World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.924

GIS BASED SUITABLE SITE SELECTION FOR FLOATING SOLAR POWER PLANT CASE STUDY; VICTORIA AND RANDENIGALA RESERVOIR AREA

***Alawathukotuwa A.G.C.D. and Illeperuma I.A.K.S.**

Department of Remote Sensing and GIS, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka.

Article Received on 27/06/2023 **Article Revised on 17/07/2023** **Article Accepted on 07/08/2023**

***Corresponding Author**
Alawathukotuwa A.G.C.D.
Department of Remote Sensing and GIS, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka.

ABSTRACT

The study conducted on site selection for floating solar power plants at the Victoria and Randenigala reservoirs in Sri Lanka highlights the growing need for renewable energy sources and the potential of solar power in the region. By utilizing a fuzzy overlay technique and considering multiple criteria such as water depth, proximity to forests, roads, utility grids, built-up areas, and solar radiation, the study successfully identifies suitable locations for floating solar panels. The results indicate that the Randenigala Reservoir emerges as the most favorable site for the installation and operation of floating solar panels. This finding provides valuable insights for future endeavors in renewable energy development in Sri Lanka. The study also acknowledges limitations such as the unavailability of data on air temperature, wind potential, aspect, and sunshine hours. The methodology and findings can serve as a guide for identifying suitable locations for floating solar power plants in other reservoirs as well. This research serves as an initial step for the government and interested organizations to consider establishing solar power plants in the study area, thereby promoting the use of floating solar panels as a viable and sustainable renewable energy source in Sri Lanka.

KEYWORDS: Fuzzy overlay, Global solar radiation, GIS, Renewable energy, Floating solar power plant.

INTRODUCTION

Renewable and non-renewable are the main types of energy sources. Non-renewable energy sources include coal, gas, and oil. Renewable energy includes solar, hydroelectric, and wind energy. Non-renewable energy resources are rapidly decreasing in today's world, Due to the increase in population, increasing energy demand has become a problem today. Therefore, the current world is trending towards renewable energy consumption. Although Sri Lanka has not had enough policies like many developing countries to encourage renewable energy consumption. The Sri Lankan government aims to be an energy-self-sufficient nation by 2030. The objective is to increase the power generation capacity of the country from the existing 4,043 megawatts (MW) to 6,900 MW by 2025 with a significant increase in renewable energy. Sri Lanka has already achieved grid connectivity of 98 percent, which is relatively high by South Asian standards. Electricity in Sri Lanka is generated using three primary sources: thermal power (which includes coal and fuel oil), hydropower, and other non-conventional renewable energy sources (solar power and wind power). (United States Department of Commerce’s International Trade Administration, 2018)

These problems can be even more significant in countries such as South Korea, where available land is scarce, so there is not enough area for the installation of solar panels. Therefore, floating PV systems, which can overcome or alleviate these problems, have attracted considerable attention in these countries. Because of these advantages, floating PV systems installed on water bodies, such as reservoirs or dam lakes, have increased worldwide and have already been deployed in several countries, including South Korea, Japan, China, and the US. (Kim et al., 2019)

Due to the water surface cooling effect, the floating PV system on the water surface has a lower temperature that reduces the cell temperature of the solar PV panel. Thus, the floating solar panel is 11% more efficient than land-based solar panels. (Nebey et al., 2020) Therefore, it can be proposed that floating solar power plants are a better option than land-based solar panels. Consequently, selecting suitable locations for a floating solar power plant is a problem. This study is being conducted to identify suitable areas for floating solar power plants in the Victoria and Randenigala reservoirs using GIS techniques.

1 METHODOLOGY

1.1 Criteria Selection and Data Creation

The study was carried out mainly under two water levels in both reservoirs (spill water level and average annual water level) to find high potential areas to establish the floating solar power plant using fuzzy overlay techniques. The suitability of the site was evaluated in the study using six different factors. They were: Depth of water, Proximity to Road, Proximity to Utility Network, Proximity to Built-Up Area, Global Solar Radiation Map, and Proximity to Forest. After that, the water levels of both reservoirs were calculated from the area at the appropriate level and the electricity capacity that could be produced.

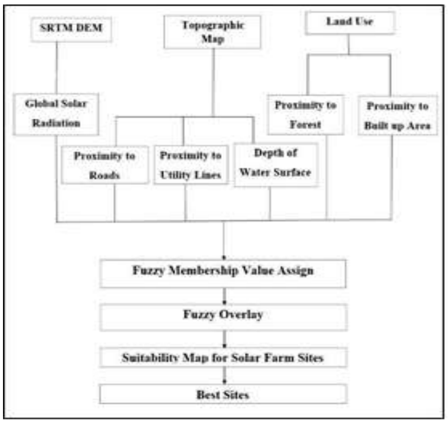
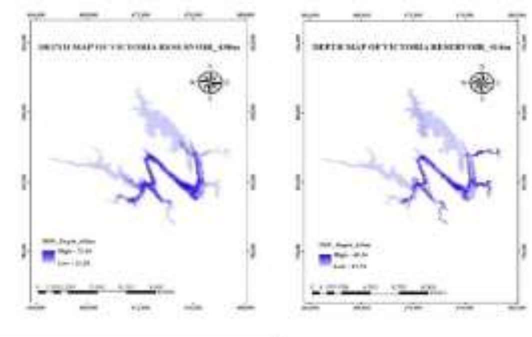


Figure 1: Methodology Workflow.

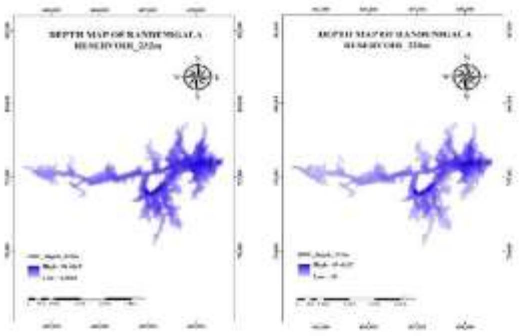
1.2 Depth of Water Surface

The depth of water surface affects the floating of panels on the surface of the water. Less depth locations were unsuitable, and the greatest depth positions were the most usable for floating the panels easily. For example, if the water is too shallow, it might be difficult to safely attach the floating power plant, which could be risky. In general, while determining whether a location is suitable for a floating power plant, the depth of the water's surface is an important factor to take into account.



(a) (b)

Figure 2: Depth of water Maps of Victoria Reservoir (a)-Spill Water Level(438m), (b)-Annual Average Water Level(414m).

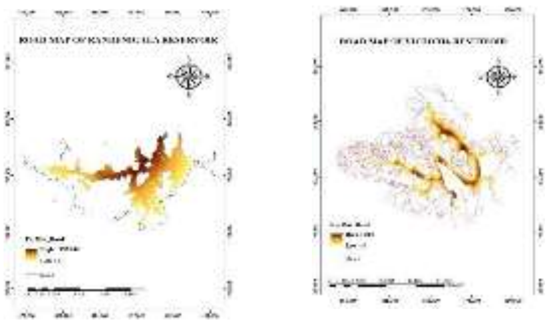


(a) (b)

Figure 3: Depth of water Maps of Randenigala Reservoir (a)-Spill Water Level(232m), (b)- Annual Average Water Level(220m).

1.3 Proximity to Road

The proximity of a floating power plant to a road is an important factor in site selection. Access to the site for maintenance and repairs is crucial for the efficient operation of the plant. If the plant is located far from a road, transportation of equipment, supplies, and personnel can be challenging and costly, potentially causing delays in maintenance activities. Therefore, considering the proximity of a suitable site to existing road networks is essential to ensure cost and time savings during project implementation.

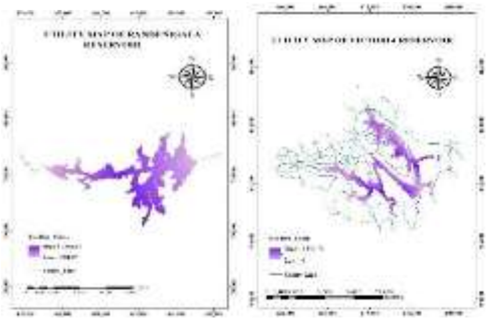


(a) (b)

Figure 4: Proximity to Road Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

1.4 Proximity to Utility Network

Proximity to the utility network is a crucial factor in the suitability analysis for a floating power plant. Efficient transmission of electricity generated by the plant to the utility network is essential. If the plant is located far from the network, additional infrastructure such as transmission lines or substations may be required, resulting in increased costs. Moreover, longer distances can lead to higher energy transmission losses, affecting the profitability and efficiency of the plant.

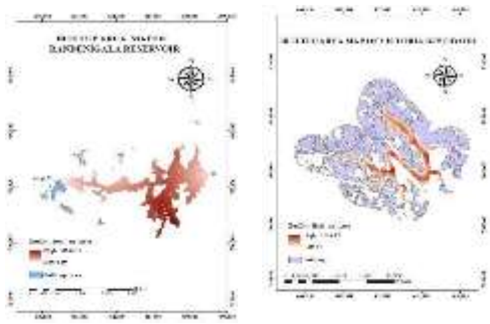


(a) (b)

Figure 5: Proximity to Utility Network Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

1.5 Proximity to Built-Up Area

Proximity to a built-up area is a significant factor to consider in the suitability analysis of a floating power plant. It can impact the visual aesthetics and security of the surrounding communities. Locating the plant too close to a built-up area may disrupt the scenic view and pose security risks such as theft or damage. Therefore, it is desirable to choose a location for the floating power plant that is sufficiently distant from built-up areas to minimize these potential impacts.

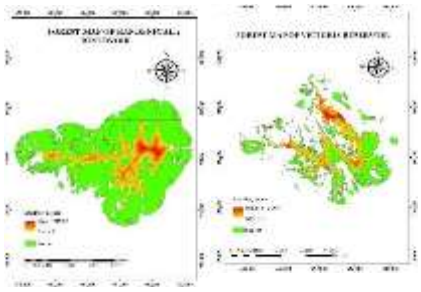


(a) (b)

Figure 6 - Proximity to Built-Up Area Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

1.6 Proximity to Forest

Proximity to a forest is a crucial factor in the suitability analysis of a floating power plant. The presence of trees can cast shadows on the solar panels, diminishing their exposure to sunlight and impacting the plant's efficiency. To ensure optimal performance, it is desirable to position the floating solar power plants at a considerable distance from forested areas, thereby minimizing the potential shadowing effects on the solar panels.

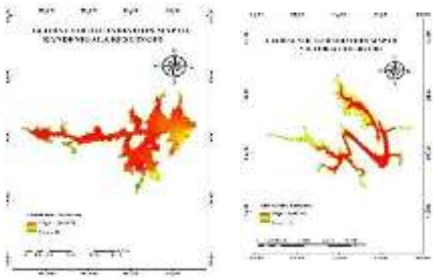


(a) (b)

Figure 7: Proximity to Forest Area Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

1.7 Global Solar Radiation Map

Solar radiation plays a crucial role in determining the electricity generation potential of floating power plants. The amount of direct sunlight received by photovoltaic panels directly affects their electricity production. While solar radiation is influenced by factors such as latitude, time of year, time of day, and weather conditions, Sri Lanka, being closer to the equator, receives an ample amount of solar radiation year-round. Solar radiation maps were generated using SRTM DEM data to account for the favorable solar conditions in Sri Lanka.



(a) (b)

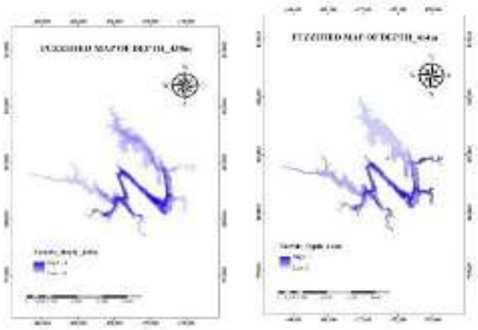
Figure 8: Global Solar Radiation Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

1.8 Assigning Fuzzy Membership Values

In this study, six continuous data factors were considered, and their membership values were assigned using a raster format. The input rasters were transformed into a scale of 0 to 1, with '0' representing the lowest importance and '1' representing the highest importance. The Fuzzy membership tool with a linear membership type was utilized for assigning membership values within the specified range. Each factor was then overlaid pairwise using the "AND" function type. The outputs with the highest importance were prioritized based on expert opinion. Through the pairwise comparison of each factor, the most suitable output was determined.

2 RESULTS AND DISSCUSION

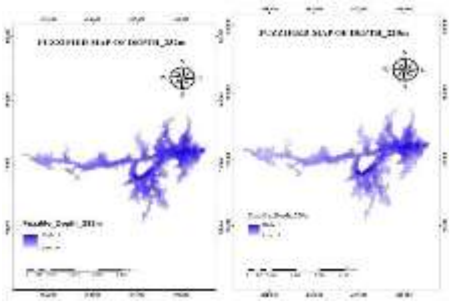
2.1 Depth of Water Surface of Victoria Reservoir



(a) (b)

Figure 9-Depth of water Maps of Victoria Reservoir (a)-Spill Water Level(438m), (b)-Annual Average Water Level(414m).

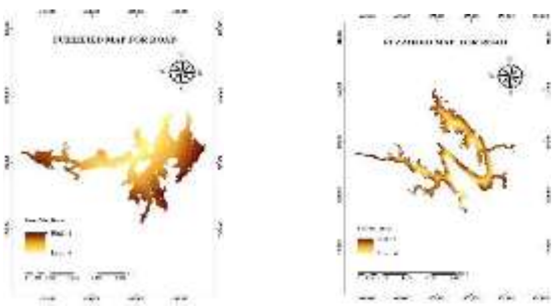
2.2 Depth of Water Surface of Randenigala Reservoir



(a) (b)

Figure 10- Depth of water Maps of Randenigala Reservoir (a)-Spill Water Level(232m), (b)- Annual Average Water Level(220m).

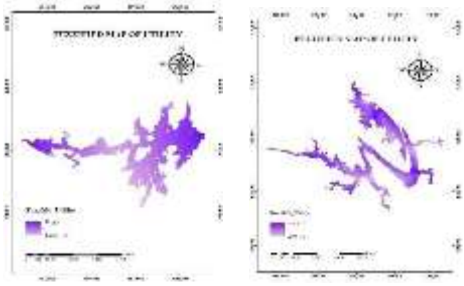
2.3 Proximity to Road



(a) (b)

Figure 11: Proximity to Road Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

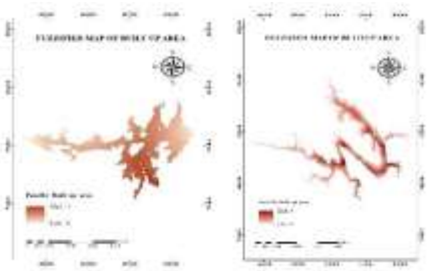
2.4 Proximity to Utility Network



(a) (b)

Figure 12: Proximity to Utility Network Maps, (a)-Randenigala Reservoir, (b)-Victoria Reservoir.

2.5 Proximity to Built-Up Area



(a) (b)

Figure 13 - Proximity to Built-Up Area Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

2.6 Proximity to Forest

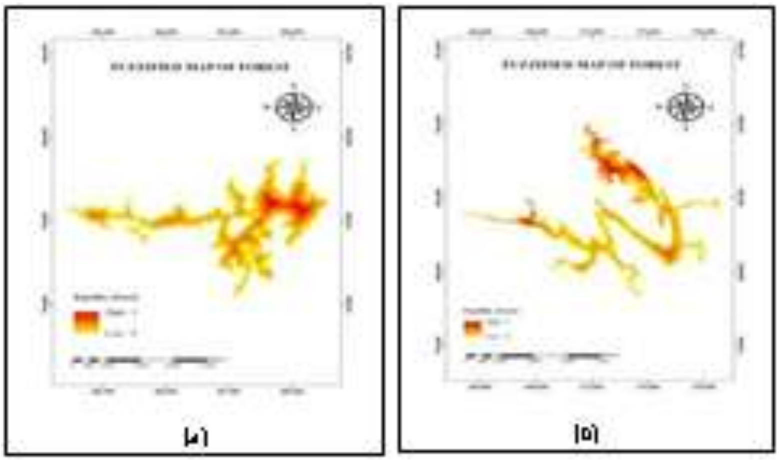
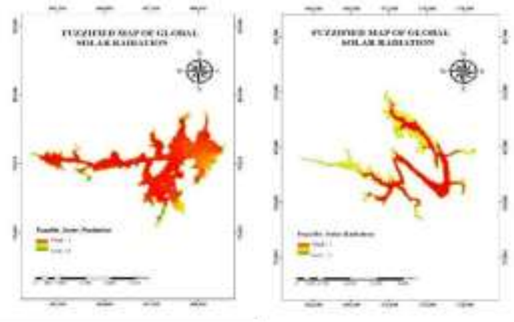


Figure 14: Proximity to Forest Area Maps, (a)-Randenigala Reservoir, (b)-Victoria Reservoir.

2.7 Global Solar Radiation Map



(a) (b)

Figure 15: Global Solar Radiation Maps, (a)- Randenigala Reservoir, (b)-Victoria Reservoir.

The main objective of this study is to identify suitable locations for a floating solar power plant in the Victoria and Randenigala Reservoirs.

Eq. (1). was used in this calculation.

Area = Area of Pixel * Number of Pixels(1).

Then calculated was used to determine the potential electricity generation of the solar panels. The amount of solar energy that is received per square meter (m2) on the Earth's surface varies by location and time of year, but in general, an estimated 1,000 watts of solar energy is received per square meter per day... ("How many watts of solar energy per square meter? - Sky Stream Energy," n.d.)

2.8 Final Suitability Map for Victoria

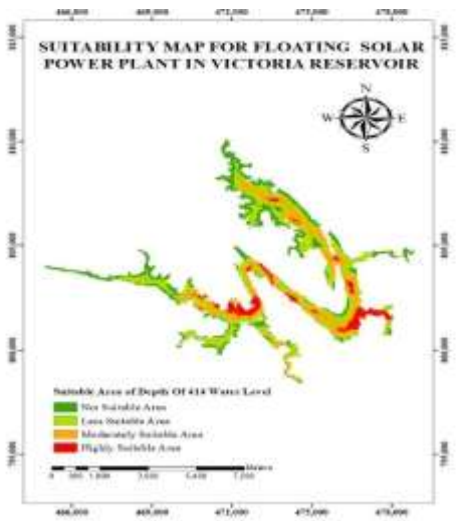


Figure 16: Suitability Map for Floating Sola Power Plant in Victoria Reservoir at 414m Water level.

Table 1: Area extent of each suitable suitability level and electrical capacity that can be calculated from that area Victoria Reservoir at 414m Water level. (Average annual water level).

Suitability Level	AREA(m^2)	Capacity(MW)
Not Suitable	5724000	572.40
Less Suitable	7205400	720.54
Moderately Suitable	5904000	590.40
High Suitable	1731600	173.16

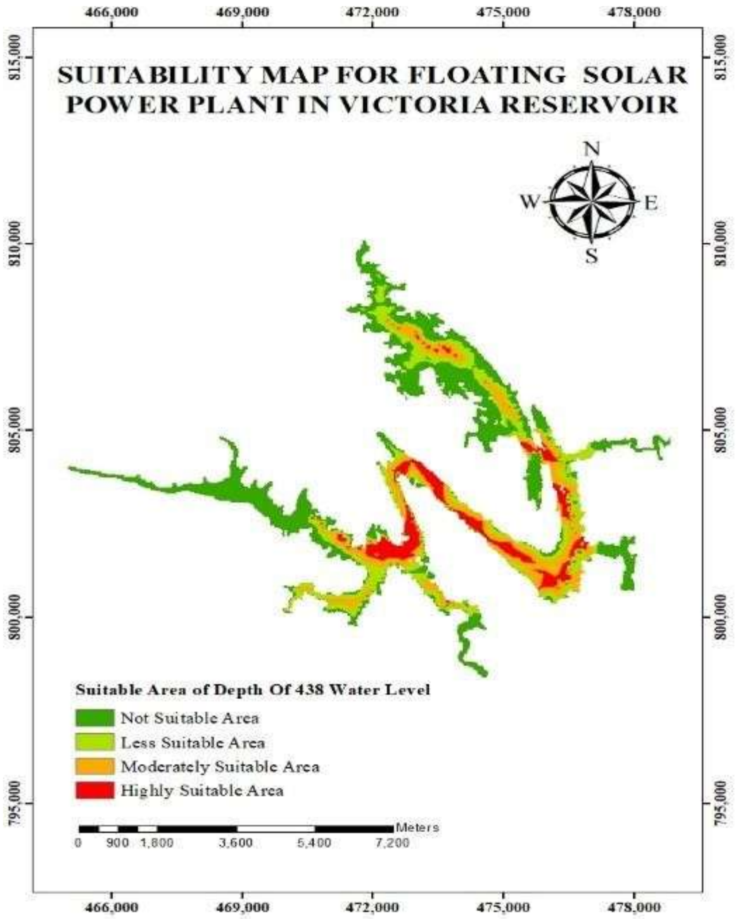


Figure 17- Suitability Map for Floating Sola Power Plant in Victoria Reservoir at 438m Water level.

Table 2: Area extent of each suitable suitability level and electrical capacity that can be calculatedfrom that area Victoria Reservoir at 438m Water level. (Spill water level).

Suitability Level	AREA(m^2)	Capacity(MW)
Not Suitable	9770400	977.04
Less Suitable	4630500	463.05
ModeratelySuitable	3978900	397.89
High Suitable	2185200	218.52

2.9 Final Suitability Map for Randenigala

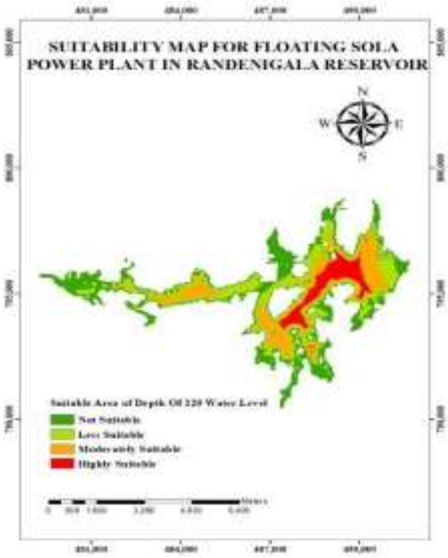


Figure 18: Suitability Map for Floating Sola Power Plant in Randenigala Reservoir at 220m Water level.

Table 3: Area extent of each suitable suitability level and electrical capacity that can be calculatedfrom that area Randenigala Reservoir at 220m Water level. (Average annual water level).

Suitability Level	Area (m^2)	Capacity(MW)
Not Suitable	8358300	835.83
Less Suitable	6178500	617.85
Moderately Suitable	4651200	465.12
High Suitable	2061000	206.10

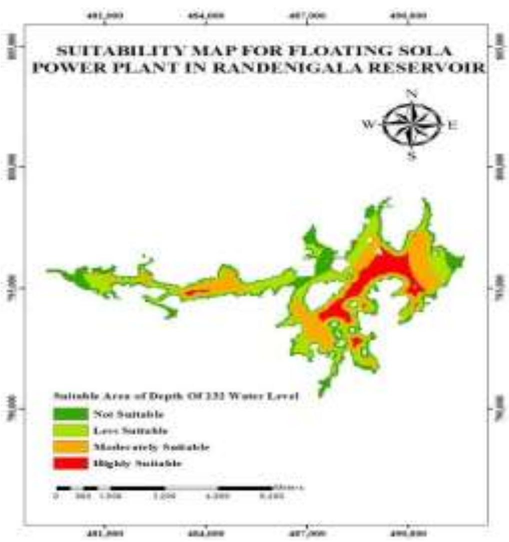


Figure 19: Suitability Map for Floating Sola Power Plant in Randenigala Reservoir at 232m Water level.

Table 4: Area extent of each suitable suitability level and electrical capacity that can be calculated from that area Randenigala Reservoir at 232m Water level. (Spill water level).

Suitability Level	Area (m^2)	Capacity (MW)
Not Suitable	6884100	688.41
Less Suitable	6783300	678.33
Moderately Suitable	5252400	525.24
High Suitable	2329200	232.92

3 CONCLUSION

Table 5: Area extent of highly suitability level and electrical capacity that can be calculated from bothreservoirs at both Water levels.

Reservoir	Suitability Level	Water level (m)	Capacity (MW)	Suitable area (%)
Victoria	Highly	438	218.52	11.87%
	Highly	414	173.16	10.62%
Randenigala	Highly	232	232.92	11.32%
	Highly	220	206.10	10.02%

According to the results, we can see that a considerable amount of electricity can be generate at the spill water level as well as the average annual water level. Analysis results also reveal that the most suitable sites are clustered over the Randenigala reservoir while in Victoria reservoir they are scattered. Taking in account all this fact, it can be concluded that Randenigala reservoir is the most suitable location to install a floating power plant compared with the Victoria power plant.

4 RECOMMENDATIONS AND FUTURE WORK

In the site selection process for floating solar power plants in Victoria and Randenigala reservoirs, it is crucial to consider the current depth of the reservoirs, as it has changed over time due to silt deposition. Utilizing up-to-date depth data would enhance the accuracy of the site selection. However, due to limited data availability and time constraints, certain parameters such as air temperature, wind potential, the base for panel installation, the angle between base and panels, profile, and sunlight hours were not included in the analysis. Incorporating these additional factors would further improve the accuracy of the obtained results.

To enhance the precision of solar radiation maps, it is recommended to create separate maps for the rainy and drought seasons by using two relevant Digital Elevation Models (DEMs). To address the electricity shortage, renewable energy projects, such as floating solar power plants, offer a viable solution. These projects not only create new job opportunities but also contribute to a cleaner environment, making them an investment in the country's long-term growth and sustainability.

REFERENCES

1. Nebey, A. H., Taye, B. Z., & Workineh, T. G. GIS-Based Irrigation Dams Potential Assessment of Floating Solar PV System. *Journal of Energy*, *2020*; 1–10. https://doi.org/10.1155/2020/1268493.
2. Kim, S. M., Oh, M., & Park, H. D. Analysis and prioritization of the floating photovoltaic system potential for reservoirs in Korea. *Applied Sciences (Switzerland)*, 2019; *9*(3). https://doi.org/10.3390/app9030395.
3. Anon. Solar power - Wikipedia. Retrieved May 11, 2023, from https://en.wikipedia.org/wiki/Solar_power, 2018.
4. How many watts of solar energy per square meter? -Sky Stream Energy. (n.d.). Retrieved May 11, 2023, from https://www.skystreamenergy.com/how-many-watts-of-solar-energy-per-square-meter/.
5. Damayanti, A., Arifianto, F., & Indra, T. L. Development Area for Floating Solar Panel and Dam in The Former Mine Hole (Void) Samarinda City, East Kalimantan Province. *International Journal on Advanced Science, Engineering and Information Technology*, 2021; *11*(5): 1713–1720.https://doi.org/10.18517/ijaseit.11.5.14097
6. Arnob, M. R. M., Nahar, S., Aziz, M., Hasan, K., & Uddin, M. N. Amelioration of the floating solar panel with Fuzzy Logic. *International Conference on Robotics, Electrical and Signal Processing Techniques*, 488–492. https://doi.org/10.1109/ICREST51555. 2021.93312, 2021; 29.