PLUREL

Land Use Relationships
In Rural-Urban regions

Module 2

August 2010

PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

D2.4.3b

Land use projections based on Moland output

Part B: The Montpellier test case

Carlo Lavalle*, Sarah Mubareka, Claudia Baranzelli (DG-JRC)

*Responsible partner and corresponding author
Tel: +39 0332 78 9111;
Email: carlo.lavalle@jrc.ec.europa.eu

Document status:

Draft:	completed
Submitted for internal review:	completed
Revised based on comments given by internal reviewers:	completed
Final, submitted to EC:	completed

SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

Objectives

The objective of the PLUREL test case series is to produce a set of scenario runs for different geographical regions using the MOLAND land use model. Each test case is unique in its geography, society and policy choices. The land use model handles each test case independently with unique datasets as provided by the stakeholders. A list of common indicators was designed in order to ensure the inter-comparability of the eclectic set of cases. In this paper, a stand-alone draft for now which will eventually be amalgamated with other test cases, we look at the behaviour of city and surroundings of Montpellier (France) according to three scenarios described by the local stakeholders.

Methodology

Four scenarios were run for Montpellier from 2000 to 2025: 'Business as usual', 'Peak oil' (B1) and two variants of the 'HyperTech' (A1). The parameters for the scenarios are described in the document entitled "Scenarios pour modèle Moland – Montpellier case study" by Jean-Paul Gambier and revised in collaboration with Françoise Jarrige and Jean-Pierre Chéry on 13 January 2010 (see annex 1).

The methodological sequence is as follows:

1. Consultation with stakeholders
2. Data acquisition and manipulation
3. Data ingestion into the Moland model and calibration
4. Scenario parameter setting and running
5. Compilation of resulting statistics

Results

The "business as usual" (BAU) scenario output for 2025 is midway between the two other extreme scenarios. The "Peak oil" (PO) scenario is very conservative in its new developments, especially in the peri-urban and rural areas. This is due to the rising oil prices and consequential energy crunch which slows the services sector linked to the port and airport; and decreases new construction of industrial areas. Discontinuous urban areas are subject to a densification and are consequentially converted to continuous urban areas. In the PO scenario, there is

also some incentive to “return to the land”. The land allocated to vineyards, pasture and arable land increase in this scenario. The opposite extreme to the PO scenario is the “Hyper Tech” scenario. In this scenario, construction is booming under planning control set by the SCoT zoning tools. Two variants have been elaborated for the HT scenarios, reflecting respectively the application of the zoning control only within the Montpellier Agglomeration (the original SCoT area) and a zoning control extended to the overall study area.

Classification of results / outputs:
For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	Regional
DPSIR framework: Driver, Pressure, State, Impact, Response	Driver/Pressure/State/Impact/Response
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	Yes
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	None
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	GIS-based maps; tables and charts

How many fact sheets will be derived from this deliverable:	**1**

1. Introduction

Moland is a land use modelling tool used within the PLUREL project to model the dynamic urban expansion for selected case studies. Based on cellular automata, the model is able to capture the complexity and random nature of urban growth and its implications on peri-urban and rural land while being able to handle large geographical areas. Moland requires a good knowledge of the principles driving the model in order to achieve a reasonable calibration as well as to drive scenarios realistically. The model is described in detail elsewhere (Petrov *et al* 2009).

This report brings the reader through the various phases of modelling with Moland, with focus on the Montpellier case-study-specific details and analyses of results.

2. Geographical extent

Prior to compiling the data, the extent of the area to be modelled as well as the spatial resolution of the land use data has to be determined. Discussions were held in regards to definition of the study area. Three possibilities were considered: the functional urban area and two extended versions thereof (figure 1).

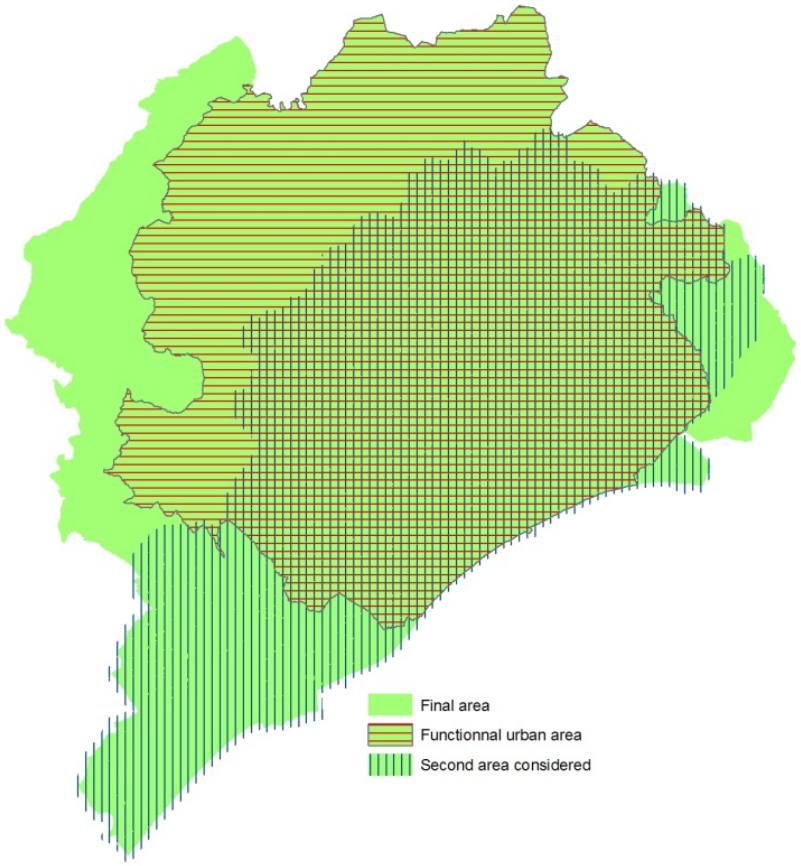


Figure 1. Montpellier areas considered for modeling

3. Model set-up and calibration

The Moland model can be run at two levels: Regional or local. The regional model has the capacity to contribute an additional economic stratum but is only appropriate if there are several competing centres of gravity (jobs, residence, economic sectors). For the Montpellier test case, the local model was applied because the city of Montpellier represents the only centre of gravity.

3.1 Legend

Different options were considered by Montpellier partners and Montpellier stakeholders. In the end, they opted for Corine data as these seemed the most reliable in terms of reported quality. Figures 2 and 3 show these data. Since Moland has already been successfully applied in many occasions using Corine data (including Leipzig case study in PLUREL project), this choice was seen as a way to facilitate comparison with other case studies. For this reason, for calibration purposes and in order to suit the needs implicitly expressed by the storylines, reclassification of original Corine layers was undertaken. Results of this reclassification are shown in figures 4 and 5.

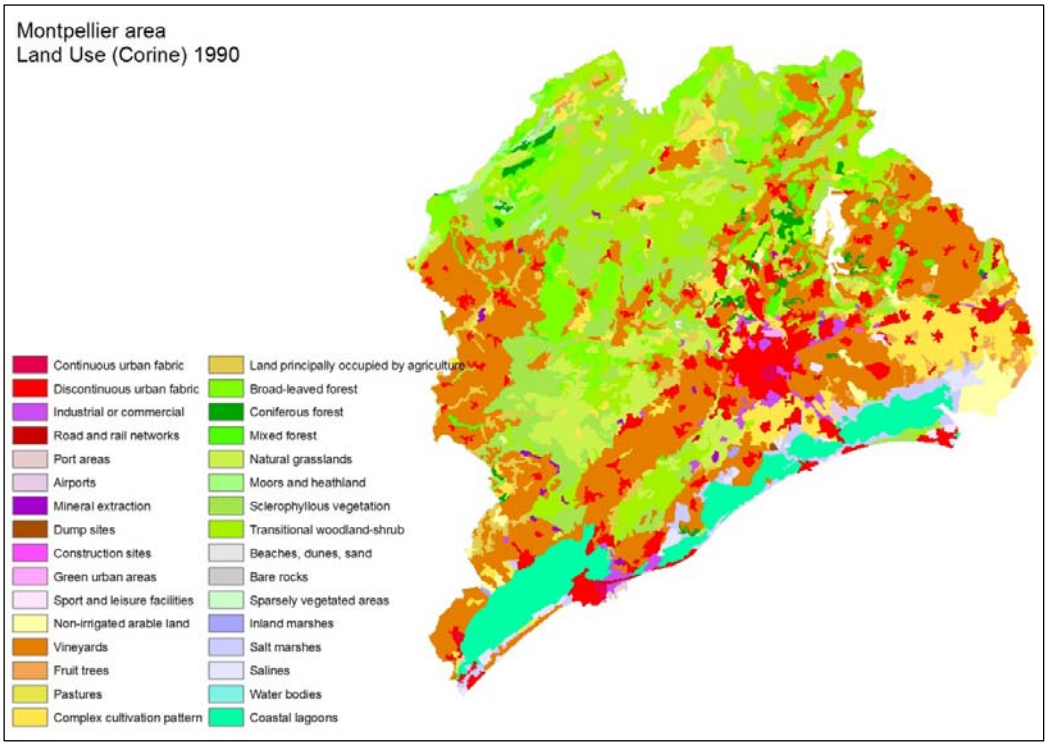


Figure 2. Original Corine data 1990. Montpellier area

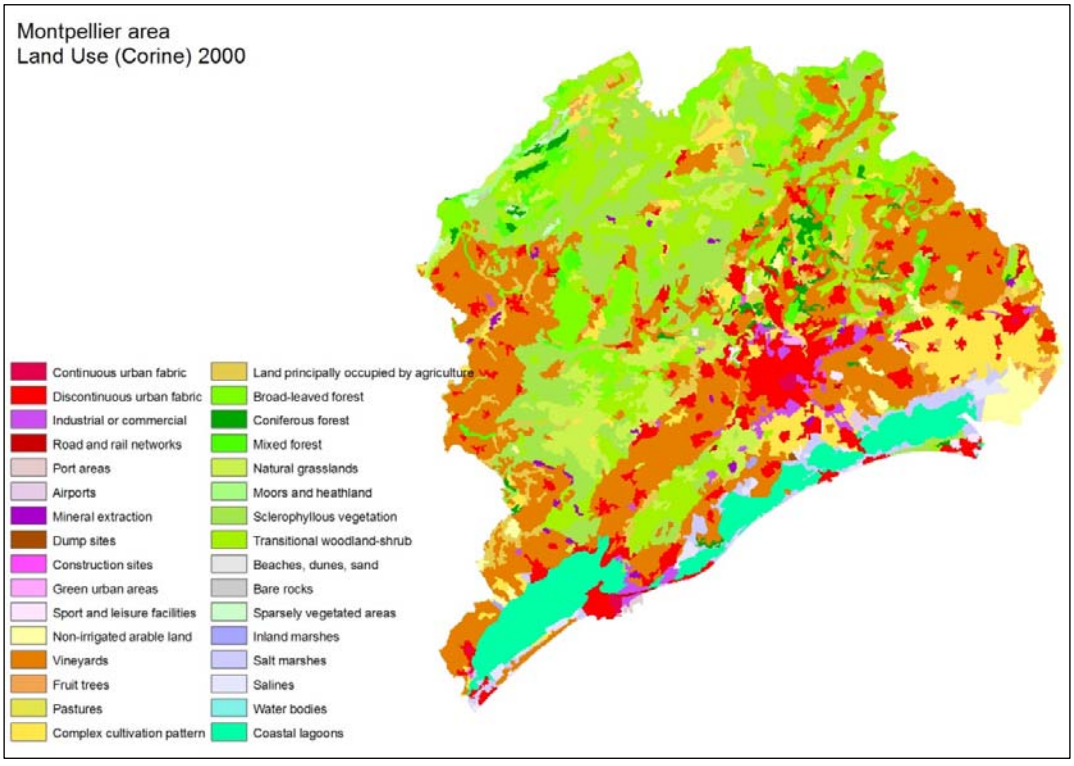


Figure 3. Original Corine data 2000. Montpellier area

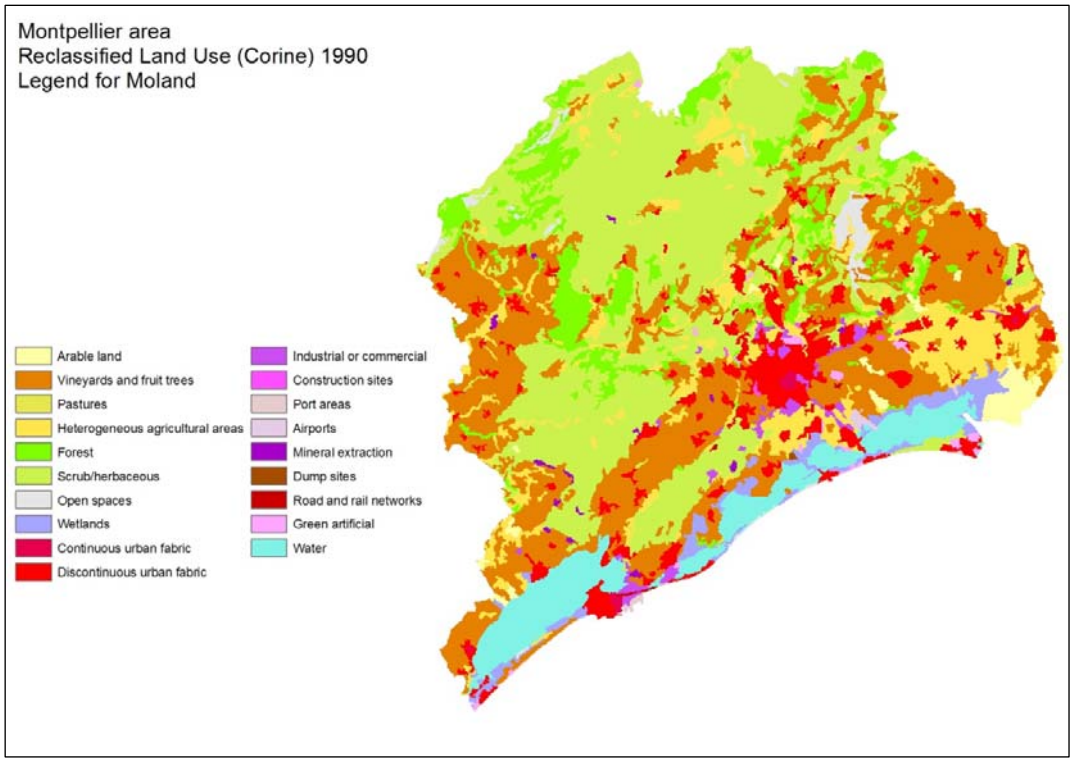


Figure 4. Reclassified Corine data 1990. Montpellier area

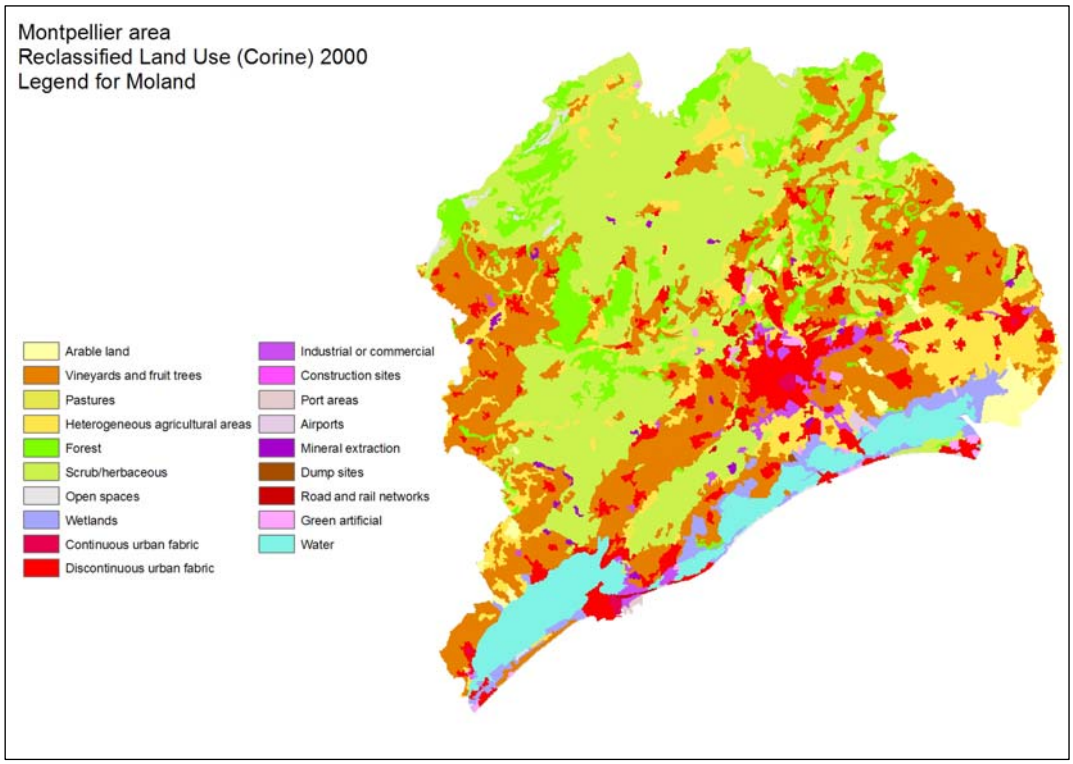


Figure 5. Reclassified Corine data 2000. Montpellier area

The reclassified Corine categories were ingested into Moland and grouped into vacant, functional and features classes, as required by the model (table 1).

Table 1. Montpellier land use legend and initial Moland parameters

Value	Category	Type
0	Arable land	Vacant
1	Vineyards	Vacant
2	Pastures	Vacant
3	Het. Agricultural	Vacant
4	Forest	Vacant
5	Shrub	Vacant
6	Sparsely vegetated	Vacant
7	Cont. urban fabric	Function
8	Discont. urban fabric	Function
9	Industrial/commercial	Function
10	Construction sites	Function
11	Port areas	Function
12	Airports	Function
13	Mineral extraction	Feature
14	Dump sites	Feature
15	Road and rail nets	Feature
16	Green artificial	Feature
17	Sand, dunes, rocks	Feature
18	Wetlands	Feature
19	Water	Feature

3.2 Land use 1990-2000

In the preliminary phases of the calibration process, the actual land use changes occurring for a determined window of time are examined in order to understand the dynamics of the region. Changes between 1990 and 2000 are summarized in table 2 and figure 6. Figure 7 shows the spatial distribution of areas have undergone changes. These trends in land cover change are used to drive the business as usual scenario.

Table 2. Changes in each category between 1990 and 2000

Category	1990 (ha)	2000 (ha)	Difference
Arable land	3155	3211	56
Vineyards	61225	60097	-1128
Pastures	110	89	-21
Het. Agricultural	22673	22516	-157
Forest	17492	18216	724
Scrub	72897	72564	-333
Open spaces	2800	1276	-1524
Wetlands	4905	4851	-54
Cont. Urban	453	453	0
Disc. Urban	15749	17220	1471
Industrial/comm.	2234	2821	587
Construction	151	128	-23
Ports	190	190	0
Airports	282	282	0
Mineral extraction	593	830	237
Dump sites	45	45	0
Road & Rail net.	162	171	9
Green artificial	938	1057	119
Water	13831	13868	37

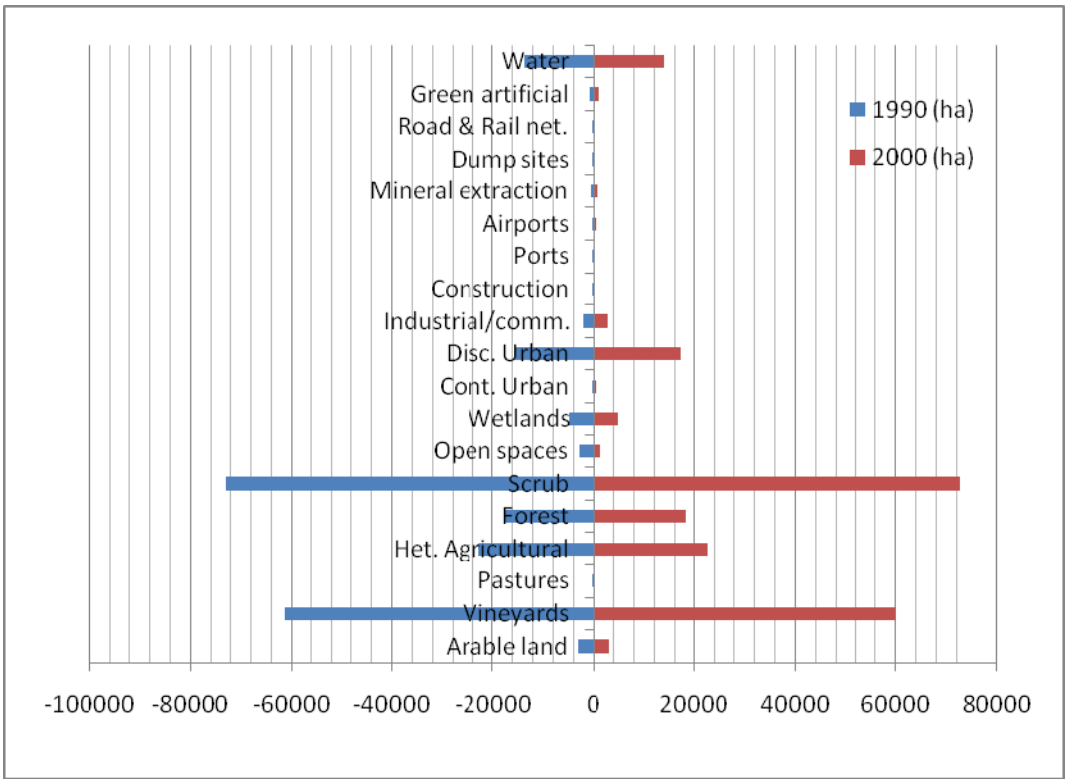


Figure 6. Land use changes (ha) between 1990 and 2000

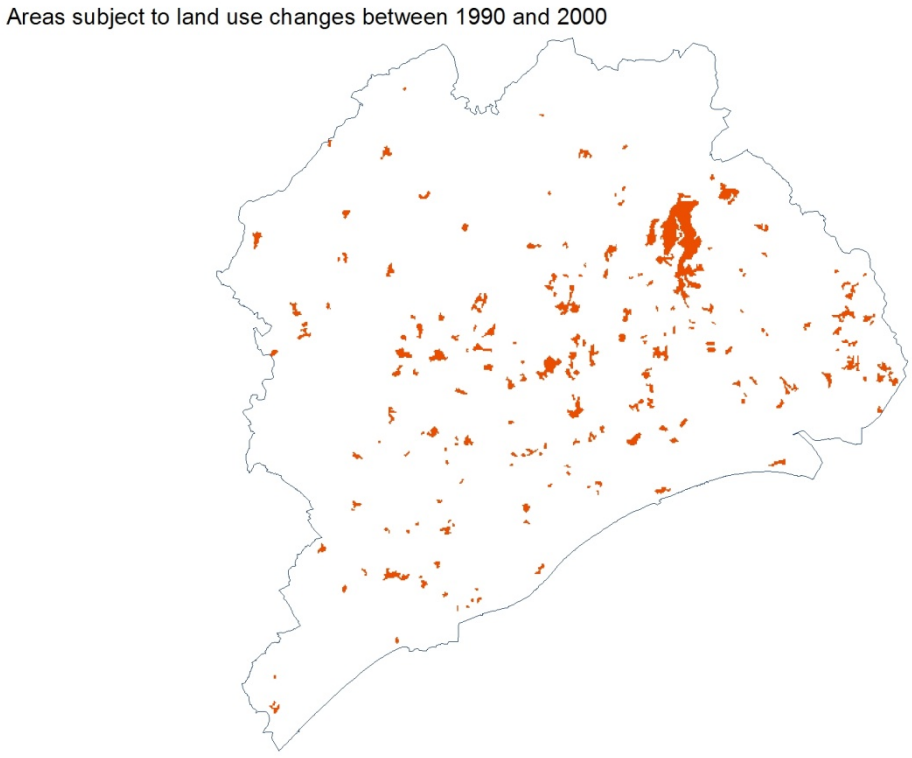


Figure 7. Areas experiencing land use changes between 1990 and 2000

The large area experiencing changes between 1990 and 2000 on the east side of the image corresponds to a bushfire. The area is covered in 2000 by scrub/herbaceous.

3.3 Transportation network

The transport layer used to compute accessibility maps is shown in figure 8. This layer contained motorways, main roads, railways and tramways

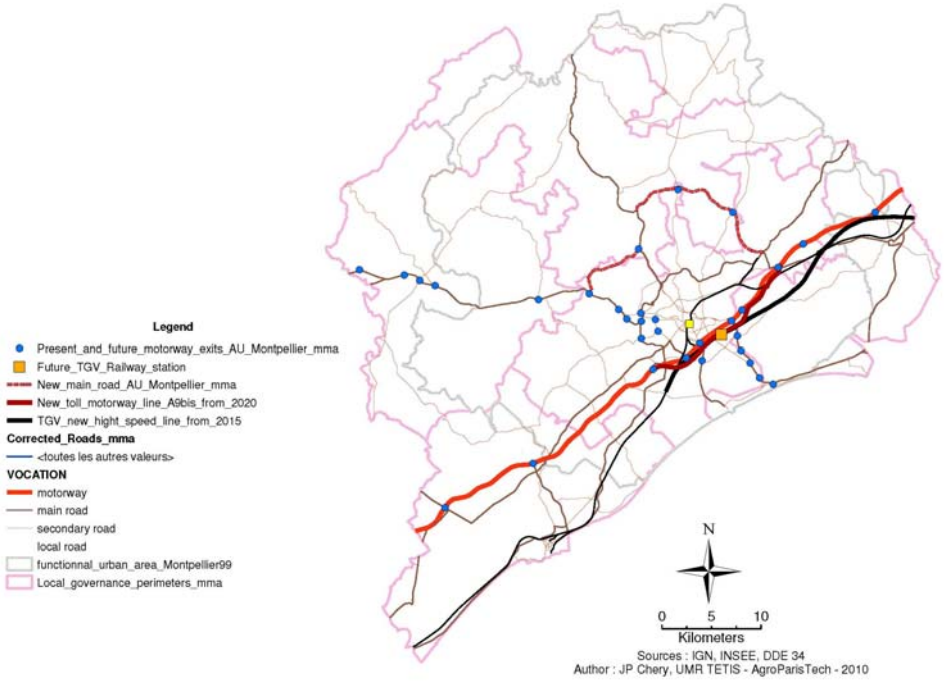


Figure 8. The transport network for the Montpellier test case

The following new extensions of were included in the simulation, according to the depicted storylines:

- Extension of tram line 3 – to be opened in 2015
- Extension of tram line 2 (West) – to be opened in 2015
- Extension of tram line 4 – to be opened in 2018
- Extension of tram line 2 (East) – to be opened in 2023
- Extension of tram line 5 - to be opened in 2023
- Settlement of the fast train connection TGV in 2015 (and relative station)
- New motorway A9bis from 2020

3.4 Zoning maps

The zoning maps play an important role in the model. They determine whether or not a land use is allowed.

Detailed zoning maps were provided for the Montpellier Metropolitan Agglomeration (referred to as MMA in this document) following the SCoT, territorial coherence scheme and were also assembled for the surrounding communes.

Figure 9 shows the zoning map for the overall study area. Figure 10 shows the delineation of the Montpellier Metropolitan Agglomeration (MMA).

The application of the zoning map followed the storylines depicted for each scenario.

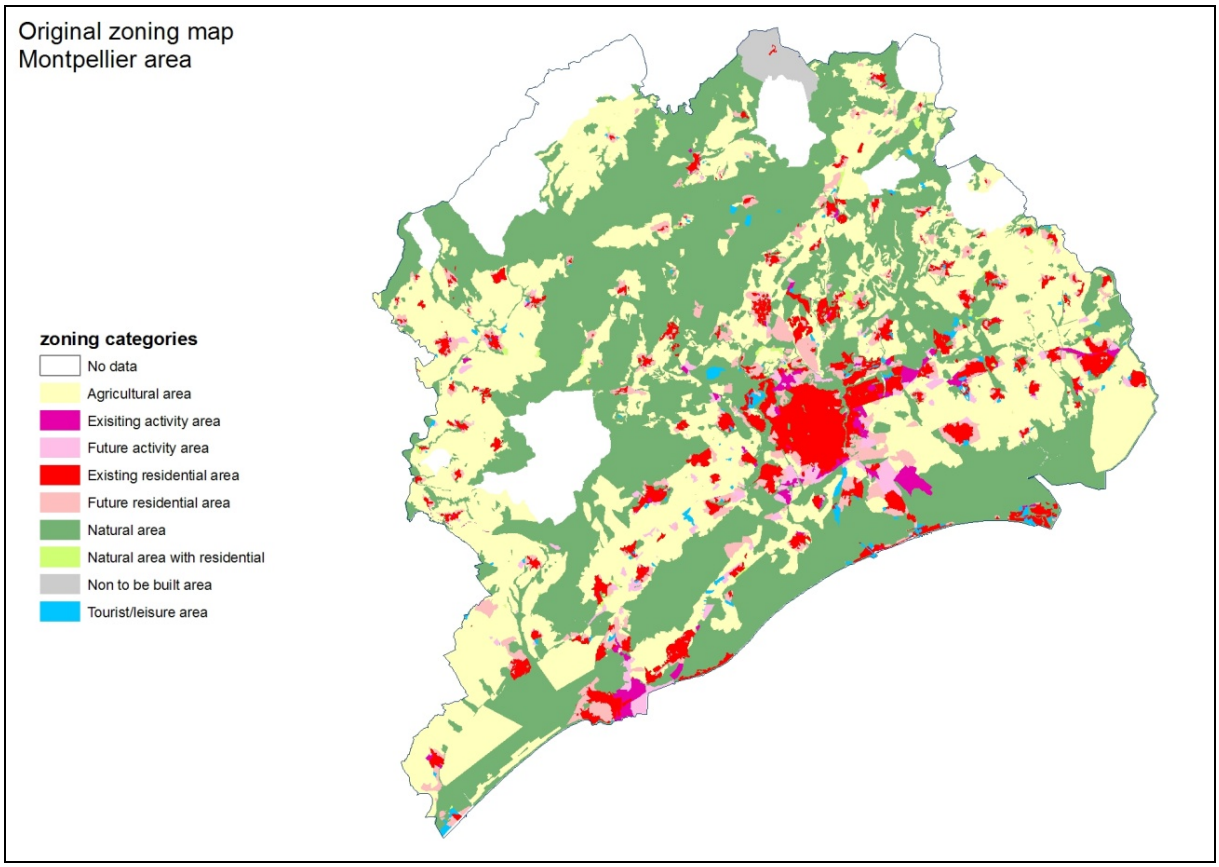


Figure 9. The zoning map for the overall Montpellier area

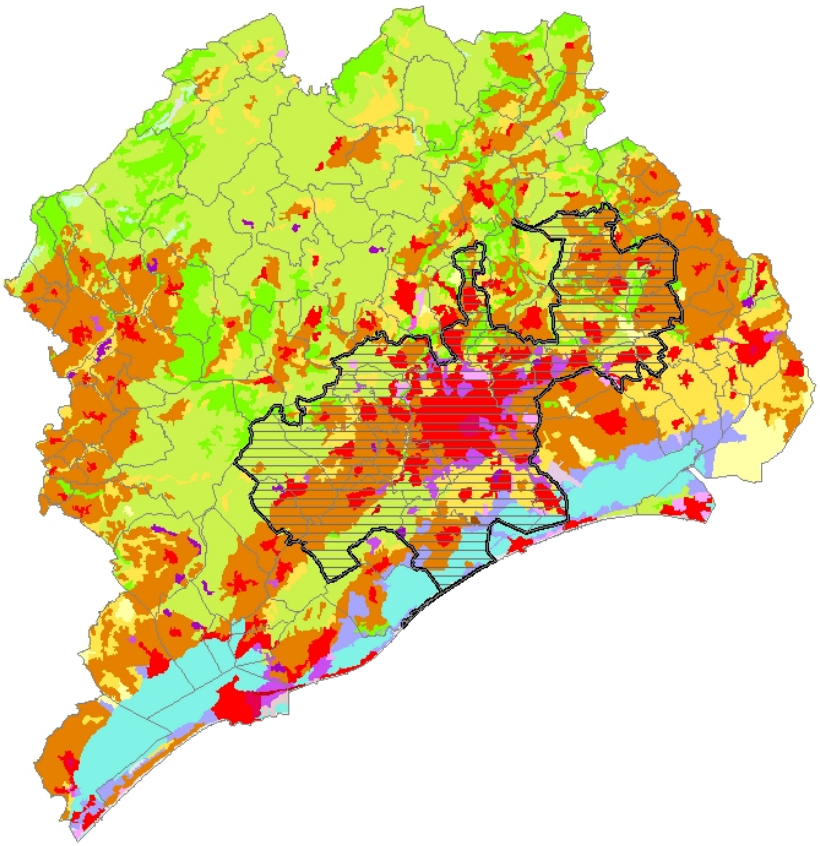


Figure 10 The Montpellier Metropolitan Agglomeration

Table 3 shows categories included in the original zoning map provided and the value assigned (1 –activity allowed- or 0 –activity not-allowed) to each of the functional classes.

Table 3. Assigned binary values to each of the functional classes based on original zoning map

	CUF	DUF	Airport	Port	Comm/ indust	Constr. site
Agricultural area	0	0	0	0	0	0
Existing activity area	0	0	1	1	1	1
Future activity area	0	0	1	1	1	1
Existing residential area	1	1	0	0	0	1
Future residential area	1	1	0	0	0	1
Natural area	0	0	0	0	0	0
Natural area with residential	0	1	0	0	0	0
Non to be built area	0	0	0	0	0	0

Tourist/leisure area	0	1	0	0	0	1

3.5 Suitability

Suitability maps in Moland represent natural-based areas where certain activities or land uses are better suited to expand while others are not. Moland requires a suitability map for each of the vacant classes in order to correctly allocate these classes. These maps range from 0 (least suitable) to 10 (most suitable). Tables 4-10 show parameters adopted for the production of each of the suitability maps and figures 11-17 show the maps produced.

Table 4. Parameters adopted for the production of a suitability map for "arable land"

	Slope (%)	Value assigned	Altitude	Value assigned	Land use	Value assigned
Arable land	0	0	< 0	0	Arable land	10
	0.01 - 3	10	0	0	Vineyards	3
	3 - 5	5	1 -1	2	Pastures	3
	> 5	0	1 - 2	8	Het. Agric	3
			2 - 50	10	Forest	0
			50 - 250	7	Shrub	3
			> 250	0	Sparsely	3
					All others	0

Suit_arable_land = INT [(slope + altitud + land_use)/3]<extract> built areas

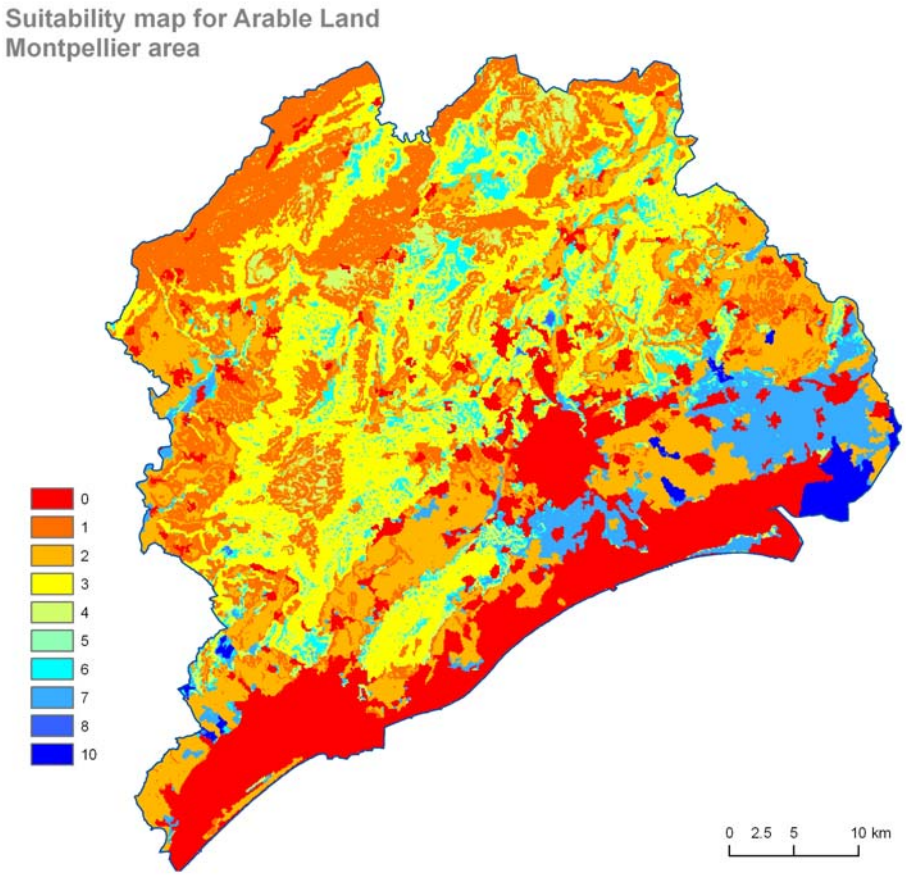


Figure 11. Suitability map for Arable land

Table 5. Parameters adopted for the production of a suitability map for "vineyards"

	Slope (%)	Value assigned	Altitude	Value assigned	Land use	Value assigned
Vineyards	0	0	< 0	0	All others	0
	0.01 - 3	10	0.01 - 50	10	Vineyards	10
	3 - 5	8	50 - 100	8		
	5 - 7	6	100 - 250	7		
	> 7	0	> 250	0		

Suit_vineyards = INT [(slope + altitud + land_use)/3]<extract> built areas

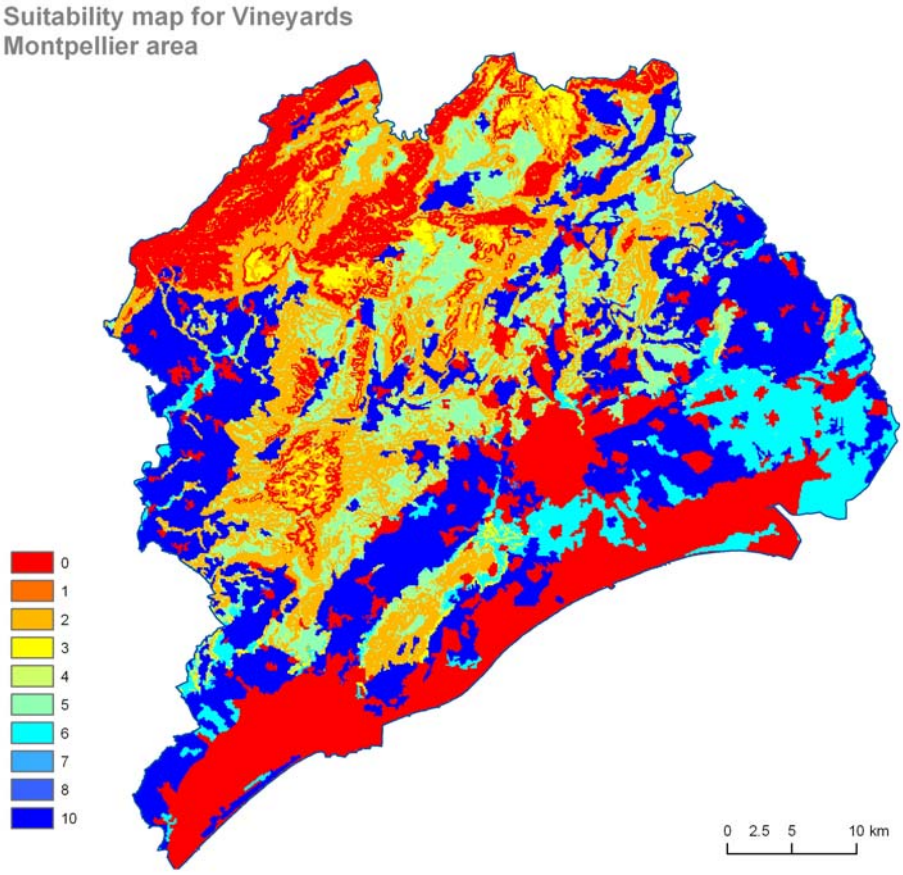


Figure 12. Suitability map for Vineyards

Pastures have a very limited presence in the area. Suitability map was produced by simply reclassifying land use classes according to the information provided in table 6.

Table 6. Parameters adopted for the production of a suitability map for “pastures”

	Land use	Value assigned
Pastures	Arable land	6
	Vineyards	6
	Pastures	10
	Het. Agric	6
	Forest	6
	Shrub	8
	Sparsely	8
	All others	0

Suit_pastures = Reclass 2000 land use

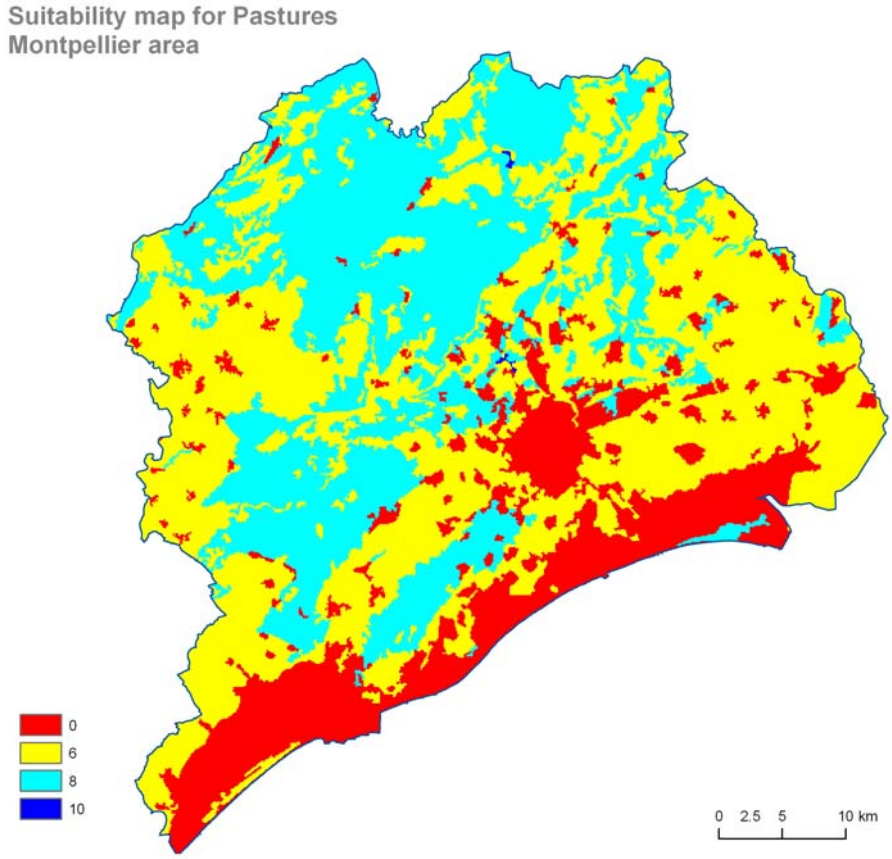


Figure 13. Suitability map for Pastures

Table 7. Parameters adopted for the production of a suitability map for “forests”

	Land use	Value assigned
Forest	Arable land	4
	Vineyards	4
	Pastures	4
	Het. Agric	6
	Forest	10
	Shrub	9
	Sparsely	8
	All others	0

Suit_forest = Reclass 2000 land use

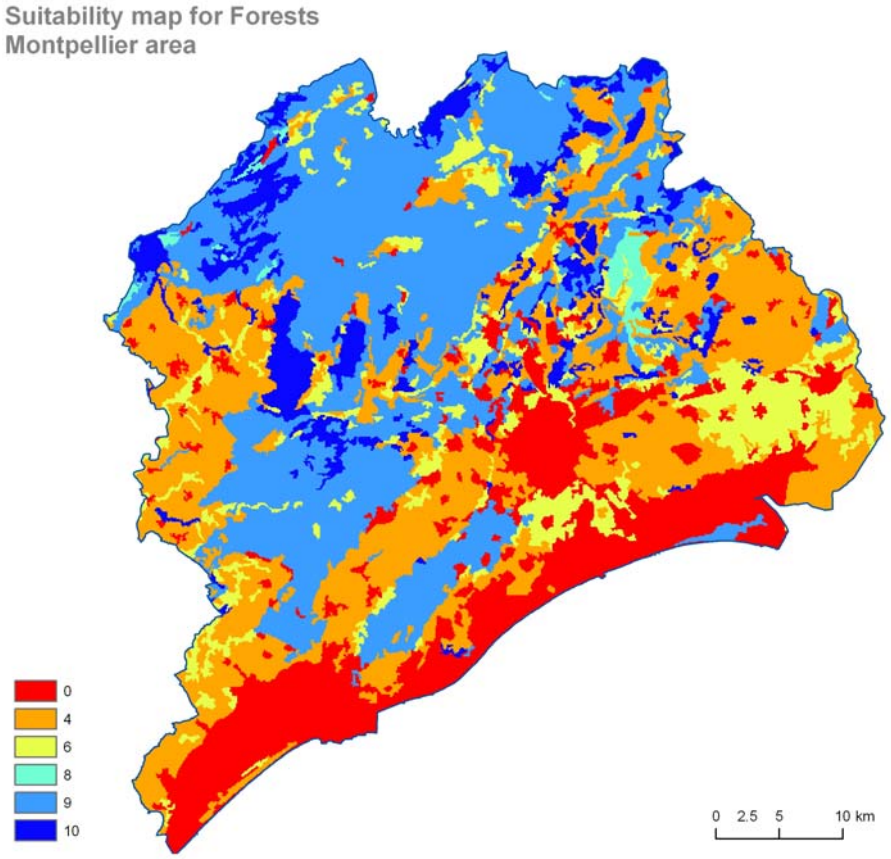


Figure 14. Suitability map for Forests

Table 8. Parameters adopted for the production of a suitability map for "heterogeneous agricultural areas"

	Land use	Value assigned
Het. Agric	Arable land	8
	Vineyards	8
	Pastures	4
	Het. Agric	10
	Forest	2
	Shrub	3
	Sparsely	4
	All others	0

Suit_het.agric = Reclass 2000 land use

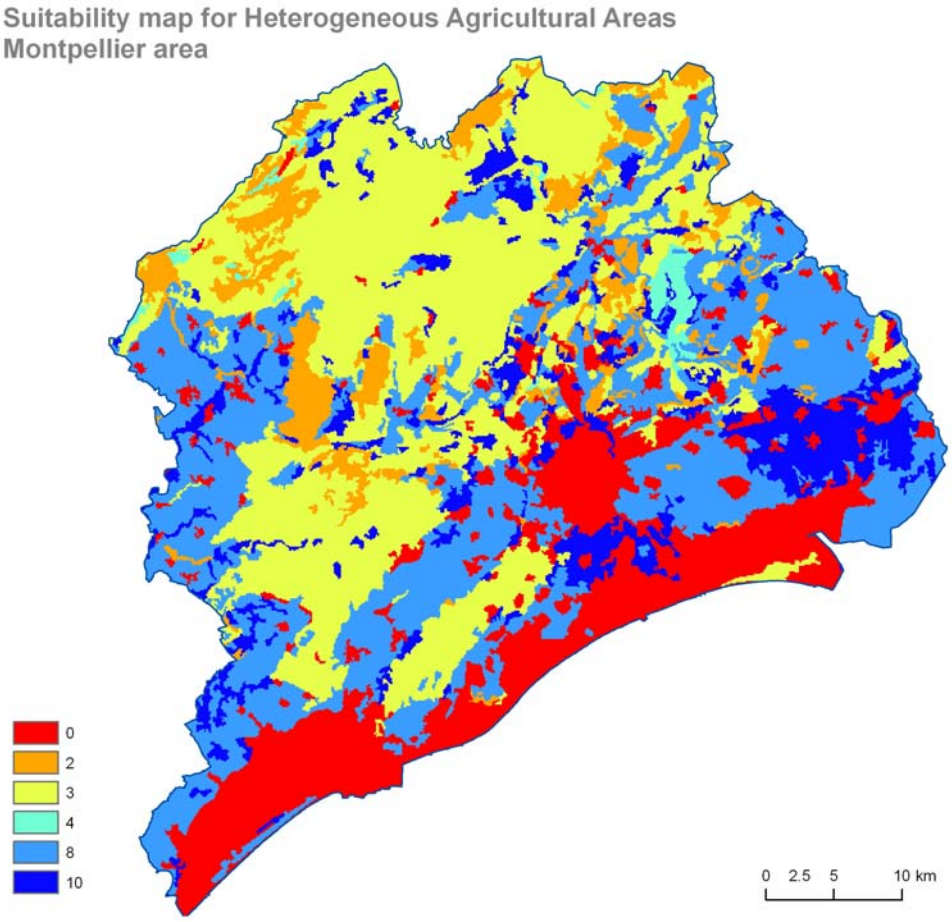


Figure 15. Suitability map for Heterogeneous Agricultural Areas

Table 9. Parameters adopted for the production of a suitability map for “shrub”

	Land use	Value assigned
Shrub	Arable land	3
	Vineyards	2
	Pastures	5
	Het. Agric	5
	Forest	1
	Shrub	10
	Sparsely	8
	All others	0

Suit_shrub = Reclass 2000 land use

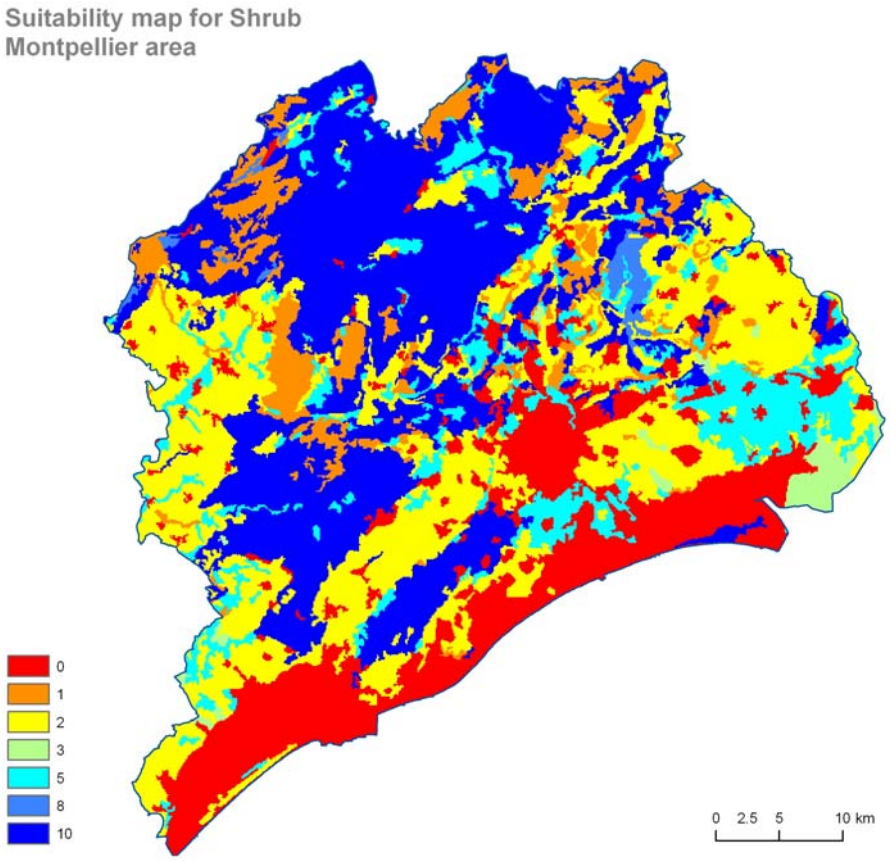


Figure 16. Suitability map for Shrub

Table 10. Parameters adopted for the production of a suitability map for “sparsely vegetated areas”

	Slope (%)	Value assigned	Altitude	Value assigned	Land use	Value assigned
Sparsely vegetated	0	0	< 25	0	Arable land	3
	0.01 - 3	1	25 - 100	2	Vineyards	0
	3 - 5	2	100 - 200	3	Pastures	5
	5 - 10	5	200 - 500	6	Het. Agric	2
	10 - 15	6	> 500	8	Forest	0
	15 - 25	7			Shrub	5
	> 25	10			Sparsely	10
					All others	0

Suit_sparsely = [INT (slope + altitud + land_use)/3]<extract> built areas

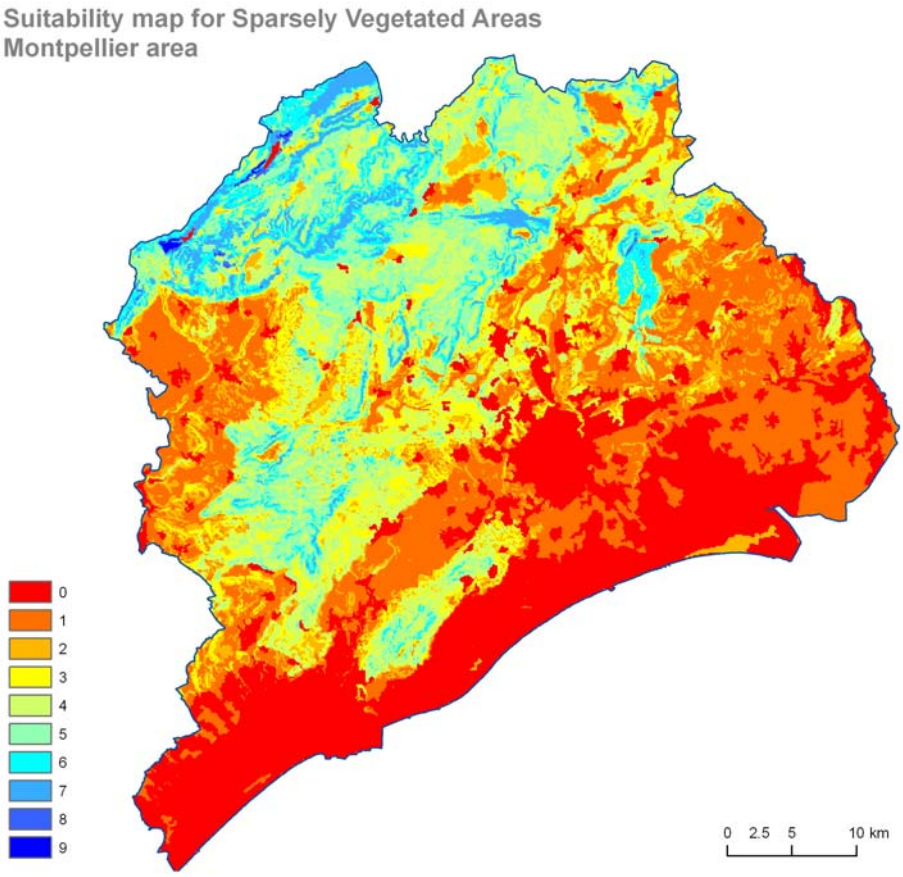


Figure 17. Suitability map for Sparsely Vegetated Areas

3.6 Calibration

Calibration was undertaken using the reclassified Corine layers of 1990 and 2000 shown in figures 4 and 5. Both suitability maps and neighborhood effects were included in the calibration process. The Kappa index results for the comparison between the Corine Land Cover 2000 and the simulated result using Moland for 2000 are shown in annex b (table b1).

4. Results

Several indicators were calculated for the Montpellier test case. The choice of these had been agreed upon by stakeholders for the different case studies during PLUREL workshops. Some indicators were not possible to calculate without ancillary data. For example, it was not possible to assess population numbers or population densities in the absence of statistics associated to densities for the

residential land use categories continuous and discontinuous urban. Below is a summary of the statistics calculated for the Montpellier test case.

1. Total amount of new urban land.
2. Amount of urban land by RUR typology (figure 18).
3. Amount of new urban land per new inhabitant. The density of residential classes is a parameter used to manipulate scenarios and is therefore not an indicator, but rather a driver. This data is shown for the respective scenarios.
4. Lost farmland and / or valuable nature.

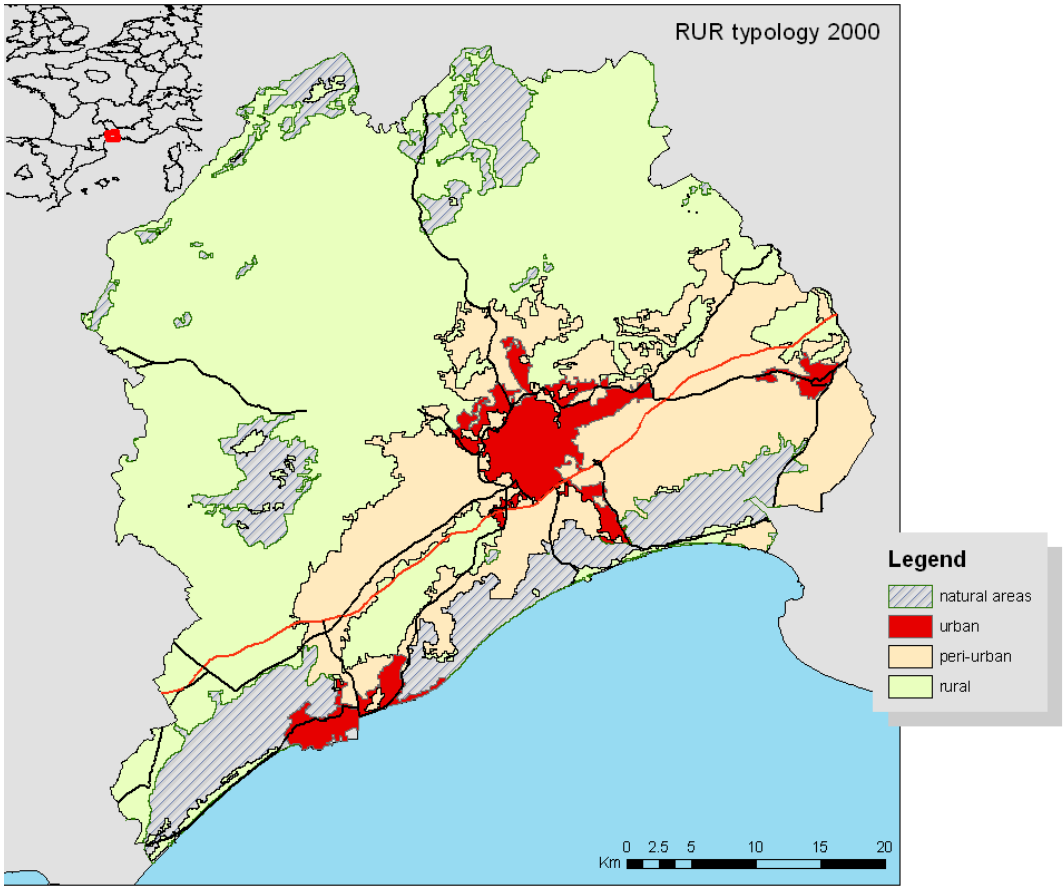


Figure 18. The RUR typology for the Montpellier test case

Table 11 summarises the categorization used in the calculations of the statistics.

Table 11. The statistical re-classification of the legend.

Class name	statistical category	statistical category
Arable land Vineyards & fruit trees Pastures Heterogeneous agricultural	farmland	
Forest Shrub Sparsely vegetated	natural	
Continuous urban fabric Discontinuous urban fabric Industrial and commercial	urban land	built-up
Construction sites Port Airport Mineral extraction Dump sites Road and Rail networks		
Green artificial Sand, dunes, bare rocks Wetlands Water	unchanged	

One specific observation concerns the “construction sites” present in the Corine Land Cover map for year 2000. The transformation of this land use class is difficult to control (i.e. to be parameterised in the model) without prior knowledge of trends in construction class conversions (e.g.: zoning and suitability maps) and timeline (this is true for all scenarios). The model assumes that ‘construction sites’ are a transitional land use class whose dynamics is governed mainly by the stochastic perturbation coefficient which typically accounts for phenomena without specific transition rules and for the stochastic (or probabilistic) aspects of the land use evolution (for ex. : scatter in land use patterns, irregularities of spatial clusters etc.).

4.1 Business as Usual (old-BAU)

The main characteristics for this scenario (referred to as the ‘back to the old business as usual’ – see Annex I for details) are:

- abandonment of existing planning tool (SCoT) which means back to uncontrolled land business and urban sprawl, as experienced in the past in Montpellier city-region;
- demographic growth of 1.3 % per year
- A9 highway is doubled, TGV is built up and operated from 2020 – no additional public infrastructures are set up.

Figure 19 shows the resulting land use map for the business as usual scenario, run until 2025.

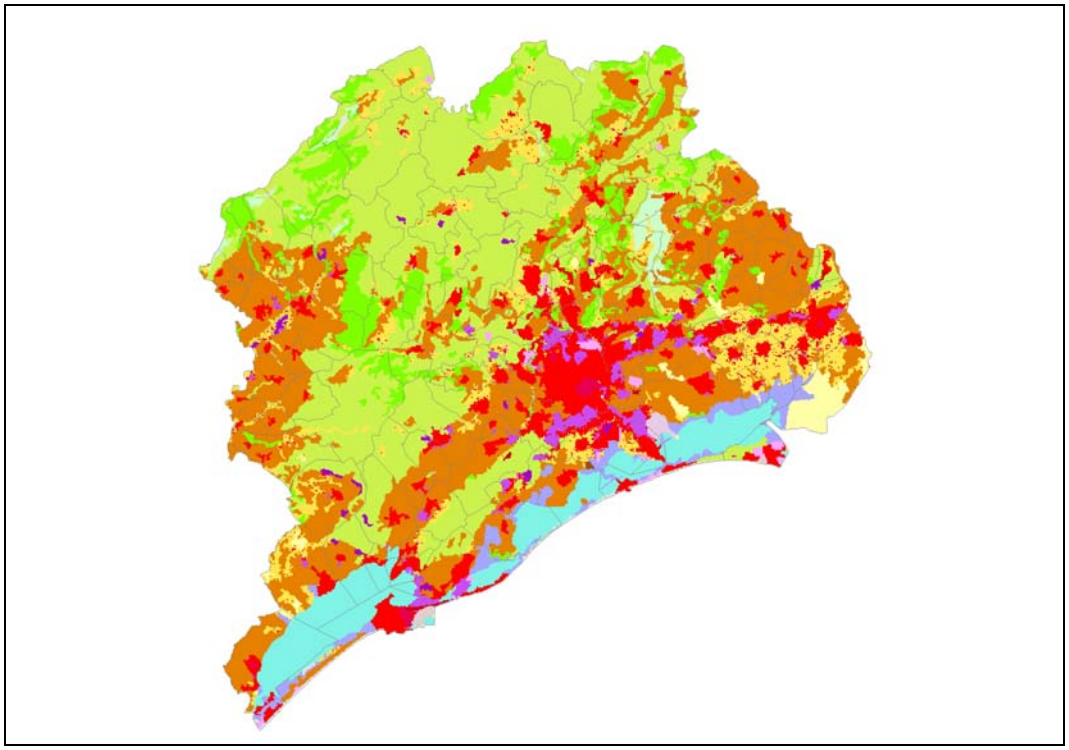


Figure 19. The output of the old-BAU scenario for 2025.

Table 12 summarises the changes in land use for the overall area from 2000 to 2025 according to the old-BAU scenario:

Table 12. Changes (ha) in land use classes from 2000-2025.

	2000 (ha)	2025 (ha)	%
Arable land	3211	3247	1.1%
Vineyards & fruit trees	60097	59310	-1.3%
Pastures	89	8	-91.0%
Heterogeneous agricultural	22516	17344	-23.0%
Forest	18216	17322	-4.9%

Shrub	72564	71118	-2.0%
Sparsely vegetated	674	2180	223.4%
Continuous urban fabric	453	650	43.5%
Discontinuous urban fabric	17220	22000	27.8%
Industrial and commercial	2821	4372	55.0%
Construction sites	128	250	95.3%
Port	190	260	36.8%
Airport	282	400	41.8%
Mineral extraction	830	830	0.0%
Dump sites	45	45	0.0%
Road and Rail networks	171	171	0.0%
Green artificial	1057	1057	0.0%
Sand, dunes, bare rocks	602	602	0.0%
Wetlands	4851	4851	0.0%
Water	13987	13987	0.0%

Figure 20 shows the differences between 2000 and 2025 for the continuous urban fabric class. This class includes housing density of type A (> 50 houses/ha) and B (> 30 houses/ha), as identified in the SCoT planning maps.

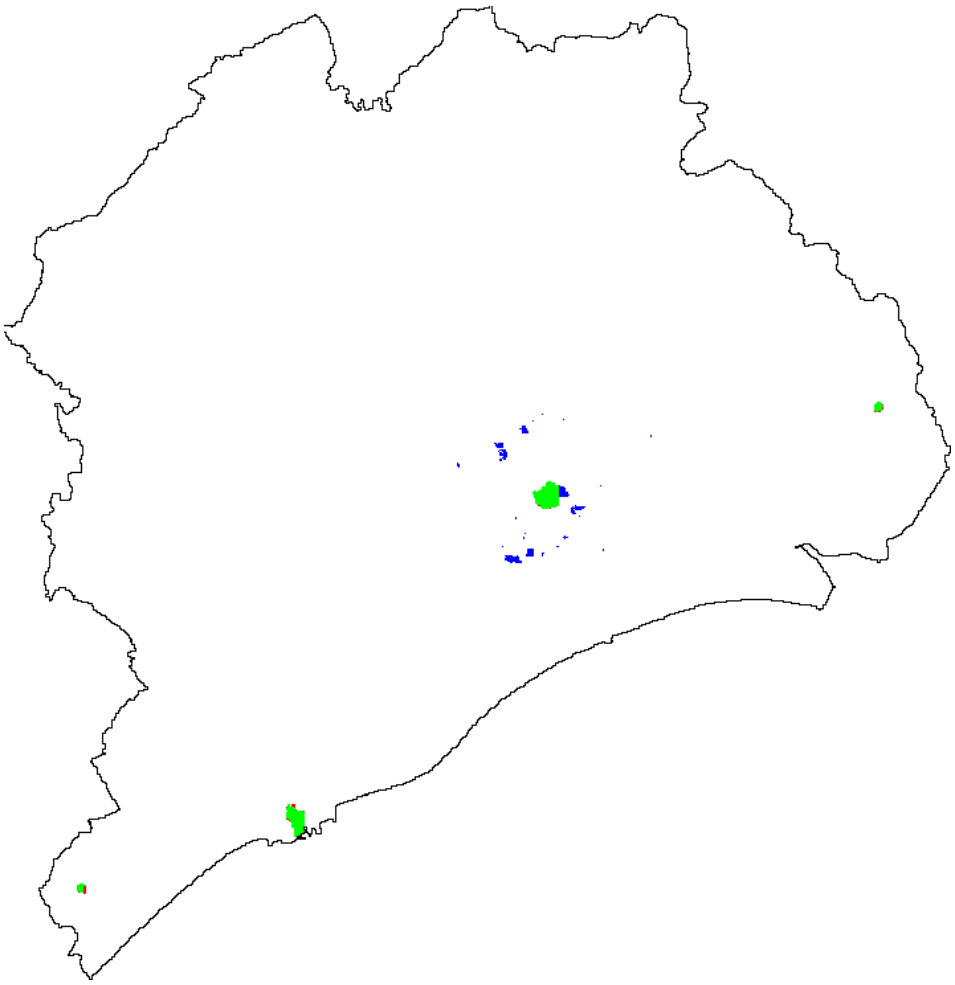


Figure 20. Growth of continuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

Figure 21 shows the differences between 2000 and 2025 for the discontinuous urban fabric class. This class includes housing density of type C (> 20 houses/ha) and also sparse residential fabric – with less density. Phenomena of urban sprawl are clearly visible not only around the main urban area of Montpellier, but also along specific directions of development.

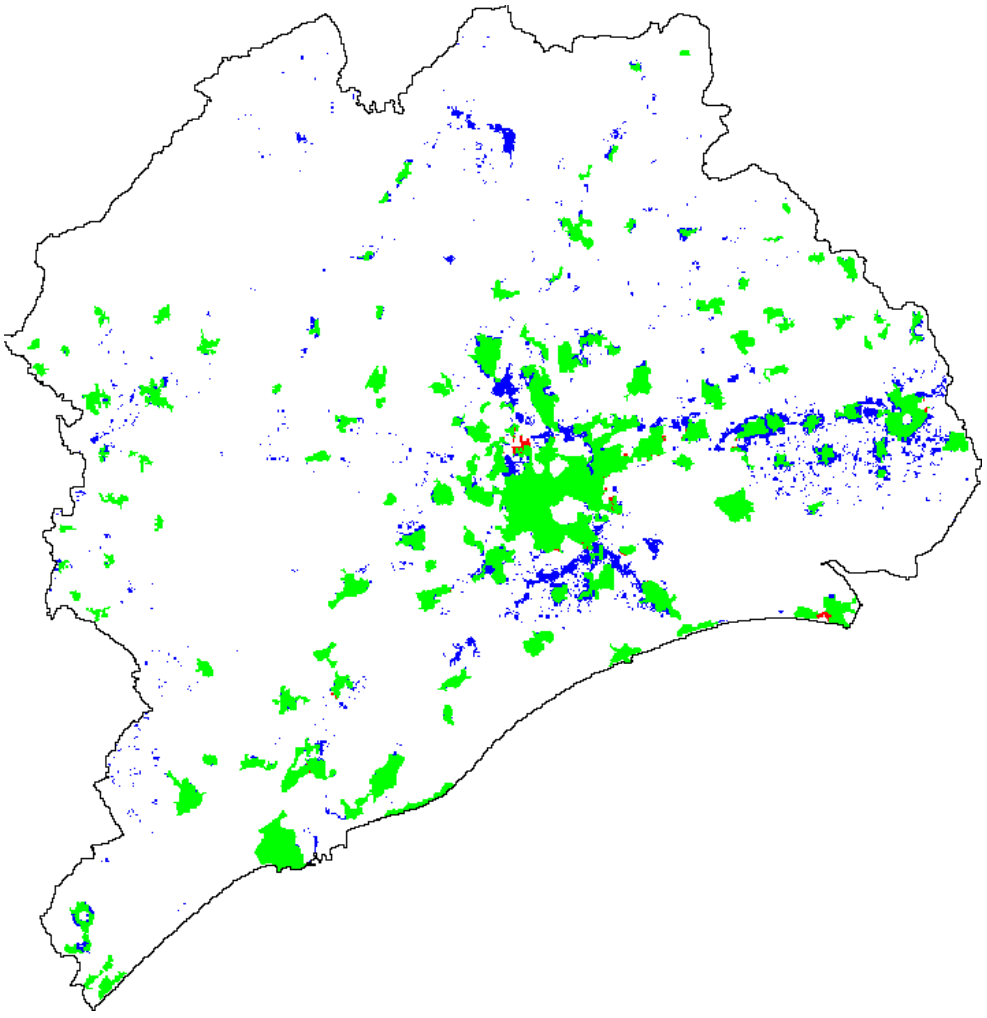


Figure 21. Growth of discontinuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000.

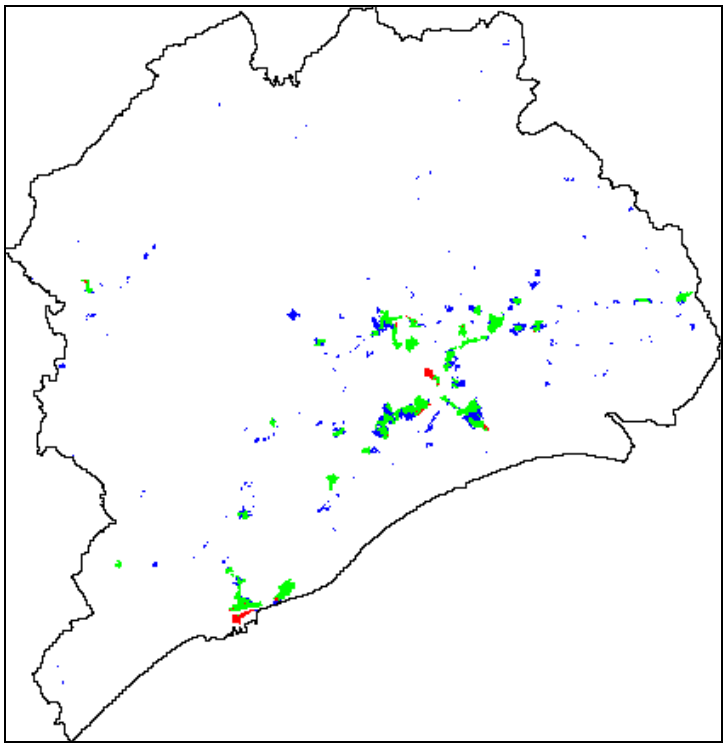


Figure 22 : Growth of industrial and commercial areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

The amount of new urban land was looked at as subdivided by the RUR typology. Table 13 summarises the growth in the RUR areas for urban land (defined as the sum of continuous fabric, discontinuous fabric and industrial/commercial areas). The decrease in urban land is due to the increase in port and airport surfaces.

Table 13. The expansion of urban and built up areas for the BAU scenario between 2000 to 2025.

Old-BAU	Change in amount of urban land (ha)		
	Urban	Peri-urban	Rural
URBAN LAND	-85	+4832	+1732

4.2 Hyper Tech (Long March Hypertech) (variant HT1)

The "long March Hyper Tech" HT1 scenario has been conceived by the stakeholders to represent the current planning situation The key planning instrument is the SCoT, which is extended beyond the Montpellier Agglomeration area.

The main characteristics for this scenario (referred to as the 'Long March or the advent of the hypertech metropolis' – see Annex I for details) are:

- Reinforcement of planning tool (SCoT), based on the reinforcement of the power of the local government, aiming towards high building density and precise urban limits.
- demographic growth of about 2% per year
- Technological and economic booming
- A9 highway is doubled, TGV is built up and operated from 2020
- new tramway network gradually put in service
- increased accessibility and mobility
- preservation of natural areas and agriculture

Figure 23 shows the output for the HT1 scenario for 2025.

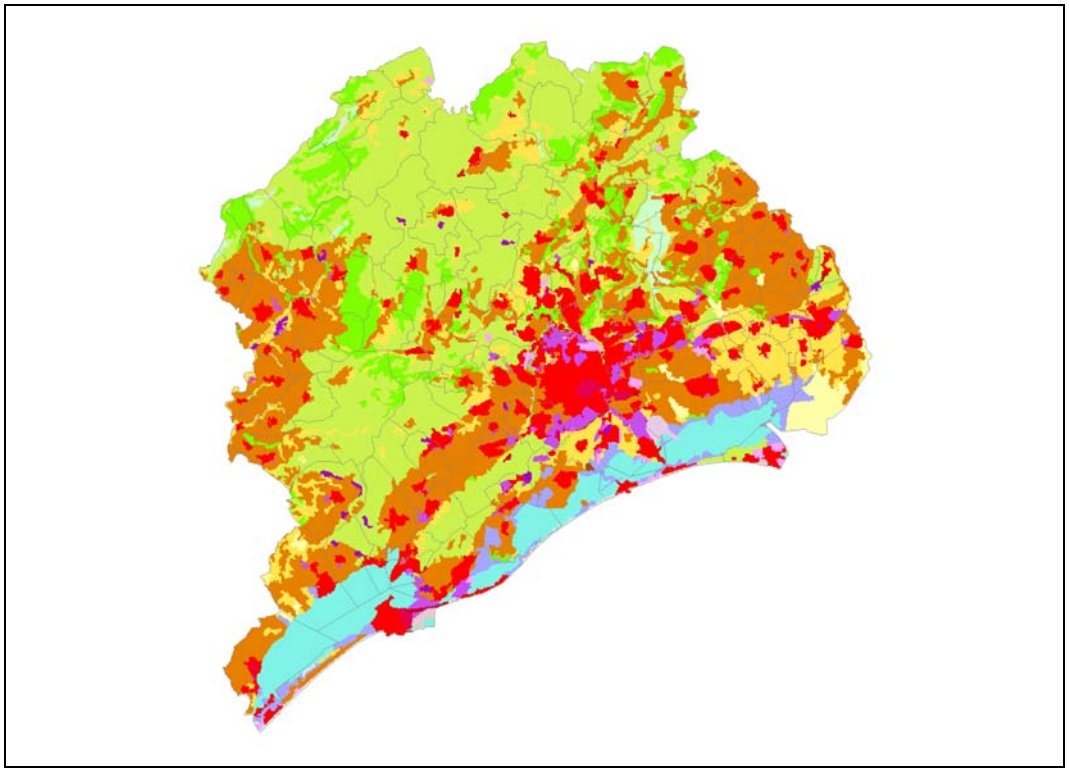


Figure 23. Land use map for the long March HT1 scenario for 2025.

The changes from one land use class to another form 2000 to 2025 according to the HT1 scenario are summarised in table 14.

Table 14. Land use changes in ha for the HT1 scenario, from 2000 to 2025.

	2000 (ha)	2025 (ha)	
%Arable land	3211	3215	0.1%
Vineyards & fruit trees	60097	56651	-5.7%

Pastures	89	71	-20.2%
Heterogeneous agricultural	22516	19988	-11.2%
Forest	18216	17238	-5.4%
Shrub	72564	70836	-2.4%
Sparsely vegetated	674	2180	223.4%
Continuous urban fabric	453	1000	120.8%
Discontinuous urban fabric	17220	22000	27.8%
Industrial and commercial	2821	4372	55.0%
Construction sites	128	250	95.3%
Port	190	260	36.8%
Airport	282	400	41.8%
Mineral extraction	830	830	0.0%
Dump sites	45	45	0.0%
Road and Rail networks	171	171	0.0%
Green artificial	1057	1057	0.0%
Sand, dunes, bare rocks	602	602	0.0%
Wetlands	4851	4851	0.0%
Water	13987	13987	0.0%

The increase of continuous urban fabric (+ 120%) is the key relevant spatial feature for this scenario. Figure 24 shows the development of high density housing mainly within the Montpellier agglomeration.

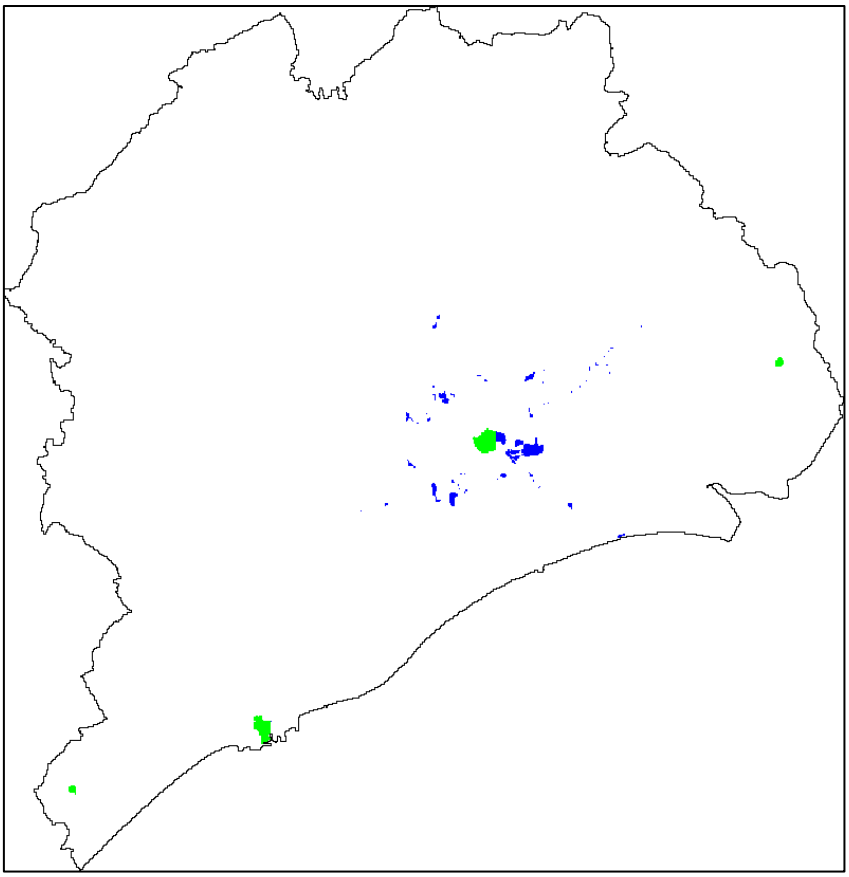


Figure 24 : HT1 Growth of continuous urban fabric areas. ■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

Commuting is encouraged by increasing mobility – but residential developments remain concentrated around main communication infrastructure. Figure 25 shows the increase of discontinuous urban fabric.

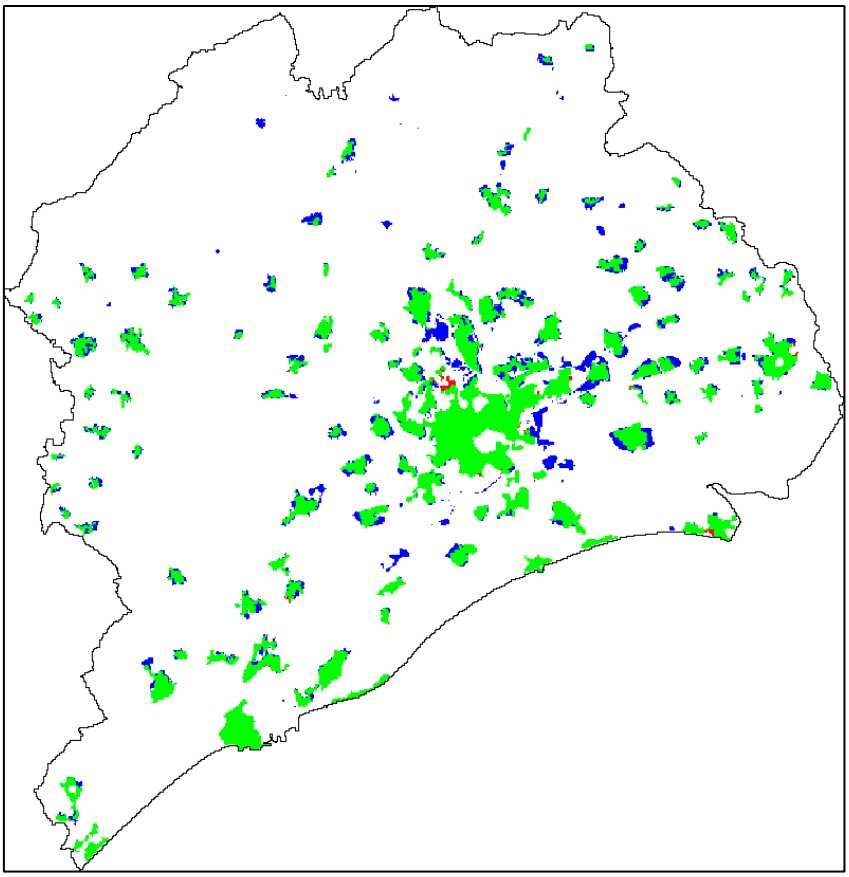


Figure 25 : HT1 Growth of discontinuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

Industrial areas (Figure 26) are also developing along main transportation corridors. However, because of the economic set up for this scenario, new firms and commercial activities related to agriculture are represented by sparse developments all over the study area.

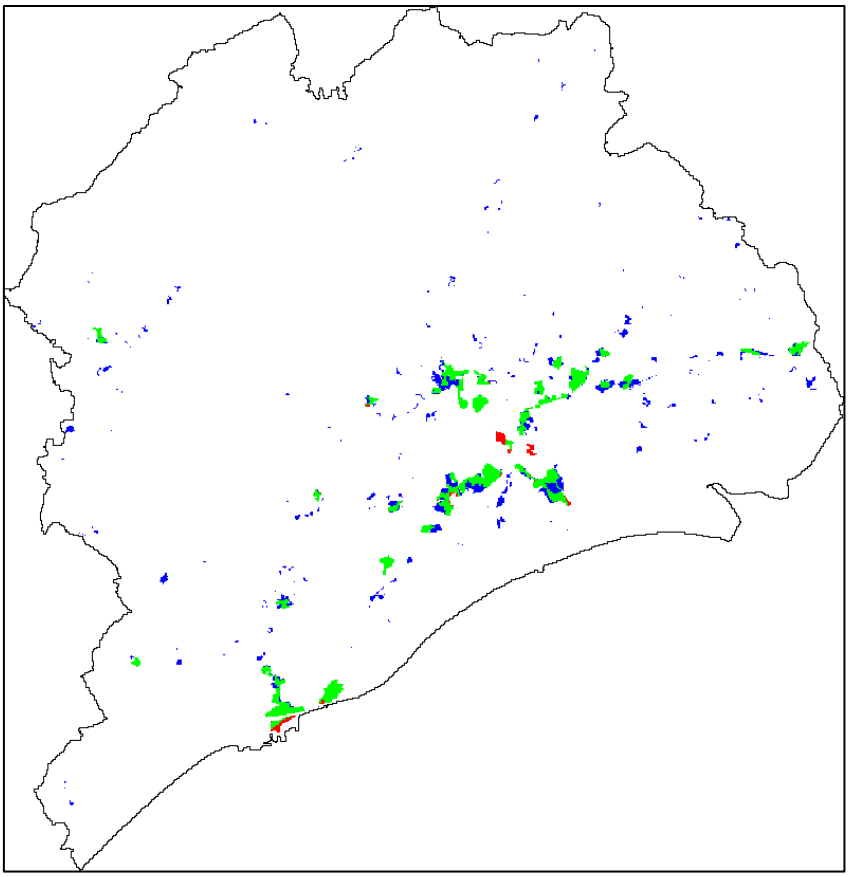


Figure 26 : HT1 Growth of industrial and commercial areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

The statistics relative to the RUR typology (Table 15) show a net increase of urban land (sum of continuous/discontinuous urban fabric and of industrial/commercial areas) in the peri-urban and rural areas. The decrease in the urban area is given by the transformation of industrial areas and discontinuous urban fabric in port and airport areas (red spots in figure 25 and 26).

Table 15. The changes in urban and impervious surfaces by RUR typology for the HT1 scenario

HT	Change in amount of urban land (ha)		
	Urban	Peri-urban	Rural
URBAN LAND	-62	4402	2518

4.2 Hyper Tech (Long March Hypertech) (variant HT2)

The “long March Hyper Tech” scenario has been conceived by the stakeholders to represent the current planning situation The key planning instrument is the SCoT, which is applied only within the Montpellier Agglomeration area.

The main characteristics for this scenario (referred to as the ‘Long March or the advent of the hypertech metropolis’ – see Annex I for details) are:

- SCoT is applied only within MMA. Constructions are permitted without limitation outside MMA
- demographic growth of about 2% per year
- Technological and economic booming
- A9 highway is doubled, TGV is built up and operated from 2020
- new tramway network gradually put in service
- increased accessibility and mobility
- preservation of natural areas and agriculture.

Figure 27 shows the output for the HT2 scenario for 2025.

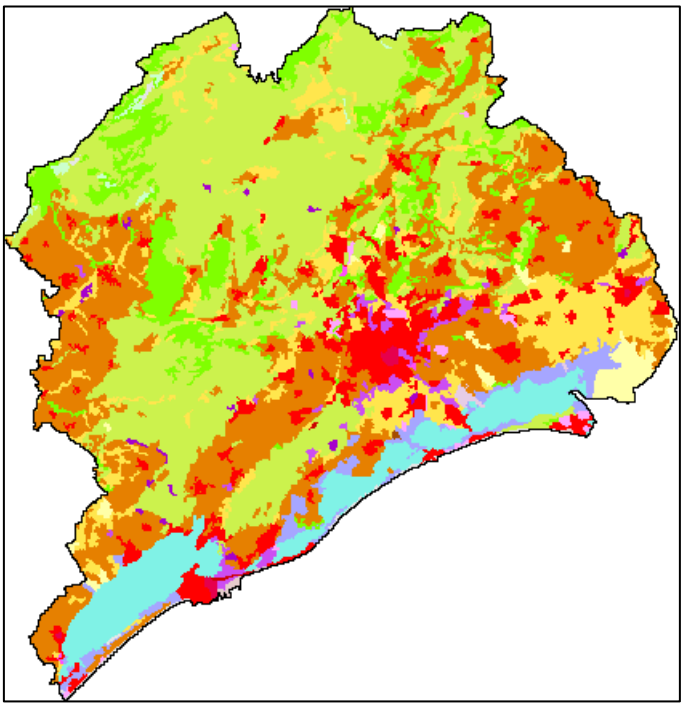


Figure 27. Land use map for long March HT2 scenario for 2025.

Land use changes for HT2 are given in table 14a

	2000 (ha)	2025 (ha)	diff (ha)	%
Arable land	3211	3211	0	0.0%
Vineyards & fruit trees	60097	56290	-3807	-6.3%
Pastures	89	74	-15	-16.9%
Heterogeneous agricultural	22516	20132	-2384	-10.6%
Forest	18216	17299	-917	-5.0%
Shrub	72564	70993	-1571	-2.2%
Sparsely vegetated	674	2180	1506	223.4%
Continuous urban fabric	453	1000	547	120.8%
Discontinuous urban fabric	17220	22000	4780	27.8%
Industrial and commercial	2821	4372	1551	55.0%
Construction sites	128	250	122	95.3%
Port	190	260	70	36.8%
Airport	282	400	118	41.8%
Mineral extraction	830	830	0	0.0%
Dump sites	45	45	0	0.0%
Road and Rail networks	171	171	0	0.0%
Green artificial	1057	1057	0	0.0%
Sand, dunes, bare rocks	602	602	0	0.0%
Wetlands	4851	4851	0	0.0%
Water	13868	13868	0	0.0%

Since the drivers (population and GDP) are identical – there are no major differences in the overall statistics between HT1 and HT2 – over the total area.

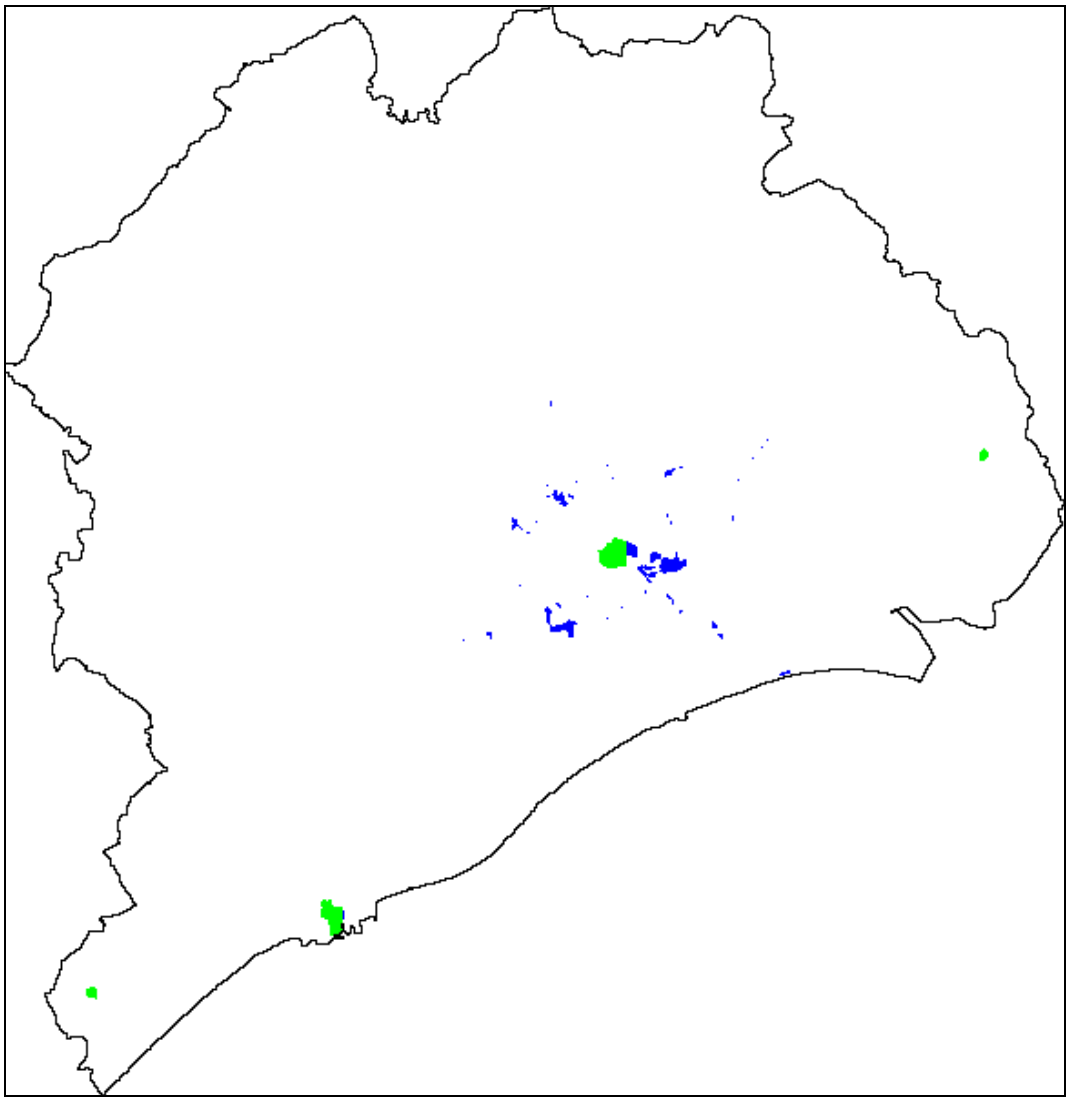


Figure 28 : HT2 Growth of continuous urban fabric areas. ■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

Commuting is encouraged by increasing mobility – but residential developments remain concentrated around main communication infrastructure. Figure 29 shows the increase of discontinuous urban fabric.

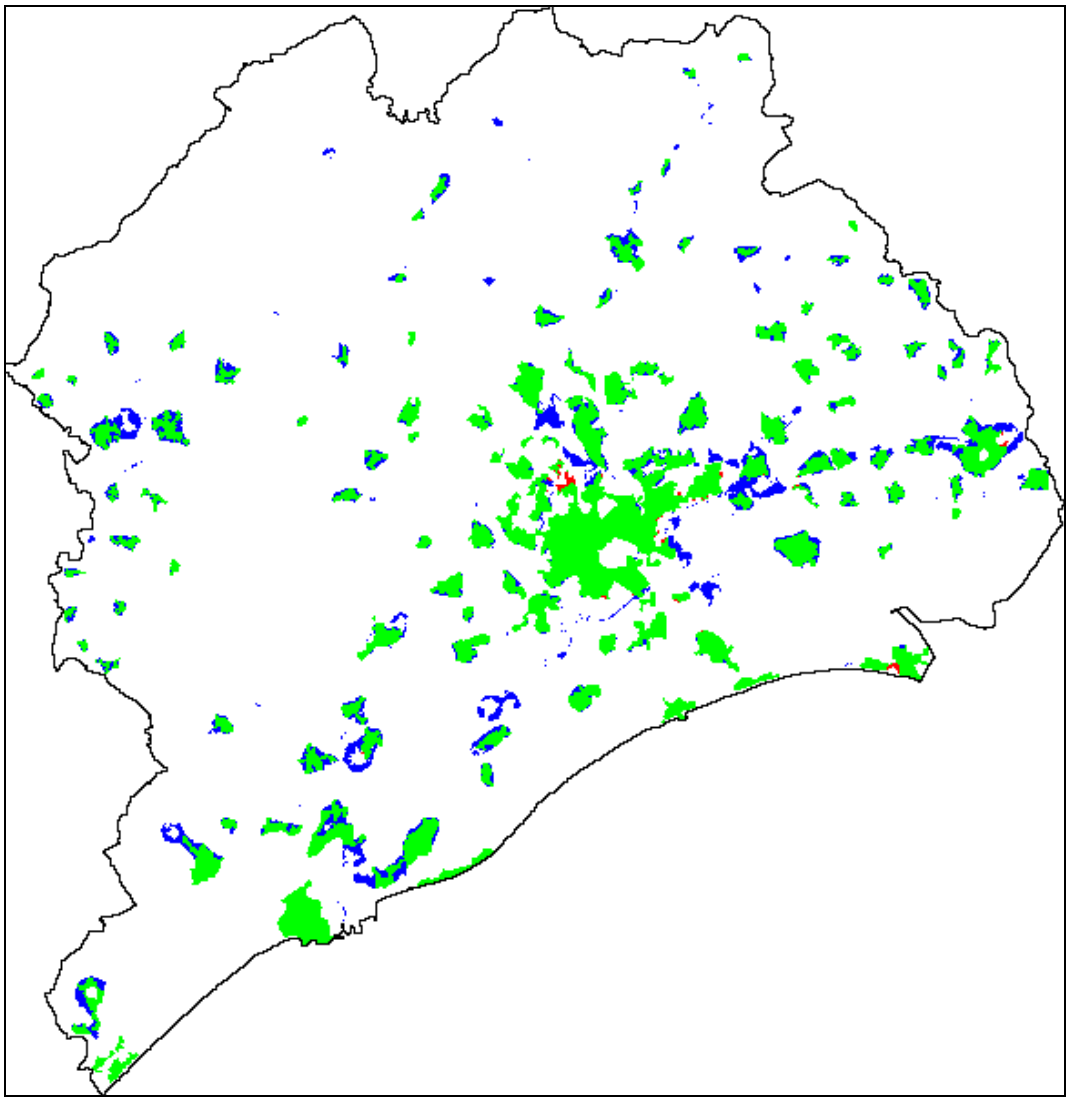


Figure 29 : HT2 Growth of discontinuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

Industrial areas (Figure 30) are also developing along main transportation corridors. However, because of the economic set up for this scenario, new firms and commercial activities related to agriculture are represented by sparse developments all over the study area. Continuous urban fabrics (high density residential class) have taken over industrial/commercial areas in the core centre of the city of Montpellier.

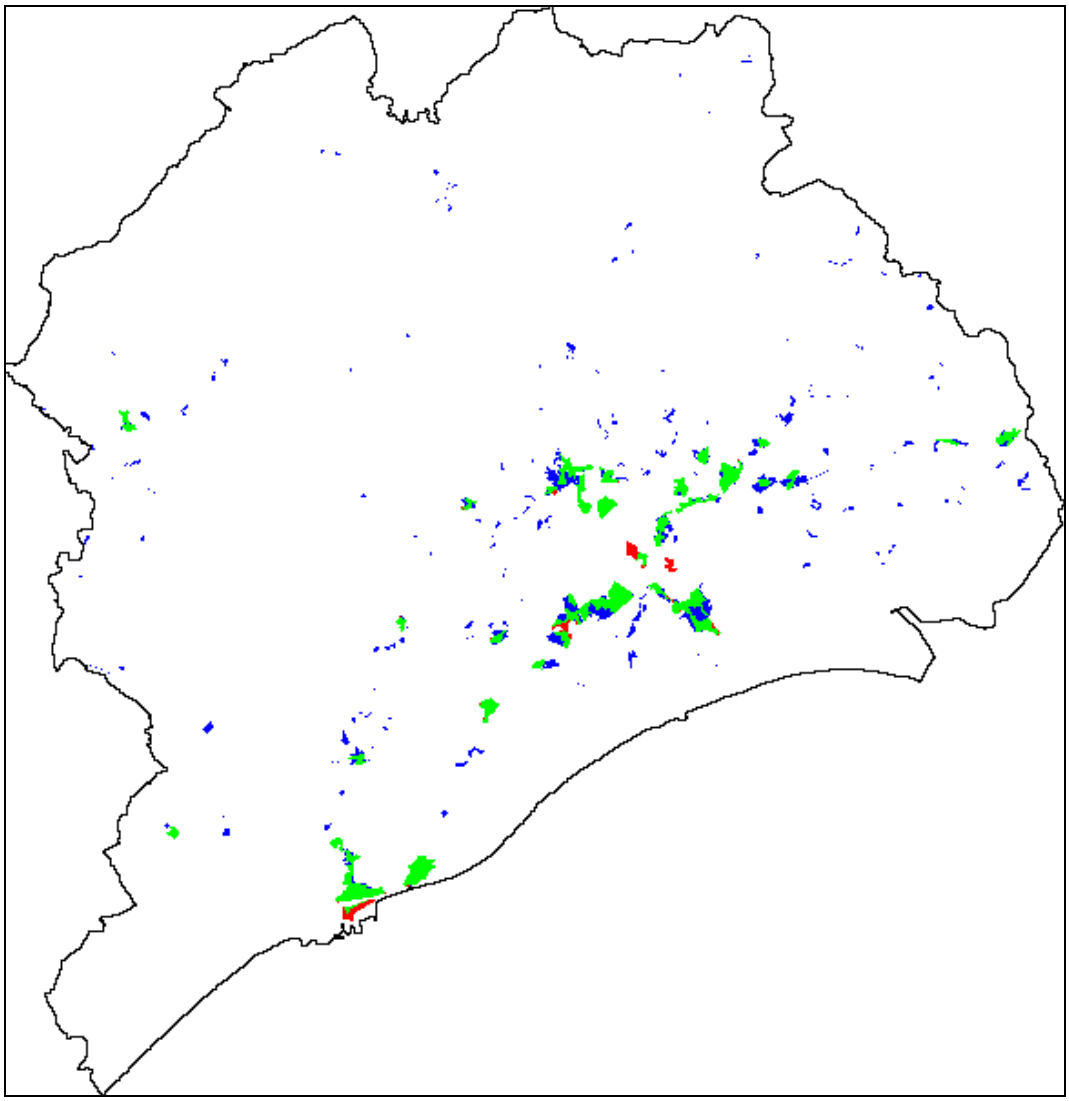


Figure 30 : HT2 Growth of industrial and commercial areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

The statistics relative to the RUR typology (Table 15a) show a net increase of urban land (sum of continuous/discontinuous urban fabric and of industrial/commercial areas) in the peri-urban and rural areas. The decrease in the urban area is given by the characteristics of the zoning measures which favour the building up outside the MMA.

Table 15a. The changes in urban and impervious surfaces by RUR typology for the HT2 scenario

HT2	Change in amount of urban land (ha)		
	Urban	Peri-urban	Rural
URBAN LAND	-62	4329	2591

4.3 Peak Oil (PO)

This scenario is identified by the stakeholders as the "Peak Oil and the technopolitan model decline" scenario. It is marked by a generic economic, social and demographic decline.

The main characteristics for this scenario (see Annex I for details) are:

- High cost of fossil fuels and consequent negative impact on economy;
- Demographic growth of 0.1 % per year
- New (limited) developments are developing along transport infrastructures.
- A9bisby bypasses Montpellier and the TGV is abandoned

Figure 31 shows the outcome of this scenario.

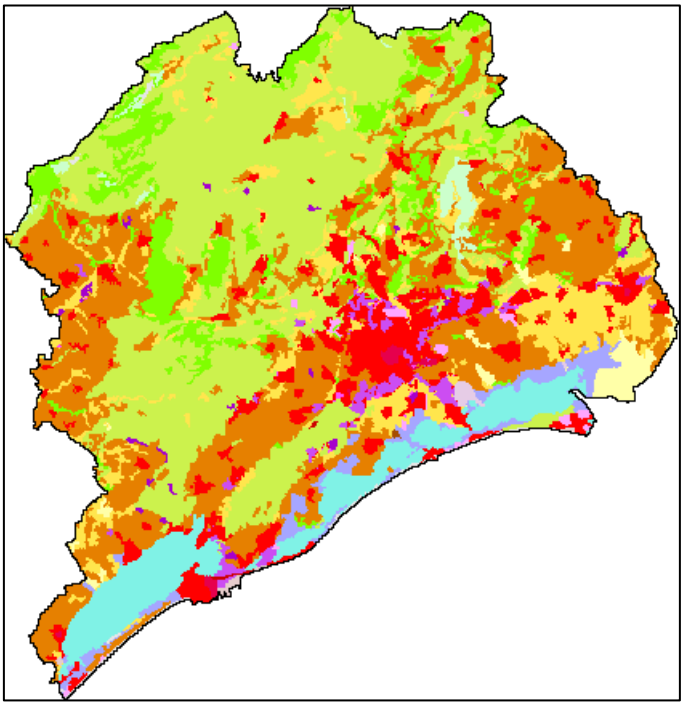


Figure 31. The resulting land use map for the PO scenario for 2025.

Table 16 summarises the changes in land use for the study area from 2000 to 2025 according to the PO scenario. The most obvious difference between this scenario and the others is the limited increase in built up classes.
Changes in continuous urban fabric, discontinuous urban fabric and industrial/commercial areas are represented in figures 32,33 and 34.

Table 16. Land use changes in ha from 2000-2025 for the PO scenario.

	2000 (ha)	2025 (ha)	%
Arable land	3211	3259	1.5%
Vineyards & fruit trees	60097	58565	-2.5%
Pastures	89	79	-11.2%
Heterogeneous agricultural	22516	20811	-7.6%
Forest	18216	17356	-4.7%
Shrub	72564	71338	-1.7%
Sparsely vegetated	674	2181	223.6%
Continuous urban fabric	453	650	43.5%
Discontinuous urban fabric	17220	20000	16.1%
Industrial and commercial	2821	3500	24.1%
Construction sites	128	250	95.3%
Port	190	190	0.0%
Airport	282	282	0.0%
Mineral extraction	830	830	0.0%
Dump sites	45	45	0.0%
Road and Rail networks	171	171	0.0%
Green artificial	1057	1057	0.0%
Sand, dunes, bare rocks	602	602	0.0%
Wetlands	4851	4851	0.0%
Water	13868	13868	0.0%

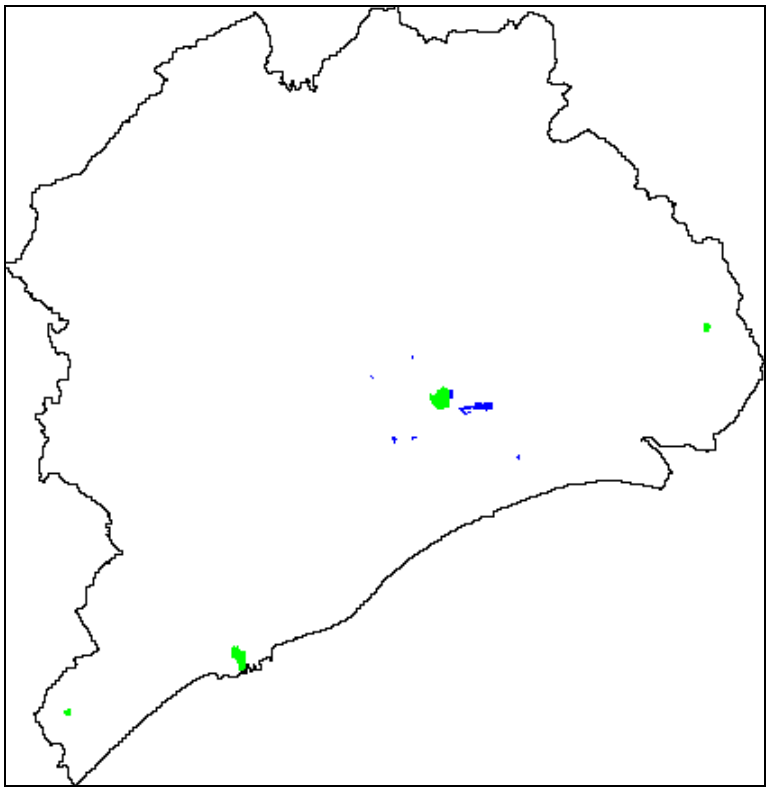


Figure 32: Growth of continuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

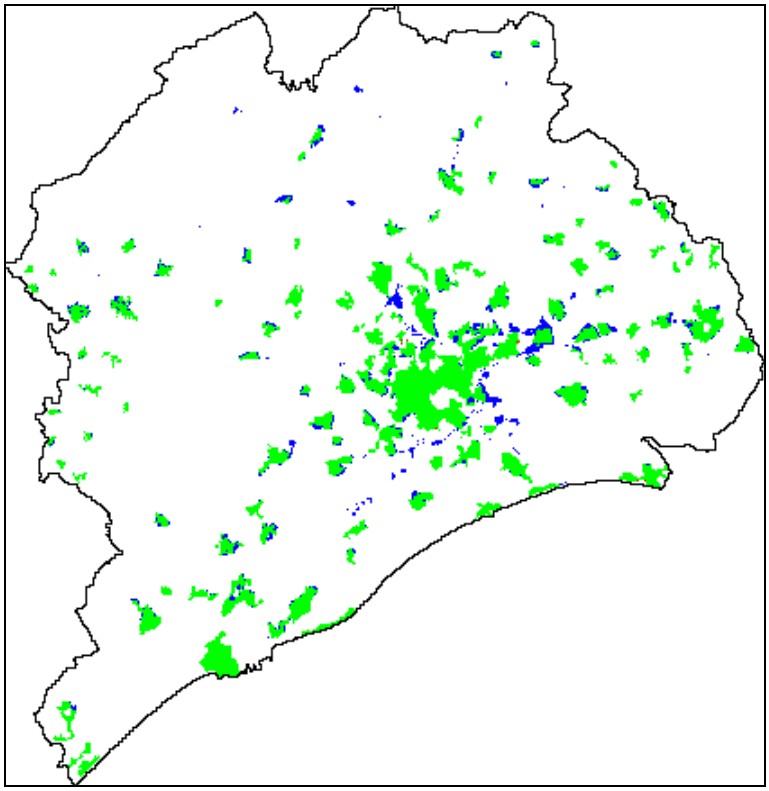


Figure 33 : Growth of discontinuous urban fabric areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

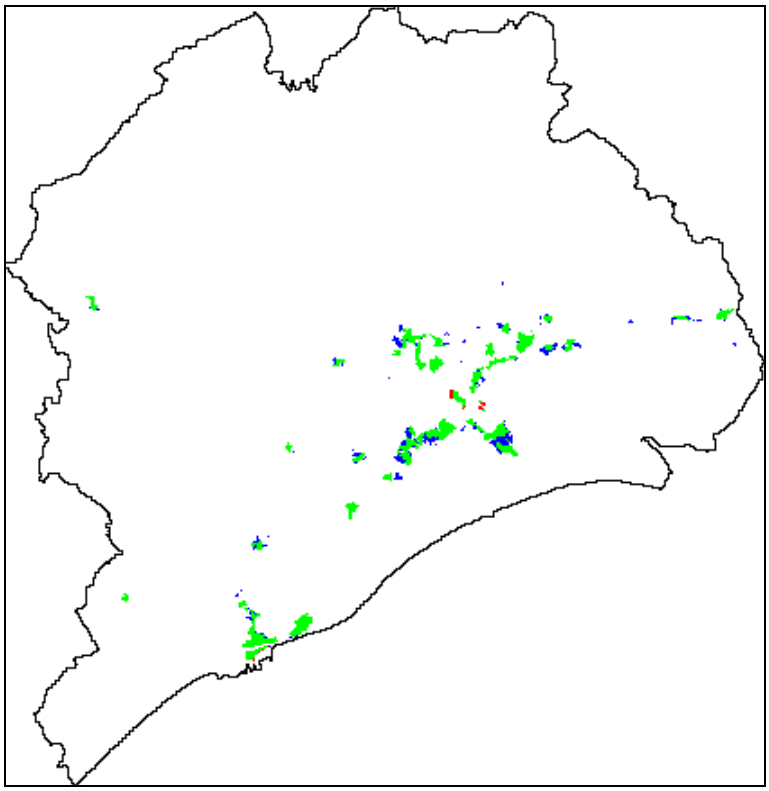


Figure 34 : Growth of industrial and commercial areas. .■ = Areas in 2000 and 2025; ■ = New areas in 2025; ■ = Areas only in 2000

As with all the scenarios, the amount of new urban land was subdivided by the RUR typology. Table 17 summarises the growth in the RUR areas for both urban areas and impervious surfaces.

Table 17. The expansion of urban and impervious surfaces for the PO scenario between 2000 to 2025.

PO	Change in amount of urban land /ha		
	Urban	Peri-urban	Rural
NEW URBAN	-7	2604	1043

4.4 Scenario comparisons

When the scenario results are compared to one another in terms of the criteria set by the indicators, the differences in the outcomes are evident. Table 18 shows the overall changes in land use for the three scenarios, as computed on the entire study area.

Table 18. The overall changes in land use classes for each of the scenarios.

Land use change, 2000-2025 (%)

	BAU	HT1	HT2	PO
Arable land	1.40%	0.09%	0.0%	1.78%
Vineyards & fruit trees	-1.23%	-5.71%	-6.3%	-2.58%
Pastures	-88.76%	-20.22%	-16.9%	-5.62%
Heterogeneous agricultural	-23.21%	-11.28%	-10.6%	-7.60%
Forest	-5.00%	-5.34%	-5.0%	-4.73%
Shrub	-1.97%	-2.39%	-2.2%	-1.67%
Sparsely vegetated	223.44%	223.29%	223.4%	223.89%
Continuous urban fabric	43.49%	120.75%	120.8%	43.49%
Discontinuous urban fabric	27.76%	27.76%	27.8%	16.14%
Industrial and commercial	54.98%	54.98%	55.0%	24.07%
Construction sites	95.31%	95.31%	95.3%	95.31%
Port	36.84%	36.84%	36.8%	0.00%
Airport	41.84%	41.84%	41.8%	0.00%
Mineral extraction	0.00%	0	0.0%	0.00%
Dump sites	0.00%	0	0.0%	0.00%
Road and Rail networks	0.00%	0	0.0%	0.00%
Green artificial	0.00%	0	0.0%	0.00%
Sand, dunes, bare rocks	0.00%	0	0.0%	0.00%
Wetlands	0.00%	0	0.0%	0.00%
Water	0.00%	0	0.0%	0.00%

The relevant increase (+220%) of 'sparsely vegetated areas' in all scenarios is due to the suitability maps built up for that class. The increase is due to a conversion from shrub and is located in a single area, north-east of Montpellier. It is the results of the suitability maps (see section 3.5) which are particularly effective for vacant land use classes, and of the calibration performed with the historical maop of 1990, when the area was indeed occupied by sparse vegetation, before being destroyed by a fire. It is therefore not due to zoning or planning policies.

The dynamics of artificial areas are the direct consequences of storylines and are therefore more interesting to remark. It is worth reminding that the three scenarios are driven by different demographic, economic and planning assumptions, which should always be considered in their comparisons.

Increase of urban fabrics (indeed these are residential areas) is typically driven by the demographic growth and by the urban planning strategies. It is therefore not surprising that the growth of continuous urban fabric is facilitated in the compact development depicted in the long March HT1/HT2 scenario. No particular assumptions were made for this class in the old-BAU and PO scenarios - therefore the similar increase.

Statistics for the discontinuous urban fabrics follow the same dynamics –here the main differences between old-BAU and HT1/HT2 is not numerical but rather in the spatial distribution.
Industrial and commercial areas evolve according to the economic storylines; rather positive for old-BAU and PO, while declining in PO.

The summary of statistics divided by the RUR typology is shown in table 20:

Table 20. The amount of new urban land and built-up surface per RUR typology for the four scenarios.

Amount of new urban land (ha)				
	BAU	HT1	HT2	PO
Urban	-85	-62	-62	-7
Peri-urban	4832	4402	4329	2604
Rural	1732	2518	2591	1043
Change in amount of built up surfaces (ha)				
	BAU	HT1	HT2	PO
Urban	-17	-10	-11	-15
Peri-urban	4970	4621	4547	2653
Rural	1844	2557	2633	1125

Changes in natural lands and farmlands, of the four scenarios, are given in table 21.

Table 21. Net change in farmland from 2000 to 2025 for the four scenarios.

Loss farmland	BAU	HT1	HT2	PO
ha	-6004	-5988	-6206	-3199
change %	-7.0	-6.9	-7.2	-3.7

Comparison between the HT1 and HT2 is of particular interest because; thou having the some socio-economic drivers the two scenarios differ in the application of the zoning restrictions. While the statistics computed on the overall study area are substantially similar, the spatial analysis of the two scenarios clearly reveals the different developments induced by the zoning characteristics.
The development of Continuous Urban Fabric (blue areas in figure 35) for the HT2 scenario presents a more scattered pattern than in HT1 – however the overall development is kept within the Montpellier Metropolitan Area. This is the

consequence of the 'attraction/repulsion' rules which have the same setting in MOLAND for both scenarios.

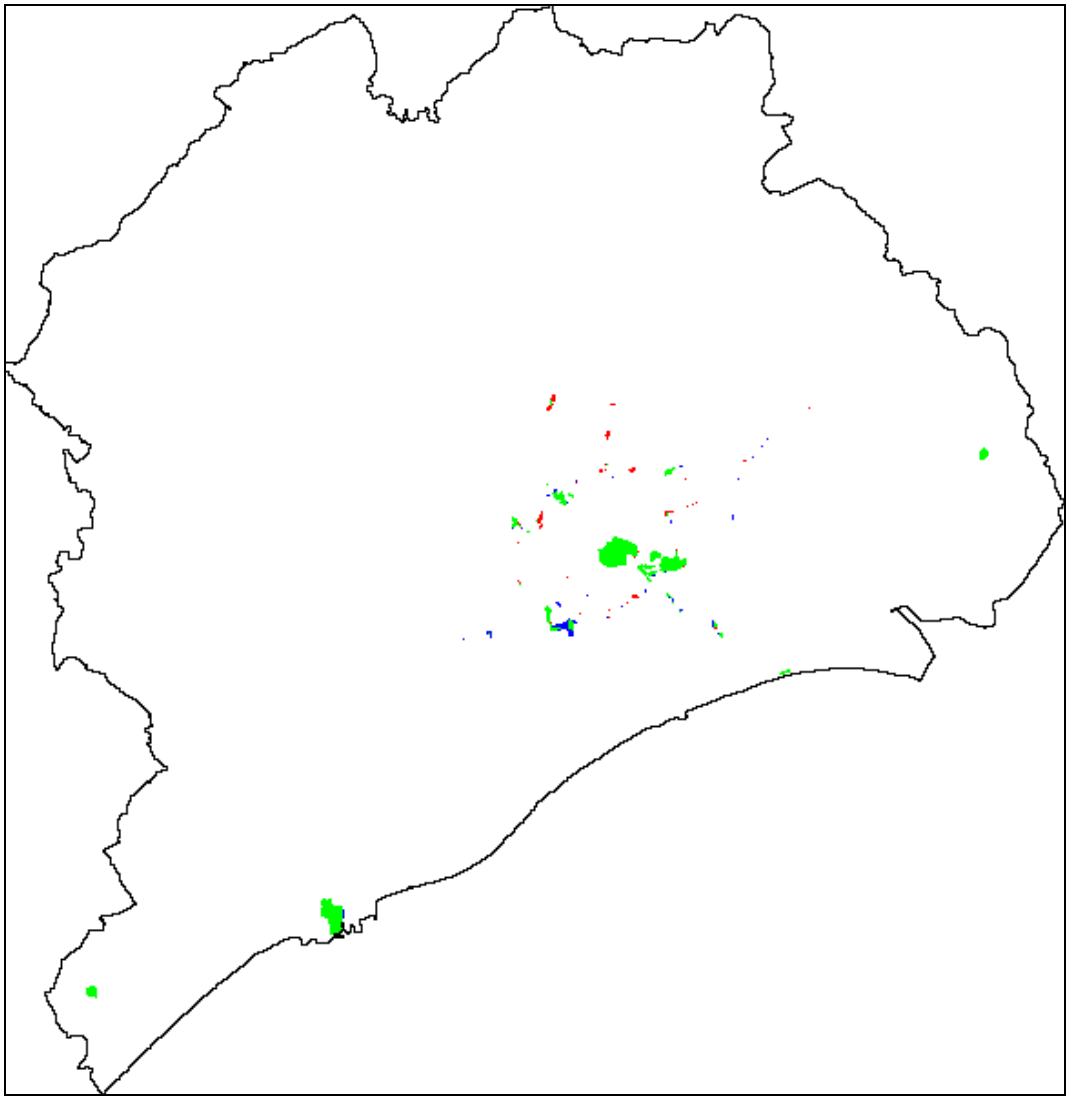


Figure 35: Continuous Urban Fabric in 2025: .■ = CUF Areas in HT1 and HT2; ■ = CUF areas only in HT2; ■ = CUF Areas only in HT1.

The development of discontinuous urban fabric (DUF) shows more clearly the impact of zoning restriction. Indeed, while for HT1 (red areas in figure 36) the DUF are growing mainly within the MMA, for HT2 (blues area in the figure) the DUF areas tend to spread also to the periphery of the overall study area. Attraction and accessibility play a key role in both scenarios.

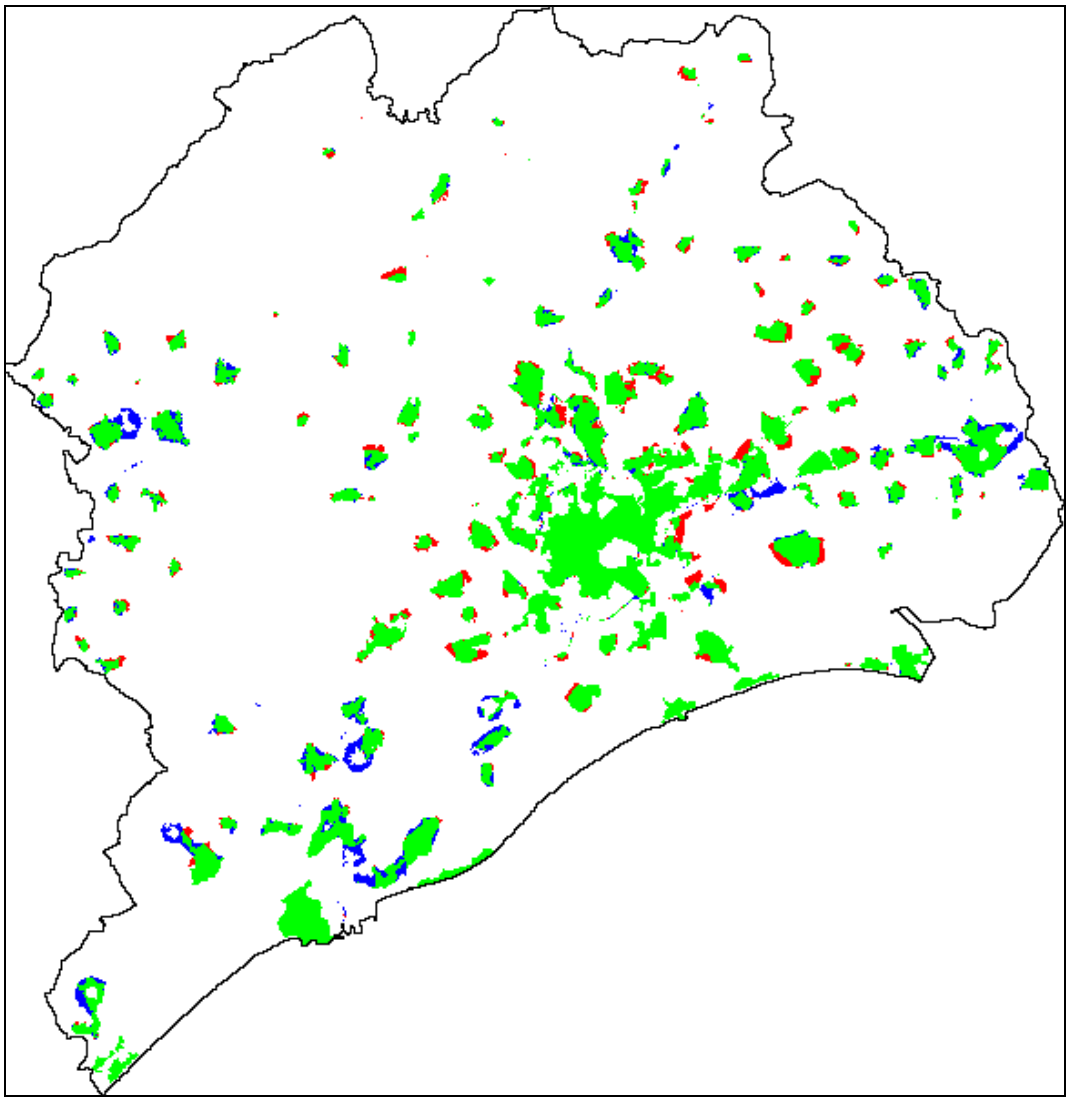
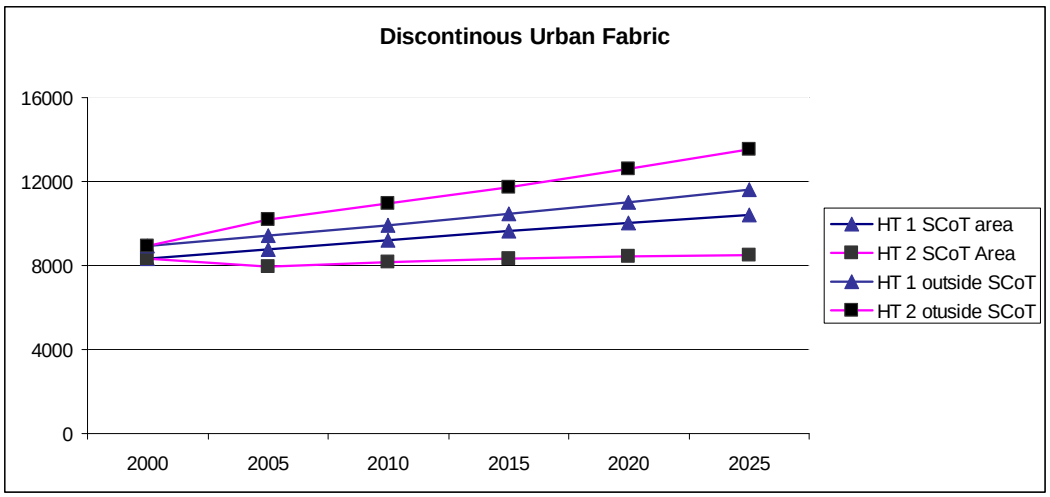


Figure 36: Discontinuous Urban Fabric in 2025: ■ = DUF Areas in HT1 and HT2; ■ = DUF areas only in HT2; ■ = DUF Areas only in HT1.

The graph below presents the evolution along time of the DUF surfaces for HT 1 and HT2, within and outside the SCoT area (which coincides with the MMA).

In the HT2 scenario, the increase of DUF outside the zoning area is evident.



5. Conclusions

Four simulations have been performed for the Montpellier study-area following the scenarios developed by local stakeholder.

The business as usual scenario assumes the abandonment of planning and zoning tools to allow market-driven developments. Sparse residential developments are the main spatial characteristics of this scenario.

The long-march HyperTech is the most realistic scenario for what concerns the application of planning and zoning policies. Two alternatives have been simulated for this scenario. Economic and demographic trends are positive for both alternatives. The resulting projected land use developments present compact urban and industrial patterns for the more controlled alternative (HT1) and a more sparse – although still aggregated around existing blocks – for the HT2 alernative.

The peak oil scenario represents a negative economic and demographic situation. The resulting developments are limited, as expected.

As final remarks, it is confirmed the decisive role of zoning maps in the modelling exercise as key drivers for spatial development. Despite the mismatch between the detailed maps - produced in the frame of the SCoT planning tool - and the coarse Corine Land cover/use does not allow precise thematic correspondence of the most important land use/cover classes (e.g. housing density classes), the simulation has allowed to distinguish main trends towards compactness or sprawl.

Annex A.

Montpellier Agglomeration.
new approaches for territorial cooridnation in the peri-urban

Jarrige F. Chery JP. Buyck J. Gambier JP. 29/11/2010

Extract from Plurel Book. Chapter 8. Montpellier case study.

Executive summary

Due to the attractiveness of the Mediterranean coastal region where it is located, Montpellier presents a positive migration balance and population keeps on growing in the city-region. Urban sprawl caused deep changes in periurban landscapes during last decades, with individual housing plots spreading around all villages. New buildings took place where vineyards used to be the quasi-unique land-use as result of historical specialization in table-wine mass-production. This sector is more and more weakened by economic crisis, as most of other traditional agricultural sectors. Local economy now largely depends on tertiary activities, such as tourism, education, research, medicine, and new technologies.

These driving forces led to both large population mix and socio-spatial segregation, uncoordinated development and changing periurban landscapes – with an increasing per capita rate of space consumption - until the creation of a new local authority, Montpellier Agglomeration, at the end of 2001. This local government, gathering 31 municipalities, is in charge of several major public policies. Among these public policies formerly implemented by municipalities are: spatial planning (at regional scale), collective transport, water management and housing policy. The creation of Montpellier Agglomeration brought about deep changes in local governance and planning practices.

How does this new authority address the challenges of sustainable development at regional scale? What are the governance issues, and what development strategies have been established? What spatial planning tools are implemented? What contrasted scenarios can be drawn for future development? And what are the impacts of these scenarios when assessed against an integrated analysis in terms of sustainable development?

Lessons can be learned from the experience of Montpellier Agglomeration in the field of periurban land use relationships, and in order to share them with European partners, experts and stakeholders of periurban land use management, this chapter presents the following items:

- The local context is broadly presented through historical changes in land uses and demographic components in Montpellier city-region. Local governance issues are also analysed, as are the different steps of the construction of Montpellier Agglomeration. The new French system of land planning is then detailed regarding the issue of periurban land use.
- The SCoT (territorial coherence scheme) of Montpellier Agglomeration is analysed and assessed as an innovative experience of regional planning. Analysing the drawing and the implementation of this new tool of spatial planning policy gives an overview on major issues for periurban land use: policy directions and governance practices, solutions (or attempts) to contain urban sprawl. The SCoT of Montpellier Agglomeration stands out because of the attention paid to the protection of open spaces (either natural zones and farmland), and the use of landscape as major vector of urban planning. It also enacts strong development rules to intensify urban development and contain urban sprawl. Expectations are also put on farming as a tool to secure urbanization limits and guarantee the sustainability of periurban landscape.
- Four land use scenarios explore the future of the Montpellier Agglomeration, according to different types of territorial governance (following up the control strategy initiated with the SCoT, or back to uncontrolled land business and urban sprawl), and under different external pressures such as rising oil prices and climate change. How well do current development paths perform under these radically different conditions? What can be concluded for the future spatial planning in the peri-urban and instruments such as the SCoT from this exercise?

Four prospective scenarios to imagine the future of Montpellier Agglomération and assess present policies

Four scenarios have been elaborated to explore future land use patterns for Montpellier Agglomération, with a special concern to urban/rural relationships and sustainability of the urban system. These scenarios are based upon local/internal factors and global/external driving forces, more or less important according to scenarios.

From a local point of view, strategic parameters for future alternative scenarios are based upon major components of the strategy analysed in the SCoT:

- Territorial governance: local political leadership and type of policies, stakeholders association and involvement
- Local economy: major leading activities, specially in innovative fields, and the future of farming, major land use in periurban areas
- Territorial perimeter: will Montpellier Agglomération remains at 31 municipalities or expand to gather cities in the north (Nîmes, Ales) and in the south (Sète, Thau)?

These local factors strongly beset the two first scenarios, 1) the “long March” or the advent of the hypertech metropolis, which can be considered as the following up the voluntary development policy and control strategy initiated by Montpellier Agglomération with the SCoT, and 2) back to old “business as usual”, which means back to uncontrolled land business and urban sprawl, as experienced in the past in Montpellier city-region.

These scenarios showcase two radically different paths concerning local governance. The first one showcases the reinforcement of the power of the local government, renewing and enlarging the vision of local development coordinated at the scale of the entire city-region, socially and spatially integrated, and strengthened around Montpellier centre. This scenario follows through the virtuous choices initiated by Montpellier Agglomération with the SCoT. The second scenario showcases a weakening of local governance that will lead to a mitigation of urban sprawl control and an increase in socio-spatial segregation. “Back to old business” means free space for market forces and no or little public control on land use, as Montpellier city-region has experimented during three decades of demographic growth and urban sprawl before the creation of Montpellier Agglomération and the drawing of the SCoT.

The comparison of these two scenarios can be considered as an assessment of the relevance and the robustness of the tool of strategic planning of Montpellier Agglomération, the SCoT.

External driving forces are decisive in the two other scenarios, 3) Peak oil and the technopolitan model decline, and 4) Extrem water: Montpellier city-region victim of the Mediterranean see. These two scenarios have been drawn in a comparison perspective with other Plurel case studies. These two last scenarios are less sensitive to local changes in governance. Whatever the future development strategies may be, external drivers have major impacts. So these two scenarios put to the test development decisions and choices made nowadays in the SCoT.

These four scenarios are presented following the same items list: policy, economy, urban planning, infrastructures, agriculture and climate.

Scenario➢ Themes⩛	The "long March" or the advent of the hypertech metropolis	Back to old "business as usual"	Peak oil and the technopolitan model decline	Extrem water
Politics	The current President of Region Languedoc-Roussillon is re-elected at regional elections in 2010. Directly or indirectly, he controls regional public policies at all levels. This coordination is accelerated by the merger in a unique regional authority (nuts 2) of the 5 General Councils (Departements, nuts 3), after their bankruptcy following the reform of local governments and their taxation system (decrease of their tax resources). Montpellier Agglomeration becomes an Urban Community, with enlarged competences, and covers an extended metropolitan area from Sète in the south west to Nîmes and Ales in the north east. Unified political management allows achieving a balance between economic, social and environmental issues at the scale of the city-region, which now fits with the functional urban area. At the end of 2025, the capacity of local actors to come into negotiation with their neighbours holding different, thus complementary, resources, becomes essential. An integrated regional governance system is achieved.	The regional elections of 2010 put an end to the current President era at Regional Council. At national level, the same President is re-elected in 2012, and locally, the political majority of the city changes. Economic liberalism, either chosen or imposed because of lack of public resources following financial crisis, drives public policies. State disengagement carries on and social inequality raises. The poorest have little access to quality of life and live mostly in cities. The spirit of gated communities now also applies to inter-municipalities. Montpellier Agglomeration becomes an Urban Community competing with neighbouring territories: Communities of Thau lagoon, Pic Saint Loup and Pays de Lunel. Contrary to the unified and centralized situation at the scale of the city-region in scenario 1, in this case there is a "balkanization of territories".	The time of finite urban world started with the disappearance of oil. A law now prohibits any new urban development without integrated solution of collective transports. It marks the end of the period known as peri-urban which was born, in France, in the 1960s with the explosion of car market. The Minister of Social Cohesion and Territorial Solidarity launches a program to support new neighbourhoods of large peripheral housing estates inherited of the old urban sprawl and penalized by their isolation.	The politics is not in the heart of this scenario. Whatever the political options may be, they have little impact compared to global / natural / external factors which play a decisive role.

Scenario➢ / Themes⮟	The "long March" or the advent of the hypertech metropolis	Back to old "business as usual"	Peak oil and the technopolitan model decline	Extrem water
Demography	There is a record population growth: +1.7% to +2% per year. Through Local Housing Program, the population increase is absorbed without problems thanks to social and territorial solidarity in housing policy at the scale of the great metropolitan area. Long-distance commuters living part of the week in residential areas, dwellers in small towns and villages adjacent to the new centres, rural metropolitans: all newcomers have ways to take advantage of the new inter-territoriality.	Demographic growth is still high (1.3% per year), but spatially segregated with "social sorting". Social barriers and local identity are at the heart of conflicts between local "ghettoized" populations.	The high cost of fossil fuels imposes a halt to population growth (0.1%). Peri-urban housing, which implies individual commuting, has become a major trap for people who have no access to employment. High social tension is transferred to the city centre. Municipalities are trying to support their citizens with difficulty.	There is a very moderate demographic growth (0.3% per year) or even a population decline. This is due to two factors: the sea level rises of 1 or 2 meters (less room for new residents or for re-housing climate refugees) and Cevennes rain episodes are now very common (natural hazards also reduce land capacity for urban fabric).
Economy	The sector of personal services knows a record development in a "French California" type new economic metropolitan model ("Sud de France" University, coupled with Research and Development of local enterprises). New technologies are booming, from firms-nurseries like the public Montpellier International Business Incubator (MIBI).	The technopolitan model is questioned. Main economic activities are in the fields of personal services and residential economy. Most investments made in local economy come from offshore funds, in real estate and high-end services.	The announcement that the forecasts of oil reserve stocks were completely overestimated has the effect of a global tsunami. Transport becomes the largest household budget item. Local economy has to be completely reviewed: it is necessary to resolve the decline of the technopolitan economic model. Logistics hubs of the languedocian corridor close one after the other. There is a widespread conversion with great difficulty. Only new technologies make the most of this delicate situation. Alternative energies are developing (solar cells, wind mills).	Local economy follows the model of Agenda 21. All urban planning schemes are reviewed to put people out of risk. Tourism activities lose the seaside component since beaches have vanished, and most direct and indirect jobs linked to tourism disappeared. On the other hand, global warming allows taking advantage of hot winds that provide good generation power in addition to mass production of solar cells.

Scenario➢ / Themes⮟	The "long March" or the advent of the hypertech metropolis	Back to old "business as usual"	Peak oil and the technopolitan model decline	Extrem water
Urban planning	The SCoT gets into version 2: the perimeter of the SCoT is extended to the whole corridor of Languedoc (from Sète to Nîmes). **High building density and precise urban limits are generalised urban planning rules**. The establishment of a Local Public Urban Planning Society, in charge of urban planning, "in house" operator of municipalities, enables the implementation of public policies without the hazards of setting competition between developers. Tested in Montpellier, it has now extended jurisdiction over the entire metropolitan area as quasi-monopoly public service.	Urban planning is going out the window: the SCoT is put on ice. "Land hunting" is reactivated. Public planning tools are given up (deletion of land pre-emption rights and of landowning public establishments) due to litigation according to European law of free market in urban planning. This gives full place to private real estate monopolistic developer. Urbanization is opened to provide access to sites with high landscape value, dedicated to high income executives and retirees. City centres are impoverished: there is no more social housing programs. Socio-spatial segregation is reinforced with new gated communities.	Public transports, which pool the costs and are affordable, are at the heart of this scenario: the long phase of housing redistribution within sprawled urban areas seems to have stabilized along transport infrastructure and near services. Urbanisation refocuses in a sense of strong polarization on Regional Express Train (TER) and tramway. Through this prism, spatial segregation is reinforced. A "gerontocratic" atmosphere prevails in peri-urban villages where high income European pensioners, released from commuting, are concentrated.	New urban developments have to respect enlarged corridors for possible flooding. The SCoT is reviewed in this perspective. Concentration of risk-free housing is the priority. It leads to the expansion of urban areas to accommodate climate refugees who fled away from littoral municipalities. Land conflicts are exacerbated on the fringes of remaining spaces. The airport disappears under water. The topping out of High Speed Train Line is the frontline of the fight against the Mediterranean Sea.
Infrastructures	The Urban Transport Plan is completed in the whole new area of the great SCoT. Tramway network reaches Mèze in 2015. All major transport infra-structures planned are now built: highway A9bis, Nîmes-Montpellier High Speed Rail Line bypass, new TGV Rail station in 2020, single airport for the metropolitain area, Sète competitive harbour. Like new TGV station district, mobility hubs gained strategic values that help structuring new metropolitan urbanity.	Public transport infrastructures like tramways are given up because of lack of public funding. The A9 highway is doubled south of the Montpellier Agglomeration area. High Speed Railway (LGV) is built and the operating of the new TGV rail station is licensed in 2020 to a private company.	Public transport is strengthened but not enlarged: the peri-urban is neglected. Regional train network is maintained for the benefit of central cities. Municipalities have no means to pay for transport extensions such as new airport. A9bis highway bypasses and High Speed Train Line (LGV) project is abandoned. There are no water projects for agriculture.	The dream of the President of Region Languedoc-Roussillon and former mayor of Montpellier materializes, but it is not "Montpellier which goes to the sea", it is the reverse… Montpellier harbour has to be built as Sète became an island, and its harbour has been overwhelmed. The High Speed Train Line is along the coast. The building of the TGV rail station in the south-east of the city is compromised.

Scenario➢				

Themes ⇩	The "long March" or the advent of the hypertech metropolis	Back to old "business as usual"	Peak oil and the technopolitan model decline	Extrem water
Agriculture	Since the demise of General Councils in France, the legal competence on natural areas has been devoluted to Regional Councils, and rural land development to urban authorities. Public supports contribute to farming activities, more and more considered as common heritage of new urban territories. In the Languedocian Metropolis, agriculture is now based on high-tech and high quality farming systems: organic crops, greenhouses,... with increasing local sourcing for food products. Some high tech vineyard remains, successfully achieving competitiveness in a globalized wine economy. Besides vineyard, multifunctional agricultural areas are dedicated to both production and recreational uses.	Horsification expands at the expense of farmland and vineyards. Owners of farmland massively turn to production equipment of solar energy. Accelerated disintegration of farming goes on because of globalized competition and the end of public support (from EU or local governments).	Although people from countryside feel they are the losers of development and spatial planning policies, "return to land" is a necessity. There is a boom in family food gardens, and for the movement "back to the land". The concept of agripark is developed. A problem remains for local food system if no solution is found to provide water for agricultural diversification.	Agriculture is delocalized in the northern rural districts of the region. Municipalities have to care and provide open space freed up to maintain public access to nature, for people in situation of ecological stress. There is a revival of some Mediterranean productions like sheep. But warming raises a problem with no possibility of irrigation: the issue of water and water for agriculture is deteriorating.
Climate	The climate is not decisive in this scenario.	The climate has no major impact in this scenario.	This scenario is sensitive to climate: warming limits the production capacity in the farm-to-fork system, imports have become expensive because of transport costs.	Sea level rises of 1 or 2 meters and the Cevennes rain episodes are more frequent and devastating. Temperatures are rising and with them the risks of sun exposure for people. The attraction of the seaside disappears, it is swarming with jellyfish and the beaches no longer exist: seaside tourism collapsed.

Annex B.

Table B1. Kappa statistics for the true land cover and simulated land cover for 2000

Method	Kappa
Map1	I:\ISPRA\PLUREL\PLUREL\Montpellier-june\land_use\land use map_2000-jan-01.rst
Map2	I:\ISPRA\PLUREL\PLUREL\Montpellier-june\mclc00rec5b.asc
Kappa	0.95181
KLocation	0.96097
KHisto	0.99047
Fraction corre	0.962

	Arable land	Vineyards & f	Pastures	Hetrogeneous	Forest	Shrub	Sparsely v	_Continuou	_Discontin	_Industria	_Constru	_Port_	_Airport_	Mineral e	Dump si	Road an	Green arti	Sand, du	Wetlands	Water	
Kappa	0.93293	0.97598	0.89443	0.91458	0.9617	0.96218	0.46525	1	0.91494	0.80322	-0.0006	1	1	0.99339	1	0.97295	0.94008	1	0.99245	0.99857	
KLoc	0.93426	0.97675	1	0.9292	0.9855	0.96253	0.9955	1	0.91494	0.80322	-0.0006	1	1	1	1	1	1	1	0.9981	1	
KHisto	0.99858	0.99921	0.89443	0.98427	0.9759	0.99963	0.46735	1	1	1	1	1	1	0.99339	1	0.97295	0.94008	1	0.99434	0.99857	
Map 1 \ Map 2	Arable land	Vineyards & f	Pastures	Hetrogeneous	Forest	Shrub	Sparsely v	_Continuou	_Discontin	_Industria	_Constru	_Port_	_Airport_	Mineral e	Dump si	Road an	Green arti	Sand, du	Wetlands	Water	Sum Map 1
Arable land	3003	0	0	21	61	102	3	0	0	30	0	0	0	0	0	0	0	0	0	0	3220
Vineyards & f	46	59014	0	432	0	0	0	0	424	89	23	0	0	0	0	0	0	0	0	0	60028
Pastures	0	0	89	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	110
Hetrogeneous	151	290	0	20497	0	0	0	0	749	109	31	0	0	0	0	0	52	0	9	0	21888
Forest	0	15	0	16	17194	188	0	0	11	2	0	0	0	0	0	0	0	0	0	0	17426
Shrub	0	263	0	354	956	70743	0	0	129	66	13	0	0	0	0	9	67	0	0	0	72600
Sparsely vege	0	0	0	36	0	1488	671	0	0	0	0	0	0	0	0	0	0	0	0	0	2195
_Continuous u	0	0	0	0	0	0	0	453	0	0	0	0	0	0	0	0	0	0	0	0	453
_Discontinuou	11	388	0	673	5	12	0	0	15870	242	19	0	0	0	0	0	0	0	0	0	17220
_Industrial an	0	124	0	370	0	31	0	0	10	2273	13	0	0	0	0	0	0	0	0	0	2821
_Construction	0	3	0	106	0	0	0	0	9	10	0	0	0	0	0	0	0	0	0	0	128
Port	0	0	0	0	0	0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	190
Airport	0	0	0	0	0	0	0	0	0	0	0	0	282	0	0	0	0	0	0	0	282
Mineral extrac	0	0	0	11	0	0	0	0	0	0	0	0	0	830	0	0	0	0	0	0	841
Dump sites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	45
Road and Rai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	162	0	0	0	0	162
Green artificia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	938	0	0	0	938
Sand, dunes,	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	602	0	0	602
Wetlands	0	0	0	0	0	0	0	0	18	0	8	0	0	0	0	0	0	0	4842	37	4905
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13831	13831
Sum Map 2	3211	60097	89	22516	18216	72564	674	453	17220	2821	128	190	282	830	45	171	1057	602	4851	13868	219885