



Socio-ecological vulnerability in rural Spain: research gaps and policy implications

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Abstract

Through a systematic review of scientific literature, we investigate the nature and the contents of vulnerability research in rural Spain. The studies reviewed ($n = 137$) are unevenly distributed across the country, with almost half conducted in the autonomous communities of Andalucía and Catalunya. We identify two main strands of research depending on the methodological approach (quantitative vs qualitative). The scale of analysis varies, from national to local level, while only 14% of the studies are grounded on vulnerability concepts (exposure, sensitivity, adaptive capacity) and related analytical frameworks. Climate change is the most studied driver of vulnerability, often considered in conjunction with other stressors such as environmental degradation, unsuitable policies, or unfavorable terms of trade. The studies reviewed pay minimal attention to sensitivity factors and to adaptive capacity, which often only appear in qualitative studies that focus on social systems. In the light of these findings, we identify research gaps and discuss the ambivalent role of rural development policy in either enabling or hindering adaptive capacity in Spanish rural areas.

Keywords Vulnerability · Climate change · Multiple drivers · Adaptive capacity · Literature review

Introduction

European governments have been increasingly concerned about how environmental and social stressors like climate change, economic crises, and demographic changes are affecting rural livelihoods (Grêt-Regamey et al. 2019; Salvia et al. 2019). In Spain, increased aridity and average temperatures over summer periods are expected to affect ecosystems as well as many economic sectors—e.g. agriculture, forestry, industry, tourism—in distinct but significant ways (IPCC 2021; Moreno et al. 2005). Climate change can reduce water availability, leading to crop productivity losses (Camps and Ramos 2012; Iglesias et al. 2012) and land abandonment (Ustaoglu and Collier 2018). Indirectly, it can also promote specific forms of agricultural intensification (e.g. irrigation and land concentration) (González de Molina et al. 2019). Furthermore, the citizens of rural areas—now representing less than 24% of Spain's total population (Collantes and Pinilla 2019)—have been out-migrating for the past 70 years, leading to aging, masculinization, gender inequality, and job precariousness (Camarero et al. 2009), thus aggravating agricultural intensification and land abandonment (ibid.).

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In this article, we systematically review how environmental, socio-economic, and demographic changes contribute to rural vulnerability in Spain. We do so to gain a better understanding of the processes that explain such vulnerability, the resulting impacts, and both existing and foreseeable adaptation strategies. Specifically, we ask the following: (i) Which are the main environmental and social drivers of Spain's rural vulnerability as covered in the literature? (ii) Which factors mediate rural populations' sensitivity to these drivers? And (iii) Which factors enable or hamper adaptation to these drivers? The review is grounded on existing vulnerability approaches as applied in political ecology and climate change science and in the study of the human dimensions of global environmental change more broadly (McLaughlin and Dietz 2008; Janssen 2006), adding to the growing body of research concerned with climate change impacts, the need to adapt, and consequences of adaptations (Jafino et al. 2021; Clark et al. 2000). All these approaches share a concern for understanding how and why various social groups or communities are exposed to environmental and socio-economic shocks and stressors, how they are differentially affected, and how spatial, physical, and social characteristics influence vulnerability (Miller et al. 2010; McCarthy et al. 2001).

We understand vulnerability as the degree to which a human social and/or ecological system is affected by some form of hazard (Turner et al. 2003), and we consider 'exposure', 'sensitivity', and 'adaptive capacity' as key components of such vulnerability (Adger 2006; Gallopin 2006; Kaspersen et al. 2005). While the concept of exposure refers to the degree to which a system experiences a given trend or shock, sensitivity can be defined as the susceptibility of this system to the effects of such exposure (Bennett et al. 2016; Adger 2000). A given stressor (or a few combined) can be unevenly experienced by various similarly exposed groups, as a result of their diverse characteristics (e.g. gender, age, social class, race, livelihoods) and entitlements (O'Brien and Leichenko 2000). Finally, adaptive capacity has to do with 'the ability to respond to challenges through learning, managing risk and impacts, developing new knowledge and devising effective approaches' (Marshall et al. 2010:5). As for sensitivity, adaptive capacity is determined by entitlements (including also human, social, physical, financial, and natural assets), capacity to organize, leadership, learning and knowledge, and other resources (Bennett et al. 2014; Bussey et al. 2012; Cinner et al. 2009; Folke et al. 2003). Therefore, we assert that adaptive capacity encompasses the set of conditions that facilitate one's ability to undertake adaptations (i.e. actions that may contribute to reduce vulnerability), and we call such conditions adaptation 'enablers' because they either build-up or contribute to realize

one's adaptive capacity. In contrast, adaptation 'barriers' are conditions that contribute to the reduction of adaptive capacity and/or hamper adaptations. When vulnerability is analyzed in relation to a specific socio-ecological system, exposure is usually associated to an external dimension, e.g. a climate stressor, while 'sensitivity' and 'adaptive capacity'—or adaptations—are seen as internal dimensions, related to features of the communities exposed to the stressors of concern (Füssel and Klein 2006).

We acknowledge that the concept of vulnerability has been mobilized by various disciplines, from economics and anthropology to psychology and engineering, among others. These disciplines have increasingly cross-fertilized over time but put distinctive relative weight on the influence of exposure, sensitivity, or adaptive capacity on vulnerability and, particularly, on the role of political economy and culture in shaping vulnerability (McLaughlin and Dietz 2008). Within these studies, there has also been a transition from a focus on a single environmental stressor (e.g. floods, or droughts) or global phenomenon (e.g. climate change), towards a focus on multiple drivers of vulnerability, including non-environmental drivers (e.g. demographic, economic, sociopolitical, or technological processes) (Füssel and Klein 2006). For example, O'Brien and Leichenko (2000) introduced the concept of 'double exposure' to analyze the interconnected impacts of globalization and climate change. Although concepts such as 'multiple stressors' (Adger 2006; O'Brien et al. 2004; Turner et al. 2003), 'multiple exposures' (Bennett et al. 2015; Belliveau et al. 2006), and 'other stressors' (Tschakert 2007) have also been proposed, the development of this stream of research is relatively new—mostly thriving since 2010—and many studies are not explicit about the interpretations and conceptualizations they use (Räsänen et al. 2016). Moreover, interactions among drivers should be analyzed more systematically to clearly demonstrate which stressors should be targeted simultaneously (ibid). The identification of archetypes or pathways of vulnerability—i.e. recurrent configurations of factors that generate vulnerability to socio-economic and ecological change (Kok et al. 2016; Sietz et al. 2011)—across case studies can be regarded as an important research frontier in that regard.

The 'Methods' section below describes the data collection and review protocols. The 'Results' section presents the results: we show the geographic and analytical patterns of the studies reviewed; we analyze how the literature accounts for vulnerability dimensions (i.e. exposure, sensitivity, and adaptive capacity); and, finally, we identify six literature clusters that differ in their conceptual and/or empirical lenses. The 'Discussion' section discusses these findings, identifies research gaps, and highlights the policy implications that derive from the systematic review.

Methods

Data sources and selection process

The methodology we followed to select, screen, and code the articles that conform this review was inspired by the PRISMA framework proposed by Moher et al. (2009). We aimed to identify English-written, peer-reviewed international academic literature exploring the drivers of and responses to rural vulnerability in Spain. We did so to capture the widest range of vulnerability studies conducted in Spain, without discriminating across disciplines, theoretical and methodological approaches, the stressor(s) chosen, and the criteria selected to quantify or qualify exposure, sensitivity, and adaptive capacity. However, since our primary interest was to understand the relationship between an environmental and/or social stressor and rural vulnerability, we discarded studies focused only on ecological and biophysical systems and those that did not have a specific social framing or reference to rural livelihoods. Additionally, by excluding other relevant research published in Spanish, Basque, Catalan, or Galician, we also acknowledge that this review cannot be considered exhaustive and our conclusions should be thus taken with caution.

We ran a targeted keyword search in Scopus in January 2021 combining concepts and drivers of the vulnerability literature as they appeared in the Title, Abstract, and/or Keywords of the article. The search string included the following: ‘Spain’ AND (‘Vulnerability’ OR ‘Exposure’ OR ‘Adaptive capacity’ OR ‘Adaptation’ OR ‘Sensitivity’ OR ‘Resilience’) AND (‘Climate change’ OR ‘Depopulation’ OR ‘Land intensification’ OR ‘Land concentration’ OR ‘Desertification’ OR ‘Food security’ OR ‘Price volatility’ OR ‘Aging population’ OR ‘Biodiversity loss’ OR ‘Soil erosion’). We tried other combinations of search strings in order to maximize the number of hits while including the most relevant studies. However, these other search strings provided different sets of articles that diverged from the issue of concern and were thus discarded.

Our search rendered 1220 articles. We split these between authors’ pairs, who then read the abstract of each article independently (see Appendix). In doing so, each of us noted if the abstract identified or made reference to *at least one* of the following elements:

- a) A process of environmental and/or socio-economic change affecting *human systems*, presumably analyzed with primary or secondary data in the article, and/or included as narrative framing—labeled as ‘impact’ in Appendix;
- b) A proximate or distal cause of such impact(s)—labeled as ‘driver’ in Appendix;

- c) A coping and/or adaptive strategy of *human systems*, at whatever scale of social organization (farm, community, government, policy, etc.), which may or has emerged in response to the above-referred drivers—labeled as ‘response’ in Appendix.

We also excluded articles that were:

- a) Focused on public or animal health (e.g. how increased temperature may affect human mortality, or how exposure to pesticides may affect animal herds’ health);
- b) Methodological (e.g. studies comparing different estimation models, or indexes, or spatial data analysis protocols) and lacked a specific linkage with farming and cropping practices, productivity, or other adaptations;
- c) Not based in Spain or did not include Spain as a case study country;
- d) Focused on *urban/peri-urban contexts*, since this study was only concerned with rural regions—and despite we acknowledge that global change can also affect cities and other densely populated regions.

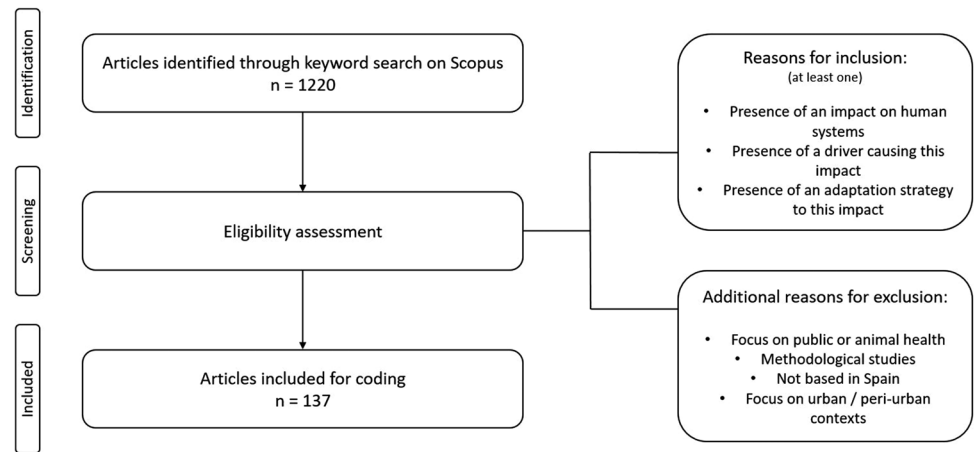
We included studies focused on coastal systems because we assumed that some rural areas are also coastal, particularly in north-western Spain, unless it was very clear that they focused on urban areas only.

Disagreements between pair members in the process of deciding whether an article had to be included for analysis were resolved collectively: all authors read the correspondent abstract together and decided whether it should or not be included. Of the 1220 articles initially identified, only 137 matched the conditions outlined above and were subsequently coded. Many of these selected articles did not make an explicit distinction between ‘exposure’, ‘sensitivity’, and ‘adaptive capacity’ which, as shown below, entailed specific challenges for data coding and interpretation. Inspired by the flowchart proposed by Moher et al. (2009), Fig. 1 outlines the articles’ selection process.

Coding procedure and data analysis

The coding addressed five domains, each comprising a set of variables (see code book in Appendix). Three of the five domains corresponded to exposure, sensitivity, and adaptive capacity issues. The other two related to auxiliary information (‘papers overview’ and ‘research attributes’). The variables included in each domain were refined throughout five rounds of pilot coding of eight articles that had been selected randomly from the full sample. In each round, the group members coded the articles individually and later met to discuss the coding exercise, proposing modifications and

Fig. 1 Phases of the selection process and criteria for inclusion and exclusion of articles



clarifications to specific variables. These rounds of pilot coding also served to create a common understanding of the variables. Eventual doubts or problems during the formal coding process were resolved in group meetings and exchanging views with the lead author.

The coding process first required an understanding of the information through the lenses of a driver/impacts/adaptation causal model. This was necessary to ensure reliable coding but was also challenging given that a fair amount of the studies were not necessarily framed within the vulnerability framework and/or covered attention to multiple drivers and adaptations in historical perspective. The coding of policy measures was particularly difficult as these could appear as both drivers of change and adaptations.

In the ‘exposure’ component, we identified the drivers of vulnerability proposed in the studies, the way they are measured by the authors, eventual interactions among them, as well as the impacts of the drivers on ecosystems and especially social groups. As for sensitivity, we identified the factors that make some groups-areas particularly prone to be affected by the drivers considered by each article, as well as their interactions and the distributional aspects related to the unequal diffusion of sensitivity among social groups, genders, and territories. Last, we explored the adaptive capacity component by distinguishing the characteristics of the adaptation actions considered in the articles, identifying adaptation enablers and barriers, as well as eventual differences in the distribution of adaptive capacity among social groups, genders, and territories. The choice to focus on adaptation actions, barriers, and enablers—rather than more specific aspects of adaptive capacity proposed by other authors (cfr Cinner et al. 2018)—was driven by the acknowledgment of the above-mentioned limitations of the reviewed articles.

Information was compiled in Excel (Microsoft Office) and data was analyzed in XLSTAT® (Addinsoft) (see database in online Supplementary materials). To explore patterns in the literature, we run descriptive and multivariate analyses. Multiple

correspondence analysis (MCA, the correspondent of PCA for a large database with categorical data) and hierarchical cluster analysis (HCA) were applied to explore the linkages and associations between different variables and similarities between cases, respectively. To define the number of axes retained for the HCA, we employed two criteria: scree test (Cattell 1996) and eigenvalue. We used Euclidean distance as the dissimilarity matrix coefficient and Ward’s method as clustering technique to minimize the error in sum of squares (Ward 1963). To contextualize the clusters, we explored associations between the groups and the variables included in the analysis (fisher exact tests), according to the motivation and objective of our study.

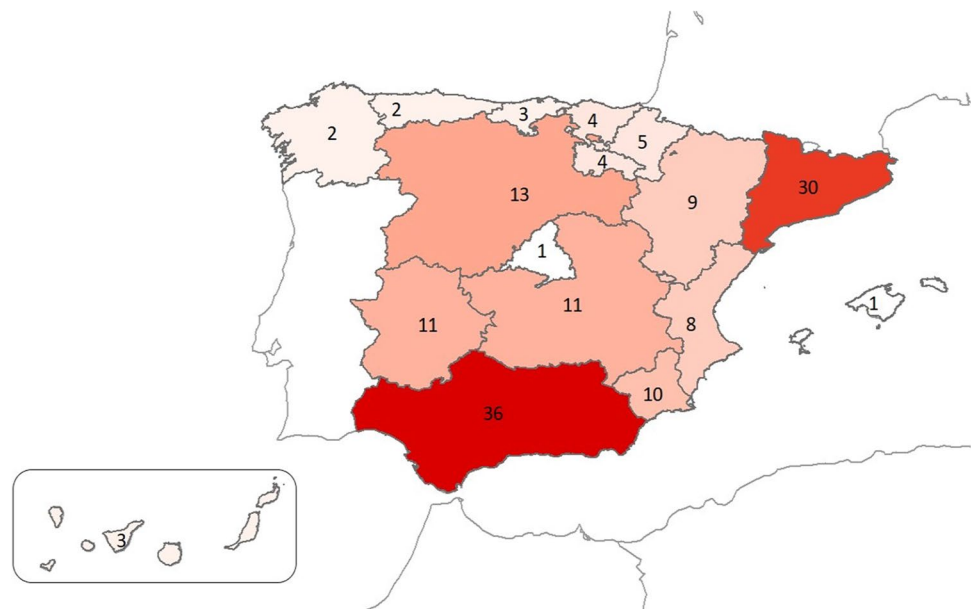
Results

Geographic and analytical overview of the literature

Figure 2 maps out the geographic distribution of case studies across the 17 Spanish autonomous communities and shows that Andalucía and Catalunya encompass a relevant share of the socio-ecological systems analyzed. Twenty-two percent of the articles analyze vulnerability issues at the autonomous community level, while 12% do so at the municipal level and 7% at the ‘comarca’ level, i.e. an administrative division that encompasses several municipalities. Fifteen percent of the articles address vulnerability issues at the provincial or national level, including sometimes a comparison with research conducted in other countries. Seven percent of the articles address vulnerability issues in more than one autonomous community and 21% consider simultaneously distinct administrative scales, e.g. the autonomous community and the municipal levels.

The reviewed articles place their analytical focus on inner land social-ecological systems (24% of the studies reviewed), coastal areas (23%), and river basins (19%), while mountains (9%) and islands (5%) are less represented. Some articles do not focus on a specific socio-ecological system (20%), as they

Fig. 2 Distribution of the reviewed articles across Spain's autonomous communities. Color intensity indicates a higher number of studies in the correspondent community



target a very large geographical region, such as a province, an autonomous community, or even the whole country.

Fifty-four percent of the considered studies were published between 2016 and 2020 and 37% between 2010 and 2015, leaving only 9% of the publications before these dates (Fig. A1). Fifty-two percent of the articles reviewed focus principally on the vulnerability of agricultural systems, while the other predominant sectors of analytical concern include water management—i.e. the large-scale control of water resources for human consumption and irrigation—and tourism, considered in 16% and 15% of the cases, respectively (Fig. A2).

Only twenty of the articles in our sample ($n=137$) rely on an explicit vulnerability framework to organize the research (14%). Drawing on the typology of vulnerability frameworks developed by McLaughlin and Dietz (2008), we inferred that six of these articles adopt a ‘biophysical perspective’, i.e. they focus only on the degradation of biophysical conditions and extrapolate how such degradation may directly (or indirectly) impact on human systems (Liverman 1990). This biophysical emphasis was common in early vulnerability studies and has been criticized for neglecting the social, economic, and political factors shaping exposure to environmental change and its impacts (McLaughlin and Dietz 2008). Ten studies adopt a ‘human-ecological perspective’ that sees human systems as embedded within ecological processes and make explicit reference to the three components of vulnerability as in the authoritative IPCC definition of the concept (McCarthy et al. 2001). The remaining four articles adopt a political ecology and constructivist perspective and reflect on the role of political economy, power, culture, and agency in shaping rural vulnerability.

Methodologically, quantitative approaches predominate in the review sample: 61% of the articles rely on quantitative data,

while 26% draw on both quantitative and qualitative and only 13% are based solely on qualitative approaches. Socio-economic and/or ecological systems modeling—appearing in close to 60% of the articles—is by far the most used methodology.

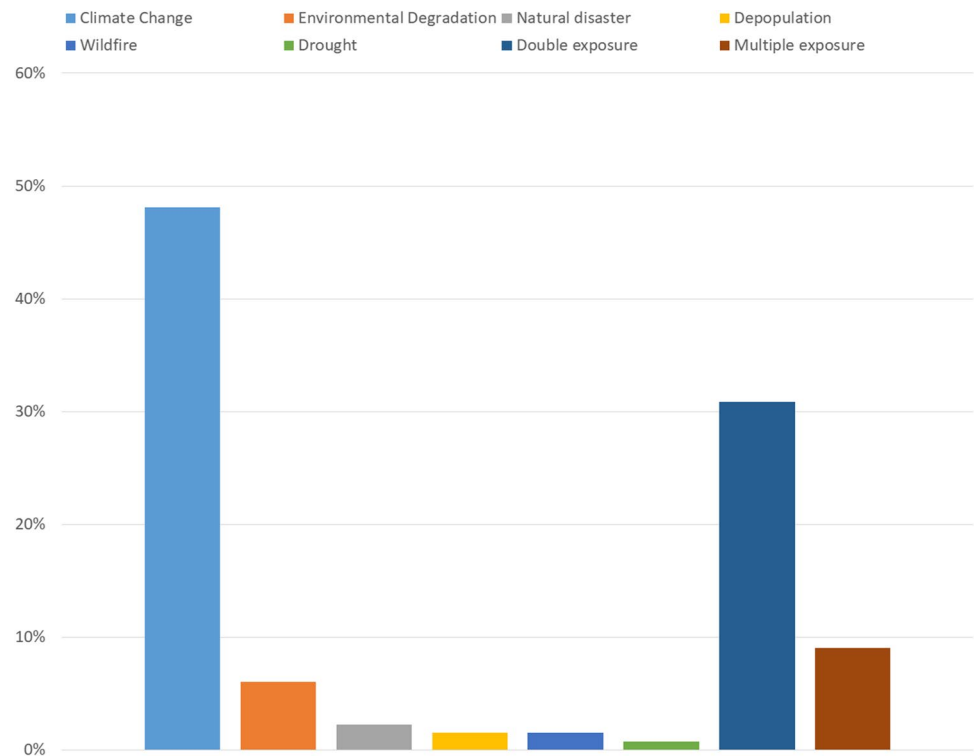
Multidimensional vulnerability

Exposure

Figure 3 represents the drivers of vulnerability identified in the review sample, in which climate change is the most recurrent one. In 48% of the studies reviewed, climate change appears as a single driver of vulnerability, while in another 35% it appears in combination with another driver (i.e. double exposure) or with more than one in 9% of the articles (i.e. multiple exposure). Environmental degradation processes—e.g. soil erosion, contamination of water and soil, etc.—are the second most analyzed vulnerability driver (9%), followed by policy and market-related dynamics such as price volatility and the influences of international markets.

Overall, 40% of the articles consider more than one driver at a time. As shown in Fig. 4, the most frequent combinations of drivers are climate change and environmental degradation (25%), climate change and drought (15%), climate change and policy (13%), and climate change and market-related dynamics (9%). However, not all the studies informing about multiple drivers explore how these are interrelated and can reinforce each other, e.g. neoliberal policies (category: policy) can foster industrialization of agriculture (category: market-related). Sixty-five percent study these interactions, while the rest just hint at their co-occurrence. Out of the studies considering interactions, most focus on

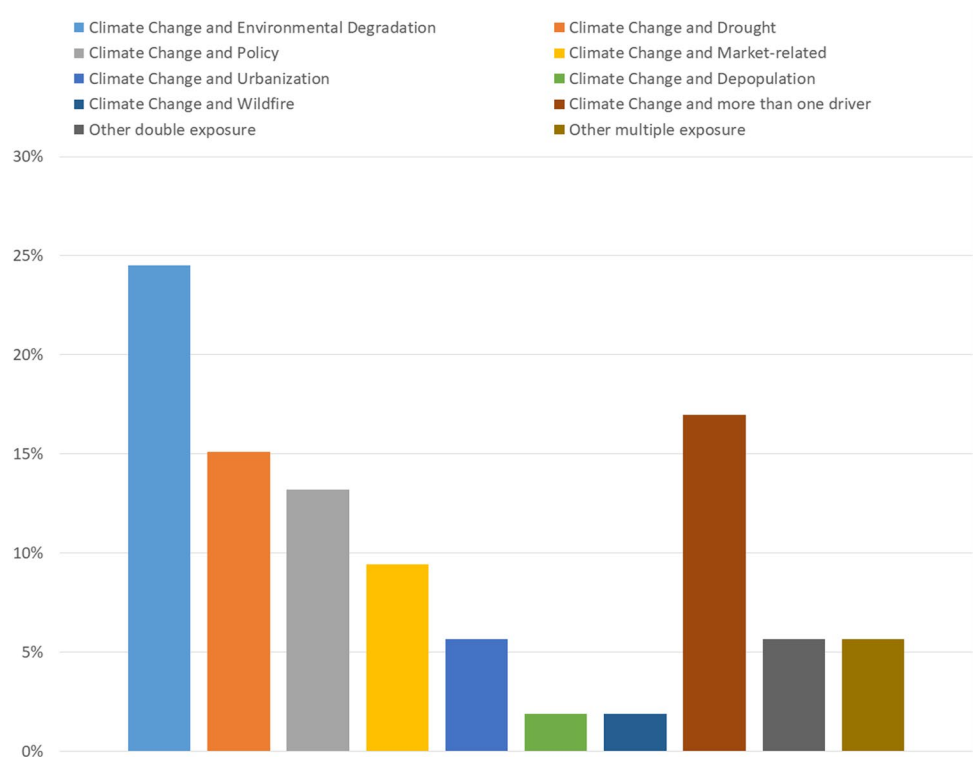
Fig. 3 Recurrence of the different drivers of vulnerability in the reviewed literature



how the effects of climate change are interconnected with environmental degradation (21%), policy (12%), and markets (12%).

Impacts of a given driver (or combination of) on social-ecological systems are addressed explicitly and investigated in detail in 66% of the reviewed articles. In 74% of these,

Fig. 4 Recurrence of combinations of drivers of vulnerability in the reviewed literature



impacts are predominantly measured through quantitative methods, including models, statistical analysis of secondary sources, and agronomic measurements and experiments, while 18% use qualitative methods, and 9% mix both quantitative and qualitative approaches.

During the coding process, we also identified and categorized the main impacts explicitly investigated in the articles, and analyzed their magnitude (see Table 1). Impacts

relating to water resources (e.g. decreasing water availability and increasing water demand, among others) are the most researched (28%), followed by agricultural impacts (22%)—mostly negative ones over crop yields, climatic (16%)—especially in terms of increasing extreme events and temperature and precipitation changes, and socio-economic and cultural impacts (e.g. economic and cultural heritage losses) (15%).

Table 1 Recurrence of impact categories

Type of category	Count	Frequency	Impact category	Count	Frequency
Agriculture	43	22%	Change in farm types	2	1%
			Decrease in farming economic benefits	6	3%
			Impacts on agricultural production (negative)	23	12%
			Impacts on agricultural production (positive)	2	1%
			Impacts on agricultural production (both positive and negative)	2	1%
Other economic sectors	12	6%	Seasonal shifts and changes in suitable areas for agriculture	8	4%
			Impacts on animal husbandry (negative)	3	2%
			Impact on silviculture production (negative)	3	2%
			Impacts on tourism (positive)	2	1%
			Impacts on tourism (negative)	4	2%
Water	54	28%	Conflicts water use	2	1%
			Decrease in water availability	34	17%
			Decrease in water quality	1	1%
			Increase in water demand	14	7%
			Salinization	3	2%
Ecosystems	25	13%	Impact in ecosystems (inc. degradation and biodiversity loss)	10	5%
			Contamination of soil and water with pollutants	3	2%
			Invasive species	1	1%
			Overexploitation	3	2%
			Changes in soil structure and properties (inc. erosion)	7	4%
Meteorological and generic environment	31	16%	Afforestation	1	1%
			Decrease in carbon stocks	3	2%
			Change in precipitation	6	3%
			Change in temperature	4	2%
			Increase in evapotranspiration	2	1%
Cultural and socio-economic (social)	30	15%	Droughts	5	3%
			Extreme events (e.g. floods, sea-level rise, storms)	8	4%
			Increase in wildfires (frequency and intensity)	3	2%
			Loss of cultural heritage	4	2%
			Loss traditional agriculture, rural practices and TEK	3	2%
			Rural abandonment	4	2%
			Casualties and damages	6	3%
			Economic benefits	1	1%
			Economic losses	9	5%
			Health problems	1	1%
Impacts on infrastructure efficiency	2	1%			
	195 ^a	100%		195	100%

^aMultiple impacts can emerge from each study

Sensitivity

Sensitivity is the least explored vulnerability component in the reviewed studies. Forty-three percent of the articles do not present any information about this component. Among the studies which do mention it, the main sensitivity factors concern agricultural and water management issues (mentioned in 33% of the articles). These issues, in turn, mostly include crop characteristics and irrigation practices that mediate the extent to which a given impact—e.g. changes in temperature and precipitation caused by climate change—affects harvests and, consequently, farmers. Topographic and soil characteristics of the geographic context where the research has been conducted are considered key sensitivity factors by 21% of this sub-set of studies. The social dimensions of sensitivity are even less explored: market integration and dynamics (e.g. price volatility or household characteristics), population density and urbanization patterns, as well as policy and governance factors (e.g. the lack of local rule enforcement or the miscoordination among authorities) were considered in approximately 10% of the studies that referred to sensitivity issues. Finally, land use change (e.g. agricultural abandonment or intensification), climatic variability (related to local climate conditions rather than anthropogenic climate change), and the relative degree of geographic isolation were also mentioned, but to a lesser extent (5%) (Fig. 5).

Adaptive capacity conditions: adaptation enablers and barriers

The analysis of or reference to adaptive capacity factors that may either enable or hinder such capacity mostly appears in the reviewed articles that focus on social systems and rely on qualitative methods. Policy and governance aspects, such as subsidies and public policy support, represent by far the most important adaptation enablers (highlighted in 51% of the studies). The next most important category of enablers only covers 14% of the data (economic enablers, e.g. the access to credit). Policy and governance aspects are also identified as key constraints (29%), or adaptation barriers. Lack of funding and economic barriers are also considered key obstacles to adaptation in 23% of the studies, together with lack of awareness about the issues that these actions would tackle or their negative perception among specific social groups (20%) (Figs. 6).

A more detailed look at policy-governance enablers and barriers unveils a relatively asymmetrical distribution across the two categories (Fig. 7). Coordination deficits (e.g. among public authorities and between these and private actors) and

planning issues (e.g. plans/policies not tailored enough to climate change) stand out as barriers, while the availability of resources (mostly economic in the form of subsidies), appropriate regulatory frameworks (mostly associated with EU action) and sufficient involvement of local authority/non-governmental organizations (e.g. from decentralization, and participatory decision-making) are more salient as enablers. In the category ‘other’, we find barriers such as the organizational and logistical complexity of adaptation actions and enablers such as the external feasibility provided by international regulations.

Distributional aspects

Less than half of the reviewed articles pay attention to the uneven distribution of sensitivity and adaptive capacity factors across territories, social groups, and genders. Thirty-three percent of the studies in the sample highlight that the geographic location of the analyzed system influences sensitivity strongly. A recurring example is the identification of contrasting impacts in terms of precipitation changes and water availability across downstream or upstream areas in river basins (e.g. Vargas Molina and Paneque 2019; Esteve et al. 2018; Garcia Galiano et al. 2015). Fifteen percent of the studies also consider this spatial aspect a determinant factor in the distribution of adaptive capacity. Specific adaptations, such as the early sowing of maize, would for example counter the negative impacts of climate change on crop yields in northern Spain but not in southern regions (Rosenzweig and Tubiello 1997).

Ten percent of the articles identify uneven distributions of both sensitivity and adaptation across social groups. For instance, small-scale diversified farmers are considered the most vulnerable and least able to adapt to climate variability and price volatility in Navarre, while large-scale intensive farmers—also thanks to their inclusion in a large-scale irrigation project—seem to be the least vulnerable to these threats (Albizua et al. 2019). Gender is basically absent from the analysis of distributive issues related to sensitivity and adaptive capacity.

Cluster analysis

To explore patterns in the literature, we run an MCA and a HCA. The variables included in the analysis are displayed in Table A1. The MCA resulted in a preliminary identification of 6 groups of variables (Fig. A3) and a preliminary understanding of the variables that would discriminate the most between clusters (e.g. type of system studied, temporal frame, methods, economic sectors). The

Fig. 5 Recurrence of the sensitivity factors emerging in the reviewed literature

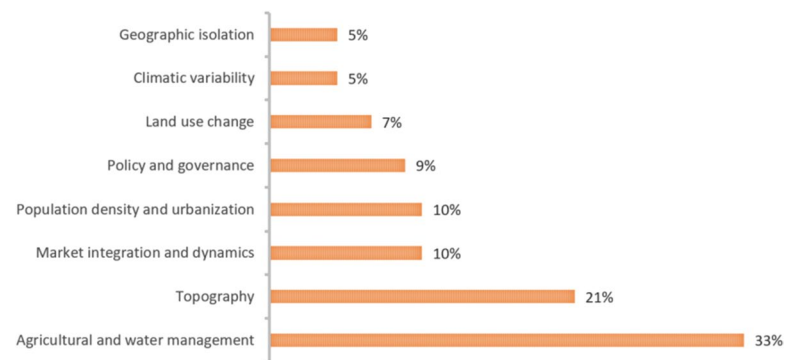


Fig. 6 Recurrence of the adaptation enablers and barriers emerging in the reviewed literature

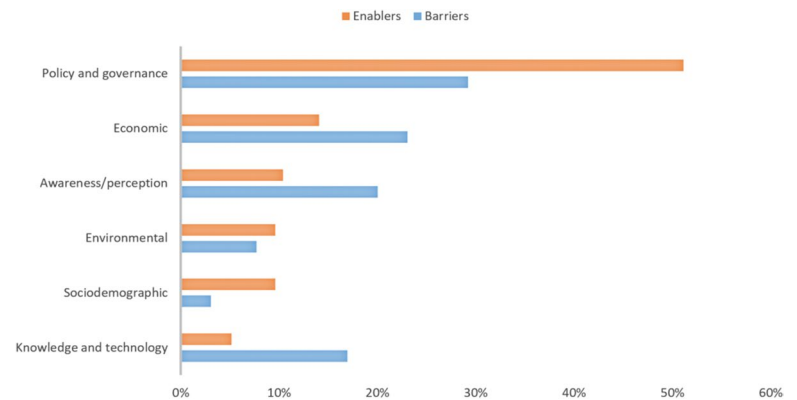
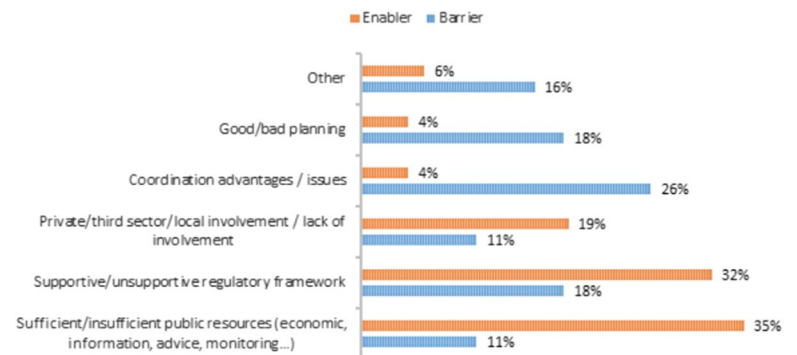


Fig. 7 Recurrence of policy and governance enablers and barriers in detail

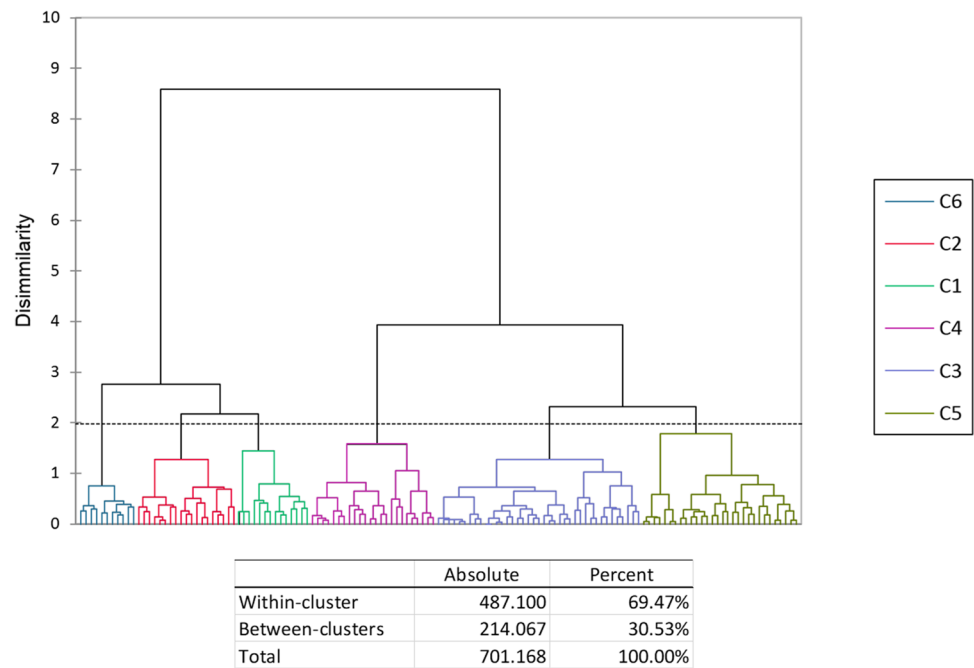


cluster analysis resulted in 6 groups of studies (Fig. 8). Table A2 includes only the variables that revealed significant differences across the clusters for any of the values of each variable.

As shown in Fig. 8, clusters 1, 2, and 6 are more similar to each other and can be distinguished from the clusters 3, 4, and 5. The former group is characterized by a qualitative and mixed methods approach, while the latter adopts a

more quantitative approach. The dendrogram also presents homogeneity between pairs of clusters within these groups. For example, cluster 3 and 5 share a forward-looking, modeling approach and are interested in climate change impacts, while clusters 2 and 1 share a focus on social systems. We describe these clusters below according to their relative contribution to the review sample, from more to less common.

Fig. 8 Dendrogram and variance decomposition resulting from cluster analysis (6 clusters)



Climate change impacts modeling studies

Among the forward-looking, modeling clusters interested in climate change impacts, cluster 5 stands out for its interest in the combined impacts resulting from the interaction of climate change with other drivers of vulnerability. Most articles in this cluster focus on the water management sector. For example, Schmitz et al. (2017) analyze the interdependence between environment and society in the island of Fuerteventura, and apply a quantitative model to identify indicators of human–landscape relationships and subsequently predict potential shifts based on simulated environmental changes. The authors show that temperature and precipitation change (‘climate change’ driver), changes in population origins and distribution (‘urbanization’ driver), and changes in predominant economic sectors (‘market-related’ driver) result in specific impacts such as the accelerated warming and decreases of rainfall, deagrarianization, deruralization, rural abandonment, and the decoupling of local people from their natural environment. Interactions between market-related and urbanization drivers are also identified, as tourism dynamics contribute to attract non-native inhabitants and foster urbanization, which also reinforces deagrarianization and the decoupling of local populations from their environment.

Studies in cluster 3 are mostly concerned with ecosystem dynamics and share an interest in the identification of sensitivity factors. A large share of these articles concern the agricultural sector. For example, Iglesias and Minguez (1997)

investigate the impact of climate change on yields and water use of two crops—maize and wheat—with different responses to increased CO₂ and which represent contrasting agricultural systems in Spain. The study finds that impacts will vary depending on the crop, its associated irrigation practices, and the location of the cultivations. The simulations suggest that summer irrigated crops such as maize will suffer yield reductions and may be forced out of production in some regions, while for winter dryland crops such as wheat, productivity may increase in other regions, leading to a northward shift of area suitable for wheat production in future climates.

Quantitative ecological studies

Cluster 4 encompasses another set of articles mostly concerned with ecological systems. These, however, do not employ models to forecast climate change impacts. For example, Fuentes et al. (2018) investigate how prescribed burning may contribute to reducing wildfire occurrence in *Pinus halepensis* forests of northeastern Spain. The authors find that prescribed burning effectively reduces fuel loads and results in less flammable forests without significant short-term changes in biodiversity. In turn, Arenas-Corraliza et al. (2019) analyze how the shade resulting from the development of agroforestry systems may affect cereal production. They find that commercial wheat and barley cultivars can adapt well to shade and, consequently, they argue that tree planting in cereal fields can contribute to climate mitigation without affecting productivity.

Qualitative social studies

Among qualitative studies focused on social systems, cluster 1 encompasses research analyzing natural disasters and/or demographic change, with an almost exclusive interest in the water sector. Hagenvoort et al. (2019), for example examine the potential reuse of treated waste-water for agricultural purposes in one of Valencia's *acequias* as an adaptation strategy to climate change and the increased frequency of droughts. They adopt a circular economy perspective, and mainly draw on interviews to explore the technological, agronomical, and social implications of the strategy.

The remaining studies fall within a less specific social systems cluster (cluster 2), which ignores driver interactions and is mainly interested in the tourism sector. For example, Torres-Bagur et al. (2019) investigate how the risks of climate change are perceived by key tourism stakeholders in the Muga River basin of north-eastern Catalonia. They find significant differences in such perceptions, depending on the type of establishment and location, and with most interviewees believing that governments should be those planning, funding and implementing adaptation actions.

Qualitative socio-ecological studies focused on driver interactions

Finally, cluster 6 stands out for a socio-ecological systems approach and an interest in interactions between environmental degradation, policy, market and population-related drivers of vulnerability. Most studies focus on ecosystem services and the agricultural sector. For example, Fernandez-Gimenez (2015) investigates interactions between ecosystem change—from herbaceous vegetation cover to shrublands in the Pyrenees, grazing practices, the decline of livestock herds and depopulation. The author documents the way sheppards experience and actively act upon these observed socio-ecological changes, and reveals the emotional and cultural aspects attached to these processes.

Discussion

Multiple drivers, missing sensitivity, and diverse epistemologies

Although environmental phenomena such as climate change and environmental degradation still stand out as the most recurring drivers of rural vulnerability, social and institutional processes such as policy, market-related dynamics, and depopulation seem to receive increased attention in Spain's rural vulnerability literature. The prevalence of biophysical stressors over social ones, however, contradicts other reviews on vulnerability literature at a global

level (Räsänen et al. 2016). More importantly, 40% of the reviewed articles reported the co-existence of more than one driver of vulnerability, which reflects the increased interest of vulnerability researchers in the study of multiple exposure patterns (Füssel and Klein 2006). Climate change, the most frequent driver by far, was observed in coexistence with the abovementioned social processes almost as frequently as alone; and this was an explanatory factor for three of the clusters identified (cluster 6 and clusters 3 and 5). We also found that interactions among drivers are addressed by a relevant share (65%) of the studies that deal with multiple stressors (see further below). However, the analysis of these interconnections often plays a marginal role in the authors' narratives, and more in-depth and precise research in this direction is needed.

A clear gap in the reviewed articles is the lack of attention to social and institutional sensitivity aspects. Forty-three percent of the articles do not include information about this component of vulnerability, and its associated factors were not very meaningful in the creation of the clusters (only appearing in cluster 3 as a distinguishing element). Sensitivity is strongly associated with distributional aspects, which probably explains why we did not find much evidence on these aspects either. These insights suggest that there is relatively little research that addresses social sensitivity factors systematically and their connection to distributional aspects (Atteridge and Remling 2018). This gap is particularly salient given the well-established fact that climate change and other drivers of global change are reinforcing social injustices worldwide (Alexandrescu et al. 2021; Martinez-Alier et al. 2016; Schlosberg and Collins 2014). The vulnerability framework and its attention to sensitivity offers a platform to trace such injustices back to specific social, biophysical, and institutional preconditions, an opportunity which is yet to be untapped in the Spanish context.

However, the absence of an explicit reliance on vulnerability definitions and frameworks was partially expected given how loosely this concept has been used in the socio-environmental literature at large (Janssen and Ostrom 2006) and its increasing integration with other concepts such as resilience and adaptation (Janssen et al. 2006). The lack of a unified analytical framework reflects the multiple epistemologies that have to date engaged with rural vulnerability issues, in Spain and elsewhere, yet this may hamper a more systematic, complementary, and thorough advancement of rural vulnerability research (Räsänen et al. 2016). For example, we found it difficult to organize the data into a common model of exposure-sensitivity-adaptation since a fair amount of papers only covered one piece of the model. Most studies either consisted of impact evaluations of specific drivers, and ignored sensitivity and adaptive capacity issues, or focused only on the latter (i.e. building on previous findings or assumptions about impacts). A lower but significant

number of the papers also included policy both as driver and adaptation strategy and were not clear about the chain cause-effect. Finally, some papers included multiple drivers but did not clarify how they affected rural vulnerability.

In addition to these observed shortcomings, the cluster analysis also shed light on two relatively distinguishable and meaningful bodies of vulnerability research in Spain. The two principal clusters identified differ mostly from each other as a result of contrasting methodologies: one relies primarily on modeling techniques and quantitative methods (3, 4, 5), while the other draws on qualitative or mixed methods and is not model-oriented (1, 2, 6). Other common characteristics within these two groups of clusters are the interest in the interactions between climate change and other drivers of vulnerability, researching also the resulting impacts (clusters 3, 5), and the focus on social systems (clusters 1, 2). This contrast can be traced to the larger disciplinary divide between environmental and engineering sciences on one hand (keener on quantitative methods and a relatively strict application of the scientific method), and the social sciences on the other (reliant on qualitative methods and diverse epistemologies). Thus, while reflecting interdisciplinarity deficits, our review also points to an opportunity for methodological cross-fertilization (Zimmerer 2015).

Policy implications

Despite the interest of a significant number of the reviewed studies in multiple drivers of rural vulnerability (i.e. the co-occurrence of climate change and other drivers of change), information about whether and how these drivers interacted was relatively scarce. The most salient exception were analyses of climate change-policy interactions in the water-agricultural sector.¹ Lessons from these studies point to the potential of water pricing and quotas to ameliorate the impact of climate change on water scarcity, although such policies may not necessarily reduce the overexploitation of water sources or guarantee agricultural profitability (Martinez and Blanco 2019; Rey et al. 2011; Varela-Ortega et al. 2011). The studies that analyze climate change-environmental degradation interactions suggest the existence of critical feedback loops. These include, for example the aggravated effects of climate change-driven droughts due to ongoing shrub encroachment processes in abandoned lands (Rolo and Moreno 2019); the increased impact of climate-change storms and sea level rise in beaches and Deltas suffering from soil erosion dynamics and/or saltwater intrusion (Toimil et al. 2018; Fatorić and Chelleri 2012); or the additive (although comparatively small)

effect of climate-change droughts on groundwater resources in an overexploitation context (Castaño et al. 2013).

These interactions and critical feedback loops have important implications for rural development. The latter should be better coordinated and integrated in ways that attend for both impacts, feedback loops, and potentially multiple, yet complex adaptations. This would be crucial given the existence of unattended distributional effects and trade-offs when dealing with different sustainability threats (Huitema et al. 2016; Eakin et al. 2009). As mentioned earlier, future research would benefit from a more systematic engagement with vulnerability, which should also translate into more specific and integrative adaptation policies (Räsänen et al. 2016). Furthermore, rural policy and related investments should pay careful attention to the factors that mediate exposure and produce different levels of sensitivity to the interactions of different stressors and their compounded feedback loops and impacts, and to the existence of distinct adaptive capacities across social groups and rural actors. Vulnerability indicators may help identify who is at risk so interventions can be well targeted, and a critical understanding of why they are at risk will tell us what can be done about it (Ribot 2011).

In this regard, the review suggests that policy and governance issues can act as both adaptation enablers and constraints, and thus become key determinants for an effective reduction of rural vulnerability. Public administration at different scales—from municipal to national governments, as well as the EU—can support adaptation through financial and other resources, and it should encourage further stakeholder involvement and public debate in rural vulnerability and development issues. However, when doing so, governments should also be aware they can hinder adaptation through coordination and planning deficits. In other words, barriers are not just the absence of enablers. Doubling subsidies to climate-smart infrastructure in the agricultural or water sectors (e.g. through the EU's Next Generation Funds) should be sensitive to the availability of human, administrative, technical, natural, and socio-cultural resources in the targeted context to avoid implementation failures.

Relatedly, the review has also shown that there is a stark contrast between the relative weight of EU regulatory action as enabler, and the issues raised around planning (at country and regional levels) as a key barrier for adaptation. Most of the evidence about EU regulatory action in the reviewed studies concentrates on the water and agricultural sector, while evidence on planning issues is much more diverse sector-wise. EU regulations in the water and agricultural sector are core to the EU. Although they could be improved, they have had an important impact on Spain's water planning and management in rural areas since the country's integration in the EU (Iglesias et al. 2012). This has not been the case in the tourism or urbanization contexts, which have indeed gone through processes of erratic regulation (Escuela et al. 2018)

¹ The evidence on climate change-markets interactions was rather scattered covering very different understandings of markets (e.g. water markets, agricultural markets, pricing...).

and deregulation (Colantoni et al. 2016), respectively. Adaptation in these contexts may benefit from more EU regulatory action.

We acknowledge, however, that failure in governmental action for adaptation is not a unique feature of the Spanish case (Huitema et al. 2016; Biesbroek et al. 2013; Eakin and Lemos 2006). Policy-makers, as well as firms, NGOs, and other stakeholders, all bring ideas about vulnerability reduction, in order to shape institutions according to their respective interests (Blyth 2002). This heterogeneity complicates coordination and may result in the appropriation of adaptation by the same interests that produce social vulnerability (Barnett 2020). For instance, Barnett (2020) claims that the ‘developmentalism’ of adaptation based on infrastructure projects enables governments to demonstrate a response to environmental change while avoiding more politically risky regulatory responses, and satisfying the interests of capital by channeling money into the hands of construction firms. In an historical period in which neoliberal globalization is shaping state capacity and delivering increased governance tasks to private companies and NGOs, re-distributive policy could represent an important tool to increase adaptive capacity among those who may be more negatively affected by climate change and other stressors (Eakin and Lemos 2006).

Conclusion

Rural areas, which used to concentrate the largest share of human populations until the mid-twentieth century, are experiencing profound transformations. Environmental, socio-economic, and demographic changes affect rural livelihoods and wellbeing in complex ways. This article was set out to investigate how environmental, socio-economic, and demographic processes impinge upon rural vulnerability in Spain. We have reviewed the resulting impacts and which factors influence rural people’s sensitivity and adaptive capacity. We have identified a series of research and policy gaps that would need to be addressed in the coming years to generate a more nuanced understanding of how rural livelihoods experience change, and how policies and investments can support adaptation actions and rural wellbeing.

First, we have shown that, in Spain, rural vulnerability studies have been interested in multiple drivers and their interactions, with environmental stressors such as climate change and environmental degradation being more often considered than policy, market-related dynamics, and depopulation. A clear research gap in this regard is the lack of attention to social and institutional sensitivity aspects, which we find particularly problematic given that climate change and other drivers may deepen social inequalities. Second, we have also shown that most studies

lack grounding on vulnerability definitions and frameworks, which limits their comparability and blurs their contribution to the advancement of vulnerability theories and methods. Third, we have shed light on two main typologies of studies that diverge in their methodological approach (quantitative vs qualitative) and that reflect larger disciplinary divides between environmental and engineering sciences on one side and social sciences on the other. Finally, we have suggested that the interactions among vulnerability drivers and potential feedback loops point at the need to better coordinate and integrate rural investments and public policy. The role of the latter is still ambivalent when it comes to reduce their sensitivity to global change and enhance rural people’s adaptive capacity, inasmuch as policy is found to be both an enabler of social adaptation—by providing resources and ensuring stakeholder involvement, and a barrier as a result of policy coordination and planning deficits.

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