ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS

LIFE ANDROS PARK

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"Conservation of priority species and habitats of Andros Island protected area integrating socioeconomic considerations"

ACTION C.2

"Final Report on the restoration of ca. 11 ha of alluvial forest with *A. glutinosa*"

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Abstract

The restoration of the deteriorated alluvial alder stands of Andros Island (priority habitat 91E0*) is one of the major aspects of the Life Andros Park project. The preparation and implementation of the restoration efforts started immediately after the beginning of the project through the concerted implementation of Actions A.1, A.3, C.1 and C.2. During the three first years of the project, more than 20000 inoculated alder seedlings have been produced at AUA's facilities and then transported to Agadaki Estate nursery (especially constructed for this purpose) to be acclimatized. The young alders were then transferred to the restoration areas (along the Vori and Lefka streams), where they were planted during three successive years. Their growth and well-being were enhanced with the help of carefully planned technical interventions (e.g., the drainage works performed at Vori in the frame of Action C.1), which also resulted in a noteworthy improvement of the ecosystem's capacity for natural regeneration; several trees previously considered dead started producing new foliage for the first time after many years. In addition to a large number of seedlings planted where judged necessary within the larger restoration area, several hundred young alders were placed into fenced sites established along the Lefka and Vori streams aiming at protecting them from feral goats. Hence, 10-15 alder-rich 'nuclei' are developed without facing the detrimental effect of grazing, hence forming starting points for the rejuvenation of this particular ecosystem through the successful re-introduction/regeneration of *A. glutinosa*. Future activities will focus on the enrichment of particular nuclei by planting a few additional alder seedlings (when/where needed), and at providing adequate protection from the summer drought and feral goats through maintenance activities until plants are adequately grown. Preservation of the vitality of such nuclei for the next few years will further ascertain the successful restoration of the degraded alder forest in Vori and the re-introduction of this plant species in Lefka (where it was extinct as a consequence of catastrophic floods). Furthermore, the experience and know-how gained by the project's team members constitutes an important legacy, which could prove valuable in the future if/when similar natural disasters occur again.

Περίληψη

Η αποκατάσταση των υποβαθμισμένων αλλουβιακών συστάδων με *Alnus glutinosa* της Άνδρου (βιότοπος προτεραιότητας 91E0*) αποτελεί μία από τις σημαντικότερες πτυχές του έργου Life Andros Park. Η προετοιμασία και η υλοποίηση των προσπαθειών αποκατάστασης ξεκίνησε αμέσως μετά την έναρξη του έργου μέσω συντονισμένων ενεργειών στα πλαίσια των Δράσεων Α.1, Α.3, C.1 και C.2. Κατά τη διάρκεια των τριών πρώτων ετών, περισσότερα από 20000 εμβολιασμένα δενδρύλλια σκλήθρου παράχθηκαν στις ειδικές εγκαταστάσεις του Γεωπονικού Πανεπιστήμιου Αθηνών και στη συνέχεια μεταφέρθηκαν στο νησί, όπου τοποθετήθηκαν προσωρινά στο φυτώριο (το οποίο κατασκευάστηκε για τον συγκεκριμένο σκοπό) του Κτήματος Αγαδάκη για να εγκλιματιστούν. Μεγάλος αριθμός αυτών φυτεύτηκαν σε επιλεγμένες θέσεις στη Βόρη και στα Λεύκα, ενώ πρόσφατα δημιουργήθηκαν και αρκετές περιφραγμένες θέσεις («πυρήνες») ώστε να προστατευτούν επαρκώς τα φυτά από την ανεξέλεγκτη βόσκηση. Οι συγκεκριμένες ενέργειες σε συνδυασμό με στοχευμένες παρεμβάσεις που έγιναν στο πλαίσιο της Δράσης C.1 (π.χ. αποστραγγιστικά έργα που αποσυμφόρησαν το ποτάμι στη Βόρη) δημιούργησαν σημαντικές προϋποθέσεις για τη μελλοντική αποκατάσταση του συγκεκριμένου οικοσυστήματος μέσω φυσικής αναγέννησης, καθώς μεγάλος αριθμός σκλήθρων που φαίνονταν απονεκρωμένα έδωσαν νέα βλάστηση μετά από πολλά χρόνια. Στο εξής, οι περιφραγμένες θέσεις πρόκειται να ενισχύονται επιλεκτικά (όπου και όταν χρειαστεί) με μικρό αριθμό νέων δένδρων, ενώ παράλληλα θα συνεχιστούν οι ενέργειες προστασίας των ήδη εγκαταστημένων νεαρών σκλήθρων από την ξηρασία του θέρους και τις ελεύθερες κατσίκες που λυμαίνονται την περιοχή μέχρι να αναπτυχθούν επαρκώς σε ύψος. Η βραχυ-μεσοπρόθεσμη διατήρηση των συγκεκριμένων πυρήνων κρίνεται πολύ σημαντική για την ολοκλήρωση των επιτυχημένων παρεμβάσεων αποκατάστασης των υποβαθμισμένων συστάδων σκλήθρων στη Βόρη και της εκ νέου εγκατάστασης ενός φυτικού είδους (που είχε πρακτικά εκλείψει) στα Λεύκα. Η εμπειρία και η τεχνογνωσία που αποκτήθηκαν κατά την υλοποίηση των σχετικών εργασιών στο πλαίσιο του έργου LIFE Andros Park συνιστούν επίσης μια σημαντική παρακαταθήκη, η οποία μπορεί να αξιοποιηθεί επιτυχώς σε μελλοντικές περιπτώσεις αντιμετώπισης των συνεπειών φυσικών καταστροφών.

Action C.2

Deliverable: "Final Report on the restoration of ca. 11 ha of alluvial forest with *A. glutinosa*"

Introduction

One of the main objectives of the LIFE Andros Park project is the restoration of the deteriorated alluvial *Alnus glutinosa* stands of Andros Island (priority habitat 91E0 *). The original restoration plan was for approx. 11 hectares (Action C.2) because this was the preliminary estimation of the damaged area, but the exact locations and sizes of the restoration sites were ultimately determined after completing Actions A.1 and A.3. Implementation of these Actions started immediately after the beginning of the project, by including three overlapping phases: (a) assessment of the structure and the variety of the plant and fungal populations inside the priority habitat (Action A.1), (b) evaluation of the condition and actual distribution of the alder trees within the target area in conjunction with the mapping of the final area to be restored (Action A.3), (c) preparation and growth of large number of inoculated alder seedlings (including collections of alder seeds and symbiotic fungi, establishment of plant nurseries, initial growth and inoculation of young seedlings, etc.; Action C.2), and (d) alders transplantation and maintenance within the restoration areas (Action C.2). In addition, implementation of the initial stages of Action C.1, notably of the activities associated with drainage interventions and works for establishing an unobstructed flow of the river at Vori, contributed significantly at the successful elaboration of plans pertaining to Action C.2. Detailed descriptions of all other activities linked with this particular Deliverable ("Final Report on the restoration of ca. 11 ha of alluvial forest with *A. glutinosa*") are included in the respective Deliverables which are already finalized.

Methodology and implementation

Implementation of Action C.2 begun immediately after the start of the project and the AUA's scientific team made several visits to Andros Island for recording and collecting biological material from the priority habitat, and to prepare and plan (together with the local partners) the activities necessary for the restoration of the alder stands.

Fig. 1. Preparation of the 1st batch of alder seedlings initially at small seed-trays (above) and later at larger pots (below). Different colors in the labels of the picture below indicate the application of different inoculation procedures.

Hence, five visits to Andros were performed from July 2017 to February 2018 and a large amount of alder seeds was collected from mature cones in the field. At the same time various microorganisms associated to *A. glutinosa*, were sampled for further study on their exact identity and ecological preferences as well as for exploiting their symbiotic potential and further use for the inoculation of young seedlings. During the same period, all necessary infrastructure was established at AUA's facilities to accommodate the germination and initial growth stages of several thousand alder seedlings. These preparatory activities resulted at the

generation of the 1st batch of about 9000 plants (winter and spring 2018). The seedlings were initially inoculated at AUA's facilities by adopting various approaches (please see Deliverable titled "Final Report on the alder seeds, the fungal (ECM) inocula and the alder seedlings produced for the restoration of alluvial forest in priority habitat 91E0*", Action C.2) and were transported for further growth – acclimatization to Andros, in a nursery created specifically for this purpose at the Agadaki Estate (Fig. 1). There, the seedlings were transferred to larger pots to allow their unobstructed growth prior to final transplantation. Unfortunately, due to the extremely unfavorable weather phenomena (hail storm) that occurred in Andros in June 2018, a large number of plants did not survive. Thus, at the end of the summer, only 3000-3500 plants were available for further use.

Fig. 2. Inoculation of alder seedlings (originating from the 1st batch) by spore suspensions of ectomycorrhizal species during large- (left) and small-scale (right) applications.

A massive reinoculation of these plants by spore suspensions of symbiotic fungi was performed in November 2018 (Fig. 2), and after verifying the success of the symbiosis establishment, the alders were transplanted in early spring of 2019 at the selected sites by the Vori and Lefka streams. Since the indigenous alder population in Lefka had vanished after the destructive floods of 2012-13, and part of the Vori river delta was still a swamp not permitting planting of new alders (while existing trees were either dead or their health was severely compromised due to anoxic conditions), it was decided to plant the majority of the seedlings available either by the river sides at Lefka (2500 seedlings, upstream and downstream from where the road crosses the river; Fig. 3) or at various sites along the Vori river (500-1000 seedlings, mainly upstream along the drier shores in order to minimize the

risk from late flood incidences). Where the landscape conditions allowed, the plants were protected by fences. Most of the plants did well until the first summer heat but eventually only those that were either shaded and/or placed very near the aquifer zone of the river managed to survive the long drought season. In addition, almost all unfenced seedlings were damaged from feral goats. Finally, although a large number of seedlings from the 1st batch were still alive at the end of summer, many of them were not in good condition, i.e., stem apices had been destroyed by goats, thus causing resprouts from the lowest buds, which do not favor a quick and vertical growth of the central stem, especially under such adverse conditions.

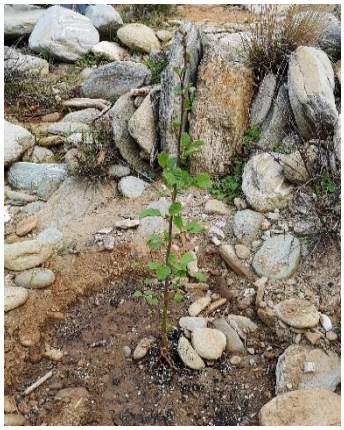

Fig. 3. Planting of new alders (originating from the 1st batch of seedlings) in the Lefka area.

This first transplanting effort within the restoration areas, albeit linked with many and serious difficulties, provided several valuable lessons regarding the selection of the appropriate sites, the optimal way to plant the seedlings, how to successfully maintain and protect them from draught and feral goats, etc. In addition, our experiments have shown that the best method for mass inoculation of alder seedlings was to incorporate the seeds into a substrate containing soil and root fragments from the priority habitat. Hence, the 2nd batch of the inoculated alder seedlings and all the relative preparations for their final transplant, were designed following these guidelines.

An additional amount of alder seeds was harvested from the priority habitat in November 2018, and a 2nd batch of approx. 9000 inoculated alder seedlings was prepared at the AUA's facilities during winter and spring of 2019. All of them were inoculated by symbiotic microorganisms by sowing the alder seeds in growth substrates including soil from the priority habitat. These seedlings were transported and successfully transplanted at the nursery of the Agadaki Estate (June 2019) and remained there until their transfer to the restoration areas (early 2020). At the same period, well-planned drainage activities and works to achieve unobstructed river flow were performed at the Vori delta (September – October 2019; Action C.1). Various large-size debris blocking the drainage of the old riverbed were removed and huge amounts of stagnant water found the way to the sea. Moreover, the old riverbed was reopened along its entire length by creating two main channels towards the sea which permitted a free water flow along the entire region. Eradication of the giant cane

(*Arundo donax*) in the same area created additional space for alder plantation, while reducing competition from this invasive alien species. Such interventions resulted at the vast improvement of the habitat's status and its capacity for natural regeneration. In parallel, a significant enhancement of the growth conditions for the tree species existing in the river delta was noted; many of the high trees showing signs of significant deterioration did recover by producing new foliage after many years (Fig. 4).

Fig. 4. Rejuvenation of old alder trees – as demonstrated by the emergence of new vegetation after many years of no growth – following the interventions performed in the frame of Action C.1 in the Vori area (the first photo of this set shows the state of trees before the interventions while all others were taken after the implementation of pertinent activities).

Hence, on the basis of aforementioned outcome and since the first transplantation focused mainly at Lefka, the area of Vori was prioritized for the second restoration effort. During early spring of 2020, approx. 7000 seedlings were transplanted in Vori covering all available open areas inside (forest glades) and outside the alder coppice as well as in several sites along the river bank (Fig. 5). Many plants were fenced but a high number of seedlings remained without fencing since it was not technically possible to do so in these localities. Almost all seedlings at Vori grew well during the spring and summer period producing thus satisfactory results.

As concerns the Lefka stream, ca. 1500 seedlings were planted downstream from the point of the road intersection with the river. Many of the fenced areas used in the previous transplantation were re-allocated to more favorable sites (on the basis of the results obtained during the past period) or restored from damages made by feral goats. Hence, most seedlings were placed within fences and as close to the stream as possible in order to protect them and promote a fast growth before the dry period of the summer. By early autumn 2020, it was

obvious that most plants growing within the fenced areas managed to survive whereas the majority of seedlings that were planted without fencing were destroyed by grazing.

Fig. 5. Planting of new alders (originating from the 2nd batch of seedlings) in the Vori (left) and Lefka (right) areas.

Although the first and (mainly) the second transplantation process resulted in several thousand newly established seedlings indicating a satisfactory restoration of the alder stands, it was decided to enrich certain localities in both Vori and Lefka areas with additional plants. Hence, in winter of 2020, by following the same procedure as for the 2nd batch, approx. 4000 inoculated alder seedlings were produced at AUA's facilities. These 3rd batch seedlings were transplanted in larger pots at AUA and then transported to the Agadaki Estate nursery (June 2020). In early 2021, they were transferred to selected sites in the restoration areas following a re-evaluation of the particularities and the needs of each site as revealed from the results obtained during the previous periods. This process resulted at the selection of fewer but clearly more suitable sites which were then carefully fenced and suitably reinforced to resist the goats attempts to break into them. In this way, more than 3000 seedlings were placed in 15 fenced areas at Vori (Fig. 6), while approx. 500 seedlings were planted along the Lefka stream within seven fenced areas (Fig. 7). Most of these seedlings, together with the already established plants from previous transplantations, have grown very well during the summer period despite the adverse weather conditions (July 2021 was the hottest month ever recorded in Andros). The fenced areas were smaller in size, in better positions and watering of plants

during summer was easier. Although two fenced areas in Vori and two in Lefka suffered from draught (they were more distant from the riverbanks), the percentage of lost seedlings was relatively low. However, in August 2021, flocks of feral goats managed to violate some fences and ate the fresh vegetation including the leaves of many alder seedlings and even of higher trees (those from the 1st batch). Fortunately, most of these plants managed to survive, they are alive as assessed from field examination, and fresh leaves appear again on their stems. The violated fences are now repaired and are regularly examined to prevent as much possible other such incidences.

Fig. 6. New alders (originating from the 2nd and 3rd batches of seedlings) growing in the Vori area.

Fig. 7. New alders (originating from the 2nd and 3rd batches of seedlings) growing in the Lefka area.

During the upcoming period, the AUA's team is planning to prepare a 4th batch of seedlings (albeit less in number in comparison to previous seasons) for supplementing selected nuclei and enrich the newly-established alder populations especially along the Lefka stream.

Restoration calendar

2017-2019: 1st batch of alder seedlings

- 11/2017: Collection of alder cones from two sites (Evrousies and Vori).
- 1/2018: Stratification of seeds and seed germination tests for assessing their germination index.
- 3/2018: Sowing of alder seeds at AUA' facilities by using trays of approx. 9000 compartments accompanied with various small- or medium-scale inoculation experiments to determine the optimum method.
- 6-7/2018: Transport of ca. 9000 alder seedlings to the Agadaki Estate nursery and transplantation to larger pots. Due to adverse weather conditions only 3000-3500 seedlings survived.
- 11/2018: Large scale inoculation of seedlings with spore suspensions from the ectomycorrhizal species *Paxillus olivellus*.
- 3/2019: Transplanting of the alder seedlings of the 1st batch at selected restoration sites in Vori (500-1000 seedlings) and Lefka (ca. 2500 seedlings) streams, and fencing installations.
- 7-9/2019: The majority of the transplanted seedlings from the 1st batch were affected by the summer drought conditions and from grazing.

2018-2020: 2nd batch of alder seedlings

- 11/2018: Collection of alder cones from two sites, Evrousies and Vori.
- 3/2019: Sowing the alder seeds following stratification at AUA's facilities, to produce approx. 9000 seedlings in a substrate mix (1:1, v/v) consisting of commercial growth medium and soil from the priority habitat.

- 6-7/2019: Transport of alder seedlings to the Agadaki Estate nursery; the majority of them finally adapting and growing well.
- 9-10/2019: Implementation of drainage works at Vori stream (Action C.1).
- 3/2020: Transplanting of the alder seedlings from the 2nd batch at selected restoration sites: approx. 7000 seedlings were transplanted in Vori stream and 1500 at Lefka stream. The majority of seedlings were placed in the same fenced areas at Lefka whereas several new fenced sites were constructed at Vori.
- 3-11/2020: The majority of the transplanted seedlings at the Vori area managed to get established. Only in few places, relatively far from the river banks, the plants failed to survive the summer drought, while some fences were violated by feral goats resulting in some plants being damaged.

2019-2021: 3d batch of alder seedlings

- 11/2019: Collection of additional cones from alder stands in Andros.
- 3/2020: Sowing the alder seeds following stratification at AUA's facilities, to produce approx. 4000 seedlings in a substrate mix (1:1, v/v) consisting of commercial growth medium and soil from the priority habitat.
- 7/2020: Transport of the alder seedlings (3rd batch) to the Agadaki Estate nursery.
- 2-3/2021: Transplanting the alder seedlings of the 3rd batch at selected restoration sites, i.e., approx. 500 seedlings at the Lefka stream and more than 3000 seedlings at Vori.
- 3-8/2021: The majority of the transplanted seedlings at Vori stream managed to get established and grow well. Some fences were violated by feral goats during August but most of the damaged plants seem to be alive and have already produced new leaves.

Results – Conclusions

In the frame of Action C.2, approx. 9000 inoculated plants were produced in each one the first two years (2018 and 2019) and about 4000 in the third year (2020). Although various inoculation methodologies were initially tested, it was eventually chosen to inoculate alder

plants by sowing seeds in substrates including natural soil from the priority habitat containing shredded fine alder roots colonized with symbiotic microorganisms. This methodology was considered to be the fastest and the safest way for successfully implementing large-scale inoculation which would consequently ascertain alders establishment in the field. The seedlings which were produced at AUA's facilities were transferred to Andros Island to be adapted/acclimatized to the local conditions. There, in the nursery specifically established for this purpose at Agadaki Estate, the young seedlings were transferred to larger pots, maintained for the entire growth period and finally transplanted to the restoration areas during the following winter-spring.

Approximately half of the total of the alder seedlings were eventually established within the restoration areas; the majority of them grow now in fenced sites at Lefka and Vori. Several alder nuclei have been created in these areas, and they will be suitably maintained (and enriched where needed) for the next few years – including the After LIFE period – or until trees will have grown enough to cope with adverse conditions (i.e., mainly summer draught and grazing). In addition, the successful interventions performed in the frame of Action C.1 in Vori (e.g., drainage works, re-opening of river flow, giant cane eradication) resulted at a significant degree of natural rejuvenation of alder trees, and this is anticipated to further enhance the habitat's capacity for natural regeneration.

In conclusion, the implementation of Action C.2 led to the restoration of the degraded alluvial alder stands in Andros through well-managed activities which enriched the priority habitat with several thousand new trees inoculated with local symbiotic microorganisms that will help them to settle and survive in a rather marginal environment. Future actions will focus at further supporting and protecting the growth of young plants, while supplementary transplantations will be performed for – at least – another season.