Energy and Buildings 139 (2017) 254–262

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

An investigation for predicting the effect of green roof utilization on temperature decreasing over the roof surface with Gene Expression Programming

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ARTICLE INFO

Article history:
Received 25 March 2016
Received in revised form
21 November 2016
Accepted 7 January 2017
Available online 9 January 2017

Keywords:
Green roof
Gene Expression Programming
Temperature decreasing
Comfort condition

ABSTRACT

This study presents that the effect of green roof usage on the temperature decreasing for Turkey's cities has been investigated with Gene Expression Programming (GEP). Training data for GEP model has been taken from summer climatic data of nine different cities around the world, which have different climate regions. Thus, wide range of climatic conditions have been considered in GEP modeling. GEP model has been used for predicting the temperature decreasing over a green roof in Turkey cities. GEP model has given sufficient result with 2.2894% RMSE and 94.01% R^2. When the effect of green roof usage in Turkey cities is compared to World cities, it is found that temperature decreasing value for Turkey's cities and World cities has shown same trend. The maximum temperature increasing is 2.91 °C in Kars at 08:00 a.m. and the maximum temperature decreasing is 29.61 °C in Izmir at 06:00 p.m.

1. Introduction

The green roof systems have started to be used commercially. It is possible to contribute to the comfort requirements of the building by increasing the insulation effect and heat gain from building by installing a green roof system on the building roof [1]. In classic rural buildings, green roof systems have been used in a natural way from the past [2]. In improving home comfort conditions, thermal insulation effect and conditioning properties of green roof systems are now being used widely [3]. In this case, it is important to evaluate the performance of green roofs according to the climatic conditions of the cities.

In many studies, standard concrete roof and green roof were compared in terms of heat losses, heat gains and temperature decreases. These comparisons give different results depending on the geographical zone and climate conditions. In one of these studies, experimental and theoretical temperature analyses were performed and created a heat transfer model of a standard green roof system [4]. In another study, the average temperature variation was observed between a standard roof and a green roof within three week-period experimental measurements, in July [5]. Investigation of the result of the green roof system for different climatic conditions is also important. Studies for the different geographical and climatic regions show that the surface temperature decrease of the green roofs is significant in all climatic conditions [6]. A limited quantity of studies have observed green roof effects in winter. Green roofs can act as insulation during cold weather, although properly applied current insulation under a green roof will increase the insulating value. In one such study it is predicted that soil moisture, a thermal mass contributor, may be the essential factor in the insulating capacity of green roof systems in winter [7].

As known, the lack of heat gain of a roof in summer and the absence of heat loss in winter is desirable. For this purpose, green roof system has been investigated experimentally in terms of heat loss and gain effects on buildings [8,9]. As a result of these studies, the green roof yields heat gain instead of heat loss in winter, while it supplies reduction on heat gain in summer. Green vegetation stands out with positive characteristics in every climatic condition [10]. With the increasing number of experimental studies in this field, it is now possible to reach large number experimental data of the green roofs and to make calculations with different theoretical and numerical methods [11–14].

The passive cooling potential of green roof is predicted with the obtained experimental results used in ANN learning data [15,16]. The traditional roof and the green roof comparison has been investigated for some European cities by using numerical methods [17]. Also, studies comparing ANN and other convergence methods are also available [18]. Besides, there are many studies using genetic

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http://dx.doi.org/10.1016/j.enbuild.2017.01.014
0378-7788/

Fig. 1. The World and Turkey cities geographical location.

algorithm program. In one of these studies, a new Gene Expression Programming (GEP) approach is presented for the prediction of the daily solar radiation. The model predicts the daily solar radiation with an acceptable accuracy and outperforms the developed regression-based model [19]. In another study, a physical habitat simulation is presented by using the GEP model and the GEP model results are compared with the ANFIS model results [20]. There are a lot of studies related to the comparison of GEP and artificial neural networks (ANNs), GEP and ANFIS [21–24]. In other studies, GEP was used for function finding [25,26]. Examining the performance of green roof system for a specific geographic area requires a few years of operating time and high cost of open space experimental studies [4,27,28]. In addition, some equations which are developed with experimental studies can be used for determining green roof performance [7,29–31].

Artificial neural networks (ANNs) are famous machine learning systems that have been used to predict the temperature decrease, evapotranspiration, solar radiation, etc. [32,19,23]. For example, Pandey successfully applied ANN for predicting the cooling load reduction using green roof over the building [16]. Conversely, a limitation of ANNs is that they cannot always be converted into explicit forms to provide the details of the prediction process [33]. Genetic Programming (GP) [34] is a new approach with remarkable simulation capabilities. It is a division of genetic algorithms that generates computer programs rather [35]. For the last time, GP has been used to formulate complicated engineering problems [34]. Gene Expression Programming (GEP) is a latest branch of GP evolving programs of various sizes and shapes [36]. Compared to other soft computing methods, it has been newly applied to energy related problems [33,37,35]. Although ANNs are used to predict the cooling load reduction, none of the existing studies have concentrated on GP-based analysis of air temperature decrease above the green roof [18,15,16].

In the present study, the temperature decrease over the green roof of the buildings in Turkey cities was examined using a GEP model [38]. Climatic data of the world cities with different climates in summer and the effect of temperature decrease on the roof were used as a learning data [6]. Using the equation obtained by GEP model, the temperature decrease is calculated for the green roof depending on the climatic data of Turkey's cities (Fig. 1).

2. Material and methods

2.1. Green roof energy balance

Vegetation has been used on building roofs and walls since ancient times, with the most famous example of the Babylonian gardens in Mesopotamia. The specific purposes of green roof installations vary, but generally hinge upon stormwater reduction or improved building energy efficiency and often both. The types of growing media and roof assemblies vary, but most green roofs consist of a drainage layer, a root barrier, and a waterproof membrane as shown in Fig. 2. Horizontal building surfaces, such as roofs, experience high thermal loads during summer conditions in climates such as the Mediterranean climate regions. Theoretical and experimental analyses of different roof assemblies to promote cooling mostly focus on evaporative and radiative heat transfer mechanisms. The green roof vegetation shades this type of roof assemblies from direct solar radiation, and it also cools the roof by means of evapotranspiration from the vegetation layer [7].

The magnitude of air temperature decreases because this transformation depends on the climatic characteristics, the amount of vegetation and urban geometry. Investigation of suitability of green roof for a place requires both long time (a few years) and high expense open-air experimental studies. Besides the calculation can be performed by some equations, which are gotten from experimental studies. However, these equations are depending on many parameters and calculation that are hard to solve. Many researchers have used green roof model given in Fig. 2 and equation in below. This equation is suggested for modeling heat flux in green roof [7,29,31,39,27]. R_n and G can be measured in experimental apparatus.

$$R_n - G - L - H = 0 \quad (1)$$

Calculation of H is so complicated and hard to solve. For solving H, plant surface and surroundings temperature should be measured sensitively. So easy to solving an equation is needed. Alexandri and Jones have researched thermal effect of the plant cover in various climate conditions [6]. They have improved 2-D mathematical model. Effect of the green-wall and green roof on thermal comfort, energy saving and air temperature decrease above the green roof have been researched with this mathematical model. The results

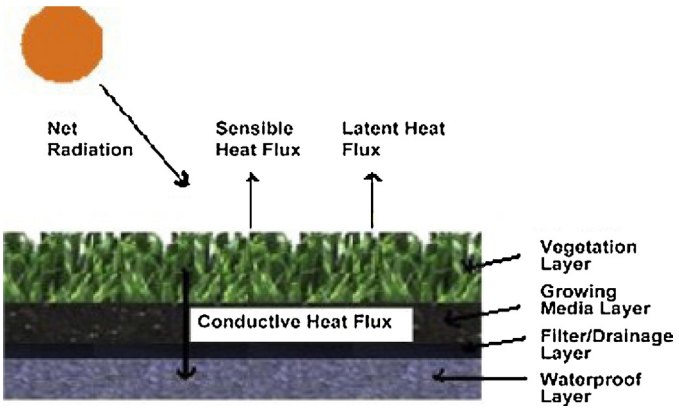

Fig. 2. Schematic view of the green roofs and energy balance on plant [4].