An Ecosystem Services Inventory: Lessons from the Northern Negev Long-Term Social Ecological Research (LTSER) Platform

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Despite the burgeoning popularity of the term 'ecosystem services', relatively little work has yet been done to identify, characterize and quantify ecosystem services and their spatial distribution across the landscape. In this study, we test a methodology for taking inventory of ecosystem services in Israel's semi-arid Northern Negev region. We survey site managers of five long-term ecological research (LTER) sites regarding the presence/absence of 86 ecosystem services, and their level of confidence regarding their answers. There was a high percentage of services in three categories (provisioning, regulating and cultural) across all sites, and no significant differences based on environmental factors between sites. The only factor that correlated with differences in the package of services offered at each site was management agency (Ministry of Agriculture or Jewish National Fund-Keren Kayemeth LeIsrael). Through principle component analysis, we find that management agencies, through their land use policies, can alter the package of services, for example by emphasizing agricultural- or forestry-oriented services or particular cultural services, like those associated with education or tourism. We conclude our analysis with a discussion on both the distribution of services and our reflections on the learning process from our ecosystem service assessment.

Keywords: *Ecosystem service assessment, semi-arid ecosystem, Long-term Ecological Research (LTER) site, Long-term Social Ecological Research (LTSER) platform, land use policy, dryland forestry, agriculture.*

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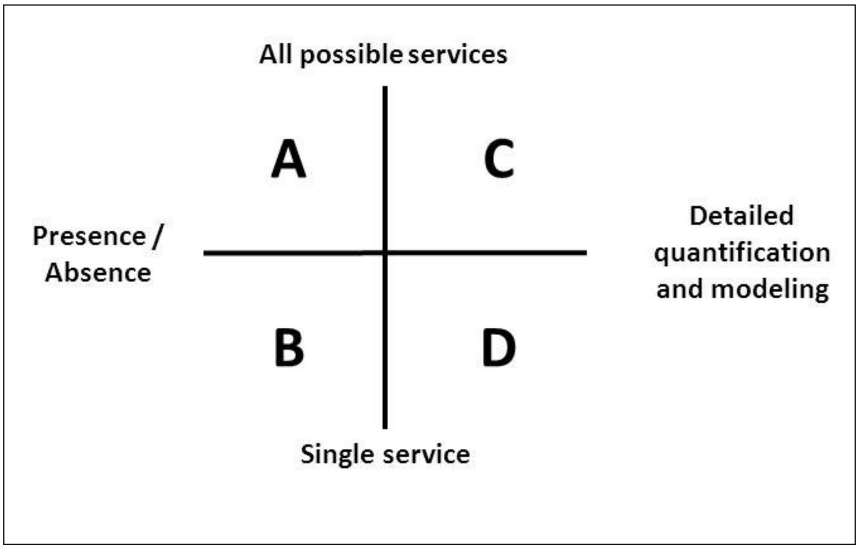
Over the past two decades, there has been an exponential rise in the number of scientific publications focusing on ecosystem services (Fisher et al., 2009) since the pioneering papers that introduced and popularized the concept (e.g. Ehrlich and Mooney, 1983; Costanza et al., 1997; Daily, 1997). The most prominent definition of the term ecosystem service, taken from the Millennium Ecosystem Assessment (MA), is "benefits provided by ecosystems to humans, which contribute to making human life both possible and worth living" (MA, 2005a). Today the term is used in diverse ways, including: 1) an empirical link between ecosystem integrity or health and human wellbeing; 2) a conceptual framework to integrate natural and social sciences towards sustainability; and 3) a vehicle for communicating the importance of nature conservation to the public (Carpenter et al., 2009; Collins et al., 2011). The use of the term, in all its diversity, is now well-established, particularly among scientists, natural resource and land managers, and environmental policy-makers. The United Nations has established in 2010 the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), and a new academic journal (*Ecosystem Services*) has been dedicated to the subject.

Although the concept of ecosystem services is now well-established, research of ecosystem services is still very much in its infancy. The discipline now demands tools to assess the presence and absence of ecosystem services, to quantify them, and to value them. Indeed, in addressing the IPBES first plenary meeting in 2011, M. Achim Steiner told the international audience that its "four overarching functions… are knowledge generation, assessment, policy support, and capacity building." Kareiva and colleagues concurred that "Mainstreaming ecosystem services into everyday decisions requires a systematic method for characterizing their value – and the change in value resulting from alternative policies or human activity" (Kareiva et al., 2011, 4).

Much scientific and policy effort is now being invested in ecosystem service assessment, i.e. the identification, characterization and quantification of services. These efforts are diverse in their motivation, focus and range. Some are trying to advance the state of the art of our ability to quantify the amount of specific services and the response of provision of the services to land use changes (Kareiva et al., 2011). Other efforts are aimed to inventory a broad range of services and assess spatial variation in the presence and amount of services across large scales (e.g. country or continental) along ecological gradients (Dick et al., 2011). This approach allows characterizing ecosystems, not by using classical habitat classification approaches, but by examining similarities between ecosystems in what they provide to people. In Great Britain, a national-scale effort is underway to identify all ecosystem services across the country and characterize them according to their geographic range (UK National Ecosystem Assessment, 2011). Intrinsic to all of these research efforts is the necessary compromise between breadth (i.e. a generalized study of many services) and depth (i.e. a detailed study of a single service; Figure 1).

Figure 1: Options and tradeoffs for studying ecosystem services with little or great depth (x-axis), and singly or in large numbers (y-axis)



Among the most common approaches to studying ecosystem services in the landscape is ES mapping (Kareiva et al., 2011; Maes et al., 2011; Naidoo et al., 2008). Such mapping utilizes, for example, hydrological models, biodiversity surveys, net primary productivity estimates (to assess carbon sequestration), and other well-tested spatial survey methods. Mapping can focus on a single service (e.g. Mendoza et al., 2011) or on a handful (or "bundle") of selected services (e.g. Pinto et al., 2010; Weinger et al., 2010). While these works benefit from depth of understanding of a single or a few services, and can leverage this depth of knowledge towards analyzing temporal change, they do not provide a broad inventory of all available services. Further, these works focus on ecological indicators, and generally do not provide insights into the presence and distribution of cultural services (those services that provide non-material benefits; Maes et al., 2011).

"Final ecosystem services" as explained by Boyd and Banzhaf (2007, 619), "are components of nature, directly enjoyed, consumed, or used to yield human well-being". As a purely anthropocentric concept (Jax, 2010), defining services must begin from the perspective of the end-user, whether land use managers or other stakeholders. Thus, a second approach to ecosystem service assessment uses social methods (surveys, interviews) to query stakeholders regarding the ecosystem services they utilize (Gee and Burkhard, 2010; Maes et al., 2011; Maynard et al., 2010; Sagi et al., 2012). Such studies yield information regarding preferences of stakeholders (e.g. aesthetic value), but cannot identify those more subtle services that, for example, provide biological life support for humans (e.g. pollination, air, water and climate regulation). Expert knowledge is required for assessing the latter services.

In this article, we report on the results of a breadth study across five sites in Israel's Northern Negev. The advantages of such a study include relative ease of collecting data, ability to utilize the data for identifying specific services for more in-depth research and to identify knowledge gaps regarding certain geographic areas of particular interest, potential for research on the spatial distribution of services, and ability to provide useful information to policy makers in real time (see Table 1 for a comparison of strengths and weaknesses of various approaches). Dick et al. (2011) called such breadth studies 'holistic' representations of ecosystem services. Their group of long-term ecological research (LTER) site managers compiled a list of 73 services derived from the MA and reported on their presence or absence from 11 LTER sites across Great Britain. This type of study, like the current study, would fall into category "A" in Figure 1 (presence/absence of many services).

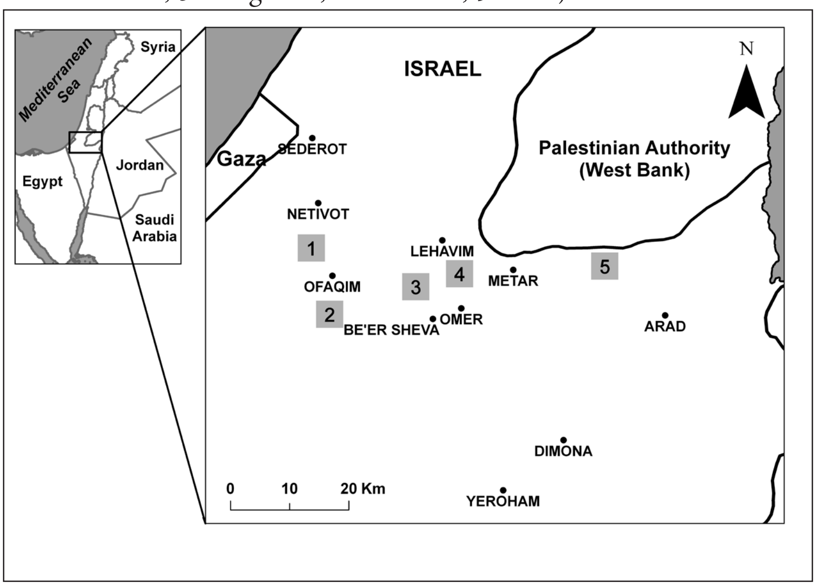
Table 1: Assessments of the advantages and disadvantages in selection of single to multiple ecosystem services for analysis

Zone (Fig. 1)	**Advantages**	**Disadvantages**
A	Provides quick inventory of all services Equivalent to "species richness" indicator – can identify an ecosystem services hotspots	Little quantitative data collected; no amounts for services Not useful in assessing relative impact of management scenarios
B	Can be done quickly and by a single researcher	Minimal information – only one service with no depth of information.
C	Most comprehensive amount of information Maximum potential for studying impact of management options on the entire range of services	Extremely work and budget intensive Requires research team to assure expertise in every area
D	Maximum information for a limited amount of services Good when a single service represents a bundle of services. Good when policy prioritizes a single or small amount of services	Limited coverage of services May ignore potentially important services by over-focusing on services that generate research or popular interest.

RESEARCH APPROACH AND METHODS

The current research adopts the approach of Dick et.al (2011), utilizing a standardized list of ecosystem services to assess the presence/absence and spatial distribution of ecosystem services in the Northern Negev (Figure 2). This study focused on three of the four types of ecosystem services as defined by the MA, including provisioning, regulating and cultural services: Provisioning services are "products obtained from ecosystems" and can include food and fiber, fuel, pharmaceuticals, genetic resources and fresh water among many others (MA, 2003, 8-11). Regulating services, or "benefits obtained from the regulation of ecosystem processes" can include air quality maintenance, climate regulation, water regulation, pollination, erosion control, and more. Cultural services are "nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences". Supporting services, "those that are necessary for the production of all other ecosystem services" (MA 2003, 11), such as biodiversity of important groups, among others, were not included in the Dick et al. (2011) study, nor in the current study (see discussion).

Figure 2: Northern Negev long-term ecological research (LTER) sites (1=Migda; 2=Shaked; 3=Shagririm; 4=Lehavim; 5=Yatir)



Note: The sites are embedded within the Northern Negev long-term social ecological research (LTSER) platform.

The original list, compiled by managers of 11 LTER sites in the British environmental change network (ECN), consisted of 73 services. In 2011, the European LTER network initiated a survey that was based on the UK study, but examines many LTER sites across Europe and including Israel and Jordan. With the initiation of the European study, another 10 services were added at a European LTER workshop in which both the British LTER team and an Israeli LTER scientist was present (Dick et al., in preparation). For the current study, another three services were added by the Northern Negev LTER research team that were deemed relevant for semi-arid and arid ecosystems and were absent from previous studies (dust/dry deposition, albedo, shade). The final list of 86 services included 23 provisioning services, 18 regulating services and 45 cultural services (Table 2).[2]

Table 2: 86 ecosystem services inventoried in the Northern Negev LTER sites and their codes shown in the ordinations

Service	Category	Ecosystem service	Ordination code
Provisioning			
Food	Farming produce: meat (1), milk/diary (3) and fish (4)	1,3,4	meat F
	Non farmed (wild) meat (2) or fish (5) utilized at site	2,5	meat Non F
	Grown or picked for human consumption on site: vegetables (6), fruit (7), mushrooms(8), honey (9), eggs (10), crops (11)	6-11	crops cons
	Crops/plants harvested for non-human consumption on the site	12	crops non-human
Fibre	Fibre produced by animals from the site	13	fibre an
	Fibre produced by crops from the site	14	fibre crops
	Wood produce (not fire wood) harvested on the site (e.g. pulp/paper/sawn timber)	15	wood paper
Fuel	Wood harvested for fuel from the site	16	wood fuel
	Hydropower electricity produced at the site	17	hydropower
	Biomass grown at the site for energy needs	18	Energy BM
Genetic Resources	Animal species within site held for use as a genetic stock.	19	genetic Anim
	Plant species within site held for use as a genetic stock.	20	genetic plants
Biochemicals & pharmaceuticals	Species or breeds grown or raised on the site for use in biochemical and/or pharmaceutical industries/research.	21	pharmaceutical plants
Ornamental resources	Site resources used in producing ornaments, arts, crafts, etc.	22	ornaments

Service	Category	Ecosystem service	Ordination code
Fresh Water	Fresh water extracted for human consumption from within site	23	water humans
Regulating			
Climate regulation	Site is considered to be a net sink (reduction) of greenhouse gas emissions	24	gas emission positive
	Site has a lower albedo than surrounding area	85	low albedo
	Site has shade	86	shade
Water regulation	Dams/Reservoirs within the site boundary	25	dams
	Flood events (water going outside normal bounds) occurs on site	26	floods
	Water storage on site	27	water storage
Water quality regulation	Removal of nutrients from water occurs on site	28	nutriens removal
	Removal of heavy metals from water occurs on site	29	H metals removal
Regulation of human diseases	Reduction of water borne diseases and/or algal blooms (e.g. for wetlands, reduction of bacterial and virus pollution)	30	water diseases
Erosion regulation	Minimal erosion to areas within site boundaries.	31	erosion min
	Significant erosion to areas within site boundaries.	32	erosion max
	Dust / dry deposition sink	84	dust sink
Regulation of human diseases	Minimal risk of human disease from ecosystem within site boundaries.	33	disease min
	Significant risk of human disease within site boundaries.	34	disease max
Pollination	Nectar plants exist on site	35	nectar plants
Natural hazard regulation	Fire occurs on site	36	fire
	Land used for fire prevention	37	fire prevention
Other hazard regulation	The site regulates noise pollution (e.g. woodland reduces sound of busy road)?	38	noise regulation

Service	Category	Ecosystem service	Ordination code
Cultural			
Cultural diversity	Does the site contain landscape, biodiversity or habitat features which are used by (or in) amateur botanists (39), recreational anglers (40), bathers (62), bird watchers (41), climbers (42), cyclists (43), education (60), farmers (44), film making (59), foresters (45), fungal forays (46), green weddings (47), horse riding (48), hunting (53), ice based sports (64), lepidopteron enthusiasts (49), model/kite enthusiasts (50), mountain bikers (51), military or emergency training (58), education (60), motorized water sports (63), picnicking or general recreation (61), bathing (62), research (52), skiing (57), snow based sports (65), special needs groups (54), walkers (55), yoga practitioners (56)?	39- 65	
Spiritual and religious values	Are there natural features in the ecosystem of spiritual/religious value to either the local or larger population (e.g. Significant mountain summits, fairy pools etc…)?	66	religious natural
	Are there manmade features in the ecosystem of spiritual/religious value (e.g. churches, chapels, standing stones)?	67	religious manmade
Educational values	Is the site used in part for formal education purposes (e.g. school visits)?	68	school visit
	Is site used for informal education?	69	informal education
Aesthetic values	Are there species of the following taxa on site: Butterflies (70), ground beetles (71), moths (72), bats (73), birds (74), vascular plants (76), bryophytes (77), and lichens (78).	70-77	
	Are there interstitial elements from the following list occurring within site boundaries? (Ditch, path/track, road, hedgerow, fence, stone wall, waterway).	75	landscape features
	Are there statutory designations governing areas within the site (e.g. Natura 2000, SSSI, SAC)?	79	Nat reserve
Social relations	Is there easy access to the site e.g. via metaled road, rail link etc…?	80	access
Cultural heritage values	Are there special features present within the site boundaries? e.g. historic, Argyll stone in Cairngorms.	81	historic sites

Service	Category	Ecosystem service	Ordination code
Recreation and ecotourism	Are there tourist visitors to the site each year?	82	tourists
	Is there accommodation for tourist visitors at the site?	83	accom-modation tourists

Note: 1-73 from Dick et al. 2011, 74-83 added at subsequent European LTER meetings, 84-86 added by authors for the present analysis.

We used the data to address the following questions:
1. What ecosystem services are represented at each LTER site in the Northern Negev?
2. How do the sites differ in their ecosystem service inventory based on environmental variables and management agencies?
3. How familiar are site managers with the services available at their sites?
4. What does this process reveal regarding the research and management value of conducting ecosystem service inventories?

Following an introductory workshop on ecosystem services for LTER site managers in spring, 2011, the inventory list (Table 2) was distributed to five managers via e-mail, who were asked the following questions regarding each of 86 services:
1. Is the ecosystem service present in your site? (1 = yes, 0 = no)
2. How confident are you in your answer to the previous question? (1 = absolutely certain, 0 = absolutely uncertain).
3. What is the time frame of your estimate (e.g. for how long into the past do you think your answer is correct)?

After the data were collected, several inconsistencies were identified by data processors and addressed with each site manager. The second iteration resulted in several modifications in answers for two of the sites. Specifically lists were modified with the inclusion of additional services which had been omitted either due to lack of familiarity with the site, confusion with regard to site boundaries, or lack of clarity regarding the particular service. No data were modified for the three remaining sites. As a final step to increase confidence in the answers, a third iteration of the survey was conducted with an ecologist and expert with extensive research experience in all five sites. Where there were disagreements between the consulting expert and the site managers, the data processors worked with the site managers to reconcile the inconsistencies and decide on a final answer, while maintaining an estimate of confidence reflecting the collective confidence in the answer.

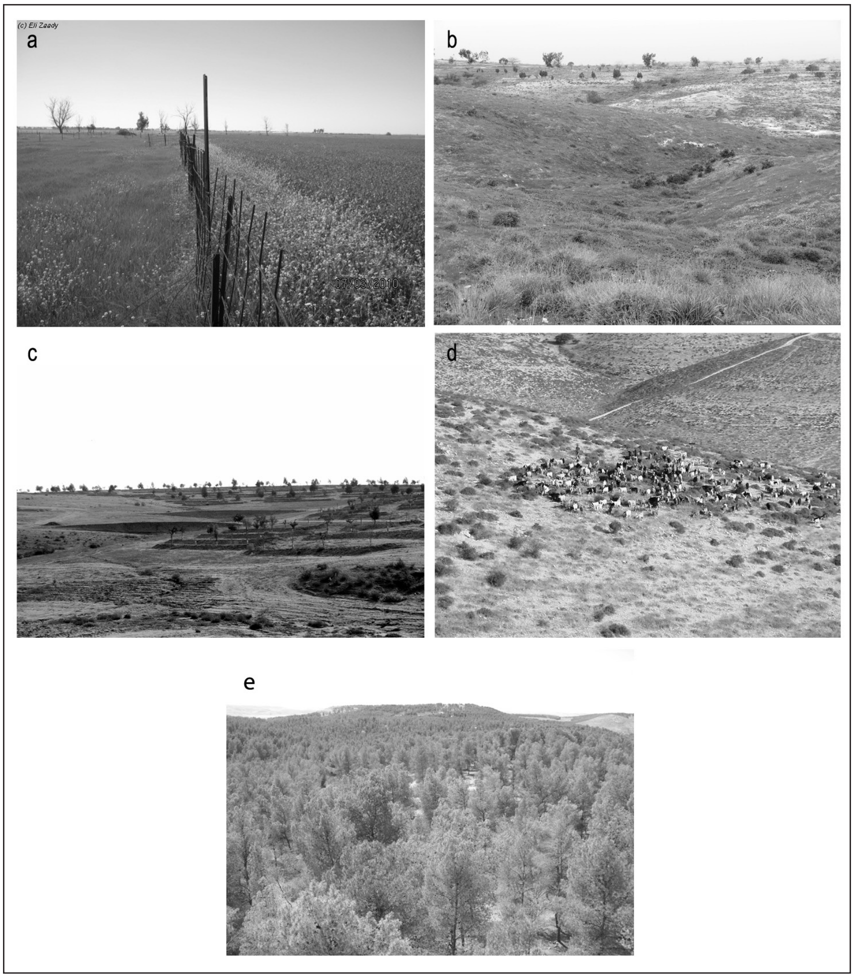
Table 3: Research sites comprising the Northern Negev LTSER Platform

Site	Altitude (m)	Area (ha)	Dominant land cover	Dominant land use	Annual rainfall (mm)	Minimum and maximum recorded temperatures (°C)	Management agency	Date became a recognized LTER site
Migda	150	5000	Agriculture	Rangeland, field crops, orchards	250	4, 39	MoA	2008
Shaked	200	300	Shrub	Terraced forestry, rangeland	150	2, 42	KKL	1994
Shagririm	270	1500	Shrub	Terraced forestry, rangeland	270	0.5, 42.2	KKL	2007
Lehavim	350-500	800	Shrub	Rangeland	300	0, 40.5	MoA	1993
Yatir	600	4000	Forest	Forestry, orchards	275	-1, 42	KKL	2000

The research was conducted in five Northern Negev LTER sites, which are all part of the broader Northern Negev Long-Term Socio-Ecological Research (LTSER) Platform. The locations of the sites – Migda, Shaked, Shagririm, Lehavim and Yatir – are shown in Figure 2, their relevant characteristics are found in Table 3, and typical landscape from each is displayed in Figure 3a-e.

The number of ecosystem services found at each site for each of the three categories (provisioning, regulating and cultural) was tallied and analyzed. Similarities in ecosystem service composition between sites were examined using multivariate analysis, in particular Principle Component Analysis (PCA) with CANOCO software (Ter Braak and Smilauer, 2006). The PCA provided graphic representation of the sites showing how similar they are to one another and emphasizing which of the services most heavily influence similarities. To show the importance of environmental variables we used redundancy analysis (RDA) in CANOCO (Ter Braak and Smilauer, 2006), followed by a Monte Carlo test of 9999 runs to test for randomness. The RDA examined to what degree the recorded environmental variables affect the similarity between sites. The variables included geographic location (latitude and longitude), altitude, annual precipitation, maximum and minimum temperature, area of site, number of land cover classes, manager of site (Jewish National Fund-Keren Kayemeth LeIsrael - KKL[3] or the Ministry of Agriculture - MoA).

Figure 3: A typical landscape scene from each of the five NorthernNegev long-term ecological research (LTER) sites (a = Migda; b = Shaked; c = Shagririm; d = Lehavim; e = Yatir)



Note: Photograph 3d courtesy of Moran Segoli.

Similarities between sites in terms of their ecosystem services were further measured on a pairwise basis using the Bray-Curtis similarity index where a resulting value of 1 represents identical services between two sites and a value of 0 represents no overlap in services between sites. The equation is:

$$BC = 1 - \Sigma \left[\left|(A - B)\right| / (A + B) \right]$$

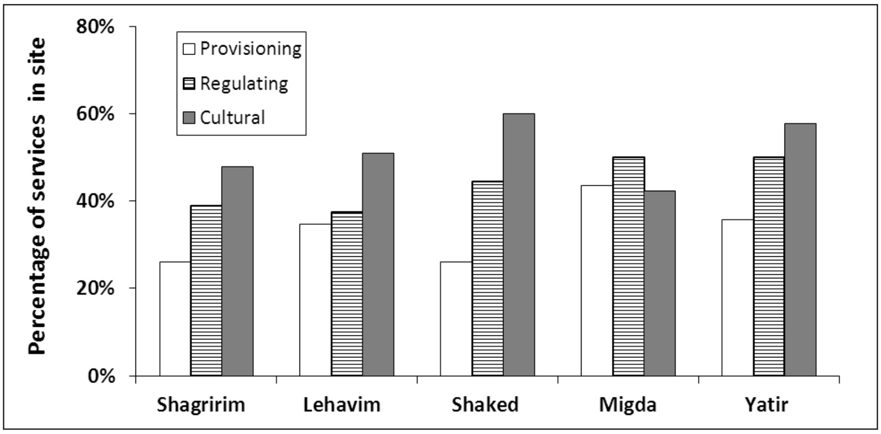
where the values of A and B vary between 1 (presence) and 0 (absence) for each ecosystem service at sites a and b, respectively.

RESULTS

Ecosystem service inventory and characterization

The five LTER sites of the Northern Negev contain a large portion of the 86 ecosystem services assessed: 66% are found in at least one of the five sites, 50% are found in at least three sites, and 23% (20 services) are found in all five sites (Figure 4). Of the remaining 29 services not found in any of the Northern Negev sites, half are generally not associated with semi-arid, water-limited ecosystems (e.g. snow- and open water-related services). Removing these services not associated to drylands, 80% of the remaining services were found in at least one of the sites.

Figure 4: Percentage of services provided in each site according to the three categories – provisioning, regulating and cultural



The Shaked and Yatir LTER sites were richest in cultural ES, with more than 80% of the cultural services present in the Northern Negev found in those sites. On the other hand, Shaked and Yatir, together with a third KKL site, Shagririm, had relatively few provisioning services (around 45%) compared to Lehavim and Migda (both MoA sites), which had more than 60% of the provisioning services present, including food and genetic resources. Yatir (KKL) and Migda (MoA) had the most regulating services.

With regard to similarity (Table 4), when considering the stock of all ES, all the sites had a high degree of similarity, with a Bray-Curtis similarity index of 0.68 or more. The most highly similar sites were Shagririm (KKL) – Yatir (KKL), Shagririm (KKL) – Shaked (KKL), Lehavim (MoA) – Yatir (KKL), and Shaked (KKL) – Yatir (KKL). The largest differences were between Migda (MoA) – Shagririm (KKL) and Migda (MoA) – Shaked (KKL). These results suggest a higher degree of similarity among the KKL sites than between KKL sites and MoA sites.

Table 4: Similarities between sites (measured by Bray-Curtis similarity index) according the ecosystem service categories

	M-L	M-Sk	M-Sg	M-Y	L-Sk	L-Sg	L-Y	Sk-Sg	Sk-Y	Sg-Y
Cultural	0.83	0.70	0.77	0.82	0.82	0.70	0.88	0.85	0.85	0.78
Provisioning	0.67	**0.50**	**0.50**	**0.57**	0.71	0.86	0.74	0.67	**0.56**	0.85
Regulating	0.73	0.82	0.75	0.78	**0.54**	0.73	0.63	0.80	0.82	0.88
All	0.77	0.68	0.70	0.76	0.75	0.73	0.80	0.81	0.80	0.81

Note: 1 = similar, 0 = different); L = Lehavim, M = Migda, Sg = Shagririm, Sk = Shaked, Y = Yatir. The most similar sites (BC ≥ 0.8) according to ecosystem service type are shaded in grey; the most dissimilar sites (BC ≤ 0.6) are marked in bold-face italics.

In general, there was greater similarity in the stock of cultural services between sites (six pairs of sites showing high similarity), and less similarity in the stock of provisioning services (only two pairs of sites showing high similarity, and four pairs showing high dissimilarity). Results for regulating services were mixed, with some sites showing a high degree of similarity (Migda – Shaked; Shaked – Shagririm; Shaked – Yatir; Shagririm – Yatir) and two sites showing a high degree of dissimilarity (Lehavim – Shaked).

Ordination

The ordination of all services inventoried (Figure 5) shows that the first two axes explain 62% of the variance. The first axis (Eigenvalue = 0.39) divides the sites into MoA sites on the right-hand side and KKL sites on the left. The Migda site (MoA) is closely associated to genetic resources, fruit and vegetable production, and landscape features used by farmers. Yatir (KKL) is uniquely associated with fire prevention, wood production, and picnics, among others. Shaked and Shagririm are associated to bird watching, religious sites, cycling, hunting and horseback riding. As with the similarity index, here, too, Shaked and Shagririm (both KKL) are found to be more closely associated to one another than to the other sites. Among the environmental variables, the most significant variable was the site management (i.e. MoA or KKL), but it was only marginally significant (F=1.6, P=0.096) in the direct test (RDA). This result, considering the management goals of each organization, is consistent with the types of services associated with each site according to the ordination for all services (Figure 5).

Ordination of provisioning services (Figure 6) shows that Migda (MoA) is separated from the other sites. Migda has many more provisioning services than the other sites due to its focus on agriculture (fruits, vegetables, biomass, genetic stock), but did lack other provisioning services that were found in other sites (e.g. honey, wood products). The other sites are similar with regard to provisioning services and have a similar value for the first axis, with Shagririm (KKL) found between Lehavim (MoA) and Yatir (KKL).

Figure 5: Principal component analysis of **all services**. Eigenvalues of axes are 0.392 and 0.229

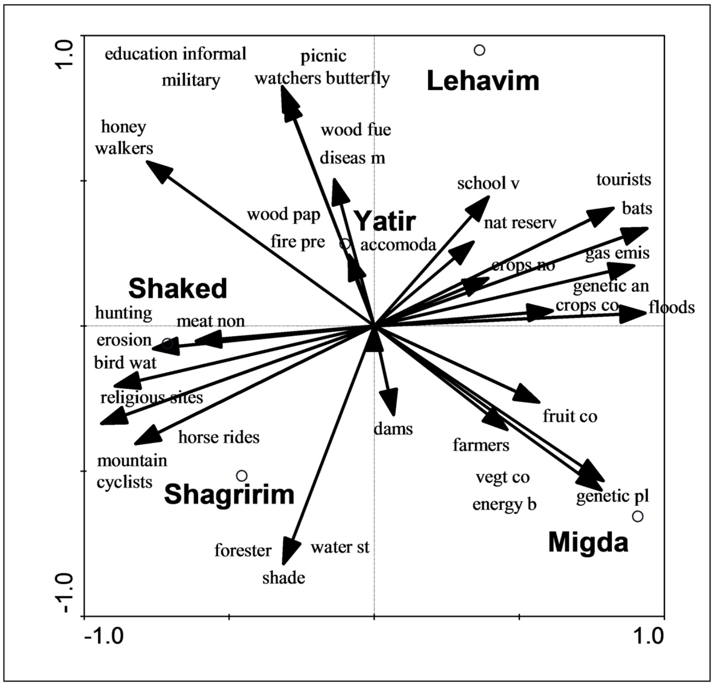


Figure 6: Principal component analysis of **provisioning** services. Eigenvalues of axes are 0.482 and 0.305

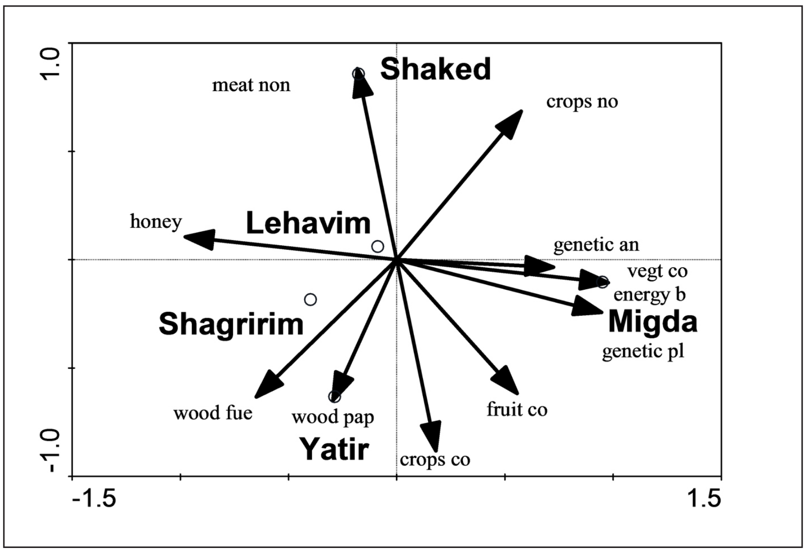


Figure 7: Principal component analysis of **regulating** services. Eigenvalues of axes 0.463 and 0.307

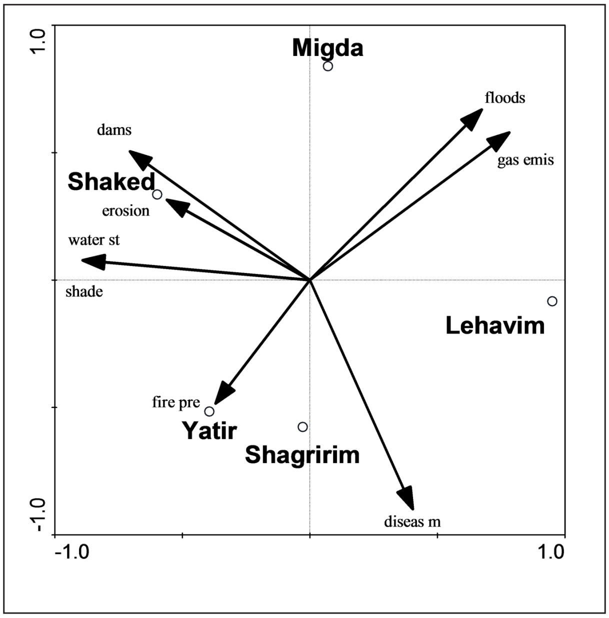
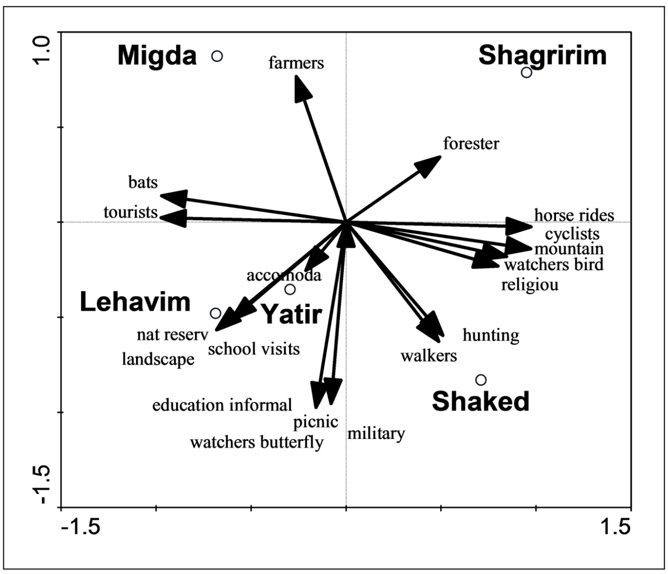


Figure 8: Principal component analysis of **cultural services**. Eigenvalues of axes are 0.458 and 0.34



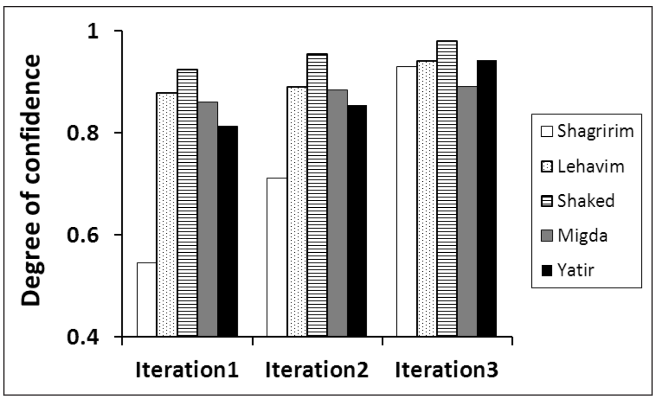
In the ordination of regulating services (Fig. 7), the first axis includes most of the parameters and shows Shaked and Yatir (both KKL) on the left side and Lehavim (MoA) on the extreme right side. This axis is separated mostly by shade (Lehavim does not have trees, while both Yatir and Shaked are forested, though at different densities). Shaked is further associated to variables related to runoff harvesting (dams, erosion control, water storage), which is a major management activity of the site.

The cultural services ordination (Figure 8) also has a clear segregation, showing Shaked and Shagririm (KKL sites) on one side with recreational services including cycling, horse riding and bird watching and Yatir (KKL), Lehavim (MoA) and Migda (MoA) on the left side, associated to services including resources for farmers (most closely associated to Migda), tourists, school visits and presence of bats.

Certainty

By conducting the survey in three iterations, uncertainty was greatly reduced between iterations by discussing each service with site managers and then, lastly, including consultation with an additional expert. By the conclusion of the survey, confidence in the presence/absence of the ecosystem services was near or over 0.9 on a 0 to 1 scale for all five sites (Figure 9).

Figure 9: Mean confidence regarding the presence or absence of 86 services at each site for successive iterations of the survey. 1=absolutely certain; 0=absolutely uncertain



In general, there was slightly less certainty regarding the presence/absence of cultural services than there was of regulating or provisioning services. This uncertainty was influenced primarily by lack of knowledge regarding particular human uses, including bird and butterfly watchers, horseback riders, hunters and habitat features used by farmers. Likewise there was uncertainty regarding the presence of certain taxa, including moths and bats (recall that biological diversity was considered a cultural service in this survey). The major uncertainties with provisioning services were regarding honey production and non-farmed meat (i.e. hunting).

DISCUSSION AND CONCLUSION

Creating an inventory of ecosystem services provided valuable lessons, not only in terms of the results, but also in terms of the process because the field of ecosystem service assessment is only beginning to develop globally.

The presence of a service may depend on at least three elements: the ecosystem, the management (land use) and the culture of the people benefiting from the ecosystem. Unlike the Dick et al.'s study (2011), which surveyed a broad range of ecosystem types, our five sites represent similar ecosystems, and despite differences in rainfall, temperature, and local ecology, these factors were not shown to be significant in differentiating between the ecosystem service stock of each site. The only discernible difference in ecosystem service stock between sites seems to be land use management strategies determined by the management agencies – KKL and MoA. The Lehavim and Migda sites are managed by the MoA with the explicit goal of conducting grazing and agricultural research. Those sites are highest in provisioning ecosystem services and lowest in cultural ES. On the other hand, the remaining three sites are managed by KKL, where goals include land development, afforestation, recreation, and research. These sites are higher in cultural services and lower in provisioning services, though as part of their sustainable land use strategy, grazing and other economic uses of the land are permitted and in some cases encouraged.

A specific example of the impact of management on an ecosystem service is shade. Shagririm (KKL) and Lehavim (MoA) are approximately five km apart, but the former provides shade while the latter does not. This is due to the different management goals of the sites: Lehavim's main goal is to provide grazing opportunity (Figure 3d), while Shagririm's goal is to provide trees for recreation, form a green belt and establish a physical presence on the land (Figure 3c).[4] Finally, some sites may differ in the services they provide (mostly cultural) because of the culture of its neighbors and the public perception of the site. The Migda (MoA) site is not readily accessible to the public and site managers did not, until recently, encourage recreational and educational use of the site beyond research. Thus, Migda does not provide services to bird and butterfly watchers, cyclists and hunters because the public does not come to that site, although there are biological characteristics that may draw them there. The public does come to Lehavim (MoA) and Shaked (KKL) to utilize these services.

With regard to process, the survey revealed a fair amount of uncertainty regarding the presence/absence of particular services as well as the limitations of expert knowledge. Site managers have extensive experience conducting research and managing their sites, but the ecosystem service inventory activity revealed that their knowledge of the sites is often highly specialized and oriented towards their particular research (e.g. grazing systems, water and soil dynamics, or herbaceous diversity and productivity). The first-round inventory results were marked by significant uncertainty in some sites and required two additional rounds of inquiry and the addition of an external expert to hone the answers and raise certainty. It is noted that in some cases, uncertainty was a function of lack of clarity regarding the question being asked, but in most cases, it was lack of knowledge regarding the presence/absence of a particular service (e.g. bats, mushrooms, or disease regulation). With regard to cultural services, this observation emphasizes the need for social assessments with stakeholders (e.g. Gee and Burkhard, 2010; Sagi et al., 2012) to supplement expert knowledge.

This problem of uncertainty is further compounded by a relatively small sample size. The small sample size is due to the small number of LTER sites in the Northern Negev. However, the fact that a significant variable (management agency) was revealed suggests relatively robust results, despite the small sample size. Nonetheless, future analyses will include a larger number of sites, either non-LTER sites in the Northern Negev (e.g. nature reserves) or LTER sites from other geographic areas, which will both enlarge the data base and strengthen the statistical analysis.

Two important management recommendations arise from this analysis. First, at each site, the system is managed to encourage a particular suite of ecosystem services and such management practices could lead to the increase of some services at the expense of others. Most often, such practices encourage the increase of provisioning services at the expense of regulating and cultural services (Foley et al., 2005; De Groot et al., 2010). However, management strategy can also be developed to maximize the diversity of ecosystem services available (Koniak et al., 2011), or alternatively, management strategy may preclude the development of certain services (De Groot et al., 2010; Dick et al., 2011; Maes et al., 2011). In the northern Negev, all of the KKL sites are encouraging the increased recreational use of their sites (interview with Zohar Tzafon, landscape architect, KKL southern division, May 2012). Recreational use, in particular use that focuses on non-consumptive and nature-focused uses (i.e. ecotourism), can be integrated without substantively altering the provision of other services. With regard to the MoA sites, the Migda site staff has begun to incorporate educational programming into the site goals, thereby increasing the cultural services offered. These will not likely compromise the ability to continue to provide the other services at the site. The inventory provides guidelines for which ecosystem services are currently absent, but also which could be added, and importantly, draws attention to where our knowledge is lacking with regard to our sites.

The research also lends further support to those conclusions reached by Dick et al. (2011), notably that Northern Negev LTER sites, like their analogous ECN sites in England, "are very well placed to contribute to the scientific assessment of the synergies and tradeoffs in ecosystem services… associated with the application of management practices" (Dick et al., 2011, 647).

Recommendations for further studies – the learning process

Many of the difficulties in conducting the inventory could be remedied through minor additions and modifications of the process, including:

1. Clear and mutually agreed-upon site boundaries should be established prior to conducting the inventory. The boundaries of the LTER site are not always clear or delineated, in which case disagreements may arise solely as a function of alternate definitions of geographic boundaries. Dick et al. (2011) found that utilitarian reasons (e.g. biogeography and managerial boundaries) best informed the site managers regarding the boundaries of their sites).
2. The inventory, while it should be standardized for use across countries and regions, should be reviewed and modified with the collaboration of site managers. There are additional important services (such as the three added for this research – albedo, shade and dust sink) that were not included in the original inventory (which was prepared for a European venue) as they are important in dryland environments, and which should be added to the original ecosystem service list.
3. While the amount of potential services extends far beyond the current list, we suggest particular consideration regarding the addition of those components of biodiversity that are crucial for supporting and regulating services (e.g. soil microfauna; MA, 2005b), but which weren't included. In the current list, biodiversity is largely restricted to cultural services, and as such the species representing biodiversity are primarily those that are visible and aesthetic.

We recognize that we have chosen, as a first step, to do a breadth-study at the expense of more in-depth studies of particular services. Yet we believe that in this new field of inquiry, it is crucial to take a first step to assess the state of knowledge regarding ES. This step is proposed as complementary to more in-depth, single- or bundled-service based studies, and to stakeholder-based assessments that can better capture cultural services (Gee and Burkhard, 2010; Maes et al., 2011; Sagi et al., 2012). In order to realize the utility of the ecosystem service concept to land management, the next steps include broadening our knowledge of our given sites to include ecosystem services that we were previously unaware of, developing the list of services that are unique to arid areas, recording temporal change in the supply of ecosystem services, and studying further how management decision making can increase or decrease the diversity of services offered in LTER sites.

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NOTES

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2. Note that in Dick et al. (2011), as in the current research, biodiversity is considered a cultural service. The MA notes that biodiversity underlies all ecosystem services, and affects their supply both directly and indirectly via ecosystem processes (MA, 2005b), although the relationship between biodiversity and ecosystem services remains contentious (see, for example, Jax, 2010; Maes et al., 2011; Naidoo et al., 2008). We return to this issue in the discussion section.
3. The Jewish National Fund is Israel's quasi-governmental forestry service, managing a significant portion of the country's open space. Its management strategies have traditionally focused on forestry, research, runoff water harvesting, and development of recreational infrastructure. For more information, see Tal, 2002.
4. This latter goal was noted repeatedly in a series of interviews with regional land use managers and is linked to ongoing land ownership disputes (Orenstein and Hamburg, 2009).

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