Economic impact of the drought in Spain: measurement for the adoption of measures

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Abstract

This paper aims to evaluate the economic implications of meteorological drought in Spain. The study seeks to provide decision-makers with crucial insights into the macroeconomic effects of drought, enabling them to devise mitigation strategies and minimise its impact on economic activity. The Partial Hypothetical Extraction Method (HEM) is employed within the Input-Output analysis framework extended to a Social Accounting Matrix (SAM) of Spain to achieve this goal. The database utilised for this analysis is the FNAM for Spain in 2017, in millions of euros, obtained from the Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) project, a collaboration between Eurostat and the European Commission. The study aims to estimate the economic impact of drought on the productive sectors of the Spanish economy in terms of sectoral production and GDP. This involves simulating the partial reduction in value-added resulting from variations in average water productivity per gross value added, based on the drought indicator SPI-24. Three scenarios are generated: 1) drought, 2) moderate drought, and 3) severe drought. In quantitative terms, the simulated drought scenarios could lead to a drop in GDP of 0.88% for the drought scenario, 1.61% for the moderate drought scenario, and 1.76% for the severe drought scenario. Additionally, it is important to recognise that water scarcity hampers the social and economic development of cities and regions beyond the results in quantitative terms.

Keywords: Input-Output Models, Social Accounting Matrix, drought, economic impact.
JEL codes: C67, C68, D57, D58, Q25, Q54

1. INTRODUCTION

Climate change is a crucial global issue due to its far-reaching consequences. While it may not be the sole cause of drought, it has been found to affect the frequency, duration, and severity of extreme weather events. Urbanisation, population growth, and increased production exacerbated the scarcity of natural resources, leading to a greater need to conserve these resources (Ding et al., 2011). To address the impact of climate change, which can increase the likelihood of droughts (Jehanzaib et al., 2020), the European Commission is taking steps to adapt the European Union (EU) policies on climate, energy, transport, and taxation. This includes an ambitious target of reducing net greenhouse gas emissions by at least 55% by 2030 (European Commission, 2019) to mitigate the effects of climate change on phenomena such as droughts.

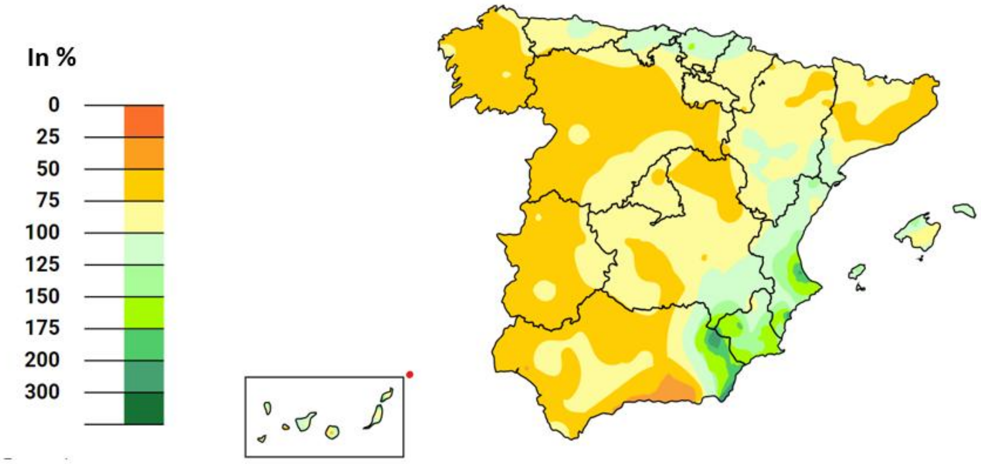
According to the Ministry of Ecological Transition and Demographic Challenge (2023), there are different types of droughts: meteorological drought, hydrological drought, agricultural or hydro-edaphic drought and socio-economic drought. In this study, we will focus on meteorological drought since it is the drought that gives rise to the other types of droughts and usually affects large areas. It is said that one is in meteorological drought when there is a continuous shortage of precipitation. The shortage origin of precipitation is related to the global behaviour of the ocean-atmosphere system, where some factors like the increase of the gases of greenhouse effect influence. There are different methods of quantifying meteorological drought. One is the Standardised Precipitation Index (SPI), which is based on the probability of precipitation in any period. McKee (1993) developed a method to quantify the precipitation deficit over multiple periods. These periods reflect the impact of drought on the availability of different water resources. SPI is calculated for periods of 3, 6, 12, 24 and 48 months, and the SPI calculation for any location is based on long-term rainfall records over the desired period. This study uses the 24-month SPI as a meteorological indicator of drought as it is a proxy indicator of long-term impacts, i.e. when precipitation anomalies over 24-month accumulation periods induce a reduction in reservoir and groundwater recharge.

Droughts arise gradually and extend for long periods, which makes it difficult to quantify their impact; however, the effects of this natural phenomenon can be direct and/or indirect (Jenkins et al., 2021; Cochrane, 2004; Rose, 2004). The first would be those specific to the sector with changes in production, added value or employment related to the activities that use water as a critical or essential part of their production process, such as public water supply, agriculture, or water supply for electricity (Freire-González et al., 2017). Indirect effects would follow from direct effects; that is, a reduction in supply could affect a company's productivity and, therefore, the flow of goods and services through sectoral interconnections and supply chains.

In this sense, Spain is facing uncertainty due to drought. Figure 1 shows the accumulated precipitation for the hydrological year 2021-2022 as a percentage of the 1981-2010 average. The 2021-2022 hydrological year has been the third driest since records have been kept in the last 61 years. The accumulated rainfall in Spain from October 1, 2021 to

September 30, was 25% below normal. Moreover, that is the average because there are large areas where the precipitation deficit hovered around or exceeded 50%. As can be seen in the map, in the western and southern thirds of the peninsula, there was less rainfall than expected, while in the Levante, from the south of Almeria to the Ebro delta, and in part of the Cantabrian coast, it has rained more than usual.

FIGURE 1. ACCUMULATED PRECIPITATION CONCERNING THE AVERAGE OF THE PERIOD 1981-2010. 2021-2022 HYDROLOGICAL YEAR. IN PERCENTAGES.



Source: Agencia Estatal de Meteorología (AEMET) (2022).

To address this issue, the Spanish government evaluated their Special Drought Plans in 2017-2018 (BOE, 2016; BOE, 2018). These new plans differentiate between drought, a natural occurrence unrelated to human water use, and scarcity caused by temporary difficulties in meeting the various socioeconomic water demands. Drought stems from a lack of precipitation, while scarcity results from mismanagement or misuse of water resources. These distinctions highlight the importance of developing and enhancing environmental policies, particularly those to mitigate long-term drought effects. This can be achieved by implementing mechanisms that allow markets to adapt to drought periods without significantly impacting production. To minimise the effects of drought, it is essential to anticipate and mitigate its impact through economic, technological, social, and environmental evaluations, which will guide resource allocation towards effective implementation and results.

The above motivates this research, which aims to assess the economic consequences of meteorological drought in Spain. The analysis focuses on the long-term precipitation shortage for the hydrological year 2021-2022 measured through the SPI-24 index, which, in turn, indicates the low level of water flows and river basins. Drought in Spain is intensifying due to water scarcity and lack of precipitation. This decrease is a severe problem and will limit the capacity to meet urban, industrial and agricultural demands (Freire-González, 2011). Therefore, we will use the change in average water productivity per gross value added (GVA) at the sectoral level as an indicator of water use performance so that we can reflect the pressure on water resources from different economic activities and thus differentiate the impact of different drought scenarios on sectoral production. The study's findings aim to provide decision-makers with valuable information on the macroeconomic implications of drought, allowing them to define mitigation strategies and minimise the impact on economic activity.

This work is divided into the following sections. In section two, the methodology and the database are explained. Then, in section three, the proposed research scenarios are described. Section four presents the results obtained. Finally, section five offers the discussion, and section six presents the main conclusions.

2. METHODOLOGICAL APPROACH AND DATABASE

Several studies have analysed the impact of drought in different countries, such as Mexico (Baja California Sur and northwest), Venezuela, Peru, and Uruguay, through climatic indicators and focused on ecological, agricultural, and hydraulic applications (Troyo et al., 2014; Cruz et al., 2014; Sosa, 2016; Olivares & Zingaretti, 2018). In contrast, other studies have focused on measuring the economic impact of droughts at the national and regional level through multisectoral modelling, such as those conducted by Freire-González et al. (2018) for the United Kingdom, Sisto et al. (2011) for Mexico, Goodman (2000) for Colorado, Pagsuyoin & Santos (2021) for the state of Massachusetts and the U.S. National Capital Region, and the one conducted by Park (2009) for Korea. Similarly, this has been done by Jenkins et al. (2021), Chuenchum et al. (2017), Bauman et al. (2013) for Colorado and Eamen et al. (2022) and Garcia-Hernandez & Brouwer (2021) for Canada, or Berrittella et al. (2008) for allocation of a scarce resource trough pricing or taxation on an international data set. All of these, with different approaches, have combined water resources or mathematical programming models of equilibrium displacement with multi-sector modelling to include the reliability of the water management system and detail its performance. The above reinforces the relevant importance of the subject in defining economic policies that anticipate and mitigate its effects.

In Spain, the problem is on the table due to the high incidence in different regions and effects already observed; studies by Monreal (2006) focused on drought management or by García-Haro et al. (2014), who explain the vulnerability of vegetation to this phenomenon. However, few studies have focused on analysing the impact of a drought in Spain despite the size of the problem in the Iberian Peninsula (Del Moral & Hernández-Mora, 2015). Espinosa-Tasón et al. (2022) analyse the economic impact of droughts by applying the economic surplus to the last severe drought in the Andalusian agricultural sector. Gil-Meseguer et al. (2020) developed an econometric model to analyse the variability of the economic performance of irrigated agriculture, which allows for determining the proportion of production that varies due to the availability of irrigation water. Berbel and Esteban (2019) analyse drought in three countries, including Spain, with similar social and climatic characteristics through a comparative analysis of the reforms implemented in the three regions and the results obtained.

Multisectoral analysis has been conducted using various methodologies in Spain, as in other countries. This type of analysis is essential in measuring the economic impact of different sectors. For instance, using the Input-Output framework, Pérez y Pérez & Barreiro-Hurlé (2009) conducted a study that estimated drought's direct and indirect economic impacts in the Ebro basin. Gomez et al. (2004) analysed a measure of water rights allocation through voluntary water exchanges to cope with droughts to measure the gains associated with the measure through a General Equilibrium Model. Freire-González (2011) analyses the macroeconomic impact of water supply restrictions by estimating aggregate production functions, including water consumption by sector, through an Input-Output Model for Catalonia.

Roibás et al. (2007) analysed water rationing pricing policies during a drought in Seville, Spain, comparing the welfare loss due to supply cut-off. Tirado et al. (2010) simulated the effects of an agricultural water market on the agricultural sector with problems of water supply reductions in the Balearic Islands through a Computable General Equilibrium (CGE) Model. Almazán-Gómez et al. (2021) used an integrated multiregional hydro-economic modelling framework (a combination of hydro-economic modelling and a multiregional Input-Output Model) to analyse the spatial and temporal dependencies between economic agents in different regions and watershed areas of the Ebro River basin. Jenkins (2013) has also contributed to the problem analysis through an input-output analysis to estimate indirect losses from direct drought shocks in Spain. The study highlights the importance of considering indirect economic losses to provide more complete economic estimates of drought losses under climate change and evaluate the benefits of future mitigation and adaptation strategies.

Accurate information on their economic and social effects is crucial to mitigate the impact of natural phenomena like drought. This information helps budget allocation and management, ensuring adequate and effective measures (Iglesias et al., 2009). Therefore, these economic effects should include the effects of declines in the output of various industries and interactions and transactions between industries and economic sectors (Cochrane, 2004; Rose, 2004; Ding et al., 2011), which are perfectly measurable through multi-sectoral models.

Several studies have found that linear and non-linear general equilibrium models are viable tools for measuring water prices and sectoral reallocation of water in Spain. These models help determine both direct and indirect impacts of external changes, such as political changes in water management. They also illustrate relationships between different economic agents.

The general equilibrium theory introduced by Walras (Debreu, 1989) has been widely used, primarily thanks to the development of Input-Output tables and Social Accounting Matrices (SAM). Linear SAM models, for instance, use a multiplier matrix to capture interdependence effects between endogenous sectors, making them suitable for analysing the economy's circular income flow (Round, 2003).

SAM models capture the flow of income from households to production sectors and the interdependence of products. They treat households similarly to productive sectors, enabling analysis of intersectoral relationships and links between household income and spending. Compared to other models, SAM models include all information reflected in the Input-Output table plus flows between value-added and final demand, making them more comprehensive (see Table 1).

TABLE 1. SCHEME OF A SAM.

	PRODUCTION	**PRODUCTIVE FACTORS**	**INSTITUTIONAL SECTORS**	**CAPITAL**	**FOREIGN SECTOR**
PRODUCTION	intermediate consumption		Public sector and household consumption	Gross capital formation	Exports
PRODUCTIVE FACTORS	Value-added factor payments				
INSTITUTIONAL SECTORS	Taxes on activities and goods and services	Allocation of factor incomes to institutional sectors	Current transfers between institutional sectors	Taxes on capital goods	Transfers from the rest of the world
CAPITAL		Consumption of fixed capital	Savings of the institutional sectors		Foreign saving
FOREIGN SECTOR	Imports		Transfers to the rest of the world		

Source: Cardenete y Moniche (2001).

Following Stone (1978) and Pyatt and Round (1979) from de SAM, the exogenous accounts determined outside the economic system and the endogenous accounts are defined, a change in these exogenous accounts is introduced, and the change simulated in endogenous accounts is analysed.

To fulfil the proposed objective, the Partial Hypothetical Extraction Method (HEM) is utilised within the framework of Input-Output analysis extended to a SAM modelling approach. The hypothetical extraction methods were first introduced by Paelinck (1965) as an alternative to classical methods and have since undergone refinement in subsequent works. This study specifically focuses on applying the method by Dietzenbacher & Lahr (2013) to address the effects of capacity constraints. Their application involves a scenario where the discontinuation of a plant within an industry leads to a reduction in the industry's capacity. Essentially, the partial HEM explores situations where a sector is only partially extracted. In our case, the value-added productivity of certain industries is reduced due to drought. The partial HEM has been incorporated into a SAM framework in studies by Pedauga et al. (2022; 2023) and Watson et al. (2017)[1]. While this research shares a similar approach, it addresses different questions. Our objective is to evaluate

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[1] This method has also been used by other authors and for different scenarios. To analyse supply chain vulnerability analysis (Shi et al. (2021); Yung et al. (2023)); to analyse public policy assessment (Weldegiorgis et al. (2023)); to analyse environmental impact (Zhao et al. (2015); Ali (2015)); to analyse effects of natural disasters (Dietzenbacher & Miller (2015)).

the macroeconomic consequences of variations in average water productivity per GVA caused by the drought in Spain, following the specifications outlined below.

We start with a structured SAM, represented as equation (1), and called T_{SAM}:

$$T_{SAM} = \begin{vmatrix} IO & 0 & C & K \\ VA & 0 & 0 & 0 \\ 0 & DI & 0 & 0 \\ 0 & 0 & S & 0 \end{vmatrix} \tag{1}$$

Similar to Zhao et al. (2015), the IO represents intersectoral relations, but we extend it by endogenising the income allocation and the capital account. In this sense, VA represents the generation and distribution of income (value-added) and describes how productive factors generate income and transfer it to their institutional sectors. C represents the final consumption expenditure, DI stands for disposable income, K denotes capital, and S represents savings.

For the purposes of HEM modelling, the SAM is then rearranged so that VA is placed as follows:

$$T_{SAM} = \begin{vmatrix} X_1 \\ X_2 \end{vmatrix} = \left|\begin{array}{ccc:c} IO & C & K & 0 \\ 0 & 0 & 0 & DI \\ 0 & S & 0 & 0 \\ \hdashline VA & 0 & 0 & 0 \end{array}\right| \tag{2}$$

To describe in more detail the type of partial extraction implemented, matrix (2) is divided into four sub-matrices representing each of the divisions taught above:

$$\begin{vmatrix} X_1 \\ X_2 \end{vmatrix} = \begin{vmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{vmatrix} \begin{vmatrix} X_1 \\ X_2 \end{vmatrix} + \begin{vmatrix} Y_1 \\ Y_2 \end{vmatrix} \tag{3}$$

Where X_1 and X_2 are the vectors m_1 x 1 and m_2 x 1, respectively, denoting the first vector the total output, disposable income and saving of the economy and the second vector the value added components. Similarly, Y_1 and Y_2 are the exogenous final demand vectors of similar magnitude as above.

The partial HEM based linkage measure quantifies how much the total output of the economy would fall in the face of a fall in VA. This implies that the sector $\bar{A}_{21} = VA(\hat{X})^{-1}$has an element that is partially extracted, leaving (3) as follows:

$$\bar{X} = \bar{A}_{-VA} \cdot \bar{X} + \bar{Y} = \begin{vmatrix} A_{11} & A_{12} \\ \bar{A}_{21} & A_{22} \end{vmatrix} \cdot \bar{X} + \bar{Y} \tag{4}$$

Where $\bar{A}_{-VA}$ is the new VA matrix, which represents a decrease in VA as a result of the change in the average water productivity per GVA, as follows:

$$\bar{A}_{21} = \Phi VA(\hat{X})^{-1} \text{ where } \Phi = (1 + \Delta\varrho_w^j) \tag{5}$$

The difference between (3) and (4) is solved for the sectoral production losses after the partial reduction of VA. $\Delta\bar{X}_{-VA}$ is used to show the difference before and after the partial removal of VA, which is solved as follows:

$$\Delta\bar{X}_{-VA} = X - \bar{X} = [(I - A)^{-1} - (I - \bar{A}_{-VA})^{-1}] \cdot \bar{Y} \tag{6}$$

The database used is a SAM based on the Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) project that provides a National Account Matrix (NAM) for Spain 2017 in millions of euros. This FNAM comprises 64 goods and services/productive activities according to the Classification of Products by Activity (CPA) and the European Classification of Economic Activities (NACE). It also presents disaggregated household consumption by classifying goods and services COICOP, the capital account by eight types of fixed assets and includes the financial account disaggregated by 15 financial instruments. This describes the flows in the Spanish economy for that year (EUROSTAT, 2019).

3. IMPACT SCENARIO

According to the Ministry of Ecological Transition in 2022, the hydrological year 2021-2022[2] closed as the third driest year in the last six decades, with a rainfall deficit of 12% according to the reference period 1981-2010. Spain's water reserves have been affected by the shortage of precipitation. For the hydrological year in question, reserves have fallen to an average of 40.10%. This is the lowest level since 1995, when severe human consumption and agriculture restrictions collapsed. The water year has been very dry overall, with a pronounced precipitation deficit in autumn and winter. This was partially mitigated by abundant rainfall in early spring.

Drought affects more territories than in previous decade, reducing water allocation and potentially threatening its availability and limitations in urban, industrial and agricultural use, being a potential risk for different Spanish sectors. The decrease in surface and groundwater availability in the Spanish management system during the last hydrological year is limiting the satisfaction of its demand, causing essential problems in the national economy. Although the level of reservoirs and the current circulating flow is below normal (hydrological drought), the current shortage's leading cause is the lack of rainfall (meteorological drought)[3]. However, meteorological drought indicators such as SPI-24 is a proxy indicator of long-term impacts as reflected in reservoir levels and flows.

Our research addresses the problem of drought from its initial phase, when meteorological drought appears, as it allows us to characterise the effects on the productive activity, as well as long-term climatic droughts leading to hydrological droughts (AEMET, 2023). In other words, meteorological conditions could determine an agricultural drought, and hydrographic levels lead to a hydrological drought and can also lead to a socio-economic drought.

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[2] The water year 2021-2022 started on 1 October 2021 and ended on 30 September 2022.

[3] As there is a time lag between the shortage of rainfall or snowfall and the reduction in river flow or lake and reservoir levels, hydrological measurements cannot be used as an indicator of the onset of drought, but they can be used as an indicator of its intensity (Entekhabi et al, 1992).

At present, there are various arguments about drought. For example, a lack of rainfall could affect agriculture in the first place since it limits the development of a certain crop in one of its growth phases due to insufficient soil moisture and appears with the slightest deviation before the onset of meteorological drought (Valiente, 2001). According to Olcina (1994), in Spain, dry years can be considered as those whose rainfall is reduced concerning the annual average in the different hydrographic basins as follows: Cantabrian, Duero and Ebro, 15-25%, Guadalquivir, 20-25%, Guadiana/Tajo, 30%, Levante and Southeast, 40-50%. Although the scarcity of rainfall is closely related to the level of water flows and reservoirs, as mentioned above, hydrological drought can be delayed for months after the onset of the rainfall shortage, or if the rains return quickly, it may not manifest itself at all. In addition, rainfall shortages can cause economic damage to a population affected by the phenomenon without necessarily restricting the water supply, as it is sufficient that some economic sectors are affected by the water shortage.

The above highlights the importance of analysing the economic impact of drought when there is an extensive and significant deviation of precipitation from the regime around which a society has established itself (Rasmusson, 1987), i.e. when meteorological drought appears. Although drought is more accentuated in certain regions, it affects more territories, so its effects could be homogeneous throughout the country. It has been found that different modelled drought episodes affect a large part of the national territory, so the effects are relatively homogeneous at the national level, according to Jenkins (2013).

Our research proposes to analyse the economic impact of the decrease in average water productivity per GVA depending on the drought indicator, using as a methodological framework the input-output analysis extended to a SAM by means of the hypothetical partial extraction method, as discussed in the previous section. We simulate the partial decrease in VA due to expected changes in water productivity per GVA by productive activity resulting from low rainfall and its intensity (according to the SPI and $\text{SPI}_{\text{intensity}}$ indices). This results in three scenarios: 1) drought, 2) moderate drought and 3) severe drought.

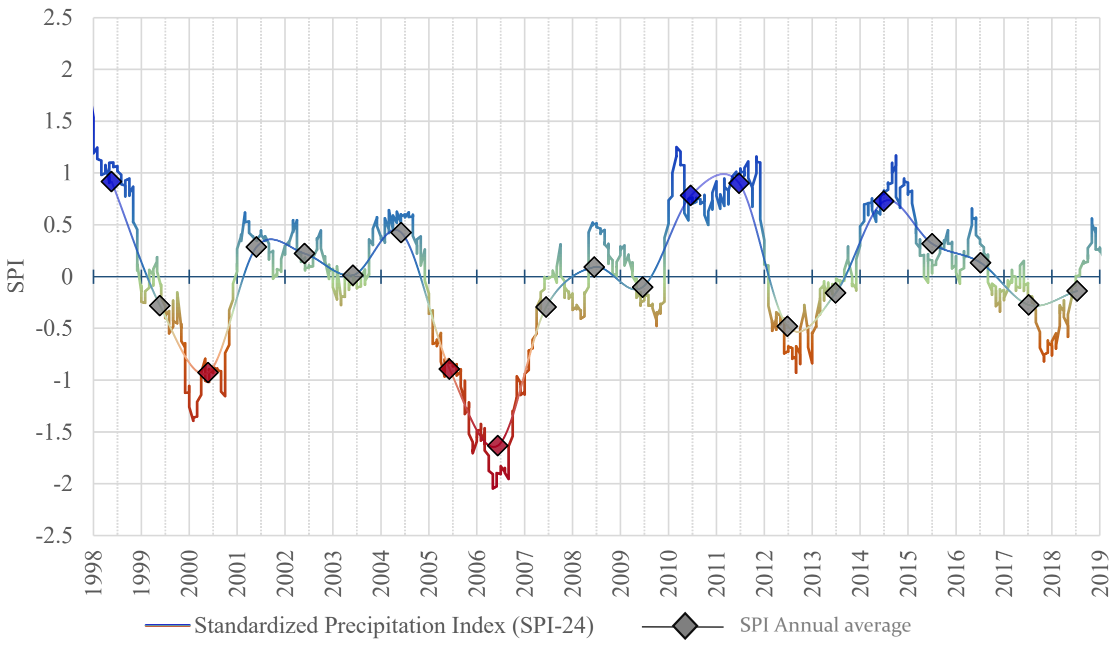
To do this, we first determine an indicator of the mean change in observed sectoral water productivity per GVA, defined as the annual percentage change in sectoral gross value added per thousand m^3 of water used, as shown in the following expression:

$$\Delta \varrho_t^j = Ln\left({WP_t^j}\big/{WP_{t-1}^j} \right) \qquad j = 1, \dots \dots, 64 \tag{7}$$

Where the subscript t represents the values observed in the period 1998-2018 and the superscript j represents 64 productive activities according to the FIGARO-NAM. $WP_t^j = \frac{VAB_t^j}{uw_t^j}$ and $WP_{t-1}^j = \frac{VAB_{t-1}^j}{uw_{t-1}^j}$, where VAB_t^j is the Gross Value Added by branch of economic activity in thousands of euros according to the National Accounts of Spain. uw^j represents water use in thousands of m^3 whose resources come from that supplied and captured from the environment by economic activity[4] according to the available information on water use by productive activity provided by the Instituto Nacional de Estadística (INE, 2014) in the Satellite Accounts of Water in Spain.

It should be noted that the variation in average water productivity per GVA was used to introduce the negative shock to VA resulting from changes in water productivity when drought reduces water abstraction into the extended input-output model. The volume of water used to calculate the water productivity indicator considers water supplied by the network and water abstractions. The indicator is constructed in a similar way to INE (2015).

FIGURE 2. DROUGHT INDICES DATASET FOR SPAIN.



Source: drought indices dataset for Spain (Consejo Superior de Investigaciones Científicas, CSIC) (n.d.) and own calculation.

The SPI and its intensity component ($\mathrm{SPI}_{\mathrm{intensity}}$) for a 24-month precipitation accumulation period calculated as the mean of daily observations for each of the years in question have been used as an indicator of drought, as shown in Figure 2[5]. As can be seen, positive values of the SPI indicate above-average precipitation and negative values indicate below-average precipitation. The SPI indicator will allow us to characterise three different drought scenarios in our model: a first scenario where drought conditions begin

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[4] The Spanish Water Satellite Account published by INE provides data for the series 1997-2010, not providing information for years after 2010. Instead, a Statistic on water supply and sanitation is generated with a series from 2000-2020 and the Survey on water use in the agricultural sector with data up to 2018. From this information, water use has been estimated for the years 2011-2018 by economic activity.

[5] In the figure, both lines represent the SPI-24. The coloured line represents the daily observations, while the smooth line represents the mean value in question. As can be seen, the mean is a good fit to the daily observations, which allows us to define the different drought scenarios represented by the index.

to appear, starting with an SPI of -0.5, corresponding to the average periods with below-average precipitation. A second scenario represents moderate drought, corresponding to the average of the SPI values recorded for three consecutive years of drought with a value of -0.93. A third scenario corresponds to the extreme drought scenario with the lowest SPI of -1.62.

Based on the SPI 24 calculated for our analysis, two additional variables were generated that differentiate the period analysed into dry and wet periods, taking as a criterion the SPI range between -0.5 and 0.5[6] , where records below -0.5 indicate drought in any of the three facets indicated in the scenarios defined. On the other hand, records above 0.5 indicate that this year has been wet. Index values between -0.5 and 0.5 would then characterise the period as "normal" by indicating that it is in the central part of the distribution.

As shown in Table 2, 22 linear regression models[7] were estimated to explain the changes in estimated water use productivities by productive activity, using equation (8). The dependent variable for the 1998 to 2018 sample for each productive activity is the change in sectoral water productivity per VA, as determined by equation (7). The independent variables used to explain this change include the SPI-24 and its intensity component, as well as the derived variables DRY and WET. Additionally, the variation in the capital (dK) and labour (dL), derived from the index of gross fixed capital formation by sector of activity and full-time equivalent jobs obtained from the INE (2023), are also considered explanatory factors. Therefore, the applied model can be expressed as follows:

$$\Delta\varrho_{i,t} = \beta_0 + \beta_1 \mathrm{spi24}_{i,t} + \beta_2 \mathrm{spi24}_{i,t}^{\mathrm{intensity}} + \beta_3 \mathrm{dry}_{i,t} + \beta_4 \mathrm{wet}_{i,t} + \beta_5 dL_{i,t} + \beta_6 dK_{i,t} + \varepsilon_{i,t} \qquad (8)$$

The equation (8) results is used to the 22 productive activities for the three drought scenarios characterised by the SPI-24 indicator and SP-I24$_{\mathrm{Intensity}}$. The decreases in water use productivity presented in each productive activity represent the shock introduced in the economy, thus corresponding to individual negative shocks according to the significance of the simulated models as shown in Table 2.

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[6] According to McKee et al. (1993) a dry period occurs when the SPI presents a continuous sequence of negative values, such that these are equal to or greater than -1. According to Agnew (2000) values below -0.84 are considered indicative of drought. For our analysis, due to the complex and differentiated spatial patterns that Spain may have, values below -0.5 will be taken as an indicator of drought.

[7] The model can be treated as a standard multiple linear regression model and can be estimated using Pooled OLS. However, this assumption is very restrictive and needs to be tested by allowing for heterogeneity across cross-sections. In this context, the pooled approach was rejected, and therefore, 22 OLS models were estimated to understand the changes in VA productivity. The remaining Total model corresponds to the average values represented by the general model shown in Figure 3.

TABLE 2. REGRESSION MODEL RESULTS FOR ESTIMATING THE VARIATION IN PRODUCTIVITY BY PRODUCTIVE ACTIVITY FOR 1998-2018

Industries (NACE)		Constant	SPI-24	SPI-24$_{Intensity}$	DRY	WET	dL	dK	R^2
1,2: Agriculture, livestock and forestry	Coef	0.055***	0.007	0.001	0.004	-0.032	1.386***	-0.137	0.450
	S.E.	[0.016]	[0.046]	[0.001]	[0.052]	[0.046]	[0.421]	[0.120]	
3: Fisheries and aquaculture	Coef	0.066**	0.105	0.002	-0.007	-0.123	-0.022	0.145	0.363
	S.E.	[0.026]	[0.080]	[0.002]	[0.094]	[0.081]	[0.422]	[0.205]	
05-09: Extractive industries	Coef	0.125**	-0.153	0.004	-0.085	0.072	0.854	-0.015	0.449
	S.E.	[0.046]	[0.172]	[0.004]	[0.196]	[0.172]	[0.543]	[0.120]	
10, 11, 12: Food, beverage and tobacco industries	Coef	0.022**	0.061*	0.002**	-0.084**	-0.066*	0.733*	-0.197**	0.794
	S.E.	[0.008]	[0.033]	[0.001]	[0.039]	[0.032]	[0.347]	[0.067]	
13, 14, 15: Textile, clothing, leather and footwear industries	Coef	0.000	-0.049	0.001	0.031	0.160	-1.147	0.137	0.305
	S.E.	[0.068]	[0.153]	[0.004]	[0.185]	[0.152]	[0.973]	[0.423]	
16: Wood and cork industries	Coef	0.151*	0.084	0.009	-0.062	-0.270	-0.106	-0.275	0.272
	S.E.	[0.074]	[0.252]	[0.006]	[0.308]	[0.249]	[0.828]	[0.542]	
17, 18: Paper and printing industries	Coef	0.023	0.008	0.001	0.107	-0.068	0.086	-0.032	0.611
	S.E.	[0.017]	[0.064]	[0.002]	[0.084]	[0.065]	[0.364]	[0.130]	
19: Oil coking and refining	Coef	-0.089*	0.304*	0.000	0.550**	-0.131	1.521	0.482	0.456
	S.E.	[0.047]	[0.168]	[0.004]	[0.194]	[0.166]	[1.050]	[0.313]	
20, 21: Chemical and pharmaceutical industry	Coef	0.052**	0.194**	0.002	0.213**	-0.206***	-0.189	0.121	0.445
	S.E.	[0.019]	[0.069]	[0.002]	[0.081]	[0.067]	[0.532]	[0.161]	
22: Manufacture of rubber and plastic products	Coef	0.053**	-0.089	0.001	-0.067	0.074	-0.080	-0.100	0.331
	S.E.	[0.019]	[0.071]	[0.002]	[0.089]	[0.070]	[0.472]	[0.167]	
23: Manufacture of other non-plastic mineral products	Coef	0.027	0.031	0.003	-0.007	-0.048	0.643	-0.182	0.205
	S.E.	[0.042]	[0.137]	[0.003]	[0.176]	[0.134]	[0.482]	[0.294]	
24, 25: Metallurgy and manufacture of metal products	Coef	0.016	0.029	0.000	0.146*	-0.014	0.236	0.108	0.562
	S.E.	[0.015]	[0.056]	[0.001]	[0.072]	[0.054]	[0.232]	[0.125]	
26, 27: Manufacture of electrical, electronic and optical equipment and materials	Coef	0.017	0.127	0.002	0.319	-0.131	-0.113	0.313	0.282
	S.E.	[0.054]	[0.163]	[0.004]	[0.203]	[0.161]	[0.784]	0.368	
28: Manufacture of machinery and mechanical equipment	Coef	0.039	-0.079	0.004	0.056	0.166*	-0.850	-0.105	0.701
	S.E.	[0.027]	[0.090]	[0.003]	[0.118]	[0.088]	[0.567]	[0.214]	
29, 30: Manufacture of transport equipment	Coef	0.022	-0.043	0.001	-0.051	0.079	0.229	0.084	0.195
	S.E.	[0.023]	[0.074]	[0.002]	[0.087]	[0.076]	[0.554]	[0.186]	
31, 32, 33: Miscellaneous manufacturing industries and repair of machinery	Coef	0.087*	0.180	0.011**	0.177	-0.203	-0.266	0.150	0.447
	S.E.	[0.047]	[0.180]	[0.004]	[0.231]	[0.181]	[0.472]	[0.361]	
35: Electricity, gas, steam and air-conditioning supply	Coef	0.052**	0.050	0.001	0.042	-0.076	0.456	-0.033	0.216
	S.E.	[0.020]	[0.073]	[0.002]	[0.082]	[0.071]	[0.310]	[0.062]	

Industries (NACE)		**Constant**	**SPI-24**	**$\text{SPI-24}_{\text{Intensity}}$**	**DRY**	**WET**	**dL**	**dK**	**R^2**
36: Collection, treatment and distribution of treated water	Coef	0.019	-0.040	0.001	-0.058	0.047	0.709*	-0.034	0.268
	S.E.	[0.015]	[0.059]	[0.001]	[0.069]	[0.054]	[0.399]	[0.067]	
37: Wastewater collection and treatment	Coef	0.056**	0.046	0.001	-0.025	-0.014	0.126	-0.005	0.313
	S.E.	[0.019]	[0.052]	[0.001]	[0.062]	[0.053]	[0.373]	[0.066]	
41, 42, 43: Construction	Coef	0.106**	-0.142	0.000	-0.148	-0.038	1.779*	-0.258**	0.533
	S.E.	[0.039]	[0.159]	[0.004]	[0.177]	[0.161]	[0.936]	[0.102]	
84.12: Public administration programmes for drinking water supply	Coef	0.045***	0.068***	0.001**	0.095***	-0.109***	0.308	0.016	0.845
	S.E.	[0.006]	[0.020]	[0.001]	[0.023]	[0.020]	[0.337]	[0.026]	
R: Other economic activities (42 to 99 excluding 84.12)	Coef	0.046**	0.050	0.001	0.123**	-0.051	-0.149	-0.084	0.418
	S.E.	[0.017]	[0.050]	[0.001]	[0.057]	[0.051]	[0.794]	[0.274]	
Total	Coef	0.046***	0.062***	0.001***	0.085***	-0.101***	0.303**	-0.012	0.873
	S.E.	[0.005]	[0.019]	[0.000]	[0.023]	[0.018]	[0.140]	[0.148]	

***p<0.001;**p<0.01; p<0.05

Source: own elaboration.

In this way, the expected decrease in average water productivity per GVA by productive activity is estimated, allowing us to define the partial decreases in VA of each drought scenario and their economic impact on GDP. It should be clarified that the drought scenarios are introduced with the productive activities that have emerged with a certain level of importance. These drought scenarios would mark the beginning of hydrological droughts. Table 3 shows the estimated average reductions.

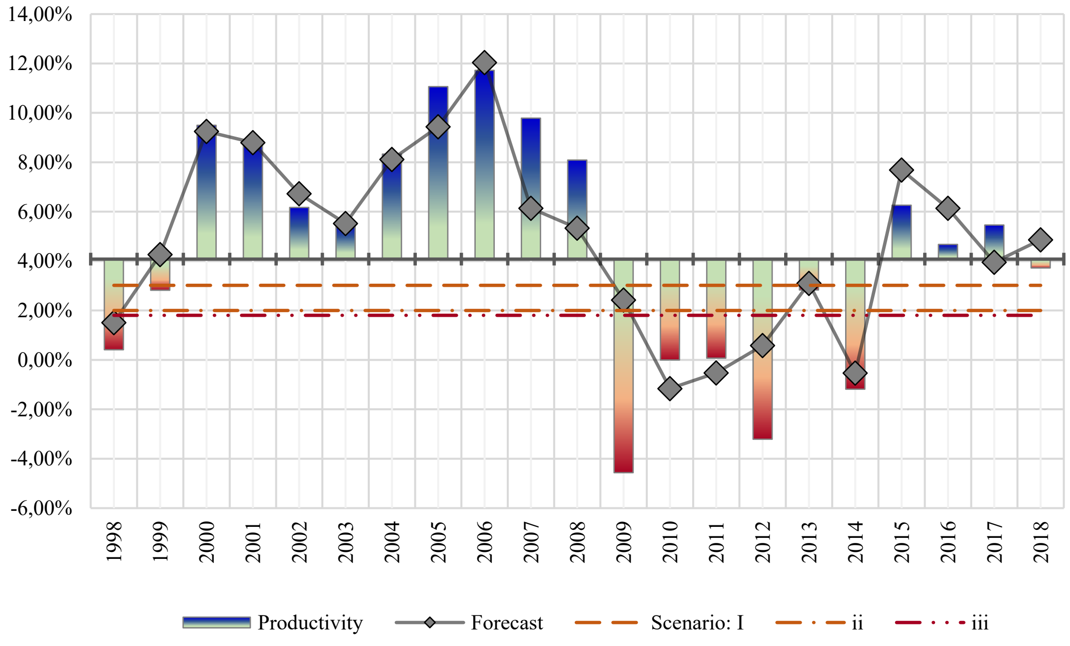
TABLE 3. DROUGHT SCENARIOS IN SIMULATION.

Scenario	SPI-24	$\text{SPI}_{\text{intensity}}$	Average partial decrease in VA
Drought	-0.50	14.94	-1.06%
Moderate drought	-0.93	26.52	-2.08%
Severe drought	-1.62	56.06	-2.27%

Source: own elaboration.

Figure 3 shows the average changes in the productivity of water use per GVA in its observed and estimated values and in the three average scenarios defined. As can be seen, the defined model generates an estimate of the decrease in average water use productivity that is in line with the observed one, except for the crisis periods of 2008 and 2016. Similarly, the estimated average productivity reductions for each scenario (Table 3) are shown with respect to the average calculated with the model represented by equation (8). As can be seen, Scenario III of severe drought records the largest drop in average productivity.

FIGURE 3. CHANGES IN AVERAGE WATER USE PRODUCTIVITY PER GVA.



Source: own elaboration.

4. MAIN RESULTS

As indicated in section 2, the drought scenarios are introduced in the economy, as represented by FIGARO-NAM, as a decrease in the VA of each productive activity through the partial HEM. Therefore, the partial decrease in VA of each productive activity is simulated according to the estimated coefficients in the linear regressions of each of the estimated models.

Table 4 shows the impact on GDP of the scenarios simulated. It shows the percentage change in the main macroeconomic variables and GDP from the point of view of expenditure, income and production.

TABLE 4. RESULTS OF THE DROUGHT SCENARIOS IN SIMULATION. IMPACT ON MACRO MAGNITUDES IN TERMS OF EXPENDITURE, INCOME AND PRODUCTION.

		Scenarios		
		I	*II*	*III*
Expenditure	Household and NPISH (S14/15)	-1.55%	-2.86%	-3.12%
	Government (S13)	0.00%	0.00%	0.00%
	Gross capital formation	-1.28%	-2.34%	-2.55%
	Exports of goods and services	0.00%	0.00%	0.00%
	Less: Imports of goods and services	-0.86%	-1.57%	-1.72%
	Gross Domestic Product	**-0.88%**	**-1.61%**	**-1.76%**
Income	Compensation of employees	-0.74%	-1.35%	-1.47%
	Taxes on production and imports less subsidies	-1.28%	-2.36%	-2.57%
	Operation surplus. Gross / Mixed-income. gross	-0.93%	-1.71%	-1.87%
	Gross Domestic Product	**-0.88%**	**-1.61%**	**-1.76%**
Production	Gross product at basic prices	-0.80%	-1.47%	-1.60%
	Intermediate Consumption	-0.76%	-1.39%	-1.52%
	Value added. gross	-0.84%	-1.54%	-1.68%
	Taxes less subsidies on products	-1.28%	-2.34%	-2.56%
	Gross Domestic Product	**-0.88%**	**-1.61%**	**-1.76%**

Source: own elaboration.

The results show that the three drought scenarios would generate a fall in GDP of 0.88%, 1.61% and 1.76%, respectively. It is observed that a severe drought scenario would generate a more significant impact. However, it is important to highlight that the Spanish economy shows signs of a strong reaction to the first signs of drought. The fact that drought appears produces a significant economic impact, while, as it intensifies, the negative impact, although greater, grows at a decreasing rate.

Regarding the impact on macro-magnitudes, in the three scenarios, the most significant impact on the expenditure side is household consumption, with a fall of 1.55%, 2.86% and 3.12%, respectively. On the income side, the operating surplus falls more than workers' compensation, falling by 0.93%, 1.71% and 1.87%, respectively. However, taxes on production and imports minus subsidies are most affected. From the point of view of production, value-added shows a significant negative impact of 0.84%, 1.54%

and 1.68%, respectively. However, the taxes less subsidies on products are affected the most.

As expected, the disaggregation at the sectoral level shows a similar trend to the macro-level results. For a better understanding, we will focus on analysing the sectoral impacts generated by a severe drought scenario, i.e., Scenario III. The main results show that the primary sector has a significant negative impact, with a fall of 1.39% in “Crop and animal production, hunting and related services”, 1.31% in “Forestry and logging” and 1.99% in “Fishing and aquaculture”.

According to Eurostat, Spain led the irrigated surface area in Europe based on data collected until 2019, and according to the report of the Food and Agriculture Organisation of the United Nations (FAO, 2020) entitled "AQUASTAT - Water and Agriculture Information System", which compiles data until 2017, Spain is among the countries with the largest irrigated surface area in the world. As the result obtained shows, although the impact is high, in periods of meteorological drought, the effect can be minimised by reserving water, which would make it possible to limit the fall in production until the hydrological drought arrives. The effect could be greater in their case, considering that the agricultural sector absorbs 90% of the available water resources due to the large amount of irrigated land (Dietzenbacher & Velázquez, 2007).

Of the manufacturing activities, "Manufacture of food products, beverages and tobacco products" shows a drop in output of 3.44%. This is mainly due to the water requirement in their production processes and dependence on the primary sector for intermediate goods, which generates secondary effects. Its production is fed by goods obtained in the agricultural sector; therefore, if its production level decreases, it will affect the level of manufactured food, beverages, and tobacco products. The interaction of the two is often referred to as the agro-industrial sector, where the latter generates the value added to the output of the former. Also affected are the Repair and installation of machinery and equipment (-1.75%); manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (-1.34%), Manufacture of coke and refined petroleum products (-1.23%), Manufacture of machinery and equipment n.e.c (-1.04%), Manufacture of other transport equipment (-1.31%), Manufacture of furniture; other manufacturing (-1.51%) and Repair and installation of machinery and equipment (-1.75%).

The activity related to the collection, treatment, and supply of water is affected by an impact of -2.07%. This activity has one of the most significant impacts because, as its main input is water, it manages or distributes water to the rest of the productive activities. In other words, the water treatment and distribution sector distributes water to the rest of the productive sectors. Therefore, its production is reduced, as are other water-intensive productive activities. This is because the water resources available for use depend in part on reservoirs or underground aquifers, and a significant part depends directly on the water collected (including reservoirs), which in turn depends on the level of precipitation in the short term; in our scenarios, when we talk about a prolonged drought, the impact may increase due to the limit to which reservoirs can reach, to the detriment of the supply to households (whose water use has been endogenised) and to the industrial fabric, accentuating the effects.

Other productive activities with a significant negative impact are Construction (-4.49%), Wholesale and retail trade and repair of motor vehicles and motorbikes (-4.49%), Accommodation; food and beverage service activities (-5.02%), Insurance, reinsurance and pension funding, except compulsory social security (-4.55%), Real estate activities (-5.05%) and Travel agency, tour operator reservation service and related activities (-4.32%).

As observed in the previous results, the impact of meteorological drought on the primary sector is important, since the lack of water (whether due to meteorological or hydrological causes) generates a moisture deficit that is prolonged over time, causing damage to land, crops and pastures. Similar results were found by Almazán-Gómez et al. (2021), but they used a hydro-economic model to assess water scarcity. However, meteorological drought has an indirect impact on the rest of the productive activities and economic agents, generating induced effects that are reflected in the results found in our analysis[8]. In turn, the circular flow of income and the endogeneity of households and other economic agents accentuate the results, negatively affecting their disposable income by 2.89%. The reduction in their income has an indirect and induced effect on the income of certain services, which are characterised by not being a priority in their income allocation and which, faced with a reduction in income, are sensitive to a consequent reduction in their income (Beltrán & Delgado, 2023).

5. DISCUSSION

Our research focuses on meteorological drought scenarios measured by the SPI-24 index and its intensity component. Our results align with other studies that have shown that the impact of drought on agriculture can be immediate due to its high water consumption and sensitivity to weather changes (Ding et al., 2011; Mechler et al., 2010). However, it should be noted that if the analysis were conducted at the regional level, the impact on the primary sector is likely to be greater in areas with higher meteorological drought impacts, such as the south of the country.

Furthermore, the results support previous studies by Jenkins (2013) and Almazán-Gómez et al. (2021), which show that drought has a significant impact on agriculture, livestock, forestry, energy, water supply and other specific industries. As a result, drought affects some productive activities more than others. However, the use of a SAM for Spain

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[8] The multiplicative *matrix M* can be multiplicatively decomposed into three different matrices according to Pyatt and Round (1979) as follows, $M = M_3 M_2 M_1$. This can be presented in an additive form as follows, $M = I + (M_1 - I) + (M_2 - I)M_1 + (M_3 - I)M_2 M_1$where $M_1 - I$ shows the net own or direct effects arising from internal transfers, $(M_2 - I)M_1$ quantifies the net open or indirect effects, and $(M_3 - I)M_2 M_1$the net circular or induced effects proposed by Stone (1978).

allowed us to include the indirect and induced effects of the reduction in VA due to drought-induced changes in water productivity, which reduced income and sectoral output.

This research explores the issue of drought, which is relevant in Spain and many other regions of the world. Drought can be approached, represented, and analysed in various ways. This study focuses on the economic impact of the lack of precipitation, providing initial indications of its effects. However, there is no standardised method or universal question to answer. Multiple factors must be considered, including methodological issues, hydrological infrastructure, water system efficiency, and economic conditions. The selection of variables depends on the objective, interest, and simulation method utilised.

As a contribution to the existing literature, part of which has been addressed in the introduction, the analysis is expanded not only to the agricultural sector but also to the rest of the productive activities through their intersectoral relations, which finally allows us to capture the direct, indirect and induced effects. Likewise, The introduction of an indicator of change in water productivity per sectoral GVA allows the impact of drought to be analysed in terms of the efficiency of water use by the economy, differentiating the impact by productive activity. This and the definition of three drought scenarios generate a more accurate approximation of the actual economic impacts.

Overall, water is essential for life on Earth and for the development of socio-economic activities by humans. The Mediterranean area is known for its susceptibility to water stress conditions resulting from significant variability in precipitation. In this context of water shortage, studies related to water use, which analyse structural relationships between economic activities and the use of water, become important (Freire-González, 2011).

6. CONCLUSIONS

In addition to being a vital element for life, water is also a strategic resource for any economic activity, so the extent to which water is available can significantly impact the development of a region (Dietzenbacher & Velázquez, 2007). However, by the very nature of the phenomenon, there is no single and definitive answer to the question: What is the economic impact of drought? The total and sectoral impacts will depend on the amount of the reduction in water availability (due to water restrictions, lack of water or duration and form of the drought, for example), as well as on the economic conditions, both structural and conjunctural (Sisto et al., 2011).

In quantitative terms, the three drought scenarios simulated could generate a drop in GDP of 0.88% for the drought scenario, 1.61% for the moderate drought scenario and 1.76% for the severe drought scenario. As can be seen, the simple phenomenon of drought from its onset would generate a significant negative economic impact in Spain, highlighting the magnitude and severity of the problem that could arise shortly.

In terms of methodology, measuring economic impacts through multi-sectoral models provides valuable information for decision-makers, as the sectoral results obtained include direct, indirect and induced effects. Although it is a widely used methodology for analysing the economic impact of natural and climatic phenomena, it offers a clean and simple way of considering the economic impact by estimating changes in the productivity of water use per GVA. One of our main contributions is to provide an updated perspective of the economic impacts in Spain, given the dimension and relevance of the problem.

Among other limitations, a drought scenario is generalised to the national level, which may underestimate local impacts. However, analysing water use and management at a given time and space should consider the various physical and climatic variables on which it depends (Almazán-Gómez, 2021).

In addition to the above in quantitative and methodological terms, it is also interesting to consider other issues, such as social or political ones. Water scarcity hinders the social and economic development of cities and regions (Aguilera-Klink, 1994). A priori, to cope with the growing problems due to water scarcity, it is clear that an extended and more efficient regulation of water consumption seems necessary. For example, since the end of 2021, restrictions on the use of drinking water have been applied to citizens. Although Spain has historically had drought problems, perhaps in the current situation of exceptional drought, this is an appropriate time to reflect and raise awareness in society about this severe problem we are facing and for which we must take measures to mitigate the future impacts that this phenomenon may cause. This work approximates the subject of study but can serve as a reference to the current problems of drought and scarcity. As future aspects for extending our results, we propose the inclusion of multi-regional Input-Output Models that would allow us to solve spatial variability.

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