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Ecological footprint analysis based awareness creation for energy efficiency and climate change mitigation measures enhancing the environmental management system of Limassol port

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ABSTRACT

Sea ports are very complex systems related to a wide variety of issues, the most important being waste production as well as water, air and soil releases. Furthermore, in port areas, several activities are carried out that may cause significant environmental impacts such as fisheries, industrial activities and storage of hazardous materials. Setting objectives and goals in terms of a comprehensive environmental management plan is of a great importance for sea ports. The main scope of this study is to introduce a novel approach to rationalize the environmental management strategies of sea ports based on the reduction of their ecological footprint. The object of the study is the Limassol sea port, a main cargo and cruise home port of the Mediterranean that serves one of the largest shipping fleets worldwide. In terms of this study, the most significant environmental aspects of the Limassol sea port are identified. An analysis of the main results of the calculation of the ecological footprint and carbon footprint is presented, by applying the Ecological Footprint analysis methodology. This study aims to deliver a comprehensive methodology that links the results of ecological footprint analysis with the environmental objectives of an ISO 14000 environmental management system.

1. Introduction

Sea ports are organizations that provide multiple activities including ship-related activities such as vessel traffic, cargo-related activities like cargo handling and storage and land transport to and from the port. Sea ports are considered as bodies of wealth production but also as sources of waste absorption, land and sea users and as a result environmental polluters. Sea ports requirements for resources and space have increased drastically their environmental impact. Environmental hazards resulting from sea ports activities include ship discharges and emissions, spills and leakage from ships, handling, hazardous materials and waterfront industry discharges. Sea ports depend on ecosystem for resources as well as spaces to host the required infrastructures and to absorb the produced wastes.

Cyprus ports authority is increasingly concerned with achieving and demonstrating sound environmental performance by controlling the impacts of Limassol sea port activities on the environment, consistent with its environmental policy and objectives. To this end, the authority is committed to adopt innovative solutions towards a sustainable management of Limassol port environmental performance. A well-established methodology employed to quantify the credits of ecosystem products and services in terms of the required bioproductive land and sea to supply the human activities is the ecological footprint (EF). The area of land or sea that is available to support a specific use is termed biological capacity (biocapacity) and is equal to the biosphere's ability to satisfy human demand for material consumption and waste disposal. EF and biocapacity calculation includes six forms of land use: cropland, grazing land, fishing ground, forest land, built-up land and also the uptake land to accept the carbon footprint.

The main scope of studies conducted in the past concerning the environmental performance of sea ports was the development of indicators to characterize the environmental impact of the usual activities in ports. Such rating systems include the Self Diagnosis Method (Darbra et al., 2004), the Strategic Overview of Significant Environmental Aspects (Darbra et al., 2005), the sustainable environmental management indicators for port authorities (Peris-Mora

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Nomenclature

Symbols

A_{CS}	global total continental shelf area (fishing grounds) [ha]
CC	carbon content of wet weight fish biomass (fishing grounds) [t C]
DR	discard rate for bycatch (fishing grounds) [−]
EF_C	carbon ecological footprint [global ha]
EQF	equivalence factor [global ha/ha]
F_{Crop}	amount of feed available from crop grown specifically for fodder (grazing land) [ha]
F_{Mkt}	amount of feed available from general marketed crops (grazing land) [ha]
F_{Res}	amount of feed available from crop residues (grazing land) [ha]
P_{Gr}	grazing land ecological footprint [global ha]
$Q_{S,i}$	estimated sustainable catch for species group i (fishing grounds) [fishing yield]
P_C	annual emissions of carbon dioxide (carbon footprint) [t CO_2]
PPR	primary production requirement (fishing grounds) [−]
PP_S	global sustainable harvest (fishing grounds) [−]
S_{Ocean}	fraction of anthropogenic emissions sequestered by oceans (carbon footprint) [%]
TE	transfer efficiency of biomass between trophic levels (fishing grounds) [%]
TL	trophic level of the fish species in question (fishing grounds) [−]
TFR	calculated total feed requirement (grazing land) [ha]
Y_C	annual rate of carbon uptake per hectare of forest land (carbon footprint) [t CO_2/ha]
Y_M	average marine yield (fishing grounds) [fishing yield/ha]

Abbreviations

EF	ecological footprint
EMS	environmental management system
ESPO	European Sea Ports Organization

et al., 2005). Issues regarding the application of environmental management systems and policy procedures in sea ports were also addressed in previous studies (Saengsupavanich et al., 2009; Marazza et al., 2010; Machado et al., 2013). On the other hand, EF research studies include attempts to further development of the methodology per se (Kitzes et al., 2007; Ewing et al., 2010) as well as to link EF and sustainability schemes (Cucek et al., 2012; Valada, 2010). Some studies also concerned the EF of particular systems, such as waste streams (Herva et al., 2010), nectarine production (Cerutti et al., 2010), swine manure fertilization in orchard (Cerutti et al., 2011) fruit production systems (Cerutti et al., 2013), and even municipalities (Buratti and Da Vinci, 2009). To the knowledge of the authors only Millan et al. (2010) conducted a study regarding the EF of a sea port, whereas no previous study is found in the literature with the aim to link the environmental performance of a port in terms of its EMS with its EF. To this end the research question which arises is to which extend the ecological footprint analysis could be incorporated into the environmental targets and objectives of an organization, with the subject of this study being a sea port.

The scope of this study is to quantify the EF of the Limassol port and to provide useful guidelines for the sustainable environmental management of sea ports in general. Following a brief section, in which the theoretical background and the methodology of this study is presented, a comprehensive literature review regarding previous studies concerning the environmental impact of sea ports and the EF is provided. In Section 4 the EF of Limassol sea port is quantified in Section 4.1 and in Section 4.2 the footprint analysis is used to prioritize the environmental management objectives of the sea port EMS.

2. Theoretical background and methodology

In this section, the theoretical background based on which this study was developed is presented. Useful information with regard to the subject of this study, the Limassol port, is given, in an effort to advise the readership for the environment and the conditions under which the study's principles are implemented. The main aspects of the ecological footprint calculation processes as well as of the environmental management systems according to the ISO 14000 are presented in Sections 2.2 and 2.3 respectively. Finally in Section 2.4 the employed methodology is introduced and explained.

2.1. Cyprus shipping fleet and the Limassol Port

Cyprus is a major ship management center worldwide with a total of around 60 ship management companies operating in its territory. As of 2014, the Cyprus ship registry ranks tenth among international fleets – with 1857 ocean going vessels of a gross tonnage exceeding 21 million tonnes (Cyprus Department of Merchant Shipping, 2014). With Cyprus an established player in the shipping industry, Limassol port (geographical location 34°39′00″N 33°01′00″E), has accumulated importance over time and is a center for numerous shipping companies. Considered as the main port of Cyprus, it commenced operations in 1974. It provides services to ships, loading/unloading of cargo and passenger traffic. The marine area of the port is 1 km^2 and its land area is 1.3 km^2. The quays at Limassol port have a total length of 1980 m and the covered spaces comprise 5 warehouses of total area 39,760 m^2. The annual amount of cargo handled in Limassol port exceeds 3.5 M tonnes whilst there are roughly 1 million passenger arrival and departures every year (Cyprus Ports Authority, 2014). The Cyprus Ports Authority currently employs at Limassol Port 242 people. The significance of the Cypriot shipping fleet as well as the size of Limassol sea port, indicate the importance of the investigated case study.

The layout of the existing infrastructure at the Limassol Port is depicted in Fig. 1.

2.2. Ecological footprint (EF)

The EF is a resource accounting tool that measures how much bioproductive land and sea is available on earth, and how much of this area is required for human use (Kitzes et al., 2007). The area of land or sea available to serve a particular use is called biological capacity (biocapacity), and represents the biosphere's ability to meet human demand for material consumption and waste disposal. The first academic publication about the EF was by William Rees in