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Global Dimming and Its Effect on Agriculture

R. K. Meena*, R. Fagodiya, S. K. Meena, R. Kumar, Raju and R. S. Bana
Indian Agricultural Research Institute, New Delhi -110 012
***Email of corresponding author: rajeshkumar2793@gmail.com**

Climate change includes both global warming and global dimming. Reduction in the solar radiation reaching the earth surface is known global dimming. Global dimming is caused due to increased cloud thickness, cloud cover and suspended particulate matter in air (aerosol). These reduced solar radiations due to global dimming adversely affects photosynthesis by plant thereby having negative effect on agriculture.

Introduction

The sun is the only source of energy for the global ecosystem. Essential condition for living things on earth is the amount of sunlight that penetrates through the atmosphere and reaches earth's surface. Long term measurements of the solar radiation from the 1960s to the early 1990s, backed up by a wide range of data and a number of independent studies, showed that there were substantial declines in the amount of the sun's energy reaching the Earth's surface (Stanhill and Cohen 2001). This phenomenon of declines in solar radiation reaching the earth is known as global dimming.

Global dimming was observed at the Earth's surface during the 1950–1980 periods. This decrease is consistent with the impacts of anthropogenic aerosols on cloud properties, water vapour and cloud feedbacks due to global warming. Increases in cloud thickness, cloud cover and scattering aerosols enhance the diffuse component of the radiation reaching the surface (Wild, 2012).

The air pollution due to anthropogenic activity is the major contributor to global dimming (O'Dowd et al. 2013). It is the result of tiny airborne soot particles, ash and sulphur aerosols compounds which reflecting the sun radiation. The pollutants that lead to global dimming also lead to various human and environmental problems, such as smog, respiratory problems, and acid rain.

Evidence of Global Dimming

1. Decadal changes in surface solar radiation: Early studies carried out in the 1990s reported a general decrease of solar radiation at widespread locations over the earth between the late 1950s and the late 1980s (Wild, 2012). Increasing air pollution and associated increase in aerosol concentrations are considered as major cause of the decline of surface solar radiation. Changes in cloud amount and optical properties, which may or may not have been linked to the aerosol changes, have also been proposed to contribute. A direct assessment of the origins of the decline of surface solar radiation is complicated by the lack of adequate long-term observational datasets of major influencing factors such as clouds and aerosols (Wild, 2009). Clouds intercept both shortwave radiation from the sun and long wave radiation from the Earth. Their effects are complex and vary in time with location, and altitude.

2. Change in pan evaporation: In 1990s Europe, Israel, and North American scientists noticed that the rate of evaporation was decreasing, although they had expected it to increase due to global warming. The similar trend was also observed in China over a similar period. A decrease in solar irradiance is responsible for decrease in evaporation (Roderick and Farquhar 2002).

Impact of Global Dimming

1. Effect on plant photosynthesis and carbon uptake: Reduced atmospheric transmissivity could have resulted from changes in the short-wave radiative properties of the sky and/or of the clouds, as well as from an increase in cloud cover. These changes could be the outcome, either directly or indirectly, of greater concentrations of aerosols in the atmosphere. The direct effect relates to the increased short-wave absorption by aerosols under both clear and overcast sky conditions, while an indirect effect refers to the role of aerosols as cloud condensation nuclei leading to increased cloud cover.

One of the study of vegetation canopy photosynthesis revealed that the interception of direct radiation is strongly determined by the leaf inclination angle. A number of studies relate changes in net primary production to changes in cloudiness: clouds, like scattering aerosols, reduce solar surface radiation and increase diffuse irradiance. However, it has to be noted that clouds influence, in addition to total PAR and diffuse PAR fraction, many other atmospheric factors such as temperature, moisture, turbulent heat fluxes and precipitation, which also have a direct or indirect influence on ecosystem carbon assimilation (Wild et al. 2012).

2. Effect on Irrigation Resources: Important issue is the potential impact of dimming on the water cycle. Solar radiation changes effectively alter the energy available at Earth's surface to drive evaporation and its energy equivalent. Since on a global level evaporation equals precipitation, any SSR-induced change in evaporation will change the intensity of the water cycle. Only if ocean gets warm, it will have the tendency to initiate the rain formation. Global dimming might have caused the droughts in Ethiopia in the 1970s and 80s where millions died, because the northern hemisphere oceans were not warm enough to allow rain formation (Wild et al. 2012).

3. Effect on agricultural crop production: The solar radiation reaching the Earth's surface is the primary driver of plant photosynthesis. Photosynthesis increases nonlinearly with incident photosynthetically active radiation (PAR), saturating at light levels that are often exceeded on bright days during the growing season. Under clear-sky conditions, a fraction of the plant canopy is illuminated by direct solar radiation consisting of bright 'sunflecks' (increases in solar irradiance) with the remaining portion of the canopy being in the shade. The sunlight fraction of the canopy has leaves that are often light saturated and therefore have low light-use efficiency, whereas leaves in the shade are more light-use efficient but suffers from a lower exposure to incoming radiation. In contrast, under cloudy or aerosol-laden skies, sunlight is more scattered and incoming radiation is more diffuse, producing a more uniform irradiance of the canopy with a smaller fraction of the canopy likely to be light saturated.

Global irradiance is one important environmental parameter influencing stomatal opening and closing, as also of the changing CO_2 concentration of the atmosphere. Changes in air temperature will also interact with change in solar radiation by altering the relative importance of the radiation balance which increases with air temperature (Penman, 1948). Crop water balance and evapotranspiration, unlike crop productivity, are closely relate to solar radiation.

Several studies document the enhanced forest net CO_2 uptake with increased levels of diffuse PAR for crops. There is clear evidence that increasing air pollution (aerosols) and cloudiness alter the partitioning of surface solar radiation towards a higher relative portion of diffuse light, in addition to a reduction of the total amount of sunlight. This diffuse light can enhance photosynthesis particularly in tall and dense vegetation canopies, as it is distributed more efficiently within the canopy compared with direct solar radiation, which is only accessible for the outermost layers (Wild et al. 2012).

The net impact of surface solar radiation change on photosynthesis occurs through both the reduction in total radiation and the increase in the diffuse fraction (or vice versa) that have opposite effects on photosynthesis. For the tall and relatively dense forest canopies, the increase in photosynthesis with increasing diffuse fraction is the dominating effect that has been verified in numerous theoretical and observational studies. Opposite characteristics with a dominance of the total radiation effect have been found for grassland with low canopies. This means that grassland cannot profit from increased diffuse ratios, but rather responds with decreased productivity under reduced light conditions as prevalent under global dimming. The impact of changes in total radiation and the diffuse fraction on agricultural crop photosynthesis (and yields) is in the majority similar as for grassland, but is supposed to depend on the individual (complex) stand characteristics (Wild et al. 2012). In addition, Changes in productivity associated with changes in radiation are often outweighed by the increase in crop yield associated with fertilization, improved varieties and more efficient management practices.

Strategies for Minimizing Effect of Global Dimming on Agriculture

1. Photo insensitive crop variety: Develop photo insensitive crop variety which can perform better under low light intensity and are efficiently able to harvest as much as light energy as it reaches to crop canopy.

2. Control environment pollution: Global dimming can be reduced by cleaning up the emissions from vehicles and burning fossil fuels. Another way to reduce the emission of particulate matter by using clean fuels and renewable energy sources (Solar, wind, biogas, bio fuels etc.)

3. Improved management practices: Cultivation of crops under green houses. Improved crop and grazing land management to increase soil carbon storage, restoration of cultivated peaty soils and degraded lands, better management of waste land, reduced desertification, livestock and manure management to reduce CH_4 emissions, improved nitrogen fertilizer application techniques to reduce N_2O emissions, dedicated energy crops to replace fossil fuel use and improved energy efficiency.

Conclusion

Global dimming caused due to increased particulate matter and cloudiness has a significant impact on agriculture as it affects photosynthesis. The forest ecosystem has positive benefit due to dimming while the grassland and crop lands are negatively affected due to reduced photosynthesis. Therefore from the agricultural perspective the global dimming is harmful and may results into substantial reduction in food production. Thus climate change which includes both global warming and global dimming might have negative impact on agriculture. Hence global dimming should also be given due consideration, to minimise or nullify its impact on agriculture.

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