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Economic approach to nature conservation - Land use change

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Economic approach to nature conservation - Land use change

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Abstract. It is important to understand the relationship between land use and biodiversity, in order to support decisions, towards sustainability. Nowadays, land use and biodiversity management is focused on protected areas, discarding other habitats, tending to favour exclusive property rights over the territory, thus creating unfeasible solutions for society. The Azorean archipelago suffered drastic changes in land use, having caused, along the time, the extinction of numerous endemic species particularly in the most disturbed Islands. Azores has 420 endemic species and subspecies, being these protected by the Directives of Habitats and Birds. In order to preserve biodiversity, natural parks were created. However, conservation tools consider only protected areas, not considering adjacent areas as beneficial for biodiversity conservation, neither any other area outside protected areas. Besides, in spite of several authors have already studied the effect of land uses on species, none of them determined the exact trade-offs between species richness of different groups of species according to different land uses, focusing their study only in some species, or in some land use, constituting this the novelty of this article. Thus, the aim of this paper is to understand the relationship between land use and endemic species richness. For this, the ATLANTIS TIERRA 2.1 database was used, and spatial endemic richness for different taxa (Bryophytes, Vascular Plants, Mollusks, Arthropods and Vertebrate) was identified at the spatial scale. After that SPSS and GeoDa were used to explain endemic species richness with the mosaic of land uses (Agriculture, Pasture, Natural Vegetation, Forest, Urban and Uncovered Areas), in order to allow soil use management and conservation measures to be determined through the integrated organization of landscape and not only by the definition of protected areas. Models were estimated considering neighbourhood effects between geographical units, using GeoDa, which revealed to be a good tool to attain the objectives of this study. Results show that all the studied groups richness of species are affected by land use, with Vertebrates, Arthropods and Vascular Plants being the ones most affected by land use change. Results are consistent, allowing to determine the trade-offs between land use and species richness, which can further be used, with valuation techniques, in order to draw up guidelines towards a compromise between social welfare and environmental sustainability.

Keywords: Biodiversity, land use, spatial interaction, integrated management

JEL code: Q00, Q01, Q15, Q57, Q56

Introduction

Globally, it is estimated that the proportion of soil that has been transformed or degraded by humans has varied between 40 and 50% since 1945 and most of the transformation of land use has led to a decline in the ecosystems quality, in naturalness and in a decrease of biodiversity. Biodiversity loss is a growing concern that went from the scientific community to the public awareness and the political arena (Vandewalle *et al.*, 2010).

Human population growth and growth in demand for natural resources are the main reasons behind the change in land use, resulting in biodiversity loss. And the link between human population density and the risk for biodiversity loss is mostly indirect, but yet correlated (Sodhi *et al.*, 2010).

Around the world several correlation patterns between human population density and species richness occurs, being cities spontaneous spaces where species appear, already confirmed in various scales and regions of Europe. However the fragments of semi natural vegetation and agricultural land, within and/or around the cities contribute to higher biodiversity rates. Most of the exotic species is introduced through cultivation, being that most of the species richness in the cities could be attributed mainly to exotic species. Indeed, plants have adapted themselves to stress or land use, preferably within cities (Kühn *et al.*, 2004).

Protected areas have been the pillar for biodiversity conservation, with 12% of the land currently under some form of protection, with a commitment to increase it from 15 to 20% by 2020. But, outside protected areas, the destruction of habitats turns the previously homogeneous landscapes in a mosaic of new land use types that may be unfavourable to some species. And, moreover, the border between the different habitats create border effects, often promoting the extinction of many species that are sensitive to disturbance's of the native habitats. There are excellent available tools for mapping priorities in conservation of protected landscapes. However, conservation tools consider only protected areas, not considering adjacent areas as beneficial for biodiversity conservation. Indeed, it is recognized that landscapes, in addition to the protected areas are important to provide ecological and evolutionary processes, essential for the long-term persistence of biodiversity, within and outside protected areas (Willis *et al.*, 2012).

Azores suffered drastic changes in land use, causing extinction of numerous endemic species, particularly in the most disturbed Islands, where a few patches of native forest remain. However some human-modified habitats such as exotic forest plantations may have endemic

and native species, but other uses, such as intensive pasture are known to be dominated by exotic species (Cardoso *et al.*, 2013).

This paper aims at explaining the spatial patterns of endemic species in Terceira Island, according to land use patterns, being considered the hypothesis that the richness of spatially identified endemic species for different taxa can be explained by the mosaic of land use, therefore allowing management and conservation to be done through an integrated organization of landscape, and not only by the definition of protected areas. Spatial analysis tools will be used, for their potential for this type of studies, recognized by several authors and nature conservation agencies (Borrea *et al.*, 2011).

1. Modelling species distribution according to land use

The relationships between land use and biodiversity is fundamental to understand the links between people, environment and land use change, as well as transformations in land management (Haines-Young, 2009). And with the latest developments of predictive distribution models, these can be used to support decisions on species conservation (Jiménez-Valverde *et al.*, 2009). Species distribution and the effect of land use on species have been analysed by several authors (e.g. Zechmeister *et al.*, 2003; Reidsma, *et al.*, 2006; Jetz, *et al.*, 2007; Beaumont, 2008; Wretenberga *et al.*, 2010 and Capotorti, *et al.* 2012). Nevertheless, none of them determined the exact trade-offs between species richness of different groups of species according to different land uses, focusing their study only in some species, or in some land use, or even analyzing the number of individuals of some species according to land use. Recently spatial interaction models have been used to study the effects of spatial aggregation (Borda-de-Água, *et al.*, 2012). Over 25 different functions have been proposed to model species distribution; being the two most widely used the logseries and the lognormal. As the continuous lognormal distribution allows fractional abundances, the Poisson lognormal is often used instead of the standard continuous lognormal (Matthews *et al.*, 2013).

2. Distribution of endemic species in the Azores

The number of endemic species and subspecies of terrestrial and aquatic organisms in the Azores is estimated to be approximately 452 (411 species). The animal phyla are the most diverse in endemic *taxa*, especially Mollusca (49 *taxa*) and Arthropoda (266 *taxa*), comprising 73% of the Azorean endemisms. Vascular Plants present 73 endemic species and subspecies, being important to the total *rate* of the Azorean endemics (Borges *et al.*, 2010).

Arthropoda consist of 950000 species, which corresponds to about two-thirds of the total number of the known alive species. Arthropods, including insects and other similar groups, like spiders, mites, other arachnids, centipedes and millipedes are the dominant life forms on planet Earth. In the Azores 2298 species and subspecies of Arthropods are known. And the 288 species of endemic known Arthropods constitute a poor estimate of reality, being estimated that this number approaches 400 species (Borges, 2008).

The Bryophytes are small plants, mainly terrestrial, characterized by the absence of vascular tissues (no roots, stems or leaves) and the predominance of gametophyte generation in relationship to the sporophyte generation. In the Azores the total number of bryophyte species and subspecies is 439: 258 mosses, 149 hepatics and 5 hornworts. Despite having relatively low growth rates and the fact that it takes many decades to develop a good coverage of the substrates, plants are the ones whose occupation area, diversity and vitality are most extraordinary in the Azores, probably due to the diversity of available substrates and the good conditions (humidity, light and temperature) favouring their development (Gabriel, 2008).

The terrestrial Mollusks are often an important component of the invertebrate's fauna of the Azorean Islands native habitats. With a total of 111 species, Mollusks are dominated by the Sytommatophora (Gastropoda) totalizing 93 species (Martins, 2008).

In six of the nine Azorean Islands, endemic plants represent more than 25% of the malacofauna, including São Jorge Island, with 33.3%. On the other Azorean islands, endemism rate lies between 17% and 24%. In Azores, only four islands have unique endemics, including Santa Maria, with about 70%. Endemism, in São Miguel and Terceira islands is above 20%, and in Faial, below 10% (Martins, 2008).

The Vascular Plants (Pterodophyta and Spermatophyta) of the Azorean archipelago are characterized by a relatively small number of native and endemic species, when compared with Madeira and Canarias, with a total of 947 taxa, including 71 pteridophytes, 5 gymnosperms, 643 dicotyledons and 228 monocotyledons (Silva, 2008).

In the Azores, the Vertebrates comprise 71 species and subspecies of terrestrial vertebrates and 582 known marine vertebrates. In spite of vertebrates (Chordata) not being the most numerous animal group in individuals or taxa, they constitute a very diverse group ranging in an evolutionary scale from Lampreys to man. With such a variety of organisms, it is easy to understand their high geographical distribution, occupying all kinds of habitats in the world (Cunha and Santos, 2012).

3. Terceira Island protected areas for biodiversity conservation

In order to preserve one of the most precious natural treasures of the Azores, biodiversity, natural parks were created, in all the islands, in order to enable a better management of the territory to attain biodiversity conservation, as well as a sustainable and reliable use of natural resources.

The creation of Natural Parks in all the Azorean Islands had as objective the aggregation of all the protected areas, with different protection statutes, serving as a management tool, thus simplifying administration issues.

The Regional network of the Azorean protected areas is based on the International Union for the Conservation of Nature (IUCN) guidelines, adapting classifications to the geographical, environmental, cultural and territorial political-administrative peculiarities of the Azores archipelago, being these denominated as follows:

- Natural Reserve (Category I – IUCN)
- Natural Monument (Category III – IUCN)
- Protected Area for the Habitats and Species Management (Category IV – IUCN)
- Protected Landscape Area (Category V – IUCN)
- Protected Area for Resources Management (Category VI – IUCN)

Terceira island protected areas (Figure 1) occupy a total area of 95.78 km², constituted by 20 terrestrial and marine areas, with 88.35 km² and 7.43 km², respectively (Silveira, 2009). Terceira Island has about 22% of its land integrated in the natural park, including private areas, which among other land use aptitudes, has also aptitudes for nature, landscape and natural resources conservation, based on specific scientific classifications, framed by international, national, regional and local guidelines (Secretaria Regional do Ambiente e do Mar, 2011).

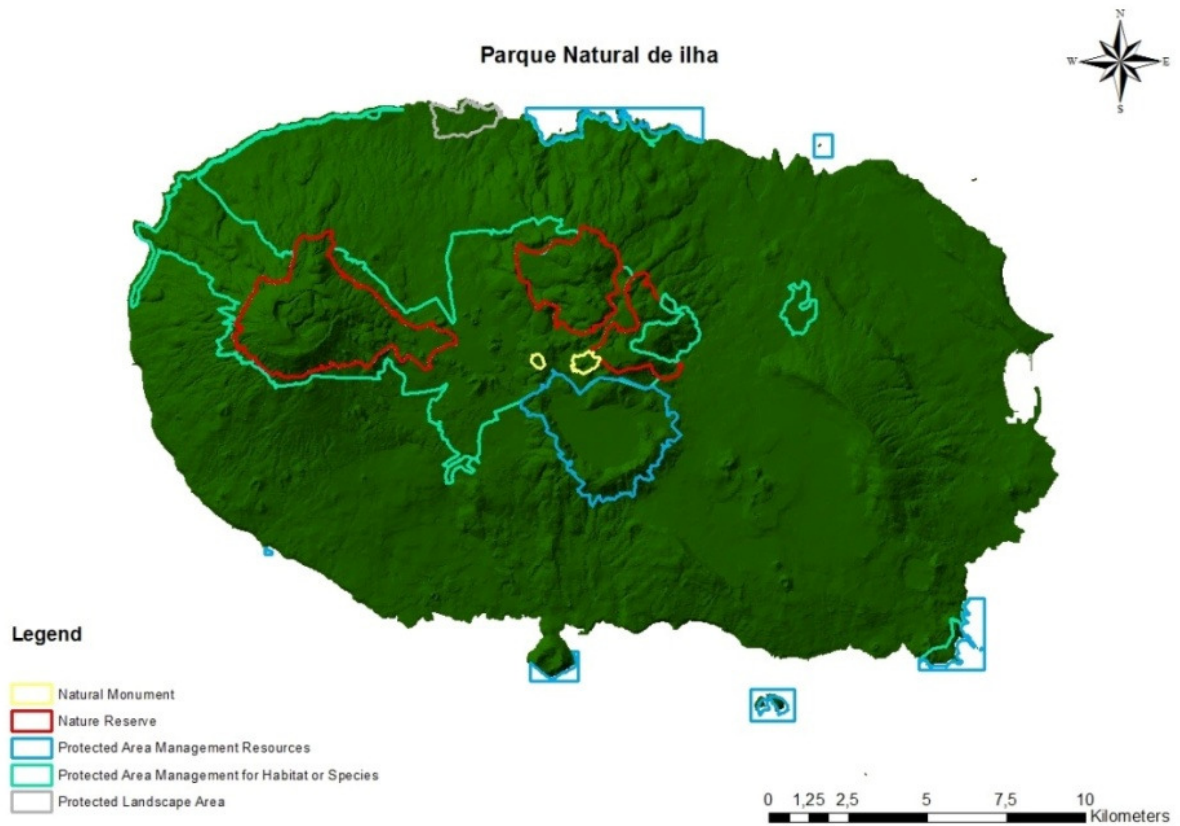


Figure 1. Terceira Island’s protected areas and reserves (Adapted from Secretaria Regional do Ambiente e do Mar, Azorean Regional Government).

4. Methodology

4.1. Study Area

This study was conducted on Terceira island, in the Azores archipelago, located in the Atlantic North, approximately between the coordinates 37° to 40 °N latitude and 25 ° to 31 °W longitude.

The Azores archipelago is constituted by nine islands and some islets, all of volcanic origin, arising in the triple junction of the euro-Asian, African and American lithospheric plates (Borges *et al.*, 2010). The minimum distance between the Azores and mainland is about 1584 km.

Terceira Island is one of the most populous islands of the archipelago. Currently, Terceira Island landscape is heavily modified by the presence of man and only in small areas, where the soil or the weather comprises adverse conditions, the primitive conditions remain

unchanged. Terceira Island has approximately 29 km length and 18 km width, with a perimeter of 90 km and an area of 402, 2 km² (Silveira, 2009).

Terceira Island has 56437 inhabitants, being that 35402 live in Angra do Heroísmo and 21035 in Praia da Vitória municipalities (SREA, 2014). According to the National Census of 2011, Terceira Island population density was nearly 141,0 persons per km², being population distributed by Angra do Heroísmo (148,2 persons per km²) and Praia da Vitória (130 persons per km²) municipalities.

In Terceira Island, people is distributed mainly around the island, near the shore (low altitude areas), while in the centre of the island (higher altitudes) there are no inhabitants. Population density in the main urban centre (Angra do Heroísmo city) ranges from nearly 955 persons per km² to 3717 persons per km² (SREA). Another important feature of urban planning in Terceira Island is that even in the urban centres, many houses have gardens.

4.2. Terceira Island endemic species database

Data from the ATLANTIS database 2.1 (available on the website of Azorean Biodiversity), was used to create the database for this study, which comprises level 1 endemic species distribution of Arthropods, Bryophytes, Mollusks, Vascular Plants and Vertebrates, by sampling areas, in a grid composed by plots of land, each with 500 m x 500 m.

The 1-level sampling considers only the species that have been sampled in a specific point by sighting, marked with GPS or by any other precise registration.

Empirical data, simulations, and theoretical developments reveal that species distribution changes when changing the sample size (Borda-de-Água *et al.*, 2012), therefore being extremely important to use large databases. Data with 1715 observations for each group of species was considered in the modeling process.

4.3. Terceira Island endemic species distribution

Figure 2 presents the spatial distribution, in Terceira Island, of the richness of species of the several analyzed groups.

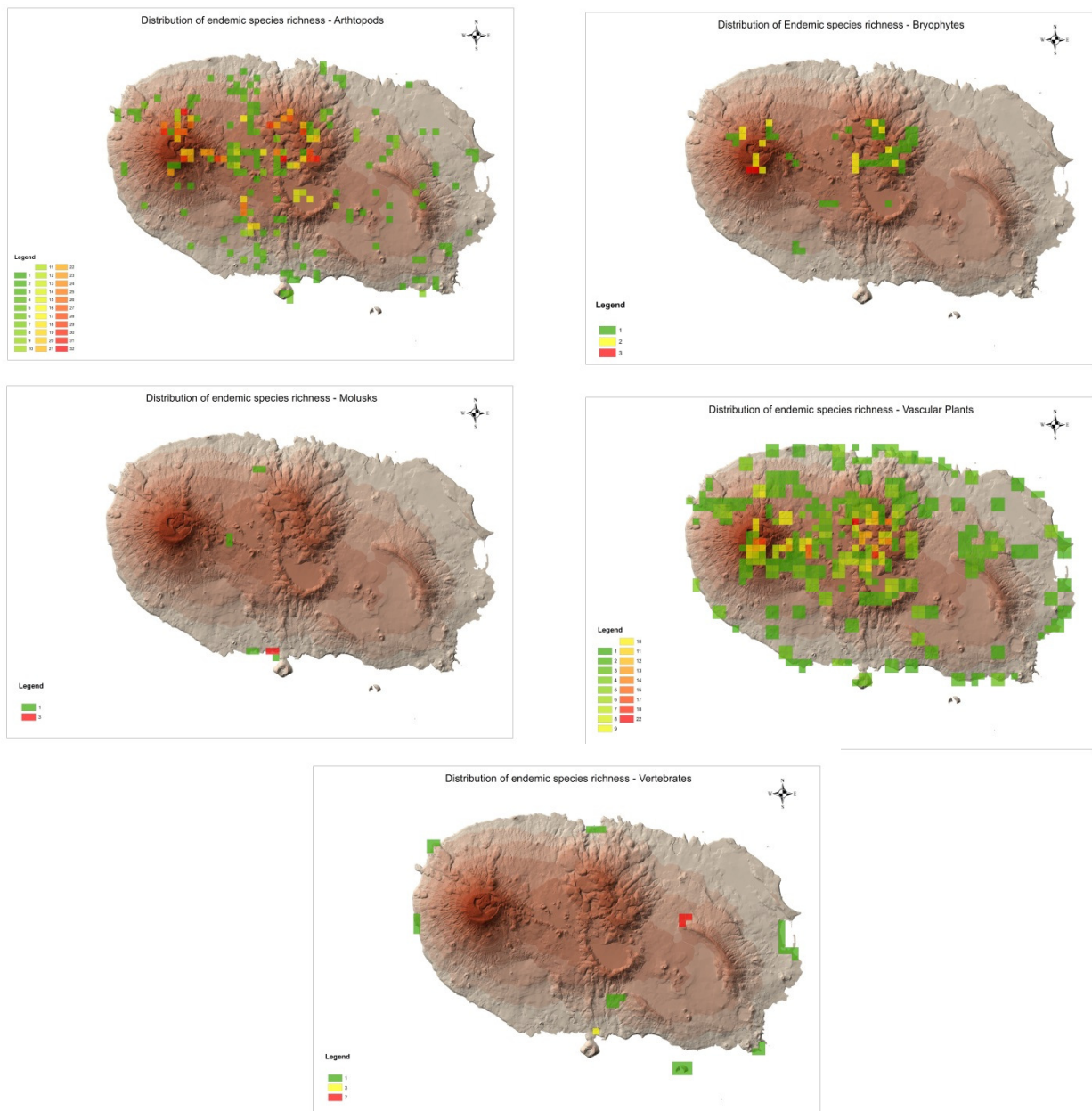


Figure 2. Richness of species of the groups Arthropod, Bryophytes, Mollusks, Vascular Plants and Vertebrates in Terceira Island

4.4. Land Use in Terceira Island

Terceira island urban occupation is nearly 8%, while about 28% of the island is occupied by forest and natural vegetation and over 60% by agriculture and pasture (Figure 3).

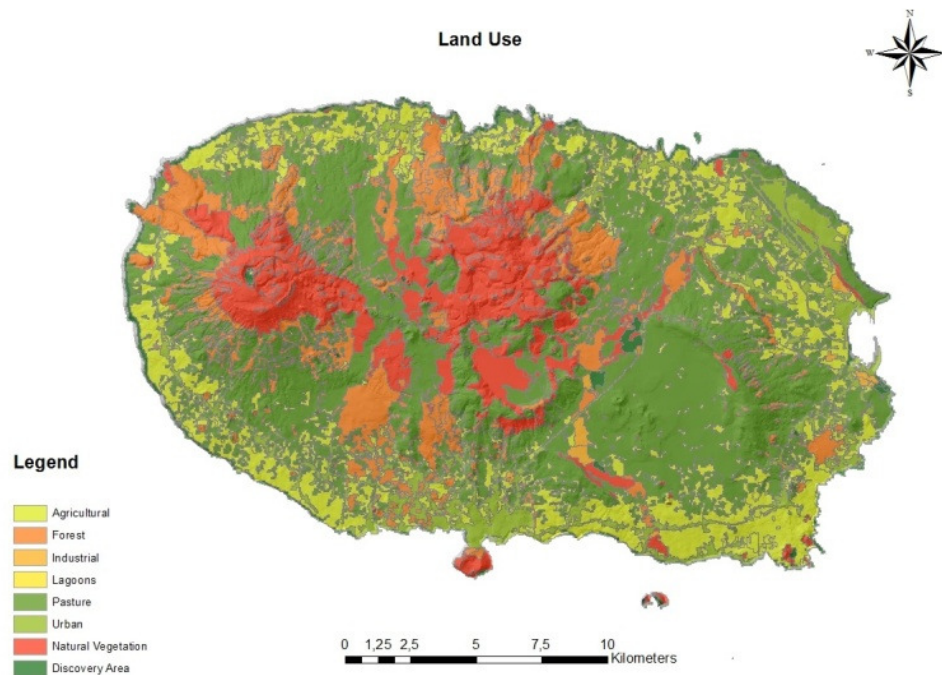


Figure 3. Land uses distribution in Terceira Island (Adapted from Secretaria Regional do Ambiente e do Mar, Azorean Regional Government).

Table I presents the land use area (ha) where endemic species from each biodiversity group were sampled (ATLANTIS database 2.1).

Table I. Land use area (ha) with the presence of sampled endemic species from each biodiversity group.*

Land use/Biodiversity groups	Agriculture	Forest	Pasture	Urban	Natural Vegetation	Uncovered Areas	Total
Arthropods	607,43	861,13	1496,20	341,42	1534,71	33,68	4874,56
Bryophytes	16,01	246,26	155,91	10,52	1021,30	0,00	1450,00
Mollusks	18,05	54,25	18,44	51,96	33,10	7,07	182,87
Vascular Plants	1378,51	2051,71	4141,67	597,77	2910,60	304,86	11385,11
Vertebrates	79,09	19,22	123,92	124,51	32,89	74,34	453,96
Total	2099,09	3232,57	5936,13	1126,17	5532,59	419,95	18346,51

*The presented areas regard solely to the ones where level 1 species were sampled.

Pasture is the land use with the highest area (5936.13 ha) with endemic species presence, while Natural Vegetation is the second, with 5532.59 ha. The land use with less presence of endemic species is Uncovered Areas, with 419.95 ha. Vascular Plants have the most prominent presence, totalizing 11385.11 ha, while the endemic species with less presence are the Mollusks, which are present at only 453.96 ha.

4.5. Modelling Species richness as a function of land use

Multiple regressions were performed to determine the best models that could explain the richness of endemic species, through land uses. Table II presents the description of the considered variables and their units.

Table II .Variables description

Agriculture	Agricultural land use (ha)
Forest	Forest land use (ha)
Pasture	Pasture land use (ha)
Urban	Urban land use (ha)
Nvegetation	Natural vegetation land use (ha)
Uareas	Uncovered areas Land use (ha)
Arthropods	Arthropod richness (number of species)
Bryophytes	Bryophyte richness (number of species)
Mollusks	Mollusks richness (number of species)
Vascularplants	Vascular plants richness (number of species)
Vertebrates	Vertebrates richness (number of species)
Totalspecies	Total endemic species richness (number of species)

SPSS was primarily used to estimate, through the Ordinary Least Squares (OLS), models to explain species richness from each biodiversity group and total species richness with the different land uses, considering linear models, logarithmic models and the CoubbDouglas function.

Latter, in order to introduce in the estimated models the neighbourhood effects between the various geographical units, GeoDa was used, to consider border effects, by incorporating a

Queen matrix (W), which considers the interactions between one plot (region) and all its neighbours/adjacent plots, whenever those neighbour plots have frontiers or vertices in common with each plot. When calculated, these matrixes are automatically normalized. In this way, the relationship with the neighbours has a specific weight in function of the number of neighbours of a plot (Nijkamp *et al.*, 2011).

Through the use of GeoDa it was possible to improve models fitness, when compared with SPSS. Therefore, the presented results in this article are the ones obtained with GeoDa.

With GeoDa, the Spatial Lag option was used, considering the estimates through the Maximum Likelihood of a spatial regression model, which includes the dependent variable spatially lagged, unlike the traditional approach, which uses eigenvalues of the matrix, being this methodology more suited to estimate large data sets. In the Spatial Lag, a distinction between the model and the prediction error is considered.

Multiple regression models were considered, with the dependent variable without any transformation, as the logarithm of the endemic species richness (Logarithmic model) and the Cobb-Douglas function.

For selecting the model that best explained the variance of the results the Akaike Info Criterion (AIC) was considered, were given a set of data models, the preferred model is the one with the minimum value (Akaike, 1974), besides the Log Likelihood, in which the preferred model is the one that has a higher value and the Schwarz criterion (SC) in which the preferred model is the one that has a lower value (Schwarz, 1978).

The AIC is given by $AIC = 2k - 2 \ln L$, where k is the number of parameters in the model, and L is the value of the maximized likelihood function for the estimated model. The AIC provides an estimate on the information lost when a given model is used. It is possible to increase the likelihood by adding parameters, nevertheless that may result in an over fitting.

The SC solves the problem by introducing a penalty term for the model parameters. The penalty term is higher in the SC than in the AIC (Schwarz, 1978).

5. Results and Discussion

5.1. Modelling richness of species according to land uses

Table III presents the best fitted models, obtained with GeoDa for the different groups of endemic species as well as for the total endemic species.

In all the presented models the dependent variable is given by the logarithm neperian of each group of species.

Table III. Models (richness of endemic species as a function of land use area (ha))

Models	1	2	3	4	5	6
dependent variables in the logarithmic (ln) form						
	Arthropods	Bryophytes	Mollusks	Vascular Plants	Vertebrates	Total species
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
	(t)	(t)	(t)	(t)	(t)	(t)
W	0,087* (3,294)	0,201*** (5,737)	0,115*** (5,601)	0,562*** (25,341)	0,092*** (4,853)	0,581*** (20,179)
Constant	-0,009 (-1,046)	-0,000 (-0,669)	-0,000 (-0,380144)	-0,041*** (-4,679)	-0,001 (-0,984)	0,045 (0,612)
Agriculture	0,023* (6,220)	-0,002 (-0,210)	-0,099*** (-35,314)	-0,004 (-1,493)	-0,010*** (-6,039)	-0,001 (-0,307)
Forest	0,059* (20,109)	-0,003*** (-3,452)	0,005*** (8,381)	0,014*** (7,07)	0,093*** (18,412)	0,006 (1,705)
Pasture	0,024* (11,56)	0,002 (1,944)*	-0,006*** (-3,206)	0,004** (2,822)	-0,007*** (-7,194)	0,000 (0,113)
Urban	0,012** (2,445)	0,002 (0,147)	0,071*** (54,388)	0,021*** (4,672)	0,023*** (25,702)	0,002 (0,325)
NVegetation	0,093* (47,004)	0,011*** (26,022)	0,002 ** (2,219)	0,041*** (24,873)	0,165*** (58,185)	0,024*** (6,653)
Uareas	0,092** (3,069)		0,013 (1,347)	0,024** (2,871)	-0,012*** (-6,645)	0,010 (0,830)
R ²	70,10%	36,96%	83,95%	63,52%	88,14%	37,77%
Log likelihood	-451,90	2467,18	4788,16	-472,43	3629,46	-1622,87
AIC	919,80	-4920,37	-9560,33	960,85	-7242,92	3261,74
SC	963,41	-4882,21	-9516,72	1004,46	-7199,31	3305,35
Observations	1715	1715	1715	1715	1715	1715

For the model with the total richness of species as a function of land uses the R^2 was low, with only one land use significant, which was probably due to existent interactions between the different groups of species. Therefore, in order to be able to achieve the goal of this article, models were developed for each group of species.

In model 1 the coefficient of determination (R^2) is 70.10%. It was found that the variables Agriculture, Forestry, Pasture and Natural Vegetation are 95% significant and the uncovered areas 99% significant. The variables coefficient are positive, which means that increasing the area of any of the land uses present in the model leads to an increase in the Arthropod richness.

In model 2 ($R^2 = 36.96\%$), the independent variable pasture is significant at 95% and Forests and Natural Vegetation are significant at 99%. Pasture and Natural vegetation variables coefficients are positive, which means that by increasing the area of these uses lead to an increase in the number of species of Bryophytes, while Agriculture and Forest variables have negative coefficients, which means that by increasing these areas lead to decreases in the species of Bryophytes.

In model 3 ($R^2 = 83.95\%$) the Natural Vegetation variable is significant at 99%, Forests, Agriculture, Pasture and Urban are significant at 99.99%. The variables Forest, Urban and Natural Vegetation have positive coefficients, which means that by increasing these areas the number of species of Mollusks increase, while the Agricultural and Pasture variables have negative coefficients, which means that by increasing these areas leads to a decrease of the number of species of Mollusks.

In model 4 ($R^2 = 63.52\%$) the variables Pasture and Uncovered Areas are significant at 99%, while Forests, Urban and Natural Vegetation are significant at 99%. Forest, Pasture, Urban, Natural Vegetation and Uncovered Areas have a positive coefficient, which means that by increasing these areas lead to an increase in the number of species of Mollusks, while Agriculture variable has a negative coefficient, which means that by increasing this area leads to a decrease in the number of species of Vascular Plants.

In model 5 ($R^2 = 88.14\%$) Agriculture, Forest, Pasture, Urban, Natural Vegetation and Uncovered Areas are significant at 99%. Forest, Urban and Natural Vegetation have positive coefficients, which means that by increasing these areas lead to increases in the number of Vertebrate species, while the Agriculture, Pasture and Uncovered Areas have negative

coefficients, which means that by increasing these areas lead to decreases in the number of species of Vertebrates.

In model 5 ($R^2 = 37.77\%$) Natural Vegetation is significant at 99% and the remaining variables are not significant. Natural Vegetation has a positive coefficient, which means that by increasing the area of this land use, the number of Total Endemic Species increases.

5.2. Land uses and richness of endemic species

Figure 4 presents the trade-offs that occur in the richness of species of Arthropods according to the land uses where they occur, with the Arthropods richness of species plotted as a function of the Natural Vegetation Area (ha), in a spot of 25 ha. If the area of Natural Vegetation in that spot is X ha, the area of the alternative use is given by 25 – X (ha), with the same being applied to Figure 5, 6, 7 and 8.

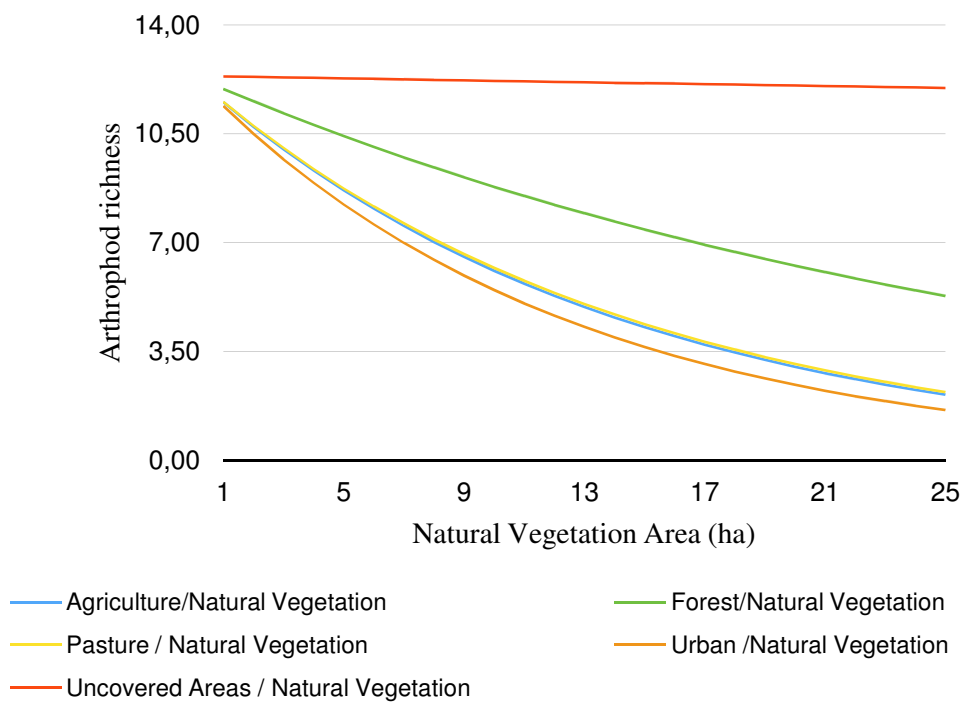


Figure 4. Trade-offs for the Arthropods

By changing the area of Urban land use to Natural Vegetation the richness of species of Arthropods has the higher variation, among all the land uses where they occur, with a decrease of 10 species of Arthropods, when one passes from 1 ha to 25 ha of contiguous area

of Natural Vegetation. When changing the area of Uncovered Areas to Natural Vegetation, the amplitude is smaller, with a decrease of 1 species of Arthropods.

Figure 6 presents the trade-offs that occur in the richness of species of Bryophytes according to the land uses where they occur. When changing land use from Forest to Natural Vegetation and from Pasture to Natural Vegetation the decrease in the richness of species of Bryophytes occur in a very similar way, with a decrease of approximately 1 species when one passes from 1 ha to 25 ha of contiguous area of Natural Vegetation.

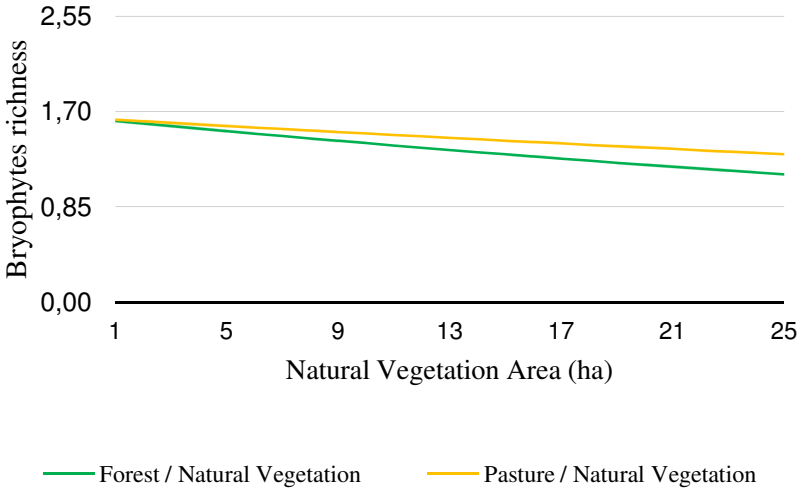


Figure 5. Trade-offs for Bryophytes

Figure 6 presents the trade-offs that occur in the richness of species of Mollusks according to the land uses where they occur. When changing from Urban land use to Natural Vegetation, richness of species of Mollusks present the highest increase among all the land uses were they occur, with an increase from 1 to 7 species of Mollusks, when passing from 1 to 25 ha of contiguous area of Natural Vegetation. When changing the area of Forest or Pasture to Natural Vegetation, nearly any change is found in the richness of species of Mollusks. And when changing from Agriculture to Natural Vegetation the decrease is nearly in 1 species.

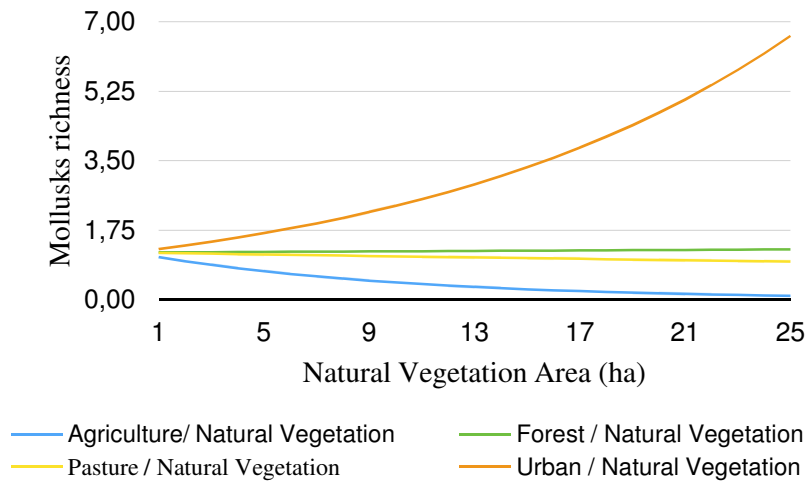


Figure 6. Trade-offs for Mollusks

Figure 7 presents the trade-offs that occur in the richness of species of Vascular Plants according to the land uses where they occur. It turns out that by changing from Forest, Urban land use, Pasture and Uncovered Areas to Natural Vegetation one can always find a decrease in the richness of species of Vascular Plants. When changing the area of Pasture to Natural Vegetation the larger decrease in species richness of Vascular Plants is found (from 5 to 2, when one passes from 1 ha to 25 ha of contiguous area of Natural Vegetation). The lowest decrease in the richness of species of Vascular Plants is found when one changes Uncovered Areas to Natural Vegetation (from 5 to 3 species, when one passes from 1 ha to 25 ha of contiguous area of Natural Vegetation).

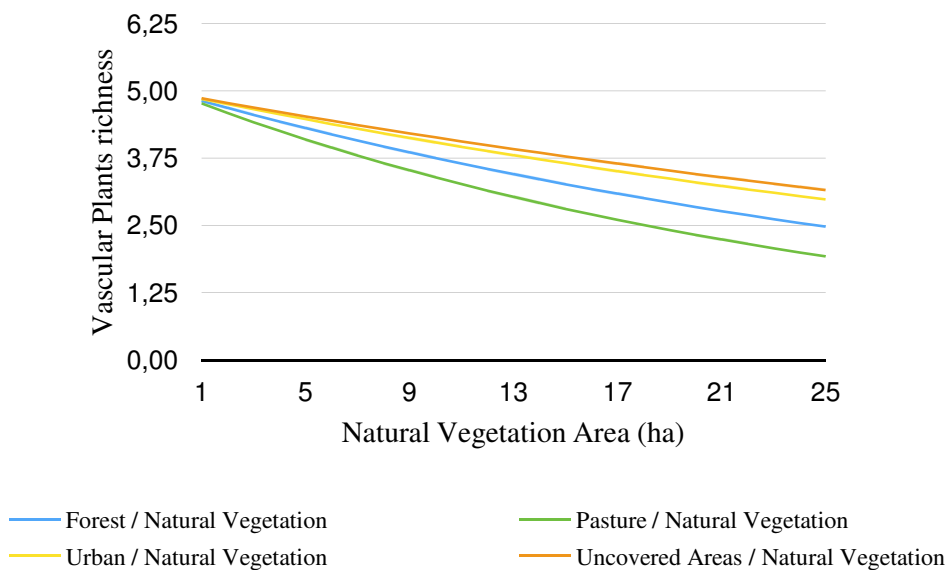


Figure 7. Trade-offs for the Vascular Plants

Figure 8 presents the trade-offs that occur in the richness of species of Vertebrates according to the land uses where they occur. In Figure 8 it is not possible to see the lines for Agriculture and Pasture as both have very similar results with the Uncovered Areas, with an overlapping of the 3 lines.

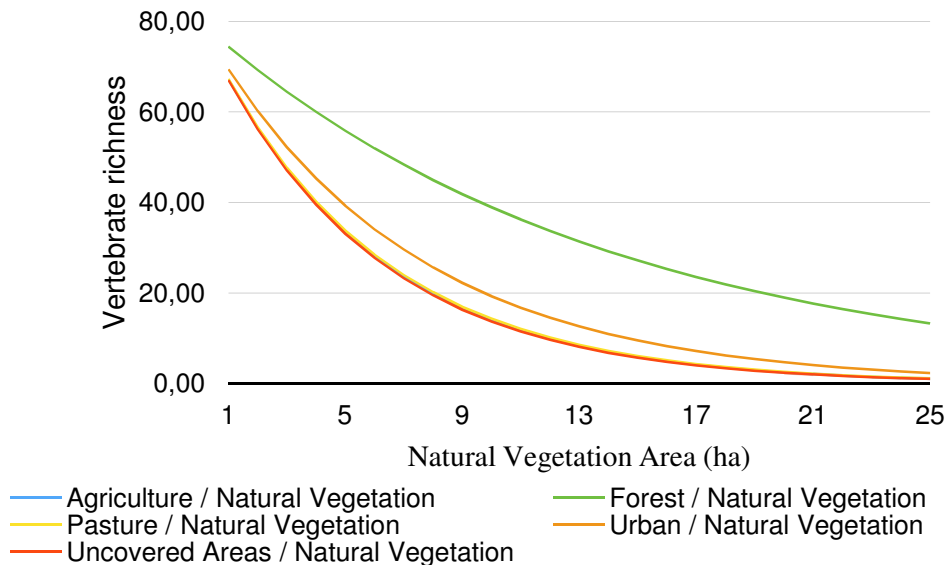


Figure 8. Trade-offs for the Vertebrates

It turns out that by changing from Agriculture, Pasture, Uncovered Areas, Forest and urban land uses to Natural Vegetation, one can always find a decrease in the richness of species of Vertebrates. The most pronounced decrease in the richness of species of vertebrates is found when changing the area of Agriculture, Pasture or Uncovered Areas to Natural Vegetation, with a decrease from 67 to zero species of Vertebrates, when one passes from 1 to 25 ha of contiguous area of Natural Vegetation. A similar behavior occurs for the change from Urban land use to Natural Vegetation, even though with a less pronounced decrease. It turns out that the land use change that leads to a lower decrease in the richness of species of Vertebrates occurs when one changes from Forest and Natural Vegetation, with a decrease from 74 to 13 Vertebrates species, when one passes from 1 ha to 25 ha of contiguous area of Natural Vegetation.

Figure 9 to 13 present the richness of species of the several studied groups of species, but now considering spots with three possible land uses (Natural Vegetation, Forest and Pasture), with several combinations of land uses in a spot of 25 ha. The reason to present only combinations with these three land uses is duo to the fact that these are the only ones were all the studied groups of species occur.

Figure 9 presents the richness of species of Arthropods, with the highest number of species of Arthropods occurring when 100% of the area is dominated by Natural Vegetation (nearly 11 species), and the lowest when 100% of the area is dominated by Pasture (2 species).

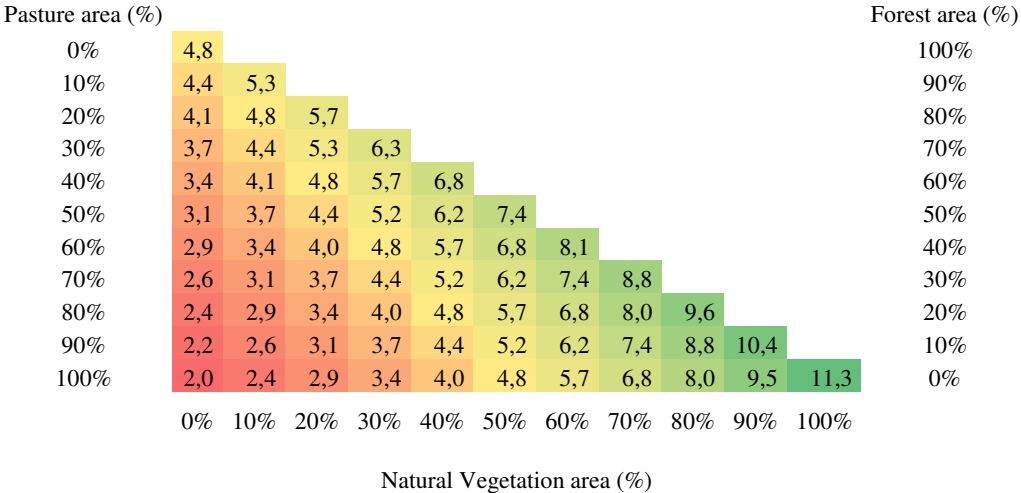


Figure 9. Richness of species of Arthropods

Figure 10 presents the richness of species of Bryophytes, where one can see that the highest number of species of this group occurs when 100% of the area is dominated by Natural Vegetation, and the lowest when 100% of the area is dominated by Forest. Even though, richness of species of Bryophytes presents a very light change when one changes among the areas of Pasture, Natural Vegetation or Forest.

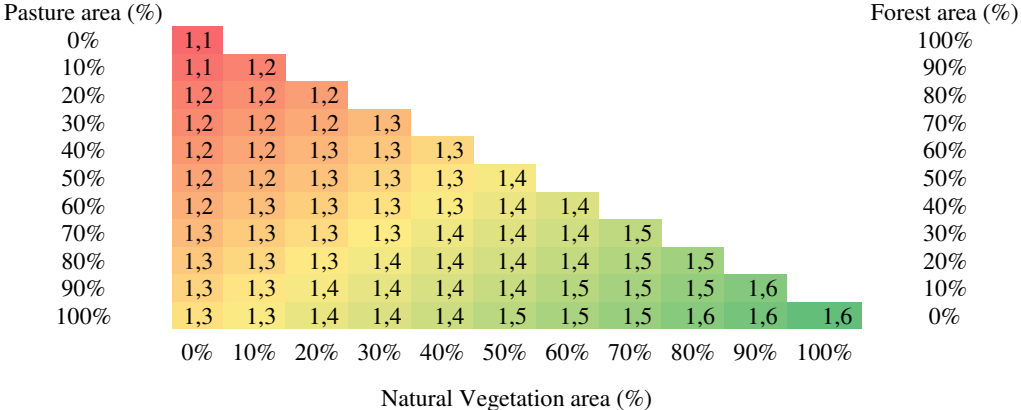


Figure 10. Richness of species of Bryophytes

Figure 11 presents the richness of species of Mollusks, with the highest number of species of this group occurring when 100% of the area is dominated by Forest, and the lowest when 100% of the area is dominated by Pasture. Even though, richness of species of Mollusks change nearly nothing with changes among the areas of Pasture, Natural Vegetation or Forest.

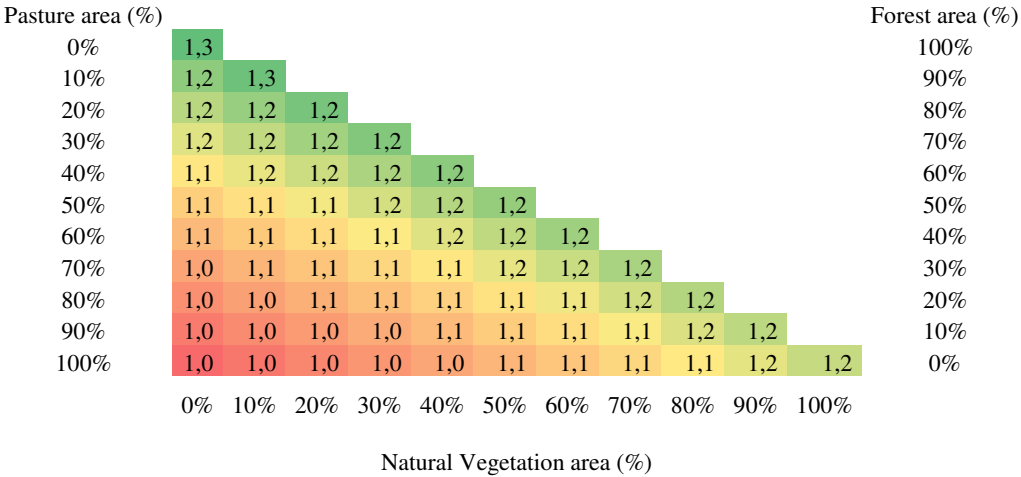


Figure 11. Richness of species of Mollusks

Figure 12 presents the richness of species of Vascular Plants, with the highest number of species occurring when 100% of the area is dominated by Natural Vegetation (nearly 5 species), and the lowest when 100% of the area is dominated by Pasture (nearly 2 species).

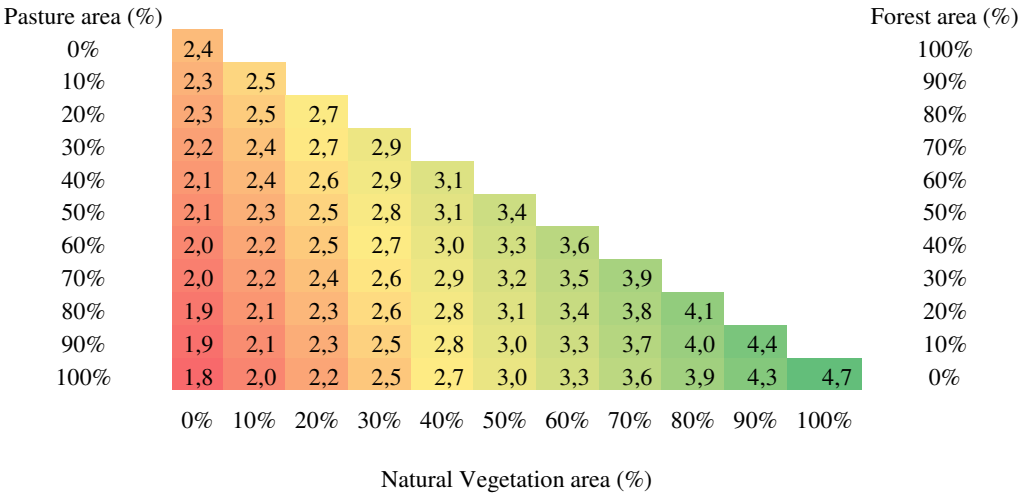


Figure 12. Richness of species of Vascular Plants

Figure 13 presents the richness of species of Vertebrates, where one can see that the highest number of species of this group occurs when 100% of the area is dominated by Natural Vegetation (nearly 68 species), and the lowest when 100% of the area is dominated by Pasture (nearly 1 species).

The changes in the richness of species of Vertebrates seem to be, among all the studied groups, the most prominent, as one change between Pasture, Forest or Natural Vegetation land use areas.

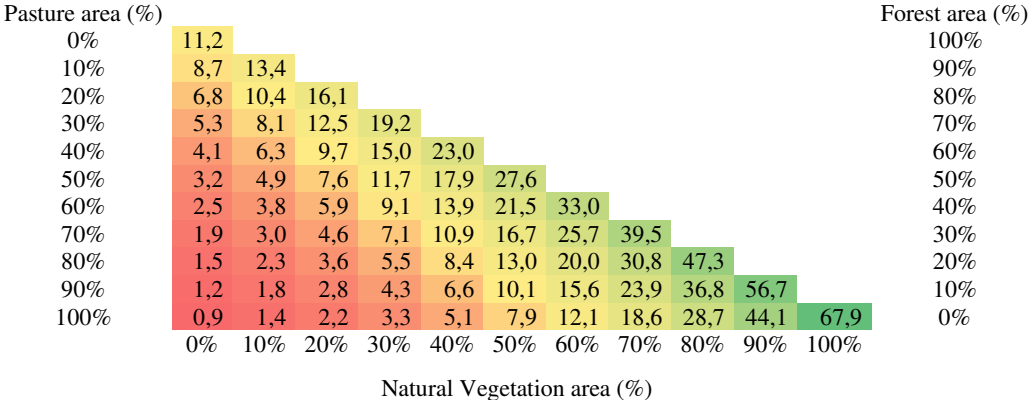


Figure 13. Richness of species of Vertebrates

It becomes clear that land use as an impressive impact in the richness of species of some groups of species, while in others it has light impacts, as previously discussed, being Vertebrates, Arthropods and Vascular Plants the ones which are more impacted by land use, with the first extremely affected, the second highly affected and the third moderately affected.

Conclusions

This study was conducted in Terceira Island, by considering several land uses (Agriculture, Forest, Pasture, Urban, Natural Vegetation and Uncovered Areas) and several groups of species (Bryophytes, Mollusks, Vertebrates, Arthropods and Vascular Plants), in order to determine the relationships between land uses and richness of species for each group of species and for the total number of species.

Data with 1715 observations for each group of species was considered in the modeling process.

SPSS and Geoda were used in order to find the best suited models to explain the relation between land uses and richness of species. Geoda proved to be a good spatial analysis tool to analyze these relationships, by incorporating neighborhood effects, providing better models than SPSS.

For the model with the total richness of species as a function of land uses the R^2 was low, and only one land use was significant, which was probably due to existent interactions between the different groups of species. To overcome that, individual groups of species were analyzed. The best suited models presented R^2 ranging from 36,96% to 88,14%, depending on the group of species being studied. Besides the determination coefficient, also other criteria (AIC and SC) were used in order to compare models.

Results show that the richness of species of all the studied groups are affected by land use, even though some being more than others, being Vertebrates, Arthropods and Vascular Plants richness of species the ones which are most affected by land use change.

This clearly shows that land use management can be a good tool for biodiversity management and conservation and that non protected landscapes are also relevant for the ecological and evolutionary processes essential for a long-term persistence of biodiversity within and outside protected areas, since many species threatened by extinction of protected species have populations outside protected areas, as stated by Willis *et al.*(2012).

Therefore, in order to supply evidences and data that could be used to manage landscapes, also outside protected areas, further studies should be done in order to determine the marginal value of biodiversity, through stated preferences methods, to be used in decision support systems.

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