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# Impact of the Disturbances for Forest Grazing on Flora Composition in a Natural Forest

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**Abstract:** Daegwallyeong is a mountain pass at an altitude of 832 m, which has been designated a conservation area because of its essential role in Korea's forest ecosystem. Simultaneously, this area is considered a suitable place for forest grazing due to the cool temperature during the summer. Some areas have been converted to grassland for livestock feeding, and the scale has continued increasing. Although livestock in a forest area is more ecofriendly than industrialized facilities, it could impact the native ecosystem, especially in terms of the flora and vegetation. We investigated the changes in flora and vegetation of Daegwallyeong before and after the grassland formation. The total number of vascular plant species changed throughout the survey period. It was decreased by thinning and forest floor removal in 2015. However, it bounced back to the original number in 2016, even after grazing. However, there was a dramatic decrease after the second forest floor removal and 3 months of grazing in 2017. The number of flora slightly increased after the fallow of grazing in 2019, but it did not fully recover. Although the number of flora seemed back to normal, the composition of the flora in 2019 was significantly changed from the forest without disturbance in 2014. First, there was the invasion of naturalized plants such as *Taraxacum officinale* and *Barbarea vularis*, as well as ecosystem-disturbing flora such as *Carex callitrichos* var. *nana* and *Rumex acetosa*. Second, the coverage of those species expanded after thinning and grazing. Most importantly, we lost five valuable rare species, *Anemone koraiensis*, *Viola diamantiaca*, *Chionanthus retusus*, *Scopolia japonica*, and *Streptopus ovalis*, from the area. Additionally, the ground condition of the area was severely damaged, and plants no longer grow in some areas. The survey and analysis of plants in this study showed the adverse effects of forest grazing practices on rare plants in Daegwallyeong. Forest grazing practices should be carefully conducted to preserve vulnerable plant species and a healthy ecosystem.

**Keywords:** Daegwallyeong; rare plant; livestock feeding; vegetation; disturbance

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## 1. Introduction

As about 63% of Korea's total land area is made up of forests, timber production has been traditionally regarded as the primary role of forestry and has accounted for most forestry [1,2]. However, forests in Korea's mountainous regions are not accessible for traditional timber production, and the types of forests vary from region to region [3]. Woody plants for timber production have a very long growing period and a low return on capital until harvest; as such, forest households needed a new form of forestry [4]. In some forests, agricultural technology was applied to produce short-term income crops in parallel [5]. Moreover, introducing economic benefits to forest grazing is a complex land-use form that combines grazing in the forest with ecological livestock technology [1,6]. However, with the emergence of goals related to preservation of the natural environment and conduction of environmentally friendly development, the number of grassland creations has declined. Within these concepts, sustainable development, which enables economic activities while minimizing environmental damage, has become comprehensive. As a result, forest grazing, a combination of forestry and agriculture (mainly livestock), tends to be activated without assessing the natural environment's impacts.

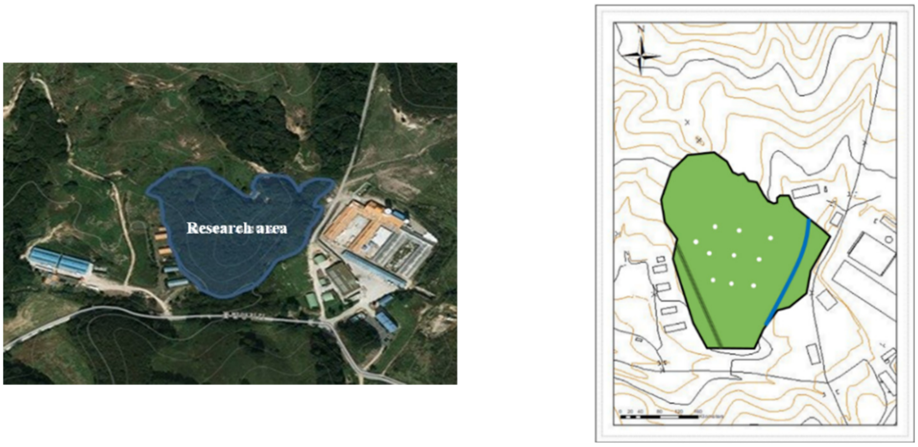
In the concept of forest grazing, Daegwallyeong was a good candidate due to its environmental conditions and location. Because Daegwallyeong is located at a high altitude, there are fewer diseases than at low altitudes, resulting in favorable conditions for raising livestock. In the 1970s, the government of South Korea provided financial support for pastoral farming, and some forests with similar conditions were converted to pasture, including Daegwallyeong high hills. Since then, there has been conflict between the two groups advocating for conservation versus development of the forest areas for forest grazing, especially at this location. Because it is an important area with high biodiversity, representing the core ecological axis of Baekdu-daegan [7], the Ramsar Wetlands in the high mountains of Mt. Odae has been designated as having unique and diverse biota and landscape characteristics [8]. By converting the abandoned forest area to pasture, some positive effects were observed in the deforested land. However, forest grazing may indeed harm the natural forest ecosystem. Therefore, an improved livestock method should be pursued in depth to develop rational and scientific alternatives to current forest grazing [9]. However, the livestock industry is focused on improving animal welfare rather than minimizing loss of biodiversity. The flora biodiversity can be more negatively affected, and these effects may be irreversible once it disappears from the natural habitats. Therefore, the flora changes should be monitored in previously established pastures to minimize harm. In particular, before grasslands in the forest are formed, the natural forest ecosystem must be identified, and problems that may arise due to grassland formation must be predicted and avoided [10].

Furthermore, it is necessary to determine which native plants can be affected by the foreign grasses, as well as which are the most significant risk factors for ecosystem disturbance. Therefore, we investigated flora and vegetation in the Daegwallyeong forest area before and after the pasture formation. We also analyzed the impact of forest grazing on plant biodiversity.

## 2. Materials and Methods

### *2.1. Study Area*

Daegwallyeong is a mountain pass at the border of Gangneung city and Pyeongchang-gun, South Korea, and it is the gateway to the Taebaek mountains that connect Yeongseo and Yeongdong. To the north of this area is Odaesan National Park. It is located in the core ecological axis of Baekdu-daegan [7] and is an area with high conservation value due to its high biodiversity. There are many wetlands at the top of the adjacent Odaesan mountain, such as Jilmoe and Sohwangbyeongsan Bog, designated the Ramsar Wetlands. It is an area with diverse and unique biota and landscape characteristics, with high-rise wetlands throughout [8]. Flora and vegetation surveys were conducted at Sky Ranch in Hoenggye-ri, Daegwallyeong-myeon, Pyeongchang-gun, and Gangwon-do. The coordinates of the study area are 37.7141° N, 128.7257° E. The study area is a 2.3 ha forest area that has not been subjected to artificial disturbances other than thinning trees with poor shape and forest grazing. The tree species observed in the study area were *Quercus mongolica*, *Pinus densiflora*, *Acer pseudo-sieboldianum*, *Fraxinus rhynchophylla*, *Tilia amurensis*, *Acer pictum* subsp. *mono*, *Prunus sargentii*, *Sorbus alnifolia*, *Betula davurica*, *Maackia amurensis*, *Juglans mandshurica*, *Prunus mandshurica*, *Cornus controversa*, and *Phellodendron amurense*, for a total of 887 trees. According to the tree shape, height, DBH (diameter at breast height), and crown shape, inferior trees were selected and thinned. The number of thinned trees was 659, representing about 74% of the covered canopy. After thinning, 228 trees and eight species remained: *Quercus mongolica*, *Pinus densiflora*, *Sorbus alnifolia*, *Betula davurica*, *Juglans mandshurica*, *Prunus mandshurica*, *Cornus controversa*, and *Phellodendron amurense* (Figure 1).




(a) (b)

**Figure 1.** (**a**) The survey area in Pyeongchang county, Gangwon province, South Korea. (**b**) The 2.3 ha survey area and 10 sites within the grasslands created in the forest. The blue line represents a valley, while the green line represents a dry valley.

### 2.2. Survey Method

The study site is a natural forest that surrounds the valley on both sides. One valley is flowing, while the other is a dry valley. Grasslands are located between the two valleys. This area is where thinning was performed. For the investigation of vascular plants, both slopes and valleys were included. Most plant species were investigated except for the trees left after thinning. Plant surveys were conducted from 2014 to 2019. From 2014 to 2017, the survey was conducted seasonally, focusing on flowering and fruiting periods. All practices applied in the area and survey are described in Table 1. Plants growing within the research area were recorded in field notes. When it was difficult to classify plants, photographs were taken, and identification was conducted by referring to recent plants [11,12]. The list of vascular plants was organized according to the Engler system [13]. According to the Checklist of Vascular Plants in Korea, the scientific name and common Korean names were listed by the Korea Forest Service [14]. Plants were organized on the basis of a list of rare plants according to the International Union for Conservation of Nature and Natural Resources (IUCN) [15]. The Korea Forest Service provided a list of rare plants in 571 taxa, and the Ministry of Environment provided a list of rare plants in 543 taxa. Plants were classified as "extinct in the wild," "critically endangered," "endangered," "vulnerable," "least concern" (LC), and "data-deficient." Plant life forms were classified according to Raunkiær's system [16]. A vegetation survey was conducted as a function of the slope except for the valley where water flowed in the study area. The phytosociology research method of Braun-Blanquet [17] was referenced at 10 designated study sites. The cover degree of plants appearing in study sites was measured in seven classes according to the cover area and number of individuals (Table 2). The rank of the cover degree represents the quantitative scale of plant species transformed into a sequence scale by a natural logarithm, which is advantageous for mathematical analysis in extracting vegetation units.

### 2.3. Analysis of the Flora Composition

All plant species found in the area are listed in Appendix A. New appearances and disappearances were determined by the year. Ordination analysis was performed to understand the characteristics of the forest caused by disturbances in the area. As an analysis tool, the Vegan package [18] was used in the R program (R version 4.1.0, GNU General Public License, New Zealand). Nonmetric multidimensional scaling was performed to establish the relationship between species in the study area. The plant coverage of each site was compared to express the site's characteristics. The formula in the analysis method from the "decorana" function in the Vegan package was used to analyze the relationship between the ratio of the growing cover degree between species in the 10 study sites.

**Table 1.** Plant survey and disturbances in time courses.

<table>
<tr><th>Year \ Month</th><th>April</th><th>May</th><th>June</th><th>July</th><th>August</th><th>September</th><th>October</th></tr>
<tr><td>2014</td><td rowspan="4">Plant survey</td><td></td><td rowspan="3">Plant survey</td><td></td><td></td><td></td><td rowspan="3">Plant survey</td></tr>
<tr><td>2015</td><td></td><td colspan="2">Thinning</td><td>Residue removal</td></tr>
<tr><td>2016</td><td></td><td>Grazing</td><td></td><td></td></tr>
<tr><td>2017</td><td>Grazing</td><td>Residue removal</td><td>Plant survey</td><td>Grazing</td><td>Plant survey</td><td>Grazing</td></tr>
<tr><td>2018</td><td colspan="7">Grasslands in fallow</td></tr>
<tr><td>2019</td><td>Plant survey</td><td></td><td>Plant survey</td><td></td><td></td><td>Plant survey</td><td></td></tr>
</table>

**Table 2.** Braun-Blanquet cover abundance scale.

| Braun-Blanquet Scale | Range of Cover |
|---|---|
| r | <5%; very few individuals |
| + | <5%; few individuals |
| 1 | <5%; numerous individuals |
| 2 | 5%–25% |
| 3 | 25%–50% |
| 4 | 50%–75% |
| 5 | 75%–100% |

$$S = \sqrt{\frac{\sum_{i \neq j} \left[\theta\left(d_{ij}\right) - \widetilde{d}_{ij}\right]^2}{\sum_{i \neq j} \widetilde{d}_{ij}^2}} \quad (1)$$

Additionally, a detrended correspondence analysis was conducted. Detrended correspondence analysis arranges rare plants and species with strong influence in cover degree on a two-dimensional line. This method makes it possible to observe the change phase by grasping species with a high ratio in the trend of rare plants and their growing cover degree. For cluster analysis, the "hclust" function of the Vegan package was used by using the cover degree of the group to determine the distance between plant groups in study sites. In this cluster analysis, there are three alternative methods, "single," "complete," and "average," depending on the scope and quantity to be investigated. In this study, hierarchical cluster analysis was carried out using the "complete" method, enabling complete hierarchical classification even when the amount of data was small.

## 3. Results

### *3.1. Total Number of Vascular Plant Species in the Study Sites over Time*

The numbers of plant taxa at each classification level in the year 2014, i.e., original composition without any forest management practices, in 2015, 2016, and 2017, when disturbed by heavy thinning and residue removal on the forest floor, and in the year after grazing (2019) are summarized in Table 3. The numbers and compositions of plants were slightly different across each year. There were 92 families, 257 genera, 311 species, eight forms, three subspecies, 44 varieties, and 366 taxa of vascular plants in the study sites in 2014 at the time of the survey beginning, prior to any disturbance. We found changes in the flora composition after each event. At first, varieties of plant species were changed after the thinning and residue removal in 2015. The total number of taxa was decreased to 360, comprising 92 families, 254 genera, 309 species, six forms, three subspecies, and 42 varieties in 2015. At this time, nine taxa appeared, but 16 disappeared. Newly emerged plants belonged to Compositae and Lilaceae, whereas three taxa of Polygonaceae were not found in 2015. More plant taxa, 366 taxa in total, were found with 93 families, 257 genera, 312 species, seven forms, three subspecies, and 44 varieties in 2016, a year after thinning and short grazing practices. In 2017, however, fewer families, 89, were found, with 243 genera, 288 species, seven forms, three subspecies, 44 varieties, and 342 taxa in total. As described in Table 1, there were severe disturbances in 2017, such as two grazing events and additional residue removal on the forest floor. While 31 plant species disappeared, only a few plant species returned at this time. When we performed a plant survey in 2019, a year after no feeding, the total number of plant taxa was 357, including 89 families, 249 genera, 300 species, three subspecies, 47 varieties, and seven forms. This number was increased from 2017 but decreased compared with 2014, 2015, and 2016. When the plant taxa were classified by family, the Compositae family was predominant, followed by Rosaceae, Leguminosae, Liliaceae, and others. The percentage of each family changed slightly as the years passed; however, compared with 2014, the proportions of Gramineae and Polygonaceae were significantly decreased in 2019 (Figure 2).

**Table 3.** Summary of plant taxa in the study sites by year.

| Year | Site | Family | Genus | Species | Forms | Subspecies | Varieties | Total |
|---|---|---|---|---|---|---|---|---|
| 2014 | Total | 92 | 257 | 311 | 8 | 3 | 44 | 366 |
| | Grasslands | 60 | 212 | 266 | 6 | 2 | 36 | 310 |
| | Valley | 32 | 45 | 45 | 2 | 1 | 8 | 56 |
| 2015 | Total | 92 | 254 | 309 | 6 | 3 | 42 | 360 |
| | Grasslands | 60 | 210 | 264 | 4 | 2 | 35 | 305 |
| | Valley | 32 | 44 | 45 | 2 | 1 | 7 | 55 |
| 2016 | Total | 93 | 257 | 312 | 7 | 3 | 44 | 366 |
| | Grasslands | 62 | 213 | 268 | 5 | 2 | 36 | 311 |
| | Valley | 31 | 44 | 44 | 2 | 1 | 8 | 55 |
| 2017 | Total | 89 | 243 | 288 | 7 | 3 | 44 | 342 |
| | Grasslands | 58 | 199 | 245 | 5 | 2 | 36 | 288 |
| | Valley | 31 | 44 | 43 | 2 | 1 | 8 | 54 |
| 2019 | Total | 89 | 249 | 300 | 7 | 3 | 47 | 357 |
| | Grasslands | 58 | 205 | 257 | 5 | 2 | 39 | 303 |
| | Valley | 31 | 44 | 43 | 2 | 1 | 8 | 54 |

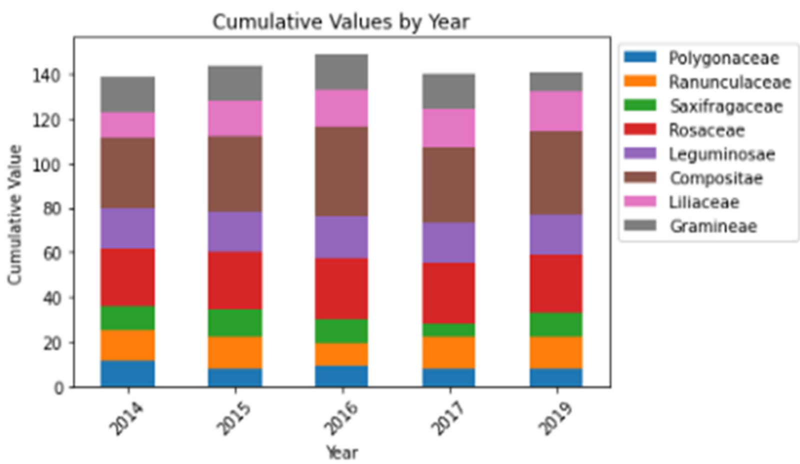



**Figure 2.** Number of taxa in each family present each year.

The plant species numbers according to Raunkiær's life-form classification are shown in Figure 3. The numbers of each life form changed every year but had a different pattern. The numbers of two types, geophyte (G) and helophyte (H), fluctuated as a function of the event each year; they increased after thinning, decreased after grazing, and increased again when there was no feeding. The number of nanophanerophytes (N) decreased significantly after thinning and residue removal. However, it bounced back in 2016 even after grazing. In contrast, there were few changes in the numbers of microphanerophytes (M) and therophytes (Th).

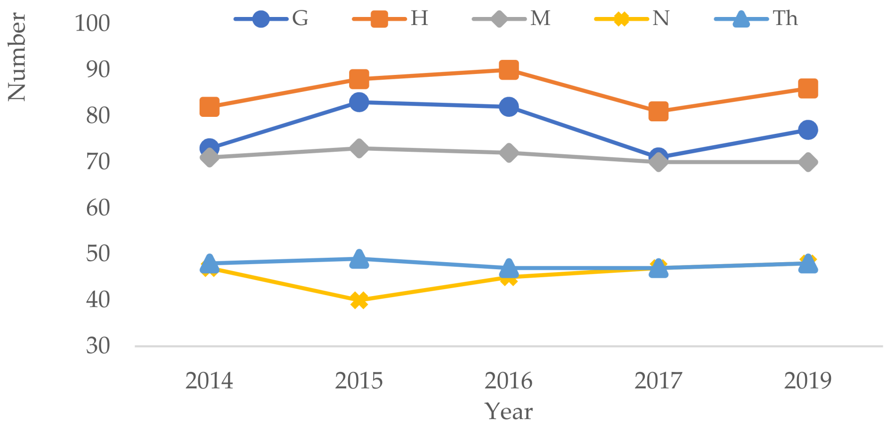



**Figure 3.** The plant species numbers according to Raunkiær's life-form classification.

### 3.2. *Changes in Plant Composition Due to the Forest Grazing Practices*

The plant composition in the study area was analyzed according to the disturbances over time. The comprehensive list of plant changes is presented in Appendix A. It was highly affected by the disturbances and resulted in the disappearance of some rare plant species and an inrush of naturalized species (Table 4). First, 16 taxa disappeared after the thinning in 2015. Many shrubs (*Rubus idaeus* var. *microphyllus*, *Rubus parvifolius* f. *concolor*, *Rubus phoenicolasius*, *Sorbaria sorbifolia* var. *stellipila*, *Sorbus commixta*, *Spiraea prunifolia* f. *simpliciflora*, *Spiraea salicifolia*, and *Stephanandra incisa*) and herbaceous plants (*Corydalis ochotensis*, *Sedum kamtschaticum*, *Sedum sarmentosum*, *Astilbe koreana*, *Astilbe rubra*, *Chrysosplenium grayanum*, *Sanguisorba officinalis*, and *Lamium album* var. *barbatum*) disappeared because of residue removal from the forest floor. Meanwhile, nine plant species, including *Populus tomentiglandulosa*, *Pennisetum alopecuroides*, and *Taraxacum officinale*, newly emerged in 2015.

In 2016, a year after thinning residual removal from the forest floor, 13 plant species among the 16 that disappeared in 2015 returned. Two plant species, *Morus bombycis* var. *maritima* and *Rubus parvifolius*, were observed for the first time from this area in 2016. Despite no residue removal from the floor, more plant species were lost in 2016. Twelve more species were lost in 2016 after a short period of livestock feeding in July.

There was a significant disappearance of plant species in 2017 due to three grazing events and additional forest floor removal. Thirty-one plant species disappeared, while 22 species did not return until 2019. Among these, two plant species (*Rubus oldhamii* and *Erechtites hieracifolia*) were not originally grown on the sites but emerged in 2016. Seven species were different from those in 2016, and they were revived ones that disappeared in 2015 and 2016. We did not notice any disappearance of plant species in 2019, which is the following year with no disturbances, i.e., thinning, residue removal, or grazing. On the other hand, 15 species appeared at this time. Six species, *Pseudostellaria heterophylla*, *Meehania urticifolia*, *Cirsium japonicum* var. *maackii*, *Convallaria keiskei*, *Calamagrostis langsdorfii*, and *Erythronium japonicum*, were revived ones that emerged in 2015 and then disappeared in 2017. The other nine species were newly observed in this area: *Barbarea vulgaris*, *Thlaspi arvense*, *Isodon inflexus*, *Weigela florida*, *Artemisia montana*, *Artemisia stolonifera*, *Paris verticillata*, *Smilax riparia* var. *ussuriensis*, and *Carex humilis* var. *nana*. When comparing the composition of plant species in 2019 and 2014, 16 species were not original components in the study area and were presumably introduced from outside the study site. Meanwhile, 31 plant species vanished from the original flora composition throughout the years.

**Table 4.** Changes in floral composition in the study area by year and the disturbances. Underlined species disappeared once and revived 1 or 2 years later; bold species disappeared and never returned; bold and underlined species were newly observed and then disappeared 1 or 2 years later.

| Year (Disturbance) | Appear | Disappear |
|---|---|---|
| 2015 (after thinning) | *Populus tomentiglandulosa*, *Pseudostellaria heterophylla*, *Lamium amplexicaule*, *Meehania urticifolia*, *Cirsium japonicum* var. *maackii*, *Taraxacum officinale*, *Convallaria keiskei*, *Erythronium japonicum*, *Calamagrostis langsdorfii*, (9) | *Corydalis ochotensis*, *Sedum kamtschaticum*, *Sedum sarmentosum*, *Astilbe koreana*, *Astilbe rubra*, *Chrysosplenium grayanum*, *Rubus idaeus* var. *microphyllus*, *Rubus parvifolius* f. *concolor*, *Rubus phoenicolasius*, *Sanguisorba officinalis*, *Sorbaria sorbifolia* var. *stellipila*, *Sorbus commixta*, *Spiraea prunifolia f. simpliciflora*, *Spiraea salicifolia*, *Stephanandra incisa*, *Lamium album* var. *barbatum* (16) |
| 2016 (1 month-grazing) | *Morus bombycis* var. *maritima*, *Lepidium apetalum*, *Sedum kamtschaticum*, *Sedum sarmentosum*, *Astilbe koreana*, *Astilbe rubra*, *Chrysosplenium flagelliferum*, *Chrysosplenium grayanum*, *Rubus parvifolius*, *Rubus phoenicolasius*, *Sanguisorba officinalis*, *Sorbaria sorbifolia* var. *stellipila*, *Sorbus commixta*, *Spiraea prunifolia* f. *simpliciflora*, *Spiraea salicifolia*, *Ligusticum hultenii*, *Lamium album* var. *barbatum* (17) | *Morus bombycis*, *Anemone koraiensis*, *Hepatica asiatica*, *Viola diamantiaca*, *Peucedanum terebinthaceum*, *Chionanthus retusus*, *Lamium amplexicaule*, *Mosla punctulata*, *Scopolia japonica*, *Viburnum opulus* var. *calvescens*, *Erechtites hieracifolia*, *Streptopus ovalis* (12) |
| 2017 (Grazing for 3 times and residue removal) | *Hepatica asiatica*, *Corydalis ochotensis*, *Rubus idaeus* var. *microphyllus*, *Rubus oldhamii*, *Stephanandra incisa*, *Peucedanum terebinthaceum*, *Viburnum opulus* var. *calvescens*, *Erechtites hieracifolia* (8) | *Dennstaedtia wilfordii*, *Coniogramme intermedia*, *Asplenium ruprechtii*, *Thelypteris palustris*, *Onoclea orientalis*, *Lepisorus thunbergianus*, *Abies holophylla*, *Betula davurica*, *Carpinus laxiflora*, *Urtica angustifolia*, *Pseudostellaria heterophylla*, *Cimicifuga dahurica*, *Cimicifuga heracleifolia*, *Cimicifuga simplex*, *Corydalis pauciovulata*, *Draba nemorosa*, *Lepidium apetalum*, *Chrysosplenium flagelliferum*, *Euonymus sachalinensis*, *Viola verecunda*, *Ligusticum hultenii*, *Meehania urticifolia*, *Artemisia feddei*, *Cirsium japonicum* var. *maackii*, *Parasenecio auriculatus* var. *matsumuranus*, *Convallaria keiskei*, *Disporum viridescens*, *Erythronium japonicum*, *Calamagrostis langsdorfii*, *Symplocarpus renifolius*, *Oreorchis patens* (31) |
| 2019 (no-grazing for 1~2 years) | *Pseudostellaria heterophylla*, *Barbarea vulgaris*, *Thlaspi arvense*, *Isodon inflexus*, *Meehania urticifolia*, *Weigela florida*, *Artemisia montana*, *Artemisia stolonifera*, *Cirsium japonicum* var. *maackii*, *Convallaria keiskei*, *Erythronium japonicum*, *Paris verticillata*, *Smilax riparia* var. *ussuriensis*, *Calamagrostis langsdorfii*, *Carex humilis* var. *nana* (15) | None |

### *3.3. Changes in Vegetation before and after Grassland Formation in the Forest*

We analyzed the similarity of the sample quadrats and how they changed over the years using hierarchical cluster analysis, as shown in Figure 4. According to the analysis, there were no differences among the quadrats in 2014. However, they could be divided into three groups (red, green, and blue) in 2019 when the forest suffered many disturbances: thinning, residual removal, and grazing. Among 10 quadrats, eight were clustered in one group, and quadrats No. 3 and No. 10 were separated into different groups. The cluster in the red zone, quadrat No. 3, was occupied by *Tripterygium regelii* and *Trifolium pretense*. Quadrat No. 10 in the blue zone was dominated by some woody shrubs, *Acer pseudosieboldianum* and *Stephanandra incisa*. Quadrats in the green group had

*Carex callitrichos* var. *nana* as a dominant species. It is thought that the topography differentiated the characteristics of the quadrats. Quadrat No. 3 was located at 900–920 m and had a gentle slope of 5–10°. The height of plants was about 0.5–1 m, and the coverage was 30–50%. There were only 11 species on average found in this quadrat, representing the fewest types of plants among the 10 quadrats. It is thought that the gentle slope led to it becoming a frequent grazing spot. In addition, the forest floor in this spot was severely damaged. Quadrat No. 10 in the blue zone was located at 910–930 m, similar to Quadrat No. 3, but the slope ranged from 10–15°, steeper than No. 3. The height of plants was about 1.5–3 m, and the coverage was 50–80%. On average, 58 species appeared in this quadrat. Various plants were observed along the dry valley, dominated by *Acer pseudosieboldianum*, *Stephanandra incisa*, *Prunus sargentii*, and *Magnolia sieboldii*, which are as tall as 2–8 m. This site was hard for cows to visit and feed, resulting in less disappearance of plant species due to grazing. The green cluster's quadrats had a gentle slope and a suitable environment for cows to move around. Two plant species, *Carex callitrichos* var. *nana* and *Festuca arundinacea* in the Gramineae family, were most prevalent, and these are known ecosystem-disturbing plant species. Although these two species occurred in several quadrats in 2014, they dramatically expanded their coverage in 2019, replacing the habitats of the existing flora that disappeared throughout the years.

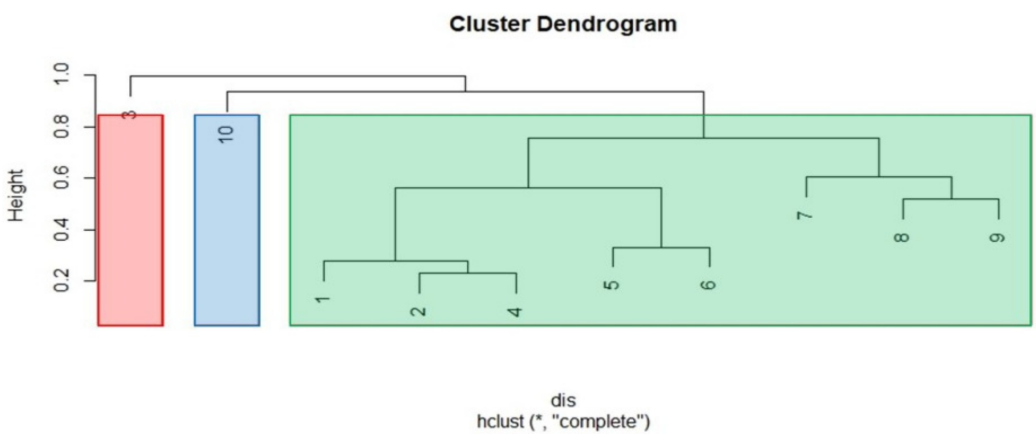



**Figure 4.** Cluster dendrogram applied to the "hclust" function in Vegan to perform hierarchical analysis with the cover degree of the plant. The "complete" option was used to express a compact cluster. The clusters in the red zone were areas occupied by *Tripterygium regelii* and *Trifolium pratense*. The clusters in the blue zone were areas dominated by *Acer pseudosieboldianum* and *Stephanandra incisa*. Green areas were inhabited by *Carex callitrichos* var. *nana*; 1–10 denote the site numbers.

The flora composition was characterized using stress plot analysis. According to the plant coverage of 10 quadrats, overlapped dots represent that the forest was covered with simple vegetation in 2014 (Figure 5a,b). On the other hand, the dots in 2019 were spread across various places, indicating that the major dominant species disappeared, and each quadrat was covered with different plant species (Figure 5c,d). Thus, it could be misread that the original flora composition was less diverse. However, there was a stable forest community with few dominant tree species and various herbaceous plants in the understory, including rare plant species. After human interruptions, the forest was covered with some heliophytes such as *Sasa borealis*, as well as plants on which cows did not feed.

Detrended correspondence analysis showed that more plant species had broader coverage in the forest (Figure 6). Ten species had relatively higher coverage in 2014, and five of them, *Symplocarpus renifolius*, *Isodon excisus*, *Symplocos chinensis* f. *pilosa*, *Sasa borealis*, and *Tripterygium regelii*, had much higher ones. The number of species with high coverage was increased to 16 species, including existing species, *Sasa borealis*, *Tripterygium regelii*, and *Aralia elata*. Fourteen species became high-coverage plants, including *Carex callitrichos* var. *nana*, *Festuca arundinacea*, *Rumex acetosa*, and *Lespedeza bicolor*.

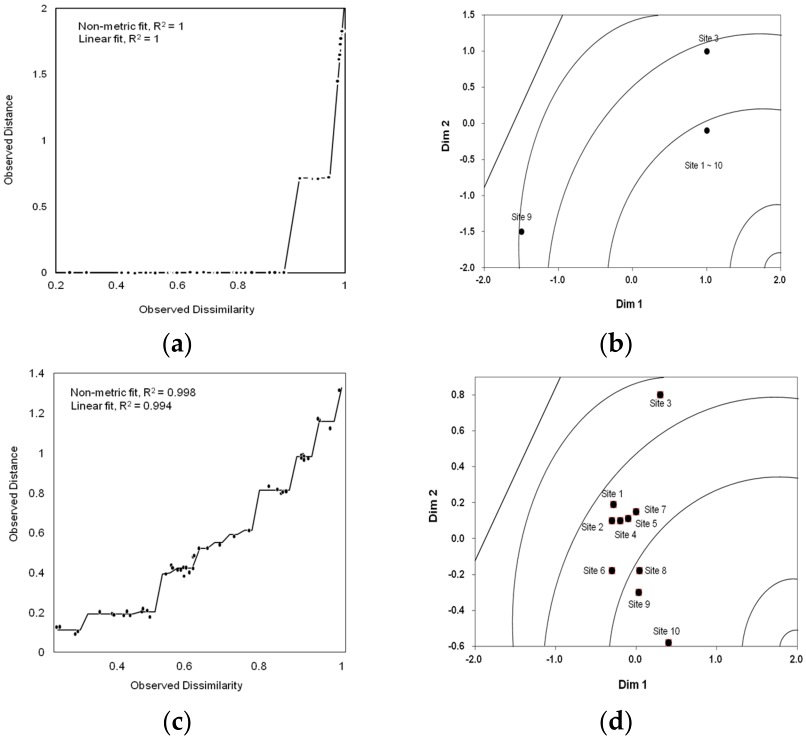



**Figure 5.** NMDS stress plot showing the location of the survey area that has changed since the formation of grasslands in forestry. In (**a**), as a result of ordination analysis, the stress plot in 2014 exhibits many overlapping lines and points. Applying this to forest vegetation reveals a simple forest vegetation structure in which a single plant type is distributed. (**c**) is the result of ordination analysis based on a plant survey in 2019. In 2019, a grassland was built in the research area and livestock was introduced. Hence, there were various factors that could disturb the understory vegetation. In 2019, the stress plot had points spread along the line. This indicates that the understory vegetation disturbances began as they formed grasslands in the forest. In (**b**,**d**), the location of the research plot was placed on the same contour line as the research area based on ordination analysis and the stress plot.

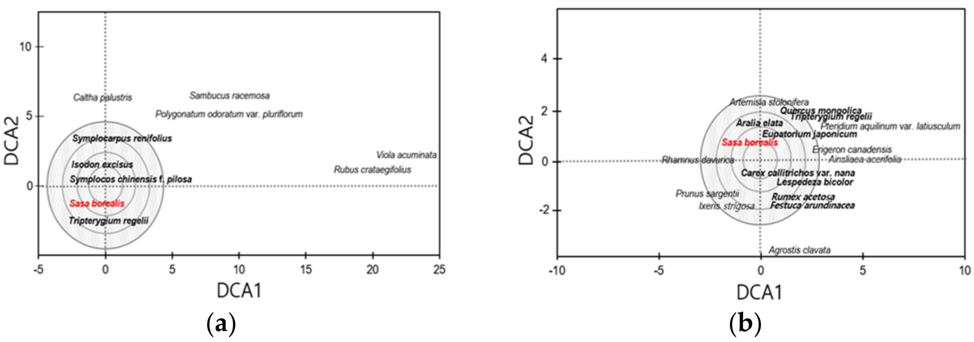



**Figure 6.** Detrended correspondence analysis (DCA). Plants that frequently appeared in the research area are shown on the graph, i.e., plants that appeared more frequently approach the center of the circle of the graph. (**a**) 2014; there were five species of plants that frequently appeared before grasslands were formed in the research area: *Symplocarpus renifolius*, *Isodon excisus*, *Symplocos chinensis* f. *pilosa*, *Sasa borealis*, and *Tripterygium regelii*. (**b**) 2019; the number of taxa increased compared to 2014 from 10 to 16, with five species increasing inside the target. The number of *Sasa borealis* increased, and the plants with increased cover were *Aralia elata*, *Carex callitrichos* var. *nana*, *Eupatorium japonicum*, *Festuca arundinacea*, *Lespedeza bicolor*, *Quercus mongolica*, *Rumex acetosa*, and *Tripterygium regelii*.

## 4. Discussion

Subalpine and alpine regions are well known as regions rich in plant diversity due to little human intervention. Daegwallyeong is also an area where the Ramsar Wetlands and primeval forests developed with high species diversity. However, some forest areas were converted to pasture for livestock due to economic reasons. The 2.3 ha research area in Daegwallyeong was also forced to convert to pasture for livestock feeding. We established 10 sample quadrats to investigate the changes in flora composition over time as a function of disturbance events. The first impact observed was a change in plant species. The number of plant species changed over time but did not significantly decrease. This could give a false indication that livestock feeding had less of an effect on the natural ecosystem [19]. However, the composition of the plant community dramatically changed. The impact on the forest differed according to disturbance type. Unexpectedly, not only woody plants but also shrubs and herbaceous plants were removed by thinning in 2015. Among the disappeared plant species, *Rubus parvifolius* f. *concolor* did not return until 2019. It also resulted in an inrush of naturalized plants, such as *Taraxacum officinale*. This species remained until 2019, along with *Populus tomentiglandulosa*. A noticeable change after the thinning was the expansion of heliophytes such as *Tripterygium regelii*, which inhibited the growth of other species. The month of grazing in 2016 and three additional grazing events in 2017, along with residue removal, significantly impacted the flora composition. The type of disturbance influenced the plant life forms differently. Geophytes (G) and helophytes (H) increased right after thinning but decreased after grazing. In contrast, nanophanerophytes (N) were influenced by thinning rather than grazing. This pattern was consistent with the appearance of new species or the disappearance of existing species in this area. Some species of nanophanerophytes (N), e.g., *Tripterygium regelii* and *Sasa borealis*, were removed by thinning. They, however, increased and expanded their coverage due to a lack of competitors even after grazing. The rare species, *Rodgersia podophylla*, *Viola diamantiaca*, *Scopolia japonica*, and *Streptopus ovalis*, in this area are geophytes, and most of them disappeared after grazing due to the impact of feeding and trampling by livestock. According to the report by Noy-Meir and Oron [20], only geophyte species are negatively affected by the grazing, although their diversity does not change much. Therefore, this suggests that grazing had a greater impact on the plant species rather than the diversity.

A high number of plant species (31) disappeared, and only a few species (eight) returned in 2017, with an absence of rare plants among the returned ones. There was no further disappearance of plant species in the absence of grazing or forest treatments for livestock feeding during 2018 and 2019, while there was an increase in the number of returned species that disappeared in 2017. Some plant species were initially classified as rare and endangered in the sample quadrats in 2014: *Anemone koraiensis*, *Aristolochia manshuriensis*, *Rodgersia podophylla*, and *Scopolia japonica*, *Viola albida*, *Viola diamantica*, *Parasenecio auriculatus*, *Trillium kamtschaticum*, and *Bupleurum falcatum*, representing eight families in total. *Trillium kamtschaticum* is an endangered plant designated by the Ministry of Environment (2013). These eight species are rare plants designated by Korea Forest Service: *Anemone koraiensis* (LC), *Aristolochia manshuriensis* (LC), *Rodgersia podophylla* (LC), *Scopolia japonica* (LC), *Viola albida* (LC), *Viola diamantica* (LC), *Parasenecio auriculatus* (LC), and *Bupleurum falcatum* (VU). However, most species disappeared in sample quadrats after grassland creation. We could no longer observe three species (*Anemone koraiensis*, *Viola diamantica*, and *Rodgersia podophylla*) in the study area. Fortunately, three plant species, *Scopolia japonica*, *Parasenecio auriculatus*, and *Trillium kamtschaticum*, survived along the valley area, which was not included in the sample quadrats.

According to Austrheim and Eriksson [21], the pattern of plant diversity in alpine regions is determined by the dominant herb. They explained that the disturbance caused by the grazing of herbivorous animals is the most significant factor that disturbs vegetation in alpine regions. In addition, such disturbances were an exception in regions with cliffs and gorges, similar to the results of this study. For the disturbed vegetation to return to its original state, time is a critical factor, and this is exacerbated in an alpine environment.

We also lost several rare plants from the research area due to livestock feeding and related practices such as thinning and ground removal. While a few plants came back to the site, some rare plants disappeared following the first stage of the livestock feeding and never returned after the fallow of grazing. The results of our study partially agree with the above study. All practices related to livestock feeding had a more adverse impact on vegetation compared to time, especially grazing and ground removal. These had an even worse effect in causing the native vegetation to disappear. When such disturbances continue to occur, it will be impossible to return to the native vegetation.

Rare plants were less competitive than naturalized plants and ecosystem-disturbing species. Plant functional types (PFTs) could be observed according to grazing. Before grazing, erect and large PFTs with a rosette growth form were evenly observed. However, after grazing, the upright and large Saxifragaceae and Gramineae decreased sharply. In addition, when grazing was performed frequently in 2017, many small PFTs with a rosette growth form of Compositae and Rosaceae were observed (Figure 3). This is similar to the results of May and Jeltsch [22]. These findings are considered significant in monitoring the process of vegetation change according to grazing in mountain areas. In addition, these results can serve as a reference plant ecosystem when implementing grassland management. Overall, there was a decrease in overall vegetation, including rare plants in the fixed irradiation area. When thinning and grazing began, the number of rare plants native to the irradiated area decreased significantly. The reason is that rare plants tend to be more sensitive to environmental changes than other plants that can adapt to different growing conditions.

According to three statistical analyses based on the coverage of the species, the characteristics of each sample quadrat changed significantly. Sample quadrats were divided into three groups occupied by different plant species, unlike in 2014. The topography was considered the main reason for this, whereby our study area reflected the nature of a terrain inaccessible to vegetation and herbivores, as it spans a flowing valley [21]. Comparisons with this area show that artificial disturbances or environmental changes can alter plants. While the results of the current vegetation analysis revealed differentiation of a monotonous forest where the types of plants increased, the area occupied by certain plants decreased. As explained above, topographic conditions might act as obstacles for livestock. More damage occurred on the gentle slope. In addition, it is challenging to grow herbaceous plants under taller plants, which resulted in less food for the livestock in one quadrat [23].

Moreover, all rare plants were eliminated in the sample quadrats; some rare plants survived in the valley where the livestock could not visit. Interestingly, there were no changes in the valley areas where water flows before (2014) and after (2019) grassland was established in the forest. This is considered to be an important observation regarding human or animal activity causing environmental changes. In addition, it was found that natural buffer zones can be set on the basis of topographical conditions rather than manufactured structures, such as fences [24]. This fact can be used positively when introducing grassland in environmentally sensitive areas, such as Daegwallyeong. Thus, topographic studies should be conducted before and during the process of creating pastures in forests.

We could define the characteristics of the area using two analyses. The vegetation of the sample quadrats changed dramatically due to the disturbances related to grassland creation. While the initial sites were divided into three groups in 2014, each had a different characteristic in 2019 after the disturbances. DCA analysis showed the vegetation changes in detail and their differences before and after the disturbances. In the initial forest, few species dominated, and those species were natural, although *Sasa borealis* represents a potential danger to the ecosystem. However, this species expanded its distribution after thinning, and more harmful species such as *Aralia elata*, *Carex callitrichos* var. *nana*, *Eupatorium japonicum*, *Festuca arundinacea*, *Lespedeza bicolor*, *Quercus mongolica*, *Rumex acetosa*, and *Tripterygium regelii* took more space in the area. Among these, *Triptery-*

*gium regelii* is notorious for prohibiting the growth of small herbaceous plants on the forest floor. Moreover, *Carex callitrichos* var. *nana* and *Rumex acetosa* are known as species that disturbs the plant ecosystem [25,26]. These changes suggest that the plant community changed to an unhealthy state due to grassland creation. According to the analysis of the disappearance of plant species, grazing practice had a worse effect than simple thinning. The present study results are similar to those of Jeong [27], who showed an increase in plants that favor light after forest thinning. However, their study observed natural changes after thinning, while the current study differed in the creation and grazing of grasslands in forests. While both studies indicated plant changes after forest thinning, the present research suggests that animals can also change plant composition. This is exemplified in the blue cluster of Figure 4, where cows moved less due to the steep slope, taller trees, and more fallen leaves than other areas. Therefore, it appeared to be a relatively more diverse microscopic environment than other areas [28]. Likewise, Ide [29] reported that the number of rapidly emergent species increased as the slope became steeper in grazing grasslands. This is thought to be caused by physical disturbances, such as cow paths and grazing habits.

Agroforestry is a prevalent farming method practiced worldwide. According to studies by Nair and Ramachandran [30] and Jose and Shibu [31], the benefits of forest grazing include improvement of water quality, mitigation of carbon emissions and climate change, improvement of soil quality, and conservation of biodiversity. Moreover, many advantages arise from the continuous implementation of this management system. The number of plants that interfere with vegetation (e.g., *Tripterygium regelii* and *Sasa borealis*) decreases where cattle paths are formed. However, in terms of forest ecology, forest grazing has many inevitable drawbacks, such as the destruction of rare plants and interference with the composition and diversity of various forest-dwelling plants. Furthermore, Jose and Shibu [32] reported that global species and ecosystem declines are steadily increasing at an alarming rate, and, although attempts are being made to preserve species in protected areas, success has been limited. Likewise, a decline in rare and endangered plants was found in the present study. If measures to protect plants are not implemented, the destruction of the ecosystem will steadily increase.

More than half of Korea's territory is forest, and grazing livestock is recommended to promote forest grazing. To continuously implement forest grazing, basic research on the creation of grasslands in forests, management, utilization technology, and environmental conservation is essential. Unfortunately, most of the items corresponding to the development stage, such as policies and feed management laws related to grassland formation, tend to ignore these basic studies. For sustainable forest grazing, clear protection laws are needed for rare and endangered plants that grow naturally. In addition, due to insufficient management measures associated with grassland formation and grazing, as well as soil erosion, lower-vegetation ecosystems are destroyed, which may lead to a decrease in the number of plants in the future [33]. Therefore, it is necessary to enact protective measures in areas where rare and endangered plants grow naturally and implement forest grazing suitable for each natural environment.

## 5. Conclusions

The present study was conducted in a forested area that spans a valley located in the Sky Ranch area of Daegwallyeong, South Korea. Overall, the number of plant species increased from 2014 to 2019, after creating grasslands in the forest. However, due to the grassland formation, the number of rare and endangered plants decreased. Due to forest thinning, the amount of light reaching the ground intensified, increasing the number of sun-loving plants, such as *Sasa borealis*. It is thought that appropriate management of *Sasa borealis* is necessary for the development of understory vegetation. As the *Sasa borealis* feed research project progresses, livestock may not need to rely on exotic pasture resources, thereby creating another advantage of forest grazing. Government-approved projects to create more grassland in forested areas are steadily increasing every year. Although permit laws exist for creating pastures, there are no provisions for rare and endangered plants native to the targeted areas. For this reason, legal measures must be taken to protect the plants in the forest and conserve the environment.

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**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Plants appearing from 2014 to 2019 (grazing in 2018). "o" indicates Occurrence in that year.

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| Equisetaceae | *Equisetum arvense* | o | o | o | o | o |
| | *Equisetum hyemale* | o | o | o | o | o |
| Ophioglossaceae | *Sceptridium ternatum* | o | o | o | o | o |
| Osmundaceae | *Osmunda japonica* | o | o | o | o | o |
| Dennstaedtiaceae | *Dennstaedtia wilfordii* | o | o | o | | |
| | *Pteridium aquilinum* var. *latiusculum* | o | o | o | o | o |
| Parkeriaceae | *Coniogramme intermedia* | o | o | o | | |
| Aspleniaceae | *Asplenium ruprechtii* | o | o | o | | |
| Dryopteridaceae | *Dryopteris crassirhizoma* | o | o | o | o | o |
| | *Polystichum tripteron* | o | o | o | o | o |
| Thelypteridaceae | *Thelypteris palustris* | o | o | o | | |
| Woodsiaceae | *Athyrium niponicum* | o | o | o | o | o |
| | *Athyrium yokoscense* | o | o | o | o | o |
| | *Deparia pterorachis* | o | o | o | o | o |
| | *Onoclea orientalis* | o | o | o | | |
| | *Onoclea sensibilis* var. *interrupta* | o | o | o | o | o |
| Polypodiaceae | *Lepisorus thunbergianus* | o | o | o | | |
| Pinaceae | *Abies holophylla* | o | o | o | | |
| | *Larix kaempferi* | o | o | o | o | o |
| | *Pinus densiflora* | o | o | o | o | o |
| | *Pinus koraiensis* | o | o | o | o | o |
| Cupressaceae | *Juniperus rigida* | o | o | o | o | o |
| Juglandaceae | *Juglans mandshurica* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| Salicaceae | *Populus alba* | o | o | o | o | o |
| | *Populus tomentiglandulosa* | | o | o | o | o |
| | *Salix caprea* | o | o | o | o | o |
| | *Salix gracilistyla* | o | o | o | o | o |
| | *Salix koreensis* | o | o | o | o | o |
| | *Salix koriyanagi* | o | o | o | o | o |
| | *Salix rorida* | o | o | o | o | o |
| Betulaceae | *Alnus sibirica* | o | o | o | o | o |
| | *Betula costata* | o | o | o | o | o |
| | *Betula davurica* | o | o | o | | |
| | *Betula schmidtii* | o | o | o | o | o |
| | *Carpinus cordata* | o | o | o | o | o |
| | *Carpinus laxiflora* | o | o | o | | |
| | *Corylus heterophylla* | o | o | o | o | o |
| | *Corylus sieboldiana* | o | o | o | o | o |
| Fagaceae | *Castanea crenata* | o | o | o | o | o |
| | *Quercus aliena* | o | o | o | o | o |
| | *Quercus dentata* | o | o | o | o | o |
| | *Quercus mongolica* | o | o | o | o | o |
| | *Quercus serrata* | o | o | o | o | o |
| | *Quercus variabilis* | o | o | o | o | o |
| Ulmaceae | *Ulmus davidiana* var. *japonica* | o | o | o | o | o |
| Moraceae | *Morus bombycis* | o | o | | | |
| | *Morus bombycis* var. *maritima* | | | o | o | o |
| Cannabaceae | *Humulus japonicus* | o | o | o | o | o |
| Urticaceae | *Boehmeria spicata* | o | o | o | o | o |
| | *Boehmeria tricuspis* | o | o | o | o | o |
| | *Laportea bulbifera* | o | o | o | o | o |
| | *Pilea hamaoi* | o | o | o | o | o |
| | *Urtica angustifolia* | o | o | o | | |
| Polygonaceae | *Aconogonon alpinum* | o | o | o | o | o |
| | *Bistorta manshuriensis* | o | o | o | o | o |
| | *Persicaria conspicua* | o | o | o | o | o |
| | *Persicaria dissitiflora* | o | o | o | o | o |
| | *Persicaria filiformis* | o | o | o | o | o |
| | *Persicaria perfoliata* | o | o | o | o | o |
| | *Persicaria sagittata* | o | o | o | o | o |
| | *Persicaria senticosa* | o | o | o | o | o |
| | *Persicaria thunbergii* | o | o | o | o | o |
| | *Rumex acetosella* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| | *Rumex crispus* | o | o | o | o | o |
| Phytolaccaceae | *Phytolacca americana* | o | o | o | o | o |
| Portulacaceae | *Portulaca oleracea* | o | o | o | o | o |
| Caryophyllaceae | *Cerastium holosteoides* var. *hallaisanense* | o | o | o | o | o |
| | *Dianthus chinensis* | o | o | o | o | o |
| | *Lychnis cognata* | o | o | o | o | o |
| | *Pseudostellaria coreana* | o | o | o | o | o |
| | *Pseudostellaria heterophylla* | | o | o | | o |
| | *Pseudostellaria palibiniana* | o | o | o | o | o |
| | *Silene firma* | o | o | o | o | o |
| | *Stellaria aquatica* | o | o | o | o | o |
| Chenopodiaceae | *Chenopodium album* var. *centrorubrum* | o | o | o | o | o |
| Amaranthaceae | *Achyranthes japonica* | o | o | o | o | o |
| | *Amaranthus blitum* | o | o | o | o | o |
| Magnoliaceae | *Magnolia sieboldii* | o | o | o | o | o |
| Schisandraceae | *Schisandra chinensis* | o | o | o | o | o |
| Lauraceae | *Lindera obtusiloba* | o | o | o | o | o |
| Ranunculaceae | *Aconitum jaluense* | o | o | o | o | o |
| | *Aconitum longecassidatum* | o | o | o | o | o |
| | *Aconitum pseudolaeve* | o | o | o | o | o |
| | *Actaea asiatica* | o | o | o | o | o |
| | *Anemone koraiensis* | o | o | | | |
| | *Anemone reflexa* | o | o | o | o | o |
| | *Caltha palustris* | o | o | o | o | o |
| | *Cimicifuga dahurica* | o | o | o | | |
| | *Cimicifuga heracleifolia* | o | o | o | | |
| | *Cimicifuga simplex* | o | o | o | | |
| | *Clematis patens* | o | o | o | o | o |
| | *Clematis terniflora* var. *mandshurica* | o | o | o | o | o |
| | *Hepatica asiatica* | o | o | | o | o |
| | *Pulsatilla koreana* | o | o | o | o | o |
| | *Ranunculus japonicus* | o | o | o | o | o |
| | *Thalictrum aquilegifolium* var. *sibiricum* | o | o | o | o | o |
| | *Thalictrum uchiyamai* | o | o | o | o | o |
| Berberidaceae | *Berberis amurensis* | o | o | o | o | o |
| Lardizabalaceae | *Akebia quinata* | o | o | o | o | o |
| Menispermaceae | *Cocculus trilobus* | o | o | o | o | o |
| | *Menispermum dauricum* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | **2014** | **2015** | **2016** | **2017** | **2019** |
| Chloranthaceae | Chloranthus japonicus | o | o | o | o | o |
| Aristolochiaceae | *Aristolochia manshuriensis* | o | o | o | o | o |
| | *Asarum sieboldii* | o | o | o | o | o |
| Actinidiaceae | *Actinidia arguta* | o | o | o | o | o |
| | *Actinidia polygama* | o | o | o | o | o |
| Guttiferae | *Hypericum ascyron* | o | o | o | o | o |
| | *Hypericum erectum* | o | o | o | o | o |
| Papaveraceae | *Chelidonium majus* var. *asiaticum* | o | o | o | o | o |
| | *Hylomecon vernalis* | o | o | o | o | o |
| Fumariaceae | *Corydalis ochotensis* | o | | | o | o |
| | *Corydalis pauciovulata* | o | o | o | | |
| | *Corydalis remota* | o | o | o | o | o |
| | *Corydalis speciosa* | o | o | o | o | o |
| | *Corydalis turtschaninovii* Besser var. *linearis* | o | o | o | o | o |
| | *Dicentra spectabilis* | o | o | o | o | o |
| Cruciferae | *Arabis gemmifera* | o | o | o | o | o |
| | *Barbarea orthoceras* | o | o | o | o | o |
| | *Barbarea vulgaris* | | | | | o |
| | *Cardamine impatiens* | o | o | o | o | o |
| | *Cardamine leucantha* | o | o | o | o | o |
| | *Draba nemorosa* | o | o | o | | |
| | *Lepidium apetalum* | | | o | | |
| | *Thlaspi arvense* | | | | | o |
| Crassulaceae | *Sedum kamtschaticum* | o | | o | o | o |
| | *Sedum sarmentosum* | o | | o | o | o |
| Saxifragaceae | *Astilbe koreana* | o | | o | o | o |
| | *Astilbe rubra* | o | | o | o | o |
| | *Chrysosplenium flagelliferum* | | | o | | |
| | *Chrysosplenium grayanum* | o | | o | o | o |
| | *Deutzia glabrata* | o | o | o | o | o |
| | *Deutzia grandiflora* var. *baroniana* | o | o | o | o | o |
| | *Hydrangea serrata f. acuminata* | o | o | o | o | o |
| | *Philadelphus schrenkii* | o | o | o | o | o |
| | *Ribes fasciculatum* var. *chinense* | o | o | o | o | o |
| | *Ribes maximowiczianum* | o | o | o | o | o |
| | *Rodgersia podophylla* | o | o | o | o | o |
| | *Saxifraga fortunei* var. *incisolobata* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| Rosaceae | *Agrimonia pilosa* | o | o | o | o | o |
| | *Crataegus pinnatifida* | o | o | o | o | o |
| | *Duchesnea indica* | o | o | o | o | o |
| | *Filipendula glaberrima* | o | o | o | o | o |
| | *Geum japonicum* | o | o | o | o | o |
| | *Potentilla centigrana* | o | o | o | o | o |
| | *Potentilla cryptotaeniae* | o | o | o | o | o |
| | *Potentilla fragarioides* var. *major* | o | o | o | o | o |
| | *Potentilla freyniana* | o | o | o | o | o |
| | *Prunus mandshurica* | o | o | o | o | o |
| | *Prunus padus* | o | o | o | o | o |
| | *Prunus persica* | o | o | o | o | o |
| | *Prunus sargentii* | o | o | o | o | o |
| | *Pyrus pyrifolia* | o | o | o | o | o |
| | *Rosa multiflora* | o | o | o | o | o |
| | *Rubus crataegifolius* | o | o | o | o | o |
| | *Rubus idaeus* var. *microphyllus* | o | | | o | o |
| | *Rubus oldhamii* | o | | | o | o |
| | *Rubus parvifolius* | | | o | o | o |
| | *Rubus parvifolius* f. *concolor* | o | | | | |
| | *Rubus phoenicolasius* | o | | o | o | o |
| | *Sanguisorba officinalis* | o | | o | o | o |
| | *Sorbaria sorbifolia* var. *stellipila* | o | | o | o | o |
| | *Sorbus commixta* | o | | o | o | o |
| | *Spiraea prunifolia* f. *simpliciflora* | o | | o | o | o |
| | *Spiraea salicifolia* | o | | o | o | o |
| | *Stephanandra incisa* | o | | | o | o |
| Leguminosae | *Amorpha fruticosa* | o | o | o | o | o |
| | *Chamaecrista nomame* | o | o | o | o | o |
| | *Desmodium podocarpum* var. *oxyphyllum* | o | o | o | o | o |
| | *Indigofera kirilowii* | o | o | o | o | o |
| | *Kummerowia striata* | o | o | o | o | o |
| | *Lathyrus davidii* | o | o | o | o | o |
| | *Lespedeza bicolor* | o | o | o | o | o |
| | *Lespedeza cuneata* | o | o | o | o | o |
| | *Lespedeza cyrtobotrya* | o | o | o | o | o |
| | *Lespedeza maximowiczii* | o | o | o | o | o |
| | *Maackia amurensis* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| | *Robinia pseudoacacia* | o | o | o | o | o |
| | *Sophora flavescens* | o | o | o | o | o |
| | *Trifolium pratense* | o | o | o | o | o |
| | *Trifolium repens* | o | o | o | o | o |
| | *Vicia amurensis* | o | o | o | o | o |
| | *Vicia chosenensis* | o | o | o | o | o |
| | *Vicia unijuga* | o | o | o | o | o |
| Oxalidaceae | *Oxalis corniculata* | o | o | o | o | o |
| | *Oxalis obtriangulata* | o | o | o | o | o |
| Geraniaceae | *Geranium thunbergii* | o | o | o | o | o |
| Euphor biaceae | *Acalypha australis* | o | o | o | o | o |
| | *Securinega suffruticosa* | o | o | o | o | o |
| Rutaceae | *Dictamnus dasycarpus* | o | o | o | o | o |
| | *Phellodendron amurense* | o | o | o | o | o |
| | *Zanthoxylum schinifolium* | o | o | o | o | o |
| Simaroubaceae | *Ailan thusaltissima* | o | o | o | o | o |
| Anacardiaceae | *Rhus javanica* | o | o | o | o | o |
| | *Rhus tricocarpa* | o | o | o | o | o |
| Aceraceae | *Acer pictum* var. *truncatum* | o | o | o | o | o |
| | *Acer pictum* subsp. *mono* | o | o | o | o | o |
| | *Acer pseudosie boldianum* | o | o | o | o | o |
| | *Acer tataricum* subsp. *ginnala* | o | o | o | o | o |
| | *Acer tegmentosum* | o | o | o | o | o |
| | *Acer triflorum* | o | o | o | o | o |
| Balsaminaceae | *Impatiens noli-tangere* | o | o | o | o | o |
| | *Impatiens textori* | o | o | o | o | o |
| | *Impatiens textori* var. *koreana* | o | o | o | o | o |
| Celastraceae | *Celastrus orbiculatus* | o | o | o | o | o |
| | *Euonymus alatus* f. *ciliatodentatus* | o | o | o | o | o |
| | *Euonymus sachalinensis* | o | o | o | | |
| | *Tripterygium regelii* | o | o | o | o | o |
| Rhamnaceae | *Rhamnus yoshinoi* | o | o | o | o | o |
| Vitaceae | *Ampelopsis brevipedunculata* | o | o | o | o | o |
| | *Parthenocissus tricuspidata* | o | o | o | o | o |
| | *Vitis coignetiae* | o | o | o | o | o |
| Tiliaceae | *Corchoropsis tomentosa* | o | o | o | o | o |
| | *Tilia amurensis* | o | o | o | o | o |
| | *Tilia manshurica* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| Violaceae | *Viola acuminata* | o | o | o | o | o |
| | *Viola albida* | o | o | o | o | o |
| | *Viola albida* var. *chaerophylloides* | o | o | o | o | o |
| | *Viola diamantiaca* | o | o | | | |
| | *Viola japonica* | o | o | o | o | o |
| | *Viola mandshurica* | o | o | o | o | o |
| | *Viola orientalis* | o | o | o | o | o |
| | *Viola rossii* | o | o | o | o | o |
| | *Viola variegata* | o | o | o | o | o |
| | *Viola verecunda* | o | o | o | | |
| Cucurbitaceae | *Schizopepon bryoniaefolius* | o | o | o | o | o |
| Lythraceae | *Lythrum anceps* | o | o | o | o | o |
| Onagraceae | *Epilobium cephalostigma* | o | o | o | o | o |
| | *Oenothera biennis* | o | o | o | o | o |
| Alangiaceae | *Alangium platanifolium* var. *trilobum* | o | o | o | o | o |
| Cornaceae | *Cornus controversa* | o | o | o | o | o |
| Araliaceae | *Aralia cordata* var. *continentalis* | o | o | o | o | o |
| | *Aralia elata* | o | o | o | o | o |
| | *Eleutherococcus sessiliflorus* | o | o | o | o | o |
| | *Kalopanax septemlobus* | o | o | o | o | o |
| Umbelliferae | *Angelica anomala* | o | o | o | o | o |
| | *Angelica gigas* | o | o | o | o | o |
| | *Anthriscus sylvestris* | o | o | o | o | o |
| | *Bupleurum falcatum* | o | o | o | o | o |
| | *Heracleum moellendorffii* | o | o | o | o | o |
| | *Ligusticum hultenii* | | | o | | |
| | *Peucedanum terebinthaceum* | o | o | | o | o |
| | *Pimpinella brachycarpa* | o | o | o | o | o |
| | *Pimpinella gustavohegiana* | o | o | o | o | o |
| | *Sanicula chinensis* | o | o | o | o | o |
| | *Sium suave* | o | o | o | o | o |
| Pyrolaceae | *Chimaphila japonica* | o | o | o | o | o |
| | *Pyrola japonica* | o | o | o | o | o |
| Ericaceae | *Rhododendron mucronulatum* | o | o | o | o | o |
| | *Rhododendron schlippenbachii* | o | o | o | o | o |
| | *Rhododendron yedoense* f. *poukhanense* | o | o | o | o | o |
| | *Vaccinium hirtum* var. *koreanum* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| Primulaceae | *Lysimachia clethroides* | o | o | o | o | o |
| | *Lysimachia vulgaris* var. *davurica* | o | o | o | o | o |
| Styracaceae | *Styrax japonicus* | o | o | o | o | o |
| | *Styrax obassia* | o | o | o | o | o |
| Symplocaceae | *Symplocos chinensis* f. *pilosa* | o | o | o | o | o |
| Oleaceae | *Chionanthus retusus* | o | o | | | |
| | *Fraxinus rhynchophylla* | o | o | o | o | o |
| | *Fraxinus sieboldiana* | o | o | o | o | o |
| | *Ligustrum obtusifolium* | o | o | o | o | o |
| | *Syringa reticulata* var. *mandshurica* | o | o | o | o | o |
| Asclepiadaceae | *Metaplexis japonica* | o | o | o | o | o |
| Rubiaceae | *Asperula odorata* | o | o | o | o | o |
| | *Galium spurium* var. *echinospermum* | o | o | o | o | o |
| | *Galium verum* var. *asiaticum* | o | o | o | o | o |
| | *Rubiaakane* | o | o | o | o | o |
| | *Rubia chinensis* | o | o | o | o | o |
| Convolvulaceae | *Calystegia sepium* var. *japonicum* | o | o | o | o | o |
| | *Cuscuta japonica* | o | o | o | o | o |
| Boraginaceae | *Trigonotis peduncularis* | o | o | o | o | o |
| | *Trigonotis radicans* var. *sericea* | o | o | o | o | o |
| Verbenaceae | *Callicarpa japonica* | o | o | o | o | o |
| | *Clerodendrum trichotomum* | o | o | o | o | o |
| Labiatae | *Agastache rugosa* | o | o | o | o | o |
| | *Clinopodium chinense* var. *parviflorum* | o | o | o | o | o |
| | *Elsholtzia ciliata* | o | o | o | o | o |
| | *Isodon excisus* | o | o | o | o | o |
| | *Isodon inflexus* | | | | | o |
| | *Isodon japonicus* | o | o | o | o | o |
| | *Lamium amplexicaule* | | o | | | |
| | *Leonurus japonicus* | o | o | o | o | o |
| | *Lycopus lucidus* | o | o | o | o | o |
| | *Meehania urticifolia* | | o | o | | o |
| | *Mosla punctulata* | o | o | | | |
| | *Prunella vulgaris* var. *lilacina* | o | o | o | o | o |
| Solanaceae | *Scopolia japonica* | o | o | | | |
| | *Solanum nigrum* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | **2014** | **2015** | **2016** | **2017** | **2019** |
| Scrophulariaceae | *Mazus miquelii* | o | o | o | o | o |
| | *Melampyrum setaceum* var. *nakaianum* | o | o | o | o | o |
| | *Paulownia coreana* | o | o | o | o | o |
| | *Pedicularis resupinata* | o | o | o | o | o |
| Phrymaceae | *Phryma leptostachya* var. *asiatica* | o | o | o | o | o |
| Plantaginaceae | *Plantago asiatic* | o | o | o | o | o |
| Caprifoliaceae | *Lonicera japonica* | o | o | o | o | o |
| | *Lonicera maackii* | o | o | o | o | o |
| | *Sambucus williamsii* var. *coreana* | o | o | o | o | o |
| | *Viburnum carlesii* | o | o | o | o | o |
| | *Viburnum opulus* var. *calvescens* | o | o | | o | o |
| | *Weigela florida* | | | | | o |
| | *Weigela subsessilis* | o | o | o | o | o |
| Adoxaceae | *Adoxa moschatellina* | o | o | o | o | o |
| Valerianaceae | *Patrinias cabiosaefolia* | o | o | o | o | o |
| | *Patrinia villosa* | o | o | o | o | o |
| | *Valeriana fauriei* | o | o | o | o | o |
| Campanulaceae | *Adenophora remotiflora* | o | o | o | o | o |
| | *Adenophora triphylla* var. *japonica* | o | o | o | o | o |
| | *Asyneuma japonicum* | o | o | o | o | o |
| | *Codonopsis lanceolata* | o | o | o | o | o |
| Compositae | *Achillea alpina* | o | o | o | o | o |
| | *Adenocaulon himalaicum* | o | o | o | o | o |
| | *Ainsliaea acerifolia* | o | o | o | o | o |
| | *Ambrosia artemisiifolia* | o | o | o | o | o |
| | *Artemisia feddei* | o | o | o | | |
| | *Artemisia gmelini* | o | o | o | o | o |
| | *Artemisia montana* | | | | | o |
| | *Artemisia princeps* | o | o | o | o | o |
| | *Artemisia stolonifera* | | | | | o |
| | *Aster pilosus* | o | o | o | o | o |
| | *Aster scaber* | o | o | o | o | o |
| | *Atractylodes ovata* | o | o | o | o | o |
| | *Bidens frondosa* | o | o | o | o | o |
| | *Carduus crispus* | o | o | o | o | o |
| | *Carpesium abrotanoides* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| | *Cirsium japonicum* var. *maackii* | | o | o | | o |
| | *Cirsium setidens* | o | o | o | o | o |
| | *Conyza canadensis* | o | o | o | o | o |
| | *Crepidiastrum chelidoniifolium* | o | o | o | o | o |
| | *Dendranthema boreale* | o | o | o | o | o |
| | *Erechtites hieracifolia* | o | o | | o | o |
| | *Erigeron annuus* | o | o | o | o | o |
| | *Eupatorium japonicum* | o | o | o | o | o |
| | *Lactuca indica* f. *indivisa* | o | o | o | o | o |
| | *Lactuca indica* | o | o | o | o | o |
| | *Lactuca raddeana* | o | o | o | o | o |
| | *Ligularia fischeri* | o | o | o | o | o |
| | *Parasenecio auriculatus* | o | o | o | o | o |
| | *Parasenecio auriculatus* var. *matsumuranus* | o | o | o | | |
| | *Serratula coronata* var. *insularis* | o | o | o | o | o |
| | *Solidago virgaurea* subsp. *asiatica* | o | o | o | o | o |
| | *Syneilesis palmata* | o | o | o | o | o |
| | *Synurus deltoides* | o | o | o | o | o |
| | *Taraxacum officinale* | | o | o | o | o |
| | *Taraxacum platycarpum* | o | o | o | o | o |
| Liliaceae | *Asparagus schoberioides* | o | o | o | o | o |
| | *Convallaria keiskei* | | o | o | | o |
| | *Disporum smilacinum* | o | o | o | o | o |
| | *Disporum viridescens* | o | o | o | | |
| | *Erythronium japonicum* | | o | o | | o |
| | *Heloniopsis koreana* | o | o | o | o | o |
| | *Hemerocallis dumortieri* | o | o | o | o | o |
| | *Hosta capitata* | o | o | o | o | o |
| | *Lilium tsingtauense* | o | o | o | o | o |
| | *Paris verticillata* | | | | | o |
| | *Polygonatum involucratum* | o | o | o | o | o |
| | *Polygonatum odoratum* var. *pluriflorum* | o | o | o | o | o |
| | *Smilax nipponica* | o | o | o | o | o |
| | *Smilax riparia* var. *ussuriensis* | | | | | o |
| | *Smilax sieboldii* | o | o | o | o | o |
| | *Streptopus ovalis* | o | o | | | |
| | *Trillium kamtschaticum* | o | o | o | o | o |

**Table A1.** *Cont.*

| Family Name | Scientific Name | Year | | | | |
|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2019 |
| | *Veratrum maackii* var. *japonicum* | o | o | o | o | o |
| | *Veratrum oxysepalum* | o | o | o | o | o |
| Dioscoreaceae | *Dioscorea quinqueloba* | o | o | o | o | o |
| | *Dioscorea tokoro* | o | o | o | o | o |
| Juncaceae | *Juncus effusus* var. *decipiens* | o | o | o | o | o |
| Commelinaceae | *Commelina communis* | o | o | o | o | o |
| Gramineae | *Agrostis clavata* | o | o | o | o | o |
| | *Alopecurus aequalis* var. *amurensis* | o | o | o | o | o |
| | *Arthraxon hispidus* | o | o | o | o | o |
| | *Calamagrostis langsdorfii* | | o | o | | o |
| | *Cymbopogon tortilis* var. *goeringii* | o | o | o | o | o |
| | *Dactylis glomerata* | o | o | o | o | o |
| | *Echinochloa utilis* | o | o | o | o | o |
| | *Festuca arundinacea* | o | o | o | o | o |
| | *Melicaonoei onoei* | o | o | o | o | o |
| | *Miscanthus sinensis* var. *purpurascens* | o | o | o | o | o |
| | *Oplismenus undulatifolius* | o | o | o | o | o |
| | *Pennisetum alopecuroides* | | o | o | o | o |
| | *Phragmites communis* | o | o | o | o | o |
| | *Phragmites japonica* | o | o | o | o | o |
| | *Sasa borealis* | o | o | o | o | o |
| | *Spodiopogon cotulifer* | o | o | o | o | o |
| | *Spodiopogon sibiricus* | o | o | o | o | o |
| Araceae | *Arisaema amurense* f. *serratum* | o | o | o | o | o |
| | *Symplocarpus renifolius* | o | o | o | | |
| Cyperaceae | *Carex humilis* var. *nana* | | | | | o |
| | *Carex neurocarpa* | o | o | o | o | o |
| | *Carex siderosticta* | o | o | o | o | o |
| | *Cyperus amuricus* | o | o | o | o | o |
| Orchidaceae | *Cephalanthera longibracteata* | o | o | o | o | o |
| | *Oreorchis patens* | o | o | o | | |

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