Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Building and Environment 40 (2005) 63–71
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

Modeling of energy distribution inside greenhouse using concept of solar fraction with and without reflecting surface on north wall

Ravi Gupta, G.N. Tiwari*

Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

Received 21 November 2003; received in revised form 4 February 2004; accepted 29 March 2004

Abstract

A considerable portion of the solar radiation falling on transparent north wall/roof inside an east–west-oriented greenhouse is lost due to low-altitude angle of sun during winter months. Replacing the transparent north wall with a reflecting surface can increase solar radiation on the floor of the greenhouse. Effect of vertical and inclined reflecting north wall on distribution of solar radiation on the floor of greenhouse has been studied for five different locations in India. These locations are Chennai (13°N), Kolkotta (22.53°N), Jodhpur (26.30°N), Delhi (28.58°N) and Srinagar (34.08°N). Evenspan greenhouse (6 m × 4 m × 3 m) has been considered for the present study. The proposed model can also be used to determine the distribution of solar radiation for any other place and shape of the greenhouse.

Keywords: Solar radiation; Greenhouse; Solar fraction; Thermal heating

1. Introduction

Solar energy is generally used for illumination and thermal heating of a building/greenhouse [1]. Some part of the transmitted solar radiation falls on north wall/roof inside the greenhouse. This radiation falling on north wall /roof further transmits through north wall/ roof. Pucar [2] has studied the use of reflecting surface on north wall for more illumination on the floor of the greenhouse. Various other attempts have also been made to increase the illumination inside a greenhouse by reflecting the solar radiation [3–7]. The solar radiation falling on north wall/roof can also be used for thermal heating of the greenhouse. European passive solar handbook [8] also describes the method for thermal heating by solar energy.

The present work analyses the distribution of solar radiation on floor of the greenhouse after its reflection by a reflecting north wall. The study was motivated by the fact that the loss of solar radiation through north wall/roof is more during winter months due to low-altitude angle of the sun. Tiwari [9] has suggested a term called "solar fraction for north wall" to quantify this loss through north wall. "Solar fraction for north wall" is the ratio of solar radiation falling on north wall to total radiation transmitted inside the greenhouse. The value of solar fraction (due to north wall) will be more [9] during winter months because of the low altitude angle of the sun and hence the losses will be more. A model has been developed to calculate "total solar fraction". Total solar fraction quantifies the loss of all transmitted solar radiation coming inside the greenhouse. These losses take place from north wall/roof and east/west wall. "Total solar fraction" is the ratio of total solar radiation loss from greenhouse to total solar radiation transmitted inside the greenhouse. The solar radiation on the floor of the greenhouse with and without reflecting surface has been evaluated by using the measured insolation data. The value of total solar fraction was comparable for different orientations of a greenhouse. The maximum loss of solar radiation takes place from north wall/roof of the greenhouse for east–west orientation. However, when a greenhouse is rotated from its original east–west position then the major losses of solar radiation occur from other sections of the greenhouse instead of north wall/roof.

2. Assumptions

1. An east–west-oriented greenhouse is considered.
2. An evenspan greenhouse is divided into six sections (south wall, south roof, north roof, north wall, east wall

* Corresponding author. Tel.: +91-11-659-1258; fax: +91-11-2659-2208.

E-mail addresses: ravigupta2300@yahoo.com (R. Gupta), gntiwari@ces.iitd.ernet.in (G.N. Tiwari).

0360-1323/$ - see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.buildenv.2004.03.014

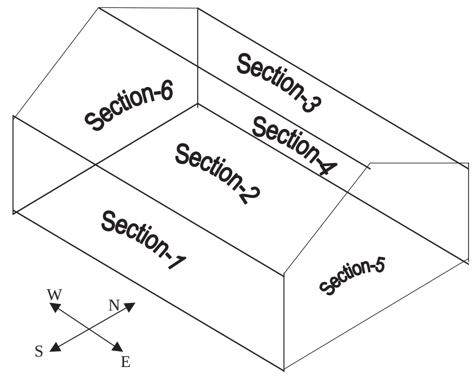

Fig. 1. SW Isomertic view of E–W greenhouse (0° orientation) showing various sections.

and west wall). These sections were named as Sections 1, 2, 3, 4, 5 and 6, respectively, as shown in Fig. 1.

3. The loss of solar radiation due to absorption and reflection at the greenhouse covering material is neglected.
4. Shading by greenhouse structural components and condensation on the covering material is also neglected.
5. The model is for clear sunny day.
6. Useful solar radiation is available from 8:00 am to 4:00 pm.

3. Theory

If the phenomenon of global greenhouse effect is taken at the micro level for a house having transparent (glass, FRP, polyethylene film) walls/roofs for maintaining suitable environment for the growth of plants then this enclosure is called as greenhouse. Solar radiation falls on each section of the greenhouse. After transmission, solar radiation either falls on the floor or north wall/roof or both of the greenhouse (Figs. 2a and b).

A reflecting surface in place of north wall can reflect the transmitted solar radiation falling on north wall towards the floor (Figs. 3a and b) and by putting an inclined reflecting surface, solar radiation losses occurring through north roof/wall can also be reflected towards the floor. Inclination of the reflecting surface must be adjusted according to the lowest altitude angle of sun so that more and more reflected solar radiation fall on the floor of the greenhouse.

4. Definition of solar fraction (F_n)

Referring to Fig. 4, the solar fraction for north wall (F_n) can be defined as the ratio of solar radiation falling on the north wall of the greenhouse (E–W orientation) to the total incoming transmitted radiation inside the greenhouse. The expression of F_n can be written as follows [6]

$$F_n = \frac{\text{solar radiation available on north wall inside greenhouse for a given time}}{\text{solar radiation measured on the north side and floor of the greenhouse at the same time}}. \quad (1)$$

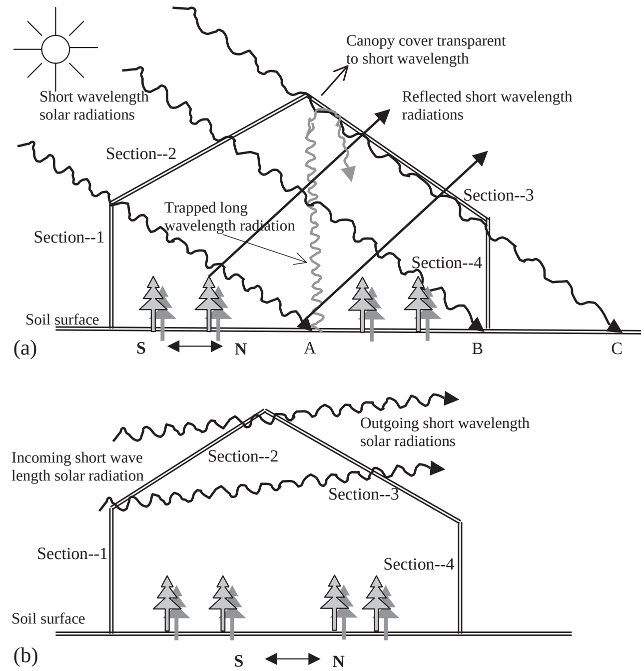

Fig. 2. (a) Short wave incoming solar radiation coming from one section and going out through another section and falling on soil surface outside the greenhouse without contributing to greenhouse; (b) short wavelength incoming solar radiation coming from one section and going out through roof into sky without contributing to greenhouse.

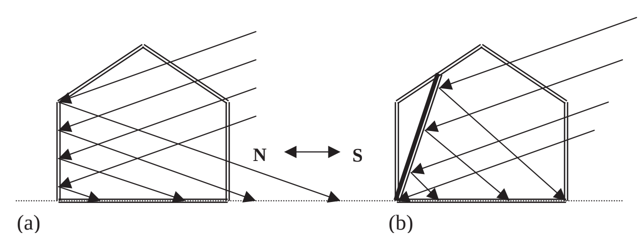

Fig. 3. Even span greenhouse with vertical (a) and inclined (b) reflecting wall.

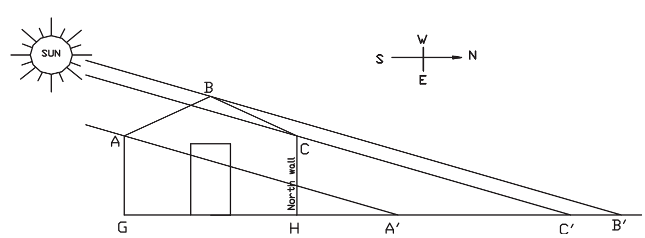

Fig. 4. Calculation of the solar fraction (F_n) of uneven span greenhouse for north wall.

For example, solar radiation fall on two sections (1 and 2) and comes out from Sections 3 and 4 at noon, as shown in Fig. 4. Solar fractions for north wall due to Sections 1