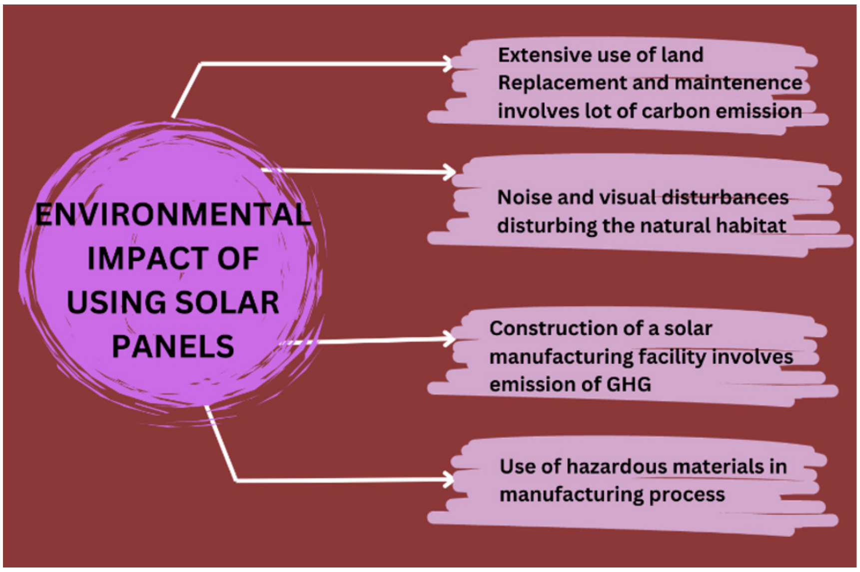
Understanding economic and ecological benefits by assessing the trade-off between solar farms and the grassland ecosystem

Introduction

Grasslands and solar farms share a common feature: both involve the absorption of sunlight (by grasses and solar panels, respectively), converting it into chemical and electrical energy, respectively. However, these forms of energy serve distinct purposes. Grasslands are natural habitats of perennial & annual grasses, seasonal herbs and shrubs, and occasional tree species providing various ecosystem services and some studies have delved into the economic worth of these services, while solar farms necessitate large amounts of investments and yield economic benefits for the manufacturing, installation, and electricity distribution companies. This article highlights the economic and ecological advantages of grasslands and solar farms.



Adapted from Tawalbeh et al. (2021). Illustrated by C.K. Arjun.

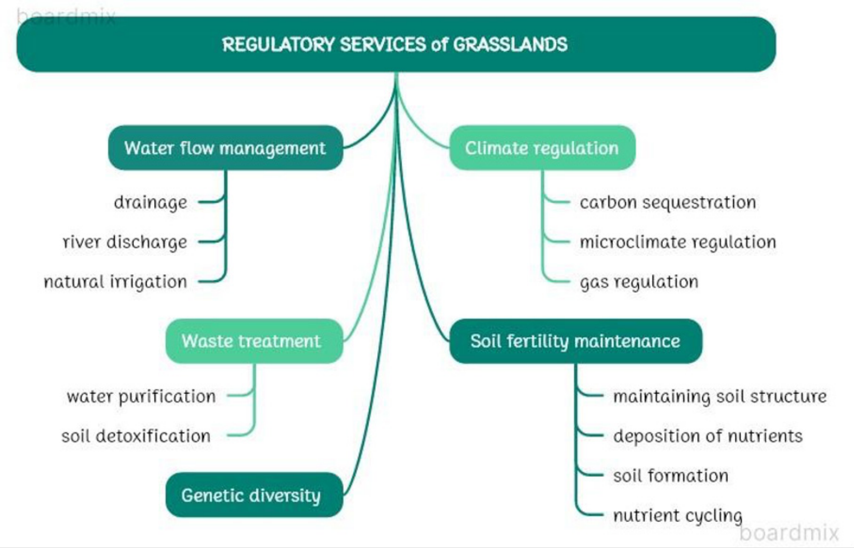
Ecological Advantages

Grasslands provide a high ecosystem service value called regulatory and cultural services like recreational value to humans; provisional services like food supply & raw material; and water supply services, erosion control, pollination etc (Liu et al. 2022).

Grasslands are also essential to the carbon and water cycles. They hold about 20% of the world's soil organic carbon (SOC) stocks (Dondini et al. 2023). On the other hand, the manufacture of solar panels involves processes such as casting, rolling, purification, foil extrusion, polymerization etc., for which raw materials such as silicon, aluminium, glass etc., are required (Nikalaos & Christopher 2013). Numerous scientific and policy reports have examined the harmful impact on the environment. Producing solar energy causes damage to the biodiversity, scenic landscape, water supplies, natural quiet, and cultural resources (Nagle 2013).

Economic value of grasslands and solar farms

According to Liu et al. (2022), the economic value of regulating services is, on average, four times more than that of provisioning services or eight times greater than that of food supply services for all grassland ecosystems across the world. They are



Adapted from Liu et al. (2022). Illustrated by M. Paridhi.

worth US$ 2,877 per ha per year, or 53% of the tropical grasslands' overall monetary value. The annual economic value per hectare of tropical grassland together of all services is US$ 5,466 per ha. On the other hand, a one-megawatt solar farm requires approximately 6–8 acres of land and a significant investment of US$ 890,000 to US$ 1.01 million. This would generate on an average US$ 40,000 annually for 6–8 acres (Coldwell Solar 2023). This means that approximately US$ 12,300–16,500 revenue can be generated per hectare per year.

The trade-off

Solar farms can be a great form of investment, however, installing solar panels in grasslands can have direct and indirect consequences on the environment. Clearing and levelling the land disrupts natural habitats for plants, insects, and small animals, leading to biodiversity loss and ecosystem disruption. Heavy machinery compacts the soil, hindering plant growth and soil health. Solar panels casting shadows can reduce grass and vegetation growth underneath, affecting photosynthesis (Gibson 2009; Kunhikannan & Rao 2013). Changes in the landscape alter water runoff patterns, increasing erosion and sedimentation in nearby water bodies. Maintenance practices involving cleaning agents can harm grass and vegetation if spilled.

Fauna displacement due to construction and operation disrupts local ecosystems (Turney & Fthenakis 2011). In a study by Rawat & Adhikari (2015), grasslands make approximately 24% of India's total land area. Assuming if 10% out of the 24% of grassland area is converted into a solar farm will pose a significant risk of irreversible damage to the ecosystem, potentially resulting in detrimental consequences for both wildlife and humans.

Carbon sequestration by grasslands: According to Bai et al. (2022), the achievable SOC sequestration potential in global grasslands is 2.3–7.3 billion tons of carbon dioxide equivalents per year (CO_{2e} year−1) for biodiversity restoration, 148 to 699 megatons of CO_{2e} year−1 for improved grazing management, and 147 megatons of CO_{2e} year−1 for sown legumes in pasturelands. Grasslands cover 26% of the world land area covering 3.5 billion hectares of land (Ghosh & Mahanta 2014).

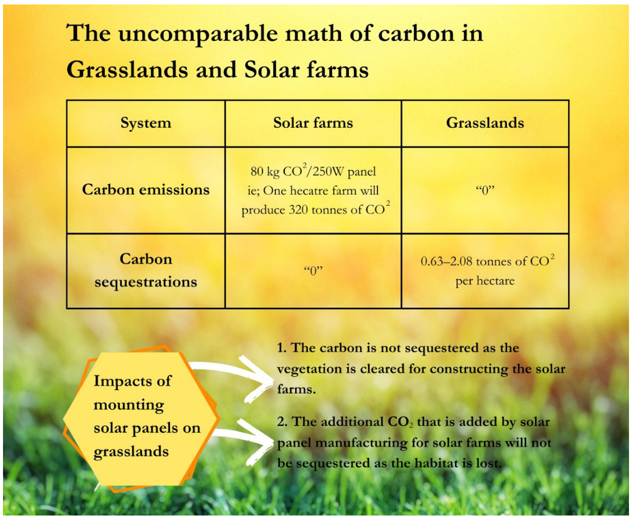
The approximate total sequestration potential of global grasslands considering the above data would be 2.5 to 8.1 billion tons of carbon equivalents per year. Following are the calculations:

<table>
<tr><th></th><th>Range Carbon equivalents per year (In billion ton)</th><th rowspan="5">1 megaton CO_{2e} = 1 million ton

1 billion ton = 1,000 million ton

1 ton = 0.907185 tonne</th></tr>
<tr><td>Biodiversity restoration</td><td>2.3 to 7.3</td></tr>
<tr><td>Grazing management</td><td>0.148 to 0.699</td></tr>
<tr><td>Sown legumes</td><td>0.147</td></tr>
<tr><td>Total</td><td>2.595 to 8.146</td></tr>
</table>

In 3.5 billion ha of grasslands, the achievable SOC sequestration potential ranges from 2.5 to 8.1 billion tons of carbon equivalents annually. This equates to sequestering 0.7–2.3 tons (which is 0.63–2.08 tonnes) of carbon equivalents per ha each year.



Carbon emissions by solar panel manufacturing: According to Stoppato (2008), the manufacturing of one panel ejects into the atmosphere the equivalent of 80 kg of CO_2 and one panel has a capacity of 250 W (A 250 W panel has the capacity to produce 1kWh power every day). The size of commercial 250 W solar panels is 2.31 sq.m. (Sykes 2024). Following are the calculations to derive the carbon emissions during the manufacturing stage.

1 hectare = 10,000 m^2

A size of solar panel is 2.31 m^2

→ 10,000 m^2/2.31 m^2 = 4,329.004 panels

Considering that some space is required in between solar panels we are approximately estimating 4,000 panels are required in one hectare of land.

And 80 kg of CO_2 is released into the atmosphere by the manufacture of one panel

→ 4,000*80 kg = 320,000 kg

320,000 kg = 320 tonnes of carbon emissions

Hence to set up 1 ha of land with solar panel 320 tonnes of CO_2 will be emitted just during the manufacturing process. Solar panels on grasslands will emit 0.63–2.08 tonnes of carbon equivalents per ha each year adding the carbon that would have been sequestered by undisturbed grasslands.

So where can we potentially place solar panels to ensure grasslands are conserved?

A fitting place for solar panels

Choosing the location for the installation of solar panels is a hypersensitive task. For a country like India, which is rich in biodiversity, it becomes more crucial. We have to consider the species diversity of the area and make sure that none of the species are affected as we know that the alarming situation of the climate crisis is increasing and the chance of species extinction is very high for the coming decades, which is around 33% by 2050 (Thomas et al. 2004). Even though solar energy is much lower in carbon emission compared to other energy sources such as fossil fuel and coal (Arcos et al. 2019), the incorrect placement of the panels can be highly detrimental as it takes a huge amount of landmass to set up and construct the solar panels. It takes away the habitat of many species, mostly grasslands becoming

Alternate spaces for instalment of solar panel

Solar panels can be best installed in occupied spaces such as parking lots, roofs, and landfills. This will be utilizing already disturbed or degraded land to install photovoltaic systems significantly lowering the impact on grasslands thereby actually contributing positively to mitigating the climate crisis.

Grasslands in focus

Grasslands are a prominent biome on Earth, covering about 40% of its land area. They are primarily characterized by grasses, herbs, some shrubs and very few trees, but they also host a variety of animals, fungi, and soil microbes, contributing significantly to the biodiversity. Grasses have developed unique characteristics that enable them to thrive in challenging environments, such as extreme climates, specific soil types, frequent fires, and grazing pressure, which collectively prevent the encroachment of woody plants and maintain the integrity of grasslands. These ecosystems can be found in nearly all climate zones, with the exception of the polar regions, extremely arid areas, and the highest mountain ranges (Petermann & Buzhdygan 2021).

the holocaust for all so-called technological advancements. Ideally, solar panels can be best installed in occupied spaces such as parking lots, roofs, and landfills, i.e., utilizing already built up or irreversibly degraded lands to install photovoltaic systems would significantly lower the impact compared to the utilization of undisturbed land (Tawalbeh et al. 2021).

Conclusion

Solar farms are indeed alternatives of energy relative to coal and fossil fuels, but destroying grasslands and natural vegetation for construction of solar farms have more adverse effects than benefits considering the climate crisis. Grasslands are one of the carbon sinks, which helps in sequestration of tonnes of carbon, and destroying the last patches of grasslands will only contribute to increased Green House Gasses, temperature rise and decreased water retention.

References

Arcos-Vargas, A. & L. Riviere (2019). Carbon Footprint of Photovoltaic Energy, pp. 67–79. In: Grid Parity and Carbon Footprint. Springer Briefs in Energy. *Springer*. https://doi.org/10.1007/978-3-030-06064-0_6

Bai, Y. & M.F. Cotrufo (2022). Grassland soil carbon sequestration: Current understanding, challenges, and solutions. *Science* 377(6606): 603–608.

Coldwell Solar (2023). How much investment do you need for a solar farm? https://coldwellsolar.com/commercial-solar-blog/how-much-investment-do-you-need-for-a-solar-farm/#:~:text=Remember%20that%20the%20typical%201,yearly%20revenues%20of%20about%20%2443%2C500. Accessed on 20 March 2024.

Dondini, M., M. Martin, C. De Camillis, A. Uwizeye, J.F Soussana, T. Robinson & H. Steinfeld (2023). Global assessment of soil carbon in grasslands: From current stock estimates to sequestration potential. FAO Animal Production and Health Paper No. 187. Rome, FAO. https://doi.org/10.4060/cc3981en

Ghosh, P.K. & S.K. Mahanta (2014). Carbon sequestration in grassland systems. *Range Management and Agroforestry* 35(2): 173–181.

Kunhikannan, C. & N.R. Rao (2013). Grasses and grasslands of Tadoba National Park, Chandrapur, Maharashtra. *Journal of Economic and Taxonomic Botany* 37(3): 500–512

Liu, H., L. Hou, N. Kang, Z. Nan & J. Huang (2022). The economic value of grassland ecosystem services: a global meta-analysis. *Grassland Research* 1(1): 63–74.

Nagle, J.C. (2013). Green Harms of Green Projects. *Notre Dame Journal of Law Ethics & Public Policy* 27. https://scholarship.law.nd.edu/law_faculty_scholarship/160

Nikalaos, S. & K. Christopher (2013). Carbon footprint of polycrystalline photovoltaic systems. *Journal of Cleaner Production* 64: 639–645. https://doi.org/10.1016/j.jclepro.2013.10.014

Petermann, J.S. & O.Y. Buzhdygan (2021). Grassland biodiversity. *Current Biology* 31(19): 1195–1201.

Rawat, G.S. & B.S. Adhikari (2015). Ecology and management of grassland habitats in India. Environmental Information System Network Bulletin, Wildlife & Protected Area, 17.

Stoppato, A. (2008). Life cycle assessment of photovoltaic electricity generation. *Energy* 33(2): 224–232.

Sykes, J. (2024). Solar Panel Sizes and Dimensions. https://www.solarchoice.net.au/solar-panels/sizes/#:~:text=Commercial%20solar%20panel%20sizes&text=They%20are%20around%2030%25%20larger,roof%20areas)%20or%20solar%20farms. Accessed on 8 February 2024.

Tawalbeh, M., A. Al-Othman, F. Kafiah, E. Abdelsalam, F. Almomani & M. Alkasrawi (2021). Environmental impacts of solar photovoltaic systems: A critical review of recent progress and future outlook. *Science of the Total Environment* 759: 143528. https://doi.org/10.1016/j.scitotenv.2020.143528

Thomas, D.C., A. Cameroon, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F. N. Erasmus, M.F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Philips & S.E. Williams (2004). Extinction risk from climate change. *Nature* 427: 145–148.

Turney, D. & V. Fthenakis (2011). Environmental impacts from the installation and operation of large-scale solar power plants. *Renewable and Sustainable Energy Reviews* 15(6): 3261–3270.

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