Agrivoltaics in Ontario Canada

Subjects: Agricultural Economics & Policy
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Well-intentioned regulations to protect Canada's most productive farmland restrict large-scale solar photovoltaic (PV) development. The recent innovation of agrivoltaics, which is the co-development of land for both PV and agriculture, makes these regulations obsolete. Burgeoning agrivoltaics research has shown agricultural benefits, including increased yield for a wide range of crops, plant protection from excess solar energy and hail, and improved water conservation, while maintaining agricultural employment and local food supplies. In addition, the renewable electricity generation decreases greenhouse gas emissions while increasing farm revenue. The background on Ontario land-use Policy and policy recommendations about agrivoltaics are discussed.

Keywords: agriculture ; Ontario ; energy policy

1. Background on Ontario Land-Use Policy

1.1. Governance

Canada's national government operates as a federal democracy as well as a constitutional monarchy. Each provincial or territorial government has a distinct legislature that oversees local matters and controls municipalities within its jurisdiction. Within the province of Ontario, municipalities are subject to a style of legislation known as "laundry list", in which the powers that are not explicitly stated or implied by the provincial legislature are not granted [1]. This is relatively restrictive. In the context of renewable energy development and agricultural land use, Ontario has made clear the rights of its municipalities through several policy documents, described below.

1.2. Agricultural Heritage

Ontario is in the heart of the Great Lakes region and possesses the most productive farmland in the country within the semicircle of area surrounding Lake Ontario. This area, known as the Greater Golden Horseshoe (GGH) [2], is highlighted in **Figure 1**. Fertile soils, abundant water resources, and a temperate climate coalesce to position the GGH as a leader in diverse and bountiful agricultural production. Within the GGH, the "Greenbelt" has been established as a band of permanently protected territory that maintains agriculture as the predominant land use and guards the agricultural land base from development. To uphold the agricultural legacy and the viability of the agri-food sector in Ontario, the province has developed a set of some of the most protective land-use policies in the world.

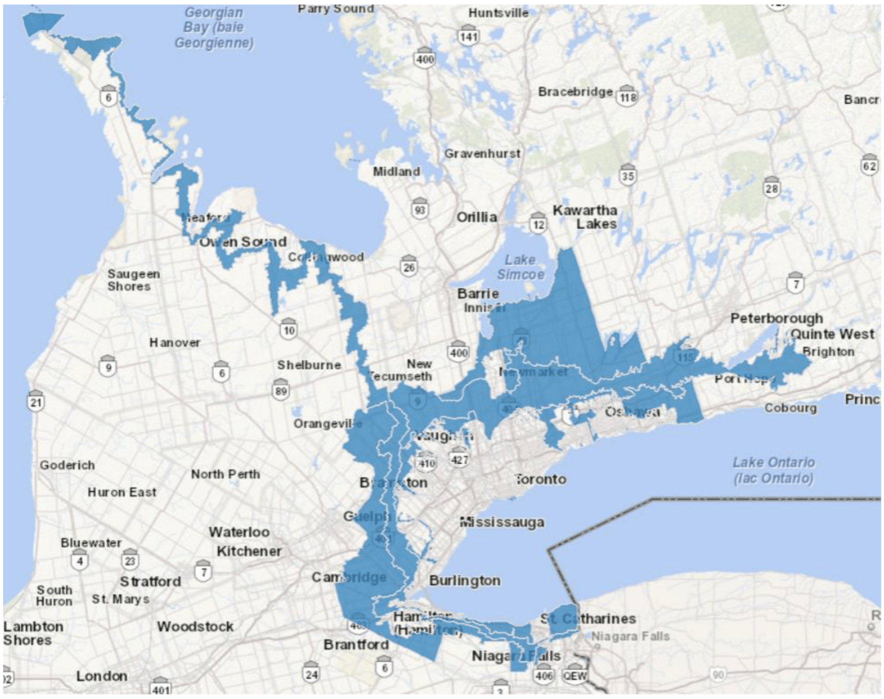

Figure 1. Land classified as green belt in Ontario [2].

1.3. Land Use Policy in the Greenbelt

The Provincial Policy Statement (PPS) (2020) lays the policy foundation for regulating the use and development of land in Ontario [3]. All subsequent ecological protection plans are built upon the PPS, including the Growth Plan for the GGH (2020), and the Greenbelt Plan (2017), which together form a provincial level fortress that protects agricultural land from development that may threaten continued use of the land for farming [4][5]. Municipal governments are tasked with further refining these sets of policies by generating place-based land designations, including prime agricultural areas and specialty crop areas in an “Official Plan”. These plans must contain related criteria for permitted uses in these designated areas; the municipal level is thus the critical leverage point for agrivoltaic development.

1.4. Renewable Energy Policy

Being the first province in Canada to implement the feed-in tariff model through the Green Energy Act (2009), Ontario is the leader in solar energy in Canada [6]. Despite this leadership role within Canada, solar electricity still makes up less than 1% of electricity generation as shown in **Figure 2**. Part of this lack of PV capacity is that although province-wide criteria are imposed as minimum standards upon solar developments, these are followed by municipal-level standards that are often more stringent and place-based.

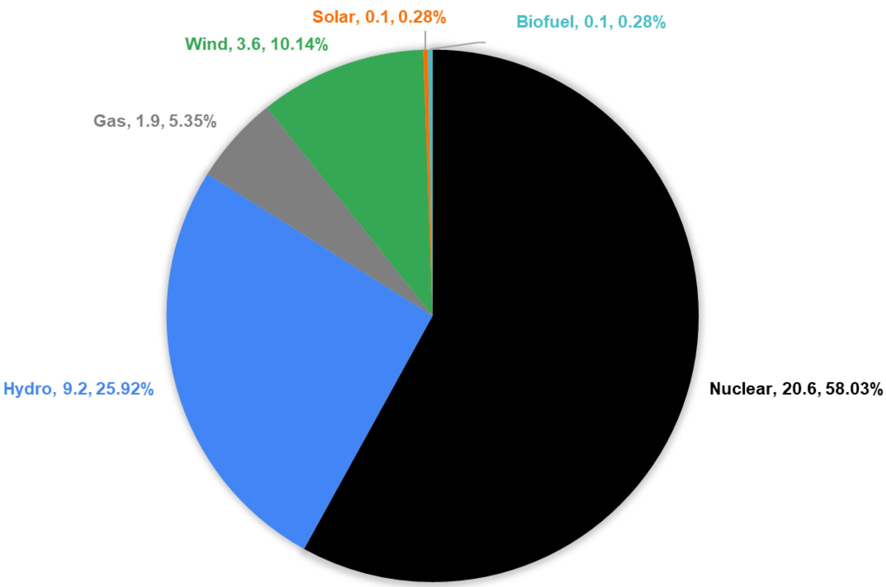

Figure 2. Electricity mix in Ontario [7].

1.5. The Intersection of Agriculture and Solar Energy in Ontario

Ontario's three-tiered land-use policies define what types of uses are allowed on prime agricultural lands, specialty crop areas, and rural areas. A full range of uses are permitted—particularly uses that increase income, diversify the tax base, and create employment opportunity—if specific criteria are met. Uses on these designated lands are organized under three categories: (1) agricultural, (2) agricultural-related, and (3) on-farm diversified [8].

Any proposed infrastructure that intersects these designated lands is subject to an agricultural impact assessment [5]. Renewable energy facilities are subject to the Green Energy Act (2009), rather than the Planning Act (1990), and therefore obtain approval under the REA rather than the PPS [9], while adhering to municipal land-use criteria. For solar photovoltaics, these rules are particularly restrictive currently, as the Provincial Policy Statement of 2020 states, "Ground-mounted solar facilities are permitted in prime agricultural areas and specialty crop areas only as on-farm diversified uses." [3]. The intention of an "on-farm diversified use" is to diversify income for farmers through a secondary, compatible, *limited* use of the land. To qualify as on-farm diversified use in designated agricultural land, all uses (including a ground-mounted solar PV) must meet the following condensed list of key criteria [8]:

- Is related to, and can coexist with, agricultural operation
- Must not impair, inconvenience, or undermine surrounding agricultural operation
- Be located on a farm actively in production and be *limited in an area based on a lot coverage ratio basis (emphasis added)*
- Meet all applicable provincial air emission, noise, water, and wastewater standards and receive all relevant environmental approvals

This is heavily restrictive to PV farms without considering agrivoltaics.

2. Policy Recommendations

2.1. Support-Applied Agrivoltaic Research in Ontario

First, the results of this analysis make it clear that agrivoltaic research in Ontario should be supported. This research should first concentrate on Ontario's major markets for agriculture. This not only includes the crops that have more than 10,000 acres devoted to them in Ontario (e.g., sweet corn with 21,834 acres used as a case study here, green peas with 15,507 acres, tomatoes with 15,223 acres, and green/wax beans with 10,208 acres), but also the dozens of other vegetables and specialty crops [10]. In addition, agrivoltaic research should be performed to consider including the more than 2.1 million acres of grain corn and over 3 million acres of soybeans as well as other grains and dried beans [11].

Agrivoltaics is under intense research in other parts of the world, but to date only a handful of crops have been investigated, including aloe vera [12], aquaponics (aquavoltaics) [13], basil and spinach [14], celeriac [15], chiltepin peppers, jalapenos, cherry tomatoes [16], sweet corn/maize [17][18], grapes [19], kale, chard, broccoli, peppers, tomatoes and spinach [20], lettuce [21][22], pasture grass [23], potato, celeriac, clover grass, winter wheat [24], and wheat [25][26]. In general, these studies showed either marginal impacts on crop production or an increase for low density shading from agrivoltaics. Increases were seen primarily with shade tolerant crops and leafy vegetables, such as lettuce, that prefer partial shading from PV to prevent bolting and increasing growth time. Decreases, however, were observed for heavy shading from close-packed non-transparent PV.

To guide agrivoltaic design, Riaz et al. introduced the light productivity factor, which can be used to start evaluating the effectiveness of irradiance sharing for specific crop types based on its effective photosynthetically active radiation (PAR) and PV array design [27]. Agrivoltaic research and optimization is far from complete. Most studies to date have focused on a single crop (or a few) and tested one basic geometry of the PV systems in one location. There is far more research needed as there are dozens of crops commercialized in Ontario and over 20,000 species of edible plants [28].

The potential permutations need to be optimized for Ontario and its crops, which represent an enormous amount of experimentation. New agrivoltaic systems need to be tested and optimized for compatibility with target crops and their associated operations (e.g., soil management, fertilization, sowing, irrigation, and harvesting, as well as dust generation during these agricultural operations). For example, greenhouse solar panels [29] could be optimized for specific crops by altering the transparency by the spacing of cells in a module. Doing this one commercial greenhouse [30][31] at a time, per crop, would be both expensive and time consuming for even one given module. This, however, becomes completely prohibitive once module experimentation is also considered. For example, 'red greenhouse modules' themselves needed to be optimized (e.g., testing the density, size, and chemical makeup of nanoparticles responsible for the spectral shifting via fluorescence [32][33][34]). They also need to be tested both for field use as well as greenhouse use. Innovation is already happening regarding this in Ontario [35]. Enabling agrivoltaics could drive additional local innovation development and job growth. Agrivoltaics would thus benefit from coordination and partnering between funders focused on energy (e.g., The Office of Energy Research and Development (OERD)) and agriculture (e.g., The Agricultural Research Institute of Ontario and the Ministry of Agriculture, Food, and Rural Affairs in Ontario).

2.2. Increase Public Awareness of Agrivoltaics in Ontario

To overcome these challenges related to the vast quantity of research needed in agrivoltaics, a parametric open-source cold-frame agrivoltaic system (POSCAS) was proposed to make low-cost agrivoltaic testing systems work in one single-module mini greenhouse at a time [36]. These devices could be used at a research station to test many variables at once. More importantly, these devices could also be used to foster public awareness of agrivoltaics using the approach of citizen science [37][38]. By enabling citizens to investigate the large number of permutations of PV designs and crops, two problems will be solved simultaneously. Such an enterprise could first, for example, target the help of master gardeners to quickly screen local produce for benefits for agrivoltaics by providing them with a free POSCAS and open-source, collaborative, well-structured, online research reporting. This would minimize R&D costs while also educating the wider population about the benefits of agrivoltaics.

Most North Americans are simply unaware of agrivoltaics, but when exposed to the idea they are in support of it [39]. Citizen science, similar to that described above, may help in part with public awareness, but broad, openly-accessible demonstrations are needed to verify the viability of the agrivoltaic approach in Ontario and to inform policymakers as well as build public trust. After preliminary experimental Ontario-based agrivoltaic studies indicate promise, open pilot studies should be conducted to allow farmers and citizens free access to the results. Opening rural lands to agrivoltaic R&D and demonstration can also prevent other types of proposed development on prime agricultural lands, while ramping up education on agrivoltaics in the province.

2.3. Streamlined Agrivoltaic System Deployment and Regulation

Given the modest agrivoltaic presence in Canada currently, in addition to more R&D and public education, there exists a need for an explicit definition and classification of agrivoltaic systems for regulation purposes. Agrivoltaics transcend traditional photovoltaic development by allowing continued use of the farmland beneath the array and is therefore uniquely positioned to enable the prosperity of agricultural producers and the diversification of their income, while stimulating rural economic growth through the generation of low-carbon electricity from sunlight. A proper definition is needed to acknowledge that agrivoltaics will not disrupt the geographic continuity of the agricultural land base. To prevent abuse of agrivoltaic-friendly regulations, it may be useful to divide agrivoltaics up into tiers, as is shown in **Table 1**. Tier 1 agrivoltaic solutions would be preferred and incentivized over Tier 2, etc. Such a tiered system would, for example, prevent a solar developer from simply seeding a conventional PV farm with wildflowers to acquire access to prime agricultural land.

Ontario can look to other jurisdictions, such as Japan, the U.S. and Europe, for examples of effective agrivoltaic policy. In Japan, agrivoltaic development exploded after the introduction of feed-in tariff (FIT) in 2012 [40]. Tajima and Iida found that the FIT was significantly more effective than a renewable portfolio standard (RPS) system previously used in Japan and that agrivoltaics is expected to play a major role in revitalizing Japanese agriculture, including reclamation of abandoned farmland [40]. Canada thus has the opportunity to reintroduce a FIT targeted specifically on agrivoltaics, and Ontario already has experience in this domain with the Green Energy Act. Perhaps even more targeted, the Massachusetts Department of Energy Resources established the Solar Massachusetts Renewable Target (SMART) program that regulates and provides incentives for PV, and agrivoltaics in particular [41][42][43]. The economics of PV are profitable in Ontario, but could be strengthened, and a program could help overcome other barriers, including access to low-interest capital and streamlining the process with utilities and other sources of bureaucracy. In Europe, a standard has been developed as a test method for agrivoltaic systems that provides a uniform way to report agrivoltaic measurement figures for legislative and funding bodies and the approval authorities, as well as for the post-testing and certification of agrivoltaic systems by experts and certification organizations [44]. Canada, in general, and Ontario specifically, could build upon and improve upon these standards to ensure they remain open access and thus freely available to all Ontario's farmers.

Table 1. Potential tiers of agrivoltaic systems to favour systems with greater land-use efficiency and greater potential for GHG emissions reductions.

Tier/Allowed Land Use	Agrivoltaic Type	Comments
1. Prime agriculture	**Crop**	**See Section 5.1 for crops investigated to date**
2. Pasture	**Grazing**	**Sheep [45][46], and rabbits [47]**
3. Marginal	**Apiculture (beekeeping)**	**Honey production [48]**
4. Non-restricted	**Insect Habitat**	**Pollinators, e.g., butterflies, that provide secondary services**

Thus, a legal recognition of agrivoltaics as an agriculture-related use, or an on-farm diversified use, by the province of Ontario and the relevant municipal permitting systems could help overcome the current barriers to PV development embedded in the regulatory process. Authorizing agrivoltaics on prime agricultural land through either of these land-use classifications will generate a distinct development opportunity for Ontario. Thus, agrivoltaic growth will be directed to uphold the economic, social, and environmental aims of the province's land-use policies without compromising the quality of agricultural land for future generations.

Finally, to increase agrivoltaic deployment velocity in Ontario, provincial and municipal policies should be aligned. Policy related to energy development and agricultural land-use in Ontario at both the provincial and municipal levels are robust, yet the regimes are stratified and siloed, which also complicates the realization of agrivoltaic systems. To minimize incompatibility between renewable energy and farmland preservation goals, provisions are needed that clearly address the overlap between the siting of energy systems on farmland which maintain the existing land use (i.e., agrivoltaics). The current policy language does not account for solar PV systems that retain the agricultural function of the land; this omission, while likely unintended (as agrivoltaics is a relatively new field), stops the potential for dual-use system development. Finally, provincial energy policy could incentivize agrivoltaics, followed by special municipal-level criteria for the siting and design of systems. Aligning energy policy regimes with place-based land use regulations would create a supportive policy landscape for the development of agrivoltaics in Ontario.

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