Does the Benefit of Pollinator Habitat at Solar Facilities Exceed the Costs?

Dr. Shruti K. Mishra[1], Ms. Minjia Zhu[2]

[1]Argonne National Laboratory , [2]The University of Chicago

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Background

In the context of increasing growth rate of installed capacity of solar energy globally (45.5% per Year) and in the US (by nearly 60 fold) in the past two decades, the tradeoff between land for solar energy generation and food production may be high in increasing land scarcity scenario. Creating and maintaining pollinator habitat at solar facilities may offer a practical solution to address the completion between the two sectors. Furthermore, in certain locations such habitats can convert the two sectors into complimentary ones by improving the pollinator supply for pollinator dependent food crops. Earlier research has shown that high-quality pollination habitat around farms can safeguard pollinators and their services. The United States has the world's largest and most active market for honeybee pollination services.

Earlier research have focused individually on the impacts of solar energy installations, understanding of declining pollinator populations, and dwindling food security; however, an integrated assessment of the sectors to identify practices that improve the energy, food, and conservation nexus has not been done. The drivers of enhancing pollinator habitat including at USSE locations—such as the habitat's economic benefits and costs have not received much attention.

Objective

We coupled the principles of agronomy and ecology with economics and integrated national-scale data on crops, pollinators, and solar facilities to

- Examine pollinator-habitat creation opportunities in the land within and adjacent to solar facilities.
- Identify the significant pollinator-dependent crops in the lead-solar states and presented the potential benefits from pollination services in those states.
- Estimate the benefits of pollinator habitat and associated costs at the USSEs.

Integrated Assessment Framework

An integrated assessment framework is developed to conduct a systematic study of pollinator dependent crops, their spatial distribution, demand for pollination services and opportunity for habitat creation at USSE facilities across the US and the associated benefits and costs. The framework couples bio-physical analysis with economic analysis (Fig. 1).

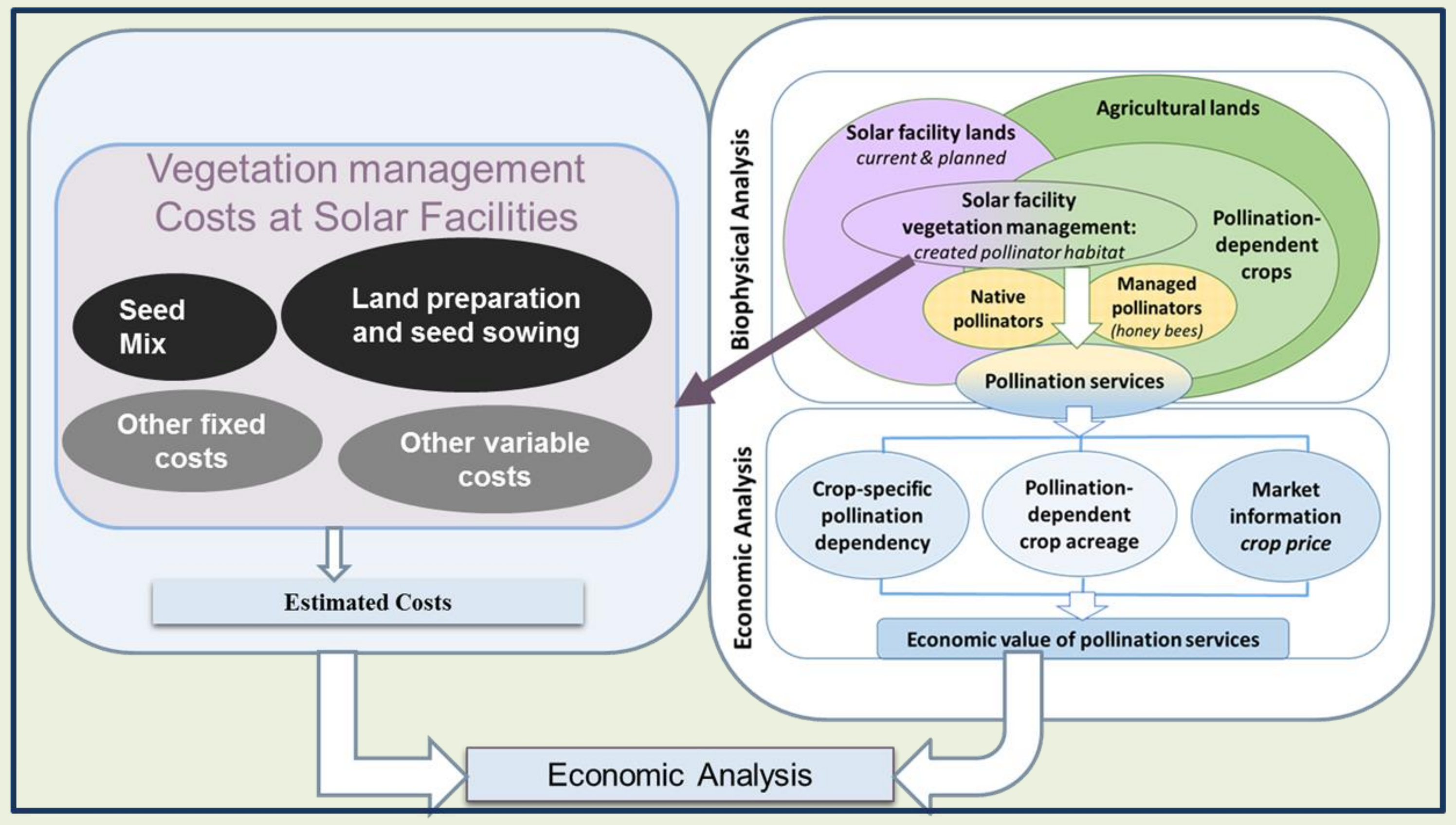


Figure 1 | **Integrated assessment framework for economic analysis of solar pollinator habitat**

Pollination Value Model

The value of pollination services is estimated using dependency ratio of crops and the location specific value of crops in a designated area.

$$V_{PS} = \sum_{ci=1}^{n} (DR_{ci_{HB}} + DR_{ci_{NP}}) \times R_{ci}$$

where DR_{ci} is the dependency ratio of crop c_i ,for native pollinator (NP) or honeybees (HB); n is the number pf crop in a defined area; R_{ci} is calculated using the yield of crop c_i in the location, price of the commodity in the state, and area of land under crop c_i.

Pollinator Habitat Development Opportunities

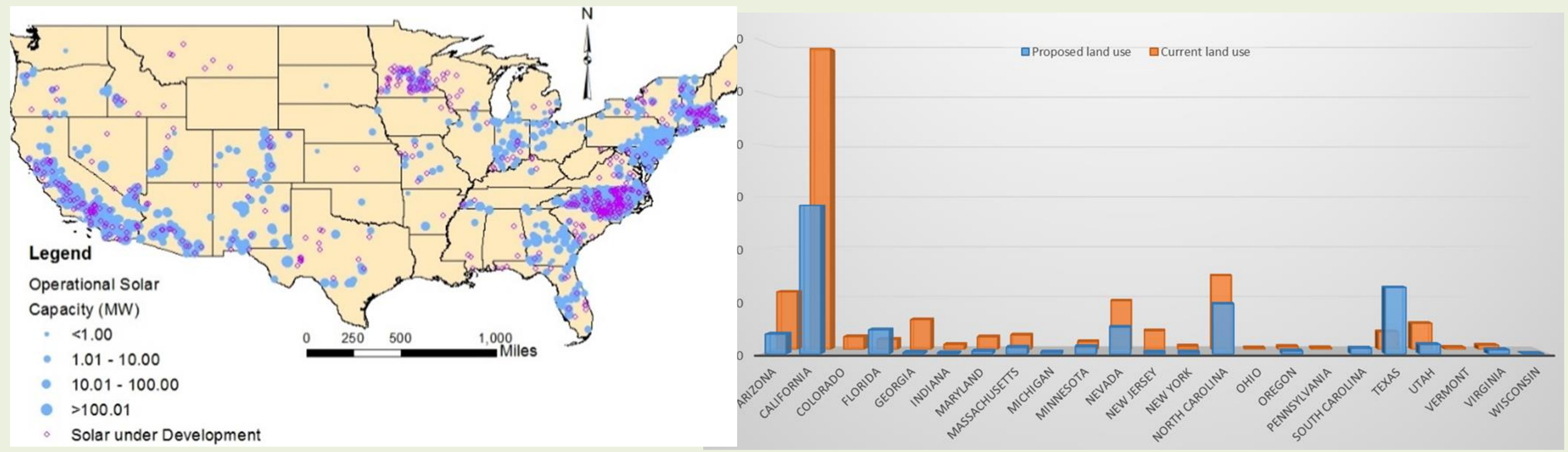


Figure 2. Distribution of current and planned solar facilities in the conterminous United States (Created using data from EIA, 2016) (in the left panel). Statewise distribution of land covered under existing and planned solar facilities (in the right panel)

The top eight states—California, North Carolina, Arizona, Nevada, Georgia, Texas, Utah, and Florida—share 84% of total solar capacity of the United States. The total area available for solar pollinator habitat development ranges from 100000 acres to 277000 acres and the states of California, North Carolina, Texas, Utah, Georgia, New Mexico, New Jersey, Massachusetts, Minnesota, Colorado, and Maryland are the top states with larger land area available for habitat development around USSEs.

Pollination Services at Utility Scale Solar Facilities

The estimated benefits from creating solar pollinator habitat at USSEs varied from state to state depending on the number of solar facilities, proximity to cropland, crop acres under pollination-dependent crops, dependency ratio of the crops on insect pollinators, spatial yield variability, and price variability.

Crops that are at least 90% dependent on honeybees for their pollination—and thus will benefit from increased honeybee population—include almond, alfalfa, apple, asparagus, avocado, blueberry, broccoli, carrot, cauliflower, cranberry, onion, rapeseed, and sunflower (Figure S1). Crops that benefit from increased native pollinators include apricot, celery, lemon, loganberry, nectarine, peach, pumpkin, squash, and strawberry.

The states with the highest benefits includes California, Florida, New Jersey, Arizona, North Carolina. The total values from pollination services potentially generated by creating pollinator habitat were estimated for low and high pollinator-habitat adoption scenarios.

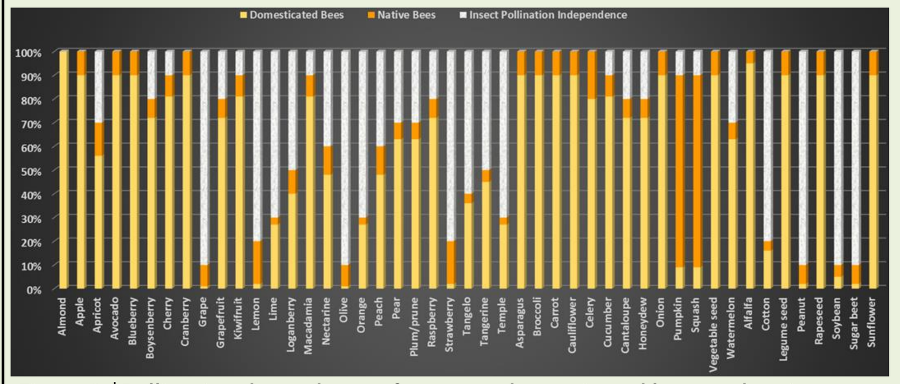
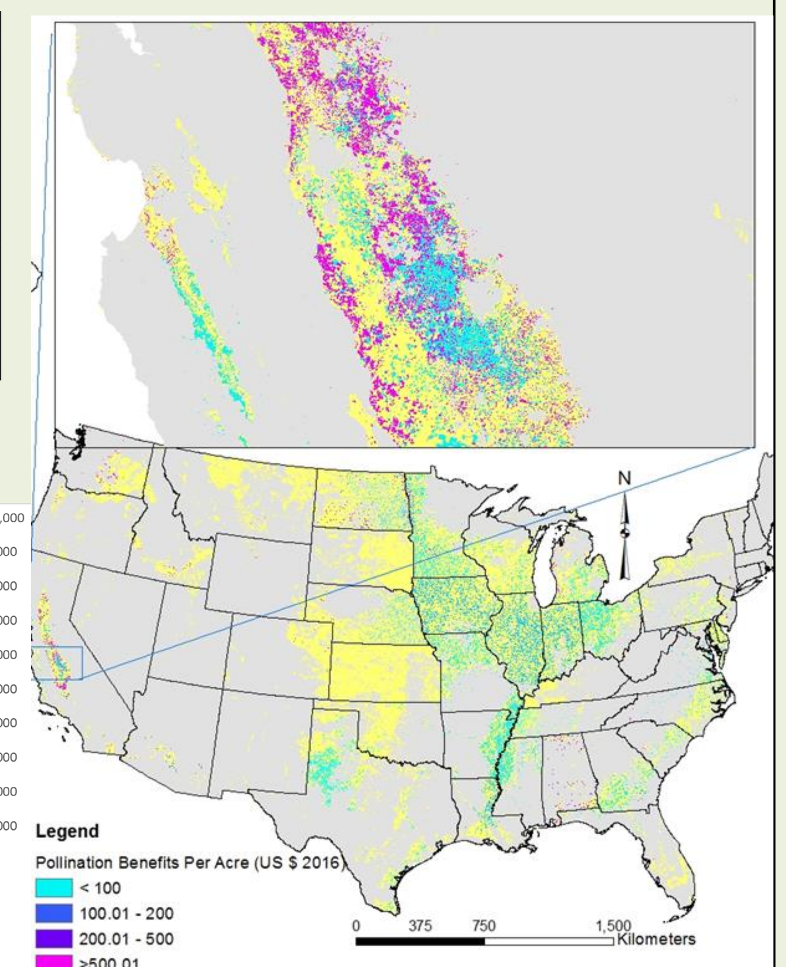
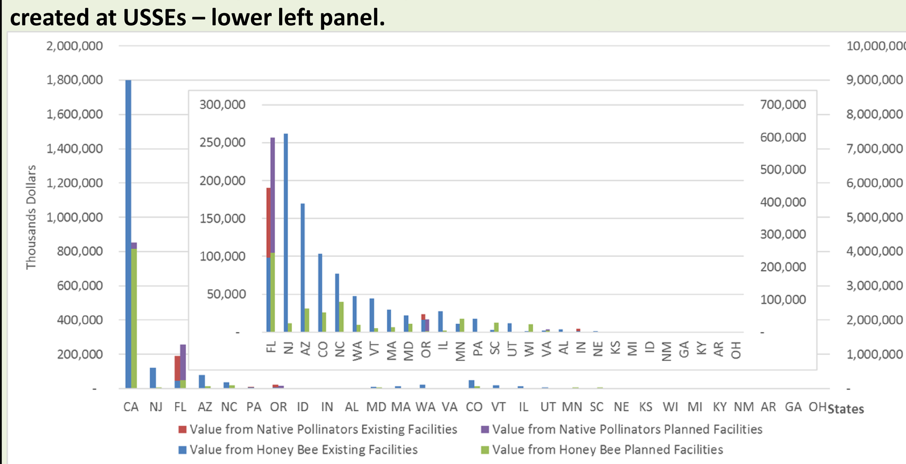


Figure 3 | **Pollination dependency of crops on domesticated bees and native pollinators-Upper left. Estimated value of pollination per acre across the croplands in coterminous US- right panel. Total potential value of pollination from habitat created at USSEs – lower left panel.**





The annual pollination benefit for twelve other states exceeds $100 million. In six states, native pollinators are relatively more beneficial (annual pollination value exceeding $100 million): CA, MN, IN,TX,FL, and GA. while other states including NC, NY, WI, and OR also reap considerable benefits from these native pollinators, in excess of $50 million a year . The total pollination benefit from native pollinators across all nineteen states is estimated at $2.5 billion per year.

Almonds are the most valuable pollination-dependent crop, with 41% ($4.3 billion) of the pollination benefit across the nineteen study states accrued to honeybees; 34% of the total benefit for all crops is associated with insect pollination. Other important crops with pollination benefits that exceed $500 million in these study states are cotton, soybean, broccoli, carrot, and onion. Per-crop benefits of native pollinators exceed $100 million for grape, soybean, strawberry, cotton, squash and pumpkin, while benefits for broccoli, peanut, celery, carrot, onion, peach and sugar beet are estimated to exceed $50 million per crop.

Cost Estimations

The total cost of vegetation management at solar sites include the costs of site preparation (SP), strip establishment (E), annual management (M) and annual opportunity cost (OC). Based on farm-level financial model developed by STRIPs research paper (Tyndall et al, 2013), the present value of total cost (PVC) for contour prairie strip is:

$$PVC = PV^{SP} + PV^{PE} + PV^{M} + PV^{OC}$$

Table 1 | **Estimated cost of vegetation management (adapted from Tyndall et al, 2013)**

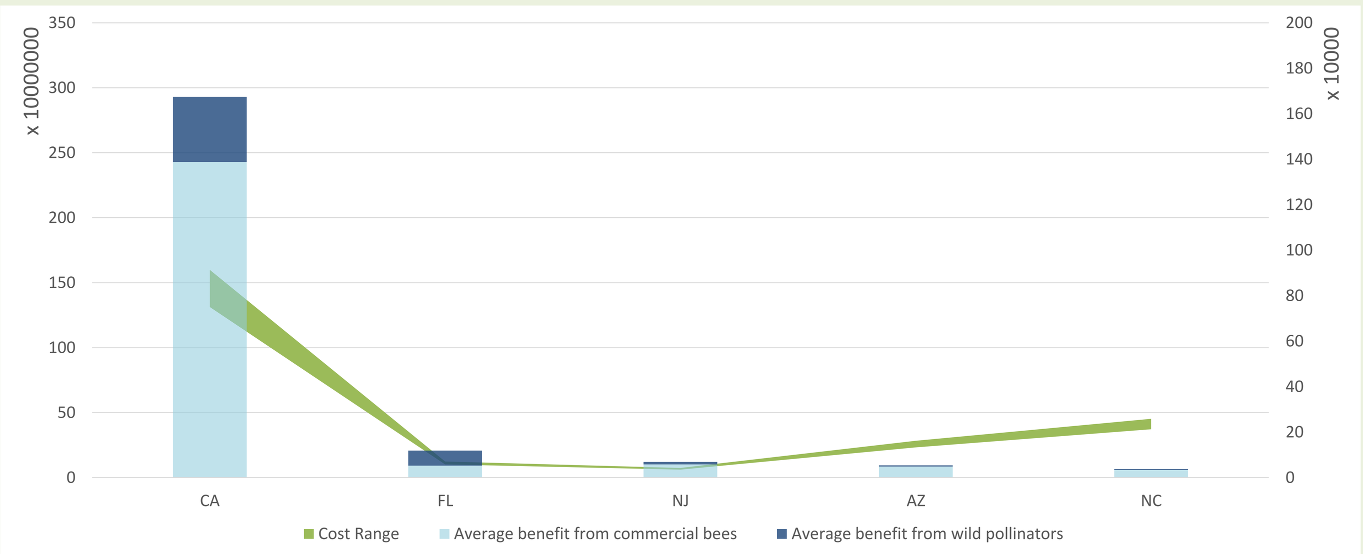
Category	Cost	Average cost ($/ac)
Site Preparation	Tillage	18.82
	Herbicide	15.68
	Herbicide application	55.4
Prairie Establishment	Seed	143.21
	Seed drilling	15.68
	Cult packing	17.77
	Total Fixed cost for VM ($/ac)	**360.65**
Management	Mowing	31.36
	Bailing	11.5
	Burning	37.63
Opportunity Cost	Land rent	0
	Total Variable cost for VM ($/ac)	**50.07**
Discount rate		4%
Number of year		15
Capital Recovery factor		0.09
NPV of Variable Cost ($/ac)		528.95
Equivalent Annual Cost ($/ac)		78.59

The vegetation management cost at solar sites varies based on the physical attributes of the sites, type of energy generation/transmission facilities, area, and the labor and inputs costs.

Some assumptions used for estimations (1) A low adoption scenario of pollinator habitat by the USSEs (20%) to high adoption scenario (50%) were used in the estimation; (2) the land area in the solar facilities used for pollinator habitat creation ranges from 20% of the total land to 30%; (3) land required solar facility 8 acres per MW).

The total costs of pollinator habitat development in 22 states ranges from $1.7 million to $ 5.2 million. The estimted costs of solar polinator habitat development in or adjacent to existing USSEs ranges from $ 1 million to $2.9 million. Similarly, for the USSEs under various stages of development, the costs for pollinator habitat development ranges from 0.7 million to 2.2 million.

Cost and Benefit Analysis



The net benefits of solar pollinator habitat development in the USSE facilities is the highest for the states of California, Florida, New Jersey, Arizona, North Carolina, Vermont, Maryland, Massachusettes, Oregan and Minnesota. The net benefits are negative for the states such as Arizona and Kentucky.

Key Findings

- Studies shows that high-quality pollination habitat around farms can safeguard pollinators and their services
- Examination of about 100 million acres of pollination dependent crops in the U.S. shows the pollinator supply demand gap and as a result potential for creating pollinator habitats.
- Our preliminary estimation shows that the average annual benefits of insect pollination for the 22 lead solar states in the US at $32 billion (2016 dollars).
- The pollination value of creating solar pollinator habitat at USSE facilities using 20% of the land within the USSE facilities ranged from $0.4 to $1 billion for wild pollinators.
- The costs of creating pollinator habitat is a quarter to half of the vegetation management costs that solar developer companies spend for managing the vegetation at USSE sites depending upon the location. The costs ranges from $1.7 million to $5.2 million for all the USSEs in 22 states.
- The top states with high benefit to cost ratio for pollinator habitat creation are California, Florida, New Jersey, and North Carolina.
- While the benefit to cost ratio and the net benefits varies spatially within states, the net benefit is negative for the states of Arizona and Kentucky.

Contact: Shruti K. Mishra,
Email: mishra@anl.gov; saishruti@gmail.com