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Assessing greenhouse gasses emitted from on-farm irrigation pumps: Case studies from Egypt

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Abstract Increasing greenhouse gas emission has become a worldwide concern as it is considered a major driver of global warming and climate change. Clear picture of greenhouse gasses emissions due to utilizing energy for on-farm irrigation pumps is a key guide for decision makers to identify strategies for greenhouse gasses emission reduction that consequently impact on the national and international level. The current study determined the carbon emitted from three common categories of diesel and electric on-farm irrigation pumps in Egypt. A set of environmental, economic, and social evaluating indicators were applied to carry out a comparative analysis among the pump categories in three study areas at El-Behera Governorate. The study showed that pumping 1 m^3 of water for irrigating the cropping pattern at the study areas produces an average of 690 ton CO_2. The study illustrated that electrical pumps are more environmentally, economically, and socially advantageous than diesel pumps.

1. Introduction

Greenhouse gas emissions depend on global population, economic, technological, and social trends [1–3]. In its effort to control greenhouse emission, the United Nation Framework Convention on Climate Change (UNFCCC) imposed obligations on developed countries to reduce their emissions through Kyoto protocol, in addition to contributing the rest of countries in the activities to combat climate change [4,5].

The United Nations Climate Change Conferences are yearly held in the framework of UNFCCC. They serve as the formal meeting of the UNFCCC Parties (Conferences of the Parties (COP)) to assess progress in dealing with climate change. Since COP1 in Berlin at the end of 1995, Egypt is sharing in all COP meetings.

Egypt signed the Kyoto protocol in 15/03/1999, ratified in 12/01/2005 and put into force in 12/04/2005. As a non-annex I country, Egypt is one of the countries expecting to face damaging effects due to climate change, although its contribution to the global greenhouse gas (GHG) emissions is negligible compared to developed countries [6]. However, mitigation measures contained in national plans and governmental studies are in progress. The objective of mitigation measures

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Nomenclature

a_i	cultivated area of crop *i*
A_e	exhaust flow rate of the engine
BCM	Billion Cubic Meter
CFE	carbon dioxide emission factor of producing energy from Power Plant
CFE_D	default CO_2 emission factor of fuel
CMLWE	Centralized Management of Land, Water, and the Environment
CO_2	carbon dioxide
CO_{2d}	CO_2 emission from diesel irrigation pumps
CO_{2E}	CO_2 emissions due to consuming fuel for producing electricity at El Mahmoudia Power Plant
CO_{2e}	carbon emission from the pump
Co_{2hi}	carbon emission per ha
CO_{2m}	concentration of CO_2 in the exhaust
CO_{2w}	carbon emission per unit volume of water
CO_{2CP}	carbon emission of current cropping pattern at the study areas
COP	Conferences of the Parties
F	Fuel consumption
GHG	Greenhouse gas
$GgCO_2$	gigagram of carbon dioxide
ha	hectare
hp	hours power
IIIMP	Integrated Irrigation Improvement and Management Projects
IIP	Irrigation and Improvement Projects
IIS	Irrigation Improvement Sectors
$KgCO_2$	kilograms of carbon dioxide
kW h	kilowatt-hour
L/s	litter per second
m^3/s	cubic meter per second
mg/L	milligram per litter
MWRI	Ministry of Water Resources and Irrigation
O&M	operation and maintenance
p	Energy consumed by the pumps' engine
P_T	total power generation from El Mahmoudia Power Plant
Q	discharge of the pump
tCO_2	ton of carbon dioxide
TJ	Terajoule
UNFCCC	the United Nation Framework Convention on Climate Change
w_i	water requirement per ha of crop *i* at the study areas

is to create a national greenhouse gas mitigation portfolio to support the process of sustainable development in Egypt [7,8].

Water management in Egypt faces numerous challenges including population increase, water scarcity, and deterioration of water quality. Additionally, these challenges include the need for adapting to climate change and reducing emissions of greenhouse gasses. In Egypt, the total GHG emission was about 318 Million tons eq. CO_2 in 2010 [9]. In irrigated agricultural areas, there are different sources for GHG emissions. These sources include enteric fermentation, manure management, rice cultivation, synthetic fertilizers, manure applied to soils, manure left on pasture, crop residues, cultivation of organic soils, burning – crop residues, burning savanna, and energy use, Fig. 1. In irrigated agricultural areas, one of the main causes of greenhouse gasses emissions is the use of energy for operating irrigation pumps. Energy use in irrigated agriculture includes field operations and tillage, seed sources, chemicals, fertilizer, harvest, and irrigation. Pumping activities in irrigation sector in Egypt take up a significant share of energy consumption.

In spite of rehabilitation of some irrigation and drainage pump stations in Egypt, they need to be monitored and evaluated regularly. Furthermore, the energy efficiency of some stations is still need to be improved. Reduction of GHG in the irrigated agriculture is one of elements that affect the improvement of mitigation and adaptation opportunities to climate change. GHG emissions associated with irrigation water management are partially been considered in water management and planning. Few studies consider the trade-offs between irrigation water and GHG emissions of the water sector.

The main goal of the current research is highlighting the importance of appending greenhouse gasses mitigation of irrigation pumps in the national strategies. The study gives a clear picture of the carbon emission due to utilizing energy for on-farm irrigation pumps in three areas at El-Behera Governorate in Egypt. This picture could be used as a key guide to identification of options for emission reduction that consequently impacts on the national level. Through the research, the carbon dioxide (CO_2) emitted due to irrigation activities was measured in the three studied areas. CO_2 emissions per unit volume of irrigation water and unit of irrigated cultivated area were analyzed. In addition, the cost of operation and maintenance, the cost of energy, and the acceptance of the farmers for different categories of pumps were determined. CO_2 emissions due to the current cropping pattern in the studied areas were appraised.

2. Irrigation system in Egypt

The Egyptian irrigation system is considered one of the most complicated systems in the world. Water in the River Nile is diverted to agricultural lands through main canals, branch canals and sub-branch canals. The branch canals deliver water into smaller tertiary channels (mesqas) and water is conveyed from the mesqas, or in some cases directly from canals, to the fields by farm ditches or "marwas".

In some regions, field pumps are used on-farm level to lift water from canals to mesqas for irrigation purpose. Mesqas feed marwas which are temporarily constructed for a single cropping season only. According to data collected from [10], the area served by irrigation pumps in year 2010 represents about 75% of the total cultivated area, as shown in Table 1. The amount of water pumped for irrigating this area is about 33.5 Billion Cubic Meter (BCM) based on the average year water consumption per hectare (ha) which is about 11,900 m^3.