"The Ecological Footprint of Industrial Water in island territories: Sustainability versus Resilience".

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Abstract: In the Ecological Footprint, water is not included as a biosphere product that is consumed; instead, it is transferred within its hydrological cycle between ecosystems and human communities. Water desalination powered by renewable energy sources can lead to provide enough water while reduce emissions and preserve biocapacity in the archipelago. In addition, conventional water depuration can switch to a biological depuration through decentralized constructed wetlands; thus resilience is enhanced not only because of the Carbon Footprint reduction, moreover desalted water is recycled raising the regional hydrological budget, and what is more, the use of vegetation (*Phargmites Autralis*) in those alternative depuration systems should increase biocapacity. While conventional industrial water cycle produces 26% of the energy production EF, the alternative scenario would compensate approximately 57% of it. According to this framework, desalted water can be recharged in the regional hydrological budget through decentralized constructed wetlands. It is a fact that desalination has environmental costs, and sewage treatment can compensate them; to certain extent resilient water management means a broad view of the whole artificial water cycle.

Keywords: constructed wetlands, drought regions, ecological footprint, renewable energies, resilience, water desalination.

1.Introduction

The diffuse aspirations in the field of sustainability can be embedded in the concept of resilience: the ability to persist and to improve the adaptive capacity (Tempkins and Adger, 2003: 5; Côte and Darling, 2010: 1). Both sustainability and resilience agree on the necessity of preventive actions in the management of natural resources, avoiding the vulnerability to emerging risks (for example, the consequences of climate change) and the preservation of the ecological integrity or biodiversity (Adger, 2003: 1). This study provides the implementation of the ecological footprint in the field of water management for an island territory considered as a semi-arid region the Canary Islands.

The Canary Islands serve as a paradigm for the serious consequences inherent in any island region devoid of conventional energy resources and not connected to continental networks. There is total foreign energy dependence, important weight of the transportation sector (sea, land or air) for the primary energy demand, fuel supplies exclusively are available by sea, and thus presents excessive vulnerability to energy crises. The island fact represents, in addition, an isolated electrical system, which in this case is extremely difficult to interconnect because of the significant depths between islands.

2. Method

To contextualize the ecological footprint of industrial water production in a region, previously we calculate its whole ecological footprint, starting from the methodology established by the Global Footprint Network (Kitzes et al., 2008). In this work, the Spanish national ecological footprint will be taken as reference- National Footprint Account (2005). The industrial production of water is segregated from the regional carbon footprint, thus it allows assessing the impact of two alternative scenarios: one completely dependent on fossil fuel, another powered by wind energy and sewage treated by constructed wetlands.

2.1.Calculation of the Ecological Footprint.

The ecological footprint is a relatively recent indicator, Mathis Wackernagel and William Rees, established their bases in the 1990s, in Canada (Wackernagel & Rees, 1996). This tool provides a measure of the biological area required to provide the resources to assimilate the wastes in a given population. To assess the consumption of goods and services we take into account national or regional productions, importations and exportations: Consumption = Production + Importation – Exportation. Their ecological footprints give us the information to get the consumption ecological footprint. The researches data are obtained mainly by regional official statistics, guided by the protocol propose at the Global Footprint Network (Kitzes et al., 2008).

2.2.The global hectare (gha).

The accounts of the ecological footprint indicate the use of the built-up areas, and the consumption of energy and renewable resources, both in crops, such as products of animal origin, timber and fish, standardized in biologically productive area units, called global hectares (gha) (Wackernagel *et al.,* 2005: 9). Each global hectare represents an equal amount of the world biological productivity average (Monfreda *et al.,* 2004: 233-234; Giljum *et al*., 2007: 8-15; Kitzes *et al.,* 2007: 6). Therefore, the conversion of units of mass in areas is feasible only for biotic products (there is no data of superficial abiotic appropriation) (Hubacek and Giljum, 2003: 138-139).

2.3.Calculation of the biocapacity.

Biocapacity is the capacity of an area to provide resources and absorb wastes. The biocapacity it is the counterpart of the footprint. The entire biocapacity of a nation or region is the sum of its bioproductive areas, also expressed in global hectares; we transform each bioproductive zone multiplying its area by the equivalence factor and the yield factor specific to that country (Ibid.).

3. Results and Discussion

Resource consumptions in the Canary Islands (4.76 gha/ha) and Spain (5.74 gha/ha) are higher than the world average (2.69 gha/ha). But more alarming is the offer of natural resources to support this level of consumption; the available biocapacity in the Canary Islands (0.5 gha/ha) is below than the Spanish one (1.34 gha/ha) and even lower than the global average (2.06 gha/ha). The abandonment of the agricultural land (up to 60%), the lack of reforestation policies, forests sustainable management and soil degradation programs are subtracting biomass of the environmental balance accounting. A long-term ecological footprint analysis would allow us to assess the advances or setbacks in the proposed interventions to address the current situation: reduce the footprint of consumption and increase the biocapacity.

3.1.Desalination's Footprint

The industrial production of water in the archipelago through seawater desalination and media-low salinity water (brackish water by marine intrusion or volcanic activity) is a consolidated effort with more than 40 years of learning. The Canary Islands produce more than 600,000 m^3/day of water by installed capacity (almost 30% at the national level and 2% at the world level), located as an international benchmark in terms of the number and range of desalination processes installed in the small area available. This activity focuses primarily on the islands of Lanzarote, Gran Canaria, Fuerteventura, and Tenerife, where exist insufficient availability to cope with water demand (51% of brackish desalination versus 46% of water desalination).

The carbon dioxide emissions related to the production of desalinated water become global hectares for the two assumptions made for the energy consumption: 3-5 kWh/m^3. Thus, it covers the range of energy consumption in the desalination plants inventory analyzed in the archipelago (the constant updating of improvements in the performance of the plants is uneven and requires a complementary analysis that is beyond the scope of this work)

Since energy production footprint represents emissions related to all economic sectors (involved in the emissions inventory of the Canary Islands), desalination is of little significance if we compare it, for example, with the transport assignment, 1,240 gha of the total amount (Campos, 2014). The energy consumption range (3-5 kWh/m^3) does not exceed 2% of all emissions related to the production of resources in the archipelago.

Focusing our attention on the Canary Islands' Production Ecological Footprint, the carbon uptake land is the greatest amount, it means 75%. The industrial production of water could be segregated from the regional production carbon footprint; thus it allows assessing the impact of various alternative energy scenarios. To have a meaningful approximation of its contribution, we detach the production carbon footprint of two broad sectors: electricity and heat production, nearly 57%, and transport sector, round about 35%. Seeing that, we will focus on the remainder 8% and the contribution of desalination to it.

As a result, while the average fossil desalination produces 21% of the production carbon footprint at the previous cluster sector, the average wind desalination decreases 40% of it. Due to this implementation, carbon dioxide emissions would be significantly reduced. Taking into account the wind farm potential, the archipelago wind qualities and improvements in the performances of wind turbines, this alternative scenario has technical and economical feasibility.

3.2. Depuration's Footprint

While conventional depuration of desalted water implies approximately 9,212 gha of the production carbon fixation land; the natural depuration of desalted water supposes roughly 1,262.5 gha.

It is a fact that constructed wetlands occupy territory; however they add positive externalities through catalyzing several economics activities around them: composting, agriculture, craftsmanship, leisure or education; in practice, the tourism business can take advantage of this multifunctional area.

In this research we assess the effects of hybrid constructed wetlands, combining sub superficial horizontal flow (SHF) and sub superficial vertical flow (SVF). To a certain extent, the regional climatology is favorable to reduce ratio of surface per equivalent person: 2.5 m^2/PE for FSV and 4 m^2/PE for SHF (DEPURANTA, 2008), but the calculations have been done with conservative data: 3 m^2/PE for FSV and 5 m^2/PE for SHF (Brix, 2004: 3-4). As a guesstimate those hybrid constructed wetlands would be assignable as agricultural land, to a certain extent 910,171,000 m^2 are abandoned and that combination will catch 17,960,000 m^2, it means 1.97% of that type unused land.

Besides, as a general rule, reed (*Pharmites australis*) should be the biomass reference, it is considered as one of the most distributed superior plants; in a sense, is considered as undesirable invasive species (DEPURANAT, 2008). The data obtained from nutrients extraction and accumulation capacity for reeds (Ruíz-Martínez *et al*., 2005 cited by Depuranat, 2008: 191), will allow estimating the amount of C fixation per year for this plant. The photosynthesis chemical equation and carbon dioxide synthesis helps to convert C into CO_2 through stoichiometric relations.

3.3 Industrial Water Cycle's Footprint

In sum, assuming that the whole water desalted is feasible to be depurated, we can estimate the amount of carbon dioxide related to those scenarios proposed; that is to say a fossil fuel scenario and a renewable scenario focus on wind desalination and biological depuration through constructed wetlands. On the one hand **fuel desalination** can contribute as average with 62,540 gha of the EF of carbon fixation (energy 3 consumption Ecological Footprint), which means 23% of the EF^*_p CO_2 (accepted as remainder after subtracting the carbon dioxide emissions related to energy production and transportation). Desalted water **fossil depuration** can be estimated as 9,211 gha, which means 3.3% of the EF^*_p CO_2. In accordance with these approximations the whole fossil industrial water production should be 71,751 gha, which represents 26% of the EF^*_p CO_2. On the other hand **wind desalination** would reduce 122,280 gha of the EF^*_p CO_2, what roughly implies a 44% reduction of the EF^*_p CO_2; moreover, a **biological depuration** with constructed wetlands (hybrid constructed wetlands) adds more advantages connected with the reduction of carbon dioxide emissions: 3,974 gha attributable to the absence of fossil fuels (- 1.4% of the EF^*_p CO_2) and the unavoidable carbon dioxide emissions imputable to the bacterial degradation of the sewage, 5,237 gha (+1.9% of the EF^*_p CO_2); even though if we implement reeds as biomass production in those wetlands, the carbon dioxide fixation through the photosynthesis should balance almost -38,104 gha (-13.8% of the EF^*_p CO_2); in that case it would have as a consequence the reduction of 159,121 gha (-57.5% of the EF^*_p CO_2).

4.Conclusions

i) the objective of this study is to estimate the viability of the Ecological Footprint as a tool for the enhancement of resilience through water management; ***ii)*** all insular constraints (geographic, climatic and socio-economic, historical, political or technical) make the water a difficult issue to analyze regionally. Each island has its own specificities to maximize its natural water resources (without endangering island ecosystems); ***iii)*** desalination is an option within a myriad of actions, for the sake of a resilient management in its natural, social and economic reality; ***iv)*** decentralize hybrid constructed wetlands offset water industrial production, enhancing biomass and bringing down carbon emissions related to conventional depuration.

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