal settlements permeate the Brazilian urban fabric and represent a challenge for planning. Because of the economic and social segregation, these areas have a well-defined social frontier and their universe contains the largest share of marginalized people in situation of vulnerability due to urban pressures, such as the housing market and right to the city. In fact, one out of five inhabitants of Belo Horizonte lives in a slum, with poor access to public services, transport or urban structures.

In addition, the rapid and unplanned growth of the city is expressed in its worst terms at the informal settlements, reflecting on the quality of life and bringing sectorial challenges. These challenges come together and mix in the space of cities, such as public safety, management of transport and traffic systems, maintenance of infrastructure, the generation of waste and the environment legislation. Therefore, urgent solutions are sought to allow standards of quality of life and the sustainable development of urban spaces.

Geotechnologies are considered a very important tool to generate predictive scenarios for the establishment of public policies and physical interventions. Geotechnologies also aid urban planners to understand the relations between those areas and the urban fabric and the impact of interventions on them. Fortunately, the use of geotechnologies and the conversion of its methodologies into PSS is widespread, with results in various fields of urban design and management.

Caragliu et al (2009, p. 70) believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. Sauer (2012, p.64) points that the concept of the smart city at once stresses the importance of investments in ICT infrastructures to enhance the quality of life and competitive capabilities of cities, as well as the

recognition that in order to achieve this smartness, investments in social capital are necessary. To become smart, cities need to innovate technologically, also by making use of the smart, innovative potentials of their citizens. For this, it is necessary that the city turn in-to a space that can be equally shared, with facilitated opportunities and access for the entire population.

Steinert et al (2011, p.94) regard the smart cities vision as an opportunity to re-think how we manage growth, both regionally and locally. In turn, Batagan asserts that the goals of sustainable development are the same as the objectives of smart cities. We need to invest in our locality to improve the quality of life. In smart cities, technical progress is the support for a lower consumption of re-sources.

Hall et al (2000, p.2) assert that in the long term Smart Cities vision, systems and structures will monitor their own conditions and carry out self-repair, as need-ed. The physical environment, air, water, and surrounding green spaces will be monitored in non-obtrusive ways for optimal quality, thus creating an enhanced living and working environment that is clean, efficient, and secure and that offers these advantages within the framework of the most effective use of all resources.

A city is smart when it allocates efforts to recognize disadvantaged portions of its territory that influence the surrounding areas; when it takes steps to ensure that these portions are integrated and reflects on the results, evaluating them and pro-posing adjustments and corrections to the adopted policies. It is also a sign of intelligence in management the compatibility of planning support systems to local scales. Steinert et al (2011, p.88) assert researchers from the European Smart Cities project, which suggests that smart cities can be defined by measuring relative progress in a number of categories, including smart governance (democratic processes and inclusion), smart people (education), smart environment (environmental sustainability/energy consumption), smart mobility (transportation), smart economy (regional/global competitiveness), and smart living (health care, social services). The authors argue that innovation can be applied to the development of smarter cities in all the dimensions above, in a variety of ways. These ways include, for the smart governance, efficient interconnecting governmental organizations and administrations, eliminating obstacles to communication and collaboration, improving community access to services (first responders, local officials, and service organizations, etc.), improving overall access to governmental services on the part of average city residents, and improving organizational processes to be more efficient.

However, Planning Support Systems (PSS) requires a degree of recognition of the territory that can only be achieved through systematic investments in data acquisition and management. More than that, these systems should always as possible be fed back with the practical results of their applications.

Only in this way adjustments, refinements or needs of change strategies or approaches can be evidenced.

The urban planner has available a variety of tools in order to instrument the decision-making processes. Yet, the monitoring of implemented actions still seems to be the best way to solve the problems of implementing proposed actions and interventions. In fact, Lee et al. (2013, p.5) point as criteria for analyzing smart city governance the following: 1) leadership, 2) strategy, 3) the presence of a dedicated organization, 4) processes, 5) principles and 6) performance measurements.

This paper describes the strategy, the principles and indicators adopted in Belo Horizonte for interventions at critical points of its territorial arrangement, which are the slums. It aims also to check the assertiveness level of the diagnosis made in 2009 and evaluate the potential of irradiation that actions brought to the vicinity of some of these settlements.

According to UN-Habitat (2014 (1)) the term "slum" is used to refer to many types of housing, including those that could be upgraded. Terms such as "slum", "shantytown", "informal settlement", "squatter housing" and "low-income com-munity" are often used interchangeably. The same source defines a "slum house-hold" as a group of individuals living under the same roof in an urban area which lacks one or more of the following: durable housing, sufficient living area, access to improved water, access to sanitation and secure tenure (UN-Habitat, 2014 (2)).

The existence of slums in the urban fabric is a global problem, with occurrences in greater or lesser extent in all continents. Also according to the UN, today, despite the comparative advantage of cities, urban areas are more unequal than rural areas and hundreds of millions of the world's urban poor live in sub-standard conditions. In some cities, unplanned or inadequately managed urban expansion leads to rapid sprawl, pollution, and environmental degradation, together with un-sustainable production and consumption patterns.

It may be considered that the phenomenon of the emergence of informal settlements in Belo Horizonte precedes the construction of the city (inaugurated in 1893), initially with a transitory character in its buildings. These settlements have evolved along the implanted large road axes, because of the lack of prediction of areas to settle workers who came to its construction and, on the other hand, as an indicative of an attempt to establish these workers near their workplace.

However, most markedly between the 40s and 50s, when the industrial center of the nearby town of Contagem was implemented and as an effect of the Brazilian urbanization process in general, it became clear the definitive character of these settlements. Their buildings are more resistant to weather conditions, but they represent a degraded social condition which remains

until the current days. This factor, combined with the real estate speculation and the absence of a policy to solve the problem of the exclusion of lower purchasing power population out of the occupation process in the formal city, did significantly increase the number of informal settlements in the city over the years. However, it was also in this period that society began to recognize the importance of spatial planning and urban land planning. In principle, the policies did not contain a broad vision of the process and were completely modern, seeking for cleanness and functional organization of space. This practice of social exclusion did not produce satisfactory results, mainly because the needs of the city's formal labor and the lack of transport infrastructures made the number and the resident population of informal settlements grow.

In the 80's, the city management took informal settlements as part of the urban fabric, starting to guide the actions towards integration. A Municipal law (PBH, 1983) has ensured to the residents of informal settlements their right to ur-ban land. This was the first step in improving quality of life at these settlements. Fifteen years after, municipal policies were consolidated and approved by the community as a public policy, called Programa Vila Viva.

The program consists in an integrated action of urban development, social development and regularization of existing slum property, which allows public man-agers to consolidate a social inclusion policy, in coordinated action with other programs. As it happens, the program causes profound changes in the structure of the settlement and in housing conditions, through implementation and improvement of its infrastructure and the promotion of socio-economic development of communities. The objectives of the Vila Viva Program are: i) the reduction of a portion of the housing deficit; II) the improvement and recovery of a stock of existing housing through physical and environmental restructuring of the settlements; III) the social and economic development of the settlement and IV) the improvement of the living conditions of the inhabitants. These goals are embedded in the Belo Horizonte Municipal Housing Policy as a way of mitigating the problems in slums, where residents do not have financial means to buy homes or pay rent, live in a precarious situation and are exposed to processes of property speculation within the settlement itself.

Alfonsín and Fernandes (2004) argue that

> It would be great if all the slums and informal settlements could be fully integrated in the best possible way, with a maximum of urban infrastructure and construction quality, so that today the informal areas had the same pattern of regularly produced areas. However, this

> discussion of technical criteria cannot be done in an isolated manner, having to take into account the scale of the problem, the existing re-sources (especially financial resources and the availability of land) and the rights involved (Alfonsín and Fernandes, 2004, p. 2).

The authors postulate that one cannot fail to recognize that the enormous historical distortions of the social distribution of wealth in Brazil left their profound mark on the social production of urban space, and the regularization of informal settlements is the first step towards recognition of this huge social and environ-mental liability.

The implementation of the Vila Viva Program began with resources from the Federal Government of Brazil and the Inter-American Development Bank. The implementation of the program has spread to other informal settlements, with funds from the Banco Nacional de Desenvolvimento Social e Econômico (BNDES) and the Federal Government. These funds represent 1.2 billion reais (approximately four hundred million dollars) and the interventions in these areas benefit 35% of families who currently live in informal settlements in the city of Belo Horizonte.

Thus, one can describe the Vila Viva Program as a smart city strategy, since it is a formal, comprehensive city strategy reviewed and revised regularly to be aligned with specific city's strategic initiatives (Lee et al, 2013, p.5).

In order to define the informal settlements by degree of instability and, consequently, those to be given priority for the interventions of the Vila Viva Program, in 2009 the city developed a study using geotechnologies as a tool. Thus, the environmental assessment of each settlement was drawn from the multi-criteria methodology and map algebra to discuss possible scenarios. The diagnosis considered the approach of biotic resources, physical infrastructure and anthropic aspects, following classification ranges used to characterize each of informal settlements and, after the consolidation of these approaches, to characterize them as a whole.

From the analysis of the variables, the diagnosis proposed the application of notes and weighting factors. The weights were calibrated by a multidisciplinary team to represent the reality assessed, allowing the establishment of priority actions and interventions in slums. The results were converted into a Planning Sup-port System, which was adopted by the municipality to put into practice interventions that took place in informal settlements in the past five years. The planned PSS is flexible for allowing the constant updating of sectorial data; their maintenance and operating costs are low, as use is made of information collected regularly by other sectors of municipal administration.

In addition, these results were also adopted in the methodology of the program Participatory Budget (“Orçamento Participativo”, henceforth OP). OP

investments increase the offer of schools, health centers, cultural centers, recreation areas, housing and above all infrastructure works which will bring the urban and social development to all parts of the city, especially the suburbs, villages and slums, contributing to the reduction of social inequalities. In its 15 years of existence, the Participatory Budget has received several awards from international organizations in recognition of successful and innovative practice of popular participation, promoting the strengthening of the democratic process (Afonso & Magalhães, 2013).

The OP considered informal settlements classified as maximum degree inter-vention priority and those with maximum degree for preparation of urban development plans (that guide the interventions) in setting priorities for urban and social inclusion. These areas are those with the highest concentration of poverty and social exclusion and are considered priority areas for the implementation of public policies. In the OP process, the demands presented by the resident community in these areas receive an additional weight in the poll choice of interventions. It is noteworthy that those settlements which already had interventions by the Vila Viva Program are no longer considered in defining the priority areas of the OP.

The Vila Viva Program differs from other government's actions in slums, mainly in two aspects: the extent of the proposed improvements, which are not restricted to occasional or emergency assistance; and its perenniality through time, required to achieve the expected objectives. In the last five years, the pro-gram executed 50km of roads and 110km of sewage networks. It also implemented 190000m2 parks and recreational areas; built nearly 4,000 housing units for the resettlement of 7,900 families removed which were also contemplated with 3,900 acquisitions of houses or severance pay of the value of the improvement, and has eradicated 80% of risk situations present in the settlements.

In addition to these physical interventions, the program promoted social inclusion initiatives in the settlements, covering health and environmental education activities, monitoring the removed families, offering professional qualification, generating of employment and income and organizing community.

Methodology

According to Malczewski (1999) spatial models can be considered an acceptable representation of reality. The author classifies them according to their nature as simple, when they belong to a certain class, or complex, when representing the interaction between multiple objects.

When dealing with an urban analysis of a complex nature it is necessary to interrelate an array of variables. Through GIS, we divided these variables in layers and spatialized the occurrence of phenomena. To these layers were attributed different weights and grades through a multidisciplinary expert consultation, as de-scribed by Moura et al. (2009). It is used then a simple map algebra: the weighted mean on a matrix basis on which the data were converted. Thus, we arrived at a representation of a complex model of the studied urban space. For this purpose, the information layers acquired were as follows.

The biotic aspects analyzed were: hydrography, including rivers, streams, ponds and springs; Areas of Permanent Protection defined as those of impact on water resources, areas with slopes above 30% and hilltops, and all areas provided as a public utility by law or in which the intervention is prohibited; The presence of Vegetation Cover and public green areas, through mapping provided by the Municipality of Belo Horizonte showing areas without installment plan of use, parks or other ones of Environmental Protection.

With regard to the physical aspects, data of the areas with risks of soil instability processes were included in the analysis, as well as the mapping of soil typology and characteristics.

Regarding infrastructure were used the mapping of areas served by sewage systems, water supply systems, garbage collection and road accessibility.

For the anthropic aspects, socioeconomic characterization was performed considering homogeneous regions (clusters of census tracts that have similar conditions and occupation profiles) and data from tables associated with these units. The reference was the work of Fundação João Pinheiro (2014), which allowed the inclusion of variables such as occupation density, household status, infant mortality and Human Development Index.

The concept of human development, as well as its measure, the Human Development Index, HDI, were presented in 1990 at the first Human Development Report of the United Nations Development Programme. Its popularity as a human development approach was due to the creation and adoption of the HDI as a measure of human development level of a country, as an alternative to gross domestic product. It also gathers three of the most important requirements for the expansion of people's freedoms: the opportunity to lead a long and healthy life - health – to have access to the knowledge - education – and to be able to enjoy a decent standard of living - income. The HDI consolidates information from the Population Census (IBGE) 2010, published in May 2012 and updated in 2013.

Finally, the analysis of the available services took into account the population´s ease of access to urban services. The following items were included: recreational areas, spaces for cultural activities, service establishments,

shops, clinics and industrial establishments. Hence, we arrive at the decision tree described in Fig. 1.

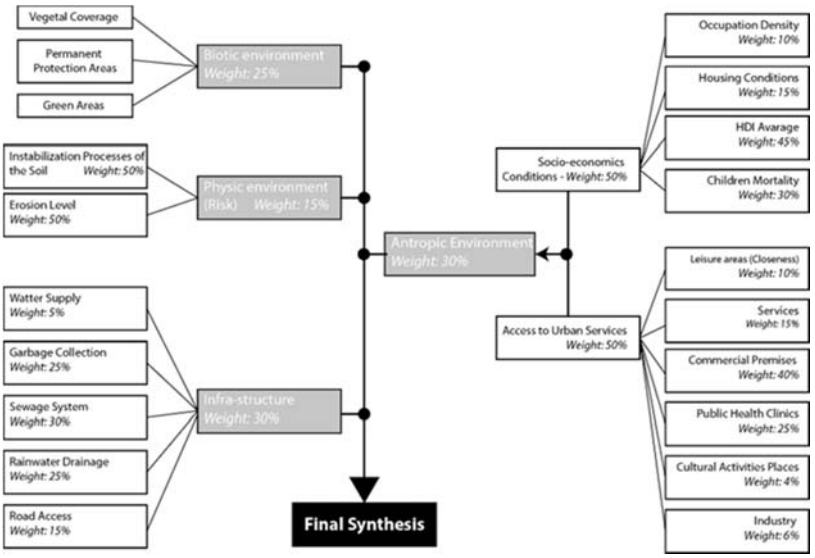

Fig. 1 – Decision Tree and weights used.

Results

After five years of interventions, the same variables were again raised and grouped into layers, in order to assess whether the improvement of urban quality expected really occurred. Through ArcGIS platform (ESRI, Inc.; Redlands, US-CA), data were crossed using the same multi-criteria analysis and the same weights used in the original study, resulting in grades that enabled the comparison of results between the years 2009 and 2014. We performed this comparison through a procedure of map algebra maps, with the subtraction of the result obtained in 2009 from those obtained in 2014. Then we performed intensive analysis of the conditions of clusters in order to detect the reasons for the observed changes. Fig. 2 shows the results for three clusters, selected among those where interventions had a greater extent: Aglomerado da Serra, Aglomerado Morro das Pedras and Aglomerado Várzea da Palma.

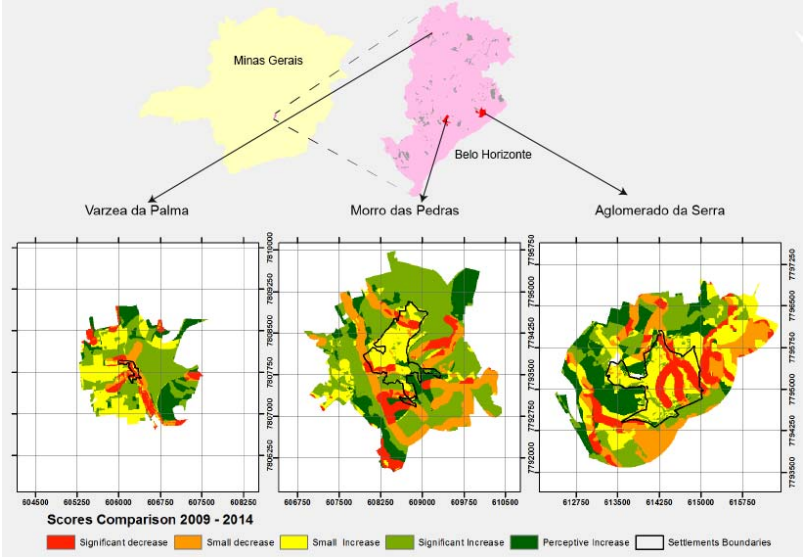

Fig. 2. Results for three selected settlements

The main alterations observed in the period refer to the urban access to services, particularly with regard to the installation of public facilities such as clinics and control stations in addition to the already referred structural improvements in the settlements and the introduction of services such as drainage, sewage and sol-id waste collection. The analysis shows that within two of the clusters predominates a small increase in scores obtained, while in the third (Aglomerado Várzea da Palma) there was a deterioration in general conditions. At the same time, there was a worsening in the conditions of the areas close to watercourses, indicating a need to emphasize revitalization actions and to protect these areas.

It must be noted that most of the areas close to settlements showed significant and noticeable improvements, indicating that the actions resulted in spreading effects to the immediate vicinity. This fact is also an indicative of the advance of formal city over the settlement. In the eyes of the vicinity, settlement remains precarious; however, one can see a process of improvement probably due to the recognition of settlements by the neighborhood as a common area.

In all analyzed settlements, there has been a deterioration in conditions of watercourses protected areas. In urban areas, these conditions are dependent on the number of illegal occupancy of permanent protection areas and the present vegetation. While it is known that due to the Program actions the number of irregular occupations decreased through the resettlement of its

residents, we attempted to analyze the temporal changes in vegetation cover. The mapping and monitoring of vegetation cover received considerable boost in recent decades, with the advent of remote sensing and digital image processing. The advances in research, the use of new satellite sensors and the more affordable distribution to the users make satellite images one of the remote sensing products most used in land cover analysis. These technologies have contributed to the mapping, monitoring, supervision and control of vegetation cover of extensive areas of the earth's surface (Ponzoni 2007). Fonseca (2000) emphasizes that the use of remote sensing images as a source of information for the production of maps is a major innovation driver in GIS branch. The great interest of its use comes from the temporality of information, combined with its relatively low cost. Since man constantly changes the landscape, the interpretation of satellite images is an indirect source of determining the dynamics of economic processes and urban sprawl.

The ratio of bands is one of the most common applications of remote sensing images. In this way one can reduce the effect of topography on the spectral response of the images and use them to enhance the spectral differences in a couple of bands, featuring certain features of the spectral signature curve of some targets (Mather 1978). According to Moreira (2004), in the literature are found more than fifty rates of vegetation, almost all obtained from the reflectance measurements in the spectral red and near infrared bands of the electromagnetic spectrum. The two most commonly used, however, are the Simple Ratio (RVI) and the Normalized Difference Vegetation Index (NDVI). The NDVI is calculated from these individual measurements as follows,

$$NDVI = \frac{(NIR\text{-}VIS)}{(NIR+VIS)} \tag{1.1}$$

where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.

To study the NDVI urban areas the data have been extracted from Landsat images (Wilson et al., 2003). However, in this study were used images from CCD (Charge-Coupled Device) CBERS-2 (China-Brazil Earth Resources Satellite), which are distributed free of charge by INPE – Instituto Nacional de Pesquisas Espaciais.

CBERS images were acquired for Aglomerado da Serra, Morro das Pedras and Aglomerado Várzea da Palma in the years 2000, 2005 and 2010. For the imple-mentation of NDVI it was used the ERDAS IMAGINE (Intergraph

Corporation, Huntsville, US-AL). The bands used were 4 and 3, meaning those of the infrared and red area of spectrum, respectively. The purpose was to identify what were the changes in the vegetation situation from 2000 to 2010, even before the actions of the Vila Viva Program.

Fig. 3 shows the evolution in the areas of undergrowth and tree vegetation. The class "other classes" includes information including urban sprawl, water and shade.

It is observed that there was a significant vegetation suppression along the period of ten years. The influence areas of the settlements, defined by a buffer of 500 meters, were the most damaged, indicating a pressure of formal city directed to the interior of settlement areas.

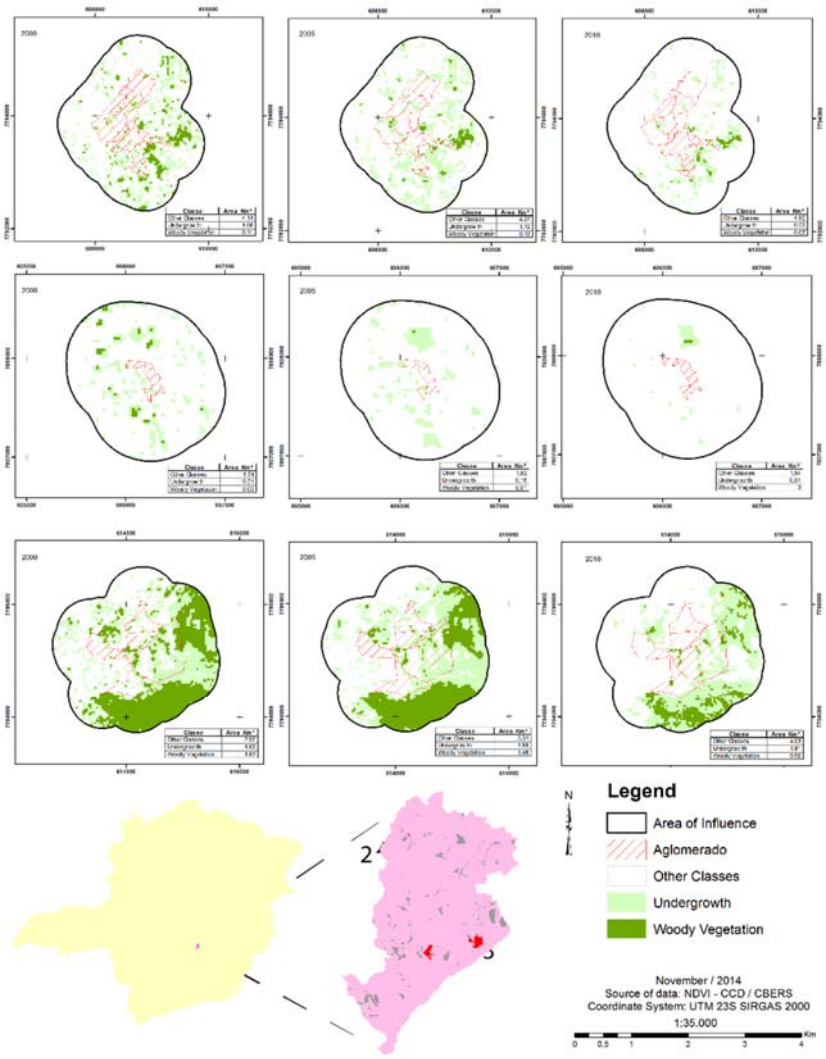

Fig. 3. Vegetation Coverage analysis

As the procedure was performed using low spatial resolution images it is only possible to identify two types of vegetation (undergrowth and tree). The shrub class is enclosed in the tree class when there is the presence of

several nearby bushes and in the undergrowth class when there are isolated shrubs in the land-scape.
It is noteworthy that the use of CBERS images, 15 meters spatial resolution, can only identify areas that have vegetation cover in a surface area or more than 225 m². Thus, the suppression of vegetation verified must be determined by high-resolution images analysis for the surroundings of the slums, as discussed in Freire (2013), but it is also an indicative of the evolution of the formal city on the vicinity of settlements.

Conclusions

The analysis allows the detection of internal and external pressures to urban settlements. The conjunctural economic gains of Brazil in the last five years are included in the analysis, which has combined as variable elements such as education, income and quality of life.
The monitoring of program actions is a useful tool in establishing priorities. It has provided new utility to data that were available, but dispersed among various organs of the municipal administration. In addition, it has established benchmarks for future actions, resulting in the efficiency and the quality of interventions. Also, comparing results through a time series is a response to society, allowing to clarify and enrich accountability of funds invested.
The neighborhoods of the settlements were clearly benefited from the interventions. The diagnosis should be explored further to see if this benefit occurs by re-placing populations (in a gentrification process of the area) or if the benefits are actually recovered by the residents of the settlements.

Recommendations

The elimination of informality in the urban fabric requires two types of interventions. One is to avoid the creation of new informal settlements. The other is to correct the shortcomings of existing settlements through programs that provide formal legal recognition of communities as well as individual forms of ownership and legal tenure or other forms of property; to reduce the gaps in public services; and to promote growth and local economic opportunities.
The integration actions of the territories of consolidated settlements occur through the implementation of structures such as roads, sewer and rainwater drainage mechanisms. These, in turn, allow the arrival of services such as

regular waste collection, public safety, home health care to the residences, resulting in improved quality of life for the people.
The diagnosis should be aware of the identification of the surroundings-slum relationship and of which elements (including symbolic ones) are important to ensure the reduction of prejudice level from part to part.
The friction between the formal and informal market is evident in the surroundings of the settlements. As the analysis found that the surroundings entered the favela, the analysis of speculative pressures around the favela is required, highlighting the need for identification speculation to reduce its effects and ensure the identity of communities.
The settlement and the surroundings had the validation of the results of the actions expressed in terms of the largest observed involutions, which are environ-mental ones. The work can proceed with the validation in the field of perception of populations living in the settlements and its surroundings, and monitoring of vegetation cover reduction trends in areas of environmental protection through remote sensors or field evaluations.

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