Can Wind and Solar Farms Green a Desert?

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ABSTRACT

A recent paper in Science reports model results to indicate that large wind and solar farms over the Sahara can decrease albedo and increase surface roughness and thereby increase precipitation and vegetation over the Sahara and neighbouring Sahel significantly by a positive feedback process. The present article examines this result and raises some unanswered questions which need to be looked into before the result is considered robust. If a similar result can occur in Rajasthan it will be useful, but modelling and field experiment specific to Rajasthan will be necessary.

Keywords: *Wind farm, Solar farm, Albedo, Roughness and Feedback.*

1. Introduction

Status of Wind and Solar Power in India

Renewable energy installations, primarily wind and solar,[1] are being established all over the world to reduce dependence on fossil fuels. According to Government of India figures the installed capacity of renewable energy, actual and planned in India is as follows.

Renewable energy capacity	GigaWatts
Installed as of October 2018	72
Under implementation	46
Target 2022	175
Mission for 2030	500+

(It is not clear whether this includes rooftop installations). Actual power produced will be less as wind and solar power is not continuously available and has to be supplemented by other means of power generation or by devising economical methods of storage. Adequate means of evacuation of power to the grid is also necessary. Wind Power Forecast (WPF) and Solar Power Forecast techniques have been developed. Cost comparisons of renewables and conventional fuels is often vitiated by not costing some of the harmful effects of the latter. Fossil fuels involve air pollution and the consequent health costs are enormous and need to be included in any cost evaluation. They also involve a large supply of water which needs to be taken into account. Nuclear power involves huge costs of containment and storage of waste (Nature Outlook, 2017). Also renewables involve only initial cost and maintenance while fossil fuel powered stations incur recurring costs of supply of fuel and its transport.

2. Environmental and Other Objections

Renewable Energy is adopted essentially to avoid the adverse environmental effects of conventional fuels. Even so, there have been apprehensions and protests about wind and solar installations from time to time citing environmental grounds. There are reports of bird deaths due to direct hits by wind mills and perhaps by turbulence generated by them. Onshore installations need a large amount of land and there have been objections from farmers. Offshore wind installations solve these problems (except bird hits) and will also perhaps benefit by larger wind speeds over the open sea. Offshore wind farms have been set up in the North Sea which has very strong winds. A study has been made of their

[1] Other renewables such as wave energy and Ocean Thermal Energy Conversion are not considered here.

feasibility in the neighbourhood of Gujarat and Tamil Nadu [See http://www.thehindu.com/todays-paper/tp-national/tp-tamilnadu/study-points-to-huge-offshore-wind-bonanza/article19928696.ece (Hindu 27/10/2017)]. But such farms are costly to install and maintain and to provide lines for evacuating power.

Besides the objections mentioned above, spurious reasons have also been raised from time to time. These apprehensions, however spurious, require to be allayed. Some years ago, farmers in southern Maharashtra complained that the wind mills were taking away their clouds and consequently producing rain deficit. The government set up a committee which found that the complaint was baseless. In fact in subsequent monsoons there was ample rain (M. Rajeevan, personal communication). Similarly when Baidya Roy et al (2004) found that wind mills can influence local circulation they were branded as stooges of the petroleum lobby!

3. Beneficial Effects

Besides the well-known benefits of avoiding emissions and pollution and saving of water, a new benefit has been envisaged in a recent paper by Yan Li *et al* (2018). In a paper in *Science* they claim that large wind and solar farms over the Sahara desert can increase rain and vegetation and thus green the Sahara and the adjoining semi-arid Sahel[2]. How is this possible?

Charney (1975) and Charney et al (1977) who modelled the problem of deserts and semi-arid regions found that the large albedo of a desert surface leads to a radiative heat loss which in turn causes a sinking and drying of air aloft. This discourages convection and results in a decrease in precipitation. That again leads to decrease in whatever vegetation there is and therefore a further increase in albedo. Decrease in vegetation also leads to decrease of evapotranspiration which causes further decrease in precipitation. This positive feedback cycle can result in further desertification.

Yan Li et al say that large solar farms in the Sahara will decrease the albedo and thus reverse this feedback cycle leading over time to increased convection, precipitation and eventually vegetation.

Sud and Smith (1985) considered the effect of the surface roughness of a desert. They assumed a roughness length of 0.02 cm for the desert and 45 cm for land elsewhere. According to them the low surface roughness reduces turbulence and the fluxes of momentum heat and moisture from the surface. The cross-isobaric convergence is also reduced leading to a reduction in precipitation. This will reduce whatever vegetation there is and only decrease the surface roughness further. Thus a positive feedback cycle of desertification results.

Yan Li et al claim that the establishment of large wind farms in the Sahara will increase the roughness length and thereby reverse the feedback cycle of Sud and Smith. According to their model results the wind farm causes significant regional warming on near-surface air temperature with greater changes in minimum temperature than maximum temperature. The greater nighttime warming takes place because wind turbines can enhance the vertical mixing and bring down warmer air from above to the lower levels, especially during stable nights. Wind farms also increase precipitation because the increased surface friction reduces wind velocity

A more dominant pressure gradient force toward the Saharan heat low is established and is enhanced by the warming induced by wind farms. This produces surface convergence and upward motion as well as moisture convergence and higher humidity. The increase in precipitation leads to increases in vegetation that further reduce surface albedo. These changes together trigger a positive friction–precipitation–vegetation feedback. Additionally, the recovered vegetation increases evaporation, surface friction, cloud cover and consequently, precipitation. Sud and Smith (1985) also find that the low roughness of the Sahara results in the ITCZ (Inter-Tropical Convergence Zone) being pushed southwards. So if the wind/solar farms increase the roughness the ITCZ may be

[2] The Sahara desert is defined in the model as the region within latitudes of 3.75N–30N and longitudes of 0–60E. Sahel region is defined as the rectangular land area with latitudes from 10N to 20N and longitudes from 20W to 30E

expected to move north and that should help increase moisture convergence and precipitation.

The solar farms directly reduce surface albedo and thus trigger a positive albedo–

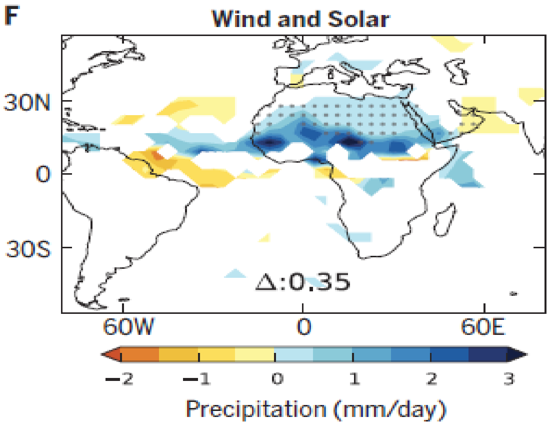

Figure 1: Reproduced from Science, 7 September 2018 (Yan Li et al.). Impacts of wind and solar farms in the Sahara on precipitation (millimetres/day). Gray dots denote the location of wind and/or solar farms. At the bottom of the plot, the number after Δ represents the change in millimetres of precipitation per day averaged over areas covered by wind and solar farms.

precipitation–vegetation feedback. This feedback leads to temperature and precipitation increase. The resulting warming is stronger in maximum temperature than in minimum temperature because albedo reduction mainly affects net radiation during daytime.

Yan Li et al go on to presume that the power requirements of the Sahara and the Sahel being rather small, power can be exported in a big way to Europe and west Asia if suitable high tension lines are laid. This will pay the cost of the project.

4. Discussion

Are these expectations realistic?

The results of this model show that land use changes can have a large impact on climate. The Inter-Governmental Panel of Climate Change (IPCC) in their Special Report 15 (2018) recognise the role of "sustainable land use" in managing global climate change.

However several questions arise about the present model.

(1). The authors say that "the effects of the largescale wind and solar farms in the Sahara re most significant locally—i.e., at or near the locations of wind and solar farms—with imited remote impact". However their model shows an increase of 0.35 mm/day over the Sahara and 1.34 mm/day over the Sahel well to the south of the area where the farms are installed. (See the dark blue shading in Figure 1 over the Sahel). The two are contradictory. The Sahel may be getting more rainfall as the moist air comes from the South. But the result has to be examined and the contradiction resolved.

(2) It is not clear whether the authors have considered variation of the effect with season. While the model shows an increase of 1.34 mm/day over the Sahel the authors say that the Sahel will get an increase of between +200 to +500 mm/year. This will be possible only if the effect is assumed to prevail over a major part of the year. They have not established that the same degree of benefit occurs in different seasons. The Charney et al (1977) and the Sud and Smith (1985) analyses which the authors depend on, are for July only.

(3) Is the expected increase of 0.35 mm/day adequate as a significant step to de-desertification? Perhaps because of the positive feedback cycle, a greater increase in precipitation as well as vegetation may occur over several years. The increased evapotranspiration that may result may hasten the process. But this aspect is not dealt with by the authors.

(4) The authors assume a solar energy conversion efficiency of 15%. If a higher efficiency results from technological improvements the albedo reduction will be much less according to the authors and the benefit from the solar farms may be nullified!

(5) The study is only a modelling of the scenario and no field experiments have been conducted. Without the latter it is difficult to judge the correctness of the model results.

Are the results applicable to other deserts or arid zones?

We in India may be particularly interested to know whether this can be replicated in Rajasthan. Charney et al. (1977) have considered the case of Rajputana (Rajasthan) and find that increase of albedo decreased precipitation there too. However as the present authors point out, the Sahara is a large desert that lends itself to establishment of wind/solar farms on a large scale. Also with very little population there is no likelihood of conflicts regarding land use. The circulation may also be different. Hence the results from the Sahara model cannot be extended to Rajasthan. A model study specific to Rajasthan needs to be carried out. If this gives an encouraging result, it may need to be followed by a field experiment using the existing wind and solar installations if they are considered large enough. Several meteorological measurements need to be added.

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References

Baidya Roy, S., S. W. Pacala, and R. L. Walko, 2004, “Can large wind farms affect local meteorology?”, J. Geophys. Res., 109, D19101, doi:10.1029/2004JD004763.

Charney J.G., 1975, “Dynamics of deserts and drought in the Sahel”, Q. J. R. Meteorol. Soc. 101, 193–202.

Charney J., W. J. Quirk, S. Chow, J. Kornfield, 1977, “A comparative study of the effects of albedo change on drought in semi-arid regions”, J. Atmos. Sci. 34,1366–1385.

Inter-Governmental Panel of Climate Change (IPCC, 2018, Special Report 15, http://www.ipcc.ch/report/sr15/

Nature Outlook, 2017, “The real cost of energy”https://www.nature.com/articles/d41586-017-07510-3

Sud,Y.C and W. E. Smith, 1985, “The influence of surface roughness of deserts on the July circulation”, Boundary-Layer Meteorol. 33, 15–49

Yan Li, E. Kalnay, S. Motesharrei1, J. Rivas, F. Kucharski, D. Kirk-Davidoff1, E. Bach, Ning Zeng, 2018, “Climate model shows large-scale wind and solar farms in the Sahara increase rain and vegetation”, *Science,* 361, 1019–1022, 7 September 2018. Supplementary materials may be seen at www.sciencemag.org/content/361/6406/1019/suppl/DC1