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Environmental Amenities and Optimal Agricultural Land Use: The Case of Israel

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Abstract

This paper evaluates the effectiveness of changing land allocation among crops as a mechanism for increasing social welfare, where production profits and amenity benefits are augmented. A positive mathematical programming model is calibrated and applied to the northern part of Israel, using a crop-discriminating amenity-benefits function. Changes in land allocation increase social welfare by 2.4% nationwide, and by up to 15% on the regional level. Regional scale farming-profit losses amount to up to 6%. Due to the decreasing-return-to-scale nature of the amenity-benefits function, the inter-regional variability appears sensitive to the manner in which the country is divided into regions.

JEL classification: Q10, Q24, Q50

Keywords: agricultural land use, environmental amenities, optimizing social welfare

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1. Introduction

The multi-functionality of farmland as a supplier of both agricultural products and other amenities, such as environmental habitats and aesthetic landscapes, is well recognized, particularly in developed countries. While agricultural products can often be transported from distances, the open-space landscape provided by agricultural areas is a non-mobile regional resource, and therefore, local communities are expected to be willing to pay for its preservation. This rationale is the driving force behind agricultural support policies established to reward farmers for the external benefits they create (EC, 2003; OECD, 2000, 2003; Peterson, et al., 2002), and thereby slow urbanization processes. The positive effects of agricultural amenities have been evaluated by various economic studies; examples include Halstead (1984), Bergstrom et al. (1985), Beasley et al. (1986), Bowker and Didychuk (1994), Hackl and Pruckner (1997), Ready et al. (1997), Ready and Abdalla (2005) and Fleischer and Tsur (2003). The implications of agricultural amenities in terms of land allocation between urban and rural uses have been studied by McConnell (1989), Lopez et al. (1994) and Brunstad et al. (1999).

The levels of amenity services, however, are not uniform across agricultural land uses. Therefore, policies designed to encourage agricultural preservation as a whole, but without discriminating among various internal agricultural land uses, may result in suboptimal agricultural land allocation from society's point of view. Evidences for such differences in the amenity benefits associated with diverse agricultural activities are provided by Drake (1992) and Brunstad et al. (1999); the latter distinguish between tilled land, woodland and pasture. In a more recent study, Fleischer and Tsur (2008) developed a unified framework for the analysis of rural-urban land allocation, while taking into account the heterogeneous amenity values of farmland across crops. They estimated demand functions for housing and agricultural-production land uses, as well as the willingness to pay for agricultural amenities. However, their farmers' land-demand function was derived subject to the assumption of a constant-return-to-scale, under which the planting area allocated to each crop is determined exogenously. This implies that the land devoted to each crop is considered constant, unless it is turned into an urban area. In other words, the farmers' option to vary land allocations among crops in order to substitute some of the supply of agricultural products with additional amenity services is ignored.

The objective of the present study is to present an empirical evaluation of the potential for increasing social welfare through changes in intra-agricultural land allocation among crops, taking into account the variability among crops with respect to both profitability and the level of amenity contribution. To this end, we develop a positive-mathematical-programming (PMP) model (Howitt, 2005) which, contrary to the constant-return-to-scale modeling approach, enables smooth variations in the land allocation among crops.

The analysis is applied to the state of Israel, where a strict farmland-protection policy prevents the emergence of a rural-urban land market equilibrium (Alterman, 1997; Feitelson, 1999), and real-estate development of rural areas is subject to official authorization. For that reason, Israel constitutes a convenient case study in the sense that changes in intra-agricultural land allocations can be analyzed separately from the rural-urban land allocation, which is assumed constant.

The evaluation focuses on the heavily populated northern half of Israel—the part above and to the left of the bold line depicted in Figure 1. The spatial units of the analysis are the 43 regions within this analyzed area, termed 'natural zones’. There are two practical considerations that underlie the selection of this particular type of partitioning into regions. First, the Israeli Central Bureau of Statistics (ICBS) routinely publishes aggregated regional data based on natural zones. Second, in our evaluation we utilize the amenity-benefits function that was estimated by Fleischer and Tsur (2008), also based on these 43 natural zones.

Figure 1 about here

In section 2, we describe the development of the PMP model and the integration of farmers' profits and amenity benefits into a comprehensive *social* welfare function. Section 3 presents the results of the evaluation and analyzes its sensitivity with respect to various impacts. Section 4 concludes the paper.

2. The Model

We employ a two-stage PMP approach, based on Howitt (2005). In the first stage, the model is calibrated separately for each natural zone, such that it reproduces the land allocation observed there, which is considered optimal under profit maximization (PM) farming behavior. In the second stage, the objective function is reformulated such that it encompasses both the farmers' profits and the amenity benefits for the region's local residents, i.e., it represents regional social welfare. The model then searches for the socially optimal (SO) agricultural land allocation and calculates the welfare increase relative to the PM solution.

2.1. Calibration

Our data include land allocation among 45 crops in each of the 43 natural zones under consideration. Let l_{ik} (in hectares) be the land allocated to crop *i*, $i = 1,...,45$, in region *k*, $k = 1,...,43$. Accordingly, $L_k \equiv (l_{1,k},...,l_{45,k})$ is a vector denoting the land-allocation in region *k*, and $l_k = \sum_{i=1}^{45} l_{ik}$ is the total agricultural land. Under the current situation in Israel, farmers are not rewarded for the amenities they provide. Hence, in the calibration stage of the PMP method, it is assumed that in each region *k*, the observed land allocation is an outcome of PM behavior. This land allocation also represents the intra-agricultural market-equilibrium solution, which is denoted $L_k^m = (l_{1,k}^m,...,l_{45,k}^m)$. Thus, L_k^m constitutes a solution to the problem:

$$\max_{l_{1,k},...,l_{45,k}} \Pi_k = \sum_{i=1}^{45} l_{ik}\left[p_i y_{ik} - \left(\gamma_{ik} + \tfrac{1}{2}\delta_{ik} l_{ik}\right)\right] \quad s.t. \quad l_k \le \bar{l}_k, \qquad (1)$$

where Π_k (in \$/year) is the annual profit associated with the vegetative agricultural activities in region *k*, $\bar{l}_k$ (in hectares) is the total agricultural land constraint of the region, p_i (in \$/ton) is crop-*i*'s nationwide output price, and y_{ik} (in ton/hectare-year) denotes the regional per-hectare annual yield. The term $\gamma_{ik} + \frac{1}{2}\delta_{ik} l_{ik}$ (in \$/hectare-year) represents the per-hectare production cost, which is expressed as a linear function of the crop's parcel, l_{ik}. This dependency is used to indirectly reflect the impact of various unobserved factors considered by farmers while contemplating their land allocation among crops, including the spatial variability of the soil quality, marketing and agronomic risks, management and know-how limitations, etc. Consequently, the total production cost becomes a quadratic function of l_{ik}, and in this way, contrary to the constant-return-to-scale-based models, this PMP model enables the optimal land allocation to be smoothly altered in response to exogenous shocks.

The only unknown parameters in Equation (1) are γ_{ik} and δ_{ik}, which are calibrated by employing the two-step calibration procedure developed by Howitt (2005). To keep our work self-contained, we briefly describe this procedure.

The first calibration step is based on transforming the quadratic programming problem into a linear programming problem. This is done by replacing the per-hectare production cost function, $\gamma_{ik} + \frac{1}{2}\delta_{ik} l_{ik}$, with the parameter c_{ik} (in \$/hectare-year), which is the observed base-year production cost. The resultant linear objective function, $\pi_k = \sum_{i=1}^{45} l_{ik}\left[p_i y_{ik} - c_{ik}\right]$, should be maximized accordingly by setting the land allocation L_k, subject to the regional total land constraint, $l_k \le \bar{l}_k$, and an additional set of 45 auxiliary land-calibration constraints, $l_{ik} \le l_{ik}^m + \varepsilon$, where l_{ik}^m is the base-year observed (PM) land allocated to crop *i*, and ε is a perturbation element, whose role is to ensure the effectiveness of the total land constraint, $l_k \le \bar{l}_k$. This linear programming stage yields the dual values of the 46 constraints, which are used for calculating γ_{ik} and δ_{ik} in the second calibration step.

Let *i* = 1 denote the crop with the lowest observed average per-hectare profit. Thus, λ_k^1 (in \$/hectare-year)—the dual value of the regional total land constraint $l_k \le \bar{l}_k$—is given by $\lambda_k^1 = p_1\left(y_{1k} - \Delta y_{1k}\right) - c_{1k}$, where Δy_{1k} is crop-1's observed lower bound of yield variation around its average yield, y_{1k}. Then, λ_{ik}^2 (in \$/hectare-year), which stands for the dual value of the auxiliary land-calibration constraint with respect to crop *i*, $l_{ik} \le l_{ik}^m + \varepsilon$, $i = 1,...,45$, can be calculated according to

$\lambda_{ik}^2 = p_i y_{ik} - c_{ik} - \lambda_k^1$. Using the observed L_k^m land allocation, and substituting the equality $c_{ik} = \gamma_{ik} + \frac{1}{2}\delta_{ik} l_{ik}^m$, we get $\delta_{ik} = 2\lambda_{ik}^2 / l_{ik}^m$ and $\gamma_{ik} = c_{ik} - \lambda_{ik}^2$ for every crop *i*, $i = 1,...,45$.

Information on prices, yields and production costs were obtained from various reports published by the Israeli Ministry of Agriculture and Rural Development (2002) for the 45 crops under consideration. Production costs vary among regions due to differences in precipitation and surface-water constraints, as calculated by Rapaport-Rom (2006). All monetary terms in this study are in 2002 dollars.

2.2. Social Welfare and Amenity Benefits

The regional social welfare, W_k, is formulated as an additively separable function:

$$W_k = \Pi_k + A_k, \tag{2}$$

where A_k (in \$/year), denotes the benefits enjoyed by the region's *local* population due to the amenities associated with the region's vegetative agricultural land uses. This amenity value is given by

$$A_k = N_k a(L_k, X_k), \tag{3}$$

where N_k is the number of households residing in the region, $a(L_k, X_k)$ (in \$/household-year), is the annual amenity value for the region's representative household, and X_k is a vector of characteristics of the local population. The public-good nature of the amenities is reflected by the multiplication of the per-household amenity value by the number of households residing in the region.

As noted above, we adopt the household amenity benefit function estimated by Fleischer and Tsur (2008) for residents in the northern part of Israel. In that study the authors found that individuals distinguish among the benefits reaped from three groups of vegetative agricultural land uses: (1) orchards and citrus, (2) vegetables, field crops and non-agricultural natural open spaces, and (3) greenhouses. We index each group, respectively, by n, $n=1,2,3$, and denote by l_{ikn} the land devoted to a crop assigned to group n. The total regional land devoted to group n's crops is given by $l_{kn}=\sum_{i=1}^{I^n} l_{ikn}$, where I^n denotes the number of crops in that group. Using the double-bounded, dichotomous choice elicitation technique of the contingent valuation method, Fleischer and Tsur (2008) estimated a household quadratic amenity benefits function:

$$a(L_k, X_k)=\sum_{n=1}^{3}\left(f_n(X_k)l_{kn}+\tfrac{1}{2}\theta_n(l_{kn})^2\right)+\eta_{12}l_{k1}l_{k2}+\eta_{13}l_{k1}l_{k3}+\eta_{23}l_{k2}l_{k3}. \qquad (4)$$

In this specification, $X_k=(x_{1k}, x_{2k})$, where x_{1k}, x_{2k} are, respectively, the average income (in \$/household-month), and the average age of the region's heads of households, and where $f_n(X_k)=\phi_{1n}+\phi_{2n}x_{1k}+\phi_{3n}x_{2k}$. The parameter θ_n, $n=1,2,3$, represents the own-quadratic effect, and is found to be negative for all n. The cross-effect parameters, η_{12}, η_{13} and η_{23}, can be of either sign, where a negative (positive) parameter represents substitution (complementary) relationships between the corresponding crop groups. Table 1 presents the estimated parameters of the amenity-benefits function and the allocation of the 45 crops among the three amenity-influential groups. Base-year agricultural land allocations, as well as the average head-of-household age and income, were obtained from the ICBS (2002). The non-agricultural natural open-space areas, which are assumed constant in the analysis, were taken from Frenkel (2001).

Table 1 about here

Inspecting the per-household amenity function, it appears that, due to the negativity of some of the estimated own- and cross-effect parameters, the marginal amenity benefits (MABs) with respect to l_{kn}, $\frac{\partial a(L_k, X_k)}{\partial l_{kn}}$, $n = 1,2,3$, diminish with l_{kn}. In other words, the amenity-benefits function exhibits a decreasing return to scale. While Lopez et al. (1994) also found the same feature, the quadratic function adopted here is more involved, because under some circumstances, the MABs become negative. The implication of negative MABs is that increasing the total regional agricultural area reduces the amenity services. Thus, if regions become large enough, the amenity value itself may become negative, implying that agricultural landscapes constitute a public bad rather than a public good. This phenomenon highlights the potential misinterpretation of this specific amenity-benefits function when it is applied to regions different from or considerably larger than those that formed the basis for estimating it in the first place, i.e., the afore-mentioned 43 natural zones. Furthermore, we should recall that the function was based on stated values of willingness to pay for the preservation of agricultural areas under threat of urbanization, and *not* when the alternative land use was, say, the replacement of low-amenity crops with high-amenity ones. Hence, attaching negative amenity values to low-amenity crops (e.g., to greenhouse crops) also leads to misinterpretation of the benefit function, because these crops may have been construed by respondents as an efficient defense against further urban sprawl. For these reasons, we argue that negative MAB values should be excluded from the analysis.

To this end, we apply the following procedure. Let l_{kn}^0 denote the land area devoted to the group of crops *n*, $n = 1,2,3$, under which, given L_k, there is $\frac{\partial a(L_k, X_k)}{\partial l_{kn}} = 0$. Also define l_{kn}^e as the land area of group *n*, which is considered effective with respect to the amenity benefits, where

$$l_{kn}^e = \begin{cases} l_{kn} & if \ \ l_{kn} < l_{kn}^0 \\ l_{kn}^0 & else \end{cases}, \ n = 1,2,3 . \quad (5)$$

That is, if the land devoted to group *n*, l_{kn}, exceeds l_{kn}^0, then, l_{kn}^0 is substituted into the amenity-benefits function instead of l_{kn}. The vector of amenity-effective lands, $L_k^e \equiv \left(l_{k1}^e, l_{k2}^e, l_{k3}^e\right)$, is used to calculate the amenity benefits expressed by Equation (4). The vector $L_k^0 \equiv \left(l_{k1}^0, l_{k2}^0, l_{k3}^0\right)$ represents the set of amenity-effective land boundaries such that $L_k^e \leq L_k^0$. However, consistency requires that each amenity-effective land boundary, l_{kn}^0, $n = 1,2,3$, be calculated by the use of L_k^e, i.e., such that $\frac{\partial a\left(L_k^e, X_k\right)}{\partial l_{kn}} = 0$. An iterative calculation procedure is implemented to overcome the problem of circular referencing.

The programming model is built on an Excel worksheet and run by the Premium Solver Platform V6.5 instrument. To overcome the non-convexity that results from the structure of the amenity-benefits function, the program seeks the global optimum by employing a multi-start search procedure. It employs a quasi-Newtonian method based on quadratic extrapolations, where central differencing is used to estimate partial derivatives (the model and the entire dataset are available from the authors upon request).

3. Application

3.1. Socially Optimal (SO) Solution

The SO solution is computed by searching for the regional agricultural land allocation among the 45 crops under consideration, L_k, that maximizes Equation (3) subject to the regional land constraint, $l_k \leq \bar{l}_k$. We denote the SO land allocation as

L_k^s. It is assumed that farmers are willing to shift from the PM land allocation, L_k^m, to L_k^s, as long as they are fully compensated for the associated profit loss. A feasible policy for stimulating such a change may take the form of compensation payments funded by the local authorities in each region. Our analysis, however, is indifferent to the potential impact of diverse mechanisms of amenity-enhancing land policies (e.g., the willingness to pay for agricultural land preservation, as indicated by Johnston and Duke (2007)) and focuses on an empirical evaluation of the farming profit loss and the increase in social welfare associated with the move from the PM to the SO land allocation.

Table 2 presents the welfare elements and land allocations under the PM and SO solutions in terms of nationwide values. The regional-scale changes in welfare elements are presented in Figure 2. Under the PM solution, farmers' profits amount to $456.5 million per year nationwide, where the associated value of the amenity benefits is $212.4 million per year. Thus, one third of the social welfare generated by the vegetative agricultural lands and natural open spaces throughout the northern part of Israel is attributed to environmental amenity services.

Table 2 about here

Figure 2 about here

The agricultural sector's annual profit loss (nationally) incurred by moving from the PM to the SO solution amounts to $2.5 million, where the annual increase associated with the amenity benefits is $18.6 million. In other words, on average, a 0.5% reduction in farming profits can increase the value of amenities by 8.5%. Put another way, for every dollar paid as compensation for farming profit losses, society would reap about $7.50 worth of benefits in the form of environmentally-enhancing agricultural amenities. Although this cost/benefit ratio may seem relatively large, the overall welfare change amounts to only $16.2 million per year, which is an increase of merely 2.4% relative to the PM solution. This "return" may be viewed as too small to justify launching a nationwide agricultural landscape amenity enhancing policy, particularly in view of the associated (unknown) implementation costs.

However, viewing the issue at the regional level reveals wide variability among regions, with welfare increases varying between 15% and no increase at all. Indeed, five regions alone in which benefits exceed $1 million a year (Figure 2) account for almost 60% of the nationwide welfare increase. Moreover, in some regions the welfare-increase/profit-loss ratio exceeds 20. This finding may provide support for a policy that would instead grant *local* communities the authority to decide on the implementation of policies regarding the provision of agricultural amenities. What, then, would be the characteristics that would warrant a shift to such a policy?

3.2. Factors Affecting the Increase in Social Welfare

Let Ω_k denote the increase in social welfare associated with the shift from the PM land allocation, L_k^m, to the SO one, L_k^s, where

$$\Omega_k = W_k\left(L_k^s\right) - W_k\left(L_k^m\right). \tag{6}$$

The larger Ω_k, the more justifiable the implementation of amenity-enhancing policies. Factors such as crops' profitability, regional population size, income and age of the representative households all affect the magnitude of Ω_k, and their impact can be examined by analyzing the functional forms and estimated parameters of Equations (1) through (4). Inspection reveals that as long as $\Omega_k > 0$, the value of Ω_k increases with the population size and decreases as the population grows older and agricultural revenues become higher, regardless of the agricultural land allocation among crops.

On the other hand, land allocation determines the income effect: the wealthier the population, the higher the amenity associated with orchards and citrus, and field crops, vegetables and natural open spaces, and the lower the landscape value attached to greenhouse crops (see Table 1). However, a necessary condition for Ω_k to be positive is that $L_k^m \neq L_k^s$. Only under this inequality do the impacts of the other factors come into play. Notably, if $L_k^m = L_k^s$, then the PM land allocation must also constitute the maximizer of the amenity-benefits function, A_k. Formally, let $L_k^a \equiv \left(l_{k1}^a, l_{k2}^a, l_{k3}^a\right)$, denote the land allocation that maximizes A_k; the equality $L_k^m = L_k^s$ then entails $L_k^m = L_k^a$. In other words, the larger the inequality $L_k^m \neq L_k^a$, the larger Ω_k. Therefore, a comparison between L_k^m and L_k^a may provide an indication of the potential increase in social welfare in any *given* region.

Note, however, that when the amenity-value function is restricted to exhibiting non-negative MABs, as in our case, the set L_k^a is non-unique. Moreover, since the constraint of non-negative MABs is associated with the decreasing-return-to-scale nature of the amenity-benefits function, a region's total agricultural area may affect the potential welfare increase there. These features are analyzed below.

Figure 3 about here

Consider the MAB curves presented in Figure 3. These curves were calculated for an average region nationwide with respect to household income and age, and therefore we omit the region index *k*. The curves were calculated as follows. First, the maximum-amenity land allocation, L^a, was computed several times, subject to increasing levels of regional land constraints, $\bar{l}$. Then, the shadow price of the land constraint, which is equal to the MAB of each group of crops *n*, was calculated for each level of $\bar{l}$, and plotted against the group's associated maximum-amenity land,

l_n^a. The resultant curves can be viewed as the crop-groups' amenity-demand curves under the maximal amenity levels, and are denoted $d_n\left(l_n^a\right)$, $n = 1,2,3$. Note the relatively low elasticity of the amenity demands for the groups 'orchards and citrus' and 'greenhouses', in comparison to the elastic demand for the group 'vegetables, field crops and natural open spaces'. Horizontal summation of the three maximum-amenity demand curves yields the amenity-demand curve of the entire region, $d\left(\bar{l}\right)$. Since $d\left(\bar{l}\right)$ is down-sloped, the amenity-benefits function exhibits a decreasing return-to-scale, and at a regional agricultural + natural open-space land size of 22,500 hectares, the (national representative regional) maximum-amenity MABs of all groups are zeroed. We denote this regional size by l^{a0}. The corresponding land allocation is $L^{a0} = \left(l_1^{a0}, l_2^{a0}, l_3^{a0}\right)$, where in our case study, we get $L^{a0} = \left(1{,}754\,, 20{,}070\,, 676\right)$ (Figure 3).

Figure 4 about here

Similar to the amenity-effective land allocation, L^e, let us denote by L^{ae}, $L^{ae} = \left(l_1^{ae}, l_2^{ae}, l_3^{ae}\right)$, the maximum-amenity-effective land allocation. The solid bold curves in Figure 4 show how the maximum-amenity-effective land allocation L^{ae} changes with regional agricultural size, $\bar{l}$. As long as a region's agricultural area is smaller than 22,500 hectares (i.e., $\bar{l} < l^{a0}$), $L^{ae} = L^a$, and a marginal change in $\bar{l}$ entails a change in L^{ae}. Note that in regions with a total land area of up to 2,400 hectares, $l_2^{ae} = 0$ (Figure 4b); i.e., the maximum amenity is achieved when no land is allotted to field crops + natural open spaces (Group 2). Figure 3 indicates that within that range of regional sizes, Group 2's associated MAB is lower than that of the other two groups. Yet, when the total regional land grows beyond 2,400 hectares, the maximum-amenity-effective allocation proceeds such that every additional hectare is devoted to Group 2. In regions with $\bar{l} \geq l^{a0}$, $L^{ae} = L^{a0}$; i.e., from 22,500 hectares up, the maximum-amenity-effective curves in Figure 4 become horizontal—L^{ae} no longer changes in response to further increases in regional size $\bar{l}$. Therefore, non-uniqueness of L_k^a is possible only in regions with $\bar{l} \geq l^{a0}$, as will be discussed later.

The maximum amenity-effective land allocation curves in Figure 4 constitute benchmarks to which the PM and SO solutions may be compared. In Figure 4, these land allocations are plotted for every region against the region's total agricultural area. The vertical solid lines connecting the PM (black dots) to the SO (white dots) allocations indicate the land-allocation changes between these two solutions.

For any region *k* and crop-group *n*, the larger the gap between the land allotted to the group under PM, l_{kn}^m, and the group's maximum-amenity-effective line, l_n^{ae}, the larger the potential increase in social welfare, Ω_k. The land devoted to the group under the SO solution, l_{kn}^s, constitutes the optimal tradeoff between the amenity-benefits increase and the farming-profits loss. Therefore, the SO land allocations are located closer to the maximum-amenity-effective curves than the PM land allocations. For instance, in the Western Sharon region (highlighted in Figure 4), the shift from the PM to the SO solution involves a large reduction in the area of orchards and citruses, coupled with relatively small increases in the lands allotted to the other two groups of crops. On the other hand, in the largest analyzed natural zone, Lakhish, the PM and SO land allocations coincide; i.e., $L_k^m = L_k^s$. Figure 2 shows no increase in social welfare in the Lakhish region. Such an occurrence can take place subject to the fulfillment of two conditions. First, the agricultural area in this natural zone, $\bar{l}$ (29,800 hectares), is larger than the l^{a0} size (22,500 hectares), so $L^{ae} = L^{a0}$. Second, $l_{kn}^m > l_n^{a0}$ for all $n = 1,2,3$—the land allocated to each group is larger than the maximum-amenity-effective size, which is, in the case of $\bar{l} \geq l^{a0}$, the one under which the MABs are zeroed, L^{a0}. Therefore, under the PM solution, the amenity-affective land allocation, L_k^e, is equal to L^{a0}, and the amenity value is maximized under the PM solution. Note that the second condition ($l_{kn}^m > l_n^{a0}$ for all $n = 1,2,3$), which leads to the non-uniqueness of the SO solution, can hold only when the first condition, $\bar{l} \geq l^{a0}$, is fulfilled. Moreover, the probability of accomplishing the second condition becomes higher as the difference $\bar{l} - l^{a0}$ grows. This finding emphasizes the importance of applying the amenity-benefits function only to regions that are within the range of the regional sizes included in the database used for the estimation of that function. For instance, it may well be that basing the analysis on a partitioning of the country into fewer—and therefore larger—regions would result in no potential increase in social welfare at all.

4. Concluding Remarks

Our analysis for the case of Israel indicates that the benefits associated with a nationwide policy to enhance agricultural amenities are relatively small, and could increase social welfare by up to 2.4%. The overall difference in land allocations between the PM and SO solutions, detailed in Table 2, are also slight. This outcome signifies that the preferred agricultural landscape from the population's point of view is fairly similar to the observed landscape, which is assumed to be the PM solution. This similarity may be a result of an adaptation of the population to its local surrounding—a potential subject of future studies.

Other topics for future research are associated with some assumptions embedded in our analysis. One of the assumptions is related to the type of population considered in the process of regional-scale landscape-enhancing policy design: should it only consist of the local residents, or should the welfare of tourists and residents of neighboring regions be taken into account as well?

Another issue is the implication of the decreasing-return-to-scale nature of the amenity-benefits function, particularly with respect to the importance of applying an adopted function to regional scales similar to those used in the function-estimation sample. While this requirement is fulfilled in the present study, the question of whether our geographical partitioning of the country into regions reflects the actual extent to which residents are exposed to agricultural landscapes in their surroundings remains an open one. This factor may depend on the joint spatial distribution of a region's population and agricultural areas, as well as on the population's travel and recreational habits. Moreover, these elements may vary with time due to the development of rural areas (Fleischer and Tsur, 2003), and the associated increase in commuting distances (Blumen and Kellerman (1990), Crane (2007)).

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Table 1 – Amenity-influential groups of crops and the estimated parameters of the amenity-benefits function.

Crop group	**Crops**	**Parameters**
Orchards and Citrus	Orange, Grapefruit, Lemon, Apple, Pear, Peach, Plum, Table Grape, Wine Grape, Banana, Olive Non-Irrigated, Olive Irrigated, Almond, Avocado, Palm.	$\phi_{11} = 2.2\times10^{-2}$ $\phi_{21} = 7.5\times10^{-7}$ $\phi_{31} = -2.1\times10^{-4}$ $\theta_1 = -9.5\times10^{-6}$ $\eta_{12} = -3.9\times10^{-7}$ $\eta_{13} = 1.3\times10^{-5}$.
Vegetables, Field Crops and Natural Open Spaces	Potato, Tomato Open-Field, Eggplant, Vegetable Marrow, Onion, Carrot, Lettuce, Cabbage, Cauliflower, Celery, Radish, Artichoke, Garlic, Bean, Wheat, Barley, Cotton, Chickpea, Corn, Pea, Groundnut, Sunflower, Winter Forage, Summer Forage.	$\phi_{12} = 4.9\times10^{-3}$ $\phi_{22} = 1.2\times10^{-7}$ $\phi_{32} = -8.0\times10^{-5}$ $\theta_2 = -1.5\times10^{-7}$ $\eta_{23} = 2.5\times10^{-6}$
Greenhouses	Watermelon, Sugar-Melon, Tomato Greenhouse, Cucumber, Pepper, Strawberry.	$\phi_{13} = 7.9\times10^{-2}$ $\phi_{23} = -1.7\times10^{-6}$ $\phi_{33} = -1.0\times10^{-5}$ $\theta_3 = -2.2\times10^{-4}$

Table 2 – Nationwide values of the welfare elements and land allocations of the PM and SO solutions.

	Profit Maximization (PM)	Socially Optimum (SO)	Difference (SO) - (PM)
Welfare Elements (10^6 $/yr)			
Farming Profits	456.5	454.0	-2.5
Amenity Benefits	212.4	231.0	18.6
Social Welfare	668.9	685.1	16.2
Land Allocation (ha)			
Orchards and Citrus	61,179	61,659	480
Vegetables, Field Crops and Open Spaces	310,794	309,002	-1,791
Greenhouses	16,189	17,579	1,390

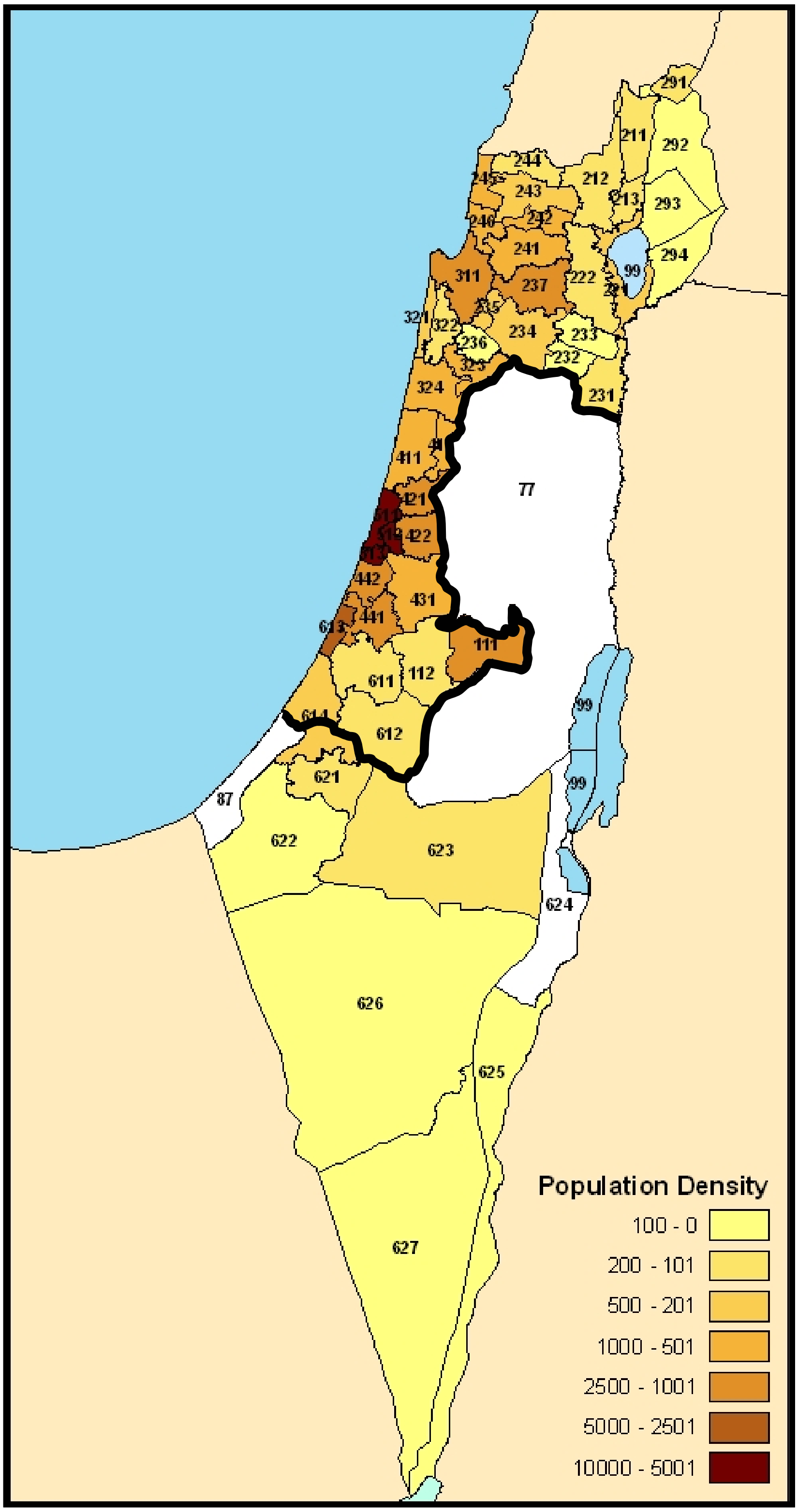

Figure 1 – Division of Israel according to natural zones.

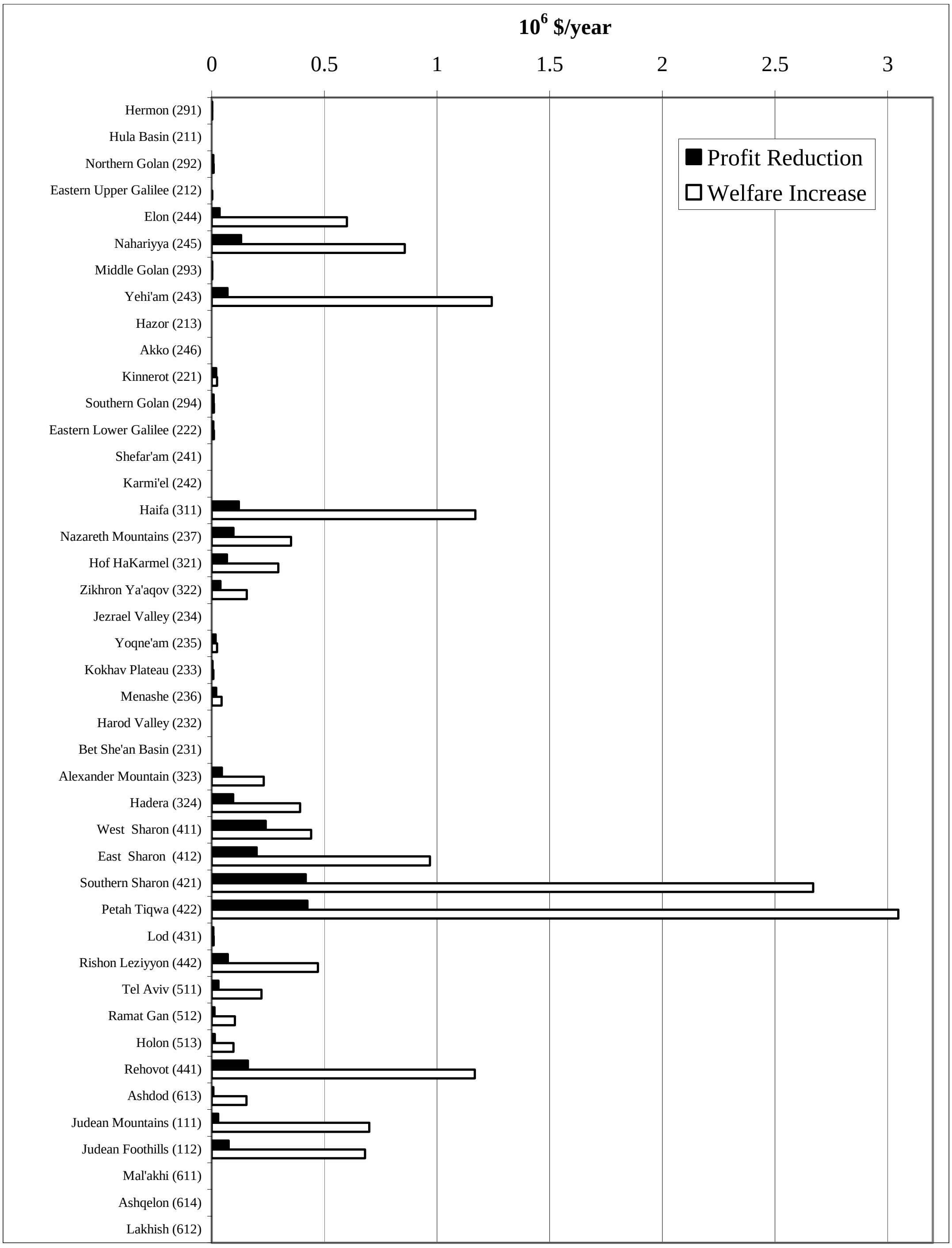

Figure 2 – Regional-scale profit reductions and increases in social welfare associated with the shift from PM to SO land allocations.

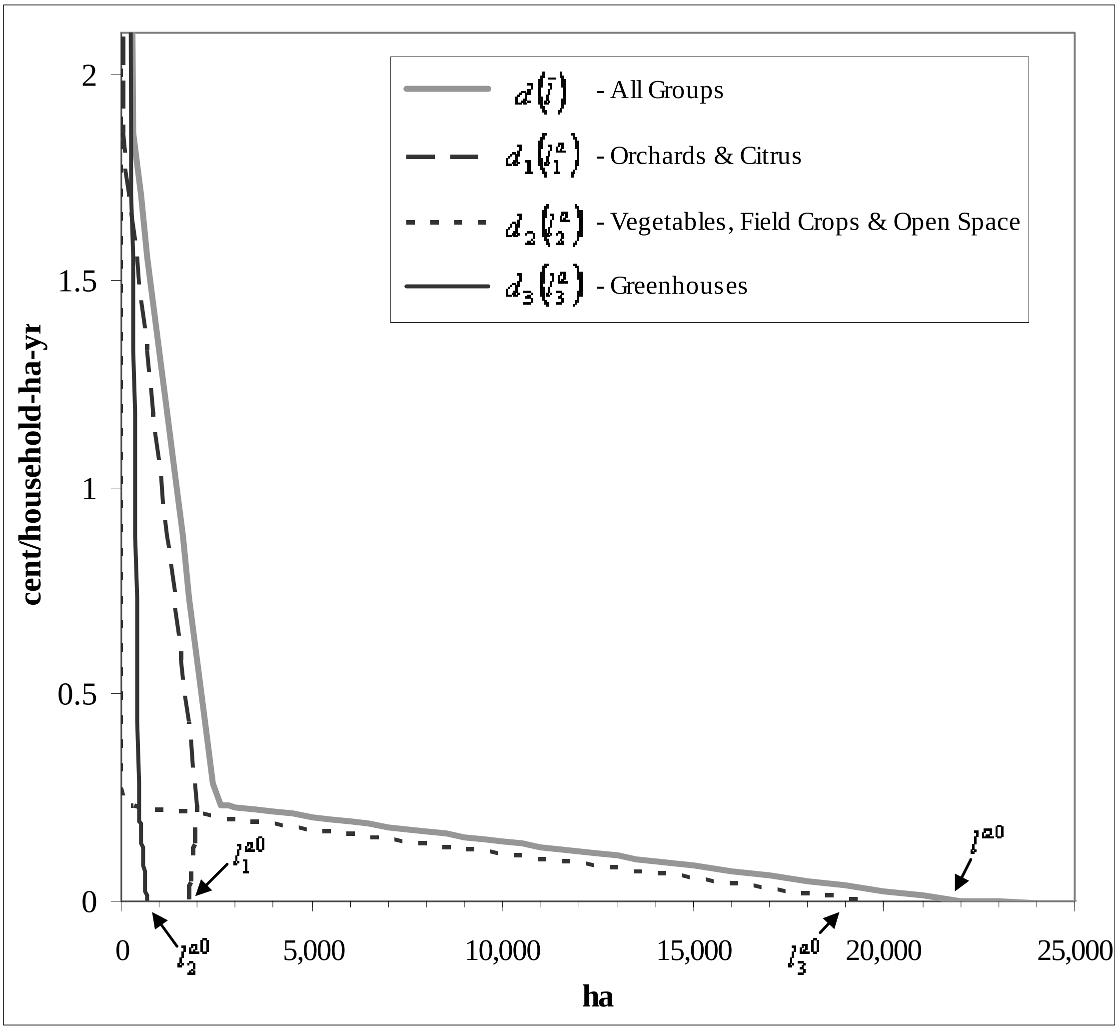

Figure 3 – Marginal-amenity-benefit curves of the three groups of crops under the maximum-amenity land allocations, $d_n\left(l_n^a\right)$, and their horizontal summation curve, $d\left(\bar{l}\right)$.

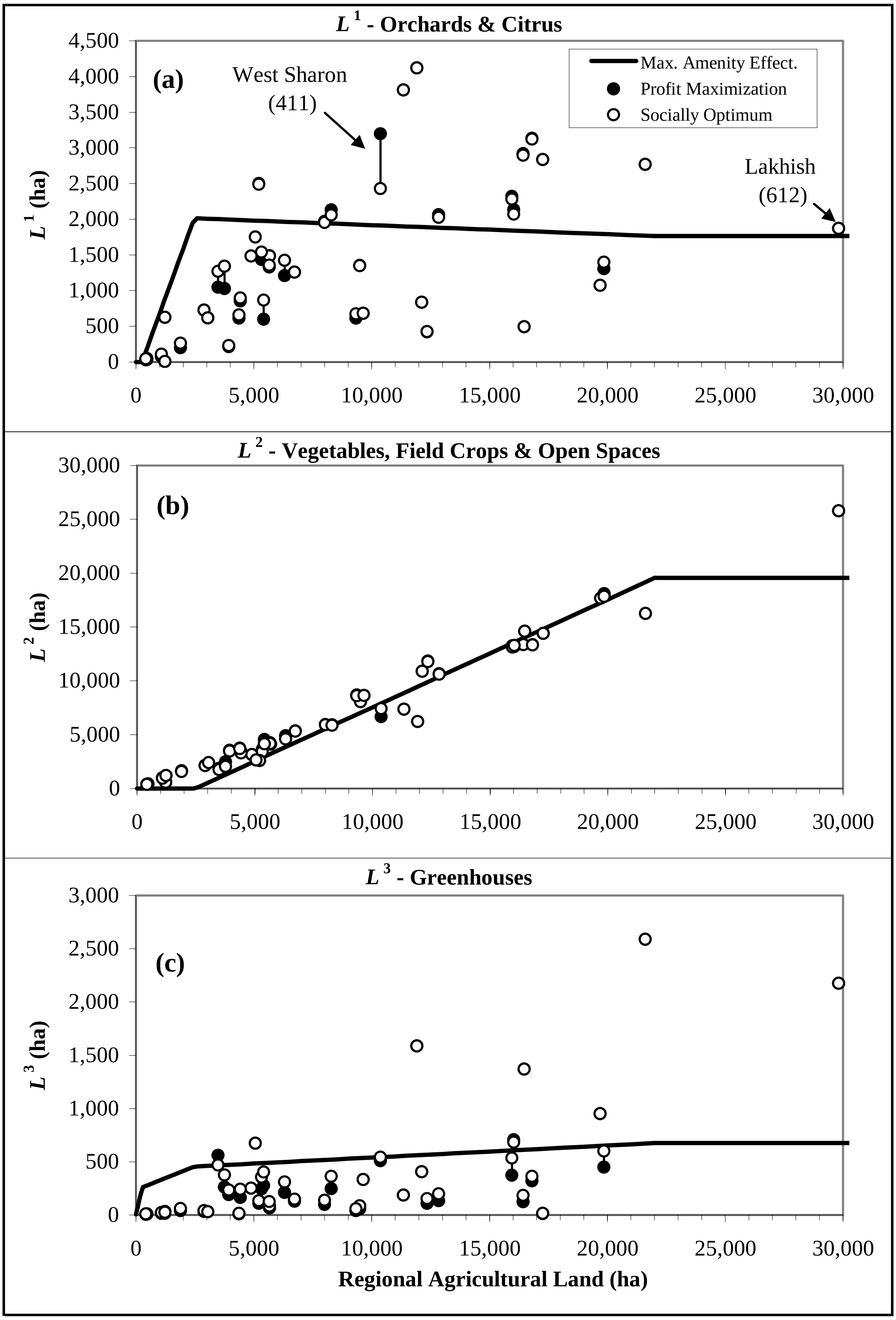

Figure 4 – Variation of the maximum-amenity-effective land allocations (l_n^{ae}), the PM land allocations (l_{kn}^{m}) and the SO land allocations (l_{kn}^{s}) for the three groups of crops (n = 1,2,3), plotted against the regions' total agricultural lands, $\bar{l}_k$.

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