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Investigating Farmers' Attitudes towards Co-Existence of Agriculture and Renewable Energy Production †

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Abstract: Agri-voltaics (AVs) refer to combining agricultural activities and photovoltaic power generation. This dual use of the land has been identified as an important measure to address some of the main current and future social and environmental challenges. AVs constitute an upward trend at a global level. However, a limited number of studies have been carried out to identify the views of the interested parties, farmers, regarding the adoption of AVs on their agricultural lands. This paper reports research findings of the investigation of farmers' views and attitudes towards the adoption of photovoltaics in agricultural lands. The non-parametric Mann–Whitney U Test was used in order to make comparisons between the group of participants that were willing to adopt AVs and those who were not. Chi-square (χ^2) test of independence was performed to identify statistically significant relationships between farmers' willingness to adopt AVs and their socioeconomic characteristics or variables that represent knowledge about agro-energy. The results reveal that educational level and age had a significant role on accepting the installation of PV agriculture. Farmers' knowledge concerning agro-energy and their participation in farmers' associations are positively related to their willingness to adopt AV as well.

Keywords: renewable energy; agri-voltaics; farmers; attitudes; adoption

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1. Introduction

Agri-voltaics (AVs) are a new approach that ensure the production of renewable energy, alongside the possibility of growing agricultural products on the same land. AV systems combining solar photovoltaic panels and food crops can optimize land use and increase overall productivity [1]. This new approach has been identified as a promising way to deal with some of the main current and future social and environmental challenges, such as climate change [2].

The majority of studies on the adoption of PV systems have focused on the adoption of solar PV systems among householders. To our knowledge, to date, a restricted number of studies have examined the key factors that influence the diffusion of PV power generation among farmers. Frantal and Prousek [3] explored why and how Czech farmers become renewable energy producers and concluded that the main reason for this is their intention for economic diversification and stabilization of their farms. Li et al. [4] investigated the variables affecting the adoption willingness of farmers regarding photovoltaic agriculture in China. According to their findings, usefulness perception and technical training positively influenced the adoption willingness of the farmers, whereas PV investment cost had a negative impact.

The present study is an attempt to investigate farmers' attitudes towards the co-existence of agriculture and renewable energy production and to examine the factors influencing farmers' adoption of AVs.

2. Methods

The questionnaire survey took place between November 2022 and February 2023 in Western Macedonia, Greece. This specific region was selected for the survey because of the high percentage of photovoltaic installations. Convenience sampling was conducted and, at the end of the collection process, 287 questionnaires had been gathered. Chi-square tests for independence were conducted between the variable that represents the question "are you willing to adopt AVs in your agricultural land?" and variables that represent the characteristics of the farmers in order to see if any of those influenced respondents' intention. Significant associations in Chi-square tests were examined by standardized residuals (stand. res.). The larger the residual, the greater the contribution of the cell to the extent of the resulting chi-square obtained value [5,6]. When the absolute value of the standardized residuals was greater than |1.96| in a cell, it was assumed that it contributed significantly to the test statistic [5,6].

For comparison of the two independent samples, that were not normal distributed (tested using Kolmogorov–Smirnov), a Mann–Whitney U-test was employed [7]. All statistical analyses were performed using SPSS 27 statistical analysis software. The level of significance was set at a = 0.05.

3. Results

Only seven farmers did adopt PV agriculture, accounting for 2.4%, which is far less than the proportion of people who did not adopt PV agriculture (97.6%). However, most respondents were knowledgeable of AVs, accounting for 79.8%. Out of a total of 287 respondents who participated in the survey, 133 (46.3%) farmers declared willingness to adopt AVs, whereas 154 (53.7%) were unwilling to adopt AVs. Table 1 reveals no significant gender difference in farmers' willingness to adopt AVs (χ^2 = 0.182, df = 1, p = 0.721). On the contrary, the adoption of AVs was significantly influenced by the educational level of the respondents (χ^2 = 68.633, df = 4, $p < 0.001$). When the educational level of respondents was higher, significantly more respondents than expected adopted AVs (stand. res. = +3.7 and +1.9), and significantly less respondents than expected did not adopt AVs (stand. res. = −3.4). Farmers' educational attainment is an explanatory variable that was found to have a positive influence on the adoption of eco-friendly approaches in agricultural lands [8,9]. Moreover, significantly more singles than expected were willing to adopt AVs (stand. res. = +1.8) (χ^2 = 13.367, df = 3, p = 0.004). Farmers' knowledge concerning agro-energy had a positive influence on their acceptance of AV adoption (χ^2 = 32.631, df = 1, $p < 0.001$). So, significantly more knowledgeable respondents on agro-energy were willing to adopt AV than expected (stand. res. = +1.9). Membership in agricultural associations was found as a strong driver in AV adoption (χ^2 = 18.160, df = 1, $p < 0.001$) as well. When they were members of agricultural associations, significantly more respondents than expected were positive to adopt AV installation in their farms (stand. res. = +2.6). On the contrary, significantly less respondents than expected were negative to adopt AV (stand. res. = −2.4).

An additional demographic characteristic that can influence farmers' decision to adopt AVs on their agricultural land may be related to their age. A significant difference in the mean age of the respondents exists between those who adopt and those who do not adopt AVs (Mann–Whitney test = 15,902, $p < 0.001$). Particularly, the mean age of those who were willing to adopt AV (40.5 ± 10.1 years) is significantly lower than those who did not adopt (49.4 ± 12.3 years). The present finding agrees with previous outcomes, suggesting that younger ages are more willing to undertake the risk of participation in innovative agricultural practices [10,11].

Table 1. Demographic variables (%) for the adoption of agro-voltaics in the region of Western Macedonia *.

Variable	Adoption/Non-Adoption of AV		Statistic (χ^2)	d.f.	*p*-Value
	% Yes	% No			
Gender			0.182	1	0.721
Males	46.8	53.2			
Females	40.0	60.0			
Education			68.633	4	**<0.001**
Primary school	0.0 (−2.7)	100.0 (2.5)			
Middle school	11.9 (−3.3)	88.1 (3.0)			
High school	38.5	61.5			
University degree	70.3 (3.7)	29.7 (−3.4)			
Post-graduate	88.9 (1.9)	11.1			
Marital status			13.367	3	**0.004**
Single	61.5 (1.8)	38.5			
Married	42.2	57.8			
Divorced–Widowed	0.0	100.0			
N/A	60.0	40.0			
Knowledge about agro-energy			32.631	1	**<0.001** *
Yes	55.0 (1.9)	45.0			
No	12.1 (−3.8)	87.9 (3.6)			
Participation in farmers' associations			18.160	1	**<0.001** *
Yes	63.5 (2.6)	36.5 (−2.4)			
No	36.6 (−1.9)	63.4			

* Numbers within parentheses are standardized residuals. The larger the residual (>|1.96|), the greater the contribution of the cell to the magnitude of the resulting chi-square obtained value.

The main reason for adopting AVs, as reported by farmers, is income growth and stabilization (41%). The coverage of energy needs has been rated as the second most important factor by those who declared themselves as willing to adopt AVs (29%). Turning to another business activity has been reported as a motivation for the adoption of AVs (12%) as well, followed by farmers' environmental protection motivation (6%) and some other reasons that gathered very low percentages.

4. Discussion and Conclusions

AV agriculture is a promising choice for achieving green energy and crop production [12]. Based on empirical analysis, it was found that among the 287 surveyed farmers, their willingness to adopt AVs was relatively high; 46.3% of farmers were willing to adopt AVs, indicating, however, that most Greek farmers maintain the traditional view about the dominant food-producing role of agriculture. The analysis revealed that both education level and age are significant determinants of their intention to adopt AVs. In addition, knowledge about agro-energy is positively correlated with adoption willingness of the farmers. Our results point, unsurprisingly, to the fact that economic aspects dominate their decision. So, an overall understanding of farmers' views and attitudes can contribute to the optimal coexistence of crops and solar panels, with better results for farmers and the environment.

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