Interreg
Danube Region

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ForestConnect

FOREST CONNECT

OUTPUT 2.2.1

Guidelines on management of transnational mosaic habitats along forest corridors

June 2026

Output 2.2.1 Guidelines on management of transnational mosaic habitats along forest corridors

Elaborated in the framework of Specific Objective 2 “Heterogeneity, connectivity and climate resilience of large carnivores’ forests is improved”, Activity 2.4 “Develop guidelines on management of transnational mosaic habitats (forests, wood pastures and pastures between forests) beneficial to large carnivores in the context of climate change”.

Output compiled by: University of Agricultural Sciences and Veterinary Medicine from Cluj-Napoca and WWF Bulgaria

ForestConnect Project “Towards a Climate-smart Forest Connectivity for Large Carnivores in the Balkan- Carpathian-Dinaric Region”, Interreg Danube Region Programme, DRP0200359.

Unlike conventional habitat restoration approaches focused on isolated habitat types, the present Guidelines promote an integrated mosaic-based management approach combining forests, semi-natural grasslands and transitional habitats within ecological connectivity sectors.

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1 About the ForestConnect project

ForestConnect "Towards a Climate-smart Forest Connectivity for Large Carnivores in the Balkan-Carpathian-Dinaric Region" is a project financed by the Interreg Danube Region Programme running from January 2024 to June 2026. The project focuses on protecting, preserving, and enhancing ecological corridors for large carnivores across six countries of Eastern and Southeastern Europe. Unsustainable management practices, infrastructure developments, and the effects of climate change pose pressures on ecosystems. Given the transboundary nature of wildlife movement, coordinated efforts are essential to guarantee provision of the habitat and ecological needs of large carnivores and their prey. ForestConnect addresses these needs by developing and integrating innovative tools and technologies for transnational monitoring of large carnivores, including mapping safe corridors under various climate change scenarios. ForestConnect proposes practical, climate-resilient measures, engaging local communities and filling critical knowledge gaps. Through capacity building, cooperation, and awareness raising campaigns, ForestConnect provides resources and actionable strategies intended to be implemented by protected area managers and stakeholders, ensuring the durability, transferability, and uptake of its results. These efforts contribute to the long-term conservation of large carnivores and the health of ecosystems across the Danube region.

2 Policy and Ecological Context

The Balkan–Carpathian–Dinaric region hosts some of the most important large carnivore (LC) populations in Europe. Their long-term survival depends on functional ecological connectivity across extensive and diverse landscapes (Oeser et al., 2023). However, this connectivity is increasingly threatened by habitat fragmentation, unsustainable land-use practices and infrastructure development (Chapron et al., 2014,)

Climate change adds an additional layer of uncertainty to these pressures. Future habitat suitability, vegetation dynamics, food availability, disturbance regimes and the spatial functionality of ecological corridors may change in ways that are difficult to predict. For this reason, mosaic habitat management should not rely on fixed, one-time interventions, but should follow a flexible and adaptive approach based on monitoring, local phenology and the adjustment of measures to emerging climate-related risks.

In the Balkan-Carpathian-Dinaric region, large carnivores — particularly the brown bear — are strongly influenced by the availability of plant-based food resources. Seasonal availability of mast, wild fruits, berries and herbaceous vegetation is closely linked to habitat heterogeneity across forests, forest edges, shrublands and semi-natural grasslands (Cisneros-Araujo et al., 2021). As a result, mosaic habitats – namely a diverse and dynamic patchwork of different micro-environments (like wetlands, grasslands, and scattered woodlands) located in close proximity - support not only movement and dispersal, but also core feeding opportunities and refuge areas across the bear's annual cycle. Herbaceous vegetation and semi-natural grasslands are also important for wild ungulates such as deer, and also for the small mammals which represent essential prey for wolves and, in some contexts, for lynx (Krofel et al. 2011). Therefore, mosaic habitats support large carnivores both directly, by providing shelter, movement routes and feeding opportunities, and indirectly, by maintaining trophic resources for their prey species.

In many parts of the region, forest habitats and adjacent open areas are undergoing structural simplification. Traditional land-use systems that once maintained heterogeneous forest–grassland mosaics are declining, while land abandonment and intensification create new pressures. Socio-economic trends, including rural depopulation (Ganchev et al. 2025), reduced extensive grazing and declining traditional mowing, accelerate shrub encroachment and the loss of transitional zones between forests and grasslands, reducing landscape permeability and weakening ecological corridors.

Climate change amplifies these challenges. Increasing temperatures, altered precipitation patterns and extreme weather events affect forest stability, vegetation dynamics and the availability of key bear food resources. As habitats lose resilience, bears may face reduced access to shelter and feeding areas. In some cases, this contributes to increased movement into human-dominated landscapes, intensifying human–wildlife conflict (Lucas et al. 2025). Reduced availability of natural food resources may further increase the probability of damages to livestock, apiaries and crops in conflict-prone areas V. Todorov – pers. comms.). These processes are summarised in the following infographic (based on: Naves et al., 2006; Rodríguez et al., 2007; Bastille-Rousseau et al., 2017; Lucas et al. 2025. Artist: Asya Koleva).

Implementation note:

Since 2021 part of the project region – Ukraine – is affected by another type of disaster – the war. The natural habitats in the country are not spared by the adverse effects of this terrible situation. The national forestry authority of Ukraine stated that the implementation of the current guidelines cannot be prioritized outside of the protected areas in the current situation due to supposed complications and economic losses.

Climate Change Impact On Large Carnivors

How climate abnormalities result in human-wildlife conflicts

Extreme draughts

Heavy rains, storms

Late spring frost, snow

Gradual climate change, as well as the increasing frequency and severity of extreme natural disasters, make forests more vulnerable.

These lead to reduced growth and size of forest fruits, acorns and other plants which are main components of brown bear's diet.

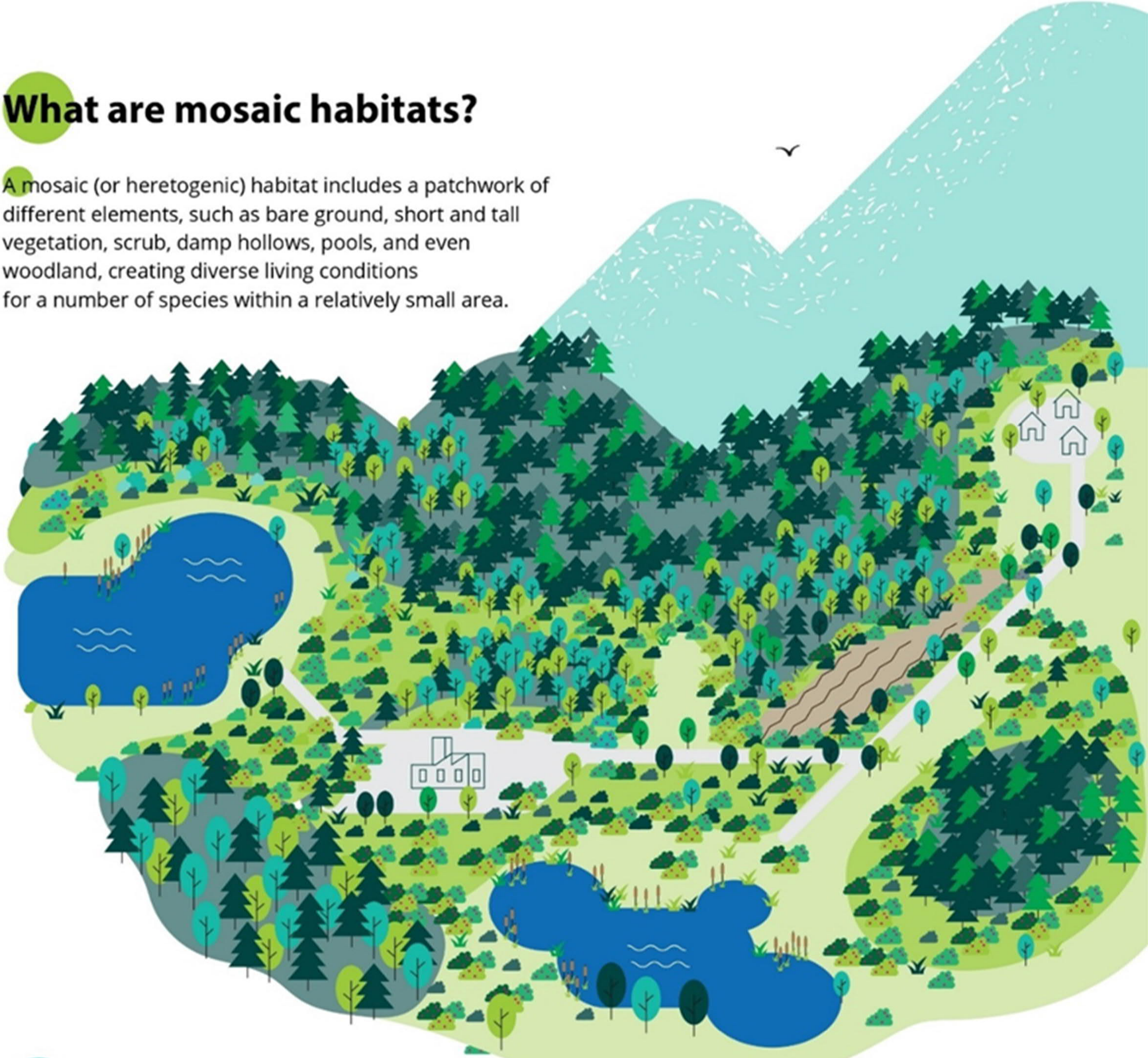
The animals have to look for alternative food source which results in potential conflicts with people in the nearby villages.

Within this context, mosaic habitats play a critical role. These heterogeneous landscape systems — composed of forests, semi-natural grasslands, shrublands, wood pastures and open areas — function as stepping-stones, buffer zones and transitional habitats. They connect forest core areas, provide microclimatic refuges and support seasonal movement of large carnivores. The following infographic is summarizing this role (based on the findings in Oeser et al., 2023; Ransom et al., 2023; Cisneros-Araujo et al., 2021, Artist: Asya Koleva).

The Importance of Mosaic Habitats

What are mosaic habitats?

A mosaic (or heretogenic) habitat includes a patchwork of different elements, such as bare ground, short and tall vegetation, scrub, damp hollows, pools, and even woodland, creating diverse living conditions for a number of species within a relatively small area.



Ecological Importance

Habitat mosaics are vital for biodiversity, especially for species with complex life cycles that require different habitat elements to forage, shelter, and breed.

They support a wide range of species, including many rare or endangered invertebrates, plants, birds, and small mammals that struggle in more uniform landscapes.

The diversity within a mosaic helps the ecosystem absorb disturbances and adapt to environmental changes, such as climate change, by providing alternative resources and refuge areas.

The species' long-term viability hinges on the availability of suitable habitats that offer both resources and corridors for dispersal, particularly in anthropogenically modified environments.

Strengthening the ecological functionality of mosaic habitats is therefore essential for improving connectivity and climate resilience at a transnational scale. Active and well-targeted management can enhance structural diversity, maintain open habitats of strategic importance and reinforce the role of forests and grasslands as interconnected components of ecological networks.

ForestConnect addresses this shared regional challenge through a combination of scientific assessment, pilot implementation and stakeholder engagement. Building on the desktop study "Enhancing habitat heterogeneity and climate resilience in transnational forest ecosystems" (Deliverable 2.1.1) and the pilot actions (Outputs O.2.1.1 and O.2.1.2) these Guidelines translate the lessons learned from this implementation into a structured and transferable framework. The Guidelines do not replace national forestry, conservation or spatial planning regulations, but provide a practical and transferable framework supporting connectivity and climate resilience objectives. They provide practical guidance for planning and managing mosaic habitats in a way that supports ecological connectivity, reduces pressures on critical corridors and contributes to coexistence between large carnivores and human communities. The guidelines also complement the Strategic Action Plan with Adaptation Actions and Climate Resilience-Enhancing Forest Management Practices for Protected Areas (Output 3.1). All documents cited documents in this chapter can be found in the library section of the ForestConnect Internet page.

3 Site Selection and Prioritisation for Mosaic Habitat Management

This chapter addresses two key implementation questions:

- Where should mosaic habitat measures be applied?
- How should intervention sites be selected?

Measures should be applied in areas where mosaic habitats are of strategic importance for large carnivore connectivity and climate resilience. Site selection must be based on a structured assessment of:

1. relevance for national and transnational ecological connectivity,
2. habitat quality and structural suitability,
3. climate resilience potential,
4. human–wildlife conflict context,
5. feasibility of long-term management.

This prioritisation logic ensures that interventions are not applied opportunistically, but in locations where they generate measurable ecological benefits.

Effective management of transnational mosaic habitats requires targeted intervention. Measures should not be applied uniformly across landscapes, but prioritised in areas where they generate the highest ecological and functional benefits for large carnivore connectivity and climate resilience.

Figure 1 Strambu Baiut site, Romania. Photo by Zoltán D. Szabó – WWF Romania

Site selection should be based on a structured assessment combining ecological, spatial and socio-institutional criteria.

3.1 Connectivity Relevance

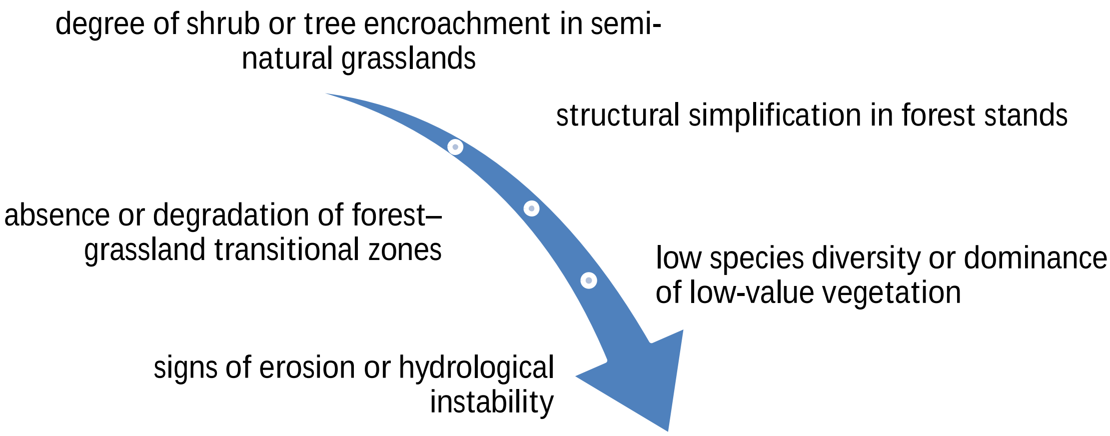
Priority should be given to sites that:

- are located within identified ecological corridors at national or transnational level
- function as stepping-stones between forest core areas
- represent bottlenecks or structurally weak segments within connectivity sectors
- contribute to cross-border corridor functionality

Spatial analysis tools (e.g. national connectivity maps, GIS databases or digital twin approaches developed under project activities and available on ccibis platform) can support the identification of such priority zones.

3.2 Habitat Quality and Structural Condition

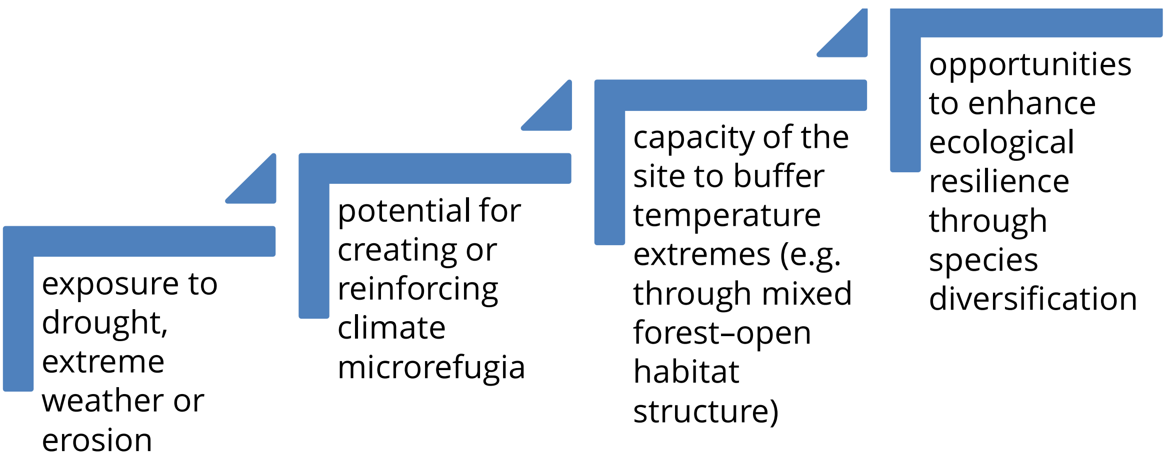
Sites should be screened based on their ecological condition and potential for improvement. Key indicators include:



Priority should be assigned to sites where relatively moderate interventions can significantly improve structural heterogeneity and habitat functionality.

3.3 Climate Resilience Potential

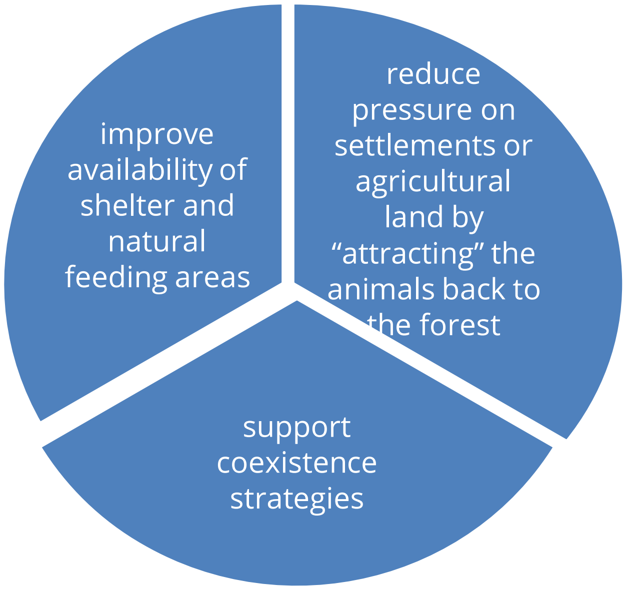
Site selection should consider:



Sites that contribute to long-term adaptation of ecological corridors to climate change should receive higher priority.

3.4 Human–Wildlife Conflict Context

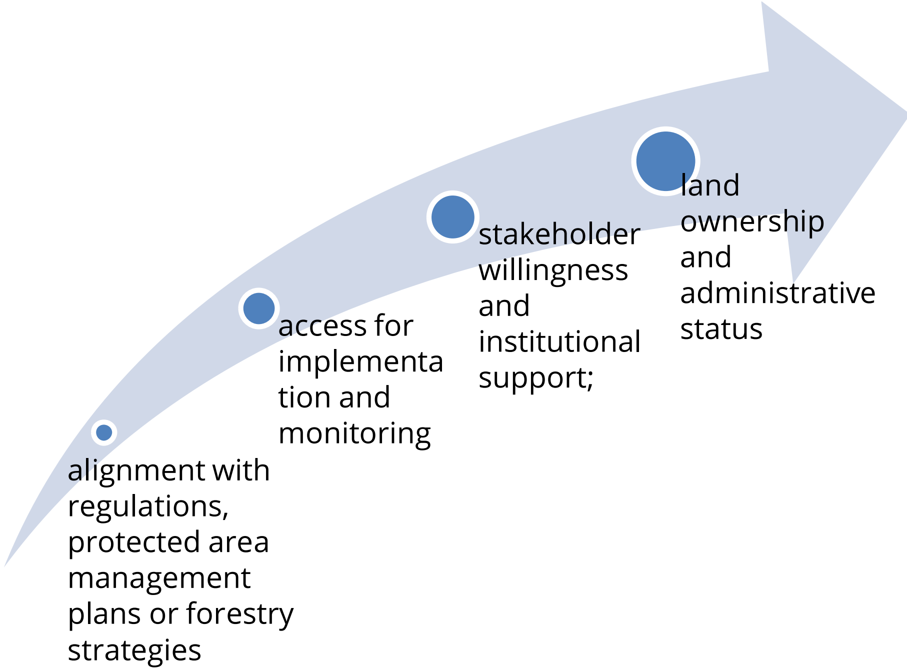
In areas where large carnivores frequently enter human-dominated landscapes, management measures for mosaic habitats may:



Therefore, conflict hotspots may represent priority areas for targeted habitat interventions. Conflict hotspots can be identified using GIS tools, and for the Balkan Dinaric Carpathian region also using the online viewer for the hotspots of conflicts developed under the ForestConnect project and online on CCIBIS platform (Output 1.2.3). It is important to apply measures to enhance the food supply network in areas distant from human settlements, in order to reduce and prevent human-bear conflicts (See case study in Annex I). In areas affected by recurrent human–bear conflicts, priority should be given to measures that strengthen natural food availability and shelter conditions within forest and mosaic habitats located away from settlements. Such measures may include the support and planting of fruit-bearing tree and shrub species, the maintenance of ecotones and the creation of forest microrefugia. By improving the availability of natural food resources and reducing the need for bears to search for anthropogenic food sources, these interventions can contribute to conflict prevention and coexistence strategies.

3.5 Institutional and Practical Feasibility

Beyond ecological criteria, feasibility considerations are essential. These include:



Measures are more likely to generate long-term impact where institutional uptake and maintenance capacity are ensured.

3.6 Integrated Prioritisation Approach

The selection of intervention sites should result from combining:

1. spatial connectivity analysis
2. ecological diagnosis
3. climate risk screening
4. stakeholder consultation
5. assessment of areas with a high frequency of HWC
6. feasibility assessment

As a first operational step, site selection should include a legal screening of land status and applicable restrictions (protected area zoning, Natura 2000 constraints, forest/grassland legal regime), before finalising the intervention package and budget. This screening should be coordinated with the competent environmental authorities and, where relevant, with paying agencies responsible for eligibility rules under agri-environment schemes.

This integrated approach ensures that mosaic habitat management measures are both ecologically meaningful and practically implementable.

The identification of priority mosaic habitats may be supported by the GIS database and, digital twin model and online viewer for the hotspots of conflicts developed under Specific Objective 1 “New tools and technologies integrated in transnational monitoring of large carnivores’ forests” of the ForestConnect project. These and similar tools can contribute to spatial analysis of connectivity sectors and structural gaps at national and transnational scale. The digital twin approach may additionally support scenario-based planning by identifying future connectivity risks under climate and land-use change. Information on the technological tools produced in the framework of the ForestConnect project can be found on the CCIBIS platform.

The application of this prioritisation framework is illustrated through a practical example presented in the **Apuseni Case Study from Romania (Annex 1)**.

4 Catalogue of Management Measures for Mosaic Habitats

The measures presented below are transferable and adaptable across the Balkan–Carpathian–Dinaric region. The measures should not be applied uniformly, but adapted to local ecological conditions, management objectives and connectivity functions.

4.1 Brief Catalogue of Applicable Measures

This section provides a brief catalogue of the main types of management measures that can be applied in mosaic habitats to improve ecological connectivity, habitat heterogeneity and climate resilience.

The practical implementation principles and operational recommendations for these measures are presented in Chapter 6 (Practical implementation steps).

Open Habitat and Grassland Measures

These measures aim to restore and maintain semi-natural grasslands and transitional habitats that contribute to landscape permeability and ecological connectivity.

Possible measures include:

- Mechanical removal of shrub and tree encroachment;
- Manual mowing (preferably without heavy machinery in erosion-prone areas)*;
- Mulching of overgrown meadows;
- Milling and stump removal to restore open habitat structure;
- Targeted removal of invasive or low-value herbaceous species;
- Management of anthills or dominant grass species where habitat quality is reduced

***Case study:** In the frame of ForestConnect project part of the habitat restoration measures were implemented in combination with Traditional hand-mowing festival. This was an excellent example for combination of real field actions with stakeholder and public engagement.

Photo: Marek Leskovjansky, NP Slovensky raj

Forest-Based Measures

These measures enhance structural diversity and climate resilience within forest components of mosaic landscapes.

Possible measures include:

- Nature-based forestry practices (continuous cover, mixed species composition);
- Selective thinning to increase structural heterogeneity;
- Retention of habitat trees and preservation of deadwood (where feasible);

- Creation of small-scale forest microrefugia in connectivity sectors;
- Pruning and crown management of fruit-bearing trees to enhance fruit production.

Planting and Afforestation Measures

These measures support long-term food availability and shelter functions within mosaic habitats.

Possible measures include:

- Planting of native fruit-bearing trees and shrubs (e.g. wild pear, wild apple, cherry plum, rosehip, wild cherry, rawberry, blackberry, raspberry);
- Underplanting in suitable forest conditions;
- Afforestation of degraded or fire-damaged areas;
- Restoration of abandoned meadows through integrated planting and mowing;
- Use of local genetic material where required by legislation;
- Individual protection of saplings (fencing, mesh, stakes);
- Establishment of long-term monitoring and maintenance plans.

5 Plant Species Selection Principles for Mosaic Habitat Management

Plant species selection plays a critical role in ensuring that mosaic habitat interventions support ecological connectivity, climate resilience and functional habitat requirements for large carnivores.

The choice of plant species should not follow a uniform approach but must be adapted to local ecological conditions, corridor relevance and long-term management objectives.

5.1 General Ecological Principles

Plant species selection should be guided by the following principles:

Compositional diversity

- mixed species compositions increase structural heterogeneity and resilience.

Native status and regional provenance

- priority should be given to native species within their natural distribution range.

Functional complementarity

- combinations of species should minimise competition while enhancing ecological functions

Climate adaptability

- preference for species or provenances with higher tolerance to drought and climatic variability.

The principle of compatibility

- the species are chosen in such a way that interspecific competition is minimal or even absent without the application of the principle leading to a reduction in the number of species chosen

The economic principle

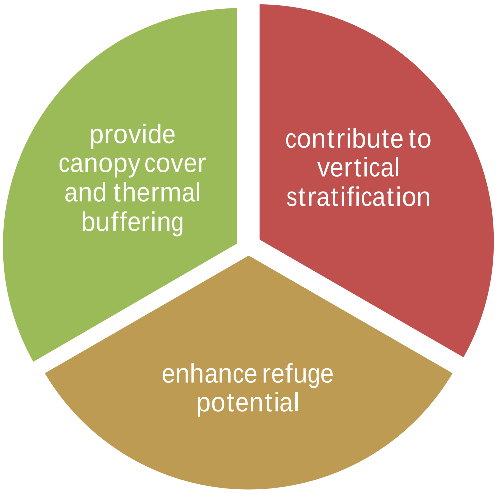
- the expenses recorded with the establishment of forest crops are compensated by the effect they have in providing food and shelter for game and reducing human-animal conflicts

Monocultures should be avoided, particularly in areas with a connectivity or refuge function.

5.2 Functional Species Groups

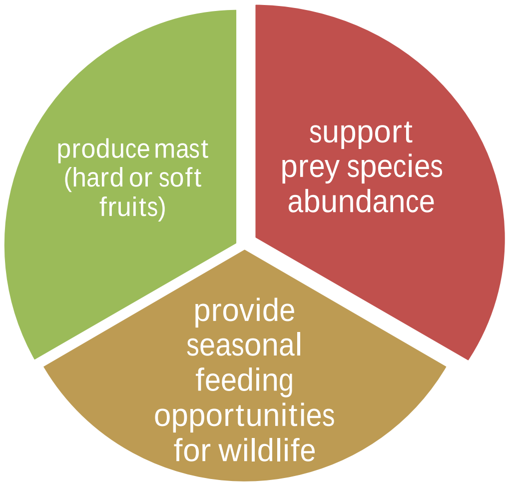
Instead of focusing solely on individual species, management planning should consider functional groups relevant for mosaic habitats:

Structural and Shelter Species



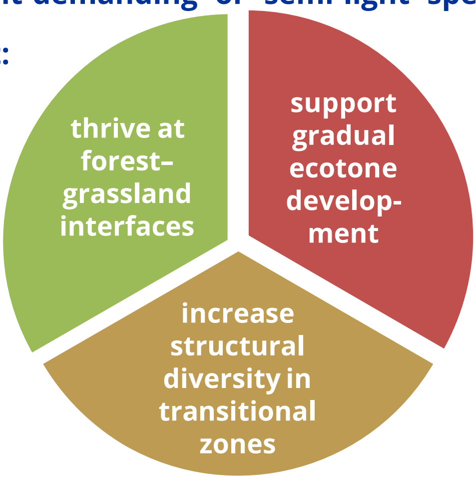
These species are particularly relevant in the creation of forest microrefugia and shelter belts within connectivity sectors as described in Chapter 3

Food-Producing Species



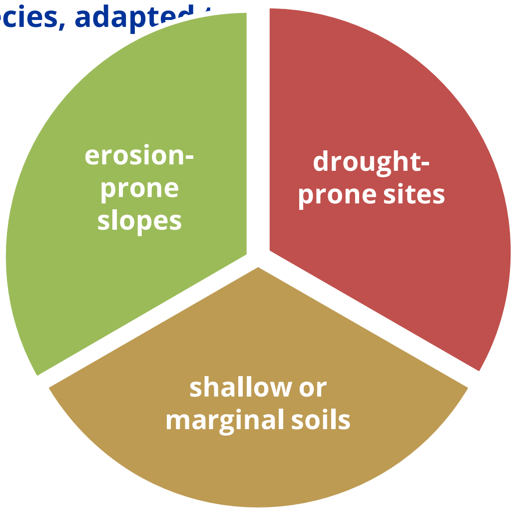
The inclusion of fruit-bearing shrubs and trees enhances the multifunctionality of mosaic habitats. These species are particularly relevant for pruning, crown management and support measures described in Chapter 3.

Transitional and Edge Species (Light-demanding or semi-light species) that:



Such species are essential for maintaining permeable and biodiverse edges.

Soil-Stabilising and Resilience Species, adapted



These species contribute to long-term stability and climate resilience of mosaic systems

A wide range of these species can be found in the bear diet as presented in the infographic below (based on Gynchev et al. 1993, Genov et al. 2008 and 2010, artist: Asya Koleva). This diversity is a prequisite for resiliance and plasticity.

Eastern Balkan Bears' Diet

Sources:
Gynchev et al. study 1993,
Genov et al. 2008 and 2010
Executive agency of Environment (2021)
Lucas et al. 2025
Paralikidis et al. 2010*
Rigg, R. & Gorman, M. (2005)*
Kavcic et al. 2015*

75%
plant based food

From Game Breeding Stations

- Corn
- Apple
- Oat

From Wild Plant Species

- Berries
- Wild Apple
- Blackberries
- Cherry Plums
- Cherries
- Dog rose fruits
- Cherry Dogwood
- Oak acorns
- Beechnuts
- Walnuts
- Blackthorns
- Raspberries
- Grasses
- Roots
- Seeds

- Mushrooms*

25%
animal based food

- Red deer remains
- Wild boar remains
- Ants
- Maggots
- Roe deer
- Snails*
- Small rodents*
- Beetles
- Amphibians*

10%
Of all food is human sourced

- Corn
- Apple
- Livestock
- Garbage

*Based on dietary research on the Dinaric-Pindos and the Carpathian populations

5.3 Species Selection in Grassland Context

In semi-natural grasslands, species considerations relate primarily to:

- maintaining or restoring native floristic composition
- avoiding invasive or aggressive dominant species
- supporting extensive grazing-compatible vegetation
- conserving habitat types of community interest (e.g. mountain hay meadows)

Active grassland restoration should aim to reinforce natural plant communities rather than introduce artificial seed mixtures incompatible with conservation objectives.

5.4 Regional Adaptation

The Balkan–Carpathian–Dinaric region includes diverse eco-regions. Therefore:

- species lists should be adapted to local biogeographical zones;
- recommendations from Deliverable 2.1.1 Enhancing habitat heterogeneity and climate resilience in transnational forest ecosystems"[1] (Chapters 3 and 4) should guide region-specific species selection;
- consultation with national forestry and protected area authorities is recommended prior to implementation.

The Guidelines do not replace national silvicultural regulations but provide a functional framework aligned with connectivity and climate resilience objectives.

[1] https://interreg-danube.eu/projects/forestconnect/library?page=2

5.5 Recommended Forest Fruit Tree and Shrub Species (Based on D2.1.1)

Chapters 3 and 4 of Deliverable 2.1.1 Enhancing habitat heterogeneity and climate resilience in transnational forest ecosystems" identify a set of forest fruit tree and shrub species suitable for enhancing habitat heterogeneity, food availability and climate resilience within mosaic connectivity sectors. The list of species is illustrated in the infographic below (Artist: Asya Koleva). The measure *Planting Fruiting Trees and Shrubs to Secure Seasonal Food Sources for a Resilient Ecosystem* is also included as a Strategic Action in the Strategic Action Plan with Adaptation Actions and Climate Resilience-Enhancing Forest Management Practices for Protected Areas (Output 3.1).

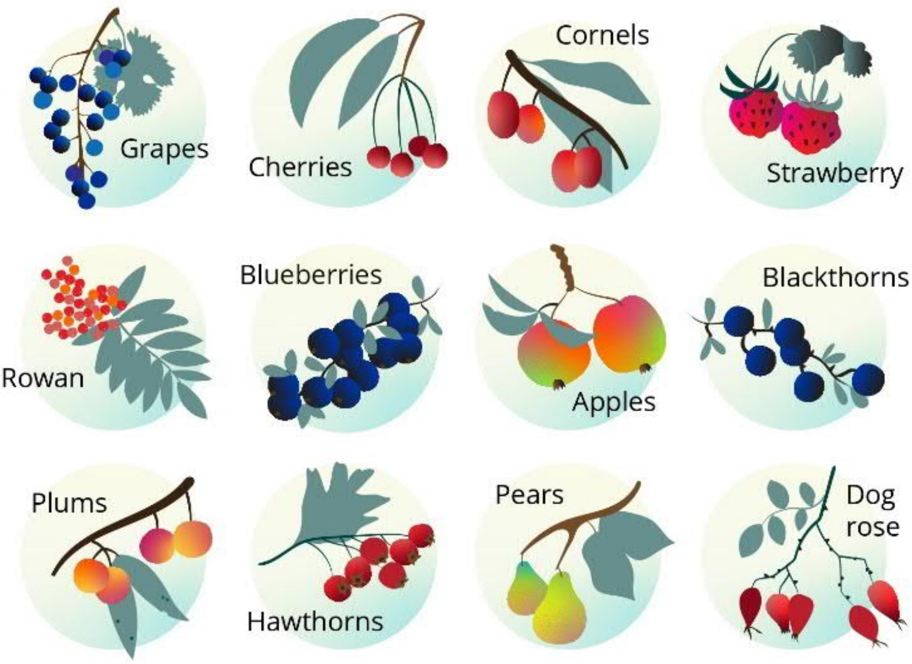
Based on a literature review and data provided by WWF Bulgaria and ForestConnect partners, Annex 2 of the current Guidelines presents a list of plant species, which are suitable for enhancing habitat heterogeneity to provide a diverse seasonal food base for large carnivores, particularly bears (*Ursus arctos*). The species, selected based on bear diet studies, are described in terms of their seed or vegetative propagation requirements, seedling production, and reforestation needs, considering climatic factors such as drought resistance.

Species Suitable For Planting Activities

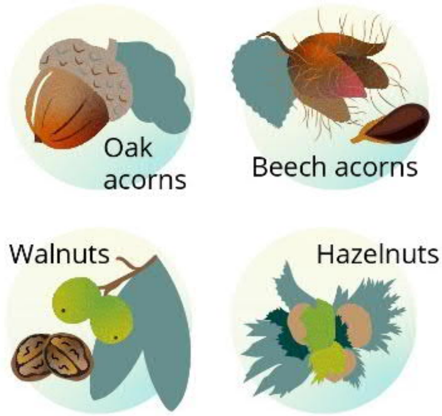
Forest fruit species enhance habitat heterogeneity by providing a diverse seasonal food base for large carnivores, particularly bears.

Common Species

Soft Mast



Hard Mast



Where do they thrive?

Most fruit-giving species are light-demanding and easily occupy abandoned territories without dense forests. Often they are found in higher numbers at the edge of denser forests, the edge of crop-fields and mowed grasslands, next to dirt roads. If overshadowed they often produce less fruit and dependent on the species might die.

Under what conditions?

Most species from Rosaceae family (where a big proportion of the forest fruits belong) require cold stratification of the seeds. This means they need to experience winter conditions (below -5°C) to break dormancy. This characteristic aligns with the natural habitat of many of the species, where winters provide the necessary chilling period. For forest adaptation purposes, this can be achieved in natural way by autumn planting or artificially by storing the seeds in a refrigerator for a given period

The following species are particularly recommended for planting and support measures in mosaic habitats across the Balkan–Carpathian–Dinaric region:

Core Tree Species

- **Wild pear (*Pyrus pyraster*)** – drought-tolerant, suitable for open and transitional habitats, high wildlife feeding value.
- **Wild apple (*Malus sylvestris*)** – adaptable to forest edges and mosaic systems, supports seasonal fruit availability.
- **Cherry plum (*Prunus cerasifera*)** – resilient, fast-growing, suitable for degraded or transitional sites.
- **Wild cherry (*Prunus avium*)** – contributes to vertical structure and fruit production.
- **Mahaleb cherry (*Prunus mahaleb*)** – suitable for dry and limestone substrates.

Supporting Shrub Species

- **Rosehip (*Rosa canina*)** – tolerant to poor soils and drought, suitable for transitional zones.
- **Hawthorn (*Crataegus monogyna*)** – high ecological value, supports birds and mammals.
- **Wild hazelnut (*Corylus avellana*)** – mast-producing species contributing to trophic networks.
- **European dewberry (*Rubus caesius*)** – ground-layer fruit resource.
- **Blackberry** (***Rubus sp***) - ground-layer fruit resource.
- **Raspberry (*Rubus idaeus*)** – ground-layer fruit resource.
- **Rowan (*Sorbus aucuparia*)** – adapted to higher altitudes and cooler climates.

Species selection must always be adapted to local altitude, soil type, exposure and national regulatory requirements regarding provenance. More details for each species is present in Annex 2.

6 Governance, Stakeholder Roles and Institutional Uptake

Effective implementation of mosaic habitat management measures requires coordinated governance and clearly defined roles among stakeholders at local, national and transnational levels.

Management success depends not only on ecological suitability, but also on institutional cooperation, stakeholder engagement and long-term maintenance capacity.

6.1 Key Implementing Actors

The implementation of mosaic habitat management measures may involve:

Protected area administrations

coordination of site-level planning, supervision of interventions and monitoring

Environmental protection agencies

regulatory oversight, environmental permitting and compliance with Natura 2000 and biodiversity legislation

Agricultural payment and intervention agencies

(e.g., national paying agencies such as APIA in Romania) – administration of agri-environment schemes, EU payments and eligibility verification for maintenance measures

Forestry authorities and forest districts

execution of forest-related measures and alignment with national silvicultural regulations

Land managers and farmers

implementation of grassland management practices (mowing, grazing, shrub control)

Local and regional authorities

integration into spatial planning and local development strategies

Hunting associations and wildlife managers

contribution to monitoring and conflict mitigation measures

Research institutions and NGOs

technical support, ecological assessment and adaptive management guidance

Operational note: Environmental permitting/compliance (typically coordinated with environmental protection agencies) and payment eligibility checks (coordinated with national paying agencies such as APIA) should be initiated early, as administrative timelines can directly affect the feasible implementation window in mountain conditions and should be reflected in the workplan. Clear allocation of responsibilities should be established before implementation begins.

6.2 Stakeholder Engagement and Social Acceptance

Mosaic habitat management may influence land-use practices, forestry operations and agricultural activities. Early engagement of stakeholders is therefore essential.

Recommended actions include:

- consultation meetings with local communities and land users
- inclusion of protected area managers and forest guards in planning phases
- communication of ecological and socio-economic benefits
- integration of feedback from pilot implementation

Stakeholder participation enhances acceptance, improves feasibility and reduces potential conflicts.

6.3 Integration into Existing Planning Instruments

To ensure long-term sustainability, mosaic habitat measures should be integrated into:

protected area management plans	**forest** management plans	**Natura 2000** conservation objectives
rural development and agri-environmental schemes where applicable		national **biodiversity** strategies
national, regional and local **spatial planning** instruments (spatial plans / land-use plans)		

Alignment with existing policy and spatial planning instruments increases financial, administrative and territorial feasibility.

Spatial planning instruments may also support the practical implementation of mosaic habitat measures by:

- identifying ecological corridors and conflict-sensitive areas during territorial planning processes;
- preventing infrastructure development that could further fragment connectivity sectors;
- integrating mosaic habitat restoration into local and regional land-use strategies;
- supporting coordination between forestry, agriculture and conservation objectives at landscape scale.

6.4 Institutional Uptake and Post-Project Application

The experience and methodological framework developed through ForestConnect pilot actions demonstrate practical applicability beyond the project duration.

In Romania, the Administration of Apuseni Natural Park intends to apply the accumulated experience in support of active management interventions within Habitat 6520 (Mountain hay meadows), in line with a recently elaborated substantiation study prepared by USAMV Cluj-Napoca (2026).

This example illustrates how tested measures developed under ForestConnect can inform concrete conservation actions within Natura 2000 habitats, strengthening institutional ownership and ensuring continuity of mosaic habitat management beyond the project framework.

Similar uptake is encouraged across the Balkan–Carpathian–Dinaric region, where mosaic habitats represent key components of ecological corridors. In addition, the project partners are actively disseminating the Guidelines and their practical recommendations to stakeholders at national level, including protected area administrations, forest authorities, environmental agencies and local decision-makers. It is expected that this dissemination process will support the adoption and gradual integration of mosaic habitat management principles into future conservation, forestry and spatial planning initiatives in the participating countries.

Financial instruments supporting the implementation and long-term maintenance of mosaic habitat measures are presented in **Chapter 6.5**.

7 Implementation Timing, Monitoring and Adaptive Management

The successful implementation of mosaic habitat management measures depends not only on appropriate site selection and species choice, but also on correct timing, consistent monitoring and adaptive decision-making.

Interventions should follow seasonal, ecological and operational constraints specific to each eco-region.

7.1 Practical implementation steps (How/How not)

This section translates the experience gained during **the tested pilot actions of the ForestConnect project** into practical implementation steps. The guidance is structured by action type and highlights both recommended practice ("How") and typical implementation risks ("How not"). Whenever possible, interventions should follow a minimum-intervention principle, applying only the intensity necessary to restore or maintain ecological functionality. The steps should be applied proportionally to site sensitivity, legal status and operational capacity.

Grassland and open-habitat measures (mulching, mowing, shrub removal, milling)

How (recommended steps)

1. **Pre-check and marking**
   - Confirm habitat type and conservation constraints (e.g., Natura 2000 grasslands, breeding season restrictions).
   - Map treatment polygons and access routes; identify erosion-prone micro-sites and exclude them if needed.
2. **Select the least-impact technique**
   - Use **manual mowing** or light mechanisation where feasible; reserve heavier equipment only for low-risk terrain.
   - Apply **mulching** mainly for overgrown meadows to enable future regular mowing.
   - Use selective shrub removal: retain ecologically valuable patches (especially fruit-bearing shrubs/trees) and design them to maintain the functional triad **(quiet–food–shelter)** (low-disturbance cover, feeding resources and refuge).
   - Keep retained patches discontinuous (small clusters/strips), avoiding continuous shrub belts that can reduce openness and corridor permeability.

3. **Implement outside sensitive periods**

   o Schedule interventions outside peak breeding periods of ground-nesting birds and other sensitive taxa.

4. **Operational execution**

   o Work in strips or patches to maintain microhabitats and avoid complete homogenisation.

   o This patch-based approach helps preserve multifunctional elements providing **(quiet–food–shelter)** while restoring overall openness.

   o Avoid soil disturbance on steep slopes; keep machinery on stable tracks.

5. **Immediate follow-up**

   o Remove or manage cut biomass where it risks smothering target vegetation.

   o Establish the next maintenance step (mowing/grazing) before the next vegetation season.

6. **Maintenance commitment**

   o Plan **repeat interventions** (mowing, light shrub control) to prevent re-encroachment.

How not (avoid)

- Avoid one-off interventions **without follow-up** (rapid re-encroachment is likely).
- Avoid heavy machinery on **erosion-prone slopes** or wet soils (rutting, compaction, erosion).
- Avoid complete removal of all woody elements where ecotones are beneficial; do not remove **fruit-bearing** shrubs/trees that support trophic networks.
- Avoid “uniform clearing” that eliminates structural heterogeneity (reduce mosaic function).

Fruit-bearing species support and planting (pruning, protection, planting, local provenance)

How (recommended steps)

1. **Prioritise existing fruit-bearing individuals**

o Identify naturally occurring wild fruit trees/shrubs; map and classify them (health, crown condition, fruiting potential).

o Clear competing vegetation around valuable individuals.

2. **Pruning and crown management**

o Apply formative pruning to improve light access and stimulate flowering/fruiting.

o Keep pruning proportional and repeatable (annual/light interventions are preferable to drastic cuts).

3. **Planting design (when planting is needed)**

o Prefer **dispersed, mosaic planting** (small clusters/lines/patches) instead of compact plantations.

o Select native species and, where required, **regional provenance**; in protected areas comply strictly with provenance rules.

4. **Site and planting preparation**

o Avoid planting on high-value semi-natural grasslands unless ecologically justified (e.g., connectivity gaps, microrefuge design).

o Prepare planting spots carefully (avoid excessive soil disturbance; ensure water retention micro-sites).

5. **Sapling handling and planting**

o Maintain root moisture (transport/temporary storage); plant in suitable seasons (autumn/early spring).

o Use individual protection (mesh/fencing/stakes) against browsing.

6. **Maintenance and replacement**

o Plan at least 2–3 years of checks; replace failed saplings early (spring replanting).

o Integrate mowing/mulching around saplings where needed.

How not (avoid)

- Avoid compact plantations requiring high maintenance where capacity is limited (high failure risk).
- Avoid planting without protection in high browsing pressure areas.
- Avoid non-local genetics where regulations forbid it; avoid species outside ecological range (altitude/aspect/soil mismatch).
- Avoid planting as a "standalone action" without ensuring long-term tending.

Forest microrefugia and forest-structure measures (deadwood, terraces, selective thinning, regeneration support)

How (recommended steps)

1. **Identify microrefugia potential**
   o Prioritise shaded aspects, sheltered gullies, moisture-retaining soils, and structurally diverse patches within connectivity sectors.
2. **Stabilise and reduce risk**
   o Where disturbance occurred (fire, bark beetle, windthrow), remove hazardous material only where necessary for safety and regeneration.
3. **Use deadwood strategically**
   o Retain deadwood and habitat trees where compatible with regulations and safety; use trunks to create **small terraces** or erosion barriers on steep terrain.
4. **Selective interventions**
   o Apply selective thinning to increase light heterogeneity and structural diversity; promote mixed regeneration.
5. **Targeted planting only where needed**
   o Plant only in micro-sites with high survival probability; avoid replacing strong natural regeneration with unnecessary planting.
6. **Post-intervention checks**

o Assess regeneration success and erosion status after heavy rainfall/snow periods.

How not (avoid)

- Avoid large-scale “cleaning” that removes deadwood indiscriminately and reduces biodiversity functions.
- Avoid excessive thinning leading to instability and drying of microclimate.
- Avoid planting where natural regeneration is already strong (wastes resources; can reduce resilience).

Forest–grassland interface management (ecotones, transitional zones, permeability)

How (recommended steps)

1. Maintain **gradients**, not sharp boundaries (retain scattered trees/shrubs, variable heights).
2. Use selective clearing to keep ecotones permeable and biodiverse.
3. Combine interface work with adjacent grassland maintenance (mowing/grazing) to prevent rapid closure.
4. Prioritise interfaces located in corridor bottlenecks and stepping-stone areas.
5. Confirm legal status and permitting needs (land tenure/consent, protected-area zoning, Natura 2000 requirements, forest/grassland legal regime; where relevant, align the planned operation with national rules for eligible agri-environment actions).

How not (avoid)

- Avoid creating artificial, abrupt edges.
- Avoid homogenisation (either fully open or fully closed), which weakens mosaic functionality.

7.2 Timing of Interventions

Timing should be aligned with ecological sensitivity, operational feasibility and local climatic conditions.

Forest-Related Interventions

Site preparation: outside the main breeding season of protected species; preferably late summer or early autumn.

Planting of forest species: autumn or early spring, depending on local climatic conditions.

Thinning and structural enhancement works: during periods minimising disturbance to wildlife (generally outside reproductive seasons).

Maintenance operations: during early vegetation stages, ensuring proper establishment.

Grassland Measures

Shrub removal and mulching: late summer or early autumn to reduce impact on nesting fauna.

Mowing operations: adapted to conservation objectives and local phenology (typically late-summer mowing in species-rich mountain meadows).

Grazing management: controlled intensity and seasonal rotation to prevent overgrazing or soil compaction.

Transitional Zone Management

Interventions in forest–grassland ecotones should avoid periods of high wildlife sensitivity and should preserve gradual structural transitions.

Correct timing reduces ecological disturbance and increases the long-term effectiveness of measures.

Indicative Seasonal Calendar for Planting and Maintenance (Mountain Mosaic Habitats)

The calendar below provides an indicative framework for planting and maintenance operations in mountain mosaic habitats (forests, wood pastures, semi-natural grasslands and ecotones). Exact timing must be adapted to:

- altitude and local phenology,
- Natura 2000 provisions and species protection requirements,
- agri-environmental scheme rules (where applicable),
- climatic variability and operational access constraints.

A. Maintenance Operations by Years After Planting (Forest & Shrub Components in the mountain zone-example); “1” and “2” are the number of interventions.

Operation	Y1	Y2	Y3	Y4	Y5	Y6–8	Remarks
Gap filling (replanting)	–	1	1	–	–	–	Applied where survival rate is below target threshold.
Inspections / revision checks	–	1	1	–	–	–	Assess browsing, drought stress, mortality.
Vegetation control (bush-cutting)	2	2	2	1	1	–	Two rounds/year typical in first 3 years.
Coppicing / cut-back after planting (only for deciduous)	1	–	–	–	–	–	For deciduous species that sprout well
Soil loosening around saplings	if needed	–	–	–	–	–	where the soil is compact and for weed control
Formative crown pruning	1	1	1	1	1	–	Light, progressive pruning preferred.
Thinning	–	1	1	–	–	periodic	Adjust according to vegetation development.
Chemical weed control*	if needed	–	–	–	–	–	Only if legally permitted and ecologically justified.
Soil fertilisation*	if justified	–	–	–	–	–	Avoid in HNV grasslands or nutrient-sensitive habitats.
Protection against browsing	✓	✓	✓	✓	✓	if needed	Maintain minimum first 5 years.
Pest control	if needed						Insects, fungi

* Mechanical/manual methods are preferred. Chemical measures should only be applied where legally allowed and ecologically appropriate.

B. Indicative Timing During the Year (Forest & Shrub Measures in the mountain zone - example)

Operation	Recommended Period
Planting (mountain areas)	Early spring (March–April); autumn possible depending on local climate
Gap filling	March–April
Inspections	March–April
Vegetation control	June–July (1st round); September-Oct (2nd round)
Coppicing after planting (only for deciduous) as needed	March–April (Immediately after planting)
Soil loosening	June–July
Crown pruning	Early spring (before bud burst)
Thinning	Outside breeding season; typically late summer–winter
Installation/maintenance of browsing protection	Dormant season (October–April)
Pest control	All year round

C. Grassland and Mosaic Maintenance Calendar

Measure	Recommended Window	Constraints / Notes
Shrub removal (grasslands)	Late summer – early autumn	Avoid breeding season of ground-nesting birds; avoid steep slopes and unstable soils
Mulching of overgrown meadows (restoration phase only)	Late summer	Used only in initial restoration phase; must be followed by regular mowing or grazing
Annual mowing (species-rich mountain meadows)	Late summer (after full flowering and seed set; typically July–August, altitude-dependent)	Biomass removal is mandatory; cut material must be removed from the site to prevent nutrient accumulation and floristic homogenisation.
Extensive grazing (optional complementary tool)	Spring–autumn (rotational, low stocking rate)	Avoid overgrazing and soil compaction; adapt to productivity and slope conditions
Temporary grazing exclusion (after restoration)	Early vegetation season (if needed)	Supports establishment of target meadow species
Ecotone selective clearing	Late summer–autumn	Maintain structural gradients and preserve functional elements providing quiet–food–shelter

Ecological Rationale

For species-rich mountain hay meadows (e.g., Habitat 6520):

- A **single late-summer mowing regime** supports seed maturation and long-term floristic diversity.
- **Mandatory biomass removal** prevents nutrient enrichment, which otherwise favors competitive grasses and reduces biodiversity.
- The mowing calendar must remain adaptive to altitude, phenology and agri-environmental payment conditions.

Clarification on Mowing versus Mulching in High Nature Value Grasslands

In species-rich mountain hay meadows (e.g., Habitat 6520), mulching is not equivalent to traditional mowing and should not replace it as a long-term management practice. Unlike mowing with biomass removal, mulching leaves fragmented plant material on the soil surface, which may:

- increase nutrient accumulation,
- favour competitive grasses,
- reduce floristic diversity over time,
- alter microclimatic and germination conditions.

Therefore, mulching may be used only as a transitional restoration tool in heavily overgrown or abandoned grasslands. It must be followed by a regular annual mowing regime with mandatory biomass removal to restore and maintain ecological balance. Beyond the project duration, it is expected that the dissemination of the Guidelines by the project partners and associated stakeholders will facilitate their adoption within protected area management, forest planning, biodiversity conservation and ecological connectivity initiatives in the Balkan-Carpathian-Dinaric region.

7.3 Monitoring Framework

Monitoring should be proportionate, feasible and designed to support adaptive management rather than create excessive administrative burden.

Monitoring components may include:

a) Vegetation Monitoring

Assessment of species composition (recommended annually during peak vegetation period);

- Evaluation of shrub cover reduction (annually);
- Measurement of structural diversity indicators (every 1–3 years, depending on management intensity).

b) Forest Monitoring

- Survival rate of planted species;
- Natural regeneration assessment;
- Structural heterogeneity indicators (canopy stratification, presence of habitat trees).

A Monitoring Example from Romania

In Romania, forest monitoring parameters—including survival rate, natural regeneration, and structural heterogeneity—are governed strictly by the Ministry of Environment, Water and Forests. The primary legal framework relies on the Romanian Forestry Code alongside updated Technical Forestry Norms (*Norme Tehnice*).

<u>**Survival Rate of Planted Species**</u>

Artificial regeneration (afforestation/reforestation) monitoring is regulated by **Technical Norms (Norma 28/2022) regarding forest regeneration and the annual control of regenerations**.

The Annual Control Framework: Every technical forestry unit must conduct an annual evaluation. This is mandatory from the first year of planting until the plot achieves a **canopy closure state**.

Assessment & Thresholds:

- **Provisional Control (Years 1–3):** Checks sapling survival and establishes filling-in requirements.
- **Final Control (Year 4 or 5):** Evaluates if the stand is successful.
- **Legal Success Requirements:**
- A survival rate at least **85 %** is considered a **full success** (no immediate intervention required).
- A survival rate between **40 % and 84 %** requires mandatory filling-in using the same target composition species.
- A survival rate less then **< 40 %** is classified as a **total failure**. It legally requires a completely new re-planting scheme.

A Monitoring Example from Romania - continued

Natural Regeneration Assessment

The Romanian state prioritizes natural regeneration under close-to-nature forestry principles, strictly managed through the same **Technical Norms (Norma 28/2022)**.

Two-Stage Monitoring System:

- **Stage I (Evaluation of Seedlings):** Tracks early-stage natural seedling development under the parent stand canopy. It determines the progression of regeneration cutting methods.
- **Stage II (Annual Control of Established Regeneration):** Evaluates the young crop once the overstory canopy is partially or fully removed.

Metric Parameters: Field assessment maps sample plots to verify specific legal criteria:

Layout and Field Marking of Sample Plots

The quantitative and qualitative verification of afforestation works, as well as the annual monitoring and control, is conducted through observations, inventories, and measurements within permanent sample plots, which are physically marked in the field using boundary markers and stakes. These plots are established during the first inspection and evaluation phase. Sample plots may have circular or rectangular shapes, with an area of 100, 200, 300, or 400 m², and their cumulative area must represent at least **8%** of the forest cultural unit (F.C.U.) surface, for surfaces between 0, 25 ha and 5 ha, **4 %** for surfaces between 5 ha and 10 ha, and **2 %** for surfaces bigger than 10 ha. For surfaces smaller than 0.25 ha, the inventory will be done in full. A systematic layout is adopted for the positioning of the sample plots. For this purpose, a grid of parallel lines intersecting at a given angle is established, and at each intersection point a reference marker is placed.

- **Sapling Abundance and Distribution:** Measured by the number of viable seedlings per unit area.
- **Target Composition Consistency:** The regeneration must mirror the official target composition goals outlined in that specific forest management plan.
- **Health Status:** Seedlings must be vigorous, structurally sound, and free of biotic or abiotic damage.

A Monitoring Example from Romania – continued

<u>Structural Heterogeneity Indicators</u>

Structural heterogeneity indicators have become vital due to EU Biodiversity Strategy alignments and *Natura 2000 management networks in Romania*. They are mapped using forest inventory indices.

- **Canopy Stratification**
- **Legal Management Tool:** Evaluated during the 10-year **Forest Management Plan revision**.
- **Application:** National norms evaluate vertical layer distribution (overstory, understory, and herb layers) to assign target production or protection functional categories. It monitors the structural resilience of stands against environmental aridity risks.
- **Presence of Habitat Trees:**
- **Biodiversity Conservation Norms:** Integrated via specific instructions regarding biodiversity conservation in harvested stands and the **National Forest Inventory (IFN)** metrics.

c) **Connectivity and Wildlife Use**

- Camera trapping where feasible (seasonally or during periods of expected wildlife activity);
- Indirect signs of wildlife presence (at least annually);
- Spatial assessment of corridor functionality (every 3–5 years or following major habitat interventions).

d) **Remote Sensing and Geospatial Tools**

- Drone-based before–after documentation (before intervention and periodically thereafter, preferably annually);
- GIS-based tracking of structural changes (every 1–3 years);
- Integration with digital databases where available (continuous updating whenever new data become available).

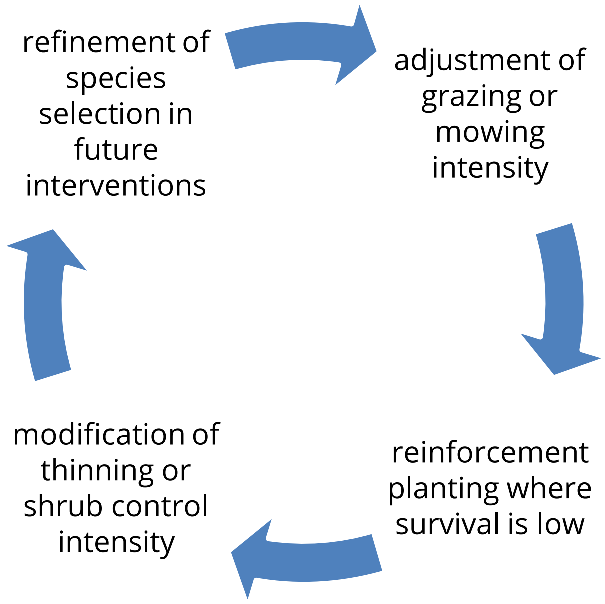
Monitoring should follow a simplified set of indicators that allow comparison before and after intervention.

Technical assistance: Monitoring design, indicator selection and interpretation of results should be supported by research institutions, NGOs or external experts to ensure comparability (before–after), ecological relevance and timely adaptive adjustments.

7.4 Adaptive Management Cycle

Mosaic habitat management should be understood as a continuous adaptive process.

Results from monitoring should inform:



The relationship between mosaic habitats, ecological connectivity, management actions and outcomes follows a circular logic, as illustrated in Figure 2.

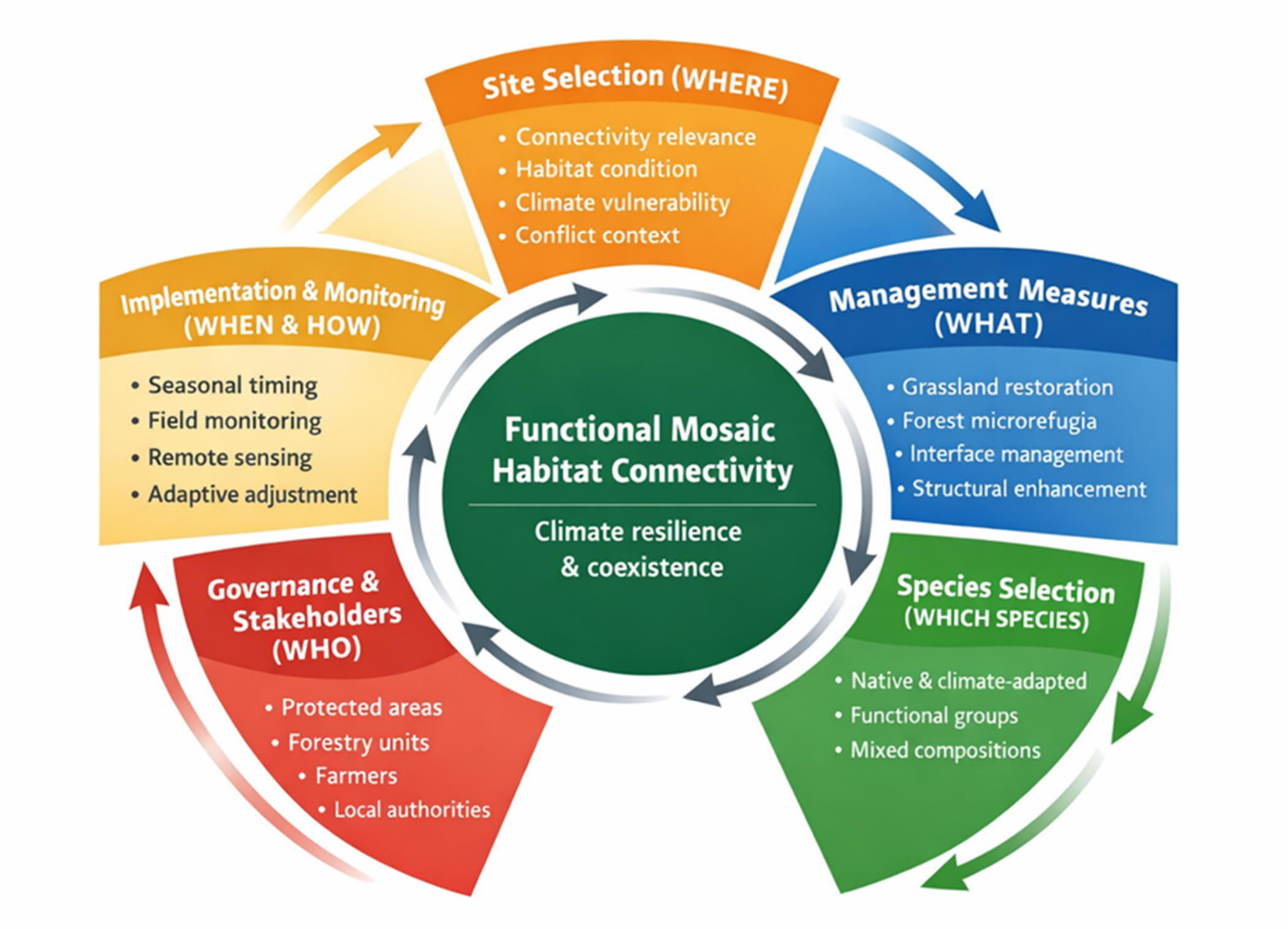


Figure 2. Adaptive implementation cycle for transnational mosaic habitat management

The figure illustrates the adaptive implementation cycle linking site selection, management measures, species selection, governance and monitoring within transnational mosaic habitats. Mosaic habitats provide the structural basis for connectivity, while targeted and adaptive management actions maintain habitat functionality. This continuous cycle strengthens biodiversity conservation, climate resilience and transnational ecological networks.

Pre-Implementation Field Checklist

Before implementing any mosaic habitat management measure, the following aspects should be verified in the field:

- ☐ Site location and boundaries confirmed
- ☐ Land ownership and management responsibilities identified
- ☐ Applicable legal restrictions reviewed (protected areas, Natura 2000, forestry regulations, agri-environmental commitments)
- ☐ Habitat condition assessed and documented (photos, field notes, GIS layers)
- ☐ Presence of target habitat features verified
- ☐ Potential risks identified (erosion, invasive species, fire risk, disturbance of sensitive species)
- ☐ Human–wildlife conflict context evaluated, where relevant
- ☐ Stakeholders and land users consulted
- ☐ Appropriate management measures selected according to site conditions
- ☐ Monitoring indicators defined before implementation
- ☐ Baseline documentation completed (photos, maps, field records)
- ☐ Implementation schedule adapted to local ecological conditions and phenology

7.5 Financing and implementation instruments (incl. EU payments – pros & cons)

Mosaic habitat management requires long-term maintenance; therefore, financing instruments should prioritise multi-annual continuity rather than one-off interventions. The instruments below can be combined depending on national frameworks and site status.

EU payments and agri-environment schemes as a financing tool

Potential advantages (pros)

- **Multi-annual predictability** (where schemes run for several years), supporting repeated mowing/grazing and follow-up.
- **Incentivises traditional practices** (extensive grazing, delayed mowing) aligned with mosaic maintenance.
- Can improve **social acceptance** by compensating labour costs in marginal mountain contexts.
- Encourages integration into formal planning and reporting, supporting institutional uptake.

Limitations and risks (cons)

- Administrative complexity and eligibility constraints can exclude small landholders or fragmented parcels.
- Payment rules may be rigid and not fully adapted to site-specific mosaic needs (e.g., selective shrub retention, patchy interventions).
- Risk of "compliance-driven management" (doing what is eligible, not what is ecologically optimal).
- Delays in contracting and payments can undermine implementation timing in mountain environments.

Recommended approach

- Use EU payments primarily to secure **routine maintenance** (mowing/grazing) and keep mosaics open.

- Use project funds / protected area budgets / forestry funds for **capital-type interventions** (initial clearing, microrefugia set-up, fencing, terraces, equipment).
- Where eligible, align intervention calendars and indicator sets so that monitoring supports both ecological outcomes and payment compliance without duplication.

Complementary instruments (examples)

- **Protected area budgets**: supervision, small-scale habitat works, monitoring.
- **Forestry funds / forest management plans**: selective thinning, regeneration support, habitat tree retention measures where permitted.
- **Local/regional co-financing**: access improvements, local maintenance capacity, co-management agreements.
- **NGO and private-sector support**: targeted co-financing for conflict-mitigation landscapes and demonstration sites.

Operational recommendation

Regardless of the financing source, every funded intervention package should include:

- minimum 2–3 years of maintenance commitment,
- a simplified monitoring set (before–after documentation),
- clear roles (who implements, who maintains, who monitors),
- contingency planning for weather and administrative delays ("Plan B").

7.6 Learning and Knowledge Transfer

Pilot implementation under ForestConnect has demonstrated that:

- moderate, well-targeted measures can significantly enhance habitat functionality;

- integrated forest–grassland approaches are more effective than isolated interventions;
- follow-up management is essential to maintain ecological benefits.

Continuous learning and cross-border exchange of experience are encouraged to refine and improve mosaic habitat management across the Balkan–Carpathian–Dinaric region.

8 Conclusions and Transnational Replication

8.1 Scientific Foundation of the Guidelines

The present Guidelines are grounded in the scientific assessment developed under Deliverable 2.1.1 Enhancing habitat heterogeneity and climate resilience in transnational forest ecosystems" (https://interreg-danube.eu/projects/forestconnect/library?page=2), which analysed the role of habitat heterogeneity, structural diversity and climate resilience in supporting ecological connectivity for large carnivores across the Balkan–Carpathian–Dinaric region.

The scientific background confirms that:

- Mosaic habitats (forests, semi-natural grasslands, shrublands and transitional zones) function as structural connectors between forest core areas.
- Structural heterogeneity increases trophic resource availability, especially plant-based food resources relevant for brown bear.
- Forest–grassland interfaces contribute to microclimatic buffering and adaptive movement under climate change.
- Simplification of landscape structure (abandonment, intensification, uniform afforestation) reduces permeability and weakens ecological corridors.

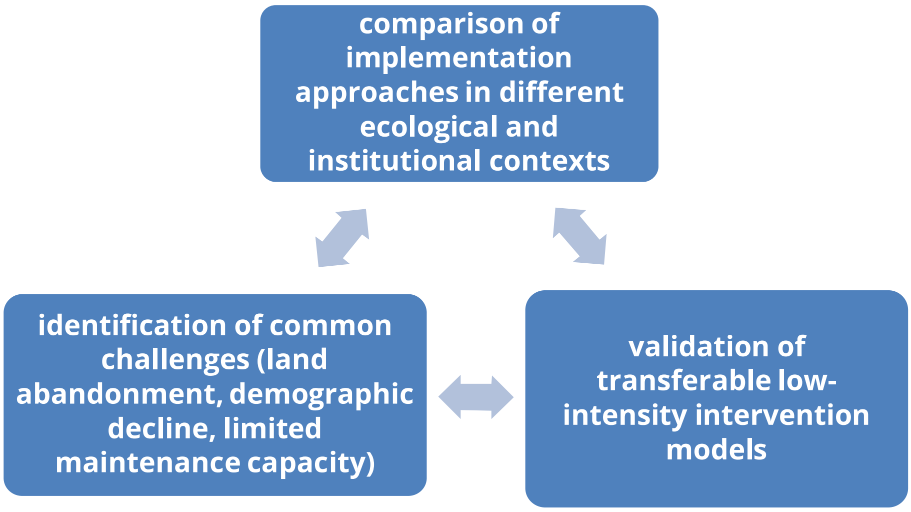
These findings provided the conceptual framework for the **pilot interventions tested within the ForestConnect project** and guided the selection of measures tested across six countries.

The Guidelines therefore represent not only a practical manual, but a direct translation of scientific evidence into applied habitat management recommendations.

8.2 Transnational Knowledge Exchange and Future Refinement

The development of these Guidelines was supported by collaborative exchanges between project partners, field experts and stakeholders across participating countries.

The transnational dimension allowed:



To further strengthen the consolidation of lessons learnt, an additional partner-level meeting or thematic workshop is recommended after completion of pilot monitoring cycles. Such a meeting would:

Continuous cross-border exchange will allow progressive refinement of mosaic habitat management strategies and ensure that the Guidelines remain adaptive and applicable under evolving climate and socio-economic conditions.

Key Strategical Conclusion

The ForestConnect experience demonstrates that mosaic habitat management can provide an effective and practical contribution to ecological connectivity, biodiversity conservation and climate resilience in the Balkan-Carpathian-Dinaric region. The following key strategic conclusions summarize the main lessons and recommendations emerging from the project. The ForestConnect Guidelines demonstrate that mosaic habitat management can serve as an effective nature-based solution for:

Key strategic conclusions

1. Mosaic habitats should be recognized as essential components of ecological connectivity networks.
2. Habitat management should follow adaptive and climate-resilient approaches.
3. Site prioritization should combine ecological, social and governance criteria.
4. Long-term success depends on stakeholder engagement and institutional adoption.
5. GIS tools and digital twins can support evidence-based planning and future scenario analysis.
6. Transnational cooperation remains essential to maintain ecological connectivity across borders.The Guidelines promote a transition from isolated habitat management towards integrated landscape-scale connectivity management.

When strategically planned and collaboratively implemented, mosaic habitat management represents a scalable and transferable model for sustaining large carnivore populations within multifunctional mountain landscapes across the Balkan–Carpathian–Dinaric region.

Annex 1

Case Study: Stakeholder Validation of Mosaic Habitat Measures in the Apuseni Mountains, Romania

The experience gained through the ForestConnect pilot actions in Romania illustrates how mosaic habitat management can be applied in practice within mountain landscapes. The Apuseni pilot area represents a typical example of forest–grassland mosaic habitats where targeted restoration measures were implemented. The tested actions focused on restoring overgrown mountain grasslands and improving forest–grassland mosaic functionality in three pilot sites - Poiana Horii village (Muște pasture), Giurcuţa de Sus village (Calul Mort pasture) and Doda Pilii village (Gruiu Mic pasture). Measures included mulching, shrub removal, selective retention of valuable woody elements, planting of forest tree and fruit tree saplings and stakeholder consultation with protected area representatives, local authorities and land users.

Figure 3 Example of overgrown mountain grassland restoration in the Apuseni pilot area. Photo: USAMV

The case study illustrates how low-intensity interventions can improve openness, structural heterogeneity and long-term management feasibility in mountain mosaic landscapes.

For the creation of a micro-refuge in Poiana Horii village (Muște pasture) intended for bear habitat, the goal is to support the regeneration of spontaneous grassland flora, which has been affected by the invasion of *Calluna vulgaris*. The selected intervention site was treated by mulching, milling and removal of shrubs. At the same time, the aim is to establish a complex

Figure 4 Saplings planting in Apuseni Ntional park, Romania. Photo: Vasile Ceuca

micro-refuge by planting fruit-bearing trees (A.2.1) and shrubs in these areas, to provide shelter, tranquillity, and food, and to facilitate bear movement between the two neighbouring basins. The woody vegetation in Giurcuţa de Sus village (Calul Mort pasture) was also removed by mulching and milling to facilitate the planting of fruit-bearing trees and shrubs. As for the Doda Pilii village (Gruiu Mic pasture) site, the objective was to remove low-value herbaceous vegetation, such as Deschampsia spp. and Nardus stricta, through mulching activities, as well as to eliminate anthills, in order to improve the overall quality of the grassland. Subsequently, fruit-bearing trees and shrubs were planted (A.2.1) to provide shelter and to create a suitable movement corridor for bears, thereby ensuring habitat connectivity. At the same time, these intervention aims to enhance the food supply network in areas distant from human settlements, in order to reduce and prevent human-bear conflicts.

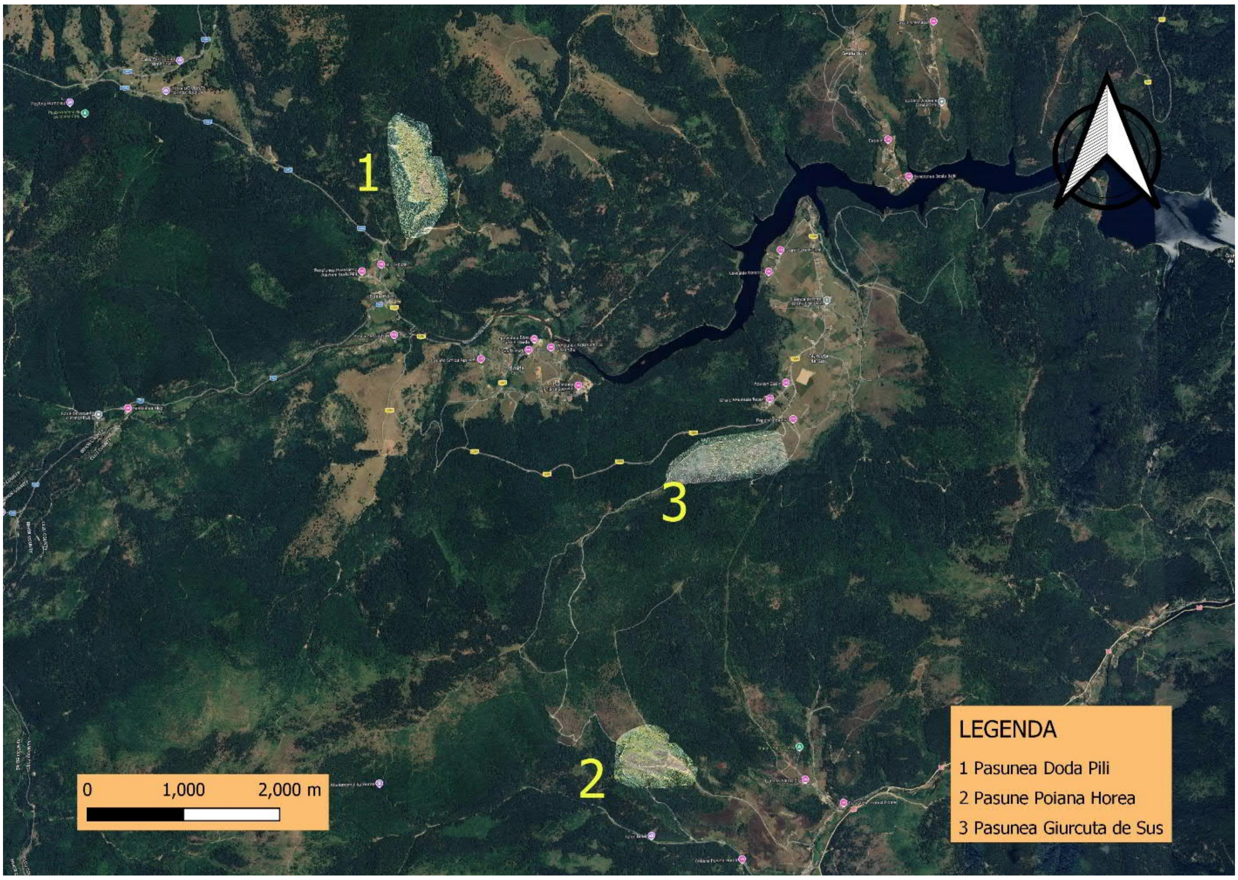


Figure 5 Location of the Apuseni case study area within the Romanian Carpathians.

Also, the mountain hay meadow restoration via mulching was implemented at these three sites (2 ha at each site).

The pilot implementation in the Apuseni Mountains demonstrates the practical feasibility of applying mosaic habitat management measures within mountain forest–grassland landscapes and provides a transferable example for similar ecological contexts.

Regeneration Composition and Determination of the Afforestation Composition

The afforestation of areas in the Apuseni Natural Park, incl. the planting density, afforestation composition and the placement of seedlings, is described in detailed below.

To determine the ecological group, we used the guidelines provided in "Technical Norms (1)", applying the forest type code and the site type code.

Legend:

Mo – spruce (*Picea abies*)
Ci – wild cherry (*Prunus avium*)
La- European larch (*Larix decidua*)
Zm- rasberry (*Rubus idaeus*)
Sr- rowan (*Sorbus aucuparia*)
Mu-blackberry (*Rubus fructicosus*)
Cr-cherry plum (*Prunus cerasifera)*

Location: Giurcuța de Sus (Calul Mort)

Latitude: 22.904926 ; Longitude: 46.635400

Regeneration Composition: 35Mo 25Sr 15Zm 10Mu 10Ci 5La (%)
Planting scheme: 2 x 1.5 m
Area per seedling: 3 m^2
Number of planting strips: 5
Distance between strips: 9 m
Strip width: 6 m
Strip length: 150 m
Row length: 150 m
Rows per strip: 3
Seedlings per row: 100 pcs
Seedlings per strip: 300 pcs
Total number of seedlings: 1500 pcs
Effective afforested area: 4500 m^2
The rows and planting strips were laid out along the contour lines

No.	U.C.F.	Afforestation Composition	Type of Afforestation Work	Work Technology		Planting Season
				Code	Description of Works	
1	Calul Mort	35Mo 25Sr 15Zm 10Mu 10Ci 5La	Afforestation	2.1.1.1.	Planting in standard pits (0.3–0.4 m depth) with bare-root seedlings, manual	Spring

	Row	Elementary area: 60 seedlings (60 VETRE)/180 m^2																				
STRIP 1,2,3,4,5	**R1**	MO	SR	MO	MO	SR	LA	SR	CI	MU	ZM	MO	SR	MO	MO	SR	LA	SR	CI	MU	ZM	repeat five more times
	R2	MO	SR	MO	MO	CI	MU	ZM	MO	SR	ZM	MO	SR	MO	MO	CI	MU	ZM	MO	SR	ZM	
	R3	CI	MU	ZM	MO	SR	MO	MO	SR	ZM	SR	LA	CI	MU	MO	SR	MO	MO	SR	ZM	MO	
	Total elementary area	21Mo 15Sr 3La 6Ci 9Zm 6Mu (pcs)																				
Total strip		105Mo 75Sr 15La 30Ci 45Zm 30Mu (pcs) 35Mo 25Sr 15Zm 10Mu 10Ci 5La (%)																				
Total Calul Mort		525Mo 375Sr 75La 150Ci 225Zm 150Mu (pcs) 35Mo 25Sr 15Zm 10Mu 10Ci 5La (%)																				

Location: Poiana Horea (Mușțe)

Latitude	*Longitude*
22.895477	*46.606179*

Regeneration composition: 35Mo 25Sr 20Zm 20Mu (%)
Planting scheme: 2 x 1.5 m
Area per seedling: 3 m2
Number of strips: 5
Distance between strips: 9 m
Strip width: 6 m
Strip length: 150 m
Row length: 150 m
Number of rows per strip: 3
Number of seedlings per row: 100 pcs
Number of seedlings per strip: 300 pcs
Total number of seedling: 1500 pcs
Effective afforested area: 4500 m2
The rows and planting strips were arranged along the contour lines.

No.	**U.C.F.**	**Afforestation Composition**	**Type of Afforestation Work**	**Work Technology**		**Planting Season**
				Code	**Description of Works**	
1	Muşte	35Mo 25Sr 20Zm 20Mu	Afforestation	2.1.1.1.	Planting in standard pits (0.3–0.4 m depth) with bare-root seedlings, manual	Spring

STRIP 1,2,3,4,5	**ROW**	Elementary area: 60 seedlings (60 VETRE)/180 m^2																				repeat five more times
	R1	MO	SR	MO	MO	SR	MU	SR	ZM	MU	ZM	MO	SR	MO	MO	SR	MU	SR	MU	MU	ZM	
	R2	MO	SR	MO	MO	MU	MU	ZM	MO	SR	ZM	MO	SR	MO	MO	MU	MU	ZM	MO	SR	ZM	
	R3	ZM	MU	ZM	MO	SR	MO	MO	SR	ZM	SR	MU	ZM	MU	MO	SR	MO	MO	SR	ZM	MO	
	Total elementary area	21Mo 15Sr 12Zm 12Mu (pcs)																				
Total strip		105Mo 75Sr 60Zm 60Mu (pcs) 35Mo 25Sr 20Zm 20Mu (%)																				
Total Poiana Horea		525Mo 375Sr 300Zm 300Mu (pcs) 35Mo 25Sr 20Zm 20Mu (%)																				

<u>Location: Doda Pilii (Gruiu Mic)</u>

Latitude *Longitude*

22.862525 *46.662455*

Regeneration composition: 46 Mo, Sr, La 54 Ci, Cr, Zm, Mu (%)
Planting scheme: 2 x 1.5 m
Area per seedling: 3 m^2
Number of strips: 5 (strip 1 with 3 rows, strip 2 with 2 rows, strip 3 with 3 rows, strip 4 with 2 rows, strip 5 with 3 rows)
Distance between strips: 10 m
Strip width: banda 1, 3, 5-6m; strip 2 and strip 4-4 m
Strip length: variable depending on terrain configuration (100–200 m)
Row length: variable depending on terrain configuration (100–200 m)
Number of rows per strip: 3 (strips 1,3, 5) and 2 (strips 2, 4)
Number of seedlings per row: 100 pcs/150 m
Number of seedlings per strip: 300 pcs/ 150 m (strip with 3 rows) or 200 pcs/150m (strip with 2 rows)
Total number of seedling: 1500 pcs
Afforested area: 4500 m^2
The rows and planting strips were arranged along the contour lines
Each row follows the following species sequence along its 150 m length:

No.	U.C.F.	Afforestation Composition	Type of Afforestation Work	Work Technology		Planting Season
				Code	Description of Works	
1	Gruiu mic	46 Mo, Sr, La 54 Ci, Cr, Zm, Mu	Afforestation	2.1.1.1.	Planting in standard pits (0.3–0.4 m depth) with bare-root seedlings, manual	Spring

STRIP 1,2,3,4,5	ROW	Elementary area: 60 seedlings (60 VETRE)/180 m^2																				
	R1	MO	CR	LA	ZM	SR	CI	MO	CR	LA	ZM	SR	SR	MU	CR	ZM	LA	CI	SR	CR	MO	
	R2	ZM	LA	MU	SR	CR	MO	ZM	CI	CR	LA	ZM	SR	MU	MO	CR	LA	ZM	SR	CI	CR	
	R3	ZM	MO	MU	LA	CR	SR	ZM	MO	CI	LA	CR	SR	ZM	MO	MU	LA	CR	SR	ZM	MO	
	Total elementary area	9Mo 10Sr 11Zm 5Mu 11Cr 9La 5Ci (pcs)																				repeat five more times
Total strip		45Mo 50Sr 55Zm 25Mu 55Cr 45La 25Ci (pcs) 15Mo 17Sr 18Zm 8Mu 18Cr 15La 9Ci (%)																				
Total Poiana Horea		225Mo 250Sr 275Zm 125Mu 275Cr 225La 125Ci (pcs) 15Mo 17Sr 18Zm 8Mu 18Cr 15La 9Ci (%)																				

If the row exceeds 150 meters in length, the species sequence specified above is repeated until the end of the row.
When row 1 of strip 1 ends, row 2 of the same strip begins with the species that follows the last species planted in row 1.
In strips with three rows, the same principle is applied for rows 2 and 3.

This case study presents the stakeholder con sultation process organised in the Apuseni Mountains during the ForestConnect pilot implementation.

On 16 October 2025, USAMV Cluj-Napoca organised an in-person expert meeting dedicated to the evaluation of implemented pilot measures and future directions for mosaic habitat management in the Apuseni Mountains.

A total of 37 stakeholders participated, including:

Representatives of the Apuseni Natural Park Administration	Mayors from eight local communities	Academic and conservation experts
Rangers and field staff	Representatives of regional councils	Members of the Romanian Alpine Club

Validation of Proposed Measures

During the meeting, experts presented the measures implemented under Activities 2.1 and 2.2, including:

- pilot site selection,
- identification of climate-resilient native fruit-bearing species,
- restoration of abandoned mosaic grasslands,
- and creation of microrefugia elements.

At the end of the session, a structured questionnaire was distributed to collect stakeholder feedback on:

- relevance of the proposed measures,
- causes of pasture degradation,
- future management directions,
- and local implementation feasibility.

Stakeholder Assessment Results

The responses indicate strong overall support for the restoration of abandoned grasslands and the maintenance of mosaic habitats.

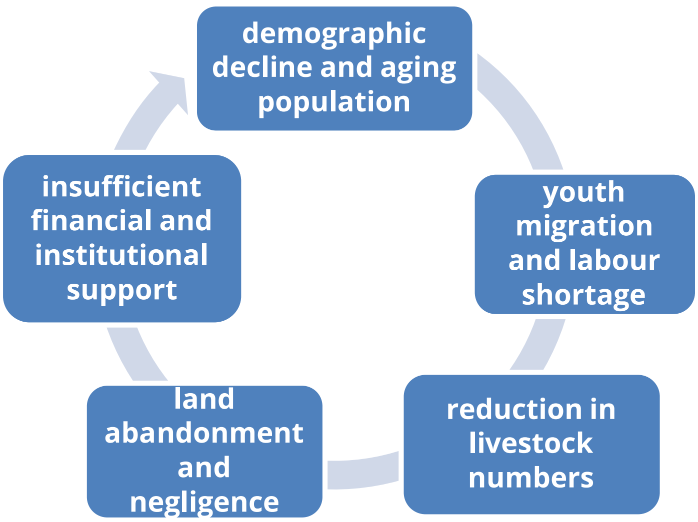
The majority of participants validated grassland restoration as:

- essential for biodiversity conservation,
- critical for maintaining traditional landscapes,
- necessary for sustaining grazing resources,
- important for tourism and local economic stability.

Stakeholders emphasized that mowing and controlled grazing represent the most appropriate long-term management tools to prevent shrub encroachment and landscape homogenisation.

Perceived Drivers of Habitat Degradation

The questionnaire results identified the following main drivers of grassland abandonment:



These findings confirm that mosaic habitat degradation is driven by interacting socio-economic and demographic processes rather than purely ecological dynamics.

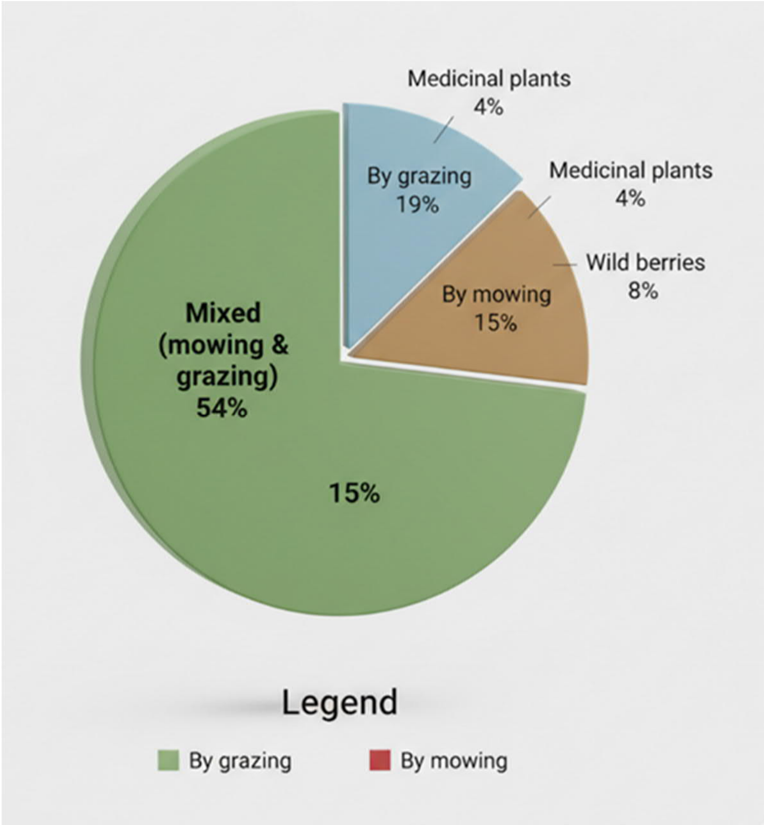


Figure 6 Stakeholder Perspectives on the Restoration of Abandoned Grasslands in the Apuseni Mountains

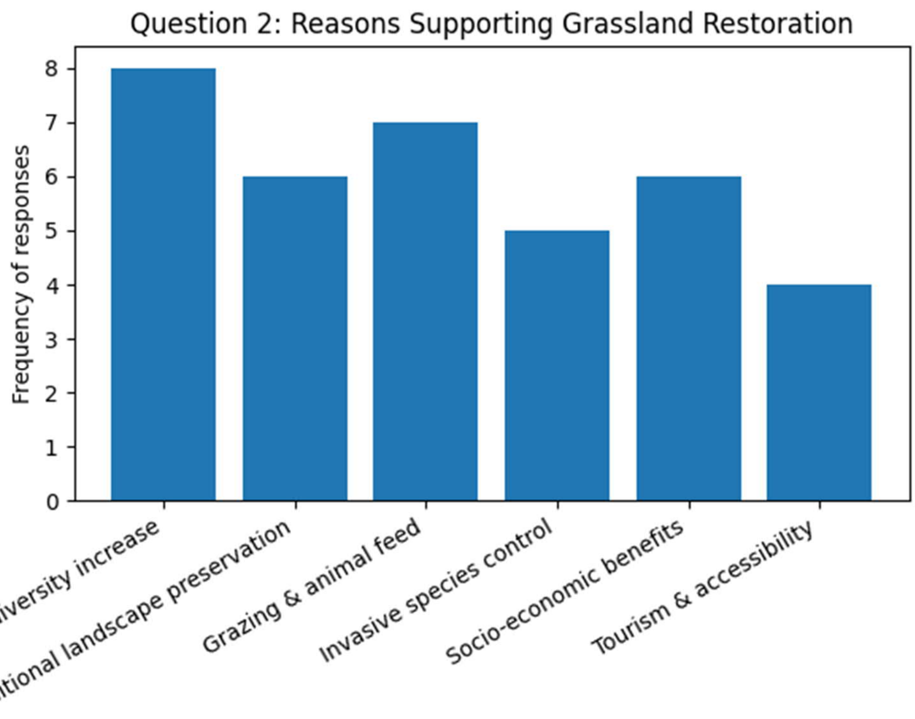
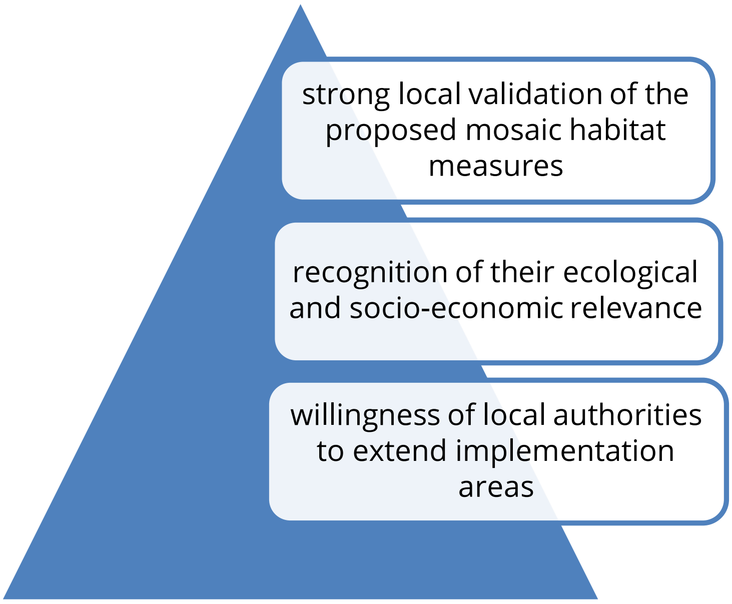


Figure 7 Main arguments supporting the restoration of abandoned grasslands in the Apuseni Mountains, based on stakeholder responses

The Apuseni stakeholder consultation demonstrates:



This validation confirms that mosaic habitat management is socially acceptable and institutionally feasible when aligned with local development needs and traditional land-use practices.

Annex 2

Suitable forest fruit tree and shrub species for planting activities to ensure availability of additional and seasonal natural food for large carnivores (desktop study)

Based on a literature review and data provided by WWF Bulgaria and ForestConnect partners, the following annex presents a list of plant species, which are suitable for enhancing habitat heterogeneity to provide a diverse seasonal food base for large carnivores, particularly bears (*Ursus arctos*). The species, selected based on bear diet studies, are described in terms of their seed or vegetative propagation requirements, seedling production, and reforestation needs, considering climatic factors such as drought resistance.

General overview of appropriate species

From the hard mast most important are various acrons of oaks (*Quercus* sp.), beech (*Fagus* sp.), hazelnuts (*Corylus* sp.), walnut (*Juglans regia*). Although oaks and beeches are vital to bear nutrition, particularly during periods of hyperphagia due to their abundance and other characteristics, the irregular fruiting cycles of the abovementioned trees necessitate a diverse selection of berries to guarantee food security.

From the soft mast important are mostly fruits of species from the Rosaceae family with high sugar content – Pear (*Pyrus* spp), plums (*Prunus* sp., mostly *Prunus cerasifera*), berries (*Rubus* sp.), apples (Malus sp.), cherries (*Prunus mahaleb*, *Prunus avium*), blackthorn (*Prunus spinosa*), cornel (*Cornus mas*). Depending on the location, namely more southern or northern and also dependent on the elevation, the species may vary. In North Macedonia, Albania, Bulgaria and other countries where these species are present, the diet also includes dog rose (*Rosa canina*), hawthorns (*Crataegus monogyna, Crataegus pentagyna*), grapes (*Vitis vinitera*), fig *(Ficus carica)* and also *Juniperus communis,* rowan *(Sorbus aucuparia),* wild strawberry ***(****Fragaria vesca) and* blueberries *(Vaccinium sp.)* in the mountains. In Slovakia and Romania, where *Pinus cembra* is naturally present the bear also consumes its seeds.

The abundance of these species varies strongly dependent on elevation and latitude. For example *Vaccinium* sp. are typical mountain species found widely in the mountains on the Balkan peninsula and more northern locations, but are not present in low-altitude warm and dry locations. On the contrary, most of the fruit-bearing species from *Rosaceae* are found at lower elevations. Oaks are generally species of lowlands and lower altitude at mountains. Beech is dominant in many mountain locations on the Balkan peninsula and becomes more important also at lower altitudes north of the Romanian part of the Carpathians.

As a rule of thumb most fruit-giving species from *Rosaceae* family are light-demanding and often have pioneer character, which mean that they easily occupy abandoned territories without dense forests. Often, they are found in higher numbers at the edge of denser forests, the edge of crop-fields and mowed grasslands, next to dirt roads. If overshadowed they often produce less fruit and dependent on the species might even die. Few can exist by reaching the canopy of denser forest (e.g. cherry).

Artificial regeneration with the aim of planting in forests (not in orchards) varies strongly on the species. The following report is based mostly on species from the *Rosaceae* family given the fact that oaks and beech are usually widely spread in forests and if there is desire to enrich the diet the focus probably will be at fruits with higher sugar content.

Most species from *Rosaceae* family would require cold stratification of the seeds. This means they need to experience winter conditions (cold temperatures) to break dormancy. This characteristic aligns with the natural habitat of many of the species, where winters provide the necessary chilling period. This can be achieved in natural way by autumn planting or artificially in refrigerator. However, seed germination is only part of the process for production of plants. Many saplings would suffer from herbivory, competition with other species, fungi diseases in more moist conditions.

Sorbus aucuparia (rowan, European mountain ash)

Typical environment and ecological requirements – mountain conditions, found usually in Norway spruce forests or other locations with cooler mountain climate. Naturally dispersed by birds and mammals. Quite often found under large spruce trees where birds have found more secure environment and thus spread the seeds there. The species has been widely used in different locations in forest restoration projects (Aerts & Pysěk, 2005; Pauli & Gruber, 2007; Kärkkäinen & Heinonen, 2012; Hughes & Roberts, 2013; Gerken & Ropert, 2014; Larcher & Moser, 2015; Mikola & Mäkinen, 2016). Authors reports as problems in these projects mostly grazing from deer. If there were very high populations of deer, management of herbivory through fencing or culling were found to be essential for the successful establishment of rowan in restoration projects. Rowen does not develop well in very dry sites or microsites which hold very low temperatures in winter. In colder environments, where there is over excess of moisture, plants also suffered if planted in locations which tend to keep high water levels.

Figure 8 *Sorbus aucuparia* (rowan, European mountain ash)

Figure 9 *Sorbus aucuparia* (rowan, European mountain ash)

Seed collection period: late autumn.

For **seed germination** most authors advise that the seed have to be subjected to a cold period of 30–60 days (typically 1–2 months), at temperatures of 1–5°C. The recommended procedure is that after harvesting the seeds (usually in late autumn), they can be placed in a plastic bag or container with a moist medium, such as sphagnum moss, vermiculite, or sand. The mixture should be kept moist but not waterlogged. The container is then stored in a refrigerator or cold storage unit to mimic winter conditions. Another method of seed removal is to let the fruits get frost, then place them in water and wash to remove the seeds. If properly removed and stored the seeds can last several years. One kilogram of seeds can provide about 15 000 saplings (Iliev et al., 2015). Alternatively the *Sorbus aucuparia* seeds can be sown directly in the ground during late autumn or early winter. **The soils for germination should be well-draining, slightly acidic or neutral soil mix (pH range of 5.5 to 7.0.)**. A mixture of compost, loamy soil, and sand works well. Seeds of *Sorbus aucuparia* generally benefit from light to germinate, so they should be either lightly covered with soil or sown on the surface in a nursery bed or tray. Germinated seeds and young seedlings should be kept moist but not waterlogged. Overwatering can lead to root rot, so make sure the soil drains well. Regular watering is essential, particularly in dry weather. Once the trees are more established, they are moderately drought-tolerant. However, consistent watering during dry spells is beneficial, particularly in the early years, to promote healthy root development.

Replanting from nursery to natural location: Young plants should be transplanted to their final location in late autumn or early spring, after the last frost but before the growing season begins. When transplanting, ensure that seedlings are acclimatized to outdoor conditions gradually by hardening them off over a period of 7–10 days, especially if they have been grown in a greenhouse or under controlled conditions.

Once planted on site the young trees would benefit from herbivory protection. This can be achieved by use of plastic or mesh tree guards around the base of the seedlings to prevent damage from browsing. These guards also help protect the seedlings from wind and physical damage while providing some shelter from harsh sunlight. In areas with high deer populations, consider installing deer fences or using temporary fencing around newly planted areas to prevent grazing. Applying mulch around the base of young plants can help retain soil moisture, suppress weed growth, and regulate soil temperature. Organic mulches, such as bark chips or leaf litter, work well for *Sorbus aucuparia*.

Very similar in terms of ecological requirements and taken niche is ***Sorbus aria*.** It is more abundant on sun-exposed locations (including with rocks) in the mountain areas.

Sorbus torminalis (Wild service tree) and *Sorbus domestica* (Service tree)


Figure 10 *Sorbus domestica* (left) and *Sorbus torminalis* (right).


Figure 11 *Sorbus domestica* (left) and *Sorbus torminalis* (right).

Typical environment and ecological requirements: These species are appropriate to plant in **warmer environments, typically where oaks from the temperate zone and the Balkan Peninsula grow well.** However, they do not tolerate well very dry sites with poor shallow soils. It is best to avoid locations of poor growth of *Quercus pubescens, Q. frainetto* or where more drought-tolerant oaks dominate (*Q. coccifera*). Given observed and expected climate changes the species can be used at lower altitudes (below 1000 m a.s.l.) with high confidence of survivability.

Seed collection period: Seeds are collected from the fruits after fruit germination (autumn).

Seed germination: Seeds should be subjected to 90–120 days of cold stratification, typically at temperatures between 1°C and 5°C. After the cold stratification period, the seeds should be sown in a well-drained, slightly acidic soil mix, with temperatures around 15–20°C for optimal germination. Like most *Sorbus* species, young *S. torminalis* trees require regular watering in the first few years, especially in dry spells. However, they do not like waterlogged soil.

Replanting from nursery to natural location: To plant select carefully the site. The species prefer well-drained, calcareous (lime-rich) soils but are adaptable to a range of soils if they are not too acidic. Replanting is at the period of dormancy. **After planting care:** Deer, hares, and rodents may browse on young trees. Protective fencing or tree guards can be used to prevent damage. Apply mulch around the base of young trees to retain moisture and suppress weeds. Organic mulches (e.g., bark chips) can also improve soil fertility as they decompose. *Sorbus torminalis* is a slow-growing species, especially in the early years. It may take several years to establish a strong root system.

Malus sylvestris (European crab apple)

Typical environment and ecological requirements: *Malus sylvestris* is common species in mixed deciduous forests at lower elevations, but it does not tolerate well the driest and warmest sites. As other fruit-giving species it needs light to develop well and provide fruits. It was used in projects for Biodiversity restoration (Zhang & White, 2009; Powell & McGregor, 2008; Pellé, 2011). The benefits are support of diet of pollinators, birds and larger animals.

Seed collection period: During late summer to early fall, when the fruits are fully ripe. Harvesting mature fruits during this period ensures that the seeds have developed completely, enhancing their viability for propagation. After harvesting the fruit, which typically ripens in late summer to early autumn, the seeds are extracted from the apples and stored in moist sand or peat. The seeds are separated by crushing in a specialized fruit crusher and washing. A sieve with 8 × 8 mm openings is suitable, allowing the seeds and small particles to pass through. In the second stage, washing is carried out using a sieve with 2.5 × 3 mm openings. The seeds are then placed in a refrigerator or cold room for the required stratification period. Seeds should undergo 30–60 days of cold stratification at temperatures around 1°C to 5°C before being sown in early spring. Aas et al. (2005) found that seeds of *Malus sylvestris* showed the best germination rates (around 50%) after 45–60 days of cold stratification. The germination rate decreased when the stratification period was too short or too long, highlighting the importance of timing. *Malus sylvestris* prefers well-drained, slightly acidic to neutral soils (pH 5.5–7.0). The seeds should be sown in early spring after the stratification process. Germination typically occurs within 2–4 weeks once soil temperatures rise to around 15°C (Thomas, B., 2010)

Figure 12 *Malus sylvestris* (European crab apple)

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After planting care: As with other fruit trees there is higher risk of damages from hares and ungulates. Protective fencing or tree guards can be used to prevent damage. Apply mulch around the base of young trees to retain moisture and suppress weeds. Another option is to do protection with branches from very thorny plants, if available nearby. If there is easier access trees will benefit from weed removal in late spring and early summer and watering if very dry summer conditions occur.

Pyrus communis (Wild pear)

Figure 13 *Pyrus communis* (Wild pear)

Typical environment and ecological requirements: Wild pear is native to temperate regions of Europe and plays an important ecological role in both forest and hedgerow ecosystems. **It is more common in warmer sunny locations. If the location is drier and hotter as for example in the southern parts of the Balkan Peninsula, then other pear species such as *Pyrus eleagrifolia*, *Pyus amygdaliformis* are becoming more common. They are more drought-resistant and should be preferred in planting activities in drier and warmer sites in the southern parts of the Balkan Peninsula. Compared to Malus sylvestris, the Wild pear tolerates higher temperatures and is more drought-resistant.**

Seed collection: Similar to other fruit species from *Rosaceae* – late summer or early fall, when the fruits are fully ripe.

For **seed germination** cold stratification is necessary. It requires cold stratification for 60–90 days to break dormancy, with optimal germination occurring after stratification at around 4°C. Germination typically takes 4–6 weeks after sowing, with optimal soil temperatures between 15°C and 18°C (Boivin & Hovorka, 2012). *Pyrus communis* should be planted in well-draining soils and is best suited for areas with a temperate climate. In habitat restoration or agroforestry projects, young trees should be protected from browsing by herbivores like deer or livestock, especially in the early years (Powell & O'Brien, 2013).

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After planting care: As with other fruit trees there is higher risk of damages from hares and ungulates. Protective fencing or tree guards can be used to prevent damage. Mulching around the base of young trees helps retain moisture and suppress weeds. Another option is to do protection with branches from very thorny plants, if available nearby. If there is easier access trees will benefit from weed removal in late spring and early summer and watering if very dry summer conditions occur.

Prunus avium (Wild cherry)

Typical environment and ecological requirements: *Prunus avium* plays a significant role in enhancing biodiversity in woodland, riparian, and hedgerow environments. Its flowers are attractive to pollinators, especially bees, while its fruit provides a food source for a variety of birds and mammals, including brown bear. **In natural habitats in Southern Europe, where it is usually found in mountain environments in mixed deciduous forests or beech forests at rich soils. This said *Prunus avium* cannot be considered as drought-tolerant and should not be planted at low elevations on the Balkan Peninsula, except if there is nearby source of moisture.** Further north it becomes a low-elevation species, but does not cope successfully with very low temperatures. If planted, it should be on locations protected from cold winds in winter (European Atlas of Forest Tree Species, 2016).

Figure 14 *Prunus avium* (Wild cherry)

Seed collection period: When fruits are fully-ripe (dark red), which usually occurs in June-July period, but depends much on the location. After the fruit collection the mushy fruit should be removed for seed storage. One option is to wash the pits under running water. Slight fermentation can help. To do this place pits in a container with water for 2–3 days to loosen any remaining pulp, then stir occasionally, then rinse and dry.

***Prunus avium* seeds exhibit dormancy**, which is typically broken through cold stratification. The seeds are collected from the fruit in summer and require a period of cold treatment to mimic winter conditions before germination. Alternatively, they can be sawn immediately in autumn. From 1 kg of seeds 2500 saplings can be grown (Iliev et al., 2015). Seeds need to undergo a cold period of approximately 60–90 days at temperatures between 1°C to 5°C. According to Nori et al. (2007)**.** The best results were observed when seeds were kept at 4°C for 60-days period, followed by sowing in spring. Iliev et al., 2012 suggests stratification with 6 weeks of warm phase followed by 5 weeks of cold phase. The same author suggests sawing under 3-4 cm of soil in rows, 40 seeds for 1 m. Soils should be well-drained, slightly acidic to neutral soils (pH 6–7)

(Prohens & Nuez, 2008). After germination watering should not be too frequent. In Bulgaria it takes 2 years for the saplings to mature and can later be planted in wilder environment.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After planting care: As with other fruit trees there is higher risk of damages from hares and ungulates. Protective fencing or tree guards can be used to prevent damage. Mulching around the base of young trees helps retain moisture and suppress weeds. Another option is to do protection with branches from very thorny plants, if available nearby. If there is easier access trees will benefit from weed removal in late spring and early summer and watering if very dry summer conditions occur.

Prunus mahaleb (Mahaleb Cherry)

Figure 15 ***Prunus mahaleb*** **(Mahaleb Cherry)**

Prunus mahaleb is similar to *Prunus avium* but grows to smaller dimensions**. Ecologically it tolerates higher temperatures and more dry locations, which makes it suitable for planting also on locations that experience higher temperatures. On the Balkan Peninsula it is often one of the species accompanying oaks. It is one of the recommended species for planting at places with abundant light up to 1000-1200 m a.s.l.** If planted north of the Romania-Hungary line in eastern Europe, locations exposed to cold north winds and locations prone to keeping cold air in winter should be avoided.

Like other species in the *Prunus* genus, *Prunus mahaleb* requires cold stratification to break seed dormancy. The stratification period typically ranges from 60 to 120 days at temperatures around 4°C. Germination rates are higher when seeds are subjected to this cold treatment, with the best results achieved when stratified for 90 days followed by sowing in early spring (Kan & Özdemir, 2007). After cold stratification, the seeds typically germinate within 2 to 3 weeks when the soil temperature is kept at around 15°C to 18°C. *Prunus mahaleb* prefers well-drained, slightly acidic to neutral soils.

Figure 16 ***Prunus mahaleb*** **(Mahaleb Cherry)**

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After-planting care is as for the other fruit species from Rosaceae with special care from hares and herbivory, because the bark of cherries is very thin and soft.

Prunus cerasifera (Cherry plum)

Typical environment and ecological requirements: *Prunus cerasifera* is quite common on the Balkan peninsula at a variety of conditions, but mostly mixed deciduous forests and often accompanying oaks. It has very wide tolerance to temperature, moist and soil conditions. If light is abundant it can climb up to 1500-1600 m a.s.l., especially close to rocks. It also tolerates higher soil pH.

Figure 27 *Prunus cerasifera* (Cherry plum)

Seed collection period: Seed collection as with other species from the *Prunus* genus is after ripening, which is usually in June-August period depending on altitude.

Seeds typically require 60–90 days of cold stratification at temperatures between 1°C to 5°C. A good method is 2 warm weeks followed by 18 cold weeks and then sawing in spring. The seeds should be sown in well-draining, slightly acidic soils, and the best germination success occurres when the seeds are stratified for 70 days (Erskine & Walker, 2008). The seeds typically germinate within 4–6 weeks. Germination rates tend to be higher when seeds are exposed to light during this period, which is common for many species in the *Prunus* genus. The optimal soil temperature for germination of *Prunus cerasifera* seeds is around 18°C to 20°C.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After-planting care is as for the other fruit species from *Rosaceae* with special care from hares and herbivory, because the bark of cherries is very thin and soft.

Prunus spinosa (Blackthorn)

Typical environment and ecological requirements: *Prunus spinosa* is common in dry locations on the Balkan Peninsula, usually associated with oak habitats. However, it can tolerate a wide variety of soils, including with high calcium content and also can tolerate colder winters It can withstand temperatures as low as -20°C in winter. It also tolerates well soil dryness, making it one of the most valuable fruit species for restoration projects. It forms dense thickets and can be used as protection for other more valuable species which grow to form higher trees with time (Pear, Cherries, Wild apple).

Figure 18 ***Prunus spinosa*** **(Blackthorn)**

Seed collection period: Late autumn, after first frosts. Then the fruits soften a bit and make it possible to remove the seed.

Seed germination: The seeds require stratification. Suggested is 2 weeks of warm phase followed by 18 weeks of cold phase. Alternatively, 4 weeks at 18–21°C and 4 to 8 weeks at 1°C. Planting is at depth of 3-4 cm.

Planting: One option is to do direct planting of seeds directly in spring after the stratification process. If the aim is to form a thicket, then dense planting is preferred (50-100 individuals/m^2). Another option is to grow the plants in nursery for a season and then plant the saplings in autumn or next spring.

After-planting care is usually not necessary. The Blackthorn has spiny and dense shrub form of growth which is efficient in self-protection from many animals.

Crataegus monogyna (Common hawthorn) and *Crataegus pentagyna* (Black hawthorn)

Figure 39 ***Crataegus monogyna*** **(Common hawthorn)**

Crataegus monogyna

Typical environment and ecological requirements: *Crataegus monogyna* grows on variety of soils, including poor and eroded ones, usually at locations with abundant sunlight in mixed deciduous forests in low mountains. On the Balkan peninsula it climbs up to about 1400-1500 m a.s.l. indicating also cold-tolerance. If the locations are drier and warmer (oak-type habitat), then *C. pentagyna* will be more common. *Crataegus monogyna* is a species with significant ecological value and a long history of use in habitat restoration, agroforestry, and biodiversity conservation (Wallace & Reilly, 2012).

Seed collection: Seed collection is done at late autumn, after fruits are fully ripe and soft. Fruits can be soaked in water for 24 to 48 hours to soften, then mesh, then water to separate the seeds from the pulp and let dry the seeds for a few days in cool shaded area.

Seed germination: *Crataegus monogyna* seeds exhibit strong physiological dormancy and require cold stratification to overcome this dormancy (Grime et al., 1988). A study by Booth et al. (2001) indicated that hawthorn seeds require a stratification period of 30–90 days at temperatures around 1–5°C. Iliev points good results if there is 3 months of 25°C period and 9 months at 3-5°C. Black hawthorn requires shorter cold period. After cold stratification, seeds of *C. monogyna* are best sown in well-draining, acidic to neutral soils with adequate light at 2-3 cm of depth. Germination is slow, often taking several months to occur, with variability in timing due to seed dormancy patterns (Grime et al., 1988). Seedlings are replanted in late autumn or early spring in dormancy.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

An option to try spreading the plants is to use seed bombs, which are appropriate for many species with hard seeds (such as *Prunus*). The bombs consist of clay (1 part), seeds (1 part) and rich soils or compost (3 parts). After they are watered and mixed to form a solid ball at size of 3-4 cm and then allow to dry for 1-2 days at cool dry place. Throwing is best done in early spring. Success is lower than single planting, but spreading is easier.

After-planting care is as for the other fruit species from *Rosaceae* with special care from hares and herbivory. However, hawthorns tend to produce spines which partly protect them from herbivory of larger animals. Usually no special care is taken. A good strategy is to plant it together with blachthorn and , dog rose and European dewberry which will quickly insure natural protection.

Rosa canina (Dog Rose)

Typical environment and ecological requirements: *Rosa canina* is one of the very important species in habitat restorations. Often it takes a pioneer role forming bush communities. **It tolerates a wide variety of temperature and soil conditions. Due to its wide-spreading root system is quite persistent and hard to remove once established.**

Figure 204 *Rosa canina* (Dog Rose)

Seed collection: Seeds are collected in late autumn, after they are fully ripe and soft. The colour of the fruits should be red (or orange), in some species of Rosa (*R. spinosissima*) darker. The fruits should then be dried or placed in refrigerator. To obtain the seeds best way is to soak the fruits in water, them mesh and water.

Seed germination: Seeds require cold stratification at 2–5°C for 3–4 months to break dormancy. This can be done by storing seeds in moist sand in a refrigerator or planting outdoors over winter. Seeds should be sown in spring in well-drained soil with partial sunlight. Germination may take several months. *Rosa* can be also propagated by cuttings: Late autumn (hardwood) or summer (semi-hardwood). The following steps are taken: 1. Cut 20–30 cm (8–12 inch) stem sections with at least 3 buds; 2. Dip the cut end in rooting hormone 3. Plant in sand or well-draining soil, keeping it moist. 3. Rooting occurs within 3–6 months.

Planting: Saplings can be planted in late autumn.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring.

After-planting care is as for the other fruit species from *Rosaceae* with care for protection from hares and herbivory. However, roses tend to produce spines which partly protect them from herbivory of larger animals. Usually no special care is taken.

Another alternative is to make seed bombs and spread them in places with abundant light. Due to the thorns plants usually do not require special after-care.

Rubus caesius (European dewberry, wild blackberry)

Typical environment and ecological requirements: *Rubus caesius* is a species in the *Rosaceae* family known for its vigorous growth, thorny stems, and edible fruit. It is commonly found in hedgerows, woodland edges, scrubland, and disturbed sites, particularly in temperate zones of Europe. The dense thickets formed by bramble species like *R. caesius* can provide excellent habitat for a variety of wildlife. Its thorns offer shelter and protection for small mammals and birds, and the fruit is a valuable food source for birds, insects, and mammals. The thickets also provide shelter for the establishment and growth of larger fruit-giving trees such as representatives of *Malus sp., Prunus sp. Pyrus sp.* (Hodgson & Ball, 2009). ***Rubus caesius* is naturally found in warmer conditions at valleys or foot of the mountains. It is drought-tolerant and suitable for planting in drier conditions.** At higher elevations, where coniferous forests predominate, *Rubus idaeus* is better fit.

***Rubus idaeus* is one of the most important mountain food sources. It requires cooler mountain temperatures and abundant light. Often it forms large bushes after large-scale clearcuts, windthrows, fires in coniferous forests.** These bushes persist for several decades until the tree species grow again and overshadow *R. idaeus*, which causes its diminishment. If the persistence of *R. idaeus* is required in such cases, there should be light-maintenance.

Figure 215 *Rubus caesius* (European dewberry, wild blackberry)

Seed collection: Seeds are collected after fully ripened, when they are soft, dark red (*R.idaeus*) or black (*R. caesius*). The period is July-August depending on altitude. After fruits are collected, they are smashed without excess power (seeds are soft), then floated to remove the seeds from the mesh.

Seed germination: The germination of *Rubus caesius* seeds is typically straightforward, but may benefit from some environmental conditions. Seeds of *Rubus caesius* require a cold stratification period of about 30-90 days at temperatures ranging from 1°C to 5°C. After cold stratification, the seeds typically germinate at a temperature range of 15°C to 20°C and the germination process can take 2 to 3 weeks, depending on the environmental conditions. Germination of *Rubus caesius* seeds is often enhanced by light exposure, so it is advisable to lightly cover the seeds with a thin layer of soil or sand, ensuring that some light reaches them.

In addition to seed propagation, *Rubus caesius* can also be propagated vegetatively through:

- **Cuttings:** Stem cuttings taken in late spring or early summer can be rooted in a soil-based medium. These cuttings are often effective and faster for establishing plants in restoration projects than starting from seed.

- **Layering:** The species can also be propagated by layering, where the stem is bent down to the ground and buried to develop roots at the point of contact with the soil. This method mimics natural processes and is commonly used for brambles in restoration contexts.

Similar in regeneration to *Rubis caesius* is *R. idaeus*. However, *R. idaeus* seeds have mixed dormancy, which sometimes can persist for many years. They benefit from passing through the digestive system of birds and animals. Before planting in nurseries, they require cold stratification of at least one month. With this species alternative regeneration method in nurseries is with root cuttings with length of 7-10 cm.

Because raspberry seeds are rather small, they can easily be distributed also by some additional methods, which do not guarantee germination, but at very cheap:

- ***Seed bombs:*** Raspberry seeds are mixed with clay, compost, and nutrients, then shaped into small balls. They protect seeds from predators and provide moisture for better germination. The bombs can be scattered by hand, drones, or slingshots in targeted restoration sites.
- ***Hydroseeding:*** A slurry of raspberry seeds, mulch, and nutrients is sprayed over degraded land. Works well for steep slopes, eroded lands, and riparian zones where traditional planting is difficult.
- ***Drone Seeding:*** Drones equipped with seed spreaders can distribute raspberry seeds over large, inaccessible areas. Ideal for post-wildfire restoration, deforested lands, and rewilding projects.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring.

After-planting care is usually not necessary as Dewberry is spiny.

In beech forests in SE and central Europe often ***Rubus hirtus*** is found. It is similar to dewberry, but is ground-spreading liana. It can be used to enrich the food sources in Beech-dominated and mixed forests in mountains by planting in small openings in the forests or under the canopy. The species if propagated easily via tip-rooting in autumn.

Corylus avellana (Common hazel) and *Corylus colurna* (Turkish hazel)

Figure 22 *Corylus colurna*

Typical environment and ecological requirements: Hazels are spread in variety of conditions. *Coryllus avellana* usually form bushlands in the mountains of SW Europe, often on habitats formerly dominated by beech, but later transformed to pastures and then abandoned. It can also tolerate various soils including with more calcium content and rocks. The species is cold-tolerant and can also tolerate short periods of drought. By forming larger *Coryllus* bushes and providing durable fat-containing fruits it is one of the important food sources for birds, rodents, larger animals. It can be planted in variety of conditions, but best where beech grows well. ***Coryllus colurna* is less spread, usually as single trees or smaller groups in forests in SE Europe.** It tolerates calcium in soils. Related to *C. avellana*, *C. colurna* it is more drought-tolerant and can be often found in oak-dominated forests on the Balkan Peninsula.

Seed collection: Seeds are collected when ripe, best when they start to fall-off naturally.

Seed germination: Hazel seeds are known to exhibit physical dormancy**,** which means they require specific environmental conditions to break dormancy and successfully germinate. In most cases, cold stratification is needed. Hazel seeds typically require a cold stratification period of 90 to 120 days at 2°C to 5°C. Seeds could also be placed in a moist medium and buried outdoors during winter. Germination occurs best when the seeds are exposed to a temperature range of 18°C to 24°C at spring. Seeds should be lightly covered with soil or sand to allow light penetration, but should not be buried too deeply.

Planting: Hazel saplings can tolerate a wide range of soil types, but heavy clay soils or waterlogged areas should be avoided. The soil should be well-aerated to encourage root development. Adding organic matter can improve soil fertility and water retention (McNamara & Harris, 2002). For optimal growth, hazel trees should be spaced about 3–5 meters apart. This allows enough room for the bushes to grow and spread without competing too much for nutrients and light. Applying mulch around the base of the plants can help retain soil moisture, suppress weeds, and improve soil fertility over time. A 2–4 cm layer of mulch is usually sufficient. If they have to be planted in hardly accessible areas there can be an attempt for spreading with seed bombs.

Replanting from nursery to natural location: As with other trees, the best period to plant the young plants is late autumn. This provides better chances of additional root growth and benefiting from abundant winter water reserves to insure better growth in spring. Early spring planting can be better if in the region winters tend to be harsh and there is higher risk of loss of the very young plants due to freezing.

After-planting care includes fencing for protection from hares and herbivory. A good strategy is to plant it together with Blachthorn and Dog rose and European dewberry which will quickly insure natural protection.

Annex 3

Synthesis of Tested Pilot Actions Implemented in the ForestConnect Project

Pilot interventions were implemented in six countries across close to 100 hectares of mosaic habitats. Although ecological responses require long-term monitoring, several common implementation patterns were observed.

Restoration of Overgrown Mosaic Grasslands

Across multiple pilot sites, abandoned or degraded grasslands were restored through:

- mulching and shrub removal (Romania, Bulgaria, Serbia) ;
- manual mowing (Slovakia);
- selective clearing around fruit-bearing species (Montenegro, Bulgaria).

Figure 23 Hand-mowing festival in Slovakia. Photo credit: Marek Leskovjanský, NP Slovenský raj

Observed short-term outcomes (in all countries):

- improved openness and structural heterogeneity ;
- increased use by ungulates and other wildlife species;
- enhanced landscape permeability within connectivity sectors.

The time frame of the project was insufficient to demonstrate direct causal effects on large carnivore presence, but habitat structure improved measurably.

Establishment and Support of Fruit-Bearing Species

Pilot actions tested both:

- planting of native fruit trees and shrubs (Bulgaria, Montenegro, Romania, Serbia, Slovakia, Ukraine);
- support and pruning of naturally occurring fruit-bearing individuals (Bulgaria, Montenegro).

Figure 64 Planting of forest fruit tree saplings in Western Stara Planina, Bulgaria. Photo: Ivaylo Angelov.

Creation of Climate-Resilient Forest Microrefugia

In fire-damaged or degraded forest areas, pilot actions included:

- removal of damaged trees (Montenegro, Serbia);
- use of deadwood to create terraces and reduce erosion (Montenegro);
- targeted planting in microclimatically suitable locations (Bulgaria, Montenegro, Romania, Serbia, Slovakia, Ukraine);.

Figure 75 Creation of anti-erosion terraces in Durmitor NP, Montenegro. Photo: Mila Zarubica and Ibrahim Fazlić

Monitoring and Adaptive Learning (all countries)

Monitoring was conducted using camera traps and field observations before and after interventions. Findings indicate:

- consistent wildlife presence in intervention sites;
- no direct causal link between measures and large carnivore increase within the short project duration (Romania);
- strong justification for long-term monitoring beyond project lifetime.

Figure 86 Camera traps image in Apuseni, Romnia.

The pilot actions demonstrate that mosaic habitat management is feasible across diverse national contexts and that relatively low-intensity interventions can improve habitat structure within connectivity sectors.

Summary Table of Tested Measures and Transferability

The table below summarises the main categories of measures tested within the ForestConnect pilot actions, the key short-term observations, lessons learned and their potential for replication across transnational mosaic habitats.

Table 1. Summary of Tested Mosaic Habitat Measures and Transferability Potential

Measure Type	Key Actions Tested	Short-Term Observations	Key Lessons Learned	Transferability Potential
Grassland Restoration	Mulching, manual mowing, shrub removal, stump removal	Improved openness and structural heterogeneity; increased use by ungulates	Follow-up management is essential; avoid heavy machinery in erosion-prone areas	High – applicable in abandoned or overgrown mosaic habitats
Support of Existing Fruit-Bearing Species	Pruning, clearing around natural fruit trees, crown shaping	Improved light access and fruiting potential	Supporting existing trees is often more effective than establishing new	High – low-cost, low-risk intervention

			compact plantations	
Planting of Native Fruit Trees and Shrubs	Planting wild pear, apple, cherry plum, rosehip, etc.; sapling protection	Establishment success variable; dependent on climate and maintenance	Nursery capacity and local genetic material are critical; long-term care required	Medium to High – requires planning and maintenance
Forest Microrefugia Creation	Removal of damaged trees; deadwood terraces; targeted planting	Strong natural regeneration in some sites; improved structural diversity	Passive regeneration may complement or outperform planting in some contexts	Medium to High – context-dependent
Nature-Based Forestry Measures	Selective thinning; habitat tree retention; deadwood preservation	Increased structural complexity	Must align with forest management regulations	High – compatible with multifunctional forest management
Monitoring and Adaptive Management	Camera traps; pre- and post-intervention assessment	Wildlife presence confirmed; no short-term causality proven	Long-term monitoring needed beyond project duration	High – essential for replication

The synthesis confirms that mosaic habitat management can rely on relatively low-intensity, site-specific interventions that are scalable across national contexts, provided that long-term maintenance and monitoring are ensured.

Strategic Conclusion

The tested measures confirm that:

- mosaic habitat restoration enhances structural heterogeneity;
- integration of open habitats and forest elements strengthens ecological connectivity;
- adaptive, site-specific management is essential for climate resilience;
- transnational replication is feasible when aligned with national legal frameworks and management plans.

Consolidated Lessons Learnt from the ForestConnect Pilot Actions

The pilot actions implemented across approximately 83 hectares of mosaic habitats generated valuable operational and ecological insights. The most relevant consolidated lessons include:

A) Ecological lessons

- Moderate, targeted interventions can rapidly improve structural heterogeneity and landscape permeability.
- Supporting existing fruit-bearing trees is often more effective and resilient than establishing compact new plantations.
- In post-disturbance forest areas, passive regeneration combined with limited structural intervention may outperform large-scale planting.
- Mosaic functionality depends on maintaining gradients and transitional structures rather than sharp habitat boundaries.

B) Operational lessons

- Early planning is critical, especially regarding sapling availability and nursery capacity.
- Timing must be adapted to mountain climatic constraints; flexibility and contingency planning are essential.
- Heavy machinery in erosion-prone terrain significantly increases ecological risk.
- Long-term maintenance (mowing, grazing, follow-up pruning) determines success more than initial intervention intensity.

- **Governance and institutional lessons**
  - Stakeholder validation strongly increases feasibility and social acceptance.
  - Clear allocation of responsibilities before implementation prevents operational delays.
  - Integration into protected area and forest management plans is essential for continuity beyond project funding.
- **Monitoring lessons**

- Short-term monitoring confirms wildlife presence but cannot demonstrate immediate causal effects on large carnivore abundance.
- Simplified, repeatable indicator sets are more feasible than complex monitoring schemes.
- Adaptive management must be embedded from the start rather than added retrospectively.

Together, these lessons confirm that mosaic habitat management is feasible across diverse national contexts when ecological logic, operational realism and institutional cooperation are aligned.

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