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The aesthetics of water and land: a promising concept for managing scarce water resources under climate change

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The eastern Mediterranean faces a severe water crisis: water supply decreases due to climate change, while demand increases due to rapid population growth. The GLOWA Jordan River project generates science-based management strategies for maximizing water productivity under global climate change. We use a novel definition of water productivity as the full range of services provided by landscapes per unit blue (surface) and green (in plants and soil) water. Our combined results from climatological, ecological, economic and hydrological studies suggest that, in Israel, certain landscapes provide high returns as ecosystem services for little input of additional blue water. Specifically, cultural services such as recreation may by far exceed that of food production. Interestingly, some highly valued landscapes (e.g. rangeland) appear resistant to climate change, making them an ideal candidate for adaptive land management. Vice versa, expanding irrigated agriculture is unlikely to be sustainable under global climate change. We advocate the inclusion of a large range of ecosystem services into integrated land and water resources management. The focus on cultural services and integration of irrigation demand will lead to entirely different but productive water and land allocation schemes that may be suitable for withstanding the problems caused by climate change.

Keywords: blue–green water approach; ecosystem services; global change; integrated land and water resources management; Middle East; water productivity

1. Water and climate change

Many semi-arid regions will suffer from the consequences of global climate change, not only because of warming but also owing to changes in annual precipitation. For example, the Mediterranean basin is one of the few regions where global

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circulation models agree in their prediction of decreasing precipitation totals (Bates *et al.* 2008). Since such regions are already water-limited, strategies for sustainable water management are urgently needed. The Jordan River basin is located in a particularly water-stressed region with world-wide record lows in per capita water availability (Smakhtin *et al.* 2004). Therefore, it is an ideal model region for investigating the consequences of and adaptation to water scarcity under climate change. For example, Israel has been classified as having roughly half of the absolute water scarcity level of 500 m^3 water per capita per year (Tal 2006), an estimate applicable to the neighbouring countries, too.

Three main factors are responsible for the emerging water crisis in the Jordan River basin:

— Natural water availability is low, ranging from extremely arid conditions (less than 20 mm annual precipitation, high variation) in the south to Mediterranean climates in the north. Both low average as well as high unpredictability of precipitation present a challenge for water management, especially as much of the current water is not used sustainably.

— Water demand is rapidly increasing due to population growth, which is among the largest world-wide (1.6–3.2% depending on country; United Nations 2007). At the same time, the Middle East already today uses more fresh water than is available from renewable resources (Vörösmarty *et al.* 2005).

— Water supply is decreasing due to climate change. Namely, global and regional climate models consistently predict an increase in temperatures, coupled with decreasing annual precipitation and an increase in the occurrence of climatic extremes (e.g. Bates *et al.* 2008; Black 2009; Kafle & Bruins 2009; Jin *et al.* 2010).

These combined factors will considerably widen the water gap in the next decades. Therefore, strategies for sustainably managing the scarce resources are urgently needed. In this study, we present a novel and maybe controversial approach for addressing the water problems in the region and possibly beyond.

2. The GLOWA Jordan River project: an integrated approach to water management

Any strategy for managing the scarce water resources in the Jordan River basin must integrate between the physical basis of water supply (e.g. scenarios of water availability under climate change) and the water demand side (e.g. adaptive land use) while at the same time taking into account the social and economic boundary conditions. Also, policy making should be based on sound scientific evidence rather than educated guesses. Thus, a new research paradigm has emerged addressing the impacts and adaptation options to global change that highlights the need for integrated approaches to applied problems. Since climate change is likely to affect many regions in the world and diverse sectors, scientists from the natural and social sciences should work together and interact with decision makers to develop scientifically sound options for management

Table 1. Traditional water productivity estimates in agriculture—gross domestic product (GDP) and agricultural water consumption (AWC) in Israel, Jordan and the Palestinian Autonomy (from FAO: http://faostat.fao.org; and Palestinian Central Bureau of Statistics: www.pcbs.gov.ps).

	Israel	Jordan	Palestinian Autonomy
GDP in agriculture, 2000 prices (US$ million)	1447	592	252
AWC (10^6 m^3 yr^{-1})	1130	611	282
water productivity: GDP/AWC	1.28	0.96	1.12

under global change (Gerten 2008). In the context of water management, such transdisciplinary approaches may be summarized under the concept of integrated water resources management (IWRM).

The design of the GLOWA Jordan River project reflects this paradigm. In particular, researchers from many disciplines and key stakeholders develop tools and management options to address the emerging water crisis (Hoff *et al.* 2006). Our ambitious goal is to develop management strategies that allow maximizing water productivity in the region under changing climatic, social and economic conditions. The project design has been based on an important assumption: *water- and land-use management are inseparable*. As a consequence, we build on a new approach to the concept of water productivity. The traditional view as 'crop produced per drop' is depicted in table 1. In that example, water productivity is calculated as the returns (measured in gross domestic product (GDP)) obtained from a certain amount of (fresh) water.

Here, we advocate a novel and integrated view on the concept of water productivity. Namely, we assume that important factors have been underscored that should be added to both the numerator as well as the denominator of water productivity. In the following, we argue that our modifications of traditional water productivity estimates may be a key to sustainable water management in the Jordan River basin and beyond.

3. The denominator of water productivity: integrating blue and green water

Our first modification addresses the common underestimation of the demand side of water management. Since fresh water supply in the region has always been limited, technologies for increasing blue water availability have been developed in the region and are frequently and successfully applied (Tal 2006). This apparent success has led to a narrow view on water policy, which ignores the fact that there are two types of water involved in (food) production: blue water in aquifers, lakes, rivers and wetlands; and the so-called green water, the water stored and recycled through plants and soils (e.g. Falkenmark & Rockström 2006). Precipitation is the only resource for green water, and therefore there is a major difference in the management of these two resources. Blue water availability can be increased by certain technologies and policies such as, for example, wastewater treatment, desalination and virtual water trade (Tal 2006).

Green water must be managed by modification of the land-cover type, which affects runoff and evaporation (Falkenmark & Rockström 2006). Therefore, green water management and land-use management can be viewed as equivalent.

Green water may account for more than 80 per cent of the global consumptive water use for a wide variety of crops (Liu *et al.* 2007). Therefore, it is surprising that it has usually been ignored in an IWRM context. Falkenmark & Rockström (2006) and Rockström *et al.* (2007) have repeatedly stressed that a blue–green approach to water management (integrated land and water resources management, ILWRM) is the key to addressing unsustainable water use, particularly in semi-arid regions. In these regions, rainfed agriculture, i.e. land use that entirely relies on green water resources, plays a major role, and many problems related to desertification may actually be linked to green water in the soil. Also, the additional water needed to fill the water gap is likely to originate from rainfed land use (Rockström *et al.* 2007). Owing to the importance of green water in producing goods and services, we advocate a change in the denominator of water productivity that considers both blue and green water resources.

4. The numerator of water productivity: appraising the full range of services provided by landscapes

The classical approach to estimating water productivity of certain land-use types is to calculate the revenue produced per unit water. Revenue is, for example, the yield of a certain crop and its associated market value or, on a larger scale, the GDP (table 1). However, the value of a certain land-use category is determined not only by its crop yield but in terms of all the services this land-use type provides to society. Since the Millennium Ecosystem Assessment (2005), awareness has increased about the fact that landscapes provide a multitude of services to society whose importance is estimated to increase (Alcamo *et al.* 2005). These services include three main classes: provisioning services (e.g. fresh water, food), regulating services (e.g. flood control, water purification), and cultural services (e.g. aesthetics, recreation). If we are to calculate the returns provided by a particular landscape, we should, theoretically, evaluate all water-related services provided to society. Clearly, the evaluation of all possible ecosystem services is not feasible, as their number is large and some services are difficult to measure. However, traditional estimates of water productivity that focus on provisioning services only (i.e. market value of food production, table 1) are clearly insufficient. The narrow focus on provisioning services and, to a lesser extent, regulating services is also characteristic of the few studies that have explicitly integrated water-related ecosystem services into ILWRM (Rockström *et al.* 1999; Falkenmark 2000, 2003; Falkenmark & Rockström 2006; Brauman *et al.* 2007). Similarly, large-scale assessments of ecosystem services have failed to quantify cultural services, too (Alcamo *et al.* 2005; Schröter *et al.* 2005). Namely, provisioning services such as crop yield, timber or fish are easily recognized and are highly valued, but other service types often go unnoticed (Vitousek *et al.* 1989). There are several reasons for the focus on provisioning services. On the one hand, they are more amenable to quantification, while modelling tools for large-scale assessments of cultural services are not available (Schröter *et al.* 2005). On the other hand, there is a lingering controversy whether contingent valuation methods provide reliable estimates for cultural services. However, Hausman (1993) summarized a critical evaluation of such studies, while later a group of experts (NOAA 1994) established good practices for contingent valuation. Based on these improved methods, cultural services (e.g. landscape value) are predicted to expand in importance considerably in the future (e.g. Metzger *et al.* 2006) because of increased demand following population growth and/or increased appreciation and availability of disposable income for recreation owing to economic growth (e.g. Fleischer & Tsur 2009). This highlights the need to include them into integrated assessments of the value of landscape and water. Furthermore, landscape values produced by natural and agro-ecosystems may be tremendous (Ellingson *et al.* 2009). With the present study, we want to address this gap in ILWRM by applying the concept of ecosystem services to estimates of water productivity. We focus here not only on natural, but also on agricultural landscapes, because they are the dominating land-cover type in most regions while their non-market value has often been ignored (e.g. Daily *et al.* 2009).

To summarize, the concept of water productivity should be expanded both by the green water concept as well as by integrating a wide range of services provided by water. In the following, we want to illustrate that our integrated approach to maximizing water productivity may be a key to addressing the emerging water crisis in the Jordan River basin. In particular, we tested the following hypotheses:

— The recreational and aesthetic value of a landscape may be much larger than returns from provisioning services.
— Water productivity of rainfed landscapes may be maintained under climate change and may exceed that of irrigation water-dependent land-use schemes.
— Water productivity of irrigated agriculture will drastically decrease under climate change, owing to a marked increase in water demand.

We illustrate our findings using Israel as a case study. However, we will discuss the applicability of our findings to other countries with different economic boundary conditions.

(*a*) *Recreational value of agricultural landscapes*

Agricultural land has been recognized as being able to provide, in addition to food and fibre, public amenities in the form of wildlife habitats, protection of natural resources, open spaces, aesthetic scenery and cultural preservation (e.g. Ellingson *et al.* 2009). The landscape value of farmland consists of the benefits derived from the scenic beauty generated by rural landscapes, such as open fields, orchards and herds of livestock grazing in green meadows. As such amenities are public goods, market forces fail to allocate them correctly, and there is a need for some sort of policy intervention. This, in turn, requires measurement of the value of this public good and the design of effective policies for its preservation. In a previous study, we have evaluated the value of agricultural landscape in two rural regions in northern Israel (Fleischer & Tsur 2000). Based on a contingent valuation approach (willingness to pay, WTP) and actual data of tourist activities in the two regions, we found that the landscape value of farmland is substantial and by far exceeds the returns from farming. Namely, the estimates

Table 2. Yearly loss in value of ecosystem services under simplified climate change scenarios that assume a change from mesic Mediterranean to three drier climatic conditions: Mediterranean, semi-arid and arid climates, respectively (for methodology see Fleischer & Sternberg 2006).

simplified change scenario	loss of total biomass (tons ha^{-1})	total WTP to prevent loss of biomass ($\$10^6\ ha^{-1}$)	loss of herbaceous biomass (tons ha^{-1})	loss of grazing services ($\$\ ha^{-1}$)	
				cattle	sheep
mesic Med. → Med.	7.8	51.5	0.009	9.1	12.7
mesic Med. → semi-arid	13.0	85.8	0.256	25.6	35.8
mesic Med. → arid	16.3	107.6	0.818	81.8	114.5

of recreational value of the landscape amounted to US\$119 myr^{-1}, while returns from food production were much less (US\$25 myr^{-1}). This is consistent with our most recent study that indicated high landscape values for open space and orchards (Fleischer & Tsur 2009). Also, Drake (1992), who estimated the WTP to preserve agricultural land against conversion into forest in Sweden, found that agricultural landscape value (about US\$130 per hectare) is higher than the return from agricultural production in most parts of Sweden. These findings illustrate that the cultural (e.g. recreational) value of a landscape is an integral part of the value produced by land use, and thus also by the water needed to maintain this value.

(*b*) *The recreational value of rangelands under climate change*

From a policy perspective, the value of water in one particular land-use type is more easily perceived when compared with another one. Therefore, we have also analysed water productivity of other agricultural practices, non-agricultural practices and of natural and semi-natural ecosystems that are often used as grazing land (Fleischer & Sternberg 2006). These economic studies were combined with ecological studies that investigated the effect of climate change on the structure and function of these ecosystems (see §2*c*). Therefore, of particular value for this study was the evaluation of simplified climate change scenarios, where we assumed that landscapes would shift to a state similar to landscapes with currently more arid conditions. Similar to agriculture, rangelands provide market services such as fodder for grazing animals, and non-market values such as landscape, culture and recreation. In our study, we have evaluated the loss in both types of services that can be expected under climate change (Fleischer & Sternberg 2006). The loss of the aesthetic landscape value was then assessed with a WTP approach that was based on hypothesized changes in landscape structure. These changes were visualized by presenting to the sampled population pictures of actual landscapes that corresponded to the assumed climatic conditions in the future. Similar to the analysis of purely agricultural systems, we found out that the recreational value of this land is several orders of magnitude higher than the grazing services (table 2). For example, a change in landscape in the northern region from mesic Mediterranean (800 mm annual precipitation) to drier conditions (less than 100 mm) was valued by the urban population as a loss in

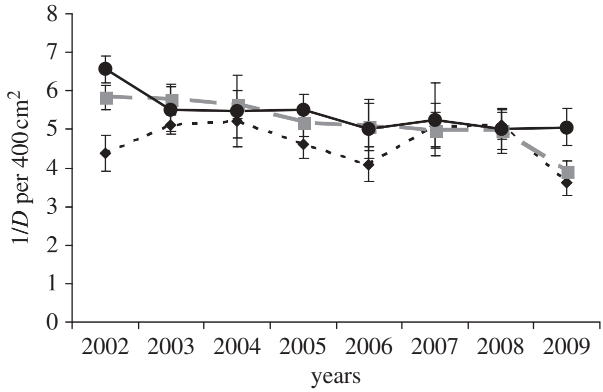

Figure 1. Mean (±s.e.) plant diversity (Simpson's index $1/D$) per $400\,\mathrm{cm}^2$ of natural plant communities that were subjected to seven years of drought (dry, filled black diamond), irrigation (wet, filled black circle) and natural (control, filled grey square) rainfall conditions in a Mediterranean site in Israel. There were no significant effects of year, rainfall treatments or their interaction on plant diversity ($n = 25$, $p > 0.39$, ANOVA with first year's diversity as covariate).

welfare between US$51.5 million and US$107.6 million (table 2). In contrast, the per-year loss for livestock growers based on a simplified scenario for productivity loss was several orders of magnitude smaller than these figures—a striking difference between the aesthetic and grazing values of these landscapes. Another interesting side result was that the aesthetic value of a landscape correlated positively with its productivity, i.e. more productive (greener) landscapes were valued more highly than less productive ones. Therefore, in water-limited regions, productivity may be an easy-to-measure proxy for the recreational value of landscapes.

(*c*) *Rangeland response to climate change*

In addition to estimating rangeland value, we have also performed field experiments for testing the actual change in the structure and function of these ecosystems to climate change. In 2001, we established climate manipulation experiments in permanent field sites along the steep climate gradient that is characteristic of the region. The sites correspond to a range from arid (less than 100 mm annual precipitation) to mesic Mediterranean (800 mm) conditions (see Petrů & Tielbörger (2008) for detailed site description and experiments). Here, we present representative findings from seven years of climate manipulation in a Mediterranean station (550 mm annual rainfall). One climate manipulation treatment was a reduction in annual rainfall by approximately 30 per cent by means of rainout shelters. In another treatment, we increased annual rainfall by 30 per cent using irrigation. A third treatment served as control (natural rainfall). Each year, we monitored soil processes and biomass, and the density and diversity of the natural plant community. The results of most measurements show a striking resistance to the manipulations. For example, there was no significant effect of the rainfall treatment on plant species diversity (figure 1). Similar findings were obtained for biomass response (Kigel & Konsens 2010, unpublished data), which affects both provisioning and cultural services provided by rangelands. Namely, the productivity and density of the herbaceous vegetation did not respond to drought, and showed a rather small response to irrigation at the Mediterranean site. In combination, these findings indicate that the natural plant communities characteristic of many rangelands in the region may be relatively resistant against climate change. Given this observation and our economic studies, natural and semi-natural systems (i.e. rangelands) may maintain their value even under climate change. Most important for water management is the fact that these systems do not require any additional input of fresh water, i.e. their value is produced entirely by precipitation and subsequent green water flow. Since these systems are apparently resistant to reductions in rain, their relative water productivity may thus even increase under climate change, because they may yield similar returns for less input of (green) water.

(*d*) *Irrigated agriculture under climate change*

The above evaluations focused mainly on recreational value and some dealt with rainfed land use only. However, most agriculture in the region depends on irrigation and thus we must look at these land-use systems, too. We have first assessed the economic effects of climate change on Israeli agriculture with a stronger focus on market values as a function of changes in temperature and precipitation (Fleischer *et al.* 2007). In this study, we have distinguished between the effects of temperature alone and the effects when irrigation water was included. Currently, about 60 per cent of the (blue) water resources in Israel are used for irrigation. Therefore, a major result from our study was that climate change will be particularly detrimental to annual revenues if irrigation water is included in the calculations, despite an increase in revenues due to increased temperatures alone. However, we did not take into account the probable decrease in water supply under conditions of warming and decreased rainfall. Thus, we expect an even more detrimental effect of climate change on annual returns, because more water will be needed for irrigation and increased water prices are probable.

This aspect was addressed quantitatively within the GLOWA Jordan River project by means of a hydrological simulation study. Here, we estimated the irrigation water demand of the main crop types cultivated in the principal agricultural belt along the Mediterranean coast in Israel and the Jordan Valley in both Israel and Jordan for different climate change scenarios (Menzel *et al.* 2009). From a current land-use map, we selected those crop types which are usually under supplementary irrigation. We then simulated irrigation water requirements with a hydro-ecological model, driven by daily data of precipitation, air temperature and other weather variables over the control period 1961–1990. Furthermore, actual evapotranspiration and water availability (runoff and groundwater recharge) were simulated for the whole area (approx. 100 000 km^2), including all existing land-use and land-cover types of the region, such as forest, shrubland and barren area. In a next step, climate change scenarios were fed into the model. These included time series of simulated weather variables from regional climate models (e.g. Jin *et al.* 2010), driven by several IPCC (Intergovernmental Panel on Climate Change) emission scenarios. Then we compared changes between the current water conditions and projections for the future (Menzel *et al.* 2007).

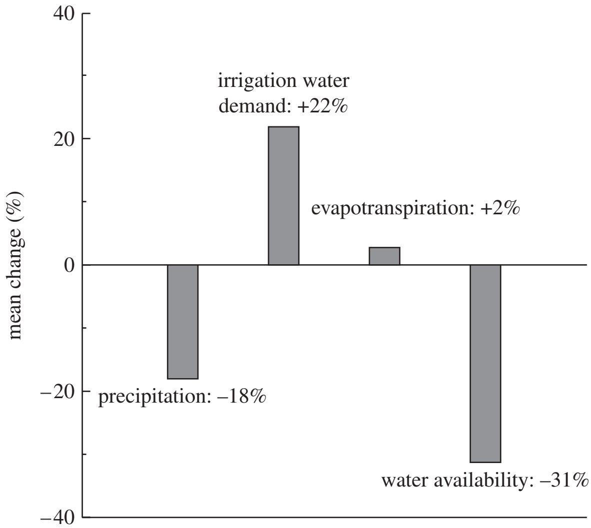

Figure 2. Mean relative change of precipitation, irrigation demand, evapotranspiration and water availability between current (1961–1990) and future (2041–2050) climate conditions based on IPCC scenario A1B (modified after Menzel *et al.* 2007).

Figure 2 presents characteristic results for the scenario period 2041–2050 with the IPCC scenario A1B as an example. According to the simulations, a projected mean reduction of precipitation of 18 per cent may lead to a drastic reduction in water availability by 31 per cent. The different numbers come from a combination of opposing developments in the hydro-climatic sub-regions of the area investigated: the over-proportional decrease of water availability results from massive reductions in runoff and groundwater recharge in those regions where today's water conditions are still relatively favourable (i.e. at the current centre of farming activity). This is a result of decreasing precipitation and rising air temperatures, with a corresponding, strong increase in the atmospheric water demand. Reduced precipitation in the extremely dry, southern and eastern parts of the region, however, where water availability is close to zero already under current climate conditions, will have no effects on the water fluxes. The relatively small increase in actual evapotranspiration demonstrates the complicated balance between a clear increase in the atmospheric water demand (potential evaporation) and reduced water availability. Even under the optimistic assumption of no increase in extent and intensity of agriculture, there will be a considerable reduction in water availability that would need to be compensated by additional irrigation. Namely, irrigation water demand in the example scenario will rise by 22 per cent since precipitation is projected to decrease and potential evaporation to increase strongly (figure 2). This additional demand is unlikely to be met without further over-exploiting the increasingly scarce (blue) water resources, even with an optimistic view (and realized options) about increased availability from desalination (e.g. Tal 2006). Therefore, adaptation measures need to be taken that either reduce the irrigation water demand or increase supply. For example, we have also simulated demand under a shift from double cropping (i.e. during the dry summer and the wet winter) to limiting growth of water-intensive crops to winter only. This scenario resulted in an increase in irrigation demand by approximately 6 per cent, i.e. the increase was markedly smaller though still substantial.

Since already today, the region uses more than the available supply of renewable fresh water (Vörösmarty *et al.* 2005), these scenarios are alarming. Sustainable management of land and water under climate change will have to find alternatives to the current blue-water intensive practices. Our findings also highlight that the widespread assumption of resistance of irrigated agriculture to climate change is misleading. Namely, increasing irrigation water can serve as an adaptation strategy (e.g. Fleischer *et al.* 2007) only when water availability is unlimited. However, our findings suggest that climate change will decrease water availability even below the current record lows. Therefore, increasing irrigation under climate change is, in this water-limited region, not only an unsustainable practice, but also a more costly one. This would in turn further decrease net revenues obtained from irrigated agriculture.

5. Discussion

Our overall results indicate that, in the face of climate change, novel approaches to land and water management in water-limited regions are urgently needed. Current practices, especially irrigated agriculture, are not sustainable in the face of global change. However, our findings also shed an optimistic light on possible adaptation strategies because we could show that returns from land use are not necessarily affected by climate change when taking non-market values into account. Including these into estimates of water productivity may help considerably in designing sustainable land and water management strategies in a changing world. In the following, we discuss a few key results in more detail and we address how these findings may be applied to similarly vulnerable regions.

(*a*) *Which land-use type is the best?*

It has been hypothesized that, under global change, ecosystems and humans will increasingly compete for water (Falkenmark 2003). Our findings for the services provided by different land-use types challenge this view. In particular, we could demonstrate that, by including landscape value into estimates of water productivity, we obtain completely different optimal land allocation schemes than by focusing on returns from farming alone. The most striking evidence stems from rangelands, which exhibited relatively low returns from grazing. Consequently, if land-use planning aims entirely at maximizing returns from provisioning services, allocation to rangeland receives very low priority. This is already apparent in the irreversible and rapid urban sprawl into natural areas and rangelands in Israel (Fleischer & Tsur 2009). As we could show, such decisions are unwise and very costly for society for two reasons. First, natural areas may be highly resistant to climate change while, at the same time, they are fully rainfed, i.e. they depend on green water only. Therefore, their water productivity relative to other land-use types may actually increase under climate change. Secondly, the recreational services provided by rangelands and semi-natural ecosystems can be tremendous and by far exceed provisioning services (Fleischer & Sternberg 2006).

Finally, the aesthetic services provided by urban 'landscapes' compared with open space are particularly low (Ellingson *et al.* 2009; Fleischer & Tsur 2009). In that context, one must consider that there are many other services that we have not even touched upon. For example, natural vegetation may also have considerably positive effects on the hydrological cycle *per se*. Perennial trees and shrubs that dominate natural vegetation and orchards provide much larger protection against erosion than irrigated agriculture with annual crops. This corroborates previous studies that highlighted the need for development and adaptation strategies for the Mediterranean that focus on reduced water use and increased soil protection (Schröter *et al.* 2005). Furthermore, the eastern Mediterranean basin harbours a worldwide unique diversity of plant and animal species (Myers *et al.* 2000), and biodiversity itself supports many important functions and services (Millennium Ecosystem Assessment 2005). Thus, other ecosystem services are likely to be maximized as well if rangelands and semi-natural ecosystems are protected (e.g. potential for carbon sinks).

In summary, our findings indicate that 'water for nature' does not necessarily compete with water for humans. This contradicts the view of even the most prominent advocates of the blue–green water approach, who have repeatedly postulated a trade-off between the partitioning of water for ecosystems and for humans (e.g. Rockström *et al.* 1999; Falkenmark 2000; Falkenmark & Rockström 2006). Part of this view is based on the correct assumption that plants are active in partitioning the water resources themselves, which may result in conflicts between rainfed land use upstream and blue water-dependent land and urban use downstream (e.g. Falkenmark 2000). However, with the incorporation of cultural services, and even more with considering a more complete range of possible services provided by agro-ecosystems, the apparent conflict may dissolve and society may profit largely from the protection of green water flows in agro-ecosystems.

Despite our evidence for the need to preserve natural areas, our findings do not provide quantitative evidence for the 'most productive land-use type', because we have no direct comparison of water productivity for all possible land-use categories. For example, greenhouses have a much lower landscape value than other land-use types but they provide very high returns to farming, partly because they have a very low (blue) water demand (Fleischer & Tsur 2000). Clearly, there may be trade-offs with other ecosystem services, and it depends on policy makers whether one particular service or a diversity of services should be maintained or maximized (Brauman *et al.* 2007). Therefore, an idealistic 'water for nature' approach may not be the only solution to the emerging water crisis. However, our results do indicate that agricultural practices with high irrigation demand may not be sustainable under changing climatic conditions. With increased temperatures and decreased precipitation, the current water gap will grow markedly, making it unlikely to meet the increase in irrigation water demand (Menzel *et al.* 2009) without compromising water security for future generations.

In summary, we believe it is time for a shift from the supply-oriented management schemes (such as in Tal 2006) to demand-oriented ones. These should explicitly consider rainfed land use as a highly productive land-cover type that is more likely to resist the consequences of climate change than irrigated agriculture. One may argue that our suggested land allocation scheme is unrealistic because it will be at the expense of food security. Yet, one must acknowledge that already today, the Middle East and North African countries rely heavily on food import (i.e. virtual water import) and this dependence will further increase in the near future (Alcamo *et al.* 2005; Tal 2006).

(*b*) *Transfer and application*

The effectiveness of ecosystem services for decision making depends largely on social norms and general economic conditions (Daily *et al.* 2009). Namely, the large difference we found between returns from landscape value versus returns from agricultural use (e.g. grazing) depends largely on the socio-economic conditions. Israel is a high-income country and different results may be expected when doing similar analyses in other countries. For example, at low income levels, the 'free' feeding services provided by rangelands may be significant (Fleischer & Sternberg 2006). Also, while most people may well appreciate ecosystem services, not all may be able to afford additional expenses. In addition, the rural population may be less engaged in outdoor recreation, and thus the difference between fodder value and recreational value should be much smaller or even reversed compared to the situation in Israel (Fleischer & Sternberg 2006). Therefore, we are currently exploring the possibility of transferring our findings to Jordan and the Palestinian Autonomy and similar regions elsewhere in the world.

A somewhat optimistic view may emerge from studies that have shown that the major problem of integrating non-market values into policy making is not one of under-valuation by individuals and society, even in low-income societies (de Ferranti *et al.* 2005). For example, cultural values could be the key to raising awareness for environmental issues and for fostering stewardship because the aesthetic value of a landscape is particularly important to the broader public and economic arguments may generate objections rather than support (Novacek 2008). This view is supported by a recent assessment of ecosystem services for Europe (i.e. including Mediterranean countries), which has identified outdoor recreation as one of two services that are most likely to expand in importance (Metzger *et al.* 2006). At the same time, it is exactly this type of service that is increasingly threatened in the Mediterranean region, because it is particularly vulnerable to land-use change (Schröter *et al.* 2005).

Since amenities like scenic beauty are mostly public goods, some sort of policy intervention is needed for preserving them. Therefore, a major challenge is in designing schemes that provide appropriate incentives for agricultural practices that are not only beneficial from a market value point of view. Interestingly, such programmes may not only be effective in Europe or the USA, but there are numerous examples for payments to environmental services in developing countries in South America and Africa (de Ferranti *et al.* 2005; Daily *et al.* 2009). Incentives cited in these studies include payments for the maintenance of natural landscapes only, but our study indicates that agricultural landscapes should also enter into similar schemes.

Unfortunately, up to now, decisions of environmental management have been largely unaffected by cost–benefit thinking (Atkinson & Mourato 2008). In particular, the use of landscape value in policy making is anecdotal at best, and it has been completely ignored in water management. As we have shown, this is highly regrettable, because managing water through managing land use may be the key to sustainable water use in this highly vulnerable region, particularly if non-market values of landscape are taken into account. We therefore advocate a serious dialogue between land and water managers and the inclusion of incentive schemes for preserving the full range of services provided by blue and green water in the landscape.

6. Conclusions

Our findings support the view that conventional water productivity estimates that focus entirely on yield : blue water ratios are incomplete and may miss effective solutions for sustainable land and water management in water-limited systems. Instead, green water management may be the key to a sustainable water future in semi-arid regions (Falkenmark & Rockström 2006). In that context, ecosystem services should be integrated into optimization of land management. If cultural services, which have been defined as important but rarely measured, are taken into account, we may obtain entirely different optimal land allocation schemes. For example, land-use types that yield a particularly large aesthetic value appear to be the most resistant to change. Therefore, replacement of irrigated agriculture by open space and aesthetic land-use types (e.g. a mixture of fields, rangelands and orchards) may yield larger and more sustainable returns under global climate change than the current practice of increasing agricultural yield by increasing irrigation water availability.

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