RFCS RESEARCH PROJECT

Recovery of degraded and transformed ecosystems in coal mining-affected areas

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Deliverable 3.4

Assessment of scenarios for Figaredo Mine

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Executive Summary

Within this Deliverable, the assessment of future scenarios for Figaredo Mine is developed.

In order to select the scenarios that should be considered for the Figaredo Mine case study area, a stakeholder consultation was used as a reference, together with the different types of land rehabilitation and ecosystem restoration alternative actions that were proposed within the RECOVERY Project in order to generate different scenarios in mining-affected areas.

The Smic Prob-Expert tool was used to facilitate the scenario selection. The Smic Prob-Expert tool is a cross-impact probability method that aims to define simple and conditional probabilities of hypotheses and events and the probabilities of combinations of the latter, taking into account interactions between events or hypotheses. The goal of this method is to tease out the most plausible scenarios for decision-makers and examine combinations of hypotheses that one would have initially excluded.

Once the scenarios to be analysed were selected, a narrative for each of them (three in total) was developed, including an overall vision for the new post-mining region. The three scenarios selected were: (1) cows reared for a nutritional purpose (Food); (2) pine tree plantation for producing wood as raw material (Fibre); and (3) the reconstruction of a Broad-leaved forest similar to the ones already present in the region (Landscape), including physical recreation but with no specific developments regarding it.

The translation of the narratives followed it into change rules, procedures and conditions for CLC land use classes using the if-then-else mode.

Finally, to expand the GIS web interface with the different scenarios, they were mapped according to previous Deliverables.

1 Introduction

Work Package Nº 3 focuses on the generation of scenarios for each case study to analyse changes in services delivery required for quantifying trade-offs among them. Specific objectives are:

1. To develop a blueprint instrument/indicator for coal mining impact assessment and post-mining landscape (e)valuation: a feasible ex-ante impact assessment planning instrument to make recommendations for future planning and development of post-mining landscapes.
2. To develop artificial substitutes for soils suitable to several plant communities that provide a wide range of ecosystem services, addressing "difficult terrains" in coal mining waste heaps.
3. To propose suitable land rehabilitation techniques that allow successful environmental and vegetal developments in coal mining waste heaps.
4. To formulate alternative land rehabilitation and ecological restoration actions for the case studies, with particular emphasis on stakeholder consultation, in order to guarantee the success of the scenario's generation process.
5. To map and quantify the new ecosystem services provision of the different scenarios.
6. To expand the GIS web interface with the different scenarios. In order to achieve a higher degree of standardisation and to avoid any overlapping or redundancy within the different categories, the hierarchical structure of the Common

The importance of using scenarios in ecosystem services assessments is beginning to be realised, as early assessments presented a static picture in a changing world.

The necessity of providing counter-facts is now being demanded in conservation research and will become the norm in ecosystem services research.

The generation of different con- and diverging scenarios is essential for monetary valuation since scenarios enable the analysis of changes in services delivery required for quantifying trade-offs among them.

Within this task, and led by GIG, alternative land rehabilitation and ecological restoration actions were defined for Figaredo Mine (UNOVI-HUNOSA), Janina Mine (GIG-TWD), Chabařovice Mine and Most-Ležáky Mine (VŠB-PKÚ), and Terezie – Ema mine dumps complex (VŠB).

Considering the recommendations for future planning and development of the post-mining landscape from the blueprint instrument/indicator with the cooperation of UBER, as well as the need to improve socio-economic outcomes and to catalyse the development of new jobs, different types of land rehabilitation and ecosystem restoration actions will be proposed in order to generate different scenarios, e.g.:

1. Recolonisation of the site by local vegetation.
2. Commercial forestry plantations.
3. Secondary forests using local plant species.
4. Development for agriculture: arable land and pastures.
5. Leisure and recreational purposes: museums and recreation areas.
6. Areas for physical recreation.
7. Space for wildlife and nature conservation.
8. Development of artificial water bodies, e.g., lakes, reservoirs, streams, etc.
9. Renewable energy generation: photovoltaic and wind power.
10. Industrial areas and business facilities
11. Residential areas, etc.

Particular emphasis was given to consultation of scenarios with stakeholders (local authorities, neighbourhood associations, coal mining industry, trade unions, and environmental NGOs) to guarantee the success of the whole process.

Each partner was responsible for the involvement of stakeholders from his case-study areas.

Although one of the objectives of Work Package Nº 3 was to map and quantify the new ecosystem services provision of each generated scenario in order to enable the analysis of changes in services delivery which are required for quantifying trade-offs among them, this work can not be done before the selection of the suitable indicators that will allow a proper quantification of every ecosystem service involved in the coal-mining affected areas. Thus, this work will be postponed to the following work packages.

The energetic valorisation of mining wastes, the extraction of valuable substances, or its use in obtaining crushed road and construction aggregates, natural aggregates, raw materials for the cement industry, void backfilling, etc., will not be considered. These valorisation processes are previous to the development of any land rehabilitation and ecological restoration action.

Deliverable 3.4 will assess scenarios for Figaredo Mine, property of Hulleras del Norte, S.A. (HUNOSA) in Spain.

2 Scenario selection for Figaredo Mine

Particular emphasis was given to consultation of scenarios with stakeholders (local authorities, neighbourhood associations, coal mining industry, trade unions, and environmental NGOs) to guarantee the success of the whole process.

For the Figaredo Mine area, the following five alternatives were considered as the most feasible by the UNIVERSITY OF OVIEDO, taking into consideration Figaredo mine area features: (1) pine tree plantation for producing wood as raw material, as the regional government in Asturias, forbids new eucalyptus plantations in many areas (Natura 2000, near the cost, and others), and as Figaredo mine is quite close to a Natura 2000 area, fibre production should be focused only on pine tree plantations; (2) cows reared for nutritional purpose; (3) the reconstruction of a Broad-leaved forest similar to the ones already present in the region; (4) recolonisation by local vegetation with no restoration actions; and (5) physical recreation area.

For CCOO (Trade Union Comisiones Obreras), an essential trade union in Spain and also in the Asturian mining districts and the company HUNOSA, do not want POTENTIAL Project to forget about the possibility of using some suitable surfaces in the coal mining waste heaps to carry out renewable energy projects, such as the implementation of photovoltaic panels.

Thus, the following six alternatives were considered as the most feasible to analyse: (1) pine tree plantation for producing wood as raw material (Fibre), (2) cows reared for a nutritional purpose (Food), (3) the reconstruction of a Broad-leaved forest similar to the ones already present in the region (Landscape), (4) installation of renewable photovoltaic energy generation (Solar), (5) recolonisation by local vegetation (No restore), and (6) physical recreation area (Recreation).

These alternatives were introduced in the Smic Prob-Expert tool as the hypothesis for developing the scenario assessment (Figure 2-1).

#	Long label	Short label
1	Pine tree plantation	Fiber
2	Cows reared for nutritional purpose	Food
3	Broad-leaved forest	Landscap
4	Photovoltaic energy	Solar
5	Recolonisation by local vegetation	No restore
6	Physical recreation	Recreation

Figure 2-1. Hypothesis list (the short label corresponds to the name given to the scenario)

After this, the first step was to define the "simple probabilities of hypotheses". For this purpose, two groups of experts have formed: the University of Oviedo (UNIOVI) and Hulleras del Norte, S.A. (HUNOSA). In the second place, the expert groups defined the "conditional probabilities of hypotheses, if other hypotheses are realised". The "conditional probabilities of hypotheses, if other hypotheses are non-realise" were defined in the third place. Figure 2-2 shows the conditional probabilities if realisation from UNIOVI.

Hypothesis	1 - Fiber	2 - Food	3 - Landscap	4 - Solar	5 - No restor	6 - Recreatio
1 - Fiber	0,25	0	0	0,25	0	0
2 - Food	0	0,25	0	0,25	0	0,1
3 - Landscap	0	0	0,25	0,05	0	0,25
4 - Solar	0,05	0,05	0,025	0,05	0,05	0,05
5 - No restor	0	0	0	0,2	0,05	0,1
6 - Recreatio	0,1	0,05	0,1	0,1	0,1	0,15

Figure 2-2. Conditional probabilities if realisation from UNIOVI

After conditional and straightforward probabilities were introduced in the tool, it was possible to determine the probability of all the possible scenarios. The objective of Smic Prob-Expert is to calculate scenario probabilities created according to defined hypotheses.

The probability of each scenario is calculated for every expert via a quadratic minimisation method. Results are also available by expert groups or experts and are calculated with mean weighted probabilities determined for each expert. The Smic Prob-Expert method transforms defined hypotheses probabilities by experts to coherent data, in other words respecting the basic probabilities' formulae. Net data computed by the software will hence replace the raw data provided by experts. Figure 2-3 presents the histogram of probability scenarios according to all the experts.

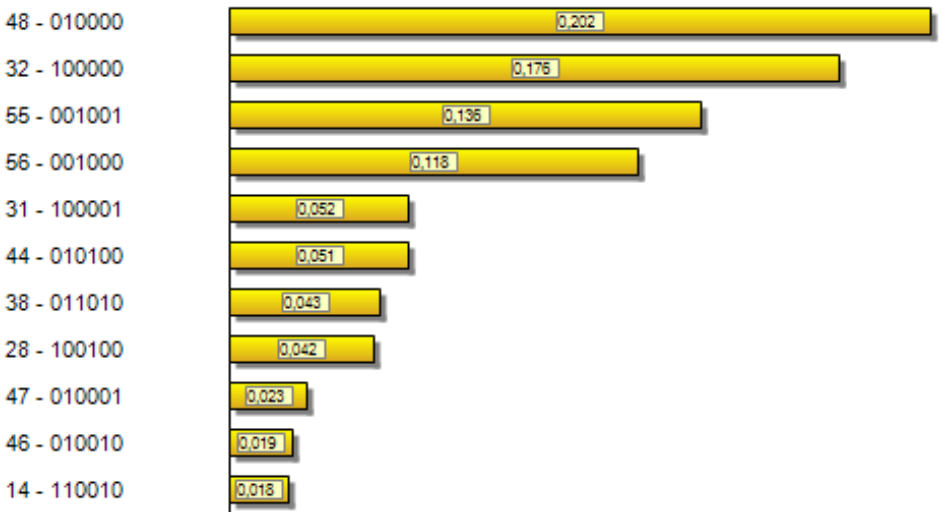

Figure 2-3. Histogram of probability scenarios (all experts)

The four scenarios with higher probability were:

1. **Scenario 010000** corresponds to the second alternative, Food, with a probability of 0.202. This scenario will be called Food.
2. **Scenario 100000** corresponds to the first alternative, Fibre, with a probability of 0.176. This scenario will be called Fibre.
3. **Scenario 001001** corresponds to a combination of the third alternative, Landscape, with the sixth alternative, Recreation, with a probability of 0.135.
4. **Scenario 001000** corresponds to the third alternative alone, Landscape, with a probability of 0.118.

Both Landscape + Recreation and Landscape alternatives have similar probabilities. Thus, a mixed scenario will be proposed for the following steps of the Recovery Project and will be called Landscape. It will correspond to the Landscape alternative. Simultaneously, it will be a physical recreation area where people will be able to walk and observe nature around the area, as it will be a Broad-leaved forest.

This solution is based on the fact that there are many recreation facilities related to coal mining within the former coal mining area in Asturias.

The Smic Prob-Expert tool also allows tracing the scenarios preferred by the experts and converging positions between experts. The closer an expert is to a scenario, the most probable is its realisation. Equally, proximity between experts is used to identify their converging positions concerning the realisation probability of scenarios in jeopardy. Factorial Analysis (FA) is used, calculated from median probability vectors of scenarios corresponding to different experts and groups.

Figure 2-4 presents the closeness map between experts and scenarios. As it is shown, UNIOVI experts are closer to the Food and the Landscape scenarios, while HUNOSA is more closed to the Fibre scenario.

It is a consequence that the company is developing pine tree plantations in other former coal mining areas to develop economic activity. Almost no other alternatives were foreseen for the rehabilitation of waste heaps.

Figure 2-5 presents the histogram of influence sensitivity for all the experts. Sensitivity analysis estimates the probability change DP_j of event *j* due to a probability change DP_i of event *i*. Results are presented in the form of an elasticity matrix. Sensitivity analysis suggests which hypotheses to keep and which to discard to push the system in the direction wanted. The elasticities can be calculated via simulations, running the model of relations between probabilities a few times.

However, when there is a high number of experts, the impact of an event on another can be estimated by comparing displacements of *P(i)*, *P(i/ j)*, *P(i/ -j)* histograms.

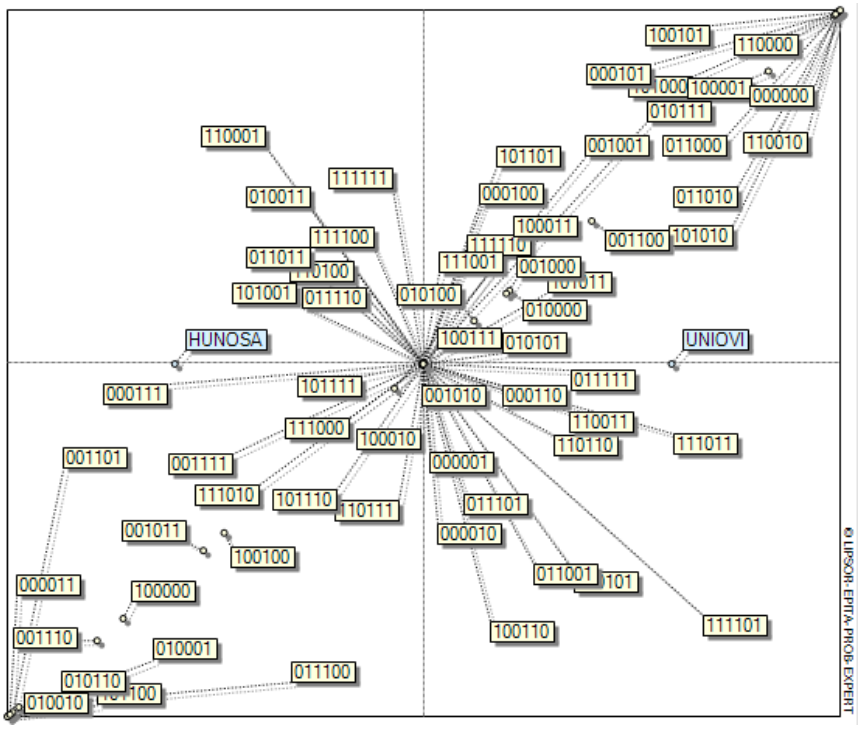

Figure 2-4. Closeness map between experts and scenarios

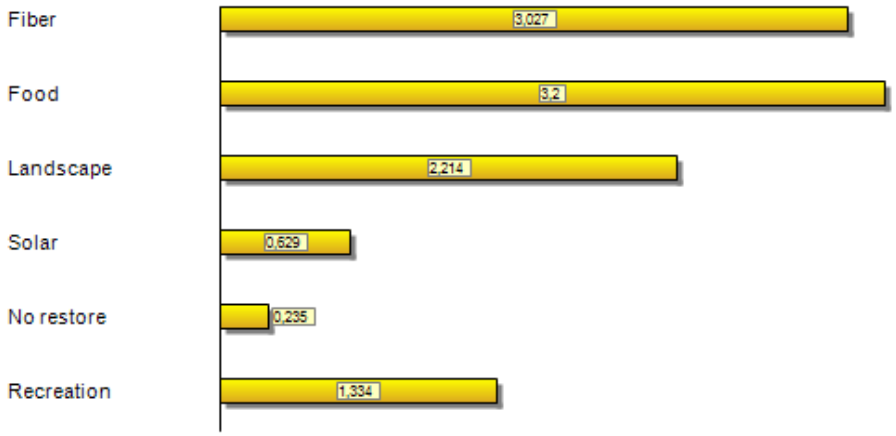

Figure 2-5. Histogram of influence sensitivity (all experts)

It has to be highlighted that the Smic Prob-Expert method transforms defined hypotheses probabilities by experts to coherent data, in other words respecting the basic probabilities' formulae. Net data computed by the software will hence replace the raw data provided by experts. An example of this is shown in Figure 2-6, which presents the conditional probability distribution of the cows reared for nutritional purpose action if non-realisation of the installation of renewable photovoltaic energy generation from UNIOVI and HUNOSA expert groups.

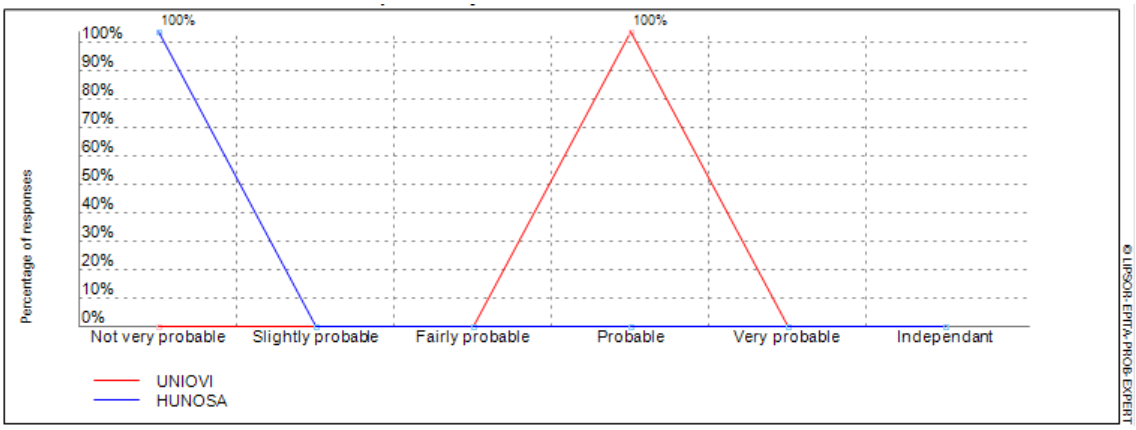

Figure 2-6. Conditional probability if non-realisation distribution: Food/Solar

Finally, it should be pointed out that some reasonings applied by UNIOVI and HUNOSA were that an installation for renewable energy generation was not feasible due to the waste heaps slopes and the primary north orientation of the area. Moreover, local vegetation's recolonisation was neither recommendable, as non-restored areas in Figaredo mine could not achieve complete spontaneous revegetation after more than eleven years.

3 The narrative for Figaredo Mine scenarios

Next, and according to Larondelle & Haase (2021), a narrative for each selected scenario will be developed, including an overall vision for the new post-mining region and some clear targets.

It has to be pointed out that as Figaredo Mine's waste heaps are uniform in their final slope configuration and with almost non-horizontal areas. The different proposed scenarios have only one predominant use, not being necessary to define alternative uses for areas with different characteristics. The narratives are presented in Table 3-1.

Table 3-1. Narrative for the different scenarios of Figaredo Mine

Foreseen projects	Current state or foreseen projects
Scenario I (Food)	Scenario I is characterised by a focus on feeding cows to produce meat, although nowadays also horses are bred for nutritional purposes, it is not so common yet. It is a very typical use even in pastures with slopes similar to Figaredo's waste heaps.
Scenario II (Fibre)	Scenario II is characterised by a focus on pine tree plantation for producing wood as raw material. The regional government in Asturias forbids new eucalyptus plantations in many areas (Natura 2000, near the cost, and others). Figaredo mine is close to a Natura 2000 area, so fibre production should focus only on pine tree plantations.
Scenario III (Landscape)	Scenario III is characterised by reconstructing a Broad-leaved forest similar to the ones already present in the region: mainly Fraxinus excelsior, Betula alba, Acer pseudoplatanus and Ilex aquifolium. Nevertheless, this can be considered a mixed scenario of a Broad-leaved forest and a physical recreation area. People will be able to walk and undertake nature observation around the area, although without developing specific infrastructure for physical recreation.

4 Change rules for CLC land use classes

Narratives were translated into change rules for CLC land use classes with the if-then-else mode, according to Larondelle & Haase (2021). These change rules procedures and conditions for the Figaredo Mine area are shown in Table 4-1.

Table 4-1. Change rules for CLC land use classes

Lad use	CLC 2006	Scenario I	Scenario II	Scenario III	Procedure & conditions
Dumpsites	10.23	0	0	0	Set to zero.
Mineral extraction sites	2.66	0	0	0	Set to zero.
Transitional woodland/shrubs	13.55	9.14	9.14	9.14	Set to zero in all the areas covering the waste heaps. Waste heaps will be re-exploited to valorise the remaining coal. After, they will undergo restoration.
Broad-leaved forest	139.38	121.27	121.27	156.68	Broad-leaved forests will be removed from areas overlying former waste heaps in order to valorise the remaining coal. They will be restored as Broad-leaved forest only in Scenario III.

5 Scenario maps

Finally, to expand the GIS web interface with the different scenarios, they were mapped according to previous Deliverables. Figure 5-1 shows Figaredo current state before restoration. Figure 5-2, Figure 5-3 and Figure 5-4 present the three scenarios considered after restoration.

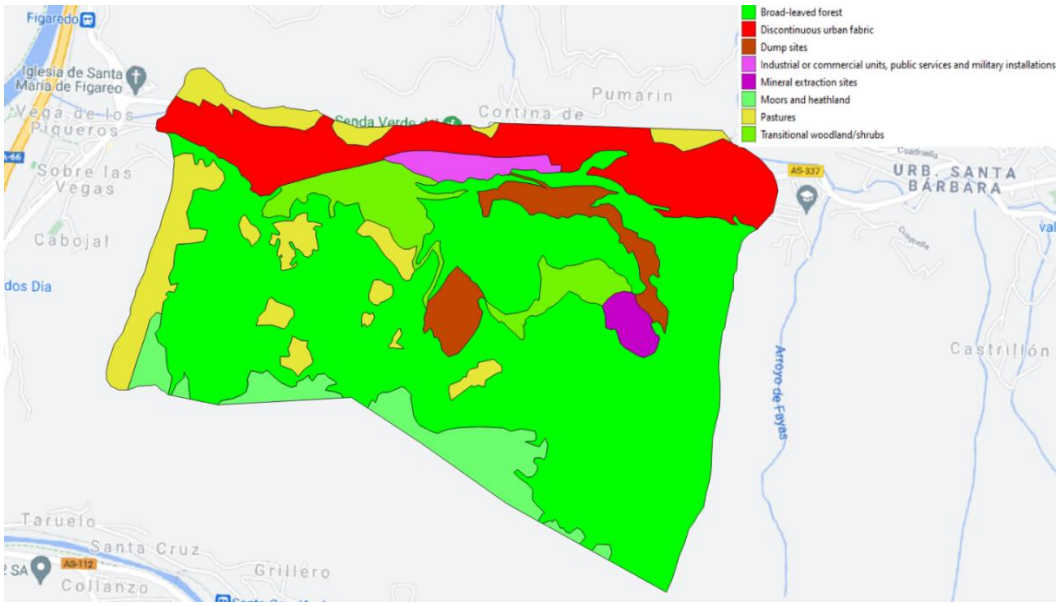

Figure 5-1. Figaredo Mine current state

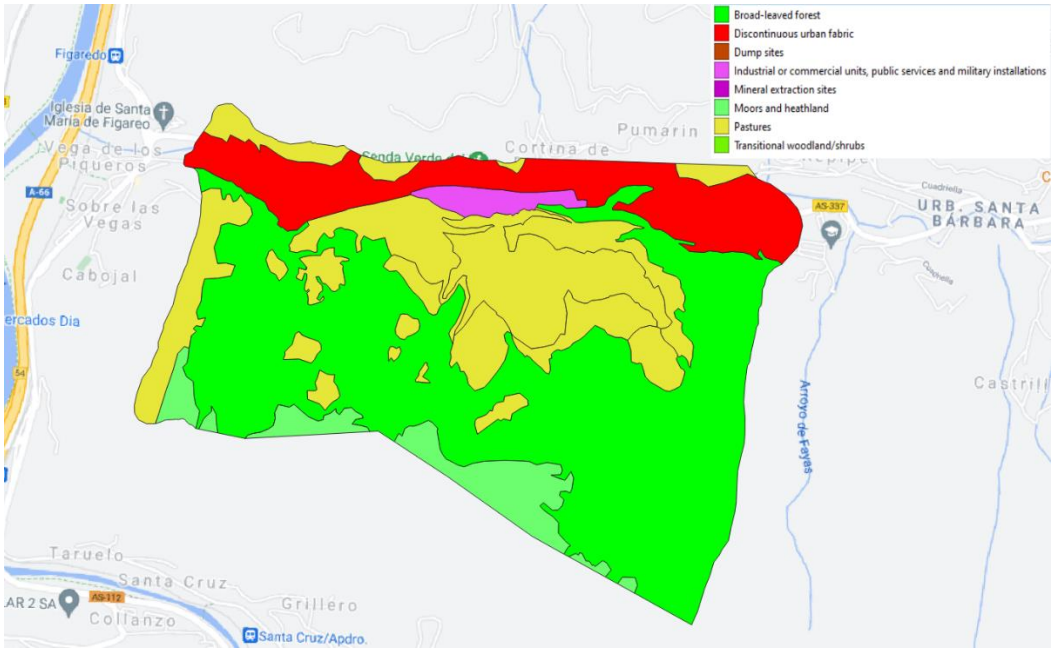

Figure 5-2. Scenario I: Food

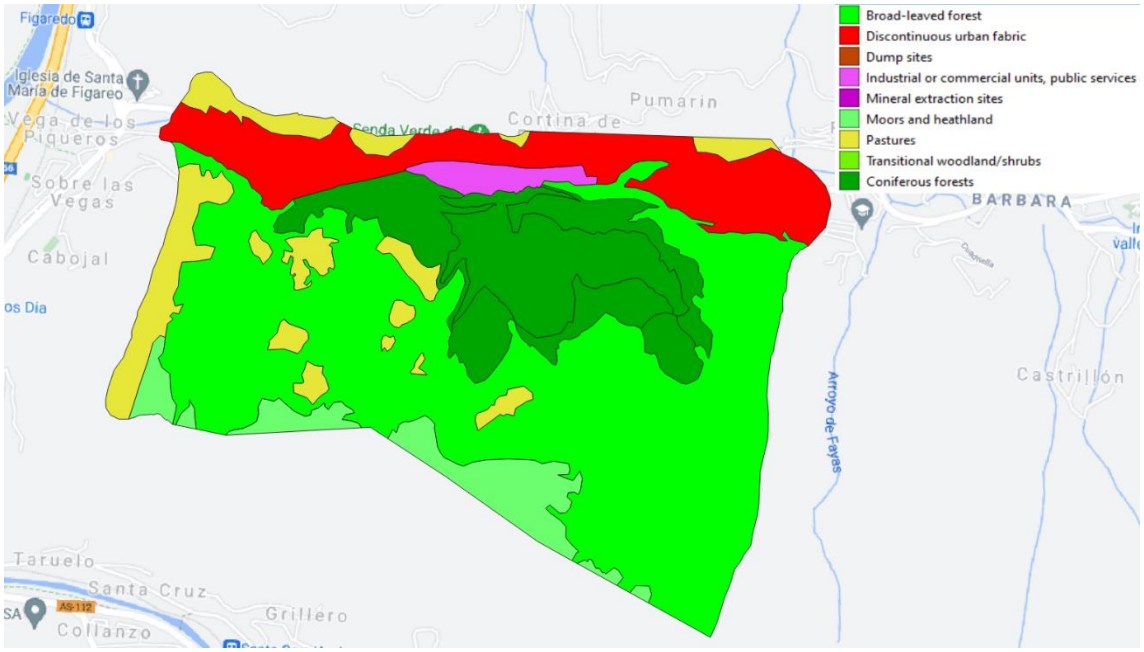

Figure 5-3. Scenario II: Fibre

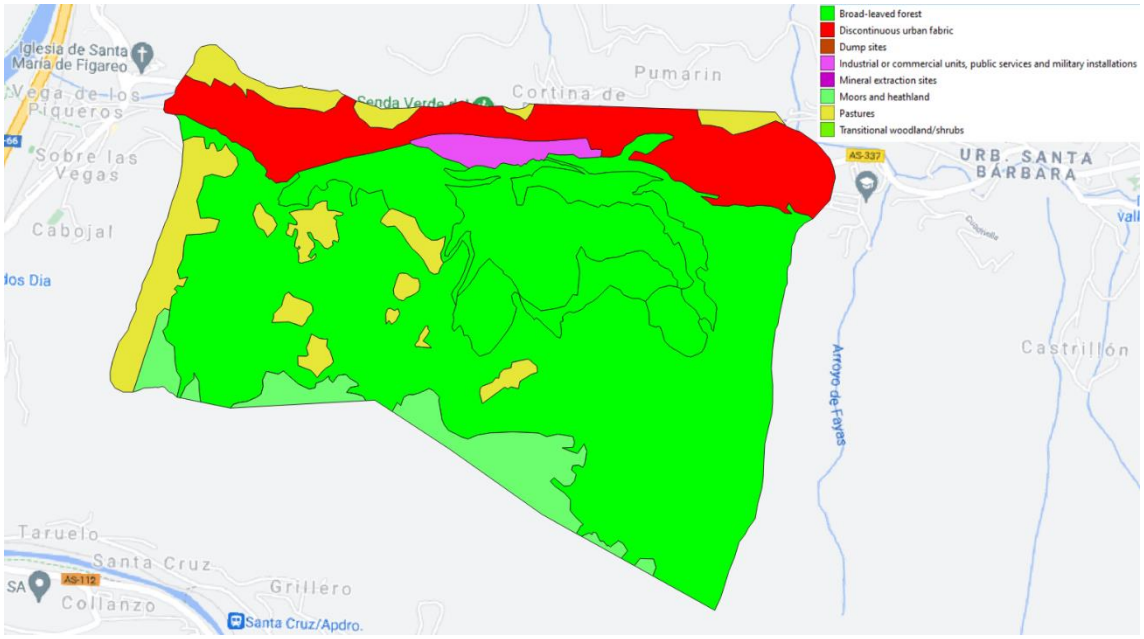

Figure 5-4. Scenario III: Landscape

6 Conclusions & lessons learned

For assessing Figaredo Mine scenarios, a workshop for selecting the different types of land rehabilitation and ecosystem restoration actions proposed to generate different scenarios in mining-affected areas was developed. It took place on May the 25th, 2021, during the 6th Microsoft TEAMS meeting of the Recovery Project.

Particular emphasis was given to consultation with stakeholders (local authorities, neighbourhood associations, coal mining industry, trade unions, and environmental NGOs) to guarantee the success of the whole process. Each partner was responsible for the involvement of stakeholders from his case-study areas. Nevertheless, in some cases it was difficult to achieve a great involvement of the stakeholders despite the efforts made by the partners.

Among the different actions that can be considered to recover the site, the following six alternatives were considered as the most feasible, taking into consideration Figaredo mine area features and stakeholders consideration: (1) pine tree plantation for producing wood as raw material, (2) cows reared for nutritional purpose, (3) the reconstruction of a Broad-leaved forest similar to the ones already present in the region, (4) installation of renewable photovoltaic energy generation, (5) recolonisation by local vegetation, and (6) physical recreation.

These alternatives were introduced in the Smic Prob-Expert tool as the hypothesis to develop the scenario assessment with the opinions of two groups of experts: UNIOVI and HUNOSA. To introduce the opinion of stakeholders in this step was not feasible, due to the statistical knowledge needed to feed the Smic Prob-Expert. The alternatives with the higher probabilities were (1) pine tree plantation for producing wood as a raw material; (2) cows reared for nutritional purpose; and (3) the reconstruction of a Broad-leaved forest similar to the ones already present in the region, plus physical recreation in order to allow people to walk and develop nature observation around the area, based on the fact that within the former coal mining area in Asturias, there are many recreation facilities related with coal mining.

Fibre production, such as pine trees and eucalyptus plantations for producing wood as raw material, is always one of the ecosystem services alternatives traditionally considered in Asturias. It has to be highlighted that the regional government forbids new eucalyptus plantations in many areas: Natura 2000, near the cost, and others. Thus, as Figaredo mine is close to a Natura 2000 area, fibre production will focus only on pine tree plantations. Food provision can be delivered in the Figaredo mine only in Pastures. In the Figaredo mine region, Pastures such as those in the study area are used to feed mainly cows reared for nutritional purposes (to produce meat). However, nowadays, horses are bred for nutritional purposes too. Finally, the reconstruction of a Broad-leaved forest similar to the ones already present in the region and physical recreation

(although no specific restoration will be considered for this) will be the third scenario to be analysed further within the project.

Next, a narrative for each selected scenario was developed, including an overall vision for the new post-mining region and some clear targets. Narratives were later translated into change rules for CLC land use classes with the if-then-else mode.

Finally, one map per scenario was developed in order to expand the GIS web interface

7 Glossary

CICES - Common International Classification of Ecosystem Services

CIF - Common Implementation Framework

CLC - CORINE Land Cover

CORINE - Coordination of information on the environment

EEA - European Environment Agency

ES - Ecosystem Service

GIS - Geographic information system

HUNOSA - Hulleras del Norte S.A.

MA - Millennium Ecosystem Assessment

MAES - Mapping and Assessment of Ecosystem Services

MFA - Morphological Field Analysis

SEEA - System of Environmental and Economic Accounting

SMIC - Smic-Prob Expert

UNIOVI - University of Oviedo

UNSD - United Nations Statistical Division

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