Speed, Emergence and Urban Growth

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Abstract

The speed variation in urban growth can produce structural changes in cities, altering the space patterns that emerge in the course of time. To test this hypothesis and to study those space patterns, simulation experiments of urban growth were carried out, considering speed variation and results compared, using the automata cellular based simulation model SACI® – City Environment Simulator – in the urban area of Pelotas in the South of Brazil. The test demonstrates that variations in the growth speed can implicate different results. The main ones are the following: a) slow growth facilitated the consolidation of remote areas, the compactness and the monocentrality; in that case, the interface of the urban area with the natural environment appeared with a low occupation index, however with tendency of integral elimination of the natural remainders; b) the fast growth produced the annexation of the remote areas to the urban structure, combined with fragmentation increase and policentrality production; in that case, the interface with the natural environment remained contrasted by higher occupation indexes than in the slow growth, however, the resulting urban fabric has a larger chance of maintaining natural environment remainder. That result questions the traditional idea that fast urban growth is the cause of environmental degradation, suggesting that the territory conversion done in a selective way could reach appropriate integration results exactly between city and nature considering exactly the fast growth. In consequence, observing the territory conversion not urbanized to have urbanized, the suppression of the natural environment for the city seems not to be a problem of excessive urban growth speed, but a consequence of the territory chosen to be destined to the urbanization or the environmental conservation.

Modeling, speed and emergence

An alternative to move forward in the urban dynamic comprehension can be achieved through modeling exercises (Martin, March and Echenique, 1975), capturing change processes, carrying out tests and observing results, which can be made by classifying the changes as complex, totally or partially self-organized and considering emerging results. To consider the changes to be complex implies that its origin is in the interaction of multiple factors, also in the possibility that evolution may not be linear and consider as well that the results may not be deterministically at random and finally that from simply change rules we can achieve diversified results (Allen, 1997; Batty, 2003); to consider the possibility of self-organization implies to diminish the importance of external and centralized control and also admit that local people behavior based on partial information could generate global patterns and make the whole to assume new features that were not prescript in the external way (Holland, 1998; Portugal 2000; Johnson, 2003). Proceeding this way, modeling exercises can be helpful in the identification of base to top spatial patterns generated, those able to push the whole to superior levels of organization, the ones called emerging patterns.

Modelizing urban growth

One of the main possibilities of the urban modeling is the speculation on future scenarios, taking into consideration previous tendencies or the influence of present day changes (Torrens, 200); unlike anticipating the future, this possibility allows to comprehend better the dynamic of some changing process and could help when it comes to take decisions (Timmermans, 1997). This way was built the urban growth simulation model SACI® – City Environment Simulator, developed by Polidori (2004), that operates as a GIS – Geographic Information's System, reaching future scenarios with simultaneous internal and external growth, fundamented in graphos theory, cellular automata and geotechnologies (Polidori and Krafta, 2005).

A study case of Pelotas, RS

The urban growth speed variation can provoke structural changes in the cities, beyond the increase of the final area occupied by the city and is expected that slower and faster growth will produce different results (McCann and Ewing, 2003). In order to test this hypothesis urban growth simulation experiments using the SACI® model and software were taken, which allows regulating the growth speed and making a compared analysis of the achievable results.

It is assumed the case of Pelotas, Rio Grande do Sul (RS), Brazil, an urban area located 250 km to the south of Porto Alegre, capital of RS state. Pelotas has an effectively urbanized surface around 5,500 ha and an urban population of approximately 320,000 inhabitants. We started the simulation in 2000 and the reference period to the real growth tax extraction is represented by the interval between 1955 and 2000 (45 years), when the medium annual growth of urban area was 2.44% a year (Silva e Polidori, 2004) – it represents the growth speed we use to regulate the simulation.

Three growth hypothesis are simulated using the year 2000 as the starting point and as temporal horizon the year 2045 (45 years) with the achieved calibration to the interval between 1955 to 2000 (Polidori, 2004). The hypotheses are the following: a) inferior growth hypothesis: the city growths with half the speed encountered in the 1955 to 2000 period (1.22% a year); b) intermediary growth hypothesis: the city grows in the same speed encountered in the 1955 to 2000 period (2.44% a year); c) superior growth hypothesis: the city grows with a speed once and a half faster than it did in the 1955 to 2000 period (3.66% a year).

The simulation model input takes into consideration the following factors: built stock, surface waters, swampy lands, fields and small sized vegetation, native forests, overflowed areas, dunes and beaches, areas uncovered by the road system, as illustrated in figure 1, following. The following worked with 45 interactions, each one representing 1 year. There are eight selected states obtained from the output, they represent the effectively urbanized cells in the growth process (brown), centralities distribution (blue), growth potential (beige), natural factors (green) and the urban-internal environmental problems (red and yellow), as appears in figures 2, 3, 4 and 5, farther on.

The inferior, intermediary and superior urban growth hypothesis interpretations follow the growth simulation model outputs using the following queries to observation and analysis: a) conversion of non urban cells into urban cells and the speed that these conversions occur; b) gathering and remote nucleus; c) formation of urban hollows; d) built stocks rarefaction and concentration; e) growth vectors and new poles of attraction; f) formation of peripheries and centers; g) potential for new growing; h) natural attributes concentration or rarefaction, observing the localization, the shape of spots and their relations with the city; i) intensity and localization of urban-internal environmental problems, as well as their relations with the urbanization dynamic.

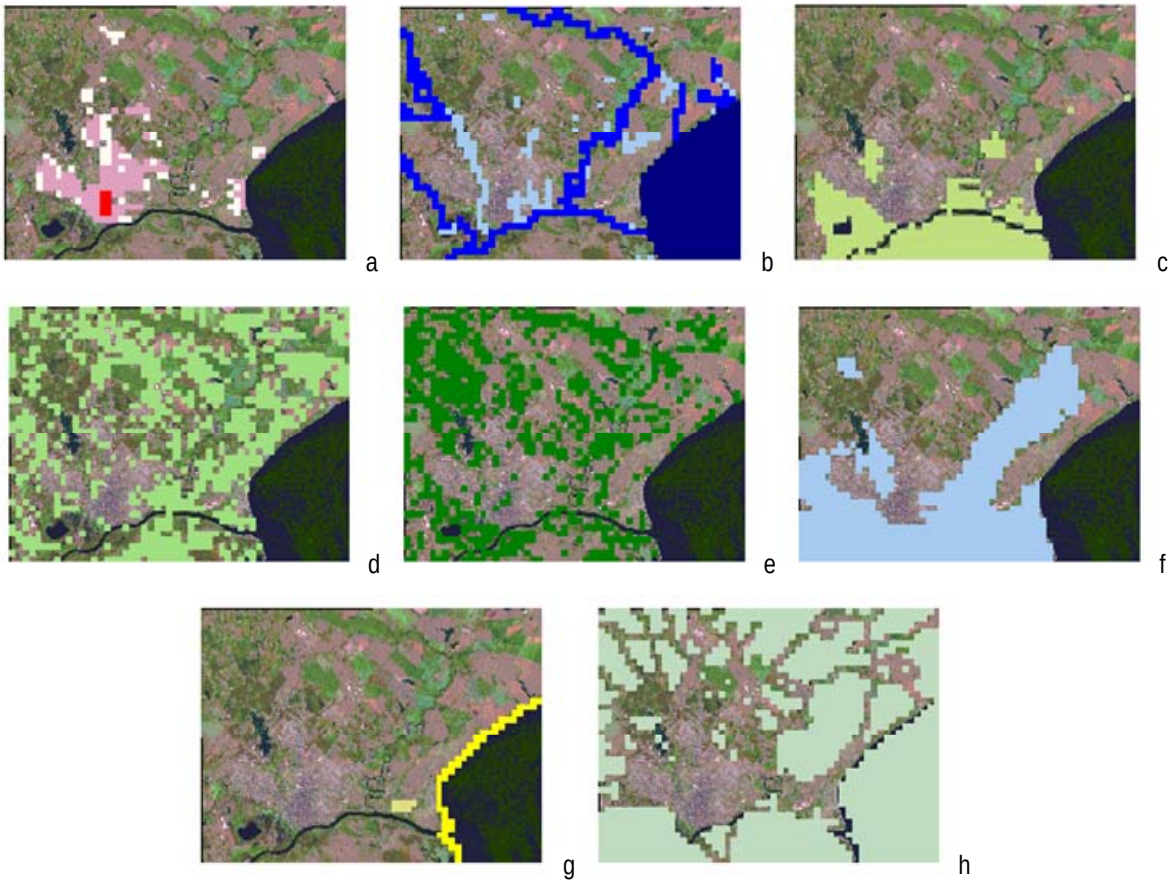

Figure 1*: inputs used in SACI® – City Environment Simulator, obtained by statistics and spatial analysis; a) built stocks; b) surface waters; c) swampy lands; d) fields and small sized vegetation; e) native forests; f) overflowed areas; g) dunes e beaches; h) area uncovered by the road system.*

Next the growth simulation results are exposed, considering a crescent speed variation.

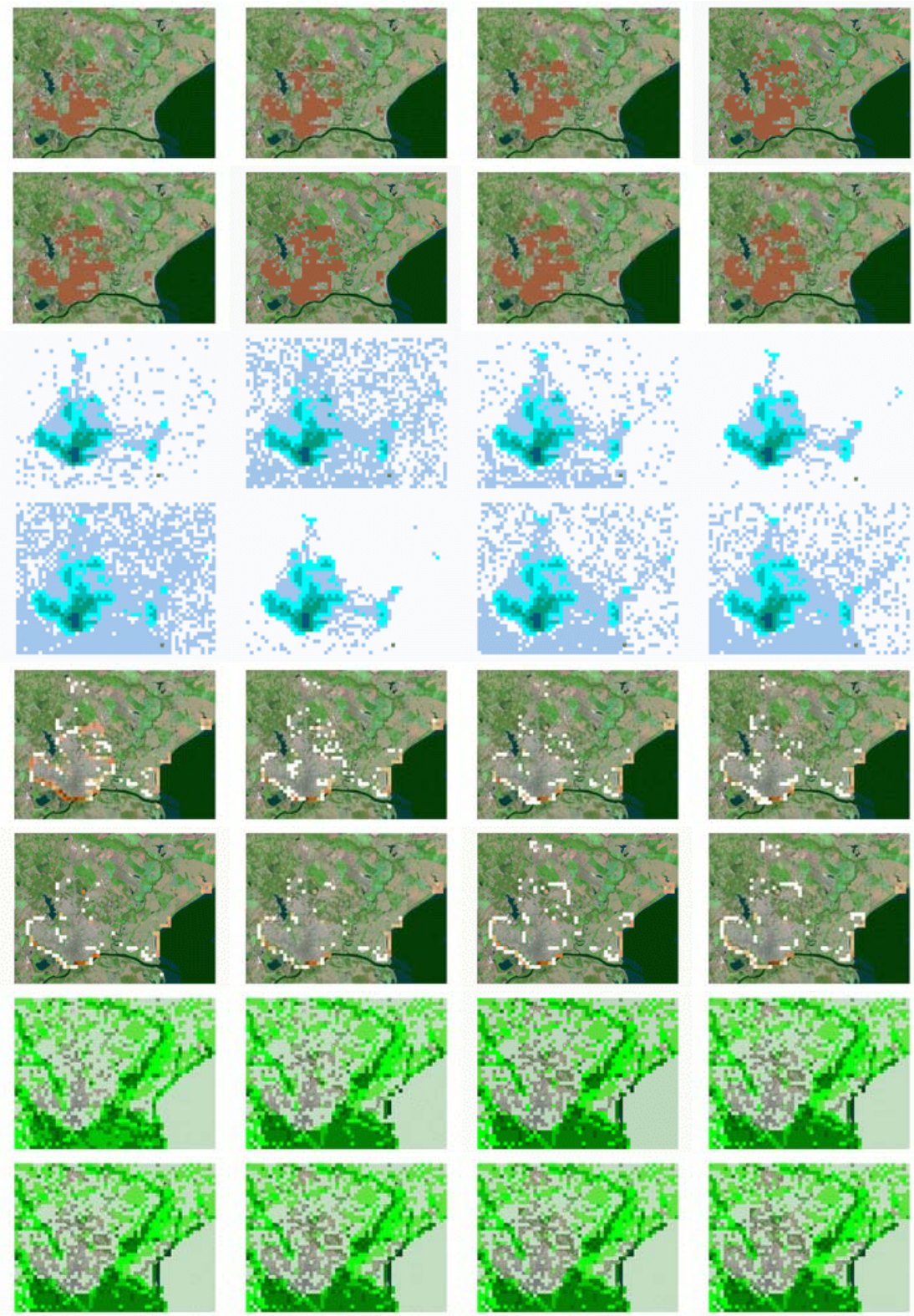

Figure 2: inferior growth speed hypothesis, shows 8 states of the system, representing the evolution of: the effectively urbanized cells in the growth process (brown), the centralities distribution (blue), the growth potential (beige) and natural factors (green).

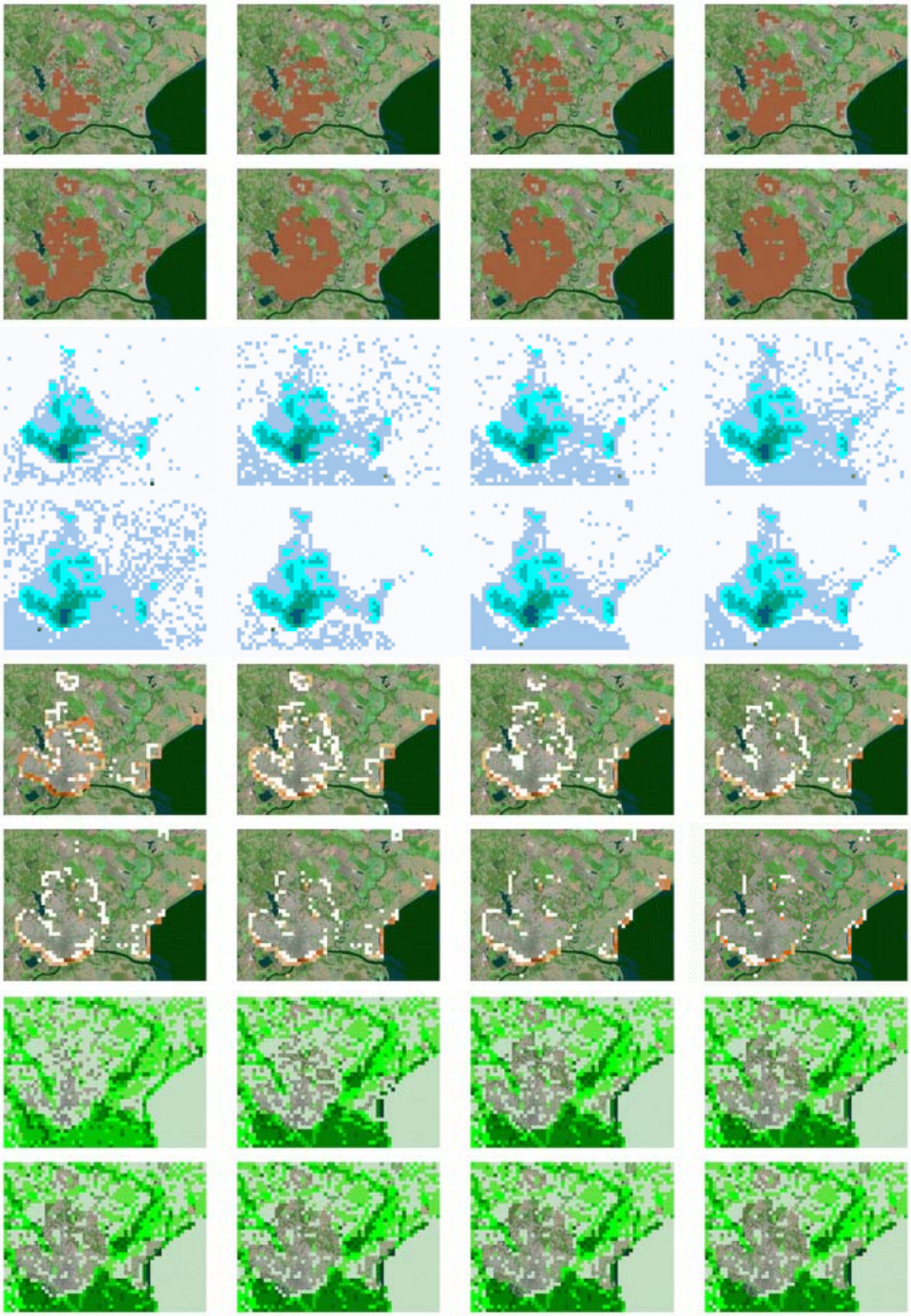

Figure 3: intermediary growth speed hypothesis, shows 8 states of the system, representing the evolution of: the effectively urbanized cells in the growth process (brown), the centralities distribution (blue), the growth potential (beige) and natural factors (green).

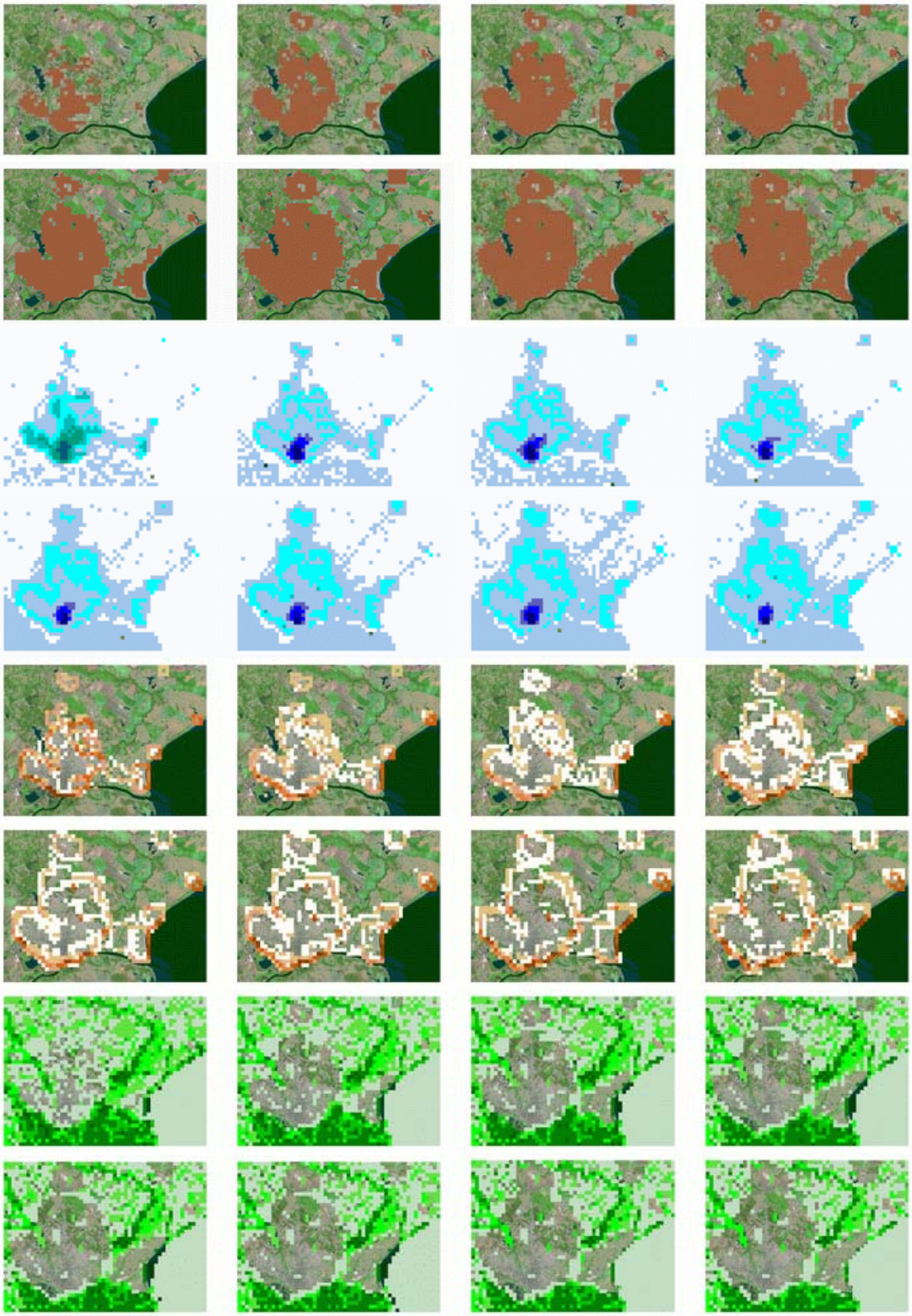

Figure 4: superior growth speed hypothesis, shows 8 states of the system, representing the evolution of: the effectively urbanized cells in the growth process (brown), the centralities distribution (blue), the growth potential (beige) and natural factors (green).

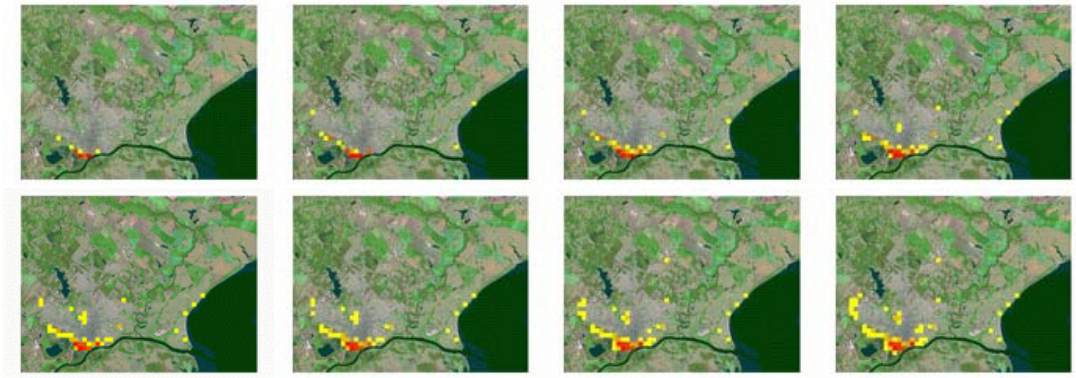

Figure 5: superior growth hypothesis shows 8 states of the system, representing the evolution of cells that presented urban-internal environmental problems (yellow and red).

Concerning the slower growth mode, the accomplished experiments allows to observe:

a) the slow growth is favorable to the permanence of preexisting separated nuclei, which show the difficulty in making connections; in this scenario, new loads derivative from the slow growth have a weak intensity, adhering to the preexisting city edges;

b) the centralities distribution maintain the hierarchy between maximums and minimums, respectively, from the centre to the periphery; neighbourhood centres occur with weak values, becoming visible only to its immediate surrounding;

c) the growth potential occurs in a mainly linear way, in the interface of the urbanized territory and the non urbanized, the maximums are concentrated where the city encounters the zones not possible to urbanize; while the external growth potential is the largest and decreasing, the internal potential is the smallest and the more stable one;

d) the interface of the natural environment and the city presents low natural resistances and slow urbanization advances; from this process results an encounter of weak contrast between urbanized and non urbanized territory, which is a typical result from slow urban growth.

In the intermediary growth hypothesis, which uses a growth speed similar to present day, the following main observations can be pointed:

e) the territory conversion process generated a main continued nuclei and separated secondary nuclei, as well as it has maintained the larger urban hollows and diminished the smaller and fragmented ones; this indicates there was some type of a stir of the urban structure, in the full-

hollow relation (urbanized and non urbanized areas), accomplished by the reproduction of the neighbor cells behavior, generating a global pattern through the repetition of local behaviours;

f) soils converted by urbanization present a medium and weak load; while the weak loads reproduce the edge formed by the inferior growth hypothesis, the medium loads constitute a different front of growth located in the opposite diameter to the main centre; the result suggests the urban growth is conducted by opposing forces: while the territory conversion occurs from inside out (centrifugal force), the occupation occurs from outside in (centripetal force);

g) the traditional centre shows strong tendency to persist the same, with very little alteration during the simulation, due to its strategic position and the load initial conditions; neighborhood centers occur but with centrality values further lower than in the main centre and in the city edges accumulate the smaller centrality values (dividing the centrality in four classes: the traditional centre is in class 1, while the neighborhood centers are in class 3 and the city edges are in class 4); this result shows the persistence of an urban structure with a defined hierarchy and commanded by the traditional centre, with expansions coincidental to the urban peripheries formation;

h) the growth potential concentration is bigger in the interface of urbanized zones with the non urbanizing ones, it usually appears as a line; in the areas where there is no impediment to the urbanization, the potential tends to occur fragmented over the territory, with medium and low values and diffuse localization;

i) in the process of urban growth, the attributes that operate as resistance to urbanization either disappear or increase its relative values in the iteration sequence; so, it may be assumed that the resistances evolve with the simulation advance, however only the strongest ones remain; in the study case, Pelotas, those permanencies are represented by the water and swamp lands subsystem;

j) in the intermediary hypothesis the intensity and type of simulated growth did not provoke a threshold surpassing, no urban-internal environmental problems were registered.

Finally, increasing the growth speed and maintaining the initial conditions, the following topics are observed:

k) the conversion of non-urbanized cells into urbanized cells shows, in a fast growth case, a tendency of consolidation and compaction of the preexisting nuclei, diminishing inner hollow fragments and maintaining the big ones that separate remote urban nuclei; this suggests a correspondence between the growth intensification and the preexisting urban structure conflict, with well defined urban spots and clearly separated externally;

l) as they grow the preexisting nuclei consolidate and compact themselves, new fragments are printed to the non-urbanized surround, like a spray arising from these nuclei; this result points to a cyclic process with compaction and fragmentation happening not only in different times but in different spaces at the same time;

m) cells with higher urbanization intensity move from the centre to the edge of the preexisting city constituting some sort of growth front; maximum load points float through the system characterizing large and ephemeral attraction poles; this result indicates that increasing the growth speed stimulates the building activity and the general urbanization situated out of the traditional centre, its increment stays influenced by centrifugal forces;

n) besides the urban soil expansion and the dislocation of the loads to the edges, the traditional centre maintain its centralities maximum values with surface retraction as well; this suggests that to each external expansion process there is a correspondent internal concentration process, with a submissive urban growth to the preexisting city structural conditions; in this case it can be assumed that to the centrifugal forces of urban load increase there are correspondent centripetal forces of centralities increase;

o) the growth potentials appear less in a line format then in the previous experiments, they appear with higher values in a broad band that includes parts of the preexisting city and non urbanized areas; however they maintain the linear pattern of maximums in the interface with the natural environment and of minimums with the preexisting city, which suggests that in the city edge the natural environment has more capacity to attract potentials then the preexisting urban environment;

p) the natural resistance are diminished quickly remaining only the surface waters subsystem, which does not get urbanized because it is frozen in an external way; despite that, fragments

of the natural system remain in bigger amounts then in the inferior and intermediary growth hypothesis; in other words, at the same time that the fast growth consumes more surface, suppressing the city surrounding natural landscape and provoking stronger contrasts, it presents higher probability of keeping natural vestiges of the urban fabric, even if in a fragmented manner;

q) the urban internal environmental problems appear concentrated in the interface of the city with areas that are unable to get urbanized, where the potential tends to be maximum and thresholds of urbanization are overcome; this result indicates a higher probability of urban internal environmental problems occurrence when there is an intensity change in the soil occupation, particularly when provoked in an external way.

Conclusions

In a gathering exam of the three-growth hypothesis that presents speed variations and are classified as inferior, intermediary and superior, there are recurrent observations such as:

1. the urban growth showed through the conversion of non urbanized territory to urbanized territory indicates three integrated tendencies: 1.1) unification of the nuclei located near the central area, forming a long area covered by urbanization; 1.2) consolidation of remote nuclei, without unification; 1.3) the emerge of new fragments that figures as consolidated nuclei satellites; this result suggests a growth process with temporal and locational cycles formed by sequences of fragmentation and compaction;

2. the urban hollows are permanent in every urban growth simulation, they appear with three main possibilities: 2.1) large and lasting hollows that separate remote nuclei; 2.2) fragmented hollows that don’t last long, they appear along with the also fragmented expansions; 2.3) hollows associated to frozen urbanization zones, such as the surface waters system or overflowed areas that assume the outline of the origin zones;

3. in the growth process slow increments tend to happen through low density urbanization edges while fast increments happen through edges of bigger urban loads; while in case one there are low contrasts with the natural environment, in the second case high contrasts appear;

4. in the urban loads case that emulate building and general urbanization efforts, the growth speed increase implies in the built stocks migration to the edge zones, when they are commanded by centrifugal forces; however the occupation process inside the expanding edge is inverted, with the more dense areas located in a diametrical opposition concerning to the preexisting cen-

tres; over the areas that concentrate the highest loads float points of maximum value which stop occurring in a stable way in the traditional centre and start occurring in an unstable manner and closer to the urban periphery;

5. centripetal forces command centralities accumulation in all three simulated hypothesis suffering the influence of simulation initial conditions (urban nuclei distribution and their urbanization intensity); this result may be indicating a positive feedback presence in the constitution of urban centres, because as bigger the city gets more concentrated gets its main centre;

6. the higher growth potential is located in transition zones between places more and less urbanized, which means that bigger urbanization differences cause higher growth potentials; this result gets even thinner when urbanized areas meet frozen urbanization areas forming a line of maximum potentials;

7. the natural landscape of city surrounds changes along with the growth speed variation becoming possible to identify two patterns: 7.1) in the slow growth less territory is converted to urban soil however the urbanization tends not to leave vestiges of the previous natural landscape; in the city edge the contrasts between city and nature tend to be smooth; 7.2) in the fast growth, more territory is converted to urban soil, however, there is more probability that previous natural fragments will remain; in the city edge appear higher contrasts between city and nature;

8. there are more chances of urban internal environmental problems appear when the growth speed increases, being the places where the city meets the frozen urbanization areas the most vulnerable ones;

9. in the specific case of Pelotas, RS, Brazil, it may be said that the city presents an urban structure that tends to the inertia, its structural modifications are very difficult and improbable and the reinforcement of preexisting conditions the general tendency of the three simulations.

Extending the presented simulations interpretations we observe six regularities in the urban growth process, which can be considered as general emergencies to the contemporary city. They can be resumed in the following items:

10. the urban growth that happens through the conversion of non urbanized soils into urbanized soils, demonstrates that the city grows through centrifugal forces however the territory conversion experiments flaws, which provokes the appearance of urban hollows;

11. in the urban growth process, the built stocks are distributed by means of the combination of centrifugal and centripetal forces with permanent instabilities; while the first ones are typical of slow growth the second ones appear when the growth happens fast, specially in the expanding edge;

12. the distribution of centralities is associated in a directly proportional way to the soil value, allocation of infra-structure, urban equipment endowing and urban facilities availability; it maintains a short term floating behaviour, however it tends to differ majority centers as the urban dynamic advances, getting self-organized in a long term;

13. the growth potential usually gets concentrated in the interface of urban and not urban and also in the interface of more urbanized and less urbanized areas; this concentration tends to demarcate expansion fronts in a line shape, determining an edge with a different behaviour from the rest of the system;

14. the experiments demonstrate that in urban growth there occurs a positive feedback mechanism in which the spaces get distinguish in a crescent way; however, when an urban threshold is found, whatever natural or institutional, a negative feedback mechanism happens, in a growth cycle, with the appearance of urban internal environmental problems and the overcoming of those problems, which produces a system self-regulation;

15. the natural landscape and its attributes represent the city previous environment that functions as an irregularities field which influences short and long term urban growth according to the intensity they resist urbanization; while in a short term the natural low resistance attracts urban growth this process increases the growth potential of higher resistance areas, increasing the urbanization pressure in a long term.

At the end the results demonstrate that growth speed variation may implicate different results since the slow growth facilitated the remote nuclei consolidation, compactness and monocentrality; in this case the interface of the urban area and the natural environment appeared with a low occupation index, however with tendency to the integral elimination of natural remainders. The fast growth produced an annexation of remote nuclei to the urban structure, which was combined with the policentrality production and fragmentation increase; in that case, the natural environment interface became contrasted by higher occupation indexes than in the slow growth, however, the urban fabric resulting has more chances of maintaining the natural environment remainders.

These results put in question the current idea that the fast urban growth is the responsible for the environmental structural degradation, as the selective territory consumption could reach proper integration results between city and nature considering exactly the fast growth. So, observing the conversion of non urbanised territory to urbanised territory, the natural environment suppression by the city seems not to be a problem of urban growth speed excess but a consequence of the territory chosen to be destined to urbanization or environmental conservation.

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