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A Permanent Research Platform for Ecological Studies in Intact Temperate Mountainous Forests from Slătioara UNESCO Site and Its Surroundings, Romania

Gabriel Duduman, Mihai-Leonard Duduman *, Daniel Avăcăriței, Ionuț Barnoaiea, Cătălina-Oana Barbu, Ioan Ciornei, Florin Clinovschi, Vasile Cosmin Coșofreț, Mihai-Gabriel Cotos, Gabriel Dănilă, Iulian-Constantin Dănilă, Marian Drăgoi, Marcel-Neculai Flocea, Sergiu-Andrei Horodnic, Ovidiu Iacobescu, Georgel Constantin Mazăre, Anca Măciucă, Andrei Mursa, Ciprian Palaghianu, Corneliu Mihăiță Pohonțu, Cătălin-Constantin Roibu, Alexei Savin, Cezar Valentin Tomescu and Ramona-Elena Scriban

Forestry Faculty, "Ștefan cel Mare" University of Suceava, Universității Street 13, 720229 Suceava, Romania; gduduman@usv.ro (G.D.); davacaritei@yahoo.com (D.A.); ibarnoaie@usv.ro (I.B.); cata.barbu1979@gmail.com (C.-O.B.); ioanciornei@usv.ro (I.C.); clinovschi@usm.ro (F.C.); cosmin.cosofret@usm.ro (V.C.C.); cotosmihaigabriel@gmail.com (M.-G.C.); gabidanila68@gmail.com (G.D.); iuliandanila@usm.ro (I.-C.D.); marian.dragoi@usm.ro (M.D.); infolemn@gmail.com (M.-N.F.); horodnic@usv.ro (S.-A.H.); oiacobescu@gmail.com (O.I.); george.mazare@gmail.com (G.C.M.); ancam@usv.ro (A.M.); m.andreimursa@gmail.com (A.M.); cpalaghianu@usv.ro (C.P.); corneliupohontu@gmail.com (C.M.P.); catalinroibu@usm.ro (C.-C.R.); alexeisavin@gmail.com (A.S.); tomcezar@yahoo.com (C.V.T.); ramonascriban@gmail.com (R.-E.S.)

* Correspondence: mduduman@usv.ro; Tel.: +40-230-522-978 (ext. 545)

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Abstract: This paper describes a permanent research platform (PRP) designed and implemented in "Codrul secular Slătioara" and its surroundings (2205.85 ha), having also the role of introductory paper for future research articles based on data collected from this platform. "Codrul secular Slătioara" is known as one of the largest temperate mountainous intact forests of Europe and, in 2017, it was included in UNESCO World Heritage List, as part of the "Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe". Moreover, the PRP overlaps other three scientific reserves, the share of strictly protected forests exceeding 70%. This platform has a multiple role, being developed for research, conservation and educational activities. The PRP was designed for an ecological analysis of the intact forest ecosystems. It contains 193 circular sample plots, each of them of 500 m^2, and it is structured on two levels. The first level contains 58 sample plots corresponding to a square grid of 500 × 500 m, stretching over the entire forested area, and the second level contains 135 plots, placed according to a square grid of 100 × 100 m, covering 136 ha within the core area of the UNESCO site. We measured the characteristics of 8296 living trees, 1743 standing dead trees, 1900 dead wood trunks, 3214 saplings, and the abundance–dominance indices of flora species. Thus, we identified 14 tree species, 17 shrub species, and 248 other cormophyte species forming the herbaceous layer. In terms of volume, the main tree species are Norway spruce, silver fir and European beech. The tallest species are Norway spruce (56 m) and silver fir (51 m). The average volume of living trees is 659 m^3·ha^{-1}, with a maximum of 1441 m^3·ha^{-1}. The mean total dead wood volume is about 158 m^3·ha^{-1}, with sample plots where the total dead wood volume exceeds 600 m^3·ha^{-1}. After presenting the results of preliminary data processing, the paper describes the main research topics to be further considered, based on the PRP, and the foresights related to the PRP's monitoring and development.

Keywords: ecosystem functioning; biodiversity analysis; forest inventory; intact temperate forest; forest dynamic; dead wood; forest regeneration

1. Introduction

Humans have rudimentary knowledge of how the biological components of the Earth's system function and thus, exploring terrestrial biodiversity is an important challenge for the future [1,2]. Studying biodiversity becomes more imperative once the awareness that a large number of species are predisposed to become threatened or extinct [3], the primary terrestrial ecosystems are disappearing and habitats are altered or destroyed [4,5] due to anthropogenic pressure [6] with a significant impact over the life quality on Earth [7,8].

A holistic understanding on how the ecological processes take place in nature is essential to the achievement of many economic and social goals of the mankind [9], but also for nature conservation through a sustainable management of renewable resources [8,10]. Through their biodiversity and carbon sequestration potential, along with oceans, the world's forests represent some of the most important ecosystems on Earth [11,12]. The world's forests cover an area of about 4 billion hectares [13], representing an important supplier of ecosystem services, and thus a pillar of the quality of life and well-being [14,15].

Studying forest biodiversity and ecosystem services developed in the last decades but, despite their major role at local, regional, and global scale, little attention has been paid for the relationship between biodiversity and ecosystem functioning [16,17]. Still, it became almost a certainty that diverse forests bring more ecological [18] and socio-economic [16,19,20] benefits than those with low diversity.

Nevertheless, diverse intact forests are more difficult to study and, unfortunately, their area at the global level is lower and lower. According to Popatov et al. (2008) [21], the global area of intact forest landscapes was estimated in 2008 to 1.31 billion hectares, but their loss rate was assessed by Heino et al. (2015) [22] at 2.5% for the period 2000–2012 and by Potapov et al. (2017) [23] at 7.2% between 2000 and 2013. The lowest share of intact forest landscapes was found in temperate broadleaf and mixed forests [21]. For example, in Europe, in the temperate zone, only small patches (100 ha in average) of intact forests survive, especially in Balkans, Alps, and Carpathians, with a total area of about 0.3 million hectares [24].

These relics of natural forests, free of significant anthropogenic degradation and called "intact forests", are important sources of information regarding the relationships between biodiversity and ecosystem functioning and their essential role in joining together the globally significant environmental values [25]. They need detailed study in order to substantiate models of sustainable management for second-growth forests, similar in ecological terms to the intact ones. The ecological and historical value of those forests are important preservation drivers; moreover, they have been included in UNESCO World Heritage-Assess, which is the case of the "Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe", laying over 12 countries (Albania, Austria, Belgium, Bulgaria, Croatia, Germany, Italy, Romania, Slovakia, Slovenia, Spain, Ukraine) [26].

Based on literature review, Sabatini et al. [27] estimated that, in 2018, the area of intact forests in Romania was 24,751.27 ha (about 8% of Europe's intact forests), but the identification and mapping process is ongoing, the area of potentially intact forests being estimated as much larger [28].

Hence, further research is needed in mixed intact forests in Romania, to clarify aspects associated to the relation between their biodiversity and the ecosystem functioning, or the provided ecosystem services. For this reason, a complex Permanent Research Platform (PRP) was designed and implemented in Northeastern Romania, within Slătioara Nature Reserve (Codrul secular Slătioara) and its surroundings (SNR-S), as part of UNESCO World Heritage.

The role of the PRP is to provide a statistically significant representation of the intact forest ecosystems, which can integrate different research objectives and further development of the exploratory site. Such research platforms were implemented in other forest reserves or cultivated forests. For example, the FUNDIVEurope exploratory sites network [29] was designed to monitor the functionality of forest biodiversity and its effects on different components of the forest ecosystems. The same network was further integrated in the project "Predicting European forest soil biodiversity and its functioning under ongoing climate change"—Soil for Europe [30].

In this context, the objectives of this paper are: To provide detailed information on the research platform developed within the SNR-S, to explain its future research potential by presenting ideas for upcoming research, and to serve as an introductory paper for the future research articles published on the collected data.

2. Material and Methods

2.1. Rationale and Research Questions

Few ecological processes in forest ecosystems are studied in great detail, within a limited number of projects or programs at European scale, like ICP Forests Level II [31], which are not specifically focused in intact forests.

The need of a PRP within intact forests and especially in SNR-S resulted from several causes:

1. Slătioara Nature Reserve is well preserved and these intact forest stands are known as resistant to natural disturbances;
2. long term studies have never been conducted till now in Romanian intact forests, based on successive inventories and intensive monitoring;
3. the mixed temperate intact forests need extensive studies in terms of ecosystem functioning, to identify management patterns worth being applied to similar second-growth and cultivated forests;
4. a wide range of forest ecosystem services provided by this forest need to be better understood through long term assessments; and
5. real time identification of causes potentially affecting intact forest ecosystems in a rapidly changing climate.

The role of a research platform in SNR-S area is manifold: Research, conservation, and educational activities. The first endeavors to protect Slătioara forest date back to 1906 [32]. As an attempt to harvest timber from this forest, in 1940, a forest management plan was drawn up for 300 ha, recommending single tree selection system; however, the provisions of that management plan were not operated [33] and, in 1941, Slătioara forest was officially recognized as a scientific reserve, having at that time a total area of 854.3 ha. According to the Romanian legislation [34], a scientific reserve is a natural protected area of national interest, established for the protection and conservation of natural terrestrial and/or aquatic habitats, including representative elements of scientific interest, has a strict protection regime, and all human activities are forbidden, excepting research, education and tourism activities, with the limitations described in the management plans. The scientific reserves correspond to IUCN category I-a "Strict Nature Reserve".

The area included in the strict forest reserve was inaccessible before 1941, which excluded it from any intervention. After 1941, the state forest administration ensured the full conservation of the area. The relevance of these ecosystems is emphasized by the context of forest management in the area surrounding the reserve, which contributed, after the second world war, to important changes of the forest structure. Forests surrounding the reserve were changed, in a large proportion, into even-aged monocultures, mainly of Norway spruce, seriously affecting their biodiversity and stability [35].

After 2006, the area of the reserve increased to 1064.2 ha (1044.8 ha of forestland and 19.4 ha of pasture land) [36]. In 2007, SNR was included in Natura 2000 sites ROSCI0212 Rarău-Giumalău and ROSPA0083 Munții Rarău-Giumalău, both sites having identical boundaries.

With a core zone of 609.12 ha and a buffer area of 429.43 ha, in 2017, both Slătioara reserve and the floristic reserve "Fânețele montane Todirescu" were included into UNESCO World Heritage List, as part of the "Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe". This natural European Site totalizes 92,023.24 ha, overlaps 12 countries and contains 78 sites [37].

2.2. Design of Research Platform

Considering Slătioara Nature Reserve as primary research objective, a research platform covering a forested area of 1724 ha was designed in 2014 and implemented in 2015. The platform partially covers the two mentioned Natura 2000 sites and it overlaps three nature reserves: Slătioara (included in UNESCO World Heritage), "Rarău-Pietrele Doamnei", and "Fânețele montane Todirescu". In the area, there is also a speleological reserve called "Peștera Liliecilor", overlying "Rarău-Pietrele Doamnei" Nature Reserve (Figure 1).

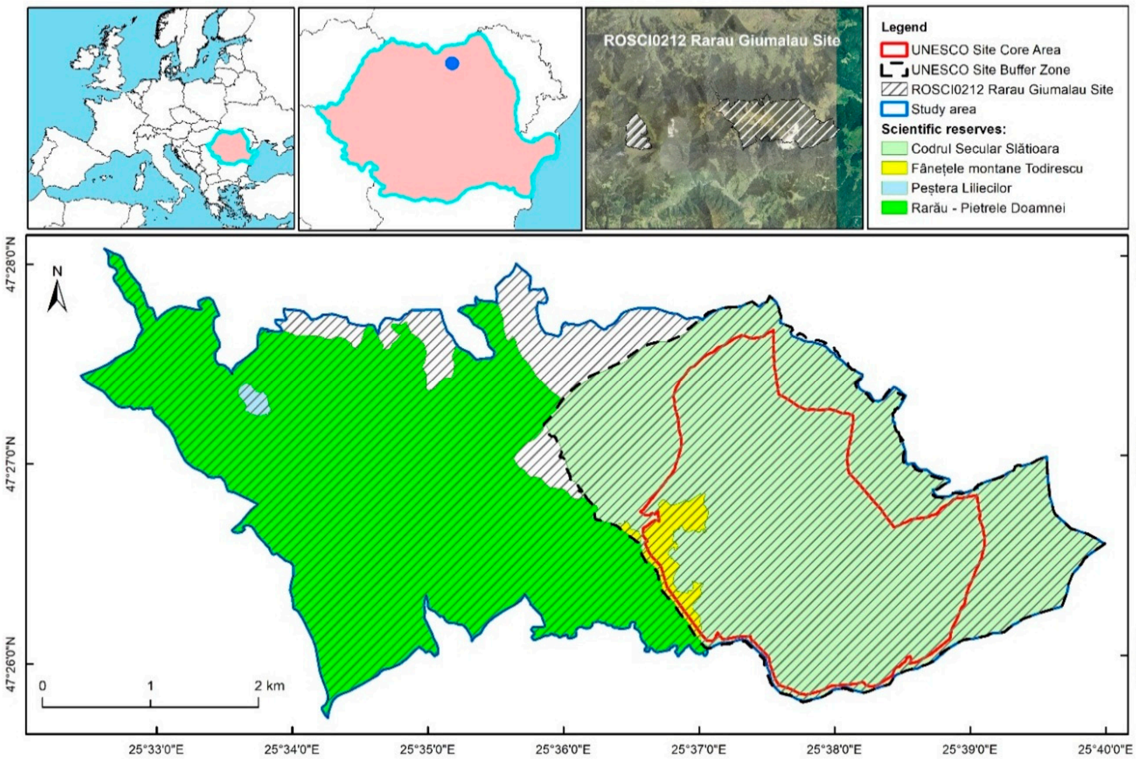

Figure 1. Study area location.

The study area is situated in the North-Eastern Carpathians, the South-Eastern part of Rarău Mountains, located at altitudes between 800 m and 1510 m above the sea level, under the influence of continental-temperate climate, with mean annual temperatures between 3.8 Celsius degrees at high elevations and 5.9 Celsius degrees at low elevations, and mean annual rainfall between 700 and 810 mm. The study area belongs to the state and stretches over three forest districts.

The area of Natura 2000 site ROSCI0212 located on Rarău Mountains (included in this study) has a high complexity of land use and management specifications. It overlaps four different types of scientific reserves, designed to preserve intact forest ecosystems (Codrul Secular Slătioara), alpine pasture ecosystems ("Fânețele montane Todirescu" and part of "Rarău-Pietrele Doamnei reserve"), geological formations (Rarău-Pietrele Doamnei) and habitat for several species of bats (Peștera Liliecilor). The land use system includes activities ranging from strict protection of forest ecosystems to sheepfolds and touristic facilities (Table 1).

Table 1. Management type within the study area.

Land Use Type	Management Type	Area (ha)	Protected Area Type
Forests	Strictly protected	1580.73	Forest reserves: Codrul Secular Slătioara, Rarău-Pietrele Doamnei, Peştera Liliecilor
	Highly protected (for erosion control)	13.67	ROSCI 0212 Rarău Giumalău
	Regular management	130.17	ROSCI 0212 Rarău Giumalău
Pasture land and forested pasture	Regular management, for hay production and grazing	435.3	Scientific reserves Rarău-Pietrele Doamnei and Fâneţele Todirescu
Constructions	Regular management (touristic facilities, weather station, antennas)	1.2	Scientific reserve Rarău-Pietrele Doamnei
Powerlines	Limited height of trees	3.75	Scientific reserve Rarău-Pietrele Doamnei
Rock formations, partially covered with forest vegetation	Strictly protected	41.03	Forest reserves: Codrul Secular Slătioara, Rarău-Pietrele Doamnei, Peştera Liliecilor

Strict protection of forest ecosystems is applied on 1580.73 ha (Table 1), including intact old-growth forests and forests that were excluded from management in the last decades. Other forest areas are subjected to low intensity management for erosion protection (13.67 ha) and regular management on 130.17 ha, in accordance with the provisions of the management plan.

Large areas of the site are covered with pastures, included into scientific reserves, some of them being managed as grazing lands by the local communities. The management plan encourages formation and maintenance of the same associations of species as those already preserved.

The buildings located into Rarău-Pietrele Doamnei reserve occupy 1.2 ha, being touristic facilities (Rarău Lodge), scientific premises (Rarău weather station) or broadcast antennas. For servicing these facilities, a powerline was constructed on the southern slope, which lies on 3.75 ha, on which management is applied, in the form of limiting the height of the trees under the line.

The geology of the area, mostly comprised of calcareous rocks, is particularly interesting, as it constitutes one of the Rarău-Pietrele Doamnei reserve objectives. Along with the large rock formations on top of Rărau mountain (Pietrele Doamnei), there are several areas with very high slopes and visible rock formations, partially covered by forest vegetation, on 41.03 ha. In particular cases, the presence of such formations has prevented the establishment of certain sample plots (SPs).

The following aspects were considered when designing the PRP in SNR-S:

- Ensuring the accurate representation of the forest ecosystems state;
- guaranteeing spatial positioning of the inventory plots within all habitat types within the studied area (randomly stratified schematic sampling);
- the number of inventory plots should allow re-measurements of all studied parameters within an easy-to-establish period of time.

Considering these aspects, Slătioara PRP is structured on two levels:

- The 1st level of PRP (1-PRP) corresponds to a square grid which overlaps the entire study area. This resulted from the intersection of the network with the boundaries of the Rarău-Slătioara part of ROSCI0212 Rarău-Giumalău (2205.85 ha total area, of which 78% is covered by forests).
- The 2nd level of PRP (2-PRP) resulted through increasing the density of the 1-PRP in the area previously described in literature as having higher ecosystem complexity and being relatively accessible for more detailed field research [38]. This component of the PRP covers approximately 136 ha, considering a 50 m width buffer area.

The design of PRP within SNR-S was preceded by the analysis of forest management plans, forest stands' maps, and an exploratory field survey for a better preliminary understanding of forest ecosystems' diversity. Thus, a square greed of 500 × 500 m was set-up for 1-PRP, resulting a total of

82 inventory plots, of which 64 plots overlapped forest ecosystems. Additionally, for the core area of SNR (Figure 2), the 2-PRP was designed as a 100 × 100 m grid, resulting in 136 inventory plots. The network design was carried out using ArcGIS 9.3 software, by creating the grid of SPs overlapping the study area.

Figure 2. Image from Slătioara forest, plot 92, 2-PRP (credits: Gabriel Duduman, 2015).

Where the inventory plots of 1-PRP and 2-PRP overlap, a single plot was considered, as belonging to the 2-PRP. This overlap was met in 6 inventory plots (39, 50, 51, 64, 65, and 66, considering the numbering of 1-PRP). The total number of inventory plots (218) resulted by summing the number of plots from the two levels of PRP and excluding the 6 overlapping plots from 1-PRP.

As shown in Figure 3, SPs 2 and 4 from 1-PRP are currently outside the study area, due to an adjustment of the borders of Natura 2000 sites ROSCI0212 Rarău-Giumalău and ROSPA0083 Munții Rarău-Giumalău, occurred in 2017, compared to the previous border. These plots were already inventoried in 2015 and were not excluded from the initial list of SPs, being considered as control SPs, nearby Natura 2000 site.

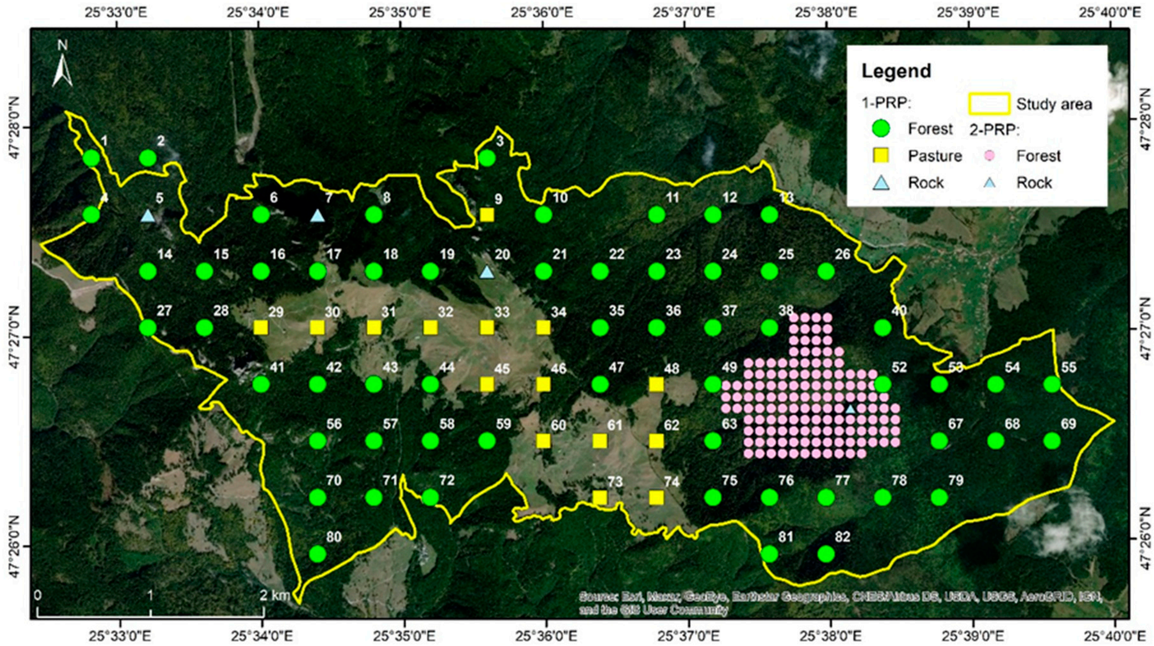

Figure 3. Design of permanent research platform within Slătioara Nature and its surroundings (SNR-S).

The SPs established in the field were circular, with a constant area of 500 m^2, reduced to the horizontal plane (by measuring the horizontal distance). Within each SP, four sub-samples were established for the inventory of saplings, consisting of four circles (subplots) with 1 m radius, at 5 m distance from the plot center, on four directions (North, East, West, South) (Figure 4).

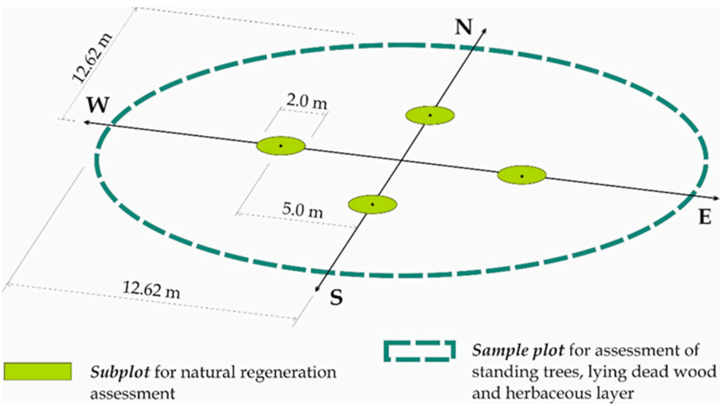

Figure 4. Structure of a sample plot within the permanent research platform (PRP) from SNR-S.

In the case of second level network, the inventory respected the international methodological recommendation: Sampling distance 100 m (between plot centers), considerations of particular plant associations, including cormophyte flora.

The inventory protocol is identical for the whole sampling network (1-PRP and 2-PRP), in regard to the shape, location acquiring, and data collection for forest ecosystems' analysis.

2.3. Establishment of Research Plots

The coordinates of all SPs were uploaded into GPS receivers and used for the identification of plot location in the field, with an estimated accuracy of max ±7 m. Since the area of study is remote and does not have enough GSM signal coverage, it was not possible to use differential corrections and we had to rely exclusively on the signal received from satellites. The ±7 m maximum error limit was related to the general conditions in the area:

- Steep slopes, where the receiver required more time to receive signal from satellites;
- forest stands traits, especially high density uneven-aged stands, where the positioning errors could not be reduced to less than ±7 m; and
- rarely, special geomorphology features (very steep slopes on valley bottom, abrupt rock formations) have urged the reconsideration of SP position.

In the end, 193 plots were installed in the field, 58 from the 1-PRP and 135 from 2-PRP (Table 2). After setting the plot onto the field, its center was marked with a metal marker (1.2 cm diameter and 30 cm length), below ground level, to be identified with metal detector in further inventories of the network. For facile re-identification, the nearest mature tree was marked with paint, recording the distance and azimuth from that tree to the center.

Table 2. Centralized data of the sample plots installed in the field.

Type of Research Network	Number of Plots Designed	Plot Numbering	Number of Plots Per Group of Habitat Type			No. of Plots Installed in the Field
			Forest	Rock	Pasture	
1-PRP	82 *	Sl5L001 to Sl5L082	64 *	3	15	58 **
2-PRP	136	S001 to S136	135	1	-	135
Total	218	-	199 *	4	15	193 **

* 6 plots from 1-PRP overlaps the second level 2-PRP. ** the overlaps were excluded.

2.4. Data Collection

The field design and the methodology of data collection were meant to quantify forest ecosystem diversity in Slătioara forest reserve and its surroundings. Hence, in the case of forest ecosystems, structural diversity is often considered as a proxy for biocoenosis general diversity [39], and the data collection methodology was focused on assessing structural diversity. This diversity indicates the variability of dimensional features of the trees within a population and is being assessed through the horizontal and vertical tree distribution [40].

Having established the SPs, we proceeded to collecting the relevant data for forest ecosystems biodiversity assessment. The first field campaign (and the only so far) was carried out in 2015, between April and October, in all the SPs from the entire PRP, collecting data on living trees, standing and fallen deadwood, regeneration, and herbaceous layer (Table 3).

Table 3. General info regarding the data collected during first inventory within the PRP in SNR-S.

Measured Elements	Sample Size (m^2)	No. of Plots		No. of Stems/Trunks	No. of Species Per Sample	No. of Trees/Saplings Measured Per Plot
		Total	With Data			
Living trees	500	193	193	8296	1 to 6	13 to 112
Standing dead wood	500	193	190 *	1743	1 to 4	1 to 44
Fallen dead wood	500	193	188 **	1900	1 to 4	1 to 32
Natural regeneration	3.14	772	518	3214	1 to 5	1 to 67
Herbaceous layer	500	193	193	-	7 to 69	-

* 3 plots with no standing dead tree. ** 5 plots with no dead wood on the ground.

For all standing trees with diameter at breast height (dbh) larger than 5 cm, the following features were measured and recorded: Species, diameter at breast height (dbh), polar coordinates (azimuth and distance) from the plot center, total height, pruned height, crown diameter and certain observations regarding health status, degree of deadwood composition, terminal bud status. Dbh was measured with a caliper (±0.1 cm accuracy), the total and pruned heights were measured with a Vertex dendrometer (Haglöf Sweden), the azimuth was measured with a compass, horizontal distances with Vertex, crown diameters with tape measurers.

In addition to the standing trees, in each SP, we collected information regarding the regeneration process from the four installed subplots: Position of subplot (cardinal point), species present in regeneration, number of saplings with dbh less than 5 cm per species, height class, degree of damage by browsing.

Standing dead wood was measured along with the living trees, with polar coordinates, species, dbh, height and degree of decomposition. The deadwood on the ground (Figure 5) was separately recorded, using separate forms, with coordinates of the log ends (for the log portion inside the plot), species (if identifiable) or species group (coniferous/broadleaved), diameter at both ends (for long pieces, at the boundary of the 500 m^2 plot), length (inside the plot) and degree of decomposition.

Figure 5. Dead wood on the ground in Slătioara UNESCO site (credits: Cezar Tomescu, 2020).

To characterize the herbaceous layer, in terms of species diversity, the methodology of the phytocenological school J. Braun-Blanquet was applied, as recognized and adopted at European level [41]. This method relies on phytocenological surveys, recording all species of plants, each species being characterized by abundance–dominance (AD) appropriate indices. The phytocenological surveys were overlapped on the SPs of the two levels of PRP (having 500 m^2). For each survey, a sheet was completed and, in addition to the identified plant species and AD indices, geographical data, location, site description, data regarding the stratification of vegetation, covering of layers (in percentages) were noted. The list of species identified within these surveys was completed with species identified "on the path", in order to have a detailed picture of species diversity in SNR-S.

3. Results

The list of cormophyte species (identified during the first inventory carried out onto the PRP) is presented in Table S1, resulting in 11 tree species identified in the SPs and other three additional tree species identified on path. Other 17 shrub species and 248 species shaping the herbaceous layer were identified within the forest ecosystems from SNR-S, including both the SPs and itinerary analysis.

The most representative trees species in terms of stem density are silver fir (*Abies alba* Mill.), Norway spruce (*Picea abies* (L.) H. Karst.) and European beech (*Fagus sylvatica* L.), followed by sycamore (*Acer pseudoplatanus* L.), silver birch (*Betula pendula* Roth), rowan (*Sorbus aucuparia* L.), wych elm (*Ulmus glabra* Huds), European larch (*Larix decidua* Mill.), Scots pine (*Pinus sylvestris* L.), common yew (*Taxus baccata* L.), and Eurasian aspen (*Populus tremula* L.). In case of the goat willow (*Salix caprea* L.), only saplings were identified in the SPs.

According to the IUCN red list [42], excepting the wych elm, insufficiently documented, all other tree species are classified as "least concern". Must of the shrub species (12) were also considered "least concern", but five of them are "not evaluated". From a total of 248 herbaceous species, 133 were considered "not evaluated", four are included in "data deficient" category and 106 fall into the "least concern" class. Additionally, three species are "near threatened" (*Aconitum toxicum* Rchb, *Aconitum variegatum* L. ssp. *Variegatum* and *Cypripedium calceolus* L.), one is "vulnerable" (*Asplenium adulterinum* Milde), and one is "endangered" (*Asplenium trichomanes* L.).

In terms of tree species and regarding their territorial spread, the Norway spruce is found all over the analyzed area (187 SPs out of a total of 193), as the prevailing species at high elevations, thus explaining the highest number of trees per SP (98), compared to any other species (Table 4). The least represented species are the Eurasian aspen and the common yew, which appear in only three, respectively four SPs, with only one tree per plot. The Norway spruce and silver fir find appropriate growing conditions, reaching exceptional heights (e.g., 56 m in case of Norway spruce and 51 m in case of silver fir). Even though the core extraction was not approved during the inventory performed in 2015, from previous measurements carried out in 2007 it resulted that, due to the site conditions, species light tolerance and natural reversed-J shape of the forest structure, even though the largest trees are below 120 cm dbh, their ages exceed 300 years in case of Norway spruce, 400 years in case of European beech, and 500 years in case of silver fir [43].

The mean basal area (BA) at SP level goes to 49.6 $m^2 \cdot ha^{-1}$, and the largest BA is almost 100 $m^2 \cdot ha^{-1}$. When it comes to species, the largest mean BA is reached by European larch (23.3 $m^2 \cdot ha^{-1}$, in the single SP where it occurs, in an uneven-sized mixt stand with Norway spruce and sycamore), followed by Norway spruce (22.1 $m^2 \cdot ha^{-1}$) and silver fir (20.3 $m^2 \cdot ha^{-1}$). The mean volume per SP is 659 $m^3 \cdot ha^{-1}$, while the highest volume is 1441 $m^3 \cdot ha^{-1}$. The largest mean volumes per species are recorded in case of spruce (293 $m^3 \cdot ha^{-1}$) and silver fir (264 $m^3 \cdot ha^{-1}$).

Dead wood was tracked down in all SPs. As expected, in most of them (188) we found dead wood of Norway spruce, followed by silver fir in 147 SPs and European beech in 89 SPs (Table 5). The mean volume of standing dead wood is about 50 $m^3 \cdot ha^{-1}$, while the mean volume of lying dead wood exceeds 110 $m^3 \cdot ha^{-1}$. The mean total dead wood volume in SNR-S is about 158 $m^3 \cdot ha^{-1}$. In some SPs, the total dead wood amount is larger than 600 $m^3 \cdot ha^{-1}$ and, in terms of species, we found SPs where only the Norway spruce dead wood volume was greater than 500 $m^3 \cdot ha^{-1}$. The maximum total volume per hectare (living trees and dead wood) was found in plot S038 (1910 $m^3 \cdot ha^{-1}$), while the average total wood volume reaches 820 $m^3 \cdot ha^{-1}$.

Table 4. Brief description of forest structure at sample plot level (living trees).

Tree Species	No. of Plots	No. of Trees Per SP			Max. dbh (cm)	Max. Height (m)	Basal Area (m^2) Per SP			Volume (m^3) Per SP		
		Min.	Mean	Max.			Min.	Mean	Max.	Min.	Mean	Max.
Acer pseudoplatanus L.	54	1	3	10	102.0	36.5	0.003	0.111	0.817	0.02	1.20	12.36
Abies alba Mill.	162	1	19	59	118.7	51.4	0.007	1.016	3.462	0.02	13.20	56.90
Betula pendula Roth	7	1	3	13	23.2	21.3	0.006	0.048	0.187	0.02	0.30	0.96
Fagus sylvatica L.	156	1	14	46	102.0	43.3	0.002	0.629	2.088	0.01	8.88	37.90
Larix decidua Mill.	1	10	10	10	51.2	30.8	1.164	1.164	1.164	13.15	13.15	13.15
Populus tremula L.	3	1	1	1	44.2	26.1	0.024	0.072	0.153	0.20	0.81	1.97
Picea abies (L.) H. Karst.	187	1	15	98	101.1	56.1	0.006	1.105	3.187	0.01	14.64	48.86
Pinus sylvestris L.	1	9	9	9	42.1	29.3	0.864	0.864	0.864	8.85	8.85	8.85
Sorbus aucuparia L.	6	1	2	5	19.2	16.2	0.018	0.025	0.037	0.09	0.16	0.24
Taxus baccata L.	4	1	1	1	18.6	10.7	0.004	0.012	0.027	0.01	0.05	0.15
Ulmus glabra Huds.	8	1	1	2	47.0	29.2	0.007	0.047	0.173	0.05	0.53	2.31
All species	193	13	43	112	118.7	56.1	0.161	2.479	4.846	0.99	32.95	72.04

Table 5. General info regarding standing and lying dead wood.

Species	No. of Plots			Dead Wood Volume (m^3) Per SP								
				Standing			Lying			Total		
	Standing	Lying	Total	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Acer pseudoplatanus L.	12	3	14	0.007	0.128	0.568	0.102	0.212	0.352	0.007	0.155	0.920
Abies alba Mill.	134	100	147	0.008	1.498	11.134	0.014	3.117	16.871	0.008	3.486	24.642
Fagus sylvatica L.	65	58	89	0.007	0.193	2.384	0.009	0.737	5.119	0.008	0.621	5.415
Larix decidua Mill.	1	1	1	0.098	0.098	0.098	0.022	0.022	0.022	0.120	0.120	0.120
Populus tremula L.	1	1	1	0.088	0.088	0.088	0.113	0.113	0.113	0.201	0.201	0.201
Picea abies (L.) H. Karst.	172	168	188	0.007	1.434	12.175	0.010	3.334	25.619	0.016	4.291	26.448
Pinus sylvestris L.	1	2	2	0.939	0.939	0.939	0.089	0.300	0.511	0.089	0.770	1.450
Salix caprea L.	1	1	1	0.012	0.012	0.012	0.105	0.105	0.105	0.117	0.117	0.117
Coniferous species *	9	22	23	0.127	1.325	7.261	0.125	5.123	14.157	0.533	5.419	17.829
Deciduous species *	-	3	3	-	-	-	0.052	0.235	0.350	0.052	0.235	0.350
Unidentified species **	-	7	7	-	-	-	0.135	2.617	6.431	0.135	2.617	6.431
All species	190	188	193	0.013	2.498	17.545	0.038	5.603	30.549	0.138	7.887	31.445

* Only the group of species could be established in the field. ** The species or the group of species could not be established in the field, due to the high decomposing degree of the wood.

4. Discussion

Diaci et al. [44] expose the stringent need of comparative studies at European level, between the very rare and fragmented remaining intact forests, especially for the improvement of silviculture and for a better understanding of environmental changes. Additionally, the study of the biodiversity of those rare primary forests can reveal the trends related to natural successions or the decline of some species [45], in a rapidly climate change scenario [46].

More than that, immediate action is needed to save the remaining unprotected intact areas [6] and studying the already preserved sites like SNR can provide more knowledge for an appropriate identification of new intact forests, based on modern techniques [47,48].

Both the expected outputs and future perspectives are presented at once, but divided on groups of exceptional values of intact temperate forests [25]: Climate regulation, biodiversity, regulating water regime, ensuring hydrological services, and human health benefits. The immediate expected outputs derive from the way the data collected during the inventory performed in 2015 will be valorised, while the future perspectives are more related to the future development of PRP (Figure 6) and to the additional data that will be collected during the future re-inventories from SNR-S, for a holistic research and understanding of those valuable forest ecosystems.

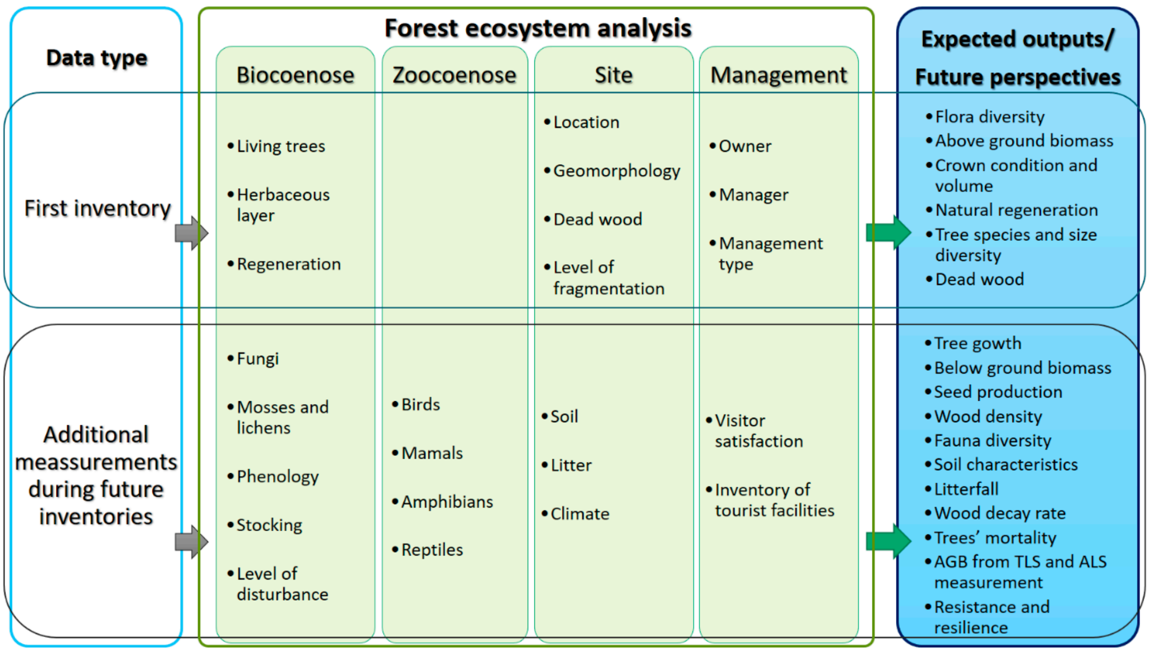

Figure 6. Foresight regarding research development in terms of forest ecosystem analysis in SNR-S.

The role of the natural systems in regulating local climate regimes [49] and reducing risks associated to climate related hazards have caught less attention [8]. Intact ecosystems have an important role in climate regulation by sequestering vast amounts of carbon [8]. Carbon sequestration in natural mixed temperate forests from Carpathian Mountains was less studied, and the existence of this inventory platform turns into an important tool for thoroughgoing research. Corroborating the data already collected within the plots (adequate for computing the aboveground carbon stock) to climate, geographical and natural hazards data, new research opportunities will be opened in relation to natural forest ecosystem functioning and forest ecosystem services.

Assessment and management of biodiversity requires that its components are clearly defined and that factors underlying the biodiversity loss can be identified [50]. Creating and applying appropriate models for the forests' sustainable management shall be based on knowledge provided by studying similar intact ecosystems like those from SNR-S. On a small scale, the species and dimensional diversity of trees were previously studied in Slătioara Natural Reserve [36,51–53], but they revealed that more detailed research is needed at a broader scale, also including the surrounding forests.

Additional research is needed in Slătioara also in relation to dead wood [38,54–56] and tree mortality. The dead wood can be considered a good surrogate for assessing the diversity of saproxylic species [57], being important to quantify the size, species, position and decay rate of dead wood pieces [58]. Such measurements have been already done during the first inventory in PRP from SNR-S, but the monitoring of dead wood is important also for a better understanding of tree mortality and dieback phenomena [59].

In intact forests a balance is supposed to exist between tree mortality and recruitment due to the fact that, among others, endogenous changes are weak [60]. It is getting more obviously that global climate change is causing increased tree mortality in forests all over the world [61–63], process that is for the moment poorly understood due to its spatial pattern and temporal variability [64,65]. Intact forests allow long-term monitoring of trees' natural mortality, and therefore the opportunity to detect any changes in mortality rates, and to identify species which record the highest mortality values. This can help sketching possible scenarios of the forest ecosystems evolution due to climate change.

Natural regeneration is essential for the ecological continuity of forest ecosystems and intact forests provide the "reference" conditions [62] for both gaining knowledge about ecosystem functioning and developing sustainable ecologically based silvicultural systems.

The data collected from PRP in SNR-S can be used for the study of regeneration spatial and temporal dynamics in correlation with a large array of factors; among them the most significant are gap characteristics, trees' ages, spatial distribution and frequency [44,66–70], light quantity and quality [71,72], canopy composition [73], and biotic factors like browsing intensity [74] and fungal pathogens [71]. The structure and composition of tree regeneration depend on other factors like herb and shrub layer competition [71,74–76], site factors like litter [71], coarse woody debris [73,77–80], soil fertility, and wetness [74,81]. It should be noted that the importance of these factors may change over time depending on different stages of tree regeneration [74].

The study of natural regeneration in correlation with the increasing mortality rates and the long term research on ecosystems dynamic in intact forests can provide a good insight regarding the natural succession of forest species and biodiversity dynamic. Thus, natural evolution of different tree species can be observed, and their adaptive strategies analysed. Species more resilient to climate change can therefore be highlighted because the natural reaction of species and ecosystems as a whole is not affected in SNR by the anthropogenic impact. As a result, it is possible to find answers from the study of intact forests to the problems raised by research in recent decades on the decrease of beech productivity (e.g., in Belgium [82], or in Spain [83], on the fir decline in mixed forests [44,66], on the replacement of Norway spruce by Birch and Scots pine (e.g., in Finland [84,85]). Appropriate management measures [86] based on modelling natural succession of forest species could be developed to increase the resilience of managed European forest ecosystems to climate change.

The analysis of intact forest ecosystems cannot be completed without a picture of herbal species. Depending on the floristic spectrum of each survey, the SPs can be grouped into types of associations, in phytocenological tables. Also, in addition to the species diversity resulting directly from the species list, the averages of the ecological indices according to Ellenberg et al. [87] for each survey can be calculated, averages that express the preferences of the present species over light, temperature, soil moisture, acidity, and free nitrogen from the soil. These mean values implicitly reflect the site characteristics in which the phytocenosis develops and can represent the basis for comparing different types of phytocenosis or studying the evolution of a phytocenosis over time, knowing that most species accurately reflect changes in the ecosystem at some point [88].

Intact forests like SNR provide also exceptional habitats for wildlife with particular ecological qualities [89]. These habitats are generally missing in younger or managed forests, require tree species richness and functional diversity with mature trees and dead wood (standing trees or laid on the ground) [90,91]. Through future research, we intend to assess especially the small and large mammalian species, their population dynamics, their dynamics in relation to habitat conditions and their impact on forest regeneration. The monitoring of big mammal species which pass through the study area can be done with cameras placed in passage spots and by analysing their specific traces. On the other hand, the PRP can be utilized for assessing the small mammals, birds, lizards, snakes, and frogs. All the assessments and observations on the fauna shall be done both from the qualitative and quantitative point of view.

Studying the capacity of intact forests to regulate the water regime is justified by the fact that tree species require a special attention from the standpoint of the adaptation plans to climate changes. In managed forests, some tree species will demand specific management interventions in order to ensure their adaptation to climate changes [92]. In Europe, the severe drought episodes have determined a decline of the forests localized on dry sites and at the limit of species distribution area [93], leading to rapid distribution changes of the forest vegetation [94,95]. Thus, it has become imperative to have an in-depth understanding of the forest response to the decrease of water availability and to the impact of extreme drought events in order to elaborate adaptive forest management strategies [93]. Identifying the most vulnerable tree species to climate change is an important step towards the development of adaptation plans to these changes for the biodiversity and society [92] and the comparison of intact forests with similar managed forests affected by climate changes might reveal some technical solutions to be implemented in practice.

Regulating the water regime also depends on the water retention and storage capacity of the soils, which are governed by morphological characteristics of the profiles such as soil depth [96]), soil granulometry, and rock fragment content [97]. Additionally, the impact of bedrock type and soil characteristics on the biodiversity of soil microflora, especially fungal microflora of the soil and litter [98,99] are research worth being deepened in SNR-S.

When it comes to hydrological services, the main issue further allowing hydrological studies in SNR-S is to create a pluviometry network needed to evaluate different hydrological processes, such as surface run-off, erosion, or alluvial deposits. SNR-S could be a benchmark from the hydrological point of view but some areas, due to the steep slopes and shallow soils, shall be excluded from the analysis. The following results can be yielded: (1) Storage capacity per square meter under different classes of slopes, canopy density, and soil depths; (2) position change of laydown deadwood after summer flush floods (which could be an important issue in optimizing the relative position of aging patches [100], found to be the least cost-effective means of sparing deadwood.

Despite the large amount of literature on the relationship between forests and human health and wellbeing [101] at small scale, which is the case of SNR-S, it is very difficult, if not impossible, to produce solid evidence on how a particular natural forest produces more benefits for human health than whatever other old-growth or second-growth forest. Marginal direct or side-effects on human health are difficult to quantify due to the multiple connections between the different nodes of the food-chain, represented by individuals difficult to monitor in different development stages. Another reason for which these benefits are difficult to evaluate is the low density of the human population nearby; beside that SNR-S is being visited by a small number of tourists. However, indirect assessments based on contingent valuation can be carried out in a consistent way due to the fact there is one main access point, with a parking lot nearby. Short surveys can be distributed to the tourists by the forest rangers prior or after visiting the SNR-S and the issue of health benefits that can be addressed by these surveys would be a localized Disease Adjusted Life Years (lDALY), based on Dempster–Shafer theory [102].

The complexity of the interactions between floral and animal species and their associations found in the study area represents a starting point in assessing the contribution of a certain biodiversity level to the stability of the entire landscape and its component ecosystems, especially in the context of forest degradation phenomena occurring in Central and Western Europe. Recent approaches of ecosystem services classifications [103] have included "habitat or supporting service" as a type of service not directly provided, but otherwise included in the general functionality of the ecosystem complexes.

An integrated assessment of the interactions and trade-offs between provisioning, regulating, cultural, and supporting services within the study area and its surrounding landscape could provide a model for landscape management in the context of scarce areas with similarly high biodiversity.

This introductory paper was written to describe a permanent research platform installed for studying the intact forest ecosystems within Slătioara UNESCO site and its surroundings. Future research articles will be published based on the data collected within this platform and on the preliminary results presented in this paper.

The PRP was structured on two levels, one overlapping the entire study area, and the second for the detailed analysis of intact forest ecosystems from the core area of Slătioara UNESCO site. The implications of the overlaps between the two levels of PRP will be always considered and emphasised in future research articles.

The research platform was installed in SNR-S due to the collective effort of the specialists within the Faculty of Forestry Suceava, and the functionality of this research network will be secured by the same team, supported by volunteering students. Development of appropriate research on the already mentioned topics involves an adequate monitoring plan and additional research equipment installed in the field. Our intention is to deploy in some SPs state-of-the-art devices, in accordance with the future research topics, hence transforming these plots into Highly Intensive Plots (HIPs).

As Noss [104] stated, monitoring is the most useful and productive when it is goal oriented and linked to research. The goals of this research platform are clearly described, and the future monitor of the elements previously measured will bring up added value in terms of biodiversity and ecological processes within the intact mixed temperate forests of Europe. We express our hope that, with future appropriate financial support, the monitoring will become realistic, and the research activity in this valuable forest will continue.

Preserving and studying intact temperate forests is of great importance, for many reasons already mentioned in this paper; this is why the need for a network of permanent research plots in all the virgin forests of our country is obvious, preferably using a unified methodology of regular data collection. It is also desirable to connect the existing networks in countries which also have similar types of intact forests (such as Poland, Czech Republic, Slovenia, Bosnia and Herzegovina, Croatia) [62] and to coordinate as far as possible data collection and research.

Supplementary Materials: The following are available online at http://www.mdpi.com/1999-4907/11/9/1004/s1, Table S1: Cormophyte species identified in the field.

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