Original Article

Thermographic Heat Assessment of Cultivated Plant Life for Semi-transparent Agrivoltaic Installation System

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Abstract

India receives good solar radiations throughout year. These solar radiations are utilized to produce solar energy through solar panels. Solar panels are installed in open atmospheric condition on the land. With the advancement of technology, solar panels are installed on iron pillar structures above the land for optimal use and the land below solar panels is used for cultivation of crops or natural vegetation. Optimal atmospheric temperature is responsible for the natural growth of plant at the land near and under the ground surface of semi-transparent solar panels. In this research a heat analysis for ground surface near and under semi-transparent solar panels in agrivoltaic installation system through matlab thermographic image processing approach percentage average degradation is calculated. Experimental results show that there is minimal difference in temperature for the ground surface near and under semi-transparent solar panels for both minimum and maximum temperature. Studies indicate maximum temperatures for ground surface under and near semi-transparent solar panels are same i. e., 44°C and minimum temperatures are 34°C and 32°C respectively. Therefore, natural vegetation or greenery helps to reduce atmospheric temperature and global warming effect. One of the most significant advantages of semi-transparent solar panels is that it has minimal effect on the albedo of earth which is suitable for plant grown under it.

Categories: Renewable Energy in Agriculture, Signal Processing and Image Analysis, Environmental and Sustainable Engineering

Keywords: agrivoltaic, albedo, solar photovoltaic, thermography, plant life, semi-transparent, tempetature, thermal loss

Introduction

Solar panels are one of the cleanest and renewable sources of energy generation now-a-days. These solar radiations emitted by sun are absorbed by solar cells which convert photon into useful electrical energy [1-2]. The effect of albedos is a critical factor in the performance of mono-facial and bi-facial solar panels, higher the albedo, higher is the energy generation. High albedo reduces heat generation at surface and reduces the surrounding temperatures [3]. Semi-transparent solar panels designed to maintain albedo when radiations fall on it by balancing absorbed light, transmitted light, reflected light [4]. Solar panel installations at the ground affect the land cover and land use area, increase the temperature, and affect the performance [5]. Thermographic approach is a non-destructive method to detect the high temperature regions with in the solar panels. [6-7]. Thermal camera captures thermal image of heated regions which are represented by bright color, whereas dark color represents low temperature regions. Matlab digital image processing is applied on thermal images to perform temperature analysis [8]. Integration of agrivoltaics with semi-transparent solar panels has more applications today. They provide almost natural sunlight necessary for cultivation and shading due to

semi-transparent solar panels is one of the most crucial factors for cultivated plants [9]. Now-a-days thermal images are processed through different image processing algorithms to study temperature effects [10]. These techniques monitor and investigate the high temperature effects on cultivation for different crops. [11].

Materials And Methods

Albedo Effect & Semi-transparent Agrivoltaic Installation Systems

When solar panels are installed at the ground surface the temperature of surrounding area increases gradually and produces heat. Agrivoltaics with semi-transparent solar panels help to reduce the temperature and increase productivity High albedo reduces temperature and heating. The heating produced by solar panels is reduced by greenery and natural vegetation in agrivoltaics installation system [12]. Depending on the surface albedo the solar radiations emitted by sun are partly reflected to atmosphere and partly absorbed by surface. The absorbed solar radiations are distributed as latent heat and sensible heat. Natural vegetation and plants lower the albedo and absorb more heat. Surface without greenery decrease surface albedo and increase the surface temperature [13]. Therefore, the land cover affects the heating of surface temperature due to change in albedo. Heat islanding is responsible for the change in albedo, greenery, and temperature of surrounding [14].

The following fig. *1* shows the semi-transparent solar panel agrivoltaics installation system with greenery on cultivated farm. The solar radiations are partly absorbed, partly transmitted, and partly reflected.



FIGURE 1: Semi-transparent Agrivoltaic Installation System

Work done for Heat Assessment of Cultivated Plant Life for Semi-transparent Agrivoltaic Installation System

The experimental work is performed at semi-transparent based agrivoltaics farm with full of natural vegetation. Semi-transparent solar panels are installed at iron pillar and different crops are cultivated beneath it. The green plants lower the temperature of surrounding which is suitable to grow agricultural vegetables. The following fig. *2* shows the semi-transparent agrivoltaics farm with cultivated brinjal plants.



FIGURE 2: Cultivated Brinjal Plants in Semi-transparent Agrivoltaic Farm

The following fig. *3* shows google map of semi-transparent agrivoltaics farm which is full greenary.



FIGURE 3: Google map of Semi-transparent Agrivoltaic Installation System

The following flowchart shown in fig. *4* represents algorithm used for analyzing the effect of heat on semi-transparent agrivoltaics installation. The work is performed by applying matlab digital image processing on thermal images obtained through thermal imaging camera.

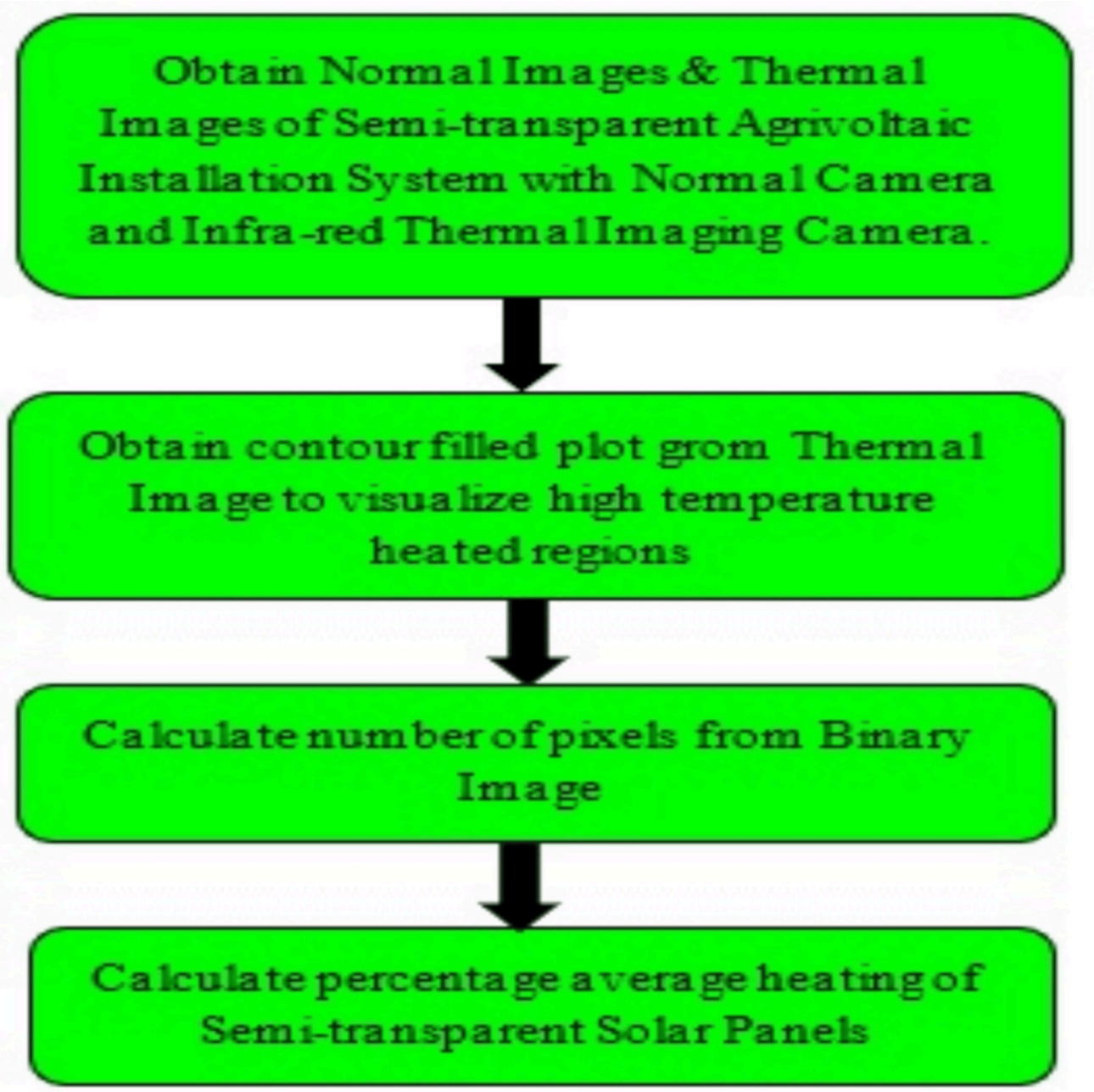


FIGURE 4: Algorithm used for analyzing heat assessment of semi-transparent agrivoltaics installation system

Normal normal android phone is used to capture normal images. The following fig *5* show an infra-red thermal imaging camera (Kusam Meco Thermal imaging camera Model TE-P) which is used to capture thermal images respectively of the semi-transparent solar panels.



FIGURE 5: Normal image of infra-red thermal imaging camera

The following fig. *6* to fig. *11* show original normal images and thermal images for semi-transparent solar panel installation at agrivoltaics farm indicating effect of heating visible at back surface, ground surface near and under semi-transparent solar panels. The thermal images show maximum and minimum range of temperature which are represented by bright and dark colors respectively.



FIGURE 6: Normal image of back surface of semi-transparent solar panel



FIGURE 7: Normal image of ground surface near semi-transparent solar panel



FIGURE 8: Normal image of ground surface under semi-transparent solar panel

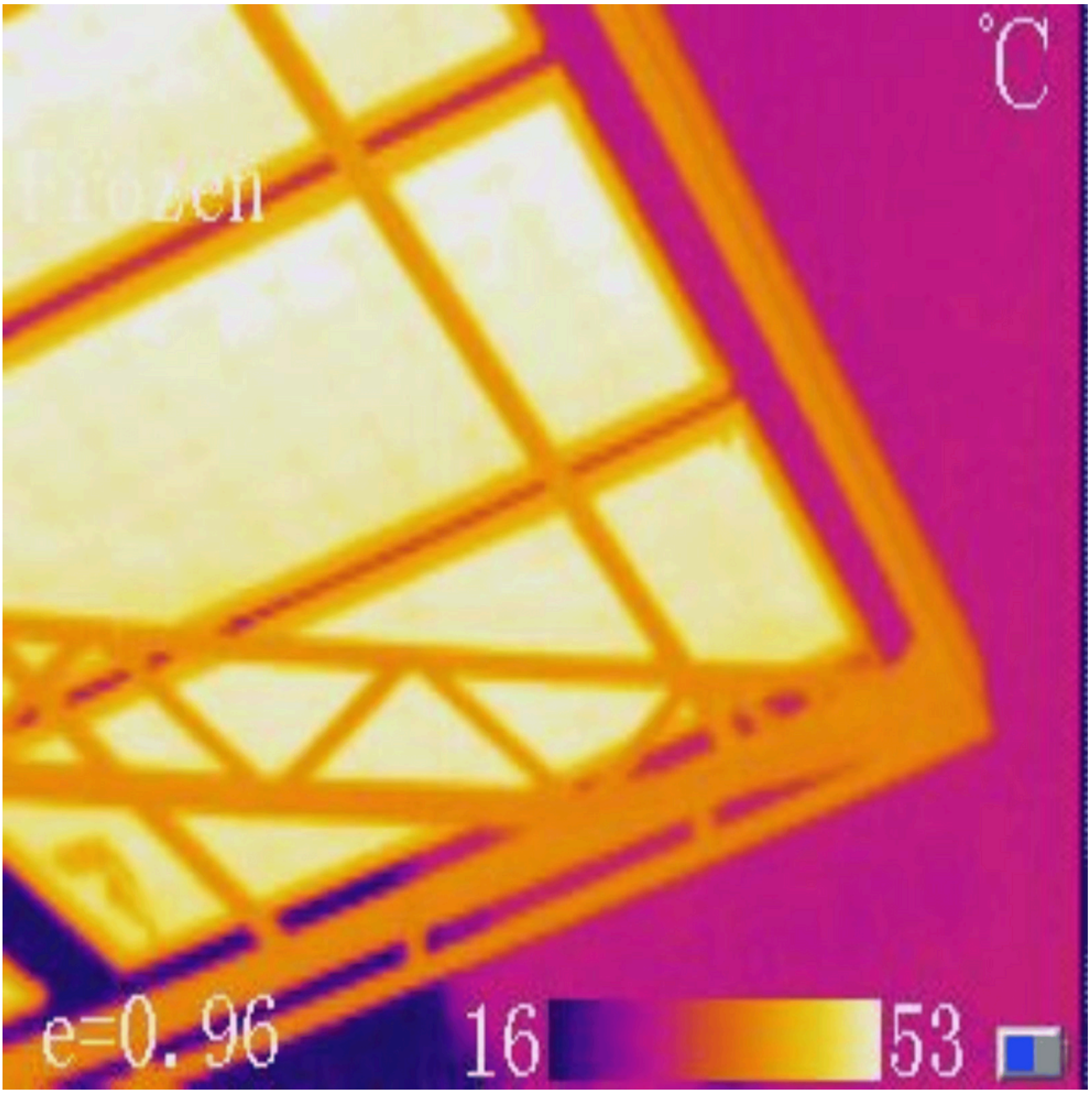


FIGURE 9: Thermal image of back surface of semi-transparent solar panel

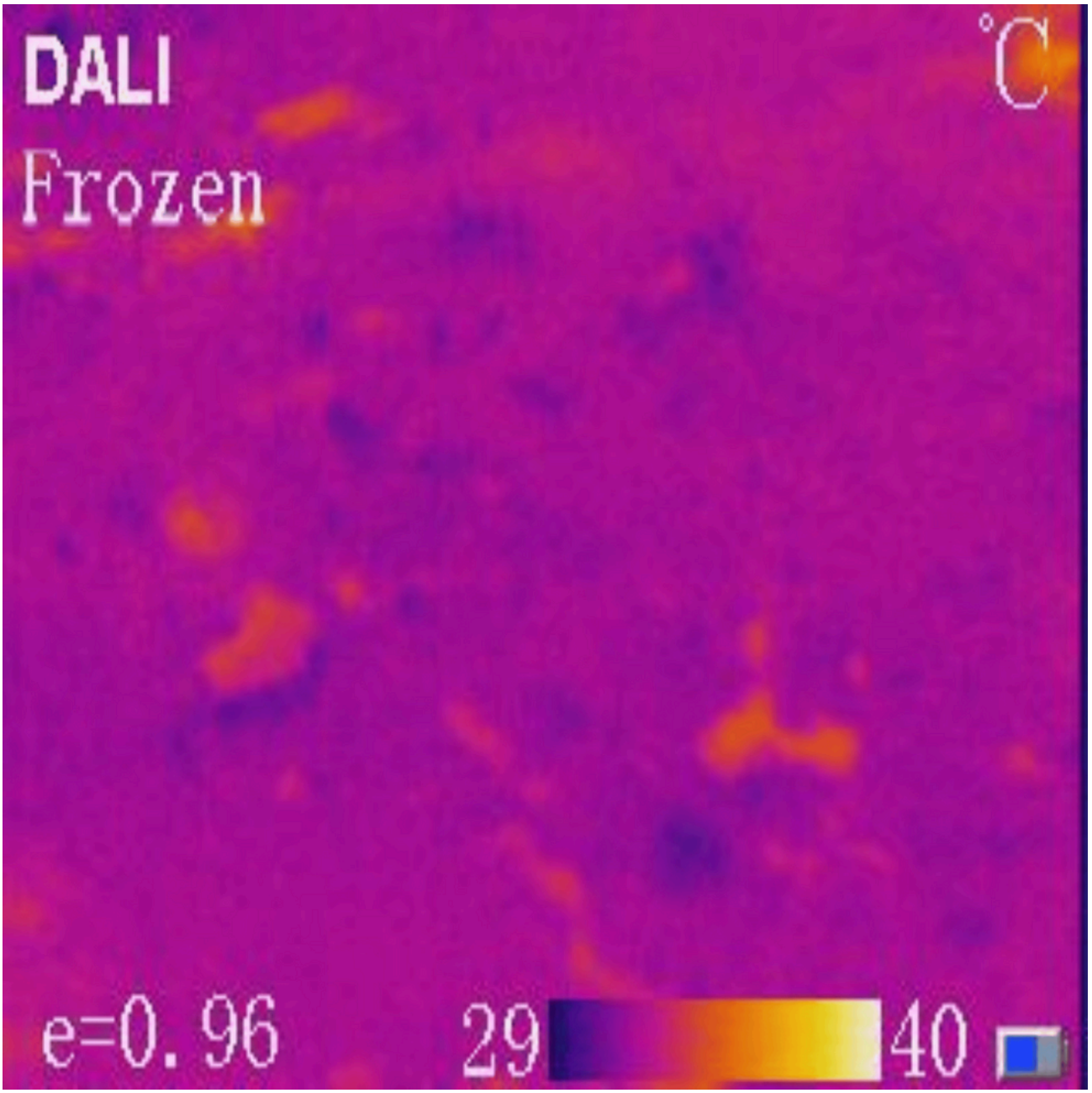


FIGURE 10: Thermal image of ground surface near semi-transparent solar panel

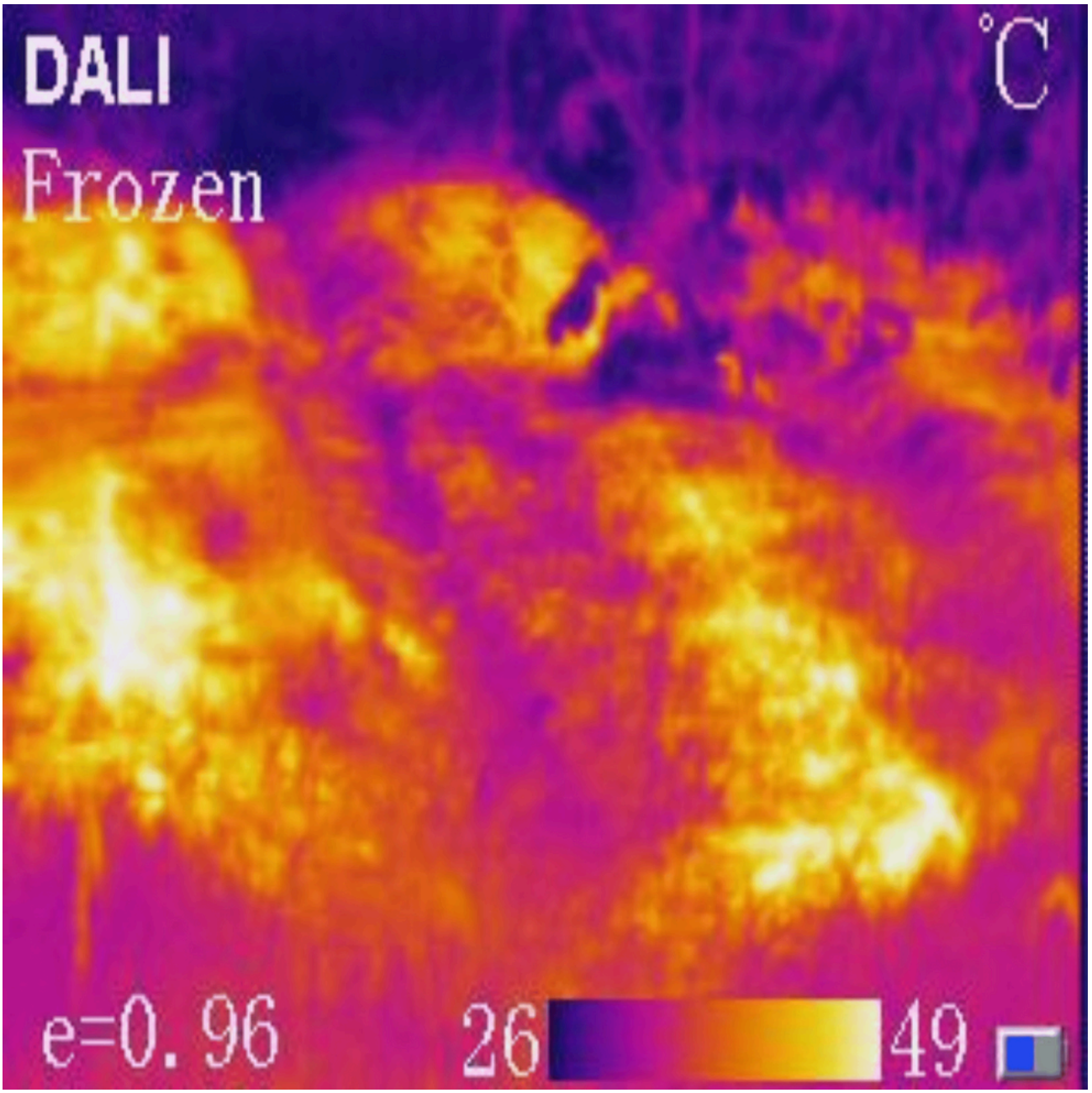


FIGURE 11: Thermal image of ground surface under semi-transparent solar panel

The following table *1* shows the temperature parameters acquired for back surface of semi-transparent solar panels, ground surface location near and under semi-transparent solar panels using thermal imaging camera with same solar irradiance obtained by solar pyranometer.

S.No	Parameters	Maximum Temperature	Minimum Temperature
1	Tbp (°C)	53	16
2	Tgsn (°C)	44	32
3	Tgsu (°C)	44	34
4	Tatm (°C)	32	27
5	SI (w/m^2)	509.544	509.544

TABLE 1: Temperature at Semi-transparent Agrivoltaic Installation obtained from Thermal Image

From above table *1* it has been noticed that the maximum temperature at ground surface near and under semi-transparent solar panels is same therefore, the percentage average heating is calculated for this case. Thermal images obtained through thermal imaging camera are processed through matlab digital image processing to obtain contour plot. Contour plot represents the depth of heating in semi-transparent solar panels. The binary image obtained from thermal image calculate the number of pixels for heated regions. White color shows hot regions while black color shows regions having low temperature. The percentage average heating in binary image of semi-transparent solar panels is calculated with the help of following formula with area of heated region and total area of image in terms of number of pixels.

$$"Percentageaverageheating" = "WhiteArea"/"TotalArea" x100$$

Percentage average heating for ground surface near semi-transparent solar panels:

The following fig *12* to fig. *15* shows original normal camera image of ground surface near semi-transparent solar panels, thermal image of ground surface near semi-transparent solar panels, binary image of ground surface near semi-transparent solar panels and contour 3D plot for thermal image showing heated region at ground surface near semi-transparent solar panels. The heating effect is visible in thermal image.



FIGURE 12: Original normal camera image of ground surface near semi-transparent solar panels

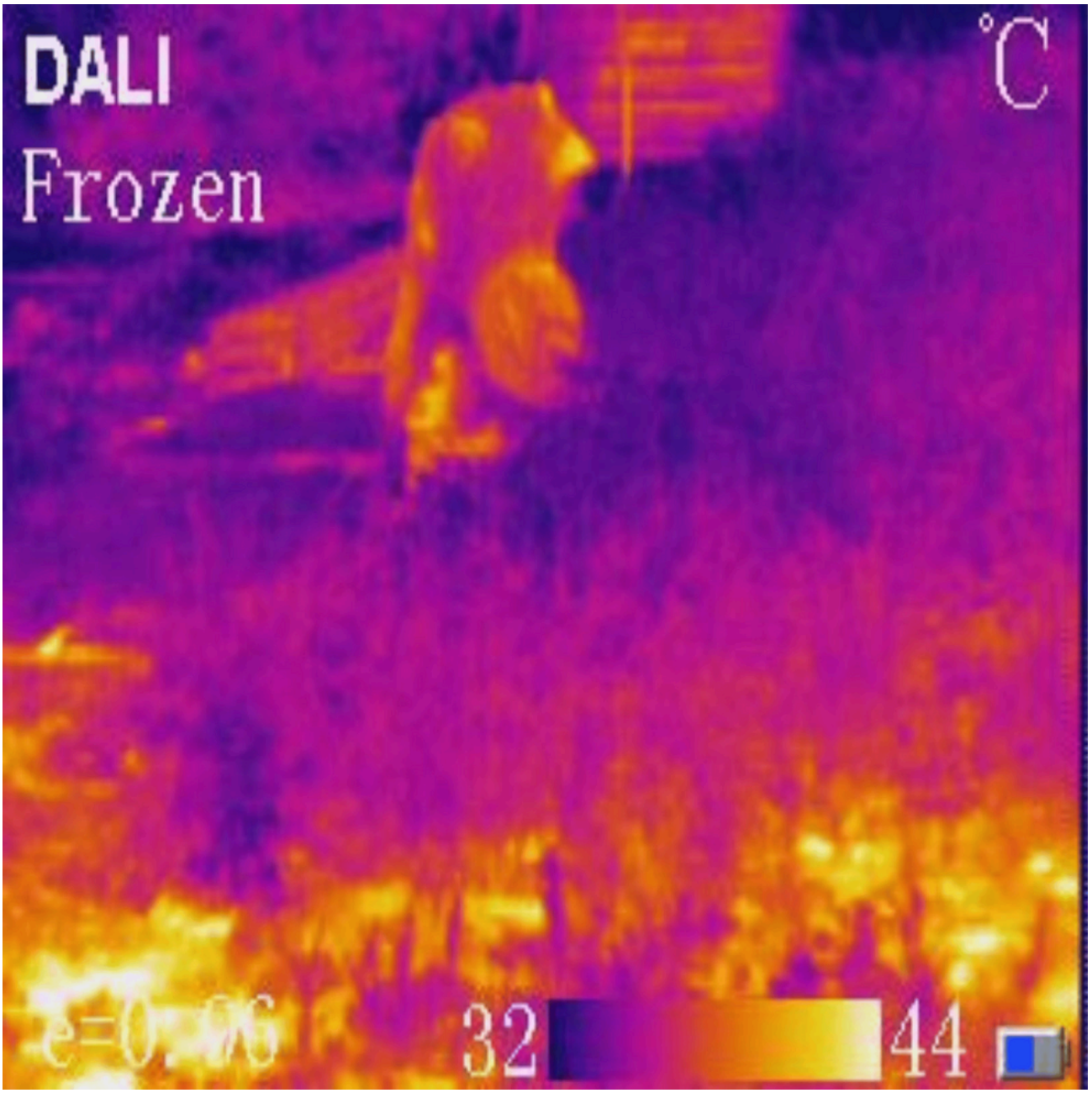


FIGURE 13: Thermal image of ground surface near semi-transparent solar panels

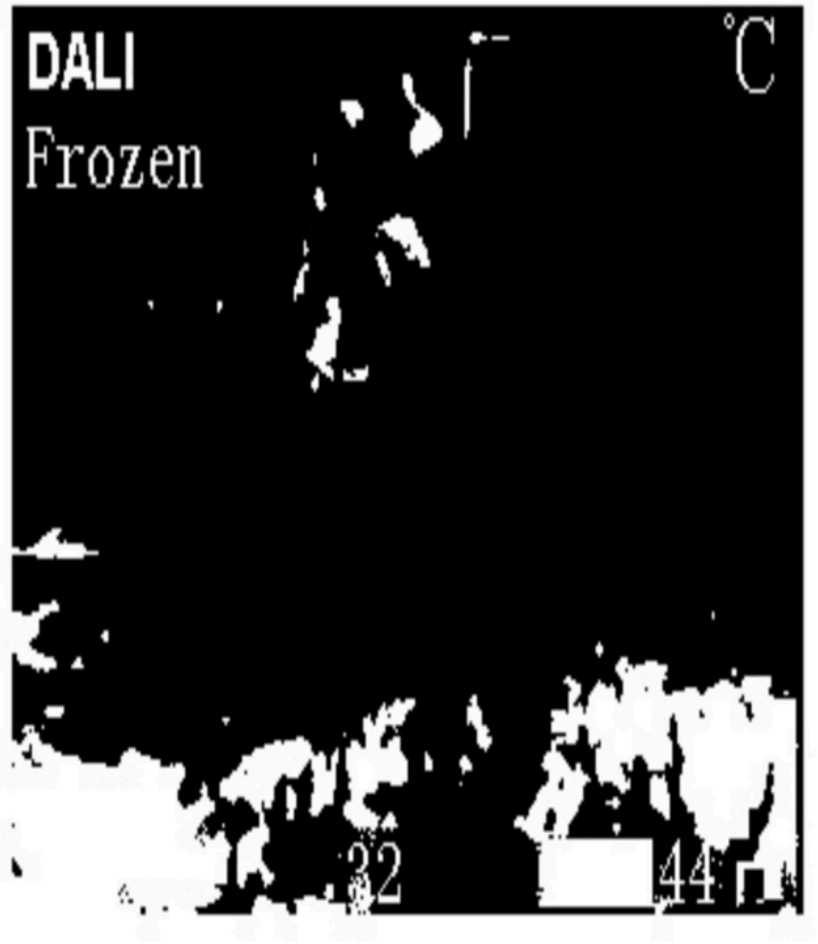


FIGURE 14: Binary image of ground surface near semi-transparent solar panels

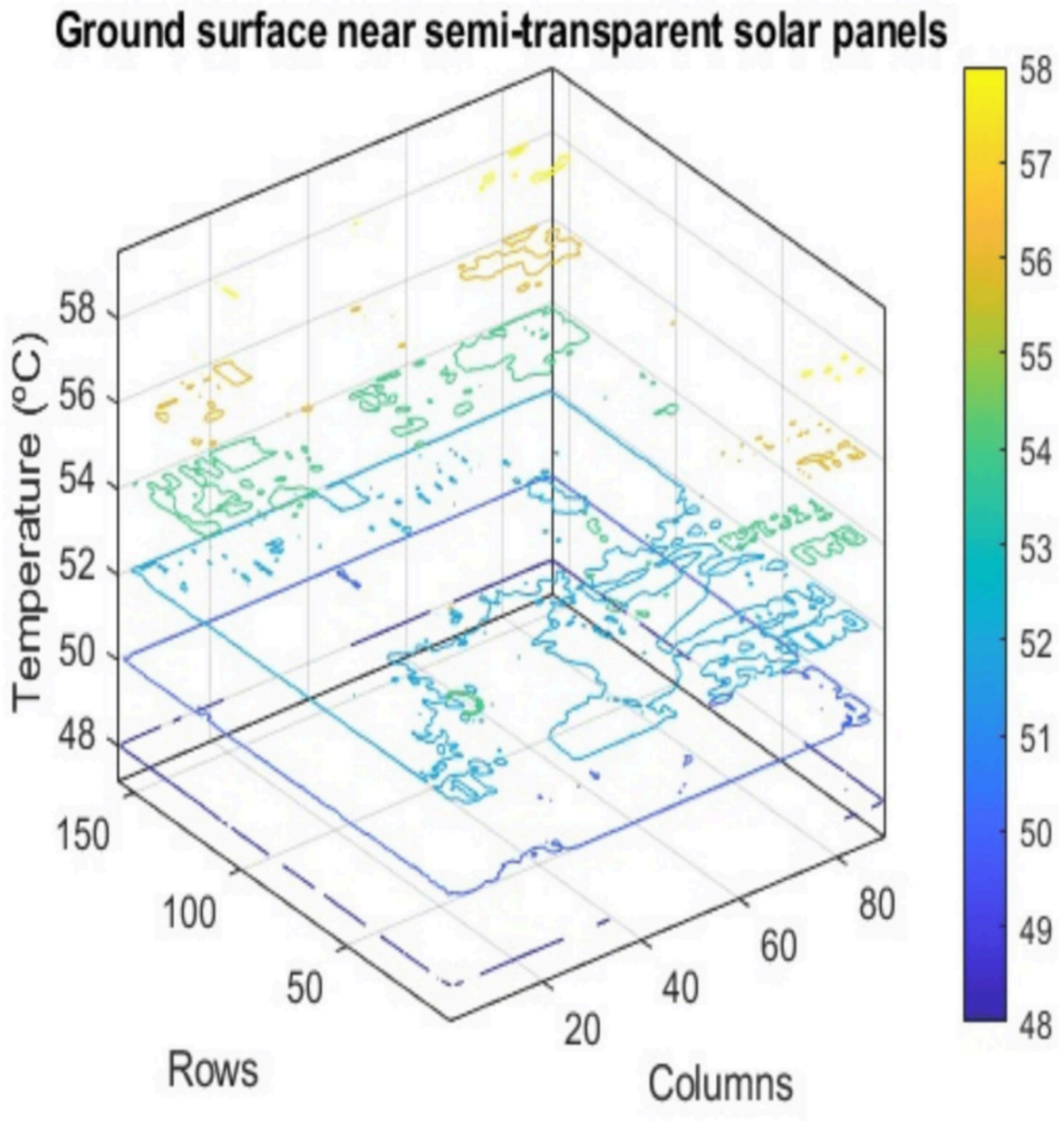


FIGURE 15: Contour 3D plot for thermal image showing heated region at ground surface near semi-transparent solar panels

The percentage average heating for ground surface near semi-transparent solar panels is calculated by formula:

Percentage Average Heating= (11016/76800) x100

=14.34%

Percentage average heating for ground surface under semi-transparent solar panels:

The following fig *16* to fig. *19* shows original normal camera image of ground surface under semi-transparent solar panels, thermal image of ground surface under semi-transparent solar panels, binary image of ground surface under semi-transparent solar panels and contour 3D plot for thermal image showing heated region at ground surface under semi-transparent solar panels. The heating effect is visible in thermal image.



FIGURE 16: Original normal camera image of ground surface under semi-transparent solar panels

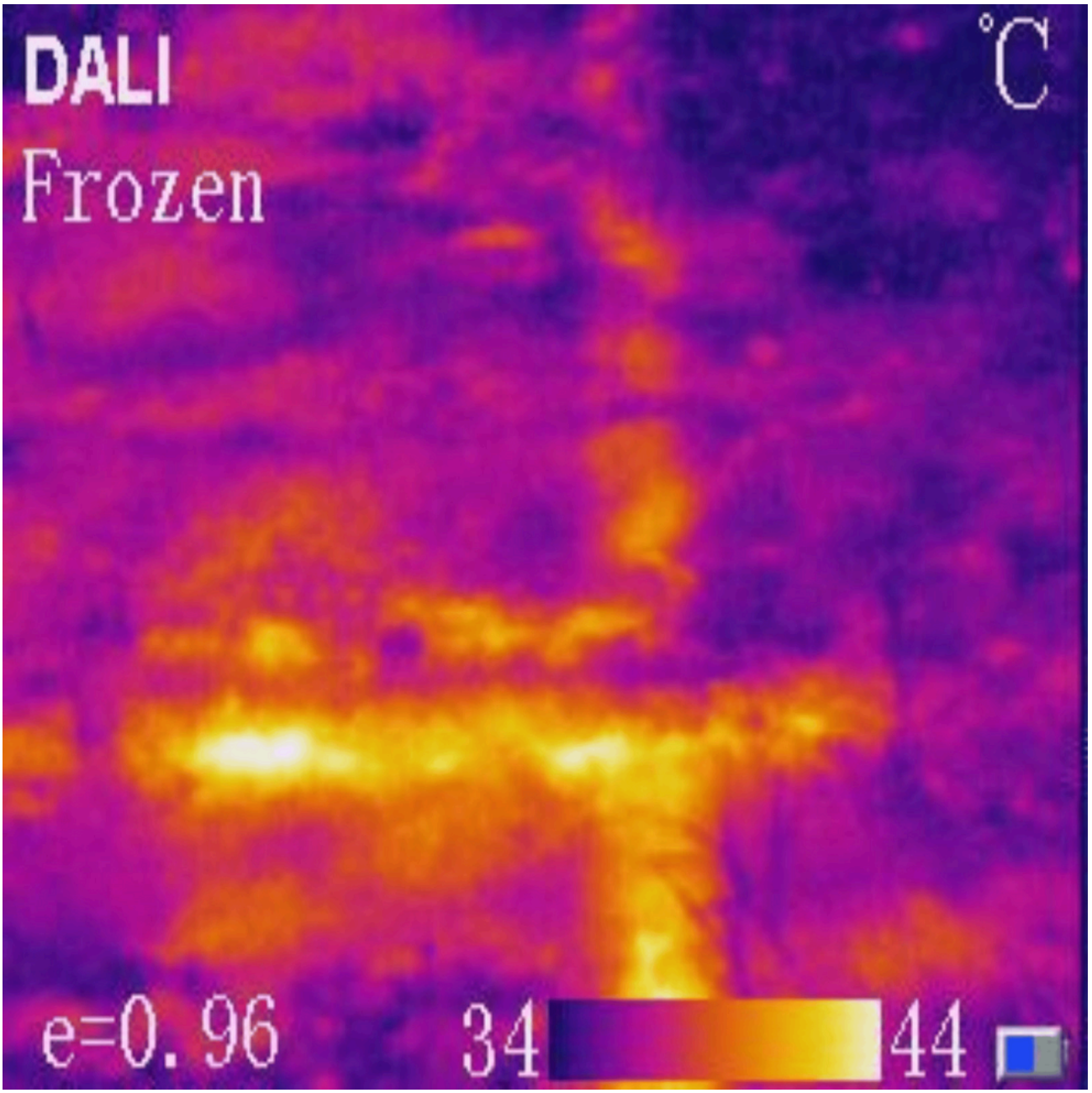


FIGURE 17: Thermal image of ground surface under semi-transparent solar panels



FIGURE 18: Binary image of ground surface under semi-transparent solar panels

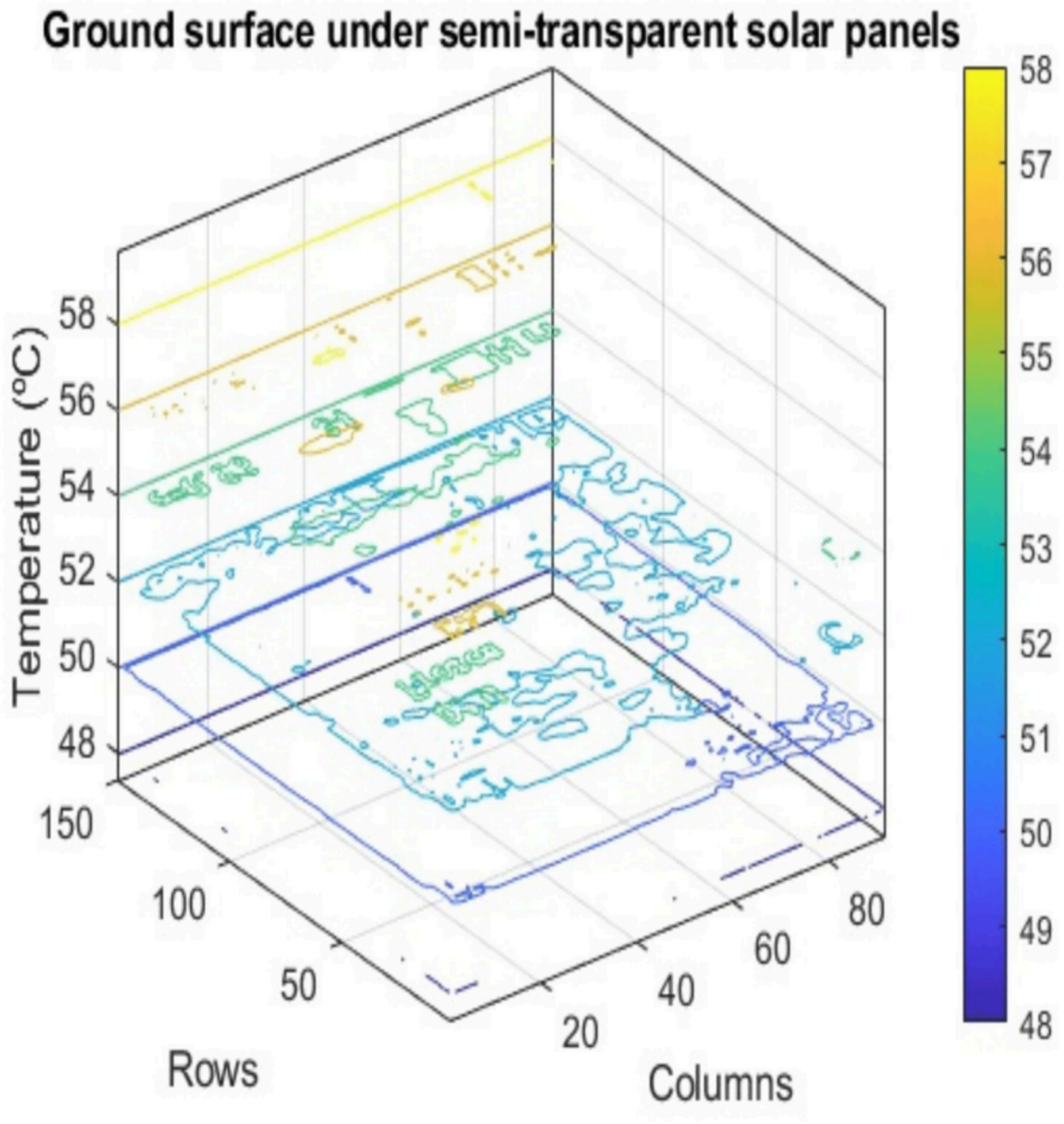


FIGURE 19: Contour 3D plot for thermal image showing heated region at ground surface under semi-transparent solar panels

The percentage average heating for ground surface under semi-transparent solar panels is calculated by formula:

Percentage Average Heating=(8837/76800) x100

=11.50%

Results And Discussion

The maximum and minimum temperatures at ground surface near semi-transparent solar panel installation obtained from thermal image are 44 (°C) and 32 (°C) respectively. Whereas the maximum and minimum temperatures at ground surface under semi-transparent solar panel installation obtained from thermal image are 44 (°C) and 34 (°C) respectively which shows that there is no significant difference in maximum and minimum temperatures at ground surface near and under semi-transparent solar panels.

The binary image represents number of pixels showing heated region as white pixels. The contour 3D plot shows the intensity of hating on temperature scale. Binary image is used to calculate the percentage average heating. The calculated percentage average heating for both locations i.e., ground surface near and ground surface under semi-transparent solar panels also show a difference of approximately 3%.

The fig. *20* shows temperature distribution in pixels for ground surface near and under semi-transparent solar panels. It explains the temperature is almost same with a negligible temperature rise for ground surface under semi-transparent solar panels.

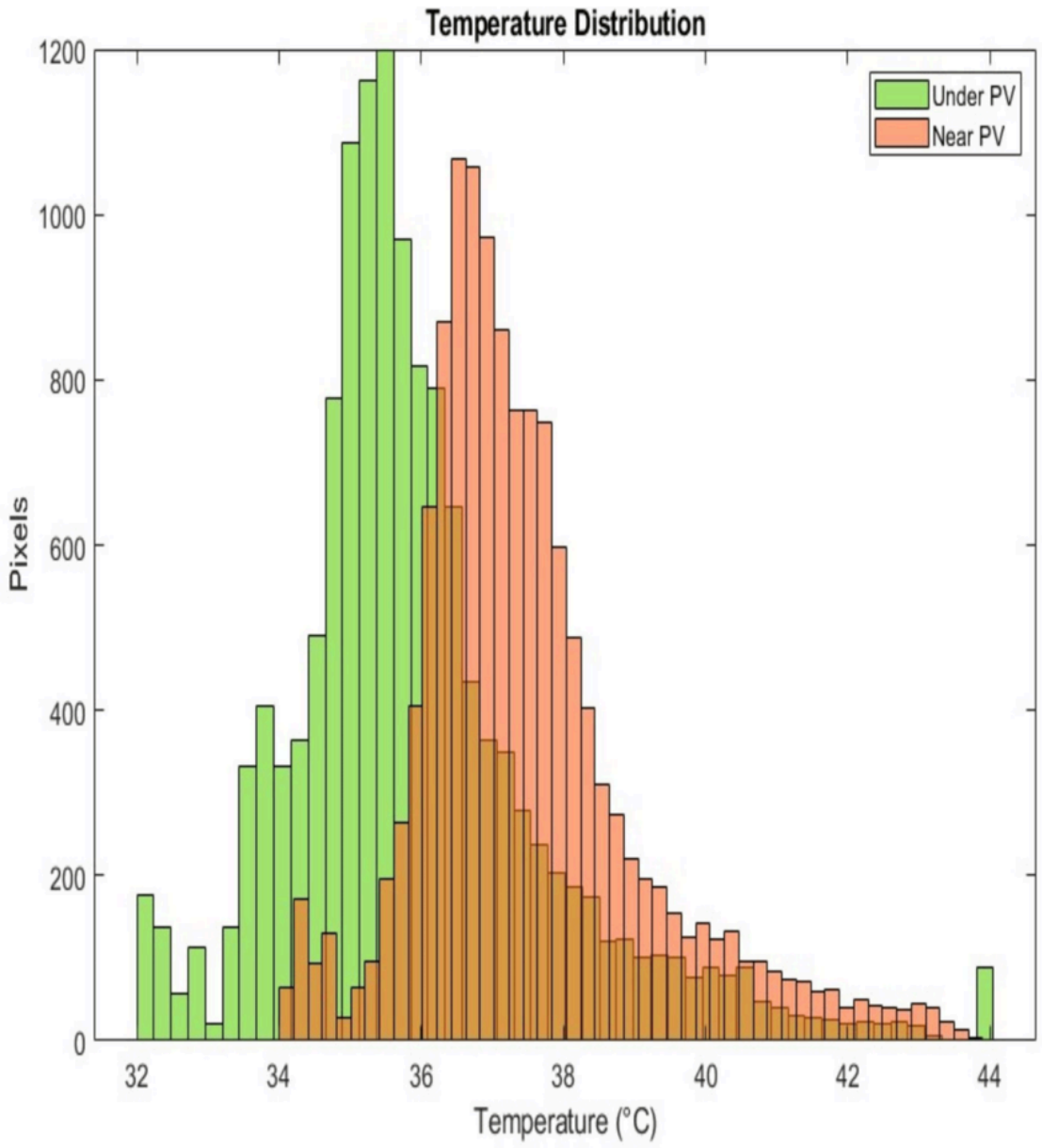


FIGURE 20: Temperature distribution for ground surface near and under semi-transparent solar panels

Conclusions

The study uses hybrid thermographic image processing approach to analyze the temperature and calculating the average percentage heating. The temperature distribution shown in fig. *20* representing temperature profile with almost no temperature difference for ground surface under and near semi-transparent solar panels which also has been verified through minimum and maximum temperature ranges mentioned in table *1*.

The research shows that to cultivate a plant or natural vegetation in agrivoltaics farm for semi-transparent solar panels the albedo is not affected by significant amount. The plants or crop grown have same maximum and minimum temperature (heating effect) at ground surface near and ground surface under semi-transparent solar panels. Therefore,

the plants, crops or natural vegetation cultivated under semi-transparent solar panels are suitable for agrivoltaics farming. One another advantage of agrivoltaics installation is optimal use of land. The greenery lowers the atmospheric temperature near the semi-transparent solar panel installation.

The work is helpful to find defects and temperature analysis in semi-transparent solar panels. Through study it has been concluded that installation of semi-transparent solar panels does not significantly affect the growth of plants cultivated under it which is justified by maximum and minimum temperatures of thermal images as well as percentage average heating.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statements

the data used in the research work need not to be shared bu can be available on reasonable request

Acknowledgements

Data can be available on the reasonable request

References

1. Redfield, D,: Solar energy and conversion". Technology and Society, IEEE Journals and Magazines,. 1978, 6:4-9,.
2. Biran, D, Braunstein, A,: Solar radiation and energy measurements". IEEE Trans. Power Apparatus and Systems,. 1976, 95:791-794,.
3. Behrouz Pirouz, Seyed Navid Naghib, Karolos J Kontoleon, Hana Javadi Nejad, Patrizia Piro,: Revealing the impact of albedo on solar panel power generation potential in various installation patterns: Case study of Italy". Energy Reports, Elsevier,. 2025, 14:473-485,. 10.1016/j.egyr.2025.06.024
4. Xia, Ruoxi & Gu, Honggang & Liu, Shiyuan & Zhang, Kai & Yip, Hin-Lap & Cao, Yong,: Optical Analysis for Semitransparent Organic Solar Cells". Solar RRL., Wiley,. 2018, 3:1-18,. 10.1002/solr.201800270
5. Haque, MI, Basak, R,: Land Cover change Detection using GIS and Remote Sensing Techniques: A spatio-temporal Study on Tanguar Haor, Sunamganj, Bangladesh". The Egyptian Journal of Remote Sensing and Space Science, Elsevier,. 2017, 20:251-263,. 10.1016/j.ejrs.2016.12.003
6. L. Dorobantu, M. O. Popescu, C. Popescu and M. Cucu: Depositions Effects and Losses Caused by Shading on photo-voltaic Panels". IEEE Conf. Proceedings, 3rd Int. Youth Conf.. Energetics, (ed): Leiria; 2011. 1-5,.
7. Kasim Ravani, Debasis Sarkar, Indrajit Mukhopadhyay, Tejas Thaker & N. Ranganath : Performance characterization and thermal imaging of large-scale ground mounted solar photo voltaic plant in Western India". Sustainable Energy Research, Springer,. 2025, 12:1-19,. 10.1186/s40807-025-00176-w
8. Chaudhary, AS, Chaturvedi, DK,: Thermal Image Analysis and Segmentation to Study Temperature Effects of Cement and Bird Deposition on Surface of Solar Panels". I.J. Image, Graphics and Signal Processing, MECS Press,. 2017, 9:12-22,. 10.5815/ijigsp.2017.12.02

9. Hernández, V., López, F.C., Toledo, C., et. al.: Comparative evaluation of semi-transparent monocrystalline silicon and cadmium telluride photovoltaics for tomato cultivation in Mediterranean agrivoltaic greenhouses". Smart Agricultural Technology, Elsevier,. 2026, 13:10.1016/j.atech.2026.101848

10. V. Kirubakaran, D. M. D. Preethi, U. Arunachalam, et al.: Infrared Thermal Images of Solar PV Panels for Fault Identification Using Image Processing Technique. International Journal of Photoenergy, Wiley,. 2022, 6427076:10. 10.1155/2022/6427076

11. Giorgia Di Domenico, Pierluigi Rossi, Esther Magadley, Andrea Colantoni,: Monitoring agrivoltaic systems: A scoping review of sensing architectures and cost-complexity trade-offs. Smart Agricultural Technology,. 2026, 14:2772-3755,. 10.1016/j.atech.2026.102121.

12. Thomas Reher, Brecht Willockx, Ann Schenk, et al. : Agrivoltaic cultivation of pears under semi-transparent panels reduces yield consistently and maintains fruit quality in Belgium". Agron. Sustain. Dev., Springer,. 2025, 45:1-20,. 10.1007/s13593-025-01019-0

13. Lucia Perugini, Luca Caporaso, Sergio Marconi, et al,: Biophysical Effects on Temperature and Precipitation due to Land Cover Change". Environmental Research Letters, IOP Publishing,. 2017, 12:1-14,. 10.1088/1748-9326/aa6b3f

14. Greg A. Barron-Gafford, Rebecca L. Minor, Nathan A. Allen, et al.: The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures". J. Scientific Reports, Nature,. 2016, 17,. 10.1038/srep35070