SOLAR RADIATION REDUCTION DUE TO SHELTERBELT

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ABSTRACT:

The benefits of shelterbelts are widely discussed in literature and proven in practice. Despite their benefits it is necessary to research their potential negative effects on the crop yields in order to obtain their net effects on agricultural production. Among different potential influences this research deals with the model of solar radiation reduction caused by shelterbelts. Solar radiation plays significant role in crop growing and its reduction could decrease the yield. In this paper the model of solar radiation reduction is considered and results for one parcel presented. The model showed that, depending on the height and orientation of shelterbelts, a significant solar radiation reduction could affect some parts of parcel.

KEYWORDS:

Solar azimuth, Solar elevation angle, Shadow length, Shadow area, Shadow duration, Land Consolidation.

1 INTRODUCTION

The importance of shelterbelts for agriculture production is widely discussed in literature and widely researched in practice [1,2]. It is proven that shelterbelts reduce the negative impacts of wind on the yield of corps as well as the negative impact of soil erosion [3]. Those facts strongly support the needs of shelterbelts in agricultural production. From the other side the possible negative effects of shelterbelts should be reduced by their careful design and orientation.

The orientation of shelterbelts and their height are dependent of the wind rose on the location and length of the parcel. Bearing in mind that the shelterbelt could protect the area from 10 to 25 heights of the shelterbelt it could be calculated the optimal height of shelterbelt in the phase of its design.

After height of shelterbelt determination, it is possible to calculate the shadow length, shadow area and consequently the shadow duration for the certain parcel for each day over the year. These parameters could be determined if the solar azimuth, solar elevation angle and azimuth of the shelterbelt is known. The solar azimuth and solar elevation angle could be calculated by applying the well-known formulas or by utilizing specialized internet platforms, while the azimuth of shelterbelt could be determined from the coordinates of shelterbelts taken from google earth platform [5] or Geosrbija platform [6]. If the azimuth of shelterbelt was calculated from the official Cartesian coordinates could contain systematic error of meridian convergence but this error should not affect the conclusion about shadow duration significantly.

This research is predominantly deals with the theoretical model of solar reduction duration for certain parcel due to shelterbelt by comparing the difference in case when shelterbelts do and do not exist.

2 MATERIALS AND METHOD

The materials for this research were obtained by utilization the web platform “Solar Geometry Calculator" [7] for the parcel position with given WGS coordinates. This platform gives the different data about solar geometry but for the purpose of this research the solar azimuth and solar elevation angle were considered in the time interval of 10 minutes for the one day.

The method for calculating the shadow caused by shelterbelt was considered both horizontally and vertically. The shelterbelt is considered as a fixed length of treeline, orientated with fixed azimuth and fixed height.

The changes of solar elevation angle and azimuth form the shadow (reduces the solar radiation) will cause the reduction of solar radiation behind the shelterbelt in the interval of time needed for changing solar azimuth in the interval (A_0, A_n).

The area covered by shadow formed by shelterbelt could be described as follows:

$$P_i = L * \Lambda_i * sin\,(A_i - A_0) \tag{1}$$

where:

- P_i – the area of shadow formed at the time i,
- L – Length of shelterbelt (approximately L=520 m),
- Λ_i – length of shadow at the time i,
- A_i – solar azimuth at the time i and
- A_0 - solar azimuth at the time 0 (when the solar azimuth equals the azimuth of shelterbelt).

Length of shadow caused by the shelterbelt is calculating as follows:

$$\Lambda_i = H * ctg\varepsilon_i \tag{2}$$

where:

- H - height of shelterbelt and
- ε_i – solar elevation angle at the time i.

Azimuth of shelterbelt is denoted as α_{AB} or α_{BA}. It immediately follows that:

$$\alpha_{BA} = \alpha_{AB} \pm \pi \tag{3}$$

The Fig. 1 and Fig. 2 illustrate the formulas (1) and (2).

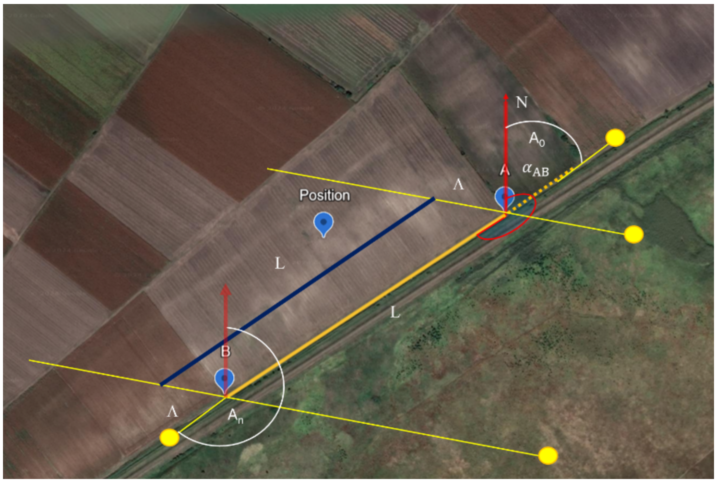

Figure 1. The concept of solar reduction calculation in horizontal sense

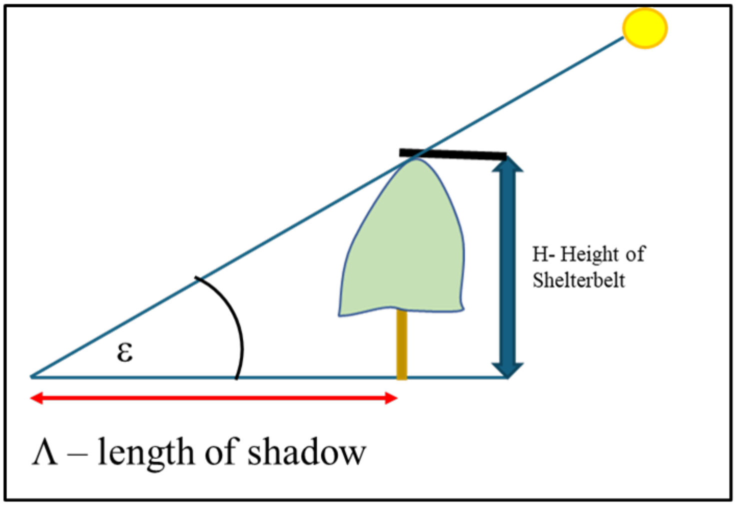

Figure 2. The length of shadow calculation in vertical sense

According to formulas (1) and (2) it immediately follows that total reduction of solar radiation per day could be calculated as sum of partial areas under shadows multiplied by the duration of shadow:

$$P = \sum_1^n P_i = \sum_1^n L * \Lambda_i * sin(A_i - A_0) \quad (4)$$

where n is the number of intervals of time considered.

3 RESULTS AND DISCUSSION

The considered area is the position given by following WGS coordinates ϕ= 45,166389° and λ= 21,328611°. the solar azimuth and solar elevation angles were calculated for June 30th, 2024. The chosen interval of time was 10 minutes. The solar elevation angle above the horizon was in the interval of 940 minutes (15,67 h). The azimuth of shelterbelt is α_{BA}=56,6819°.

The graphical presentation of solar azimuth and elevation angle are given on the Fig. 3 and Fig. 4, respectively.

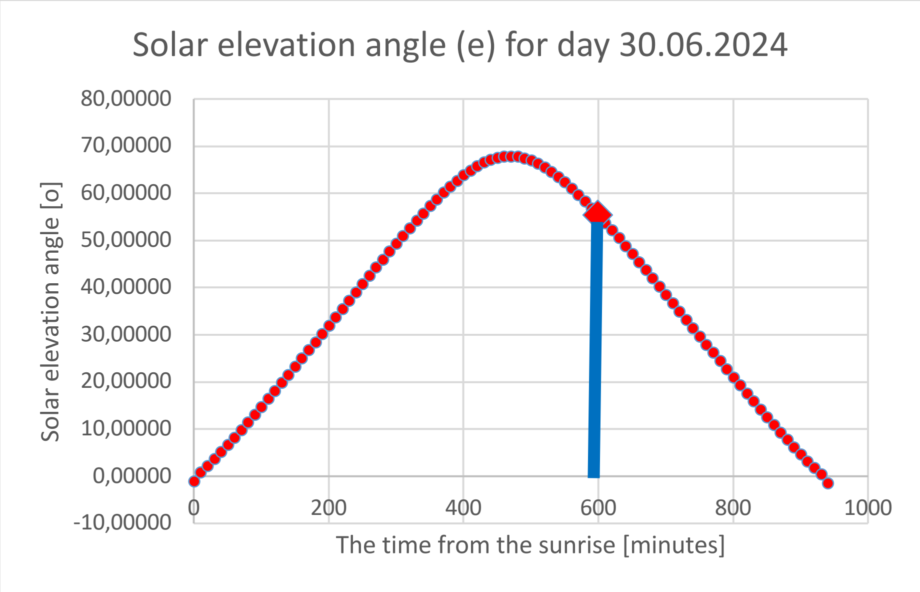

Figure 3. The solar elevation angle changes during the day

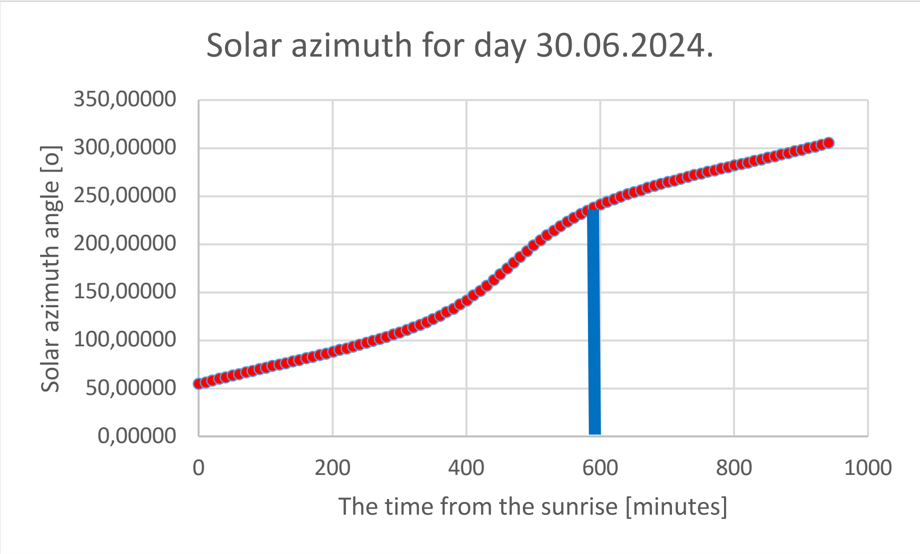

Figure 4. The solar azimuth changes during the day

The blue lines represent the moments when the shadow disappears because the solar azimuth exceeded the value of 236,6819º. Figure 5 shows the length of the shadow obtained by (2).

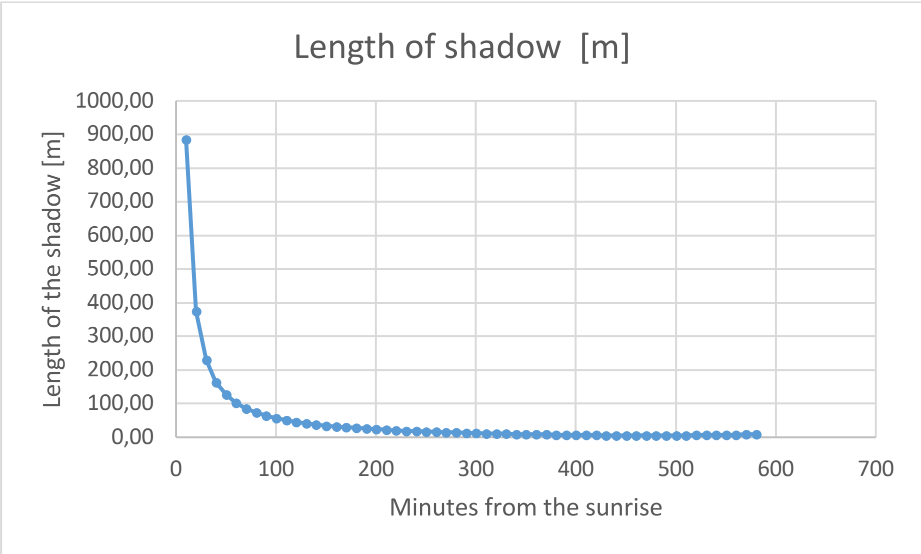

Figure 5. The length of the shadow

Utilizing formula (3) it is obtained that total area shadowed by the shelterbelt during the insolation. The figure 6 illustrates the shadowed area caused by shelterbelt during the day.

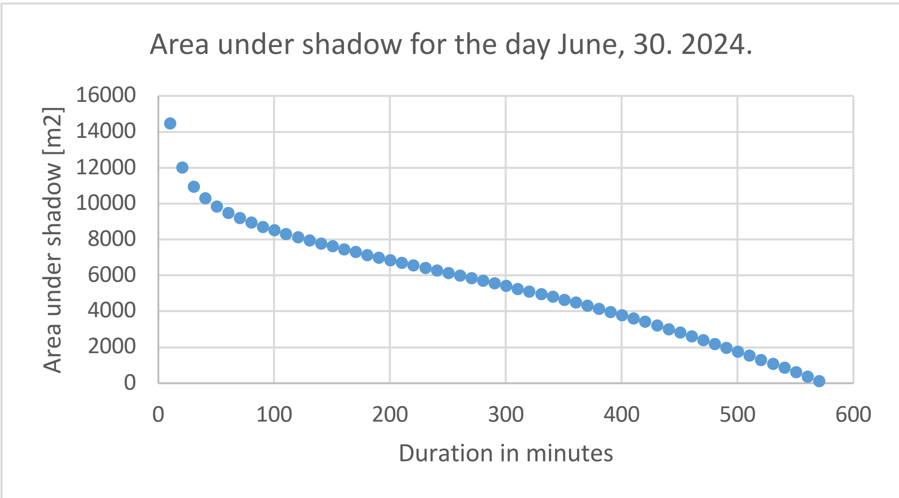

Figure 6. Shadowed area

The figure 6 might not be quite illustrative because it shows only the area but does not show the total loss of the solar radiation caused by shelterbelt. The smallest area is shadowed all period when the solar azimuth is smaller than 56.6819°.

Another approach which illustrates the relative duration of shadow depending on the shadow length. This approach might be given by following formula:

$$D_\rho = \sum_1^n L * \Lambda_i * sin\frac{(A_i - A_0) * t_i}{T} \tag{5}$$

where:

- D_ρ – relative duration of shadow at the length of shadow Λ_i and azimuth A_i,
- t_i - i-th period and
- T – total time of insolation (in this case T=580 minutes).

Fig. 7 illustrates approach given by (7).

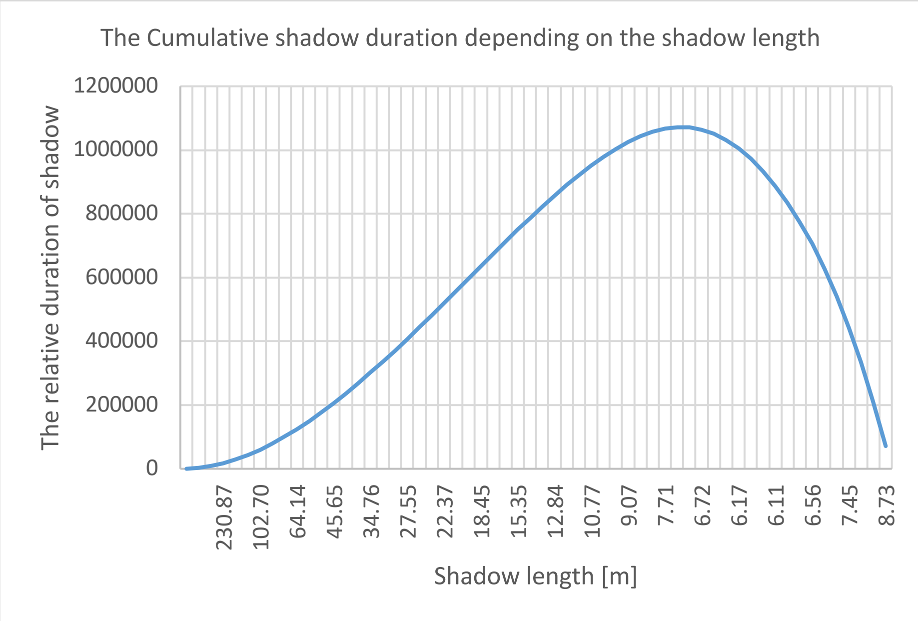

Figure 7. The relative duration of shadow depending on its length

According to result obtained by formula (7) immediately follows that area which is nearest to the shelterbelt is mostly covered by shadow in the analysed case.

The proposed method is appliable in the case of shelterbelts designed to solve the problem of negative wind influence on the crops. The variation of shelterbelt's height might reduce the negative influence of solar radiation reduction. Further research shall include the transparency of shelterbelt and its influence on solar radiation reduction.

Also, the method could be improved by utilizing the smaller intervals of time in process of solar azimuth and elevation angles calculation.

4 CONCLUSION

Applied method enables the calculation and interpretation of solar radiation reduction caused by shelterbelt. Proposed method might be helpful in the process of solar radiation reduction during the shelterbelts design. In this research only one shelterbelt was considered but it is possible to apply this approach in the case when shelterbelts cover all parcel or group of parcels. Further research should encompass complexity of solar radiation influence caused by shelterbelts on the crop yield as well as from the aspect of reduction of its potential negative influences. Bearing in mind that this research was based on the theoretical assumptions it is necessary to provide additional practical experiments in order to check its wider applicability.

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