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Research article

Energy efficiency and reduction of CO_2 emissions from campsites management in a protected area

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ABSTRACT

Campsites can be a pollution source, mainly due to the energy consumption. In addition, the green areas, thanks to the direct CO_2 sequestration and the shading, indirectly prevent the CO_2 emissions related to energy consumption.

The methodology presented in this paper allowed assessing the annual CO_2 emissions directly related to the campsite management and the consequent environmental impact in campsite clusters in Tuscany. The software i-Tree Canopy was exploited, enabling to evaluate in terms of "canopy" the tonnes of CO_2 sequestered by the vegetation within each campsite. Energy and water consumptions from 2012 to 2015 were assessed for each campsite. As far as the distribution of sequestered CO_2 is concerned, the campsites ranking was in accordance to their size. According to the indicator "T-Tree" or canopy cover, a larger area of the canopy cover allows using less outdoor areas covered by trees for the sequestration of the remaining amount of pollutants.

The analysis shows that the considered campsites, that are located in a highly naturalistic Park, present significant positive aspects both in terms of CO_2 emission reductions and of energy efficiency. However, significant margins of improvement are also possible and they were analysed in the paper.

1. Introduction

The atmospheric temperature rise is the consequence of increasing levels of carbon dioxide (CO_2) and other greenhouse gases (GHGs), such as methane (CH_4), chlorofluorocarbons, nitrous oxide (N_2O), and tropospheric ozone (O_3). Climate change, linked to the increase of GHG emissions, led the international community to significant efforts in order to reduce CO_2 emissions, according to the United Nations framework convention on climate change (United Nations, 1998) as well as the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009 (Accord, 2009). The CO_2 emissions, from 1990 to 2000, increased tenfold (IEA, 2014). Climate change can be affected by trees and by forests, as trees are sink for CO_2 through carbon fixing during photosynthesis and carbon storage as biomass. On the other hand, the mankind can affect CO_2 source/sink forest management, through fossil fuel emissions and biomass use (Nowak et al., 2002).

The international, effort aiming at reducing GHGs, was officially enshrined through the Kyoto Protocol (1997), an international agreement on global warming. The countries that signed this agreement, formulated action plans, according to the different degree of economic development, in an attempt to enforce regulations for the effective reduction of total emissions of GHGs. The "20 20 20 targets", also called EU Climate and Energy targets, includes a minimum 20% reduction in GHG emissions below 1990 levels, 20% renewable energy in final energy consumption, and a 20% reduction in primary energy use to be achieved by improving energy efficiency (Decision No, 2009; Union, 2009a, 2009b).

The rapid industrialization have led to the consequent intensive use of energy, the energy crisis, the environmental damages and the increase of CO_2 emissions. An inefficient use of energy causes high emission of Carbon Dioxide (CO_2) and can contribute to local pollution and other ecological damages. For this reason the estimation of CO_2 emission reduction, by saving energy consumption in small scale industries, can help to achieve their sustainability (Ganesan et al., 2011). For instance, a well defined control technique, in order to regulate voltage and frequency for high penetration of renewable energy in small island system, improved the efficiency and power quality indexes for critical loads and, consequently, reduced CO_2 emissions (Solanki et al., 2014). The estimation of the quantitative relationship among the carbon intensity of quality of economic growth and energy efficiency can predict future energy-saving targets in carbon emissions constraints (Nongnong, 2011). Some estimation methods were applied for reducing potential CO_2 emissions. In particular, the use of a special designed

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scenario analysis allowed to estimate the potential reduction of CO_2 emissions. For instance, it was shown that in Pakistan carbon tax, energy price reforms, diversification of energy supply in favour of cleaner energy and energy conservation are critical for the potential emission reduction (Lin and Ahmad, 2017). In addition, modelling represents a robust method in order to achieve sustainability in terms of economy, environment and natural resources, the assessment of potential energy saving and CO_2 emission reduction. For instance, a method based on modelling proved to be effective in measuring potential energy saving and CO_2 emission reduction for efficiency improvement (Bian et al., 2013). Furthermore, the implementation of an optimization model of energy demand, into which reduction paths were incorporated, showed that energy consumption varies under different emission reduction paths (Han et al., 2017).

As sustainability of the urban areas development is a priority, energy and CO_2 emission should be reduced. Particularly in the urban transportation systems, a simplified system dynamic model was developed in order to simulate the effects of urban transportation management policies and to explore their potential in reducing vehicular fuel consumption and mitigating CO_2 emissions. The results showed that both the fuel tax and motorcycle parking management policies are the most potential effective methods for limiting the growth of the number of private vehicles, the amount of fuel consumption, and CO_2 emissions (Cheng et al., 2015). Furthermore, in order to improve the urban areas sustainability and inform urban planning and climate change adaptation, a strategy for the reduction of CO_2 emissions from urban activities was developed, by assessing the carbon-reduction potential of rooftops equipped with solar panels in the 30% of their area (Lin et al., 2017).

The increase of CO_2 concentration, the main GHG, in the atmosphere is largely due to the use of fossil fuels and, to a lesser extent, to deforestation. Trees, through their growth process, play a key role in CO_2 sequestration, through their leaves, and in its storage. Therefore, the increase of the number of trees can slow down the accumulation of CO_2 in the atmosphere. Trees contribute to the so-called "ecosystem services" by mitigating the global warming and, consequently, the climate change, as they can be both CO_2 sources and storages. The ecosystem services are defined as the many and varied benefits that the mankind gains from the natural environment and from ecosystems.

Cities are the main sources of CO_2 emissions. In urban areas, the main function of trees consists in providing some ecosystem services by the carbon sequestration and pollution (mainly caused by traffic) control. The amount of CO_2 which can be sequestered by a tree is higher than 18 kg per year (Ferrini and Fini, 2011). A recent study showed the importance of the reduction of emissions generated by fossil fuels. Planting new trees may increase CO_2 sequestration and mitigate the effects of emissions from traffic. The study results show that 73.59 tons of CO_2 are removed by trees planted on the sides of the city streets of Vadodara (India). This amount represents the 22% of total estimated CO_2 emissions. For this reason, in this city the number of trees must be increased, in order to recover the 88% of CO_2 emissions (Kiran and Kinnary, 2011).

The urban forests can also improve the local climate through the ecosystem services, such as the shading, which reduces the radiant energy absorbed, stored and irradiated by building surfaces; on the other hand, the air flow, which affects the transport and diffusion of energy, water vapor and pollutants, is changed. Trees in urban areas also contribute to other ecosystem services by improving air quality, providing large areas where particulate matter can be trapped. In addition, the quantification of the mitigation the ultraviolet (UV) radiation on the ground by urban trees has been assessed through the exploitation of a mathematical model (Na et al., 2014). This model, implemented within the i-Tree model (Nowak et al., 2008), was used for assessing the effects of trees on UV exposure. Trees produced average UV Protection Factors (UPF) for pedestrians in tree shade, due to the highest percent canopy cover. Results can be used in developing landscape design strategies, in order to protect populations from UV radiation exposure and, consequently, to reduce health impacts. Better understanding how and to what extent urban trees may affect the environment will lead to a better management of urban green areas, resulting in significant cost savings for cities and more pleasant and healthy urban environment. Over the last 30 years the role of street trees has been emphasized, considering their aesthetic function as well as their importance in storm water reduction, energy conservation and air quality improvement. Along with environmental ecosystem services, street trees can produce also positive economic and social impacts (Mullaney et al., 2015). Concerning their environmental ecosystem services, street trees reduce water runoff, improve air quality, store CO_2, provide shade and improve biodiversity. In addition, trees have an important role in reducing emissions and noise from road traffic, being effective at diminishing noise and capturing pollutants, such as ozone, nitrogen oxides, sulphur oxides, sulphur dioxides, carbon monoxide, CO_2 and particles lower than 10 μm in size (Tallis et al., 2011). By providing shade and insulation, trees contribute to the decrease of consumption of fuel for heating and cooling (Ferrini and Fini, 2011). Concerning the social aspects, the well-maintained vegetation can reduce crime levels, due to a sense of community care by residents (Kuo and Sullivan, 2001). On the other hand, trees provide a physical screen for protecting pedestrians by vehicle injury. In addition, evapotranspirational (ET) cooling by trees decreases air temperatures and produces additional cooling energy savings (McPherson et al., 1994). Another study has showed that trees on the west and south sides of a house reduce summertime electricity use, while trees on the north side of a house increase summertime electricity use (Donovan and Butry, 2009). As far as the economic ecosystem services are concerned, street trees can contribute to the reduction of energy costs and to the income increase. About that, relatively dense shade during the summer can reduce cooling costs, as trees shade on homes and buildings reduces the inside temperatures and consequently reduces demand for power to cool buildings during hot periods of the year (Pandit and Laband, 2010). As the reduction of storm water flows is closely linked to the root uptake and canopy cover interception, the economic ecosystem services of street trees are mainly correlated with their physical variables (Killicoat et al., 2002). The possibility to quantify economic aspects can allow to easily understand and report them to policy and decision makers.

Concerning the tourist sector, the impact of the interaction of visitors with resources in parks and protected areas has been already assessed (D'Antonio et al., 2013). As the tourist numbers is expected to significantly increase in the near future, related direct and indirect impacts are foreseen. A recent study aimed to prevent, minimize or restore the possible negative ecological impacts of tourism (Tolvanen and Kangas, 2016). Furthermore, the integration of different techniques provides useful results from social science as well as recreation ecology assessment, through practical applications for the park and protected areas management. In order to achieve a sustainable tourism within protected areas, some guidelines have been developed to provide a conceptual background aiming to understand the park tourism and its management (Eagles et al., 2002). Furthermore, the success in the long-term can be guarantee through the stakeholders interactions.

Within the tourist sector, the campsite can be seen as a small urban area, due to the number of customers and, consequently, to the traffic increase during the summer. Therefore this important economic activity for many areas in Italy and in Europe represents also a source of pollution and of CO_2 emissions, mainly due to the energy consumption linked to the campsite activities (Katircioglu, 2014; Liu et al., 2011). Furthermore, in the tourist sector, transport significantly contributes to energy consumption and CO_2 emissions. Recently, the identification of new technological transport alternatives, particularly in touristic areas included in natural parks, has been an important step forward the reduction of air emissions, not only GHGs but also other pollutants (Del Moretto et al., 2017). In addition, the green areas represent an important tool for reducing emissions, thanks, on one hand, to the direct