A spatio-temporal analysis of longevity in an Italian region

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1. Introduction

Emilia Romagna shows one of the oldest age structure in Europe: 23.0% persons aged 65+, and 7.3% person aged 80+ in 2013 (total population of 4,377,847)

The region is characterized by a great geographical variability: mountain, hills and a wide flat land, with a consequent heterogeneity in environmental context, social conditions and economic resources (Roli et al. 2013)

We aim at:

– investigating the pattern of longevity in Emilia-Romagna at a municipality level ;

– identifying clusters of areas characterized by extreme longevity;

– depicting the temporal evolution of the phenomenon;

– evaluating the effects of some territorial covariates and the structure of mortality on a cohort of long-lived.

Part of the presented results have already been published in Roli, Samoggia, Miglio, Rettaroli, 2012, Longevity pattern in the Italian region of Emilia Romagna: a dynamic perspective, Geospatial Health 6(2).

2. Centenarian Rate

In order to measure the different spread of longevity in the regional area, we use a modified version of the Centenarian Rate (CR), as firstly proposed by Robine and Caselli (2005)

$$CR_{kit}^{95+} = \frac{P_{kit}^{95+}}{P_{ki(t-40)}^{55-64}}$$

individuals aged 95 and over

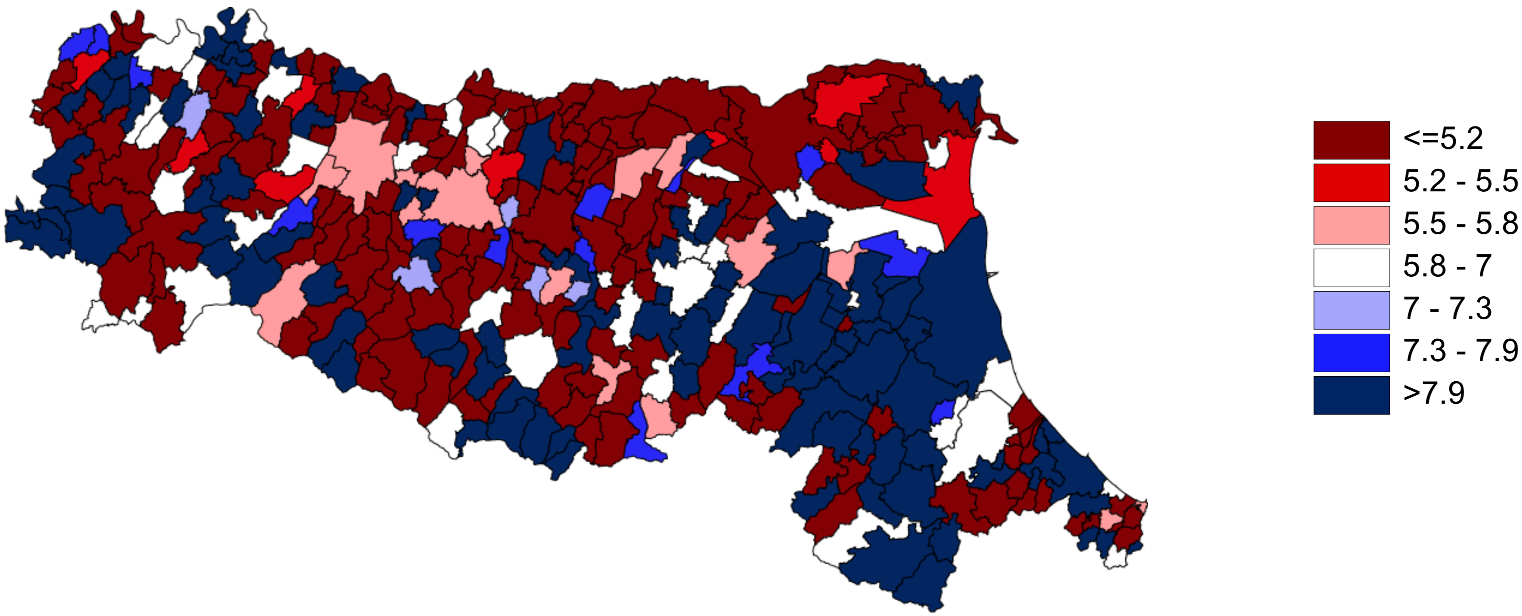
number of 55-64 years old Persons living in the same area 40 years earlier

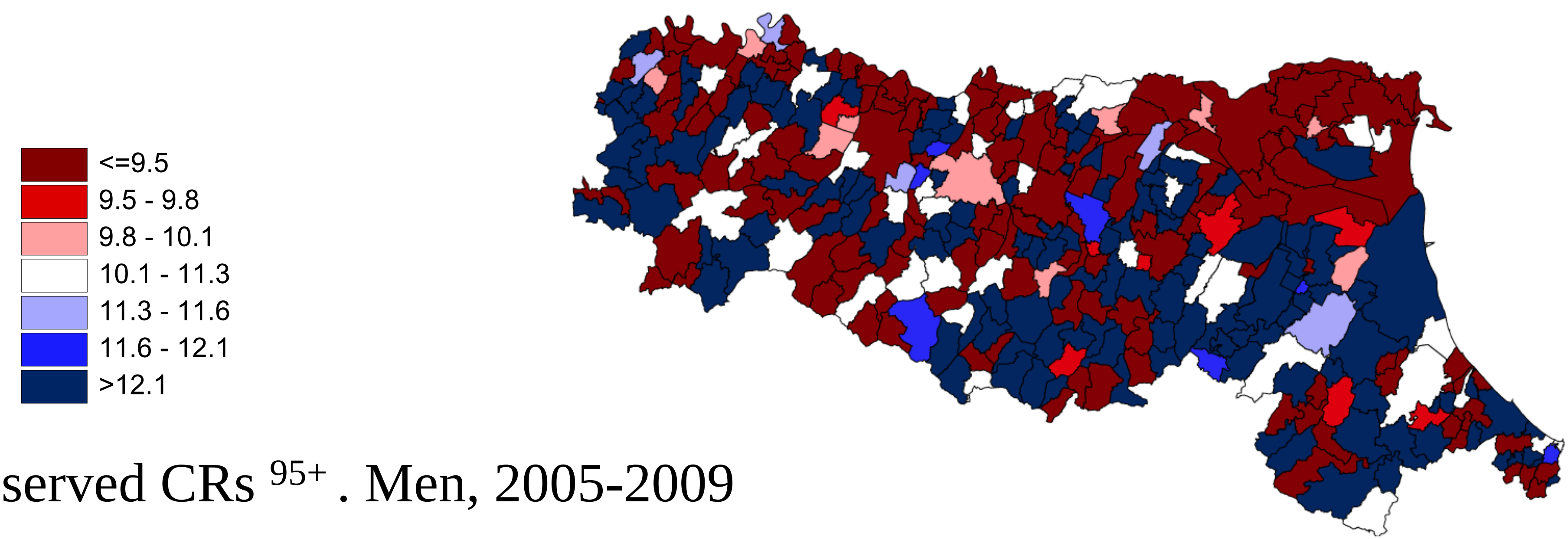
For each time *t*, gender *k* and municipality *i*.

Observed CRs $^{95+}$ are characterized by strong fluctuations, reflecting random variations in the occurrence of long-lived individuals, due to the rareness of such events and to the small dimension of the areas.

11,459 individuals aged 95 and over live in Emilia Romagna on 1-1-2013 (79.2% female)

Observed CRs $^{95+}$. Men, 1995-1999





Observed CRs $^{95+}$. Men, 2005-2009

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3. Spatio-temporal model

- Random intercept model on the log-linear formulation of the CRs (1995-1999;2005-2009) .

$$\log\left(CR_{it}^{95+}\right) = \alpha_t + \beta x_i + u_i + v_i$$

where

a_t is the time-varying intercept,

x_i is a covariate representing altimetry and population density for the *i-th* municipality,

β is the corresponding effect on the log rate,

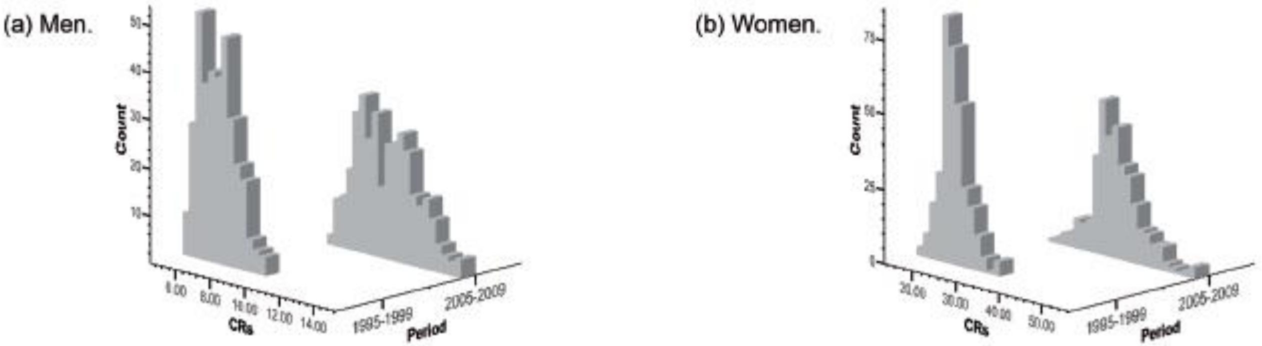
u_i and u_i are the correlated and uncorrelated spatial heterogeneity, respectively.

- For the correlated spatial component u_i , we assume a Gaussian conditionally autoregressive (CAR) model .
- The random effects v_i are supposed to follow an ordinary exchangeable normal prior.
- We specify vague and proper distribution for the other (hyper-) parameters.

Average CRs $^{95+}$ (x1000) for the overall region

Period	Men	Women
1995-1999	6.39	21.47
2005-2009	10.68	37.54
Difference	4.29	16.07

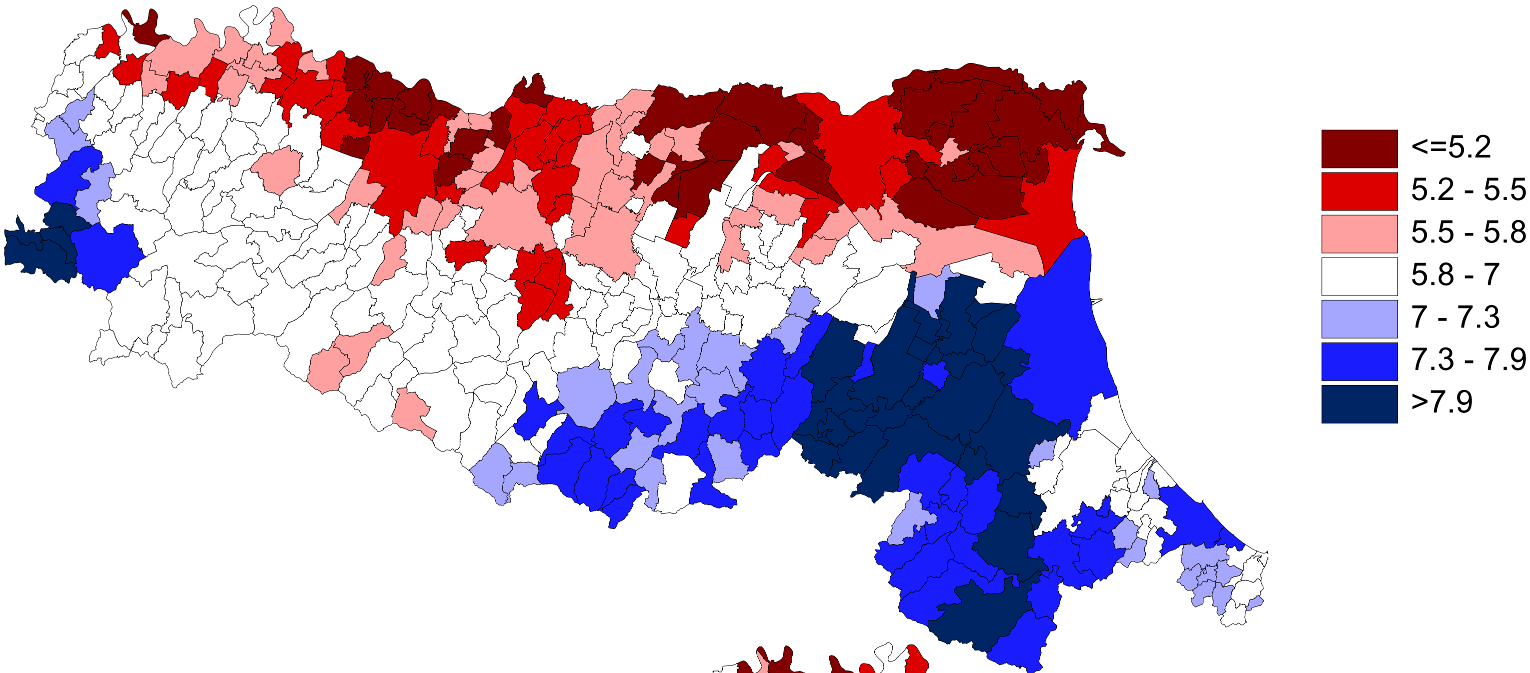
Frequency distribution of the estimated CRs $^{95+}$

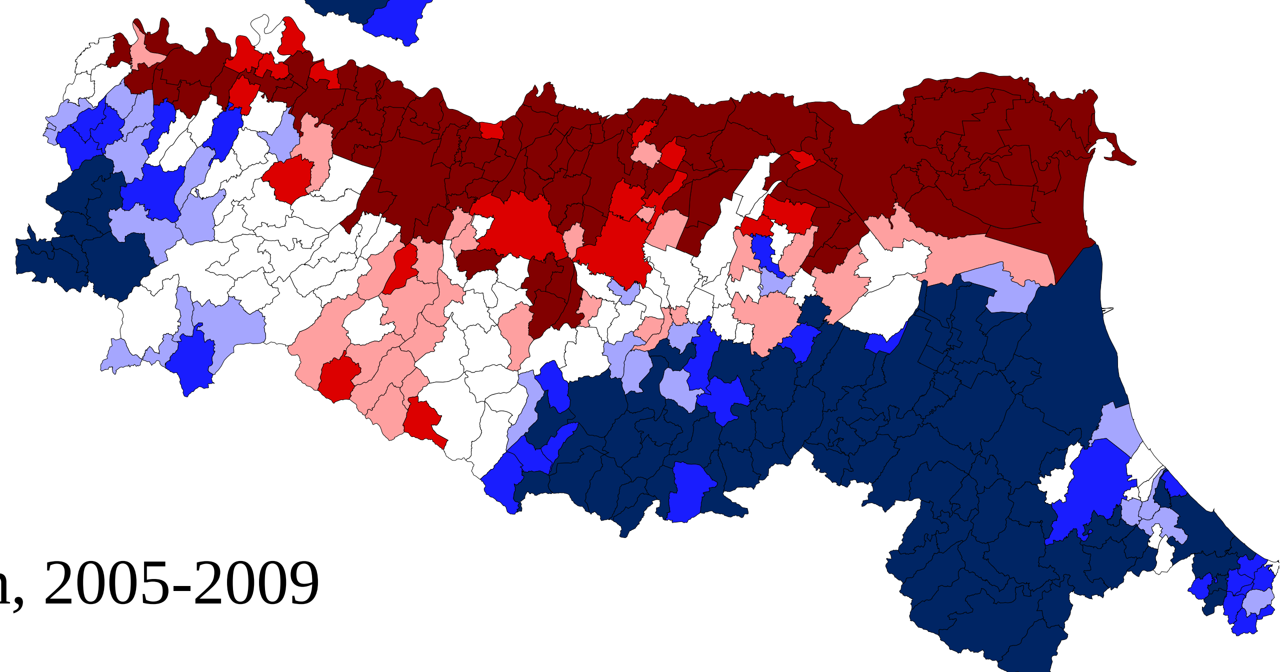


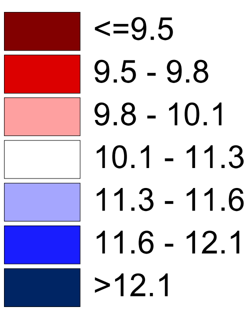
Covariates' effects

	Men		Women	
	Fitted rate ratios	90% CrI	Fitted rate ratios	90% CrI
Hill and density < 78	0.961	0.827-1.114	0.956	0.872-1.047
Hill and density 78-193	0.978	0.846-1.127	1.132	1.037-1.233
Hill and density > 193	0.852	0.741-0.973	1.027	0.936-1.126
Coastal hill	0.895	0.620-1.295	0.751	0.590-0.952
Plain and density < 78	0.772	0.611-0.972	0.743	0.640-0.862
Plain and density 78-193	0.794	0.690-0.912	0.942	0.859-1.033
Plain and density > 193	0.906	0.801-1.021	1.015	0.935-1.103

Estimated CRs $^{95+}$. Men, 1995-1999

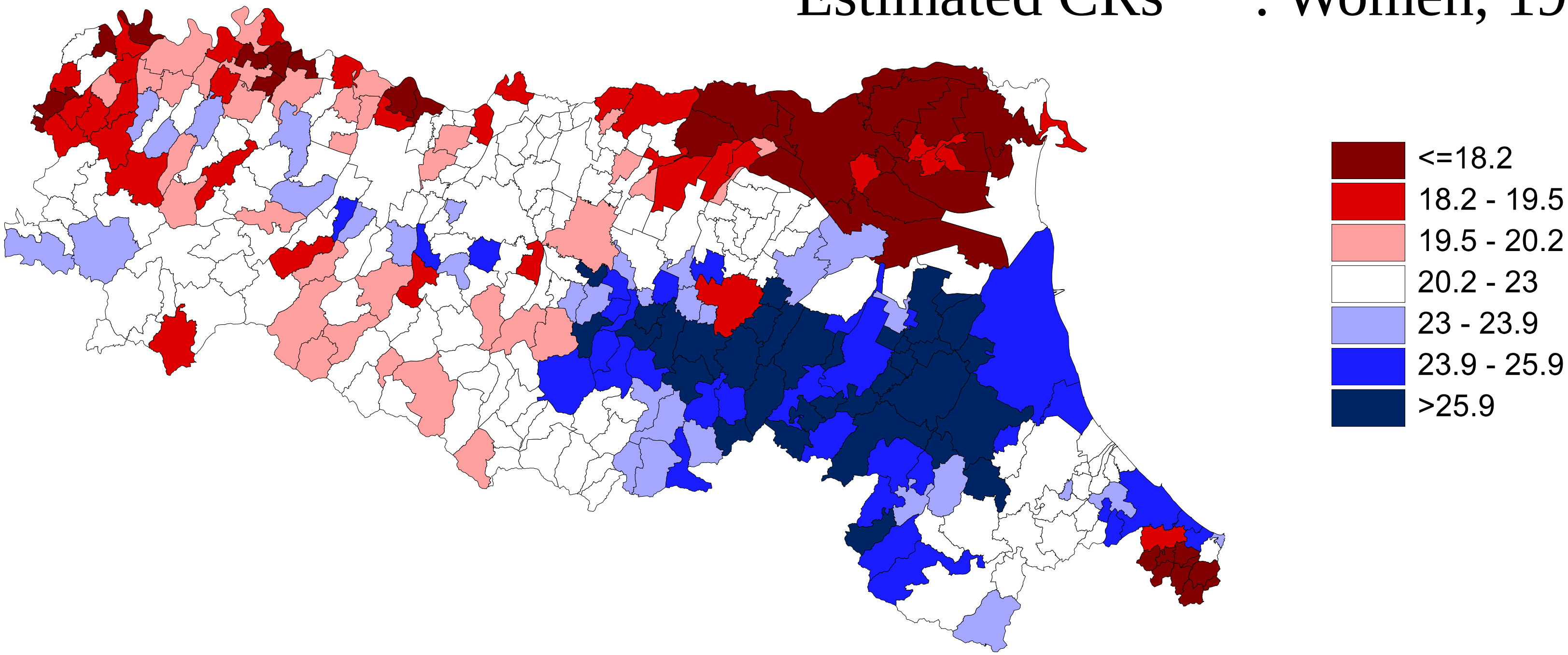


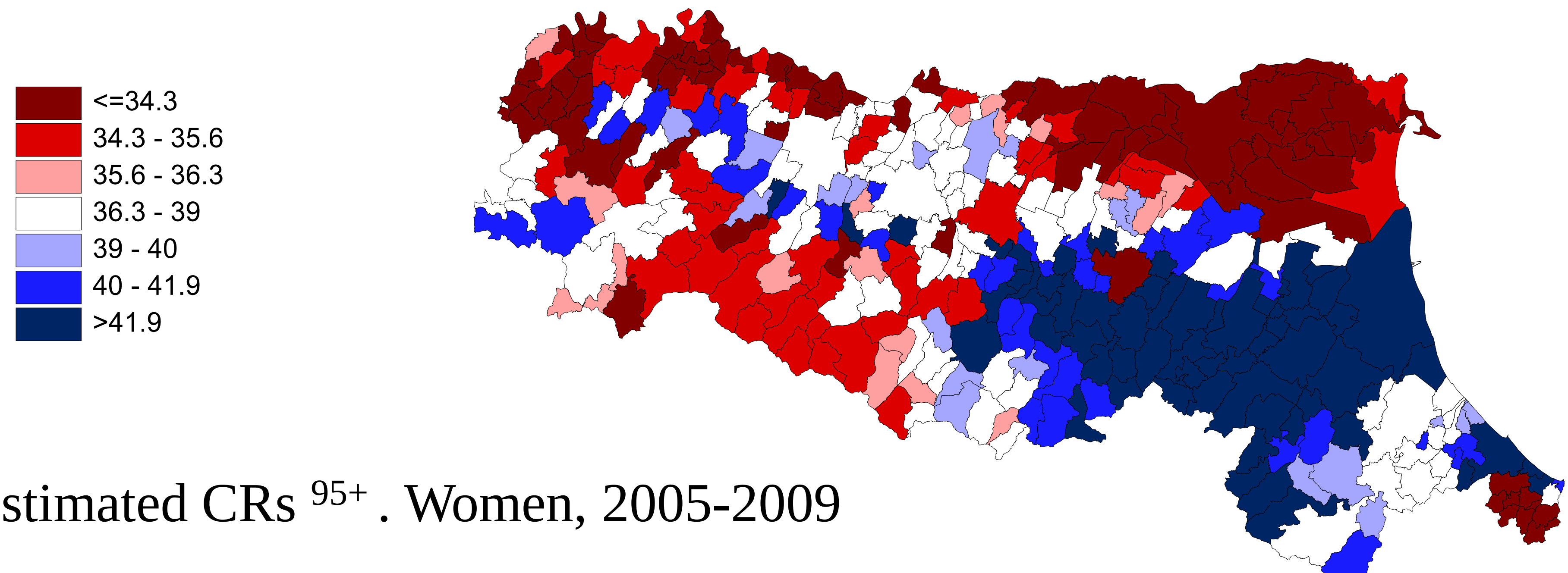




Estimated CRs $^{95+}$. Men, 2005-2009

Estimated CRs $^{95+}$. Women, 1995-1999





Estimated CRs $^{95+}$. Women, 2005-2009

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4. Spatial cohort analysis

- Spatial model on a five years period (2005-2009) longevity.
- A longitudinal perspective is adopted to investigate the effects of the past structure of mortality for people aged 80-89 (in 1990-94) and 90-99 (in 2000-2004) on the same cohort of individuals who reach 95 years of age and over in 2005-2009.
- SMRs by causes of death were grouped into 3 levels of mortality based on their quintile distribution.
- The model is:

$$\log\left(CR_i^{95+}\right) = \alpha_0 + \beta x_i + \sum_{a,d} \gamma_{ad} z_{iad} + u_i + v_i$$

where z_{iad} denotes the groups of SMRs by cause *d*, age group *a* and municipality *i*.

- We allow for a correlation among causes of death and among the repeated measure of mortality over age group by modeling the priors γ_{ad} of the effects through a non-informative multivariate normal distribution.

Effect of the past mortality on the cohort of P $^{95+}$ in 2005-2009

	Men	
	Fitted rate ratios	90% CrI
All causes[a] (80-89)		
Medium mortality	1	-
Low mortality	1.005	0.904 - 1.116
High mortality	0.864	0.783 - 0.953
All causes[a] (90-99)		
Medium mortality	1	-
Low mortality	1.304	1.192 - 1.425
High mortality	0.719	0.638 - 0.811

[a] Excluding injuries and poisoning.

Effect of the past mortality on the cohort of P $^{95+}$ in 2005-2009: by cause

	Men		Women	
	Fitted rate ratios	90% CrI	Fitted rate ratios	90% CrI
Circulatory diseases (age group 80-89 years)				
Medium mortality	1	-	1	-
Low mortality	1.091	0.996-1.195	1.005	0.947-1.067
High mortality	0.980	0.878-1.094	0.979	0.920-1.042
Circulatory diseases (age group 90-99 years)				
Medium mortality	1	-	1	-
Low mortality	1.197	1.081-1.326	1.068	1.009-1.130
High mortality	0.797	0.714-0.914	0.848	0.795-0.906
Malignant neoplasms (age group 80-89 years)				
Medium mortality	1	-	1	-
Low mortality	1.124	1.012-1.248	1.000	0.937-1.066
High mortality	0.828	0.752-0.909	0.997	0.943-1.054
Malignant neoplasms (age group 90-99 years)				
Medium mortality	1	-	1	-
Low mortality	1.070	0.963-1.190	1.036	0.974-1.100
High mortality	0.896	0.808-0.991	0.926	0.871-0.983

Effect of the past mortality on the cohort of P $^{95+}$ in 2005-2009: groups of areas

	Fitted rate ratios	
	Men	Women
Mountain and medium mortality at ages 80-89 and 90-99 years	1.000	1.000
Hill and density <78 people per km² and medium mortality at ages 80-89 and 90-99 years	1.046	0.989
Hill and density 78-193 people per km² and medium mortality at ages 80-89 and 90-99 years	1.076	1.207
Hill and density >193 people per km² and medium mortality at ages 80-89 and 90-99 years	0.824	0.982
Coastal hill and medium mortality at ages 80-89 and 90-99 years	0.864	0.667
Plain and density <78 people per km² and medium mortality at ages 80-89 and 90-99 years	0.682	0.772
Plain and density 78-193 people per km² and medium mortality at ages 80-89 and 90-99 years	0.767	0.908
Plain and density >193 people per km² and medium mortality at ages 80-89 and 90-99 years	0.889	0.974
Mountain and low mortality at ages 80-89 and 90-99 years	1.311	1.243
Hill and density <78 people per km² and low mortality at ages 80-89 and 90-99 years	1.371	1.230
Hill and density 78-193 people per km² and low mortality at ages 80-89 and 90-99 years	1.410	1.501
Hill and density >193 people per km² and low mortality at ages 80-89 and 90-99 years	1.080	1.220
Coastal hill and low mortality at ages 80-89 and 90-99 years	1.132	0.829
Plain and density <78 people per km² and low mortality at ages 80-89 and 90-99 years	0.894	0.960
Plain and density 78-193 people per km² and low mortality at ages 80-89 and 90-99 years	1.005	1.128
Plain and density >193 people per km² and low mortality at ages 80-89 and 90-99 years	1.165	1.211
Mountain and high mortality at ages 80-89 and 90-99 years	0.622	0.857
Hill and density <78 people per km² and high mortality at ages 80-89 and 90-99 years	0.650	0.847
Hill and density 78-193 people per km² and high mortality at ages 80-89 and 90-99 years	0.669	1.034
Hill and density >193 people per km² and high mortality at ages 80-89 and 90-99 years	0.512	0.841
Coastal hill and high mortality at ages 80-89 and 90-99 years	0.537	0.571
Plain and density <78 people per km² and high mortality at ages 80-89 and 90-99 years	0.424	0.662
Plain and density 78-193 people per km² and high mortality at ages 80-89 and 90-99 years	0.477	0.778
Plain and density >193 people per km² and high mortality at ages 80-89 and 90-99 years	0.553	0.834

All the causes of deaths (excluding injuries and poisonings) are considered.

5. Spatial model – period 2009-2013

- Random intercept model on the log-linear formulation of the CRs(2009-2013) .

$$\log\left(CR_i^{95+}\right) = \alpha_0 + u_i + v_i$$

where

a_0 is the intercept

u_i and u_i are the correlated and uncorrelated spatial heterogeneity, respectively.

- For the correlated spatial component u_i , we assume a Gaussian conditially autoregressive (CAR) model .
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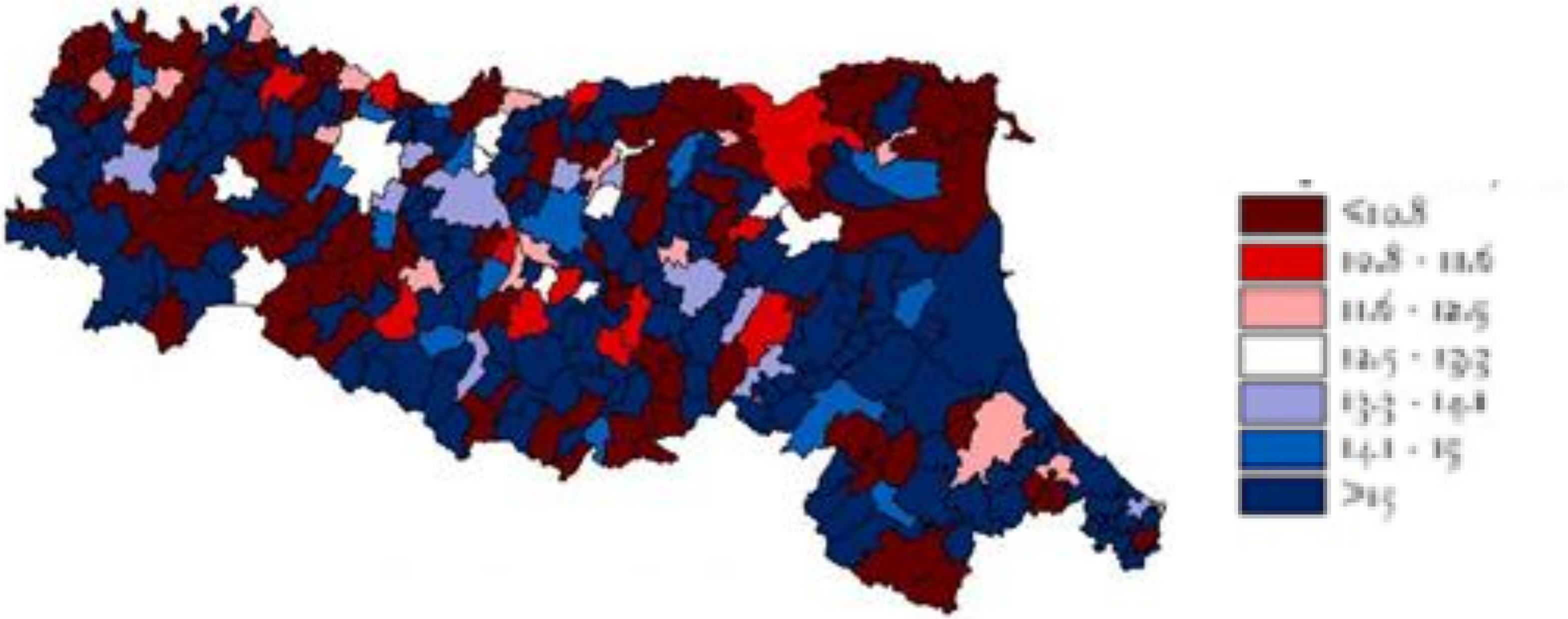
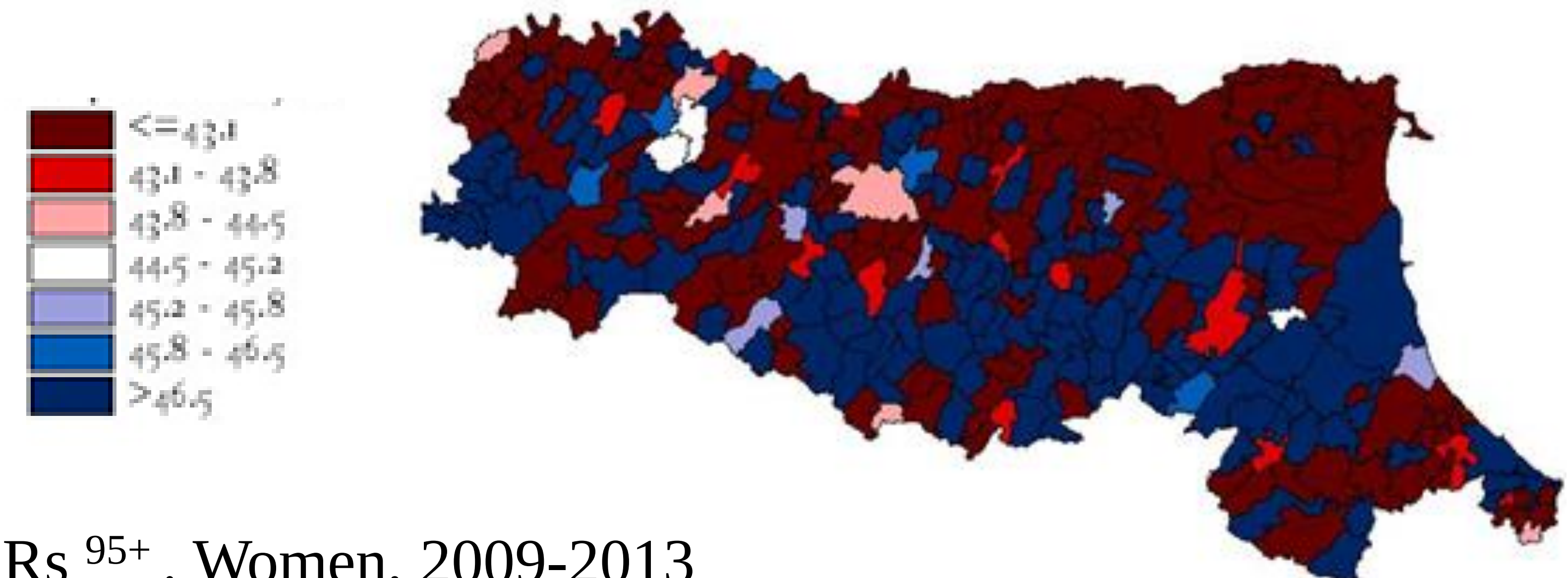
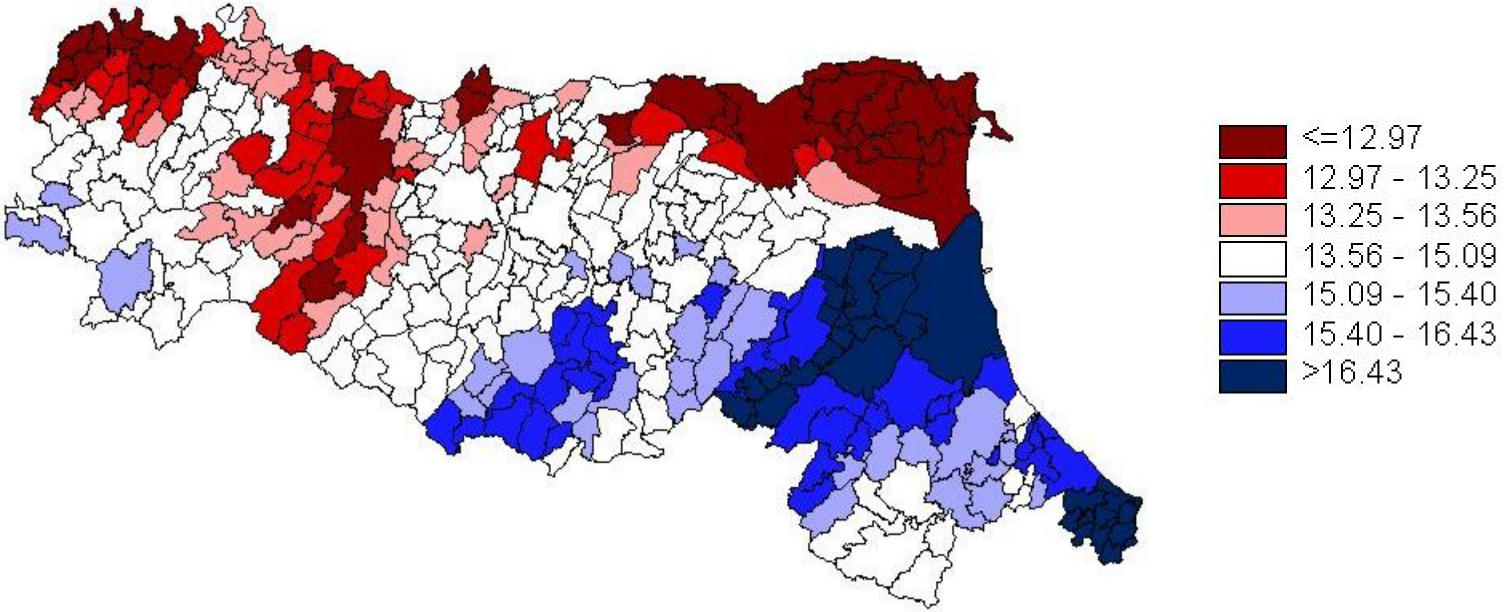
Observed CRs 95+ . Men, 2009-2013

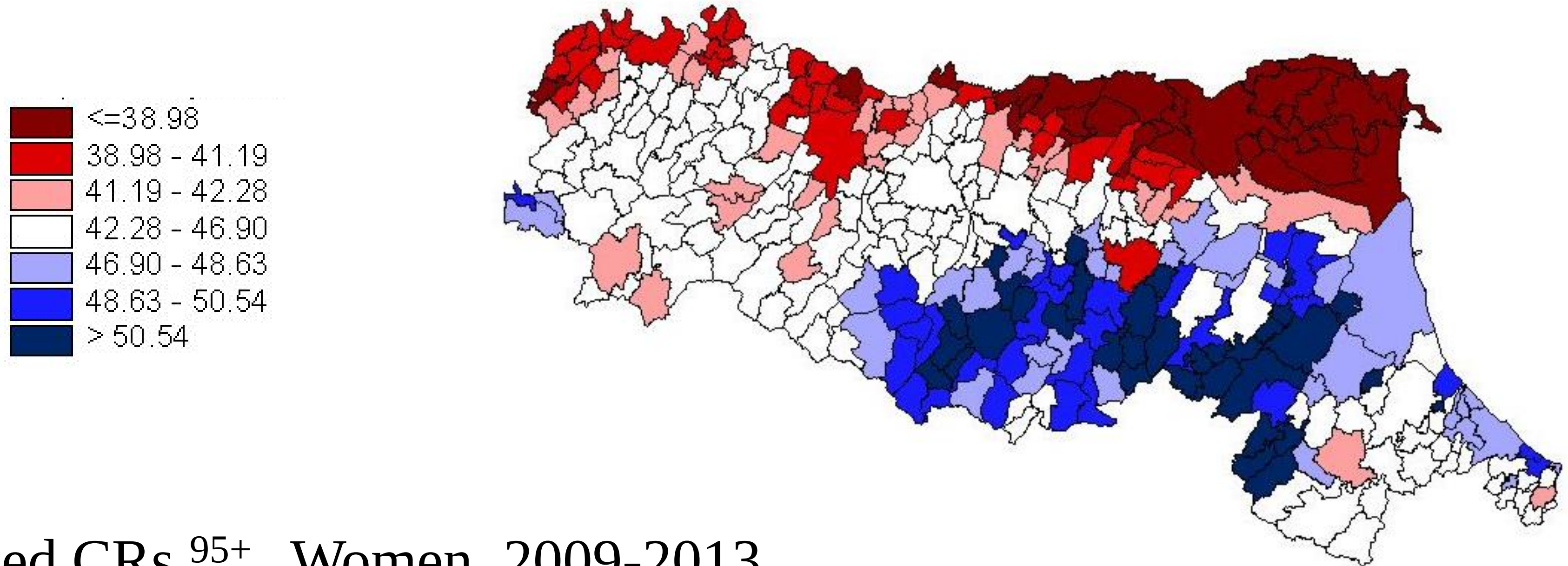




Observed CRs 95+ . Women, 2009-2013

Estimated CRs [95+]. Men, 2009-2013





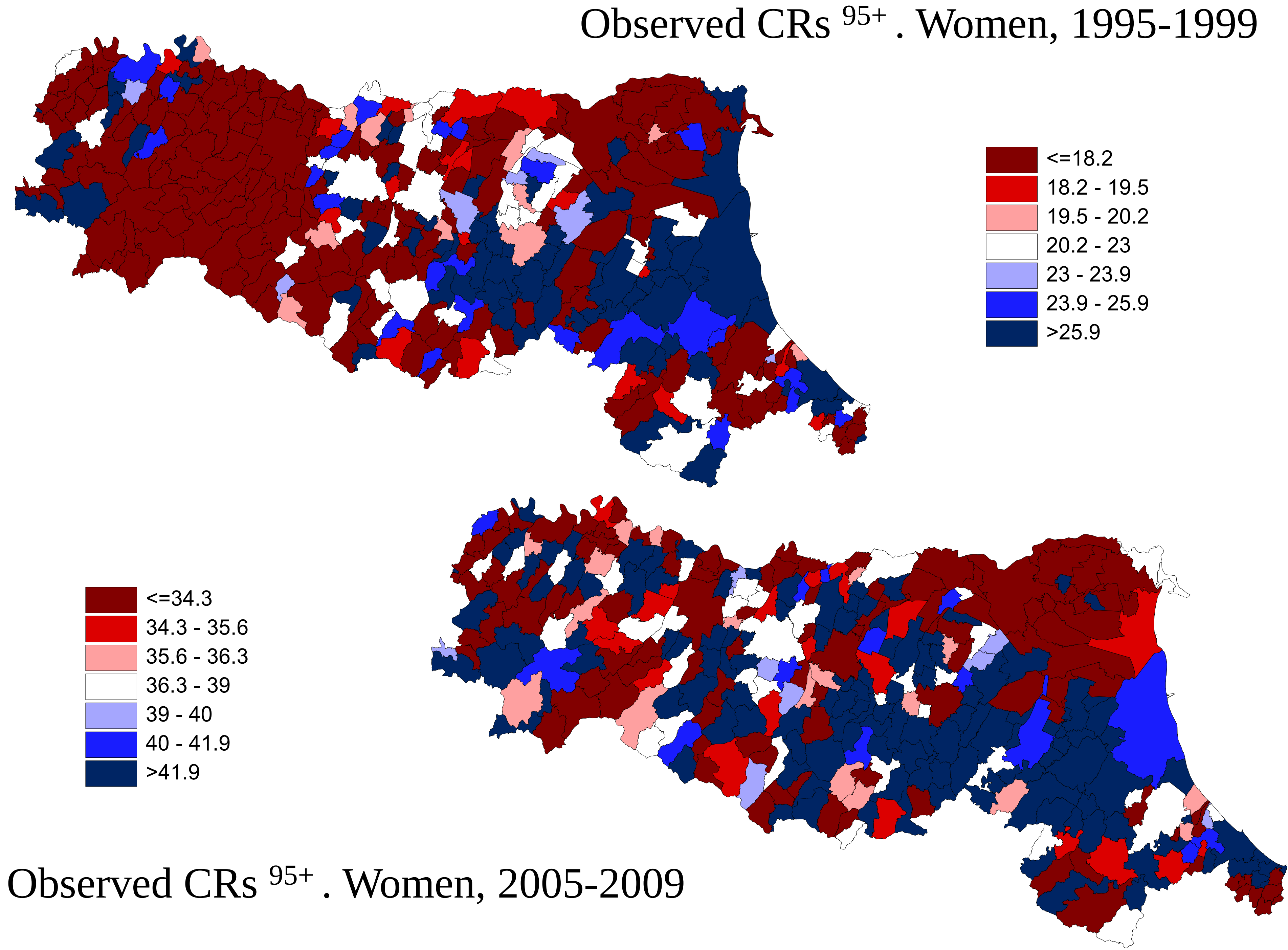
Estimated CRs [95+]. Women, 2009-2013

5. Concluding remarks

- The use of a hierarchical Bayesian modeling for spatial and spatial temporal data to analyze the longevity pattern in small area aims to confirm the usefulness of these methods also in socio-demographic research.

- This method has allowed to achieve our main purpose but other covariates would need to be included to explain the spatial variability across the areas (eg number of retirement homes, deprivation index, etc.).

- Another development of the analysis should consist in the use of a multinomial spatial approach to model the “risk” of becoming long-lived under a cohort perspective.


Observed CRs 95+ . Women, 1995-1999
<=18.2
18.2 - 19.5
19.5 - 20.2
20.2 - 23
23 - 23.9
23.9 - 25.9
>25.9
<=34.3
34.3 - 35.6
35.6 - 36.3
36.3 - 39
39 - 40
40 - 41.9
>41.9
Observed CRs 95+ . Women, 2005-2009

- Posterior estimates of variances for clustering and heterogeneity components and δ:

$$\delta = \frac{sd(\mathbf{u})}{sd(\mathbf{u}) + sd(\mathbf{v})}$$

	$\widehat{Var}(U \mid Y)$	$\widehat{Var}(V \mid Y)$	$\widehat{\delta}$
Men	0.054	0.003	0.783
Women	0.037	0.005	0.670

- Heterogeneity. Women.