JRSSEM 2025, Vol. 05, No. 05
E-ISSN: 2807 - 6311, P-ISSN: 2807 - 6494

Performance Analysis of Polycrystalline and Monocrystalline Solar Modules in Dry-Land Crop Environments of Arachis Hypogaea (Peanut Plants)

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Abstract

Nusa Tenggara Timur (NTT) is characterized by prolonged sunlight (up to nine months annually) and extensive dry agricultural land (~3.6 million hectares), offering substantial potential for agrovoltaic development. Agrovoltaics integrates agriculture with solar power generation on the same land, optimizing land use while enabling mutual benefits between crops and solar panels. Solar panel performance is significantly influenced by temperature, with higher temperatures reducing power output and efficiency. Previous studies have explored temperature mitigation strategies, including the use of surface films and the placement of evapotranspirative vegetation for natural cooling, which can enhance panel efficiency. This research aims to analyze the effect of the dryland crop Arachis hypogaea L. (peanut), as part of an agrovoltaic system, on the output performance of polycrystalline and monocrystalline solar panels. Both panel types were tested with Arachis hypogaea planted beneath them and compared to identical panels without vegetation. The results showed that placing Arachis hypogaea beneath the panels led to a reduction in panel surface temperature, which in turn resulted in an increase in output voltage—both V_{oc}(open-circuit voltage) and V_{mp}(maximum power voltage)—for both monocrystalline and polycrystalline panels. This temperature reduction contributed to an increase in output power and efficiency, ranging from approximately 0.7% to 1.5%, indicating that Arachis hypogaea has the potential to serve as a natural cooling medium in agrovoltaic systems for dryland tropical environments such as NTT.

Keywords: Agrovoltaic, Arachis H., Solar Panel, Temperature, Efficienc

INTRODUCTION

Nusa Tenggara Timur (NTT) is one of the provinces in Indonesia that has a longer summer than the rainy season. The rainy season in NTT lasts only around 4–5 months on average, while the rest is summer. The highest intensity of solar radiation in Indonesia occurs in NTT, especially on *Sumba Island* and *Timor Island*, reaching around 6.0 kW/m² (Kompas, 2020). On *Timor Island* itself, in October, the sun's intensity can reach 7.3 kW/m² (Weather Spark, n.d.).

A solar power plant is one of the renewable energy generation system technologies that converts sunlight into electrical energy using solar cell (PV cell) panels. The higher the solar radiation (irradiance) hitting the panel surface, the higher the current produced. In addition to electric current, electric voltage also results from the conversion. The relationship between the light absorbed by the solar cell and the current produced is linear, while the voltage generated depends on the temperature and the material used in its manufacture (GÖKÇEN & KAYA, 2023; Jamali et al., 2020; Manasrah et al., 2021; Sharma, 2022; Singla et al., 2016).

Several studies have explored controlling the influence of temperature on solar panel performance, such as using heatsinks under panels to circulate air (Rahman et al., 2023), immersing panels in water (Abdulgafar et al., 2007), applying water flow on the panel surface, coating panels with color film (Abdulmunem et al., 2018), or using blocking film (Manasrah et al., 2021). These studies showed considerable increases in both panel power output and efficiency.

In addition to controlling panel temperature, research has addressed environmental temperature, such as placing water-filled containers under polycrystalline solar panels or positioning vegetation like evapotranspiration plants (*Ocimum sanctum* or *Tulsi* and *Mentha* or *Pudina*) under or around solar panels. The results showed an increase in panel efficiency of about 3–4% for water containers under panels and 1.2–2% for vegetation (Ahmad et al., 2016; Kande et al., 2016; Karakilic et al., 2022; Samah et al., 2024; Tripathi et al., 2020).

In addition to abundant irradiation, NTT has large dryland agricultural potential—around 3.6 million hectares—though most remains underutilized. Lowland food crops commonly developed in NTT include corn, *padi gogo* rice, sorghum, *kacang tanah*, *kacang gude*, cassava, mung beans, and peanuts. In the highlands, crops include *padi gogo* rice, corn, *jawawut*, *jali*, kidney beans, *kacang koro*, sweet potatoes, and *gembili* (BRIN, n.d.).

Agrivoltaics is a system that combines agriculture and solar power plants (*PLTS*) on the same land, enabling simultaneous production of both. These systems are also known as collocation, dual-use solar, or solar farming. Agrivoltaics allows the same land to generate electrical energy and agricultural products. Some crops, including legumes, yield better under solar panel shade due to increased humidity and shading. In the NTT area, solar panels in agrivoltaic systems can provide shade and help retain soil water, benefiting such climatic conditions (BRIN, n.d.).

Regarding agrivoltaics and solar PV, in 2024, Luo et al. (2024) studied the impact of solar power plant placement on agrivoltaic agriculture. Conducted in Southeast China, the study used *Lolium perenne* L. and *Arachis hypogaea* L. plants. The results showed that agrivoltaics increased soil moisture and pH, organic carbon content, microbial biomass, and soil conductivity.

Although research exists on the impact of agrivoltaics on plant growth, little has examined the impact of plants on solar PV performance. This is especially true for *Arachis hypogaea* L., a dryland crop under high-irradiance and high-temperature conditions in NTT.

In this study, performance measurements (solar panel output) assessed the impact of placing *Arachis hypogaea* L. (*peanut*) dryland plants under panels. Measurements evaluated dryland plant impacts on both polycrystalline and monocrystalline panels under NTT irradiation and temperature conditions.

Therefore, this study aims to analyze the influence of *Arachis hypogaea* placement beneath solar panels on the performance of polycrystalline and monocrystalline solar modules. The research evaluates changes in panel temperature, voltage, current, power output, and efficiency in the presence of this crop. The findings are expected to provide insights into the potential of *Arachis hypogaea* as a natural cooling agent in agrivoltaic systems, supporting more efficient and sustainable land use in dry tropical regions such as NTT.

RESEARCH METHOD

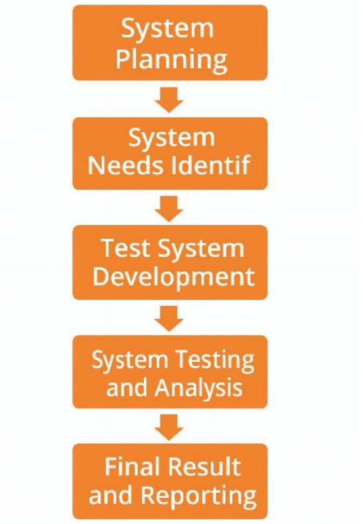

Figure 1. Research Stages

Source: Author's analysis (2024)

At this stage, problem identification and literature studies related to the problems raised are carried out. The image below is a big picture of the system plan that will be tested.

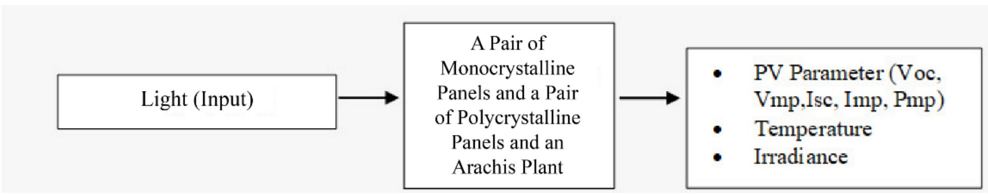

Figure 2. Research Overview

Source: Author's illustration (2024)

Some of the main components of the System are

1. Polybags, soil and Seeds of Hypogaea L Plants (Peanuts)
2. Solar Panel Polycrystalyne and Monocrystalyne 100 Watt
3. The measuring instruments are in the form of I-V Curve analyser, Thermometer, and Light Meter.

The design of the system to be tested can be seen in the image below:

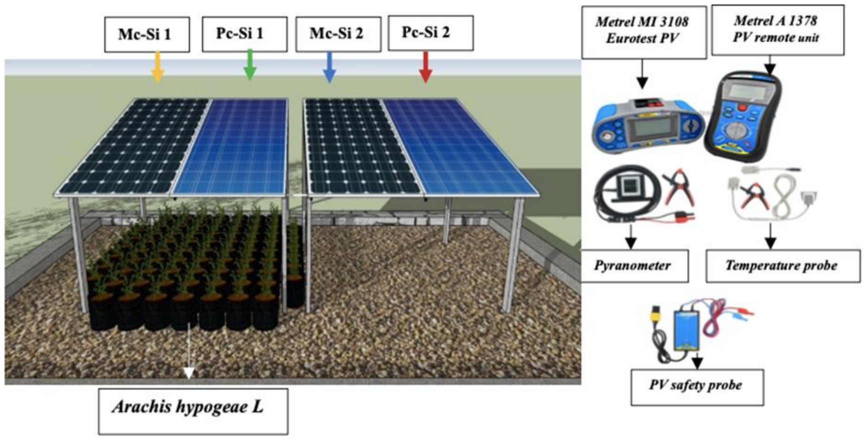

Figure 3. Test System Setup

Source: Author's experiment design (2024)

In this test, an I-V Curve analyzer will be used to measure the performance of the module. An I-V curve tester brand Metrel MI 3108 Eurotest PV is used to record the output parameters of the Solar Panel. The device is equipped with a Metrel A 1378 PV remote unit as a device to measure temperature and solar irradiation. The appliance operates at Vmax 1000 Volts, Imax 15 Ampere, and Pmax 400 Watts. The specifications and drawings of the Metrel MI 3108 Eurotest test equipment can be seen below:

Table 1. Specification of Metrel A 1378

PV Remote unit:	**Pyranometer**
Measuring principle:	Polycrystalline PV cell, temperature compensated
Measuring range:	0 – 999 W/m2 (resolution 1) and 1.0 – 1.75 kW/m2 (resolution 10)
Working temperature range:	-20 ^{oC} – 55 ^{oC}
Protection degree:	IP 44
Temperature (cell and ambient) Measuring range:	-10 ^{oC} – 85 ^{oC}

Source: Metrel MI 3108 Eurotest PV manual (2023)

Below is a picture of the I-V curve tester

Gambar 4. Metrel MI 3108 Eurotest PV dan Metrel A 1378 PV remote unit

Source: Metrel instrument documentation (2023)

Measurements in this study will be carried out at 11.00-02.00. The tool automatically recalculates the measured current and voltage values to Standard Test Conditions /STC where Irradiance is 1000W/m2, Module temperature 25 oC, AM =1.5. It is very important to compare the performance of the panels in the field with the ideal (factory) specifications. The specifications of the panels used can be seen in the table below

Table 2. Specification of Solar Panel

Parameter	Monocrystalline	Polycrystalline
Pmpp (W)	100	100
Voc (V)	23,0	22,1
Isc (A)	5,53	6,00
Vmpp (V)	19,0	18,3
Impp (A)	5,26	5,49

Source: Manufacturer datasheet (2023)

Testing and Data Analysis.

This stage serves to determine the performance of the PV system built under the climate conditions of Kupang City. Performance indicators of the PV system built include current (isc and Imp), voltage (Voc and Vmp), radiation and panel temperature. Some tests that will be carried out:

Performance PV System with Polycrystaline Module equipped with a Heatsink with Sansevierie Sp. placement under the panel.

1. Performance of PV System with Polycrystaline Module equipped with Heatsink without the placement of Sansevierie Sp. under the panel.
2. These two tests will be carried out simultaneously under the same lighting and temperature conditions.

The parameters or outputs of the panel that will be evaluated include open circuit voltage (Voc), short-circuit current (Isc), maximum power (Pmax), and overall efficiency (η). The efficiency of each panel is calculated using the following formula:

$$\eta = Pout/Pin \times 100\%$$

Where the Pin is the Input Power received by the panel surface area due to exposure to sunlight, and the Pout is the maximum power output of the panel captured by the Metrel IV Curve Analyzer.

Current, voltage, radiation, and temperature values are processed to obtain output power and efficiency values. All parameters are measured and calculated in percentages in the form of graphs or tables for comparison.

RESULTS AND DISCUSSION

The results of measuring the impact of Arachis H. placement on the output or performance of Monocrytalyine and Polycristalyne type panels can be seen in the table below. The parameters measured include Voltage (Voc and Vmp), Current (Isc and Imp), Power (Pmp), Irradiance (Irr) and Temperature (T).

Table 3. Test results on Polycrystalline with Arachis H.

Polycrystalline with Arachis H.									
Time	**Voc (V)**	**Isc (A)**	**Vmp (V)**	**Imp (A)**	**Pmp (W)**	**Tcell ($^{0C)}$**	**Irr (kW/m2)**	**Pin (W)**	**Efficiency**
11.00	20	4	15,2	3,73	56,7	45,6	0,718	483,5	11,73
11.30	19,9	4,02	15,3	3,79	58,0	51,4	0,71	478,1	12,13
12.00	19,7	4,65	15,1	4,35	65,7	50,8	0,836	562,9	11,67
12.30	21,1	4,47	15,5	4,14	64,2	50,8	0,794	534,6	12,00
01.00	19,8	4,33	15,6	4,07	63,5	49,8	0,78	525,2	12,09
01.30	19,9	3,8	15,8	3,5	55,3	50,6	0,677	455,9	12,13
02.00	19,9	3,59	15,8	3,35	52,9	49,4	0,641	431,6	12,26
Average	**20,04**	**4,12**	**15,47**	**3,85**	**59,47**	**49,77**	**0,74**	**495,97**	**12,00**

Source: Primary data collected using Metrel MI 3108 Eurotest PV (2024)

Table 4. Test results on Polycrystalline with Arachis H.

Polycrystalline Without Arachis H.									
Time	**Voc (V)**	**Isc (A)**	**Vmp (V)**	**Imp (A)**	**Pmp (W)**	**Tcell ($^{0C)}$**	**Irr (kW/m2)**	**Pin (W)**	**Efficiency**
11.00	19,7	3,71	15	3,55	53,3	46,1	0,72	484,8	10,98
11.30	19,8	3,78	15	3,61	54,2	50,5	0,707	476,1	11,37
12.00	19,6	4,9	15,2	4,64	70,5	50,1	0,836	562,9	12,53
12.30	20,1	4,49	15,7	4,24	66,6	52,3	0,794	534,6	12,45
01.00	19,7	4,3	15,5	4,06	62,9	52,7	0,78	525,2	11,98
01.30	19,7	3,78	15,3	3,57	54,6	50,9	0,681	458,6	11,91
02.00	19,7	3,52	15,8	3,4	53,7	49,8	0,641	431,6	12,45
Average	**19,76**	**4,07**	**15,36**	**3,87**	**59,40**	**50,34**	**0,74**	**496,26**	**11,95**

Source: Primary data collected using Metrel MI 3108 Eurotest PV (2024)

Table 5. Test results on Monocrystalline with Arachis H.

Monocrystalline with Arachis H.									
Hours/Time	**Voc (V)**	**Isc (A)**	**Vmp (V)**	**Imp (A)**	**Pmp (W)**	**Tcell ($^{0C)}$**	**Irr (kW/m2)**	**Pin (W)**	**Efficiency**
11.00	20,8	5,28	16,4	4,9	80,4	52,9	0,709	477,4	16,83
11.30	21	4,95	16,5	4,59	75,7	51,9	0,707	476,1	15,91
12.00	21,1	5,36	16,3	4,95	80,7	51,4	0,837	563,6	14,32
12.30	20,9	4,71	16,3	4,42	72,0	51,3	0,796	536,0	13,44
01.00	21	4,48	16,3	4,12	67,2	52,4	0,786	529,3	12,69
01.30	20,9	4,18	16,7	3,84	64,1	53,9	0,665	447,8	14,32
02.00	21,1	3,78	16,8	3,5	58,8	52,5	0,641	431,6	13,62
Average	**20,97**	**4,68**	**16,47**	**4,33**	**71,27**	**52,33**	**0,73**	**494,53**	**14,45**

Source: Primary data *collected using Metrel MI 3108 Eurotest PV* (2024)

Table 6. Test Results on Monocrystalline Without Arachis H.

Monocrystalline without Arachis H.									
Hours/Time	Voc (V)	Isc (A)	Vmp (V)	Imp (A)	Pmp (W)	Tcell $(^{0C})$	Irr (kW/m2)	Pin (W)	Efficiency
11.00	20,7	4,91	16,2	4,62	74,8	52,4	0,721	485,5	15,42
11.30	20,7	5,06	16,4	4,5	73,8	52	0,71	478,1	15,44
12.00	21	5,08	16	4,72	75,5	51,8	0,836	562,9	13,42
12.30	20,8	4,98	16,2	4,65	75,3	52,4	0,795	535,3	14,07
01.00	20,7	4,57	16,2	4,24	68,7	52,4	0,782	526,6	13,04
01.30	20,8	4,24	16,3	4,01	65,4	54,4	0,674	453,8	14,40
02.00	20,9	3,71	16,5	3,45	56,9	52,1	0,645	434,3	13,11
Average	**20,80**	**4,65**	**16,26**	**4,31**	**70,07**	**52,50**	**0,74**	**496,64**	**14,13**

Source: Primary data collected using Metrel MI 3108 Eurotest PV (2024)

Impact of Arachis H on Panel Temperature.

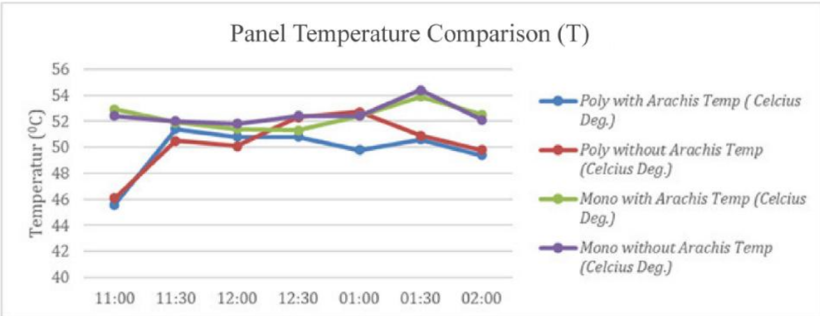

Figure 5. Panel Temperature Comparison

Source: Primary data processed by authors (2024)

The table above shows the variation in temperature changes in the panel during the data collection period. Based on the table above, it can be seen that both the Monocrystalyne and Polycrystalyne type panels with the placement of Arachis H. below have a lower temperature value compared to panels of the same type but without the placement of Arachis H. below.

Impact of Arachis H. on Panel Output Voltage (Voc and Vmp)

Based on the table above, the impact of Arachis placement on the output of the panel can be seen in the image below.

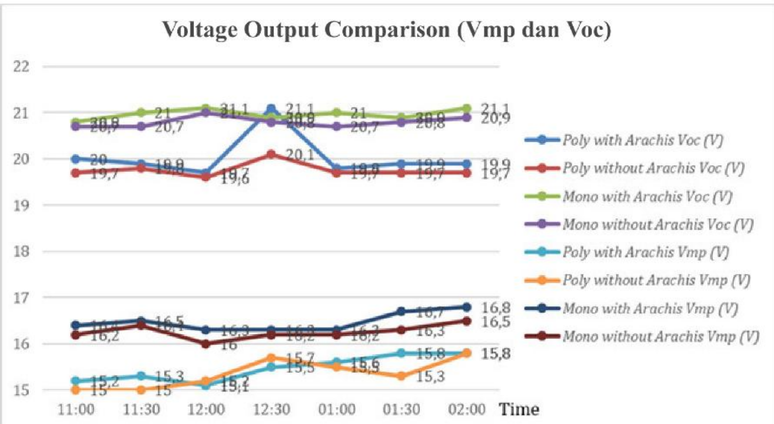

Figure 6. Panel Output Voltage Comparison

Source: Primary data processed by authors (2024)

From the graph above, the output values of Voc and Vmp voltages varied quite a bit during the data collection period. However, the placement of Arachis H. under the panel contributed to an increase in the voltage output value of both Voc and Vmp for both polycrystalylene and monocrystalyne type panels compared to panels without Arachis underneath. When viewed from the average value of the Voc and Vmp voltages produced, the placement of Arachis H under the panel contributes to an increase of approximately 0.8%-1.5% compared to the panel without the Arachis below.

Impact of Arachis H. on Panel Output Current (Isc and Imp).

Based on tables 1-4 above, the variation in the output of the panel current during the retrieval period can be seen in the graph below.

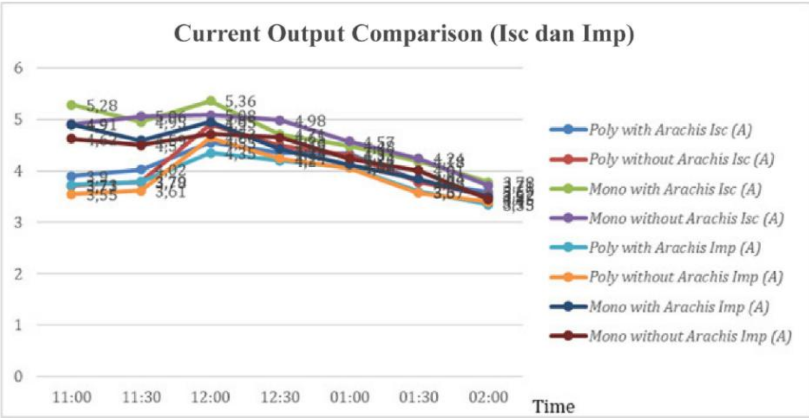

Figure 7. Panel Current Output Comparison

Source: Primary data processed by authors (2024)

From the graph above, it can be seen that the placement of Arachis H. under the panel does not have a significant impact on the increase in current value. When viewed from the average value of the current output of both Isc and Imp, the difference in current output (Isc and Imp) between panels that do not have Arachis H. and panels that have Arachis H. below it differs only by about 0.2%-0.5%.

The Impact of Arachis H. on Panel Power (Pmp).

The variation in maximum power output during the data collection period can be seen in the graph below.

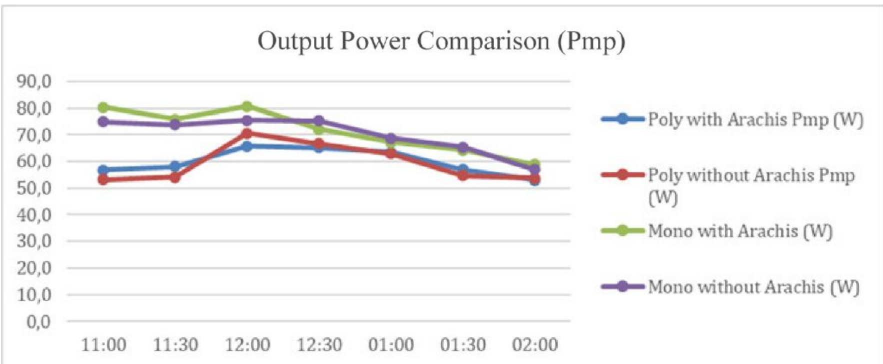

Figure 8. Panel Output Power Comparison

Source: Primary data processed by authors (2024)

From the graph above, the panels with Arachis H. below have a higher maximum Power output value compared to the panels without Arachis below. On average, the maximum power output value (Pmp) for Polycrystalyine and Monocrystalyne type panels with Arachis below them is 59.47 W and 71.27 W, respectively. For Polycrystalyne and Monocrystalyne panels without Arachis, the maximum power generated is 59.40 W and 70.07 W. The placement of Arachis H. under the panel contributes to a maximum output power spike of about 0.7%-1.8%. The maximum power output value depends on the maximum voltage value and the maximum current generated. The maximum voltage value (Vmp) produced by the panels with Arachis is higher than the panel without Arachis H as well as the maximum current value (Imp) produced thus contributing to a higher output value of the Maximum Power (Pmp).

Overall, a comparison of the average values of the measured parameters can be seen in the chart below.

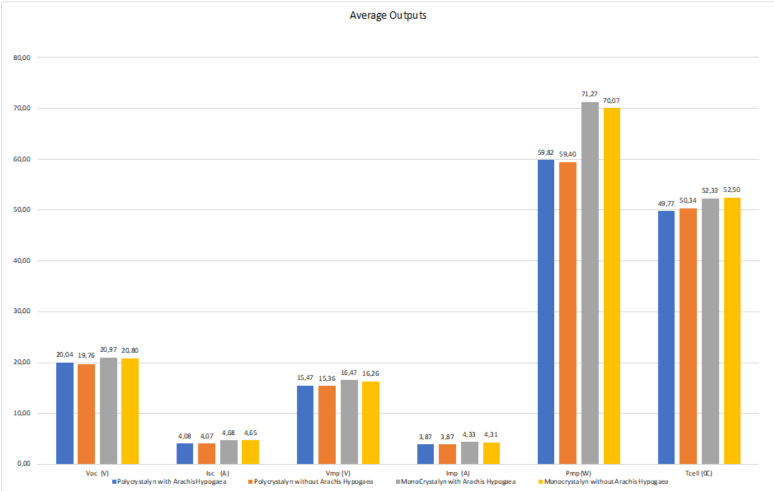

Figure 9. Panel Output Comparison

Source: Primary data processed by authors (2024)

The chart above shows that the placement of Arachis under the panel for both panel types (Monocrystalline and Polycrystalline) provides a good cooling effect on the panel. In theory, the increase in temperature influences the decrease in voltage value. Cooling by Arachis causes an increase in the output value to voltage and has an impact on the increase in power output. Furthermore, the increase in maximum output power contributes to the increased efficiency of the panel. Based on tables 1-4 above, the value of placing Arachis H. under the panel contributes to increased efficiency. A comparison of panel efficiency with and without Arachis can be seen in the chart below.

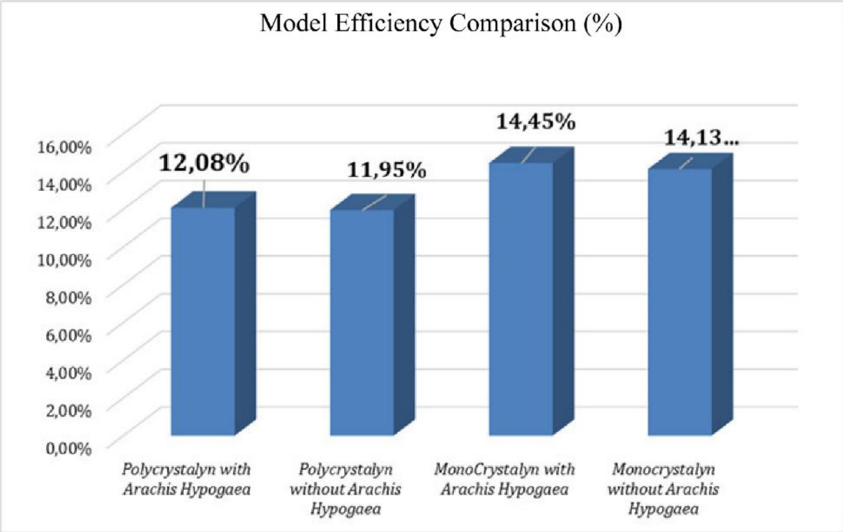

Figure 10. Panel Efficiency Comparison

Source: Primary data processed by authors (2024)

CONCLUSION

The placement of Arachis H. under the panel is good for the Monocrystalyine type to provide a good cooling effect on the panel. This cooling effect makes a special contribution to the increase in the output value of both Voc and Vmp by around 0.8%-1.5% which also has an impact on increasing the maximum output power value and also the efficiency of the panel. Based on these results, it is recommended that agrivoltaic systems integrating peanut plants beneath solar panels be considered for dry and hot climates like NTT to improve solar panel efficiency while optimizing land use. Further research could explore other types of dryland crops and evaluate the long-term impacts of agrivoltaic systems on crop productivity and local environmental conditions. Additionally, integrating plant-based cooling into renewable energy development policies in tropical regions could support more sustainable and climate-adaptive development.

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