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ANALYSIS

The economic impact of global climate change on Mediterranean rangeland ecosystems: A Space-for-Time approach

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A B S T R A C T

Global Climate Change (GCC) can bring about changes in ecosystems and consequently in their services value. Here we show that the urban population in Israel values the green landscape of rangelands in the mesic Mediterranean climate region and is willing to pay for preserving it in light of the expected increasing aridity conditions in this region. Their valuation of the landscape is higher than that of the grazing services these rangelands provide for livestock growers. These results stem from a Time-for-Space approach with which we were able to measure changes in biomass production and rainfall at four experimental sites along an aridity gradient.

1. Introduction

In studies dealing with global climate change (GCC) issues, a division between the life and social sciences is commonly found. Life scientists emphasize the forecasting of different future climate change scenarios or the resulting changes on ecosystems and their functioning. On the other hand, the economic impact of GCC on the human community is generally dealt with by social scientists. In their analyses, the life science aspects (e.g. change in plant biomass production, biomass loss) are either assumed or taken as a given from other works. Studies of the economic effects of GCC focus on either market impacts, such as possible changes in farm income, or non-market impacts, such as changes in the value of an ecosystem's services (e.g., life support and aesthetic enjoyment for the human community). Natural rangelands, the ecosystem considered in this study, provide both market services, such as grazing, food supply, and genetic resources, and non-market services, such as landscape, recreation and culture.

In this study we evaluate both types of impact of GCC on natural rangeland ecosystems. We do so by integrating findings from both life science and economic analyses.

Market impacts of GCC have been estimated in several studies mainly by analyzing changes in farm income using the production-function approach (e.g., Decker et al., 1986; Adams, 1989; Adams et al., 1990), the Ricardian approach

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(Mendelsohn et al., 1994) or as it was recently named the Hedonic approach (Schlenker et al., 2005). These studies have used current market data to evaluate changes that may occur in the future. For example, in studies evaluating non-market impacts of GCC on ecosystems, such as those by Layton and Brown (2000) and Turpie (2003), stated preference techniques were used to elicit the value of the present population's preferences to preserve ecosystems for future generations. The change in ecosystem considered in the former study was forest loss along the Colorado Front Range of the Rocky Mountains. Four alternative levels of forest loss were assumed and analyzed by computerized photographs of a typical mountain range. In Turpie's (2003) study, the researcher used maps of current biomes in South Africa and a simulation of the future distribution of biomes in a scenario that could be brought about by an increase in the current concentration of atmospheric carbon dioxide (CO_2) of 374 to 550 ppm. Both studies used only computerized manipulations to illustrate the changes: one of the landscape pictures and the other of the biome maps.

In the present study, an integrated approach was implemented to evaluate the impact of GCC on the value of natural rangeland services along an aridity gradient in Israel. The integration in this study has different dimensions. Firstly, both market and non-market impacts are considered. Secondly, we integrate natural and social science approaches to study natural ecosystems and potential changes in their services. We use real measurements of herbaceous and woody plant biomass at different sites along the aridity gradient as proxies for productivity changes.

The challenge of predicting ecosystem responses to climate changes is based on the multi-dimensional and multi-scale nature of the problem (Osmond et al., 2004). Complex ecological interactions make it difficult to extrapolate from individual species to communities and to predict the ecosystem response when only a few organization levels are targeted. In addition, the lack of realistic climatic scenarios (climate modelling) at the relevant scales adds further complexity to the up-scaling process (Harvey, 2000).

Predictions about ecosystem functioning in relation to GCC along climatic gradients rely on two major research assumptions. The first considers that existing environmental gradients can be used as spatial analogues (climosequences) for future climate change. In this case, environmental and ecological characteristics are described for existing climates in present locations and compared along a gradient. Such predicted climatic scenarios are then imposed on existing conditions, e.g. an increase in rainfall would result in a set of conditions that are similar to current areas in more mesic parts along the climatic gradient. The second assumption is that biotic responses to climatic changes can be inferred from current species distributions and their correlations with abiotic factors. Such 'climate envelope' approaches use mapped current distributions and predict future distribution solely on changes in abiotic (namely climatic) conditions. This approach is known as the *Space-for-Time approach*.

Another challenge facing researchers analyzing impacts of GCC is the difficulty of experimentally mimicking changes in climatic conditions on larger scales (e.g., large watersheds, whole ecosystems or regions). Most economic papers in this field assume a certain climate scenario for their analysis. Natural scientists, however, perform a more detailed analysis of the impacts on soil characteristics, and changes in the composition and structure of the vegetation and animal community. In the Space-for-Time approach, changes in climatic conditions are simulated by comparing areas that differ naturally in their climatic regimes. Natural climatic gradients, which include environmental factors such as altitude, topography, temperature and rainfall variations, provide a useful framework for studying the effects of climatic changes (Kutiel et al., 1995; Diaz and Cabido, 1997; Dunne et al., 2003). Moreover, comparisons of ecosystems and biotic communities along gradients are powerful approaches to investigating and understanding the effects of climatic variation on ecosystems (Le Houerou, 1990; Koch et al., 1995; Shaw and Harte, 2001; Austin, 2002). Approaches based on aridity gradients have been frequently used in Mediterranean ecosystems (e.g., Holzapfel et al., 1992; Imeson and Lavee, 1998; Kutiel et al., 2000).

The actual changes that will occur in the future are difficult to predict and even more so to illustrate, due to the complexity of ecosystems. However, the Space-for-Time approach allows one to better illustrate for the general public the different possible scenarios. It also enables linking climate changes to ecosystem processes, such as measurements of changes in herbaceous and woody biomass (primary productivity) and their economic impact. Since changes in biomass affect both landscape values, i.e., a non-market impact, and feeding costs for sheep and cattle growers, i.e., a market impact, we can evaluate both effects in the same research context. The use of biomass measurements is pivotal to our integrated approach. It is a life science measurement used for the estimation of both types of economic impacts.

The paper is organized as follows: Section 2 describes the sites and data measurements used for the GCC scenarios in the Space-for-Time approach. Sections 3 and 4 depict the evaluation of changes in landscape and feeding costs, respectively. The total welfare evaluation is presented in Section 5. Section 6 lists the conclusions.

2. Description of study sites, plant cover, plant biomass measurements and the GCC scenarios

Four sites were established in 2001 along a climatic gradient in Israel, running from the Galilee in the north to the Negev Desert in the south (gradient length 245 km) (Fig. 1). These sites represent, respectively, mesic Mediterranean, Mediterranean, semiarid and arid climatic conditions (Table 1). All sites share the same calcareous bedrock (hard limestone) and are positioned on south-facing slopes. The basic climate is Mediterranean with mild and rainy winters (October–April) and prolonged dry and hot summers. The plants' growing season is closely associated with the temporal distribution of rainfall. The amount of plant biomass at the sites determines the type of landscape, e.g., in Mediterranean ecosystem the higher the biomass, the denser the vegetation. Moreover, the study sites share similar climatic conditions (radiation, temperature, etc.), except for rainfall (Table 1). This links the transformation in landscape and grazing costs to the cardinal issue of the region: water scarcity.

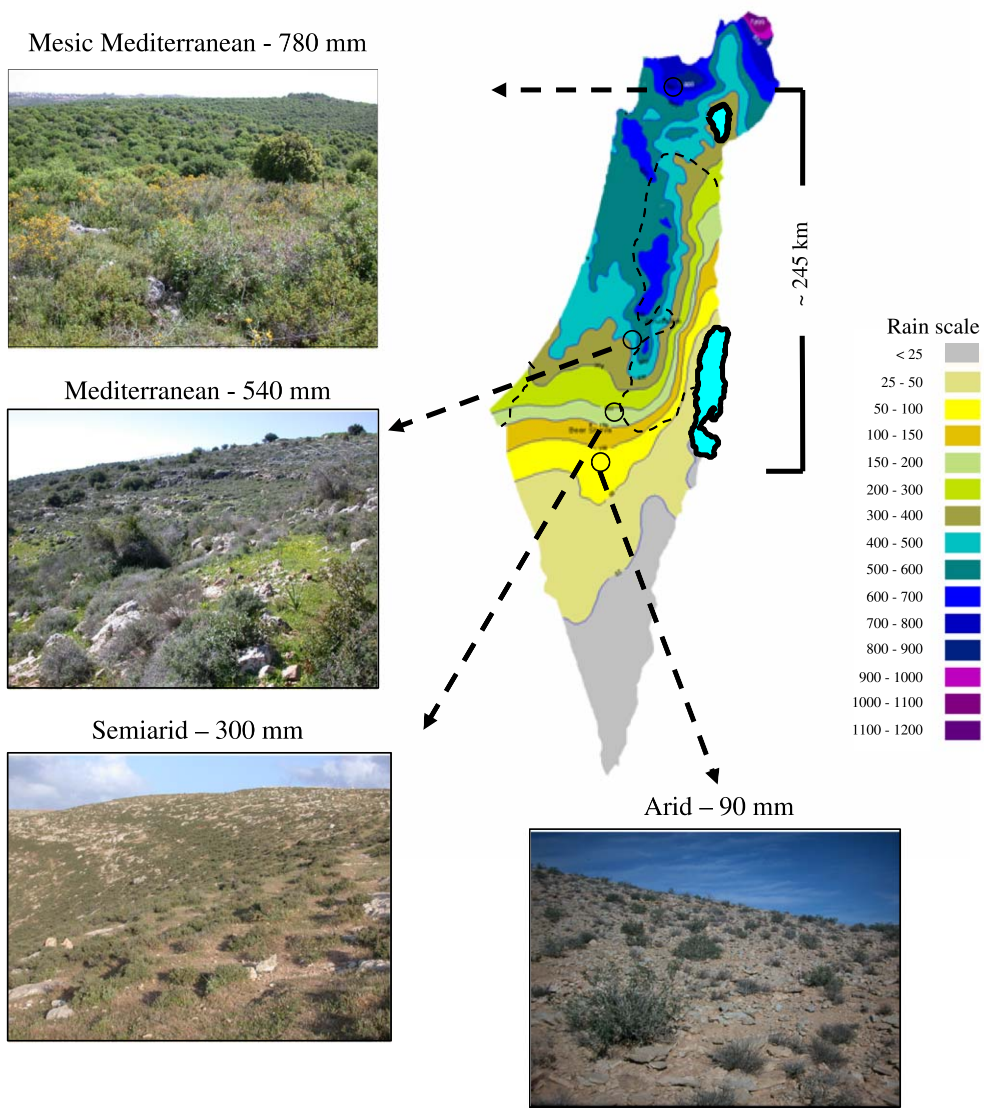

Fig. 1 – The study sites along the climatic gradient Israel.

Plant cover and biomass of the herbaceous and woody vegetation were measured at each study site. Five 10×25 m quadrats were randomly selected and marked. Vegetation was monitored in spring (mid-April), during the peak season of primary production. Within each quadrat, plant cover was estimated and perennial species composition inventoried by using two 25-m long transects placed on the edges of each quadrat. On each transect, a point was read every 20 cm, for a total of 125 points per transect, 250 points per quadrat. A point was read using a slender bar positioned vertically to the ground (Müeller-Dumbois and Ellenberg, 1974). Relative plant cover (in percent) was calculated by excluding rock and bare ground cover. Woody vegetation was sampled according to life-form categories: dwarf shrubs (<0.5 m height), shrubs (>0.5 m <2.5 m height) and trees (>2.5 m height). Herbaceous plant biomass was considered by sampling five 20×20 cm quadrats. After harvesting, plants were brought to the laboratory. The samples were then dried in an oven at 80 °C for 3 days. After removing from the oven, samples were weighed at room temperature to a resolution of 0.01 g. Woody plant biomass was measured by an indirect procedure. Based on their relative cover, woody biomass estimations were calculated using parameters similar to those presented by Sternberg and Shoshany (2001a,b). In their study, they estimated the plant biomass of woody species similar to those found at the study sites. It can be seen in Table 1 that herbaceous and total biomass declines continuously in the transition from mesic Mediterranean to Mediterranean, semiarid and arid. These data enabled us to quantify the landscape changes in Fig. 1.

Using the data from the four sites, we were able to simulate four possible scenarios of climate change for the mesic Mediterranean region. In the first, the mesic Mediterranean site maintains the same climate. In each of the other three scenarios, the mesic Mediterranean site evolves into one of the other three climatic zones, i.e., to Mediterranean, semiarid and arid climates. This allows for four levels of climatic change, ranging from 'no change' to a slight decrease in rainfall in the second scenario (i.e., the mesic Mediterranean site is transformed into a Mediterranean site with a decrease in rainfall) proceeding to a more drastic change (the mesic

Table 1 – Physical and biotic characteristics of the study sites along the aridity gradient

Ecosystem type	Rainfall (mm)	Temperature (°C) Min.–Mean–Max.	Elevation (a.s.l.)	Soil type	Vegetation formation	Herbaceous biomass (ton ha^{-1})	Total biomass (ton ha^{-1})
Mesic Mediterranean (N 33°0′ E 35°14′)	780	13.5–18.1–23.4	500 m	Montmorillonitic Terra Rossa	Closed oak maquis (*Quercus calliprinos*) and open garigue formations dominate shrubs (e.g. *Calicotome villosa*, *Sarcopoterium spinosum*, *Cistus* spp.) and associated herbaceous plants.	0.832	19.1
Mediterranean (N 31°42′ E 35°3′)	540	12.8–17.7–23.6	620 m	Terra Rossa	Dwarf-shrubland dominated by *Sarcopoterium spinosum* and a high diversity of herbaceous (mostly annual) plant species.	0.741	11.3
Semiarid (N 31°23′ E 34°54′)	300	13.2–18.4–24.8	590 m	Light brown Rendzina	Dwarf shrubs of *Sarcopoterium spinosum* and *Coridothymus capitatus* associated with herbaceous (chiefly annual) plant species.	0.576	6.1
Arid (N 30°52′ E 34°46′)	90	13.6–19.1–26.1	470 m	Desert lithosol	Open vegetation dominated by small shrubs and semi-shrubs such as *Zygophyllum dumosum*, *Artemisia sieberi* and *Hammada scoparia* and sparsely growing desert annuals, geophytes and hemicryptophytes.	0.014	2.8

Mediterranean site transforms to a semiarid site) and finally to a very drastic change (the mesic Mediterranean site is transformed to an arid site). The existence of various site scenarios in the Space-for-Time approach enabled us to contemporaneously measure temperature and precipitation, take current pictures of the landscape and measure the biomass levels at these sites.

3. Evaluating landscape services

Economists have responded to the need to evaluate environmental and natural resources in the absence of markets by developing an array of non-market evaluation methods. Some of the methods depend on markets related to the environmental good, whereas others are based on stated preference techniques. Since the impact of GCC on landscape will occur in the far future, beyond the lifetime of the present population, we had to use a stated preference technique. One of these is the well-known contingent valuation method (CVM). This method is highly controversial and concerns regarding the validity of its results have been expressed as a result of: strategic bias, yea-saying, insensitivity to scope variations, framing and other causes (Bateman et al., 2002; Nunes, 2002).

A more recently developed method, which seems to better simulate the respondents' choice process, is choice modeling (Bennett and Blamey, 2001). In this method, the environmental good is described according to its attributes and the levels they take. The different alternatives vary in their attribute levels and respondents have to choose the alternative they prefer. The attributes in the different alternatives can include environmental damage and abatement costs. By choosing an alternative, the respondents are actually ascribing a value or price to a level of attribute (the alternatives used in this work are illustrated in Fig. 2).

3.1. The model

The probability of an individual choosing a specific alternative can be estimated using the standard logit model. However, these models impose three strong restrictions (McFadden, 1973; Train, 1986, 2003): (1) model coefficients are the same for all individuals, i.e., there are no differences in individuals' preferences, (2) the well-known Independence of Irrelevant Alternatives (IIA), and (3) in the case of repeated choices (e.g., where an individual receives a few sets of alternatives to choose from), unobserved factors are assumed to be independent for each decision. Following Train (1998, 1999, 2003), we use the random-parameters logit (RPL) model (also known as mixed logit) for repeated choices. The utility of alternative j for the ith individual is:

$$U_{ij} = X_{ij}\beta_i + \varepsilon_{ij} = X_{ij}\bar{\beta} + X_{ij}\tilde{\beta}_i + \varepsilon_{ij}, \quad (1)$$

where X is a vector of attributes of alternative j, β_i is a random vector with density $f(\beta)$, and ε_{ij} is an iid independent of β_i and X. The coefficient vector for each individual β_i can be expressed as the sum of the mean $\bar{\beta}$ and the individual's deviation from the mean $\tilde{\beta}_i$. The unobserved portion of the utility function by the researcher, $X_i\tilde{\beta}_i + \varepsilon_{ij}$, reflects the individuals' tastes and is thus correlated over alternatives and choices.

Assuming all correlation is due to $\tilde{\beta}_i$, then the probability that an individual i will choose alternative j from a set of

Program 1 No action	Program 2 Forestation is used to slow down greenhouse effect	Program 3 Reduction in the use of greenhouse gases	Program 4 Forestation and greenhouse-gas reduction	Program 5 Drastic reduction in greenhouse gases
Landscape in the Galilee[a] will become arid, also loss of plant life will occur	Landscape in the Galilee[a] will become semiarid	Landscape in the Galilee[a] will become semiarid	Landscape in the Galilee[a] will have less plant life	Landscape in the Galilee[a] will not change
\$0 per month	\$7.5 per month	\$7.5 per month	\$15 per month	\$20 per month
Mesic Mediterranean 	Mesic Mediterranean 	Mesic Mediterranean 	Mesic Mediterranean 	Mesic Mediterranean 
Arid 	Semiarid 	Semiarid 	Mediterranean 	

[a]the Galilee is the region with mesic Mediterranean climate

Fig. 2 – An example of one set of alternatives: respondent had to choose one program from each set.

alternatives is:

$$P_{ij} = \mathrm{prob}(X_{ij}\beta_i + \varepsilon_{ij} - X_{ik}\beta_i > \varepsilon_{ik}, \forall k \neq j), \tag{2}$$

which implies

$$P_{ij} = \int_{-\infty}^{\infty} \left[\frac{e^{x_{ij}\beta_i}}{\sum_{k=1}^{k=m} e^{x_{ik}\beta_i}} \right] f(\beta) d\beta. \tag{3}$$

The probability in Eq. (3) can be simulated by R draws of β_i from $f(\beta)$ (Train, 2003) as

$$\hat{P}_{ij} = \frac{1}{R} \sum_{r=1}^{r=R} \frac{e^{x_{ij}\beta_{ir}}}{\sum_{k=1}^{k=m} e^{x_{ik}\beta_{ir}}}. \tag{4}$$

Following Layton and Brown (2000), the model in Eq. (4) is extended to multiple choices, i.e., each respondent receives three sets of alternatives from which he/she has to choose. The attributions of the alternatives vary between sets while preferences of respondents β_i stay the same. The probability is

$$\hat{P}_{ij} \frac{1}{R} \sum_{r=1}^{r=R} \left[\prod_{t=1}^{t=T} \frac{e^{x_{ijt}\beta_{ir}}}{\sum_{k=1}^{k=m} e^{x_{ikt}\beta_{ir}}} \right]. \tag{5}$$

Assuming $f(\beta)$ is multivariate normal, then it is possible to simulate the probability of each individual's choice from each set of alternatives and estimate it by maximum likelihood.

3.2. *Data*

The data collection was performed in three stages: focus groups, pre-tests and face-to-face surveys. *Focus groups*: This stage was based on three focus groups of adults over the age of 18 from different socioeconomic backgrounds. The purpose of this stage was to identify the level of understanding of GCC, landscape, and abatement programs. Another was to identify the range of bids and the vocabulary used by the participants in describing these issues. This information enabled us to design a first draft of the questionnaire. *Pre-test*: Extensive pre-testing of the questionnaire was performed with over 50 individuals, and the final version was arrived at. *Survey*: A face-to-face survey was administered to a sample of the adult population (above the age of 18) in all 15 cities in Israel having more than 30,000 households. The population in these cities accounts for about half of the 6.8 million Israeli residents. Sample size was set at 500 and the number of respondents from each city was chosen according to the relative weights of the city households. Within each city, respondents were chosen randomly. Response rate was 73%. Each respondent received three different sets of alternatives (see Fig. 2 for an example of such a set) and each set contained five possible programs. The use of three sets per respondent allowed for the collection of more information. That is, instead of 500 observations there were 1500, three per respondent. *Questionnaire*: The design of the questionnaire relied on the work of Layton and Brown (2000). It starts with a short and simple description of GCC and its possible impact on the eastern Mediterranean region. It ends with questions concerning the demographic and socioeconomic characteristics of the respondents. The main part of the questionnaire contains three sets of alternatives (these sets are denoted a, b, and c in the following discussion) for possible changes in climate in the Galilee, a region with mesic Mediterranean climate. Twelve versions of the questionnaire were administered by alternating the sets. The versions differed in the order of the sets: one-third of the respondents received the three sets in the order a, b, c, one-third, a, c, b, and one-third c, a, b. Since set c always had higher bids, it was important to mix the sets. Half of the respondents received three sets with a higher level of bids than the other half. Half of the respondents received a scenario in which the time horizon for materialization of the GCC impacts was 100 years and the other half 30 years. The 12 versions and their distribution in the sample appear in Table 2.

Each alternative that the respondents had to choose from had four attributes: landscape, forestation, other abatement measures and bids. The respondents were told they will have to pay the bid by increase in fuel bill and tax payments. The attributes varied as follows: four different landscapes depicted by pictures from the four sites, two levels for forestation (utilizing and not utilizing forestation as a preventive measure), three levels of abatement (none, some, vigorous) to reduce greenhouse gases, and 14 levels of bids ranging from 0 to $50.

Alternatives set ‘a’ in Fig. 2 depicts five programs that respondents had to choose from. The changes in landscape are demonstrated in the pictures taken at the sites in the

Table 2 – Distribution of versions by time horizon, bid levels, and order of sets (number of respondents for each version appears in parentheses)

Time horizon	30 years (255)		100 years (245)	
Bids	High bids (123)	Low bids (132)	High bids (124)	Low bids (121)
Order (a, b, c) (164)	Version 1 (42)	Version 2 (43)	Version 7 (40)	Version 8 (39)
Order (a, c, b) (172)	Version 3 (40)	Version 4 (48)	Version 9 (42)	Version 10 (42)
Order (c, a, b) (164)	Version 5 (41)	Version 6 (41)	Version 11 (42)	Version 12 (40)

spring of 2003 when biomass was at its peak. Pictures in the first row are all taken from the mesic Mediterranean (Galilee) site, while pictures in the second row are from the other three sites: arid, semiarid-appearing twice, and Mediterranean. In program 1, no action is taken, abatement cost is zero and the landscape changes from mesic Mediterranean (Galilee) to arid. In programs 2 and 3, the landscape changes from mesic Mediterranean to semiarid and the abatement cost is $7.5 per month. The alternatives differ in the abatement method, forestation vs. reduction in greenhouse gases. In program 4, there is a cost of $15 a month for reduction in greenhouse gases, and forestation changes to a Mediterranean landscape. Program 5 is the most expensive one in the set. For $20 a month, drastic abatement measures are taken and the mesic Mediterranean landscape is maintained.

3.3. Estimates

Eqs. (3) (4) and (5) are developed under the assumption that the observed part of the utility function is linear in the parameters (Train, 2003). Accordingly, the following variables were entered linearly as the attribute of each program:

1. *cost* — there are 14 values of program costs ranging from $0 to $50;
2. *forestation* — dummy variable receives a value of 1 when the method appears in the program and 0 otherwise;
3. *reduction* — dummy variable receives a value of 1 when any level, moderate or vigorous, of greenhouse reduction appears in the program and 0 otherwise;
4. *biomass loss* — tons of biomass are lost in the transition from mesic Mediterranean climate zone to the other climate zones. Measurements of biomass at each of the four sites enabled us to translate the changes in landscape to biomass loss. For example, the transformation from mesic Mediterranean to Mediterranean landscape is caused by a loss of 7.8 tons per hectare (see Table 1).

The parameter of *cost* is expected to receive a negative value for all respondents and thus it is assumed to be constant for all respondents. Chen and Cosslett (1998) and Layton and Brown (2000) used the same assumption to guarantee a negative coefficient for cost and consequently a normal independent distribution for willingness to pay (WTP). All other coefficients are assumed to vary and to have normal distribution. The signs for the variables *reduction* and *forestation* can be either negative or positive, depending on people’s preferences for the two methods. In the case of *biomass loss*, although green landscape is held in high esteem in Israel (this was tested in the focus groups), there are still people who would prefer the desert-like landscape. The model parameters were estimated by LIMDEP 8 (2002).

The model estimates can be seen in Table 3. The means and standard deviations of *reduction* and *forestation* reveal the heterogeneity in the population preferences for the two abatement methods. The mean coefficient in the case of *reduction* is 1.66 and the standard deviation is 2.7, that is, 70% of the population likes this method. In the case of *forestation* the coefficient is not significant, that is, the population is indifferent between using or not using this method of abatement.

Table 3 – Estimation of random parameter model with biomass loss

Variable	Parameter	Value	Standard error
Cost	Mean of coefficient	−0.033*	0.008
	Standard deviation of coefficient	0	0
Biomass loss	Mean of coefficient	−0.069*	0.018
	Standard deviation of coefficient	0.260*	0.081
Forestation	Mean of coefficient	−0.221	0.194
	Standard deviation of coefficient	2.507*	0.223
Reduction	Mean of coefficient	1.664*	0.794
	Standard deviation of coefficient	2.752*	0.977
R^2 (a)		0.18	
Number of observations		1500=(500×3)	

Cholesky matrix

	Price	Biomass loss	Forestation	Reduction
Price	0			
Biomass loss	0.025	0.0087		
	(0.056)	(0.101)		
Forestation	−2.44*	0.162*	0.562	
	(0.297)	(0.068)	(0.838)	
Reduction	−1.426	−0.201*	0.148	2.34*
	(1.299)	(0.056)	(1.512)	(1.22)

Note: Standard errors are in parentheses.
a $R^2=1-[(\text{Log-likelihood of the model})/(\text{Log-likelihood }(\beta=0))]$.
* Denotes significance at 5%.

The significant values in the Choleski matrix indicate heterogeneity in preferences.

The ratio of the biomass coefficient to cost coefficient measures the average WTP (Bateman et al., 2002, p.283) in order to prevent the loss of 1 ton of biomass per hectare. In this case, the ratio has a normal distribution since *biomass loss* is normally distributed and cost is constant. Thus, the mean WTP is $2 per ton of biomass loss per hectare with a standard deviation of 7.8. The range of WTP is relatively large, which indicates a wide variation in the population's WTP.

In the Space-for-Time approach, the choice of experimental sites enables us to focus only on changes in rainfall. That is, rainfall is the main factor that varies along the gradient in the production of biomass. As we move south, the amount of rainfall drops, while temperature and other factors remain almost constant. Thus, we can substitute biomass loss with drop in rainfall and estimate, accordingly, the WTP to prevent this change in rainfall. This substitution allows us to link the landscape choice of the respondents to an important factor in climatic change. The variable used in this case is '*drop in rainfall*'; it measures the difference in rainfall between the mesic Mediterranean climate zone to the other climate zones. The estimated model substituting *biomass loss* with *drop in rainfall* appears in Table 4. The average WTP for the prevention of a drop in rainfall is estimated to be $0.05 a year per one millimeter reduction in rainfall, with a standard deviation of 0.13, or $5 per 100 mm drop in rainfall.

4. Evaluating grazing services

Grazing services of the ecosystem at issue consist of free food for cattle and sheep growers. Sheep and cattle consume

Table 4 – Estimation of random parameter model with drop in rainfall

Variable	Parameter	Value	Standard error
Cost	Mean of coefficient	−0.0498*	0.01
	Standard deviation of coefficient	0	0
Drop in rainfall	Mean of coefficient	−0.0026*	0.0005
	Standard deviation of coefficient	0.0066*	0.0015
Forestation	Mean of coefficient	−0.239	0.189
	Standard deviation of coefficient	2.361*	0.22
Reduction	Mean of coefficient	1.455**	0.845
	Standard deviation of coefficient	2.809*	1.45
R^2 (a)		0.19	
Number of observations		1500=(500×3)	

Cholesky matrix

	Price	Drop in rainfall	Forestation	Reduction
Price	0			
Drop in rainfall	0.0002	0.00205		
	(0.0013)	(0.0023)		
Forestation	−2.28*	0.0039*	0.613	
	(0.3)	(0.001)	(0.84)	
Reduction	−0.259	0.0049*	−2.75*	0.47
	(1.4)	(0.0014)	(1.44)	(1.58)

*,**Denotes significance at 5% and 10%, respectively.
Note: Standard errors are in parentheses.
a $R^2=1-[(\text{Log-likelihood of the model})/(\text{Log-likelihood }(\beta=0))]$.
* Denotes significance at 5%.

Table 5 – Savings in food costs for cattle and sheep

	Cattle ($ per hectare)	Sheep ($ per hectare)
Mesic Mediterranean	83.23	116.5
Mediterranean	74.14	103.79
Semiarid	57.66	80.72
Arid	1.45	2.03

mostly herbaceous biomass. Therefore, the more herbaceous biomass there is at the site, the more the grower saves on food costs. Assuming a constant coefficient production function, we can evaluate the change in costs and thus in profits of farmers that depend on these sites. Individual cows and sheep consume 10 and 1.5 kg, respectively, of herbaceous biomass (dry material) per day. Alternatively, growers have to pay $1 for food per day per cow, $0.21 per sheep. Based on the total dry herbaceous biomass at each site, Table 5 shows how much growers save in food costs per year. In the mesic Mediterranean area, the savings are naturally the largest and stand at $83.2 per hectare for cattle and $116.5 for sheep.

5. Evaluating loss of ecosystem services

Based on the last two sections, we can evaluate the loss in value of the two ecosystem services, landscape and grazing, when climatic conditions change from mesic Mediterranean to any of the other three climates. The landscape is determined by the amount of plant biomass per hectare, and the population values one ton of plant biomass per hectare at $2. As seen in Table 6, a change in landscape in the northern region from mesic Mediterranean to Mediterranean is valued by the urban population as a $51.5 million loss in welfare. Alternatively, by looking at changes in rainfall, it is valued at $39.6 million. Similarly, the transformation to a semiarid climate is valued at, respectively, $85.5 or $79.2 million and to an arid one at $107.6 or $113.8 million. In none of the three cases are there any significant differences between alternative values.

If the land is used for cattle growing, then growers will lose $9.1 per hectare; for sheep raising, the increase in food costs is $12.7. The total area of grazing land in the mesic region is 630 ha. The loss for cattle growers in the mesic Mediterranean region can range between $5733 and $51,534 a year. In the case of sheep growers, the yearly range of losses in food costs is higher and varies between $8001 and $72,135. Currently, the grazing land in the northern site is used mostly for cattle, thus the loss values for cattle are more relevant.

6. Concluding remarks

The Space-for-Time method provides the population with an illustration of the impact of GCC on landscape in the form of actual photographs of the sites. Furthermore, the use of biomass measurements enables linking these changes in landscape to changes in biomass and, even further, to changes in rainfall. This link lets us assign a value to a climatic variable based on tangible illustrations, rather than on just a narrative describing the changes in climate. This result is made possible by the interdisciplinary nature of this research.

Based on the aforementioned method, we show that the urban population in Israel values green landscape. They are willing to pay for it even though they might not be here when the changes take place. Furthermore, the loss in welfare from the change in landscape is valued much higher than the loss in income for farmers that depend on the land for grazing. The population is willing to pay about $80 million a year to prevent the mesic Mediterranean landscape from changing to a semiarid one, whereas cattle and sheep growers will lose $16,000 to $22,000, respectively, if this climate transformation occurs.

It should be noted that the result obtained here, whereby the population assigns a higher value to the landscape in rangelands than its additional income to livestock growers, is conditional on the fact that Israel is a high-income country. In the case of low-income countries, we expect the results to be reversed. The ‘free’ feeding services provided by rangelands are significant at low income levels. Moreover, the latter population engages much less in outdoor recreation and thus does not value the landscape as much as high-income countries.

Table 6 – Yearly loss value of ecosystem services in the transformation from mesic Mediterranean to Mediterranean, semiarid and arid climates

	Drop in rainfall	Total WTP to prevent drop in rainfall [a] ($ 10^6 ha^{-1})	Loss of total biomass (ton ha^{-1})	Total WTP to prevent loss of biomass [b] ($ 106 ha^{-1})	Loss of herbaceous biomass (ton ha^{-1})	Loss of grazing services for cattle [c] ($)	Loss of grazing services for sheep [c] ($)
Mesic Med. → Med.	2.4	39.6	7.8	51.5	0.009	5733	8001
Mesic Med. → semiarid	4.8	79.2	13.0	85.8	0.256	16,128	22,554
Mesic Med. → arid	6.9	113.85	16.3	107.6	0.818	51,534	72,135

a The average WTP of $0.05 is multiplied by 3.3×10^6 residents of large urban centers and by the drop in rainfall.
b The average WTP of $2 is multiplied by 3.3×10^6 residents of large urban centers and by the loss of total biomass.
c The difference between mesic Mediterranean region and the other region in saving in food costs is calculated from Table 5 and multiplied by 630 ha the total grazing area in the mesic Mediterranean region.

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