Interreg CENTRAL EUROPE

Co-funded by the European Union

PoLaRecCE

# Action plan developed for land degraded by long-term poor agricultural farming

## WP2 - Best available practices and on-site techniques for environmental site assessment and soil recovery

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# Executive summary

The goal of the PoLaRecCE project is to revitalize polluted and/or degraded agricultural soils. After performing of field measurement campaigns, professional discussions and a review of the literature it the frame of this project, it was concluded that a new type of non-food, energetic plantation or tree row technology could be applied as an alternative for the revitalization of contaminated lands.

The works performed under this Action plan provide several new perspectives how to handle the degraded and non-used lands. This project is considered as a novel approach, since it suggests application of a mixture of fast-growing tree species, to maximize their accumulation capabilities and vitality-health status. The priority is given to non-food agriculture, since the investigated areas (including pilot site) cannot be temporarily or permanently utilized for food production. The chosen tree species will serve as an energy source, which means either unsliced firewood or wood chips as a final product, in addition to the fact that cellulose or industrial wood utilization is also possible in some of these plantations.

This report provides also technical guidelines and financial calculations, showing positive aspects of the proposed strategy. The main benefit is that the tree planting serves local community. Additional plantations are foreseen within the framework of other community activities.
As indicated by the EU policy it is necessary to significantly limit the greenhouse gas emissions by 2030. The plantations capturing $CO_2$ are of great importance, since these provide an additional step to fulfil this goal. This also creates an opportunity for the proposed plantations and tree rows to be more competitive on the local and EU market in the case of financial benefits.

We interpret every tree planting as a community action. During the creation of the strategy, we aimed to ensure that the target groups using our methods (farmers, local land users, agricultural experts) can easily and cheaply adapt them and multiply the effects of the project.

These new types of energy plantations also have significant, measurable and calculable $CO_2$ sequestration potential. The growth of trees is the only truly effective and cheap $CO_2$ absorption mechanism in the world today. We encouraged the members of our target groups to feel responsible for this. With our strategy, we want to give farmers and local land users the skills that will make tree planting a simple routine for a wide range of target groups.

# 1 INTRODUCTION

## 1.1 Objectives

Overuse of agricultural soils is a problem throughout Europe, but in fact a phenomenon experienced all over the world. Crop rotation of agricultural soils appeared in parallel with the industrial revolution: an interesting addition is that soil protection was one of the goals of crop rotation itself. With the mass appearance of agricultural tractors, another paradigm shift took place in agriculture and forestry (since the 1920s).

Mechanized, factory-style agriculture has therefore been shaping a significant part of the Earth's surface for over 100+ years (in the EU alone, we cultivate about 100 million ha of arable land). Mechanical trampling, pesticides and fertilizers, same cultivation depth in long time, irrigation and many other factors have also resulted in drastic and large-scale soil degradation during this time. Soil life deteriorated, significant soil compaction developed, and soils became airless. In Eastern and Southern Europe, groundwater levels have also been falling for decades due to climate change.

Grasslands and forests are much less exposed to soil degradation, as cultivation is significantly more extensive in these areas. These areas are typically richer in species and closer to natural soil conditions.

Within the framework of the PoLaRecCE project, we have established an experimental area, specifically for demonstration purposes, to illustrate that local soil conditions can be noticeably improved by planting tree rows and tree groves to revitalize locally the degraded agricultural soils. The concept basically aims for farmers to plant energy forests in three different designs:

- full-area afforestation (unfavorable terrain, steep areas, waterlogged areas, saline areas)
- detailed area afforestation (corners, strips, meandering edges, tree groups or small groves)
- treeline afforestation (tree-rows around the fields)

These afforestations basically provide raw materials for the energy and fiber industries (in firewood and fiberwood quality).
The objective of this document is to describe the strategy and action plan for the Dél-Alföld pilot site, including one or more alternative development paths and the selection of the optimal procedure to be implemented in the pilot area. The Action plan also includes the financial model of the investment and the cost-benefit analysis for end users.

## 1.2 Scope

The subject of the report is Dél-Alföld pilot site located in south-eastern Hungary. The report includes the site description, containing information about its location in relation to the potential sources of pollution, both current and historical. Climatic conditions and their changes in the last decades. Based on earlier investigations the current state of land degradation is analysed as the starting point for the further strategy of development and possibility of adaptation for non-food agricultural production (energy and fiber are main focus). The proposed land management directions are discussed including also possible alternatives for food production or non-food agriculture. The relevance of the planned investments for local communities and municipal management plans. The development strategy involves also financial models of investment, and cost-benefit analysis related to the local market for the agricultural product. The report also includes technical guidelines for development and maintenance of the facility and risk assessment for the investment.

## 1.4 Intended Audience

This document is intended for local and regional administration, advisors and policymakers involved in soil management, farmers and landowners.

The younger generation knows very little about soil conditions (basically about soil as well). We also go to kindergartens and primary schools, where we give presentations on soil and soil protection, and plant trees together. Planting trees is a forgotten skill among the younger generations. We have a vision to rebuild this skill for young people, so that it becomes part of the general knowledge among young people, just like someone can ride a bike or swim.

Planting trees is currently practically the only effective solution in terms of $CO_2$ absorption, so it serves to mitigate the effects of climate change and protect the soil in parallel (regardless of whether we plant trees on the edge of an agricultural area, in a city or in any polluted area).

## 1.5 Usage guidelines

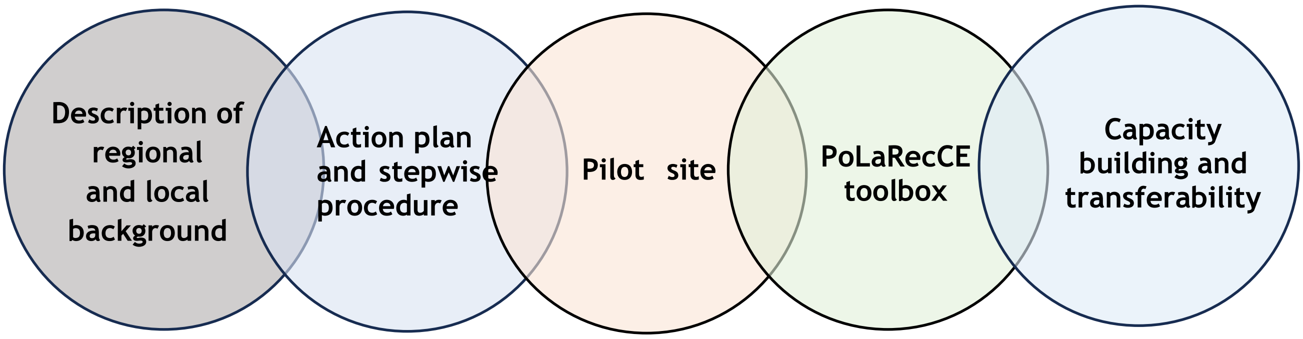
As a training material for end-users, this document has been written in an easy-to-understand language, supported by explanatory schemes, tables and figures. However, proper references are provided to allow those interested to further explore the topic.

# 2 METHODOLOGY

During the further development of the action plans prepared within the framework of the PoLaRecCE project, we built some elements in the same way, but of course, independent thinking and different outputs were created for each pilot site type.

Building of the strategy and action plan for management of soils poor agricultural consists of 5 connected elements (Figure 1):

*1. Figure: Five-element PoLaRecCE strategy diagram*




The background section constitutes the analytical part of the study, identifying and monitoring emerging issues and signals of change in both the internal and external environment, while describing the current situation at the regional and local levels. Primary step is to properly identify driving forces and evaluate the state of the art with collection of **background data** concentrated on the situation in agricultural areas of Sout-East Hungary (Hungarian Great Plainland "Alföld"), especially Dél-Alföld region, Gyomaendrőd municipality.

The starting point of each **action plan** is a clear vision and strategy for the plan as the most interactive stage of the process is devoted to the development of goals, alternatives solutions in reaction to the identified challenges, problems and potentials. The expected outcomes of the plan and associated objectives and targets should be developed and assessed from the point of their coherence, achievability and responsibilities of actors. Different scenarios should be considered discussed and assessed. They should be confronted with existing local, regional and national policies. Finally, the **stepwise procedure** should be developed to ensure control, better planning and efficiency by carrying out activities in a specific sequence, often based on management functions: planning, organizing, leading and controlling.

The procedure was tested at a **pilot site** located in the Gyomaendrőd municipality. The optimal solution was selected from several possible alternatives, taking into account local environmental conditions, climate change impacts, social circumstances, and the investment financing model, as well as a cost-benefit analysis for end users.

**Capacity building** involves the development of skills and the enhancement of competencies among local and regional authorities, landowners and managers, as well as individual farmers and members of farmers' organizations. It improves institutional structures, management practices, and operational strategies at various levels through training, mentoring, exchange of experience, and improved access to technology and financing. A crucial element of the strategy is **transferability**, understood as the potential to apply the developed solutions in other areas of Central Europe degraded by long term agricultural management, resulting from historical soil contamination (chemical contaminations made by last 100 years).

# 3 BACKGROUND

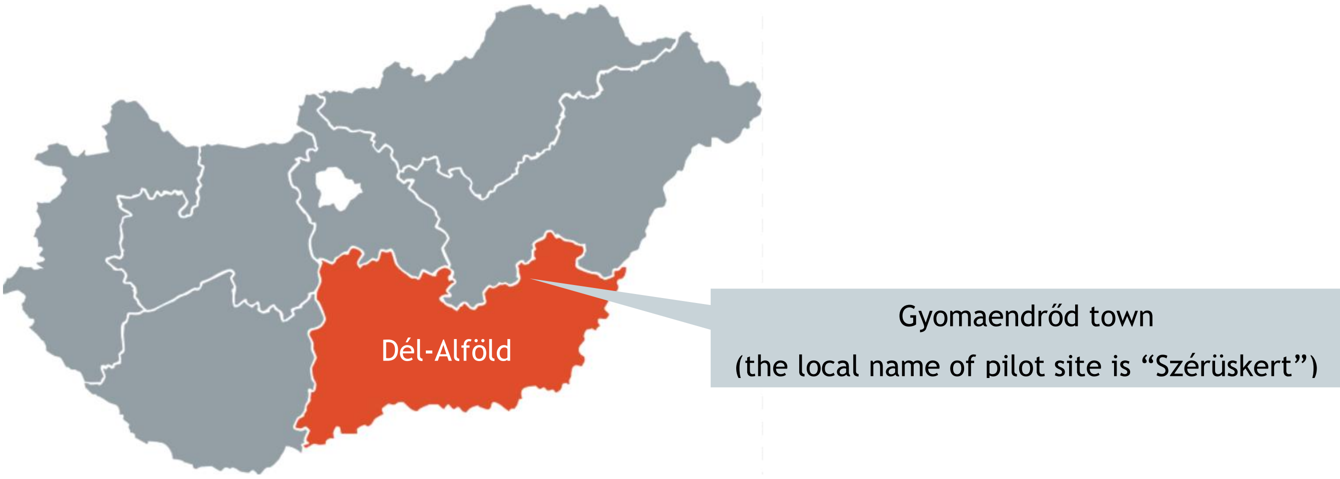
## 3.1 Regional background

The total arable area of the Carpathian Basin is approx. 14 million ha, of which approx. 4.5 million ha are in Hungary (approx. half of Hungary is arable). A large part of today's arable land and grasslands were typically formed in the Middle Ages. There were three main reasons for deforestation:

- in mountainous areas, forests typically served the timber needs of mining, and the extracted areas were converted to grazing, this process began to be regulated during the time of Maria Theresia and the forests were partly reforested;
- in hilly and lowland areas, crop production became increasingly intensive (crop rotation also appeared in agriculture), and grazing/mowing also became important, settlements also needed space, roads and railways (national infrastructures) were built,
- in the era of river regulation, river valleys changed drastically, forests were cut down and new forests were created, but the forest area typically decreased even after this.

So, arable land was formed in place of forests and casting areas. Terraforming therefore became increasingly intensive over time, and this intensive period still continues today. The widespread use of agricultural tractors since the 1920s has also brought drastic changes in land use and the intensity of land use. Today, there are 120,000 active tractors in use in Hungary (on average, each tractor covers about 40-50 hectares of land).

*2. Figure: Location of "Dél-Alföld" regio, as main focus of pilot site - the region is the gateway to climate change in the Carpathian Basin*




**Organic farming**

In Hungary (and in the Carpathian Basin, except for Burgenland/Austria), the proportion of organic farming (farms that are chemical-free or use reduced chemicals) is extremely low, regionally it is between approx. 6-8%. The growth rate is also low. In Hungary, organic farming was able to develop to this level in 35 years. The situation is similar in the surrounding countries (Burgenland/Austria is an exception, where it is around 30-35%).

Organic farming is an excellent solution in terms of soil life and soil health, the restoration of degraded soils here also takes 10-15 years, a demonstrably effective solution. In Hungary, there have been several government programs in recent decades to develop organic farming, and there is such a government program now. Based on conservative estimates, the doubling of the current areas can be forecast on a decade scale.

**Energy plantations (in different form of tree lines, groves, partial afforestation, agroforestry)**

There was a government program in the socialist years of the 1970s and 1980s when tree rows and partial afforestation were planted en masse around large-scale arable fields. There were 35,000+ hectares of tree rows and partial areas, at that time, and in some settlements in the Great Plain/Alföld, every edge was afforested. There were several types of tree rows and partial afforested areas: typically, a mixture of fast-growing and slow-growing, deciduous and evergreen species, but there were also areas of single species. Numerous studies and articles have examined the positive effects of these activities on the microclimate.

These tree rows and partial afforestation projects typically became old after the privatization of the 1990s, and farmers cut them down. The EU's agricultural subsidies also had an extreme impact on the tree rows and partly afforested agricultural areas: according to Hungarian rules, these were not eligible for agricultural subsidies for more than a two decades, so farmers had them uprooted en masse, because if they were found during on-site inspections, they were removed from the eligible area. The result of this was that the tree rows/groves were lost, today only a fraction of the former tree rows and edgy forests can be found.

Since 2025, the area of tree rows and tree groups has been eligible for support again under EU area-based subsidies, and a new tree row or partial afforested planting support is also available for farmers. The success of the new application is perhaps demonstrated by the fact that after the first round of submissions: only 60 farmers from all over the country submitted applications (there are 196,000 farms in Hungary). Together with the University of Göttingen, WOODTECH & Gyoma-Felsőrészi Olvasó és Gazdakör (as local farmer association) is preparing an international agroforestry survey, within the framework of which the motivations of farmers planning tree rows and partial afforestation are monitored. The research is still ongoing, but the first results have brought the following results:

- farmers have an extremely low level of knowledge about the importance of tree lines/groves and partial afforested areas, they know that they are necessary and that they are a good thing, but they cannot define the benefits precisely, and they simply do not know many of the benefits,
- there are few mixed farms where arable land and forest are together, so many farmers do not have any forestry knowledge,
- they feel that the area of the trees "steals" the arable land, so they are reluctant to use it,
- little time has passed since the EU support rules "punished" trees, and farmers cannot change so quickly that they will at least spare the tree rows from now on, since previously they had to be cut down for 20 years for the farmer to receive support,
- they have almost no knowledge about what tree species should be planted, in what arrangement and with what care requirements,
- as with schoolchildren and we have also seen in kindergartens that even among farmers, knowledge of tree planting is lacking, and since there is no stable knowledge, few dare to plant trees.

The regional outlook is therefore gloomy. However, the mission to have tree rows/groves/partial afforested areas around arable land again cannot be saved. This must be undertaken and every opportunity must be seized. One of the objectives of the PoLaRecCE project is to revitalize degraded agricultural soils, and one excellent way to do this is to (re)develop with trees around field edges.

**Normal (full-area) forestry**

In Hungary, areas over 5,000 $m^2$ covered with trees are legally considered as forests. Below this, it is only called "woody area", which has much fewer restrictions (e.g. it can be liquidated and converted back to arable land at any time). Areas over 5,000 $m^2$ that are used for forest cultivation cannot be converted into arable land. Farmers do not convert their land over 5,000 $m^2$ into forests due to strict forestry regulations.

However, temporary energy plantations, tree rows, and partially wooded areas are a good opportunity to effectively revitalize overused agricultural areas and preserve farmers' arable land.

Of the three variations above, we recommend small-area (maximum 5,000 $m^2$) energy plantations in various spatial/areal forms (tree lines, groves, tree groups, agroforestry, tree strips, small-area afforestation). In section 4.3, we examined further alternatives, but the energy plantation was the most suitable for local needs and opportunities.

## 3.2 Local background

As part of the project, we planted a sample area with 500 trees on an area of 1800 $m^2$. The goal is basically to produce energy wood (thin and thick firewood, wood chips) and pulpwood as a diversification target for farmers. This is a demonstration tree plantation. The goal is to test different tree species on the site, and at the same time to show the farmers the steps of planting and maintenance, and to document the entire process.

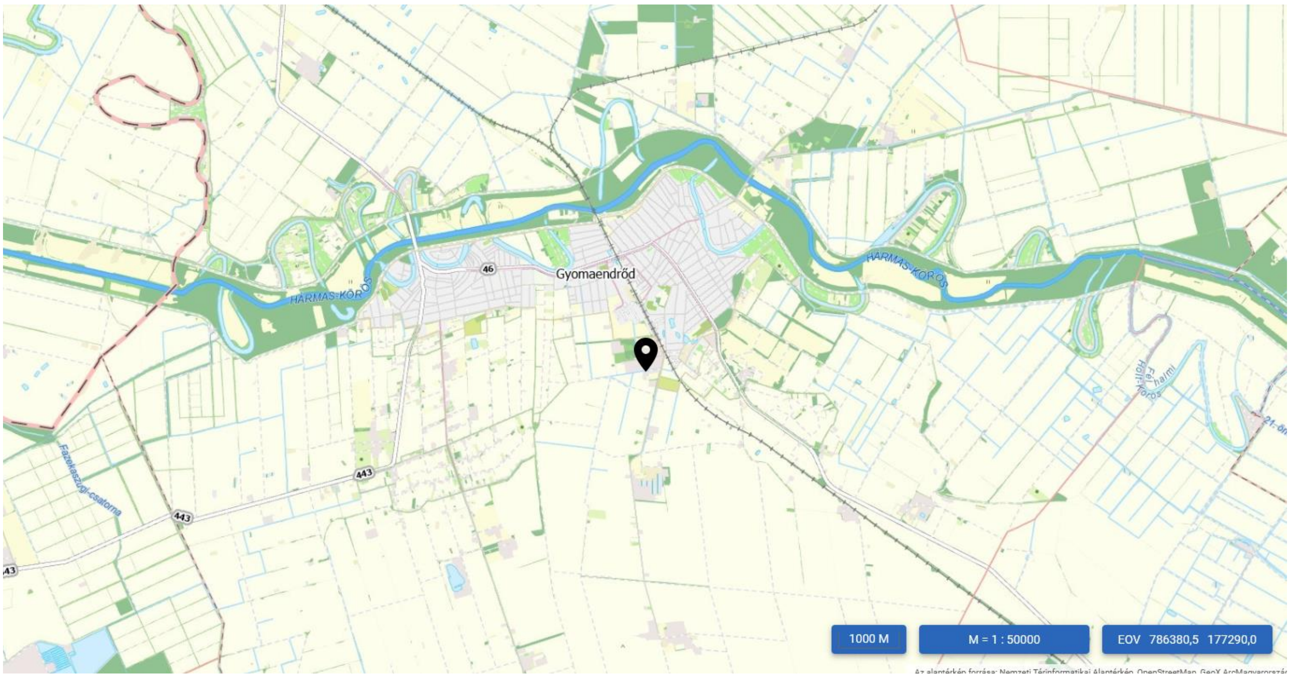
### 3.2.1 Area location and climatic conditions

The Dél-Alföld pilot site (Figures 1-3) is in SE part of Hungary, and its area reaches 1.800 $m^2$ (GPS coordinates: 46.916200, 20.821489). Similarly, as the Dél-Alföld pilot site it is situated in the zone of continental climate with very hot and dry summers. Drought season has been lately observed in this region, which significantly affects the production of crops. For many years Dél-Alföld pilot site (NUT2 region is Dél-Alföld) was used for agricultural cultivation, however from the 1980s, it acted as an abandoned wasteland. Different types of waste were deposited in the area (e.g. concrete, residential waste) and at the same time old machines were stored at this location, which caused oil contamination. Moreover, the investigated site was affected by periodic floods (from Hármas-Körös River), which additionally contaminated the local soil. The area of the investment is owned by the “Gyoma-Felsőrészi Olvasó és Gazdakör”, acting as a local farmer association (as member of nationwide active “Gazdakörök” farmers movement).

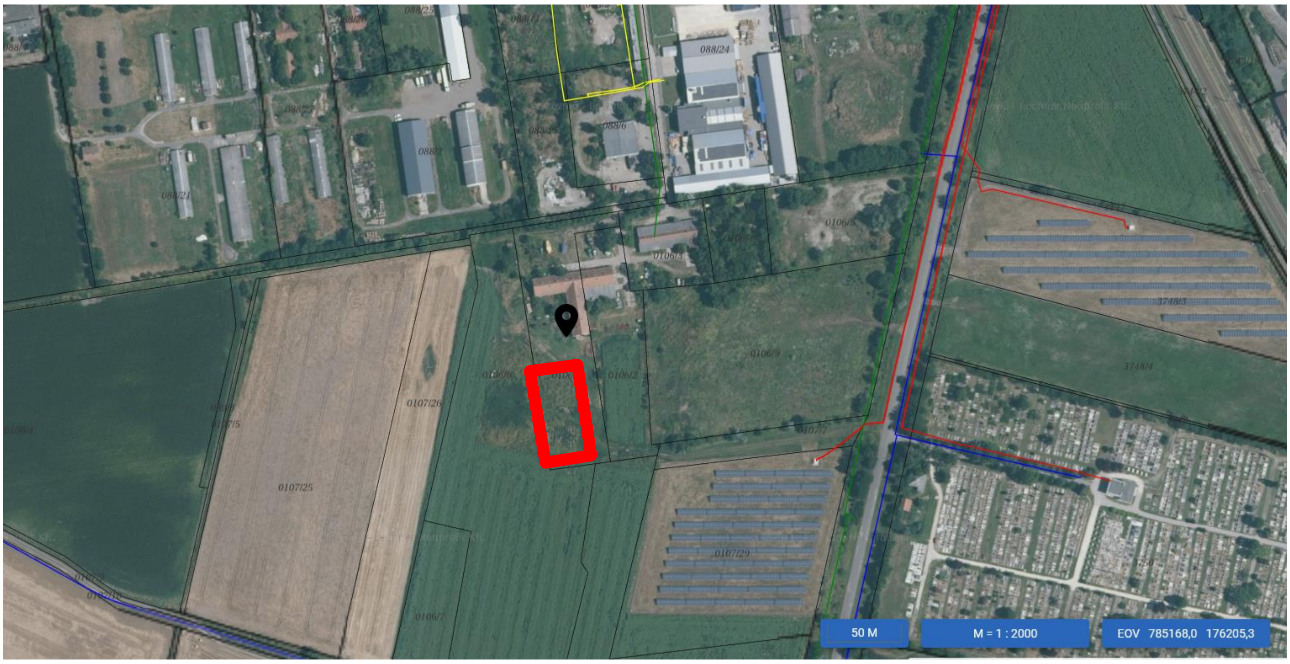
In August 2024, the local farmer association cleaned the area, replaced the stolen soil with local soil, leveled the surface, removed the concrete debris, and made it suitable for cultivation. Many smaller pieces of concrete may still be in the ground. The local soil is classified as the “meadow soil”; it from the flood of the ancient Hármas-Körös river. Altitude is 89 meters from sea level. To this report the old maps from the archives were collected (Figures 4-9) in order to track the “cultivation path” of the area belonging to the Dél-Alföld pilot site that took place for several centuries.

We planted the trees in the spring of 2025 and replaced them in the winter of 2025 and the spring of 2026. In May 2026, the trees also received a unique protective net because there are many roedeer and hares in the area, and previous damage from wildlife was significant.

*3. Figure: Local map (2021) indicating Dél-Alföld pilot site*

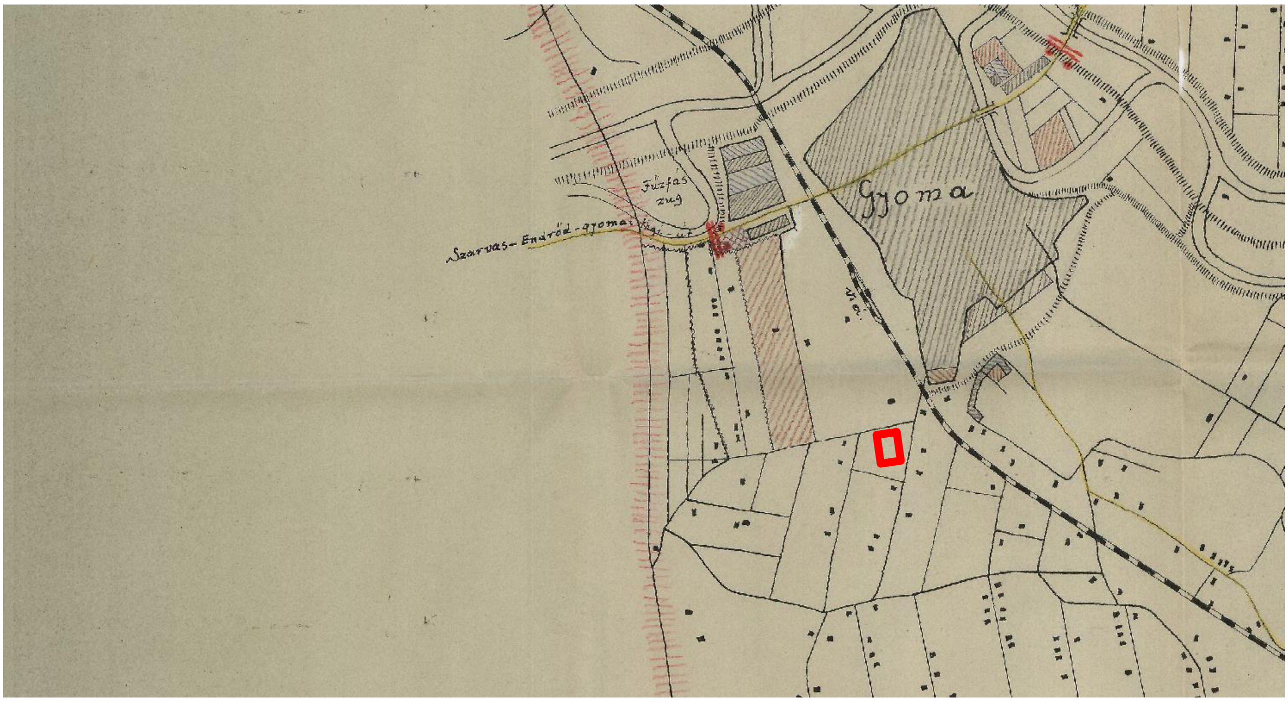


*4. Figure: Ortophotomap (2023) showing the location of Dél-Alföld pilot site (red rectangle)*

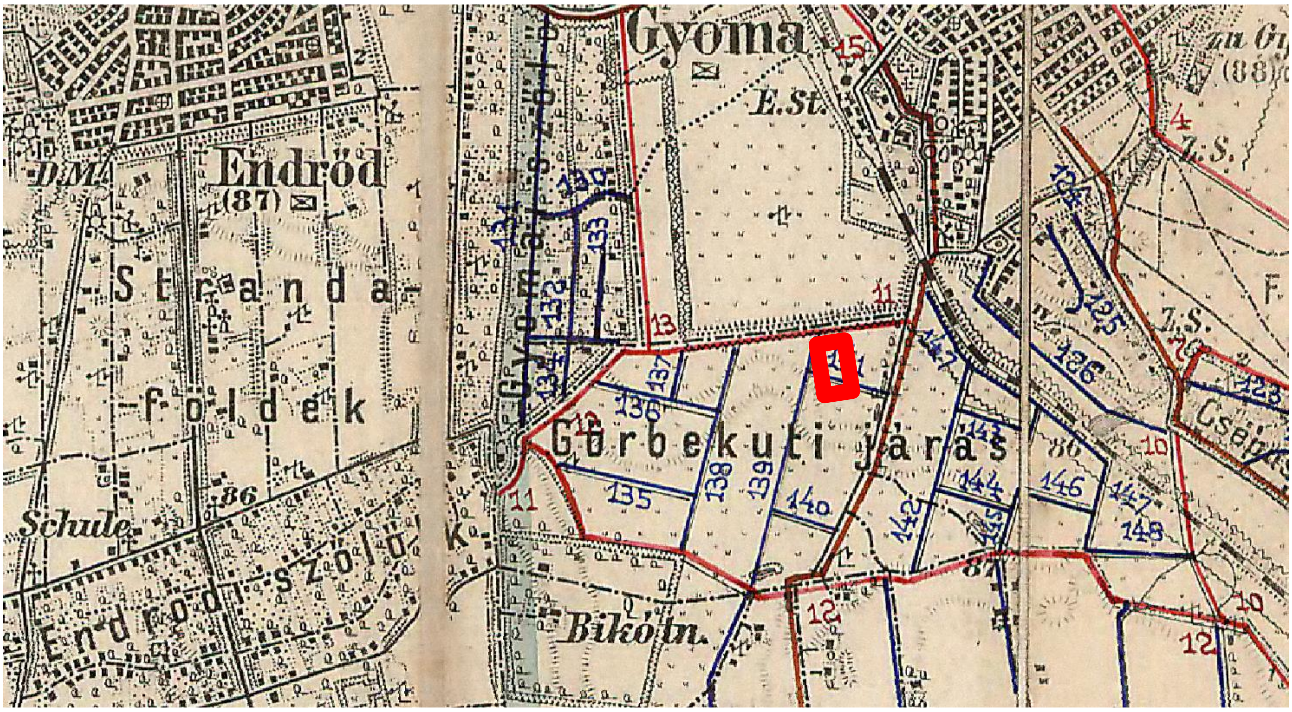



*5. Figure: Ortophotomap (2005) showing the location of Dél-Alföld pilot site (red rectangle)*

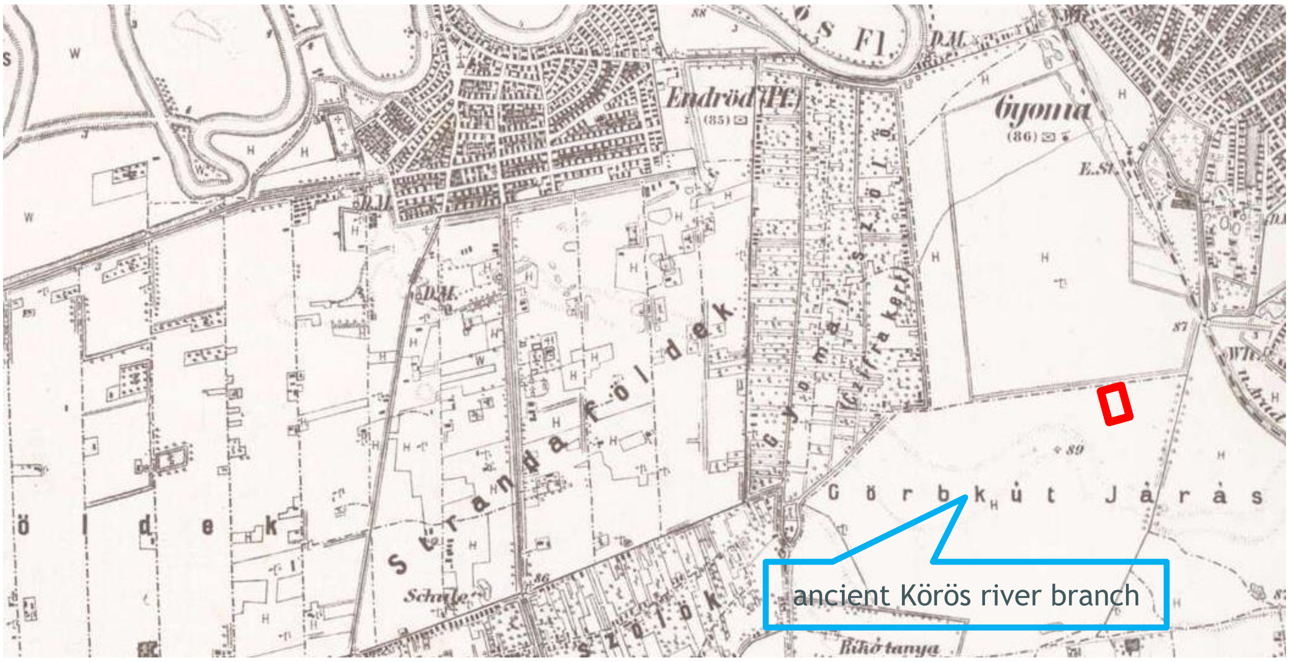
*6. Figure: Map from the Year 1945, after II. WW, showing agricultural area. The Dél-Alföld pilot site is marked by the red rectangle*



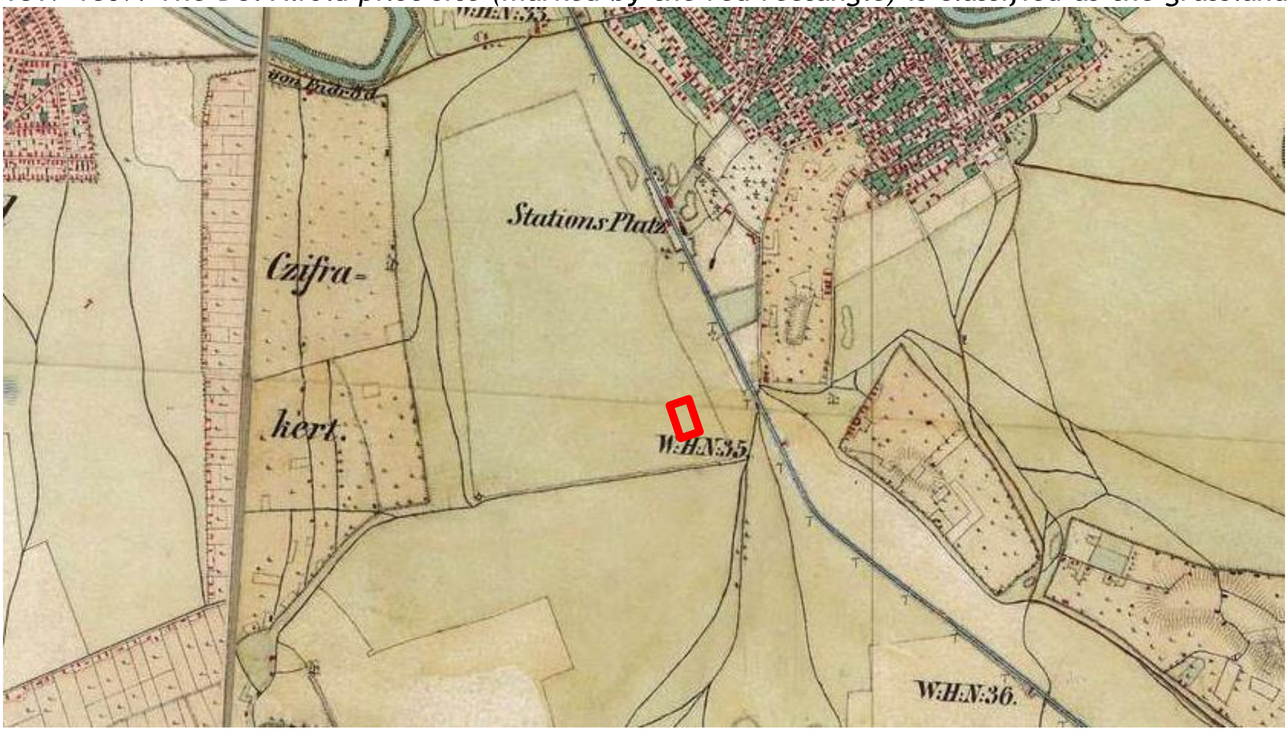

*7. Figure: Map from the Year 1909, Austro-Hungarian Monarchy, showing agricultural area. The Dél-Alföld pilot site is marked by the red rectangle*



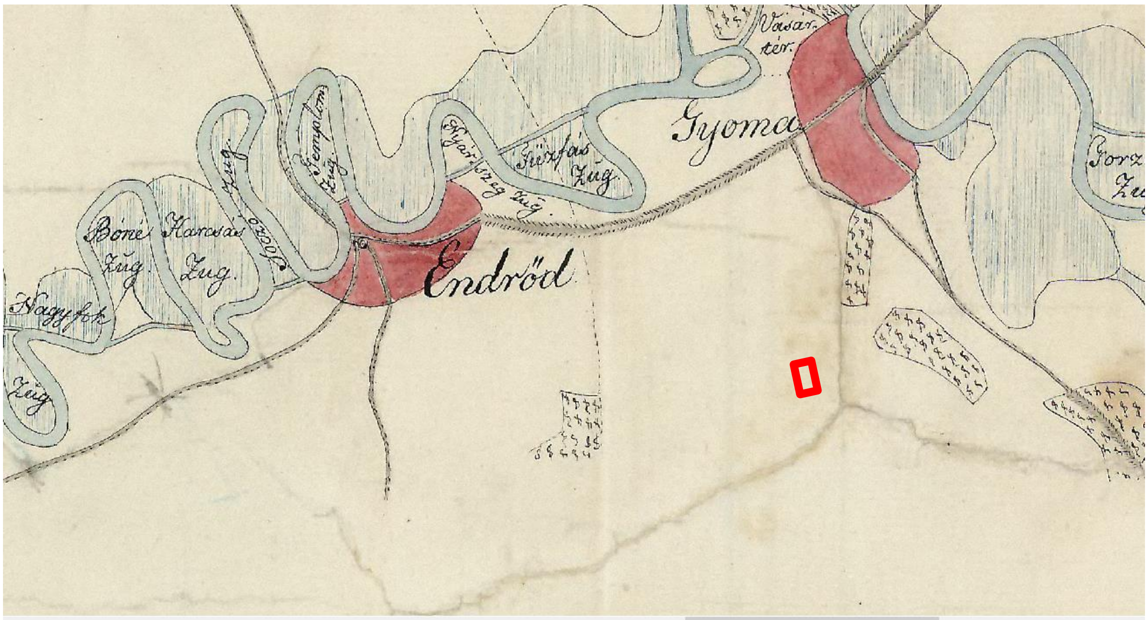
*8. Figure: Map created during 3rd military mapping in Habsburg Empire – Kingdom of Hungary in 1869-1887, agricultural area. The Dél-Alföld pilot site (marked by the red rectangle) is located on the partly wet meadow*




9. *Figure: Map created during 2nd military mapping in Habsburg Empire – Kingdom of Hungary in 1819-1869. The* Dél-Alföld *pilot site (marked by the red rectangle) is classified as the grassland*



*10. Figure: Map from the Year 1836, agricultural area. The Dél-Alföld pilot site (marked by the red rectangle) is located on the partly wet meadow (vineyards from before the phylloxera epidemic are also visible)*




*11. Figure: Map created during 1st military mapping in Habsburg Empire – Kingdom of Hungary in 1782-1785. The Dél-Alföld pilot site (marked by the red rectangle) is classified as the community grassland*

## 3.2.2 Initial state of land degradation and soil quality

In previous report (D.2.3.2), the investigated pilot site has been affected by long-term poor agricultural practices (e.g., nutrient depletion, over-fertilization, pesticide contamination) and by discharges from a landfill. In general, the concentrations of most investigated metals and metalloids are below the Hungarian national threshold values and do not pose a significant risk for non-food agricultural use. Poor agricultural practices—particularly over-fertilization and the application of sewage sludge—are responsible for elevated nickel concentrations in the central and eastern parts of the pilot site. Across the entire site, cadmium concentrations exceeded the threshold value (0,756 mg/kg). The concentrations of pollutants should not adversely affect tree species, and their potential accumulation in wood biomass used for energy purposes is not expected to pose an ecological risk.

Because of long-term poor agricultural practices, these soils are significantly depleted in carbon. Conversely, their quality, as assessed by the Visual Soil Assessment (VSA), is rated as good. This apparent discrepancy is primarily due to a mismatch between soil organic carbon stocks and physical properties. Indeed, these soils do not exhibit any major physical limitations, as indicated by both bulk density measurements and the visual assessment of key physical characteristics such as texture and porosity. As a result, root growth is not restricted, and there is no evidence of water stagnation (e.g., no mottling or ponding observed). The VSA methodology is based on the visual assessment of key indicators of soil status and crop performance. The good physical condition of these soils clearly supports plant growth, particularly for tree species. However, good soil management practices will be necessary to prevent further degradation.

Nutrient analyses conducted at the pilot site revealed low $N_{min}$ values, below 40 kg N $ha^{-1}$. Therefore, the total amount of nitrogen required should be applied. For grasslands with legumes, the recommended rate is 0–40 kg N $ha^{-1}$ per year, while for grasslands without legumes, 40–80 kg N $ha^{-1}$ should be applied annually. Slight exceedances of Nmin in some individual spots can be disregarded. Phosphorus contents are low; therefore, fertilization is recommended at a rate of 50 mg P $kg^{-1}$. In contrast, potassium (K) contents are high, so only small amounts—or none at all—of K fertilizers should be applied.

# 4 ACTION PLAN

The plantation established for the purpose of this project has already been visited by the representatives of the local government and the vice-president of the county government. The local and county governments agree with the development goals, and they will help with the demonstration tasks. The project objectives are also in line with the ones described in the Gyomaendrőd City Development Plan document (green economic objectives).

The formation of energy plantations can be transformed into a community movement. A significant part of urban society has never planted a tree in its lifetime, or if it has such experience, it often involves very inconvenient and complicated processes.

When establishing new types of energy plantations, a practical approach is applied that does not require special forestry or horticultural knowledge. An affordable, forest-grown seedlings can be planted in rows or in a defined grid, using simple tools (wedge digger, hand hole drill), a unique protective net, mulching, and simple irrigation solutions. Farmers and other interested parties can also learn these techniques easily and safely.

The establishment of energy plantations can be converted into a community program. With a little organizational input, this can be expanded into a social activity with community-building power. Such a community experience creates a living connection between farmers and young people: it is possible to encourage a significant number of people to be more attracted to forests/trees, agriculture, forestry and gardening.

Energy plantations bring also an additional benefit to community life (fresh air, landscape aesthetics, shade effect, etc.). With the tree planting experience, we can raise the awareness of the local community about these “unnoticeable” improvements.

It is a common practice to plant a tree in schools or by politicians, as a demonstration. These one or a few trees have neither a commercial and a real environmental impact. However, well-thought-out, planned energy plantations have a measurable and multipliable impact on a community.

The issue of forests/trees is always in the interest of communities. The EU takes the relationship between forests/trees and society extremely seriously, and this is also reflected in the regulations. The EUTR (EU Timber Regulation) has been in place for years, also due to the special relationship between trees/forests and society. There is a huge political debate about the new EUDR (EU Deforestation Regulation), which will bring extraordinary administrative and regulatory innovations and burdens to the EU/global trade in trees/timber.

This project provides a response to these trends by developing a new type of energy plantation system, for farmers, incorporating community goals at the same time. Not only do the existing trees provide benefits for communities, but their establishment itself can be converted into a community experience.

## 4.1 Recognizing the problem (PoLaRecCE - EU-policy)

In Central Europe (CE), the sustainable management of agricultural soils contaminated or degraded by chemical pollution resulting from industrial and urban deposition poses significant administrative and social challenges. Contaminated soils are typically removed from production and become wasteland, representing a substantial loss of the soil's biological potential. There is a lack of common and harmonized guidelines that could be applied across countries and administrative levels. The procedures developed within the project enable effective soil condition assessment based on innovative, predominantly field-based measurement techniques and methodologies. This makes it possible to evaluate the suitability of degraded soils for direct non-food agricultural production or to determine the need for reclamation measures aimed at restoring their biological activity and productivity.

The assumptions of the PoLaRecCE project are fully aligned with the European Union's policy on reducing environmental pollution and restoring the functional value of degraded areas. The main objective of the Soil Monitoring Law (Directive (EU) 2025/2360), as well as the PoLaRecCE strategy, is to reduce soil pollution to levels that are no longer considered harmful to human health and the environment. The practical implementation of the project strategy will contribute to the gradual improvement of soil conditions in the Dél-Alföld region and may be adopted in other regions touched with poor-agricultural practice of Central Europe and the entire EU territory. This project represents one of the first comprehensive attempts to improve the quality of soils degraded by industrial and urban deposition to achieve healthy soils by 2050, given that soils host more than 25% of global biodiversity and constitute the second-largest carbon pool on the planet. Healthy soils, which capture and store carbon, also contribute to achieving the Union's climate objectives. The project also represents an important step toward enhancing biodiversity, ecosystem functions and services, ecological integrity, and connectivity, in line with the Convention on Biological Diversity.

Finally, the PoLaRecCE project strategy aims to develop innovative tools and approaches that support land management practices to better adapt degraded soils to the environmental, social, and economic needs of local communities. The guidelines developed within the project emphasize the need to assess soil condition before restoring its productive role to propose appropriate land management directions.

## 4.2 Effective environmental site assessment procedure (Ecological Services)

**EFFECTIVE ENVIRONMENTAL SITE ASSESSMENT PROCEDURE** is a fundamental element in the development of strategies for the recovery of degraded agricultural land for purposes other than food production.

The starting point is:

**A. Characterization of the site based on existing/current soil and climatic conditions**

This characterization includes the following elements:

1. Geographical location of the site (geographic coordinates, province, municipality, land use). Graphical representation based on GIS tools.

2. Climatic conditions (based on multi-year data) considering parameters such as: length of the growing season, average annual air temperatures, average temperatures during the growing season, amount of precipitation during the growing season, length of the frost-free period).

3. Current soil conditions (soil type and subtype, fertility class) include the determination of the degree of soil degradation based on national and EU legal acts (e.g. Directive (EU) 2025/2360) Determining the sources and causes of soil degradation based on historical data.

Environmental assessment of the site and its immediate surroundings, including the state of habitats and valuable existing fauna and flora species. Determining whether there are any protected areas nearby according to Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora; Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

### B. Analysis of potential directions of land development and use within the framework of current environmental conditions and local land development and agricultural plans within individual municipalities and agricultural organisations

Local land development plans should consider assumptions at the regional level. A Regional Climate and Energy Action Plan has been established Dél-Alföld region in year 2020.

One of the goals of the European Union's climate and energy policy until 2030 is to increase the share of energy from renewable sources to at least 32% of gross final energy consumption. Energy plantations are part of this goal.

### C. Ecosystem services

Soils are considered as important and strategic natural capital. Soil ecosystem services can bring provisions in nutrition, materials and energy, can bring also mediation of wastes, toxic elements. In addition, non-degraded areas can provide cultural services (physical, spiritual and symbolic interactions with soil biota or landscape). Quantity and quality of soil ecosystem services depend on proper management. On degraded areas soil cannot be capable to fulfill all its services, especially food production.

The determination of the potential of ecosystem services results from the implementation of the following stages:

1. Initial State – Analysis of applicable legislation and strategic plans at the local and regional levels. Identification of existing obstacles and assessment of factors encouraging the development of degraded soils.
2. Advanced stage – creation of recommendations and tools at the municipal level to support the management of degraded soils.
3. Assessment of soil ecosystem services in each project.

*1. Table: Example of table for assessment of soil ecosystem services*, especially covered with energy plantations

| ***Ecosystem Services*** | ***Service Importance Level of energy plantations*** | | | | |
|---|---|---|---|---|---|
| | ***Pivotal*** | ***Important*** | ***Necessary*** | ***Not necessary*** | ***Irrelevant*** |
| *Provisioning services* | | | | | |
| *- food* | | | | | ***x*** |
| *- water* | ***x*** | | | | |
| *- genetical sources and medicines* | | | ***x*** | | |
| *- wood* | ***x*** | | | | |
| *Regulating services* | | | | | |
| *- clima and air* | ***x*** | | | | |
| *- water and soil protection* | ***x*** | | | | |
| *- pollination* | | ***x*** | | | |
| *Cultural services* | | | | | |
| *- recreation and tourism* | | | | ***x*** | |
| *- cultural values* | | | | ***x*** | |
| *Supporting services* | | | | | |
| *- soil formation* | ***x*** | | | | |
| *- nutrient cycling* | ***x*** | | | | |
| *- photosynthesis* | ***x*** | | | | |

## 4.3 Considered solutions for the recovery of soil degraded by poor agricultural practices

The selected land management direction for the Dél-Alföld pilot site is the energy plantation. We recommend establishing plantations for energy purposes with the following parameters:

- planting areas under 5,000 m2 (because at this point it is not yet legally considered a forest);

- planted in 1-3 rows in a tree-lined manner on the edge of the agricultural area;

- planted in a grove or more densely to cover small areas with unfavorable shapes (e.g. triangular areas, long narrow plots, meandering area edges, steep areas, roadsides, ditches, areas with standing water, areas far from the farm center, polluted agricultural areas, isolation zones, etc.)

During the planning of the Gyomaendrőd experiment, we set up several alternatives. We chose the plantation for energy and fiber purposes, because the region has had very little available wood for centuries, and the forest cover is the lowest in Hungary.

Additional alternatives at the Gyomaendrőd pilot site:

- One possible alternative was bamboo. However, this is a Far Eastern species, which is invasive, and several EU directives do not recommend its planting. It is very water-intensive, therefore not optimal.
- Miscanthus was also considered, but there is no infrastructure in the area to utilize the final product (chips). There were such plantations before, but they were not successful in the region.
- Energy grass breeding is taking place in the neighboring settlement of Szarvas. They are also experimenting with irrigation methods here. We were there for an on-site meeting. The product is hay that can be used for energy purposes, but it can only be used in a boiler after baling. During baling, either plastic string or wire is put into the boiler room. Neither solution is optimal, so we rejected this one too.
- We did not want a classic forest because it's payback is slow, it causes numerous legal restrictions in the legal forest area, and the farmers did not like this solution.
- Organic farming is a super solution for degraded agricultural land revitalization. In Hungary it is about 6% of total area, very slowly increase. This is a real alternative, but in this project, we were not focusing on for-food solutions.
- We rejected another solutions for-food from the outset.

Based on the above considerations, we established a model plantation with a quick cutting cycle for energy and fiber purposes, mixed with native and foreign species, specifically with seedling species. Thus, the cost of renovation after harvest is minimal, and the plantation can withstand numerous rotations. The plantation provides an optimal solution for achieving the goals set out in the project from a nature conservation and environmental perspective.

It is important to note that we also consider a single-row tree plantation (treeline) as an energy plantation if it can provide wood for energy (or fiberwood) purposes in the future.

## 4.4 Initiation and activation of local administration and landowners/farmers

The activation of citizens and local farmer groups, as well as active collaboration with local administrations and landowners, constituted a core horizontal activity of the PoLaRecCE project and was pursued through a combination of early engagement, targeted dissemination, and field-based cooperation.

The project objectives, governance structures, communication approaches, and the Interreg Central Europe framework were discussed with all relevant stakeholder groups. This established the basis for long-term cooperation focused on remediation and non-food land use. International meetings and events should be used to disseminate the project strategy among professional stakeholders, companies, and institutional representatives from the agricultural, environmental, and bioeconomy sectors to increase its visibility and support networking activities relevant to soil restoration and land management.

Technical exchange visits to pilot sites where solutions have already been implemented, combined with meetings involving local authorities and stakeholder organizations, are an effective tool for knowledge transfer. Also, the field visits to see already existing solutions in different regions of CE are the part of the PoLaRecCE activities. On-site discussions can facilitate the exchange of practical knowledge on soil diagnostics, pollution sources, and remediation options, while supporting the identification of site-specific challenges and opportunities for non-food land use. Educational and awareness-raising activities may serve as an important complementary pathway for long-term stakeholder engagement. Dissemination activities targeting high school students and the broader educational community are also part of this strategy.

Overall, the activation of local administrations and landowners should be achieved through consistent engagement, alignment with policy frameworks, and the combination of scientific expertise with practical, field-based interaction. These actions will strengthen cooperation between research institutions and local stakeholders and support informed decision-making for the revitalization of degraded and contaminated lands.

## 4.5 Influence of national legislative for implementation of „Action plan”

The strategy developed for soils degraded by long term poor agricultural practices and implemented at the Dél-Alföld pilot site.

The Action Plan directly influences the creation of community energy plantations as a community energy project through our members of the Hungarian Farmers' Association (in Hungarian: Gazdakörök). The Békés County Development Plan includes green areas that can be established as part of community tree planting, for local energy and fiber wood production purposes, basically for community purposes. Farmers can also create the same as a microclimate protection network around their own arable and grassland areas. There is currently EU and national support for the establishment of tree rows in Hungary. The project supports these synergies and common thinking on the subject.

# 5 PILOT SITE AND ECONOMIC DEVELOPMENT

## 5.1 Renewable backgrounds

In Hungary, the renewable energy mix has undergone drastic development in the last 10 years. Solar energy today accounts for about 20% of electricity production (solar energy is also used for heating). Classic wood burning still accounts for 30% in Hungary, which is a very high proportion. However, the price of firewood is low, as the price of piped residential natural gas is the lowest in Europe, which is why families typically use wood burning as a second solution, or only in very cold periods (supplementary heating), when they do not feel that gas burning is sufficient. As a result, the price of firewood is permanently low, and the demand is also permanent. When the price of natural gas creeps up (due to political uncertainty or drastic changes in the world market), the price of firewood will be high again. The market price of firewood fluctuates every 5-7 years, the last time the price was very high in 2022, now it is much more moderate, but the demand for it is stable.

## 5.2 Financial model for investment

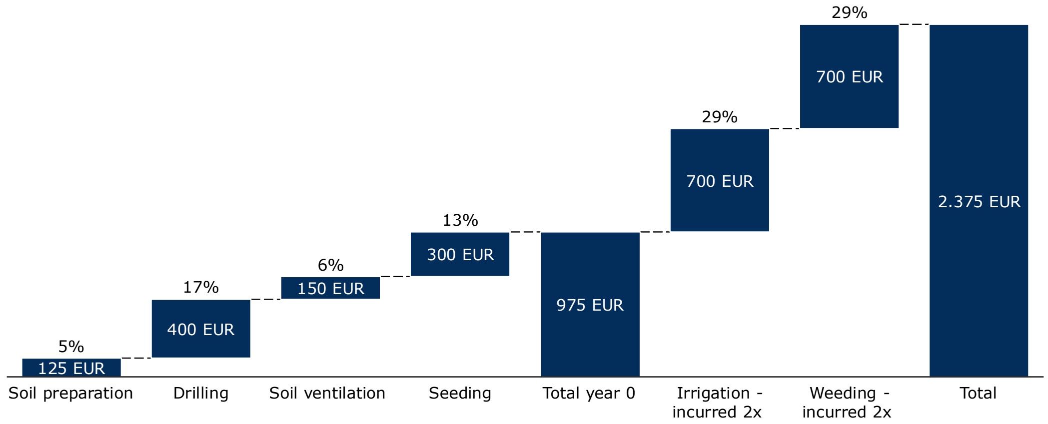
Following the pre-feasibility assessment outlined in a previous document, wood biomass (mainly firewood) has been identified as a strategic solution for revitalising degraded land affected by soil overutilisation and pollution. The pilot targets a 1.800 sqm plot of land, which would demonstrate the feasibility of wood biomass for private farmers, and create additional green space for municipal residents.

Given Hungary's commitment to renewable energy and the 28% projected increase in biomass energy production by 2030, local firewood production addresses both soil degradation and energy supply security. The model assumes municipality-led investment with eventual farmer replication as the primary objective.

In this section we are presenting the financial model detailing the financial costs and benefits of the selected investment.

*12. Figure: Project investment costs (year 0)*

| Cost category | EUR | Period |
|---|---|---|
| Soil preparation | 125 | Year 0 |
| Drilling | 400 | Year 0 |
| Soil ventilation | 150 | Year 0 |
| Seeding | 300 | Year 0 |
| Irrigation | 350 | Years 1-2 |
| Weeding | 350 | Years 1-2 |
| **TOTAL** | **2.375** | **Years 0-2** |




The total initial investment amounts to for a similar plantation is EUR 2.375. This represents the establishment phase capital expenditure required to prepare the degraded site and establish commercial wood biomass production. The investment breakdown comprises six principal cost categories, detailed in the table above, reflecting the specific requirements of establishing forestry operations on historically overutilised agricultural land. The modest investment scale makes this pilot accessible for farmer replication whilst demonstrating commercial viability.

*Soil Preparation (EUR 125)*

Soil preparation accounts for 5% of total investment and addresses the compacted soil resulting from decades of intensive agricultural use. The allocation covers several critical activities designed to create optimal conditions for tree establishment. The equipment used includes subsoilers or rippers that penetrate 30-40 cm depth without inverting soil horizons, preserving soil structure whilst alleviating compaction. Given the site's history of overutilisation, this preparation phase proves essential to ensuring adequate growing conditions for the selected tree species.

*Drilling (EUR 400)*

Drilling represents 17% of investment and covers the creation of planting holes for seedlings. The allocation reflects mechanised drilling operations using tractor-mounted augers, which prove more cost-effective than manual excavation at pilot scale.

The drilling operation includes site marking to ensure proper spacing between trees, accounting for the mixed-species planting plan. Populus, Tilia, Gleditschia, Acer, Robinia, Ulmus, and Fraxinus require 2 m x 2 m spacing (2.500 trees/ha), whilst Populus uses wider 3 m x 3 m spacing (1.100 trees/ha).

*Soil Ventilation (EUR 150)*

Initial soil ventilation accounts for 6% of investment and represents an innovative approach to addressing soil degradation without conventional deep ploughing. The technology employs compressed air injection at depth to create fracture networks that restore soil porosity and improve drainage. This method avoids the soil structure disruption associated with mechanical tillage, preserving beneficial soil biology whilst addressing compaction.

The allocation covers equipment mobilisation, operator time, and compressed air generation for treatment of the entire 1.800 $m^2$ area. This technology proves particularly valuable for the pilot's demonstration objectives, as it showcases modern soil management approaches applicable to degraded agricultural lands across the municipality.

*Planting (EUR 300)*

Planting represents 13% of investment and covers procurement of quality seedling material. The allocation includes purchase of bare-root seedlings of Robinia pseudoacacia, Ulmus minor, Fraxinus angustifolia, Tilia cordata, Acer campestre, and Populus alba, Gleditschia triachantos selected for their adaptation to local conditions and fuelwood quality. The species mix (two-thirds Robinia/Ulmus/Fraxinus/Acer/Tilia, one-third Populus/Gleditschia) balances yield potential with species diversification, reducing biological risk whilst optimising revenue generation.

Seedling quality proves critical to establishment success and long-term productivity. The budget prioritises certified material from reputable nurseries, ensuring disease-free stock with well-developed root systems. One-year-old seedlings (height 60-80 cm) represent optimal balance between establishment success and cost. The allocation includes contingency stock (10% oversupply) to replace any mortality during the establishment phase, ensuring target planting density is achieved.

*Irrigation (EUR 700 – invested over 2-year period 350 EUR each year)*

Irrigation accounts for 29% of total investment, reflecting the critical importance of water availability during the establishment phase. The allocation covers two growing seasons (Years 1-2) of supplemental irrigation to ensure seedling survival and promote vigorous growth. Young trees prove particularly vulnerable to water stress, and adequate moisture proves essential for root development and canopy establishment.

The budget encompasses both infrastructure and operational costs. Basic irrigation equipment includes water storage tanks, distribution pipes, and manual or low-cost automated delivery systems suited to the pilot scale. Operational costs cover water supply, system maintenance, and labour for monitoring soil moisture and adjusting irrigation schedules. The allocation assumes supplemental irrigation during dry periods rather than continuous watering, reflecting the species' drought tolerance once established. From Year 3 onwards, trees rely on natural rainfall, eliminating ongoing irrigation costs.

*Weeding (EUR 700 – invested over 2-year period 350 EUR each year)*

Weeding represents 29% of investment and addresses competition from herbaceous vegetation during the critical establishment phase. Young trees compete poorly with aggressive weeds for light, water, and nutrients. Without adequate weed control, establishment failure rates increase substantially, and growth rates decline, delaying the first harvest and reducing long-term productivity.

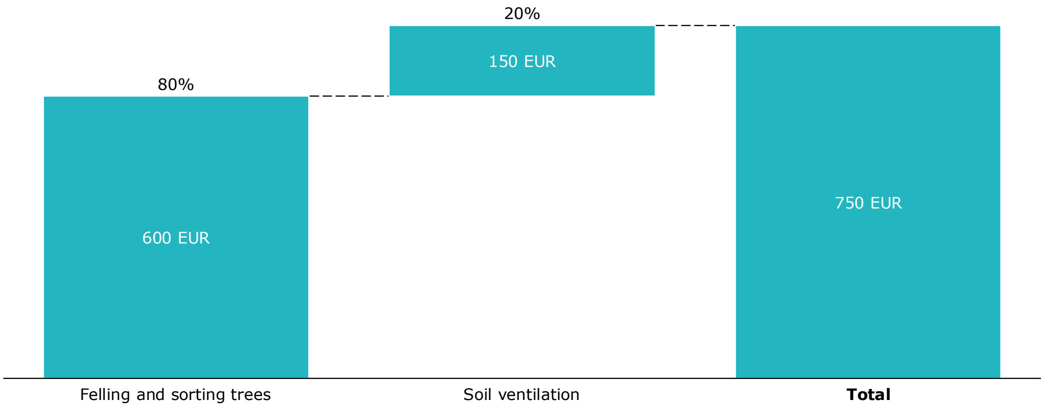
The allocation covers two years of intensive weed management using manual or mechanical methods. Manual weeding around individual trees prevents damage to seedlings whilst removing competing vegetation in the critical root zone (1 m radius). Between-row weeding uses mechanical cultivation or mulching to suppress weed germination. The labour-intensive nature of this operation explains the substantial allocation, with approximately 4-6 interventions required annually during the establishment phase.

From Year 3 onwards, tree canopy closure significantly reduces weed pressure, and the root systems prove sufficiently developed to outcompete herbaceous vegetation. This transition eliminates ongoing weeding requirements, substantially reducing maintenance costs. The front-loading of weeding costs during establishment reflects biological reality: investing in early vegetation control proves far more cost-effective than attempting to remediate establishment problems later.

The investment structure reflects the perennial nature of forestry operations, where substantial upfront capital establishes productive capacity that generates returns over extended periods. The municipality's access to PoLaRecCE funding eliminates financial barriers for the pilot whilst demonstrating commitment to innovative land use solutions. The modest EUR 2.375 investment makes farmer replication economically feasible, particularly when scaled to larger areas where per-hectare costs decline through economies of scale.

*13. Figure: Operational costs (every 5$^{th}$ year)*

| Cost category | EUR |
|---|---|
| Felling and sorting trees (labour) | 600 |
| Soil ventilation | 150 |
| **TOTAL** | **750** |




Following the establishment phase, the plantation transitions to a five-year harvest cycle. Trees are felled and sorted in Year 5, Year 10, Year 15, and continue every five years thereafter. The operational cost structure reflects the periodic nature of forestry operations, with costs incurred only during harvest years.

*Felling and Sorting Trees, harvesting (EUR 600 base)*

Felling and sorting constitute 80% of operational costs and represent the primary recurring expense. The allocation covers semi-mechanised harvesting operations suited to the pilot scale. Harvesting teams use chainsaws for felling, followed by delimbing, crosscutting to standard lengths (typically 1 m for firewood), and sorting by diameter class and species.

Labour requirements vary with yield, creating natural cost scaling. The base EUR 600 assumes 25 $m^3$ harvest volume (Year 5 level), with labour productivity of approximately 3-4 $m^3$ per person-day for manual operations. As yields increase to 30 $m^3$ (Year 10) and stabilise at 35 $m^3$ (Year 15+), labour costs scale proportionally. The model accounts for this through inflation indexing, which approximates the volume-driven cost increases whilst avoiding complexity.

The allocation includes on-site stacking of sorted material, facilitating collection by buyers or municipal transport. For farmers considering replication, this cost component proves highly flexible: own labour can substitute for hired workers, substantially reducing cash outlays. This flexibility enhances economic viability for smaller operators whilst maintaining commercial feasibility at scale.

*Soil Ventilation (EUR 150 base)*

Soil ventilation accounts for 20% of operational costs and represents the second component of the harvest cycle. Following each cutting cycle, the site receives soil ventilation treatment to restore porosity and prepare for regeneration. The regrowth of trees from stumps after harvest drives the economic model, eliminating replanting costs and accelerating subsequent rotations.

Soil ventilation between rotations serves multiple functions. It alleviates any compaction caused by harvest operations (equipment traffic, log extraction), improves water infiltration to support new development, and creates favourable conditions for root expansion from the established stump system. The mature root network present after the first rotation significantly enhances subsequent growth rates.

The operational cost structure demonstrates the economic efficiency of forestry compared to conventional agriculture. Costs occur only every five years, eliminating annual input requirements (fertiliser, pesticides, fuel for tillage). This periodic structure suits absentee landowners unable to provide continuous management whilst generating positive cash flow.

*2. Table: Revenue projections*

| Parameter | Robinia/Ulmus/Fraxinus/Acer/Tilia ($m^3$) | Populus/Gleditschia ($m^3$) |
|---|---|---|
| Year 5 | 16,67 | 8,33 |
| Year 10 | 20,00 | 10,00 |
| Year 15+ | 23,33 | 11,67 |
| Base Price (Year 1) | EUR 80/$m^3$ | EUR 40/$m^3$ |
| Annual Price Escalation | 5% | 5% |
| **Total Revenue Year 5** | **2.127,14** | |
| **Total Revenue Year 15** | **4.850,83** | |
| **Total Revenue Year 30** | **10.084,53** | |

The plantation generates revenue through firewood sales on a five-year rotation cycle. Revenue projections account for biological yield increases as trees mature, species-specific pricing differentials, and conservative price growth assumptions reflecting long-term market dynamics. The revenue structure demonstrates strong growth over the 30-year planning horizon, driven by yield stabilisation and sustained price appreciation.

Yield projections reflect the biological development pattern of forestry agriculture. The first rotation (Year 5) generates 25 $m^3$ total yield (16,67 $m^3$ Robinia/Ulmus/Fraxinus, 8,33 $m^3$ Populus), representing establishment phase productivity. This initial harvest validates the species selection and site suitability while still providing revenue.

The second rotation (Year 10) demonstrates the productivity gains from regrowth from the established stumps. Yields increase to 30 $m^3$ (20,00 $m^3$ Robinia/Ulmus/Fraxinus/Tilia/Acer, 10,00 $m^3$ Populus/Gleditschia), representing 20% growth. This improvement reflects the mature root system's capacity to support vigorous new growth.

From Year 15 onwards, yields stabilise at 35 $m^3$ (23,33 $m^3$ Robinia/Ulmus/Fraxinus/Tilia/Acer, 11,67 $m^3$ Populus/Gleditschia), representing full biological potential under the five-year rotation regime. This plateau reflects the equilibrium between stump vitality, new growth, and rotation length. The consistent 35 $m^3$ yield from Year 15 onwards simplifies long-term revenue forecasting and demonstrates sustainable productivity without degradation.

## Pricing Structure

Firewood pricing reflects species quality differentials and market positioning. Robinia, Ulmus, and Fraxinus command EUR 80/m³ wholesale, reflecting high calorific value, low moisture content, and excellent burning characteristics. These hardwood species produce long-lasting heat with minimal smoke and ash, making them premium products for residential heating. Populus, whilst faster growing, yields EUR 40/m³ due to lower density. The species mix (two-thirds premium, one-third economy) generates weighted average pricing of EUR 66,67/m³.

These wholesale prices assume sales to distributors such as DALERD Délalföldi Erdészeti Zrt or direct sales to bulk consumers. The pricing structure incorporates 5% annual growth, reflecting long-term firewood market dynamics. Hungarian consumer firewood prices increased 9% annually from 2000-2024, but the model deliberately adopts conservative 5% growth. This is done account for increased biomass production capacity, potential substitution by other renewables, market saturation, and the fact that the model does not sell directly to consumers, rather it uses the distributor system hence the same price cannot be given.

*3. Table: Financial assumptions*

| Assumption | Value |
|---|---|
| Inflation Rate (Costs) | 3% per annum |
| Price growth rate | 5% per annum |
| Discount Rate | 6% per annum |
| Corporate Income Tax Rate | 10% |
| Project Timeline | 30 years |
| Harvest cycle | 5 years |

The financial model employs a conservative assumption framework appropriate for a municipal pilot intended to demonstrate commercial viability to private farmers. Each parameter reflects careful consideration of local conditions, national policy objectives, and biological constraints inherent to forestry systems.

*Discount Rate (6%)*

The 6% discount rate exceeds typical municipal project rates (3-4%) to reflect three specific risk factors. First, the periodic cash flow structure creates timing risk compared to annual revenue systems. Second, the farmer replication objective introduces implementation risk beyond the pilot itself. Third, biological yield variability creates revenue uncertainty even under competent management. The 6% rate approximates the Weighted Average Cost of Capital (WACC) for small-scale agricultural enterprises in Hungary, ensuring the model generates returns sufficient to attract private farmer participation.

*Inflation Rate (3%)*

The 3% inflation assumption aligns with European Central Bank medium-term price stability targets. Hungary experienced elevated inflation (2022: 14,6%, 2023: 17,0%) following energy price shocks, but these peaks represent temporary deviations from long-term trends. The 3% rate drives operational cost escalation through labour wage indexing and input price increases.

*Price Growth Rate (5%)*

The 5% firewood price growth assumption represents deliberately conservative modelling despite stronger historical performance. Hungarian consumer firewood prices increased 9% annually from 2000-2024, but the model reduces this to 5% to account for expanded biomass plantation capacity, potential renewable technology substitution, market maturation, and international competition. Furthermore, the 9% increase reflected the consumer price inflation, which we cannot fully take into account in this model, as we do not envisage direct consumer sales, rather we chose to sell wholesale and through distributors, both require a reduction in price growth. The 5% rate exceeds inflation (3%), generating 2% real price appreciation reflecting biomass's role in energy transition strategies.

*Corporate Tax Rate (9% or 10%)*

The 10% corporate tax rate reflects Hungarian taxation on business activities and small-scale agricultural enterprises (basic level is 9%, but it is some modifying aspects in corporate taxation). The model applies tax to EBITDA rather than net income, creating conservative tax burden estimates whilst avoiding complexity around depreciation schedules and capital allowances.

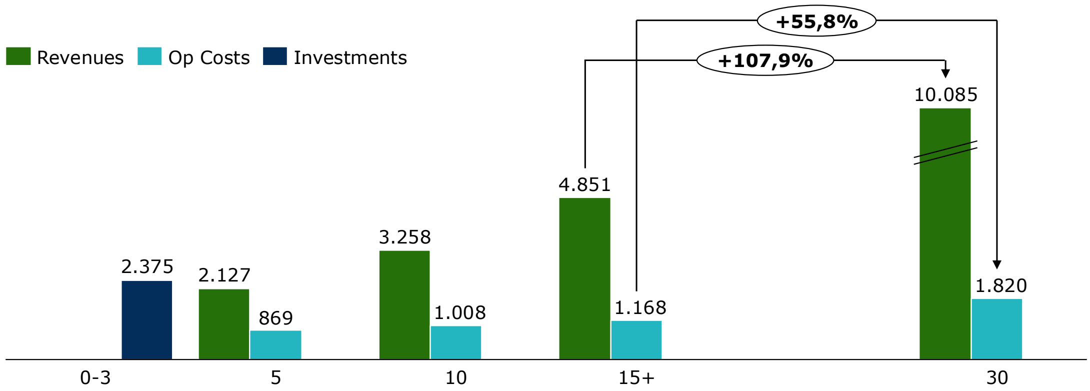
*Project timeline (30 years)*

The 30-year planning horizon captures six complete harvest cycles, demonstrating long-term sustainability and productivity trends. This duration aligns with municipal capital planning timeframes and exceeds typical farmer investment horizons, providing comprehensive assessment of biological and economic performance. Thirty years also matches realistic tree longevity under five-year rotations, after which we expect the plantation will no longer be productive.

*Harvest Cycle (5 years)*

The five-year harvest cycle represents optimal balance between biological growth, economic return, and management simplicity for the selected species. Five-year rotations suit Robinia, Ulmus, Fraxinus, and Populus growth characteristics: stems reach 8-12 cm diameter, suitable for firewood processing, whilst maintaining vigorous regrowth capacity.

*14. Figure: Assumption summary*




The chart above projects the relevant project investment assumptions in the first 3 years, as well as first three harvest cycles. Furthermore, it showcases the projected growth in prices and costs due to inflation between the year 15 and year 30.

Revenue assumptions demonstrate strong growth trajectory over the planning horizon. Year 5 gross revenue of EUR 2.127 reflects the combination of initial 25 $m^3$ yield and five years of 5% annual price growth. This is done as the prices are influenced by external factors not related to our project, we need to take into account that our revenue is "on-the-spot" revenue realised after harvest based on market prices at that time.

Year 10 gross revenue increases to EUR 3.258, driven by higher yield (30 $m^3$) and continued price appreciation.

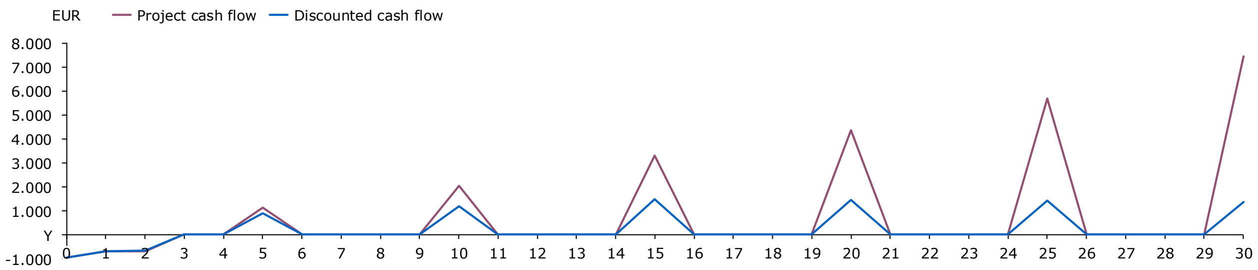
From Year 15 onwards, revenues accelerate as both yields stabilise at maximum biological potential (35 $m^3$) and prices continue compounding. This progression demonstrates the long-term value creation potential of forestry systems, where biological productivity stabilises whilst market prices continue rising.

The operational costs are incurred only at harvest cycles, as outside of harvests and the initial investment period the plantation is self sufficient and does not require maintenance. This makes it perfectly suited for supplemental business in the ongoing agricultural operation, or for someone who is not able to fully dedicate their time to agriculture. Similarly to revenue, operational costs are subject to annual growth of 3%, which again occurs outside of the project and is modelled as such. The harvests costs are larger than baseline estimates as we take into account the time spent between the harvests.

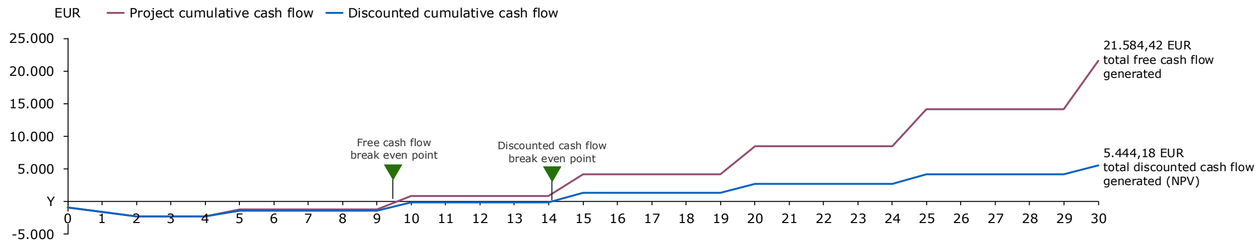
Investment costs on the other hand occur in the initial three years of operations, as it is explained in the investment portion of this chapter. They are accounted at the beginning and there is no recognised need for subsequent investments after the initial period.

### Financial model results and interpretation

*15. Figure: Projected project cash flow (free and discounted)*



*16. Figure: Projected project cumulative cash flow (free and discounted)*




| Metric | EUR |
|---|---|
| Net Present Value (NPV) | 4.071,51 |
| Internal Rate of Return (undiscounted) | 14,01% |
| Internal Rate of Return (discounted) | 7,80% |
| Money Multiple | 2,11 |
| Payback Period (undiscounted) | 10 years (2nd harvest) |
| Payback Period (discounted) | 15 years (3rd harvest) |
| **Total Cumulative Cash Flow (30 years)** | **21.584,42** |
| **Total Discounted Cumulative Cash Flow (30 years)** | **4.999,59** |

The table above, and the two charts, summarise the key financial performance metrics derived from the 15-year financial model.

*Year 0-5: Establishment Phase*

The project begins with negative cash flow as establishment costs accumulate. By Year 2, cumulative cash outflow reaches EUR 2.375. The plantation then enters dormancy until Year 5, when the first harvest generates EUR 1.132 net revenue. This initial return recovers 48% of total investment, reducing cumulative deficit to EUR 1.243.

*Year 6-15: Growth Phase*

The Year 10 harvest yields EUR 2.025, pushing cumulative cash flow positive at EUR 782. This marks the undiscounted payback point. Year 15 contributes EUR 3.314, reflecting both yield maturation and 5% compounded price growth. By Year 15, cumulative cash flow reaches EUR 4.096, generating return multiple of 1,72× on the EUR 2.375 investment.

*Year 16-30: Maturity Phase*

Yields stabilise at 35 $m^3$ but revenues continue growing through price appreciation. Year 20 delivers EUR 4.353, Year 25 generates EUR 5.698, and Year 30 produces EUR 7.438. By project end, cumulative cash flow totals EUR 21.584, achieving 9,10× return on investment without discounting.

The undiscounted NPV of EUR 19.209 demonstrates strong absolute returns. Discounting at 6% reduces this to EUR 4.072, still representing 171% return on the EUR 2.375 investment. The discounted IRR of 7,80% exceeds the discount rate, confirming positive economic value.

The 15-year discounted payback period aligns with typical forestry investment horizons. For municipal planning, the 10-year undiscounted payback provides a clearer milestone. However, what needs to be noted is the fact that the harvest cycles means that for 5 years the plantation is dormant. For this reason we should also note that the discounted payback period is in 3rd harvest, where the plantation reaches biological maturity, after which it is generating pure return. On the other hand the undiscounted payback is in 2nd harvest, even before the biological maturity is reached.

These metrics confirm financial viability under conservative assumptions. The model withstands price growth reductions to 3% (from 5%) whilst maintaining positive NPV, though payback extends beyond Year 20. This sensitivity indicates robust fundamentals despite periodic cash flow structure.

## 5.3 Cost-benefit analysis

The financial analysis demonstrates strong economic returns with NPV of EUR 4.072 and IRR of 7,80% (undiscounted IRR 14,01%). However, the true value proposition extends considerably beyond monetary metrics. The investment delivers environmental, social, and strategic benefits that strengthen the investment case and position the project as a catalyst for broader municipal development.

*Green Space Creation and Urban Amenity*

Unlike agricultural landscapes that dominate Gyomaendrőd, the plantation creates accessible green space without land use conflict. Mature trees provide shade, noise absorption, providing an ideal area for a municipal park or outdoor sports area. This arrangement addresses a frequent planning tension: municipalities need green infrastructure but face budget constraints for non-revenue land uses. The biomass plantation resolves this by generating income whilst delivering ecosystem services. Residents gain recreational space without additional municipal expenditure, a compelling model for peri-urban areas where agricultural zoning limits park development.

*Soil Restoration and Agricultural Sustainability*

The pilot site exemplifies soil overutilisation from decades of industrial farming. Continuous cropping with heavy machinery compacted the soil, reducing water infiltration and root penetration. The plantation reverses this degradation through three mechanisms: deep-rooted tree species break up compaction layers, organic matter from leaf litter rebuilds soil structure, and periodic soil ventilation restores porosity.

For farmers, this presents a soil rehabilitation strategy that generates revenue during the recovery period. Rather than leaving degraded plots lay dormant, sacrificing income for multiple years, farmers can plant biomass species that actively improve soil whilst producing marketable output. After 15-20 years, plots can return to food crop rotation with restored fertility, having generated

EUR 10.000-15.000 in net revenue during the restoration phase. This economic buffer removes a key constraint to adopting restorative practices: farmers need income during soil rest periods.

The soil restoration benefits extend beyond individual plots. Municipality-wide adoption could rehabilitate hundreds of hectares of degraded agricultural land, rebuilding the productive asset base for future generations.

*Emigration Resilience and Absentee Land Management*

Gyomaendrőd experiences significant emigration to Budapest and abroad, leaving land parcels unused as owners lack time or capacity for cultivation. Traditional crops demand regular attention: planting, pest management, irrigation, harvest, all requiring physical presence or hired labour. This makes conventional farming unviable for absentee owners, resulting in abandoned plots that degrade further through weed invasion and erosion.

Biomass plantations require labour only at planting (Year 0) and harvest (every five years). Between these events, minimal intervention suffices. For emigrants maintaining property, this enables productive land use without continuous management. Furthermore, the project enables full absentee land management through the use of hired labour, which is needed only twice per decade, making the economics manageable even with coordination costs of EUR 200-300 per intervention for contractor engagement. This model transforms stranded assets into income-generating holdings.

At municipal scale, enabling productive use of absentee-owned land preserves the agricultural land base and maintains tax revenues from productive use. Properties abandoned to weed growth generate no economic activity and require municipal intervention to prevent fire hazards or pest management. Biomass plantations convert these liabilities into assets, stabilising the rural economy despite demographic pressures.

*Energy Security and Import Substitution*

Gyomaendrőd currently imports firewood and biomass from external suppliers, incurring logistics costs that inflate local heating expenses. Long-haul transport from forested regions adds 15-25% to wholesale prices, a burden particularly acute for lower-income households dependent on wood fuel. Local production eliminates transport premiums, with firewood available at EUR 66,67/$m^3$ base price (Year 0), rising to EUR 85/$m^3$ by Year 5 and EUR 132/$m^3$ by Year 30. These prices remain below delivered import costs throughout the planning horizon, generating 10-15% savings for bulk buyers.

The municipality can also use output for social programmes: distributing firewood to vulnerable households as winter fuel assistance. Allocating 5-10 $m^3$ annually (14-29% of Year 5 yield, 6-12% of Year 30 yield) addresses energy poverty whilst converting cash welfare expenditure into internal circulation. This social use creates multiplier effects: rather than exporting EUR 500-1.000 annually to distant suppliers for welfare firewood, the municipality pays local contractors for harvesting whilst retaining wood for distribution. The harvesting income employs local labour, creating secondary economic activity.

Scaling the pilot across multiple farmers strengthens these effects. With 100 hectares under biomass (achievable with 10-15 participating farmers replicating the model), annual output would reach 14.000 $m^3$ at maturity (400 ha × 35 $m^3$/ha ÷ 5-year cycle). This supply cushion stabilises local prices and reduces vulnerability to supply chain disruptions or price volatility in external markets. The 5 year cycle can be offset by staged implementation of the reforestation projects, ensuring that some plots mature each year, enabling steady supply of firewood for the municipality.

*Innovation Demonstration and Technology Transfer*

The pilot incorporates soil ventilation technology, an emerging practice in central European forestry. Rather than deep ploughing (which further damages compacted soil), ventilation uses targeted aeration to restore porosity without mechanical disturbance. This technique remains uncommon in Hungarian agriculture, where traditional tillage dominates despite mounting evidence of soil structure damage.

By testing this approach in a municipal setting, the project creates a demonstration site for local farmers. Visitors can observe soil improvement outcomes, compare establishment costs against conventional methods (subsoiling: EUR 200-250/ha vs ventilation: EUR 150-180/ha plus superior results), and assess applicability to their own holdings. This reduces adoption barriers for innovations that lack local track records.

The demonstration value extends beyond technique to mindset: showing farmers that degraded land retains economic potential. Many landowners view compacted plots as permanently damaged, suitable only for low-value uses (grazing, hay). The pilot challenges this assumption, demonstrating that appropriate interventions restore productivity for commercial forestry. This psychological shift proves as valuable as technical knowledge, rebuilding confidence that drives investment in land improvement.

*Climate Mitigation and Carbon Sequestration*

Though not quantified in the financial model, the plantation sequesters atmospheric carbon in biomass and soil. Over 30 years, 210 $m^3$ harvested across six rotations (35 $m^3$ × 6) represents approximately 150-180 tonnes $CO_2$ equivalent stored and released through combustion, with additional permanent sequestration in roots and soil organic matter estimated at 30-50 tonnes $CO_2e$. This contribution aligns with Hungary's 2030 climate commitments (40% greenhouse gas reduction vs 1990, 21% renewable energy share) without requiring carbon credit monetisation.

The substitution benefits deserve emphasis: local firewood displaces fossil heating fuels (natural gas, heating oil) or long-distance wood imports. Each cubic metre of local firewood avoids 0,6-0,8 tonnes $CO_2e$ from fossil fuel combustion or 0,1-0,2 tonnes $CO_2e$ from transport emissions..

Scaling to 100 hectares (40 pilot-equivalent units) generates 7.200-9.200 tonnes $CO_2e$ benefit, equivalent to removing 1.500-2.000 passenger vehicles from roads annually. This positions Gyomaendrőd as a contributor to national climate goals whilst generating local economic activity, demonstrating the feasibility of aligning environmental and economic objectives.

### Financial Conclusions

The cost-benefit analysis confirms that financial returns, whilst strongly positive (NPV EUR 4.072, IRR 7,80%, 15-year payback discounted), constitute only part of the value proposition. Green space provision converts degraded land to community amenity. Soil restoration rebuilds productive capacity for future agricultural use. Emigration resilience enables absentee owners to maintain productive holdings. Energy security reduces import dependence and stabilises local prices. Technology demonstration accelerates innovation adoption. Climate mitigation contributes to national environmental goals.

These co-benefits collectively generate social returns exceeding direct financial metrics. For Gyomaendrőd municipality, this justifies public investment even under conservative financial scenarios. For private farmers, the financial model alone suffices (2,11× money multiple, 7,80% IRR), with co-benefits providing additional rationale. The pilot's dual function as proof-of-concept and operational revenue source positions it as a scalable solution to interrelated challenges: soil degradation, demographic change, and energy transition.

## 5.4 Site specific actions for “Dél-Alföld” pilot site

From the development paths assessed and considered during the PoLaRecCE project, we concluded that the best solution with the most advantages is the establishment of energy plantations on degraded and/or polluted/contaminated agricultural areas.

When establishing, maintaining and eliminating a plantation, we recommend that you follow the steps described in the previous chapter. Each country has its own unique regulatory environment for establishing and maintaining tree plantations, and several EU rules also apply to them. These regulations can be provided by the local agricultural chamber or forestry administration.

The tree species that are already present around planned new plantation are of good quality. With thorough preparation (good seedlings, mulching, irrigation, wildlife protection), these forest trees will start growing quickly, and the plantation will remain productive for a long time. These plantations can later be converted into other types of plantations (e.g. agroforestry plantations) or forests, but they can also be eliminated without a trace and transformed back into agricultural land (arable land or grassland or garden).

One of the basic ideas of this project was to develop a new system that does not require special expertise, special machines and materials, or special conditions. We believe that anyone can plant trees. Our surveys of young generations (kindergarteners, elementary school children) revealed that half of small-town children have planted trees in their lives, while only 10% of big-city children have. So tree planting is a dying skill. Farmers have already planted fruit trees in their lives, typically a few dozen, but hundreds or thousands of trees (energy plantation) are beyond their experience.

Farmers can safely carry out the establishment, maintenance and harvesting of new types of energy plantations with their own machines and expertise. The expert body of the Hungarian Chamber of Agriculture can provide advice and support with respect to this issue. During the frame of this project, it is planned to organize an additional training for the chamber's advisors.

The selection of tree species and the planting network require preliminary planning. In Hungary, no permit is required for the establishment of tree plantations under 5,000 $m^2$. For areas above this limit, a simple notification to the government office is required. The regulations to be followed are general agricultural regulations, as the area will remain agricultural land (it will not officially become a forest).
Some examples of the legal interpretation of "forest" in the project countries:

- Under the Polish Act on Forests, a piece of land must have a minimum area of 0.10 hectares to be legally classified as a forest. Additionally, this area must be covered by compact forest vegetation, intended for forestry production, or designated as a nature reserve or national park.
- Under the Austrian Forest Act, land is legally defined as a forest if it meets the following minimum criteria is the minimum area at least 1,000 square metres (0.1 hectares). An average width of at least 10 metres. Must be stocked with forest tree species.
- Under Italian national law (Legislative Decree No. 227/2001), the minimum area for an area to be officially classified as a forest is 2,000 $m^2$ (0.2 hectares).To qualify as a forest,

the land must also meet these criteria: a minimum crown cover density of 20%. An average width of no less than 20 meters. Covered by arboreal forest vegetation (with or without associated shrub vegetation).

- Under the Slovenian Forests Act (*Zakon o gozdovih*), the minimum area for land to be legally classified as a forest is 0.05 hectares (or 500 square meters). Additionally, the land must have a minimum width of 20 meters to be designated as forest land.

The Dél-Alföld pilot site has undergone thorough soil tests. It was proved that the soil of the Dél-Alföld pilot site is contaminated, since for several years it acted as an illegal landfill. Moreover, the local soil is of poor quality due long-term agricultural use. After collecting the data from historical archives, gaining opinions from local administration and farmer associations, studying the demands of the local and EU market it was decided that the formation of tree rows and small-scale plantations is the best solution to tackle the main environmental and socio-economic problems with respect to the Dél-Alföld pilot site.

The area preparation is similar as to agricultural crops (ploughing, discing). Planting is also possible with a tractor-mounted hole drill or a hand-held planting tool (wedge spade), depending on the area in which the planting is taking place. The seedlings to be planted are container (ground ball) forestry seedlings, which can be purchased at any licensed forestry nursery. The size of the seedlings may vary; there is no specific recommendation for it. The grid can start from 2x2 meters, or it is possible to apply less dense net (we typically plan a row and plant spacing of 3 meters).

A special soil preparation method is soil ventilation. During this procedure, 12 bars of compressed air is forced into the soil at a depth of approx. 80 cm. Due to the design of the spike, the air drastically increases the macroporosity of the soil at a depth of approx. 1.2-1.5 meters, cuts the roots and ensures that winter precipitation can penetrate lower parts of the soil. The procedure was first tested by PP4 WOODTECH in forestry conditions, in a large area. The obtained results were of great value, since the growth of trees doubled in the summer after the treatment, which means that the condition of the trees improved drastically. The treatment has an effect for approx. 4-5 years, after which the soil can be ventilated again. The procedure in often successfully applied for horticultural crops in Hungary (typically in vineyards and orchards), but it also works excellently with forest tree species.

The trees receive unique protection, which is a biodegradable plastic net (120-150 cm high against wild animals). The net is held by an 180 cm long bamboo pole or/and robinia pole, which is drilled 40 cm deep into the ground and the net is attached to it with a quick-release fastener.

After planting, the mulch (wood chips) is spread in a 30-50 cm radius and 10 cm thick around the trees. This block spreading of the weeds for two years and keep the soil moist under the mulch throughout the summer. This is especially important during drought seasons, where there is not enough summer rainfall.

*17. Figure: Photograph showing hole drilling at the pilot site*

*18. Figure: Robot drilling holes at the pilot site*


*19. Figure: Mulching performed at the pilot site.*

*20. Figure: Soil ventilation procedure (12 bar pressed air, 1-1,5 m deep)*

The trees can be watered with drip irrigation, or with individual bag irrigation (typically in rows of trees), or from a tanker truck. In addition to drip irrigation, micro-furrow irrigation is also possible if the energy plantation is established on a flat area. This is an old type of irrigation method, which was introduced in Hungary during the Monarchia, and which vegetable gardeners still use today.

Tree maintenance consists of plant health monitoring, e.g. pruning and replacement of infected seedlings. Trees require special attention during growth stage, but this is more of a passive observation than an active intervention.

Below are some basic insights about fertilization requirements for the chosen pilot site.

## NITROGEN-tests

*4. Table: Austrian guidelines for Nitrogen*

**Austrian guidelines for considered fertilization in agriculture and greenland:**

**TABLE 9: CLASSIFICATION OF NITROGEN MINERALIZATION POTENTIAL BASED ON ANAEROBIC MINERALIZATION, MINERALIZATION POTENTIAL ACCORDING TO EUF NORG, AND HUMUS CONTENT**

| Classification of Mineralization Potential | Anaerobic N-Mineralization (mg N / 1000 g fine soil per week) | Mineralization Potential according to EUF Norg (mg / 100 g fine soil) | Classification according to Humus Content (%) |
|---|---|---|---|
| low | < 35 | < 1.5 | < 2 |
| medium | 35 – 75 | 1.5 – 2.5 | 2 – 4.5 |
| high | > 75 | > 2.5 | > 4.5 |

*5. Table: Pilot site values for Nitrogen*

| FIELD 2: Gyomai Gazdakör | Nmin (kg/ha) |
|---|---|
| GAZ 1 | 11,92 |
| GAZ 2 | 12,75 |
| GAZ 3 | 10,65 |
| GAZ 4 | 7,72 |
| GAZ 5 | 12,57 |

*6. Table: Guideline for fertilization with Nitrogen in kg N/ha at medium yiedl expectation (in German):*

Tabelle 31: Empfehlungsgrundlage für die Stickstoffdüngung in kg N/ha bei mittlerer Ertragserwartung

| | | kg N/ha |
|---|---|---|
| **Getreide** | Weizen, Durum | 110 - 130 |
| | Roggen | 80 - 100 |
| | Dinkel | 80 - 100 |
| | Winterfuttergerste | 100 - 120 |
| | Winterbraugerste | 70 - 90 |
| | Triticale | 90 - 110 |
| | Sommerfuttergerste | 80 - 100 |
| | Sommerbraugerste | 50 - 70 |
| | Hafer | 70 - 90 |
| **Hackfrüchte** | Mais (CCM, Körnermais) | 120 - 140 |
| | Silomais | 140 - 160 |
| | Zuckerrübe | 110 - 140 |
| | Futterrübe | 120 - 140 |
| | Speisekartoffel, Industriekartoffel | 130 - 150 |
| | Früh- und Pflanzkartoffel | 90 - 110 |
| | Körnerhirse/-sorghum | 120 - 140 |

The measurements showed that the N content in the soil is very low. Based on the Austrian and Hungarian recommendations, a N supply of 0-40 kg is recommended. In forestry, fertilizers are usually not applied (except for seedling production). In the case of a plantation, fertilization is possible, but in this case not in the entire area, only next to each planted tree. It can be applied directly under the mulch, at the same time as planting (by spoon dosing, proportionally redistributing the required amount calculated for the area).

In the pilot site area, the N value in the upper 20 cm level was above 100 mg/kg according to Hungarian measurements. This is considered high, but the measured N in the following layers was very low. Ploughing was not performed at the pilot site, since the topsoil is stony and contaminated with solid pieces. At the final stage (during the installation) N supplementation was not applied. It is planned to carry out another soil ventilation treatment when the plantation is 2-3 years old, then liquid N fertilizer will be distributed into the deep soil layers using air at a pressure of 12 bar.

## PHOSPHOR and POTASSIUM tests

*7. Table: Austrian guidelines for P and K levels*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Austrian guidelines for considered fertilization in agriculture and greenland:** | | | | | | |
| | | | | | | |
| **Assessment of Phosphor content:** | | | | | | |
| | | **Agriculture** | **Greenland** | | | |
| | Nutrient supply | | mg P/1000 g | | | |
| Content class | | | | | | |
| A | very low | < 26 | < 26 | | | |
| B | low | 26 - 46 | 26 - 46 | | | |
| C | adequate | 47 - 111 | 47 - 68 | | | |
| D | high | 112 - 174 | 69 - 174 | | | |
| E | very high | > 174 | > 174 | | | |
| | | | | | | |
| **Assessment of Potassium content:** | | | | | | |
| | | | **Agriculture** | | **Greenland** | |
| | | | Clay content (%) | | mg K/1000 g | |
| | Nutrient supply | light | medium | heavy | | |
| Content class | | < 15 | 15 - 25 | > 25 | | |
| A | very low | < 50 | > 66 | > 83 | < 26 | |
| B | low | 50 - 87 | 66 - 112 | 83 - 137 | 26 - 46 | |
| C | adequate | 88 - 178 | 113 - 212 | 138 - 245 | 47 - 68 | |
| D | high | 179 - 291 | 213 - 332 | 246 - 374 | 69 - 174 | |
| E | very high | > 291 | > 332 | > 374 | > 174 | |

*8. Table: Pilot site values for P and K*

| FIELD 2: Gyomai Gazdakör | **Phosphor (mg/kg)** | **Potassium (mg/kg)** |
|---|---|---|
| 1_GAZ1 | 555,80 | 1557,51 |
| 2_GAZ2 | 417,14 | 1136,36 |
| 3_GAZ3 | 228,10 | 734,52 |
| 4_GAZ4 | 60,31 | 214,17 |
| 5_GAZ5 | 36,08 | 221,91 |

*9. Table: Guideline for fertilization with Phosphor and Potassium at content class C (in German):*

Tabelle 41: Richtwerte für die Düngung mit Phosphor und Kalium bei Gehaltsklasse C
(Angaben in kg/ $P_2O_5$ bzw. $K_2O$/ha und Jahr)

| | Kultur | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| **Getreide (Weizen, Durum - Weizen, Roggen, Wintergerste, Dinkel, Triticale, Hafer, Sommergerste)** | | 55 | 80 |
| **Hackfrüchte** | Mais (CCM, Körnermais) | 85 | 200 |
| | Silomais | 90 | 225 |
| | Zuckerrübe | 85 | 320 |
| | Futterrübe | 85 | 320 |
| | Speise- und Industriekartoffel | 65 | 200 |
| | Früh- und Pflanzkartoffel | 60 | 180 |
| | Körnerhirse/-sorghum | 85 | 210 |
| | Silohirse/-sorghum | 95 | 375 |
| **Öl- und Eiweißpflanzen** | Körnererbse | 65 | 100 |
| | Ackerbohne | 65 | 120 |
| | Sojabohne | 65 | 90 |
| | Körnerraps | 75 | 200 |
| | Sonnenblume | 65 | 200 |
| | Ölkürbis | 50 | 180 |
| **Zwischenfruchtfutterbau** | mit und ohne Leguminosen | 25 | 80 |
| **Sonderkulturen** | Mohn | 55 | 100 |
| | Kümmel | 60 | 80 |

*10. Table: Correction factor to be considered for the content classes (in German)*

Tabelle 42: Korrekturfaktoren für den Wert aus Tabelle 41 in Abhängigkeit von der Gehaltsklasse für Ackerkulturen

| | | $P_2O_5$ | | | | $K_2O$ |
|---|---|---|---|---|---|---|
| Gehalts-klasse | Spezifikation | Korrekturfaktor | | | Spezifikation | Korrekturfaktor |
| A | | 1,5 | | | | 1,5 |
| B | | 1,25 | | | | 1,25 |
| C1 | | 1 | | | | 1 |
| C2 | 90 - 111 mg/1000 g P | 0,5 | Getreide, Stärke-indusrtrie-kartoffel | Ton < 15 % | 148 - 178 mg/1000 g K | 0,5 |
| | | | | Ton 15 - 25 % | 177 - 212 mg/1000 g K | |
| | | | | Ton > 25 % | 205 - 245 mg/1000 g K | |
| | | | übrige Kulturen | Ton < 15 % | 148 - 178 mg/1000 g K | 0,75 |
| | | | | Ton 15 - 25 % | 177 - 212 mg/1000 g K | |
| | | | | Ton > 25 % | 205 - 245 mg/1000 g K | |
| D1 | Unterschreitung des Mindestgehalts gem. Tabelle 11, > 15 % Ton* | 0,5 | | | | 0,5 |
| D2 | | 0 | Getreide | | | 0 |
| E | | 0 | | | | 0 |

*... P-Gabe als Unterfußdüngung

The P and K content is very high in the pilot site area (at surface). In the analysis prepared by the KEFAG and BAY ZOLTÁN laboratories (measurements were also done for each soil horizon), the results showed that the P content is very high in the upper 20 cm layer, however it reaches much lower levels in the deeper parts. Soil ventilation changes the state of the soil colloid, allowing water-soluble substances to penetrate deeper layers. The high content of P, found in the upper layer, helps seedlings to grow quickly.

*11. Table: Measurement results from the KEFAG laboratory*

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Cégjegyzékszám: 03-10-100107

4 / 4. pages

Municipality: Gyomaendrőd
Block:
Lot #.: 0106/6
Subcompartment:
Soil profile: 1.

## Soil Test Results

Lab report # 2024/058

| Sample ID | Depth | Soil pH | | Acidity | | Carbonate content | Phenolphtalein alkalinity | Salt content | Arany's placticity index | Kuron's hygroscopy | 5h capillarity | Organic matter |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | pH($H_2O$) | pH(KCl) | Hydrolitic (y1) | Exchangeable (y2) | in $CaCO_3$ | in $Na_2CO_3$ | (water soluble) | $K_A$ | hy | | |
| | [cm range] | [-] | | [cmol/kg] | | [m/m %] | [m/m %] | [m/m %] | [m/m %] | [m/m %] | [cm/5 h] | [m/m %] |
| 597 | 0-20 | 7,8 | 7,1 | | | 1,7 | 0,000 | 0,15 | 68 | 4,30 | | 4,80 |
| 598 | 20-60 | 8,2 | 7,2 | | | 0,4 | 0,000 | 0,08 | 63 | 4,66 | | 1,86 |
| 599 | 60-110 | 8,7 | 7,6 | | | 13,2 | 0,032 | 0,10 | 57 | 3,05 | | 0,56 |
| 600 | 110-150 | 8,4 | 7,6 | | | 22,9 | 0,018 | 0,39 | 58 | 3,12 | | 0,00 |
| 601 | 150- | 8,5 | 7,7 | | | 2,1 | 0,021 | 0,20 | 44 | 1,88 | | 0,00 |
| **Uncertainity:** | | ± 0,1 | ± 0,1 | ± 5 rel. % | ± 5 rel. % | ± 7,5 rel. % | ± 7,5 rel. % | ± 7,5 rel. % | ± 3 | ± 5 rel. % | ± 5 rel. % | ± 7,5 rel. % |

| Sample ID | Depth | Stone (>2,0 mm) | Mechanical particle size analysis | | | | Bulk density | Phosphorus pentoxide (AL) | Potassium oxide (AL) | Nitrite+nitrate-nitrogen (KCl) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Coarse sand (2,0 - 0,2 mm) | Fine sand (0,2 - 0,02 mm) | Silt (0,02 - 0,002 mm) | Clay (<0,002 mm) | (undisturbed) | AL-P | AL-K | $NO_3 + NO_2$ - N |
| | [cm range] | [m/m %] | [m/m %] | | | | [m/m %] | [mg/kg] | [mg/kg] | [mg/kg] |
| 597 | 0-20 | | | | | | | 858,4 | 1197,4 | 109,2 |
| 598 | 20-60 | | | | | | | 28,5 | 688,9 | 8,2 |
| 599 | 60-110 | | | | | | | 24,3 | 296,5 | 3,6 |
| 600 | 110-150 | | | | | | | 14,9 | 333,1 | 7,1 |
| 601 | 150- | | | | | | | 228,8 | 293,0 | 24,2 |
| **Uncertainity:** | | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 5 rel. % | ± 10 rel. % |

Equipment Used: balance(Ohaus AR5120), analitikal balance(Sartorius AC2110), pH meter (VWR pH1100L), conductometer (WTW Cond 3110), calcimeter (Lab-Intern 84-11), shaker (Heidolph Reax20), drying oven(Memmert UN110), spectrohotometer (Shimadzu UV-1800), flame photometer (MOM Flamom-B)

Note: The examination results are related to air-dry soil. The results only pertain to the soil sample(s). The laboratory does not take responsibility for the accuracy of the sample origins. Without the permission of the testing laboratory, the report may only be reproduced in its full extent. The sample submitted to the laboratory will be retained for thirty days from the date of the examination report's issuance. Any comments or objections regarding the examination should be made within thirty days. The examinations are not accredited.

This report contains 4 numbered pages.

**Dated.:** Kecskemét, 2024.10.22.

Plc. of Seal

KEFAG Kiskunsági Erdészeti és Faipari Zártkörűen Működő Részvénytársaság

Maleczné Barányi, Anita
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*12. Table: Measurement results from the BAY ZOLTÁN laboratory (Hungary)*

Bay Zoltán Kutatóközpont

| | | | | | |
|---|---|---|---|---|---|
| B2 | | | | | 0,351 |
| C | | | | | 0,504 |
| A1 | | | | | 59,6 |
| A2 | | | | | 7,45 |
| B1 | 0106/6 | | | | 1,99 |
| B2 | | | | | 5,56 |
| C | | $NO_2^- + NO_3^-$ - N (KCl) | MSZ 20135:1999 5.4.5. section | mg/kg d.m. | 18,7 |
| A1 | | | | | 7,58 |
| A2 | | | | | 4,5 |
| B1 | 0286/11 | | | | 6,06 |
| B2 | | | | | 1,84 |
| C | | | | | 1,55 |
| A1 | | | | | 762 |
| A2 | | | | | 26,4 |
| B1 | 0106/6 | | | | <20 |
| B2 | | | | | 54,6 |
| C | | $P_2O_5$ (AL) | MSZ 20135:1999 5.1. section | mg/kg d.m. | 242 |
| A1 | | | | | 33,8 |
| A2 | | | | | 57,4 |
| B1 | 0286/11 | | | | 23,7 |
| B2 | | | | | <20 |
| C | | | | | <20 |
| A1 | | | | | 1430 |
| A2 | | | | | 766 |
| B1 | 0106/6 | | | | 355 |
| B2 | | $K_2O$ (AL) | MSZ 20135:1999 5.1. section | mg/kg d.m. | 402 |
| C | | | | | 284 |
| A1 | | | | | 375 |
| A2 | 0286/11 | | | | 317 |
| B1 | | | | | 248 |

Bay Zoltán Alkalmazott Kutatási Közhasznú Nonprofit Kft.
Biotechnológiai Divízió
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Adószám: 23497980-2-43
Levelezési cím: H-6726 Szeged, Derkovits fasor 2.
Telefon: +36/62-432-248
Web: www.bayzoltan.hu
E-mail: bayzoltan@bayzoltan.hu

Siker a tudomány hullámhosszán

By the end of the 4th or 5th summer, the trees will be of harvestable size. Under favorable conditions, they will produce a trunk diameter of 10-12 cm, which is suitable for firewood or wood chips without splitting (splitter is not needed, since the diameter of the logs is small). There is a significant market demand for both, and the farmer can enter the short supply chain of this local product. Harvesting is done with a chainsaw or a woodchipper.

The timber is harvested mainly by chainsaw. If there is no need for firewood, or if a buyer appears who wants to buy wood chips only, the entire plantation can be shredded.
The technical work-system is designed so that farmers can perform all work operations themselves, based on their existing machinery. However, during certain situations it is possible that the works performed by subcontractors will be required e.g. the production of wood chips, it is typically performed by a subcontractor.
The work to be done at the plantation can be planned for summer and winter seasons, in order to avoid agricultural work peaks.

The raw material (firewood or wood chips) can be easily stored, even for a long time periods, and sold directly from the plantation area or farmer's premises.
The timber can be transported safely using the farmer's standard tractor-trailer equipment. According to one working system, the wood is cut into 2–3-meter pieces in the plantation, loaded onto a trailer, and then processed on site. The other solution is to produce the final product right next to the stem. The third working system is complete wood chipping, i.e. a subcontractor produces and delivers industrial chips.

The plantation consists of well-germinating tree species. The harvested plantation does not need to be replanted in the 5th year; it simply sprouts again with its existing root system. The new generation will grow more intensively than the first one. It does not require special care, the sprouting trees grow in large numbers and quickly. It can be harvested again in another 4–5-year cycle.

The number of production cycles can be 5-10, when the stems start to rot, the plantation must be liquidated. These plantations can be converted later into traditional forest or transformed back into agricultural land. Neither transformation poses any danger.

The structure of degraded soils (macroporosity, carbon content) is drastically improved by growing woody vegetation. The microclimate also changes: the humidity under and around the plantations will be higher, the soil will dry out more slowly due to the shadow effect, the plantation stores precipitation for a long time and distribute it to the surrounding environment.

During preliminary measurements, field visits and calculations, we came to the conclusion that these areas can be best utilized with new types of tree rows.

We have established a model plantation in Gyomaendrőd, on 1800 m2. This is a demonstration plantation, consisting of 16 rows, with diverse tree species. Among the tree species, there are fast-growing and medium-growing ones, since our goal is to achieve spectacular fast results, but at the same time, what we establish should be functional in the long term. Each tree species has a different accumulation effect on different soil contaminants. Since we plant trees in a diverse way, this effect can also be active on a wider spectrum.

## 5.5 Risk assessment for “Dél-Alföld” pilot site

During the establishment and maintenance of tree rows, special attention should be paid to some hazards:

- biological hazards for individual tree species (e.g. invasiveness, spread of pathogens),
- technical hazards due to road or other damage caused by large-growing trees,
- work safety hazards during planting, maintenance and logging/shredding,
- chemical hazards during establishment and maintenance, and during the burning of trees.
- general business hazards for road/railway operators.

### Biological hazards

Biological hazards can be reduced by following generally accepted schemes and relevant legislation when planning energy plantations. The Hungarian Chamber of Agriculture provides forestry advice free also for farmers and outher land users. In diverse stands, fast-growing and slow-growing tree species are planted in a mixture, which significantly improves the resistance of plantation to harsh conditions.

### Technical hazards

When establishing energy plantation on agricultural lands near to the traffic routes, care must be taken to ensure sufficient distances (tree height/edge width). Trees that fall onto neighboring plots, roads, railways, or used ditches (e.g. after a storm) must be removed. The chances of this happening are low because the trees are young (max 5-6 years old between harvesting periods) and do not grow large due to the 5-6-year cycle. However, later, when trees grow large enough, especially in the abandoned plantations, the risk of falling is high (e.g. due to dynamic weather conditions). Nevertheless, the local fire department has a sufficient practice and technical equipment to resolve such problems.

### Work safety hazards

During planting, maintenance and logging/shredding, various occupational safety problems may arise. Operators have their own occupational safety documents (risk assessment, regulations, etc.). During logging, the small-sized trees are harvested (diameter 10-12 cm, height 4-6 meters), and such works can be done by operator’s workers without special qualifications. If necessary, a short, technical course can be organized to explain the basic techniques.

During community tree planting, motorized machinery is usually not used. The trees are planted with simple hand tools (shovel, hoe, rake, bucket). During such event, a verbal briefing about the dangers and safety before planting is generally sufficient.

### Chemical hazards

The chemicals will not be applied during planting and maintenance procedures. However, some plant health interventions may require chemicals and, in such cases, the applicable legislation on general plant protection products must be implemented. Chamber advisors may provide support in planning and carrying out plant protection tasks.

While logging, the chain oil is used, generally bio-certified, biodegradable version is recommended.

During combustion of wood materials, $CO_2$ and many other elements are released into the air. The quality of the emitted smoke, soot and ash depends also on the quality of the incinerator. Soot and ash can be reused in plantations; both are excellent micronutrient fertilizers.

### Business hazards

This report includes financial analysis of the planned actions (planting and maintaining of plantations) and description of major business opportunities and risks (chapter no. 5). It was concluded that with careful planning (proper selection of tree species, planting scheme, irrigation, maintenance), the risk of failure can be significantly reduced. Wood has been part of the global business for thousands of years, and the product, timber, will be even more important in the coming years and decades than it is today. Long-term business estimates clearly state that wood (in any form) will continue to be an important part of world trade in the future.

## 5.6 Ecosystem services for “Dél-Alföld” pilot site

Soil ecosystem services can bring provisions in nutrition, materials and energy, can bring also mediation of wastes, toxic elements. Site assessment is a first step prior determination of the potential of ecosystem services. The value of individual soil services should be determined for each project.

The basic types of ecosystem services are set out in EU regulations. Based on these, we have classified the characteristics of energy plantations.

*13. Table: Assessment of soil ecosystem services for Dél-Alföld pilot site*

| *Ecosystem Services* | *Service Importance Level of energy plantations* | | | | |
|---|---|---|---|---|---|
| | *Pivotal* | *Important* | *Necessary* | *Not necessary* | *Irrelevant* |
| *Provisioning services* | | | | | |
| - *food* | | | | | x |
| - *water* | x | | | | |
| - *genetical sources and medicines* | | | x | | |
| - *wood* | x | | | | |
| *Regulating services* | | | | | |
| - *clima and air* | x | | | | |
| - *water and soil protection* | x | | | | |
| - *pollination* | | x | | | |
| *Cultural services* | | | | | |
| - *recreation and tourism* | | | | x | |
| - *cultural values* | | | | x | |
| *Supporting services* | | | | | |
| - *soil formation* | x | | | | |
| - *nutrient cycling* | x | | | | |
| - *photosynthesis* | x | | | | |

# 6 DURABILITY, UPSCALING AND DISSEMINATION PLAN

## 6.1 Durability model in practice

### 6.1.1 Durability models in practice

The Gyoma-Felsőrészi Olvasó és Gazdakör has developed a more-pillar sustainability model. Within this framework, it aims to achieve a lasting impact with the project. These pillars work closely together and reinforce each other.

Pillar 1

We give field lectures to farmers with practical demonstrations. A good permanent venue for this will be the Dél-Alföld pilot site, where we have established a model energy plantation. We will invite farmers to a chamber event and introduce them to tree species, planting methods, soil cultivation methods, wildlife protection, the effects of mulching, and irrigation options. Chamber experts will present the current EU and national support options for establishing energy plantations in different forms (there is currently agroforestry support). The farmers' association provides long-term professional support to farmers based on their own experiences.

Pillar 2

The farming community can use wood from its own plantation to heat its own headquarters building. The heated floor area of the building is 200 m$^2$, which is heated occasionally in winter (during events). The plantation will provide enough wood for this. The farming community will hand over the remaining wood to the local government for social purposes, who will distribute it among citizens in need. This means a permanent source of wood with a cycle recurring every years, since as an energy plantation it will be possible to harvest it approximately every 4-5 years.

It is important for the local government to be able to distribute firewood to those in need in winter, and the farming community will be happy to help the local government with this. The model can also strengthen cooperation between other local governments and local farming organizations.

Pillar 3

Tree planting, as a skill, is fundamentally lacking in the younger generations. Based on our own experience, we see that young people in small towns have approx. Half of the urban youth, about 10%, have experience planting trees. We hold soil protection and tree planting sessions in kindergartens and primary schools. During this, we perform a simple soil analysis in the kindergarten or school yard (soil drilling, pH value, colors, macroforms). We talk about the trees in the yard and their history. We planted 15-20 trees together with the children and teachers.

### 6.1.2 Financing

During the project's maintenance period, approximately 50 years, the plantation has basically no additive maintenance costs. Trees sprout, and harvesting is possible every 4-5-6 years. The cost of harvesting is divided between the farmer association and the municipality, and in exchange for social firewood, the municipality partially covers the cost of logging or has its own workers carry it out. It was also a basic design principle to ensure that the plantation would have minimal maintenance costs.

The farmer association and the municipality have all the necessary equipment (saws, tractor, trailer, loader) to maintain the plantation.

### 6.1.3 Promotion and Replication

The farmer association has established a pilot project within the framework of PoLaRecCE: it has established a community-based energy plantation that closely fits the concept of new types of

European energy communities. Here, energy is not purchased on a community basis, but the production of the energy carrier is carried out, which is an inverse solution, but offers extremely exciting prospects.

When the trees are spectacular, we plan demonstrations on the energy plantation created within the framework of the project, where other farmer associations, local governments and people from the agricultural chambers and farmers will also participate, and we try to support the establishment of new plantations.

Two farmer associations have so far indicated their serious interest in the plantation, its establishment and maintenance mechanism, and its financial model. These plantations could operate anywhere in Central and Eastern Europe and could provide good examples for community-planned energy- and tree-planting initiatives.

### 6.1.4 Sustainability and Durability Mechanisms

During the design of the project and the model plantation, our basic idea was that the plantation should be able to produce a product that does not require any special investment, especially external investment that is not available in Gyomaendrőd or elsewhere. Therefore, we designed the technical implementation, maintenance and extraction in such a way that it can be operated safely with the help of existing infrastructure and tools, and with skills that farmers can also learn. This means that we only planned technical tasks that farmers can perform with their own machinery (tractor, trailer, chainsaw, hand tools). The product is typically unsplit firewood or fiber wood cut into meters that can be sold on the open market.

The fiber industry will be booming in the next decade, with significant fiber industry investments expected to come to Central and Eastern Europe, which is why the demand for fiber wood will also increase. Cellulose is a high-tech material, its uses are almost unlimited, cellulose will be the new plastic raw material when petroleum-based plastics become very expensive, and cellulose comes from a renewable source. It is important to prepare farmers for when grain production is already facing difficulties due to climate change and soil degradation, and new ways must be found. The production of raw materials for the fiber industry could be an excellent opportunity in the future, but farmers need to be educated about this. This is also what the project aims to do.

## 6.2 Comprehensive upscaling plan

In addition to the involvement and activation of farmers, the involvement of younger generations was also achieved through early, targeted dissemination, field cooperation and alignment with EU policy frameworks in all activities. These measures strengthened the cooperation between farmers and local stakeholders, supporting informed and sustainable decision-making on the revitalization of degraded agricultural areas in Hungary and other regions of Central Europe, where these problems are also known.

*21. Figure Integrated upscaling concept*


Scaling up the project results is a priority task, as the PoLaRecCE project is essentially a demonstration project.

During the project planning, we defined the target groups and the tools planned to reach the target groups.

*14. Table: Planned means to reach the target groups*

| **Target group** | **Tools for reach of target groups** |
|---|---|
| local administration | Individual meetings with individuals or small groups<br>Publication in local papers or specialist magazines |
| regional administration | Organizing meeting, seminaries, workshops |
| farmers groups | Organizing meeting, seminaries, workshops<br>Individual meetings with individuals or small groups |
| students | Organizing meeting, seminaries, workshops<br>Lessons or courses in schools |
| business & SME | Organizing meeting, seminaries, workshops<br>Individual meetings with individuals or small groups |

We can scale up the project results with the planned tools. A significant part of the professional content for the communication channels is already available (these are practically the results and outputs created within the project). We will shape communication products from these professional materials and build the scale-up from them.

n the final phase of work, we will prepare all necessary measures to reach the target groups as widely as possible with the planned tools. We will also work closely with the consortium partners on this topic.

## 6.3 Dissemination plan

Based on the scale-up plan, the dissemination events and results implemented and planned activities so far are summarized in the table below.

*15. Table: Dissemination plan*

| Date of the event | Description | Responsible project partner (PP) |
|---|---|---|
| 20th of September 2024 | The presentation of PoLaRecCE at the OPENDISTAL event supported early dissemination among researchers, companies, and institutional stakeholders from the agricultural, environmental, and bioeconomy sectors. | PP2 |
| November 2024 - June 2025 | Dissemination activities targeted on high school students and the wider educational community in Bologna and the Emilia-Romagna region. Through presentations, workshops, and hands-on activities, participants were introduced to soil functions, soil degradation, and remediation strategies for polluted land. | PP2 |
| March 2025 | The integration of PoLaRecCE concepts into a master's thesis at the University of Bologna demonstrated effective knowledge transfer to higher education. Engaging students in project-related research supported dissemination objectives and contributed to capacity building for future soil management professionals. | PP2 |
| May 2025 | Community tree planting campaign with young children at the Zsilip Utcai Kindergarten in Sopron (80 participants) | PP4+PP8 |
| May 2025 | Reception of the Mongolian delegation in Gyomaendrőd, from Csojbalszan City: adapting Robinia plantation opportunities to Eastern Mongolia | PP4+PP8 |
| May 2025 | Alternatives to Reduce Soil Degradation - conference by Hungarian Academy of Sciences - oral presentation by Dr. Sandor Horvath: Soil ventilation - a new way to revitalization | PP4 |
| September 2025 | The solutions developed for the PoLaRecCE pilot sites were presented at the EUROSOIL 2025 Congress in Seville, Spain, as a poster on soil degradation, contamination, remediation strategies, and the adaptation of degraded land for non-food agricultural purposes. | LP and PP2 |
| October 2025 | The solutions developed for the PoLaRecCE pilot sites were also presented to the Commission on Soils of Urban, Industrial, Traffic, Mining and Military Areas during the 13th SUITMA Conference in Pisa, Italy. | LP and PP2 |

| Date of the event | Description | Responsible project partner (PP) |
|---|---|---|
| Jan 2026 | Joint professional meeting with the ClimaPannonia project, we presented the project's results so far, the diversification opportunities inherent in community tree planting, and discussed agroforestry solutions for berries and forest trees | PP4 |
| April 2026 | Community tree planting campaign with young children at the Jókai Úti Kindergarten in Gyomendrőd (45 participants) | PP4+PP8 |
| April 2026 | Community tree planting campaign with young children at the Jókai Úti Kindergarten in Gyomendrőd (45 participants) | PP8+PP4 |
| May 2026 | International Conference on Alternatives to Reduce Soil Degradation - ARSD2026 - presentation by Dr. Sandor Horvath | PP4 |
| May 2026 | Community tree planting campaign with children at the Kis Bálint Primary School in Gyomendrőd (50 participants) | PP4+PP8 |
| May 2026 | Community tree planting campaign with children at the Kis Bálint Primary School in Gyomendrőd (50 participants) | PP8+PP4 |
| May 2026 | Community tree planting along Road Highway 46 in cooperation with the Road Authority | PP4 |
| June 2026 | The developed methodology for site assessment of areas polluted by urban and industrial deposition will be presented at the scientific conference *The Biennial Castle Meeting - New Trends in Rock, Paleo- and Environmental Magnetism*, held in Collonges-la-Rouge, Corrèze, France. | LP |
| June - July 2026 | The developed methodology for site assessment of areas polluted by urban and industrial deposition of PTEs will be published in a high-ranking environmental science journal. | All project partners |
| September - October 2026 | Case studies on the application of soil magnetometry in areas degraded by urban and industrial deposition of PTEs will be published. | LP |
| October 2026 | Community tree planting campaign with young children at the Kossuth Úti Kindergarten in Gyomendrőd (50 participants) | PP8+PP4 |
| October 2026 | Community tree planting campaign with children at the Hősök Úti Primary School in Gyomendrőd (50 participants) | PP8+PP4 |
| October 2026 | Community tree planting along Szolnok-Békéscsaba Railway Section in cooperation with the Hungarian Railway Company | PP4 |
| Ocotber 2026 | SME-focused field presentation in collaboration with the Chamber of Agriculture for farmers planning agroforestry | |

| Date of the event | Description | Responsible project partner (PP) |
|---|---|---|
| November 2026 | The final toolbox/handbook, providing a set of procedures for quick, inexpensive, and effective environmental site assessment, as well as criteria for selecting the best available solutions for development and management strategies (with a special focus on non-food farming, including analysis of ecological and environmental benefits), will be published | All project partners |
| December 2026 – 2027 | The handbook will be disseminated among local and regional administrations in Poland and other Central European countries. | All project partners |
| **From 2024-** | professional posts in topic of soil protection and forestry plantations - LinkedIn profile together by WOODTECH CAMPUS | **PP4+PP8** |

# 7 POLICY TOOLS AND INSTRUMENTS

Within the framework of the PoLaRecCE project, the consortium developed a package of policy tools and instruments to ensure the widest possible demonstration of the project's results.

The following policy tools were developed:

- development and sending of **questionnaires** to local governments in Central Europe (we basically found that the local government level is where we can obtain relevant information on local soil pollution and overuse)
- building of a **database** from the responses received from local governments, on a digital basis, with descriptive data and map display
- **toolbox** containing procedural solutions, presenting a simple soil quality monitoring solution and providing a simple communication solution for decision-makers and stakeholders
- we are preparing a **handbook** from the strategic studies, action plans, practical information and practices completed within the project
- we have developed a system of **pilot areas** in Poland, Italy, Slovenia and Hungary, where we demonstrate different utilization solutions in approximately the same areas (mischanthus plantation, peony plantation, mulberry plantation, energy plantation, phytoremediation forest plantation)

The **questionnaires** were developed by the consortium through extensive consultation. We developed simple answer options for 18 questions, covering the topic of contaminated and overused soils. The questions asked were:

- contamination from urban and industrial dust deposition
- leakage of oil and petroleum products
- leakage of waste waters or sewage sludge deposition (biological contamination)
- volatile organic compounds (e.g. PAHs)
- cyanides (e.g. from coking industry)
- dumping of waste materials from coal mining

- dumping of waste materials from ore mining
- dumping of ashes from power industry
- dumping of non-degradable trash or plastics (municipal wastes)
- former quarries and areas after exploitation of natural resources
- flooding areas
- military areas
- heavily acidified soils
- saline or highly alkaline soils (e.g. from chemical, cement or ceramic industry)
- long-term poor agricultural farming practices (depletion of soil organic carbon and soil nutrients, over-fertilization, contamination by pesticides)
- wind or water erosion
- soil sealing or compaction
- others (give additional information)

THE response options accordingly:

- Degree of importance of the Problem (0-3)
- If possible, please estimate the area affected by each type of land degradation (in % or $km^2$)
- Additional information or comments

During the completion of the questionnaires, we spoke to several Hungarian local governments in person, telephone inquiries were also made, and most responses were received by e-mail.

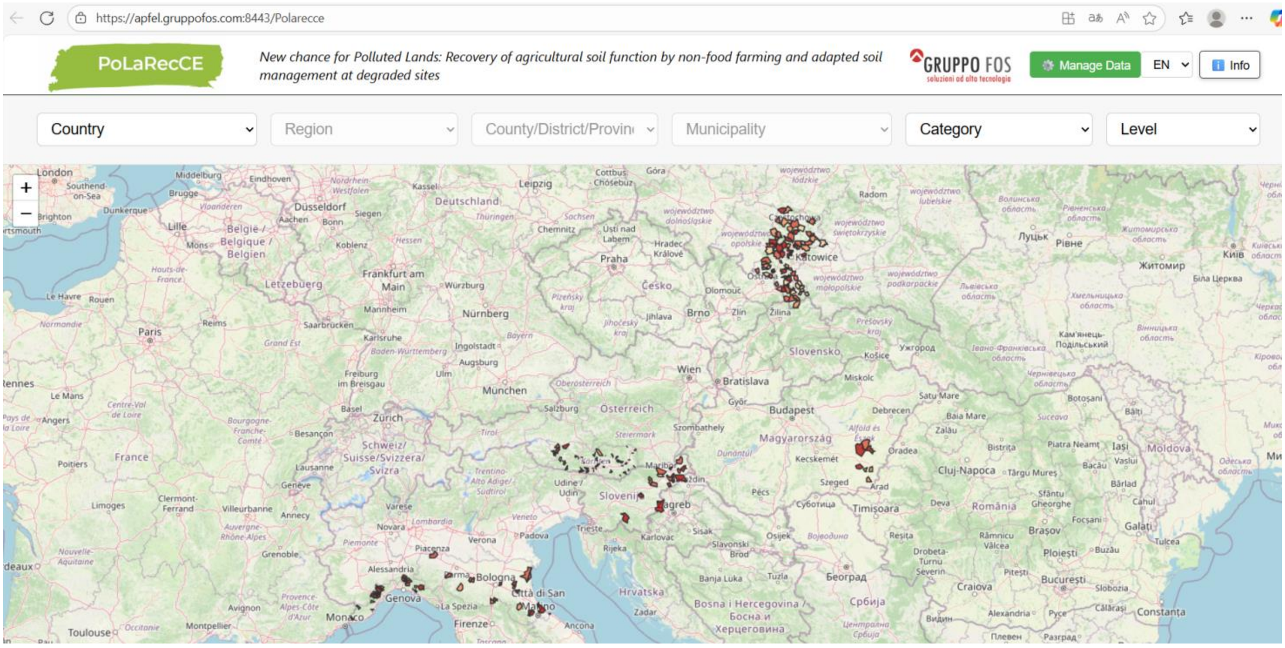
The responses came mainly from the local governments of Békés County, but in the fall of 2026, we will also contact additional Hungarian local governments to obtain as many responses as possible.

The analysis of the responses revealed that small (rural, small town) local governments typically have little information about their own area, and there is a significant lack of information on the topic. Everyone has heard that soil protection is an important topic, and that there are significant pollution and overuse throughout Europe, but practical solutions related to this, or specific small-scale action plans are hardly known.

A common Central European **database** was created from the responses sent to and received from local authorities. The technical provider of the database is PP FOS, and its professional manager is the Polish lead partner. The database is an online, open access program consisting of map and descriptive data, which can be freely expanded with data from additional municipalities during the project period and beyond.

The basic goal of the database is to present the patterns of soil pollution and overuse in each programme region and to serve as a single data source for further professional and policy materials.

*22. Figure: Database of answers by local governments*




Each programme country has its own soil protection action plan and there are national-scale soil pollution monitoring systems, but this is a bottom-up initiative that excellently complements, refines and brings knowledge related to the topic to the local level.

Based on the results of the database, significant motives are already apparent: In Békés County, pollution from industrial or mining sources is negligible, but agricultural overuse is significant, and we have also seen that local governments have very limited knowledge of the quality and problems of the soils in their own areas.

We developed a **toolbox** during the management of the program. In Hungarian local governments, this issue is basically assigned to environmental experts, but for them this topic is very marginal. There is also a significant lack of knowledge and information among local governments regarding their own soils. For this reason, the number of questionnaires sent out was also very low (out of 75 questionnaires, barely 8 were returned in the first round, which is a result of around 10-11%).

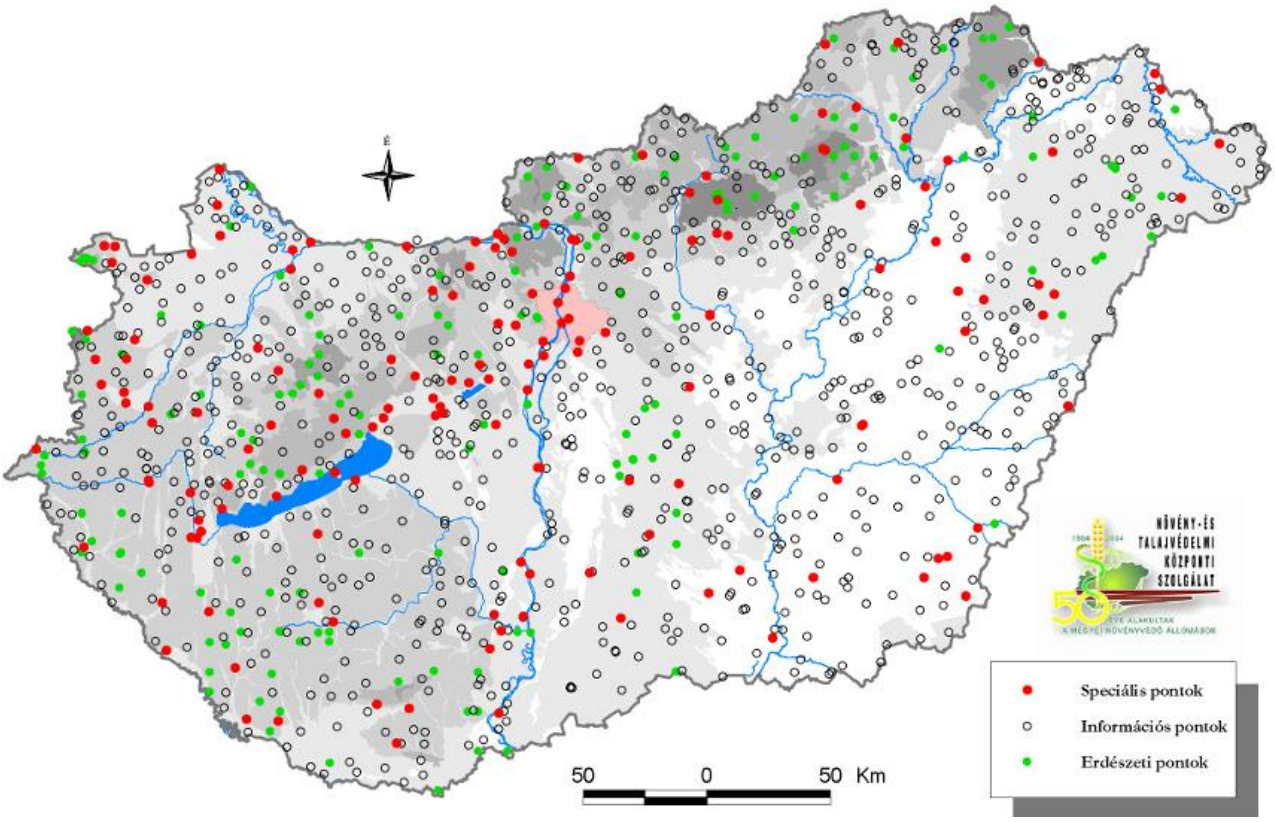
The national soil monitoring data are not known to local governments, they do not receive such information directly from a central organization. The soil protection authority is a government agency, its operation typically coordinates humus rescues found in construction areas, they have an official task in the licensing of pesticides, they authorize the application of sewage sludge, and they monitor the use of organic and synthetic fertilizers applied by farmers.

There is a "Soil Protection Information and Monitoring System" in Hungary. The aim of the system is to objectively assess the quality of agricultural soils, to learn about continuous changes and their trends. Knowledge of changes in the processes taking place in soils provides an opportunity for effective and efficient state control, to promote and strengthen favourable changes, to prevent unfavourable changes, or to keep them within certain limits.

The system was developed by a committee consisting of experts from the Soil Science and Agrochemistry Research Institute of the Hungarian Academy of Sciences, the ministry responsible for agriculture, and the soil protection authority. The state survey and the first soil tests took place in 1992.

Soil sampling is carried out at 1,235 points annually within the framework of TIM. A fundamental requirement when selecting sampling points was representativeness, i.e. that the measurement point adequately characterizes the soil conditions of the natural geographical unit, thus creating an opportunity to characterize the soil condition.

23. *Figure: Hungarian Soil Protection Information and Monitoring System since 1992*




The national core measuring network represents the soil condition of the country's agricultural areas with 864 points. The forestry measuring points characterize the soils under forest ecosystems with 183 points. The special measuring points serve to characterize endangered or already polluted areas at 188 points.

Types of special points:

- Degraded areas. Mainly in agricultural areas, erosion caused by wind and water, acidification, salt accumulation, salinization, compaction, soil structure deterioration, biological degradation, soil pollution.
- Hydrogeological protection areas of drinking water bases.
- Watersheds of major lakes and reservoirs.
- Heavily polluted industrial areas.

- Agricultural areas with sewage sludge, wastewater, liquid manure.
- Heavily polluted agglomeration areas, recreational areas.
- Surroundings of waste and hazardous waste dumps.
- Degraded surfaces (surfaces damaged by surface mining, industry, infrastructure, reclaimed waste heaps, etc.).
- Areas affected by traffic, the vicinity of motorways.
- Nature conservation areas.
- Environmentally sensitive areas (e.g. buffer zones of protected areas)

To record the baseline state, very extensive investigations were carried out in the first year. Some of the parameters to be examined were determined only once, in the first year. Depending on the temporal variability of individual soil properties, the investigations are repeated annually, every 3 or 6 years.

Within the framework of the TIM program, on-site investigations and sampling are carried out by soil protection inspectors of the Plant and Soil Protection Directorates of the county Government Offices. Laboratory examination of soil samples is the responsibility of the 3 regional soil protection laboratories of the NÉBIH. Soil biological tests are carried out in the Soil Biological Laboratory of the National Institute of Soil Science and Technology, where all laboratories are accredited. The coordination of TIM's field and laboratory work and the organization of the test results into a database are carried out by the Directorate of Plant, Soil and Agri-Environmental Protection of the National Institute of Soil Science and Technology.

Together with the data obtained from the soil protection monitoring system, we are planning an information campaign within the framework of the project in the fall of 2026, where we will inform local governments about the importance of soil protection, the Hungarian and international changes and practical solutions experienced in recent decades.

**Handbook** as a tool developed during the PoLaReCE project is a primary document intended for the local and regional officials including decision makers responsible for soil management practices. It will contain a full description of the tools designed during implementation of the PoLaReCE project (questionnaires, database and toolbox). Furthermore, it will provide criteria for selecting the best possible revitalization procedure as well as detailed instructions on how to perform the cost-benefit analysis for selected investment options. Pilot sites selected for the purpose of handling different soil degradation types will provide a robust example to stakeholders on how to effectively process and manage lands affected by various pollution sources.

We established an energy tree plantation in the "Dél-Alföld" pilot area, specifically for the revitalization of degraded agricultural soils.

We have established an energy tree plantation in the Southern Great Plain pilot area, specifically for the revitalization of degraded agricultural soils. In this manual, we summarize the establishment and maintenance practices of this area, demonstrating that tree planting and the maintenance of non-food agroforestry systems are an easy-to-learn, quick and effective solution for any farmer to combat soil degradation.

Within the framework of the project, we have established five active **pilot areas**, in Poland, Italy, Slovenia and Hungary. The explicit aim of the demonstration areas is to develop new types of land use alternatives for the target groups. One of the Hungarian non-food pilot areas is an energy plantation (typically with fast-growing tree species, but there are also medium-growing tree species, mixed, mulched and irrigated), the other is a phytoremediation forest (where fast, medium-growing and slow-growing tree species are planted in a mixed manner, for the purpose of accumulation and carbon dioxide absorption, to demonstrate the revitalization of contaminated and compacted/mixed soils along roads and railways).