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Teaching about biodiversity from phytosociology: evaluation and conservation

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Abstract

In order to transform the previous erroneous ideas acquired by many of the students, a teaching outside the classroom is proposed, making the students themselves the ones who build their own knowledge from practice. Analyzing alpha, beta and gamma diversity, intrinsic alpha diversity must be measured through the characteristic species, gamma through the companion species, and beta through the gamma/alpha relationship, taking into account this relationship the lower the beta. The higher the conservation status of the community, if beta = 1 it means that there is a balance between characteristic species and companions, if beta is < 1 it means that there is a predominance of characteristic species over companions. As a result to be taken into consideration, it is observed in the inventory analysis that anthropic action is the cause of the changes in diversity, which translates into an instability of the association, being able to change one community for another. For this reason, we consider it is necessary to teach about the meaning of characteristic and companion species, since the student must know how to discern between both types of species, which leads us to learn the ecological niche of the species.

Keywords

Conservation, diversity, flora, grassland, higher education, indices

Introduction

We currently have several challenges related to the use of scientific knowledge to face current social issues, such as climate change or the need for sustainable development (Díaz Cordero 2012; García-Vinuesa et al. 2022). But without forgetting as the main challenge, the need to know how to transfer this scientific knowledge from generation to generation, which will make society a committed society, favoring the participation of the population in decision-making.

As a result of this, we indicate the need for a teaching in values, and above all for a scientific literacy of the students of the different academic degrees (Furio et al. 2001).

We refer to scientific literacy as an essential component of education that can promote citizen participation in decision-making about problems related to techno-scientific development, contribute to the formation of a critical spirit and convey the excitement of exciting challenges. that the scientific community has faced (Gil and Vilches 2004).

Since the 1980s and 1990s, curricular reforms have been carried out in which social aspects of interest to students have been included (National Research Council 1996). These social aspects introduced in the curricular content is what promotes the interest of the students.

Although, from an epistemological perspective, science teaching should contribute to the understanding of knowledge, procedures and values. These are the things that enable students to make judgments and see the utility of science, as well as its application in enhancing the quality of citizens (Furió et al. 2001). Based on this epistemological vision, we see active teaching in the study of plant communities as of special interest, as well as their ecological niche; so that their knowledge gives rise to

the ability to acquire skills such as the determination of companion species or characteristics in their constitution (Muñoz and Charro 2021). And through the determination of these, to be able to study the state of diversity and therefore of conservation of said communities (Jiménez et al. 2022).

For this, we propose a didactic practice that stimulates reflection and subsequent reasoning about what the student observes, building knowledge of it through experimentation and problem solving

The complexity of the knowledge to be acquired makes us focus this work on students of various science careers, such as Biology, Environmental Sciences, Agricultural Engineering, or for those students who are heading to develop positions as managers of natural spaces, relying on master's degrees or training modules. In view of this training capacity that future managers must acquire, both in vocational training and in university, the acquisition of capacities that confer desirable competencies is required. Currently there is an extensive knowledge about plant communities (Rivas-Goday 1964; Rivas-Goday and Rivas-Martínez 1963; Rivas-Martínez et al. 1999, 2001, 2003, 2007; Cano et al. 2012, 2015; Galán et al. 2000; Séchaud et al. 2002; Blasi et al. 2011; Cano-Ortiz et al. 2013; Piñar Fuentes et al. 2017; Diamond et al. 2019; Borhidi 1991, 1996; Borhidi et al. 1979; Galán and Orellana 2006), but they are not reflected in the capacities of environmental managers, what is due to the lack of Geobotany studies in many universities, however those managers who received such training, assumed this knowledge that they have been able to apply in environmental management. Therefore, it is essential to influence the knowledge of plant communities in terms of their ecology, floristic diversity and state of conservation (Caruso 2022).

There is a need for readjustment in the education process, not only in terms of how to educate students, but also in regards to the content that should be taught at different educational levels. This change is far- because it should make us change our conception of teaching.

This learning must be based on previous conceptions acquired by the students, which makes it necessary to talk about previous alternative conceptions. Relying on a meticulous study of them, we will go on to build the new conceptions (Oliva Martínez 1999; Santiado and Bergmann 2018).

The university student is provided with the necessary tools to go from knowing to being able to do. Based on this, the student builds knowledge of it by establishing relationships with previous theoretical knowledge acquired. We propose the study of these concepts and the calculation of alpha, beta and gamma plant diversity, from an active teaching methodology, for which it is necessary to know how to differentiate the characteristic species from the companions that appear in a plant association. What generates a teaching framework that implies that the student must think, act and speak with scientific terminology, to build your mental schemes. The students carry out their own phytosociological inventories, associating theoretical knowledge with practical reality in the field. This makes them determine what problems they have when applying this knowledge, as well as possible ways to solve them. These abilities are not acquired immediately, but rather a progressive attainment of them is required, as they are complex cognitive actions. Therefore, the student must acquire them during their academic life, where these skills are taught and promoted. Skills that are acquired with the study of plant communities, through which the different constituent species of the plant association are differentiated, as well as through the analysis of biodiversity (Cano-Ortiz et al. 2005; Cano-Ortiz et al. 2021a, 2021b), according to these authors, in all plant associations there are characteristic species and companions, the former being the ones that give character to the community, while the companions correspond to neighboring plant communities, which usually exist in a low percentage, but if the parameters are modified environmental conditions favor the entry of these plants into the community, sometimes acting as invaders. Alpha diversity is represented by species at the local level, gamma is the diversity of species at the regional level, and beta diversity is a relationship between the two (Moreno 2001).

We consider the measurement of the floristic diversity of plant communities to be of great interest, because it provides us with information on the state of conservation and maturity of the community. Although apparently the greater the floristic diversity, the greater the conservation of the phytocoenosis, this is not necessarily the case. There are studies in which the increase in diversity does not agree with an increase in the conservation status of the phytocoenosis. Thus, Cano-Ortiz et al. (2018), in a study on mangroves, state that by changing environmental factors, these mangrove communities are enriched with opportunistic or invasive species. The aim of the current paper is to show that high diversity is not synonymous with good conservation status. For this, it is intended that the student knows how to inventory the plant communities, using the Braun-Blanquet indices, as well as the diversity indices.

Methodology

The methodology used is based on the Activity Theory (Jorba and Sanmartí 1996) which considers that for an action to take place, an associated problem is necessary to promote it, as well as an objective that is considered by the students as necessary. Consequently, what is sought is that students become actively involved in the construction of their own knowledge; for this, the activities that we will propose must have specific characteristics that bring them closer to solving everyday problems, so that the student considers that what has been learned will give answers to a real problem posed (Read et al. 2018; Domínguez and Palomares 2020).

According to Gómez de Erice (2000), skills are articulated from wanting to know in order to be able to do. Scientific thought is developed in the successive academic levels transversally to the acquisition of knowledge.

Based on this, the study of the floristic diversity of the plant community is proposed to the students, as a necessary tool to establish good environmental management aimed at alleviating climate change.

Due to the need to develop scientific thinking in students, specific tasks are proposed where the teacher is a mere guide, leaving the main role for learning to the student himself.

Teachers should encourage direct observation of nature and the recording and interpretation of phenomena through the verbal and graphic. Didactic outings or field trips are a type of activity that allow procedures such as observation and interpretation to be worked on very well (Cano-Ortiz et al. 2022). Based on this, we move the classes outside the classroom, thus giving rise to learning that is not only asynchronous on some occasions, but also active.

Previously, some items are applied to the students to know the degree of knowledge they have about Botany and Geobotany. We worked with the students of the Geobotany and Botany subjects of the Biology degree, with a total of 143 students. They had ages that fluctuated between 19 and 25 years. The male gender being the predominant one representing 63% compared to 47% represented by the female gender of the total number of students in the research group (Table 1).

Table 1.- Showing the satisfactory responses of the students in the working group, which was carried out prior to the teaching-learning process.

Botany, and specifically Geobotany, a science that studies the relationships between plant communities, as well as their relationship with abiotic factors, are complex sciences that require well-established conceptual foundations, so that the student is able to learn new knowledge (Bessey and Bessey 2008). For this reason, we place special emphasis on the importance of teaching rich in environmental concepts at the different educational levels.

To study the state of conservation of a plant community, carried out at the foot of the field, the student will have to know concepts such as:

- Calculation of minimum area.
- How to make a phytosociological inventory?
- Braun-Blanquet indices.
- Characteristic species of the study community.
- Companion species from communities with catenal contact.
- Calculation of Alpha, Beta and Gamma diversity.

To calculate the minimum area, we will base ourselves on previous published studies (Cano-Ortiz et al. 2005). We apply the concept of minimum area collected in Martín and Paddy (2002), and we will combine it with the phytosociological method of Braun-Blanquet (1979), to obtain a mixed method, of great value for carrying out studies of diversity, dynamics and conservation of phytocoenosis.

We propose the learning of the concepts of plant community, companion species and characteristics, calculation of plant diversity, as well as study of ecological niche based on a constructivist model. For them, we must previously indicate the need for the study of plant communities and their ecological niches, which include concepts such as: plant community, their constitution, ecological niche, floristic diversity, conservation. It is essential to acquire this knowledge at different educational levels so that students can face new challenges and internalize and activate new concepts, thus obtaining training that trains them in environmental management.

Students are taught in field practices, which are considered homogeneous plots according to the dominant species (Alcaraz 1999). Once the plot has been chosen, the community to be sampled must be determined, bearing in mind the plant dynamics (herbaceous, shrubby and arboreal). The minimum area depends on the community to be sampled, understood as the maximum floristic diversity in the minimum surface unit, which includes the set of characteristic individuals of the same plant association, and accompanying species from nearby areas that belong to other plant associations plants in contact (Fig. 1). This minimum area is different depending on the structure of the community (arboreal, shrubby, herbaceous) (Cano-Ortiz et al. 2005) (Table 2). General standardizations on the size of the plots have been tried, but the floristic richness of each territory influences said size. In theory, the so-called minimum area should be determined, a parcel with the smallest surface within which an appropriate representation of a plant community of a given structure can be found. Knowing this minimum area for a certain type of vegetation will speed up the sampling process, and establish the diversity of a certain association, the basis for applying the classic diversity indices, and find out the state of conservation. One of the classic forms of sampling is the selection of the homogeneous plot from the ecological point of view, with pre-established values, which allows us to study the vegetation in a descriptive way and carry out a qualitative study; in this case, it is the presence or absence of species that are taken into consideration, but it is not possible to quantitatively assess the diversity, being precise the calculation of the minimum area (Cano-Ortiz et al. 2005; Cano-Ortiz et al. 2021c).

Figure 1. Minimum sampling area for grasslands (Southern Spain). Mountain Morena-Jaen. 1 m² (Cano-Ortiz et al. 2005).

Table 1. Showing the satisfactory responses of the students in the working group, which was carried out prior to the teaching-learning process.

INITIAL QUESTIONNAIRE					
FUNDAMENTAL QUESTIONS	**CORRECT ANSWER**	**GEOBOTANY STUDENTS (Nº)**	**DATA IN %**	**GENERAL BOTANY STUDENTS (Nº)**	**DATA IN %**
To what extent do you think there is a relationship between diversity and conservation?	Very high	12	100	131	100
Do you think it is important to know the diversity of an ecosystem to know its state of conservation?	Very important	12	100	131	100
Do you consider that in a plant community, a greater number of species that form it, is indicative of a greater conservation of the same.	No	7	58	63	48
Do you know how to calculate the minimum area?	Yes	3	25	0	0
Do you know how to make a phytosociological inventory?	Yes	1	8	0	0
Do you know how to calculate Alpha, Beta and Gamma diversity?	Yes	0	0	0	0
What sciences are involved in the concept of biodiversity?	Correct answer	12	100	130	99
Define the concept of biodiversity	Correctly defined	11	92	87	66
Do you know the differences between characteristic and companion species within Botany?	Yes	10	83	33	25
Do you know what sustainable development means?	Yes	12	100	131	100
Define what is sustainable development.	Correctly defined	12	100	122	93
The set of terrestrial ecosystems that, because they share similar climatic conditions, present the same types of living beings, is called:	Correct answer	12	100	72	55
What is the action plan to conserve biodiversity?	Correct answer	0	0	1	1
Biodiversity is…	Correct	12	100	94	72
How is biodiversity measured?	Correct answer	12	100	2	2
What are endemic species?	Correct answer	12	100	127	97
What is a biodiversity hotspot?	Correct answer	12	100	88	67
AWARENESS QUESTIONS	**CORRECT ANSWER**	**GEOBOTANY STUDENTS (Nº)**	**DATA IN %**	**GENERAL BOTANY STUDENTS (Nº)**	**DATA IN %**
To what extent do you think biodiversity conservation is related to sustainability?	Very related	12	100	131	100
The concepts of biodiversity, conservation and climate change, are they related?	Very related	12	100	131	100
Do you think knowledge about biodiversity is necessary to face present and future environmental problems?	Very necessary	12	100	131	100
At school, do you consider that you have been educated about biodiversity adequately or sufficiently?	Very inappropriate	12	100	131	100
Do you consider it necessary to study climate change in the classroom?	Very necessary	12	100	131	100
Do you consider it necessary to study climate change in the classroom?	Very necessary	12	100	131	100

After that, and once the community to be studied was chosen, we applied this case to the grasslands of *Glebionis coronaria* (L.) Cass. ex Spach (= *Chrysanthemum coronarium*) (Cano et al. 2017) (Fig. 2), the phytosociological inventory is carried out using the Braun-Blanquet indices (1979) and noting data of importance, altitude, orientation, slope, X and Y coordinates, coverage of the study plot. The species present within the minimum selected area will then be recorded and their Braun-Blanquet index will be recorded. Once this process has been carried out, the analytical stage is passed in which the student will learn which species are characteristic of the community, that is, they are in the ecological optimum, and which species are companions, that is, they come from catenal contacts with other communities, or they are species that are introduced because the studied community is not in its ecological optimum, but in a transition process with other communities.

Table 2. Minimum area calculated for a grassland community (Cano-Ortiz 2007).

VEGETATION TYPES	AREA m²
Herbaceous	0.5-2.0
Shrubs	200-300
arboreal	500-600

Once the analytical study has been carried out and the phytosociological table has been obtained with the Braun-Blanquet dominance-abundance indices, a comparative study is carried out with the samplings carried out years before in the same places, for which the same coordinates are used; later they are compared inventories for the year 2004 and 2017/2018. Next, the diversity indices are calculated, for which the phytosociological indices

Figure 2. Inventoried grassland of *Glebionis coronaria* (L.) Cass. ex Spach (= *Chrysantemum coronarium* L). Farm Barahona Portugal.

are previously transformed into those of Van der Maarel (1979), later the calculation of alpha, beta and gamma diversity is carried out (Baselga and Gomez Rodríguez 2019; Whitaker 1960). In this way, through the number of characteristic species of the studied association, alpha diversity is determined. Subsequently, gamma diversity is determined through the number of companion species noted in the phytosociological inventory. Finally, we move on to the study of beta diversity through the relationship between gamma/alpha ($Diversity_{beta}$ = $Diversity_{gamma}$/$Diversity_{alpha}$). To calculate the diversity and consequently the state of conservation, the PAST.EXE program (2020) is applied, through which the Simpson, Shannon, and Margalef indices are obtained (Cruz García et al. 2015; Cano et al. 2017; Mulya et al. 2021).

Results

Applying the Braun Blanquet abundance-dominance indices for data collection, they built a phytosociological table that contains the different inventories made, with a total of 24 phytosociological inventories, which correspond to the same plots but sampled in different years, 12 in the year 2004 and 12 in 2017/2018 (Table 4). A total of 58 characteristic species and 30 companion species are observed in them. Observing the highest abundance-dominance index for *Glebionis coronaria* (5), indicating a coverage equal to, greater than or less than 80%, depending on the sampling year. In the case of companion species, the most frequent indices of abundance-dominance of the species present are (1. +), but there is also a dependence on the year of sampling, in this case the coverage of the species present is less than 5 %.

In the calculation of the alpha, beta and gamma diversity indices (Baselga and Gomez Rodríguez 2019; Cano-Ortiz et al. 2021b), it can be seen both in Table 4 and in figures 4a, b, c and Table 5 that the type F inventories carried out in the years 2017/2018 present lower diversity values than the type A carried out in the year 2004. Evidently there has been a loss of floristic diversity in the sample plots separated in time 13-14 years.

Once carried out as the work proposal through active methodologies (inquiry), and taking the teaching out of the classroom (Santiago and Bergmann 2018). Where the student has a direct relationship with the natural environment, as well as perceives the information through the senses and emotions, derived from the observation of nature and the study plant communities (Mediterranean vegetation). After completing the questionnaire for the second time, it is observed a substantial increase in the satisfactory assimilation of all the concepts we deal with through this process (see Table 3). Being in 100% of both groups, the concepts of biodiversity, endemism, and differences between characteristic species and companions assimilated correctly.

On the other hand, when they are specifically asked about terms such as how biodiversity is measured, what is a hot spot or what are endemic species; These concepts have been acquired by all the respondents in a satisfactory manner after the teaching-learning process (in the field through the inquiry). Compared to much lower percentages obtained prior to the teaching process. When observing the data in percentage for the initial and final questionnaire, it becomes clear how there has been an increase in the assimilation of knowledge by the students, after the teaching methodology used.

As can be seen in the following graph (Fig. 3), there is a substantial improvement in the assimilation of knowledge by the students of the general study group. Getting to be practically 100%, the knowledge assimilated in the stage after the teaching process. On the other hand, it can be seen that at the beginning of this process, said assimilation of knowledge related to this block was well below this range.

In the survey used for the study of learning, awareness questions have been included, which demonstrate how the students (with 100% of the individuals surveyed), are sensitized in relation to the duo between conservation-biodiversity, the sustainability of ecosystems, as well as the relationship between biodiversity and the mitigation and prevention of climate change (see Table 3).

Questions have also been carried out to test the opinion of the students for the teaching system carried out. Such as:

- Do you consider that this teaching process carried out has helped you to assimilate knowledge more efficiently?
- Is there a significant improvement in your learning if we extrapolate the teaching outside the classroom?
- To what extent do you consider that the teaching of botany requires the use of methodologies such as inquiry?
- Do you consider the study of biodiversity important for the implementation of territorial sustainable development?

Table 3. Where the satisfactory answers (in number and percentage) of the students of the work group are shown, after the teaching-learning process.

FINAL QUESTIONNAIRE					
FUNDAMENTAL QUESTIONS	**CORRECT ANSWER**	**GEOBOTANY STUDENTS (Nº)**	**DATA IN %**	**GENERAL BOTANY STUDENTS (Nº)**	**DATA IN %**
To what extent do you think there is a relationship between diversity and conservation?	Very high	12	100	131	100
Do you think it is important to know the diversity of an ecosystem to know its state of conservation?	Very important	12	100	131	100
Do you consider that in a plant community, a greater number of species that form it, is indicative of a greater conservation of the same.	No	12	100	131	100
Do you know how to calculate the minimum area?	Yes	12	100	100	76
Do you know how to make a phytosociological inventory?	Yes	12	100	100	76
Do you know how to calculate Alpha, Beta and Gamma diversity?	Yes	12	100	50	38
What sciences are involved in the concept of biodiversity?	Correct answer	12	100	131	100
Define the concept of biodiversity	Correctly defined	12	100	128	98
Do you know the differences between characteristic and companion species within Botany?	Yes	12	100	131	100
Do you know what sustainable development means?	Yes	12	100	131	100
Define what is sustainable development.	Correctly defined	12	100	131	100
The set of terrestrial ecosystems that, because they share similar climatic conditions, present the same types of living beings, is called:	Correct answer	12	100	131	100
What is the action plan to conserve biodiversity?	Correct answer	8	67	78	60
Biodiversity is…	Correct	12	100	131	100
How is biodiversity measured?	Correct answer	12	100	131	100
What are endemic species?	Correct answer	12	100	131	100
What is a biodiversity hotspot?	Correct answer	12	100	131	100
AWARENESS QUESTIONS	**CORRECT ANSWER**	**GEOBOTANY STUDENTS (Nº)**	**DATA IN %**	**GENERAL BOTANY STUDENTS (Nº)**	**DATA IN %**
To what extent do you think biodiversity conservation is related to sustainability?	Very related	12	100	131	100
The concepts of biodiversity, conservation and climate change, are they related?	Very related	12	100	131	100
Do you think knowledge about biodiversity is necessary to face present and future environmental problems?	Very necessary	12	100	131	100
At school, do you consider that you have been educated about biodiversity adequately or sufficiently?	Very inappropriate	12	100	131	100
Do you consider it necessary to study climate change in the classroom?	Very necessary	12	100	131	100

The answer to it has been carried out by collecting data by nominal scale and Likert scale. Resulting in the case of the first of the questions surveyed, about whether the teaching process used has helped them to better assimilate knowledge in 98% of the students, it is indicated that this teaching methodology has helped them to a more effective fixation of knowledge.

For the second question discussed, where they are asked if extrapolating teaching outside the classroom has facilitated the learning process, 100% of the students surveyed have answered "very facilitated". In the case of the third question, where they are asked to reflect on whether they determine that the investigative methodology is adequate for the study of botany, 89% of the answers collected have indicated that it is considered "very necessary". Regarding the fourth question, where they are asked if the study of biodiversity is important for the implementation of territorial sustainable development, the students answer 100% that it is "very important".

Students perceive vegetation as part of biology, and of ecosystems. An essential part to understand nature, being one of the links in the trophic chain. In this sense, 100% of the working group determines from the beginning the importance of this science within Biology, (according to information collected in the awareness and opinion block of the questionnaire); but there are fluctuations in their answers when they are asked about the fundamentals, (by means of a questionnaire prior to the teaching-learning method), for example, for the case in which they are asked about how to make a phytosociological inventory, they answer 0 % of the students of the General Botany group correctly, which means that 100% have these concepts without acquiring.

Table 4. Phytosociological table, which shows the results of the 24 inventories carried out. *Glebionis coronaria* (L.) Cass. ex Spach (= *Chrysantemum coronarium* L.).

Inventory number	1F	1A	2A	2F	3A	3F	4A	4F	5A	5F	6A	6F	7A	7F	8A	8F	9A	9F	10A	10F	11A	11F	12A	12F
Coverage (%)	100	100	100	90	100	100	100	100	100	95	100	0	100	80	100	100	100	95	100	0	100	0	100	95
Area (m²)	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1		1	1
Altitude (m)	407	407	412	412	369	369	373	373	438	438	406	406	319	319	446	446	446	446	333	333	249	249	240	240
Average vegetation height (m)	0.90	0.90	1.30	0.30	1.50	0.40	1.30	0.60	1.00	1.00	1.40	0	1.20	1.00	1.50	0.90	1.90	0.90	1.25	0	1.20	0	1.70	1.00
Average height of the dominant species	0.90	0.95	1.50	0.30	1.70	0.40	1.45	0.60	1.30	1.00	1.60	0	1.40	1.00	1.60	0.90	2.00	0.90	1.35	0	1.30	0	2.00	1.00
Date	5/2/2018	3/20/2004	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017
Association	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh
Characteristic species																								
Glebionis coronaria (L.) Cass. ex Spach	3	5	5	·	5	·	5	·	5	·	5	·	5	·	5	·	5	·	5	·	5	·	5	·
Bromus diandrus Roth s.l.	1	2	1	·	1	·	1	1	1	·	1	·	1	·	+	·	·	·	·	·	·	·	·	·
Erodium malacoides (L.) L'HÚr.	·	1	1	·	1	2	+	+	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·
Avena sterilis L.	·	·	1	·	2	2	1	+	·	·	1	·	1	·	+	·	2	·	·	·	·	·	·	·
Lactuca serriola L.	·	+	1	·	·	·	+	·	·	·	+	·		·	+	·	+	·		·		·	+	·
Malva parviflora L.	·	·	+	+	1	4	·	·	1	·	·	·	1	·	·	·	·	·	·	·	·	·	+	·
Malva neglecta Wallr.	·	+	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Calendula arvensis L.	1	1	1	·	·	·	·	2	·	·	+	·	1	·	·	·	·	2		·	+	·	·	·
Sinapis alba L. subsp. *mairei* (H. Lindb.) Mairei	2	·	2	·	+	·	·	·	+	·	·	·	+	·	·	·	+	·	+	·	·	·	·	·
Medicago polymorpha L.	·	+	·	·		·	·	·	3	·	·	·		+	+	·	·	·	·	·	·	·	·	·
Echium plantagineum L.	·	·	·	·	+	·	·	·	+	·	3	·	+	·	·	·	·	·	·	·	1	·	·	·
Rapistrum rugosum (L.) All.	·	·	·	·	2	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	·	+	·
Hordeum leporinum Link	·	2	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Diplotaxis catholica (L.) DC.	+	+	·	2	·	·	·	·	·	·	·	·	1	·	·	·	+	·	·	·	·	·	+	+
Galium parisiense L.	·	·	·	·	·	·	·	·	·	·	+	·	+	·	+	·	·	·	·	·	·	·	·	·
Centaurea pullata L. subsp. *baetica* Talavera	·	·	·	·	·	·	+	2	·	·	·	·	+	·	·	·	·	·	·	·	+	·	+	·
Rumex conglomeratus Murray	·	·	·	·	1	·	+	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Papaver rhoeas L.	·	·	+	·	·	·	·	·	·	·	·	·	1	·	+	2	·	+	·	·	·	·	·	·
Anagallis coerulea Schreber	·	·		+	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	·
Sonchus tenerrimus L.	·	·	+	·	·	·	+	·	·	·	·	·	+	·		·	·	·	·	·	·	·	·	·
Lolium rigidum Gaudin	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·
Eruca sativa Mill subsp. *longirostris* (R.Uechtr.) Rouy	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	+	·	·	·	·	·	·	·
Crepis vesicaria L. subsp. *haenseleri* (Boiss.) Sell.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	1	·	·	·
Avena longiglumis Durieu,	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	+	·	+	·
Nonea vesicaria (L.) Rchb.	·	·	·	·	·	·	·	1	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Melilotus indica (L.) All.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·
Medicago arabica (L.) Hudson	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lolium multiflorum Lam.	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Lathyrus clymenum L.	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	+	·	·	·	·	·
Geranium rotundifolium L.	1	+	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	+	·	·	·
Erodium moschatum (L.) L'HÚr.	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Erodium ciconium (L.) L'HÚr.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	+	·
Diplotaxis virgata (Cav.) DC.	·	·	·	·	·	2	·	·	·	5	·	·	·	4	·	4	·	4	·	·	·	·	·	·
Bromus madritensis L.	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Vicia sativa L. subsp. *nigra* (L.) Ehrh.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·

Table 4. Continuation.

Inventory number	1F	1A	2A	2F	3A	3F	4A	4F	5A	5F	6A	6F	7A	7F	8A	8F	9A	9F	10A	10F	11A	11F	12A	12F
Coverage (%)	100	100	100	90	100	100	100	100	100	95	100	0	100	80	100	100	100	95	100	0	100	0	100	95
Area (m²)	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1		1	1
Altitude (m)	407	407	412	412	369	369	373	373	438	438	406	406	319	319	446	446	446	446	333	333	249	249	240	240
Average vegetation height (m)	0.90	0.90	1.30	0.30	1.50	0.40	1.30	0.60	1.00	1.00	1.40	0	1.20	1.00	1.50	0.90	1.90	0.90	1.25	0	1.20	0	1.70	1.00
Average height of the dominant species	0.90	0.95	1.50	0.30	1.70	0.40	1.45	0.60	1.30	1.00	1.60	0	1.40	1.00	1.60	0.90	2.00	0.90	1.35	0	1.30	0	2.00	1.00
Date	5/2/2018	3/20/2004	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017
Association	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh
Vicia monthana Retz.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·
Vicia hybrida L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Vicia benghalensis L.	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Stellaria alsine Grimm	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Stachys arvensis (L.) L.	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Sonchus oleraceus L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	+	·	·	·	·	·	·
Raphanus raphanistrum L.	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Plantago lanceolata L.	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·
Plantago lagopus L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·
Ononis viscosa L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Ononis biflora Desf.	·	·	·	·	·	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·	+	·	·	·
Medicago orbicularis (L.) Bartal.	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Medicago doliata Carming. var. *muricata* (Bentham) Heyn, in Davies	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lolium temulentum L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lactuca virosa L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Glossopappus macrotus (Durieu) Briq. in Burnat	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Gastridium ventricosum (Gouan) Sch. et Th.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Galactites tomentosa Moench	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fumaria reuteri Boiss.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Euphorbia helioscopia L.	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Bromus intermedius Guss.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Brassica nigra (L.) Koch	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Bellardia trixago (L.) All.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Avena barbata Potter	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Companion species																								
Silybum marianum (L.) Gaertner	·	·	·	·	1	·	·	1	+	·	·	·	·	·	1	+	+	·	+	·	·	·	+	·
Carduus bourgaeanus Boiss. & Reuter	·	·	·	1	+	·	1	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	1	·
Foeniculum vulgare Miller	·	·	+	+	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·	·	·
Phalaris minor Retz.	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+	·
Convolvulus althaeoides L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	+	·	·	·
Carduus pycnocephalus L.	·	·	·	·	·	·	·	1	·	·	·	·	·	+	1	1	1	·	·	·	1	·	·	·
Holcus setiglumis Boiss. et Reuter	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Trifolium tomentosum L.	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Silene coeli-rosa (L.) Godron	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Oryzopsis miliacea (L.) Asch. et Sch. subsp. *thomasii* (Duby) Pign.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·

Table 4. Continuation.

Inventory number	1F	1A	2A	2F	3A	3F	4A	4F	5A	5F	6A	6F	7A	7F	8A	8F	9A	9F	10A	10F	11A	11F	12A	12F
Coverage (%)	100	100	100	90	100	100	100	100	100	95	100	0	100	80	100	100	100	95	100	0	100	0	100	95
Area (m²)	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1		1	1
Altitude (m)	407	407	412	412	369	369	373	373	438	438	406	406	319	319	446	446	446	446	333	333	249	249	240	240
Average vegetation height (m)	0.90	0.90	1.30	0.30	1.50	0.40	1.30	0.60	1.00	1.00	1.40	0	1.20	1.00	1.50	0.90	1.90	0.90	1.25	0	1.20	0	1.70	1.00
Average height of the dominant species	0.90	0.95	1.50	0.30	1.70	0.40	1.45	0.60	1.30	1.00	1.60	0	1.40	1.00	1.60	0.90	2.00	0.90	1.35	0	1.30	0	2.00	1.00
Date	5/2/2018	3/20/2004	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	4/29/2004	3/28/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017	5/15/2004	3/29/2017
Association	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh	RCh
Onopordum nervosum Boiss.	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	5
Mercurialis annua L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·
Marrubium vulgare L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lamarckia aurea (L.) Moench	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Geranium dissectum L.	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Ecballium elaterium (L.) A. Rich.	·	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	1	·	·	·	·	·
Daucus carota L. subsp. *maximus* (Desf.) Ball	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Dactylis glomerata L.	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·
Calystegia sepium (L.) R.Br.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
New species																								
Rumex sp.	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fumaria capreolata L.	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Veronica hederifolia L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	2	·	·	·	·	·	·
Urtica urens L.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Anchusa undulate L.	·	·	·	1	·	·	·	·	·	·	·	·	·	1	·	+	·	·	·	·	·	·	·	·
Galium aparine L.	·	·	·	·	·	1	·	·	·	+	·	·	·	1	·	·	·	2	·	·	·	·	·	·
Fumaria sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·
Galium minutulus Jordan	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Anagallis arvensis L.	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Arenaria serpyllifolia L.	·	·	·	·	·	·	·	·	·	·	·	·	·	3	·	·	·	·	·	·	·	·	·	·
Sagina apetala Ard.	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·

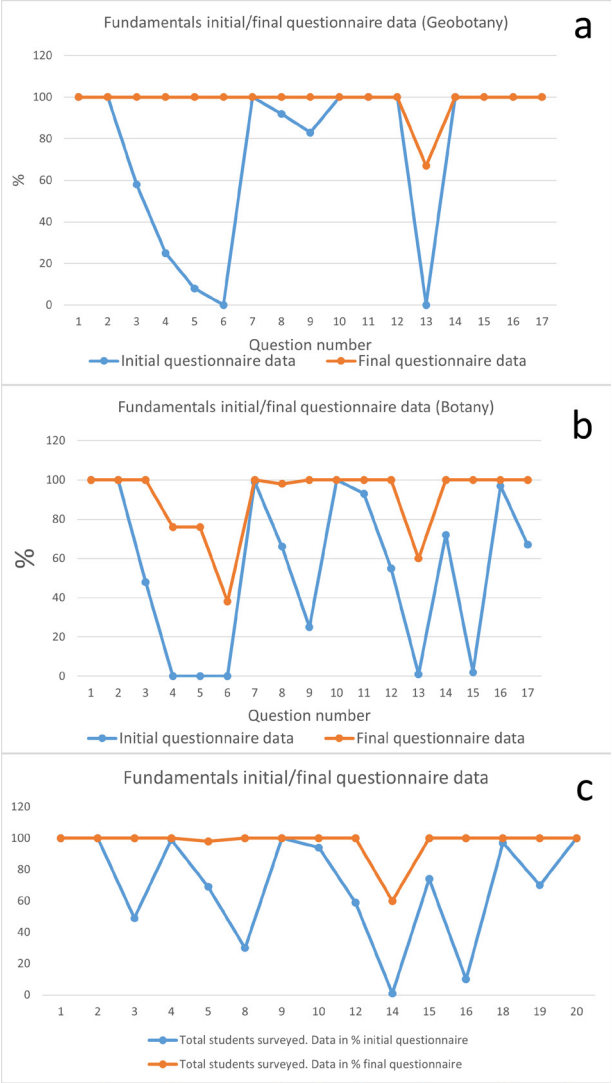

Figure 3. Response in % a) for the total number of students (Geobotany and General Botany), b) for the stage prior to the teaching process (blue trend line) and c) for the stage after the application of the proposed educational methodologies (line red tendency).

In the case of the students of the Geobotany group, they present said knowledge acquired in a minority, with 8% of the students surveyed, answering said question satisfactorily. On the other hand and in a higher way, the students of the work group do not know in detail the differences between companion and characteristics species, these concepts being less assimilated for the group of students belonging to the subject of Botany (second year of the degree of biology), noting that only 25% of the respondents know the concepts about companion and characteristics species; compared to the students who belong to the Geobotany group, where there is an assimilation of these concepts that is much more adjusted to their reality, with 83% of the respondents responding satisfactorily (see Table 1).

Likewise, the questionnaire presents awareness questions. In this case, in the initial questionnaire, it is shown that the students of the Biology degree in both groups are fully aware, answering questions related to sustainability, biodiversity and climate change. This level of awareness (100% of those surveyed) is maintained before and after the teaching process. In the same way (after completing the package of questions in the questionnaire through which the opinion is tested), the students consider that in previous educational levels the teaching they have been given about biodiversity has been very insufficient.

These data demonstrate a high level of satisfaction on the part of the students regarding the methodology used for teaching biodiversity related to Botany.

Discussion

Once the homogeneous plot has been chosen from the ecological point of view and the minimum area has been calculated by the students, once the samplings have been carried out in the same plots (years 2004-2017/2018), the phytosociological analysis is carried out, comparing inventory to inventory, it is observed. In general, the 2017/2018 type F samples present fewer species than those corresponding to 2004 type A, so it is assumed that there has been a loss of floristic diversity (Leiva 2021). Specifically, in all inventories 2F to 12F, the guideline species of the herbaceous community, the *Resedo albae-Chrysanthemetum coronarii* O. Bolòs & Molinier 1958 association, has disappeared, and in the 3F inventory Malva parviflora dominates and the *Urtico urentis-Malvetum neglectae* (Knapp 1945) Lohmeyer in Tüxen 1950 association is obtained, which is interpreted as due to an increase in the organic matter plot, however, in inventories 5F and 7F to 9F *Diplotaxis virgata* has become dominant, in this case the community of *Glebionis discolor* (d´Urb.) Cano et al. has evolved towards that of *Papaveri rhoeadis-Diplotaxietum virgatae* Rivas-Martínez 1978, which is due to loss of organic matter and soil plowing (Piñar et al. 2021). With regard to the analysis of alpha, beta and gamma diversity, in inventories 3F, 5F, 7F to 9F no loss of floristic diversity is noted, this is due to the substitution of some species for others; which does not imply that the association is well preserved. When there is a decrease in alpha diversity compared to gamma (Table 5) in some type F inventories, such as 2F, 5F, 7F, 12F, the value of beta diversity rises, when beta = 1 there is a balance between species characteristics and neighboring companion species of close associations (Fig. 4), if beta > 1 there is a tendency towards the disappearance of the association, if beta < 1 there is a tendency towards conservation, all this is due to the change in the environmental factors, which are generally of anthropic origin; when these factors are modified sharply, such as excessive use of agrochemicals or infrastructure construction, the diversity is nil, as occurs in inventories 6F, 10F and 11F (Cano-Ortiz 2021; Cano-Ortiz et al. 2022).

The students relate that a greater number of species does not mean that the plant community is better preserved, but rather that it is in a process of fluctuation to-

Table 5. Result of the calculation of plant diversity. Determination of the state of conservation.

Inventory number	1F	1A	2A	2F	3A	3F	4A	4F	5A	5F	6A	6F	7A	7F	8A	8F	9A	9F	10A	10F	11A	11F	12A	12F
Global number of species	9	13	14	7	11	6	11	9	13	4	15	0	19	8	11	10	11	7	10	0	15	0	14	2
Number of characteristic species	7	12	12	2	9	5	8	7	11	1	13	0	17	3	8	5	7	4	8	0	11	0	11	1
Number of companion species	2	1	2	4	2	1	3	2	2	3	2	0	2	5	3	5	4	3	2	0	4	0	3	1
Gamma diversity	2	1	2	4	2	1	3	2	2	3	2	0	2	5	3	5	4	3	2	0	4	0	3	1
Alfa diversity	7	12	12	2	9	5	8	7	11	1	13	0	17	3	8	5	7	4	8	0	11	0	11	1
Beta diversity	0.28	0.08	0.16	2	0.22	0.20	0.37	0.28	0.18	3	0.15	0	0.11	1.66	0.37	1	0.57	0.75	0.25	0	0.36	0	0.27	1

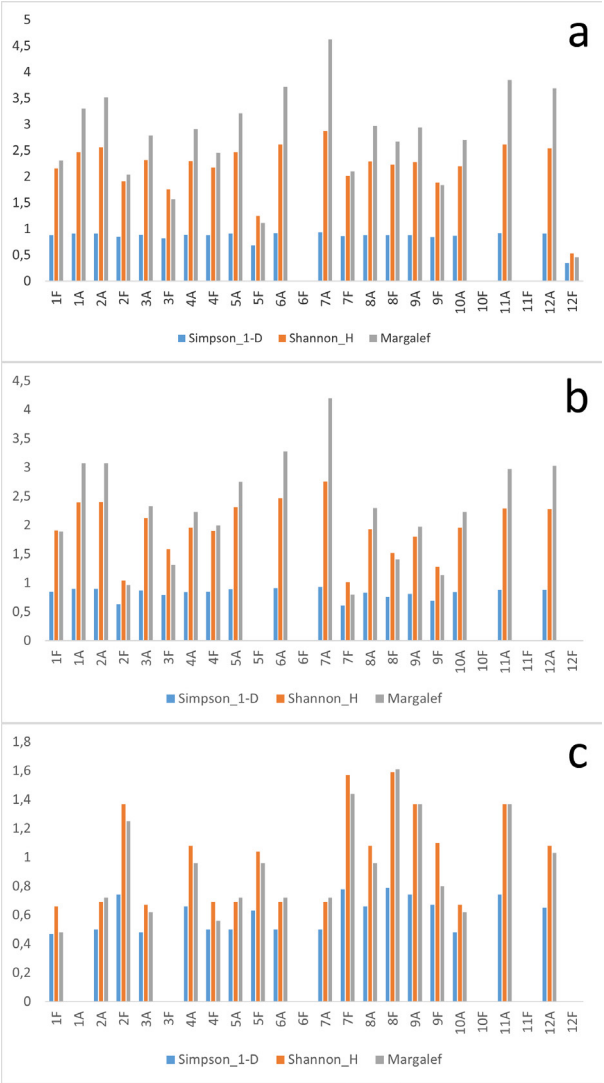

Figure 4. Diversity indices a) for all species present in the association, b) for characteristic species and c) for companion species.

wards other communities. Being relevant information, not only to determine the state of conservation of the study community, but also in its use to mitigate Climate Change already evident today, as well as land use planning (Lobelli et al. 2012).

We must not forget that plant communities are large carbon sinks and O2 producers, within their life cycle and in the process carried out by their photosynthetic organs they make this biochemical exchange possible and this makes them a tool to keep in mind within of the mitigation processes to be carried out (Macias 2004; Rosas 2018).

Consequently, when studying whether the measure of floristic diversity provides us with information on the state of conservation, not only should the number of different species be taken into account, but also the environmental factors that condition the maturity of the phytocoenosis, and what is its floristic composition. For this, phytosociological sampling is essential in which the characteristic species and companions of the plant association appear, since the conservation status of a plant community is given by the number and abundance of the characteristic species, consequently the more characteristic species present. This is the best preserved and stabilized plant community.

Conclusion

The significant learning of the students is carried out after the development of thinking skills in a problematic context. Without forgetting that through this resolution of daily problems, the student's motivation is achieved, making him an active participant in his own learning.

In this study, which has motivated the interest of the student, it has been possible for them to acquire skills regarding the identification of plant communities, the concept of plant association, and above all, how to measure floristic diversity to find out if the association studied is good or bad preserved, or it has been transformed into another type of community, with the disappearance of the original community. In this case, the student understands the concept of plant dynamics as a consequence of the transformation of one association into another due to the loss of the guiding species and dominance of new species. The work carried out has a Piagentist and constructivist basis, which allows for a deeper and more effective acquisition of botanical knowledge, as well as an understanding of how to use it in environmental management and in the mitigation of Climate Change.

In this research we have observed how the abundance-dominance indices are modified by the influence of anthropic factors, therefore, when organic matter increases in the soil, the abundance of *Malva parviflora* and *Malva neglecta* increases. However, if it is an increase in plowing, it is *Diplotaxis virgata* that becomes dominant and replaces the communities of *Glebionis coronaria*.

With this methodology, an effective construction of the mental structures and capacities of the students has been achieved, stimulating their interest and involving them sensorially and emotionally with the subject of study. As stated by teachers of learning, "It is not enough for students to be active in their work methods if the activities they perform are arbitrary or meaningless" (Ausubel 1968).

The teaching of botany, as well as other complex sciences, requires a triple change on the part of the teaching staff: a conceptual, methodological and attitudinal change.

Acknowledgments

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