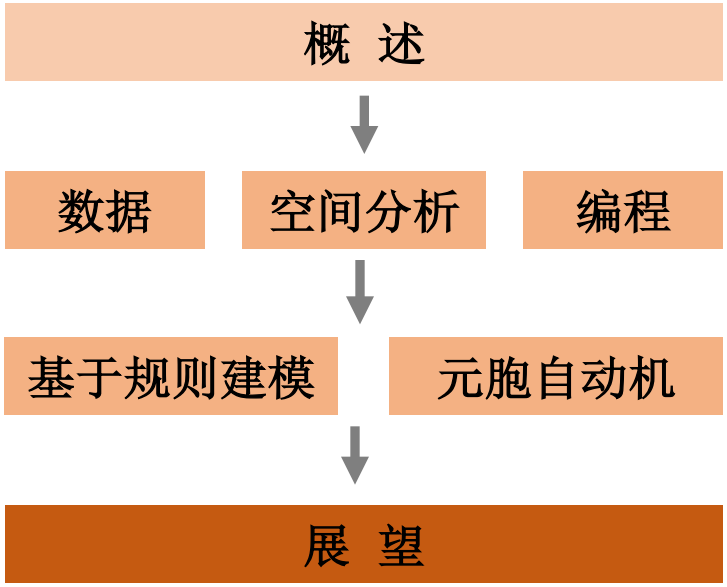
元胞自动机模型（矢量）

Vector Cellular Automata Model for Modelling Urban Growth

龙 瀛
清华大学建筑学院
2018年4月10日

《城市模型概论》教学大纲

1. 2月27日W1：城市模型概论之概论
2. 3月06日W2：模型基础数据
3. 3月13日W3：基于规则建模
4. 3月20日W4：城市空间分析方法
5. 3月27日W5：模型开发语言
6. 4月03日W6：元胞自动机模型（栅格）
7. 4月10日W7：元胞自动机模型（矢量）
8. 4月17日W8：大数据时代的城市模型展望



2017-2018 学年度春季学期和夏季学期

周次	日/星期/月	一	二	三	四	五	六	日
0	2018 二	19	20	21	22	23	24	25
1		26	27	28				
					1	2	3	4
2		5	6	7	8	9	10	11
3	三	12	13	14	15	16	17	18
4		19	20	21	22	23	24	25
5		26	27	28	29	30	31	
								1
6		2	3	4	5	6	7	8
7		9	10	11	12	13	14	15
8	四	16	17	18	19	20	21	22
9		23	24	25	26	27	28	29
10		30						
			1	2	3	4	5	6
11		7	8	9	10	11	12	13
12	五	14	15	16	17	18	19	20

清華大學

2017-2018 学年度校历

春季学期（2018 年）

1. 2 月 24 日、25 日教职工照常上班，本科生、研究生 2 月 25 日前完成注册。
2. 2 月 26 日全校本科生、研究生开始上课。
3. 妇女节：3 月 8 日正常上课，女教工放假半天。
4. 清明节：4 月 5 日-7 日放假调休，共 3 天。
5. 校庆及“五一”：4 月 28 日、29 日（校庆日）教职工照常上班；4 月 30 日-5 月 4 日放假调休，共 5 天。
6. 端午节：6 月 18 日放假，与周末连休。
7. 第 8 周期中测验。 第 17 周、18 周期末考试。

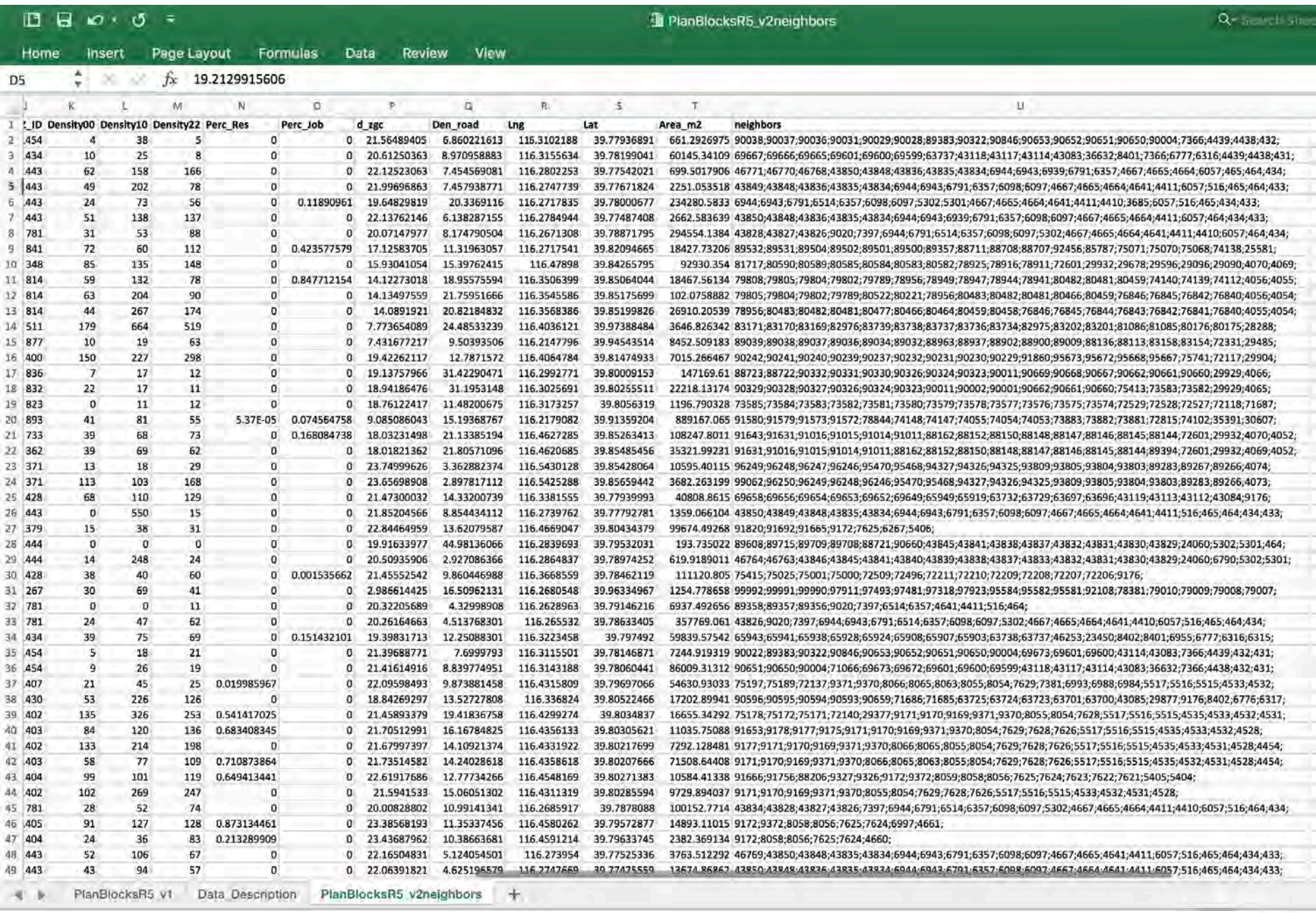
数据更新 v2

Date_name	Data_Description	Date_Note
Block_ID	地块唯一编码	
Far_2004	2004年容积率	
Far_2017	2017年容积率	
Area_m2	地块面积	单位：平方米
d_tam	距天安门距离	单位：千米
d_metro	距最近地铁站距离	单位：千米
d_cbd	距CBD距离	单位：千米
d_zgc	距中关村距离	单位：千米
in_Eco	是否在生态红线内	1表示在生态红线范围；0表示不在生态红线范围
in_Ind	是否在产业功能区内	1表示在产业功能区范围；0表示不在产业功能区范围
in_His	是否在历史保护区内	1表示在历史保护区范围；0表示不在历史保护区范围
Den_road	道路密度	500m缓冲区内道路密度，单位km/km^2
Density00	0点人口密度	数据来源：2015年06月12日00点宜出行数据
Density10	10点人口密度	数据来源：2015年06月12日10点宜出行数据
Density22	22点人口密度	数据来源：2015年06月12日22点宜出行数据
Perc_Res	其中现状的居住用地占比	
Perc_Job	其中现状的就业用地占比	
Lng	经度	GPS坐标
Lat	纬度	GPS坐标
TAZ_ID	所在TAZ编号	

neighbors 这一字段表示每个地块周边500米内的地块的ID（BLOCK_ID）

（如果要考虑邻域，建议用v2版本的数据）

PlanBlocksR5_v1 | Data_Description | PlanBlocksR5_v2neighbors | +



_ID	Density00	Density10	Density22	Perc_Res	Perc_Job	d_zgc	Den_road	Lng	Lat	Area_m2	neighbors
454	4	38	5	0	0	21.56489405	6.860221613	116.3102188	39.77936891	661.2926975	90038;90037;90036;90031;90029;90028;89383;90322;90846;90653;90652;90651;90650;90004;7366;4439;4438;432;
434	10	25	8	0	0	20.61250363	8.970958883	116.3155634	39.78199041	60145.34109	69667;69666;69665;69601;69600;69599;63737;43118;43117;43114;43083;36632;8401;7366;6777;6316;4439;4438;431;
443	62	158	166	0	0	22.12523063	7.454569081	116.2802253	39.77542021	699.5017906	46771;46770;46768;43850;43848;43836;43835;43834;6944;6943;6939;6791;6357;4667;4665;4664;6057;465;464;434;
443	49	202	78	0	0	21.99696863	7.457938771	116.2747739	39.77671824	2251.053518	43849;43848;43836;43835;43834;6944;6943;6791;6357;6098;6097;4667;4665;4664;4641;4411;6057;516;465;464;433;
443	24	73	56	0	0.11890961	19.64829819	20.3369116	116.2717835	39.78000677	234280.5833	6944;6943;6791;6514;6357;6098;6097;5302;5301;4667;4665;4664;4641;4411;4410;3685;6057;516;465;434;433;
443	51	138	137	0	0	22.13762146	6.138287155	116.2784944	39.77487408	2662.583639	43850;43848;43836;43835;43834;6944;6943;6939;6791;6357;6098;6097;4667;4665;4664;4411;6057;464;434;433;
781	31	53	88	0	0	20.07147977	8.174790504	116.2671308	39.78871795	294554.1384	43828;43827;43826;9020;7397;6944;6791;6514;6357;6098;6097;5302;4667;4665;4664;4641;4411;4410;6057;464;434;
841	72	60	112	0	0.423577579	17.12583705	11.31963057	116.2717541	39.82094665	18427.73206	89532;89531;89504;89502;89501;89500;89357;88711;88708;88707;92456;85787;75071;75070;75068;74138;25581;
348	85	135	148	0	0	15.93041054	15.39762415	116.47898	39.84265795	92930.354	81717;80590;80589;80585;80584;80583;80582;78925;78916;78911;72601;29932;29678;29596;29096;29090;4070;4069;
814	59	132	78	0	0.847712154	14.12273018	18.95575594	116.3506399	39.85064044	18467.56134	79808;79805;79804;79802;79789;78956;78949;78947;78944;78941;80482;80481;80459;74140;74139;74112;4056;4055;
814	63	204	90	0	0	14.13497559	21.75951666	116.3545586	39.85175699	102.0758882	79805;79804;79802;79789;80522;80221;78956;80483;80482;80481;80466;80459;76846;76845;76842;76840;4056;4054;
814	44	267	174	0	0	14.0891921	20.82184832	116.3568386	39.85199826	26910.20539	78956;80483;80482;80481;80477;80466;80464;80459;80458;76846;76845;76844;76843;76842;76841;76840;4055;4054;
511	179	664	519	0	0	7.773654089	24.48533239	116.4036121	39.97388484	3646.826342	83171;83170;83169;82976;83739;83738;83737;83736;83734;82975;83202;83201;81086;81085;80176;80175;28288;
877	10	19	63	0	0	7.431677217	9.50393506	116.2147796	39.94543514	8452.509183	89039;89038;89037;89036;89034;89032;88963;88937;88902;88900;89009;88136;88113;83158;83154;72331;29485;
400	150	227	298	0	0	19.42262117	12.7871572	116.4064784	39.81474933	7015.266467	90242;90241;90240;90239;90237;90232;90231;90230;90229;91860;95673;95672;95668;95667;75741;72117;29904;
836	7	17	12	0	0	19.13757966	31.42290471	116.2992771	39.80009153	147169.61	88723;88722;90332;90331;90330;90326;90324;90323;90011;90669;90668;90667;90662;90661;90660;29929;4066;
832	22	17	11	0	0	18.94186476	31.1953148	116.3025691	39.80255511	22218.13174	90329;90328;90327;90326;90324;90323;90011;90002;90001;90662;90661;90660;75413;73583;73582;29929;4065;
823	0	11	12	0	0	18.76122417	11.48200675	116.3173257	39.8056319	1196.790328	73585;73584;73583;73582;73581;73580;73579;73578;73577;73576;73575;73574;72529;72528;72527;72118;71687;
893	41	81	55	5.37E-05	0.074564758	9.085086043	15.19368767	116.2179082	39.91359204	889167.065	91580;91579;91573;91572;78844;74148;74147;74055;74054;74053;73883;73882;73881;72815;74102;35391;30607;
733	39	68	73	0	0.168084738	18.03231498	21.13385194	116.4627285	39.85263413	108247.8011	91643;91631;91016;91015;91014;91011;88162;88152;88150;88148;88147;88146;88145;88144;72601;29932;4070;4052;
362	39	69	62	0	0	18.01821362	21.80571096	116.4620685	39.85485456	35321.99231	91631;91016;91015;91014;91011;88162;88152;88150;88148;88147;88146;88145;88144;89394;72601;29932;4069;4052;
371	13	18	29	0	0	23.74999626	3.362882374	116.5430128	39.85428064	10595.40115	96249;96248;96247;96246;95470;95468;94327;94326;94325;93809;93805;93804;93803;89283;89267;89266;4074;
371	113	103	168	0	0	23.65698908	2.897817112	116.5425288	39.85659442	3682.263199	99062;96250;96249;96248;96246;95470;95468;94327;94326;94325;93809;93805;93804;93803;89283;89266;4073;
428	68	110	129	0	0	21.47300032	14.33200739	116.3381555	39.77939993	40808.8615	69658;69656;69654;69653;69652;69649;65949;65919;63732;63729;63697;63696;43119;43113;43112;43084;9176;
443	0	550	15	0	0	21.85204566	8.854434112	116.2739762	39.77792781	1359.066104	43850;43849;43848;43835;43834;6944;6943;6791;6357;6098;6097;4667;4665;4664;4641;4411;516;465;464;434;433;
379	15	38	31	0	0	22.84464959	13.62079587	116.4669047	39.80434379	99674.49268	91820;91692;91665;9172;7625;6267;5406;
444	0	0	0	0	0	19.91633977	44.98136066	116.2839693	39.79532031	193.735022	89608;89715;89709;89708;88721;90660;43845;43841;43838;43837;43832;43831;43830;43829;24060;5302;5301;464;
444	14	248	24	0	0	20.50935906	2.927086366	116.2864837	39.78974252	619.9189011	46764;46763;43846;43845;43841;43840;43839;43838;43837;43833;43832;43831;43830;43829;24060;6790;5302;5301;
428	38	40	60	0	0.001535662	21.45552542	9.860446988	116.3668559	39.78462119	111120.805	75415;75025;75001;75000;72509;72496;72211;72210;72209;72208;72207;72206;9176;
267	30	69	41	0	0	2.986614425	16.50962131	116.2680548	39.96334967	1254.778658	99992;99991;99990;97911;97493;97481;97318;97923;95584;95582;95581;92108;78381;79010;79009;79008;79007;
781	0	0	11	0	0	20.32205689	4.32998908	116.2628963	39.79146216	6937.492656	89358;89357;89356;9020;7397;6514;6357;4641;4411;516;464;
781	24	47	62	0	0	20.26164663	4.513768301	116.265532	39.78633405	357769.061	43826;9020;7397;6944;6943;6791;6514;6357;6098;6097;5302;4667;4665;4664;4641;4410;6057;516;465;464;434;
434	39	75	69	0	0.151432101	19.39831713	12.25088301	116.3223458	39.797492	59839.57542	65943;65941;65938;65928;65924;65908;65907;65903;63738;63737;46253;23450;8402;8401;6955;6777;6316;6315;
454	5	18	21	0	0	21.39688771	7.6999793	116.3115501	39.78146871	7244.919319	90022;89383;90322;90846;90653;90652;90651;90650;90004;69673;69601;69600;43114;43083;7366;4439;432;431;
454	9	26	19	0	0	21.41614916	8.839774951	116.3143188	39.78060441	86009.31312	90651;90650;90004;71066;69673;69672;69601;69600;69599;43118;43117;43114;43083;36632;7366;4438;432;431;
407	21	45	25	0.019985967	0	22.09598493	9.873881458	116.4315809	39.79697066	54630.93033	75197;75189;72137;9371;9370;8066;8065;8063;8055;8054;7629;7381;6993;6988;6984;5517;5516;5515;4533;4532;
430	53	226	126	0	0	18.84269297	13.52727808	116.336824	39.80522466	17202.89941	90596;90595;90594;90593;90659;71686;71685;63725;63724;63723;63701;63700;43085;29877;9176;8402;6776;6317;
402	135	326	253	0.541417025	0	21.45893379	19.41836758	116.4299274	39.8034837	16655.34292	75178;75172;75171;72140;29377;9171;9170;9169;9371;9370;8055;8054;7628;5517;5516;5515;4535;4533;4532;4531;
403	84	120	136	0.683408345	0	21.70512991	16.16784825	116.4356133	39.80305621	11035.75088	91653;9178;9177;9175;9171;9170;9169;9371;9370;8054;7629;7628;7626;5517;5516;5515;4535;4533;4532;4528;
402	133	214	198	0	0	21.67997397	14.10921374	116.4331922	39.80217699	7292.128481	9177;9171;9170;9169;9371;9370;8066;8065;8055;8054;7629;7628;7626;5517;5516;5515;4535;4533;4531;4528;4454;
403	58	77	109	0.710873864	0	21.73514582	14.24028618	116.4358618	39.80207666	71508.64408	9171;9170;9169;9371;9370;8066;8065;8063;8055;8054;7629;7628;7626;5517;5516;5515;4535;4532;4531;4528;4454;
404	99	101	119	0.649413441	0	22.61917686	12.77734266	116.4548169	39.80271383	10584.41338	91666;91756;88206;9327;9326;9172;9372;8059;8058;8056;7625;7624;7623;7622;7621;5405;5404;
402	102	269	247	0	0	21.5941533	15.06051302	116.4311319	39.80285594	9729.894037	9171;9170;9169;9371;9370;8055;8054;7629;7628;7626;5517;5516;5515;4533;4532;4531;4528;
781	28	52	74	0	0	20.00828802	10.99141341	116.2685917	39.7878088	100152.7714	43834;43828;43827;43826;7397;6944;6791;6514;6357;6098;6097;5302;4667;4665;4664;4411;4410;6057;516;464;434;
405	91	127	128	0.873134461	0	23.38568193	11.35337456	116.4580262	39.79572877	14893.11015	9172;9372;8058;8056;7625;7624;6997;4661;
404	24	36	83	0.213289909	0	23.43687962	10.38663681	116.4591214	39.79633745	2382.369134	9172;8058;8056;7625;7624;4660;
443	52	106	67	0	0	22.16504831	5.124054501	116.273954	39.77525336	3763.512292	46769;43850;43848;43835;43834;6944;6943;6791;6357;6098;6097;4667;4665;4641;4411;6057;516;465;464;434;433;
443	43	94	57	0	0	22.06391821	4.625196579	116.2747669	39.77475559	13674.86862	43850;43848;43836;43835;43834;6944;6943;6791;6357;6098;6097;4667;4664;4641;4411;6057;516;465;464;434;433;

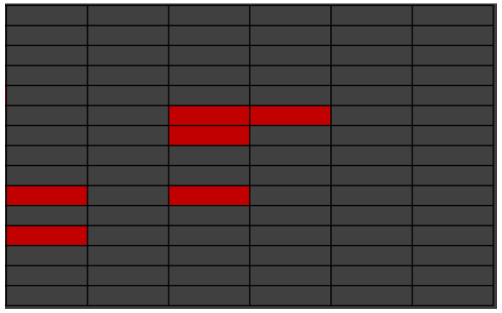
SPSS常用功能

- 数据处理
  - 计算字段
- 统计性描述
- 相关分析
  - 0.8
- 主成分分析（PCA）
- 回归分析
  - 回归前的自相关（autocorrelation）检查（VIF）
  - 二元/多元回归、线性/非线性回归
    - 部分数据的回归分析
    - 对数ln（如房价）
- 聚类分析
  - K-means

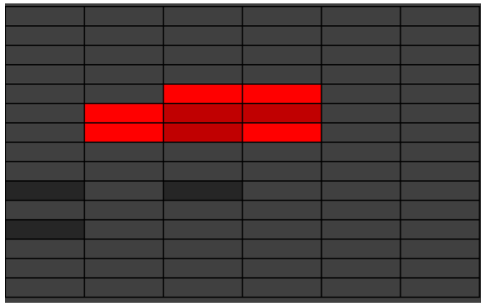
- 软件展示

基于规则建模 vs 元胞自动机

维度	基于规则建模	元胞自动机（CA）
理论基础	领域知识	复杂科学+领域知识 （约束性Ca模型需要考虑领域知识）
空间与否	非空间或空间模型	空间模型
时间动态	1-多个步骤 （可以不考虑时间过程）	多个步骤（iteration）
邻域 （空间单元之间的相互作用）	可以不考虑	一定要考虑
模型核心	规则（rules）	状态转换规则（transition rules）



开始时刻T_0

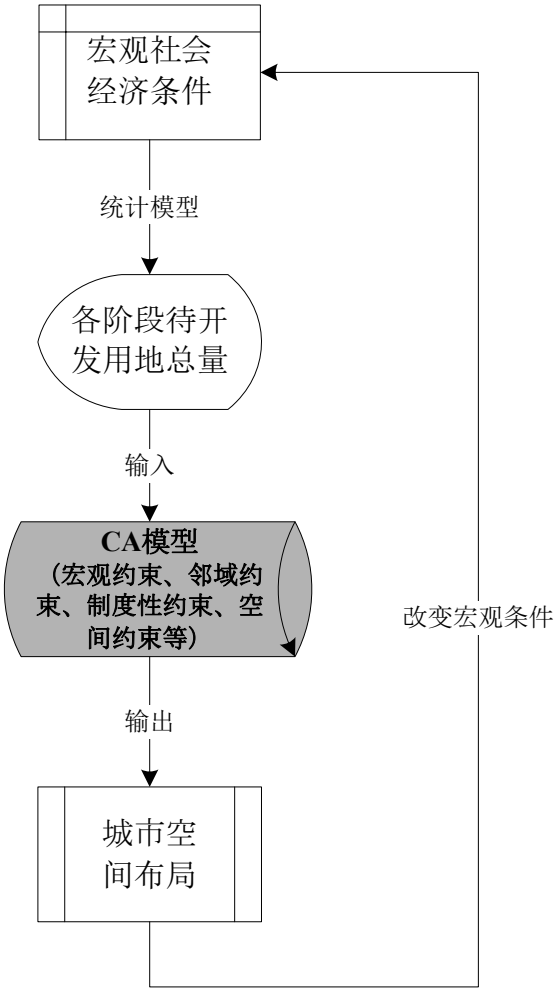


中间时刻T_1

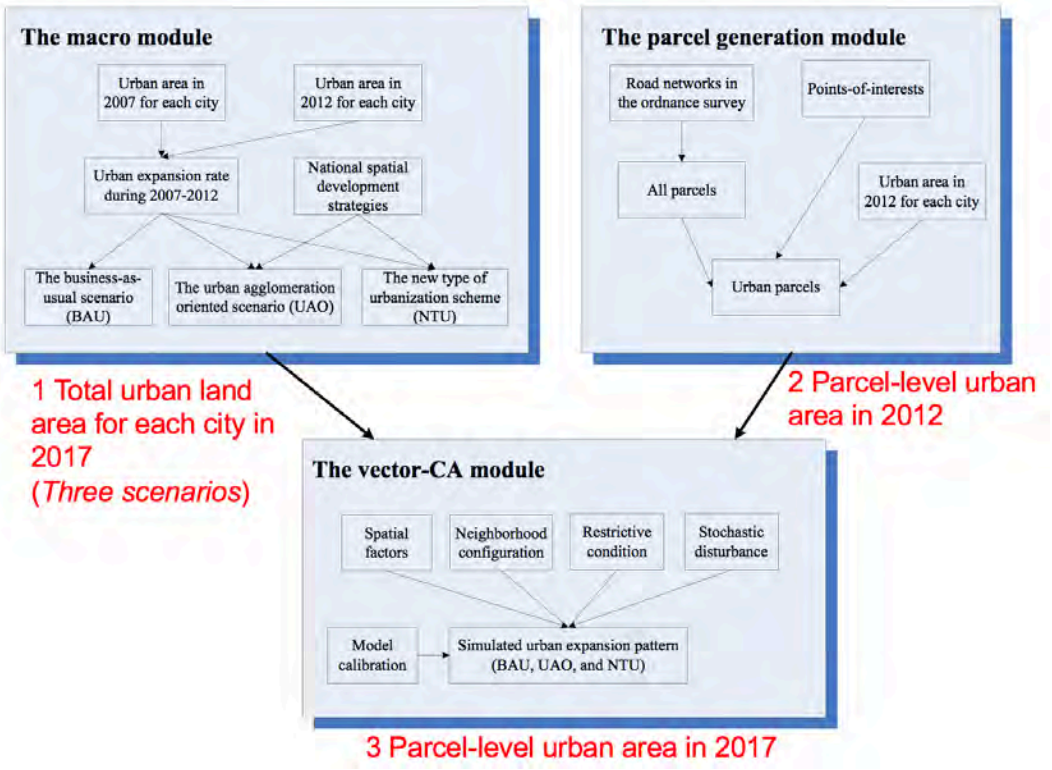
模拟终点时刻T_2 ？

- 请注意邻域的不同
- 基于规则建模（开始→终点）
- 元胞自动机（开始→中间→...中间→终点）
- 两个模型有交叉，不能说哪个包括哪个

宏观（自上而下）与微观（自下而上）模块的结合



BUDEM



MVP-CA

一、矢量元胞自动机

Vector Cellular Automata

矢量元胞自动机城市模型

- **Grid CA extensively applied for simulating urban expansion/growth**
  - Batty, Clarke, Engelen, Li, White, Wu, Xie, Yeh
- **Simulation results of grid CA sensitive to grid resolution and neighbourhood configuration**
  - Jenerette and Wu (2001), Chen and Mynett (2003), Jantz and Goetz (2005), Ménard and Marceau (2005)
- **Irregular CA, more representative to the real world**
  - Or vector-CA
  - Geographical entities (e.g. parcels, with Shi and Pang 2000 as an exception using Voronoi polygon) replace grids

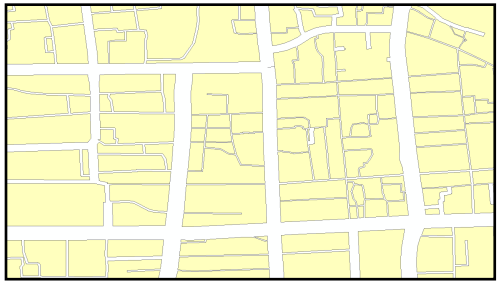
Why parcel/block?

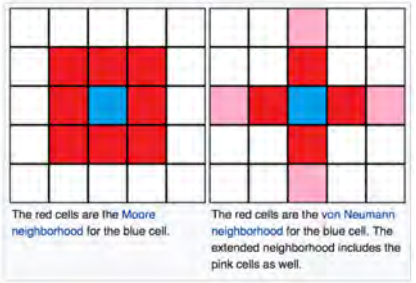
It is worth noting that the term PARCEL 地块 in this study, having no relationship with ownership, corresponds to a BLOCK in western world.

- **Raster CA models sensitive with the grid size**
- **Urban planning and management**
  - **Spatial plans, zoning, building permits**
- **Urban studies**
  - **Urban form and its impact (travel behavior, energy consumption, health, quality-of-life, etc.)**

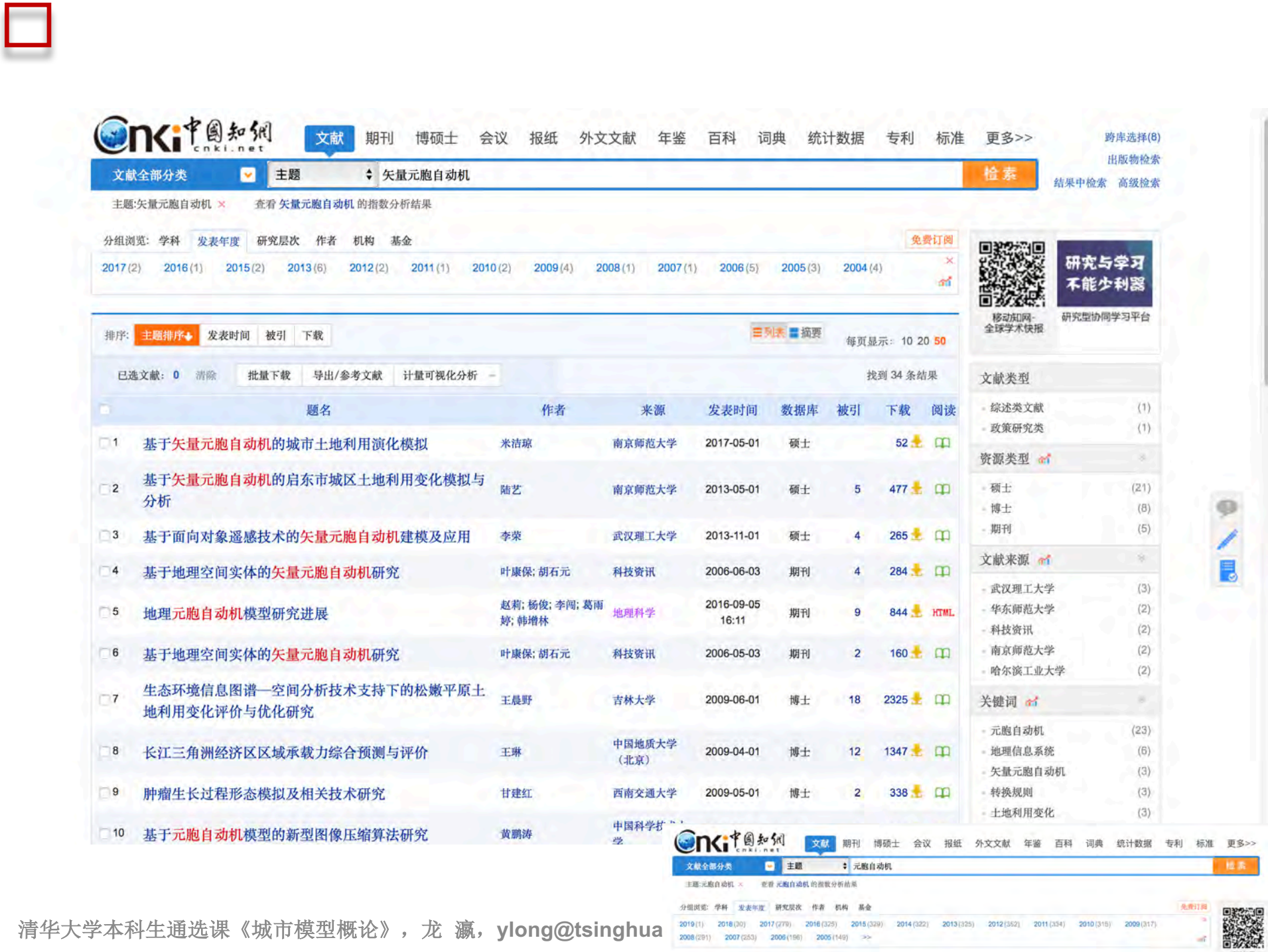
矢量元胞自动机 vs 栅格元胞自动机

	矢量元胞自动机	栅格元胞自动机
元胞（cell）	非规则多边形	网格
邻域类型	一定距离内的元胞	Moore或者von Neumann
计算速度	相对较慢	较快
已有研究	日益增多	丰富
体现真实世界程度	更好	一般
基础数据和指标准备要求	较高	一般





- 栅格元胞自动机的研究已经基本比较成熟（大量的已有文献）
- 研究单元的演变：网格→非规则多边形
  - 泰森多边形（Voronoi polygons）
  - 地块/街区
- 模拟对象的演变：城市扩张→土地使用类型变化→密度模拟等


文献 期刊 博硕士 会议 报纸 外文文献 年鉴 百科 词典 统计数据 专利 标准 更多>>
跨库选择(8)
出版物检索
结果中检索 高级检索
文献全部分类
主题
矢量元胞自动机
检索
主题:矢量元胞自动机
查看 矢量元胞自动机 的指数分析结果
分组浏览: 学科 发表年度 研究层次 作者 机构 基金
免费订阅
2017 (2) 2016 (1) 2015 (2) 2013 (6) 2012 (2) 2011 (1) 2010 (2) 2009 (4) 2008 (1) 2007 (1) 2006 (5) 2005 (3) 2004 (4)
移动知网-全球学术快报
研究与学习不能少利器
研究型协同学习平台
排序: 主题排序 发表时间 被引 下载
列表 摘要
每页显示: 10 20 50
已选文献: 0 清除
批量下载 导出/参考文献 计量可视化分析
找到 34 条结果
题名 作者 来源 发表时间 数据库 被引 下载 阅读
1 基于矢量元胞自动机的城市土地利用演化模拟 米洁琼 南京师范大学 2017-05-01 硕士 52
2 基于矢量元胞自动机的启东市城区土地利用变化模拟与分析 陆艺 南京师范大学 2013-05-01 硕士 5 477
3 基于面向对象遥感技术的矢量元胞自动机建模及应用 李荣 武汉理工大学 2013-11-01 硕士 4 265
4 基于地理空间实体的矢量元胞自动机研究 叶康保; 胡石元 科技资讯 2006-06-03 期刊 4 284
5 地理元胞自动机模型研究进展 赵莉; 杨俊; 李闯; 葛雨婷; 韩增林 地理科学 2016-09-05 16:11 期刊 9 844 HTML
6 基于地理空间实体的矢量元胞自动机研究 叶康保; 胡石元 科技资讯 2006-05-03 期刊 2 160
7 生态环境信息图谱—空间分析技术支持下的松嫩平原土地利用变化评价与优化研究 王晨野 吉林大学 2009-06-01 博士 18 2325
8 长江三角洲经济区区域承载力综合预测与评价 王琳 中国地质大学(北京) 2009-04-01 博士 12 1347
9 肿瘤生长过程形态模拟及相关技术研究 甘建红 西南交通大学 2009-05-01 博士 2 338
10 基于元胞自动机模型的新型图像压缩算法研究 黄鹏涛
文献类型
综述类文献 (1)
政策研究类 (1)
资源类型
硕士 (21)
博士 (8)
期刊 (5)
文献来源
武汉理工大学 (3)
华东师范大学 (2)
科技资讯 (2)
南京师范大学 (2)
哈尔滨工业大学 (2)
关键词
元胞自动机 (23)
地理信息系统 (6)
矢量元胞自动机 (3)
转换规则 (3)
土地利用变化 (3)

Google Scholar

vector cellular automata

Articles

About 52,400 results (0.05 sec)

Any time
Since 2018
Since 2017
Since 2014
Custom range...

Sort by relevance
Sort by date

include patents
include citations

Create alert

Cellular automata for simulating land use changes based on support **vector** machines [PDF] geosimulation.cn
Q Yang, X Li, X Shi - Computers & geosciences, 2008 - Elsevier
Abstract **Cellular automata** (CA) have been increasingly used to simulate urban sprawl and land use dynamics. A major issue in CA is defining appropriate transition rules based on training data. Linear boundaries have been widely used to define the rules. However, urban …
☆ 99 Cited by 186 Related articles All 7 versions

[BOOK] The nonlinear workbook: Chaos, fractals, **cellular automata**, genetic algorithms, gene expression programming, support **vector** machine, wavelets, hidden …
WH Steeb - 2014 - books.google.com
The Nonlinear Workbook provides a comprehensive treatment of all the techniques in nonlinear dynamics together with C++, Java and SymbolicC++ implementations. The book not only covers the theoretical aspects of the topics but also provides the practical tools. To …
☆ 99 Cited by 200 Related articles All 13 versions »

Vector space theoretic analysis of additive **cellular automata** and its application for pseudoexhaustive test pattern generation
AK Das, PP Chaudhuri - IEEE Transactions on Computers, 1993 - ieeexplore.ieee.org
A novel scheme for utilizing the regular structure of three neighborhood additive **cellular automata** (CAs) for pseudoexhaustive test pattern generation is introduced. The **vector** space generated by a CA can be decomposed into several cyclic subspaces. A cycle …
☆ 99 Cited by 122 Related articles All 5 versions

[PDF] **Vector cellular automata** based geographical entity [PDF] hig.se
H Shiyuan, L Deren - Geoinformatics, 2004 - fromto.hig.se
Abstract **Cellular automata** (CA) are simple mathematical systems that exhibit very complicated behaviour. The integration of GIS and CA shows tremendous capability in simulating spatio-temporal dynamic process in geography world. But standard CA has some …
☆ 99 Cited by 27 Related articles

[BOOK] Lattice-gas **cellular automata** and lattice Boltzmann models: an introduction [PDF] awi.de
DA Wolf-Gladrow - 2004 - books.google.com
… Velocity and thereby also momentum can be assigned to each particle by the **vector** connecting the node to its next neighbor node along the link … These **vectors** are called lattice velocities … 1.3 The basic idea of lattice-gas **cellular automata** and lattice Boltzmann models 11 1.3 …
☆ 99 Cited by 1576 Related articles All 20 versions »

清

矢量元胞自动机城市模型已有研究

O'Sullivan 2001 EPB & GA (Graph-CA)

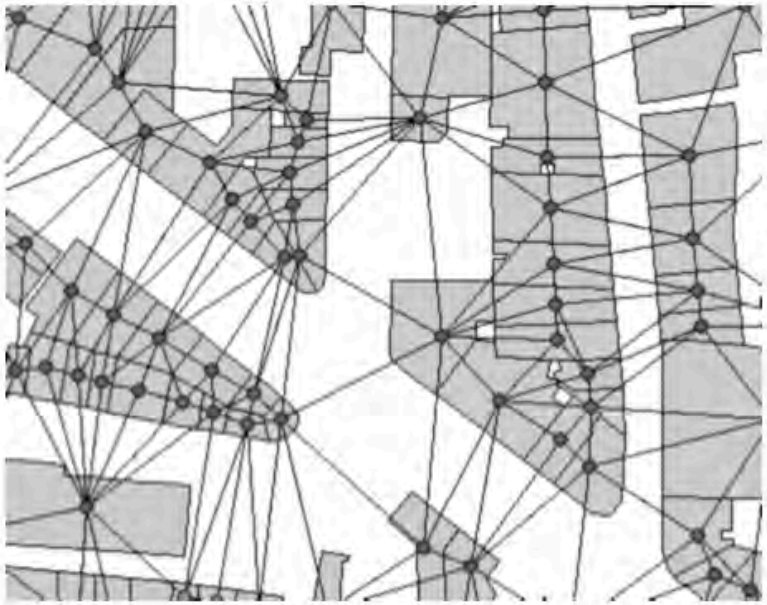


Figure 1. A portion of a graph-CA model. 'Cells' in this model are individual buildings and the graph structure shown represents cell neighbourhoods which are used to determine the evolution of particular cell states.

- **Combined CA and graph theory to generate sets of neighbourhood-scale irregular cells.**

矢量元胞自动机城市模型已有研究

Torrence and Benenson 2005 EPB
(Geographic automata systems, GAS)

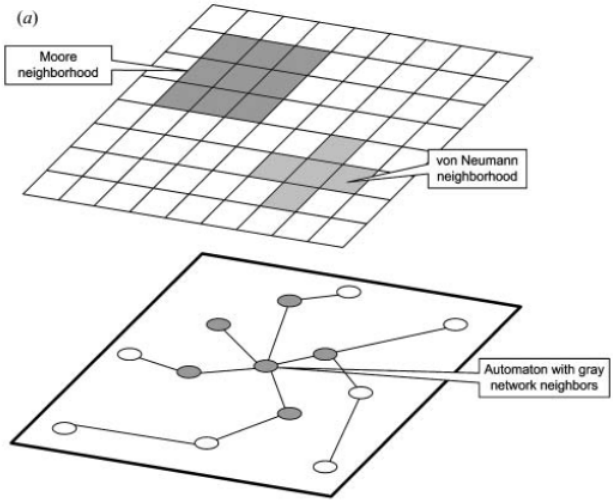


Figure 1. (*a*) Grid and network neighborhoods. (*b*) Voronoi neighborhood (gray), based on property coverage.

- **Proposed the geographic automata system (GAS) that combined characteristics of both CA and multi-agent models, which incorporated irregular vector objects as automata to represent real-world entities such as roads, buildings and parks.**

矢量元胞自动机城市模型已有研究

Stevens and Dragićević 2007 EPB (iCity)
Stevens et al. 2007 CEUS

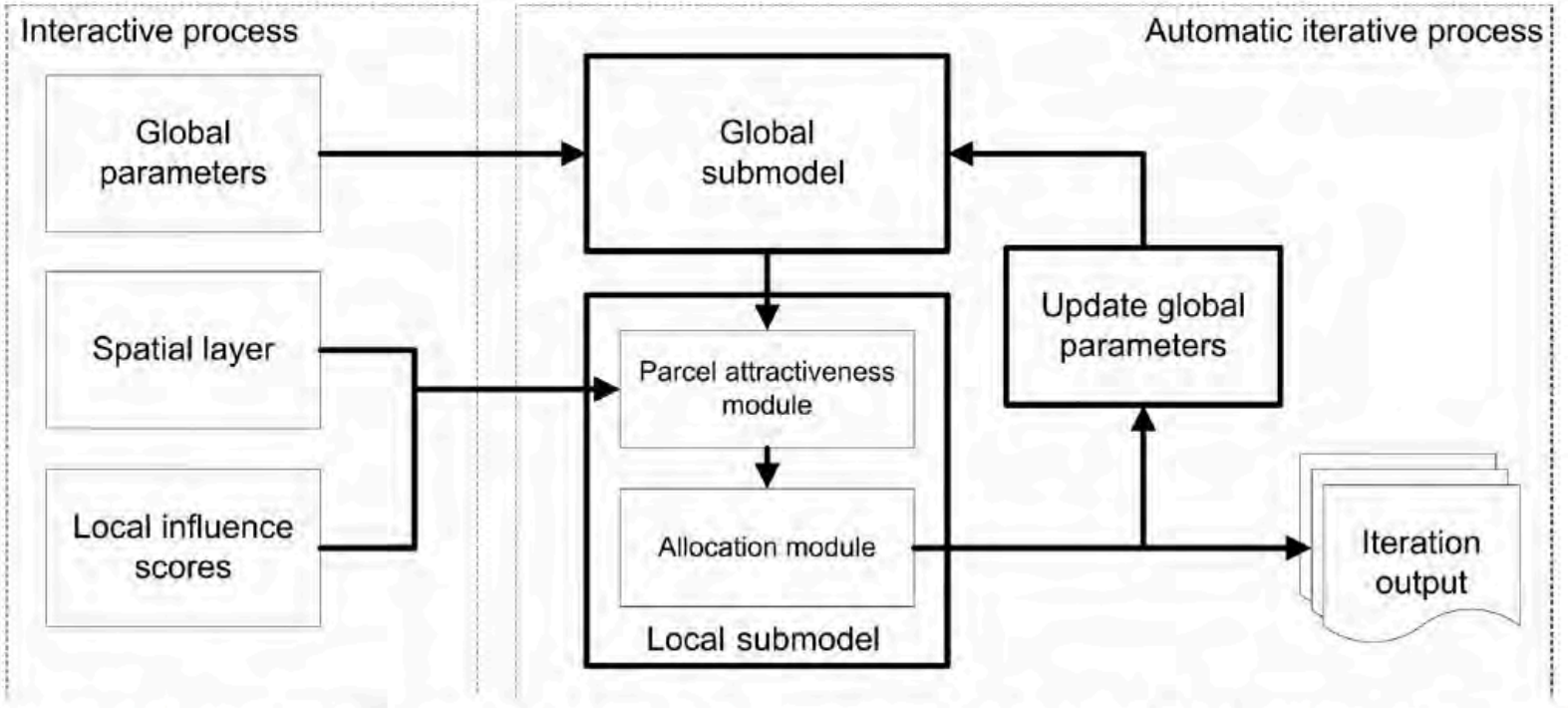


Figure 1. Flow chart of the model, showing the inputs (on the left) and the iterative process and output (on the right).

- **An urban area was partitioned into discrete land use units based on cadastral information and represented as a collection of polygons.**

矢量元胞自动机城市模型已有研究

Moreno et al 2008 EPB and 2009 CEUS (VecVGA)

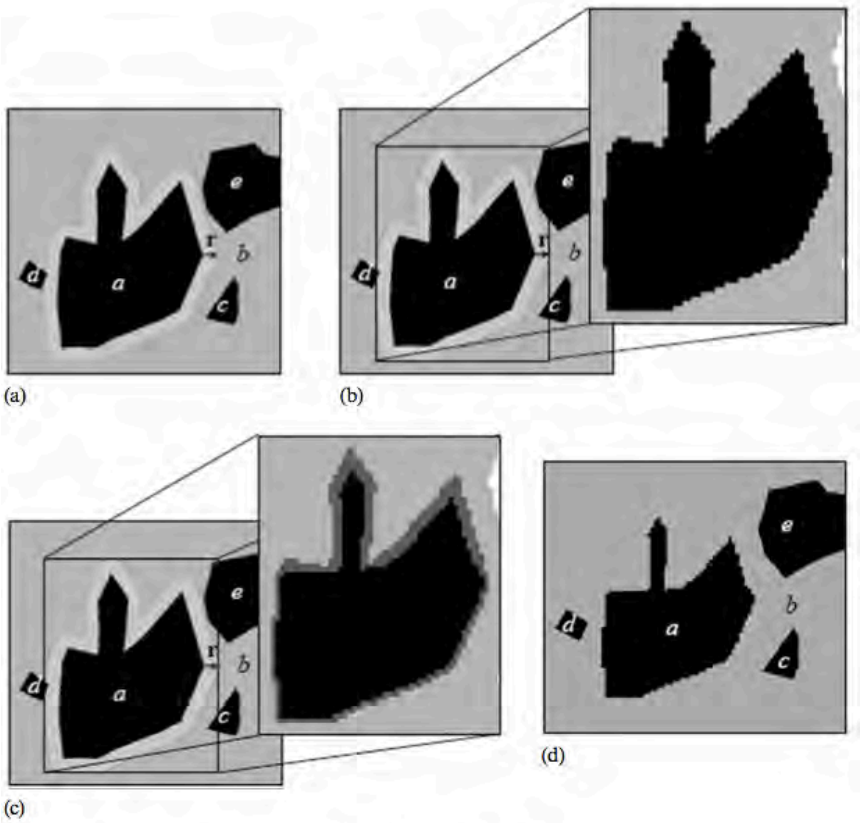


Figure 2. Procedure of geometric transformation of polygons.

- A vector-based geographic cellular automata model allowing geometric transformations of objects using a rasterized approach.
- The shape and size of each object can also change and a dynamic neighbourhood was semantically implemented.

矢量元胞自动机城市模型已有研究

Shen et al 2009 EPB

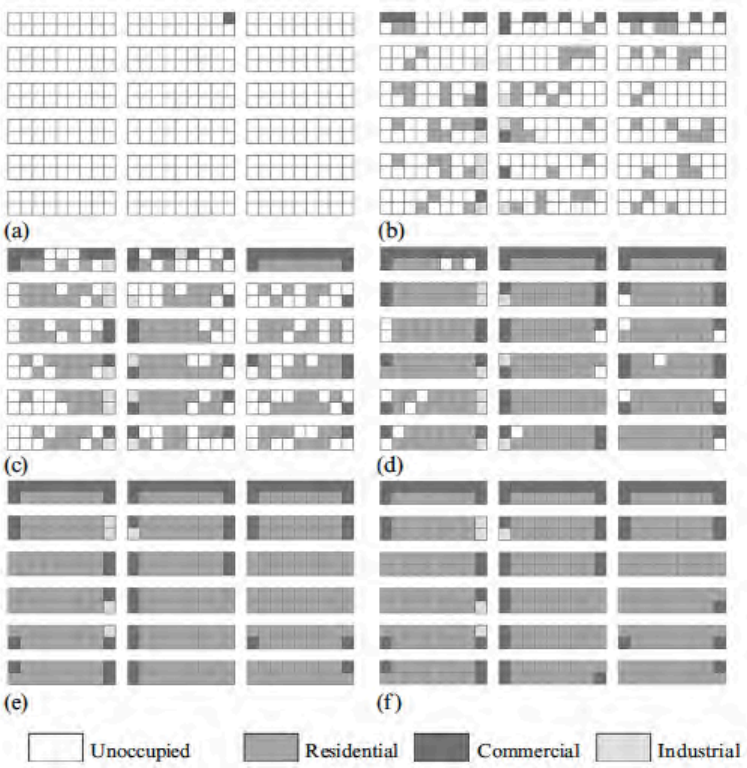
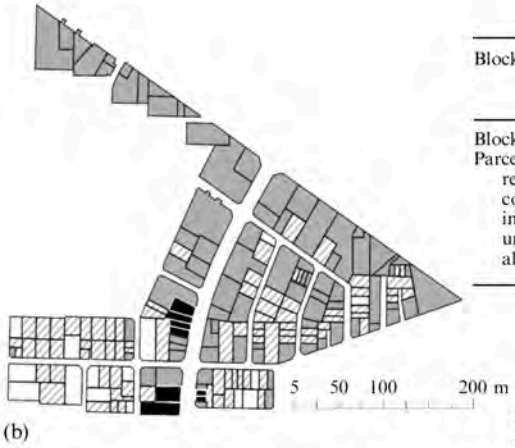


Figure 11. [In colour online.] Spatial distribution of occupied parcels during simulation steps 20, 40, 50, 60, 80, and 100 shown in (a), (b), (c), (d), (e), and (f), respectively. A simulation step is two months.



Blocks/parcels		Front road	
		main street	collector street
Block	14	4	5
Parcels			
residential	83	0	0
commercial	82	25	19
industrial	8	0	8
unoccupied	15	0	0
all parcels	188	25	27

Figure 16. Comparison of spatial patterns between (a) real space and (b) simulated quasi-industrial districts.

- **A geo-simulation model using the vector-based CA to visualise land use patterns in urban partitions (R/C/I)**
- **Tested in both a virtual city and Kanazawa City.**

矢量元胞自动机城市模型已有研究

Pinto and Antunes 2010 EPB

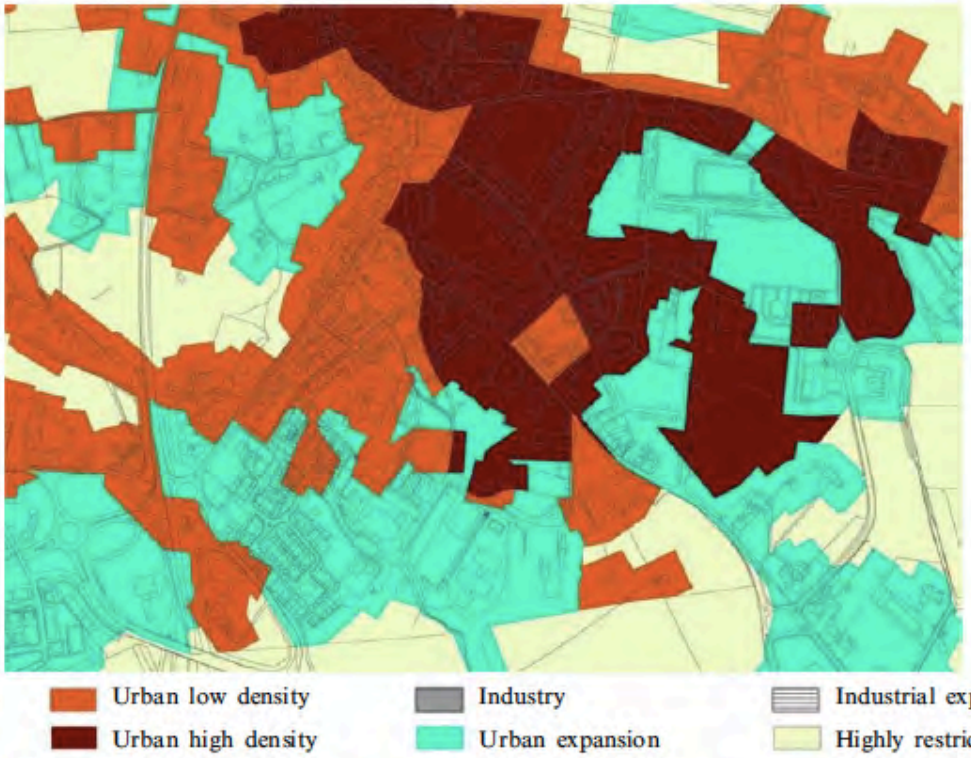
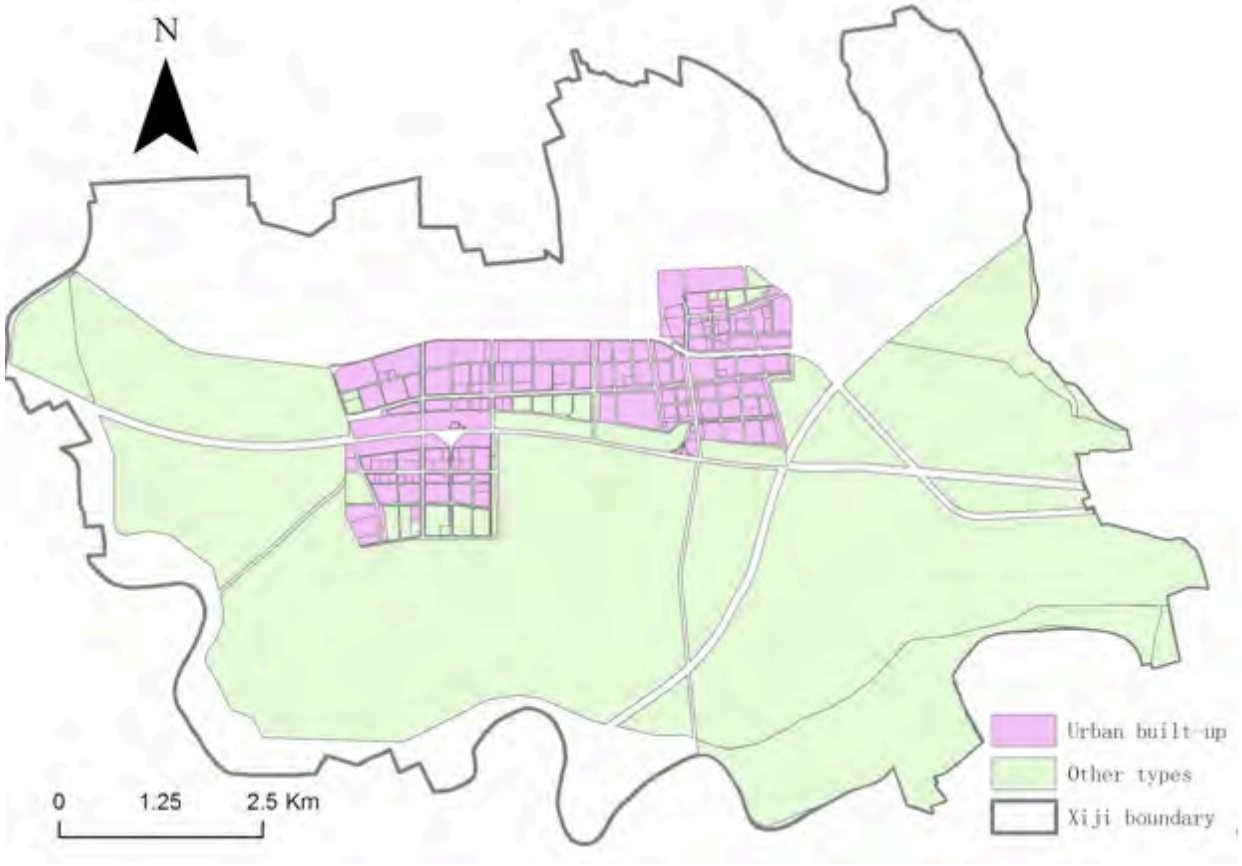


Figure 3. [In colour online.] Irregular land-use cells in the centre of Condeixa-a-Nova, Portugal.

- Developed a well-calibrated irregular CA based on census blocks to determine the land use demand by considering the evolution of population and employment densities over time.
- Both land use type and density accounted

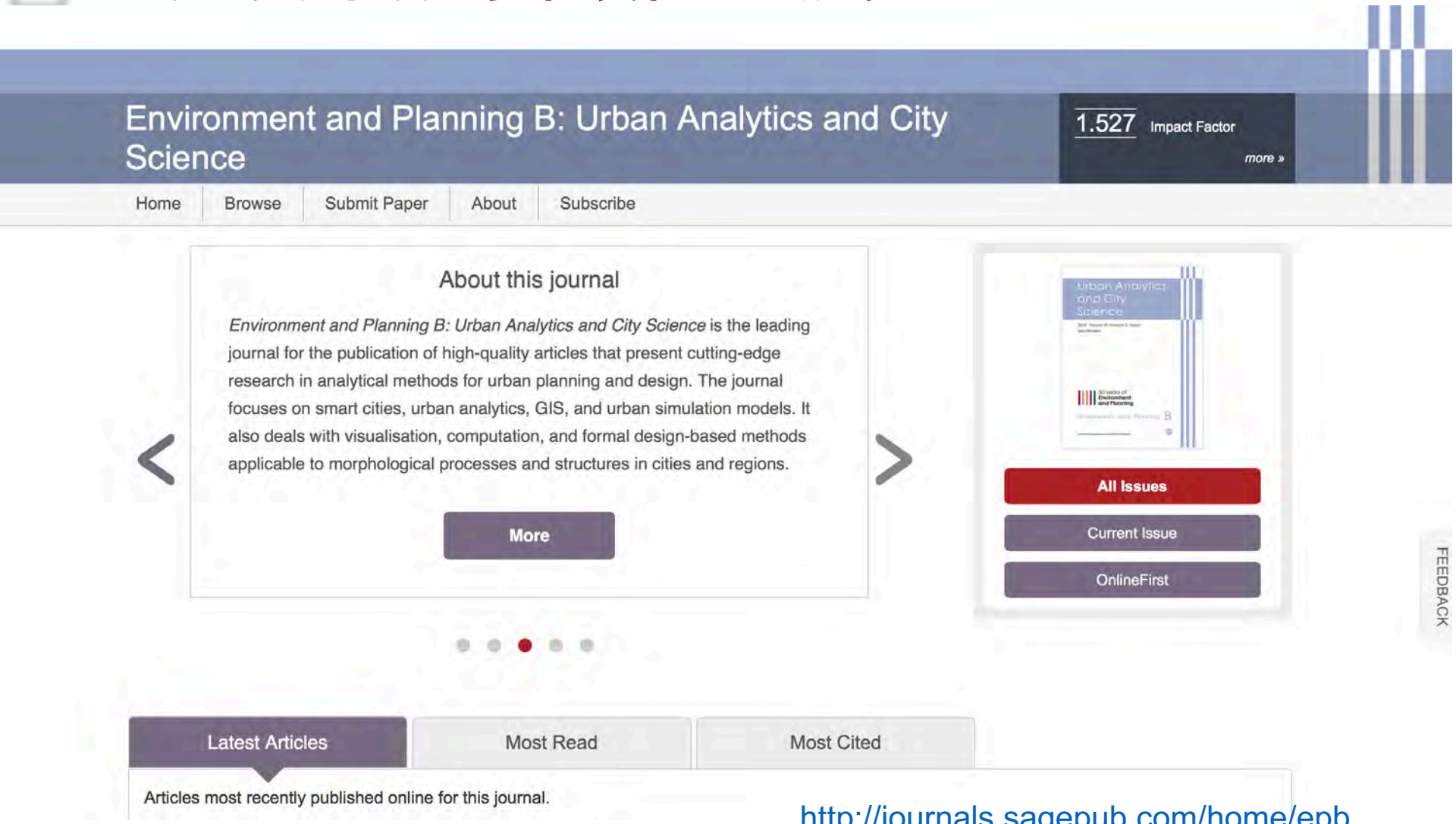
矢量元胞自动机城市模型已有研究

Zhang and Long 2013 SPSD (V-BUDEM)



- The updated version of grid-CA based BUDEM (urban/non-urban)
- Applied in a town of Beijing and will expand to the whole Beijing Metropolitan Area (BMA).

经典的城市模型多首发在EPB期刊上



http://journals.sagepub.com/home/epb

- 2017年更改了期刊副标题
  - 原来：Planning and Design
  - 现在：Urban Analytics and City Science

CEUS也是发表城市模型文章的主要刊物

ISSN: 0198-9715

Submit Your Paper

View Articles

Guide for Authors

Abstracting/ Indexing

Track Your Paper

Order Journal

Sample Issue

Journal Metrics

SEARCH MENU

Computers, Environment and Urban Systems

> Supports Open Access

Editor-in-Chief: T. H. Grubesic

> View Editorial Board

See also Elsevier's Geography, Planning and Development portal

Computers, Environment and Urban Systems is an interdisciplinary journal publishing cutting-edge and innovative **computer-based research** on **urban systems, systems of cities, and built and natural environments**, that privileges the **geospatial** perspective. The journal provides a stimulating presentation...

Read more

Most Downloaded | Recent Articles | Most Cited | Open Access Articles

Electricity consumption and household characteristics: Implications for census-taking in a smart metered future Ben Anderson | Sharon Lin | ...

Integrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure Jing Ran | Zorica Nedovic-Budic

Utilizing Cloud Computing to address big geospatial data challenges Chaowei Yang | Manzhu Yu | ...

> View All Most Downloaded Articles

- https://www.journals.elsevier.com/computers-environment-and-urban-systems

二、基于矢量元胞自动机模型的中国城市扩张模拟

Simulating urban expansion at the parcel level for all Chinese cities

Research background

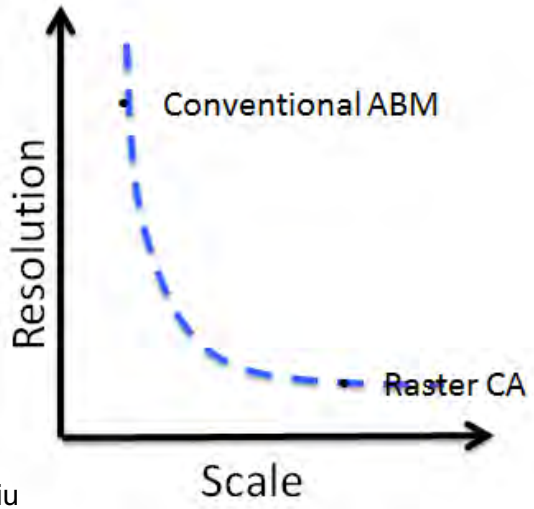
- Booming urban expansion in China
  - 46,751 km^2 (annual expansion rate 5.2% 2007-2012)
- Urban expansion simulation models developed for supporting decision making

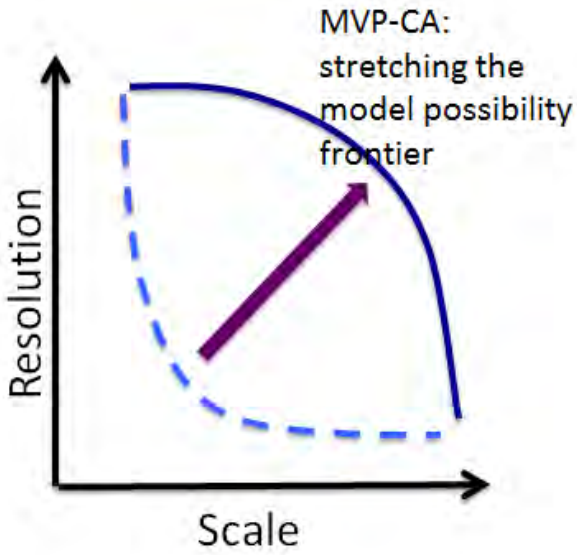
  1 City or district level models
  - Almost all for big cities, e.g. Beijing, Shanghai, Guangzhou, Hangzhou, using grid cellular automata (CA) models
    - V-BUDEM for Beijing using vector CA (see the poster of Zhang and Long)

  2 Regional or national models
  - Pearl River Delta, Beijing-Tianjin-Tangshan, Northern China
  - Associated with low spatial resolution e.g. several km^2, a county

Research question

- **Can we develop an urban expansion model for a super large geographical extent (e.g. the whole China), at a fine scale (e.g. parcel/block), for a short or mid term (e.g. five years)?**





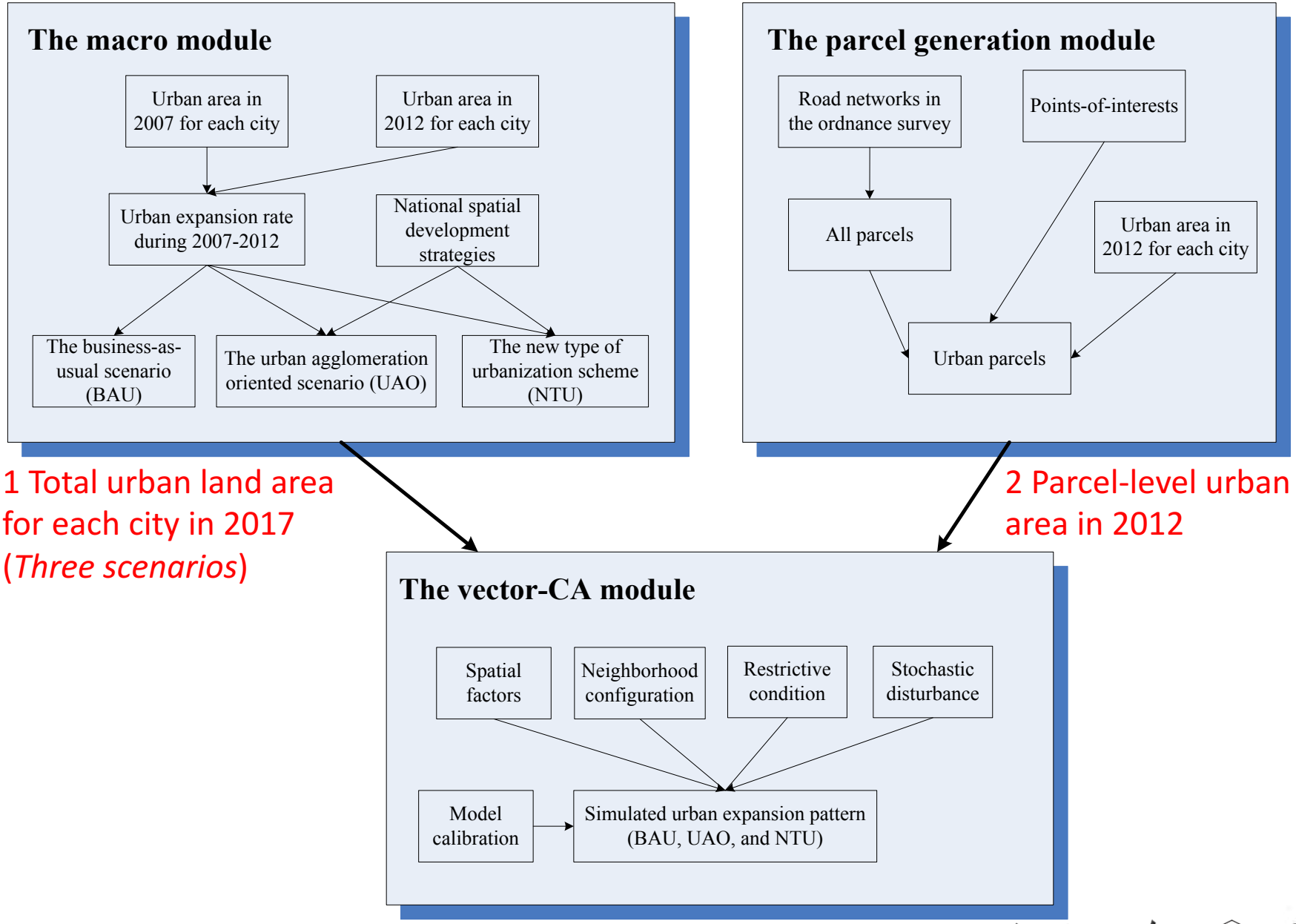
Courtesy of Dr. Xingjian Liu

- **Every city, big or small, would have an urban expansion model in China**
- **To inform decision makers, developers, planners and local residents our simulation results**

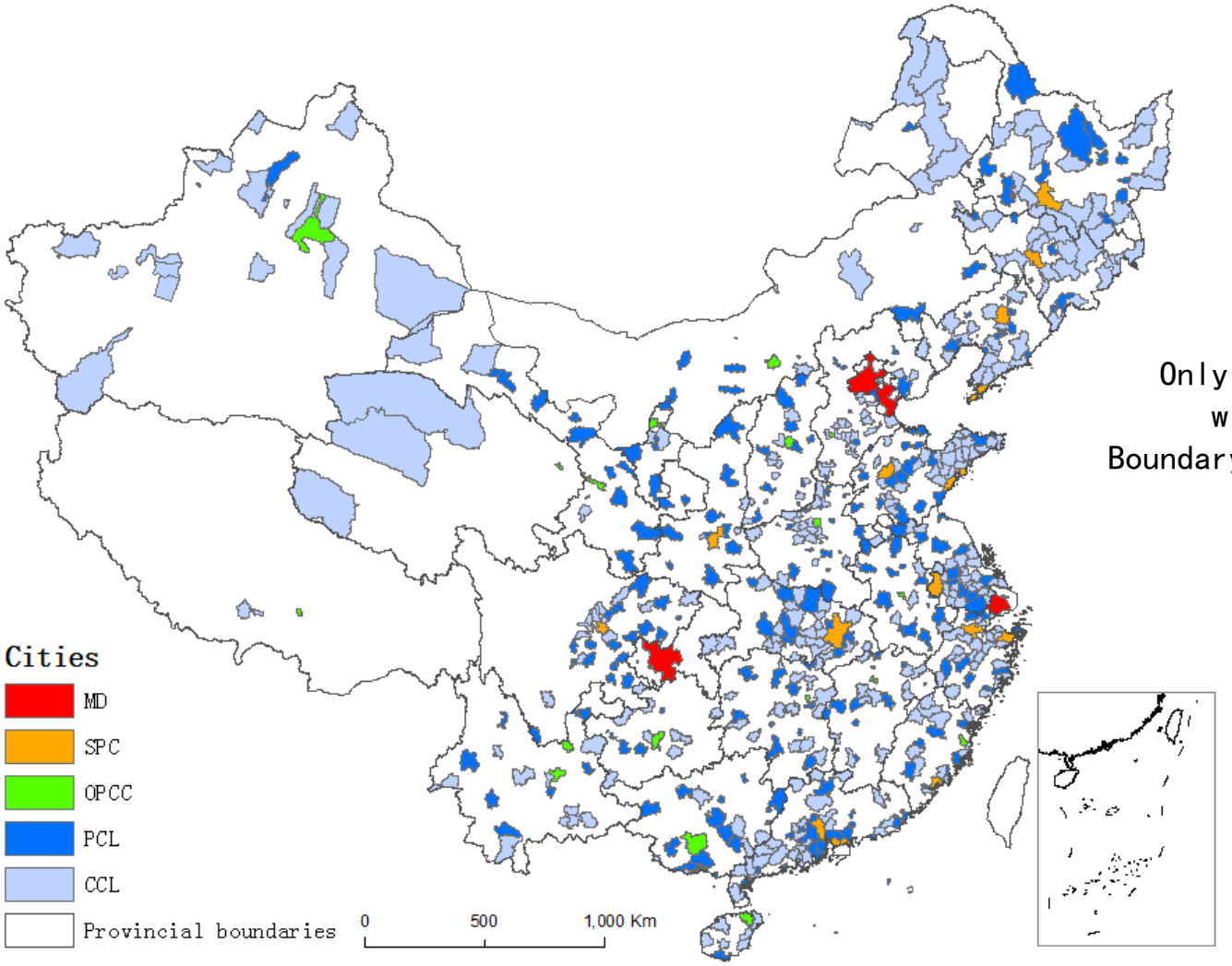
This study will

- Extend the existing framework of AICP by replacing OSM road network by the ordnance survey roads
  - To generate 2012 parcels for all Chinese cities (297→655)
- Develop a maga-vector-parcels cellular automata model (MVP-CA) for simulating urban expansion of China
  - 2012-2017
  - 654 cities

The structure and flow diagram of MVP-CA



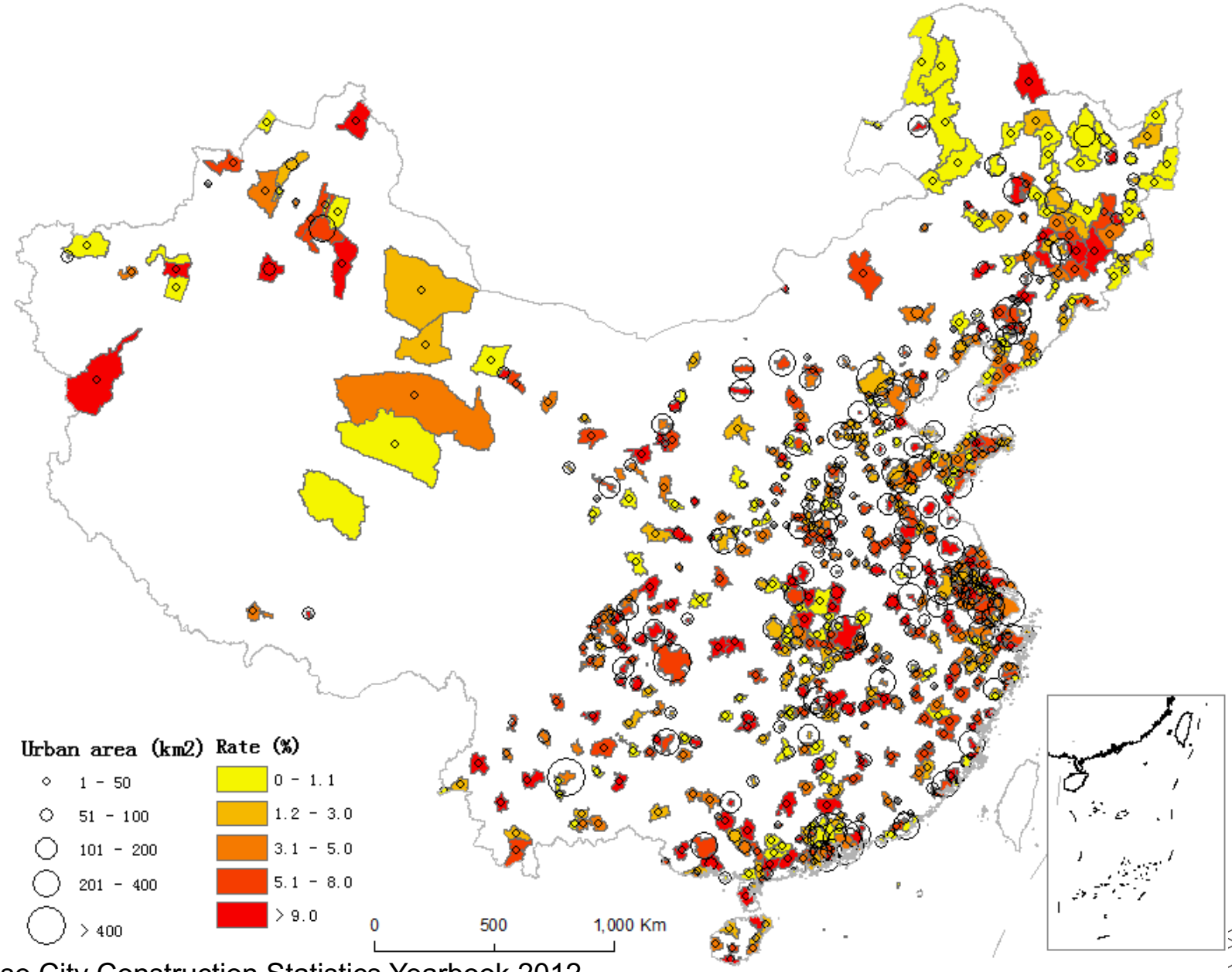
Administrative boundaries of 654 Chinese cities



Only a portion land within each city Boundary is developed.

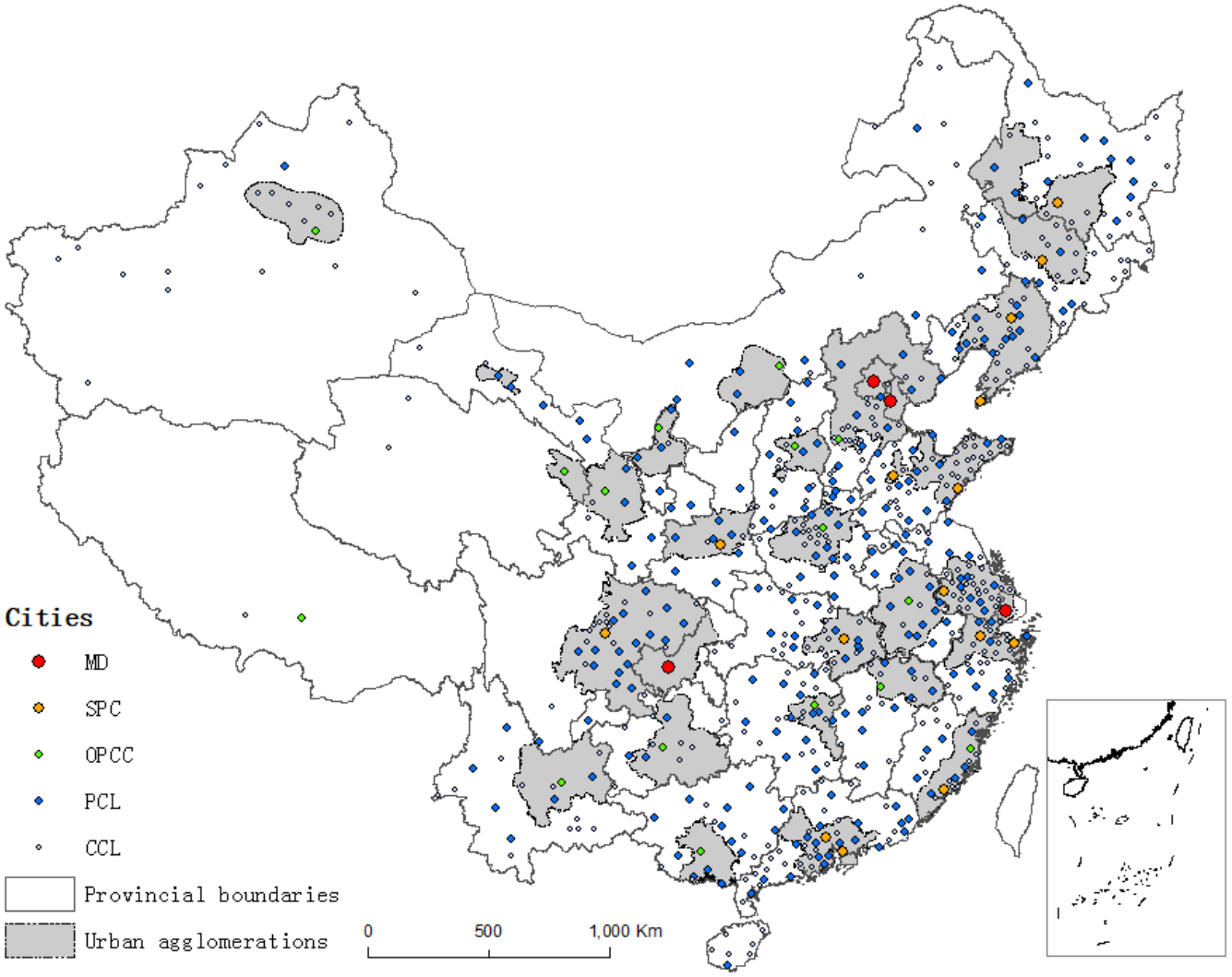
- **Five levels of cities in China:**
  - **municipalities directly under the Central Government (MD, 4 cities), sub-provincial cities (SPC, 15), other provincial capital cities (OPCC, 17), prefecture-level cities (PLC, 250), and county-level cities (CLC, 368)**

City size of each city in terms of total urban area in 2012 and the urban expansion rate during 2007-2012



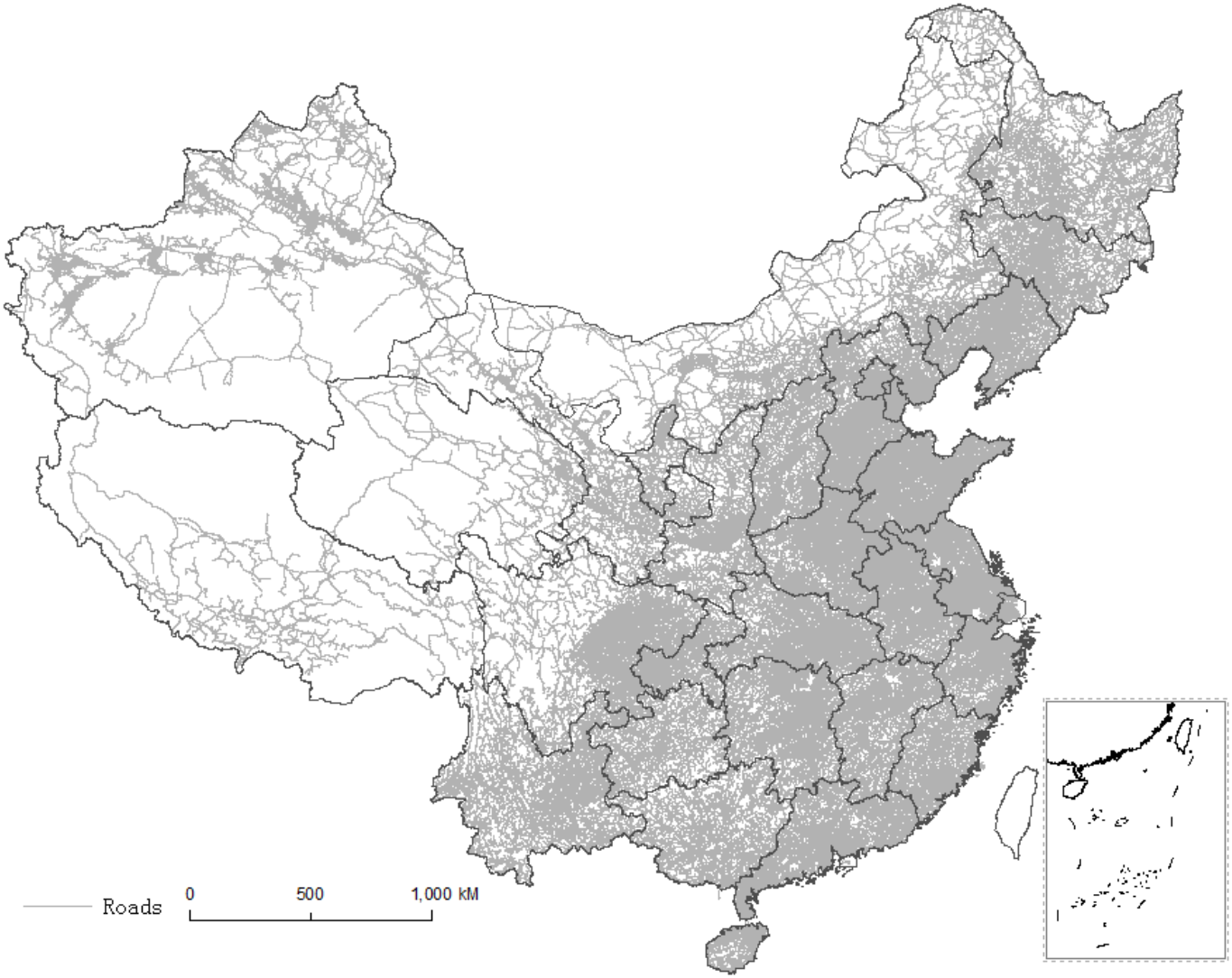
Chinese City Construction Statistics Yearbook 2012

Urban agglomerations (city regions) of China (23)



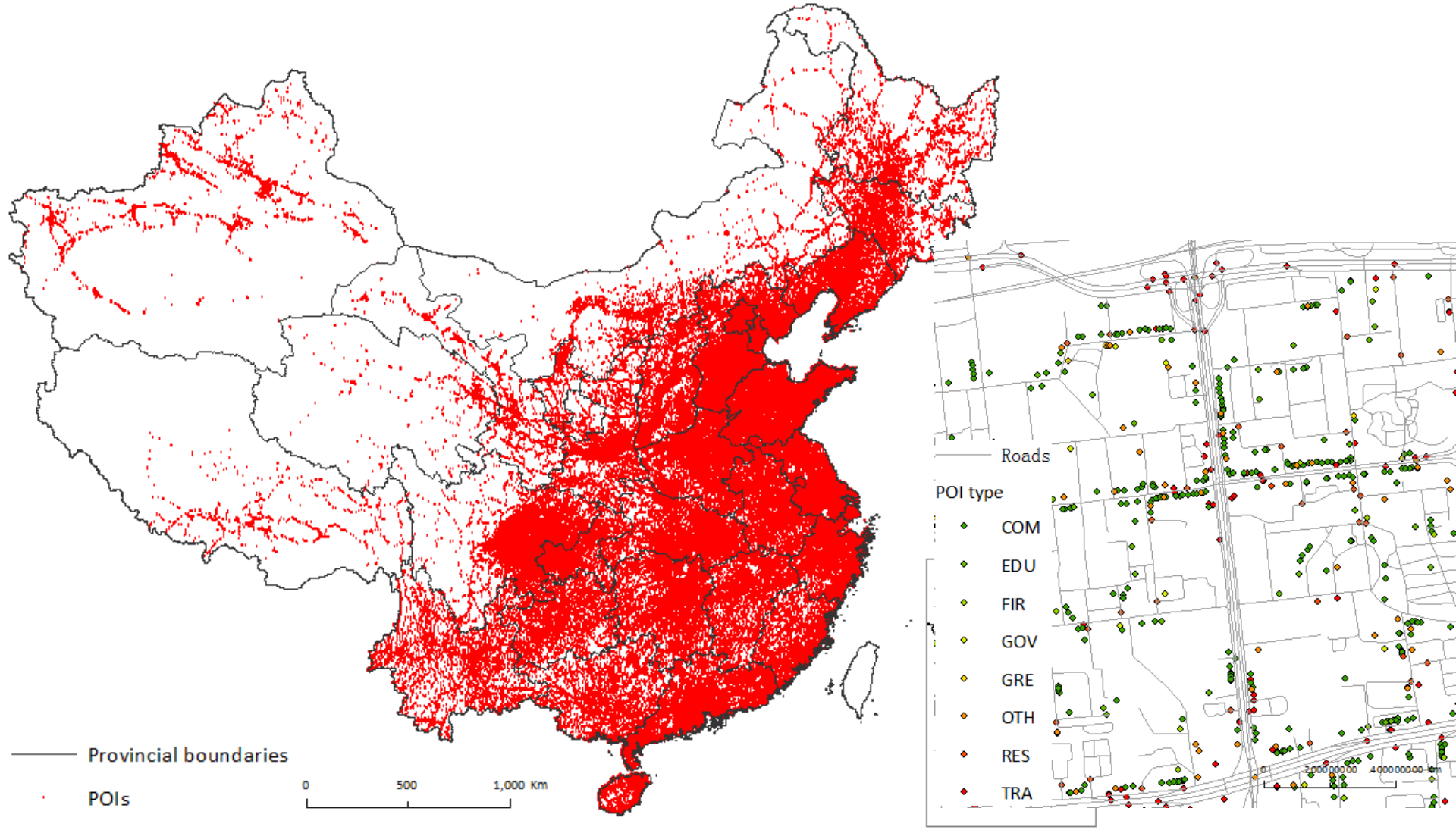
- **Urban agglomerations in China are highlighted in the future urbanization in China (Wu et al, 2013)**
- **For setting simulation scenario**

Ordnance roads of China in 2012



- **6.03 million road segments of 2.62 million kilometers**

Points-of-interest in 2012



- **Five million POIs gathered from and geocoded by business cataloging websites**
  - **9 categories, including commercial, transport, government, education, residence, green space, etc**

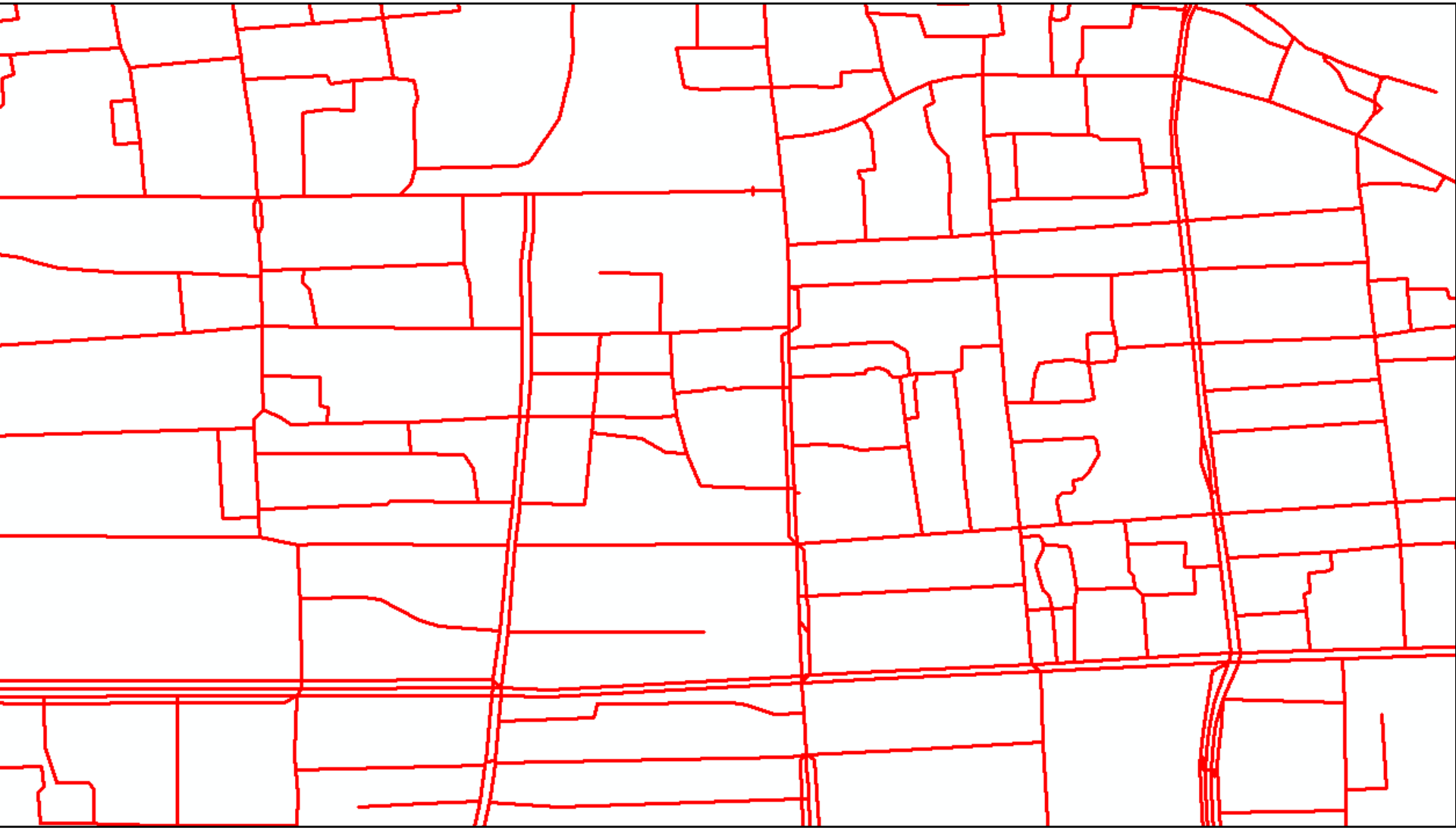
1 The macro module:

Three scenarios on city-level urban area totals in 2017

1. Business-as-usual (BAU):
   - Each city replicates its urban expansion rate during 2007-2012 (5.2% for the whole China)
2. Urban agglomeration oriented (UAO)
   - 355 cities in UAs: 5%
   - Other cities: 4%
3. New urbanization planning (NUP)
   - The larger a city is, the lower its expansion rate would be in the next five years
     - Urban area > 400 km^2 in 2012, 3.0%
     - Urban area 200-400 km^2, 4.0%
     - Urban area 100-200 km^2, 5.0%
     - Urban area < 100 km^2, 6.0%.
   - This scenario is to be updated according to the new urbanization plan of China announced on March 16th, 2014

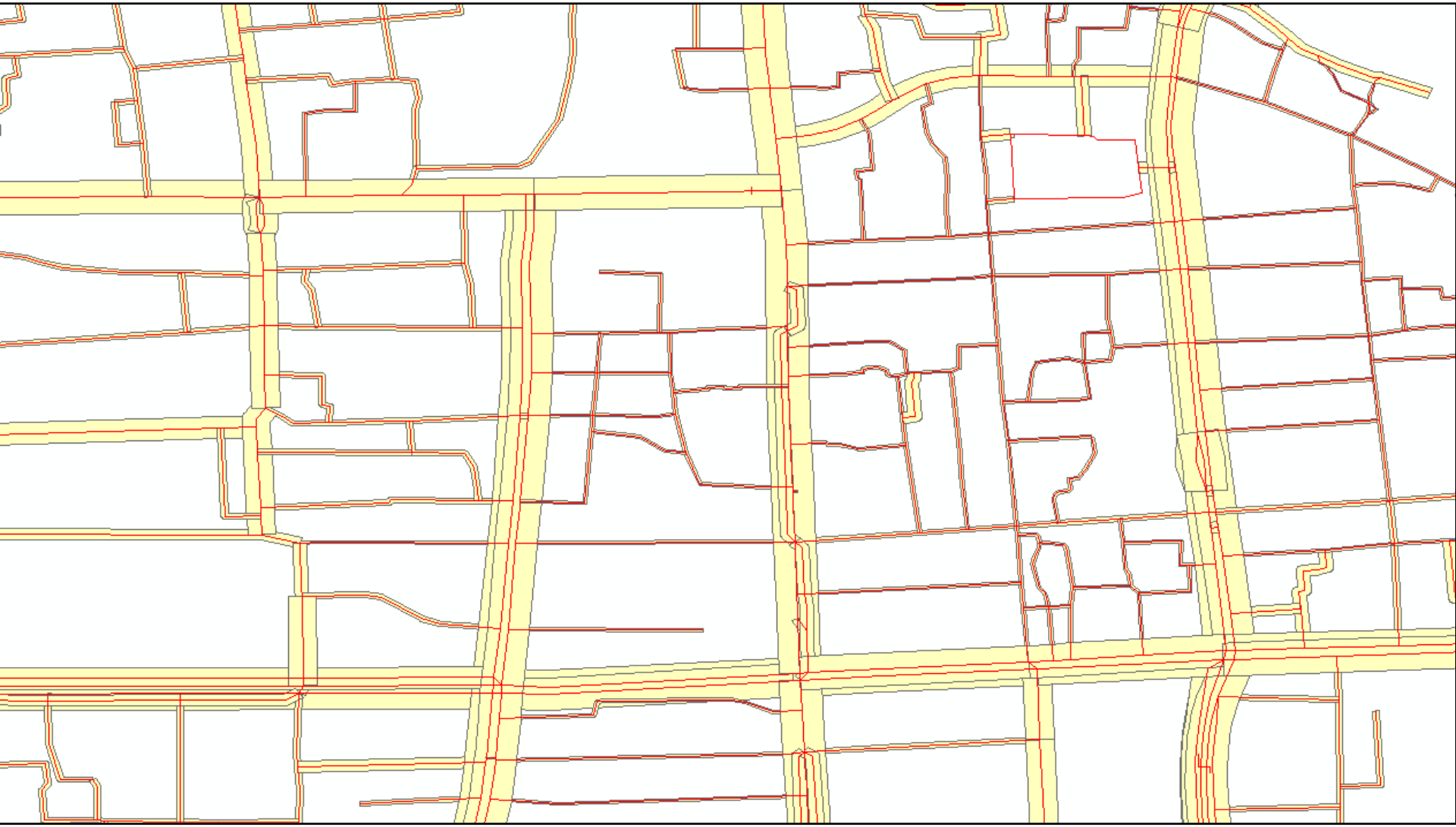
2 The parcel generation module (AICP):

(1) delineating parcel boundaries



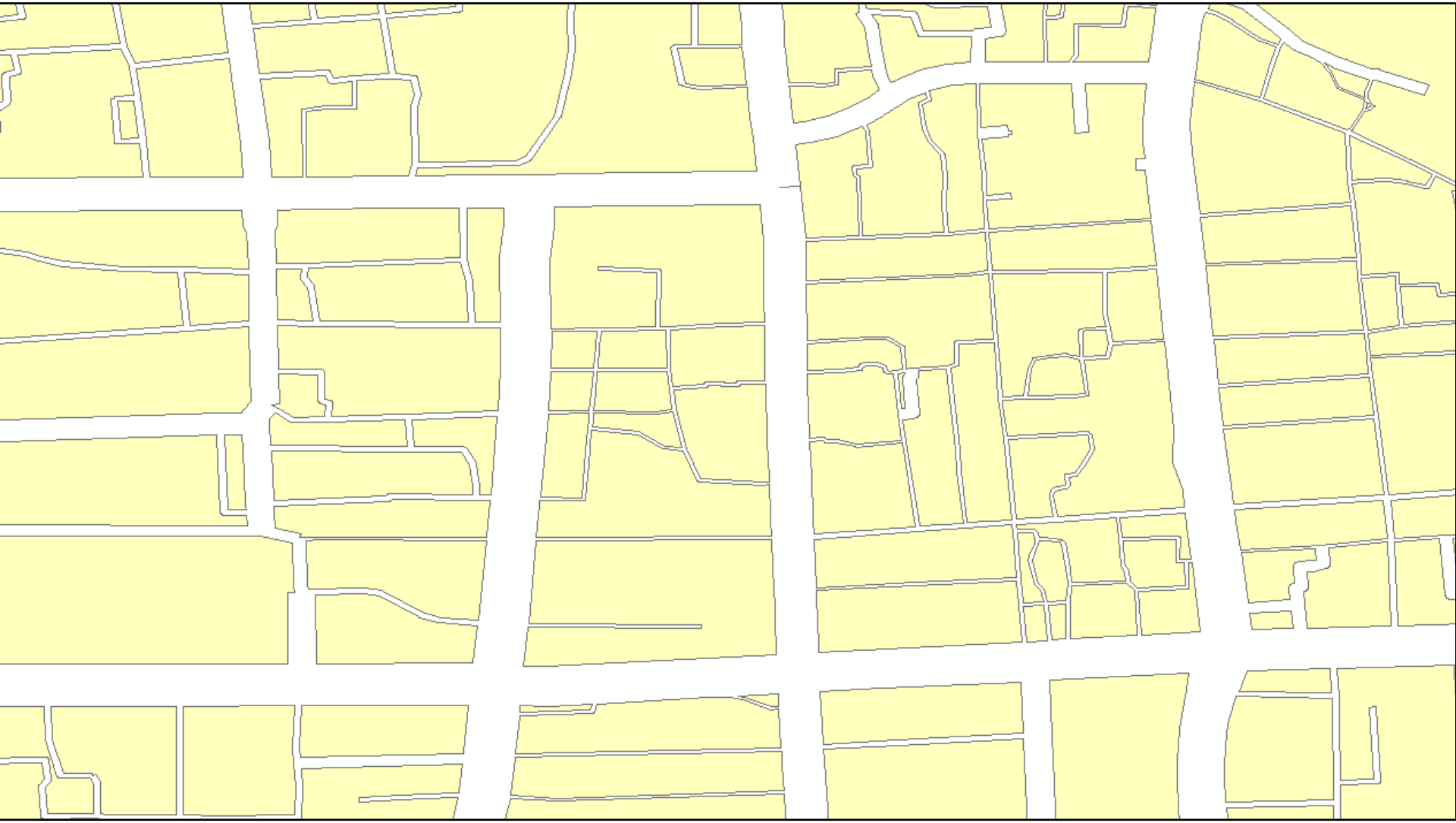
- Raw OSM roads
- Various of road types: primary, secondary, footpath, etc

(2) Delineating parcel boundaries



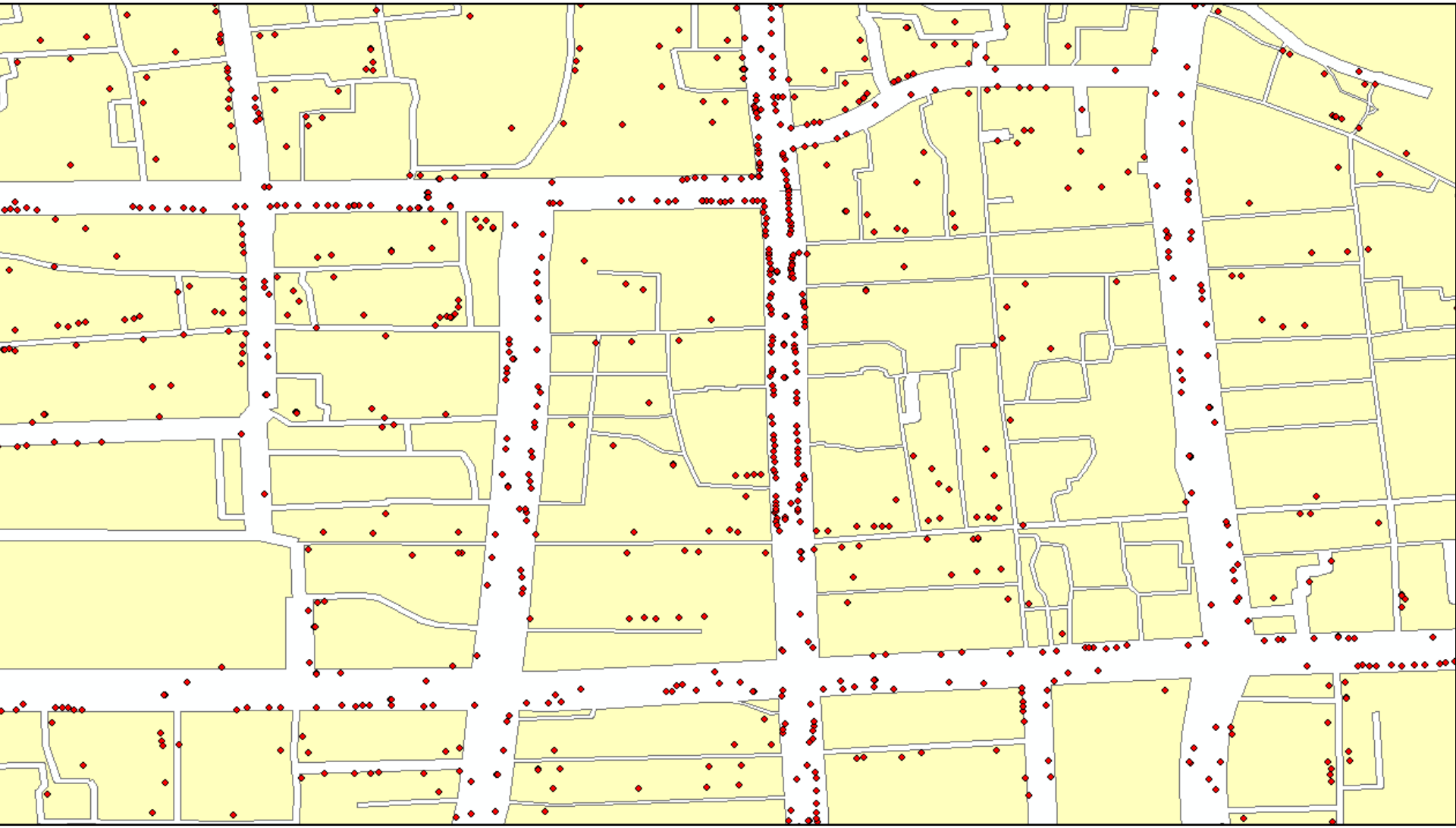
- Buffer OSM roads
- Buffer width varies from road types (2 - 30 m)

(3) Delineating parcel boundaries



- Erase road space from the study area
- Road space retained as the land use ”Transport”

(4) Calculating POIs density for all generated parcels



- Density = (The counts of POIs in/close to a parcel) / (The parcel area)
- Other measures (e.g., online check-ins and floor area ratio) can substitute POIs and approximate the intensity of human activities

(4) Calculating POIs density for all generated parcels

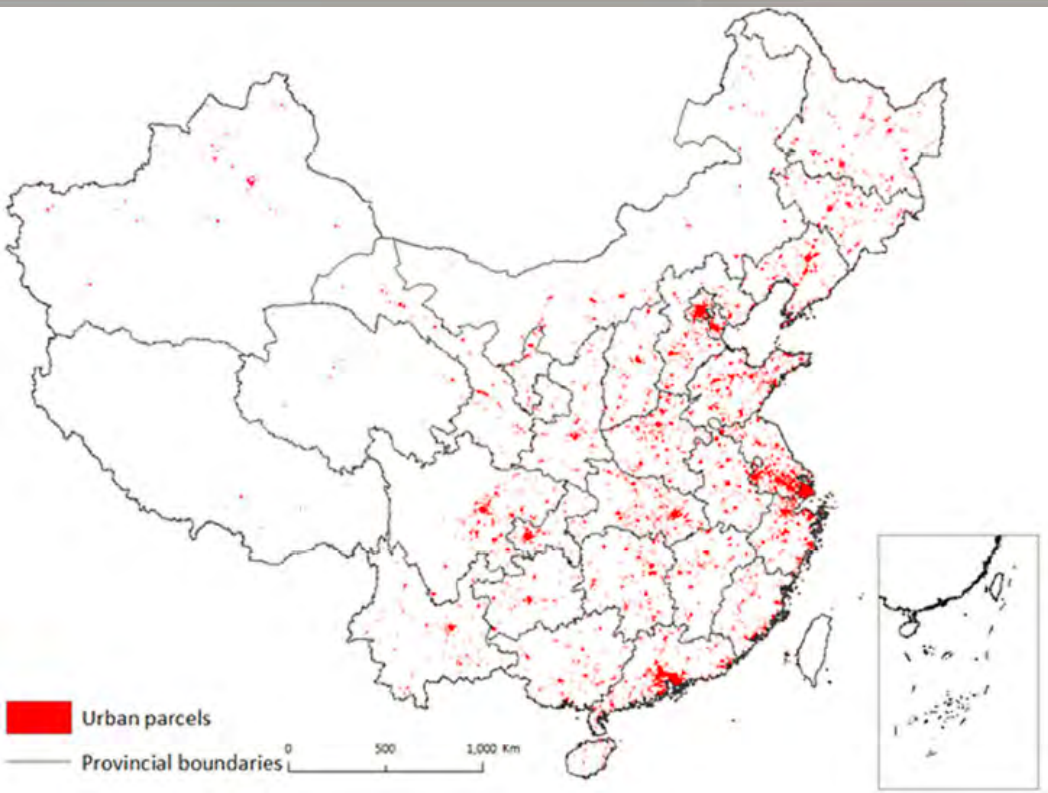
- Density = (The counts of POIs in/close to a parcel) / (The parcel area)
- Other measures (e.g., online check-ins and floor area ratio) can substitute POIs and approximate the intensity of human activities

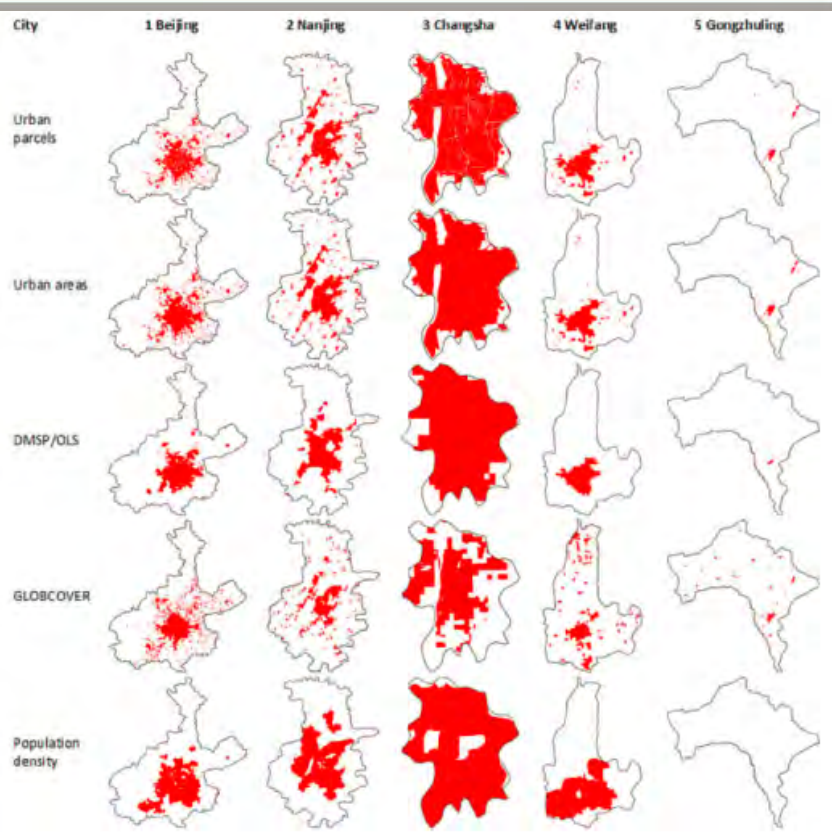
(6) Inferring urban parcels in 2012

MAPPING URBAN BUILT-UP AREAS WITH ROAD NETWORK AND POINTS OF INTEREST USING VECTOR CELLULAR AUTOMATA

A Parcel-based Perspective of A Large Geographical Area

Yao SHEN (The Bartlett, University College London, UK) & Ying LONG (Beijing Institute of City Planning China & Department of Architecture, University of Cambridge UK)



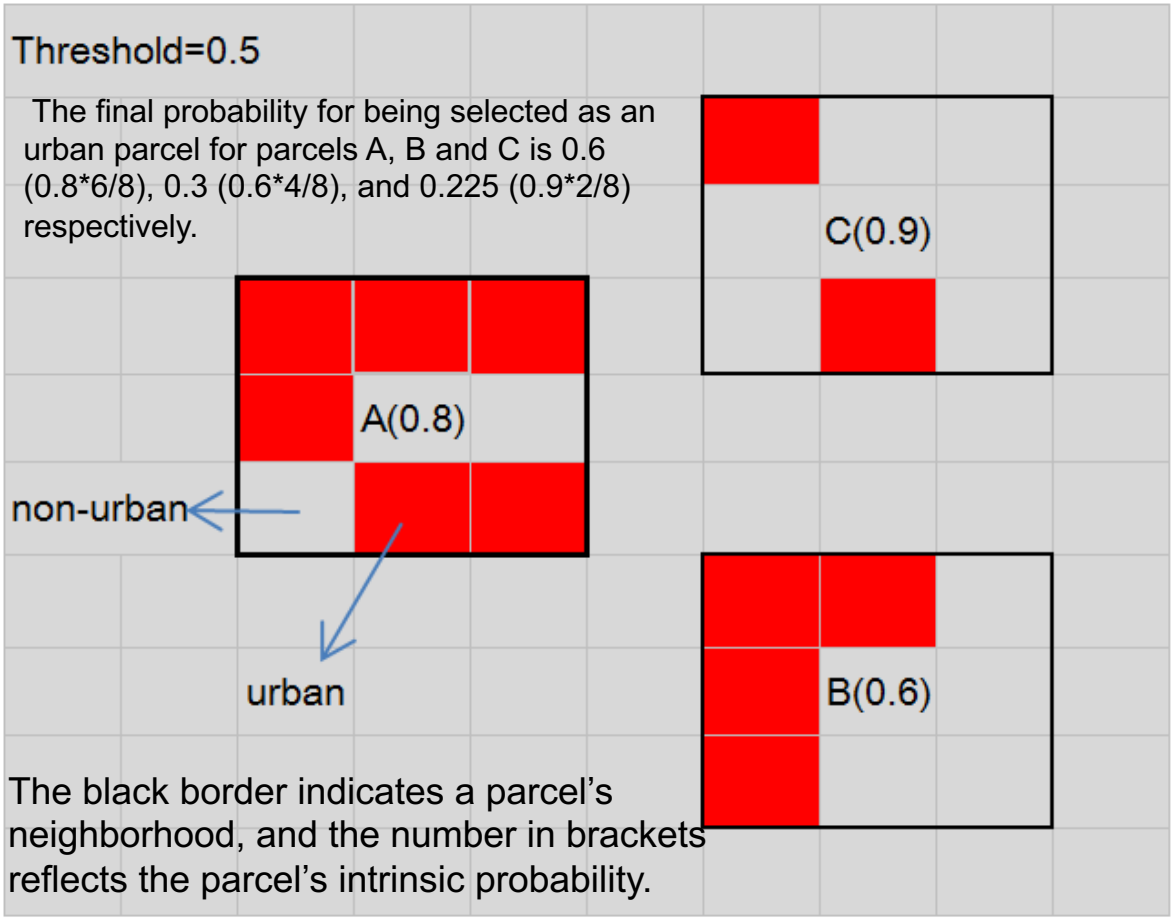


- Various methods can be applied in this process
  - Benchmarking road junction density and population density, referring to other LUCC products

(7) Selected urban parcels in 2012

3 The vector CA module

Selecting urban parcels using vector cellular automata



$$P_{ij}^{t} = (P_l)_{ij} \times (P_\Omega)_{ij} \times con(\cdot) \times P_r$$

$$(P_l)_{ij} = \frac{1}{1+\exp[-(a_0 + \sum_{k=1}^{m} a_k c_k)]}$$

$$(P_\Omega)_{ij} = \frac{\sum con(S_{ij}^{t} = urban)}{n}$$

$$con(cell_{ij}^{t} = suitable)$$

$$P_r = 1 + (-\ln \gamma)^{\beta}$$

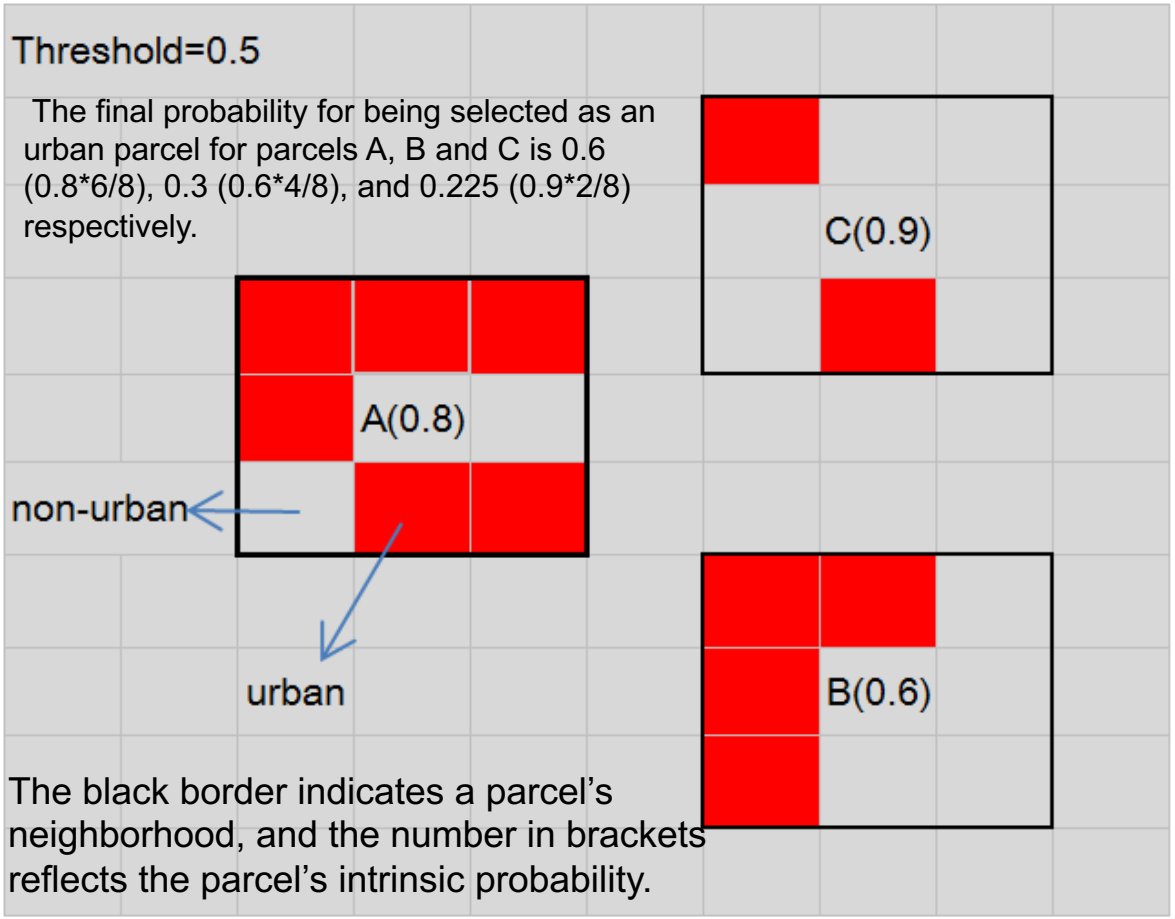
$$S_{ij}^{t+1} = \begin{cases} Urban \text{ for } P_{ij}^{t} \succ P_{thd} \\ NonUrban \text{ for } P_{ij}^{t} \le P_{thd} \end{cases}$$

- **One vector cellular automata model for each city**
- **Neighborhood configuration: 500 m radius of each parcel**
- **Constraints: size, compactness, distance to city centers, and POIs density (parameters calibrated using the Beijing parcels)**
- **Overall accuracy = 83.2%**

清華大學 BCL

3 The vector CA module

Selecting urban parcels using vector cellular automata



$$P_{ij}^{t} = (P_l)_{ij} \times (P_\Omega)_{ij} \times con(\cdot) \times P_r$$

$$(P_l)_{ij} = \frac{1}{1+\exp[-(a_0 + \sum_{k=1}^{m} a_k c_k)]}$$

$$(P_\Omega)_{ij} = \frac{\sum con(S_{ij}^{t} = urban)}{n}$$

$$con(cell_{ij}^{t} = suitable)$$

$$P_r = 1 + (-\ln \gamma)^{\beta}$$

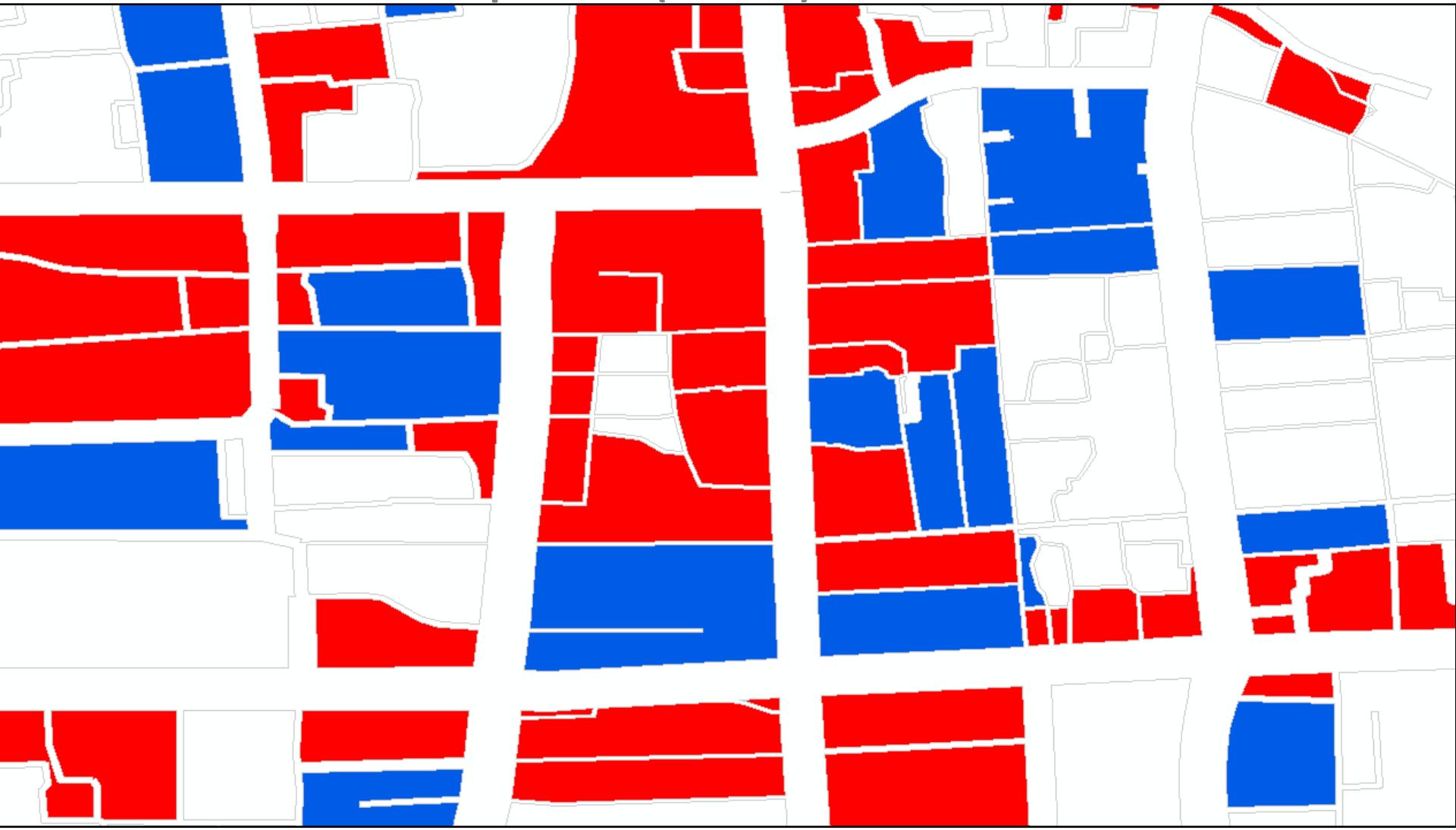
$$S_{ij}^{t+1} = \begin{cases} Urban \text{ for } P_{ij}^{t} \succ P_{thd} \\ NonUrban \text{ for } P_{ij}^{t} \le P_{thd} \end{cases}$$

Factor	Coefficient	S.E.	Wald	Sig.
SIZE_LN	-0.197	0.007	693.572	0.000
COMPACT	1.933	0.962	4.033	0.045
CENTER	-.101	0.002	1891.809	0.000
DENSITY	2.230	0.110	407.554	0.000
Constant	2.224	0.082	739.440	0.000

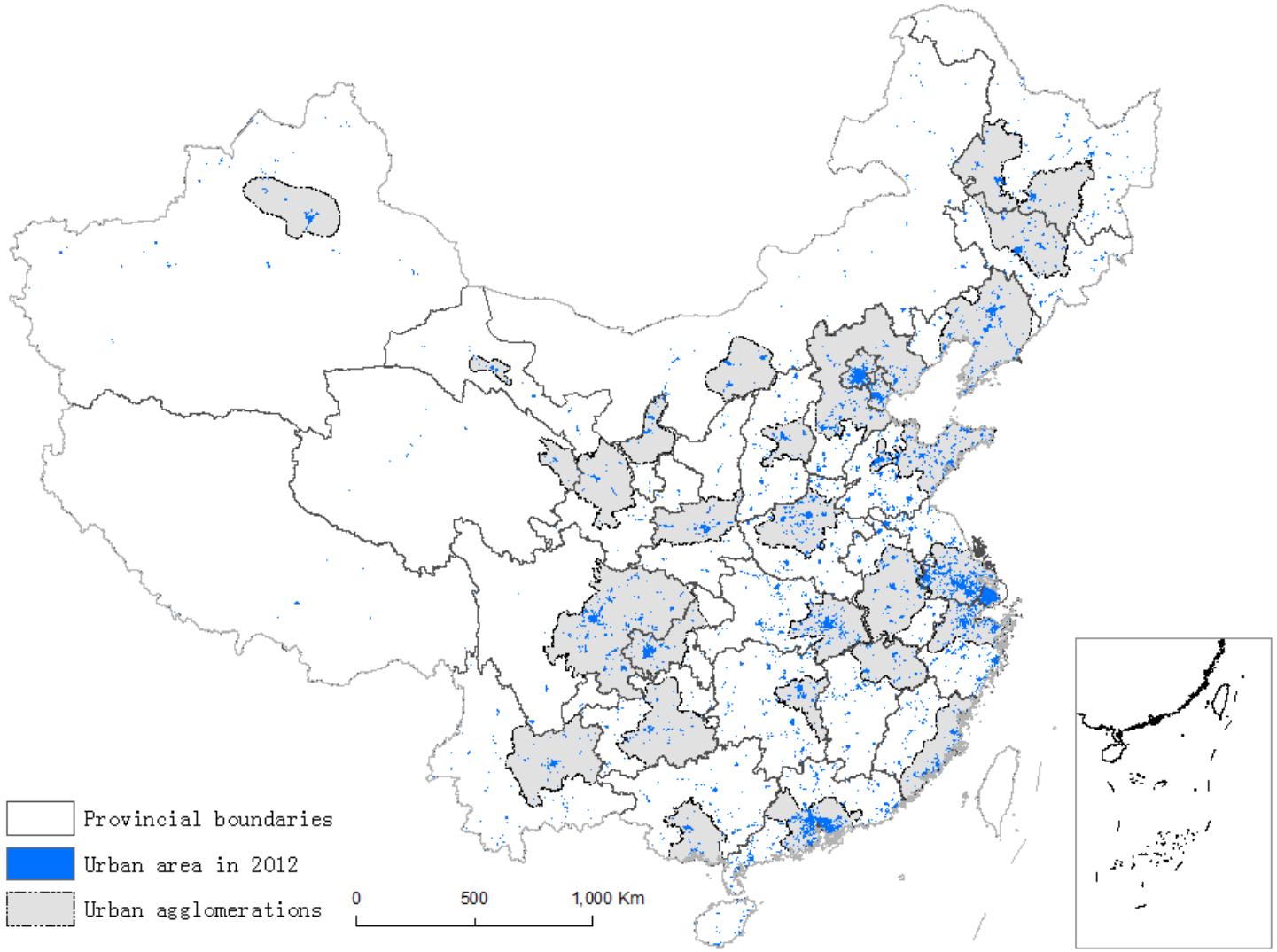
BCL

3 The vector CA module

Simulated urban expansion (in blue)

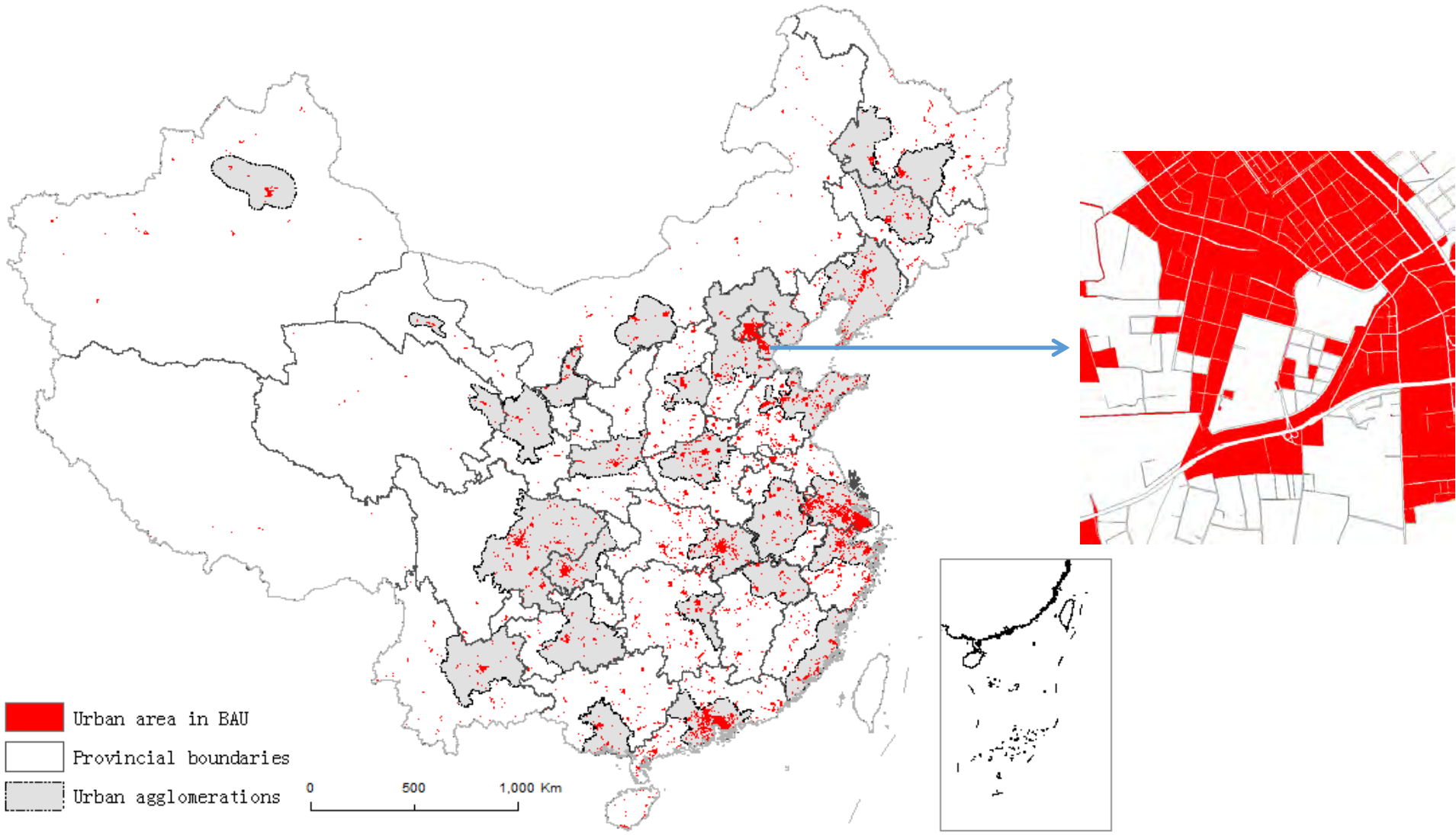


Urban areas of all Chinese cities in 2012



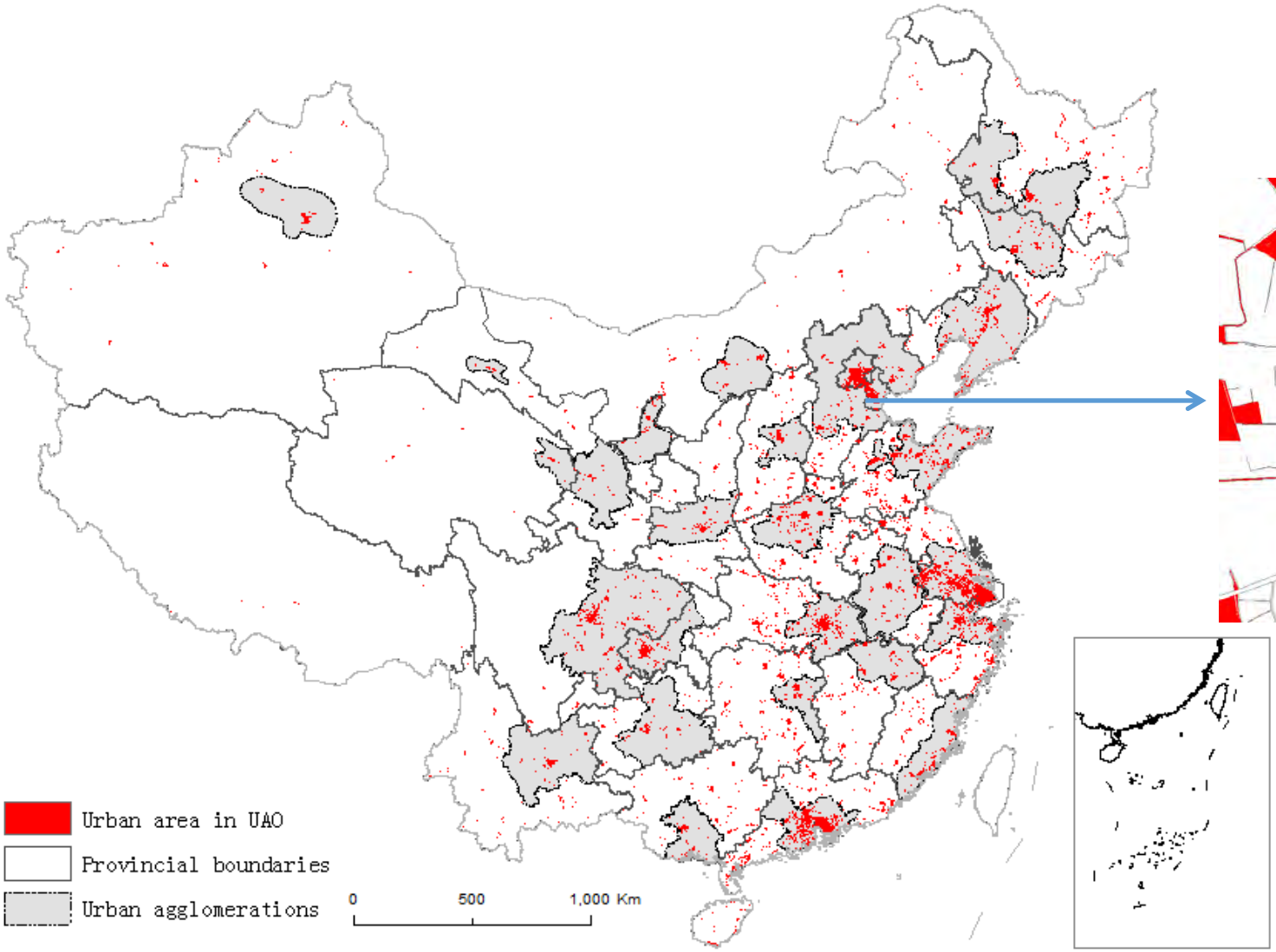
- **There are totally 761,152 urban parcels (among all 1.2 million parcels) for all 654 Chinese cities and with a total land area 46,751 km^2 (the average urban parcel size is 6.1 hectares, 200 m*300 m)**

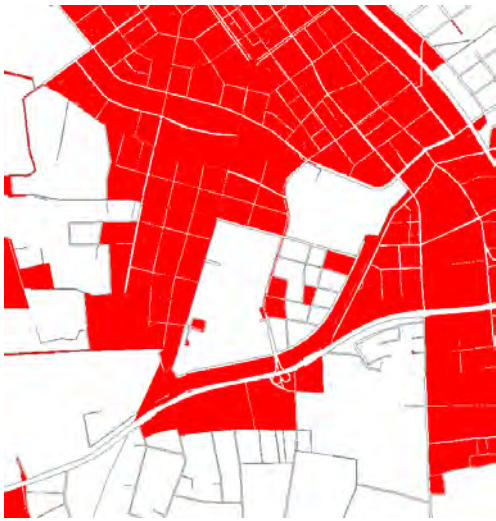
Simulation results: BAU



- **Total urban land areas estimated by BAU are 62,835 km^2 in 2017, increased by 34.4% compared to 46,751 km^2 urban land in 2012.**

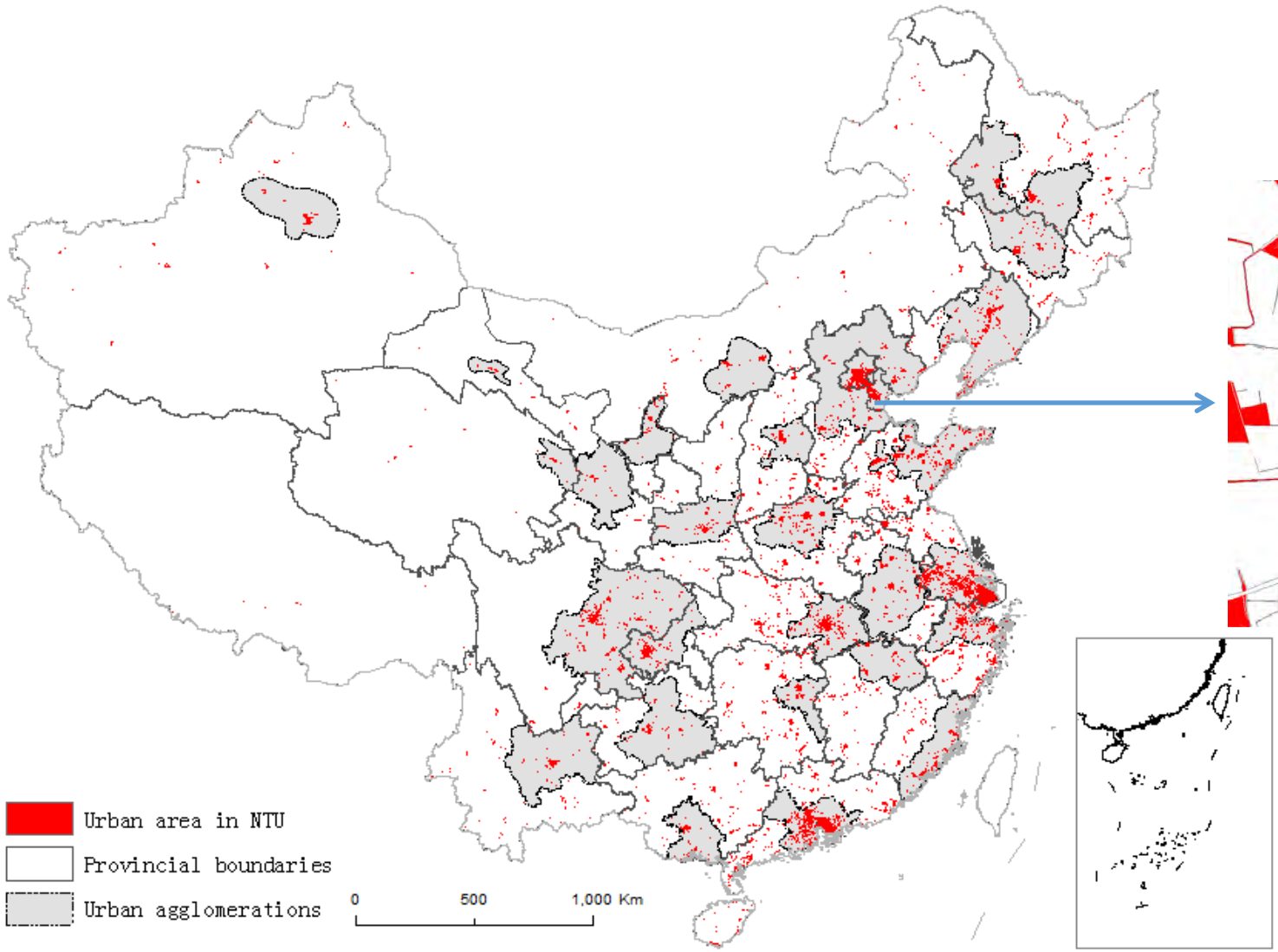
UAO

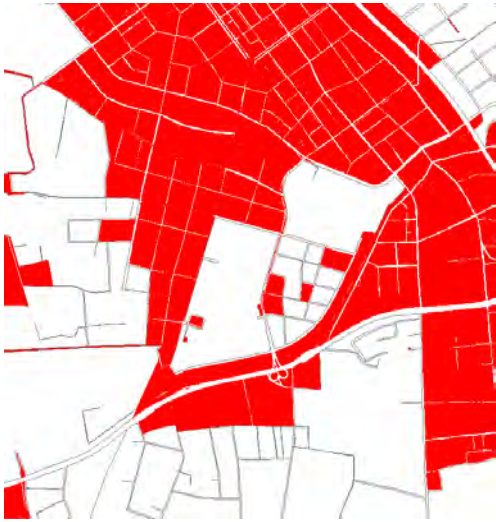




- **Total urban land areas of UAO are 58,394 km^2 in 2017, increased by 24.9% compared to urban land in 2012, while 4,441 km^2 less than BAU.**

NUP

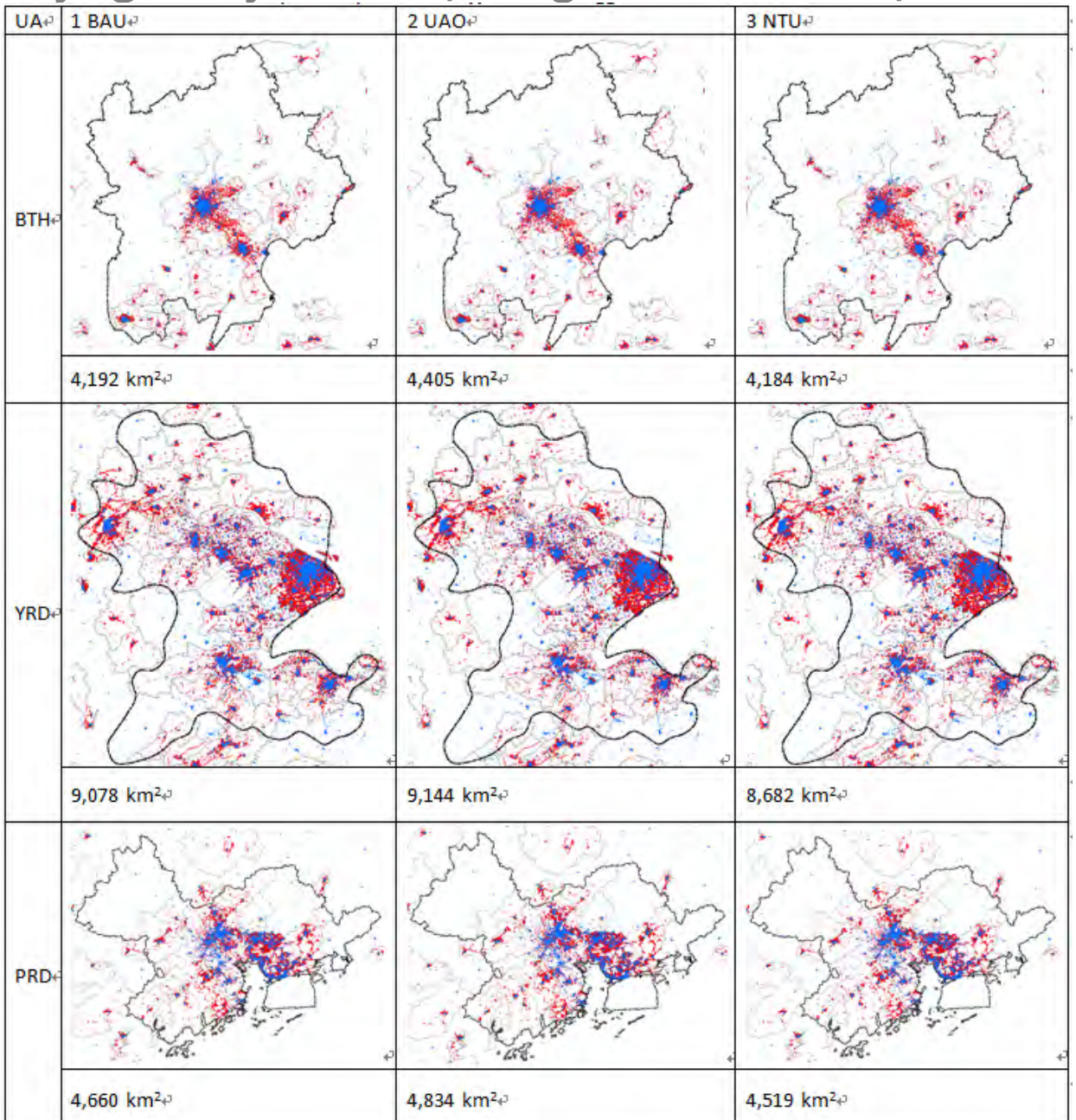




- **The total urban land areas of NUP are 58,930 km^2 in 2017, increased by 26.1% compared to urban land in 2012, while decreased 3,905 km^2 in comparison with BAU.**

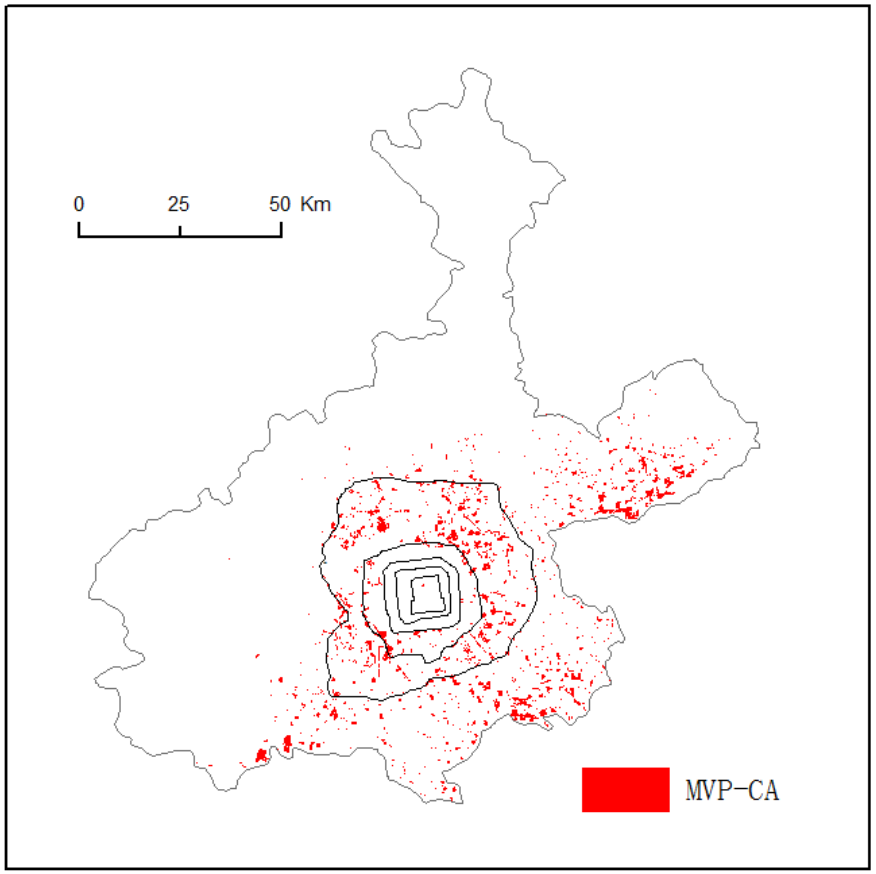
Urban expansion patterns in typical city regions

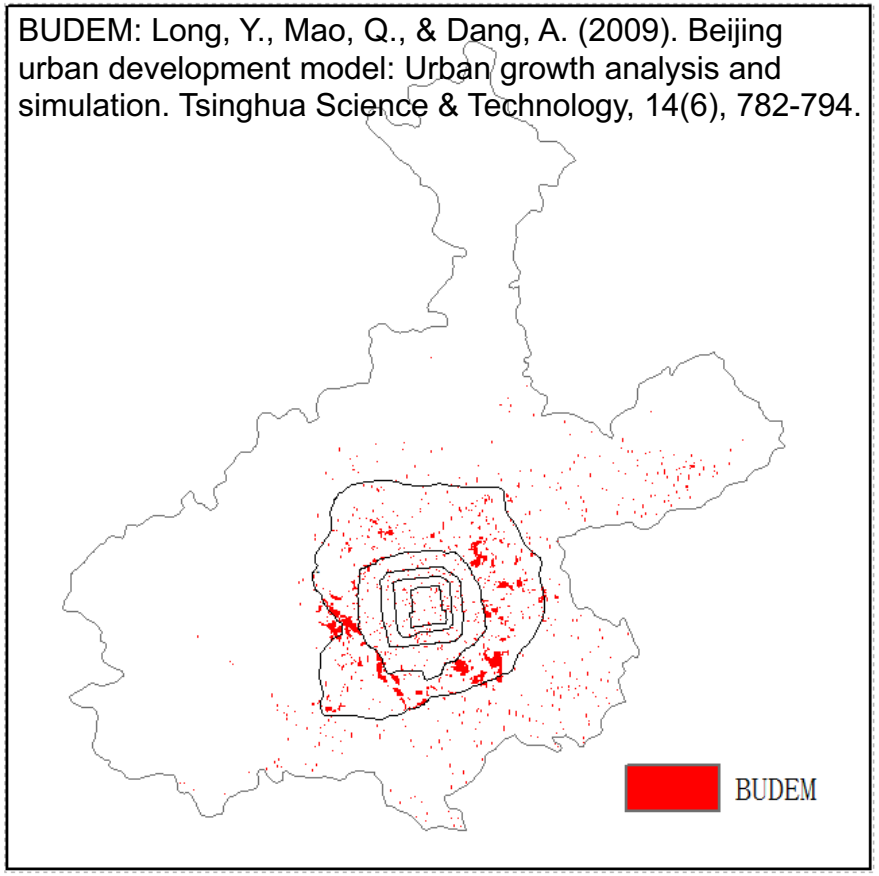
Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta



Red denotes simulated urban expansion during 2012-2017 and blue denotes existing urban land in 2012.

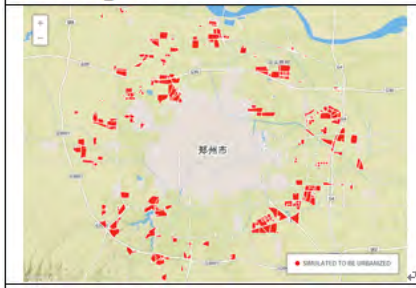
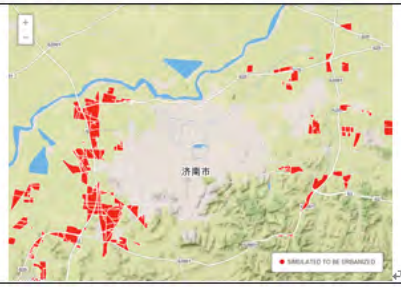
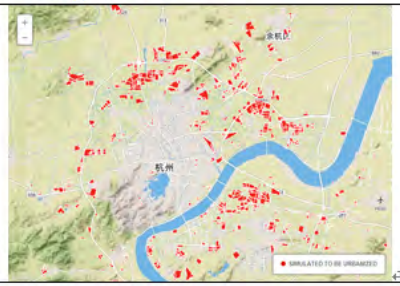
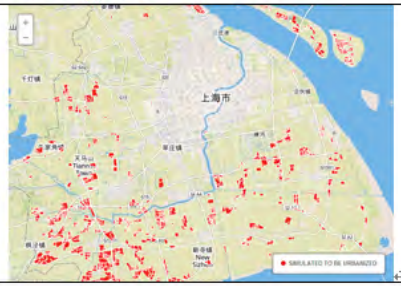
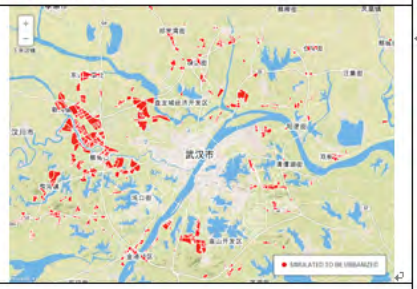
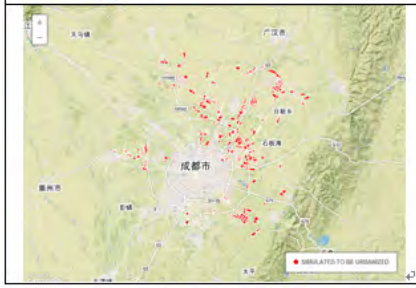
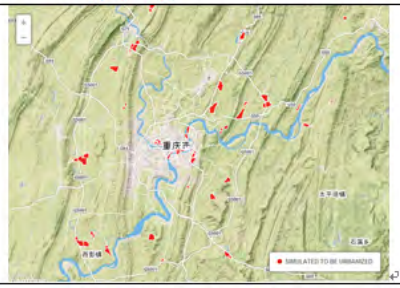
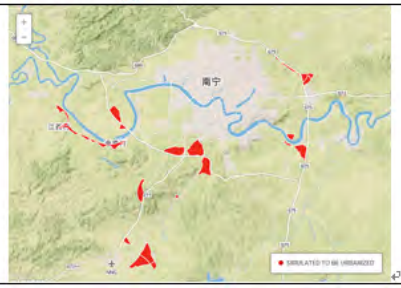
Validation: Comparing the BAU scenario with a 500m-raster-CA model BUDEM in the city of Beijing





- **Expanded areas in both models exhibit similar patterns according to the visual judgement.**
- **The overlaid area shared by both patterns was 119 km² (68.4% of the total expansion)**
- **The simulated pattern for long term is not realistic due to developed large parcels when MVP-CA is adopted to predict for a longer time.**

Validation: By online browsers on the released simulation results at CartoDB (an online WebGIS)

Zhengzhou	Beijing	Jinan	Shenyang
			
Nanjing	**Hangzhou**	**Shanghai**	**Wuhan**
			
Chengdu	**Chongqing**	**Nanning**	**Guangzhou**
			

- **76 comments for 12 cities received at Sina Weibo. Most of them are positive "Happy to see my city's future development"**
- **Some potential simulation bias due to being lacking of planning intervention in MVP-CA**

Concluding remarks

- **A data-driven and straightforward model for simulating urban expansion in a super large geographical scale in the parcel level.**
- **Datasets on existing urban areas and expanded parcels shared online for both practitioners and researchers.**

20 Expanded parcels during 2012-2017 by MVP-CA

2014

"The BCL voice on future urban development of China"

Expanded 43,247 parcels during 2012-2017 in the business-as-usual simulation scenario (BAU) for 654 Chinese cities **(the preliminary results),** by Dr Ying Long, Dr Kang Wu, and Dr Qizhi Mao.
Details are available in our arXiv paper (also available in the BCL "Data released" channel), http://arxiv.org/abs/1402.3718
Welcome cite: Long, Y., Wu, K., & Mao, Q. (2014). Simulating urban expansion in the parcel level for all Chinese cities. arXiv preprint arXiv:1402.3718.
Download: https://www.dropbox.com/s/05id7nhn5i5qcwi/DT20.zip
Data format: ShapeFile

Data download
DT20.zip
Compressed Archive in ZIP Format [31.7 MB]

Download

https://www.beijingcitylab.com/data-released-1/data1-20/

Potential applications

Results shared online to promote applications

1. **Evaluating national spatial development strategies via linking macro policies to local developments.**
   - **Visualized at a fine scale using MVP-CA**
2. **Informing decision makers, developers, planners and local residents on simulated local developments**
   - **“Parcels” make more sense to them**
3. **Evaluating urban expansion impact based on simulated results**
   - **E.g. environment, ecology and social impacts**

The codes show for the MVP-CA model

三、基于个体建模与地块细分

Agent-based Modeling and Parcel Subdivision

基于个体建模（Agent-based Modeling）

- 或称为多智能体模型（Multi-agent System、MAS）
  - 元胞自动机模型被认为是MAS模型的一种特殊形式
  - 元胞不能移动（不能移动的agent），而agent多数可以移动
- An agent-based model (ABM) is a class of computational models for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.
- It combines elements of game theory, complex systems, emergence, computational sociology, and evolutionary programming. Monte Carlo methods are used to introduce randomness.
  - https://en.wikipedia.org/wiki/Agent-based_model


Computer Science Review

Volume 24, May 2017, Pages 13-33

Review article

Agent Based Modelling and Simulation tools: A review of the state-of-art software

Sameera Abar, Georgios K. Theodoropoulos, Pierre Lemarinier, Gregory M.P. O'Hare

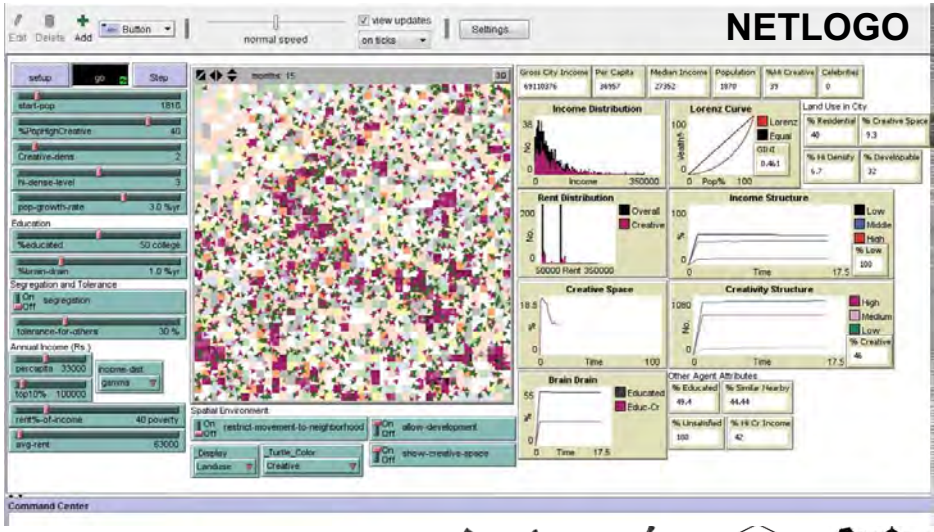
Show more

https://doi.org/10.1016/j.cosrev.2017.03.001

Get rights and content

Abstract

The key intent of this work is to present a comprehensive comparative literature survey of the state-of-art in software agent-based computing technology and its incorporation within the modelling and simulation domain. The original contribution of this survey is two-fold: (1) Present a concise characterization of almost the entire spectrum of agent-based modelling and simulation tools, thereby highlighting the salient features, merits, and shortcomings of such multi-faceted application software; this article covers eighty five agent-based toolkits that may assist the system designers and developers with common tasks, such as constructing agent-based models and portraying the real-time simulation outputs in tabular/graphical formats and visual recordings. (2) Provide a usable reference that aids engineers, researchers, learners and academicians in readily selecting an appropriate agent-based modelling and simulation toolkit for designing and developing their system models and prototypes, cognizant of both their expertise and those requirements of their application domain. In a nutshell, a significant synthesis of Agent Based Modelling and Simulation (ABMS) resources has been performed in this review that stimulates further investigation into this topic.



Coupling CA with ABM

- **Coupling**
  - CA – fixed position (environmental factors, physical process)
  - ABM (agent-based modeling) –moveable agents (players/actors, socioeconomic process)

    Agents: government, planners, developers, residents
- **Grid CA equipped with ABM for modeling urban expansion/urban growth/LUCC (land use and cover change)**
  - Evans and Kelly, 2004; Li and Liu, 2008; Vancheri, 2008; Robinson and Brown, 2009
- **Limited studies for integrating irregular CA and ABM**
  - The following pages focus on this aspect

Coupling CA with ABM

Li et al 2011 IJGIS (GeoSOS)

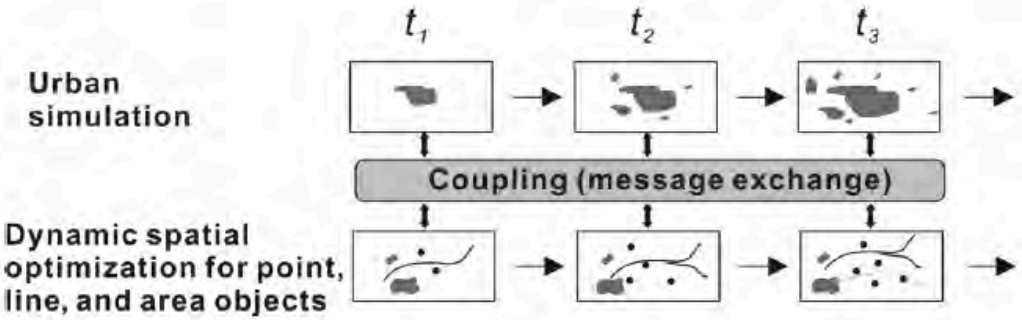
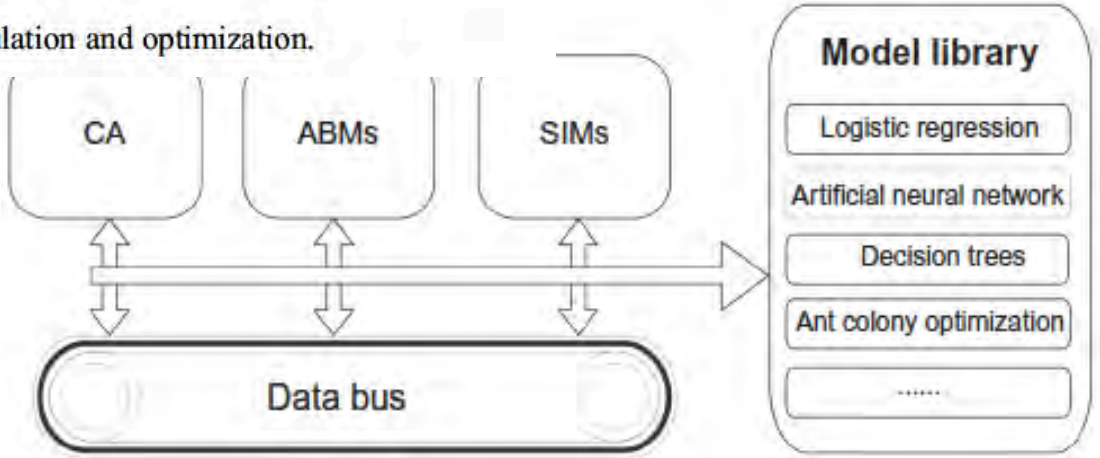


Figure 1. A loose coupling strategy between simulation and optimization.



- **Discussed the concepts and methodologies of a geographical simulation and optimization system (GeoSOS) coupling grid CA and ABMs.**

Coupling CA with ABM

Jjumba and Dragićević 2012 ASAP (*Agent iCity*)

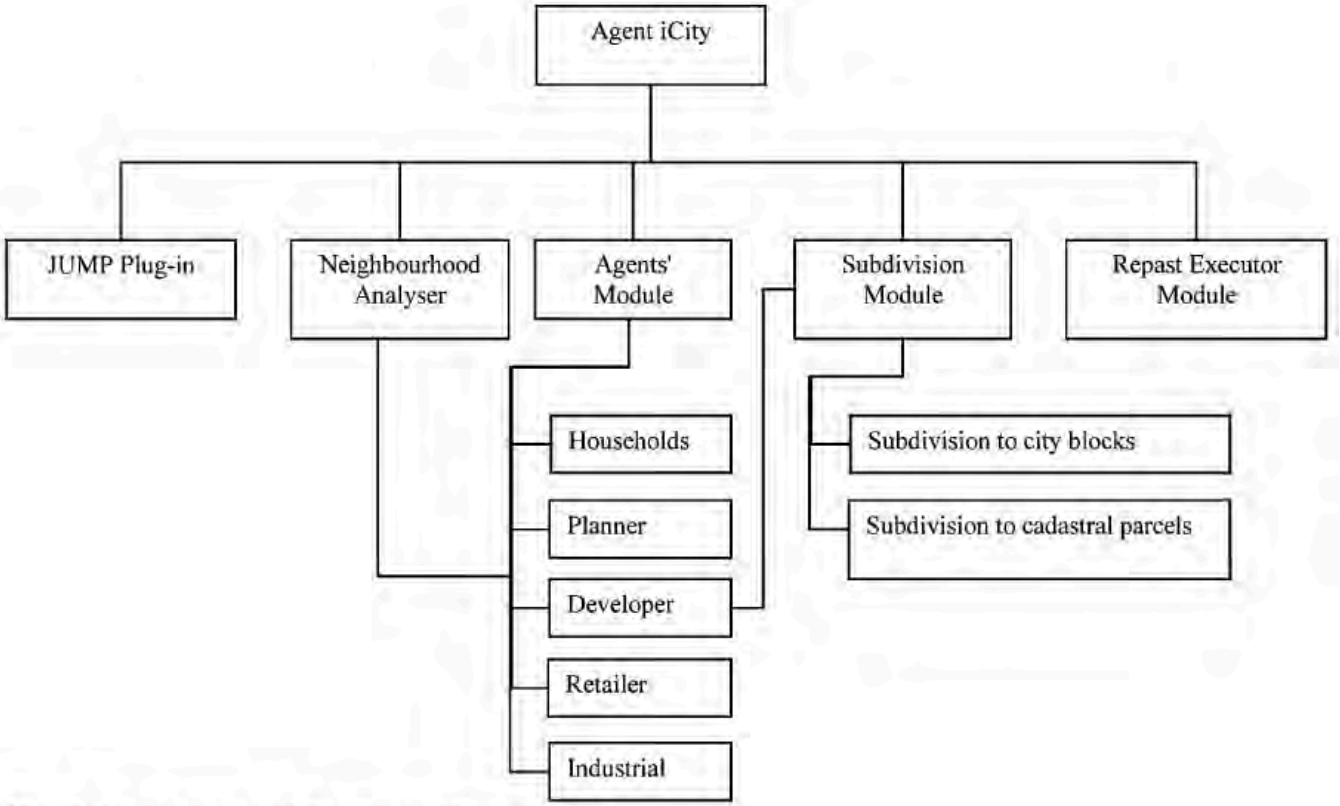


Fig. 3 Components of the Agent iCity mode

- The new version of iCity by Stevens and Dragićević (2007) EPB
- An agent-based model that simulates the process of urban land-use change by using irregular spatial units at a cadastral scale and by incorporating the interactions of the key stakeholders.

Coupling CA with ABM

Zhao and Peng 2012 JTG (LandSys)

- CA
  - Land use types
  - 50m cell
  - MNL based calibration
- Agents
  - Household, employment and developer
- Land market equilibrium
  - Demolition of existing and redevelopment
  - Development of vacant land cells
- Developer Agent
  - Demolition model
  - Construction model
- Application
  - Orange county, FL, USA

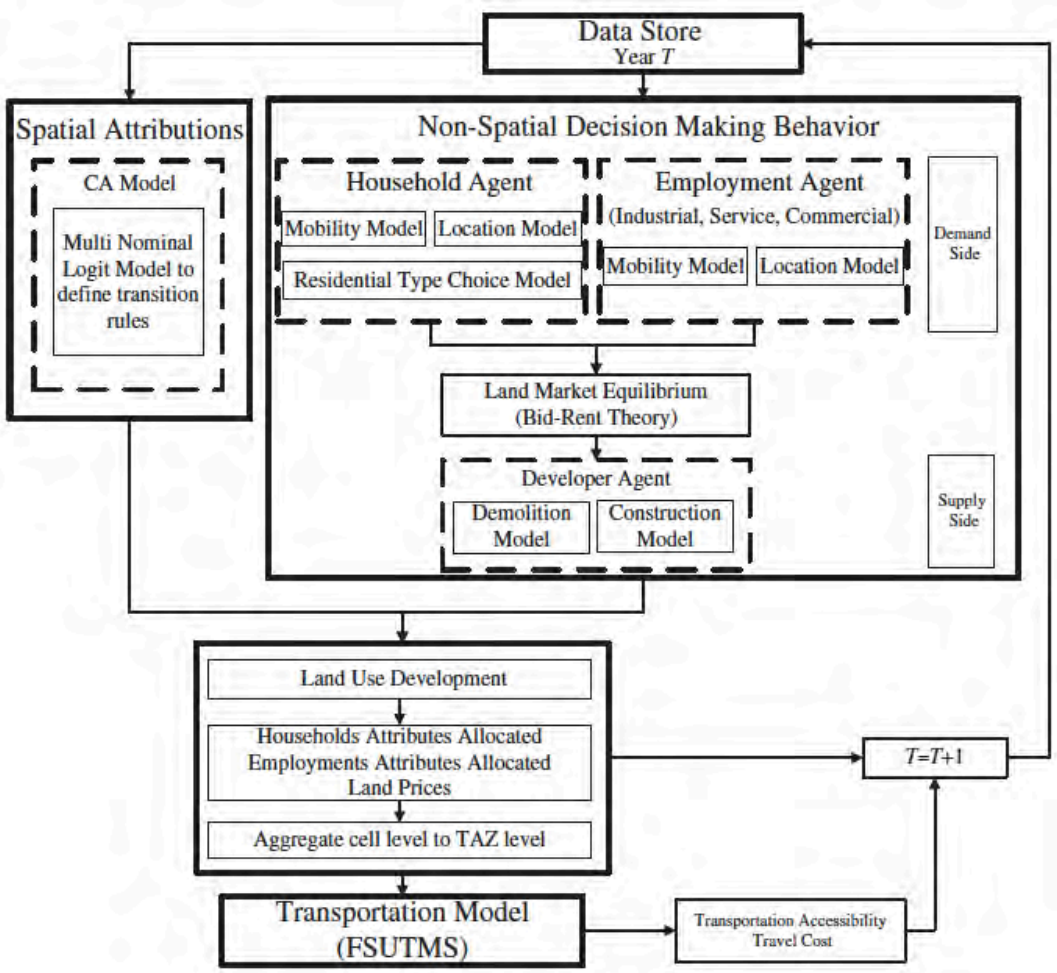


Fig. 3. Framework of the LandSys model.

Coupling CA with ABM

A comparison on aforementioned simulators

	Cells	Subdivision	Geometry change	Planner agent	Other agents	Density	Redevelop ment
Agent iCity	vector	Y	N	Y	Y	N	Y
GeoSOS	grid	N	N	N	Y	N	N
LandSys	grid	N	N	N	Y	N	Y
Hammam et al.	Vector	N	Y	N	Y	N	N
GAS	vector	N	N	N	Y	N	N
Pinto and Antunes	vector	N	N	N	N	Y	Y
Shen and Kawakami	vector	N	N	N	N	N	Y
VecVCA	vector	N	Y	N	N	N	N
Planner Agent	vector	N	N	Y	Y	Y	N

- **All with exogenous demands as input**
- **Emerging tools Agent iCity and LandSys**
- **All CA+ABM with residential, developer and government agents**
- **All focusing on multi land uses except our V-BUDEM and LandSys**
- **Density, subdivision, geometry change and urban redevelopment less explored**

Parcel subdivision for urban expansion process

- **Subdivision is the act of dividing land into pieces that are easier to sell or otherwise develop, usually via a plat (Wikipedia).**
- **Parcel subdivision is an important process in simulating land use change, especially for urban redevelopment.**
  - E.g. as a tool in land readjustment in Japan, Turkey, and Germany
- **More attention is focusing on parcel subdivision, with the trend of find-scale spatial simulation**
  - Raster vs vector data model used
- **Fialkowski and Bitner (2008) found universal rules of parcel size distribution in both urban and rural areas**
- **An important part for spatial simulator**
  - Visualization and accounting
  - More realistic simulation results

Parcel subdivision for urban expansion process

Wickramasuriya et al. 2011 EMS (LSS)

Name of software: Land Subdivision Simulator
Developer: Rohan Wickramasuriya
Software required: ArcGIS 9 (ArcView license)
Program language: ArcObjects and VBA

- **Presented a fully-automated land subdivision tool that uses vector data and is capable of generating layouts with both lot and street arrangements for land parcels of any shape**
- **Software availability and now testing (irregular_subdivision.mxd)**

Parcel subdivision for urban expansion process

Vanegas et al. 2012 Computer Graphics Forum

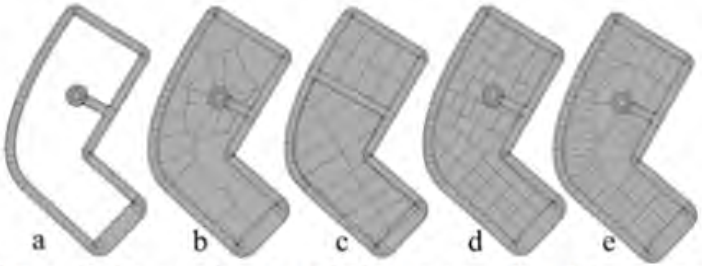


Figure 2: *Comparison to existing approaches. Given a street network (a), several systems have been proposed to create parcels. The Voronoi tessellation of points near the border of the street is one geometrical approach (b), while a minimum area bounding box approach has also been suggested [WCP*11] (c). Cube packing is another approach that leads to badly formed parcels in concave areas (d). We show our result (e) which gives a statistically realistic result. A comparison to [WMWG09] is presented in Appendix C.*

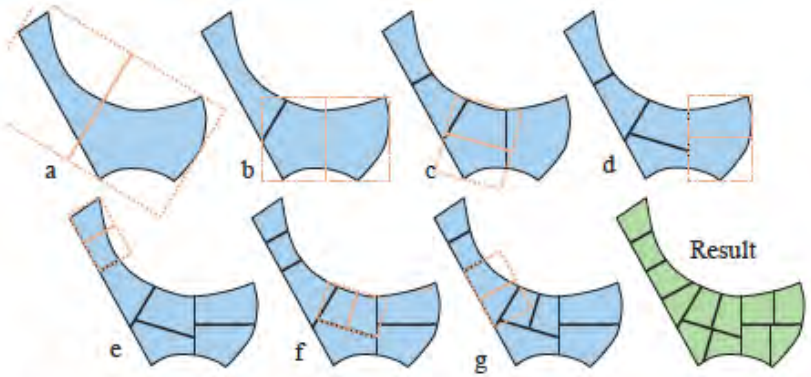


Figure 6: *Oriented bounding box subdivision. This adaptive algorithm recursively splits a parcel into two smaller parcels along the minor axis of the oriented bounding box of the original parcel. The subdivision continues until user-specified shape attributes are satisfied.*

- **Interactive procedural generation of parcels within the urban modeling pipeline**
- **Performs a partitioning of the interior of city blocks using user-specified subdivision attributes and style parameters**
- **“become a standard in parcel generation for future urban modeling methods”**
- **To be embedded in UrbanSim**

Parcel subdivision for urban expansion process

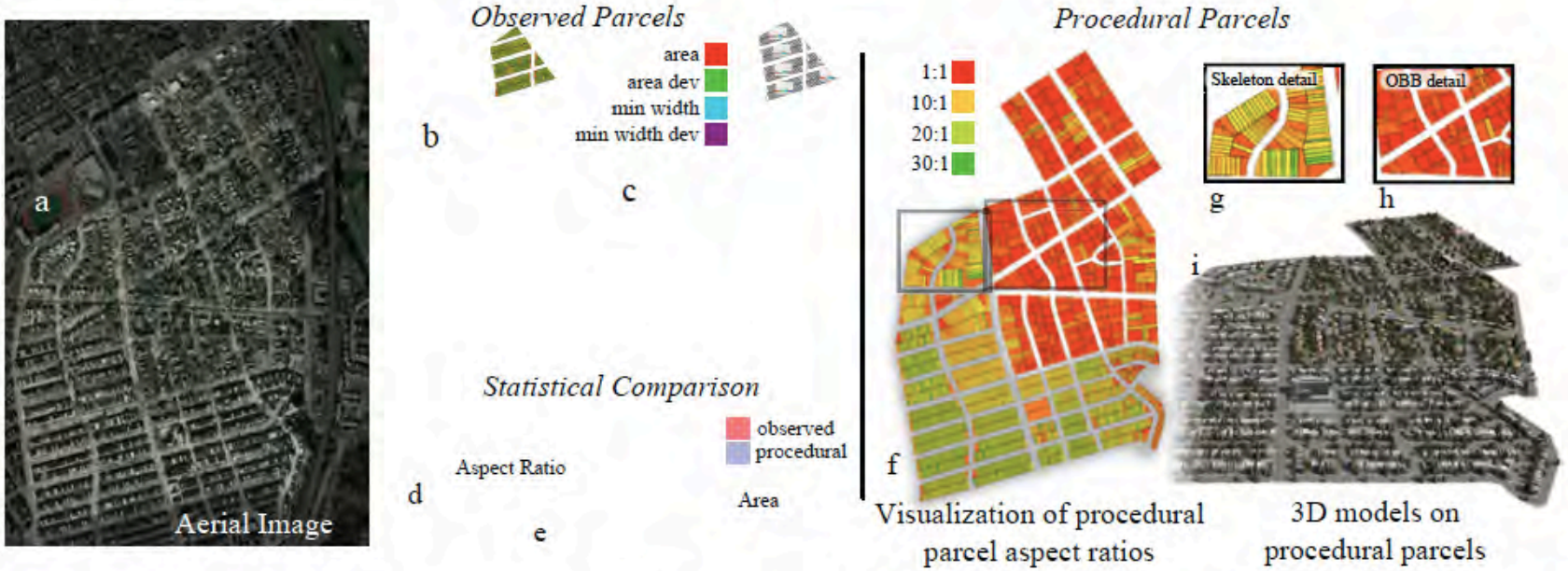


Figure 1: *Procedural Parcel Generation. Our method creates parcels inside city blocks (f,i) using two different subdivision techniques —* skeleton *(g, shaded part of f) or* OBB *(h, unshaded part of f). The subdivision attributes are automatically extracted from observed real-world cities (a,b,c) or determined by the user. The resulting parcel configurations closely resemble real-world subdivisions, as shown by our statistical and visual comparison of procedural and observed parcel datasets (d,e).*

Parcel subdivision for urban expansion process

Jjumba and Dragićević 2012 ASAP (*Agent iCity*)

- **Subdivision of a large tract of land, first into blocks and roads (b), and then cadastral parcels (c)**
- **Activated by the planning agent**

Parcel subdivision for urban expansion process

Wickramasuriya et al. 2013 IJGIS

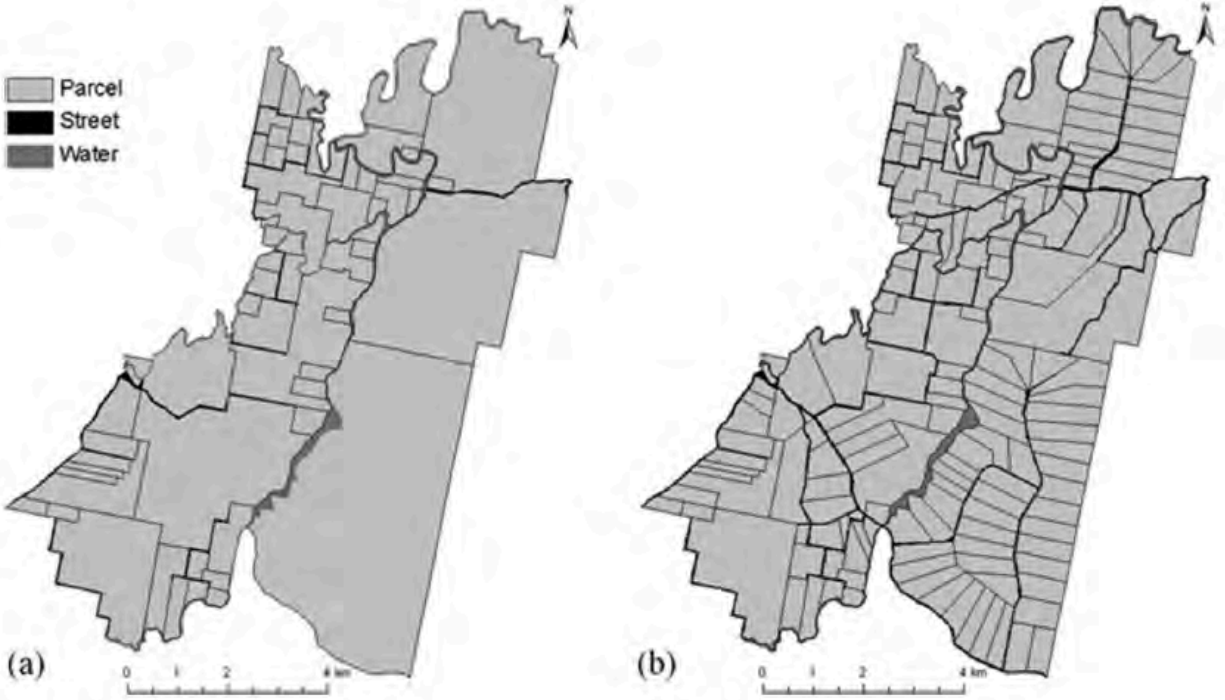
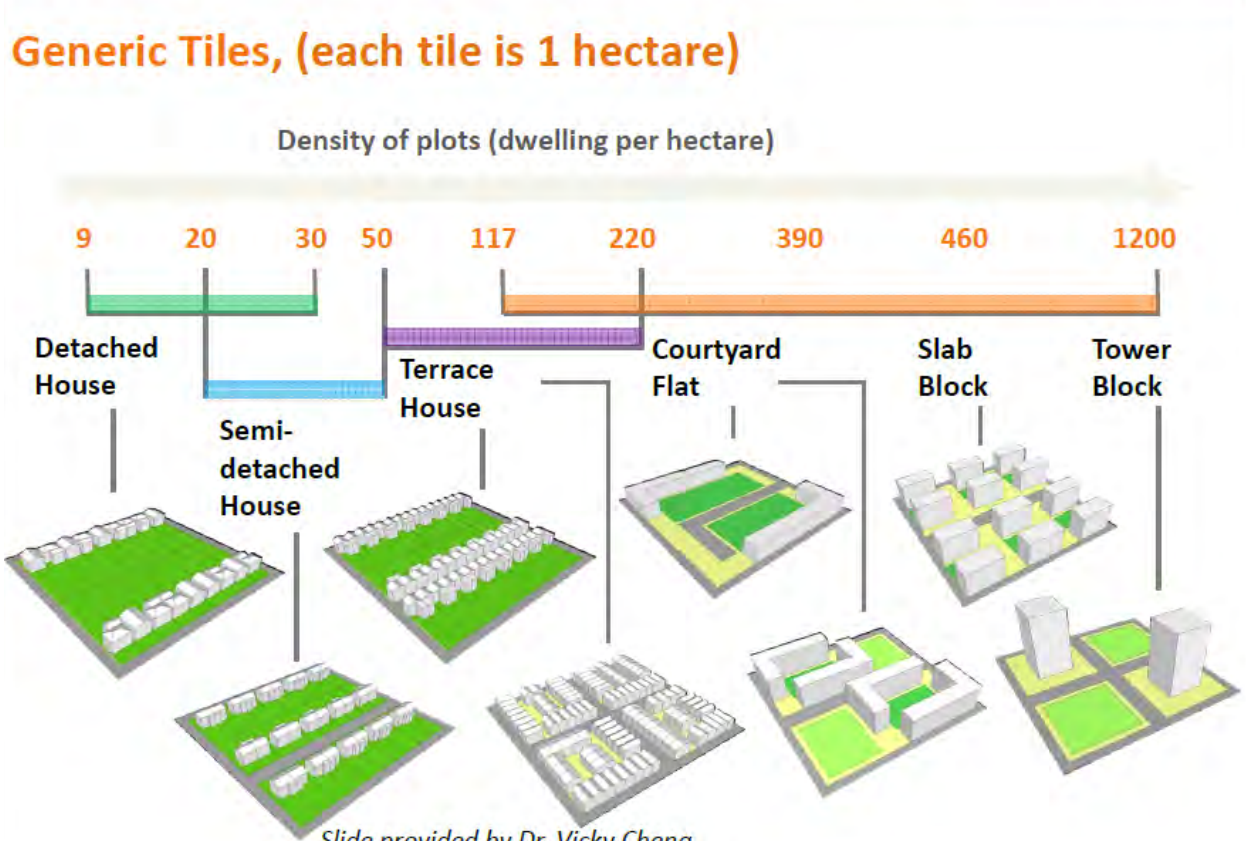


Figure 8. Change in property boundaries during the simulation: (a) beginning of the simulation and (b) end of the simulation.

- **Improved LSS to dynamically subdivide parcels in land use change models.**

Parcel subdivision for urban expansion process

After the parcel scale: Tony et al 2013 (Tile)



- ReVISIONS project report
- From parcel to building scale and very promising

考核方式：考查

- 成绩构成：出勤及过程（30分）+大作业（70分）

- 大作业（任选一种形式）：
  - 形式1：每人撰写某一类城市模型综述的课程论文
  - 形式2：每人撰写城市模型发展趋势与未来展望的课程论文
  - 形式3：利用课程发放的北京五环内数据，开发一个地块尺度的轻量级城市模型（straight forward and light-weight），并附模型介绍（建议2-3人一组）
    - 建议选题：城市开发密度模拟(2035年)
    - 欢迎与任课教师讨论（建议OPEN OFFICE HOUR时间）

- 提交方式：W13周末（5月27日）前提交给助教陈婧佳
  - W8结课后也同样欢迎约任课教师讨论大作业

课后安排

- 阅读材料待放到课程网站
  - https://www.beijingcitylab.com/courses/aium2018/

- OPEN OFFICE HOUR
  - 每周二下午12:30-13:30
  - 需要提前通过info预约
  - ylong@tsinghua.edu.cn, 新建筑馆501, 13661386623

- 答疑邮箱
  - ylong@tsinghua.edu.cn

BCL 北京城市实验室 Beijing City Lab
http://www.beijingcitylab.com