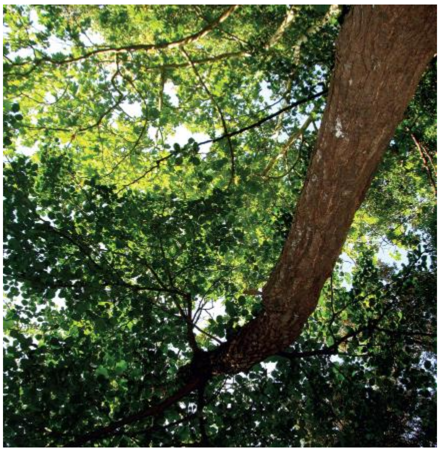
LIFE ANDROS PARK

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



ACTION C.2

Manual with guidelines for the restoration of *A. glutinosa* alluvial forests at the lowest latitudinal distribution limits of the habitat

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Abstract

A brief introduction is provided about the biology, ecological requirements and distribution of the black alder (*Alnus glutinosa*). In addition, ecological restoration concept is presented together with the main techniques for habitat restoration. Then, the specific growth requirements of alder plants are provided in conjunction with restoration practices in southernmost limit of alder distribution.

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Deliverable titled: "Manual with guidelines for the restoration of *A. glutinosa* alluvial forests at the lowest latitudinal distribution limits of the habitat"

Introduction

Alnus glutinosa (black alder) is a species occurring mainly in Europe, extending eastwards to Anatolia and Caucasia, and southwards to NW Africa (Fig. 1). Alluvial forests with A. glutinosa (91E0*) are extremely important at regional and national level since they are rare and threatened throughout Europe, where although they are widely distributed, presently only remnants of narrow stripes or lines of trees exist along rivers.

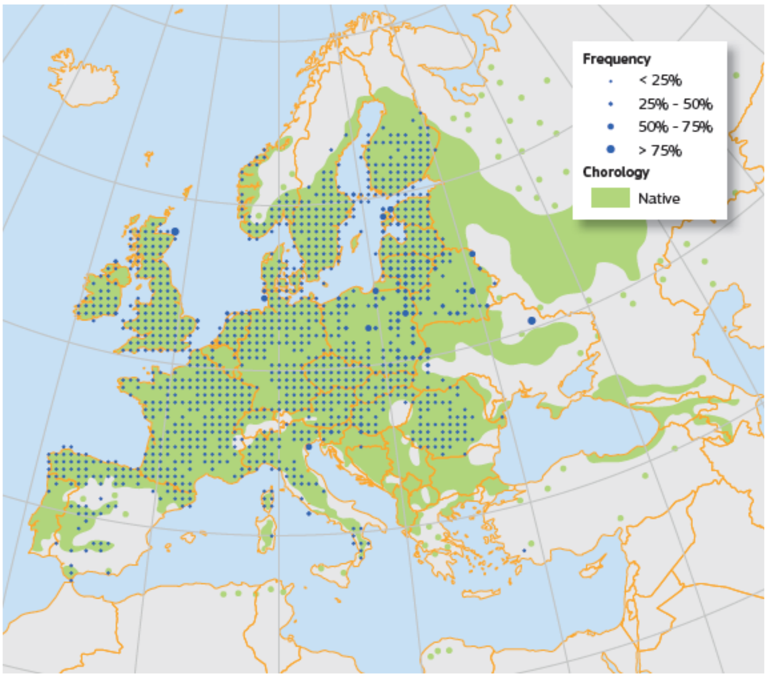

Fig. 1. Plot distribution and simplified chorology map for *Alnus glutinosa*. Frequency of *A. glutinosa* occurrences within the field observations as reported by the National Forest Inventories. The chorology of the native spatial range for *A. glutinosa* derives from EUFORGEN (2008).

Their incidence is particularly decreased in the greater Mediterranean area, which constitutes their southern distribution limit. Most river forests (riparian forests and alluvial woods) have disappeared and only some fragments remain in certain deltas, as is the case of Nestos and Evros rivers in northern Greece (Bacchetta et al. 2015). The habitat type 91E0* has been recorded in 20 NATURA 2000 sites in Greece and only two of them are located in the Aegean Islands. Most importantly, the only *A. glutinosa* alluvial forest in central Aegean Archipelago is located in Andros and therefore this is the southernmost limit of this species distribution in the Balkan Peninsula.

Alnus glutinosa plays a very important ecological role since it is associated with numerous microorganisms and contributes significantly to the unique biodiversity of river habitats (Dussart 1999). Moreover, it assists the rivers ecosystem services by water filtration and purification of waterlogged soils (Schnitzler & Carbiener 1993), while alder roots help to control floods and stabilize riverbanks (Piégay et al. 2003).

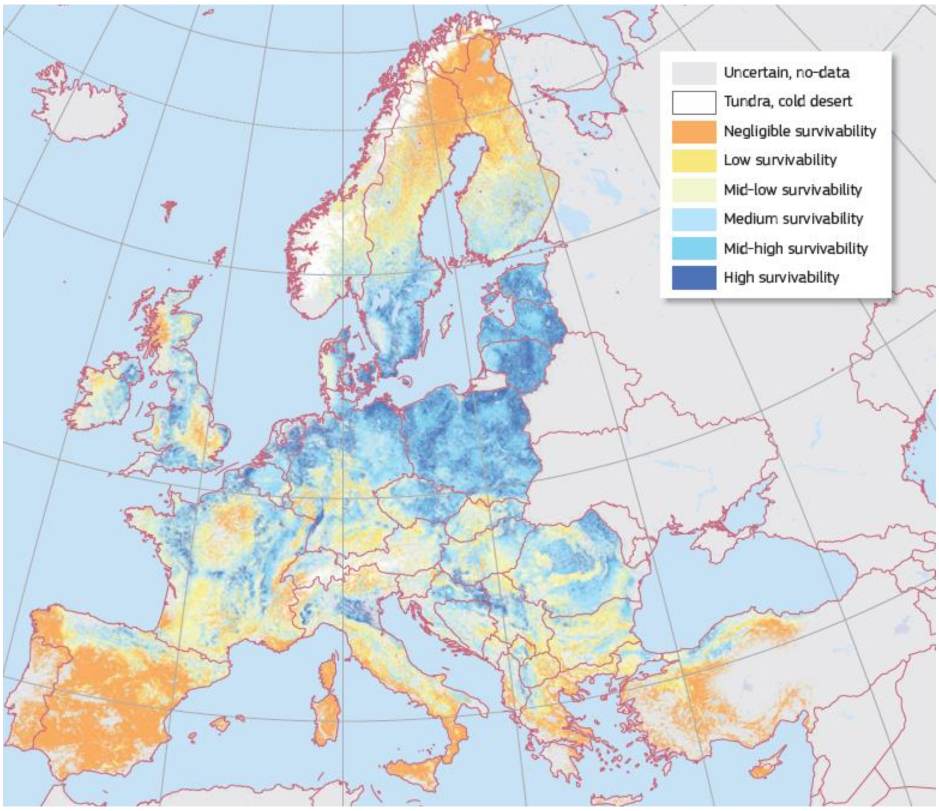

Fig. 2. High resolution map estimating the maximum habitat suitability (Houston Durrant et al. 2016)

Since high increase in floods is foreseen due to climate change, alders could play an essential role in the protection of riverbanks from erosion (Claessens, 2005). Indeed, alder is one of the species best adapted to flooding and is very suitable for the restoration of functional alluvial ecosystems (Schäfer and Joosten, 2005); therefore, its protection and restoration fits perfectly to conservation objectives. Moreover, marginal – rather than main – populations (like the alder alluvial forests of Andros, Fig. 2) commonly harbor the bulk of the species' genetic diversity; moreover, low-latitude populations are often disproportionately important for its survival and evolution since they are characterized by increased regional diversity, differentiation, local adaptation and drought stress tolerance. Hence, the preservation of their genetic variability is highly important.

2. Specific requirements of alluvial forests with *Alnus glutinosa* (91E0*)

The natural distribution of black alder indicates that the species is adapted to a wide range of temperatures and is relatively frost-tolerant (McVean 1953). There are three main site types – in relation to the type of water supply – where black alder grows (Dethioux, 1974; Noirfalise 1984, Claessens, 2003): (a) marshy sites that have waterlogged subsoil throughout the year (Alnetum community), (b) alluvial riverside sites in which the soil in the root zone is well aerated during the growing season, like priority habitat (91E0*) (Alno-Padion community), and (c) Plateau sites with high soil moisture contents (Carpinion community). Riparian stands with *A. glutinosa* (91E0*) can be home to alders but also to other broadleaved trees. Alder can grow well in continental climates of both North and Southern Europe (Claessens et al. 2010). The range of the species is limited in the East by aridity (where annual rainfall is below 500 mm). At the drier limits of its range, it finds refuge in the humid microclimates of valleys (Claessens et al. 2010). Occurrence of black alder is closely linked to the availability and abundance of water, and atmospheric humidity must remain high during all phases of its reproductive cycle. Black alder is a typical water-demanding species because its leaves have no mechanism for controlling transpiration (Braun, 1974, Herbst et al. 1999); evapotranspiration in a black alder stand is equal to total annual rainfall. This means that the tree can suffer from water deficits during dry and warm periods in summer. In consequence if growth is to be satisfactory and access to groundwater is not possible, annual precipitation must be high. Atmospheric humidity must remain high during all phases of its reproductive cycle. Moreover, roots are well-adapted to growing on very wet soils, it can survive flooding better than most other forest tree species (McVean 1956).

Fig. 3. Foliage and female catkins of *Alnus glutinosa*.

Black alders are relatively small, short-lived species; individuals normally live to around 60 years (with a maximum of up to 160 depending on the region) and normally grow to between 10 and 25 m tall, exceptionally 35-40 m (Krstinic et al. 2002, Schütt et al. 2002, Ellenberg 2009). The leaves are almost orbicular, shallowly serrate and characteristically glutinous when young. The flowers appear in early spring in distinct pendulous elongated male and short ellipsoid female catkins; the latter are eventually transformed to woody fruits (Fig. 3). Their root system is adapted to very wet soils where it can develop strong, vertically growing, sinker roots which anchor the tree on riverbanks and penetrate deeply into wet and anaerobic soils (Mac Vean, 1956; Schmidt-Vogt, 1971). Under anaerobic conditions, an oxygen supply for the roots comes from the aerial parts of the tree via enlarged lenticels on the stem (Gill, 1975) connected to well-developed aerenchyma cells, which can also provide a route for the removal of toxic gases produced under anaerobic conditions (Crawford, 1992). The tree is able to fix atmospheric nitrogen in symbiotic root nodules (Fig. 4) with bacteria in the genus *Frankia* (Bond et al., 1954). It also retains relatively high levels of foliar nitrogen and contributes highly to the soil nitrogen quantity when leaves are falling (Moiroud, 1991).

Fig. 4. Nodules formed by nitrogen-fixing bacteria of the genus *Frankia* that live in symbiosis with alder trees in the priority habitat in Andros.

Trees of the genus *Alnus* are also known to form symbiotic (ectomycorrhizal) relationships with various basidiomycetes and ascomycetes (Harley and Smith, 1983); approx. 120 species of macrofungi are considered to be symbiotic (Boyle 1996, Dimou et al. 2002, Polemis et al. 2012) (Fig. 5). Most of them show a remarkably high degree of host specificity compared with other tree species (Griesser, 1992; Arnolds et al., 1995, Pritsch et al., 1997a,b).

Fig. 5. Ectomycorrhizal basidiomycetes recorded to grow in association with alder trees in the priority habitat in Andros.

Both symbiotic partners (alders and fungi) depend heavily on each other for their survival. For that reason, young alder seedlings should be inoculated prior to restoration so they could adapt easier and faster to the local environment.

3. Ecological restoration concept

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2004). It is an intentional activity aimed at returning an ecosystem to its historic/past trajectory. An ecosystem has recovered -and is restored- when it contains sufficient biotic and abiotic resources to continue its development without further assistance, it sustains itself structurally and functionally, demonstrates resilience to normal ranges of environmental stress and disturbance and interacts with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions (Bacchetta et al. 2015). A restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and provides appropriate community structure (SER 2004). Since ecological restoration of natural ecosystems attempts to recover a historic state, the use of native species and the reduction or elimination of exotic/introduced species at restoration project sites is highly desirable. Native species are adapted well to cope with the local environment, and support native biodiversity and ecosystem resilience to a greater extent, especially if they originate from local seed sources (Bozzano et al., 2014). It is important to use locally adapted seeds because they often show home-site advantages, while a genetically adapted material represents a minimum level of intraspecific diversity to ensure that it will be able to produce viable offsprings. Non-local genotypes may be maladapted to local environmental conditions or even cause genetic contamination of local populations (Vander Mijnsbrugge et al. 2010, Bozzano et al., 2014). Ecological restoration projects need an effective supply of seeds of native species. Obtaining seeds of wild species is a significant challenge for local, regional or even landscape scale restoration. Therefore, seed banking of native species is a crucial link in the restoration chain.

4. Techniques for habitat restoration

4.1 Organizing and planning restoration actions

As previously demonstrated (Dimitrov et al. 2018), for the implementation of the restoration activities in riparian habitats, several specific and/or general preliminary measures should be taken before the project starts to achieve the target objectives. These include:

• Determining the location and accessibility of the specific area of interest, as well as the topography. Positions with different altitudes or under erosion, sites important to flora and fauna etc. should be mapped before. Groundwater levels should also be investigated.

• Investigation of the special characteristics of the habitat

• Determining land use limits, ownership and area size

• Defining the goals and the methods of achieving them

• Checking the suitability of the activities planned for implementation

• Writing a technical plan for reforestation or for natural regeneration practices.

• Preparation of specialized plans for the construction of hydraulic installations for corrosion control (if necessary) - diversion structures, retaining walls, dams, sills, water inflow or outflow systems, etc.

• Drafting specifications for the assignment of activities (for state and municipal forest administrations), invoices, etc.

4.2 Implementation of restoration actions

In order for the various restoration projects to improve the structure and functioning of ecosystems, it must be decided what interventions are needed to achieve the goal (Table 1). This depends primarily on the level of ecosystem degradation. In mild degradation, management practices are primarily aimed at removing stressors. In other cases, however, in addition to inhibiting degradation factors, intervention may be required in relation to biological, physical and/or chemical environmental conditions. In the most extreme cases, when the habitat may have been completely or partially destroyed, an effort must be made to recover not only the vegetation in the priority area but also the morphology and/or the topography of the area. (Bozzano et al., 2014).

Table 1. Anthropogenic threats of alluvial habitats with *A. glutinosa*, consequences on the ecosystem services and strategies to overcome them together with techniques to achieve it.

Main Human pressures	*Consequences*	*Strategies*	*Techniques*
-Forest fires -Land uses (agriculture, urbanization) -Resource overexploitation (overgrazing, firewood, timber, etc.) -Flood control (dams, weirs) - Channelization (levees and bank stabilization) -Water diversions and ground water pumping -Pests and diseases -Pollution	-Forest surface reduction -Biodiversity loss -Invasive species -Habitat fragmentation -Soil loss and desertification -Channel incision and bank destabilization -Water quality deterioration (physical, chemical and biological)	-Antifire regime -Revegetation -Stabilize slopes to prevent soil erosion. -Implementation of the environmental flow regime -Recover fields to increase forest area and connectivity. -Improve riparian connectivity and continuity -Protection from grazing. -Pest and disease control	-Fire prevention -Reforestation and afforestation with native plants -Native plant species reintroduction -Invasive species control -Adequate sylvicultural practices implementation -Recovery of land to enlarge floodplain -Stabilization of slopes with natural material structures -Channelization removal -Transversal infrastructures removal -Stabilization of banks with natural material -Bank fencing -Fencing or other measures to prevent overgrazing

Therefore, the type of interventions required will depend on the initial conditions of the degraded areas. Those concerning the level of interactions between the organisms (soil seed bank status, percentage of seedlings surviving after the last disturbance, number of breeding individuals, presence of wildlife dispersal etc.) as well as those referring to abiotic parameters (rainfall and temperatures, soil condition and characteristics, erosion levels, etc.). Current threats, potential risk factors, and even the environmental conditions around these disturbances should also be taken into account (Fig. 6). The degree of isolation of the disturbed habitat will affect the migration phenomena of plants, animals and/or predators. In addition, the recovery process will also be affected by the various technical difficulties. These difficulties may arise from unfavorable topographic conditions, lack of accessibility, the nature of the substrate, the lack of availability of suitable genetic material or the lack of knowledge about the development of specific seedlings and nursery cultivation techniques that favor it (Bozzano et al., 2014). Finally, restoration projects should take into account both the knowledge available about habitats of the degraded area and other relevant rehabilitation experiences (and their effectiveness). However, given that different conditions prevail in each location, restoration projects do not necessarily have to copy projects that have already been implemented - but could use more innovative solutions.

Fig. 6. Various threats and restoration techniques: a) giant cane eradication b) antiflooding measures c) antifire measures d, e) feral goats and overgrazing effect on young trees f) fencing to prevent overgrazing.

4.3 Restoration techniques

Many techniques for habitat restoration have been developed empirically or on the basis of research initiatives. Revegetation is usually the most important part of restoration projects. In addition, several protective structures are necessary or complementary to the reintroduction of plants, such as the antifire, anti-erosion, anti-flooding and anti-grazing measures with the use of environmentally friendly and aesthetically attractive materials (when needed).

The primary impact on Mediterranean riparian and wetland habitats is the modification of flow regimes or water availability, so restoration policies have to take measures related to the quality and dynamics of water. Apart from water management, hydrological restoration may include establishing structures to prevent soil erosion and recovering bank vegetation in the short-term. When living vegetation is not enough as an engineering material to stabilize banks, then other low impact techniques must be used, combining them with vegetation if possible. Forest fires may be the most dramatic anthropogenic pressure in Mediterranean ecosystems, followed in by overgrazing and overcutting. Besides fire management strategies and other measures to control overexploitation, both reforestation and afforestation plans are needed. Alien species development should also be controlled in maintenance to avoid post-planting competition with native species. *Arundo donax*, like other shade-intolerant species, could be controlled to some extent by creating a tree cover. Secondarily, in some cases various pest or diseases could severely affect the riparian vegetation. If those threats couldn't be addressed indirectly through other measures (e.g., antiflooding), then mild plant protection methods may be used.

5. Restoration practices in southernmost limit of alder distribution.

5.1 Guidelines for producing forest reproductive material

5.1.1 Seed collection

Seeds should be harvested after they have reached physiological maturity to ensure high germination rate and viability during storage (Fig. 7). Favorable climatic conditions during post-maturation and pre-harvest periods are also vital for the quality of seeds at harvest time. November and December are the most appropriate months for harvesting mature alder cones at the southern limits of its distribution. In a year with favorable conditions, germination rates of alder seeds are usually 60–70% for harvests in October – December and 25–45% for harvests in February – March (Dimitrov et al. 2018). Stored seeds should better be stratified for 3–5 weeks at a temperature of 1–5°C, to enhance their germination rates. Stratification promotes the break of seed dormancy, the increase of overall germination rate and the uniform germination of all seeds over time. In addition, in southern areas of alder distribution, the stratification period together with the time required for drying the alder cones and extracting the seeds after harvesting, is about as long as it takes for the late winter/early spring to arrive at the right time for sowing.

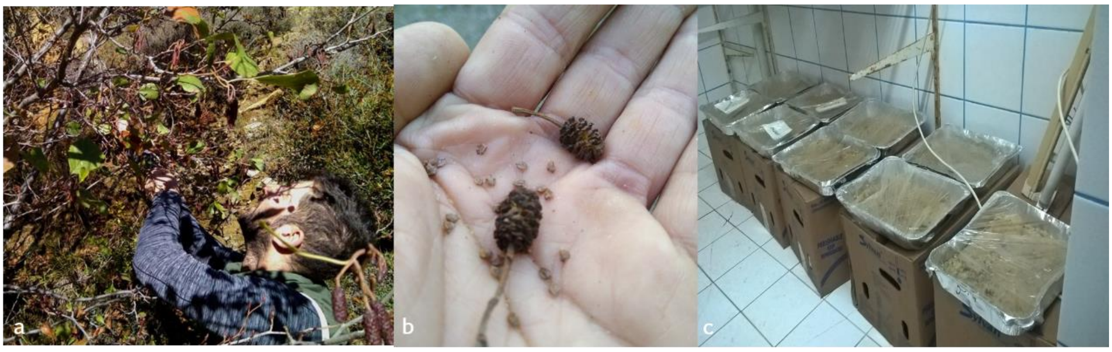

Fig. 7. (a) Seeds harvesting, (b) alder cones with seeds, (c) alder seeds wet stratification.

5.1.2 Seedlings' production

Seedlings of alders are produced in nurseries in wet and shaded localities (Fig. 8), because although alders are tolerant to high temperature, the evapotranspiration would be more intense in sunny places for the young seedlings. In southern Europe, February – April is a favorable period for sowing after saturating the seeds in water for 2–3 days. Seeds should be placed at a very shallow depth of 2-5 mm, because they are tiny (1-2 mm), in a substrate with a well aerated material (sand, vermiculite, turf, etc.) mixed with soil from healthy alder stands which contains symbiotic microorganisms. Mulching should be applied for the first period until germination of the majority of seeds, and then frequent and light watering is needed to maintain soil moisture. Germination starts within the first 2–3 weeks and is completed within the first 3-4 weeks. In the first months, the seedlings are small and grow very slowly. The seedbeds should be weed out and slightly shadowed. As alder seeds are tiny, it is very difficult to sow one or two seeds per seeding place in the trays; moreover, this should be avoided due to the fluctuation of the germination rate. Therefore, the most usual practice is to place 3-5 seeds per seeding spot and then, after 4-6 weeks (when the massive emergence of seedlings occurs), to thin out and keep only the fittest at every seeding place. After 3-4 months the young seedlings should be transplanted in their larger, final containers. Standard seedlings with a height of about 40 cm can be produced on the first year if planting containers are large enough.

Fig. 8. (a, b) Alder seeds and their sowing at planting trays, (c) Mulching of seedbeds until seedlings emerge, (d) Emerging of initially more than one seedling per planting spot, which afterwards will be thinned out.

5.2 Site preparation

Site preparation plays an important role in relation to water supply and the physicochemical properties of the soil. In order to choose the appropriate technique, the characteristics of the soil, the slope of the site, the impact on the landscape, the size of the reforested area, but also the economic parameters must be taken into account. Site preparation can be limited to planting sites and can be implemented by digging manually or mechanically (Fig. 9).

Native species originating from local populations should be selected for planting. Bare root or container-grown plants can be used for reforestation. In both cases, high quality plant stocks from local plant material should be used. Direct seeding is another approach which has lower rates of efficiency but also significantly lower cost. When growing plants, care must be taken in nursery management to produce suitable seedlings able to resist drought, i.e., a critical limiting factor in dry areas (type of container, inoculation practices, etc.). One-year old plants give the best results in reforestation with black alder, but two-year old plants could also be used in some cases.

Fig. 9. (a) Young seedlings in plastic bags containers at restoration area, before being planted, (b) digging holes for planting, (c) transplanted alder 1-year old seedling, (d) 2-year old seedlings at the nursery before transplantation, (e) fenced 'nuclei' with alder plants the following summer after their transplantation.

Holes at least 40-45 cm deep should be prepared, especially when planting container-grown plants. The appropriate planting time is during the dormant period of the plants, i.e., from late autumn to early spring, to allow the plants to benefit from the seasonal rainfalls. The roots should not bend upwards in the holes made during planting. Care must be taken to place the plant straight and slightly above the root collar, and to compact the soil sufficiently when refilling the hole to ensure good root contact with the soil. Small ditches or furrows could be created around the plants after planting to maintain them after irrigation and rainfall. Plants could also be surrounded by mulch to avoid water loss and weed competition. Properly designed fenced areas and/or individual tree fences or shelters are useful for reducing mortality by grazing. Fences should be removed when plants reach a certain height. The reforestation process should be monitored in the autumn of the first years after plantation to assess restoration success. Replanting to replace dead plants is recommended. Plants should be watered regularly during dry periods throughout the first year after plantation. Temporary bank fencing or individual plant protectors must be used if there is threat of livestock or native animal grazing or high recreational pressure. Invasive species should be removed manually or mechanically as much as possible before planting.

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