Science-based trade-off and synergy evaluation of hotspots and problem spots in future ESS supply

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Chapter 1. Introduction

Ecosystems are undergoing strong modifications related to land use transitions and climate change induced by Human societies. Still, the services ecosystems provide make them essential for Human well-being. In order to sustain Human well-being, it is utterly important to evaluate the potential impact of future policy strategies on the future of ecosystem service supply in Europe.

At the crossroad between stakeholders and ecological assessment, WP12 aims at disentangling the impact of policy-driven land use changes on ecosystem service supply by integrating science-based and value-based trade-off analysis methods. To this aim, ecosystem services modelled in WP8 will be mapped under the contrasting VOLANTE scenarios in order to foresee potential problems in future ES supply. Here we present the scientific assessment of synergies and trade-offs between ecosystem services under the VOLANTE scenarios and policy alternatives using model outputs from WP7 and WP11. Ecosystem services were calculated using the models presented in Deliverable D 8.1 and their changes assessed as compared to the 2010 baseline values presented in D 8.2. Synergies and trade-offs were assessed using the so-called ‘scientific’ methods developed in deliverables 8.2, 8.3 and 12.1, aiming to identify hotspots in individual services and repeatable associations among ecosystem services, known as ecosystem service bundles.

The analysis of ecosystem service supply under alternative land use scenarios: integrating scales and ecosystem services associations will then serve as input to inform the roadmap of future land resource management in Europe (WP13).
Chapter 2: Presentation of the scenarios and analyses performed

2.1. Overview of the ecosystem services studied

In VOLANTE a comprehensive list of twelve ecosystem services (ES) is considered for the assessment of the current and future benefits from ecosystem to Europe’s society. Spatially-explicit models developed and applied for these services were presented in Deliverable 8.1, and modelled ES maps at the scale for the EU for the 2010 baseline were presented and analysed in deliverables 8.2 and 8.3. For this Deliverable 12.2, WP8 partners calculated ES projections under VOLANTE's marker scenarios and policy alternatives (see below). Among the full list of 12 ES, the indicators of water purification and alien threat could not be projected for VOLANTE scenarios. The future state of nitrogen sources implied in the water retention model is not modelled for VOLANTE scenarios. Moreover, the water purification index mainly depends on the structure of basins and rivers that are not predicted to change. The ecological impact and invasive potential of alien species can hardly be projected in the future. Notwithstanding the fact that programs may be implemented to control invasive and alien species other than the one considered here may invade Europe in the future. Consequently, the two services were removed from the analyses performed in this deliverable. The tables provided in appendix A summarize the ES indicators and models used.

2.2. Overview of VOLANTE marker scenarios and policy alternatives

VOLANTE’s visions of land use in Europe were developed around four marker scenarios. Marker scenarios are based on the storylines of four modified SRES marker scenarios as described in VOLANTE deliverable 7.3:

“**V-A1** represents a globalised world with strong economic growth, high growth of food and feed demand, weak regulation on land use change, declining tropical forest areas, a fully liberalized CAP, and phased-out bioenergy mandates.

**V-A2** represents a fragmented world with modest economic growth, high population growth, high growth of food and feed demand, weak regulation on land use change, declining tropical forest areas, no change in the CAP, and phased-out bioenergy mandates.

**V-B1** represents a sustainable world with modest economic growth, slow growth of food and feed demand, strong regulation on land use change, protected tropical forest areas, a liberalized CAP, and modest bioenergy demand.

**V-B2** represents a fragmented world with modest economic growth, modest growth of food and feed demand, some regulation on land use change, some protection of tropical forest areas, no change in the CAP, and modest bioenergy demand.”
These four marker scenarios were further detailed using 11 variants called “policy alternatives” (abbreviated “VPA”) described in Deliverable D11.1 (see appendix B):

- VPA1: Nature protection
- VPA2: Nitrogen/water quality policies
- VPA3: Agricultural productivity increase
- VPA4: Bio-based economy and bioenergy
- VPA5: PES: Payment for carbon sequestration
- VPA6: PES: Payment for recreational services
- VPA7: CAP reform for rural employment
- VPA8: Zoning for compact cities
- VPA9: Climate change impacts/flood protection
- VPA10: Climate change mitigation/agricultural emission taxes
- VPA11: Increased trade barriers for higher EU self-sufficiency

Storylines from marker scenarios and policy alternatives were used to parameterize the VOLANTE top-down modelling chain, which resulted in a list of output indicators like global GDP per capita from ReMIND/MAgPIE, change in nominal agricultural prices from LEITAP/MAGNET or Net change in EU-27 arable land from Dyna-CLUE. Among the models used in VOLANTE, only CAPRI, EFISCEN and Dyna-CLUE directly feed ecosystem service assessment. Consequently, we chose to work on VPA involving these three models: VPA1, VPA5, VPA6, VPA8 and VPA9 (Table 1).

Table 1. Summary of model projections from D7.3 and D11.2 used in ecosystem service projections for each policy alternative.

<table>
<thead>
<tr>
<th>VPA</th>
<th>CAPRI</th>
<th>EFISCEN</th>
<th>Dyna-CLUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPA1 Nature protection</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>VPA5 PES for carbon sequestration</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>VPA6 PES for recreational services</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>VPA8 Zoning for compact cities</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>VPA9 Climate mitigation</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

2.3. Projections and identification of future coldspots and hotspots of ecosystem services

Indicators of ecosystem services described in D.8.1. and D.8.2. (except water purification and alien threat) were projected for the 2040 time step. Outputs from CAPRI, Dyna-CLUE and EFISCEN runs using marker and VPA parameters, were used to project ecosystem services with WP8 models. Specifically, projected outputs of Dyna-CLUE and EFISCEN directly fed the assessment of dead wood, wood supply and carbon sequestration. Moderation of fires, pollination, biocontrol of pests, outdoor recreation and flood regulation used Dyna-CLUE land cover outputs. The moderation of fire and wind disturbances also accounted for age structure and species information from EFISCEN projections. Finally, CAPRI outputs were used to assess the food-feed-fibre indicator. Considering the long procedure to project the CAPRI model for VPA, food-feed-fibre was projected for VPA related to the A2 marker scenario only.

Hotspots, or coldspots, are defined as places where the indicator value is in the upper, or respectively lower, tail of the distribution of the indicator value. Following Qiu & Turner (2013)\(^1\), we used, respectively, the lower and the upper 10\(^{th}\) percentiles of the distribution of values of a given ES in 2010 to define the threshold values to identify coldspots and hotspots of the ES supply in both 2010 and 2040. Consequently, for a given ES, thresholds are the same in 2010 and 2040 so we could compare the proportion of hot- (cold-) spots in 2010 and 2040 and study their evolution, i.e. the number of cells (1km\(^2\)) that either would become hot- (cold-) spots under a given scenario or hotspots turning into cold or intermediate spots of supply (see section 3.3.).

2.4. Estimating changes in ecosystem services from 2010 to 2040

Each proxy was first standardized using Paracchini et al. (2011)\(^2\) (i.e. subtracting the minimum value observed and then dividing by the difference between the maximum and the minimum values observed) for each time step separately (see D.8.1. and D.8.2., both available at http://volante-project.eu/). To facilitate the interpretation of our analyses, both wind disturbance and fire risk indicators were converted into services by using the formula \(1 - x\) (\(x\) being the indicator value). To assess changes in ecosystem services, we first compared the mean values of projected values of ES at the EU-27 scale in 2010 to the mean values in 2040.

Finally, for each scenario and policy alternative we also built a self-organizing map (hereafter called “SOM”) (Kohonen 2001)\(^3\) to represent the spatial clustering of pixels according to their similarity in ES associations. This analysis thereby captures bundles of ecosystem services, i.e. sets of ES which consistently co-occur in space across the EU. A self-organizing map derives from artificial neural networks and defines classes of locations (i.e. pixels) sharing common features. To ease comparison between projected bundles and bundles in 2010, we run the SOM analyses on ES modelled using land use under the A1 marker scenario and excluding water purification and alien threat services, to define the baseline bundles. When an ES was not

\(^1\) Qiu & Turner (2013) Spatial interactions among ecosystem services in an urbanizing agricultural watershed. PNAS. 110: 12149-12154.
projected on a given VPA, the missing VPA predictions were replaced by the values of the ES under the corresponding marker scenario. For example, deadwood (DW) was not projected under VPA 8 and 9. Consequently, the values of DW estimated under A2 and B2 were used instead. Bundles under A1 and B1 scenarios were calculated without the biocontrol service.

Finally, we checked for the consistency of results across spatial scales by comparing the trends observed at the Europe scale to the trends observed at the NUTS2 scale.
Chapter 3: Predicted changes of ES supply in 2040

3.1. Hypotheses to be tested

VOLANTE policy alternatives are expected to mainly affect ES supply through changes in land use/land cover like land abandonment or increased nature protection. We summarized in table 2 the hypothesised changes in ES supply in response to each of the five selected VPA chosen. In the majority of cases, the expected overall responses at EU level of ES to VPA are either positive or mixed. In this latter case, the supply of ES will either be positively or negatively affected depending on local land use. Mixed effects depict spatially heterogeneous effects of land use on ES supply. For instance, remaining agricultural lands in VPA5 and 6 may be more intensively exploited leading to a higher supply of food-feed-fibre to compensate the loss of agricultural lands for carbon supply or recreation purposes. In the case of biocontrol, it may increase in these strongly intensified remaining agricultural lands but may decrease in the extended natural (protected or not) areas (in VPA1 and 5 for instance). Indeed, biocontrol is defined by the presence of agricultural pests and the presence of agricultural lands. Thus, a decrease in biocontrol might translate a decrease in pests, which may be considered as return to healthier state of the ecosystem. VPA1 and 5 are expected to have overall negative impacts on wood supply and moderation of wind disturbances due to reduced wood supply and/or the maintenance of old trees, which are more vulnerable to extreme events.

The hypotheses on ES – VPA responses might be modulated by marker scenarios A (1 or 2) and B (1 or 2). For instance, effects of natural land expansion and management of agricultural lands might be exacerbated in the marker scenario B, which assumes a modest economic growth, slow (B1) to moderate (B2) consumption of food and energy, or even a stronger regulation on land use change.
Table 2. Summary of the hypothesised effects of policy alternatives on ecosystem services studied in VOLANTE’s framework. Policy alternatives may entail an increasing ES supply (in blue), a decreasing ES supply (in pink), mixed effects on ES supply (in grey) or no effect (in black). (BioC – biocontrol; Fire – fire control; WS – wood supply; DW – deadwood; Wind – moderation of wind disturbances; FFF – food/feed/fibre from agriculture; flood – flood regulation; Leis – outdoor recreation; Poll – pollination; Cseq – carbon sequestration).

<table>
<thead>
<tr>
<th>VPA1 - Nature protection</th>
<th>VPA5 - PES for C sequestration</th>
<th>VPA6 - PES for recreational ES</th>
<th>VPA8 - Zoning for compact cities</th>
<th>VPA9 - Climate (flood) mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BioC</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mixed effects: biocontrol might decrease with the loss of pests as an answer to the expansion of protected areas but could increase with the intensification in remaining agricultural lands</td>
<td>Overall increasing supply due to maintenance of management system delivering some ecosystem service.</td>
<td>Overall, relatively little influence expected as the impact on natural areas might be limited</td>
<td>Positive effects limited to the areas targeted by the policy. The encouragement of natural areas could help preserving habitats of species providing biocontrol but biocontrol may decrease if pests decrease according agricultural land management</td>
<td></td>
</tr>
</tbody>
</table>

| **Fire**                 |                               |                               |                                 |                                 |
| Propagation of wildfires may be facilitate by a reduced management intensity and increasing fuel loads (biomass) | Overall increasing supply due to maintenance of management system delivering some ecosystem service. | Overall, relatively little influence expected as the impact on natural areas might be limited | Overall, slightly decreasing supply of fire moderation where nature is promoted |

| **WS**                   |                               |                               |                                 |                                 |
| Reduced wood supply due to restrictions on management in protected areas | Reduced wood supply due to incentives to store more carbon | Mixed effect | Overall, relatively little influence expected as the impact on forested areas might be limited |

| **DW**                   |                               |                               |                                 |                                 |
| Increased deadwood due to reduced wood harvest | Mixed effect | Overall, relatively little influence expected as the impact on forested areas might be limited |

| **Wind**                 |                               |                               |                                 |                                 |
| Protecting nature will favour larger share of old trees that are more vulnerable to wind disturbance | Mixed effect | Overall, relatively little influence expected as the impact on forested areas might be limited |

| **FFF**                  |                               |                               |                                 |                                 |
| Expected increase per hectare, in order to guarantee FFF supply with less available agricultural land | Spatially heterogeneous effect: decreases in grasslands due to restrictions to conversions, increases in other areas due to agricultural expansion/intensification to meet the FFF demand on less available agricultural land | Spatially heterogeneous effect: decreases in agricultural areas targeted by the policy, increases in other areas to counter this | Overall, relatively little influence expected on FFF provision, as urban expansion is only one among many factors explaining changes in agricultural land expansion/abandonment | Overall, slight positive increase expected in FFF provision, as higher supply/ha is expected to meet FFF demand on less available agricultural land |

| **Flood**                |                               |                               |                                 |                                 |
| Positive effects on flood regulation due to increase in (semi-) natural land cover and forests | Positive effects on flood regulation due to increased pasture and forest extent | Positive effects | Slight overall increase of flood regulation due to weak growth of cities / sealed surface | Positive effects on flood regulation due to increased forest extent and traditional agricultural management in upper catchments and flood prone areas |
Table 2. Summary of the hypothesised effects of policy alternatives on ecosystem services studied in VOLANTE’s framework (continued). Policy alternatives may entail an increasing ES supply (in blue), a decreasing ES supply (in pink), mixed effects on ES supply (in grey) or no effect (in black). (BioC – biocontrol; Fire – fire control; WS – wood supply; DW – deadwood; Wind – moderation of wind disturbances; FFF – food/feed/fibre from agriculture; flood – flood regulation; Leis – outdoor recreation; Poll – pollination; Cseq – carbon sequestration).

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<th>VPA8 - Zoning for compact cities</th>
<th>VPA9 - Climate (flood) mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leis</strong></td>
<td>Increasing outdoor recreation due to the expansion of protected areas beyond Natura2000 and restrictions on human intervention and land cover changes within them</td>
<td>Increasing outdoor recreation due to increased forest extent and limited grassland conversion</td>
<td>Overall positive but limited effect due to maintenance of management system delivering some ecosystem service. However, the contribution of agricultural land to outdoor recreation is relatively limited compared to protected areas and natural/semi natural land which are not much affected by this policy alternative</td>
<td>Limited positive effect: urban expansion is likely to occur near already urbanized areas suitable for developments (e.g. peri-urban agricultural land), with relatively low recreation potential rather than in areas with high degree of naturalness</td>
</tr>
<tr>
<td><strong>Poll</strong></td>
<td>Spatially heterogeneous effects: forest expansion increases pollination potential near the edges of forests but decreases it in the cores. Restrictions on land uses conversion within the enhanced protected network will mostly prevent decreases rather than determine significant increases</td>
<td>Slight positive effects on pollination in area targeted by the policy. Uninfluential elsewhere</td>
<td>Slight positive effects in areas targeted by the policy. I.e. urban fringes and peri-urban areas, where urban expansion is more likely to occur, relatively uninfluential elsewhere</td>
<td>The increasing extent of forests in catchment areas may have positive effects at the edges of forests and flood prone areas but negative overall slightly negative, especially within cores</td>
</tr>
<tr>
<td><strong>Cseq</strong></td>
<td>Increasing carbon sequestration due to increased natural lands, less gross conversions and restrictions on wood removals</td>
<td>Increasing carbon sequestration in biomass due incentives to store more carbon in forest biomass</td>
<td>Increasing carbon sequestration due to less gross land use conversions, especially from pasture. Smaller effects expected than for VPA1, as the amount of forest doesn’t change. Also displacement effects expected, so mixed effects could occur locally</td>
<td>Spatially heterogeneous effects. Positive effects on carbon sequestration are expected in places where forest extent and traditional agricultural management in both upper catchments and flood prone areas, increase. Negative effects are expected elsewhere, where agricultural land or built-up rebounds as a consequence of the protection in flood prone / upstream areas</td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td>Regarding deadwood, the real effect should be mixed, slowly increasing levels of larger deadwood fractions (stems), but less input of smaller deadwood fraction from harvest residues</td>
<td></td>
<td>This scenario aims at decreasing the spatial extent of urbanization and makes no direct hypothesis on ES so the effects on ES might be limited</td>
<td>In practice, this scenario does not explicitly modelled forests, so there might be no impact on related ES projections</td>
</tr>
</tbody>
</table>
3.2. Changes in mean ES supply at the EU27 level

The average projected supply of each service for 2040 vary little across scenarios with a few exceptions (Fig. 1). On average, over EU27 and across scenarios, values for fire moderation, biocontrol and pollination supply are (slightly, in the case of fire moderation and pollination) lower than in 2010. Mean values of flood regulation, outdoor recreation and wind disturbance moderation are similar to the baseline and increase in the case of wood supply, deadwood and food-feed-fibre. Biocontrol of pests and carbon sequestration are the only ecosystem services whose supply is expected to vary across policy alternatives. Obviously, these figures are averages at the scale of the whole EU and do not inform on regional and local trends. Indeed, the overall observed trend could result either from the maintenance of similar levels of ES supply in 2040 as compared to 2010 or from the compensation of regional/local gains and losses of supply.

Figure 1. Mean values of modelled ES supply in Europe in 2010 and 2040. Mean values are estimated on standardised ES indicators ranging between 0 (no supply) and 1 (maximal supply). Scenarios are referred as follow: Ax and Bx for marker scenarios, Ax_x and Bx_x stand for the combination of marker and policy alternatives.

Table 3 shows that the mean difference between the current supply and the projected supply of an ES is projected to be consistent throughout scenarios with a few exceptions. Below we detail effects for each ES.

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</thead>
<tbody>
<tr>
<td>BioC</td>
<td>-26.34</td>
<td>-60.45</td>
<td></td>
<td></td>
<td>-25.52</td>
<td>-25.66</td>
<td>-26.10</td>
<td>-26.00</td>
<td></td>
<td>-24.88</td>
<td>-25.01</td>
<td>-25.47</td>
<td>-25.49</td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>-1.38</td>
<td>-2.80</td>
<td>-2.30</td>
<td>-2.20</td>
<td>-2.37</td>
<td>-2.98</td>
<td>-4.00</td>
<td>-3.52</td>
<td>-2.75</td>
<td>-1.91</td>
<td>-3.09</td>
<td>-4.13</td>
<td>-2.61</td>
<td>-3.33</td>
</tr>
<tr>
<td>WS</td>
<td>68.74</td>
<td>69.05</td>
<td>84.26</td>
<td>87.74</td>
<td>63.84</td>
<td>43.31</td>
<td>64.73</td>
<td></td>
<td></td>
<td>61.92</td>
<td>59.45</td>
<td>83.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>0.39</td>
<td>0.77</td>
<td>0.42</td>
<td>0.62</td>
<td>0.33</td>
<td>0.12</td>
<td>0.54</td>
<td></td>
<td></td>
<td>-0.14</td>
<td>0.31</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFF</td>
<td>10.53</td>
<td>10.05</td>
<td>15.39</td>
<td>9.58</td>
<td>5.03</td>
<td>2.54</td>
<td>6.81</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood</td>
<td>0.26</td>
<td>-0.40</td>
<td>0.15</td>
<td>0.11</td>
<td>0.03</td>
<td>-0.07</td>
<td>-0.27</td>
<td>-0.09</td>
<td>-0.34</td>
<td>0.51</td>
<td>0.38</td>
<td>0.21</td>
<td>0.33</td>
<td>0.16</td>
</tr>
<tr>
<td>Leis</td>
<td>-0.23</td>
<td>-0.79</td>
<td>-0.17</td>
<td>-0.33</td>
<td>3.14</td>
<td>-0.81</td>
<td>-0.79</td>
<td>-0.40</td>
<td>-0.81</td>
<td>3.55</td>
<td>-0.12</td>
<td>-0.31</td>
<td>-0.09</td>
<td>-0.33</td>
</tr>
<tr>
<td>Poll</td>
<td>-10.25</td>
<td>-10.55</td>
<td>-5.77</td>
<td>-10.60</td>
<td>-4.99</td>
<td>-10.52</td>
<td>-10.66</td>
<td>-9.93</td>
<td>-10.64</td>
<td>-6.54</td>
<td>-7.81</td>
<td>-10.52</td>
<td>-10.21</td>
<td>-10.76</td>
</tr>
<tr>
<td>Cseq</td>
<td>-47.20</td>
<td>13.58</td>
<td>33.18</td>
<td>-2.08</td>
<td>42.68</td>
<td>-20.44</td>
<td>-17.05</td>
<td></td>
<td></td>
<td>-55.11</td>
<td>-44.04</td>
<td>-30.74</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows that the mean difference between the current supply and the projected supply of an ES is projected to be consistent throughout scenarios with a few exceptions. Below we detail effects for each ES.
- In the case of biocontrol, the mean projected value is lower than the baseline with B2 VPAs being slightly higher than A2 VPAs (except B2).

- Likewise, the mean projected value of wildfire moderation is lower than the baseline but, conversely to the biocontrol service, B2 VPAs are not always higher than A2 VPAs. Considering marker scenarios, A1 would lead to the closest values of the ES to the baseline and A2 the most different. Likewise, the highest difference between the baseline and the 2040 mean value is found for VPA6 (A2 or B2, -4% and -4.1% respectively), followed by A2 VPA8 (-3.5%) and B2 VPA9 (-3.3%).

- All marker scenarios and policy alternatives are projected to result in an increase in the mean wood supply at the EU scale, this being greatest under the B1 (+84.3%) and B2 (+87.7%) marker scenarios, and for VPA6 (+64.7% for A2 and +83.9% for B2) as a policy alternative. In contrast to VPA6, in the case of VPA1, increase in wood supply would be slightly greater under A2 than B2 (+63.8% and +61.9% respectively).

- In the case of deadwood, trends are similar to those for wood supply but the mean deviation between 2010 and 2040 is projected to be more moderate, ranging from +18.5% (A1) to +20.8% (B2) for marker scenarios, and from +16.5% (A2 VPA6) to +24.1% (A2 VPA1) for VPA.

- At the EU scale, food-feed-fibre supply per hectare of Utilised Agricultural Area is projected to be, on average, higher than in 2010 in all scenarios reflecting more intensive agriculture on less total agricultural land. The increase appears largest under the B1 marker scenario as compared to other marker scenarios (+15.4%).

- The pollination service is predicted to decrease by up to 10% in all projections, with B1 and VPA1 (A2 and B2) projected to lead, on average, to the least decrease. Contrary to what happens with the Outdoor Recreation Potential index, urbanization processes are less relevant in determining changes in the pollination index, as they mostly occur at the expense of agricultural land at the urban fringes, which already have a relatively low pollination potential due to low values of floral availability and nesting suitability. Land take by urban areas becomes significant instead if it occurs at the expense of land covers with higher floral and nesting values, such as semi-natural vegetation or permanent crops. Besides, forest expansion has a mixed effect on the pollination value, depending on whether this expansions leads to a densification of the forest cover or a fragmentation of the edge’s perimeter. If land use transitions lead to a densification of forests, the edges will decrease and cores increase, with an overall reduction of nesting potential and floral availability. This explains a large share of the projected decreases of the index at 2040, as in all scenarios forests are foreseen to significantly expand, on average by 19%, primarily at the expense of semi-natural vegetation in woodland clearings. Within VOLANTE simulations, this effect is amplified by the spatial resolution of the model, as forest edges have a thickness of 1 km, being the cell resolution.

- The response to scenarios of carbon sequestration is the most contrasted of all ES considered. Marker scenario A1 might entail a strong loss in carbon sequestration at the EU scale (-47%) whereas B1 would generate a significant increase (+33%). All VPA would also conduct to a decrease in carbon sequestration (from -20% to -55% of loss) but except for VPA1 in the A2 context (+43%).
- Changes in the supply of wind disturbance moderation, outdoor recreation and flood regulation are projected to be almost non-significant between 2010 and 2040. In fact, changes in the outdoor recreation index are relatively limited in magnitude since for all scenarios except VPA1, protected areas and distance from sea costs and inland water are assumed static. Therefore, changes in the indicator value are determined only by changes of the hemeroby sub-index, in turn driven by land cover changes. Even in such cases, however, some land use transitions may not result in changes of the outdoor recreation indicator, as different land cover classes have the same degree of naturalness. For instance, a succession from recently abandoned arable land to semi-natural vegetation or forest would not imply any change of the outdoor recreation index, as all these land use classes share the same hemeroby value (3 – semi natural or Mesohemerobe). In VPA1, conversely, the expansion of the protected areas network leads to a slight but not negligible increase of the service.

### 3.3. Changes in hotspots and coldspots of ES supply in Europe

![Figure 2. Percentage of hotspots over Europe. This percentage is calculated as the proportion of pixels whose value is below a threshold defined, for each ES, as the 10th superior upper percentile of the distribution of the ES values in 2010.](image)
Figures 2 and 3 summarize the percentage of hotspots and coldspots over the EU27 in 2010 and in 2040 under the different scenarios and policy alternatives. In the case of wildfire moderation, pollination and carbon sequestration (A2 VPA 1 excepted), the number of hotspot pixels tends to increase as compared to the baseline while the number of coldspots tends to decrease, showing a compensation among regions. The number of hotspots and coldspots of flood regulation, outdoor recreation and wind disturbance moderation remain very similar to the baseline. Hotspots for wood supply, deadwood and food-feed-fibre are more numerous than in 2010 but the number of coldspots either stays stable or is slightly reduced. All these tendencies are coherent which the changes in mean ES values (Fig. 1). The behaviour of the biocontrol indicator is a little more contrasted with a decline of the ES supply on average while both hotspots and coldspots increase (except for B2).

We also investigated the net changes in hotspots (Table 4). The difference between the percentage of hotspots (Fig. 2) and the net change in hospots is that the net change in hotspots takes into account the trajectory of pixels. In other words, the net change in hotspots is the difference between pixels that turn into hotspots and the number of pixels that should leave the status of hotspot. Indeed, the net change helps determining whether the increases or decreases in hot and coldspots compensate each other. Here, we can compare the net change of hotspots to the area of hospots that should be gained or lost because all pixels have the same area (1km²).

Trends in the changes in hotspot area are very consistent with trends of the average difference of ES supply between 2010 and 2040 at EU level: a lower supply in 2040 is usually related to the loss of hotspots and conversely (except for biocontrol). As for average supply, changes tend to be consistently positive or consistently negative across all scenarios for a given ES (Table 4).
Table 4. Net changes in hotspots expressed as the percentage of gain (in red) or loss (in blue) in total hotspot area.

<table>
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<tr>
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<th>A1</th>
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<th>A2_6</th>
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<td>11.98</td>
<td>12.35</td>
<td></td>
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3.4. Overview of ES bundles in Europe

Self-organising maps applied on 2010 ES values revealed four bundles of services (“clusters” on Fig. 4):

- Bundle 1 is essentially driven by a strong supply of wind disturbance moderation (a high moderation of wind disturbance results from the lack of forests potentially disturbed in such sparsely vegetated places) and the absence of provision of wildfire moderation, pollination (not estimated in these pixels), food-feed-fibre (not estimated in “non-agricultural” land uses) and deadwood (not estimated in “non-forested” pixels). This bundle, which only covers a small fraction of the total European area, is rather artificial and should be considered as an “artefact” bundle.

- Bundle 2 is the only bundle including food-feed-fibre. It characterized by an intermediate supply of biocontrol of pests, carbon sequestration and flood regulation and no supply of deadwood and wood supply and almost no pollination. Bundle 2 corresponds to pasture and arable lands.

- Bundle 3 is also characterized by a strong supply of wildfire and flood regulation but also a strong supply of wind disturbance moderation. In contrast to bundles 2 and 4, the high provision of wildfire and wind disturbance moderation is biased in Greece because these ES were not projected in this country (further explained at the end of this section). Deadwood, wood supply, food-feed-fibre are not provided in these sites. Considering the geographical location of bundle 3, it most certainly overlaps with semi-natural areas (but not forested).

- Bundle 4 is characterized by a strong supply of wildfire and flood regulation and an intermediate supply of carbon sequestration and wind disturbance moderation. Bundle 4 gathers locations (i.e. pixels) that supply low levels of food-feed-fibre. The low levels of food-feed-fibre and the geographic distribution of the bundle suggest that it corresponds to forested areas.
The apparent high supply of fire and wind disturbance moderation in bundles 2 and 3 (and 1 for wind disturbance moderation) may not represent an actual high supply of the service by the ecosystem but a lack of risk due to the absence of forested areas or fire prone vegetation. Indeed these two indices have been constructed as 1-risk. In the case of wind disturbance moderation, where there is forested land cover, there is no risk of disturbance so the moderation service is maximal. Similarly, where there has been few or no fire recorded from 2000-2006, the risk is also very low and, thus, the moderation is maximal. The algorithm used to build the self-organising maps did not accept missing values. In order to keep as much pixels as possible (rather than deleting the pixels for which we had one or more missing ES values), we replaced the missing values by 0. This also contributes to an overestimation of moderation services and flood regulation, notably in the case of Greece where flood regulation was not quantified.

Figure 4. Spatial bundles (or clusters) of ES bundles produced by the Self Organizing Map method for 2010. ES bundles are represented on the left panel and the spatial distribution of the bundles on the right. The length of the chunks on the left panel is proportional to the average supply of each ES over the pixels in the cluster. Pixels on the map are colored according the clusters in the left panel. The names of the ES on A are abbreviated: “BioC” = biocontrol of pests, “Cseq” = carbon sequestration, “DW” = deadwood, “Fire”= wildfire moderation, “Flood” = flood regulation, “FFF” = food-feed-fibre, “Leis” = outdoor recreation, “Poll” = pollination, “WS” = wood supply, “Wind” = wind disturbance moderation in forests.

As bundles of ES are associated to land-uses cluster, their evolution and variations shall be linked to what have been identified, within the VOLANTE Project, as “megatrends” i.e. land use trajectories that appear to occur whatever the marker scenario or VOLANTE Policy Alternative considered, though with some difference in magnitude.
In terms of foreseen land-use transitions, the following patterns are projected to occur in all scenarios:

- Decrease of agricultural land (most significant in marker A1 and B1)
- Increase of built-up area
- Significant decrease of semi-natural vegetation
- Significant increase of forests

Such trends in turn reverberate on absolute ES provision and bundles, although not in the same way for the different services included in this study.

In marker scenario A1 (Libertarian Europe) at 2040, clusters are similar to those identified in the benchmark, but it can be noted that the variety of ES provided by each cluster decreases. For instance, the “agricultural cluster” (“Cluster 2”, Fig. 4), includes 7 ES (Wind, BioC, Cseq, Fire, FFF, Flood, Leis) in the benchmark, whilst in the projected A1 scenario it includes 6 (BioC is no longer present) (see “Cluster 2”, Fig. 5). Moreover, only the food-feed-fibre (FFF) service increases in 2040 in this cluster, whilst the other ones either remain stable or decrease (as in the case of carbon sequestration). Similar patterns can be observed in the other clusters. In this scenario storyline, global free trade policies with very little intervention from States are in place: agricultural subsidies are removed and land use regulation are lessened: as a consequence, agricultural land competes on a global level, many small farms go out of business and are incorporated into larger units. This leads to a further specialization of agricultural land that, in terms of ecosystem services, entails an increase of FFF production and a decrease both of the absolute values and the variety of other services. The same applies to forests: the related bundle at 2040 shows an increase of
services directly linked to forestry – wood supply, deadwood, wind moderation - and a stability or decrease of the other ones. Overall, these results indicate that the strong liberalization policy envisaged in this scenario will lead to a simplification of landscape diversity and to a “specialization” of land-uses according to an optimal allocation pattern at the European scale mainly based on economic parameters. Land-use clusters will therefore increase the absolute magnitude of some delivered ecosystem services (those more directly related to their “specialization”) whilst overall decreasing their multifunctionality, i.e. the ability to deliver multiple services at once.

Figure 6. Spatial clusters of ES bundles produced by the Self Organizing Map method for marker scenario B2. Further details are given in the legend of figure 4.

Conversely, marker scenario B2 (European Localism) has a strong focus on environmentalism and localism. Four clusters again are identified by the SOM, with bundle 2, 3 and 4 roughly corresponding to agricultural land, semi-natural areas and forest respectively, but some important differences emerge too (see Fig. 6). Bundle 2 in fact shows an increase both in the variety and absolute level of ES delivered compared to the previous scenario (and a very close situation with respect to the benchmark). Bundle 3 (“semi-natural”) has a larger extension, both compared to the benchmark and marker A1 scenario. The locations associated to this bundle supply higher levels of carbon sequestration and outdoor recreation than the corresponding ones in marker A1, and the same variety of the benchmark (although absolute values are lower in this case). Similar observations apply to the “forest” cluster: here, wood supply increase, but the cluster is still able to provide all services as in the benchmark, and more than compared to A1 (in terms of both variety and absolute levels). Again, these results may be interpreted in the light of the hypothesis at the base of the scenario’s storyline and related land-use transitions: agriculture becomes more regionalised and less specialised; small, mixed farms are common and there is a shift from large,
industrial type farms towards more sustainable farm management systems. Forests are exploited both as sources of timber and energy but also to conserve biodiversity. Overall, these assumptions entail a more multifunctional landscape at different scales, which is in fact what emerges from the SOM. Whilst the increase of the “forest” cluster is to a large extent explained by a significant increase of forest cover in this scenario (+20.6% compared to benchmark), the same is not valid for the “semi-natural” one, as semi-natural areas are anyway projected to decline in this scenario (as in all of them). This implies that the cluster actually comprises also forest and agricultural cells, which is a further indication of the increased multifunctionality of landscape in several areas across Europe: many semi-natural cells adjacent to cropland and woods in 2010 convert into forest and cropland in 2040, but they are still able to provide a certain variety of ecosystem services, so as to be clustered together with remaining semi-natural ones. Accordingly, it can be observed that the “agricultural” cluster significantly shrinks in this scenario, whilst in absolute terms agricultural area is projected to decrease only by 1.8%, which means that a portion of agricultural cells are now comprised in the “semi-natural” bundle.

These two marker scenarios represent the extreme positions in the policy space of VOLANTE. Very synthetically, SOMs indicate that trade liberalization and decreased State intervention tend to produce a more specialised landscape with clear delimitations between different land functions, and consequently with increase of some services (mainly provisioning one) at the expense of multifunctionality. Local policy (particularly related to agricultural production) and state intervention seem to counter – at least partially - such trends.

Figure 7. Spatial clusters of ES bundles produced by the Self Organizing Map method for marker scenario A2. Further details are given in the legend of figure 4.
Marker scenarios A2 (Eurosceptic Europe) and B1 (Social Democracy Europe) lie somewhere in between as they feature mixed policy options in terms of globalisation vs regionalisation and shift towards sustainability (Fig. 7 and 8). In fact, the related SOMs show a nearly identical pattern. In both A2 and B1, bundle 4 can be considered as the predicted “forest bundle” of the baseline but the projected “agricultural” and “semi-natural” bundle seems to merge into bundle 2 (Fig. 5, 7 and 8). The main difference between marker A2 and A1 scenarios lies in the trade policy: in opposition to the completely liberalised trade envisaged in “Libertarian Europe” (A1), in A2, a protectionist policy is in place that enables home-grown agriculture. More emphasis is given to sustainable management techniques, prevention of soil erosion and resource efficiency. Farm size increases and exclusion of small farmers from the market are less pronounced than in A1. Decrease of agricultural area is in fact less marked in this scenario. Marker scenario B1 features a strong and cohesive Europe following a Nordic model of social democracy with a free trade policy but a stronger focus (compared to marker A1) on sustainable development, social equity and environmental conservation. Local food production is considered important, more sustainable production systems are in place and within the CAP, farmers are compensated for the delivery of public goods through a suite of specific ecosystem services payment schemes.

These policy options seems to partially contrast the landscape polarization processes identified in marker scenario A1, as demonstrated by the fact that two clearly distinct “agricultural” and “semi-natural” bundles are no longer identifiable, whilst a broader cluster that delivers a variety of ecosystem services emerges from the SOM. In A2, this is likely linked to more diversified agricultural production and forestry systems across Europe - a direct consequence of the less liberalised trade policy – as well as efforts on resource efficiency, which appear to contrast the decrease of multifunctionality of regions in terms of ecosystem services. The same in fact is observable in the “forest” bundle, where not only wood supply, but also other services increase compared to both marker A1 and the benchmark, It is also worth noting that in the case of A2, biocontrol of pests is closer to the “forest bundle” than in the baseline (Fig. 7).

Similarly, in B1 the observed patterns can be linked to the projected shift from industrial-style farming methods to more sustainable techniques, more efficient use of resources, compensations to farmers for the provision of ecosystem services and increase in forests, devoted to both timber production and conservation. ES delivered by the “forest” bundle are in fact higher compared to marker A1 (but lower than the benchmark) (Fig. 8).

As for VPA, it emerges that they may modulate the schemes under marker scenarios but the variation in bundles is even more marginal across VPA for a given marker scenario than across marker scenarios (bundles presented in Annex C). All B2 VPAs scenarios in fact present the same 4 bundles identified in marker A2, with limited variations in the patterns. In the case of VPAs derived by the marker A2 scenarios, it emerges that SOMs show very similar patterns in the case of VPA1 (nature protection), VPA6 (payment for recreational services), VPA8 (zoning for compact cities) and VPA9 (flood protection). The only exceptions is VPA5 (payment for carbon sequestration) in which, again, 4 different bundle are identified. This is probably linked to the strong increase in pasture and grassland projected for this policy alternative particularly in Spain, Italy and Greece, where bundle 3 is actually visible.
Overall, it emerges that bundles under A2 (Eurosceptic Europe) - and A2 VPAs - and B2 (European Localism) appear to more dichotomously segregate between semi-natural and agricultural lands than bundles predicted under B2 VPAs.

Figure 8. Spatial clusters of ES bundles produced by the Self Organizing Map method for marker scenario B1. Further details are given in the legend of figure 4.
Chapter 4: Regional analyses of changes in ES supply

4.1. Regional changes in mean ES supply

Figure 9 shows the variability in mean values of ES across NUTS and by scenario, quantified by the standard deviation. Among all ES, the average supply of wildfire moderation, biocontrol and carbon sequestration at the NUTS2 level appears to be much more variable than in other ES.

Figure 9. Variability of the mean values of the ES indicators across NUTS and scenarios.

The mean differences between 2010 and 2040 values for biocontrol are contrasted from one NUTS2 region to another across scenarios (Appendix D). In the B2 scenario, the biocontrol indicator is overall lower than the baseline in all regions except in the UK. Similar trends are expected whatever the marker scenario or policy alternative (except for B2): an increase in the supply of biocontrol in southern Scandinavia, Estonia, Romania, SW Greece, Toscana, Slovenia, Austria, SW and central France or Galicia, and a decrease in southern Spain, the Alentejo and Algarve regions (Portugal), Brittany (France), UK, Benelux, and eastern Bulgaria.

Projected values of wildfire moderation are overall close to the baseline across NUTS2 regions and scenarios. All marker scenarios and policy alternatives are projected to lead to decreased wildfire moderation (with the exception of Greece where values cannot be projected). This increase might be stronger in southern Europe, which may be related to an increase in the land covers prone to wildfires.

Carbon sequestration is projected to consistently decrease (A1, VPA5 A2 and B2, VPA6 A2 and B2 and B2 VPA1) or increase (A2 VPA1 and B1) across NUTS2 regions. Only B2 shows contrasted trends among regions.

As far as forest-related services are concerned, deadwood and wood supply are projected to increase in all NUTS regions and especially in central and eastern Europe. Changes in wind disturbance moderation at the regional level are very low.
On the country and NUTS2 scales, differences in the supply of flood regulation among the various countries and scenarios are limited. In the baseline, the supply is highest in Latvia, Estonia and Denmark, and lowest in Belgium, Malta, and Hungary. Largest increases in average supply across all scenarios are featured by Finland, Greece, and Italy, while the largest average decreases are experienced by Cyprus, Malta and Czech Republic. Losses in supply are more pronounced than gains: In all scenarios, the majority of regions lose flood regulation supply and the average and maximum gains are smaller than the average and maximum losses across all regions. The largest inter-regional variability of change can be found in Cyprus, the Netherlands, and Belgium. A main reason for this development can be concurrent trends in urbanization and reforestation or agricultural abandonment.

As for pollination, variations in the values of standard deviation with reference to the value calculated for the benchmark scenario are relatively limited, but in all scenarios, a decrease is projected. As already pointed out, forest increase and densification is an explaining factor, as it tends to reduce the fragmentation of the forest edge/core patterns hence the variation of the index.

Conversely, food-feed-fibre supply in all projected scenarios at 2040 feature a significantly higher variability compared to benchmark, with increases in the standard deviation comprised between 16 and 30%. This reflects the already identified trend of a polarization of agricultural production in Europe, with land abandonment in some marginal areas and increases in highly competitive ones that have to meet the food demand on less available land by intensifying the production. Areas where an increase in energy content per ha is consistently projected in all scenarios include the Po Plain in Italy, eastern England, vast areas in Central-Northern France, (particularly the Region Centre, Brittany, Picardy), the North-Eastern German Plain, Saxony and Thuringia (SE Germany), SW Slovakia and Hungary. Decreases are explained to a certain extent by projected abandonment of agricultural area particularly in SE Spain, Central-Southern France and SE Germany or along the Apennine foothill in Italy.

In the case of outdoor recreation the index values are more dispersed in projected scenarios compared to the benchmark, but in absolute term changes are very limited (< 1%). As already noted, the exception is VPA1 (A2 and B2), due to the expansion of protected areas. Regions where increases are located in SE EU countries, and in particular in the Carpathians and Transylvanian Plateau in Romania, the Bulgarian Balkan and the Thracian Region in Bulgaria and Greece.

4.2. Regional changes in hotspots

Changes in the areas of hotspots at the NUTS2 level are illustrated in appendix E.

- The hotspots of biocontrol of pests are susceptible to increase compared to the baseline, in the major part of EU27 except northern Scandinavia, southern Portugal, central and southern Spain, Czech Republic, Netherlands, UK (except SE regions), Brittany (France), Northern Greece and Bulgaria. The scheme of regional gains and losses of hotspots moderately vary across scenarios.
- The transition of pixels towards hotspots of carbon sequestration supply may be null to negative in all NUTS but western and southern Transdanubia (Hungary) and Portugal (Lisboa region excluded). The regional gains and losses in hotspots could be well contrasted between A2 and B2 but the VPA seems to level out the contrasts. However, A2 VPA1 and B1 should induce high gains in all NUTS while A1, B2 VPA1 and VPA5 and VPA6 (A2 and B2) should bring to losses principally.

- Overall, changes in hotspots of dead wood supply would vary between -5% and +5%. Aquitaine, Alps, Champagne-Ardenne and central France, Scotland, Slovenia, Romania, Lower Austria, central Hungary, Aland Island (Sweden), Carinthia region (Austria), the Polish Lublin and Wielkopolska Provinces should always have the highest rate of hotspots as well as Brittany in all VPA related to A2 and B2. In the context of VPA5 (A2 and B2), the number of hotspots should increase in NE of France, Sussex, Navarra region (Spain), eastern Germany and NW Czech Republic also. In the context of VPA1 (A2 and B2), the loss of hotspots in Namur area (Belgium) and Luxembourg and (B2) central Transdanubia (Hungary) should decrease by 5 to 10%.

- The effects of scenarios on fire moderation are quite similar. All NUTS should loose hotspots. This loss should be more pronounced in Ireland, northern and western UK, Sweden, southern Finland, northern Italy, Austria, Slovenia, central and southern Germany, eastern Czech Republic, NE Romania and Slovakia. It could reach up to 100% of loss in northern Ireland, SW Scotland and Tyrol.

- Most NUTS should have a similar level of hotspots of flood regulation supply as in the baseline. A2 VPA1, A2 VPA5 and B2 VPA1 could lead to a more important number of locations turning into hotspots.

- For the reasons already explained in the previous sub-section, the strongest changes in hotspots of food-feed-fibre should occur in the northern part of France, Denmark, throughout Germany, NE Italy, Lithuania, southern Sweden and eastern UK. Up to 20% of loss in NE Scotland and Bedfordshire and Hertfordshire (England) are predicted under A2 VPA6.

- In all scenarios but VPA1 (A2 and B2), the gains and losses of hotspots of outdoor recreation are minor. Under VPA1 (Nature Protection), almost all NUTS should gain up to 5% of hotspots and, in particular, NW Ireland, northern Greece, Tirol, Calabria (Italy), Luxembourg, Liege (Belgium), SE Netherlands and Styria (Austria), central Greece and Greek islands, Campania (Italy), Scotland and Kujawy-Pomerania Province (Poland).

- The hotspots of pollination are predicted to overall decrease, particularly in south EU27, except in northern Portugal and Asturias area (Spain). B1 and B2 seem to be slightly more favourable to pollination with several additional NUTS where the proportion of hotspots should increase (e.g. Sicilia, Baleares Islands, southern Greece or Northern Portugal in B2 VPA1).

- The hotspots of wood supply should overall increase, especially in France, Highlands (Scotland), Romania, Bulgaria, NE Germany, Sweden and southern Finland, and less in south of Europe (Corsica in particular). VPA1 (A2 and B2) should entail a loss of hotspots in eastern Europe (e.g. Poland, Slovakia) and Luxembourg.

- All scenarios should lead to a global loss of wind disturbance moderation hotspots.
Based on the behaviour of ES regarding scenarios, we can identify general trends in the changes of hotspots across scenarios: (i) pollination, wind disturbance and fire moderations should decrease in all NUTS, (ii) wood supply and biocontrol of pests should gain in hotspots of supply in the majority of NUTS with some exceptions, and (iii) hotspots of dead wood, carbon sequestration (except in the context of B1 and A2 VPA1), food-feed-fibre, outdoor recreation and flood regulation supplies should increase in some NUTS and decrease in others.
Chapter 5. Conclusions

Our results reveal that different ES may respond very differently to scenarios. In addition, we also found that for some ES (e.g. fire moderation or food-feed-fibre) policy alternatives may significantly modulate the response of ES supply to marker scenarios. The mean difference in the supply in a given ES between 2040 and 2010 are rather consistent from one scenario to another except for outdoor recreation (Leis) in VPA1, carbon sequestration (Cseq) and flood regulation (Flood). The mean values in 2040 for biocontrol of pests by vertebrates (BioC), fire moderation (Fire) and pollination (poll) are projected to be lower than the current mean value across Europe. On the contrary, future average supply of deadwood, food-feed-fibre, wood supply and moderation of wind disturbances are projected to be higher than under the 2010 baseline. The mean values of outdoor recreation, flood regulation and, particularly, carbon sequestration in 2040 are projected to either increased or decreased as compared to this baseline depending on the scenario. However, biocontrol of pests, wildfire moderation and pollination decrease regardless of the policy. Wind disturbance moderation, flood regulation and outdoor recreation would remain stable. Finally, at the EU scale, PES (Payments for Ecosystem Services – see Appendix B) for carbon sequestration (VPA5) or recreational services (VPA6) would not appear to reach their goals. On the contrary, protecting nature (VPA1) without targeting a specific service appears to be the most efficient for all ES (in the context of the A2 marker scenario).

Predicted bundles are rather close to the current bundles. However the A2 marker scenario may entail a more distinct segregation of services between forests and other types of land cover. That might arise from a lighter regulation of land use that would result on a higher conversion of semi-natural areas into arable lands or pasture.

The consequences of transitions in land use may be tough to disentangle as ES supply may also respond to other pressures (e.g. climate that is not straightforwardly addressed in VPA). For instance, the Relative Pollination Potential index estimates the capacity of land cover cells to provide crop pollination by short flight distance pollinators (in these case, wild bees). The biocontrol model mainly relies on species distribution modelling and might thus be more sensitive to climate changes than to land use transitions. Changes can also occur as a rebound of changes in the surroundings of a location. As an example, the changes in the pollination Index and synthetic statistical indicators (mean, standard deviation) do not depend only on the aggregation of individual cell's transitions to one land cover to another, but also on the spatial patterns of such variations. This is due to how the pollination process is modelled and, in particular, the foraging range and the forest component. As regards the former, a moving window of 3 x 3 km is applied to each cell to determine the foraging potential, as bees are supposed to have a forage range of 1 km. This entails that changes of value for one cell do no depend only on land-cover transition of that cell, but also of the 8 adjacent ones. Therefore, a cell might have different pollination values in different scenarios even if its land cover does not change.

From the comparison of global (i.e. EU27) and regional (i.e. NUTS2) analyses, we can conclude that:

- Concerning the average differences in ES supply between 2010 and 2040, two groups of services stand out: (i) carbon sequestration, deadwood wood supply, fire moderation
and outdoor recreation (only for B2 VPA1) exhibit the same trends across scales, and (ii) biocontrol, carbon sequestration (in a B2 context), flood regulation, pollination, wind disturbance moderation, food-feed-fibre and outdoor recreation show a contrasted response to marker scenarios and policy alternatives across NUTS2 regions and, consequently, between individual NUTS2 and the EU27 overall.

- Changes in hostpots between 2010 and 2040 also underlined two groups of ES: (i) wind disturbance moderation, carbon sequestration, pollination, fire and outdoor recreation (in a context of B2 VPA1, B1, A1 and A2 VPA1) are consistent across NUTS2 regions and for the EU27 overall, while (ii) biocontrol, wood supply, flood regulation, food-feed-fibre, deadwood, outdoor recreation, wind disturbance and carbon sequestration (in a context of A2 or B2) are projected to have very contrasted responses to scenarios across NUTS2 regions.

- In all cases except biocontrol, losses and gains in hotspots/coldspots are consistent with changes in supply between 2010 and 2040. When the supply of a given ES remains stable on average, so are the areas of hot- and coldspots. If the supply of a given ES is predicted to increase, that is associated to a stable or slight loss of coldspots compensated by an increase in the area of hotspots. Conversely, when the supply of a given ES is predicted to decrease, it is linked to a stable or slightly decreasing area of hotspots and to an increasing area of coldspots. In the case of biocontrol, both hotspots and coldspots are projected to increase while the average supply of the ES is projected to decrease. This translates a bimodal distribution of the supply of this ES in 2040 (see Appendix I). The increase in hotspots should not compensate for the increase in coldspots.

Overall, our analyses demonstrate that expected trends in ES supply (table 5) are not always met (e.g. fire moderation). Pollination, biocontrol of pests, deadwood, outdoor recreation and flood regulation either responded as expected or proved to be insensitive to marker scenarios and/or policy alternatives.
### Table 5. Main expected changes in ES supply in the horizon 2040. Policy alternatives may entail an increase (in blue), a decrease (in pink) in ES supply or mixed (grey) effects on ES supply. Further results are described in appendixes F to K.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BioC</strong></td>
<td>Spatially heterogeneous. Positive difference (gain) in Central and south of France, north and central Italy, southern Sweden and Finland and Baltic region. Negative (loss) in southern Spain, UK and Benelux. Does not vary much among VPA and markers.</td>
</tr>
<tr>
<td><strong>Fire</strong></td>
<td>Mean index values are lower than the baseline. Overall, the index values are higher than the baseline with limited differences among VPA and marker scenarios. The highest gains are expected in SE UK, Spain, France, Italy, and most part of Poland. SE Europe but Greece.</td>
</tr>
<tr>
<td><strong>WS</strong></td>
<td>The index values globally increase compared to the baseline. A2: the strongest increases will take place in southern Scandinavia, central and SW France, southern Germany, Czech Republic, Austria and Slovenia. B2: higher index values in southern Germany, Hungary, Austria and southern Scandinavia.</td>
</tr>
<tr>
<td><strong>DW</strong></td>
<td>Mean value slightly higher than the baseline. Diffuse and widespread increase throughout Europe.</td>
</tr>
<tr>
<td><strong>Wind</strong></td>
<td>The mean index value very close to the baseline and similar trends across VPA. A2: Increases in the index value are expected in southern Spain and Portugal. Central Europe (e.g. Czech Republic and Austria). Greece and Scandinavia. B2: trends are slighted more contrasted than in the corresponding A2 VPAs.</td>
</tr>
<tr>
<td><strong>FFF</strong></td>
<td>Increases in already ‘strong’ agricultural areas (e.g. the Po Plain in Italy). Widespread decreases explained to a certain extent by projected abandonment (e.g. in Castilla Y Leon Region, northern Greece)</td>
</tr>
<tr>
<td><strong>Flood</strong></td>
<td>The index value is very slightly lower than the mean index value at the baseline (A2 and B2) at the EU scale but results are contrasted at the regional scale. A main reason for this may be the concurrent developments in urbanization and reforestation or agricultural abandonment.</td>
</tr>
<tr>
<td><strong>Leis</strong></td>
<td>The mean index value is higher than in other VPA and marker scenarios due to expansions of protected areas. This is mostly evident in the Baklans, the Carpathian range, the Transylvanian Plateau. Greece, the highland region in Scotland, western Ireland. Pomerania (North Poland) Tyrol and Central Austria, and several scattered protected areas in Spain (A2 and B2). Negative hotspots are mainly due to urban expansions.</td>
</tr>
<tr>
<td><strong>Poll</strong></td>
<td>A2: areas of decrease due to forest expansion/densification are localised in the southern France. Rhodopes and Balkans ranges in Bulgaria. Carpathians in Romania, Central Spain, and the Sierras the Cebollera (Central-Northern Spain), central Portugal and NW Greece. Negative hotspots area due to others land use transitions that are detectable e.g. in western Spain, where significant shares of permanent crops are projected to convert to pasture, which implies a decrease in floral availability and nesting suitability. In Central-eastern Germany, negative hotspots are causes by urban expansion on semi-natural land. B2: presence of both widespread negative and positive hotspots largely explained by the strong forest expansion. Increases are expected to occur in western countries, in central Adriatic regions in Italy, where arable and permanent crops are decreases and are substituted by semi-natural vegetation. NW Italy and Northern Spain, as result of transition from pasture/recently abandoned pastures to semi-natural vegetation and forests, and in Central Western Portugal, where a significant number of cells converts from permanent crops and pasture to semi-natural vegetation.</td>
</tr>
<tr>
<td><strong>Cseq</strong></td>
<td>Overall values are higher than the baseline in the A2 (except in southern Greece) and lower in the B2 VPA.</td>
</tr>
<tr>
<td><strong>Notes</strong></td>
<td>A strong focus on nature protection implies expansion of protected zones beyond Natura2000, a robust ecological corridor network and strengthened constraints on forest management and land cover conversions. This lead to the expansion of natural areas, including forest, semi-natural vegetation as well as abandoned pasture and arable land.</td>
</tr>
</tbody>
</table>

Overall values are lower than the baseline (A2 and B2).
Table 5. Main expected changes in ES supply in the horizon 2040 (continued). Policy alternatives may entail an increase (in blue), a decrease (in pink) in ES supply or mixed (grey) effects on ES supply. Further results are described in appendixes F to K.

<table>
<thead>
<tr>
<th>Biological Character</th>
<th>VPA6 - PES for recreational ES</th>
<th>VPA8 - Zoning for compact cities</th>
<th>VPA9 - Climate (flood) mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioC</td>
<td>Spatially heterogeneous. Positive difference (gain) in Central and south of France, north and central Italy, southern Sweden and Finland, and Baltic region. Negative (loss) in southern Spain. UK and Benelux. Does not vary much among VPA and markers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire</td>
<td>Mean index values are lower than the baseline. Overall, the index values are higher than the baseline with limited differences among policy and marker scenarios. The highest gains are expected in SE UK, Spain, France, Italy, most part of Poland. SE Europe but Greece.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WS</td>
<td>Trends are similar to those of VPA1 but with higher increase in Romania and Poland.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DW</td>
<td>The mean index value very close to the baseline. Diffuse and widespread increase throughout Europe.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>More significant and widespread decreases are expected to occur in The Po Plain (but not entailing agricultural abandonment), and northern Greece. Less pronounced variations are projected e.g. in Brittany and Pays de la Loire (North-West France) and Castilla y Leon (Spain).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood</td>
<td>The mean index value is very slightly lower than the mean index value at the baseline (A2 and B2) at the EU scale but results are contrasted at the regional scale. A main reason for this may be the concurrent developments in urbanization and reforestation or agricultural abandonment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leis</td>
<td>Mixed results are expected depending on if this expansion is at the expense of recently abandoned pasture (in which case a decrease of the value occurs) or replaces arable. A2: in eastern Europe, expansion of semi-natural vegetation is observed on previous arable and pastureland (increase), but transitions form recently abandoned pastures/arable to semi-natural vegetation and arable land is expected also to occur, especially in the Northwest of the country. In UK, beyond urbanization patterns similar to others VPA, expected increase in some areas of Wales and northern England, following pasture abandonment (transition to recently abandoned pastureland or semi-natural vegetation). Conversely, reversion of recently abandoned pastureland to pasture or semi-natural vegetation explains the observed slight decrease of the index in the Alpine areas. B2: patterns of changes are similar to those observed in VPA6 A2, but overall decreases are less frequent and increases are more diffused. Diffused transitions from arable to semi-natural vegetation, not projected in VPA6 A2 are expected to occur e.g. in Sicily or Southern Romania. Pasture abandonment in Lower Bavaria should lead to expansion of semi-natural vegetation and recently abandoned pastureland. Significant arable reversion to land uses with higher hemeroby value are foreseen also in several areas of eastern Poland.</td>
<td>A2: diffused decrease of the index to urbanisation can be observed, particularly in Central England, Benelux, Carpathians, Pyrenees, Apennine, northern Spain. B2: This scenario has the closest mean value of the index to the baseline. B2: land take by new urbanization is much more limited in this case, which leads to much less evident decreases of the index in the surroundings of metropolitan areas as Paris, London, Milan, Madrid, Dublin, Midlands, Flanders. Such positive effects are less evident in Eastern Europe, where increased urbanisation in urban centres is expected, that in marker scenarios.</td>
<td>Effects of this on the index values are often not significant. and results are mixed. A2: for example in Extremadura and Portugal most of permanent cropped areas are expected to be maintained, whilst in marker A2 scenarios they are projected to change to pasture, which determines a slight increase of the hemeroby value. B2: patterns are similar to VPA9 A2 but expansion of urban areas is more limited, which overall contributes to a higher mean value of the index. In Extremadura and Portugal, most of permanent cropped areas are expected to be maintained, which determines a slight increase of the hemeroby value. Expansion of urban areas is more limited, which overall contributes to a higher mean value of the index.</td>
</tr>
<tr>
<td>Poll</td>
<td>A2: both positive and negative hotspots of change with increases of the index values slightly dwindling in some regions (e.g. in NW Italy), and slightly more pronounced in other ones (e.g. Sicily and NE Poland). B2: this scenario presents a slightly higher mean value compared toVPA6 A2. Diffused transitions from arable to semi-natural vegetation, not projected in VPA6 A2 are expected to occur e.g. in Sicily, or Southern Romania with consequent more evident increase of the index value.</td>
<td>A2: overall minor changes in the index values, as urban growth would occur mainly at the expense of cells with already relatively low index values (arable land), although a positive effects is detectable for example in Flanders and in the metropolitan areas of London and Paris. B2: trends similar to those described in VPA8 A2, but in this case the mean value is a bit lower due to stronger forest densification processes taking place.</td>
<td>A2: increases of the index values slightly dwindling in some regions (e.g. in NW Italy), and slightly more pronounced in other ones (e.g. Sicily and NE Poland). B2: effects of this VPA on the index values are often not significant, and results are mixed.</td>
</tr>
<tr>
<td>Cseq</td>
<td>Overall values are lower than the baseline (A2 and B2).</td>
<td></td>
<td>Urban developments are constrained nearby areas already urbanized to constrain urban sprawl.</td>
</tr>
</tbody>
</table>

Notes: Urban developments avoided while semi-natural vegetation and extensive agriculture encouraged in flood-prone areas.
### Appendix A. Overview of ES models in the VOLANTE project.

This table is based on tables 1 and 2 of D8.1. (http://www.volante-project.eu/images/stories/DELIVERABLES/VOLANTE_D8.1_A_framework_for_trade-off_analysis_of_ecosystem_service_indicators.pdf)

Maps of ES indicators are given in D8.2.

#### Table A.1. Overview of ES models

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Proxy</th>
<th>Code</th>
<th>Description</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural</td>
<td>Leisure</td>
<td>Leis</td>
<td>Potential provided by the landscape related to the degree of naturaleness, presence of water and established protected areas</td>
<td>Adimensional continuous index</td>
<td>JRC</td>
</tr>
<tr>
<td>Provisioning</td>
<td>Food-feed-fibre</td>
<td>FFF</td>
<td>Energy content of all biomass produced by agricultural systems</td>
<td>MJ/ha UAR *year</td>
<td>JRC</td>
</tr>
<tr>
<td>Raw material</td>
<td>Wood supply</td>
<td>WS</td>
<td>Round wood and harvest residues from thinning and final felling</td>
<td>m³/ km² forest/yr</td>
<td>EFI</td>
</tr>
<tr>
<td>Climate regulation</td>
<td>Carbon sequestration</td>
<td>Cseq</td>
<td>Amount of carbon that is sequestered from land use, land use change and forestry</td>
<td>C/km²/yr</td>
<td>IVM</td>
</tr>
<tr>
<td>Water purification</td>
<td>Nitrogen retention capacity</td>
<td>WP</td>
<td>Amount of nitrogen retained in water bodies</td>
<td>Ton of nitrogen removed/km²/yr</td>
<td>JRC</td>
</tr>
<tr>
<td>Moderation of extreme events</td>
<td>Fire risk index⁴</td>
<td>Fire</td>
<td>Estimated on the vegetation vulnerability to wildfires, climatic conditions and topography</td>
<td>Probability</td>
<td>LECA/EFI</td>
</tr>
<tr>
<td>Relative water retention</td>
<td>Flood</td>
<td>Flood</td>
<td>Related to flood regulation. Based on the variability of the peak discharge at the outlet of a catchment in dependence of land use and soil distribution</td>
<td>Adimensional continuous index</td>
<td>IVM VU</td>
</tr>
<tr>
<td>Wind disturbance risk in forests⁵</td>
<td>Wind</td>
<td>Wind</td>
<td>Based on the vulnerability of forest to wind disturbance (see appendix E in this deliverable)</td>
<td>Adimensional index</td>
<td>EFI</td>
</tr>
<tr>
<td>Biological control mechanisms</td>
<td>Species providing natural control of invertebrate and rodent pests</td>
<td>BioC</td>
<td>Based on the overlaid distributions of species providing pest control</td>
<td>Number of species</td>
<td>LECA</td>
</tr>
<tr>
<td>Pollination</td>
<td>Relative pollination potential</td>
<td>Poll</td>
<td>Estimates the capacity of land cover cells to provide crop pollination by short flight distance pollinators (in this case, wild bees)</td>
<td>Adimensional continuous index</td>
<td>JRC</td>
</tr>
<tr>
<td>Maintenance of genetic diversity</td>
<td>Dead wood</td>
<td>DW</td>
<td>Indicator for biodiversity in forests Related to the resource availability and species richness</td>
<td>Mg dry matter/km² forest</td>
<td>EFI</td>
</tr>
</tbody>
</table>

| Dis-service     | Invasive species | Alien threat score | Alien | Based on the ecological impact and the invasive potential of species | Scores | LECA |

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⁴ Wind disturbance risk and fire risk indices are related to the vulnerability of an ecosystem to wind or fire. Consequently, the higher the value, the higher the vulnerability and the lower the corresponding ES supply.

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D12.2. Science-based trade-off and synergy evaluation of hotspots and problem spots in future ESS supply
Appendix B. Description of policy alternatives (extract from D11.1).  

VPA1: Nature protection  
As a future vision, large areas of nature throughout Europe are effectively connected, undisturbed and protected from fragmentation and urban sprawl. The policy goal is a strong focus on nature protection, with expansion of protected zones beyond Natura2000, a robust ecological corridor network and strengthened constraints on land cover conversions. Policy implications include increased restrictions on human intervention and land cover change within an improved network of European protected areas (as listed in the World Database of Protected Areas (WDPA) up to level IV), and incentives to limit fragmentation and increase connectivity according to the Pan-European Ecological Network (PEEN). As a side effect, strong restrictions on land cover conversion in protected sites could result in more intensive use of unprotected areas as well as less abandonment of agricultural land.

VPA5: PES: Payment for carbon sequestration  
In this VPA, policies aiming at reducing carbon emissions and stimulating carbon sequestration are introduced or strengthened. Reducing emissions from agriculture, forestry and land use sector (AFOLU) is stimulated using incentives to limit the conversion of grassland. Also, a Payment for Ecosystem Services (PES) scheme is introduced that protects areas that are prone to carbon emissions due to their high soil organic carbon contents. In these areas, there are incentives for not converting land with higher carbon content into arable land. Emissions from deforestation are limited by avoiding deforestation as much as possible. This is part of the international REDD policy (Reduced Emission from Degradation and Deforestation).

VPA6: PES: Payment for recreational services  
One of the possible methods to ensure the provision of ecosystem services is through incentives and direct payment to farmers or landowners in exchange for managing their land to provide a certain service. These are commonly called Payments for Ecosystem Services (PES) schemes. In this VPA, areas with a high supply of specific cultural or habitat services get incentives. The goal of this VPA is to stimulate a continuation of current agricultural land management of areas with a high supply of ecosystem services. As a stimulation, for land stewardship in ecosystem-service-rich areas, policy mechanisms need to be established that offer regional incentives to farmers or landowners in exchange for managing areas with specific services, e.g. cultural heritage landscapes and landscapes with high recreational values.

VPA8: Zoning for compact cities  
The goal of this VPA is to limit urban sprawl and create and maintain compact urban settlements and cities. The impact on land use change will be derived in a scenario where population density per unit of land varies according to household size. Strict spatial policies will be implemented, leading to (urban) zones defining where settlement is allowed and encouraging increased urban density. Expected effects include reduced area and higher concentration of urban areas and improved conservation of rural areas close to urban settlements.

VPA9: Climate change impacts/flood protection  
The future vision behind this VPA is European-wide adoption of climate change adaptation measures, in the form of planning and management of land use to regulate flood risk. The goal of this scenario is to reduce the effect of flood damage, by means of discouragement of flood prone areas (both related to sea and to river floods). Nature and extensive agriculture is promoted in these areas. Furthermore, water retention is

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promoted in upstream catchments, by encouragement of forest, nature or extensive agriculture in these areas. This VPA focuses on the areas that face additional flood risk compared to the current and project future situation within the scenario runs. Planning with restrictions for flood-prone regions and other planning tasks to reduce flood risk are related to the policy set-up of the EU Flood Directive (Directive 2007/60/EC). Member countries are required to assess the flooding risk of all water courses and coast lines, to map the flood extent and to take adequate and coordinated measures to reduce this flood risk. As part of the directive, flood risk management plans based on flood risk maps are expected in 2015 for every member country.
Appendix C. Projected bundles of services.
D12.2. Science-based trade-off and synergy evaluation of hotspots and problem spots in future ESS supply
Appendix D. Projected changes in mean ES supply across NUTS2
D12.2. Science-based trade-off and synergy evaluation of hotspots and problem spots in future ESS supply
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Appendix E. Evolution of hotspots across NUTS2
D12.2. Science-based trade-off and synergy evaluation of hotspots and problem spots in future ESS supply
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Appendix F. Flood regulation. Scenarios comparison

Date: April 24, 2014

Version: 1.0

Authors: Julia Stürck

Keywords: Ecosystem services, scenarios, flood
1. Outline of the analysis

The analysis incorporates the following parts:

a) A comparison of the difference between the supply in the scenarios in the year 2040 and the baseline.

b) An analysis of supply hotspots and changes in the spatial extent of supply hotspots across the various scenarios

The baseline land cover map used for the analysis represents the A1 scenario, year 2010. Included in the analysis are the marker scenarios A1, B1, A2, B2, and the policy option scenarios VPS1, VPS5, VPS6, VPS8, and VPS9 for A2 and B2, respectively, all covering the year 2040. Water bodies are excluded in this analysis. Grid cells which have a supply indicator value greater than the 95th percentile of the distribution are defined as positive supply hotspots. Grid cells which have a supply indicator value less than the 5th percentile of the distribution are defined as negative supply hotspots. To compare the various scenarios, the difference in hotspot area extents are quantified (Table F4). A country-wise comparison per scenario is performed as well (Table F5 and Table F6).

2. Results

All scenarios suggest slight decreases in average flood regulation supply with respect to the baseline (Table F1). Across Europe, largest decreases are associated with the A2 VPS6 scenario, while slightest decreases are associated with the B2 VPS1 scenario. However, on a European scale, the differences in projected supply are limited. On the country scale, differences among the various countries and scenarios are more apparent. In the baseline, the supply is highest in Latvia, Estonia, and Denmark and lowest in Belgium, Malta, and Hungary. Largest average supply increases across all scenarios are featured by Finland, Greece, and Italy, while the largest average decreases are experienced by Cyprus, Malta, and Czech Republic (Table F2). Losses in supply are more pronounced than gains: In all scenarios, the majority of countries lose flood regulation supply (minimum: 14 countries in B2 VPS1), and also the average and maximum gains (0.006; 0.015) are smaller than the average and maximum losses (-0.008; -0.029) across all countries. The largest variability of supply change can be found in Cyprus, the Netherlands, and Belgium (Table F3). A main reason for this development can be concurrent developments in urbanization and reforestation or agricultural abandonment.
Table F1. Mean flood regulation supply across Europe. Synthetic comparison of all scenarios, with respect to the baseline ($m = 0.520$, std. dev. $= 0.229$).

<table>
<thead>
<tr>
<th>Scenario year 2040</th>
<th>Δ mean</th>
<th>Δ standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>-0.002</td>
<td>0.051</td>
</tr>
<tr>
<td>A2</td>
<td>-0.005</td>
<td>0.054</td>
</tr>
<tr>
<td>B1</td>
<td>-0.003</td>
<td>0.058</td>
</tr>
<tr>
<td>B2</td>
<td>-0.003</td>
<td>0.051</td>
</tr>
<tr>
<td>A2 VPS 1</td>
<td>-0.004</td>
<td>0.058</td>
</tr>
<tr>
<td>A2 VPS 5</td>
<td>-0.002</td>
<td>0.060</td>
</tr>
<tr>
<td>A2 VPS 6</td>
<td>-0.007</td>
<td>0.053</td>
</tr>
<tr>
<td>A2 VPS 8</td>
<td>-0.005</td>
<td>0.051</td>
</tr>
<tr>
<td>A2 VPS 9</td>
<td>-0.005</td>
<td>0.055</td>
</tr>
<tr>
<td>B2 VPS 1</td>
<td>-0.001</td>
<td>0.054</td>
</tr>
<tr>
<td>B2 VPS 5</td>
<td>-0.003</td>
<td>0.052</td>
</tr>
<tr>
<td>B2 VPS 6</td>
<td>-0.002</td>
<td>0.051</td>
</tr>
<tr>
<td>B2 VPS 8</td>
<td>-0.002</td>
<td>0.049</td>
</tr>
<tr>
<td>B2 VPS 9</td>
<td>-0.003</td>
<td>0.052</td>
</tr>
</tbody>
</table>
Table F3. Country statistics: Δ standard deviation 2040 – 2010 and standard deviation in 2010
Positive and negative supply hot spots are defined as the top and bottom 5% of the distribution in the baseline scenario (top 5%: 0.90 – 1 and bottom 5%: 0 – 0.14). Changes in spatial extent in hotspot area between scenarios are listed in Table F4. The highest positive hotspot increase per scenario is apparent in the B2 VPS 1 scenario, the lowest in the A2 marker scenario. The A2 marker scenario does also show the highest increase in negative hotspot extent, while the lowest increase is apparent in the B2 VPS8 scenario. Overall, the variability between scenarios in terms of negative hotspots is higher than for positive hotspots. It is interesting to note that in all scenarios, the extent of both negative and positive hotspots increases, while the average supply decreases in all scenarios to different extents.

Country-wise, the highest increases (in percent) in positive hotspot extent are apparent in Austria, France, and Spain, across all scenarios, while Denmark, Belgium, and Ireland feature decreases in all scenarios (Table F5). Ambivalent developments of positive hotspot area extent are projected for Czech Republic, Hungary, Luxemburg, and The Netherlands. The highest increases (in percent) in negative hotspots extent are apparent in Ireland, Poland, and Slovakia (Table F6). Cyprus, Italy, and France show strongest decreases in (part of) the various scenarios. The A2 VPS1, B2 VPS1, and B2 VPS9 scenario are most beneficial for most countries in terms of positive hotspot increases, while the A2 marker scenario and A2 VPS 6 are the least beneficial. The B2 VPS1 scenario and B2 VPS8 are most beneficial for most countries in terms of negative hotspot reduction, while the A1, A2 and B1 marker scenario are the least beneficial for most countries.

While the increase of positive hotspot area, particularly in Austria, seems large, it is mostly attributable to decreases of production levels in forests, which leads to only low absolute gains in flood regulation supply.

Table F4. Change of positive and negative hotspot area per scenario in percent with respect to the baseline.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Positive Hotspot</th>
<th>Negative Hotspot</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>20.60</td>
<td>8.26</td>
</tr>
<tr>
<td>A2</td>
<td>17.65</td>
<td><strong>9.59</strong></td>
</tr>
<tr>
<td>B1</td>
<td>19.97</td>
<td>8.17</td>
</tr>
<tr>
<td>B2</td>
<td>17.89</td>
<td>5.32</td>
</tr>
<tr>
<td>A2 VPS1</td>
<td>20.46</td>
<td>7.38</td>
</tr>
<tr>
<td>A2 VPS5</td>
<td>20.70</td>
<td>7.61</td>
</tr>
<tr>
<td>A2 VPS6</td>
<td>18.28</td>
<td>7.72</td>
</tr>
<tr>
<td>A2 VPS8</td>
<td>18.28</td>
<td>5.36</td>
</tr>
<tr>
<td>A2 VPS9</td>
<td>18.61</td>
<td>7.18</td>
</tr>
<tr>
<td>B2 VPS1</td>
<td><strong>20.74</strong></td>
<td>3.43</td>
</tr>
<tr>
<td>B2 VPS5</td>
<td>19.77</td>
<td>3.58</td>
</tr>
<tr>
<td>B2 VPS6</td>
<td>18.44</td>
<td>3.61</td>
</tr>
<tr>
<td>B2 VPS8</td>
<td>18.39</td>
<td>2.18</td>
</tr>
<tr>
<td>B2 VPS9</td>
<td>18.93</td>
<td>3.24</td>
</tr>
</tbody>
</table>
Table F5. Extent of positive hotspot area per country in the baseline and change per scenario in percent.
Table F6. Extent of negative hotspot area per country in the baseline and change per scenario in percent.
3. Appendix

The following selection contains hotspot change maps, covering the scenarios which are most (and least) beneficial in terms of positive hotspot increases and most (and least) beneficial in terms of negative hotspot development across selected European countries.

Figure F1. Positive hotspot changes in western Czech Republic in B2 VPS1 scenario (left) and A2 VPS6 scenario (right) with respect to the baseline. Growth is indicated in dark blue, loss in red.

Figure F2. Positive hotspot changes in the Netherlands in A2 VPS 5 scenario (left) and B2 VPS 6 scenario (right) with respect to the baseline. Growth is indicated in dark blue, loss in red.
Figure F3. Positive hotspot changes in the United Kingdom in B2 VPS 5 scenario (left) and A2 marker scenario (right) with respect to the baseline. Growth is indicated in dark blue, loss in red.

Figure F4. Negative hotspot changes in Italy in B2 VPS 8 scenario (left) and B1 marker scenario (right) with respect to the baseline. Growth is indicated in brown, negative hotspot loss in blue.

Figure F5. Negative hotspot changes in Cyprus in B2 VPS 8 scenario (left) and A2 marker scenario (right) with respect to the baseline. Growth is indicated in brown, negative hotspot loss in blue.
Figure F6. Negative hotspot changes in Ireland in B2 VPS8 scenario (left) and A2 marker scenario (right) with respect to the baseline. Growth is indicated in brown, negative hotspot loss in blue.
Appendix G. Relative Pollination Potential (RPP) Index. Scenarios comparison

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Authors: Maria Luisa Paracchini, Carlo Rega, Claudia Bulgheroni, Adrian Leip, Grazia Zulian

Keywords: Ecosystem services, scenarios, outdoor recreation potential
This document provides an analysis of the projected changes of the Relative Pollination Potential index in Volante Marker and Policy scenarios with respect to the benchmark data, i.e. marker scenario A1 at year 2010.

**Projected changes at 2040 with respect to the benchmark scenario – general trends.**

The Relative Pollination Potential (RPP) index estimates the capacity of land cover cells to provide crop pollination by short flight distance pollinators (in these cases, wild bees). As a general consideration, it shall be noted that, contrary to what happens for the Outdoor Recreation Potential, the changes in the RPP Index and synthetic statistical indicators (mean, standard deviation) do not depend only on the aggregation of individual cell’s transitions to one land cover to another, but also on the spatial patterns of such variations. This is due to how the pollination process is modelled and, in particular, the foraging range and the forest component. As regards the first, a moving window of 3 x 3 km is applied to each cell to determine the foraging potential, as bees are supposed to have a forage range of 1 km. This entails that changes of value for one cell do not depend only on land-cover transition of that cell, but also of the 8 adjacent ones. Therefore, a cell might have different RPP values in different scenarios even if its land cover does not change. Furthermore, cells classified as forest do not have all the same values of nesting suitability and floral potential, but these values decrease exponentially from the forest’s edge, where they are maximum, towards the cores. The result is that forest expansion has a mixed effect on the RPP value, depending on whether this expansions leads to a densification of the forest cover or a fragmentation of the edge’s perimeter. If land use transitions lead to a densification of forests, the edges will decrease and cores increase, with an overall reduction of nesting potential and floral availability. This explains a large share of the projected decreases of the index at 2040, as in all scenarios forests are foreseen to significantly expand, on average by 19%, primarily at the expense of semi-natural vegetation in woodland clearings. Within Volante simulations, this effect is amplified by the spatial resolution of the model, as forest edges have a thickness of 1 km, being this the minimum cell’s size.

Another feature of the model is that bees’ activity rate increases linearly with temperature, therefore, other things being equal, the general pattern of the RPP index is a general increase of the value along a north-south gradient. Figure G1 show the index value for the benchmark scenario: the general trend is evident, with Southern countries - Italy, Spain, Portugal, Greece, South of France - having the highest values. Hotspots can also be identified along the Carpathians in Romania and Balkans range in Bulgaria. Lowest values of the index are to be found in urban areas and regions where arable is the predominant land use, as in the Po Plain, eastern England, Castilla y Leon (Central-Northern Spain), the Danubian and Wallachian Plains (Bulgaria and Romania), Normandy, Brittany and Nord-Pas de Calais (Northern France), as well as in the North European Plain (Flanders, Netherlands, Denmark, Northern German and northern Poland). In Fennoscandia values are medium-low due to the combined effect of the presence of forest fragmented by patches of semi natural vegetation and low temperatures.
Relative Pollination Potential index

Benchmark scenario A1 2010

VALUE [0-1]

- Low (0 - 0.07)
- Medium - low (0.07 - 0.16)
- Medium (0.16 - 0.29)
- Medium - high (0.29 - 0.45)
- High (0.45 - 1)
The following diagram depicts the mean value of the RPP Index for all scenarios at 2040 compared to the baseline scenario (Marker scenario A1 at year 2010 = 100, horizontal red line).

In all cases the projected mean values are lower than the benchmark, with decreases comprised between 5% in VPS1 A2 and 11,8% (VPS9 B2). Marker scenarios A1, A2 and B2 show very similar mean values, with 10-11% decrease compared to the benchmark, whilst marker scenario B1 presents a higher value, but still almost 6% lower than the benchmark. Among policy scenarios, VPS1, as expected, feature the highest mean values (95,0 and 93, 4 respectively), followed by VPS5 B2 with 92,2. VPS8 scenarios (zoning for compact cities) follow, with mean values around 90. For policy scenarios 6, 8 and 9, variations between A2 and B2 sub-scenarios are very limited. Contrary to what happens with the Outdoor Recreation Potential index, urbanization processes are less relevant in determining changes in the RPP index, as they mostly occur at the expense of agricultural land at the urban fringes, which already have a relatively low pollination potential due to low values of floral availability and nesting suitability. Land take by urban areas becomes significant instead if it occurs at the expense of land covers with higher floral and nesting values, such as semi-natural vegetation or permanent crops.

The diagram below shows, for each scenario, the total areas of hotspot, defined as areas where the normalized (0-1) value index is higher than 0,45 (break value of the last class using Jenks natural breaks method) (benchmark scenario’s hotspot area normalized at 100).

The trend is similar to that of the mean values, but with some differences. VPS1 A2, VPS1 B2 and marker B1 still present the highest values, but in this case VPS1 B2 has the top value, meaning that variations in this
scenarios are more marked that in the cognate VPS1 A2. Similarly, VPS6 B2 has a slightly higher mean value but a lower hotspot areas compared to VPS A2.

Identified trends in individual scenarios

In the following, a description of the main identifiable trends of changes of the RPP index for each scenario is provided.

Marker Scenario A1

In marker scenario A1 the mean value of the RPP index is 89.7 (baseline=100). One of the main driver of the identified decrease is, as said above, forest densification. Forest cover at 2040 in fact is projected to increase by some 266,000 sq km in 2040 (+20.3% with respect to 2010). The combined effect is a decrease of the RPP value where forests become denser, and an increase along the (new) forests’ edges. However, since forest expansion mostly (90%) occurs in clearings at the expense of semi-natural vegetation, which in turn presents high scores of nesting potential and floral availability, this determines an overall decrease of the RPP value. This pattern is evident along mountain ranges, where most of European forests are concentrated: in Italy along the Apennine range and the Alpine foothills, in the Maritime Alps (Italy-France) and Provence (Southern France) (Fig. G2), in the Pindus range (central Greece), the Pyrenees (in particular
the Spanish side), the Bulgarian Balkans and the Carpathians. In Spain, diffused transitions from semi-natural vegetation to forest is foreseen also along the Iberian System and in particular in the area of the National park of Alto Tajo (Eastern Castilla-La Mancha), and the Sierras the Cebollera at the border with La Rioja. Similarly, densification is projected to occur in the forests of Rhodope Mountains (Southern Bulgaria), in central Portugal and in the Landes Forest (South West France, one of the few large forest on Plain land in Southern Europe) as well as across all Fennoscandia and in Baltic Countries.

Positive hotspots of change are identifiable mainly in areas facing agricultural abandonment and transition to land covers with higher floral and nesting potentials as semi-natural vegetation and recently abandoned pasture/arable land. This is the case for example in Langhe area, Piedmont (NW Italy), where pasture and permanent crops leave way to semi-natural vegetation and forest, or along the eastern foothill of the Apennine range in central and Southern Italy, where the foreseen increases are the results of a combination of different factors: transition from pasture and arable to semi-natural vegetation and recently abandoned arable/pasture land, and forest expansion with consequent shift of forest edges eastwards (Fig. G2).

The same occurs extensively in Sicily, the Massif Central in Central Southern France (Auvergne, western Rhone-Alps and north-Eastern part of Midi-Pyrénées) where strong decrease of pastureland is expected. Another positive hotspots is the Tras-os-Montes region (North-Eastern Portugal, part of the administrative Norte Region), where pasture and permanent crops are expected to decrease in favour of semi-natural vegetation and recently abandoned arable/pastureland. Transitions from agricultural use to non-agricultural covers also explains the increases in Eastern Bayern (SE Germany, particularly due to pasture abandonment), Hungary (South of Budapest and along the North Hungarian Mountains bordering Slovakia) and in the Transylvanian Plateau (central Romania). Scattered increase of forest dotted with remnants of semi-natural vegetation (and consequent complex patterns of forests edges) determines the increase observed in South-East Bulgaria. Forests and semi-natural vegetation also increases in North-East Romania.

**Marker Scenarios A2 and B2**

Overall, patterns of changes in marker scenarios A2 and B2 are similar to each other and to those of marker scenario A1, but positive changes are more limited, as abandonment of arable land and consequent transitions to more favourable (for pollination) land covers is less pronounced in this case. No increase is projected to occur for instance in the Massif Central in France or in South-East Germany; the increases in Hungary and Romania, whilst following the general pattern described for marker scenario A2, are less marked.

**Marker Scenario B1**

Marker scenario B1 presents the highest mean value of the RPP index amongst the four marker scenarios. Spatially, the patterns of changes and hotspots areas are similar to the ones described in marker scenarios A1, but increases are more pronounced and spatially widespread. This is evident for instance in Sicily, central-southern Italy, the Massif Central area or along the Pyrenees (France) (Fig. G3), and in southern Andalusia (Southern Spain) where diffused abandonment of arable land and consequent transition to semi-natural vegetation is projected. Increase of semi-natural vegetation along main rivers in Poland determines a very recognizable pattern of changes (as already highlighted for the Outdoor Recreation Potential Index).
Increases of the index are also visible in scattered areas in Central Germany and South West Germany (Black Forest).

Volante Policy Scenarios 1 A2: Nature protection

In policy scenarios VPS1, the strong focus on nature protection implies expansion of protected zones beyond Natura2000, a robust ecological corridor network and strengthened constraints on forest management and land cover conversions. In terms of land use changes, this leads to the expansion of natural areas, including forest, semi-natural vegetation as well as abandoned pasture and arable land (see deliverable D 11.1, pag. 77). This trend reverberates on the observed changes in the RPP Index, but in different ways in the two scenarios. In VPS1 A2 the mean RPP values is the highest among all the examined scenarios (94,98). This derives from the fact that his scenario is the closest to the benchmark. As a consequence, not only changes on the RPP index are more limited compared to other scenarios, as reflected by the mean value, but the standard deviation of the calculated variations (value at 2040 minus value at 2010) is also the lowest among all examined scenarios (SD = 0,0398). Similarly to what happens in other cases, areas of decrease due to forest expansion/densification are localised in the Maritime Alps and Provence, Northern Apennine, Landes Forest (SW France), Rhodopes an Balkans ranges in Bulgaria, Carpathians in Romania, the area of the National park of Alto Tajo (Eastern Castilla-La Mancha, Central Spain), and the Sierras the Cebollera (Central-Northern Spain), central Portugal and NW Greece in the Pindus range. However, decreases are less pronounced as forest expansion in VPS1 A2 occurs at a lower rate compared to other scenarios (+8,9% vs + 18,1% and +20,6% in marker scenarios A2 and B 2 respectively) (Fig. G4). Negative hotspots area due to others land use transitions are detectable e.g. in Extremadura Region (western Spain), where significant shares of permanent crops are projected to convert to pasture, which implies a decrease in floral availability and nesting suitability. In Saxony-Anhalt and Brandenburg Regions (Central-eastern Germany) negative hotspots are caused by urban expansion on semi-natural land.

Volante Policy Scenarios 1 B2

As the previous one, VPS1 B2 has a mean index value close to the one of the benchmark (93,42), but in this case, this figure is the result of the presence of both widespread negative and positive hotspots. This is reflected by the standard deviation of the calculated variations, the highest among the examined scenarios (SD = 0,708). Again, strong forest expansion largely explains the observed variations: VPS1 B2 is in fact the scenario with the largest shares of forest area among the examined one (+22,6% with respect to benchmark). With comparison to VPS1 A2 scenario, negative hotspots are therefore more evident and widespread (featuring very similar patterns as those observed in marker scenario B2), particularly in Southern Iberian System in Spain (Southern Aragon and northern Valencian Community), the Pindus range (central Greece), Balkans and Carpathians (Fig. G4). As noted, positive hotspots are more diffused and widespread as well: the main ones are identifiable in eastern European countries, as Romania and Bulgaria (Fig. G3), where the expansion of natural areas is more evident (see also the descriptions of changes in the Outdoor recreation potential), along major rivers in Poland and in Northern Hungary. Increases are expected to occur in western countries as well, in central Adriatic regions in Italy (Marche and Abruzzo, were arable and permanent crops decreases and are substituted by semi-natural vegetation), Langhe e Roero (Southern Piedmont, NW Italy), Asturias (Northern Spain) as result of transition from
pasture/recently abandoned pastures to semi-natural vegetation and forests, and in Central Western Portugal, where a significant number of cells converts from permanent crops and pasture to semi-natural vegetation.

**Volante Policy Scenarios 5 A2 - Payment for carbon sequestration**

Changes of the RPP index in these scenarios follow a very similar pattern to those observed in marker scenario A2, the two scenarios having in fact very close mean index value (≈89.47). The main differences can be spotted in Castilla Y Leon (Central Spain), north to Madrid, where scattered forest expansion takes place on arable and pasture increasing the RPP Value, whilst in Extremadura the decrease is more marked and widespread than in marker scenario A2 as in some cells permanent crops expands at the expense of semi-natural vegetation and in other cases is replaced by pasture (Fig. G5). Conversion from arable to permanent crops and semi-natural vegetation occurs more extensively in Southern Andalusia, explaining the more pronounced increase of the RPP index with respect to marker A2. In Ile de France (Paris Area, Central-Northern France), increases of the index are determined by scattered transitions from arable to pasture and forest, whilst in marker A2 a trend of decreased is instead observed in the region, due to urban expansions at the expense of forests.

**Volante Policy Scenarios 5 B2 - Payment for carbon sequestration**

This scenario has the highest mean value of the RPP index (92.18), among policy scenarios excluding VPS1. Compared to VPS5 A2 in fact urban expansion is more limited as well as loss of semi-natural vegetation. Spatially, hotspots of changes are distributed similarly to VPS A2, but positive variations are amplified whilst negative ones are diluted. Areas where such differences are more visible are Extremadura (Western Spain – Fig. G5), the French side of Pyrenees, the Rhone-Alps region (increase of semi-natural vegetation on agricultural land), Brittany (arable abandonment and replacement by semi-natural vegetation), Southern England and Cornwall (same transitions), Black Forest (SW Germany), Central Adriatic Regions in Italy where large share of arable land are replaced by semi-natural vegetation and pastures, and SE Poland.

**VPS6 A2 PES: Payment for recreational services**

The mean value of the RPP index in this scenario is 89.30, slightly lower than he relative marker scenario A2 (89.47). Both positive and negative hotspots of change in this scenario follow already described general patterns of marker scenario A2, with increases of the index values slightly dwindling in some regions, e.g. in Piedmont (NW Italy), and slightly more pronounced in other ones (e.g. Sicily and NE Poland).

**VPS6 B2 Payment for recreational services**

This scenario presents a slightly higher mean value compared to both VPS6 A2 (89.47 vs 89.30) and marker scenario B2 (89.38). Again, general patterns of variation resemble those of the cognate B2 scenario with some local variations, evident for example in SW Andalusia, where forest densification is projected to occur in the Sierra Morena, north to the natural park of Sierra de Hornachuelos (the area identified in circle also
in fig. G5). Diffused transitions from arable to semi-natural vegetation, not projected in VPS6-A2 are expected to occur e.g. in Sicily (Italy), or Southern Romania, with consequent more evident increase of the index value.

**VPS8 A2 Planning for compact cities**

This scenario aims to contrast urban sprawl by constraining developments nearby already urbanized areas. As a result, less urban sprawl is projected to occur in certain areas, particularly Central England and Benelux. However, as said, this has overall minor consequences on the RPP index, as in such areas urban growth would occur mainly at the expense of cells with already relatively low index values (arable land), although a positive effects is detectable for example in Flanders (northern Belgium) and in the metropolitan areas of London and Paris. (Fig. G6). As a results, patterns of variation closely resemble those of Marker scenario A2, with VPS8 A2 having a higher mean value though (90.04 vs 89.47).

**VPS8 B2**

Trends in this scenario are similar to those described in VPS8 A2 (see also fig. G6), but in this case the mean value is a bit lower (89.79 vs 90.04) due to stronger forest densification processes taking place. The mean value however is higher compared to Marker scenario B2 (89.38).

**VPS9 A2-B2**

The aim of this policy scenario is to avoid new urban developments in flood prone areas and to encourage semi-natural vegetation and extensive agriculture on such areas. However, effects of this on the RPP values are often not significant, and results are mixed. These scenarios in fact have the lowest mean RPP values among VPS scenarios (89.38 and 89.22 respectively), slightly lower than the relative marker scenarios A2 and B2 (89.47 and 89.38). Overall, patterns of changes feature minor differences with these scenarios.

In the following, some focus figures on previously described hotspots of changes are provided.
Figure G2: Difference in the RPP index values (Marker scenario A1 at 2040 minus baseline). Focus on Northern Italy and South-East France. Forest expansion and densification in Maritime Alps and along the Apennine. In southern Piedmont the increase is due to substitution of permanent crops with semi-natural vegetation.
Figure G3: Changes in the RPP index values in marker scenarios B1 (left) and B2 (right) at 2040. Focus on Southern France. In B1 scenario abandonment of agricultural land replaced by semi-natural vegetation leads to significant increases of the RPP values in Massif Central.
Figure G4: Changes in the RPP index values in VPS1 A2 (low-left) and B2 (low-right) and marker scenarios A2 (upper left) and B2 (upper right). Focus on Hungary, Romania and Bulgaria. The image shows the different patterns of changes in VPS1 A2 compared to VPS1 B2. In the first case the high mean value of the index is due to less pronounced decreases, whilst in the second case negative hotspots persist, but more pronounced positive hotspots are also present.
Figure G5: Changes in the RPP index values in VPS5 A2 (left) and VPS5B2 (right) with respect to benchmark. Focus on the Iberian Peninsula. Circles identify areas where the differences between the two scenarios are more relevant.
Figure G6: Changes in the RPP index values in VPS8 A2 (left) and VPS8B2 (right), Marker A2 and Marker B2 scenarios at 2040. Focus on northern France, Belgium and Southern England. The effects of the zoning for compact cities compared to marker scenarios A2 is evident in the Flanders and around the metropolitan area of London.
Appendix H. Outdoor Recreation Potential (ORP) Index. Scenarios comparison

Date: April 17, 2014
Version: 1.0
Authors: Maria Luisa Paracchini, Carlo Rega, Claudia Bulgheroni, Adrian Leip, Grazia Zulian

Keywords: Ecosystem services, scenarios, outdoor recreation potential
This document provides an analysis of the projected changes of the Outdoor Recreation Potential index in Volante Marker and Policy scenarios with respect to the benchmark data, i.e. marker scenario A1 at year 2010.

Changes of the ORP index in 2040 with respect to the benchmark scenario – general trends

As a general consideration, it shall be noted that changes of the ORP Index are relatively limited in magnitude since for all scenarios except VPS1, two of the three sub-indexes concurring to determine the overall index value – protected areas and distance from sea costs and inland water – are assumed static. In these cases, changes to the index value are therefore determined only by changes of the hemeroby sub-index, in turn determined by land cover changes. Even in such cases, however, some land use transitions may not reflect in changes of the index, as different land cover classes have the same degree of naturalness. Therefore, for instance, a succession from recently abandoned arable land to semi-natural vegetation or forest would not imply any change of the ORP index, as all these land use classes share the same hemeroby value (3 – semi natural or Mesohemerobe). The result is that one of the most evident effect in marker as well as policy scenarios (except VPS1) projection of the Index value at 2040 are related to urbanization processes.

The following diagram depicts the mean value of the outdoor recreation Index compared to the baseline scenario (Marker scenario A1 at year 2010 = 100, horizontal red line).
In all cases except the two VPS1, the mean values are slightly lower than the benchmark, with decreases comprised between 0.13% and 0.81%. B2 policy scenarios present a slightly higher value than the relative A2 scenarios. Among marker scenarios, A1, B1 and B2 present very close mean values, whilst A2 has a projected value at 2040 0.77% lower than the benchmark. Among all policy scenarios except VPS1, VPS8 is the one with the highest mean value, followed by VPS5. The two VPS9 scenarios feature very similar mean values, being the one with the highest decrease with respect to the baseline; in the case of VPS, the difference between A2 and B2 is more pronounced.

Conversely, VPS1 A2 and B2 scenarios feature an increase of 3.13 and 3.54% of the mean index value, due to the strong focus given by the scenario storyline on nature protection, with the combination of expansion of protected zones beyond Natura2000 and strengthened constraints on land cover conversions. As the ORP index is sensitive to the state of protected areas, this policy goal reflects in an overall increase of the Index, although changes are not evenly distributed in spatial terms (in fact, these scenarios also present the highest standard deviation values of the index). Changes are more evident in South Eastern EU countries, and in particular in the Carpathians and Transylvanian Plateau in Romania, the Bulgarian Balkan and the Thracian Region in Bulgaria and Greece. Hotspots of changes can also be found in several scattered areas in Spain, Alentejo Region in Southern Portugal or the Pomeranian Province in Poland, where an extensive network of protected area is present. In the following, a brief description of changes for each scenario is provided.

The following diagram shows the total areas of hotspots, defined as areas where the normalized (0-1) value index is higher than 0.53 (blue areas in the pictures, corresponding to the fifth quintile in the benchmark scenario).
With respect to the previous diagram, it can be noted that, whilst general trends are similar, differences with the marker scenarios are more pronounced. This is particularly the case for VPS1 scenarios, where an increase of 7.88% and 11.02% of areas with high recreation potential value is observed for A2 and B2 scenarios respectively. This is mainly due to the expansion of protected areas and, to a lower extent, to constraints on certain land use transitions. It’s worth noting also that marker scenarios A1 and B1, whilst showing a slight lower mean value of the index with respect to the benchmark, have at the same time a slightly higher value of hotspot (+1.35% and 1.57% respectively), indicating that values are more dispersed. In fact, standard deviation in A1 and B1 is respectively 0.1759 and 0.1760 whilst in A2 and B2 the figure is 0.1753 and 0.1750. Again, hotspot areas in B2 policy scenarios is systematically higher than in relative A2 scenarios.

**Identified trends in individual scenarios**

**Marker Scenario A1 and B1.**

These scenarios show similar patterns of changes of the ORP Index. In both cases “negative hotspots” (areas where the index value decreases more than 0.15) are mainly concentrated around major urban areas and are due to new urban developments. This is particularly evident in the surroundings of major European cities, like Great London, Paris, Madrid, Milan, Rome, Naples, Athens, and metropolitan areas as the Ruhr Region in Germany, the Greater Manchester and Liverpool areas and the West Midland conurbation in the UK, or the Randstad in the Netherlands (see Fig. H1). Intense urbanization process are projected to occur also in the area of Valencia and Alicante in Spain at the expense of non irrigated arable land.

Increases on the index are mainly related to abandonment of agricultural activity in marginal areas and consequent transition from arable or pasture to semi-natural vegetation or forest (in some cases: recently abandoned agricultural land). Overall, arable land at 2040 on marker scenario A1 is in fact projected to decrease by more than 8% compared to 2010, and pasture land by 12.5%. This is evident for instance along the eastern piedmont of the Apennine range in Italy, in Langhe area in Piedmont (NW Italy), in the Massif Central region and Auvergne in France, Northern Portugal, Wales and Northern England, Hungary (south of Budapest), in the eastern part of Bavaria boarding the Czech Republic, in Transylvania and Carpathians in Romania, as well as in Northern Poland. In marker scenario B1 it can be detected a pattern of transition from pasture and arable land to semi-natural vegetation along buffer strips around the Vistula and other major rivers determining slight increases in the ORP index (Fig. H2)

**Marker Scenario A2**

Marker scenario A2 is the one with the lowest value of the ORP index among the four marker scenarios. This is due to the strong expansion of urban area (+15%) and a relative stability of arable land that causes only minor changes of the hemeroby value to occur. Other detectable changes of the ORP index are projected to occur Along the Apennine range in central Italy, due to transition from recently abandoned
pasture land to pasture or arable land, or semi natural vegetation. The same occurs in the Carpathian range in Romania (Fig. H3) whilst in some other cases the slight decrease of the value is caused by transition from recently abandoned pasture to forest, as in the Balkan range in Bulgaria and Slovakia. In northern Poland, the projected decrease of the index value are due to reconversion of recently abandoned pasture land to pasture and arable. In southern Finland slight increase of the index are expected as result of expansion of woodland at the expense of arable and pasture, whilst the opposite trend is foreseen in Satakunta Region (South West Finland). In Extremadura Region (Western Spain), western Catalonia and central-south Portugal, conversion of permanent crops to pasture is the main driver of the observed increase of the ORP value. Along the Pyrenees range, the observed decrease is due to conversion of recently abandoned pastures to arable or semi-natural vegetation. A general decrease is also foreseen in the Black Forest region (in Baden-Württemberg, South-western Germany) where recently abandoned pasture land converts to pasture and forest.

**Marker Scenario B2**

In this cases the negative hotspots (decreases in the index value) follow a similar pattern as in A2. Increase of the outdoor potential in this scenario are less diffused as some transitions to high value hemeroby cover classes, (e.g. from pasture to recently abandoned pasture land, or from permanent crops to pasture) are less frequent.

**Volante Policy Scenarios 1 A2/B2: Nature protection**

In these policy scenarios, the strong focus on nature protection implies expansion of protected zones beyond Natura2000, a robust ecological corridor network and strengthened constraints on forest management and land cover conversions. In terms of land use changes, this lead to the expansion of natural areas, including forest, semi-natural vegetation as well as abandoned pasture and arable land (see deliverable D 11.1, p. 77). This trend reverberates on the observed changes in the ORP Index, particularly due to expansions of protected areas. This is mostly evident in the Balkans, the Carpathian range, the Transylvanian Plateau, Greece (Fig. H4), the highland region in Scotland, western Ireland, Pomerania (North Poland) Tyrol and Central Austria, and several scattered protected areas in Spain. Negative hotspots are mainly due to urban expansions.

**Volante Policy Scenarios 5 A2 - Payment for carbon sequestration**

In this scenario, slight decreases of the index are evident in the Carpathian Range in Romania mainly due to transition from recently abandoned pasture to pasture. Conversely, increases are also observed in near Transylvanian Plateau as a result of arable reversion to semi-natural vegetation, probably grassland as consequence of the payment for ecosystem service scheme hypothesized by the scenario, that incentives carbon sequestration. In Italy, along the Apennine and in central Sicily, the driving force behind the observed slight decrease is conversion of recently abandoned pasture or arable land to pasture and permanent crops. Conversely, in some par of Tuscany a transition from permanent crops to land uses with closer to natural condition, like pasture, semi natural vegetation or forest is observed. A similar pattern explains the increases of the ORP index in Extremadura Region (West Spain) and Alentejo (South-Central Portugal), where transition from permanent to arable crops or pasture is expected to occur. In Castilla y León (Spain), north to the Madrid Region, expansion of forest on previous pasture and arable land determines the observed increases. In Pomerania and Warmia-Masuria (North Poland) instead, the index
value decrease as a result of re-conversion to arable of previously recently abandoned arable/pasture land. In southern Finland ORP is expected to increase due to expansion of forest on land previously devoted to agriculture (arable), which is probably again a result of the policy settings to increase carbon sequestration. The strong expansion of forests expected in Finland and Sweden do not imply, in general, variation of the OPR index as it occur mostly at the expense of semi-natural vegetation, having the same hemeroby index.

**Volante Policy Scenarios 5 B2 - Payment for carbon sequestration**

In this scenarios, areas where a decrease of the ORP index is expected are similar to the relative VPS5 A2 scenario, whilst more areas are expected to increase their value. Beyond those already previously described, increases are also expected e.g. in Rhone Alpes Region and Brittany (France) due to transition from pasture and arable to semi-natural vegetation. The same is observed also in the plain of Northern Bulgaria or in Western and Southern Transdanubia regions in Hungary. Along the piedmont of the Apennine in Emilia-Romagna (North Italy), a strong pattern of abandonment of arable land and conversion to semi-natural vegetation (in some cases forest) determines the increase of the ORP index. In South Piedmont, Italy, abandonment of vineyards is expected to occur with consequent expansion of semi-natural vegetation. Abandonment of arable and pasture is foreseen also in central West Midlands and Yorkshire and the Humber (England).

**VPS6 A2 PES: Payment for recreational services**

As in others scenarios, conversion of recently abandoned pasture to semi-natural vegetation or pasture is expected to occur in the Carpathian range, as well as in Cantabria and Asturias (Northern Spain), along the Pyrenees, both in France and Spain, and Slovakia. Other hotspot areas of changes are the same already identified in previous scenarios, as Central- Southern Portugal (conversion of permanent crops to pasture and semi-natural vegetation). In Rhone Alp (France) expansion of semi-natural vegetation and forest area is expected, but the effects on the ORP index are mixed, depending on if this expansion is at the expense of recently abandoned pasture land (in which case a decrease of the value occurs) or replaces arable. In Great Britain, beyond urbanization patterns similar to others VPS, the index value is expected to increase in some areas of Wales and northern England, following pasture abandonment (transition to recently abandoned pastureland or semi-natural vegetation). In Arnsberg Region (North-Rhein Westfalia, Germany) increases in outdoor recreation potential is due to arable conversion to semi-natural vegetation and forest. Reversion of recently abandoned pastureland to pasture or semi-natural vegetation explains the observed slight decrease of the index in the Alpine areas of Trentino-Alto Adige (Italy) and Tyrol (Austria). Mixed results of the policy hypothesis for this scenario can be observed in eastern Europe: for example in Central-South Poland expansion of semi-natural vegetation is observed on previous arable and pastureland (with a consequent increase of the value), but transitions form recently abandoned pastures/arable to semi-natural vegetation and arable land is expected also to occur, especially in the Northwest of the country. As in marker scenario A2, expansion of arable land on forest is observed in South Western areas in Finland, facing the Gulf of Bothnia.
VPS6 B2 Payment for recreational services

Spatially, the patterns of changes of the ORP index are similar to those observed in VPS6 A2, but overall decreases are less frequent and increases are more diffused. Urban areas also expand less in this scenarios compared to the A2 version (this is particularly evident for instance in the Paris Area, France, or Flanders-Belgium). Diffused transitions from arable to semi-natural vegetation, not projected in VPS6-A2 are expected to occur e.g. in Sicily (Italy), or Southern Romania. Pasture abandonment in Lower Bavaria leads to expansion of semi-natural vegetation and recently abandoned pastureland. Significant arable reversion to land uses with higher hemeroby value are foreseen also in several areas of South-eastern and North-eastern Poland.

VPS8 A2 Planning for compact cities

This scenario aims to contrast urban sprawl by constraining urban developments nearby already urbanized areas. As a result, less diffused decrease of the ORP index to urbanisation can be observed, particularly in Central England or the Benelux. Other changes of patterns are similar to those already described in the marker A2 scenario, like decreases in Carpathians, Pyrenees, Apennine, northern Spain, Black Forest in South West Germany.

VPS8 B2

This scenario has the closest mean value of the ORP index to the benchmark scenarios. Patterns of changes are overall similar to those of marker scenario B2, but land take by new urbanization is much more limited in this case, which leads to much less evident decreases of the ORP index in the surroundings of metropolitan areas as Paris, London, Milan, Madrid, Dublin, Midlands, Flanders. Such positive effects are less evident in Eastern Europe, where increased urbanisation in urban centres is expected, that in marker scenarios would be spread throughout the countryside as highlighted in deliverable D.11.

VPS9 A2-B2

The aim of this policy scenario is to avoid new urban developments in flood prone areas and to encourage semi-natural vegetation and extensive agriculture on such areas. However, effects of this on the ORP values are often not significant, and results are mixed. Overall, observed patterns of changes are similar to those described for marker A2 scenario, with some exceptions: for example in Extremadura and Portugal most of permanent cropped areas are expected to be maintained, whilst in marker A2 scenarios they are projected to change to pasture, which determines a slight increase of the hemeroby value. Patterns in VPS9 – B2 are similar, but expansion of urban areas is more limited, which overall contributes to a higher mean value of the ORP index.

In the following, some zoomed figures on previously described hotspots of changes are provided.
Figure H1: ORP value changes in Marker Scenario A1-2040. Urbanization processes around major urban areas. Land take due to urban developments is particularly evident around the metropolitan areas of London and Paris, as well as in Flanders. In Wales, increases of the ORP index due to abandonment of pastureland are visible.
Figure H2: ORP value changes in Marker Scenario B1-2040. Focus on Poland. Pasture and arable land converts to semi-natural vegetation along the Vistula and other major Polish rivers determining slight increases in the ORP index.
Figure H3: ORP value changes in Marker Scenario A2-2040. Central Romania. ORP decreases along the Carpathian range mainly due to reconversion to pasture of recently abandoned pastureland. Scattered urban expansions (red pixels) are also detectable. Conversely, in the Transylvanian Plateau, arable and pasture abandonment leads to expansion of semi-natural vegetation (light green pixels).
Figure H4: ORP value changes in Scenario VPS1 A2 (left) and VPS1 B2 (right) at 2040. In both scenarios, strong increase of the index in Romania, Bulgaria and Northern Greece is the result the protected areas network’s expansion (dark green). Along the Carpathian range, recently abandoned pastureland reconverts to pasture leading to slight decrease of the ORP index in VPS1 A2 (yellow). In VPS1 B2 widespread increases of the ORP value are visible, due to arable land abandoned and transition to semi-natural vegetation and forests in the Transylvanian Plateau and North-East Romania (light green).
Figure H5 ORP value changes in Scenario VPSS A2 (left) and VPSS B2 (right) at 2040. North-Western Spain and Central-Northern Portugal. Observed increases of the index value mainly following abandonment of permanent crops. The blue circle identifies an area where permanent crop instead is expanding on previous semi-natural vegetation. VPSS_B2 (right): the blue circle highlight areas where forest expands on former arable and pastureland.
Figure H6: ORP value changes in Scenario VPS6 A2 (left) and VPS6 B2 (right) at 2040. Focus on Eastern Czech Republic, Slovakia, and Southern Poland. Recently abandoned pastureland is replaced by pasture, forest and semi-natural vegetation. Red pixels indicate scattered urban expansion, more pronounced in A2 than in B2.
Figure H7 ORP value changes in Scenario VPS8 A2 (left) and VPS8 B2 (right) at 2040. Focus on North-West Italy. Abandonment of permanent crops (mainly vineyards) in Langhe-Roero, Piedmont (Italy) in both scenarios and in Tuscany in VPS8 B2 leads to expansion of semi-natural vegetation and pasture and increase the ORP index value. Urban expansion around the metropolitan areas of Turin and Milan is also visible, more pronounced in A2 than in B2. The compact city zoning policies prevents scattered urban growth in rural areas.
Appendix I. Energy Content Output (ECO) Index. Scenarios comparison

Date: April 17, 2014

Version: 1.0

Authors: Maria Luisa Paracchini, Carlo Rega, Claudia Bulgherioni, Adrian Leip

Keywords: Ecosystem services, provision service, scenarios, energy content output
This document provides an analysis of the projected changes of the Energy Content Output (ECO) in Volante Marker and Policy scenarios with respect to the benchmark data, i.e. marker scenario A1 at year 2010.

**Changes of the ECO at 2040 in different scenarios with respect to the benchmark scenario – general trends**

The total Energy Content Output is the sum of the following components: food, feed, pruning of trees, residues of permanent crops, and straw. The results presented here derive from the disaggregation at hsmu (homogeneous soil mapping unis) level of the results at NUTS2 level elaborated by the CAPRI model. This is a projection at 2010 based on the baseline values present in the CAPRI database (baseline year: 2004 see also the document CAPRI.doc in the Volante FP server). Figure I1 depicts the values of ECO (expressed in mega joules per hectare of Utilised Agricultural Area) as of 2010, whilst figures I2-8 show the differences between the values calculated for elaborated scenarios at 2040 and the benchmark. In all cases non-agricultural areas as resulting from CLUE simulations where masked out. It shall be recalled that the scenarios elaborated with CAPRI are the four marker scenarios A1, A2, B1 and B2 plus Volante Policy Scenarios VPS1 A2, VPS5 A2 and VPS6 A2. As regards provision services from agriculture, VPS8 A2 and VPS9 A2 are assumed equal to the relative marker scenarios A2.

Consistently with results emerged from other simulations within the Volante Project, the main identifiable general trend for EU 27 is a decrease of land devoted to agriculture in 2040. Overall, this entails an increase of the intensity of use, which is visible in the increase of the mean value of the ECO in all scenarios. This trend is more pronounced in marker scenarios A1 and B1 with increases of 21% and less pronounced in VPS 5 A2 (+12,7%). The following diagram shows the mean value for all examined scenarios (benchmark 2010 normalized at 100, the actual value being 70082 Mj/ha UAA).

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6 For the purpose of statistical analysis, outliers of the ECO values resulting from the disaggregation in CAPRI have been identified and corrected. As a first approximation, values greater than the mean value + 3 times the standard deviation of the original distribution have been considered as outliers: these values have been rescaled to the maximum value of 260000 Mj/ha UAA (circa = mean + 3 SD in benchmark scenario). Considering all examined scenarios, the number of outliers defined in this ways varies between 0.15% and 0.39% of all observed values.

7 These statistics have been calculated considering only hsmu that have a non-zero value as resulting from the disaggregation in CAPRI.
Energy Content Output

Benchmark scenario A1 year 2010

Mj/ha UAA * year

- Non-agricultural area
- Low (< 10.000)
- Medium - Low (10.000 - 50.000)
- Medium (50.000 - 90.000)
- Medium - High (90.000 - 130.000)
- Very High (130.000 - 260.000)

Figure I1: energy content output in benchmark scenario at 2010
Identified trends in individual scenarios

Marker Scenario A1

Figure I2 shows the changes of the ECO value in marker scenario A1 a 2040 compared to the benchmark.

![Map showing changes in Mj/ha UAA](image)

*Figure I2: projected changes of the ECO in marker scenario A1 a 2040 vs benchmark scenario*
The main patterns of changes, identifiable also in other scenarios, are increases projected to occur in already “strong” agricultural areas, as the Po Plain in Italy, eastern England, vast areas in northern Central-Northern France, (Particularly the Region Centre, Brittany, Picardy), the North-Eastern German Plain, Saxony and Thuringia (South East Germany), South-West Slovakia. Decreases are explained to a certain extent by projected abandonment (as simulated by CLUE) of agricultural area particularly in south-eastern Spain, central-southern France and South-East Germany or along the Apennine foothill in Italy. Figure I3 below allows discerning areas where significant decreases (red areas in Fig. I2 above) derive from agricultural abandonment from those where changes in ECO occur on land that retain its agricultural use.

Figure I3: Significant decreases of ECO in Marker scenario A1 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
Negative hotspots not imputable to agricultural abandonment are projected to occur in some areas of the Po Plain (Northern Italy) as those currently occupied by paddy fields in Piedmont, Capitanata area (Puglia, Southern Italy), in Castilla la Mancha (central Spain), in scattered areas in central and northern France and in the Romanian Danube plane.

**Marker Scenario A2**

The differences in ECO as for Marker scenario A2 at 2040 vs the benchmark are depicted in figure I4 below.

![Figure I4: projected changes of the ECO in marker scenario A2 at 2040 vs benchmark scenario](image-url)
General trends are similar to those observed for Marker scenario A1, especially as for observed increases, but significant decreases are more widespread. Again, this is a combination of abandonment of agricultural land as projected by CLUE scenarios and changes in ECO as simulated by CAPRI, as illustrated in the following Figure I5.

Figure I5: decreases of ECO in Marker scenario A2 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
It can be noted that in this scenario the ECO decreases in some areas that maintain their agricultural land use not identifiable in the previous scenarios, e.g. in Castilla y Leon (Northern Spain). Some negative hotspots present in marker scenario A1 are identifiable in this scenario as well, as in the Piedmont Po Plain or in Rumania.

**Marker Scenario B1**

Figure I6 shows the difference in the ECO in marker scenario B1 at 2040. In this case, some specific patterns already identified in the analysis of other ecosystem services are detectable, like agricultural abandonment along main rivers in Poland.

![Figure I6: projected changes of the ECO in marker scenario B1 at 2040 vs benchmark scenario](image)
Figure I7: decreases of ECO in Marker scenario B1 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
Marker Scenario B2

Marker scenario B2 is the one with the lowest ECO mean value among marker scenarios. Whilst general patterns are the same already identified, areas where increases are less pronounced and widespread are eastern England, or North-Eastern France. Contrary to what happens in marker scenario A1, ECO increases in central Finland, whilst less significant increase are projected e.g. in the Bulgarian Danube Plain.

Figure I8: projected changes of the ECO in marker scenario B2 at 2040 vs benchmark scenario 2010
Figure I9: decreases of ECO in Marker scenario B2 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
Figure I10: projected changes of the ECO in VPS 1 A2 (Nature protection) at 2040 vs benchmark scenario
In the Nature Protection Scenario VPS1 A2 the mean ECO is very close to that of the relative marker scenario A2 (116,5 and 116,7 respectively). As for variation patterns, differences can be identified in Castilla y Leon Region (Central Spain), and other scattered area across the Iberian Peninsula, where less decrease is projected to occur compared to marker A2, as well as in Puglia (southern Italy), the Romanian Banat Plain (western Romania). Conversely, stronger decreases are expected to take place in northern Greece due to agricultural abandonment (Fig. I11) or in Andalusia (not imputable to cessation of agriculture activity)

Figure I11: decreases of ECO in VPS1 A2 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
Volante Policy Scenarios 5 A2 - Payment for carbon sequestration

VPS5 A2 (Payment for carbon sequestration) features the lowest mean ECO among examined policy scenarios. Decreases of ECO (but not determined by land abandonment, see fig. I12 and I13) not projected in previous scenarios are identifiable for example in the eastern part of the Po Plain (Italy), south of the Po delta area.

Figure I12: projected changes of the ECO in VPS 5 A2 (Carbon sequestration) at 2040 vs benchmark scenario
Figure 113: decreases of ECO in VPS5 A2 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
VPS6 A2 PES: Payment for recreational services

The mean ECO of VPS6 A2 is slightly lower than the one of the cognate marker scenario A2 (115.7 vs 116.7). Compared to changes simulated for the later, more significant and widespread decreases are expected to occur in The Po Plain (but not entailing agricultural abandonment, see fig. I14 and I15), and northern Greece. Less pronounced variations conversely are projected e.g. in Brittany and Pays de la Loire (North-West France) and Castilla y Leon (Spain).

![Image: Difference between VPS6 A2 2040 and benchmark scenario 2010](image)

*Figure I14: projected changes of the ECO in VPS 6 A2 (Carbon sequestration) at 2040 vs benchmark scenario*
Figure I15: decreases of ECO in VPS6 A2 2040 compared to benchmark. Red cells indicate transitions from agricultural to non-agricultural use; blue cells indicate decreases of ECO on cells that maintain their agricultural use in 2040.
Appendix J. Biocontrol of pests. Scenarios comparison

Date: July 11, 2014

Version: 1.0

Authors: Rémy Lasseur, Maud Mouchet

Keywords: Ecosystem services, scenarios, biocontrol, pests
This document provides an analysis of the projected changes of the Biocontrol of pests index in Volante Marker and Policy scenarios with respect to the benchmark data, i.e. marker scenario A1 at year 2010.

**Projected changes in the EU27 average supply at 2040 compared to the benchmark scenario**

The supply of biocontrol of pests in 2040 is projected to decrease, regardless of the scenario (but A1, B1 and VPS9 for which the service was not projected). Figure J1 illustrates the evolution of the mean supply of biocontrol at the EU27 scale from 2010 to 2040. This decrease should be stronger in the marker scenario B2 (-60.45% in 2040 as compared to 2010). In the other scenarios, this loss of biocontrol supply should range from -24.88% (B2 VPS1) to -26.34% (A2).

![Difference (in %) of mean from 2010 for biological control](image)

Figure J1. Evolution of the average supply of biocontrol of pests for each scenario of the VOLANTE project. The evolution is based on the difference between the ES supply in 2040 compared to the ES supply in 2010 (0, on the y-axis, being the baseline level of biocontrol in 2010). The ES was not projected on A1, B1 and VPS9 (A2 and B2).
At the scale of NUTS 2, the evolution of the mean supply if more contrasted. Figure J2 illustrates the variability across NUTS. Figure J2.A represents the evolution of the average supply of biocontrol within each NUTS between 2010 and 2040 in the context of the marker scenario A2. London (England), Lisboa (Portugal) or Madrid (Spain) areas should experience, on average, a significant loss of biocontrol certainly related to urban expansion. Conversely, southern Scandinavia (Götaland, Eastern Finland Province), Latvia, Estonia, Galicia and Asturias regions (Spain), central and southern France, central Italy, NW Romania, southern Austria and Slovenia should gain in biocontrol of pests. In the context of B2 marker scenario (Fig J2.B), most NUTS should undergo a loss in biocontrol compared to the baseline. Only in UK and Ireland, the biocontrol supply would increase following pasture and arable abandonment (transition to semi-natural vegetation and expansions of protected areas).

Figure J2. Evolution of the average supply of biocontrol of pests at the NUTS 2 level, in the context of (A) A2 marker scenario and (B) B2 marker scenario. The evolution is based on the difference between the ES supply in 2040 compared to the ES supply in 2010, gains are colored in red and losses in blue.

Although the loss of biocontrol supply in the neighbourhood of megacities may be well explained by urbanisation, the gains (and losses) of biocontrol in more rural areas might be related to different phenomena. Indeed, the biocontrol model is based on both Dyna-Clue land cover and species distribution modelling. Hence, the distributions of species providing biocontrol are susceptible to change with climatic changes first. More than 100 species were included in the biocontrol modelling so the response of the biocontrol index to climate change as the distribution of each species evolves independently of the others. Some might move towards northern latitudes enriching higher latitudes with biocontrol supply. The biocontrol index is also dependent on the types of land use that are favourable to species providing biocontrol. Then, an
increase in natural areas (due to land abandonment or instance) might be beneficial for those species. However, it is worth noting that, in theory, the biocontrol service is strongly linked to agricultural or intensively managed areas. Then, if agricultural areas tend to be concentrated to leave more space for natural areas, then the biocontrol might, on average, decrease but increase on the remaining agricultural land that would be extremely intensively managed. The opposition between figure J2.A and J2.B suggests that the index well reverberate the changes of climate changes. The biocontrol index might be more sensitive to climate change than land use transitions (see the slight differences between maps corresponding to VPS for a given marker scenario in Annex D).

Figure J3. Losses (in blue) and gains (in red) of biocontrol supply under A2 marker scenario at 1km2.

At the local scale (1km2), the spatial heterogeneity of the evolution of the supply remains and is similar across scenarios but B2 (discussed below).
Figure J4. Regional variability in the evolution of biocontrol supply under A2 scenario.

Figure J4.A clearly reveals the loss of biocontrol in the urban areas of Paris and London under A2 marker scenario. Figure J4.B illustrates the increase in biocontrol supply in mountainous areas (Carpathians Mountains, Alps, Apennine Mountains, Balkans and Massif Central) as well as a decrease in the Po Basin (NE Italy), the Hungarian valley and the Walachia plain (Romania).

Figure J5. Losses (in blue) and gains (in red) of biocontrol supply under B2 marker scenario at 1km2.
Under B2 marker scenario, Paris and London areas are also characterized with a strong decrease in biocontrol supply. But, there is no longer a contrast between plains and mountains. Indeed, biocontrol should decrease in most part of Europe. Ireland and UK are among the few regions where biocontrol should increase between 2010 and 2040.

**Projected changes in the hotspots of supply at 2040 compared to the benchmark scenario**

Figure J6 shows the net evolution of hotspots between 2010 and 2040 in the case of A2 marker scenario (left panel) and B2 marker scenario (right panel). In the context of A2 (Fig. J6.A), the proportion of hotspots should increase in all NUTS but NUTS in southern Spain and southern Portugal, northern Greece, southern Bulgaria, UK, Norrland (Sweden), northern Finland and Czech Republic. Conversely, the supply of biocontrol, in the context of the B2 marker scenario, should decrease in all NUTS but Ireland and UK essentially (Fig. J6.B).

![Figure J6. Net evolution of the number of hotspots per NUTS expressed as a percentage under A2 marker scenario (left panel) and B2 marker scenario (right panel).](image)

**In a nutshell**

In most scenarios, we can expect a loss in biocontrol supply in urban areas and several intensively managed plains. The average biocontrol supply should decrease at the EU27 while the number of hotspots (and coldspots) should increase. Indeed, biocontrol supply should either be very low or very high as illustrated by figures J7 and J8.
Figure J7. Comparison of the distributions of the values of the biocontrol index in Lombardia between 2010 and 2040 (scenario A2). The blue dashed line (left) symbolizes the coldspot threshold and the red dashed line (right), the hotspot threshold.
Figure J8. Comparison of the distributions of the values of the biocontrol index in Catalonia between 2010 and 2040 (scenario A2). The blue dashed line (left) symbolizes the coldspot threshold and the red dashed line (right), the hotspot threshold.
This document provides an analysis of the projected changes of the Fire moderation index in Volante Marker and Policy scenarios with respect to the benchmark data, i.e. marker scenario A1 at year 2010.

Projected changes in the EU27 supply at 2040 compared to the benchmark scenario

![Graph showing the difference (in %) of mean from 2010 for fire across different scenarios.]

Figure K1. Evolution of the average supply of biocontrol of pests for each scenario of the VOLANTE project. The evolution is based on the difference between the ES supply in 2040 compared to the ES supply in 2010 (0, on the y-axis, being the baseline level of biocontrol in 2010). The ES was not projected on A1, B1 and VPS9 (A2 and B2).
For all scenarios, the supply of fire moderation is expected to decrease at the EU27 scale (Fig. K2, left panel). The loss of the ES supply is similar across scenarios ranging from -1.38 for A1 to -4.13 for A2 VPS6 compared to the baseline (see Annex D). This trend remains at the NUTS 2 level and is also confirmed by an overall loss in hotspots (Fig. K2, right panel).

In a nut shell

Figures K2 (left panel) and K3 reveal a latitudinal gradient in the loss of fire moderation but this trend is not confirmed by all scenarios (see Fig. K2 right panel).

Overall, the decrease in the ES supply and in the number of hotspots is consistent among all scenarios and at all spatial scales (continental, national and NUTS 2). However, the decrease is, in general, very small.

Figure K2. Evolution of the average supply of fire moderation (left) and the net evolution of the number of hotspots expressed as a percentage (right) at the NUTS 2 level, under A2 VPS6 scenario. The evolution is based on the difference between the ES supply in 2040 compared to the ES supply in 2010, gains are colored in red and losses in blue.
Figure K3. Losses (in blue) and gains (in red) of fire moderation supply under A2 VPS6 scenario at 1km2.