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The Invasive Niche, a Multidisciplinary Concept Illustrated by Gorse (*Ulex Europaeus*)

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Abstract: This study analyzes the natural and social factors influencing the emergence and publicization of the invasive status of a fast-growing bush, gorse (*Ulex europaeus*), by comparison between countries on a global scale. We used documents collected on the web in a standardized way. The results show that in all the countries studied, there are several public statuses attributed to gorse. The invasive status is the one that is most shared. The other most frequently encountered status are those of noxious weed, and those of which are economically useful. The invasive status is publicized in nearly all countries, including those where gorse is almost absent. We quantified the publicization of the invasive gorse status of gorse by an indicator with 5 levels, and then performed a multivariate analysis that combines natural and social explanatory variables. The results lead us to propose the concept of invasive niche, which is the set of natural and social parameters that allow a species to be considered invasive in a given socio-ecosystem

Keywords: biological invasions; invasive species; status; ecological niche; invasive niche; *Ulex europaeus*

1. Introduction

Biological invasions, which are considered part of global change and a major threat to biodiversity, are matters of nature and societies [1,2]. It is a matter of nature because they concern species introduced into a new territory, within a new ecosystem, that adapt, evolve biologically and genetically, and interact with other species, including humans. It is a matter of society because human activities are at the origin of their introduction, voluntary or not, because their dispersion is often promoted in the new environment, and because they impact biodiversity, society, and economy.

There are numerous concepts in invasion biology [3], but the status of invasive species is granted according to two criteria that seem objectified. In most administrative documents and regulations, they are called Invasive Alien Species (IAS), and a definition is provided. The first criterion is that IAS have to be "alien", i.e., "outside their natural past or present distribution" (Convention on Biological Diversity/FAO, IUCN [4]) or "into a natural environment where they are not normally found" (European Commission [5]). This criterion is not so easy to assess scientifically, and the categorization of a species as "alien" may depend on the authors [6–9]. Despite recent attempts to unify the definitions [10], many uncertainties and disagreements remain.

The second criterion is that of invasiveness. This criterion, initially relied to the rate of spread of the species in its new environment [11], is now related in most official definitions to its negative impact. An IAS "threatens biological diversity" (FAO/CDB), has "serious negative ecological, economic or health consequences for their new environment", "becomes problematic" (UICN), or "threaten[s] or adversely impact upon biodiversity and related ecosystem services" (European Regulation [12]). This definition is problematic, because the assessment and measure of a negative impact is not only limited by scientific knowledge and technical capacities, but it also depends on the relative value accorded to each of these impacts by the evaluators. Therefore, above the linguistic, psychological, and epistemic components identified in [13], the categorization of invasive species, their impact, and the need to control them is not consensual, even among scientists [14–16].

Outside of the academic sphere, economic and social interests may also interfere with the scientific definitions. For example, because the European Regulation (2014) prohibits the exploitation and commercial exploitation of invasive species, species whose exploitation is of economic importance are excluded of the European list of IAS. Furthermore, the categorization as invasive species, even when shared by institutional actors, often finds little resonance among local populations, who categorize a species as domestic or wild, useful or harmful, rather than endemic or exotic [17]. Many species classified as invasive might provide both benefits and negative impacts, some provide key ecosystem services (e.g., tree species [18]), some are iconic species and promote touristic attractivity (e.g., Hydrangea macrophylla in the Canaria [19]), some are considered as part of their culture by the local populations (e.g., Eucalyptus trees in California [20], Guava in Reunion [21]) or are protected by regulations and associations (e.g., feral cats [22]), while others are of economic and aesthetic interest (e.g., Acacias, Robinia pseudoacacia [23]),). It is thus possible to argue that "determining whether the impacts of introduced species are negative cannot be based solely on science" [24]). We propose to combine the two registers of categorization—those that rely on scientific ecological arguments, and those that rely on socio-economic arguments—into the concept of invasive niche.

The ecological niche of a species can be considered as the set of environmental conditions necessary for its establishment [25]). Its main dimensions are the bioclimatic dimension, the edaphic dimension, and the ecosystem dimension (e.g., competitors, pollinators, etc.). This concept has been widely used in invasive studies to estimate the potential geographical range of expansion of introduced species, to prioritize conservation measures, or to assess the impact of climate change on invasive species distribution [26]. Indeed, the fight against invasive species is difficult, expensive, and not always successful, so early management actions are considered to be a determining factor in their effectiveness. However, the presence of an alien species in a territory is not sufficient for the species to be considered as invasive and managed as such. As previously pointed out, the status of invasive species varies among ecologists but even more so among managers, public institutions, and populations, according to geographical areas, periods, and socio-economic context [27–29]. Understanding what can lead a species to be considered as invasive therefore implies taking into account not only natural factors (biological properties of the species and biophysical properties of the receiving territory), but also social factors (geographical and social characteristics of the territory). These dimensions would shape what we propose to call "the invasive niche", which is the set of natural and social parameters that allow a species to be considered invasive in a given socio-ecosystem.

The common gorse, *Ulex europaeus*, is a good candidate to test the pertinence of the concept of invasive niche. This thorny bush, originating from Europe, was introduced in a lot of different countries, where it is considered a major invasive species by IUCN [30], and its geographical expansion is still ongoing [31]. It is a very common plant on the Atlantic coast of Europe, in Spain, France, UK, and Ireland, where it has long been used in agriculture as fodder for hedges, litter, etc. This, combined with the aesthetic aspect of its flowering (it flowers 8 months a year, and produces fragrant, bright yellow flowers), made it the emblematic plant of several regions, such as Brittany (West of France) and Galicia (Northwest of Spain) [32]. The species was introduced into most European colonies during the 19th century on a voluntary basis as hedges (due to its spiny branches and its fast vegetative growth) or fodder (because it is rich in nutriments). However, it quickly spread out of control in agricultural and natural areas. In addition to occupying space and challenging local species, it is a pyrophilous species: gorse promotes the flammability of the vegetation, and fire promotes its seed germination [33]. Many countries have implemented control programs, the oldest of which dates back to the 1930s in New Zealand, while others were gradually implemented in Australia, Tasmania, Hawaii, Chile, and Reunion Island [29,31,34]. It has been a highly studied species since the 1970s and it is easily identifiable from afar. As a consequence, a great deal of data is available not only in the scientific literature but also on a variety of other documents and websites. Its worldwide distribution, compiled from various sources, is available in Open Access [35], and its global bio-climatic niche was assessed by SDM modelling [36].

The sociological analysis of the emergence and spread of the invasive status of gorse was carried out by our team on Reunion Island [29], a territory that has the advantage of being small, well circumscribed, and documented by abundant archives. The study combined archive analysis, literature review, field survey, and semi-structured interviews. It highlighted how the geographical expansion of the plant, as well and its status in the public sphere, depended on both ecological and socio-economic factors. Results also showed that gorse had several status beside the status of invasive. Five types of status were identified (useful, nationalistic, indigenized, agricultural pest, and invasive), each peaking at a certain time, and then reverting to a low-key presence [29]. These statuses partly overlap with those identified by historical surveys in New Zealand [37,38], suggesting that they are not restricted to a given territory. The in-depth field study in Reunion Island made it possible to guide the choice of natural and social factors to be explored in other countries. To make a global surveys of the statuses of gorse, and on the factors that led the plant to be considered invasive, we analyzed information collected on the web for 21 different countries. The aims of this analysis were (1) to identify the different status of gorse, (2) to test the effect of natural and social macroscopic factors in the emergence and spread of the invasive status of gorse, and (3) to assess whether the concept of invasive niche can enlighten the invasive status of gorse in the countries studied.

2. Methods

2.1. The Countries Studied

The analysis took place in two stages. First, we identified all the representations and status of gorse on a subset of 14 countries. Second, we focused on the invasive status, and added another set of 7 countries, to reach a sample of 21 countries that includes all of the countries where gorse is significantly present. In the subset of 14 countries, the identification of the different status of gorse was made by a qualitative analysis. In the set of 21 countries, the level of publicization of the invasive status was quantified with an indicator, and this indicator was analyzed with multivariate statistics.

The first 14 countries were chosen either because our team had already studied there the sociological and ecological aspects of the presence of gorse in the research program MARIS (described in the "funding" section) or because they allow to compare a variety of situations within the same continent, thus limiting confounding factors. The three countries studied in the MARIS program were Reunion Island (France Overseas, Indian Ocean), Tenerife Island (Spain, Atlantic Ocean), and New Zealand (Pacific Ocean). The 11 other countries belong to South America (Argentina, Bolivia, Brazil, Costa Rica, Ecuador, Falkland, Mexico, Peru, Uruguay). In these 14 countries, we carried out a complete analysis to identify all the statuses of gorse. We then constructed an indicator of the publicization of the invasive status. This indicator has been evaluated for the first set of 14 countries and for the 7 other countries where gorse is significantly present (South Africa, Australia, Canada, Hawaii, Madagascar, Sri Lanka, USA).

2.2. Identification of the Different Types of Status

Data were collected between August and October 2016. We used three sets of keywords on three search engines (Table 1). We have made requests with the name of gorse in the local languages, in English, and with its scientific name in Latin. When there were several common names for the same country we started with a Google Image search to see which one brings out the most photographs or illustrations of gorse, and retained that one for the analysis. For each combination, we consulted the first 20 results. For English-speaking countries, the name in the country's language and the name in English are identical, and we consulted the first 40 results. Two combinations were discarded (Google

Scholar with local name, because scholars use preferentially the scientific name of species, and Google News with Latin names, because the media preferentially use the common name of species).

Table 1. Details of the research carried out to identify the status of gorse in the countries studied.

Request	Google	Google Scholar	Google News
gorse local name country name in local langage	sites housed in the country	/	national and local press of the country
gorse latin name country name in local langage	sites housed in the country	language of the country	international press
gorse latin name country name in English	all sites	all languages	/

The main types of documents obtained with these requests were scientific articles, scientific reports, websites linked to public institutions, national or local press articles, regulatory texts, private non-commercial websites (e.g., blogs), private commercial and touristic websites. We identified six statuses, and for each country studied, we counted the total number of documents corresponding to each status. We also noted in which types of spaces gorse is present (land use, land status, type of natural habitat, etc.), which types of actors or social groups use these spaces, which stakeholders are mobilized on gorse, with whom they are in network, which are the most often cited types of impacts of gorse, what are the techniques of control used, and what are the most cited usages.

Beyond this systematized research, we looked for factors related to the country's mobilization on the more general themes of environment and biodiversity. For the theme of invasive species, we looked for the existence of an official list by the government and for the existence of research institutions that devote part of their work to that topic. For nature protection, we looked for the existence of national parks, nature reserves, research institutions on ecology, the proportion of the country classified as protected areas, the presence of natural or mixed UNESCO sites, and the involvement of IUCN. For land use, we looked for the country's proportion of agricultural land and permanent grassland.

2.3. Construction of an Indicator of the Invasive Status

In order to compare the different countries with a quantitative analysis, we created a five-level indicator that aims to reflect the publicization of the invasive status. We use the word "publicization" to designate the processes by which an issue is integrated and gains visibility in the public sphere [29,39]. This indicator increases as the number of institutions and social groups expressing the invasive status of gorse increases, with a minimum when it is only a concern of experts, and a maximum when it is spread in the general population.

- Level 0: no publicization of the invasive status
- Level 1: only publications of specialized literature by scientists and environmental managers
- Level 2: Level 1 + mention of gorse on the official national list of invasive species or on sites of public institutions, or both
- Level 3: Level 2 + implementation of gorse management action
- Level 4: Level 3 + mention by amateurs (often naturalists) and by the general public (through blogs, private sites, local press)

The assignment of a level of this indicator was first based on the set of data collected on Google, Google Scholar, and Google News for the 14 countries. In order to assign a level of the indicator to a complementary set of countries with a shorter request, we performed a more targeted research, focused on the invasive status: scientific or specialized publications, regulations, list of invasive species, management strategies, and mention of invasive status by amateurs and the general public (see details in Appendix A). For the first set of 14 countries, this targeted research was tested, and it did not change the level of the indicator previously attributed. For the 7 supplementary countries (Canada, USA, Australia, South Africa, Hawaii, Sri Lanka, Madagascar), we did only the targeted researches. All targeted researches were done in February 2017.

To analyze the factors that may explain the value of this indicator, we identified and estimated a set of explanatory variables. The choice of the explanatory variables tested was based on our previous work on gorse, in biology [36,40], history [32,41], and sociology [29]. These variables had to be both relevant and available in a standardized way for all the countries studied.

Bioclimatic factors. At large geographical scales, climate is considered to act as the main filter of invasive species distribution [42,43]. To estimate the proportion of the country where the climate fulfills the requirements of gorse, we used the results of the global Species Distribution Model (SDM) of the bioclimatic niche of gorse designed by our team [36]. According to the literature, we retained the presence probability threshold calculated using the maximum likelihood [44]. We then used GIS data to calculate the proportion of the country whose climate is above that threshold.

The effective presence of gorse. In natural areas, gorse is considered problematic mainly in protected areas, because of their high level of endemic plants and the high concern to protect them. In agricultural areas, gorse is eradicated with labor and is mainly problematic in permanent grasslands where it has first been introduced for hedges [32]. We thus retained three variables: the presence of gorse in protected natural areas, the presence of gorse in agricultural areas, and the proportion of the country in permanent grasslands. The localization of natural protected and agricultural areas have been extracted from several sources, mainly https://www.cia.gov/library/publications/the-world-factbook. The presence of gorse in these areas has been deduced by crossing these data with the geolocalized distribution of gorse [35]. It would have been interesting to include the abundance and total area occupied by gorse, but these data were not available.

A geographical variable, the latitude. We have retained this variable because in high latitudes (equatorial and tropical zones), gorse is present in mountains, while in temperate zones it is present at sea level [36,40]. Latitude is therefore a proxy for the kind of environment occupied by gorse (mountain or sea level). Mountainous areas are often the least anthropized, the richest in biodiversity, or are protected areas, promoting the invasive status of gorse. Lowlands generally host more agricultural or sylvicultural areas and are less protected (except for wetlands, in which gorse cannot settle), promoting the agronomic pest status of gorse [29]. As countries can extend over a wide range of latitude, we have chosen to group them into three main classes (tropical, temperate, equatorial) rather than averaging or choosing centroids.

Sociological variables. The study in Reunion has shown the importance of the environmental and biodiversity concerns in the emergence of the invasive status of introduced species [29]. To estimate the sensitivity to the protection of biodiversity we used the proportion of the country classified as protected areas (Source: https://www.protectedplanet.net/), and the Social Progress Index (SPI), a multidimensional index that includes environmental quality. This index considers information on biodiversity and habitats, greenhouse gas emissions, waste treatment, and mortality attributed to outdoor air pollution (Source: www.socialprogressimperative.org/global-index/).

The explanatory variables were coded as follows:

CLI = Proportion of the country above the bioclimatic threshold of gorse presence

PRO = Proportion of the country classified in protected natural area

GPN = Presence of gorse in protected natural: 0 = none, 1 = one area, 2 = 3 or more areas

PER = Proportion of the country in permanent grassland

GA = Gorse presence in agricultural areas. This variable has two states: GA=Y means Yes, confirmed presence, GA=N means No, absence or no information.

LAT = Latitude 1: (0–15), 2 = (16–30), 3 = (31–60).

SPI = Social Progress Index

We then conducted a multivariate statistical Hill and Smith analysis (performed with the package Ade4 of the R software [45]), to assess how these social and ecological variables explain the level of publicization of the invasive status of gorse. The Hill and Smith analysis allows the combination of quantitative and qualitative variables.

3. Results

3.1. Identification of the Status of Gorse in a Subset of 14 Countries

In the 14 countries for which the complete web requests were made, we observed several statuses attributed to gorse (Table 2). The number of occurrences was highly variable, from 5 in Bolivia to 82 in New Zealand (the type of document for each status is provided in Supplementary Table S1). The invasive status is the most shared; it is present everywhere except in Peru, and it is often the most frequent. The second most frequently encountered status is that of agronomic pest/noxious weed. These two statuses are present mainly in academic documents, i.e., written by scientists or environmental mangers, or related to public institutions (73% of the occurrences). The status of useful plant is plural. We have divided this status into three sub-categories: economically useful (agricultural uses as hedges or fertilizers, economic valuation of flowers or cutting wastes), expressed at 80% in academic documents; ecologically useful (mention of positive biotic interactions with native animal or plant species), expressed at 90% in academic documents; and medically useful (herbalism and phytotherapy), expressed at 70% in academic documents, the other 30% are generally blogs or personal sites. The useful status can be the most frequent, but only in countries where the status of invasive plant is absent or low (Peru, Bolivia, and Argentina). Finally, the status of landscaping plant is also present in several countries, but it is never the most frequent, and it is expressed at 52% by non-academics (newspapers, tourist sites, private sites, blogs).

Table 2. The status of gorse identified in the different countries by web requests. In bold, the most frequent.

	Country	Invasive	Agronomic Pest	Useful			Landscaping	Total
				Economy	Ecology	Medical		
South America	Argentina (AR)	3	4	5		1	1	14
	Bolivia (BO)	1		2		2		5
	Brazil (BR)	**22**	7	3		4		36
	Chile (CL)	15	**40**	7	1		3	66
	Colombia (CO)	**50**		3	1	1	3	58
	Costa Rica (CR)	7	1			4	7	19
	Ecuador (EC)	3				5	5	13
	Falkland (FK)	**13**	1	2	3		11	30
	Mexico (MX)	1	1	1		5	1	9
	Peru (PE)			1		**14**	3	18
	Uruguay (UY)	15	**16**	1		1	1	34
MARIS	Tenerife (TE)	**19**	1				5	25
	New Zealand (NZ)	9	**31**	3	21	1	17	82
	Reunion (RU)	**38**	8	4	3	5	6	64
				32	29	43		
	TOTAL	196	110		104		63	473

3.2. Analysis of the Factor Determining the Publicization of the Invasive status

For each country studied, we assessed the presence of documents corresponding to the different levels of the invasive status indicator, and calculated its value (Table 3).

The multivariate statistical analysis of Hill and Smith explains 85% of the variance of the indicator. The first three axis of the analysis explain 43.2%, 27.9%, and 12.6% respectively. The spatial structure of the level of publicization between the first two axis is clear (Figure 1). The variables contributing to each axis are presented in Table 4. The first axis mainly includes latitude (LAT) and socio-ecological variables: presence of gorse in protected natural areas (GNA), absence of gorse in agricultural areas (GAN), and Social Progress Index (SPI). The second axis corresponds to land use variables, the proportion of the country in protected natural areas (PRO) and in permanent grasslands (PER). The third axis corresponds to the variables related to the ecology of gorse: CLI, the proportion of the country climatically favorable to gorse.

Table 3. Type of documents where the invasive status of gorse is publicized and corresponding level of the indicator of the publicization of the invasive status.

	Type of Documents	**Scientific Publications Manager's Reports**	**Regulations Government Website**	**Gorse Management**	**Popularization Books, Amateur Websites**	**Private Websites Blogs, Local Newspapers**	**Invasive Status Indicator**
	Autors/Public	**Scientists and Managers**	**Politics, Jurists**	**Managing Organisations**	**Amateur Naturalists**	**General Public**	
South America	Argentina (AR)	X	X				2
	Bolivia (BO)	X					1
	Brazil (BR)	X	X	X	X	X	4
	Chile (CL)	X	X	X	X	X	4
	Colombia (CO)	X	X	X	X	X	4
	Costa Rica (CR)	X	X				2
	Ecuador (EC)	X					1
	Falkland (FK)	X	X				2
	Mexico (MX)	X					1
	Peru (PE)						0
	Uruguay (UY)	X	X	X			3
MARIS	Tenerife (TE)	X	X	X	X	X	4
	New Zealand (NZ)	X	X	X	X	X	4
	Reunion (RU)	X	X	X	X	X	4
supplementary countries	South Africa (SA)	X					1
	Australia (AU)	X	X	X	X	X	4
	Canada (CA)	X	X	X			3
	Hawai (HI)	X	X	X	X	X	4
	Madagascar (MG)						0
	Sri Lanka (SK)	X	X	X			3
	West Coast USA (US)	X	X	X	X	X	4

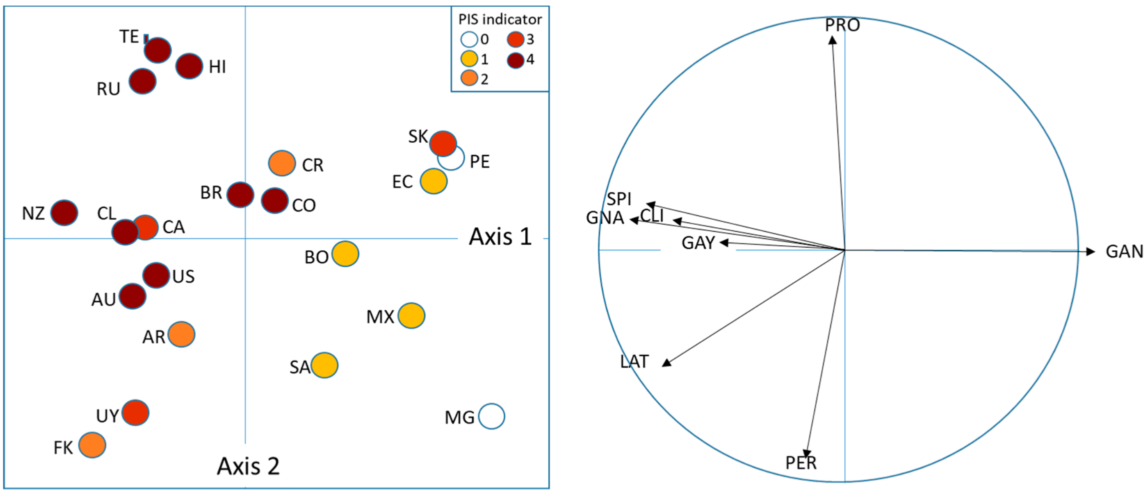

Figure 1. Results of Hill and Smith Analysis on the Publicization of Invasive Status (PIS) indicator. **(Left)**: distributions of the countries studied on the first two axis. (**Right**): projection of the explanatory variables on the first two axis. Country abbreviations are given in Table 3, variables abbreviations are given in Methods, Section 2.2.

Table 4. Absolute contribution of the first three axis and relative contribution (%) of each variable to these axis. In bold, contribution > 15%.

	Axe 1 (43.2%)	**Axe 2 (27.9%)**	**Axe 3 (12.6%)**
CLI Climatic niche	**10.27**	4.11	**61.41**
LAT Latitude	**22.32**	5.61	3.28
GPN Gorse in Protected Natural areas	**20.06**	7.06	10.00
GAN Gorse in Agricultural areas: No	**16.9**	1.49	2.26
GAY Gorse in Agricultural areas: Yes	5.28	0.46	0.71
PRO proportion of Protected areas	0.67	**35.9**	**18.34**
PER proportion of Permanent Grasslands	1.44	**39.47**	1.32
SPI Social Progress Index	**23.05**	5.9	2.68

4. Discussion

4.1. The Diversity of Status of Gorse in the Public Sphere

We identified several statuses of gorse. In the 14 countries studied in depth, the invasive status is the most expressed, but is never alone. The invasive status is related to the presence of gorse in natural areas, particularly when they are protected (National Parks, Reserves, etc.). In many tropical countries, the locations of gorse and of protected natural areas overlap, as gorse grow at high altitudes, in habitats with low human impact and high levels of biodiversity. The type of argumentation to explain the invasive status is scientific, based on the need to protect biodiversity, ecosystems, habitats, and the increasing scarcity of indigenous and endemic species. The publicization of these kinds of arguments began in the early 2000s. The other status with a high level of publicization is the status of agricultural pest, or noxious weed. It is directly related to the presence of gorse in agricultural areas (mainly permanent grasslands). The negative impacts described are related to loss of lands and productivity, and the type of argument is agro-economic. The publicization of these kinds of arguments began in the second part of the 19th Century.

The agronomic pest status is mainly expressed in specialized literature such as reports and institutional texts, but also in newspapers and private sites. Several scientific and specialized articles combine agro-economic arguments with ecological arguments. The countries concerned by this process are rather the countries of temperate regions, where most gorse populations, like most agricultural areas, are located at low altitude (New Zealand, Australia, Chile, Uruguay, USA). It is within this group of countries that the pioneering teams on gorse control techniques, whether mechanical, chemical, or biological, are found. In other countries, weed status is either absent or completely dissociated from invasive plant status in the public sphere, and the invasive status is the most frequent. In these countries, research teams working on gorse are often more linked to institutes of ecology and environmental management than to agronomic institutions. The countries concerned by this process are rather the countries of tropical latitudes, where gorse and protected natural areas are both located at high altitudes (Colombia, Brazil, Sri Lanka, Hawaii, Reunion Island). These two statuses, invasive plant and agronomic pest, correspond to the presence of gorse in two different spaces, agricultural and natural areas, but also to two different socio-ecological models

Two other status of gorse where identified. The status of a useful plant is expressed in several countries. The economic utility (agricultural for hedges and fertilizer, valorization of flowers or cutting waste) is partly related to the initial causes of the voluntary introduction of gorse [32], but other uses, such as dyeing, are also described. Ecological utility (positive effect as a shelter for animals, nursery effect for plants, ability to retain soil) is the least frequently mentioned, and mainly in recent academic documents, probably reflecting the emergence of the concept of "novel-ecosystem" [46,47]. Biomedical utility is more often mentioned, but applied on a small scale and the therapeutic indication is rarely described (except for Bach flowers, where gorse is used to "fight deep despair"). The greatest diversity of projects for the economic development of gorse is found in countries where it grows mainly in agricultural areas. This can be explained on the one hand because gorse is easier to manage and collect mechanically in agricultural areas than in natural areas, and on the other hand because these countries express less incompatibility between economic development and eradication research than those where gorse was mainly present in (protected) natural areas. The last status of gorse is the "landscaping" status, linked to its abundant flowering and photogenic aspect. This status is rarely expressed by long texts, but is characterized by the abundance of gorse photos, in private sites, in tourist blogs, and in travel guides and documents.

All of these statuses have already been identified in New Zealand [37,38], and in Reunion [29], confirming that there is a limited number of status that can be attributed to a species during a given period. However, their relative importance differs depending on the countries, and have evolved through time. (This is obviously the case for the invasive status, since the concept began to be widespread only after 1980 [11]). The presence of the same species, gorse, can thus lead to very different appreciation and categorization depending on the time period, the type of agronomy and the socio-economic context. We consider that the combinations of factors that promote the expression of the invasive status of gorse in the public sphere corresponds to its invasive niche.

4.2. Factors Explaining the Publicization of the Invasive Status of Gorse

We have constructed an indicator based on the presence of the invasive status of gorse in the public sphere, and analyzed its variation for 21 countries. This analysis explains 85% of the variance, which shows that the variables used have a very good explanatory power. Axis 1 alone structures 43.2% of the variance; it includes in particular the presence of gorse in protected areas, and its absence in agricultural areas. These localizations correlates with direct estimates, but also with latitude, since it is a proxy for the kind of environment occupied by gorse (mountain or sea level), and thus the likelihood of gorse to be located in agricultural or natural protected area. The studies of all status in a subset of countries has shown that the presence of gorse in agricultural areas, although considered as negative, minors the invasive status by enhancing the perception of the species as an agricultural pest, and to a lesser degree, as a useful plant. The presence of gorse in natural protected areas is thus the main determinant of its invasive niche, while its absence in agronomic areas may help the invasive status to dominate in the public sphere. The Social Progress Index (SPI) also contributes largely to this axis. A high SPI may promote the invasive status of exotic species, either because it reflects the greatest ecological concern of governments and inhabitants of these countries (that can result in a higher protection of endemic and indigenous species), or because it reflects a higher level of science and scientific arguments in the public sphere.

The second axis is composed of land use variables, the proportion of the country in protected natural areas, and the proportion of the country in permanent grasslands, which are negatively correlated. Protected natural areas are linked with the publicization of the invasive status, and permanent grasslands are linked with an attenuation of the invasive status. As for the first axis, this attenuation may results from the fact that the presence of permanent grassland, which are highly susceptible to be colonized by gorse, enhances the perception of the species as an agricultural pest. However, although the dichotomy looks similar, the first axis is mainly related to ecological properties of gorse, while the second axes is related to environmental and agronomic policies of the country.

The main variable contributing to axis 3 is the fit with the bioclimatic niche of gorse, i.e., the ability of gorse to grow in large areas of the country. The relatively weak explanatory power of the bioclimatic niche in our model must be tempered by the fact that we have only included countries where gorse is present, i.e., where at least part of the territory is bioclimatically favorable to the establishment of the species. Once the country has a climate compatible with gorse, it is rather the type of spaces occupied, which are linked to the variables of land use and social progress that plays a decisive role.

From this global study, we can deduce that the invasive niche of gorse implies bioclimatic compatibility with gorse ecological requirements, a high proportion of protected areas, the presence of gorse (thus the bioclimatic compatibility of gorse) in at least one protected area, agricultural areas with few permanent grasslands or mainly devoid of gorse (thus not bioclimatically compatibility with gorse), and a relatively high Social Progress Index. These dimensions are not exhaustive. On a finer scale, a multidisciplinary field study of each territory may lead to include a higher number of natural and social variables, but these are the main dimensions of the invasive niche of gorse.

5. Conclusions

To test the concept of invasive niche on gorse, we chose to work at a global scale, which increases the heuristics of the methods but implies several limitations. Data were collected on the web via Google's search engines and reflects the publicization of the invasive status on a particular media (although that media compiles a lot of different sources). The indicator calculated from these data thus depends on the capacity of institutions, social groups and individuals to publish their works or their personal thoughts on the web. It may not always reflect the experience of the populations that daily use and manage the environments. Finally, to carry out a quantitative study at such a large scale, we had to select only variables that could be obtained in a standardized way for all the countries studied, while additional variables may also have been relevant.

Despite these limitations, the model with natural and social variables explains 85% of the variance of the invasive status of gorse in the public sphere. This shows that at this large scale, the variables we used are relevant and provide a fairly good prediction. The analysis shows that the publicization of the invasive status of gorse combines ecological, socio-economic, and geographical factors. We propose to call this combination of factors the invasive niche of gorse. It reflects both the status attributed by scientific experts (which depends on impacts that themselves depend on land uses and protection), and the status attributed by institutions (including governments) and the general public.

As the concept of ecological niche, the concept of invasive niche does not need to collect all the dimensions of the niche to be useful and to allow predictions. The concept of invasive niche, i.e., the set of natural and social parameters that allow a species to be considered invasive in a given socio-ecosystem, can be applied to any species that is actually or potentially introduced in a new environment.

Supplementary Materials: The following are available online at http://www.mdpi.com/1424-2818/11/9/162/s1, Table S1: List of the statuses of gorse identified in 14 countries with a systematic web survey.

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Appendix A

Targeted Research to Attribute a Level to the Indicator of the Publicization of the Invasive Status of Gorse

Level 0: no publicization of the invasive status
Level 1: only publications of specialized literature by scientists and environmental managers
Level 2: Level 1 + mention of gorse on an official national list of invasive species
Level 3: Level 2 + implementation of gorse management action
Level 4: Level 3 + mention by amateurs and by the general public

To validate levels 0 and 1:

To assess the presence of articles on the invasive status of gorse by scientists or environmental managers, we first used Google Scholar. The key words entered were "*Ulex europaeus*", "gorse", and "invasive species", in English and in the language of the country concerned. The first 20 results were reviewed and as soon as an article mentioning the invasive status of gorse was identified, the transition to level 1 was validated. If nothing has been found, the same search was done on Google, which can give more gray literature (technical or student's reports, etc.). If no information was found, the country was assigned a level 0.

To validate level 2:

On Google, we checked in the language of the country the presence of an official national list of invasive species, and if so, if gorse is listed. For level 2 to be validated, gorse must be registered on lists written by the country and not only by international organizations. This information is generally found on the websites of the Ministries of the Environment.

To validate level 3:

On Google, we searched in English and in the language of the country the mention of management actions against gorse. The key words entered were "*Ulex europaeus*", "gorse", "management strategy", "struggle", in English and in the language of the country concerned. The first 20 research results were reviewed and as soon as information attests to a strategy implemented in the field, the transition to level 3 was validated.

To validate level 4:

On Google, we checked the presence of the invasive status of gorse on local press, private sites and blogs. The key words entered were "gorse" and "invasive species" in the language of the country. The first 20 search results were reviewed and as soon as a site was identified, the transition to level 4 was validated.

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