Supplemental Materials 1.

The tree species of the Lithuanian hemi-boreal forest (Table 1) are Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* L. Karst), silver birch and downy birch (*Betula pendula* Roth and *B. pubescens* Ehrh.), black alder and grey alder (*Alnus glutinosa* L. Gaertn. and *A. incana* L. Moench), white willow and crack willow (*Salix alba* L. and *S. fragilis* L.), Eurasian aspen (*Populus tremula* L.), European ash (*Fraxinus excelsior* L.), English oak (*Quercus robur* L.), small-leaved lime (*Tilia cordata* Mill.), European white elm and wych elm (*Ulmus laevis* Pall. and *U. glabra* Huds.), Norway maple (*Acer platanoides* L.), bird cherry (*Prunus padus* L.), wild apple (*Malus sylvestris* L. Mill.), and wild pear (*Pyrus pyraster* L. Burgsd.); the northern borders of field elm (*Ulmus minor* Mill.), and European hornbeam (*Carpinus betulus* L.) cross Lithuania [1]. European beech (*Fagus sylvatica* L.) could expand its range into the Baltic [2]. Sessile oak (*Quercus petraea* Matt. Liebl.) is supposed to be an introduced species [3]. Wild cherry (*Prunus avium* L.) is spreading to forest stands naturally from domesticated sources [4,5]. Large-leaved lime (*Tilia platyphyllos* Scop.) is not found as a native tree in Lithuania.

Table 1. A description of the life history dynamics of hemi-boreal forest tree species and their position in successional categories for Lithuania.

Tree species	Life history dynamics
Gap colonizers/pioneers	
Betula pendula *Betula pubescens*	Silver birch and downy birch are pioneer species that thrive during early stages of secondary vegetation succession [6]. In the later successional forests of the boreal zone of northern Europe, they can dominate [7]. Birches are opportunists in steady-state woodland systems [8]. There is no clear evidence as to their adaptiveness of the environmentally caused variation [9].
Pinus sylvestris	Through much of its range Scots pine may be considered post-pioneer to birch and pre-climax to Norway spruce; it is able to colonize nutrient-poor soils after stand-replacing disturbances [10–12]. Scots pine is usually replaced by Norway spruce if there is a lack of fire [13]. It is to be emphasized that the protection of older trees not only promotes well-balanced development of saplings but also gives a necessary impetus to the reproduction [14].
Populus tremula	Eurasian aspen is an early clonal pioneer species with fast early growth [15]. A disturbance adapted species and a colonizer of clear disturbed areas such as after fire, clear-cutting, wind-throw, or defoliation are beneficial [16]; it is shade-tolerant and a stable part of a mixed stand woodland, especially with species that allow sunlight through the canopy, such as Scots pine and birches [17].
Alnus glutinosa *Alnus incana*	Both species are able to quickly colonize disturbed sites and improve soil conditions for other species [18,19]. Grey alder regenerates vigorously with root suckers, especially in open places [20] and is regarded as a more light-demanding species compared to black alder, which tends to be out-competed by other species once the canopy closes [21].
Salix alba *Salix fragilis*	White willow is a fast-growing tree, very tolerant of maritime exposure [22], but is shade intolerant [23]. It is closely allied to crack willow, with which it freely hybridizes [24].
Prunus avium *Prunus padus*	Wild cherry and bird cherry colonize early successional stages as a result of forest disturbances [25,26]. It is a seed recruitment pioneer colonization species, which can be followed up by extensive root suckering [27]. Wild cherry seeds easily, germinating under a canopy [28] but prefers full sunlight between the ages of 3 and 5 years [29]. This species has a fast growth rate, which is not paralleled by any other tree species. In open light, wild cherry can outcompete other species but needs a head start of 3–5 years' growth [30].
Gap competitors—post-pioneers	
Quercus robur *Quercus petraea*	Large gaps favor the recruitment of these light-demanding species created by old dying trees, wind, and insects [31–33]. *Q. robur* prefers rich fertile calcareous soils, whereas *Q. peraea* prefers lighter and more acidic soils [34]. In central Europe, their main competitor is beech and other shade or half-shade tolerant trees that block light [35]. Ligot et al. [36] found that beech saplings naturally outcompete oak and ash saplings that have increased light requirement with age. The initial number of plants that survive to form the seedling bank is inversely related to the distance of the nearest parent tree as well as canopy cover [37].
Fraxinus excelsior	European ash can be shade tolerant as seedling but in older age are shade intolerant [38]. Young plants show very rapid growth, although full overhead light is necessary for developing vigorous

	trees [39]. Ash is considered an intermediate tree in ecological succession and can take advantage of disturbances at the stand level [40].
Ulmus laevis	European white elm is a light-demanding and fast-growing riparian habitat specialist with limited dispersal [41,42]. It can outcompete willows and aspens to become co-dominant with European ash and English oak in the downstream areas of floodplain succession [41].
Malus sylvestris	Unlike wild pear, wild apple occurs mostly below the canopy of other broadleaves such as English oak, Eurasian aspen, European ash. Floodplain forests, which are dominated by light-demanding canopy trees, provide favorable conditions for the establishment and reproduction of the wild apple [43]. It prefers permeable clayey soil with shallow ground water [4].
Pyrus pyraster	Wild pear prefers fresh calcareous soil for the establishment and growth in gaps or under the see-through canopy of shade-intolerant trees [4].
Forest colonizers (pre-climax)	
Picea abies	Norway spruce, a secondary colonizer, depends largely on advance regeneration to capture small-scale gaps in the mature canopy [44,45]. It is not dependent on the protection of the mother tree; it grows best in depressions under extremely sheltered environmental conditions, where it is immune to all outside influences [14]. The seedlings of Norway spruce can tolerate lateral shade and can outcompete nearly all deciduous trees and ground vegetation [46–49].
Acer platanoides	Norway maple germinates and grows rapidly in shade, even under a closed forest canopy [50]; its rapid early growth may cause suppression of the other mixed species [17]. It possesses high density regeneration properties under the canopy near larger gaps [32] and can outcompete nearby plants for nutrient uptake [51–53]. At maturity, it becomes more light-demanding and can co-dominate with other broadleaves such as English oak and small-leaved lime [20,54].
Ulmus glabra	Wych elm is found in moist rich forests and in riparian zones with higher, less variable precipitation [55,56]. It is shade tolerant and with Norway maple can outcompete oaks and ashes [57]. In Lithuania, wych elm is mainly found in mature stands dominated by European ash [58]. Formerly, wych elm was the precursor to the climax formation [59].
Ulmus minor	Field elm prefers low lying forest along rivers and can tolerate both floods and droughts [56] and is often associated with English oak and European ash [60]. Niinemets and Valladares [61] classified wych elm and field elm as having similar shade tolerance, namely 3.53 and 3.36, respectively, on a scale of 0 (very intolerant) to 5 (very tolerant). Lithuania contains the northern borders of field elm [1].
Forest competitors (natural climax)	
Tilia cordata *Tilia platyphyllos*	Small-leaved lime and large-leaved lime are shade-tolerant and highly competitive [20]. They tend to grow in close proximity to other species in mixed stands [3, 62–64]. In Britain, limes are generally associated with English oak and European beech, and their presence is often taken as an indicator of ancient woodland [17].
Fagus sylvatica	European beech is the most shade-tolerant broadleaved tree in its range [39] and the strongest competitor among the trees in its range [65,66]. The high growth rate can remain steady until late maturity [2]. The seedlings are able to tolerate both lateral and vertical shade [47]. In suitable soils and under a closed canopy, very few other species can grow in a beech forest [22].
Carpinus betulus	European hornbeam is one of the few strongly shade-tolerant trees [64], though slightly less than beech [17]; it grows mostly in mixed stands below the canopy of other broadleaves such as English oak, European ash, and Norway maple [67]. European hornbeam can be a dangerous invader, regenerating better and faster than English oak, European ash, or Scots pine [39]. It can be grown in mixed stands alongside oaks to produce straighter trees with less epicormic branches [68]. Lithuania contains the northern borders of European hornbeam [1].

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