Evaluación del uso del agua y la energía en instalaciones de riego de campos de golf. Algunos resultados en un caso de estudio

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Resumen

Generalmente, en la mayoría de las instalaciones de riego a presión y particularmente en las instalaciones de riego de los campos de golf se requiere una gestión eficiente de agua y energía. Por medio de una gestión eficiente de estos recursos los consumes excesivos se controlan los consumes excesivos y se pueden conseguir ahorros de explotación. Una de las herramientas que permiten controlar e identificar los consumes de agua y energía es el uso de indicadores de gestión. Con el empleo de estas herramientas pueden ser controlados varios parámetros que afectan en la eficiencia del uso del agua y la energía en los bombeos, la configuración de la red de riego y la instalación de energía asociada. En esta comunicación se muestra la metodología y la implementación de vario sindicadores de agua y energía adaptados a cuatro campos de golf del sureste de España. Para ello, se presentan algunos datos de un estudio desarrollado entre 2008 y 2011 en las instalaciones de riego de estos campos de golf y su influencia en la mejora de eficiencia del uso del agua y la energía.

Palabras clave: indicador, eficiencia, optimización, auditoría.

Evaluation of water and energy use for irrigation systems in golf courses. Some results in a case study

Abstract

Generally, in most of the pressure irrigation systems and particularly in irrigation systems of golf courses, an efficient management of water and energy use is required. By means an efficient management of these resources the excessive consumptions are controlled and a savings in exploitation costs could be achieved. One of the tools that allow controlling and identifying the water and energy consumption is the use of management indicators. With the employ of these tools several parameters that affect in the efficiency of water and energy use of pumping systems, water network configuration and the associated energy system could be controlled. In this paper the methodology and implementation of several water and energy indicators and their productivity adapted to four golf courses in south-east Spain are shown. For this purpose, some data of a developed study among 2008 and 2011 in the irrigation systems of these golf courses and their influence in the improvement of the efficiency in the water and energy use are presented.

Keywords: indicator, efficiency, optimization, audit.

INTRODUCTION

Golf courses represent the best example of water demand for sports and other leisure purposes. Although their water consumption is relatively small, less than 0.5% of the total water diverted for agriculture in Spain (Rodríguez Díaz et al., 2007), it is rapidly growing in many countries. However in countries where water resources are under stress, there is a perception that irrigating golf courses represents a significant additional abstraction which causes a major impact on the environment and other abstractors, including irrigated agriculture.

Thus, water use efficiency has been a major issue in the sustainability of golf courses and National legislation increasingly requires the implementation of programs to ensure that water is used efficiently (Junta de Andalucía, 2008). Carrow (2006) highlighted the role of water conservation programmes to ensure efficient water use on golf courses. This objective was to be achieved through the development and implementation of a site-specific ´Best Management Practices´ (BMP) programme. Related to this, benchmarking and performance indicators represent useful tools to detect if water is used efficiently. By comparing the performance indicators of similar organizations or systems, gaps between the most efficient and poorly performing ones are highlighted and, by identifying the best practices, guidelines to improve performance can be established.

In this work, a new methodology for water and energy audits in golf courses is developed and applied in 4 courses in the Southeast of Spain. Also, the role of automation and remote control systems for automatic data collection and heightening efficiency is discussed.

MATERIALS AND METHODS

A set of key performance indicators and descriptors for water and energy is developed in this work. These proposed water and energy indicators are then calculated using real data collected in four case studies in the Southest of Spain.

Background information on each study area is necessary for locating the case study and outlining its main characteristics. This data describes the study area in each golf course with information such as location, soil type, size, irrigation infrastucture, turfgrass varieties and number of staff (Rodriguez Díaz et al., 2011). This information provides baseline information on the golf course (GC). The specific information in every golf course is presented in Table 1.

The four GC included in the study are located in the Southeast of Spain. The total area of each of the golf courses is very similar. All of them have 18 holes. The total irrigated area is 45 ha in each case, with the exception of GC 4 which has 55 ha. The number of members of the staff is typically 30 to 40, however in the GC 1 there are 62 people.

The information required in the calculation of the performance indicators can easily be made available and can be automatically collected as part of the day to day operation of the golf courses. In general, water and energy use indicators add relevant information about the operation of a complex system and can contribute to the decision making process.

RESULTS AND DISCUSSION

Data was collected from each course over a three-year period 2008–2010. Most of the data was systematically recorded within the automatic irrigation control system. Other

data was provided by the golf course management staff. Additionally, confidentiality was maintained during data gathering to ensure data could not be used inappropriately. All the performance indicators were then calculated. The averages for each course are shown in Tables 2 and 3.

CONCLUSIONS

Several water and energy performance indicators has been developed which represents a new advance in the adaptation of methodologies from agriculture to the golf sector.

The new proposed set of energy performance indicators has added to the initial proposal of Rodriguez Diaz et al. in 2011 for benchmarking water use in golf courses. These indicators have been tested in four Spanish golf courses.

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Table 1. Specific information of golf courses.

Data	Golf course 1	Golf course 2	Golf course 3	Golf course 4
Soil	Greens and tees: USGA spec with 15 cm gravel and 30 cm sand. Fairways and roughs: 18% sand, 44% silt and 38% clay.	Greens and tees: USGA spec with 15 cm gravel and 30 cm sand. Fairways and roughs: clay loam soil.	Greens and tees: 30 cm gravel and 50 cm sand. Fairways and roughs: clay soil.	Greens and tees: USGA spec with 15 cm gravel and 30 cm sand. Fairways and roughs: 62% sand, 20% silt and 18% clay.
Size	45 ha (irrigated area 40 ha) 18 holes.	45 ha (irrigated area 40 ha) 18 holes.	45 ha (irrigated area 45 ha) 18 holes.	55 ha (irrigated area 38 ha) 18 holes.
Water source	Main source: Wastewater (100%)	Main source: Wastewater (90%) Secondary source: Groundwater (10%)	Main source: Wastewater (100%)	Main source: Wastewater (100%)
Drainage system	Yes (fishbone in shape) There is no devices for measuring drained water	Yes (fishbone in shape) There is no devices for measuring drained water	Yes (fishbone in shape) There is no devices for measuring drained water	Yes (fishbone in shape) There is no devices for measuring drained water
Pump capacity	4 pumps: 220 $m^3 \cdot h^{-1}$	7 pumps: 220 $m^3 \cdot h^{-1}$	3 pumps: 165 $m^3 \cdot h^{-1}$	7 pumps: 280 $m^3 \cdot h^{-1}$

Data	Golf course 1	Golf course 2	Golf course 3	Golf course 4
Infrastructure	1633 sprinklers with pressure regulator and electrovalves Rain-Bird Eagle 500, 550, 700 and 750 Central control Automatic weather station	1250 sprinklers with pressure regulator and electrovalves Rain-Bird Eagle 730 and 750 Central control Automatic weather station	1136 sprinklers with pressure regulator and electrovalves Rain-Bird Eagle 700 and 750; Rain Bird 47 and 51. Central control Automatic weather station	1449 sprinklers with pressure regulator and electrovalves Rain-Bird 700 and 750 Central control Automatic weather station
Turfgrass varieties	Greens: *Agrostis Stolonifera* L.cv L93 (11,000 m^2; 2.59%) Antigreens and fairways: *Paspalum Vaginatum* SW. (155,000 m^2; 36.47%) Roughts and tees: Bermuda (*Cynodon Dactylon* L. x *Cynodon Transvaalensis BD.*) (259,000 m^2; 60.94%)	Greens and antigreens: *Agrostis Stolonifera* L.cv Cato (36,600 m^2; 9.15%) Fairways, roughs and tees: Bermuda (*Cynodon Dactylon* L. cv Jasckpot and cv Princess (363,400 m^2; 90.85%) completed with Ray Grass	Greens and antigreens: *Agrostis Stolonifera* L.cv Penncross in greens, cv Sea Side in antigreens) (20,000 m^2; 4.44%) Tees, fairways and Roughs: Bermuda (*Cynodon Dactylon* L. cv Persicum) (430,000 m^2; 95,56%)	Green: *Agrostis Stolonifera* L.cv L-93 (11.495 $m^{2;}$ 3,02%) Antegreens: *Agrostis Stolonifera* L.cv Seaside II (13,630 m^2; 3.59%) Tees: Bermuda (*Cynodon Dactylon* L. cv Princess 77) (13,590 m^2; 3.58%) Fairways and rough: Bermuda (*Cynodon Dactylon* L. cv Tifway 419) (341,285 m^2; 89.81%)
Staff	62	32	40	32

Table 2. Water use indicators of the studied golf courses.

Water use indicators	Golf course 1	Golf course 2	Golf course 3	Golf course 4
1.1 Total annual volume of irrigation water supply received by the golf course (m^3)	296,366.00	320,000.00	439,634.48	296,693.00
1.2 Total annual volume of irrigation water applied (m^3)	269,135.00	240,000.00	400.616.00	282.693.00
1.3 Total annual volume of water that comes into the system (m^3)	391,166.00	442,748.00	470,552.13	347,421.37
1.4 Annual irrigation water supply per unit irrigated area ($m^3 \cdot ha^{-1}$)	7,409.15	8,000.00	9,769.65	7,807.71
1.5 Annual irrigation water applied per unit irrigated area ($m^3 \cdot ha^{-1}$)	6,728.37	6,000.00	8,902.58	7,439.29
1.6 Annual irrigation water applied per hole (m^3 per hole)	14,951.94	13,333.00	22,256.44	15,705.16
1.7 Delivery efficiency (%)	90.81	75.00	91.12	95.30
1.8 Annual relative water supply (RWS)	0.9387	0.9000	0.9500	0.8000
1.9 Annual relative irrigation supply (RIS)	0.8361	0.7200	0.9400	0.5800
1.10 Water delivery capacity (%)	2.89	6.19	4.83	3.26
1.11 Irrigated area in greens and tees and total irrigated area ratio (%)	4.50	9.15	11.92	13.33
1.12 Maximum potential soil moisture deficit (PSMDmax)	827.09	762.42	990.73	725.00

Table 3. Energy use indicators of the studied golf courses.

Water use indicators	Golf course 1	Golf course 2	Golf course 3	Golf course 4
2.1 Total contracted electric load (kW)	379.40	166	230	183.64
2.2 Total measured absorbed power (kW)*	83.92	111.86	147.22	109.12
2.3 Annual consummed active energy (kWh)	711,622.00	215,612	141,937	164,091
2.4 Annual reactive consummed energy (kVArh)	357,069.00	51,852	17,542	70,205
2.5 Power factor (%)*	69.93	67	64.01	60
2.6 Global power factor (%)	89.00	89.00	98.00	93.00
2.7 Contracted electric load per unit command area (kW·ha-1)	9.48	4.15	5.11	4.83
2.8 Total measured absorbed power per unit of irrigated area (kW·ha-1)*	2.98	2.8	3.27	2.87
2.9 Maximum registered power (kW)*	96	152	172	130
2.10 Measured maximum power (kW)*	94.69	140.30	148.69	160.10
2.11 Registered power efficiency (%)**	76.43	92.00	74.78	71.00
2.12 Measured power efficiency (%)*	78.91	85.00	64.65	87.00
2.13 Active consummed Energy per unit irrigation supply (kWh·m-3)	2.40	0.67	0.32	0.55
2.14 Active consummed energy per unit irrigation delivery (kWh·m-3)	2.64	0.90	0.35	0.58
2.15 IDE: Energy dependence index (%)	90.81	75.00	91.12	95.30
2.16 ICE: Energy load index (m)	89.90	90.50	49.99	85.77
2.17 EEB: Average energy efficiency of the pumping system (%)	53.52	53.41	48.49	55.37
2.18 ESE: Efficiency of the energy supply (%)	98.07	98.62	100.02	98.05
2.19 * EEG: General Energy Efficiency (%)	52.48	49.05	48.50	54.29

* The measured data in the energy audit correspond to the pumping group of the irrigation system of the golf course

** The maximum registered power is the summation of maximum registered power by the maximeter in the contracts of the golf course