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Solar Pollinator Habitat

Soscol Ferry Solar P19-00338-UP
Planning Commission Hearing Date December 18, 2019

POLLINATOR PARTNERSHIP

Protect their lives. Preserve ours.

Assessment of Solar Pollinator Habitat: Soscol Ferry Solar Project

July 2019

Report

Submitted to:
Renewable Properties, LLC

RP Napa Solar 2, LLC

Pollinator Partnership

Executive summary

This report was commissioned to provide Renewable Properties, LLC and RP Napa Solar 2, LLC a defensible, cited assessment of how the development of the Soscol Ferry Solar Project's pollinator-friendly habitat can quantifiably benefit area agricultural producers, to be used in presentations to local residents and policymakers. In addition, it was requested that ecological and community benefits and opportunities be evaluated. Pollinator Partnership has provided an in-depth literature review of the agricultural, conservation, and industry benefits of pollinator solar habitat. In addition, site-specific calculations and assessments of benefits to surrounding area agriculture, and other potential site-specific benefits to the environment, communities, and research opportunities and options are explored.

Solar installations in agricultural areas are sometimes seen as unfavorable to the landscape because they temporarily take land out of agricultural production. However, solar installations that integrate pollinator habitat can be directly beneficial to agriculture by creating more heterogeneous landscapes and by providing habitat that can enhance ecosystem services and crop yields, while also increasing biodiversity.

There is an abundance of research showing that increasing habitat in agricultural landscapes increases pollination and pest control services, which lead to better crop yields and lower need for exogenous inputs such as pesticides and managed pollinators (i.e. honeybee hive rentals) *[Agricultural Intensification: loss of biodiversity and ecosystem services, pg. 5]*. Despite demonstrated benefits of large- and small-scale habitat incorporation, and incentives for habitat creation *[Incentivization, pg. 14]*, uptake of agri-environmental practices is nevertheless limited and large areas of agricultural landscapes in the US are highly homogeneous. The homogenization of farmland increases farm inputs, decreases sustainability of production, and ultimately threatens future food security and the ability to meet the increasing global demand for food.

Rather than being a threat to agricultural production, solar installations can be part of the solution. By integrating pollinator habitat within solar arrays, sites can be multi-functional; delivering clean, renewable energy as well as ecosystem services to agriculture and wider conservation benefits.

Solar pollinator habitat is relatively new in North America, and assessment of agricultural and ecological benefits, as well as cost-savings and other benefits to the solar industry are preliminary at this point. This offers a unique opportunity for early adopters to be at the forefront of a growing movement to encourage and legislate adoption of low-impact solar.

While benefits can be multi-faceted, habitat creation needs to be done with the best available, science-based information, and with consideration of local factors. Additionally, consultation with pollinator experts and local restoration experts can ensure meaningful value and long-term success is achieved. The surrounding land matrix, plant selection, and long-term maintenance are all important factors that impact habitat value to agriculture and conservation *[Considerations for maximizing pollinator-solar habitat, pg. 18].*

The Soscol Ferry Solar Project ("Project") located in Napa County off of Soscol Ferry Road, Napa, CA 94559, could provide multiple benefits to local agricultural operations, in particular vineyards, and the ecology of adjacent lands, some of which are riparian waterways. Additional benefits to the landscape and surrounding agricultural operations are not easily quantifiable or monetarized, however, hold significant value. These benefits include increased soil health, reduced storm water runoff, reduced erosion, greater soil moisture retention, enhanced carbon sequestration, and increased biodiversity and ecosystem function.

The site lies in a region that is an important habitat for the western monarch butterfly population, which has experienced an 86% decline since last year's population count and a catastrophic decline of 99.4% since the 1980's (https://xerces.org/save-western-monarchs/; accessed 2/17/2019). Monarchs are milkweed obligates; milkweed species are the only plant that monarchs can use for reproduction and caterpillar growth stages. Restoring native milkweeds, including narrow-leaf (*Asclepias fascicularis*) and showy (*A. speciosa*) which occur within Napa County, and native nectar plants which are the food and nutrient source for adult butterflies within the solar array would be an invaluable contribution to monarch conservation and provide opportunities for community education, community engagement (such as monarch tagging and monitoring), and relationship-building *[Monarch butterflies, pg. 21]*.

In the face of increasing land degradation and homogenization, climate change, and the loss of biodiversity, all of which threaten sustainable agricultural production and ecosystem function, creation of native plant habitat for pollinators in solar installations can be an innovative and noble part of the solution. Combining clean energy production with agricultural service provision and conservation is a promising way forward for humanity and the planet that we rely upon.

Contents

Introduction

Solar installations in agricultural areas are sometimes seen as unfavorable to the landscape because they temporarily take land out of agricultural production (Beatty et al., 2017; Walston et al., 2018). Reduction of farmland through conversion to non-agricultural purposes, such as urban or industrial development, threatens food security and poses a problem in the US and globally (Francis et al., 2012; He et al., 2017). Solar installations are sometimes perceived to be similar to urban or industrial developments (although their project characteristics are substantially different) and thus are considered a similar threat to the protection of habitat, agricultural land, and food production.

However, solar installations that integrate long-term quality pollinator habitat, comprised of native plant species, can be directly beneficial to the agricultural landscape. These efforts create heterogeneity in the landscape and provide habitat that can enhance ecosystem services, increase crop yields, and sustainability of production while also benefiting natural ecosystems and conservation of biodiversity (Montag et al., 2016; Walston et al., 2018).

Insects are essential for ecosystem function and provide services that are directly linked to human well-being, with crop pollination being a primary example (Garibaldi et al., 2014; Potts et al., 2016). Declines in wild pollinators and health problems of managed pollinators have raised concerns about the long-term stability of crop production (Allen-Wardell et al., 1998; Garibaldi et al., 2011a; Garibaldi et al., 2011b; Potts et al., 2010). One of the primary drivers of pollinator and overall insect decline is the loss of habitat (Holzschuh et al., 2011; Kovacs-Hostyanszki et al., 2017; Ricketts et al., 2008). As utility solar developments expand across the United States, there is the opportunity to increase the compatibility of the installations with agricultural production and conservation, thereby contributing to restoring ecosystem services such as pollination and biodiversity.

In this report, we review the value of ecosystem services in relation to agriculture, habitat, and biodiversity, as well as how pollinator habitat relates to the growing solar industry and the proposed +/-15 acre Project (situated on a +/-22 acre parcel) in Napa County, CA. We assess the potential direct benefits to agricultural production in the area from enhanced pollinator habitat, primarily considering pollination, soil health, and pest control. Further, we consider other benefits and uses of habitat for the surrounding community, the agricultural landscape, and the native landscape including improved biodiversity and ecosystem health.

Part 1. Literature Review

Agricultural intensification: loss of biodiversity and ecosystem services

Rapid agricultural extensification (expansion) and intensification (more production per area), globally and in North America, has led to the homogenization of terrestrial landscapes and loss of biodiversity and ecosystems services that are essential for sustainable food production (MEA, 2005; Tilman et al., 2002; Tscharntke et al., 2012). While intensive and homogenous agricultural landscapes support high crop yields in the short term, they also require high chemical and mechanical inputs, resulting in negative environmental impacts on soil, water, air, plant, and wildlife communities (Firbank et al., 2008; Matson et al., 1997). This current model of high inputs with little consideration of natural ecosystem services and biodiversity conservation is threatening the long-term sustainability of agriculture and the ability to meet future growing food demands (Landis, 2017). Removing land from production is often seen as detrimental to food production. Yet, evidence shows that both integration of conservation land and *land use* mosaics in agriculture can benefit production and reduce the need for inputs (Kennedy et al., 2013; Rusch et al., 2016; Tscharntke et al., 2012).

Two primary examples of ecosystem services that benefit from habitat creation and that can increase crop production while decreasing the need for exogenous inputs are insect pollination and biocontrol of pests by natural enemies.

Pollination services

Pollinators are indispensable in agroecosystems, yet they are often overlooked in most farm and landscape-level planning (Garibaldi et al., 2014; Kremen et al., 2012). Approximately 75% of leading global food crops require or benefit from insect pollinators (primarily bees) for seed and fruit production (Klein et al., 2007). Managed honey bees provide much of the agricultural pollination in North America; however, there is increasing evidence that native bees provide critical pollination services that are not replaceable by managed honey bees (Garibaldi et al., 2011; Garibaldi et al., 2013). In addition, ongoing honey bee health issues and uncertainty surrounding long-term health of managed hives make it unfavourable to solely rely on these managed pollinators for agricultural pollination services (Becher et al., 2013; Potts et al., 2010). Further, abundant and diverse native pollinator populations provide reliable and consistent services in variable conditions, and buffer against potential agricultural pollination problems that may result from factors such as reduced honey bee populations and climate change (Kremen and Miles, 2012).

The primary threat to native pollinator populations is loss of habitat. Natural or semi-natural land within agroecosystems has proven repeatedly to directly benefit pollinators and pollination services in agricultural landscapes (Blaauw and Isaacs, 2014; Garibaldi et al., 2014; Goulson et al., 2015; Kennedy et al., 2013; M'Gonigle et al., 2015; Martins et al., 2015; Morandin and Kremen, 2013). An economic model, based on native pollinators and pollination services in a canola growing region, showed that landscape-level profit is maximized when *less* land is under cultivation (up to 30% uncultivated) providing increased yields and profits at a landscape level (Figure 1) (Morandin and Winston, 2006). Similarly, Kremen et al. (2004) calculated that watermelon farms in California would need to reserve about 40% of the land as habitat within a 2.4 km radius**,** or 30% within 1.2 km radius**,** for full pollination by native bees. They note that much smaller proportions of natural habitat are sufficient to ensure a substantial contribution to pollination.

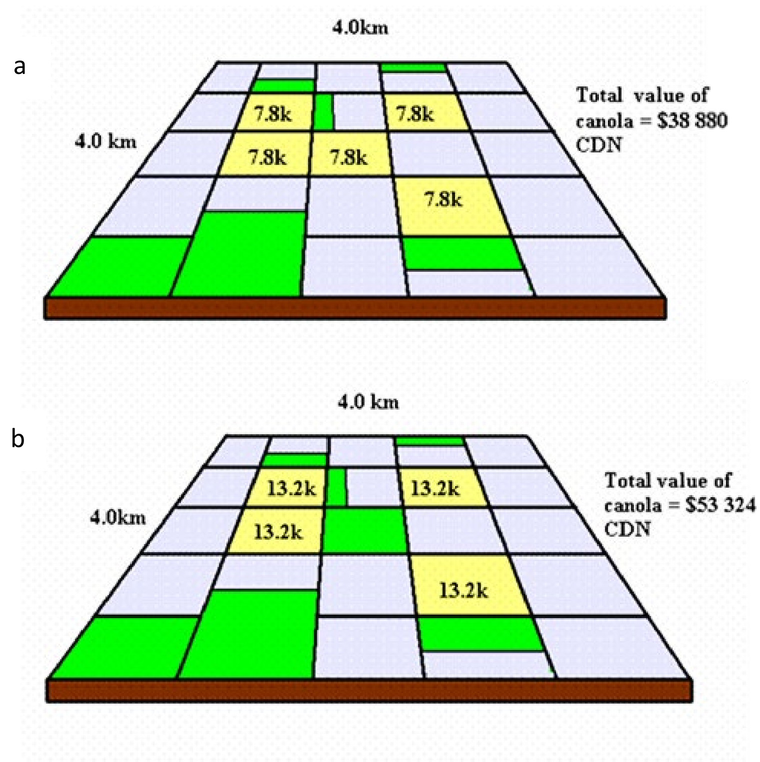

Figure 1. A hypothetical agricultural landscape showing net returns from canola cultivation in two landscapes, a. with a central cultivated section and b. with a central section that is uncultivated and providing habitat for wild pollinators (Morandin and Winston, 2006). Profit is greater in each cultivated field ($13.1K vs $7.8K) when there is a central area that is left as an uncultivated native habitat area due to higher seed production from increased pollination services. Landscape profit also is greater in scenario b despite less land under cultivation. While the model is based on a canola production system, it can be applied to any agricultural landscape that includes pollinator-dependent crops.

Small-scale habitat restoration such as hedgerow creation and diversification of landscapes within farmlands enhance pollination and other ecosystem services while not taking land out of production (Lichtenberg et al., 2017; Long et al., 2017; Morandin et al., 2007). Importantly, it has been found that practices which diversify both farms and landscapes can result in greater diversity of arthropod communities and provide temporal and spatial stability of ecosystem service provisioning (Lichtenberg et al., 2017). Notably, land does not need to be taken out of agricultural or other use *per se* for biodiversity and ecosystem service benefits to be realized. For example, in an intensive agricultural area in southern Alberta, pollinator-dependent crop fields that were within 1000 m of pasture land had greater bee abundance and diversity than fields surrounded by a more homogeneous matrix of cultivated land (Morandin et al., 2007).

Diverse landscapes including farm systems and conservation lands that incorporate areas that enhance wild pollinators can benefit agricultural production while reducing reliance on inputs such as commercial honey bee colonies. Additionally, high-quality habitats around farms may offset impacts of intensive monoculture agriculture (Kennedy et al., 2013), reducing the need for farmers to create and manage habitat on their lands.

Pest control

Another benefit of integrating pollinator habitat within agricultural areas is greater biocontrol of pests by natural enemies, resulting in less need for chemical insecticide inputs (Bianchi et al., 2006; Chaplin-Kramer and Kremen, 2012; Chaplin-Kramer et al., 2011; Holland et al., 2017; Koh and Holland, 2015; Morandin et al., 2014; Morandin et al., 2016). An average of 35% of potential crop yield is lost to pre-harvest pests worldwide and despite a 15–20 fold increase in the amount of pesticides used in the last 60 years, the proportion of crop loss from insects has increased (Oerke, 2006). Overuse of pesticides in intensive agricultural systems has led to the inadvertent destruction of natural pest enemies, the emergence of resistant pests, and outbreaks of secondary pests that emerge after control of primary pests (Oerke, 2006). In addition to the growing ineffectiveness of pesticides, greater restrictions on pesticide use (Hillocks, 2012) make it imperative that pest control practices include enhancement and protection of natural enemy insects.

More semi-natural habitat can benefit pest control by increasing availability of alternative hosts or prey and by increasing nectar and pollen resources for beneficial predatory arthropods and parasitoid insects (parasites that eventually kill their hosts)**;** as well as, by reducing beneficial insect exposure to pesticides, providing refuges from disturbance, and by providing necessary overwintering habitat areas (Bianchi et al., 2010; Landis et al., 2000; Long et al., 1998; Meehan et al., 2011; Morandin et al., 2014; Tscharntke et al., 2007). Additionally, enhanced floral resources have been found to increase the longevity and efficacy of parasitoid wasps which can enhance pest control (Geneau et al., 2012; Winkler et al., 2006).

Rusch et al. (2016) conducted a meta-analysis of aphid control by natural enemies in various crop systems in relation to the simplification of the surrounding landscape. They found increasing cultivated land, from 2 to 100% within a 1 km radius, reduced the level of natural pest control by 46%, suggesting that landscape was the major determinant of pest control functioning and insect pest outbreaks in agriculture (Figure 2). They concluded that preserving and restoring semi-natural habitats is fundamental to maintaining and enhancing top-down pest control services provided by predatory arthropods.

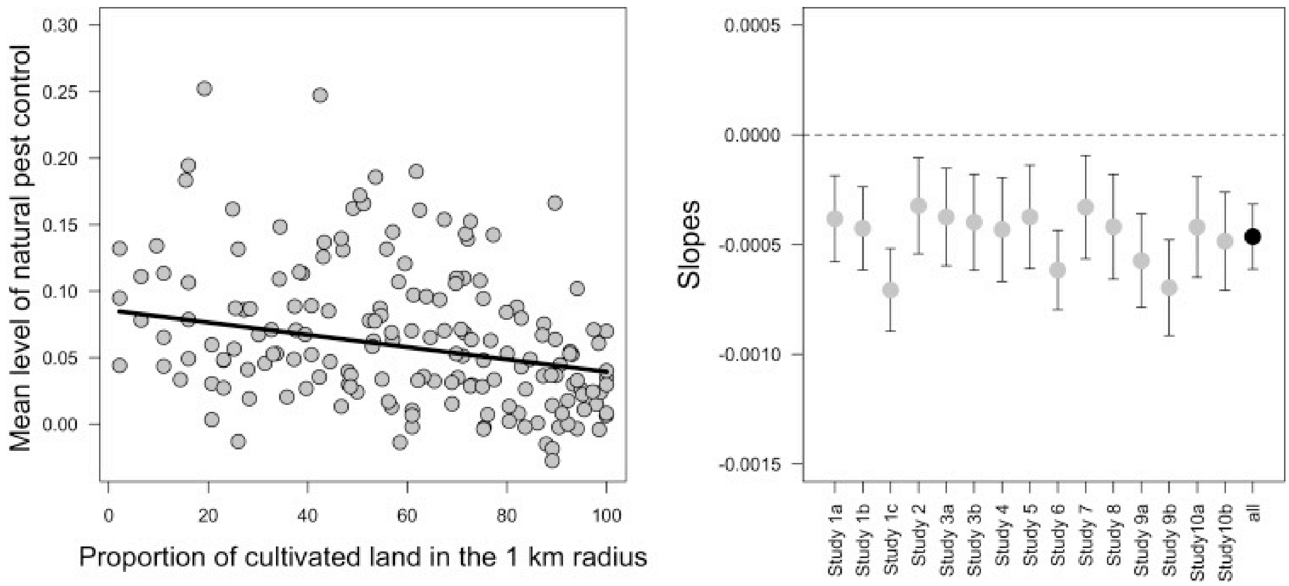

Figure 2. From Rusch et al. (2016): Mean level of overall natural pest control in relation to the proportion of cultivated land in a 1 km radius around fields. The level of pest control was measured by the difference in growth rates of aphids between the total exclusion treatment and the open treatment. On the left, each point represents a field site within a study and the line represents the overall regression estimated from the linear mixed effect model. On the right, each point represents the slope of the model for each study (grey) and overall mean slope for all models (black), resulting from the random intercept and slope model.

While there is concern that greater amounts of habitat could increase pests as well as beneficial insects, (pollinators and predatory insects such as spiders, lady beetles, and parasitoids), most research indicates that habitat creation with native plants preferentially increases beneficial insects, not damaging pest insects (Isaacs et al., 2009; Long et al., 1998; Morandin et al., 2014). Morandin et al. (2014) assessed pests and beneficial insects in hedgerows in the central valley of California planted with native plants and compared the insect communities to weedy field edges. They found a similar abundance of predatory insects in both types of vegetation but a significantly greater abundance of beneficial parasitoids on the native plants than in the weedy non-native vegetation (Figure 3). Further, the majority of pest insects were far more abundant on the weedy vegetation than on the native plants, and the beneficial to pest ratio was greater within native plant hedgerows in comparison to weedy sites. They concluded that native vegetation enhances beneficial insects and pest control and does not support pest insects or pest pressure in adjacent crops.

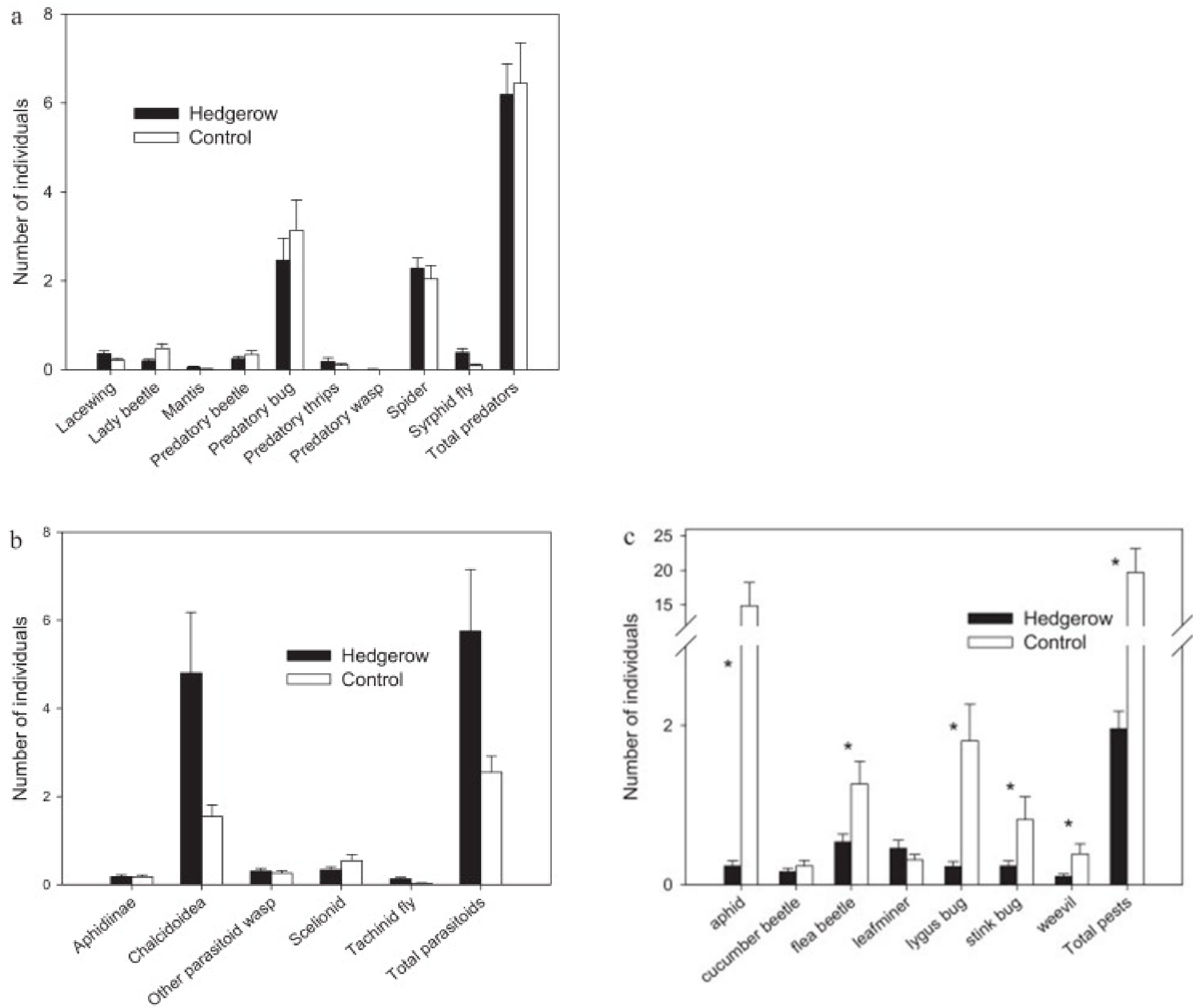

Figure 3. From Morandin et al. (2014): Mean (+standard error) abundance of (a) predators, (b) parasitoids, and (c) pests in control and hedgerow field edges over two years per sweep net sample. Data are from four hedgerows and four control edges over two years. Stars above bars for each group indicate differences in mean abundance per sample between hedgerow and control sites (P < 0.05).

While studies largely show that pests are lower in crops in diverse landscapes, few studies directly measure yield or economic benefits of lower pest populations. Morandin et al. (2016) assessed the number of insecticide treatments required in tomato fields with weedy edges compared to fields with native plant hedgerows based on actual pesticide applications and field quantification of economic threshold levels of pests based on University of California Integrated Pest Management Guidelines. Fields with hedgerows were paired, where possible, with fields with weedy edges that were managed by the same grower and greater than 1 km but less than 3 km away. Over the two-year study, one in eight fields with native plant hedgerows required insecticide applications, whereas four of eight fields without native plant hedgerows required insecticide application. It was noted that the one field with a native plant hedgerow that reached economic threshold for pest treatment had a high cover of non-native weedy plants (*Brassica spp.)* in the hedgerow which was harboring a high abundance of aphids. The lower requirements for pesticide treatment in fields with native plant hedgerows resulted in a 75% savings from the reduced need for insecticides. Native plant hedgerows in this study were all over

15 years old, and a return on investment of hedgerow creation, incorporating both pollination and pest control benefits, was realized within 5-7 years of hedgerow installation. (Figure 4).

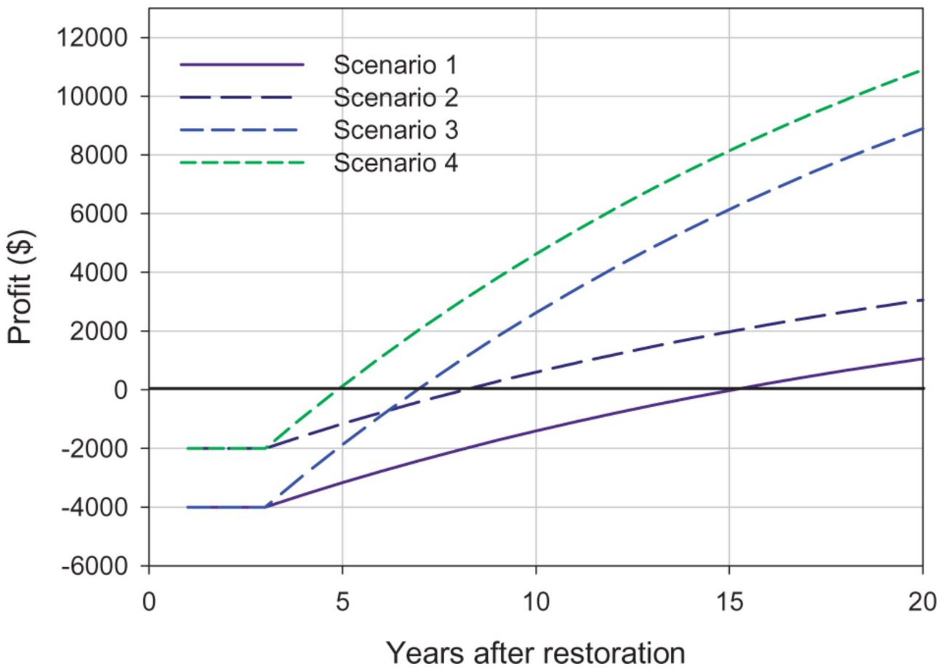

Figure 4. From Morandin et al. (2006): Discounted profit (US$ 1.05% discounted rate per annum) from installation of a 305-m hedgerow of native California flowering plants on a field crop edge, calculated from the cost of installation and potential cost savings incurred from hedgerows from reduction in insecticide application and pollination benefits from natural enemies and pollinators. Scenario 1: benefits from reduction in insecticide treatments alone each year (either no pollinator-dependent crops in the rotation or managed honey bees in the system provide all pollination needs). Scenario 2: same as Scenario 1 but with a 50% USDA EQIP cost share program. Scenario 3: benefits from reduction in insecticide treatments each year and enhanced pollination in a pollinator-dependent crop every 3 yr. Scenario 4: same as Scenario 3 but with a 50% USDA EQIP cost-share program. We do not show a potential for cost-benefit from reducing the number of honey bee hives needed for pollination. However, a grower could also gain from the enhancement of native bees if they needed to rent fewer honey bee hives. Hedgerows were planted on field borders, so there was no loss in crop production.

Another study that measured economic impacts explored the relationship between landscape simplification, pest pressure, and insecticide use over a wide range of environments and crops using remotely sensed land cover data from the national census of farm management practices, and data from a regional crop pest monitoring network across 562 counties in the Midwestern United States (Meehan et al., 2011). They found there were greater numbers of pests in areas with more land under cultivation and less semi-natural habitat. In addition, a greater proportion of cropland was treated with insecticides as the proportion and patch size of cropland increased (associated with less semi-natural habitat) (Figure 5). They estimated that across a seven-state region in 2007, landscape simplification was associated with an increase in insecticide application to 1.4 million hectares. The direct cost increase, from landscape simplification, amounted to between $34 and $103 million.

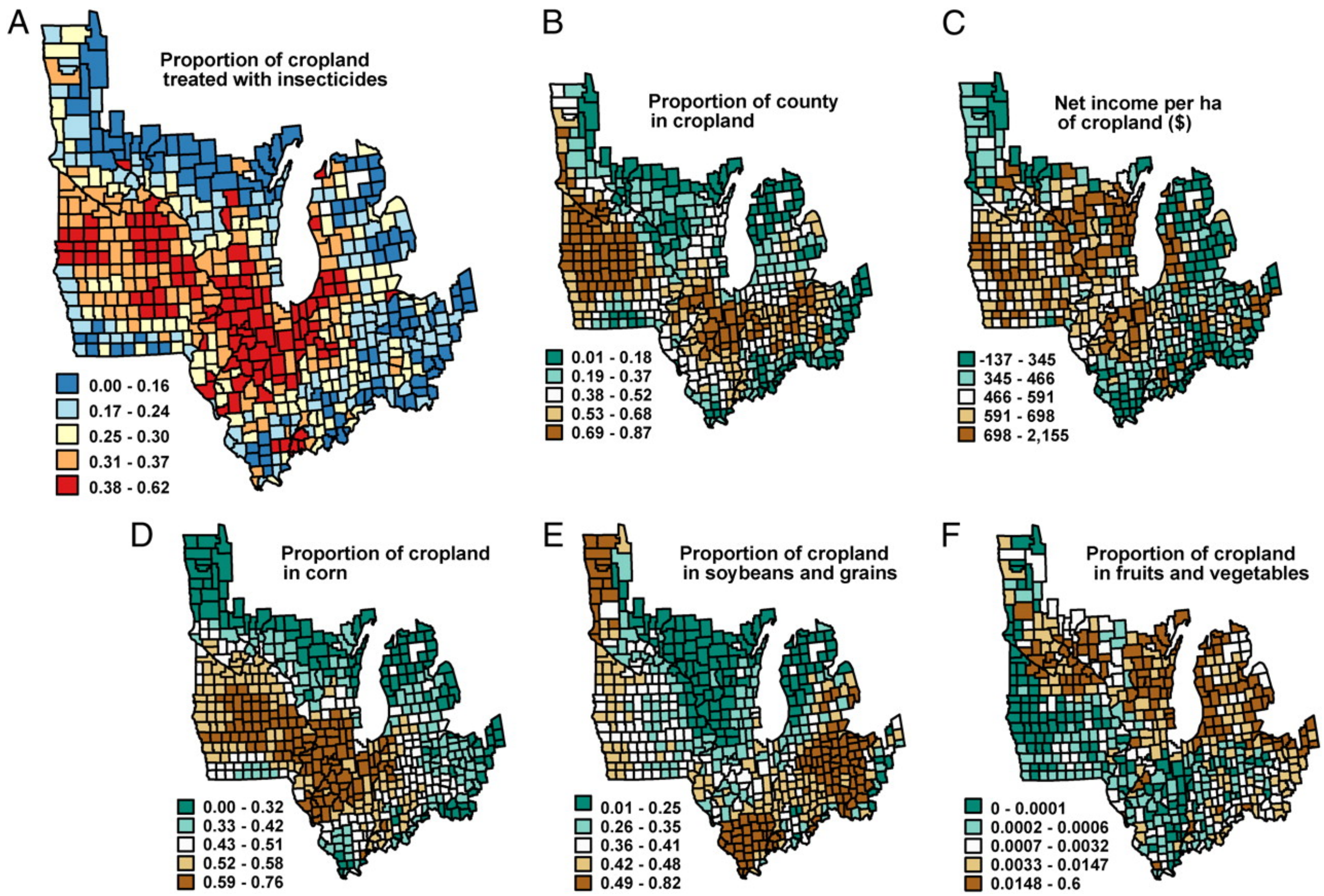

Figure 5. From Meehan et al. (2011): Spatial distribution of model variables. Proportion of harvested cropland in a county that is treated with insecticide (*A*) compared with the proportion of a county in cropland (*B*), the net income per hectare of harvested cropland (*C*), and the proportions of cropland planted in corn (*D*), soybeans and small grains (*E*), and fruit and vegetable crops (*F*). For all maps, each color shade denotes 20% of the observations.

These studies provide strong evidence that beneficial insects are enhanced by less cropped land and more semi-natural habitat in an agricultural landscape, which, in many cases, results in lower pest pressure and pesticide inputs. The lower inputs benefit both the economics of farm systems and biodiversity conservation. Additionally, society benefits from lower pesticide input through greater biodiversity and recreational opportunities (e.g., hunting, fishing, birding, other wildlife observation), and lower human exposure to insecticides. Solar arrays that incorporate native plant-pollinator habitat will increase the proportion of non-cropped area in agricultural landscapes which helps reduce pesticide use and provides multiple benefits.

Other agricultural benefits and opportunities

Other potential benefits to agricultural landscape resulting from installation of solar fields with native plant-pollinator habitat include soil health improvement, reduced storm water runoff, reduced erosion, water purification, and greater carbon sequestration.

Soil health can be improved on solar farms managed with native plants. Many agricultural lands have soils that are degraded from years of production. According to the Building Research Establishment (BRE) National Solar Centre report (2013), siting solar projects on former agricultural land can provide a 25-year fallow period, which increases soil health and thus long-term sustainability. Further, establishing a diverse community of native plants rejuvenates the soil by adding soil organic matter (Robles and Burke, 1997). If the land used for the solar installation was previously grazed, adding native plants and controlling invasive grasses and forbs can allow for the natural ecosystem to regenerate. This is largely a function of the deeper root systems of these native plants which increase water infiltration and thereby reduce storm water runoff and increase moisture retention in the landscape. Additionally, the deep root system from native plantings can increase carbon sequestration when well managed (Conant, 2010).

Co-location of agricultural at solar sites includes livestock grazing, honey bee pasturing and honey production, and crop production under panels (Dinesh and Pearce, 2016; Dupraz et al., 2011; Semeraro et al., 2018).

The National Renewable Energy Laboratory summarizes the key benefits to landowners and companies of co-locating agriculture (e.g., livestock, crops, or honey bees) and solar in the following table:

Table 1. From NREL https://www.nrel.gov/technical-assistance/blog/posts/solar-sheep-and-voltaic-veggies-uniting-solar-power-and-agriculture.html: benefits to landowners and solar developers from co-location of agriculture with solar arrays.

Benefits to Land Owners	Benefits to Solar Developers
Self-generation of electricity and reduced energy bills	Reductions in site preparation and installation costs
Control of wind and soil erosion	Reductions in operation and maintenance costs
Compatible with grazing activities, provides shade and cover for livestock	Reduced need for dust suppression
Market opportunity for shade tolerant crops	Decreased permitting time
Improved habitat for pollinator species	Increased solar production from cooler air zone created under modules
	Reduction in environmental mitigation investments

Sheep grazing has been combined successfully with solar installations (Figure 6), eliminating the need for mowing (https://www.onpasture.com/wp-content/uploads/2017/05/solar_on_farms_report_2017.pdf and https://www.nrel.gov/technical-assistance/blog/posts/solar-sheep-and-voltaic-veggies-uniting-solar-power-and-agriculture.html). Grazing can be compatible with bee habitat if land is grazed outside of prime flowering and beeactivity periods. Cow grazing within solar arrays also is feasible, but likely only when panels are above the height of the cows (see previous links).

Figure 6. Sheep using the solar array as a refuge from the heat on a hot day at Open View Farm. After panel installation, the area was seeded with a sheep grazing mix, clover and trefoil. The owners have noticed an increase in bees.

Honey bees are the main pollinators of agricultural crops and in the United States domestic honey bees contribute more than $16 billion annually to the agricultural economy by pollinating fruits, nuts, vegetable crops, and seed crops (Calderone, 2012). An estimated 75% of crop varieties are dependent on, or significantly benefit from bee pollination, and therefore honey bees play a key role in our food systems. The honey industry has also grown significantly with increasing consumer demand for domestic honey and hive products in the US.

Issues in bee health and management are now at the forefront of concerns not only for beekeepers, but also farmers, regulators, and the public. Maintaining vigorous hives that are able to survive winter, combating mite infestations, pests, and pathogens are annual challenges for beekeepers (Berthoud et al., 2010; Borst, 2013). A lack of adequate forage and poor nutrition resulting from loss of natural and semi-natural land is thought to be one of the main factors leading to poor honey bee colony health and colony losses (Decourtye et al., 2010; Vaudo et al., 2015). One of the overarching goals issued by the White House in the Pollinator Partnership Action Plan (2016; https://www.whitehouse.gov/sites/whitehouse.gov/files/images/Blog/PPAP_2016.pdf) was to restore or enhance 7 million acres of land for pollinators over the 5 years following the plan's publication. Adding habitat to landscapes through incorporating pollinator habitat in solar developments can aid honey bees since they can forage up to 3 miles from their hive locations, as well as by intentionally creating bee pasture and resource foraging areas. Data show that Conservation Reserve Program (CRP) lands enhanced with pollinator seed mixes (CP42) can increase honey production by a mean of [15 kg] 33 lbs./colony over traditional CRP mixes (Wojcik and Morandin, 2017; unpublished Farm Service Agency Report).

Recently, co-location of 48 honey bee hives at the Eagle Point solar installation in southern Oregon met the criteria for the land to be classified as agricultural (https://www.fastcompany.com/40588875/this-new-solar-farm-combines-clean-energy-and-beehives).

Figure 7. Co-location of 48 honey bee hives at the Eagle Point solar installation in southern Oregon met the criteria for the land to be classified as agricultural.

Incentivization

Despite well-established evidence for heterogeneous landscapes and habitat integration within agricultural systems, intensive, homogeneous agricultural landscapes continue to dominate in many areas of North America (Meehan et al., 2011). Conservation of biodiversity and ecosystem services on private lands, such as in agricultural areas, is both necessary yet challenging (Kamal et al., 2015). The value of semi-natural land, habitat, and biodiversity, integrated within the agricultural matrix, is rarely considered in the contemporary economy (Francis et al., 2012). Subsequently, large swaths of agricultural land across North America have virtually no options for the biodiversity and ecosystem services that sustainable agricultural production relies upon (Tilman et al., 2011; Tilman et al., 2002). This has led to increasing inputs on farms, such as managed honey bees for pollination and chemical insecticides for pest control, to compensate for lack of ecosystem services (Tscharntke et al., 2012).

Many countries recognize the need for integrating habitat into agricultural lands, both for the direct short and long-term benefits to agricultural production, and the preservation of biodiversity and other ecosystem services that are beneficial to ecosystems and humans over the long term. Additionally, they recognize that private landowners cannot solely bear the cost of habitat creation and other environmental measures and provide incentives and voluntary or mandatory programs aimed at increasing adoption of these measures on private lands.

The European Union financially supports voluntary and mandatory ‘greening measures’ and agri-environment schemes with the purpose of safeguarding and improving biodiversity on farms. The rationale is that farmers should be rewarded for the services they deliver to the wider public, such as landscapes, farmland biodiversity, and climate stability even though they have no direct market value. The mandatory program was reviewed by the EU one year after implementation in 2015 (http://ec.europa.eu/agriculture/direct-support/pdf/2016-staff-working-document-greening_en.pdf). It was found that the choices with the lowest coefficient for biodiversity had the highest uptake and features such as hedgerows with the highest potential to benefit biodiversity had very low uptake. The program is being reviewed to find solutions that will increase uptake of greening options that provide higher value for biodiversity and ecosystem services.

In the United States, two programs under the Farm Bill that encourage and incentivize conservation measures in agricultural landscapes are the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP). The Conservation Reserve Program (CRP) is a voluntary program that began in the 1950s with the initial focus of shifting highly erodible land from agricultural production to permanent vegetative cover. The program has evolved to encompass reduction of soil erosion, water supply enhancement, water quality improvement, reduction of damage from weather events, and enhancement of wildlife habitat including pollinators. The CRP pays farmers to create vegetative cover and over 20 million acres (~7%) of US cropland was enrolled in CRP in 2016 (ref). However, fluctuating crop prices, acreage caps, and other factors hinder the long-term extent and value of CRP lands as biodiversity reservoirs and ecosystem service provision areas.

Despite cost share and other incentive programs, there has been poor uptake of farm-scale environmental measures in the United States (Garbach and Long, 2017), and little uptake of the most biodiversity-enhancing measures in the EU. Creating solar installations, with high-quality native habitat within the agricultural matrix reduces the burden on private landowners within these areas to create and maintain habitat on their lands.

Solar Pollinator Installations are a Win-Win (Win)

Utility-scale solar construction sometimes includes removing vegetation that supports biodiversity. Vegetation is viewed as problematic and is removed or discouraged, sometimes managed with herbicides, and land is sometimes covered with gravel or other material to stop regrowth. Because of these common practices, solar farms sometimes are seen as unfavorable in agricultural landscapes, temporarily taking up land that was, or could be, used for pasture or crop production, while reducing biodiversity (Beatty et al., 2017).

Utility-scale solar energy (USSE) (>1MW) grew at an average rate of 72% between 2010 and 2016, with a total capacity of 22 GW installed and an additional 13 GW construction projects planned at the end of 2016, (Walston et al. 2018). Total area of USSE is projected to be approximately 1.8 million acres in 2030 (NREL 2017). As USSE expands across the US, there is the opportunity to develop installations in ways that reduce agricultural conflicts and enhance environment and agricultural productivity and sustainability (Walston et al. 2018).

Solar installations, with high-quality habitat that supports native and managed bees integrated within agricultural landscapes, provides a way to increase ecosystem services into agriculture. Utilizing these techniques decreases the burden of habitat creation and maintenance off of the farmers within a ~2 km radius of the installation.

As outlined in previous sections of this report, there is abundant evidence that habitat areas in agriculture enhance native pollinators, pollination to crops, and other ecosystem services such as pest control, and it is logical that solar arrays, restored with native plants that benefit pollinators, pest control insects, and other wildlife will also provide these same benefits. In addition, solar fields are not subject to pollutants that are associated with other power generation such as fossil fuel (https://www.solarpowerworldonline.com/2017/05/pollinator-friendly-solar-vegetation/), and therefore can be particularly valuable as reservoirs for pollinators and other wildlife.

However, solar installations managed as wildlife habitat, or other 'low impact' designs are relatively new, and consequently there currently is limited direct data on benefits. Yet, a recent report showed that biodiversity, wildlife, and pollinator benefits could be substantial. Montag et al. (2016) compared plants, pollinators, and other wildlife on 11 solar fields in the UK to adjacent, traditional use agricultural areas that were cultivated or high-intensity grazed land. While only 3 of the 11 solar sites were specifically managed for wildlife, they found evidence that pollinators such as bees and butterflies, birds, and other wildlife, (including an at-risk mammal), were more abundant in solar fields than adjacent traditional-use agriculture areas (Figure 8).

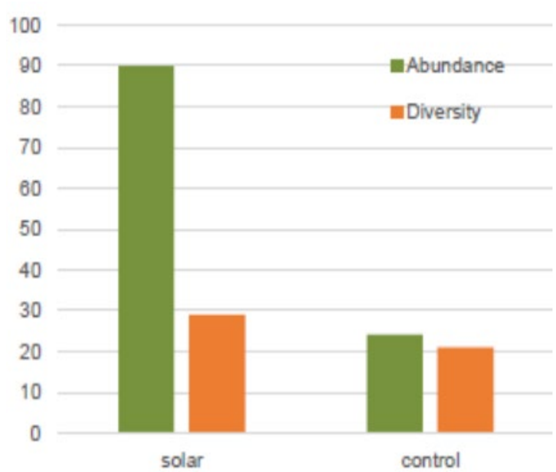

Figure 8. From Montag et al. (2016): Abundance of bumble bees and butterflies at 11 solar sites and paired control sites in the UK. Despite monitoring solar sites that were both managed and not managed for wildlife, biodiversity, including bumble bees and butterflies, and birds were more abundant on the solar sites than the control sites which were arable crop or intensive pasture.

A recent study modeled the benefits to crop pollination of pollinator habitat at solar facilities in the United States (Walston et al. 2018). They assessed the overlap between USSE facilities and surrounding pollinator-dependent crops. They calculated that approximately 1.3 million km^2 of the conterminous U.S. is cultivated with crops, and approximately half a million km^2 (38%) are crops that are at least partially dependent on insect pollination. Within a 1.5 km radius of the solar installations, 9% of the area included crops that benefit from insect pollination (Figure 9). By assuming a conservative 1% increase in production from enhanced pollinators from the solar pollinator plantings of 3 crops: soybeans, almonds, and cranberries, there could be a $1,750,000, $4,000,000, and $233,000 additional crop value respectively.

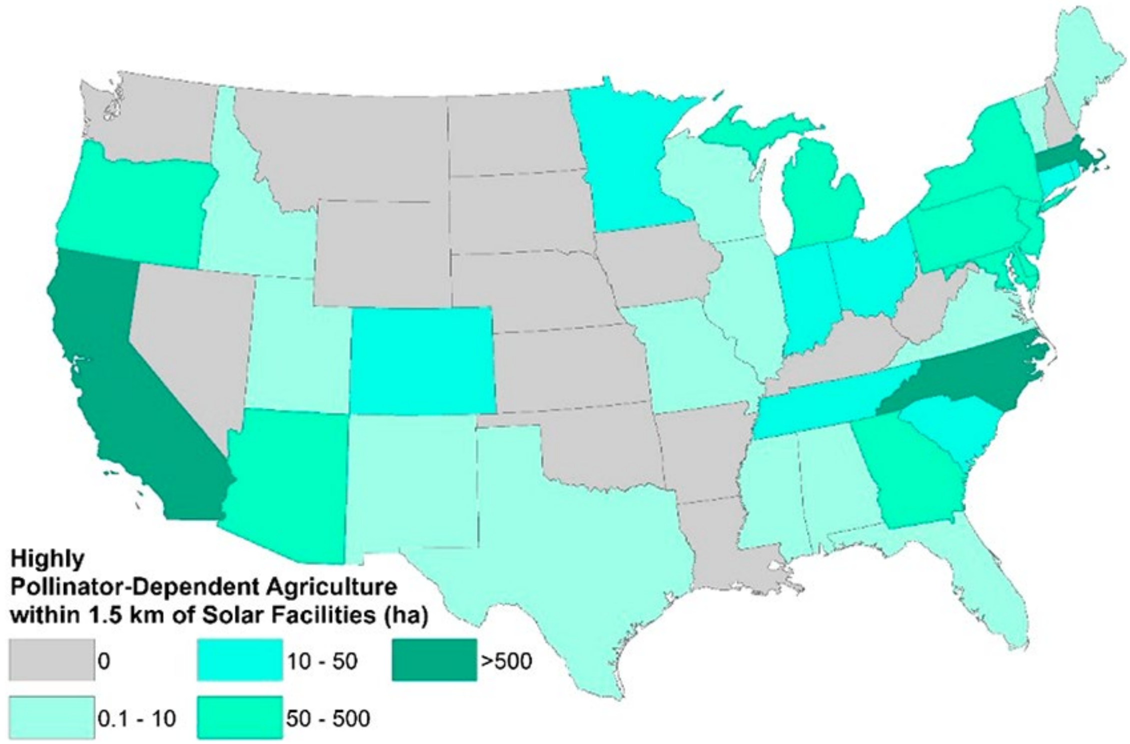

Figure 9. From Walston et al. (2018): 6. Amount of highly dependent pollinator agriculture near existing and planned utility-scale solar energy facilities in the United States within a 1.5 km radius of existing planned utility-scale solar energy installations.

The Walston et al. (2018) and Montag et al. (2016) studies provide an initial, first step towards valuing the potential of solar pollinator habitat to agriculture. Interest in creating pollinator solar habitat, legislating and creating guidelines, and assessing benefits is rapidly growing. For example, in May 2017, Governor Larry Hogan of Maryland signed the Department of Natural Resources — Solar Generation Facilities — Pollinator-Friendly Designation (SB1158) bill into law. It was strongly supported by the Senate and General Assembly. SB1158 establishes a state preference and a process for supporting pollinator-friendly habitat with a commercial ground-mounted solar facility. The law is intended to help pollinators and benefit farmers and gardeners. (http://www.oneenergyrenewables.com/news/maryland-paving-way-commercial-solar-power-plants-become-pollinator-friendly/). Similarly, in 2016 Minnesota signed the Pollinator Friendly Solar Act into law, laying out voluntary standards for managing native habitat in solar fields (https://www.smithsonianmag.com/innovation/solar-power-and-honey-bees-180964743/). In the

State of Virginia, Department of Environmental Quality recently issued a request for proposals for creating an "Ecological Responsible and Pollinator-Smart Virginia Solar Industry".

A growing number of solar companies are establishing pollinator solar habitat, and in some cases teaming up with researchers to assess value and develop best management practices. A 3-year, $100,000 study, has just been initiated between Cypress Creek Renewables and Cornell's College of Agriculture and Life Sciences, designed to assess ecological and economic benefits of planting pollinator-friendly wildflowers and habitat on solar farms in New York (https://ccrenew.com/news/cypress-creek-research-partnership-with-cornell-university/). The growing number of solar-pollinator projects, combined with research, will further refine best management practices in various regions and habitats and optimize ecosystem service provision value.

Considerations for maximizing pollinator-solar habitat benefits

The value of habitat established on solar installations to ecosystems and agriculture will depend on many factors including the location, land use history, surrounding land types, existing insect communities, soil types, types of plants used for restoration, planting density, other restoration practices, weed control and long-term maintenance. It is important that pollinator specialists and restoration specialists with knowledge of the local environment are consulted in order that the best available science and practices are considered in the restoration and maintenance plan.

Distribution and Size: To be valuable to agriculture production, the distribution of solar fields with pollinator habitat should be considered in order to maximize ecosystem service provision. That is, higher amounts of 'edge' habitat and smaller installations scattered throughout the landscape may better provide services to a greater area of agricultural land than fewer, larger installations (Brosi et al., 2008). However, larger installations may serve to support larger, more robust populations of pollinators and other wildlife. While there is some evidence that up to ~30% semi-natural land can increase agricultural profit in a landscape with pollinator-dependent crops (Morandin and Winston, 2006), optimal patch size and distribution of pollinator habitat within the agricultural matrix likely varies among systems (Aguirre-Gutierrez et al., 2015).

Matrix: The surrounding landscape or matrix within which the habitat will be created is also an important consideration and will greatly impact the value of the habitat to pollinators and ecosystem service provision (Steffan-Dewenter, 2003; Steffan-Dewenter and Tscharntke, 1999). Some evidence indicates that small restoration patches within extremely homogenous agricultural land may not have enough of a 'source' population to quickly populate new habitat areas, and therefore larger patches are needed (Brosi et al., 2008). Conversely, landscapes that already have a high proportion of semi-natural habitat may not benefit substantially from additional habitat creation (Winfree et al., 2008). It is likely that restoration will have the most impact when done in a matrix of intermediate homogeneity, although highly homogeneous areas may benefit from larger restored areas after a lag time for population reassembly.

Native vs. non-native plants: The decision to use native plants, non-native plants, or a combination will impact native pollinator communities and service provision, with the greatest benefit to native bee abundance and diversity realized with native plants (Hopwood, 2008; Morandin and Kremen, 2012; Tuell et al., 2008). Also, choosing seed mixes that result in continuous bloom are important for enhancing native pollinator populations (Williams et al., 2015). Control of invasive plants is important for maintaining the abundance and diversity of the original floral mix. Plant mixes for solar pollinator arrays should focus on native flowering plants and grasses, taking into account availability and pricing.

Solar assessment standards: Recently, pollinator habitat scoring systems have been developed for a number of states including Minnesota, Maryland, and Vermont (http://eanvt.org/wp-content/uploads/2017/05/Pollinator-Solar-Scorecard-FORM-2.pdf). Assessment includes consideration of percent of the site to be planted with flowering species, whether the seed mix includes only native species, the diversity of the mix, whether species bloom in multiple seasons, mowing and monitoring plan, insecticide use, and buffers. A score of at least 70 is required to meet the 'Pollinator-friendly Solar' Standard.

Conclusions

Integration of habitat within an agricultural matrix is recognized as an essential component of long-term productive agriculture, contributing direct benefits to growers through ecosystem service provision such as crop pollination from enhanced native pollinator populations and biological control of pests. Additionally, agricultural benefits could include reduced storm water runoff and erosion reduction. Habitat further contributes to the landscape by increasing biodiversity, soil quality, carbon sequestration, hunting and recreation opportunities, community engagement, corporate public relations, and aesthetics.

Agriculture takes up large areas of the earth, and sustainable agriculture is not possible without the integration of ecosystem service-providing habitat. Solar installations that provide high-quality habitat for pollinators and other organisms, within agricultural landscapes, will increase renewable energy while benefiting ecosystems and food production. Further, they can reduce the need for growers and agricultural land managers, within a few km of solar pollinator habitat, to create and manage habitat on their lands. In addition to direct benefits to solar companies such as reduced site preparation and maintenance costs and demonstration of corporate social responsibility integration of native pollinator habitat within solar arrays, provides wins for multiple sectors.

Part 2. Soscol Ferry Solar Pollinator Habitat

Introduction

The many potential benefits that the Soscol Ferry Solar Project native pollinator installation will have for surrounding agricultural endeavors include those that produce direct economic benefits to the surrounding crops from enhanced biocontrol, as well as, other benefits such as improved storm water retention, reduced erosion, and soil quality improvement. To the wider surrounding landscape, the solar-pollinator plantings at the site will improve water quality, increase carbon sequestration, create biodiversity reservoirs with increased plant and wildlife habitat, provide forage for native and honey bees, and improve landscape aesthetics. The project site, with close proximity to highway 12 and a nearby office park, will allow for increased public exposure to showcase exemplary conservation practices on a solar installation.

Site-specific economic benefit calculations

While many ecosystem services are enhanced by habitat within agricultural landscapes, research to provide quantification in economic terms is limited. However, there are studies that allow quantification and extrapolation of the benefit of enhanced pollination services from habitat creation for native bees, and some research that allows pest control benefit estimations.

The majority of ecosystem services that humans require cannot be monetized at this time due to lack of data and a framework for assigning monetary value. The partial economic benefit analysis above does not take into account many other potential benefits that the Soscol Ferry Solar Project native pollinator installation will have for the solar-pollinator land and for the surrounding agriculture and landscape. However, there likely are some direct economic benefits to the surrounding crops from enhanced biocontrol. Much of the agricultural operations adjacent to the proposed site are vineyards producing grapes for winemaking. While, wine grapes do not require insect pollination, there are many benefits of having nearby pollinator habitat to this cropping system. Pollinator habitat will benefit the local vineyards through increased natural enemies of pests as described above. This increase of beneficial insects also deters avian pests that prefer to eat wine grapes. Instead, birds will predate the beneficial insects resulting in less impact on the crop. Additionally, studies have found that despite the commercial grape vine (*Vitis vinifera L.*) being self-pollinating, vintners observed an increase of crop yield with the increase of functional biodiversity (Richards AJ, 2001). Bees have been observed foraging on grape flowers, playing a role in grape yield, yet more significantly, increasing pollination of cover crops, wild plants, and other crops that may be in the agroecosystem such as fruit trees, vegetables, and berries (Kratschmer S, et al. 2019).

Other benefits that cannot be monetized with current information include improved storm water retention, soil quality improvement, reduced erosion, greater plant and wildlife biodiversity, and improved aesthetics. To the wider, surrounding landscape, the solar-pollinator plantings at the site will improve water quality, increase carbon sequestration, create biodiversity reservoirs, reduce the need for farmers to create ecosystem service habitat in the immediate area, provide forage for native bees and honey bees, and improve landscape aesthetics. This project site has several nearby creeks and waterways that would benefit from the installation of pollinator habitat. The Soscol Creek runs directly north of the proposed site with the Napa River approximately 700 m to the west. The installation of pollinator habitat in the form of buffer strips, hedgerows, and meadows helps to mitigate nonpoint source pollution from industrial and agricultural areas. In particular, these types of riparian restoration elements can help prevent an influx of Nitrogen and Phosphorus inputs that can be detrimental to the local watershed (Clausen et al, 2000; Peterjohn and Correll, 1984).

Other site-specific benefits and opportunities

Monarch butterflies

The Soscol Ferry site is located in a critical area along the migratory path and breeding area of the western monarch butterfly population (Figure 10, 11). These charismatic pollinators are well-known by people across North America. The better-known eastern population that overwinters in Mexico has declined by over 80% since the 1990's when there were over an estimated 700 million monarchs. The western population overwinters in forested groves on the coast of California and in the 1980s, populations were estimated to be 4.5 million. Today the western monarch population numbers have plummeted 86% since last year's population count and have realized a catastrophic decline of 99.4% since the 1980's (https://xerces.org/save-western-monarchs/; accessed 2/17/2019).

Northern California is prime monarch migration habitat for the western population, feeding adults as they travel and breed throughout the spring, summer, and fall. Monarchs require a diversity of nectar plants to fuel adults and milkweed for the larvae, and loss of habitat is one of the biggest threats to monarchs. Similar to other monarch migration corridors, critical habitat is declining in Northern California due to a number of factors which include land conversion to agriculture, pesticide and herbicide use, climate change, fire suppression, urban and industrial development, and intensive grazing (SO Monarchs http://somonarchs.org/, Xerces Society for Insect Conservation https://xerces.org/, Monarch Joint Venture https://monarchjointventure.org/).

There are 15 native milkweed species found in California; the six most common species include: narrow-leaf milkweed (*Asclepias fascicularis*), showy milkweed (*A. speciosa*); California milkweed (*A. californica*), purple milkweed (A. cordifolia), Indian milkweed (A. eriocarpa), and woolly milkweed (A. vestita). Of those narrow leaf milkweed and showy milkweed are known to occur in Napa County. Narrow leaf milkweed which grows to 1.5 to 3 ft., is found in a variety of settings including valleys and foothills, dry areas, and occasionally wetlands. It tolerates a variety of soils including sandy, clay, and saline conditions, therefore, will likely be the most successful milkweed addition to a pollinator seed mix. Showy milkweed is a commonly propagated variety; however, it can reach up to 6ft in height in ideal growing conditions and therefore could be included around the perimeter of the array, demonstration, edge or other areas not immediately under panels that are below 6ft in height at full tilt.

Figure 10. From Monarch Joint Venture: the eastern and western monarch butterfly migratory route. Note that the western monarch population migrates through Napa, CA to overwinter on the California coast.

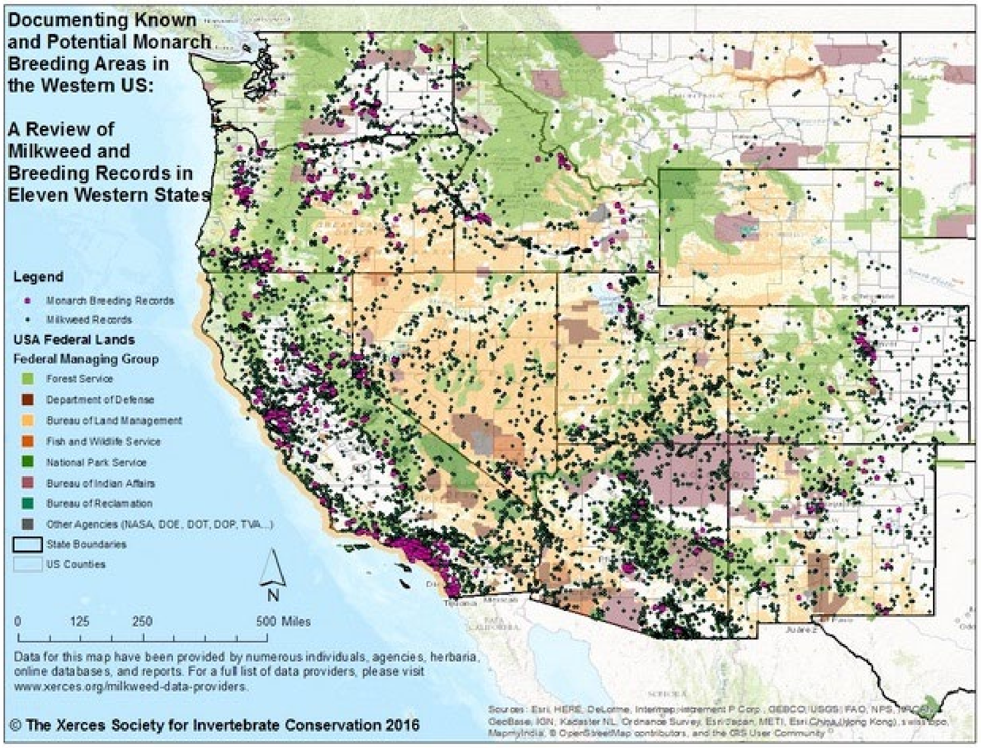

Figure 11. From the Xerces Society for Invertebrate Conservation: Documented and potential monarch breeding areas in the western US. Note that there are milkweed records in the Napa region and a monarch breeding records near the proposed pollinator solar installation.

Inclusion of native milkweed in the solar plantings will provide a larval host plant for the severely imperiled western monarch population. In addition, the diverse pollinator plantings will provide the nectar resources needed by adults, providing an ideal ‘waystation’ monarch habitat. Inclusion of monarch habitat could lead to greater community engagement, streamlined permitting, and opportunities for outreach and education.

Community outreach and education

Being a leader in the solar industry and incorporating pollinator habitat in installations, opens many opportunities for outreach and advancing community relations. School and naturalist groups could be brought to the site for guided tours, learning about renewable energy and the importance of habitat in all types of landscapes. Citizen scientist monitoring could be included so that the community could take part in monitoring pollinators and see first-hand the value of pollinator habitat.

Interpretive signage and brochures can be a more passive but highly effective method for teaching about pollinators and the multiple benefits of solar pollinator habitat. Pollinator Partnership is experienced in all aspects of community outreach and education including designing and conducting workshops, teaching community and school groups pollinator monitoring, and creating brochures, interpretive signage, and other outreach material.

Summary and conclusions

By incorporating pollinator habitat, solar farms not only play a key role in the transition to a clean fuel economy, they also can provide much-needed habitat reservoirs, improving the land and landscape, increasing biodiversity, and reducing greenhouse gases. As the solar industry expands, leaders in the field can make positive impacts on landscapes, contributing to conservation targets and potentially reducing the problem of large-scale monoculture and simplified agricultural landscapes that lack pollinators and ecosystem services, biodiversity, and threaten agricultural sustainability.

The Soscol Ferry Solar Project with inclusion of pollinator habitat will provide agricultural benefits, particularly to nearby vineyards, such as pollination, pest control from beneficial insects, and soil and water enhancement. Ecological benefits such as increases in biodiversity and native ecosystem function will also be realized. In addition, if planted with native milkweed, the habitat can provide a much-needed waystation for the imperiled western monarch population, that has decreased by 99.4% since the 1980's, within a broader area that is of critical concern to its survival. Additionally, because the Soscol Ferry Solar Project is located adjacent to highway 12 and near an office park there is an excellent opportunity to broadly exhibit habitat rehabilitation work which will, most likely, grant an appreciation of improved landscape aesthetics and create the possibility for future opportunities to engage the general public through educational installations. Further, many diverse opportunities for community outreach and relations, agricultural co-location (e.g., honey bee pasturing or livestock grazing), and research are available.

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