Integrating a Regional Social Accounting Matrix With Environmental Accounts (Samea). An Illustration For a Spanish Region[1] [2]

Integração de uma Matriz de Contablidade Social Regional (Samea). Uma Ilustração Para uma Região de Espanha

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Abstract /Resumo

The increasing awareness of the deterioration of the environment during the past three decades has given rise to the enhanced development of environmental accounts by governments and international agencies. However, as they are generally compiled at a national level, they may not be sufficient to yield accurate information for environmental decision-making processes at the regional level. This paper provides a description of a method followed in elaborating the Greenhouse Gases (GHG) and water accounts for a regional economy under conditions of limited information. This methodology provides a solution to the recurring compilation divergences between these environmental and the economic accounts generally incorporated in the Social Accounting Matrix including Environmental Accounts (SAMEA) structure. As an illustration, the SAMEA for air emissions and water resources is applied for the case of a NUTS 2 Spanish region, Extremadura, for the year 2005. The proposed methodology is sufficiently general to create SAMEAs by replicating the water and the atmospheric emissions accounts in other regions.

A crescente sensibilização para a deterioração do meio ambiente, durante as últimas três décadas, determinou um reforçado interesse em contas ambientais por parte dos governos e agências internacionais. No entanto, como estas contas são geralmente compiladas a nível nacional, podem não ser suficientes para dar informações precisas para os processos de tomada de decisão ambientais a nível regional. Este artigo fornece uma descrição de um método seguido na elaboração de contas de emissão de gases de efeito estufa e da água para uma economia regional, em condições de informação limitada. Esta metodologia fornece uma solução para as divergências de compilação recorrentes entre as contas do ambiente e económicas, geralmente incorporadas na Matriz de Contabilidade Social com Extensão Ambiental (SAMEA). Como ilustração, uma SAMEA para as emissões atmosféricas e recursos hídricos é aplicada para o caso de uma região espanhola NUTS 2, a Extremadura, para o ano de 2005. A metodologia proposta é suficientemente geral para criar outras SAMEAs, replicando as contas da água e das emissões atmosféricas em outras regiões.

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Keywords: environmental accounts, social accounting matrix, atmospheric emissions, water resources, input-output table.

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Palavras-chave: contas ambientais, matriz de contabilidade social, emissões atmosféricas, recursos hídricos, quadro de input-output

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1. INTRODUCTION

Continuous economic growth combined with an increasing population, especially in developing countries, has led to an inappropriate use of environmental resources for years. Nevertheless, after years of stagnation, the awareness of the deterioration of the environment has become an increasing preoccupation of national governments and international agencies during the past three decades.[3] Along with the growing environmental concerns, environmental accounting has received a great deal of attention in its relationship with the economy. The information made available by integrated environmental and economic accounts (United Nations, 1993) provides descriptive statistics that help policy makers monitor interactions between the environment and the economy. In addition, work in this area is of considerable interest for strategic planning and policy analysis to identify the most appropriate sustainable tools. For these reasons, governments around the world have included environmental accounts in their national income accounting systems to enhance decision-making processes.

The creation of such databases has facilitated their links to different economic record-keeping structures, such as Input-Output (IO) tables and Social Accounting Matrices (SAMs), as exemplified by the National Accounting Matrix including Environmental Accounts (NAMEA).[4] Within the framework of the economy-environment linkages analysis presented by the NAMEA, a Social Accounting Matrix including Environmental Accounts (SAMEA) can be considered as the next relevant approach to integrate traditional monetary accounts with environmental data in physical units. Thereby, it is possible to obtain a hybrid accounting framework covering the multi-faceted attributes of sustainability which are environment, society and economy.

However, the construction of this kind of tool is not a minor issue, since building a SAMEA requires collecting a large volume of data that is often not fully available. In particular, elaborating a SAMEA for a regional economy faces problems that are not found at the national level. The extensive development of environmental data at the scale of the national level and the lack of affordable regional information of this nature become relevant constraints for the construction of these tools at a regional level. Hence, to keep track of environmental interventions in a regional economy, users of SAMEA often employ these tools at a national level, which could influence accuracy of regional results because of the differences among the national and regional environmental burdens. Consequently, as have been pointed by some studies (see Su and Ang, 2010 and Bouwmeester and Oosterhaven, 2013), the dependency on spatial aggregation for obtaining results may result in ineffective environmental policies or divert the focus from the most urgent regional environmental problems.

On the other hand, a recurring problem when constructing regional SAMEAs is that economic and environmental accounts are often not compiled by the same statistical agency. Therefore, they often differ with respect to either their classification frameworks, the base year, their sampling methods or their definitions. Specifically, for the construction of the GHG accounts, it becomes necessary to reclassify these emissions based on the International Panel on Climate Change (IPCC) or the Core Inventory Air Emissions (CORINAIR) inventories by the National Classification of Economic Activities, NACE-93 rev.1. (INE, 1993) involved in the SAMEA compilation. In these cases, methodological techniques aiming at producing these missing data and identifying the economic agent generating the GHG emi-

[3] The 20th Conference of the Parties (COP 20) held in Lima at the end of 2014 constituted the last major step towards offering a policy response to the key environmental issues.

[4] The NAMEA, introduced by the De Haan et al. (1994) consists of the framework of National Accounts with the supply and use of goods and services expressed in monetary units linked with integrated environmental accounts where the input of natural resources and the output of emissions and pollutants are expressed in physical units.

ssions and water use would enable regional governments to improve their knowledge base for sustainable development policies.

The difficulties encountered to develop these databases have indeed constrained the regional development of such tools. However, the elaboration of these matrixes at the national level has been more extensive. The first national development of these kinds of schemes was by Keuning and Timmerman (1995), who constructed a SAMEA for the Netherlands. Since then, Resosudarmo and Thorbecke (1996) incorporated GHG data along with the associated health effects of these emissions into the SAM of Indonesia. Alarcón *et al*. (2000) expanded the SAM of Bolivia in 1989 with social and environmental indicators related to emissions of GHG and fuel use in physical units. Xie (2000) constructed a Chinese SAMEA for 1990 incorporating emissions data jointly with the costs of reducing environmental pollution, taxes and the investment in natural environment. Lenzen *et al*. (2004) extended the Brazilian SAM with GHG information to assess the interactions between the production structure, income distribution, and atmospheric emissions. In Spain, Morilla (2004) developed a national SAMEA for 2000 applied to water resources and GHG emissions from the official data of the Spanish National Statistics Institute (INE). At the regional level, Flores (2008) incorporated water uses, water pollution and atmospheric emissions to the SAM of Aragon in 1999. More extensively, Sansoni *et al*. (2010) applied the National Accounting Matrix including Environmental Accounts (NAMEA) methodology to build a Regional NAMEA for three European regions: Emilia-Romagna (Italy), Noord-Brabant (the Netherlands) and Malopolska (Poland).

This paper describes, in detail, the elaboration steps of a regional SAMEA applied to water resources and atmospheric GHG. Therefore, the relevance of this study is clear because, to the best of our knowledge, there are no published works illustrating how a SAMEA including GHG emissions and water accounts could be built for a region under conditions of limited information. In addition, because of its sub-national scope, this study becomes even more important in countries such as Spain, where regional governments are responsible for promoting sustainable development. The methodology will be illustrated for Extremadura, a southwest NUTS 2[5] region of Spain, for 2005 year (SAMEAEXT-05).

Although exemplified for Extremadura, this methodology can be used as baseline for the construction of SAMEAs that represent the GHG emissions and the water use in other sub-national economies. SAMEAs created using this method may be useful inputs into IO and Computable General Equilibrium (CGE) models analyzing the role of water and GHG under various policy scenarios. In the case of Extremadura, its economic composition specially oriented towards a relatively polluted agrarian sector would justify the study of the air emissions by implementing these modeling techniques. As such, these regional models would also allow investigation into the economic costs of establishing diverse carbon abatement policies, such as: emissions standards, emissions taxes or the creation of a market for tradable emission permits. Firstly, it may enable farmers to take rapid and more targeted climate-smart responses. Secondly, it may help policy makers find the most adequate GHG mitigation options. Regarding water, these regional models facilitate an accurate assessment of the effects of different policies aimed at encouraging resource conservation in Extremadura:[6] for instance, a water pricing scheme to discriminate among different categories of users, such as an appropriate budget-neutral combination of water taxes or a reallocation of water among sectors to improve allocative efficiency.

The following sections describe the different steps of the method. Starting from the necessary construction of the economic accounts, section 2 elaborates a brief overview of the two stages that were followed in the development of a SAM for Extremadura in 2005 (SAMEXT-05). Afterwards, in section 3, the methodology to build the GHG emissions and water accounts for the same year is explained in detail. Once these satellite accounts are constructed, this information is used to build the SAMEAEXT-05. Finally, last section provides the main conclusions of the paper.

[5] The Nomenclature of Territorial Units for Statistics (referred to by the French acronym NUTS) is a hierarchical system for dividing up the economic territory of the European Union (EU) for statistical purposes. Above NUTS 2 is the 'regional' level of the Member State.

[6] It is worth noting that Extremadura is the region with the greatest length of interior coastline in the Iberian Peninsula, measuring almost 2,000 kilometers, and with the largest fresh water reserves in Europe.

2. ESTIMATION OF THE SOCIAL ACCOUNTING MATRIX OF EXTREMADURA IN 2005 (THE SAMEXT-05)

Estimating regional SAMs for a recent year is a difficult and challenging problem. The lack of an updated IO table and the problems in reconciling information from a variety of sources is often an inevitable reality. Given these difficulties when creating such a subnational database, we provide a procedure for estimating a consistent regional SAM starting from an outdated IO table and incorporating data that is not always compatible from different sources. As such, the process of implementation may easily enable the creation of these extended SAMs for other regions.

For the particular case of the region of Extremadura, the construction of an actual SAM by means of survey methods is not possible given the data constraints and financial resources available in this region. In this regard, it should be noted that only one input-output table, for 1990, has ever been constructed for Extremadura. In addition, although De Miguel (2003) already constructed a Social Accounting Matrix (SAM) for Extremadura in 1990, the need for a higher level of disaggregation of productive activities and institutional sectors entailed the construction of a New Social Accounting Matrix of Extremadura for that same year (NSAMEXT-90). Hence, along with the earlier input-output table for Extremadura (*Junta de Extremadura*, 1995), both the Regional Accounts and the National Accounts of Spain published by the *Instituto Nacional de Estadística* (INE) were used to compile the NSAMEXT-90.

The NSAMEXT-90 meets the need of a higher level of sectorial disaggregation for the purposes of a precise environmental-economic analysis. The primary sector has been divided into the agriculture, livestock and forestry activities because of the key relationships between each one of these sub-sectors and the natural environment of Extremadura.

The NSAMEXT-90 contains a total of 39 accounts, of which 26 correspond to production sectors (see table 1), that are partially grouped according to the industry categories at the NACE-93 rev.1. In addition, the NSAMEXT-90 the following accounts: two for production factors, labor and capital, two for the private sector (households and corporations), five accounts for the government (due to the specific disaggregation into different indirect taxes), one for saving/investment, and three for foreign sectors including the rest of Spain (RS), the rest of the European Union of 12 member states (EU-12) and the rest of the world (RW). Both the same number of accounts and the format used by the NSAMEXT-90 will be also adopted by the SAMEAEXT-05[7].

Table 1. Production sectors at the NSAMEXT-90

Production Sectors	
1. Agriculture.	14. Electric and electronic equipment.
2. Livestock.	15. Transport material.
3. Silviculture.	16. Other manufacturing industries.
4. Energy products.	17. Construction.
5. Water supply.	18. Commerce.
6. Food, drinking and tobacco manufacturing.	19. Hotels and restaurants.
7. Textile industry.	20. Transport.
8. Wood and cork industry.	21. Banking.
9. Paper.	22. Real estate sector.
10. Chemical industry.	23. Public administration.
11. Nonmetallic minerals.	24. Education.
12. Metallurgy.	25. Health.
13. Machinery.	26. Other services and social activities.

Source: Authors ‘elaboration.

Subsequently, the second step in developing the SAMEXT-05 is to update the NSAMEXT-90 to the year 2005 by using the Cross Entropy Method (CEM) proposed by Robinson *et al*. (2001). In the context of the

[7] The SAMEAEXT-05 is available upon request to the corresponding author.

SAM updating problem, this method estimates a new set of coefficients, a_{ij}^{1} (each element of the SAM divided by the total of its column or row) of a new matrix, SAMEXT-05, which minimizes the so-called "cross entropy" distance between coefficients of a prior SAM a_{ij}^{0} , the NSAMEXT-90, and these new estimated coefficients matrix, subject to a series of constraints.

In this research, the information used as constraints for the update mainly involved the use of data from INE sources, such as the Regional Accounts. Particularly, the sectorial compensation of employees and the gross operating surplus/gross mixed income vectors for 2005 are primarily used when applying this method. Subsequently, by subtracting these values from the gross value added by sectors from the Regional Accounts, restrictions are imposed on the sectorial net taxes on production. Furthermore, using the Spanish Household Budget **S**urvey (HBS) in 2005, Extremadura household consumption from production activities is also estimated (INE, 2004). Finally, it should be noted that the methodology preserves zero flows in the base year in the updating process.

Once the SAMEXT-05 is completed, the following section details the methodology used to elaborate the accounts of atmospheric GHG emissions and water resources, specifying those adaptations for the environmental context in the same year, 2005. Finally, once these satellite accounts are constructed, the SAMEAEXT-05 can be compiled.

3. THE ESTIMATION OF A REGIONAL SAMEA ON YEAR 2005: THE SAMEAEXT-05

A majority of sub-national economies face their own environmental problems, which may differ in intensity or importance from those associated at the national level. As pointed out by Su and Ang (2010: 10), "for a large country like (China, economic development and CO_2

Table 2. Aggregate Social Accounting Matrix and Environmental Accounts of Extremadura in 2005: The SAMEAEXT-05

<table>
<tr><th></th><th>(1-26)</th><th>(27-28)</th><th>(29-35)</th><th>(36)</th><th>(37-39)</th><th>CO_2</th><th>CH_4</th><th>N_2O</th><th>HFCs</th><th>PFCs</th><th>SF_6</th><th>Total GHG emissions</th><th>Residual waters to the public sanitation system</th><th>Direct water returns</th></tr>
<tr><td>Production Activities (1-26)</td><td colspan="5" rowspan="5">SAMEXT-05</td><td colspan="9" rowspan="8">ENVIROMENTAL ACCOUNTS</td></tr>
<tr><td>Production Factors (27-28)</td></tr>
<tr><td>Institutions (Government, Households and Corporations (29-35)</td></tr>
<tr><td>Saving/Investment (36)</td></tr>
<tr><td>Foreign Sector (37-39)</td></tr>
<tr><td>Water collection</td><td colspan="5" rowspan="3"></td></tr>
<tr><td>Water distribution</td></tr>
<tr><td>Physical water consumption</td></tr>
</table>

Source: Authors' elaboration.

emission intensities are quite different among its various provinces or regions." In addition, the geographical area for which data are collected and analyzed may influence accuracy of estimates obtained at a different spatial levels. Consequently, it is necessary to find ways to attribute those environmental problems to the structure of production and consumption existing in each economy. Within that context, we propose a methodology for the construction of the GHG and water accounts at a regional level that can be used for other sub-national economies.

Exemplified for the case of Extremadura in 2005 year, these accounts are aligned in 3 new rows and 9 new columns within the SAMEAEXT-05 (see table 2). Specifically, on the one hand, water accounts are represented by the addition of 3 different rows (water collection, water distribution and physical water consumption) and 2 new columns (residual water generated and discharged into the sewage system, and the amount of used water directly returned to the environment). In addition, GHG emissions are incorporated with 7 additional columns: Carbon dioxide emissions (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and total GHG emissions in terms of carbon dioxide equivalent (CO_2-eq).

The following subsections present the construction process of these environmental modules that finally assembles the SAMEAEXT-05.

3.1 Methodology for the estimation of the GHG emissions accounts.

A national inventory measuring a country's GHG emissions in a year is required by the United Nations Framework Convention on Climate Change (UNFCCC) to provide a benchmark for the country's emission reductions and subsequently to evaluate international climate policies. In Europe, countries have built these physical emissions accounts based on a system called Core Inventory Air emissions (CORINAIR). Hence, this database[8] provides a starting point in the compilation of the accounts for GHG.

This inventory presents data on GHG emissions according to the process-based SNAP-97 (acronym for Selected Nomenclature for Air Pollution, base 1997) classification. As consequence, the CORINAIR does not conform to the requirements of the NAMEA methodology that is based on the System of National Accounts (SNA) which classifies the activity units by economic sector according to the National Classification of Economic Activities, NACE-93 Rev. 1. To turn the CORINAIR inventory into the NAMEA classification, we use the correspondence between the SNAP-97 processes and the NAMEA economic activity-based classification developed by Tudini and Vetrella (2004).

While some categories of SNAP emissions can be easily assigned to NACE activities following the suggestions of these authors, other processes pose some problems in identifying the NAMEA activities in which they take place. It is thus necessary to assume some hypotheses and obtain additional data about certain processes (e.g., amount of used fuel, vehicle type or distance travelled, energy use data, etc.) in order to estimate the emissions distribution among the corresponding NAMEA activities. Table 3 provides the background information used as a criterion for the distribution emissions from all the Extremadura CORINAIR processes with no links with the NAMEA production sectors. The construction of this table required considerable labor-intensive work to analyze the different classification frameworks, disaggregate and then recompose these emissions according to the NAMEA requirements.

Once these emissions have been assigned, the next step consisted of distributing the emissions with multiple links to the NAMEA activity-based classification, according to Tudini and Vetrella (2004). Considerable time and effort were also devoted to reclassifying these emissions by NACE-93 Rev. 1. In this case, the different methods used to distribute all the Extremadura emissions with multiple NACE associations are noted in table 4.

Since different types of GHG have different environmental effects, it is necessary to obtain an equivalent measure in order to make them comparable in equal units. For that reason, we multiply the diverse GHG emissions in the SAMEAEXT-05 by their res-

[8] In the Extremadura case, this environmental database is obtained from the Spanish Ministry of Agriculture, Food and Environment.

Table 3. Distribution of the emissions from Extremadura CORINAIR processes without direct link to the NAMEA economic activity-based classification

<table>
<tr><th colspan="2">CORINAIR PROCESSES</th><th>BACKGROUND INFORMATION</th><th>CORRESPONDING SAMEAEXT-05 SECTORS</th></tr>
<tr><td colspan="2">04 06 18, “Limestone and dolomite use”</td><td>This type of rock is traditionally used for the production of cement.</td><td>Nonmetallic minerals including the cement production process.</td></tr>
<tr><td colspan="2">04 06 19, "Soda ash production and use”</td><td>This chemical could be especially found in many industrial and household products such as dishwashers, soaps or dyes.</td><td>Chemical industry.</td></tr>
<tr><td colspan="2">06.01.08, “Other industrial paint application”</td><td>Industrial coating paint application on metals, plastics, paper or glass not mentioned before in previous activities of this subgroup.</td><td>Metallurgy, machinery, electrical and transport industry.</td></tr>
<tr><td colspan="2">06 01 09, “Other non-industrial paint application”</td><td>Other coating paint application on iron structures, concrete and other materials, as well as other non-industrial coatings not included in other activities of the SNAP classification.</td><td>Commerce.</td></tr>
<tr><td rowspan="6">06 05 "Use of HFC, N_2O, NH_3, PFC and SF_6"</td><td>06 05 01, "Anesthesia"</td><td>Highly consumed in health service.</td><td>Health.</td></tr>
<tr><td>06 05 02, “Refrigeration and air conditioning equipment using halocarbons”</td><td>According to the Spanish GHG emissions account on 2005 year published by the INE, 4% out of the HFC emissions come from chemical industry, 14% from households[9], whereas the origin of the remaining 82% is not determined. In addition to that, 51% out of the PFC emissions come from metallurgy, 1% belongs to households, whereas the origin of the remaining 48% is not determined. Additionally, it is known that this process occurs in domestic refrigerators and freezers, air conditioning and refrigeration for retail (food coolers), compartments of cargo or passengers in all types of vehicles, industrial facilities, etc.</td><td>4% out of the HFC emissions is allocated to the chemical industry and 14% to the households. According to the background information available, the remaining 82% is distributed among the commerce, the hospitality industry and the transport, in accordance to their production. As for the PFC emissions, 51% is allocated to the metallurgy and 1% to the households. The remaining 48% is distributed among the commerce, the hospitality industry and the transport, in accordance to their production.</td></tr>
<tr><td>06 05 04, “Foam blowing except the use of polystyrene foam”</td><td>The total emissions from this process are also taken from the Spanish GHG emissions account on 2005 year and distributed by using the same percentages calculated in the previous process. The total HFC emissions arising from this process come from a wide variety of insulation applications including refrigerators buildings, automobiles, walls, furniture, packaging, etc.</td><td>4% out of the HFC emissions is allocated to the chemical industry and 14% to the households. According to the background information available, the remaining 82% is distributed among the transport material, the other manufacturing industries and the construction, in accordance to their production.</td></tr>
<tr><td>06 05 05, “Fire extinguishers”</td><td>The total emissions of this process are also taken from the Spanish GHG emissions account on 2005 year and distributed by using the same percentages calculated in the previous process.</td><td>4% out of the HFC emissions is allocated to the chemical industry and 14% to the households. The remaining 82% is distributed among the rest of the SAMEAEXT-05 production activities in the same proportion. As for the PFC emissions, 51% out of these total gases is allocated to the metallurgy and 1% to the households. According to the background information available, the remaining 48% is distributed among the rest of the production activities in the same proportion.</td></tr>
<tr><td>06 05 06, “Aerosol cans”</td><td>The total emissions of this process are also taken from the Spanish GHG account on 2005 year and distributed by using the same percentages calculated in the previous process. The emissions arising from this process come from different applications: firstly, for industrial purposes in the manufacture of ceramic and rubber products or the repair of agrarian tools and, secondly, for housing purposes in the use of paint, personal care, insecticides or medicines.</td><td>4% out of the HFC emissions is allocated to the chemical industry and 14% to the households. According to the background information available, the remaining 82% is distributed among the agriculture, the livestock and the industrial sectors of food processing, textiles, wood and cork, paper, non-metallic minerals, metallurgy, machinery, other manufacturing industries, construction and health, in the same proportion.</td></tr>
<tr><td>06 05 07 Electrical equipment (except 06.02.03)</td><td>According to the Spanish GHG emissions account on 2005 year published by the INE, the total sulfur hexafluoride (SF_6) emissions are fully allocated to the electric and electronic equipment.</td><td>Electric and electronic equipment.</td></tr>
</table>

Source: Authors’ elaboration

[9] Emissions by households come from transport activities, heating and others.

Table 4. Distribution of the emissions from Extremadura CORINAIR processes with multiple links to the NAMEA economic activity-based classification.

CORINAIR PROCESSES	CORRESPONDING NAMEA ACTIVITIES (NACE-93 Rev.1 CLASSIFICATION)	DISTRIBUTION METHODS
02 01 03, "Non-Industrial combustion plants<50 MWt (boilers)" 02 01 04, "Stationary gas turbines" 02 01 05, "Non-Industrial stationary engines"	Codes 10-95	This distribution method is based on the energy consumption by each production sector in the SAMEAEXT-05. According to Tudini and Vetrella (2004), this 3 low heat generation processes are related to the use of heating in institutional buildings. Hence, those economic activities using more energy for heating, emit more GHG.
02 03 02, "Combustion plants<50 MWt (boilers)" 02 03 04, "Stationary engines"	Codes 01, 02, 05[10]	This distribution method is based on the energy consumption by the agrarian sector in the SAMEAEXT-05. According to Tudini and Vetrella (2004), those economic activities using more energy for heating, emit more GHG.
03 01 03, "Industrial combustion plants < 50MWt (boilers)" 03 01 04, "Gas turbines" 03 01 05, "Stationary engines"	Codes 40	As 4 (*Energy products*) and 5(*Drinking water*) SAMEAEXT-05 production sectors include the 40 NAMEA activity, emissions arising from it are proportionally distributed between those two sectors in accordance to their production.
06 01 07, "Paint application: wood"	Codes 20 and 36	As 8 (*Wood and cork*) and 16 (*Other manufacturing industries*) SAMEAEXT-05 production sectors include the 20 and 36 NAMEA economic activities, emissions from them are proportionally distributed between those two sectors in accordance to their production.
06 04 05, "Glue and adhesives application"	Codes 19, 20, 35, 36, 50, 51 and 52	Emissions from these NAMEA activities are distributed among 7 (*Textiles*), 8 (*Wood and cork*), 15 (*Transport material*), 16 (*Other manufacturing industries*) y 18 (*Commerce*) SAMEAEXT-05 production sectors, which include the prior NAMEA economic activities.
07 01, "Passenger cars"	Codes 01-95, and 101[a]	Emissions from passenger cars are distributed among all production sectors and households in accordance to their expenses on the *commerce* production sector. Hence, those economic branches and households using more passenger cars, emit more GHG.
07 02, "Light duty vehicles < 3,5 t"	Codes 01-95, and 101	Emissions from light duty vehicles are distributed among all production sectors in accordance to their expenses on the *commerce* production sector.
07 03, "Heavy duty vehicles>3,5t and buses"	Codes 01-95, and 101[a]	Emissions from heavy-duty vehicles are distributed among all production sectors and households in accordance to their expenses on the *commerce* production sector.
07 04, "Mopeds and motorcycles < 50 cm^3"	-	Emissions from this process are fully allocated to households, which mostly own this kind of transport.
07 05, "Motorcycles > 50cm^3"	-	Emissions from this process are fully allocated to households, which mostly own this means of transport.
08 08, "Industry"[11]	Codes 10-37, and 45	Emissions from this process are distributed among the industrial and construction sectors in accordance to their expenses on the *commerce* production sector.
09 10 01, "Waste water treatment in industry"	Codes 15, 17, 21, 23, 24 and 27	Emissions from this process are distributed among 4 (*Energy products*), 6 (*Food processing*), 7 (*Textiles*), 9 (*Paper*), 10 (*Chemical industry*) y 12 (*Metallurgy*), in accordance to their production.

Source: Authors' elaboration. [a]Note: Households are included in the distribution.

[10] The processes 02 03 02 and 02 03 04 are related to combustion plants with low thermal capacity, mainly for heat generation and Combined Heat and Power (CHP) for individual use in agriculture, forestry and aquaculture.

[11] In this section, the emissions from the vehicle fleet and non-road mobile machinery, mainly in mining, construction, public works and industry, are included.

pective Global Warming Potential (GWP).[12] Specifically, in this paper, we use the potentials proposed in 1995 by the Intergovernmental Panel on Climate Change (IPCC)[13] for a horizon of 100 years (IPCC, 1995).

According to our estimates, the Spanish region of Extremadura emitted 7,982 CO_2-eq kilotonnes (kt) for 2005, which accounts for about 2% of the national GHG emissions during that year (432,328 CO_2-eq kt). This percentage is higher than the one that represents its GDP (1.68%) and slightly lower than the percentage for its population (2.47%) in Spain for the same year. Accounting for 8.2% of the total national area (41,634 km^2 versus 505,989 km^2), the emissions per km^2 in Extremadura (192.72 tonnes CO_2-eq/km^2) are 77% lower than those for Spain as a whole (854.42 tonnes CO_2-eq/km^2). However, in spite of the relatively small contribution of Extremadura to the greenhouse effect, compared to other Spanish regions, there remains a similar responsibility of this regional economy to implement GHG policies and thereby to contribute to the carbon emissions decrease worldwide.

In sectoral terms, the amounts of CO_2-eq generated by the livestock[14] and agriculture sectors amount to around 40% and 22% respectively of the total emissions generated by all productions sectors. Although it is of much lower relative importance, we could also highlight the CO2-eq emissions by the non-metallic minerals sector (6.62% of the sectoral CO2-eq emissions), the energy sector (6.35%) and other services and social activities (5.11%).

Nevertheless, within each sector, the generation of one tonne of CO_2-eq might involve a lower or a higher production, depending on the technology and/or process used. Hence, estimating the CO_2-eq emissions per monetary unit (referred to as *intensity factor*) of sectors may provide us with relevant information in order to apply the most sustainable policy measures aimed at reducing these air emissions. In this regard, livestock is the sector with the highest CO_2-eq emissions intensity factor. Consequently, the adoption of existing best practices and most efficient technologies in feeding, health and husbandry, and manure management could help Extremadura livestock herders cut GHG emissions. Other remarkable sectors with a significantly higher intensity factor than the average sectoral intensity (0.24 CO_2-eq tonnes per thousands of euros) are non-metallic minerals and agriculture. Measures aimed at reducing the CO2-eq emissions intensity factor in non-metallic minerals would be limited, since this is an energy-intensive industrial sector with limited substitution and energy reduction possibilities (Tarancón and Del Río, 2007). However, as for agriculture, in Extremadura this sector could still make an effort to decrease its intensity factor by specially reducing the use of mineral fertilizers and the burning of stubble and crop residues.

3.2 Methodology for the estimation of the Water Accounts.

By 2030, the Organization for Economic Co-operation and Development (OECD) predicts that over half the world's population will be living under conditions of water scarcity (OECD, 2009). As consequence, the lack of water will be expected to limit economic opportunity. Because this natural resource is used by many economic processes and is also for consumption, it is necessary to develop a platform that allows us to examine the exchanges of water between the environment and the economy at different territorial levels. This platform would allow us to develop more localized water management and to design the most appropriate policies for the optimal use of this natural resource. In this subsection, the construction of the water satellite accounts at sub-national level is presented.

Basically, by using multiple rows and columns, the water accounts represent the so-called integrated water cycle.[15] To illustrate this entire cycle, the water accounts cover the following: water collection, water distribution,

[12] The Global Warming Potential (GWP) is a relative index that measures the contribution to greenhouse effect of different gas emissions compared to the impact caused by a unit of CO_2.

[13] The IPCC periodically conducts a review process of these guidelines by providing updated emission factors. In this paper, we use the global warming potentials proposed in 1995, which is the base year of the Kyoto Protocol for the case of perfluorocarbons (PFC), hydrofluorocarbons (HFC) and sulfur hexafluoride (SF_6).

[14] Mainly, these CO_2-eq emissions are caused by methane releases from cattle.

[15] According to this term, water in the natural environment flows into the economy through direct collection or through extraction for treatment and distribution to other users. As a result of the production and consumption processes, wastewater is generated and, if not sanitized by a sewerage facility, may affect the quality of the water returned to nature. The difference between the total water use by every sector or household and the total volume of this resource, purified or not, less the return amount to the environment, reflects the physical consumption of water by each economic agent.

residual water generated and discharged into the sewage system, physical water consumption and the amount of used water directly returned to the environment.

However, regional accounting for water is considerably more complex than other resource accounts. The few accessible water statistics at the regional level usually lack detail with respect to the structural requirements of the SAMEA accounts. The compilation of water accounts requires the use of a wide range of national water data and the complementary estimation of a large amount of missing information.

The steps that were followed focused on *Agriculture* are (1) the obtaining of the national proportion of water use by this sector as well as the production of distributed water by the activity 01.41.00 from the NACE-93 Rev. 1, "*Operaciones de los sistemas de riego,*" by using data in 2005 from the INE satellite water accounts. Afterwards (2), this ratio was multiplied by the amount corresponding to the total water supply in Extremadura for 2005 by the same activity 01.41.00.

The quantities collected by *Livestock* and *Forestry* sectors are determined from both the relationship between the national amount of water collected by these sectors and from the total output of each sector at basic prices, according to the symmetric input-output table from the National Accounts of INE. Once these national proportions are estimated, they are multiplied by the total output of the livestock and forestry activities in the SAMEXT-05.

Regarding the amount collected by the Extremadura industrial activities in 2005, and with the exception of the sector *Drinking water*, these values are estimated from the data of the only Extremadura INE Survey on industry water use referring to 1999. Given these data constraints and to better adjust these quantities to reflect the actual reality of the region, they were updated using the growth rate of the water collected for industrial use in the whole of Spain during the period 1999-2005. Finally, with respect to the amount collected by the service sector, the same procedure as that followed for the livestock and forestry activities was used.

Water collection can entail either the direct consumption of this natural resource or its distribution to other end-users. This second procedure is performed by the activities 01.41.00, "*Operaciones de los sistemas de riego*" and 41.00, "*Captación, depuración y distribución de agua.*" For this first activity, the total amount of water distributed for its use in irrigation is obtained from the INE survey on the use of water in Extremadura agriculture. For the second activity, the amount of water treated and subsequently released by the activity 41.00 is obtained from the survey on the supply and treatment of water by the INE. Hence, the specific amount of water distributed to every production sector is estimated according to the share of each one in the 2005 total output of Extremadura at basic prices. Nevertheless, for the specific case of the drinking water supplied to households, this value is directly obtained from the survey on the supply and treatment of water.

As a result of the use of water in production and consumption processes, wastewater is generated and is either discharged directly to the natural environment, or is used as input by companies dedicated to the collection and treatment of residual water. The main activity of these companies is classified in the NACE-93 Rev. 1 code 90.01, "*Recogida y tratamiento de las aguas residuales.*" The wastewater discharged both by the production sectors and by Extremadura households is estimated from the ratios of the water amount discharged and the water volume obtained by every national economic agent in Spain for 2005. Following this same procedure and the same data sources, direct water returns to the natural environment by the different production sectors are determined.

Having estimated all the data related to water accounts, the physical consumption of this resource by the different economic agents can now be calculated. These data show that the total water consumption in Extremadura for 2005 accounts for 1,195.95 hm^3. According to our figures, the production subsystem accounts for the dominant share (99%) as compared to the consumption by households (1%). Within the production system, the agricultural sector is by far the largest consumer of water in Extremadura with a consumption by about 1,122.7 hm^3. Furthermore, among the rest of the production sectors, it is also worth noting the amount of water consumption by livestock (47.3 hm^3), silviculture (25.6 hm^3) and drinking water (4.8 hm^3). The 6.2 hm^3 of water consumed by households in 2005 is equivalent to a consumption of 15.9 liters per day per capita. This last amount accounts for a bigger volume of water than was consumed in Spain as a whole (over 15.1 liters per day per capita). One of the main reasons for this may be found in the lower price of drinking water in Extremadura (1.49 euros/m^3 in 2013 according to the survey on the supply and treatment of water by the INE) than the national average (1.83 euros/m^3 in 2013).

Next, just as we did in the case of the CO_2-eq emissions, we will summarize the most remarkable intensity factors obtained from the water accounts. Results show that agriculture uses the largest input of water per unit of economic output, followed by silviculture, drinking water and livestock. In other words, besides being the sectors with the highest water consumption, the data confirm that their water use is higher than their respective productions. Public administration, education and health are the sectors with the highest amount of water discharges to the public sanitation system per unit produced. This result primarily reveals the appropriate sewage facilities with which these sectors are usually equipped in order to treat their wastewater effluents before returning water back to the natural environment. The highest amount of water discharged without use into fresh surface waters or groundwater per unit produced occurs primarily during silvicultural and agricultural activities. As only a certain volume of the water used by these sectors is effectively consumed by crops, the remaining amount of this natural resource returns to rivers and aquifers and is available for other uses. Finally, as the other services and social activities involve those activities eliminating contaminants from wastewater, this production sector also shows a high intensity factor of water returns.

4. CONCLUSIONS

Building a social accounting matrix that includes including environmental accounts is very important, mainly on account of two reasons. On the one hand, a SAMEA includes a large amount of information that allows the estimation of the interactions between the economy and the environment. On the other hand, it can be used as a central core for modeling analysis. Thus, it may provide valuable appropriate sustainable development policies that would be sensitive to environmental-information that can help policy makers design economic interactions. In addition, at a lower spatial aggregation level, this regional table would lead to more accurate and refined results.

However, as noted previously, the difficulties in compiling a regional SAMEA are significant due to both the serious limitations in the information available and the existence of different classification typologies. Given the absence of a standard form for the compilation of these environmental accounts at regional scale, this paper presents an original and feasible problem-solving method that could be implemented to construct a SAMEA for any other sub-national economy.

Thus, the main purpose of this paper is to present a methodology to build a SAMEA for the case of a small regional economy under conditions of limited data. This regional SAMEA is composed of environmental accounts concerning atmospheric GHG emissions and water resources, both in physical terms. The paper particularly addresses two different subjects.

First, it tackles the difficulties in homogenizing data across the SNAP system and the NACE classification adopted in the SAMEA. Hence, tables 3 and 4 provide the results of some techniques that illustrate the linking of each process-based emission with the economic activity that makes use of that process. Secondly, this study deals with the problem centered on the estimation of regional water accounts when official data is not available. This way, a thorough analysis of the best available information sources has been made to reallocate the different water uses to their appropriate economic agents.

Illustrated for the case of Extremadura, a Spanish region where data constraints are particularly relevant, the methodology involves the following steps. Firstly, a Social Accounting Matrix of Extremadura in 2005 (SAMEXT-05) is prepared by updating the SAM for 1990. Then, the GHG emissions and water accounts are compilated. Finally, these two satellite accounts are integrated into the previously constructed SAMEXT-05 in order to obtain the SAMEAEXT-05.

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