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EU wide regional impacts of climate change

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Abstract

The current paper investigates the medium term impact of climate changes on EU agriculture. We employ CAPRI partial equilibrium modelling framework. The results indicate that within the EU, there will be both winners and losers, with some regions benefitting from climate change, while other regions suffering losses in production and welfare. In general, there are relatively small market effects at the EU aggregate. For example, the value of total agricultural income, land use and welfare change by approximately between -0.3% and 2%. However, there is a stronger impact at regional level with the effects increase by a factor higher than 10 relative to the aggregate EU impacts. The price adjustments reduce the response of agricultural sector to climate change in particular with respect to production and income changes.

Keywords: climate change, regional impacts, CAPRI, market effects

JEL classification: Q54

1. INTRODUCTION

With a growing concern of changing global temperature and precipitation patterns, an extensive list of studies have been conducted to examine the impact of climate changes on agricultural production and farming sector (Easterling et al., 1993; Chang, 2002; Peiris et al., 1996; Hakala, 1998; Brown and Rosenberg, 1999; Rotter and Van de Geijn, 1999; Craigon et al., 2002; Jones and Thornton, 2003). Many studies have concluded that the effects of climate change on crop yields would highly depend upon the geographical location of the crop production with crops in some regions benefited (Cuculeanu et al., 1999; Ghaffari et al., 2002) while crops in other regions showed adverse effect under new climatic conditions (Woodward et. a., 1991; Rosenzweig and Parry, 1994; Wheeler et al., 1996; Batts et al., 1997; Morison and Lawlor, 1999; Jones and Thornton, 2003; Parry et al., 2004). An increase in spring/summer air temperatures would be beneficial to crop production at northern temperate latitude sites where the length of growing season would increase. By contrast, warmer temperatures during crop development could depress yields in those regions where summer temperature and water are already limiting (Rosenzweig and Tubiello, 1997). This regional variation of the impact of climate change on agricultural production eventually leads to regional differences in farmers' responses.

There are a growing number of studies in recent years on determining the effects of climate change on EU agriculture (e.g. Reidsma et. al., 2007; Ciscar 2009). Studies indicate a strong regional divergence in climate change effects in EU (Olesen and Bindib 2002; Olesen 2008 Iglesias et al. 2009). Most of the studies focus on biophysical and environmental consequences of climate change (Bazzaz and Sombroek 1996; Gornall et al. 2010). Few studies analyse the EU wide economic impacts at regional level. The literature in the field of climate change effects mainly focuses on the impacts in small restricted geographical areas or in selected regions (e.g. Kaiser et. al., 1993; Brereton and O'Riordan, 2001; Sweeney et. al., 2003; Holden et. al, 2004; Holden et. al., 2008; Walker and Schulze, 2008; Quiroga and Iglesias 2009) or global market impacts (e.g. Darwin et. al., 1995; Parry et. al., 2004).

The objective of this paper is to simulate regional impact of crops yield changes under different climate scenarios. More specifically, we attempt to answer the following questions: Are market impact of climate change large or small? What are the regional effects on the EU agricultural sector? To analyze the scenarios we apply the CAPRI, a partial equilibrium modelling framework (Britz and Witzke, 2008). The advantage of CAPRI is that it can capture the market effects at EU regional level and takes into account interlinkages with and feedbacks from global agricultural markets.

2. METHODOLOGY

We employ the CAPRI model to investigate the economic and environmental impacts of climate change in the EU agricultural sector. CAPRI is a comparative static partial equilibrium model for the agricultural sector developed for policy and market impact assessments from global to regional and farm type scale. A detailed description of CAPRI is available in Britz and Witzke (2008). It is solved by iteratively linking its supply and market modules. The market module is a global spatial Multi-Commodity Model using 45 trade blocs and 75 countries. Based on the Armington approach (Armington, 1969) products are differentiated by origin, enabling to capture bilateral trade flows. The supply module is composed of separate, regional, non-linear programming models. The regional programming models are based on a model template assuming profit-maximizing behaviour under technological constraints, most importantly in animal feeding and fertilizer use, but also constraints on inputs and outputs such as young animal, land balances and set-aside (Jansson and Heckelei, 2011). The supply module currently covers all individual Member States of the EU-27 and also Norway, Turkey and the Western Balkans broken down to about 280 administrative regions (Nuts2 level) and more than 50 agricultural products.

2.1. Modelling climate change

A number of economic approaches and models are applied for assessing the economic impacts of climate change. They can be classified as either 'structural' or 'spatial-analogue' approaches. The first approach is interdisciplinary and interlinks models from several disciplines (Schimmelpfennig et al. 1996; Adams et al. 1998a). A common method applied to interlink different type of models consists of using biophysical models to predict crop yield effects of climate change scenarios which are then used as an input into the economic model to predict economic impacts (e.g. Adams et al. 1998b). The key distinguishing feature of the 'spatial-analogue' approach is that it is more explicit in taking into consideration spatial variation in climate change (e.g. Darwin et al. 1995). In our paper we apply the 'structural' approach. The advantage of this approach is that it provides a more explicit representation of causal effects and adjustments of the agricultural sector to climate change.

In agricultural production, one of the major impacts of climate change is manifested through the change in crop yields. The supply module of CAPRI has the capability to examine the economic impacts and land-use effects of changes in crops yields. The impact assessment can be done at the geographic resolution of regions (Nuts2). Although climate parameters (e.g. temperature, average participation) directly can not be fed into the model, changing crop yields due to climate change is a straightforward way to assess the economic impacts of climate change.

The CAPRI model relies upon the crop yield data provided by the modelling platform BIOMA - Biophysical Models Application (Confalonieri et al. 2009; Stöckle et. al., 2003) that includes biophysical models. Changes in crop yields are reported by BIOMA as a direct effect of changing climatic parameters. As there is no direct link of CAPRI with the climate change scenarios, the BIOMA platform and CAPRI naturally have the same climate assumptions in the scenarios. For this study, the BIOMA provided crop yield data for two A1B emissions climatic scenarios; a 'warm scenario' provided by the HadCM3 model and a 'mild' scenario provided by the ECHAM5 model. The 'warm' scenario estimates more than 3° C increase in global average temperature relative to pre–industrial levels (IPCC, 2007). The 'mild' scenario limits global warming to less than 2° C (JRC, 2011).

The yield changes for the two scenarios are provided in Table 1 and Figure 1 for selected crops and for five EU zones: Southern Europe, Central Europe South, Central Europe North, British Isles and Northern Europe.[1] Table 1 shows weighted average yield changes[2] and Figure 1 shows their dispersion for Nuts2 regions. Overall, the variation of yield changes at Nuts 2 in the mild scenario tends to be lower than in the warm scenario. Further, yield changes in the warm scenario at Nuts 2

[1] Southern Europe (Portugal, Spain, Italy, Greece, Cyprus, Malta and Bulgaria); Central Europe South (France, Austria, Czech Republic, Slovakia, Hungary, Romania, and Slovenia); Central Europe North (Belgium, The Netherlands, Germany, Luxemburg and Poland); British Isles (Ireland and UK); and Northern Europe (Denmark Sweden, Finland, Estonia, Latvia, and Lithuania).

[2] UAA in baseline was used as the reference period.

level tend to fluctuate around zero (Southern Europe, Central Europe South) or below zero (Central Europe North, British Isles, Northern Europe), whereas in the mild scenario they either have the same tendency to vary around zero (Southern Europe) or above zero (Central Europe South, Central Europe North, British Isles, Northern Europe) (Figure 1). Surprisingly, in British Isles and the Northern Europe the yield changes are reversely related to the global temperature change estimated in the two scenarios: yield changes tend to be positive in the mild scenario and negative in the warm scenario in these two zones (Figure 1). For specific crops, with exception of maize, weighted average yield changes for wheat, barley, rapeseed and sunflower are higher in the mild scenario as compared to the warm scenario (Table 1).

The version of the CAPRI model used for this study has the base year 2004 (averaged data for 2003, 2004 and 2005) and simulates a baseline scenario projected to 2020. The baseline captures development in exogenous variables such as policy changes, population growth, GDP growth and agricultural market development until the year 2020, drawing mostly on existing medium term outlooks.[3] The baseline is used as the reference situation for the counterfactual scenario analysis of climate change. The same time horizon (i.e. 2020) is considered for the scenario runs.

3. SIMULATION RESULTS:

We consider four climate change scenarios (warm, mild, warm-global and mild-global) plus the reference baseline scenario (business as usual). The four climate change scenarios differ with respect to whether price effects are considered or not. Warm and mild scenarios assume fixed prices of agricultural commodities. They simulate supply response of EU agriculture to climate change without taking in consideration market price effects. The other two scenarios (warm-global and mild-global) consider adjustment of EU and world prices of agricultural commodities to supply shock induced by climate change. The aim is to quantify the price effects of climate change on the EU agriculture. We consider both EU and non-EU price adjustments. Note that climate scenarios are introduced only for European countries. For Non-EU countries yields are kept unchanged. For this reason, the price effects

[3] The CAPRI baseline construction relies on the combination of three information sources: the Aglink-COSIMO baseline analysis of historical trends and expert information (Blanco Fonseca et al., 2010). It includes recent assumptions on macroeconomic drivers (such as GDP growth, population, oil price) and assumptions on policies (e.g. the Common Agricultural Policy). Because the regional resolution of the Aglink-COSIMO is limited to EU aggregates, the CAPRI baseline includes also national expert information. Furthermore, the baseline includes specific expert information from the PRIMES energy model (Capros et al., 2010) for the bio-fuel sector and expert projections from the seed manufacturer KWS on the sugar sector. Trends and expert information combined might be inconsistent in some aspect and might violate basic technical constraints such as crop area and/or young animal balances. As a consequence all expert information is usually provided in the form of target values. For consistency reasons (such as production quantity equalization with activity levels and yields), deviations from target values are allowed but to avoid large deviations they are penalized during the model estimation process. Another important input into the baseline constructions is detailed information on policy measures. The policy assumptions complete the definition of the CAPRI baseline and together with other data form the basis for parameter calibration.

may bias our results downward or upward depending on the supply response to climate change in non-EU regions.

3.1. Prices and production

Our simulation results indicate that climate change will reduce prices of agricultural commodities.[4] The price changes occur in the warm-global and mild-global scenarios because we allow in these scenarios for both EU and Non-EU price adjustments. EU agricultural prices decrease with a maximum rate of -13% relative to the baseline. The only exceptions are oilseeds which price increase in the warm-global scenario. Most price changes are in the interval between -5% and 0%. The highest price impact is observed for maize in the warm-global scenario due to strong yield effect of climate change (Table 2). The difference in the two scenarios varies by crop and in general they follow the yield changes. Cereal prices tend to decrease more in the warm-global scenario than in mild-global scenario, whereas oilseed prices decrease in the mild-global scenario and increase in the warm-global scenario. For the rest of commodities the picture is mixed.

In general, climate change tends to have positive impact on agricultural production although there are strong differences in adjustment pattern between sectors. Overall cereal production increases in all four scenarios. However there is strong difference for specific cereal crops between warm and mild scenarios. In the warm scenario, wheat and barley production is replaced by maize as farms shift to higher yielding maize crop. In the mild scenario, wheat and barley production increase, while there is a relatively small impact on maize production. In the case of oilseeds, due to farm production substitution towards cereal, oilseeds production is reduced in both warm and warm-global scenarios. In the mild scenarios, the cereal substitution effect is much lower, hence oilseeds production also adjusts upward. Adjustment of animal production (with exception of milk) to climate changes is relatively low and positive for most commodities and in all four scenarios. The overall increase in animal production is induced by lower crop prices which reduce animal feed costs (Table 3). Note that the small animal production adjustment could be due to the fact that we assumed zero impact of climate change on animal yields. This is based on the assumption that the direct effect climate change on individual animals would be very small for the next fifty years (Parsons et al., 2001).

Price adjustments of agricultural commodities tend to reduce the impact of climate change on production. Comparing scenarios with market price effects (warm-global, mild-global) and scenarios where only supply adjustments are considered (warm, mild), production change is substantially lower in the former two scenarios as compared to the latter two scenarios. This is valid in

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[4] Note that we implement climate change scenario only in European courtiers which implies that the actual price effects may be different.

particular for crop sectors. For animal sector, production adjustment is small (with exception of milk) with and without price adjustment assumption (Table 3).

Production adjustment to climate change varies strongly among EU regions and commodities. The variation in regional production adjustment follows the variation in yield changes induced by climate change (Figure 1). This adjustment follows the strong local specificity of climate change. For example, Figure 2 to Figure 5 report simulated production changes for cereals and oilseeds at Nuts2 level. The figures indicate that the variation in production change is stronger for warm scenario as compared to the mild scenario. For cereals, in most Nuts2 regions production change is in the interval between -20% and 10% (-1% and 8%) relative to baseline for both warm scenarios (mild scenarios) with the global one being right skewed. For oilseeds, the production change for most Nuts2 is distributed between -10% and 10% (-5% and 10) for both warm scenarios (mild scenarios) with the global one being right skewed.

3.2. Land use

The impact of climate change on EU aggregate land use is relatively small. Total utilized agricultural area (UAA) in EU remains almost affected (between -0.01% and -0.27%) relative to the baseline in all four scenarios. Same holds for arable land and pastures. More important are land relocation effects between different crops (between -4% and 11%) (Table 4).

At regional level climate change tends to cause a reduction in UAA in Central Northern EU in warm scenarios, while an increase in southern EU. In mild scenarios the there is not clear pattern (Figure 6). The regionally differentiated pattern of UAA adjustment in the warm scenarios is driven by yield changes. In Central and Northern Europe yields tend to decrease more in warm scenario than in other EU regions (Figure 1).

3.3. Income and welfare effects

Climate change will lead to a small positive impact on agricultural income and welfare. The total welfare improves but the change is very small (close to zero). The agricultural income reacts stronger but the effect is still relatively low: between -0.20 and 2%.[5] With exception of the mild-global scenario, the income improves caused by overall increase in yields which more than offset price decrease. When considering adjustment of prices (warm-global and mild-global scenarios), the income change is smaller as compared to scenarios with only supply adjustments considered (warm and mild scenarios).

[5] The calculation of the income of the agricultural sector follows the concept of the gross value added. This is the value of the total outputs increased with subsidies minus the value of intermediate inputs.

The variance in agricultural income change is much stronger at regional level. Most Nuts2 regions experience income change due to climate change between -5% and 5% relative to baseline. However, in some Nuts2, income increases up to 20% or decreases up to -10% (Figure 7).

At regional level climate change tends reduce income in Central Northern Europe in warm scenarios. In mild scenarios there is not observed a clear pattern. Figure 8 shows the regional disaggregation of income effects with negative effects prevailing particularly in Central and Northern EU in warm scenarios, but stronger when price adjustments are allowed (warm-global scenario) as opposed to the scenario with no price adjustments (warm scenario). In mild scenario without price adjustments, income changes are small and predominantly positive. When price adjustment are taken into consideration (mild-global), the number of loosing Nuts2 regions increases due to declining prices but they are evenly distributed across EU.

4. DISCUSSION

The current paper investigates the medium term impact of climate changes on EU agriculture. We employ CAPRI modelling framework to identify the EU aggregate effects as well as regional impacts. The results indicate that within the EU, there will be both winners and losers, with some regions benefitting from agricultural production adjustment as a result of climate change while other regions suffering losses in production and welfare. In general, there are relatively small effects at the EU aggregate. For example, the value of total agricultural income, land use and welfare change by approximately between -0.3% and 2%. However, there is a stronger impact at regional level with some negative effects prevailing particularly in Central and Northern EU and smaller impacts are observed in Southern Europe. Regional impacts of climate change increase by a factor higher than 10 relative to the aggregate EU impacts. The price adjustments reduce the response of agricultural sector to climate change in particular with respect to production and income changes.

From a policy perspective our results indicate that targeting intervention (e.g. through the CAP) might be more efficient if differentiated at regional level rather than implementing a uniform approach applied across the whole EU to address the climate effects and to support adaptation of the agricultural sector to climate changes. Indeed, regions are affected differently depending on the location and sector which requires a site specific adjustment to climate change. An effective policy design may thus require a micro regionalized approach with strong focus on local needs.

The results in this paper must be analyzed in the context of limitations imposed on the study. In particular we do not take into account full adaptation of EU agricultural sector to climate changes. We investigate the medium term effect of climate change on EU agriculture. Full adjustment may mitigate some of the effects while other sectoral and/or regional impacts maybe stronger than our results indicate. The use of stylized template models which are structurally identical and express differences between regions solely by parameters alone might fall short of capturing the full regional diversity of farming systems in EU and their response to climate change. In particular, this is the case for the evaluation of climate change impact on cropping systems, technology adaptation, such as fertilization, manure handling, feeding practices and sectoral demand behaviour. The relatively simple representation of agricultural technology in the CAPRI model compared to approaches parameterised based on biophysical models understates the farm response to natural and local constraints. However, the current structure of the approach gives a good balance between increased detail of represented regions and robustness of the model results for medium term horizon economic analysis of climate changes.

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Table 1: Yield changes in climate change scenarios by EU zones (% change relative to baseline)

	Warm					Mild				
	Soft wheat	Barley	Maize	Rape	Sun flower	Soft wheat	Barley	Maize	Rape	Sun flower
Southern Europe	-0.7	0.6	57.0	-3.8	-1.4	3.1	2.0	-3.2	2.8	-0.2
Central Europe South	-3.8	-3.6	44.7	-3.8	1.1	3.4	3.5	2.2	5.2	1.2
Central Europe North	-3.7	-3.4	0.6	-2.5	3.72	2.4	2.3	2.7	3.1	1.0
British Isles	-8.6	-7.1		-5.5	0.0	6.0	6.4		4.6	0.0
Northern Europe	-1.7	-1.9	0.8	-0.5	0.0	4.5	4.2	1.5	1.5	0.0
EU-27	-4.0	-2.7	43.9	-3.0	0.5	3.6	3.3	0.7	4.2	0.7

Source: own elaboration

Table 2: Producer price changes in EU-27 (% change relative to baseline)

	Warm-global	Mild-global
Cereals	-4.93	-1.82
Soft wheat	-1.68	-2.02
Barley	-3.84	-1.89
Grain maize	-12.71	-1.26
Oilseeds	1.13	-2.9
Rape seed	1.69	-3.41
Sunflower seed	-0.59	-1.58
Meat	-0.81	-0.53
Beef	-0.65	-0.67
Milk	-1.12	-0.64

Source: own elaboration

Table 3: Production change in EU-27 (% change relative to baseline)

	Warm	Mmild	Warm-global	Mild-global
Cereals	9.89	3.02	5.03	2.14
Soft wheat	-5.27	4.03	-5.99	2.92
Barley	-3.54	3.66	-5.79	2.77
Grain maize	60.5	0.49	42.13	-0.17
Oilseeds	-4.47	5.18	-0.79	1.19
Rape seed	-5.91	6.68	-1.27	1.47
Sunflower seed	-0.1	0.65	0.68	0.08
Meat	-0.09	0.02	0.35	0.21
Beef	0.04	0.07	0.25	0.24
Milk	-103.87	-103.87	0.13	0.1

Source: own elaboration

Table 4: Land use change in EU-27 (% change relative to baseline)

	Warm	Mild	Warm-global	Mild-global
Cereals	1.2	0.19	-0.42	-0.1
Soft wheat	-0.97	0.32	-1.08	-0.11
Barley	-0.43	0.22	-1.53	-0.08
Grain Maize	10.52	0.02	2.59	-0.29
Oilseeds	-2.32	1.38	1	-1.28
Rape sees	-3.11	2.3	1.65	-1.92
Sunflower	-1	-0.12	0.07	-0.37
Pasture	-0.28	-0.15	-0.24	-0.11
Arable land	0.05	0.06	-0.28	-0.2
UAA	-0.06	-0.01	-0.27	-0.17

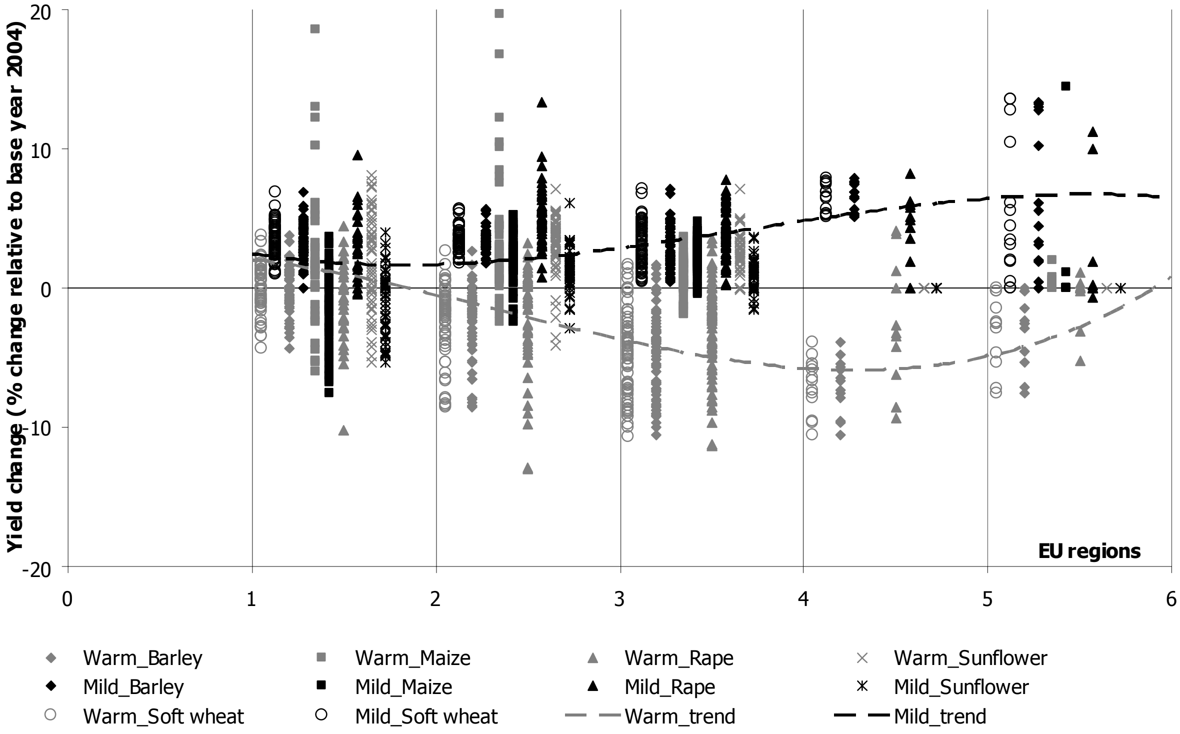
Source: own elaboration

Table 5: Welfare and agriculture income in EU-27 (% change relative to baseline)

	Warm	Mild	Warm-global	Mild-global
Total welfare	-	-	0.02	0.01
Agricultural income	2	0.5	0.97	-0.21

Source: own elaboration

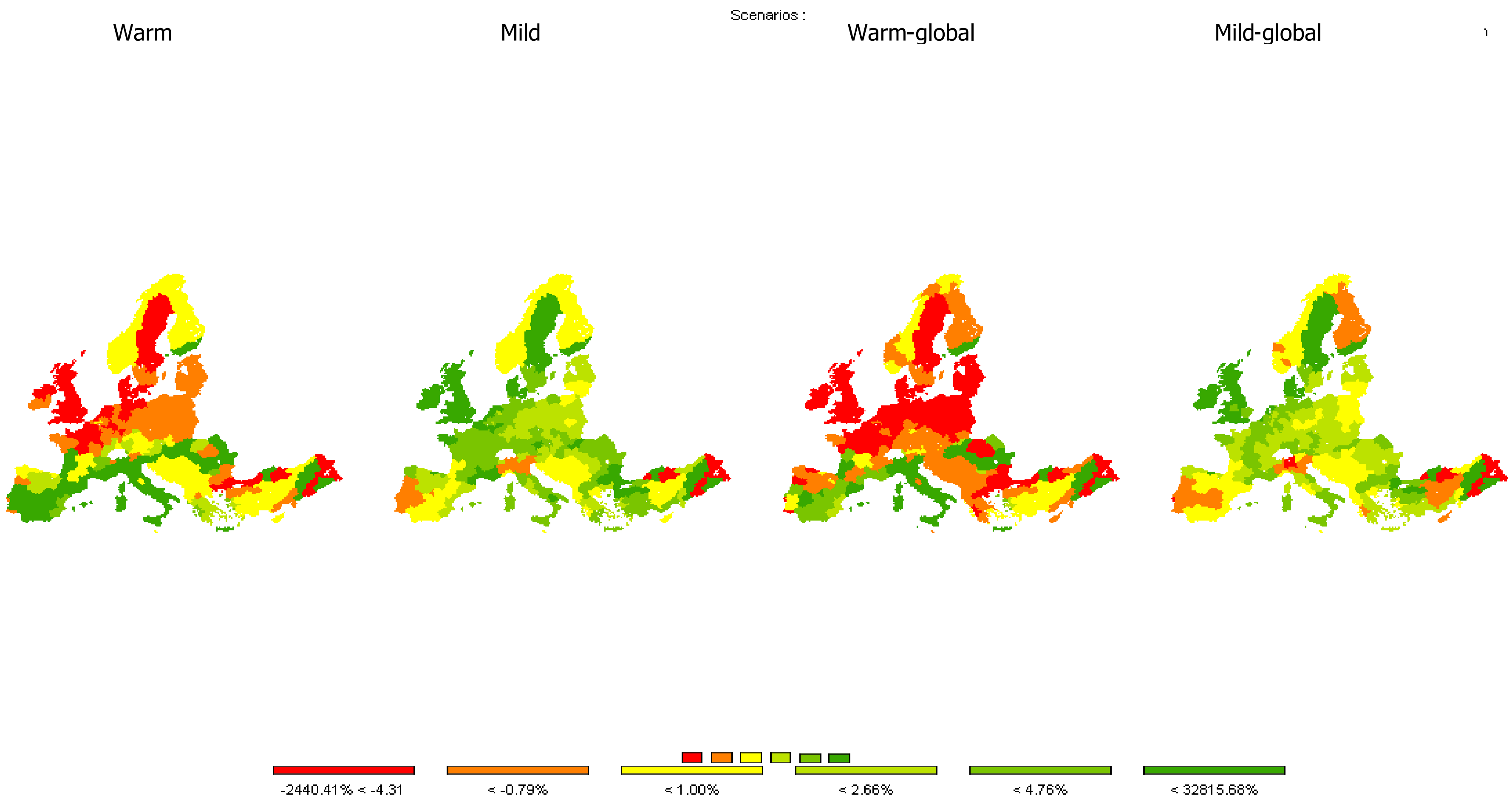
Figure 1: Yield changes in climate change scenarios by Nuts2 and EU zones (% change relative to baseline)



Notes: 1 = Southern Europe; 2 = Central Europe South; 3 = Central Europe North; 4 = British Isles; and 5 = Northern Europe.

Source: own elaboration

Figure 2: Change in cereal production in EU-27 (% change relative to baseline)



Source: own elaboration

Figure 3: Distribution of cereal production changes at Nuts2 in EU-27 (% change relative to baseline)

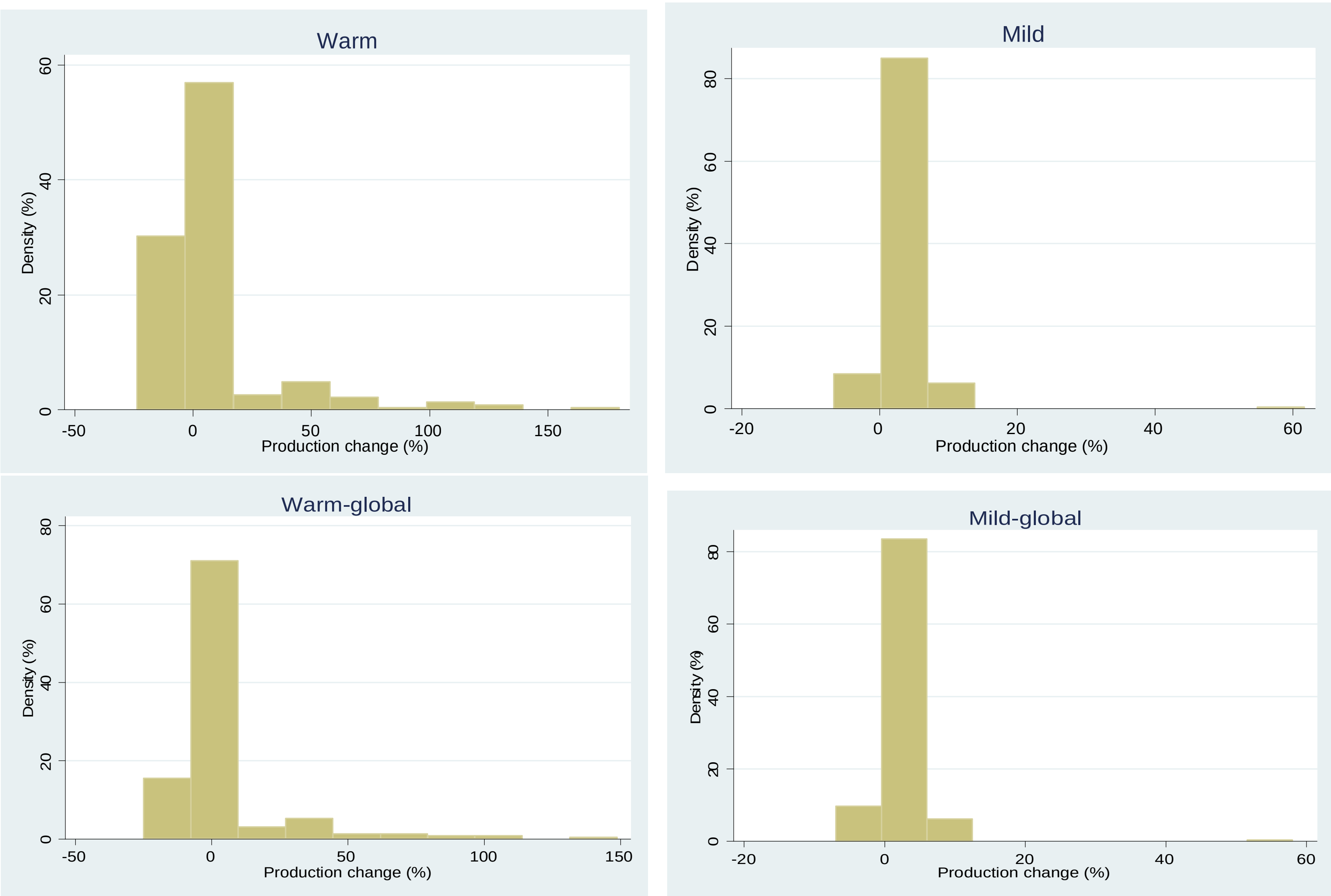
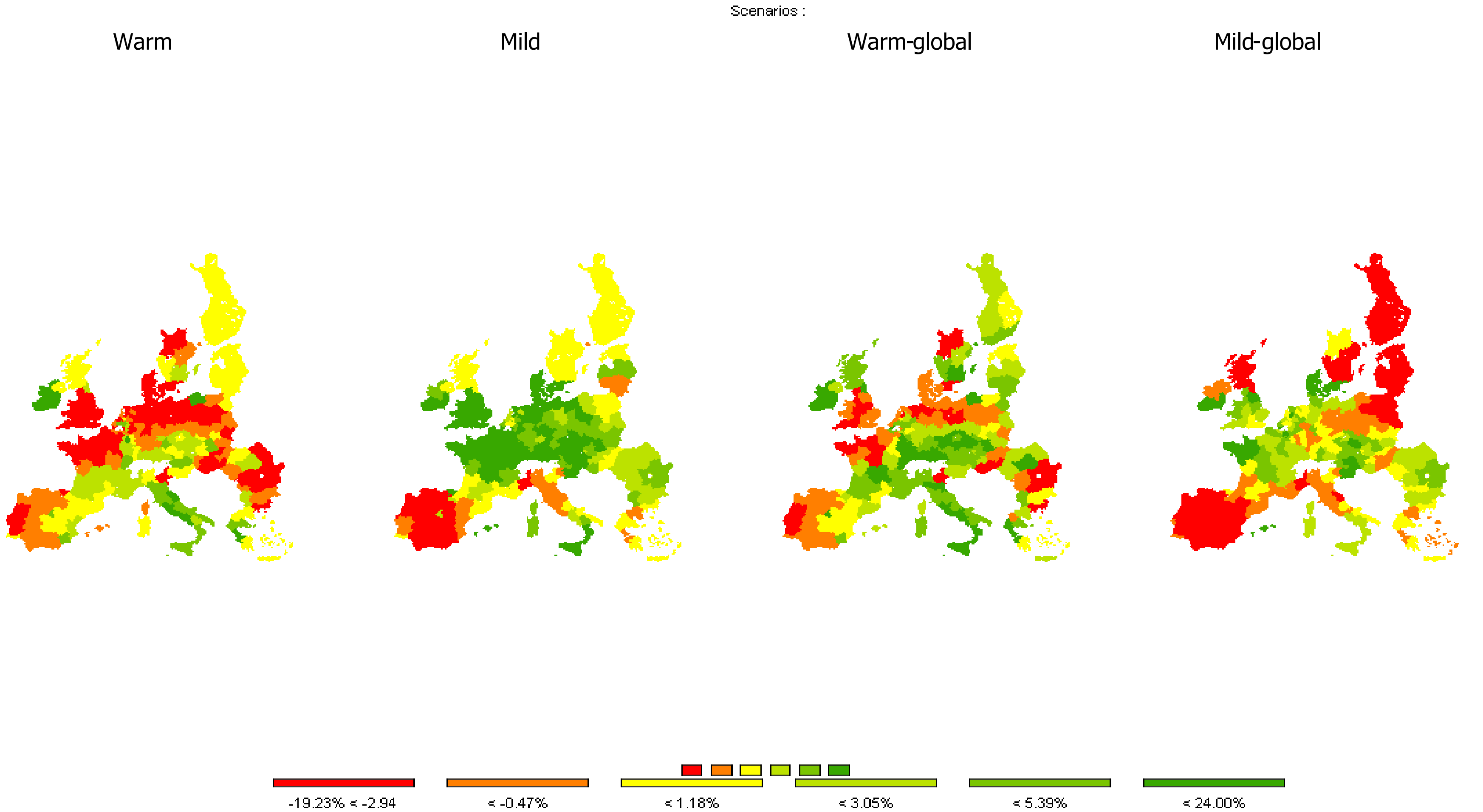


Figure 4: Change in oilseeds production at Nuts2 in EU-27 (% change relative to baseline)



Source: own elaboration

Figure 5: Distribution of oilseeds production changes at Nuts2 in EU-27 (% change relative to baseline)

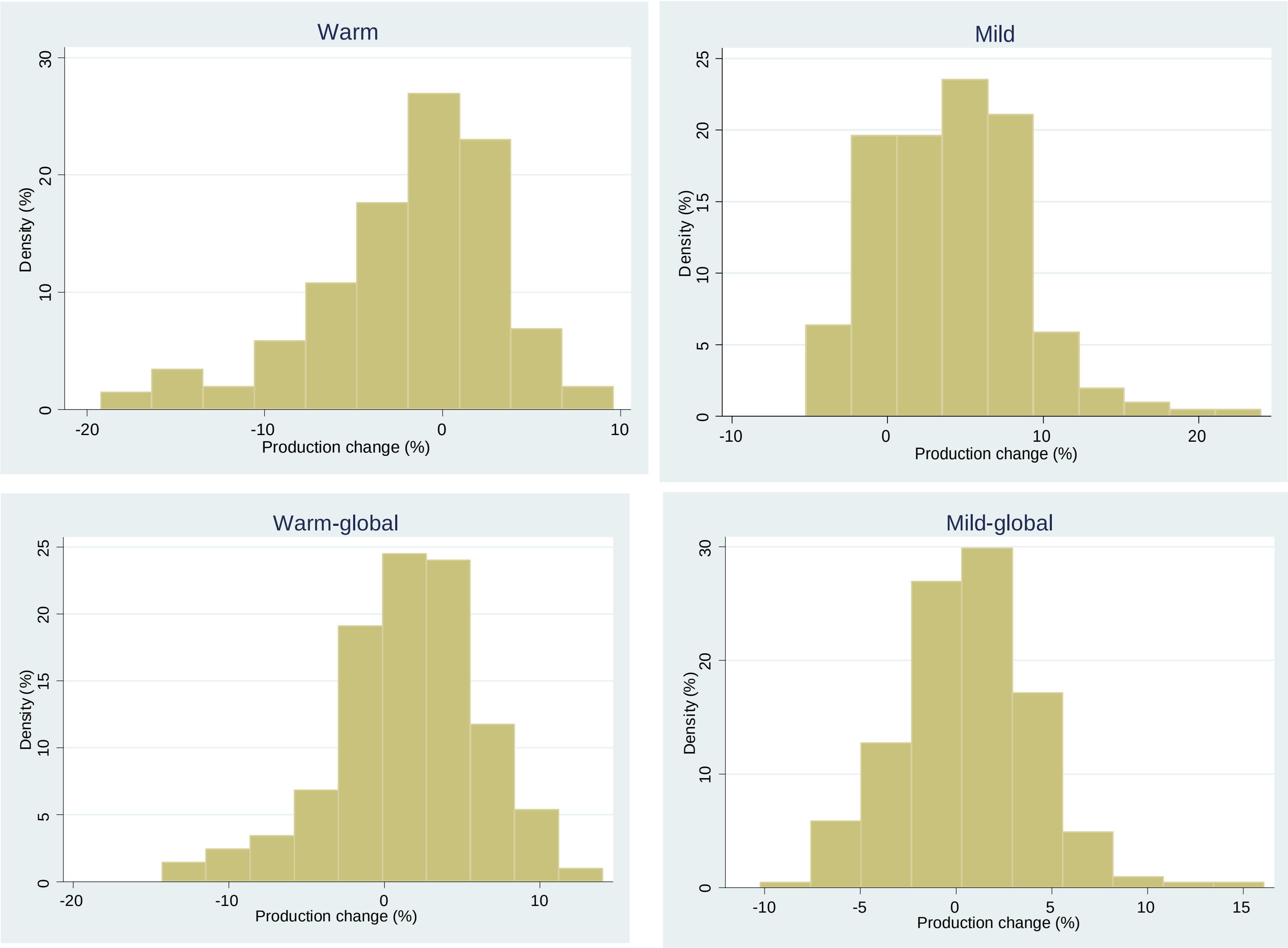
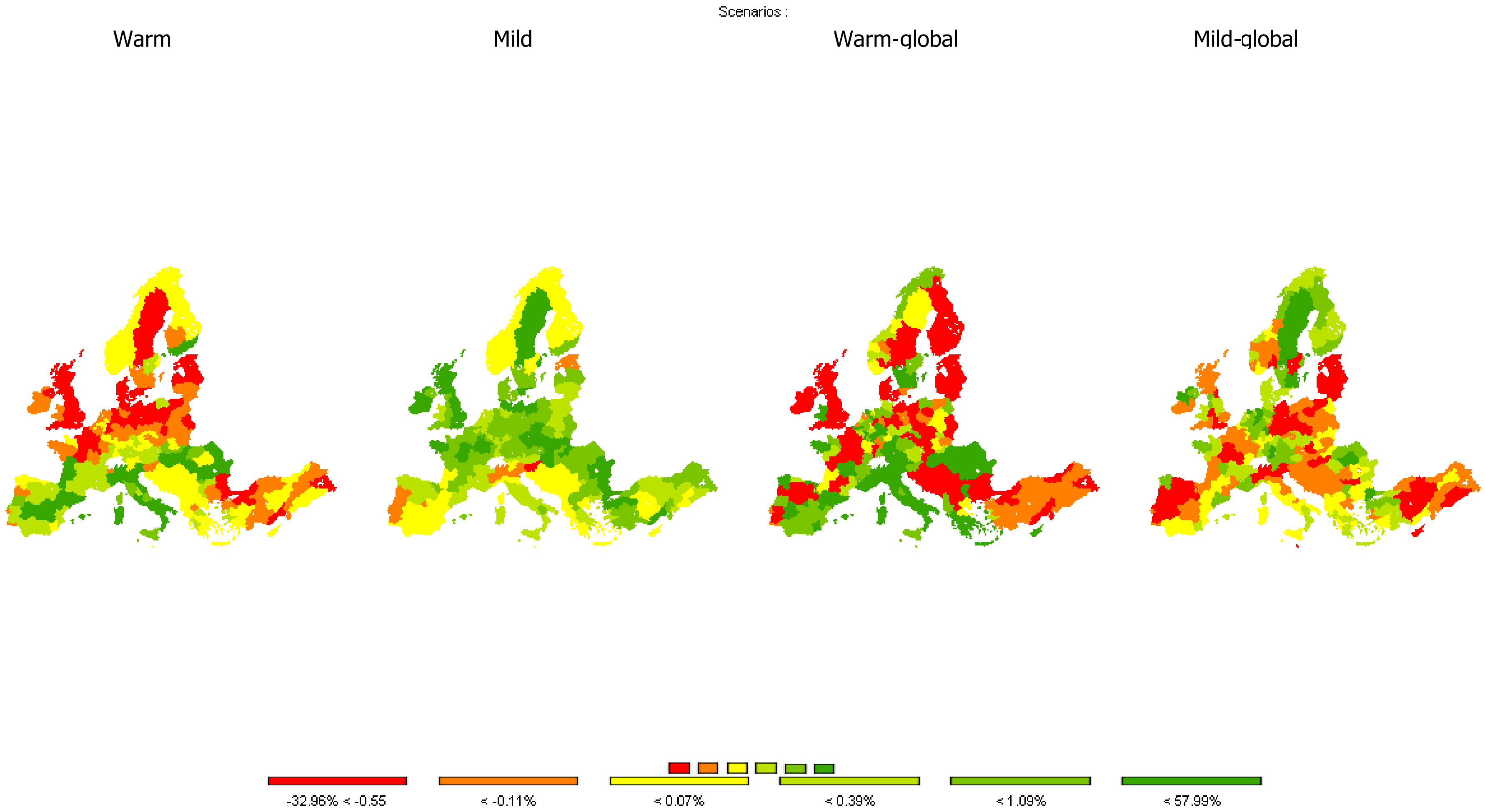
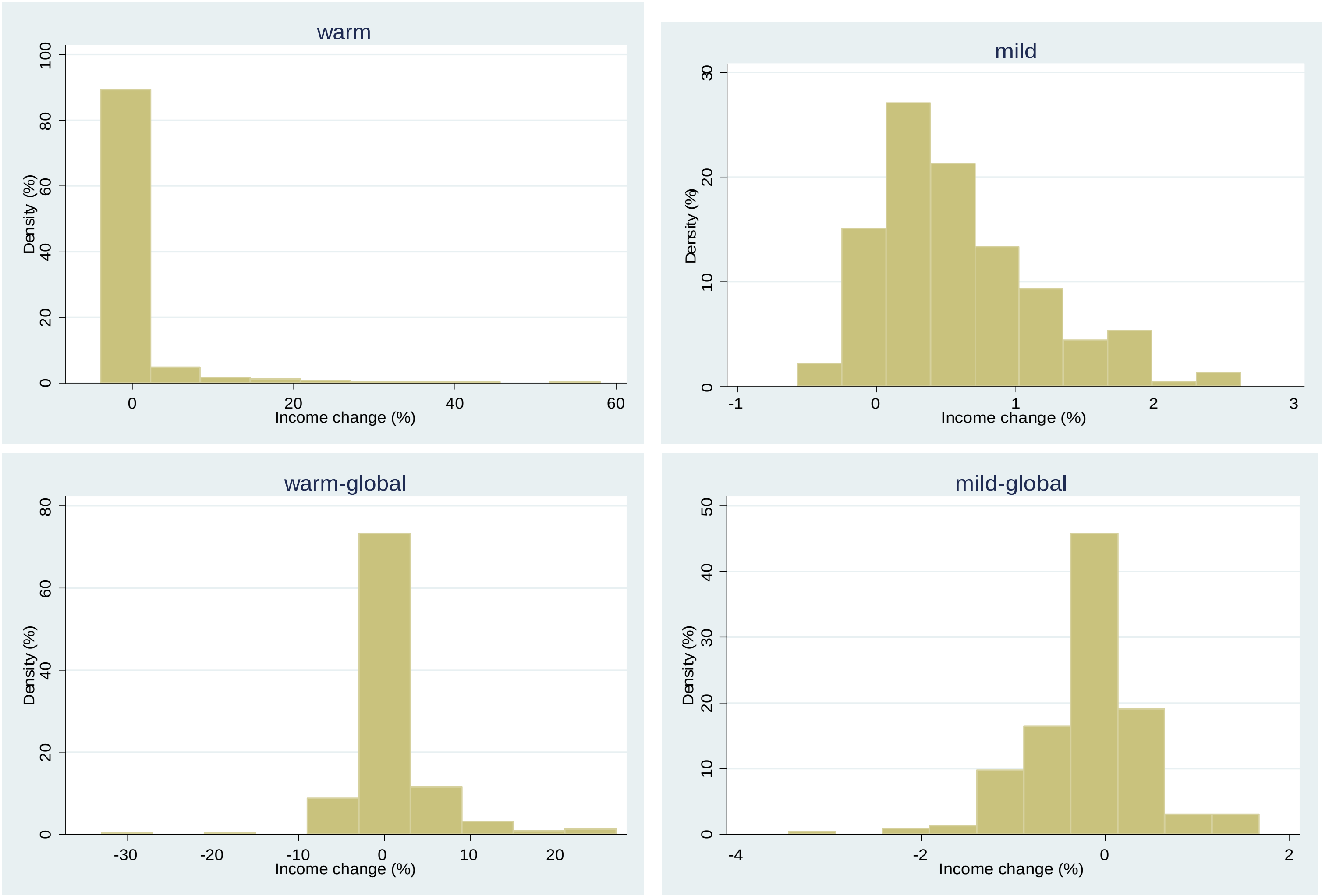


Figure 6: UAA land use change at Nuts2 in EU-27 (% change relative to baseline)



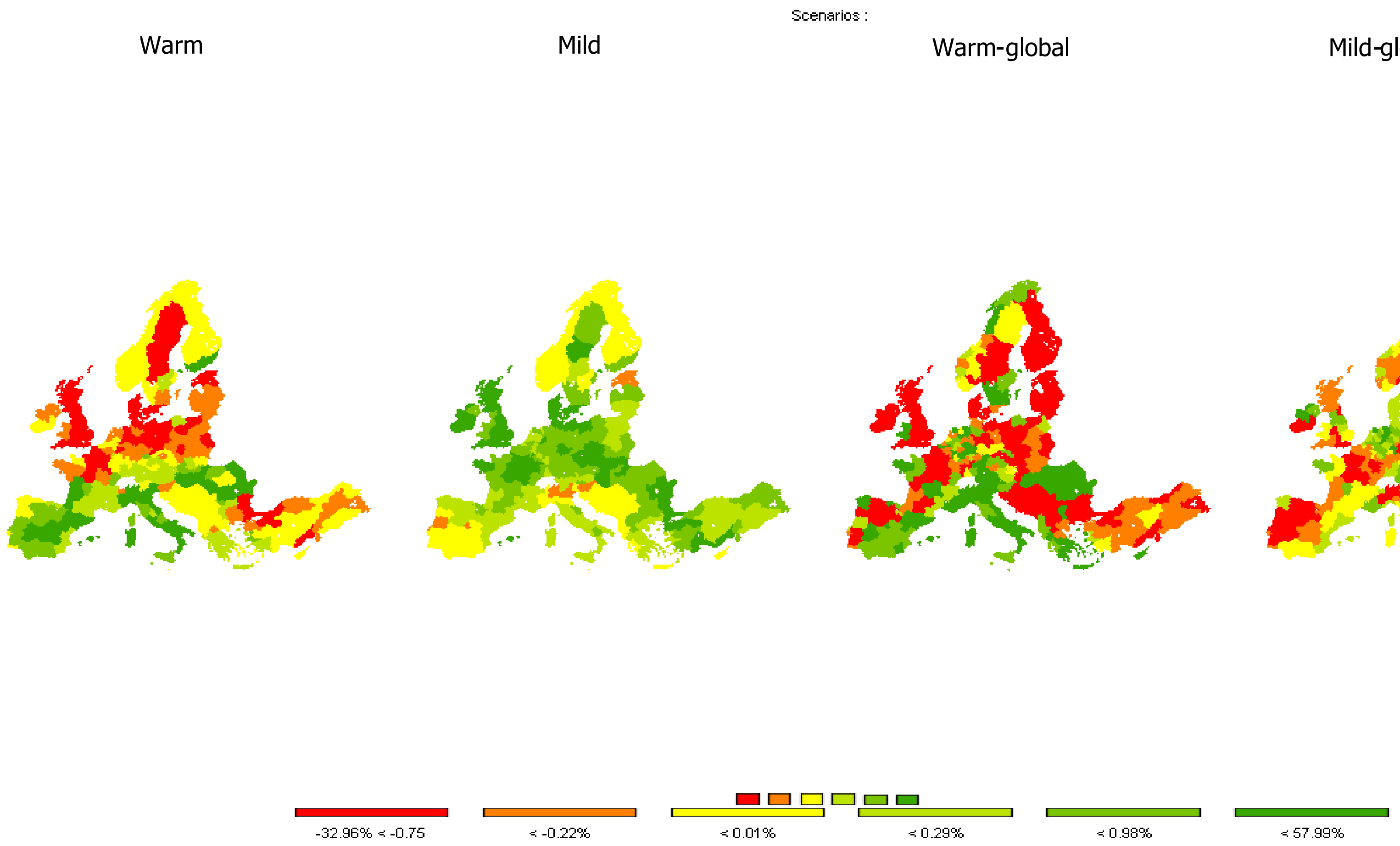
Source: own elaboration

Figure 7: Distribution of income changes at Nuts2 in EU-27 (% change relative to baseline)



Source: own elaboration

Figure 8: Income change at Nuts2 in EU-27 (% change relative to baseline)



Source: own elaboration