THE ECONOMICS OF LAND DEGRADATION

Jordan Case Study

An economic valuation of a large - scale rangeland restoration project through the Hima system in Jordan

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Economics of Land Degradation Initiative: **An economic valuation of a large-scale rangeland restoration project through the Hima system in Jordan**

A case study in Jordan

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Executive summary

Jordanian rangelands are a source of valued livestock produce, carbon storage, biodiversity, and medicinal plants. They also serve as watersheds that receive rainfall, yield surface water, and replenish groundwater throughout the area east and south of the western Jordan highlands. Appropriate land management, which is currently lacking, can protect and maximize these services for society. With the acceleration of desertification, land degradation and drought during the twenty-first century in the arid and semi-arid regions of Jordan, these services are becoming jeopardized. It is therefore increasingly urgent to define and pursue viable strategies to reverse this trend. One approach which is gaining increasing attention in Jordan is the 'Al-Hima' land management system. This is a historical and traditional system of land management in the Arab region that encourages the sustainable, shared use of common resources amongst relevant communities.

To inform the debate surrounding this approach, this paper presents an ex-ante cost-benefit analysis of large-scale rangeland restoration through the Hima system within the Zarqa River Basin, drawing on experience from a pilot initiative by IUCN and the Jordanian Ministry of Agriculture (MoA) since 2010. The ecosystem services that arise from rangeland restoration are valued using a combination of stated preference, avoided costs, replacement cost and market prices approaches. The economic analysis has built on high-resolution remote sensing, GIS, and biophysical soil and water assessment tools, and was elaborated to rigorously calibrate the impact of land use changes on forage availability, ground water infiltration, carbon sequestration, and sediment stabilisation.

Benefits of large-scale rangeland restoration from the Hima system were found to outweigh the management and implementation costs at a discount rate of 8 per cent. Given this encouraging result, different policy instruments that may be used to incentivize the restoration of rangelands in Jordan are discussed. In particular, ensuring pastoral communities have long-term stakes in rangeland resources, the government should first and foremost assign appropriate land tenure rights to pastoral communities, (e.g., through long term leases) allowing them to effectively manage access to rangeland resources. To finance a change in the governance structure around rangelands, the use of a cross-compliance scheme is suggested, where scarce resources currently dedicated to unconditional fodder subsidies are instead partially diverted to promoting sustainable rangeland management. For example, pastoral communities practicing water harvesting and grazing protocols could become eligible to receive feed subsidies. Such a scheme should be coupled with the provision of regular extension services to increase sustainable resource management capacities within the community.

The case is also made for setting up voluntary contractual payments for ecosystem service agreements, where downstream beneficiaries of rangeland restoration compensate upstream communities for their efforts. Appropriate policy instruments that engender sustainable rangeland management and Hima practices are likely to be found in a mix of regulatory and economic incentives.

الملخص التنفيذي

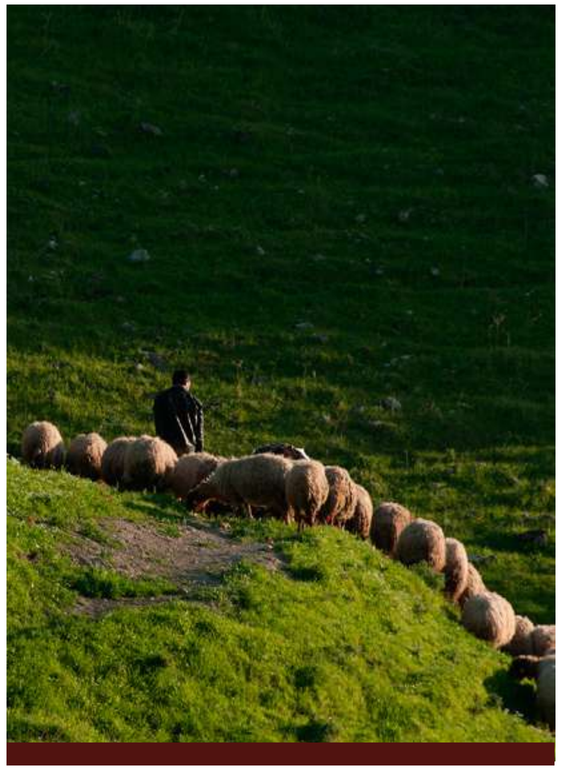
تعتبر المراعي الأردنية مصدراً قيّماً لإنتاج المواشي واختزان الكربون والتنوع الحيوي والنباتات الطبية، كما أنها تقوم بدور المساقط المائية بما تتلقاه من مياه أمطار وما يجري خلالها من مياه سطحية وتمدُّ به مخزون المياه الجوفية وذلك في كافة المناطق الواقعة شرق وجنوب المرتفعات الغربية للأردن، ومن شأن الإدارة القويمة للأراضي حماية وتنظيم هذه الخدمات للمجتمع، فبتسارع التصحر وتردي حالة الأراضي والجفاف خلال القرن الحالي في المناطق الجافة وشبه الجافة من المملكة صارت هذه الخدمات مهددة، لذلك غدا لزاماً وضع واتباع استراتيجيات ناجعة لكبح هذا التهديد.

من المنهجيات التي يتنامى الاهتمام بها في الأردن ما يطرحه نظام "الحِمى" لإدارة الأراضي، حيث أن الحمى هو نظام تقليدي وتاريخي لإدارة الأراضي في المنطقة العربية يشجع الاستخدام المشترك المستدام للموارد المشتركة بين المجتمعات ذات الصلة، وبهدف توضيح ماهية هذا النظام تقدم هذه الورقة تحليلاً مسبقاً لتكاليف وفوائد إصلاح واسع النطاق للمراعي من خلال تطبيق نهج الحِمى ضمن حوض نهر الزرقاء بالاستفادة من خبرة المبادرة الاسترشادية التي قام بها الاتحاد الدولي لحماية الطبيعة – المكتب الإقليمي لغرب آسيا بالتعاون مع وزارة الزراعة الأردنية منذ عام ٢٠١٠.

يتم تقييم خدمات النظام الإيكولوجي الناشئة من إصلاح المراعي باستخدام المزج بين منهجيات التفضيل الافتراضي والتكاليف المتفاداة وتكاليف الاستبدال وأسعار السوق، وقد قام التحليل الاقتصادي على استخدام الاستشعار عن بُعد عالي الدقة ونظم المعلومات الجغرافية وأدوات التقييم الفيزيائي-الحيوي للتربة والمياه المولّفة لتقيس بدقة أثر التغير في استخدام الأراضي على توفر الأعلاف ونفاذ المياه الجوفية واحتجاز الكربون واستقرار الترسبات.

تبيّن لنا من خلال نظام الحِمى أن فوائد الإصلاح الواسع النطاق للمراعي تفوق تكاليف تطبيقه وإدارته وذلك بمعدل انخفاض يبلغ ٨٪، وهي نتيجة تشجعنا على مناقشة أدوات السياسات المختلفة التي يمكن استخدامها لتحفيز عملية إصلاح المراعي في الأردن. ونعتقد أن توفير دور طويل الأمد للمجتمعات الرعوية في موارد المراعي يُوجب على الحكومة قبل كل شيء توفير حقوق مناسبة
لحيازة تلك المجتمعات للأراضي، مثلاً من خلال التأجير لمُدة طويلة بما يتيح لها الإدارة الفعالة للوصول إلى مواردها.

وحتى يَتسَنّى تمويل التغير في هيكلية حوكمة المراعي نقترح



استخدام خطة "مكافأة الامتثال"، حيث يُستعاض عما هو قائم حالياً من تخصيص الموارد الشحيحة أعلافاً مدعومة بغير شروط بتخصيص قسم منها للتشجيع على الإدارة المستدامة للمراعي، إذ يمكن مثلاً اعتبار المجتمعات الرعوية الممارسة للحصاد المائي وأصول الرعي مؤهلة لتلقي الأعلاف المدعومة.

ينبغي لهذه الخطة أن تقترن بتوفير خدمات إرشاد منتظمة لتعزيز قدرات المجتمع في مجال الإدارة المستدامة للموارد، كما نحث على عقد اتفاقيات طوعية للدفع لخدمات النظام الإيكولوجي يساعِد بموجبها المنتفعون اللاحقون من إصلاح المراعي على تعويض المجتمعات السابقة في الانتفاع على جهودها الإصلاحية، لذلك تتمثل الأدوات السياسية المناسبة لإيجاد إدارة مستدامة للمراعي وممارسات الحِمى في مزيج من الحوافز التنظيمية والسياسية.

كلمات مفتاحية:
تحليل التكاليف والفوائد، الاستعداد للدفع، تبيُّن الخيارات، أدوات تقييم التربة والمياه، (ArcSWAT)، الاستشعار عن بعد، إدارة المراعي، الحِمى، الأردن، حوض نهر الزرقاء، أدوات السياسات.

Acronyms and abbreviations

AG	Above ground (carbon sequestration)
AGC	Above ground carbon
ArcSwat	Soil and Water Assessment Tool
BG	Below ground (carbon sequestration)
CE	Choice Experiment
DLDD	Desertification, land degradation and drought
ELD	Economics of Land Degradation (Initiative)
FAO	Food and Agriculture Organisation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IUCN	International Union for Conservation of Nature
JOD	Jordanian Dinar
LDN	Land degradation neutrality
MCM	Million cubic meters
MoA	Ministry of Agriculture, Jordan
NPV	Net present value
OECD	Oganisation for Economic Cooperation and Development
PES	Payment for ecosystem services
SLM	Sustainable land management
SOC	Soil organic carbon
SCC	Social cost of Carbon
UNCCD	United Nations Convention to Combat Desertification
WTP	Willingness to Pay

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The economics of land degradation

Sustainable land use is a prerequisite for ensuring future water, food, and energy security. Given the increasing pressure on land from agriculture, forestry, pasture, energy production, and urbanization, urgent action is needed to halt land degradation and restore already-degraded lands. The United Nations Convention to Combat Desertification (UNCCD) was established in 1994 to specifically address desertification. The convention was born as a result of the 1992 Rio Earth Summit, which highlighted climate change, biodiversity loss, and desertification as the greatest challenges facing sustainable development. All three challenges have been attributed to failures in markets and policies. The UNCCD's core emphasis is on securing productivity and resilience of land for the well-being of dryland inhabitants, particularly in drought-prone areas. In 2007, a ten year strategy for the convention was adopted with a more explicit goal for its 195 parties, *"to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effects of drought in affected areas in order to support poverty reduction and environmental sustainability"* (UNCCD, 2012). The ten year strategy is supported and implemented through key stakeholder partnerships with the aim of mainstreaming sustainable land management (SLM) into decision-making policies and practices.

The UNCCD definition of desertification is land degradation (linked to the loss of productivity of land) in drylands with the exception of hyper arid areas. Although there appears to be a general consensus amongst the parties to the convention that drylands, particularly in Africa, face severe impacts of desertification, land degradation, and drought (DLDD), land degradation is not restricted to drylands. The far-reaching impacts of DLDD affect both livelihoods and ecosystems globally, resulting in the loss of critical ecosystem services ranging from carbon sequestration to losses of fertility and nature conservation. The impacts of DLDD are local but can also be experienced off-site, e.g., when deforestation or poor management of land upstream results in siltation of dams downstream. Impacts of DLDD can be cross-border or even inter-continental, e.g., dust storms where the dust is generated on one continent and travels with prevailing winds and manifests as a dust storm on another continent. The importance of an international convention on desertification becomes strikingly apparent when considering these off-site/cross-boundary impacts that result from DLDD.

In 2013, the 2nd Science Conference of UNCCD was held in Bonn, Germany, to discuss and showcase scientific contributions on the theme *"Economic assessment of desertification, sustainable land management, and resilience of arid, semi-arid, and dry sub-humid areas"*. Throughout the conference, scientists and practitioners presented robust methodologies and evidence to suggest that preventing DLDD can be more cost effective than restoring degraded land. However, there are significant data gaps in the biophysical and economic data and methodologies need to be extensively tested to identify the most efficient methods to collect and compile the data required to fill these gaps. It is evident that the field of economic assessment of SLM is still, emerging but nonetheless an important one.

Central to the debate on the economics of DLDD is the concept of land degradation neutrality (LDN). LDN is a novel idea that was presented in the outcome document from Rio+20 and adopted by UNCCD (UNCCD, 2012). Its aim is to secure the productivity of land and natural resources (such as soil) for sustainable development, food security, and poverty eradication. In principle, LDN would translate into avoided degradation of productive land and restoration of already degraded lands to obtain a degradation-neutral outcome. Cost-benefit analyses of SLM is an important approach in strengthening the case for investments in improved land management practices, and is one of the steps necessary to achieve land degradation neutrality.

Promoting SLM and effectively communicating the nexus of benefits derived from SLM has been at the heart of the work of IUCN's Global Drylands Initiative (GDI). GDI is further collaborating with the IUCN Global Economics and Social Science programme (GESSP) that provides technical expertise in the domain of ecosystem service valuation. The SLM nexus highlights the inter-linkages between climate, biodiversity and land, where synergies between the three UN conventions (UNCCD, United Nations Framework Convention on Climate Change [UNFCCC], and the United Nations Convention on Biodiversity [UNCBD]) lie, and where a large portion of IUCN's dryland work is focused. IUCN brings communities and multiple government sectors together to enable more coherent resource planning at the ecosystem level for SLM in the drylands.

IUCN - GDI and GESSP have a history of using economic valuations to demonstrate the benefits of ecosystems and SLM strategies specifically applicable to drylands. To strengthen these existing economic assessments, IUCN has built relationships with other initiatives who share similar goals and objectives, such as the Economics of Land Degradation (ELD) Initiative. The ELD Initiative highlights the potential benefits derived from adopting SLM practices, using quantitative ecosystem valuation studies. Through funds from the ELD Initiative, IUCN carried out an assessment of the economic costs and benefits of SLM and its natural resource governance interventions over several years in Jordan, Mali, and Sudan. These three country studies provided a detailed analysis of the costs and benefits of interventions, information on non-market values of ecosystem services, improved understanding of the value of ecosystem services to local livelihoods, and improved monitoring and evaluation for total ecosystem assessments.

The studies demonstrated that long and short term social, economic, and environmental benefits can be derived from adopting SLM practices on a wide scale. These studies also informed the development of policy recommendations which will feed into on-going dialogue with policy- and decision-makers in these regions. Hence, IUCN hopes these studies have provided a fresh insight with innovative methodologies and new data, plus a more comprehensive review of the diversity of ecosystem services that are important in drylands.

01 Introduction

The case for rangeland restoration through the Hima management system

The Arabic word 'Hima' means protected place. In Islamic law, it signifies a natural area that is set aside permanently or seasonally for the public good and cannot be privately owned. For more than fourteen hundred years, Hima areas have been used to help conserve natural resources and biodiversity in the Arabian Peninsula and adjacent areas (IUCN, 2007). At the same time, pastoralism is part of a long cultural tradition in Jordan and enables many rural communities to maintain a valued and traditional way of life.

However, the pastoral livestock sector relies on healthy rangelands, which also deliver valuable ecosystem services in terms of climate change mitigation and adaptation, purification and infiltration of ground water, medicinal herbs, and storage of genetic diversity of flora and fauna. These ecosystem services have been in decline over the past five decades in the eastern Jordanian desert, also known as the Badia, resulting in livestock feed deficits, soil erosion, loss of biodiversity and vegetation cover, and expanding desert margins. This happened as a result of various policy reforms and was reinforced by declining rainfall and the abandonment of natural water harvesting and Hima practices (Al-Satiri et al., 2012).

Fifty years ago, nomadic Bedouins in Jordan raised their livestock without restrictions of political borders, venturing into Syria and Saudi Arabia, as well as locations around the Iraqi border. They migrated in search of seasonal resources, thereby allowing the forage and resources at each non-grazed site time to regenerate, using a Hima-like system (Al-Tabini et al., 2012). With the establishment of border restrictions, there has been a major breakdown in traditional pastoral migration. This was coupled with an analogous breakdown in pre-existing tribal land tenure systems that had evolved over centuries when ownership rights over rangelands were transferred to state-ownership in 1973 (Agriculture Law, 1973; Al-Jaloudy, 2006). The change in the governance system is one of the major factors that has since led to the degradation of Jordanian rangelands.

The shift from a tribally-held tenure management system to one where rangelands were 'free for all' or 'open access' without restrictions and rules to govern the resource use, livestock owners began to take advantage of pasture and fodder resources as available. Little consideration was given to the effects this kind of utilisation would have on soil fertility and edible plant resources for the future (MoA, 2001). Thus, the shift from de-facto tribal landownership to de-jure government ownership meant that rangeland resources became subject to the classical tragedy of the commons associated open-access to pastures.

With the consequential decline in rangeland resources, Jordanian pastoral communities began to supplement natural forage production with purchased feedstock. When feedstock prices began rising in the 1980s, the government introduced a subsidy on livestock feed. The subsidy however, encouraged flock owners to increase their herd size beyond the carrying capacity of lands, exacerbating rangeland deterioration (Al-Tabini et al., 2012). In this context, it is of critical importance to study how the revival of Hima systems can help contribute to the long-term viability of rangelands, climate change mitigation, water, and food security.

To this end, a comprehensive economic valuation study of a large-scale rangeland restoration scenario was undertaken within the Zarqa River Basin. High-resolution remote sensing and ArcSWAT (Soil and Water Assessment Tool) were integrated with economic analyses of key regulating and provisioning ecosystem services provided by the Hima systems. The costs associated with establishing Hima systems were also considered, to better understand the immediate constraints to restoring rangelands. Finally, the social benefits of Hima restoration were shown to be substantially larger than the investment costs over a 25 year[1] time horizon. A case is thus made for scaling up Hima systems within the Zarqa River Basin and the Jordanian Badia[2] as a whole.

Al-Hima restoration can be shaped differently, according to the aspirations of the community managing the Hima. In this paper, what underlies Hima restoration is the development of grazing protocols whereby herds or flocks are regularly and systematically moved to 'rested' areas with the intent to maximize the quality and quantity of forage growth overall. Resting grazed lands allows the vegetation to renew energy reserves, rebuild shoot systems, and deepen root systems, resulting in long-term maximum biomass production (Beetz and Rinehart, 2004). This system was formally termed intensively managed rotational grazing or cell grazing.

On-going interventions in the study sites of Bani Hashem, Duleil, Hashemeyeh, and Hallabat communities are at early stages of rangeland restoration, where resting land and the use of simple rotational grazing have had a rapid and significantly positive impact. In Jordan, this system is broadly referred to as Al Hima, which in itself includes a much wider range of land management systems where the common denominator is to set aside land permanently or seasonally (IUCN, 2007). The terminology adopted for Al Hima in this paper reflects what is used in policy contexts in Jordan. Authors will therefore be referring to rotational Hima, or Hima restoration instead of 'intensively managed rotational grazing'.

The remainder of the paper is arranged as follows:

First, the baseline scenario of rangelands in the Zarqa River Basin and how they were expected to evolve in the absence of changes in current land use management schemes is described. A future scenario associated with large-scale adoption of the Hima system within the Zarqa River Basin is then proposed. To do this, the management regime of the Bani Hashem Hima (described below) was mirrored. With a 'baseline (no change) and a 'large-scale Hima restoration' scenario defined, different biophysical models were used to predict how key ecosystem services were affected by these two differing land uses. The biophysical changes were then translated into economic values using a combination of stated preference, avoided costs, replacement costs, and market prices valuation approaches (see Hanley and Barbier, 2010). Using these approaches, the value of large-scale Hima restoration was estimated in terms of increased edible biomass, the premium associated with natural forage over concentrated feed, the extent of water infiltration resulting from biomass and the value of that water, and the value of reduced sedimentation of dams in terms of increased storage capacity over the 25 year time horizon.

[1] 25 years is a standard time horizon used in cost benefit analyses. It is long enough to ensure that land use management interventions have a visible effect on ecosystem services, while short enough to avoid unreasonable assumptions about the future.

[2] Jordan can be divided into three main geographic and climatic areas: the Jordan Valley, Mountain Heights Plateau, and the Easter Desert, also known as the Badia region. Comprising around 75 per cent of Jordan, this area of desert and desert steppe is part of the North Arab Desert. It stretches into Syria, Iraq, and Saudi Arabia, with elevations varying between 600 - 900 m above sea level and has an annual mean rainfall below 200 mm.

02 The case study area

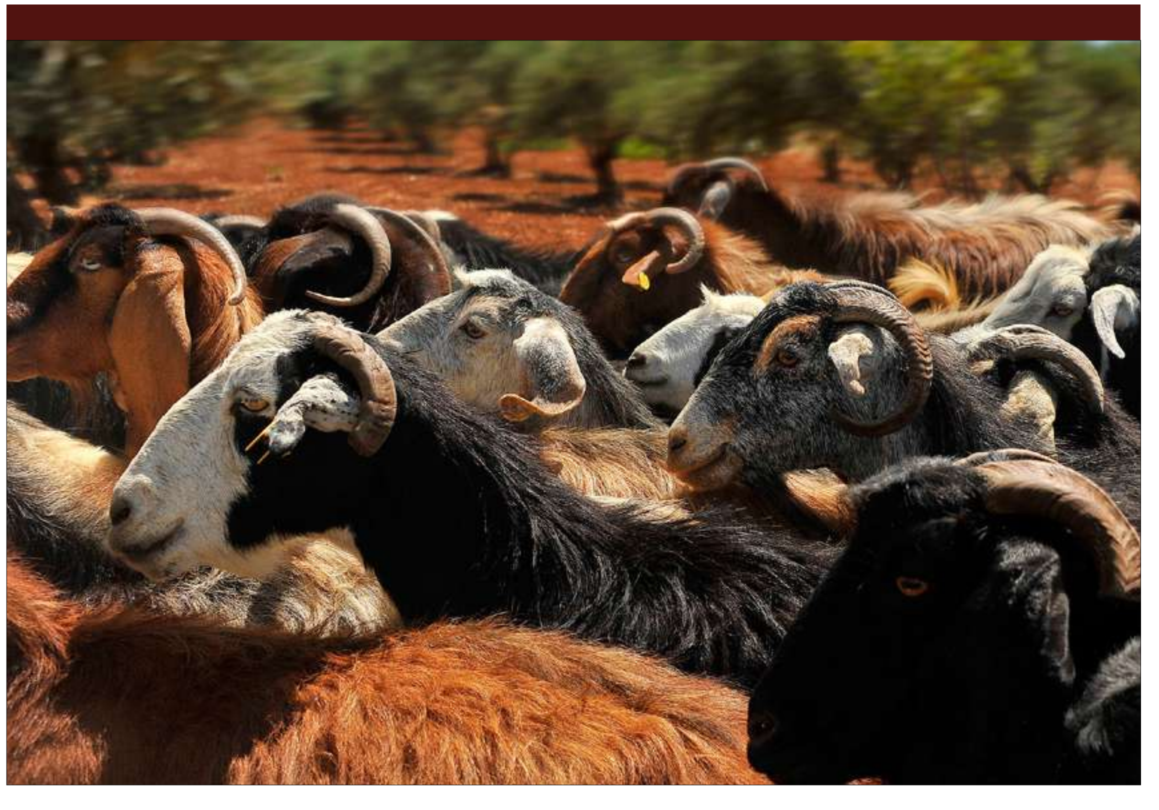
The full range of potential benefits derived from rangeland restoration using Hima systems may not be realised unless the Hima system is implemented on a large scale. Therefore, for this study, wide-scale Hima adoption within the Zarqa River Basin has been explored.

The valuation study built on the experience of existing initiatives in the Bani Hashem area, which was chosen as a pilot study site by IUCN and the Jordan MoA to illustrate the benefits of Hima site restoration. The MoA has ownership over the site, located in the Zarqa Governorate approximately 12 km northwest of Zarqa City. The Zarqa River is the second largest tributary of the Jordan River, and is of critical economic, social, and agricultural importance to the Zarqa Governorate for its contribution to horticultural exports (FAO, 2009).

The Zarqa River Basin is located in the northern part of Jordan, extending from Jabal Druz in the east, to the Jordan River at Ghor in the west. It covers an area of 379,995 ha from the upper northern point to its outlet near King Talal Dam and includes five governorates, namely: Amman, Balqa, Jarash, Mafraq, and Zarqa. It is considered one of the major productive ground water basins in Jordan *(Figure 1)*.

To identify the total area suitable for Hima restoration in the Zarqa River Basin, areas which had existing rangelands belonging to the state and areas with rainfall levels between 100 and 200 mm were selected[3]. These criteria were defined during an expert workshop, including experts from the International Centre for Agricultural Research in the Dry Areas (ICARDA), MoA, International Fund for Agricultural Development (IFAD), the National Center for Agricultural Research and Extension, and the University of Jordan in Amman, in March 2014[4].

Approximately 109,093 ha were estimated to be suitable for potential Hima restoration, of which areas with the greatest potential in terms of the rainfall gradient are located in the south-eastern part of the basin *(Figure 2)*.



[3] The reliability of rainfall estimation is 80 mm at a 95 per cent confidence interval.

[4] www.iucn.org/news_homepage/news_by_date/?14627/Economic-Valuation-of-the-Hima-System-Bani-Hashem-Villages--Jordan

FIGURE 1

Current land use in the Zarqa River Basin, Jordan

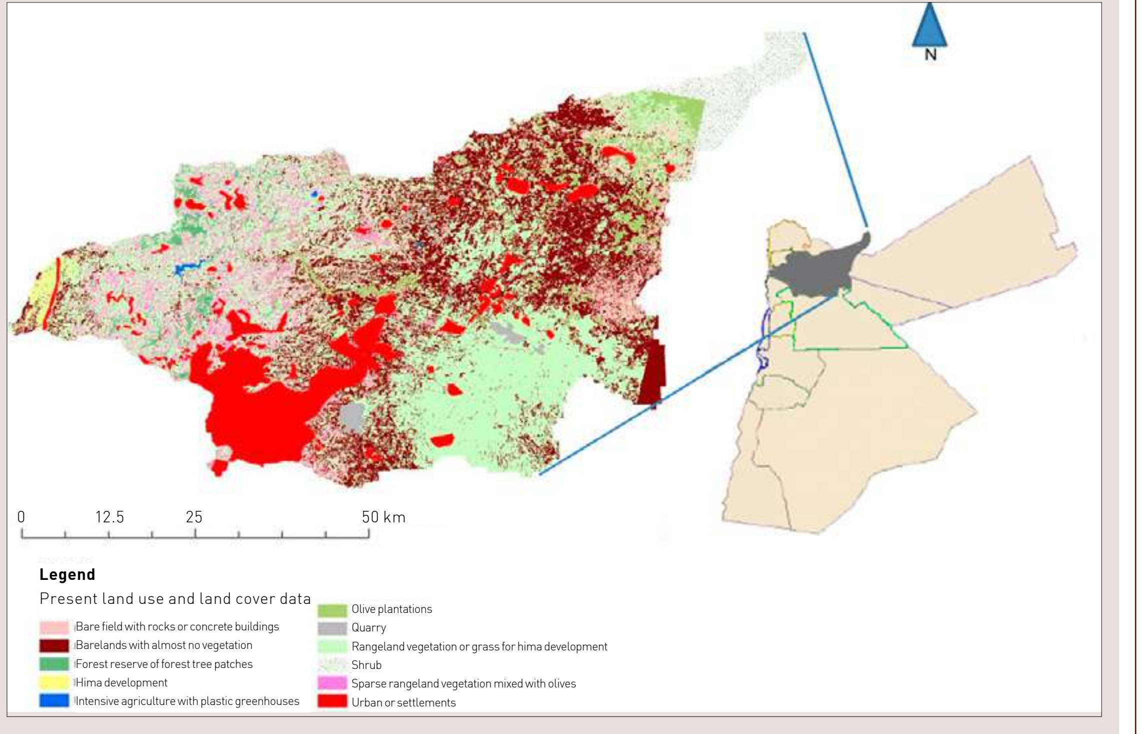
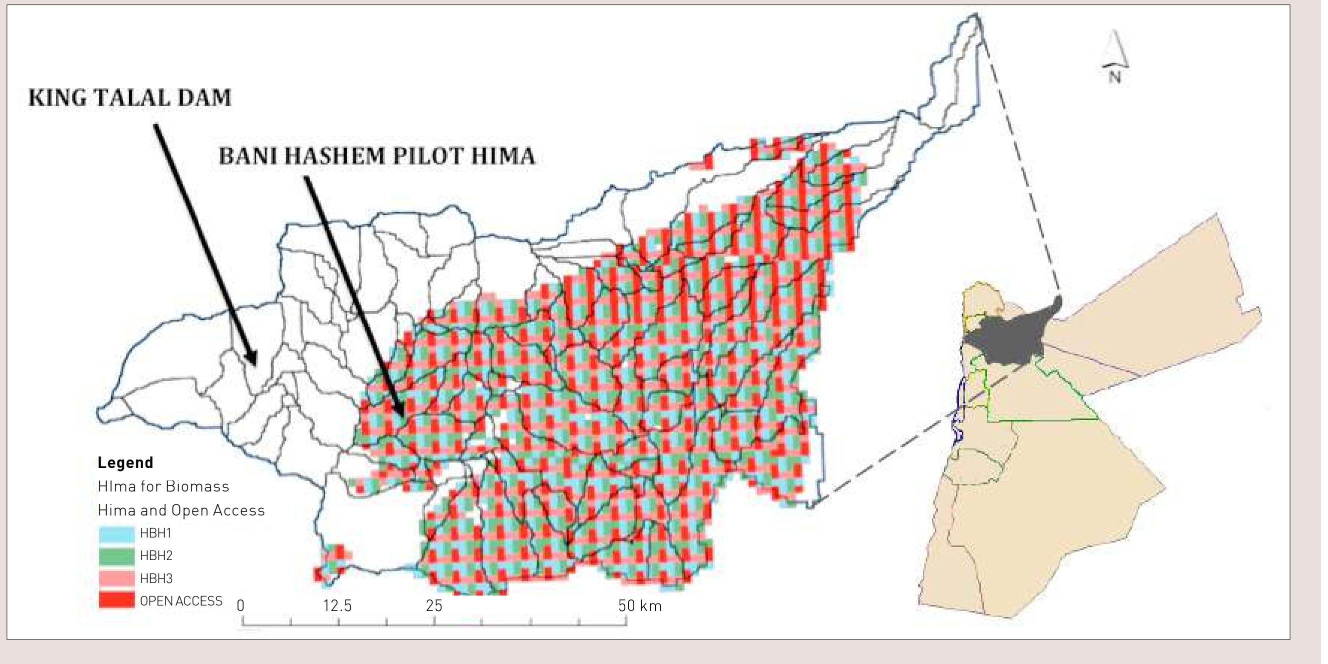


FIGURE 2

The Zarqa River Basin and the potential for rangeland restoration through the Hima system



03 Methods

Valuation scenarios

Baseline scenario

Rangeland productivity in the Jordanian Badia has halved over the last two decades and many indigenous plant species have disappeared. Edible dry matter per hectare decreased from 80 kg/ha in 1990 to 40 kg/ha in 2010 (MoA, 2009). With no signs of reductions in total livestock numbers and a downward trend in the level of precipitation (Myint, 2014), the baseline scenario was expected to show continued declines in rangeland productivity at the same rate that has been observed over the last 20 years. Carbon sequestration rates were also predicted to decline in proportion to decreasing biomass. The baseline scenario was also associated with high run-off, high levels of erosion, and poor groundwater percolation and river recharge.

Future Hima system restoration scenario and the generalised Hima management principle

In creating a future large-scale Hima restoration scenario for the Zarqa River Basin, lessons and a generalised Hima management principle were drawn from the Bani Hashem Community, where a Hima system has been piloted by IUCN in partnership with the Jordanian MoA. More precisely, it was assumed that the same management regime is applied in all the areas considered suitable for Hima systems within the Zarqa River Basin in terms of allowed stocking density, allowed grazing periods, and spatial arrangement of grazing allowances *(Figure 2)*.

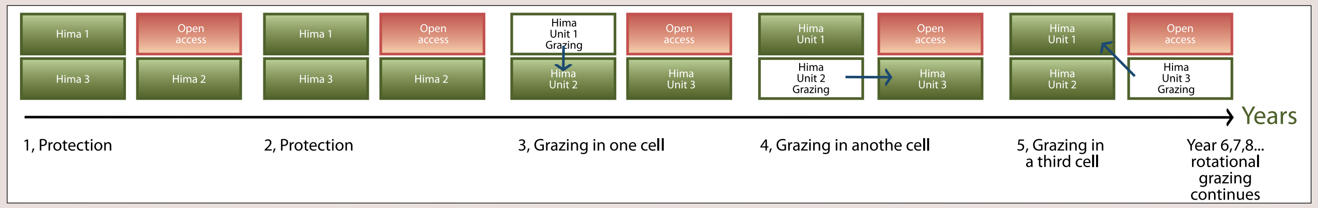
The land where the Bani Hashem Hima system was implemented was organised into three management units, and land outside of these units was open access (open access here refers to the ability to graze the land by livestock of any number, ownership, and length of time). During the first two years of the system being established, grazing was altogether excluded from the three Hima management units *(Figure 3* and *4)*. In the third year, one of the units was opened for grazing. In the fourth year, a second unit was opened for grazing, while the previous unit was closed, and so on. This rotation may be continued thereafter, assuming that there are no significant obstacles, such as the inability to protect the Hima from outsiders. To ensure sufficient regeneration of biomass cover, grazing was only allowed during the autumn months and only on 50 per cent of the land with the units. Additionally, edible biomass indicators are used each year to establish management objectives such as allowed stocking density and grazing period and duration. Goats are not allowed in the Hima system (at least in the initial stages).

To scale up the Hima system to the wider Zarqa River Basin, it was assumed that each Hima management unit would be 400 ha[5], further subdivided into cells of 100 ha each, subject to rotating enclosures.

[5] Any unit of analysis could have been chosen, provided 3/4 of the area would be subject to rotating cell grazing and 1/4 to open access grazing, as stipulated in Equation 3.1 to 3.9. The appropriate size of any Hima system depends on the physical characteristics of the site and political feasibility.

FIGURE 3

Hima management principle over time



Within the system and adapted to local conditions, another 100 ha would be allocated to open access grazing *(Figure 4)*. In the open access unit, grazing is by definition allowed any time by any number of animals, including goats. This open access unit was incorporated as it allows for more flexibility in grazing management and therefore realistically reflects how Hima systems have been carried out (Al-Satiri, personal communication 2014). The open access unit therefore ensures that there is a space where ruminants can graze when the other cells are closed. More sophisticated herding arrangements could evolve as Hima becomes more widespread, which could further improve fodder availability and reduce the need for open-access grazing zones. However, this study was restricted to the scaling-up of Hima as currently relevant to the Zarqa River Basin.

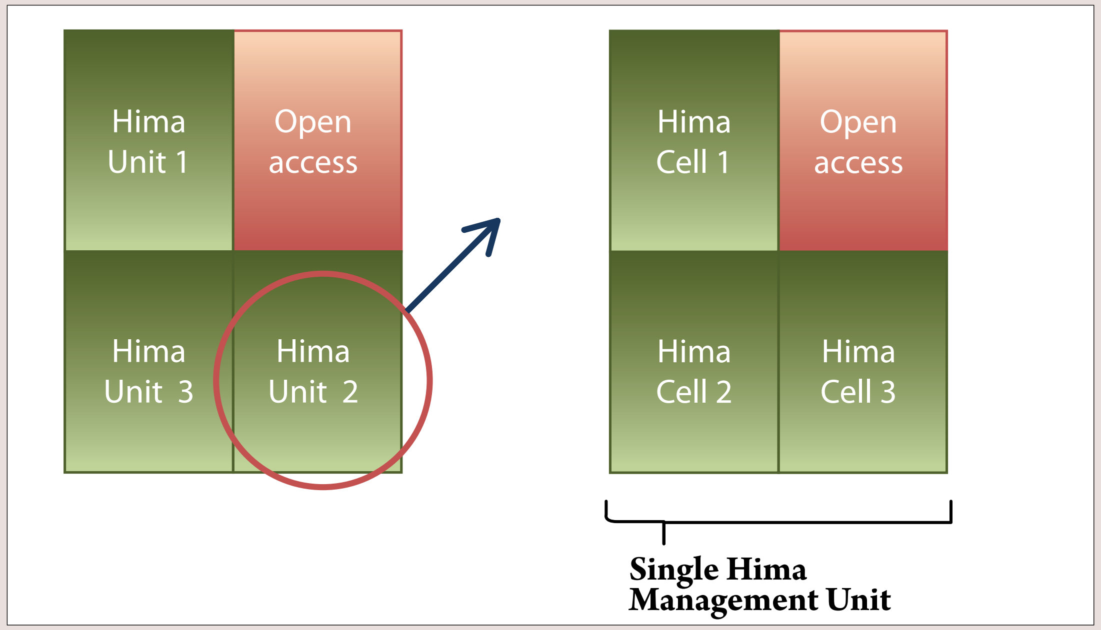
In the first years after the establishment of the Hima system when edible biomass per hectare was low, the actual period during which each Hima unit was opened was limited. For example, in 2013, approximately 250 sheep were allowed to graze for 30 days in one cell. In the open-access regime, there is no upper limit on livestock numbers allowed to graze in the area. Hence, given that there are an estimated 10,000 sheep and goats in the Bani Hashem community, it is probable that they would all have grazed within the specific open access cell at some point during a 30-day period. Assuming that herd sizes remain the same as prior to the implementation of the system, this also means there is more grazing pressure in the open access area. This implicit 'displacement cost' is incorporated into the biomass equations in *Chapter 3 (Equations 3.2 to 3.6)*. Detailed, present, and future land use and land cover maps incorporating this future land use scenario are found in *Appendix 2*.

The valuation of enhanced rangeland productivity from Hima restoration

Increased productivity of pastures is an immediate benefit derived from adopting Hima systems. The value of this productivity was calculated by estimating the discounted sum of avoided fodder purchases associated with Hima restoration across a 25 year time horizon. The model presented assumed a parcel of land is best used for grazing since the parcel of land under investigation has been classified as suitable for 'rangelands' by the MoA (2013) and has been historically used for pastoralism. The model subsequently aimed to determine whether Hima system management was better than that of an open access system in terms of rangeland productivity. Stocking rates and allowed grazing times were predetermined

FIGURE 4

Single Hima management unit further divided into four cells



according to the Hima system as designed for the Bani Hashem area (as explained previously).

Baseline scenario

The Bani Hashem Hima was used as a reference point for the valuation, as it was considered largely representative of Zarqa River Basin rangelands. Prior to the invigoration of the Hima in 2011, rangeland expert Yahya Al-Satiri (2014), roughly assessed that there was approximately 40 kg of dry yield/ha. After two years of protection, a biomass study (Al-Satiri, 2013) revealed that there was an average dry yield of 113 kg/ha across the three cells. Results and margins of error are in *Appendix 3*.

To establish how rangeland productivity would evolve over a 25 year time horizon in the Hima restoration scenario, a predator-prey model of rangeland evolution as analysed by Noy-Meir (1976) was used. Noy-Meir was interested in the stability of such grazing systems as well as determining appropriate stocking rates to maintain rangeland productivity in a stable condition[6]. The general Noy-Meir model of forage growth is specified as follows for *Equation 3.1.*, where γ is maximum growth rate per unit of time, $biomass_t$ is vegetation density per unit of land (dry yield/ha) in year *t*, and $biomass_{MAX}$ is the maximum plant biomass for a unit of land (carrying capacity).

Maximum growth rate per unit of time was calculated using an estimate of dry biomass growth per hectare for a Hima site under protection, and an estimate of the maximum plant biomass for a unit of land (Al-Jaloudy, 2006). Knowing that only 50 per cent of all biomass within a cell may be grazed (Al-Satiri et al., 2013) one could trace how biomass growth would evolve in the Hima restoration scenario over a 25 year time horizon. The result is shown in *Figure 5.*

Finally, the baseline scenario is one in which rangeland productivity is expected to continue to decline at the rate observed over the last 20 years. This corresponds to a 2 kg decrease in dry biomass/ha/yr, as illustrated in *Figure 5*.

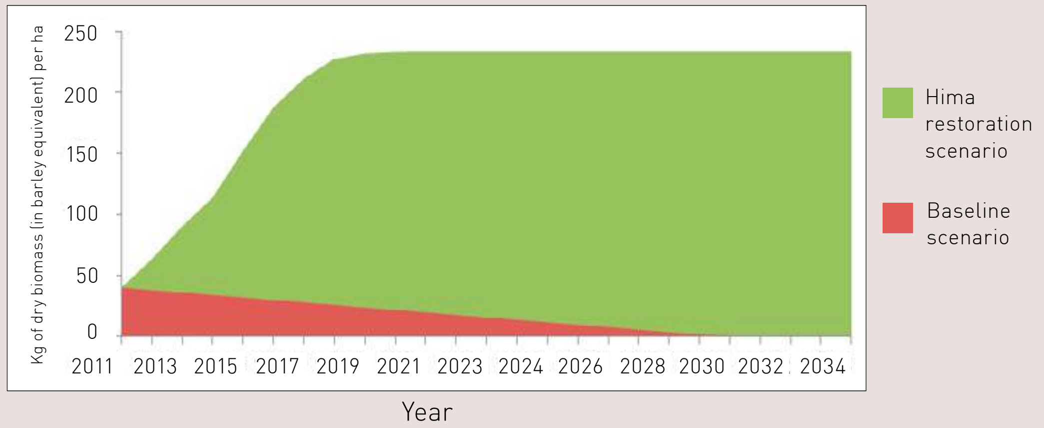
Valuing rangeland forage production - theoretical framework

An increase in rangeland productivity will result in increased availability of natural forage, thus positively impacting livestock herders by reducing fodder purchase costs. A household survey conducted in the Bani Hashem community in March 2014 revealed that the average livestock owner purchased approximately 1,700 kg of forage/month (descriptive statistics are found in *Appendix 5*) at a value of 380 JOD[7]. Livestock owners, report this to be 75 per cent of their monthly forage requirement. Other studies have found that rangeland herders purchase more than 80 per cent of their forage (Al-Tabini et al., 2012). In this situation, any

$$Growth(biomass_t) = \gamma * biomass_t(1 - \frac{biomass_t}{biomass\ MAX}) \qquad \text{(Equation 3.1)}$$

FIGURE 5

Predicted evolution of dry biomass yield in kg/ha in the baseline scenario versus the Hima restoration scenario



[6] *The rotational Hima system fullfils the Noy-Meir assumption that grazing is not allowed on a tract of land outside the growing season.*

[7] *JOD is the abbreviation for Jordanian Dinar, the prevailing currency of Jordan. The 2014 exchange rate is 1USD to 0.7 JOD.*

marginal increase in rangeland forage production will directly substitute for the need to purchase additional feed. The value of increased rangeland biomass may therefore be estimated as the avoided costs associated with forage purchase.

In this model, the individual herder aims to minimize costs associated with feed purchase while achieving a fixed level of benefits in terms of livestock products. In this case, feed purchase will decrease when more biomass is grazed (*Equation 3.2*), and any additional biomass grazed through Hima restoration will represent an avoided fodder purchasing costs. Fodder grazed is converted into feed barley equivalents to estimate the avoided cost associated with fodder purchase.

Using *Equation 3.1,* one can establish how biomass grows annually within the system, when a cell is open to grazing (*Equation 3.3*) versus when a cell is protected from grazing (*Equation 3.6*). Another condition characterizing Hima systems stipulates that only half of the biomass available in any one year may be grazed that year (*Equation 3.4*). In the absence of this management principle and conservation threshold, biomass will not regenerate over time. Therefore, relative to the open access scenario, stocking rates will be lower in the early years of adopting a Hima system, to avoid future productivity decreasing.

In the open access area, it was assumed that all of the biomass available at the outset would decline by 10 kg/ha/yr after establishment of the Hima system (*Equation 3.6*). This hypothesis is consistent with Al-Satiri (2013), who shows that 2.5 years after Hima establishment at Bani Hashem, biomass had declined from approximately 40 kg of dry matter/ha to 10.8 kg in the neighbouring open access area (Al-Satiri 2013; *Appendix 3A)*.

In the baseline scenario, it is expected that rangeland productivity will continue to decline at the rate of 2 kg dry matter/ha/yr (*Equation 3.7*), which is consistent with observed trends over the past 20 years (MoA, 2009). Through re-arrangement, the implied take-off per hectare can be estimated (*Equation 3.8*).

Feed $purchase_t$ = feed $requiremen_t$ – own biomass $production_t$ – biomass $grazed_t$ *(Equation 3.2)*

Within the Hima system scenario (in kg of dry biomass/ha terms):

Biomass in Hima $cell_{t+1}$ = $biomass_t$ + Growth $(biomass)_t$ - biomass $grazed_t$ *(Equation 3.3)*

Biomass grazed in Hima $cell_{t+1}$ = 0.5 × $biomass_t$ *(Equation 3.4)*

Biomass in protected Hima $cell_{t+1}$ = $biomass_t$ + Growth $(biomass)_t$ *(Equation 3.5)*

Biomass in open access cell within the Hima $system_{t+1}$ = $biomass_t$ – 10kg $biomass_t$ *(Equation. 3.6)*

In the baseline open access scenario (in kg of dry biomass/ha terms):

Biomass of open $access_{t+1}$ = $biomass_t$ – 2kg $biomass_t$ *(Equation. 3.7)*

Biomass grazed in open $access_{t+1}$ = Growth $(biomass_{jt}$ + 2kg $biomass_t$ *(Equation. 3.8)*

Through these relationships the total biomass (per hectare) generated in a Hima system over and above that which might be generated in an open access regime was estimated. On this basis, the present value of additional feed generated through Hima restoration (in terms of avoided purchase of fodder), can also be estimated as shown in *Equation 3.9*.

Present value of feed through Hima restoration =

$$\sum_{t=0}^{24} \frac{(\text{Barley eq. grazed in hima scenario}_t - \text{Barley eq. grazed in open access scenario}_t) * \text{price of feed}_t}{(1+r)^t} \times \text{Area} \qquad \text{(Equation 3.9)}$$

, where *price of feed* = price for a tonne of coarse grain barley feed at year *t*, *Barley eq. grazed* = barley equivalent of rangeland forage grazed in tons/ha (each ton of dry forage from rangelands is equivalent to 0.8 ton of barley in terms of nutritional value), and *Area* = Total area suitable for Hima restoration in the Zarqa River Basin in ha (109,093 ha).

Feed prices

Barley is the main supplementary feed for livestock in Jordan. The majority of it is imported, since barley production in Jordan is negligible. Sheep and goat herders receive subsidized barley according to the actual number of animals that each household has registered. The estimated cost of subsidising wheat and barley on the Jordanian Treasury is around 290 million JOD (410 million USD) for 2014, based on current international prices (Jordan Times, 2014). World market prices – the price at which the Ministry of Industry and Trade (MIT) imports feedstock – were used to derive an estimate of the true economic benefit to Jordanian society of avoided feed purchase.

OECD-FAO Outlook (2013) was used to retrieve coarse grain barley world prices since 1990. The data was used to predict how barley feed prices may evolve over the next 25 years, using a first order auto-regressive model. By simultaneously estimating the regression coefficients and the autoregressive error model parameters, the procedure corrects the regression estimates for autocorrelation.

$$\text{Feed price}_t = \beta_0 + \beta_1 \text{feedprice}_{t-1} + e_t, \; t = 2011, 2012$$
$$e_t = \phi e_{t-1} + \varepsilon_t \qquad \textit{(Equation 3.10)}$$

The structural part of the model is used to obtain an estimate of the unconditional mean of the coarse grain prices at future date *t*. The estimated model is shown in *Table 1* and predicted future prices are illustrated in *Figure 6*.

All the coefficients in *Table 1* are significant and the regressions showed a high adjusted R-squared, suggesting that the estimated parameters have a strong explanatory power of historical price movements.

TABLE 1

AR (1) model of feed prices

Parameter	Estimate	Pr → |t|
β_0	-12114	0.011
β_1	6.12	0.010
ϕ	0.59	0.0021
Regress R-Square 0.2751,Total R-Square 0.7187, AIC Durbin-Watson 1.7136.		

[8] http://stats.oecd.org/viewhtml.aspx?QueryId=48184&vh=0000&vf=0&l&il=&lang=en# http://www.oecd.org/site/oecd-faoagricultur-aloutlook/48186214.pdf.

As shown in *Figure 6*, barley grain feedstock prices are predicted to rise. This is in line with forecasts made by OECD-FAO (2013), suggesting that agricultural commodity prices, in real terms, will remain on a higher plateau during the next ten years compared to the previous decade. OECD-FAO (2013) argues that land available for agriculture in many traditional supply areas is increasingly constrained and production must expand into marginal lands with lower fertility and higher risk of adverse weather events. At the same time the cost of energy is likely to remain high, while resource pressure; in particular those related to water and land are increasing (OECD-FAO (2013[8])). In view of these circumstances additional natural forage from Hima restoration will become more valuable over time because the relative feed prices are increasing.

Avoided cost of fodder purchase

The flow of returns as the value of fodder is shown in *Figure 7* under the Hima system compared to the baseline/open access scenario and using a discount rate of 5 per cent as justified in *Chapter 4 (Discount rates)*. The sensitivity of the results to other discount rates is also found there. On this basis the avoided cost/ha of rehabilitated rangeland associated with fodder purchase over a 25 year time horizon was calculated. The results are shown in *Table 2* (*Columns 4 and 5*). They show that the total discounted value of a large-scale Hima restoration within the Zarqa River Basin amounts to 16.2 million JOD (23 million USD) over a 25 year time horizon, assuming that the entire 109,093 ha deemed suitable for Hima systems (areas classified as rangelands by (MoA, 2013) and not used for other activities such as mining at present) actually falls under the Hima system.

For the sake of illustration, the present value returns of rangeland restoration, assuming all rangeland is converted to rotational cell grazing, is also demonstrated. It is estimated how many sheep or goats the land would be able to support in its steady state if, 360 days' worth of fodder were to come from the land (i.e., no purchase of feed). It was found to be 18,000 livestock - a figure far below the current 600,000 sheep and goats that exist in the Zarqa River Basin (Madat, 2014). This significant difference illustrates the unsustainable management of Jordanian rangelands, possibly due to a combination of feed subsidies and resultant overstocking and prevailing land tenure structures. *Appendix 3B* explains how this figure is derived. However, this should be held against the baseline scenario, in which the livestock carrying capacity of land is predicted to reach zero by 2030. The final columns in the table shows the welfare economic value associated with natural forage (deduced from the 'choice experiment', explained in *Chapter 3*).

FIGURE 6

Actual and predicted price trend in Jordanian Dinars of barley grain for feed to 2035 (nominal prices)

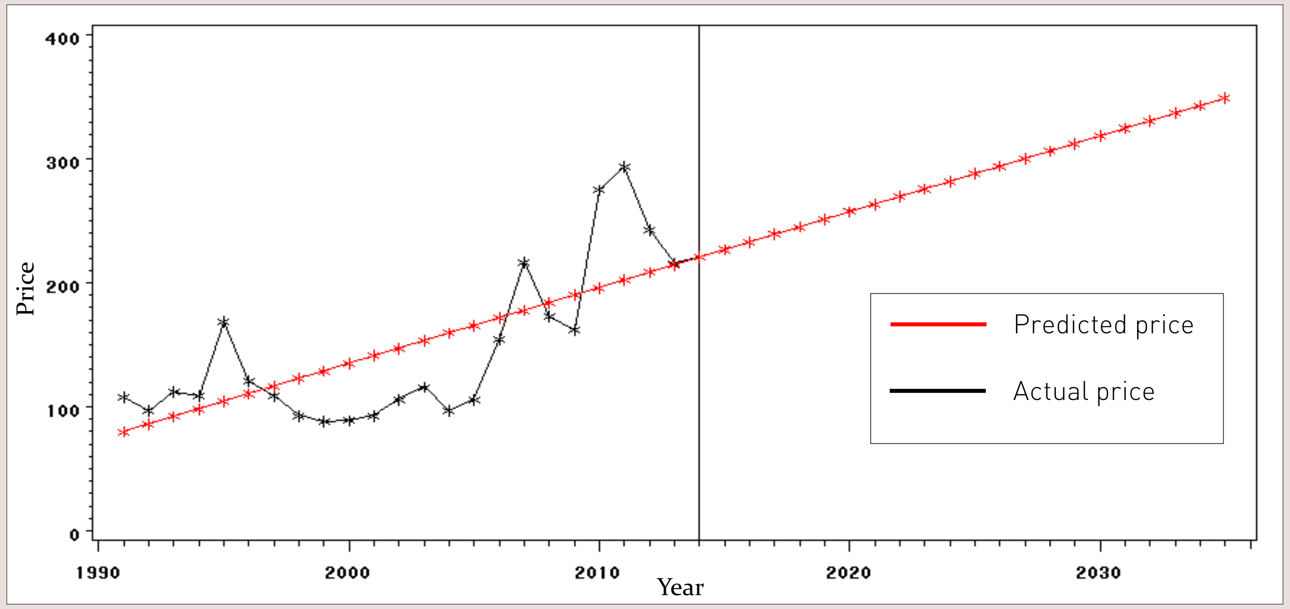
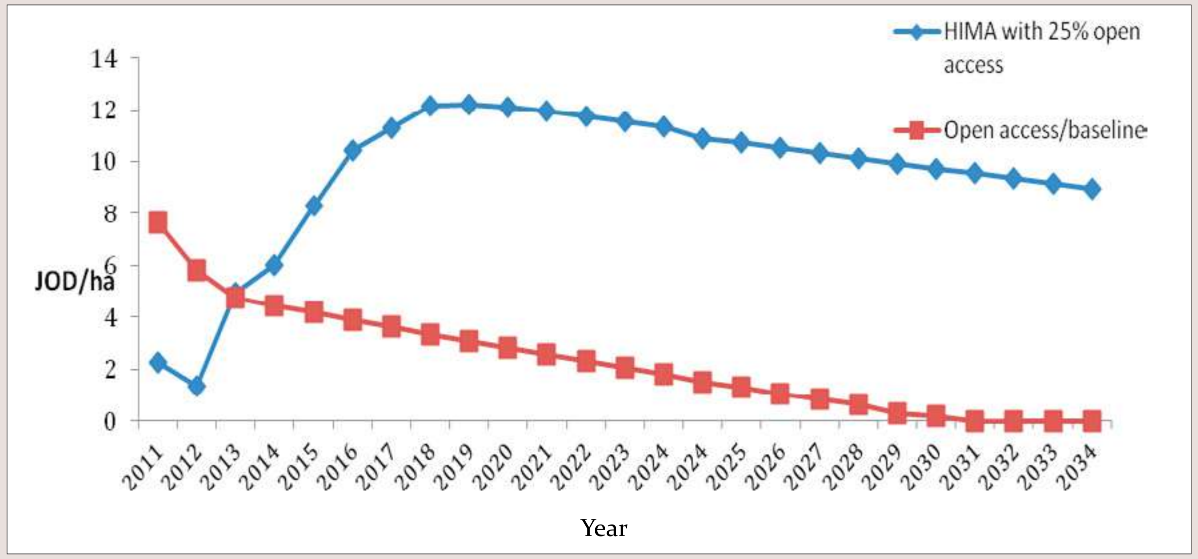


FIGURE 7

Present value returns to the baseline scenario versus restoration through the Hima system with 25% open access



Welfare economic value of natural forage and stream-flow availability

While doing fieldwork in preparation for the economic valuation in March 2014, it became clear that livestock owners attributed a special value to natural forage over concentrated feed. Meat and milk products are considered to be of superior quality from animals nourished on natural feed, as opposed to concentrated, due to the higher nutritional and medicinal value of natural forage. Pastoralists in recent years have observed an occurrence of livestock diseases previously absent or uncommon such as: enterotoxaemia, wool and hair loss, respiratory infection, and diarrhoea. Rangeland plants such *as Artemisia* judaica (Ibeithran, in Arabic) *Artemisia herba-alba* (Shieh) and *Achillea fragrantissima* (Gaisoom) grow naturally in healthy rangeland pastures in the study area (Al-Satiri et al., 2013) and have traditionally been used to avoid and treat these illnesses (Al-Tabini et al., 2012). Focus groups and face-to-face interviews undertaken in March 2014 with the Bani Hashem community furthermore revealed that the appreciation for rehabilitated landscapes was closely linked to the pastoralists' assessment of its forage equivalent properties.

Rehabilitated pasture vegetation is also likely to reduce run-off, enhance water infiltration, and improve lateral return flow to rivers and streams outside precipitation events. This latter ecosystem service has both landscape and utilitarian values, as herders may be able to use the water for livestock or in supplementary irrigation schemes. However, as natural forage, grazing or enhanced stream flows cannot be purchased in competitive markets, and it is therefore not possible to use market prices to deduct the economic value of these services.

Choice experiment

A stated preference choice experiment (CE) was conceived and implemented in Bani Hashem, in order to assess the welfare economic values associated with rangeland restoration, natural forage, and sustained stream-flow. During a stakeholder workshop in Amman in March 2014, it was decided that the Bani Hashem rangelands can be considered representative of the rangelands in the Zarqa River Basin as a whole (IUCN, 2014), legitimizing a focus on this area.

TABLE 2

Rangeland productivity and barley equivalent value per ha from open-access/baseline regime and through Hima restoration (r = 5%)

System	1. Total predicted Barley Equivalent biomass grazed over 25 years	2. Total predicted barley equivalent biomass grazed per year in steady state	3. Total barley equivalent present value of grazing over 25 years	4. Present economic value of forage from HIMA restoration	5. Present value of forage from HIMA restoration over 25 years	6. Total animal units allowable in steady state	7. Present welfare economic value of natural forage from Hima restoration*	8.Present welfare economic value of natural forage from Hima restoration* over 25 years
a. In an open access regime	0.3 ton/ha		55.1 JOD/ha					
b. In a Hima system with 25% open access	1.4 ton/ha	67 kg/ha	209.5 JOD/ha	155.5 JOD/ha	**16.8 million JOD**		193.2 JOD/ha	21.1 million JOD
c. In a strict Hima system	1.9 ton/ha	89 kg/ha	274.1 JOD/ha	219.1 JOD/ha	**23.9 million JOD**	18 023	274.3 JOD ha	29.9 millionJOD

*Including a price of 61.8 JOD/ton forage price premium on natural forage derived from the choice experiment outlined in this chapter.

Focus group and pre-testing of the choice experiment valuation survey with a Bedouin family, March 2014

In CEs, a number of respondents are asked to select their preferred option from a range of potential management alternatives, usually including a status quo alternative. Discrete choices are described in a utility maximising framework and are determined by the utility that is derived from the attributes of a particular good or situation (as shown in the following section on econometric specification. It is based on the behavioural framework of random utility theory (Manski, 1977) and Lancaster's theory of demand (Lancaster, 1966). For an in-depth description of the method, the reader is referred to Bateman et al. (2002).

The experimental design underlying the choice experiment was created using d-error minimised efficient design in Ngene software (www.choice-metrics.com), with parameter priors different to zero (b ≠ 0). The degrees of freedom demanded a minimum of six choice sets, and respondents were asked to evaluate those six choice situations. Those interested in learning about efficient experimental designs are referred to ChoiceMetrics (2010).

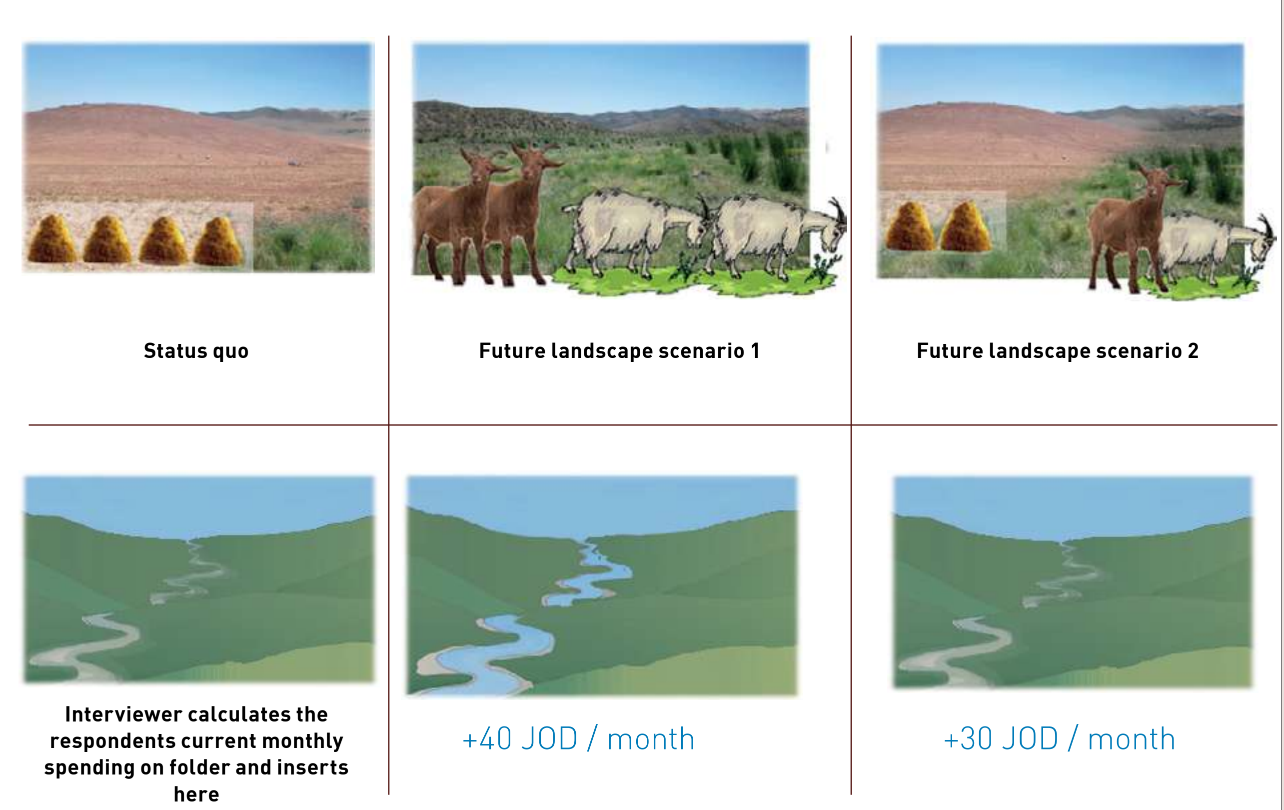
Questionnaire design and data collection

Data collection was undertaken using personal interviews conducting at respondents homes in March 2014. The population from which the sample was selected were livestock owners living within the Bani Hashem area, numbering 500 households. Descriptive statistics of the households are provided in *Appendix 3.*

Respondents were asked to evaluate six choice sets (see *Figure 8*) and to choose between three landscape scenarios: a continuation of the present landscape and two future restoration scenarios. Each future restoration scenario was associated with a monthly cost, over and above that which the livestock owners currently pay for fodder. The livestock owners were asked to choose their preferred scenario, and identify if they thought either of the two future scenarios was too expensive to pay, in which case they should choose the present situation. Visual aids were used to depict changes in landscape and forage availability and help reduce unfamiliarity with the attributes. In total, 42 households undertook the choice experiment survey. While this number might seem low compared to other studies, each respondent evaluates six choice sets, so a total of 252 (6 x 42) choices were actually collected.

FIGURE 8

Example of a choice set



Survey implementation in the Bani-Hashem community, March 2014

Econometric specification

To describe discrete choices in a utility maximising framework, a CE employs the behavioural framework of random utility theory (RUT). In RUT, the individual *i*'s utility *U* from alternative *j* is specified as

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad \textit{(Equation 3.11)}$$

, where V_{ij} is the systematic and observable component of the latent utility, and ε is a random or "unexplained" component assumed IID and extreme value distributed (Louviere et al., 2000). Observed preference heterogeneity is incorporated into the deterministic part of the utility function by interacting respondent characteristics with the management attributes[9]. With the expectation that different population segments might have different Willingness To Pay (WTP), a piece-wise linear-in-spline cost parameter was incorporated in the deterministic part of the utility function (Morey et al., 2003; Scarpa et al., 2007). On this basis, the most elaborate utility function, specified to be linear in the parameters, takes the following form:

$$V_{ij} = \beta_{ASC} + \beta_1 X_{50\%\ pasture\_feed} + \beta_2 X_{100\%\ pasture\_feed} + \beta_3 X_{Stream\_flow} + \beta_4 X_{Cost} + 1(X_{Cost} \cdot S_{high\_income})\delta_1 \qquad \textit{(Equation 3.12)}$$

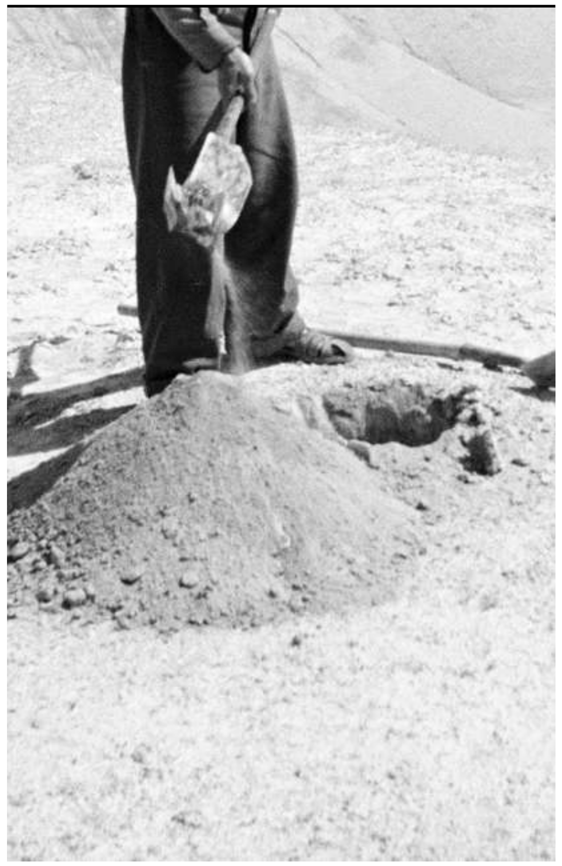
, where 1(·) is a binary indicator function. The β_{ASC} is the parameter for the alternative specific constant (ASC), which accounts for variations in choices that are not explained by the attributes or socio-economic variables. The vector of coefficients $\beta_{1...}$ β_K and δ_1 is attached to a vector of attributes (X) that influence utility. The WTP is calculated using *Equation 3.13*.

$$WTPk = -(\beta_k/\beta_{Cost}) \qquad \textit{(Equation 3.13)}$$

Given the presence of interactions between the cost parameter and the socio-demographic and attitudinal characteristics, the cost parameter was also adjusted to take into account this heterogeneity in the underlying sample. The linear-in-spline adjusted cost parameter employed in calculation of average welfare estimates is:

$$\beta_{adj\ cost} = \beta_{cost} + \beta_{cost \times high\_income} \times High\_income \qquad \textit{(Equation 3.14)}$$

Within *Equation 3.14*, the share of higher income earners within the sample are inserted (Morey et al., 2003; Scarpa et al., 2007).



[9] Since social and economic characteristics are constant across choice occasions for any given respondent, they can only enter as interaction terms with the management attributes.

04 Results

Conditional logit model

As shown in *Table 3*, all the attributes are significant factors in the choice of a future management scenario, at a 99 per cent level of confidence. Signs are as expected and the overall fit of the model, as measured by the adjusted McFadden's ρ^2 of 0.31, is very good by conventional standards used to describe probabilistic discrete choice models (Ben-Akiva and Lerman, 1985; Louviere et al., 2000).

Willingness to pay and welfare estimates

Table 3 reports willngess to pay (WTP) for households earning less than 2,000 JOD (2,800 USD) per year, households earning more than 2,000 JOD per year, and for the average household in the sample (WTP^A). When the cost attribute is used as the normalising variable, the most important attribute is the extent of restoration of the rangeland ecosystem and the natural forage provided by a rehabilitated ecosystem. In particular, results indicate that if 100 per cent of forage were to come exclusively from natural pastures in the landscapes surrounding the households, the average household would have an increased WTP of 120 JOD (170 USD) per month. The welfare economic benefit for each household is halved when only part of the landscape is rehabilitated. If the landscape is furthermore associated with the replenishment of streams that have gone dry over the past 20 years, the average livestock herder is willing to pay an additional 56 JOD per month. Consistent with expectations, low-income earners are willing to pay significantly less.

TABLE 3

Conditional logit estimates and WTP for rangeland restoration

Parameter	Estimate	t Value	Pr > |t|	WTP - Low income	WTP - High income	WTP^A Whole sample
Alternative specific constant	2.06	5.25	***			
Intermediate Hima restoration: *Half of food from natural pastures*	1.28	3.63	***	41.2	67.9	**61.5 JOD/month**
Advanced Hima restoration: *All food from natural pastures*	2.51	6.63	***	81.0	133.2	**120 JOD/month**
Water return to streams that have gone dry over the past decades.	1.06	3.74	***	33.9	55.9	**51 JOD/month**
Price	-0.019	-5.63	**			
Price*High income	-0.012	-2.07				

N=45, Obs=270, AIC=377.5, McFadden r^2=0.31
**Significant at the 95% level of confidence ***Significant at the 99% level of confidence

A price premium on natural forage

On the basis of the household survey, the average household purchases approximately 1.7 tonnes of forage per month (descriptive statistics in *Appendix 3*). Since the average household is willing to pay 120 JOD more per month to ensure their forage is natural, this WTP is an additional premium of 70.6 JOD (90 USD) per ton of natural forage (120 JOD/1.7 tons). This represents a 40 per cent premium above that which respondents currently pay per ton of government-subsidised barley (175 JOD), giving way to a review of the present value estimates of rangeland restoration through the Hima system provided in *Table 2*. Taking into account the welfare economic value that households associate with natural forage, the present welfare economic value of additional natural feed associated with restored rangelands may be calculated in *Equation 4.1* as follows:

Present welfare value of feed from Hima restoration =

$$\sum_{t=0}^{24} \frac{(\text{Barley eq. grazed in hima scenario}_t - \text{Barley eq. grazed in baseline}) \times (\text{price of feed}_t + 70.6 \text{ JD})}{(1+r)^t} \times \text{area}$$

(Equation 4.1)

, where *Feed price* = price for a tonne of coarse grain barley feed at year *t*, *Barley eq* = Barley equivalent of rangeland forage grazed in tons/ha (each ton of dry forage from rangelands is equivalent to 0.8 ton of barley in terms of nutritional value), and *Area* = total area suitable for Hima restoration in the Zarqa River Basin in ha.

Water and soil analyses

Jordan is located in one of the most water scarce regions in the world, with fresh water per capita estimated at just 10 per cent of the global average (UNDP, 2013). However, the Jordanian rangelands serve as watersheds that receive rainfall, yield surface water, and replenish groundwater throughout the region east and south of the western Jordan highlands. They are consequently an essential part of Jordan's national water conservation strategy (Al-Tabini et al., 2012). Restoration of Jordanian rangelands through Hima restoration will positively impact hydrological services (see *Appendix 4*).

In this study, ArcSWAT is integrated with GIS to simulate runoff, water yield, ground water percolation, and sediment yield. SWAT is a physically based and computationally efficient hydrological model which uses a range of data inputs, summarised in *Table 4* and described in *Appendices 1, 2,* and *4*. SWAT was developed to predict the impact of land management practices on water, sediment, and agricultural yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time (Neitsch et al., 2005). Streamflow data for modal calibration of the ArcSWAT model was unfortunately not available at the time when this study was prepared. However, as the authors were interested in relative magnitudes of watershed services for the economic valuation; that is, the difference between the present baseline and the future restoration scenario, the non-calibrated model responds perfectly to the needs of this study. Moreover, because high-quality-high-resolution inputs were, there is strong confidence in the quality of the results. The model was re-calibrated with actual streamflow data in December 2014, as a result of expert and ministerial interest in absolute estimates of water cycle parameters for the Zarqa river basin[10].

[10] *For the full report, please visit: www.iucn.org/about/work/programmes/ecosystem_management/about_work_global_prog_ecos_dry/gdi_projects*

TABLE 4

Data inputs used for SWAT analyses

Variable	Land use scenario inputs	Source
Digital Elevation Modal	DEM SRTM	USGS EROS Data Center (http://dads.create.usgs.gov/SRTM) and National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA)
Soil	FAO Soil	FAO/UNESCO Soil Map of the World, FAO, 1971-81
Climate data	1990-2010 daily data (224 real and virtual weather stations)	The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalyses (CFSR) from Texas A&M university http://globalweather.tamu.edu
Land use	Present land use and future land use cover	See *Appendix 1*
Software	ArcSWAT	ArcSWAT 2009.93.7b Texas A&M university http://swat.tamu.edu/software/arcswat

Value of ground water aquifer infiltration from Hima restoration

Table 5 shows the main outputs from the ArcSWAT analysis with respect to the average yearly changes in aquifer recharge and surface runoff. These are then converted into million cubic meter (MCM) equivalent for the area affected by Hima management within the Zarqa River Basin. As shown in *Table 6*, Hima restoration results in a significant change in the level of aquifer recharge within approximately five years after system establishment. The majority of water percolates to the shallow aquifer, with the rest ending up in the deep aquifer. In this analysis, the value to society of the water percolated to the shallow water aquifer is focused on, as costs associated with extracting groundwater from the deep ground water aquifer are unknown.

To estimate the value of the additional ground water to Jordanian society, interviews with rangeland field workers and herder was held in March 2014, to elicit how much herders are willing to pay for water that is trucked in for their livestock. Livestock owners pay between 1 and 5 JOD depending on the aridity of the environment and their distance to natural springs, but majority of livestock owners within the study area are willing to pay no more than 2 JOD/m³ of water[11] on average, as shown in *Table 6*. Interestingly, the price of 2 JOD/m³ of water is similar to the costs associated with generating additional water storage capacity through the construction of dams (see next section) and thus represents a good approximation of social WTP for additional water. Hence, the authors believe that this value adequately reflects societal marginal WTP for water.

Ground water recharge varies stochastically from year to year, depending on the rainfall (*Figure A4.5* in *Appendix 4*). To estimate changes in ground water percolation resulting from rangeland restoration, the same climatic data was used as those recorded for the last 20 years (See *Appendix 4*, *Table A.4.1*), subsequently averaged in order to derive an estimate of the average annual quantity of water infiltrated to the shallow groundwater aquifer under both the present land use and future rehabilitated land use scenarios. The present value of groundwater recharge over a 25 year time horizon is estimated on the basis of the equation where r = 5 per cent:

$$\text{PV of enhanced aquifer percolation} = \sum_{t=5}^{24} \frac{\Delta \text{ in aquifer percolation} * \text{price of water}_t}{(1+r)^t} \qquad \textit{(Equation 4.2)}$$

[11] The price at which water sells through the public distribution network was not used as an indicator of the value of water, as it is artificially low and therefore forbidden as drinking water for animals.

The ArcSWAT analysis demonstrates that on average, an additional 9.2 MCM of water are infiltrated annually to the shallow aquifer as a result of large scale Hima restoration within the Zarqa River Basin. This is a significant result in the light of the high demand for water and excessive abstraction within the basin. According to Kuisi (2014), the ground water safe yield of the basin is about 65 - 70 MCM per annum, while the true abstraction rate exceeds 140 MCM. In the Zarqa Governorate, the water consumption by various sectors is as follows, the Amman municipalities consume approximately 40 MCM of groundwater per annum, while the industries consume approximately 8 MCM per annum, and the agricultural sector consumes approximately 110 MCM per annum for irrigation purposes. Hima restoration can thus help to increase the safe yield of the basin by 13 - 14 per cent.

With an estimated economic value of 2 JOD/m³ of water, the total present value over a 25 year time horizon of groundwater infiltration as a result of Hima restoration amounts to 188.5 million JOD (r = 5 per cent). This is equivalent to an annuity value of 13.4 million JOD (19 million USD)[12].

Value of reduced sedimentation of downstream dams

Water runoff harvesting is common in Jordan. Ten dams have been constructed in the last five decades with a total capacity of around 275 MCM. They serve to generate water for irrigation, store treated waste water, provide hydropower electricity, replenish underground aquifers, and allow for recreational activities and storage of treated wastewater. However, a major obstacle to proper dam functioning is sediment deposition (much of it originating from barren rangelands), which reduces storage capacity, shortens their lifespan, and reduces hydropower potential. The hypothesis here is that large-scale Hima restoration and resulting improved vegetation cover may help trap incoming sediments and stabilize soil particles when compared to the baseline scenario.

[12] If water was valued using prevailing market prices for irrigation water, the benefit estimate would have been substantially lower. Market prices for irrigation water are in the order of 0.007 - 0.098 JOD/m³) (Venot et al., 2007). However, these prices are clearly undervalued and not representative of the scarcity value of water, since they lead to abstraction rates that are double the safe-yield. They neither approximate rangeland inhabitant's WTP (as shown in this report), nor society's WTP as reflected in the per cubic meter price of constructing dams.

TABLE 5

Changes in water cycle as a result of rangeland restoration and the present value of ground water infiltration (r = 5%)

	Present baseline land use scenario	Future Hima land use scenario*	Δ as a result of Hima restoration*	Δ as a result of HIMA restoration within the basin	Present value over 25 year time horizon
	m³/ha/yr	m³/ha/yr	m³/ha/yr	MCM/yr	JOD
Shallow aquifer recharge	160.6	184.8	**+ 24.2**	9.2	188.5 million
Total aquifer recharge	187.5	215.8	**+ 28.3**	10.8	
Surface runoff	447.9	394.6	**- 53.3**	16.4	

*Within 5 years after establishing the Hima system.

TABLE 6

Livestock owners WTP for water in the Jordanian Badia

Source	Response	Average value per m³
Yehia Al-Satiri, NCARE researcher	15 JOD, but at times up to 20 JOD for truck with water of 6m³	2 JOD
Amer Madat, IUCN Senior field Officer	From 1 JOD/m³ to up to 4 - 5 JOD/m³	2 JOD

This protecting service has important economic value in terms of avoided maintenance costs or maintaining reservoirs for profitable economic activities. This latter life maintenance service is valued through the replacement cost approach.

As this study applies to the Zarqa River Basin, the study focused on the only dam within the basin - the King Talal Dam, located within sub-watershed 39 (*Figure 1*), and the largest reservoir in Jordan. Its main purpose is to store winter rains and treated wastewater from Amman and Zarqa for irrigation in the Jordan Valley. The dam was completed in 1978 with a height of 92.5 m above the riverbed, and work to raise the dam to a height of 106 m began in 1984, and was terminated in 1987. It has a total capacity of 85 MCM, of which 11 MCM is dead storage. Dead storage refers to water in a reservoir that cannot be drained by gravity through a dam's outlet works or spillway, whereas active storage is the portion of the reservoir that can be utilised for downstream releases such as agriculture. According to the Ministry of Water and Irrigation, there were 13.5 MCM of sediment deposited in the reservoir in 2009 (MWI, 2014), implying that any sediment deposited after this date infringes on the active storage of the dam. As water demand is forecasted to increase in Jordan, it is assumed that any water storage lost through sedimentation will need to be replaced on an annual basis. An estimate of the avoided reservoir replacement costs associated with rangeland restoration was conducted as follows:

1. Undertake ArcSWAT model simulation and calibration and forecast outputs for the sub-watershed located immediately after the King Talal Dam (*Figure 2*);
2. Estimate to what extent sediment loading of the entire watershed contributes to the sedimentation of the King Talal Dam for both the baseline and the restoration scenario;
3. Subtract the sediment yield estimates of the baseline scenario from the restoration scenario to estimate the change in weighted sediment loading as a result of restoration on an annual basis;
4. Convert the weighted average mass of sediment deposited in King Talal Dam to volume using the average bulk density for the soils in the Zarqa River Basin (1.4 t/m^3) derived as shown in *Appendix 5*;
5. Assess the average costs of constructing 1 MCM of additional water storage capacity;
6. Estimate the avoided cost basis associated with replacing the storage capacity that would be lost in the baseline scenario relative to the restoration scenario on an annual basis, and;
7. Discount average annual avoided costs over a 25 year time horizon in order to yield a present value of avoided replacement costs.

Table 7 shows the change in sediment loading over 25 years for the King Talal sub-watershed, as a result of Hima restoration. It shows that restoration serves to reduce total sediment deposited in the King Talal Dam by 1.4 million tons over 25 years, presuming that the full soil retention capacity of Hima sites do not materialise until 5 years after the system has been established. Using the average bulk density of Zarqa River Basin soils, 6.2 MCM of sediments can be trapped over 25 years and not deposited in the King Talal Dam.

TABLE 7

Total sediment loading for sub-watersheds affecting the King Talal Dam over a 25 year time horizon

	Present baseline land use scenario	Future Hima land use scenario	Δ In sediment loading as a result of Hima restoration	Δ In King Talal storage capacity
Average annual sediment loading*	9.5 t/ha	8.911 t/ha	-0.578 t/ha	0.72 m^3
Average annual sediment loading in King Talal for the whole watershed	3,605,774.5 t/ha	3,386,137.2 t/ha	-219,637 t	**307,492 m^3**
Sediment loading for the whole watershed over 25 years	90,144,361 t/ha	84,653,431 t/ha	-5,490,931 t	7,687,303 m^3

*Within 5 years after the establishment of the Hima system

TABLE 8

Construction costs associated with the expansion of the King Talal Dam's reservoir capacity

What	When	Compounded Present Value cost in JOD (millions)	Additional storage Capacity in MCM	Implied replacement cost per MCM of storage in JOD (millions)	Source
14 meter heightening of the King Talal dam	Completed 1988	65	30	2.2	Wikipedia
Reservoir immediately downstream of King Talal	Pipeline	26	10	2.6	MWI 2014
Average				**24**	

Reservoir replacement may occur through desalination projects, water imports from Israel, or further expansion of reservoir capacity. The average cost of generating 1 MCM (million m^3) of additional storage capacity was calculated by consulting the most recent estimates associated with expanding water storage capacity of the King Talal Reservoir. The costs per MCM of heightening the dam in the 1980s was considered, as well as a recent plan to create an addition reservoir of 10 MCM immediately downstream of the King Talal Dam in order to help still sediments (MWI, 2014). It is expected that the additional reservoir construction will cost 26 million JOD, representing an implicit WTP of 2.6 JOD/MCM to enhance water storage capacity for irrigation (MWI, 2014). On the basis of data shown in *Table 8*, the average cost of generating 1 MCM of storage was estimated at approximately 2.4 million JOD (or 2.4 JOD/m^3).

Using *Equation 6.1,* the present value benefits associated with the avoided loss in storage capacity of the King Talal Dam over 25 years with r = 5 per cent is in the order of 7.6 million JOD.

This estimate assumes that every cubic meter of water storage lost will eventually have to be replaced through dam construction at costs similar to those incurred during the heightening of the King Talal Dam, or the already planned expansion of the reservoir to be constructed immediately downstream of the King Talal Dam. However, the value of prevented sedimentation (2.4 JOD/m^3 or 3.4 USD/m^3) should be considered as a lower bound estimate of the true value of limiting erosion. For example, sediments also limit ground water infiltrations of dams and clog up irrigation systems, inducing significant repair costs (MWI, 2014).

Carbon sequestration and storage

Sustainable management of rangelands can aid in the mitigation of rising atmospheric carbon dioxide concentrations via carbon storage in biomass and soil organic matter, a process termed carbon sequestration (Derner and Schuman, 2007). Grazing facilitates the physical breakdown, soil incorporation, and decomposition of residual plant material (Schuman et al., 1999), and thus grazing intensity and frequency are thought to be the primary determinant of carbon storage across rangelands (Bruce et al., 1999). In rangelands where management changes are occurring over time, biomass carbon stock changes can be significant (e.g., improved pasture management leading to increased sequestration) (IPCC, 2003). This study

$$\text{PV benefit of avoided loss in storage} = \sum_{t=5}^{24} \frac{\Delta \text{ in storage capacity}_t \times \text{replacement cost}}{(1+r)^t}$$

(Equation 4.3)

attempts to estimate the benefits associated with a marginal increase in carbon sequestration rates as a result of Hima restoration.

Social benefits are estimated by establishing the extent to which Hima restoration contributes to carbon sequestration over and above the baseline scenario. The sequestered carbon is translated into a monetary value by using the avoided 'social cost of carbon' estimates, which approximates the avoided global damages associated with a marginal increased carbon sequestration (explained below).

Above and below ground carbon sequestration

Total carbon sequestration resulting from particular land uses are calculated as the aggregate of above ground and below ground carbon stocks. In estimating soil Organic carbon (SOC), authors drew on the work of Al-Adamat et al. (2007), who used the Global Environmental Facility - Soil Organic Carbon (GEFSOC) modelling system to predict changes in soil organic carbon stocks in Jordan, between 2000 and 2030, in accordance with the advanced IPCC Tier 3 methodology[13]. Al-Adamat et al. (2007) predicted a significant decline in Jordan SOC stocks due almost exclusively to the degradation of pasture and rangeland in Jordan. Using the CENTURY model[14] output from the GEFSOC modelling software, the authors found that carbon content varied in linear proportion to rainfall from 2.3 to 15.3 t C/ha in 2000, resulting in an average SOC of 6.8 t C/ha in 2000. This figure was predicted to decrease to an average value of 5.9 in 2015 t C/ha by 2030. The latter estimate represents a 44 per cent decline relative to 1990 average levels of 7.2 t C/ha (Al-Adamat et al., 2007).

Excessive overgrazing began in the Badia during the 1990s and has had a long-term effect on SOC stocks (Al-Adamat et al., 2007). For the purpose of estimating SOC associated with Hima restoration, 1990 carbon sequestration levels were assumed to offer a viable indicator of the SOC that may be associated with Hima restoration. Above ground biomass estimates calibrated from the Bani Hashem Hima were used to estimate above ground carbon (AGC) sequestration rates, following IPCC 2003 Tier 1 methodology. The steady-state biomass estimates achieved through Hima restoration are in accordance with biomass estimate ranges for the Jordanian Badia in 1990 (MoA, 2009) and therefore consistent with expectations that SOC stocks may revert to 1990 levels as a result of rangeland restoration.

To derive an estimate of AGC sequestration resulting from Hima restoration, the IPCC Tier 1 approach was used, where the annual change in stocks of carbon dioxide over a 25 year time horizon was calculated for both the baseline and restoration scenarios, using *Equation 4.4*.

The same procedure was followed for SOC, with the exception that SOC estimates by Al-Adamat et al. (2007) were used, and therefore authors only converted annual changes in carbon stocks/ha to carbon dioxide equivalents according to *Equation 4.5*.

$$\Delta CO_2e_{AGB(s)} = \frac{AGB_{t+1} - AGB_t}{t_{t+1} - t_t} * CF * CO_2eC * Area \qquad \text{(Equation 4.4)}$$

, where ΔCO_2e = Annual change in CO_2 equivalent carbon stocks in above ground biomass for scenarios (Hima and baseline) in *t CO_2e/ha*, *AGB* = Above ground biomass in tonnes dry matter/ha in year *t*, *CF* = Carbon fraction of dry matter (default 0.49 t C / t dry matter), CO_2C = CO_2 equivalent content of carbon (default 3.67 t CO_2 / t C), and *Area* = Total area suitable for Hima restoration in the Zarqa River Basin in ha.

$$\Delta CO_2e_{SOC(s)} = \frac{SOC_{t+1} - SOC_t}{t_{t+1} - t_t} * CO_2eC * Area \qquad \text{(Equation 4.5)}$$

, where ΔCO_2e = Annual change in CO_2 equivalent soil organic carbon stocks for scenario s (Hima or baseline) in tonnes per ha, *SOC* = Soil organic carbon in tonnes per ha in year *t*, CO_2e = CO_2 equivalent content of carbon (default 3.67 t CO_2 / t C), and *Area* = Total area suitable for Hima restoration in the Zarqa River Basin in ha.

[13] *The tier structure used in the IPCC Guidelines (Tier 1, Tier 2 and Tier 3) is hierarchical, with higher tiers implying increased accuracy of the method and/or emissions factor and other parameters used in the estimation of the emissions and removals. For a simple overview of these methodologies the reader is referred to: http://community-foundationfootprint.com/FoundationFootprintHelpCentre/Miscellaneous/IPCC-Tiers.aspx or IPCC Guidelines on Agriculture and LULUCF from: http://unfccc.int/national_reports/annex_i_ghg_inventories/reporting_requirements/items/5333.php*

[14] *The CENTURY model is a general model of plant-soil nutrient cycling, which is being used to simulate carbon and nutrient dynamics for different types of ecosystems including grasslands, agricultural lands, forests and savannas. For more information, the reader is referred to: http://www.nrel.colostate.edu/projects/century/*

The total above and below ground (BG) carbon stocks, as well as annual rates of change for selected years, are shown in Column 1 through 4 in *Table 9*. In the literature, sequestration rate estimates for restored lands range from 0.28 t C/ha/yr in the surface 20 cm on highly restored sites in a semi-arid savannah in the western Chaco of Argentina (Abril and Bucher, 2001) to 0.90 t C/ha/yr for conserved lands from Texas to North Dakota (Frank, 2004).

From carbon sequestration to economic valuation

The social cost of carbon (SCC) estimates the discounted value of the damage associated with climate change impacts that would be avoided by reducing carbon dioxide (CO_2) emissions by one metric ton in a given year (Anthoff et al., 2009). These damages include decreased agricultural productivity, damage from rising sea levels, and harm to human health. SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. SCC estimates devised by an American interagency working group were used (White House, 2013). Estimates were derived on the basis of damage estimates from DICE, FUND, and PAGE integrated assessment models in the 'Interagency Working Group on Social Cost of Carbon Technical Paper' (White House, 2013).

The monetary equivalent of avoided damage are combined with above derived changes in AG and BG carbon dioxide equivalent stocks, as a result of Hima restoration, in order to estimate the present value of carbon sequestration, as seen in *Equation 4.6*.

Some of the data (years) that has been used for this calculation are shown in *Table 9*. Assuming Hima restoration can re-establish 1990 levels of rangeland productivity, the additional carbon sequestered over a 25 year time horizon is worth 21.5 JOD/ha (in 2011 prices) in terms of avoided damages to agriculture, human health, etc., when carbon costs are discounted at a rate of 5 per cent (*Table 9*).

Since a large portion of climate change damages are expected to occur many decades into the future, one of the most important factors influencing SCC estimates is the discount rate. The authors therefore also show the extent to which these estimates change when using a discount rate of 2.5 per cent (*Table 10*). At discount rates of 7 per cent or higher the SCC estimates are zero or even negative for conservative models (Murphy, 2013; Anthoff et al., 2009). Without any consensus as to whether it is justifiable to discount the value of carbon emissions above 5 per cent, authors have refrained from attempting to do so here.

Using *Equation 4.4* and assuming that the Hima system is scaled up to the whole of the feasible rangeland areas in the Zarqa River Basin (109,093 ha), the present value benefit of avoided carbon emissions over a 25 year time horizon amounts to 6.9 million JOD using a discount rate of 5 per cent. This figure testifies that Jordanian rangelands have significant additional carbon sequestration potential. However, it should be noted that because carbon dioxide emissions are dispersed by large-scale weather patterns to other parts of the world, pastoral communities will not benefit from carbon sequestration in proportion to their efforts. In the absence of the possibility to sell 'emission reductions', e.g., under a global emission trading schemes or a voluntary carbon scheme, carbon sequestration can therefore in itself not offer sufficient incentives for pastoral communities to undertake Hima practices. In other words, the avoided damages associated with sequestering carbon are external to the communities undertaking the land use changes.

$$PV\ of\ carbon\ sequestered = \sum_{t=0}^{24} \Delta CO_2e_{AG+BG(HIMA)_t} - \Delta CO_2e_{AG+BG(BASELINE)_t} * Area * SCC_t \qquad \text{(Equation 4.6)}$$

, where ΔCO_2e = Annual change in CO_2 equivalent content of carbon AG and BG in the baseline and restoration scenarios, and *Area* = Total area suitable for Hima restoration in the Zarqa River Basin in ha.

TABLE 9

SCC estimates, 2010-2035 (converted from 2011 USD to JOD in per metric tons)

	1. SOC baseline scenario	2. Below SOC in HIMA restoration scenario	3. Change in SOC sequestered in a Hima system relative to the baseline	4. Change in AGC sequestered in a Hima system relative to the baseline	5. SCC estimater = 0.05%	7. Avoided social cost of carbon per hectare
Source	Al-Adamat 2007	See above assumption	Based on *Equation 7.2* and Al-Adamat et al., (2007)	MoA 2009 and IPCC Tier 2 methodology	Interagency Working Group on Social Cost of Carbon (White House 2013)	Column (3+4)*5/6
UNIT	SOC t/ha	SOC t/ha	ΔSOC ton/ha/yr	ΔAGC ton/ha/yr	JOD/ton CO_2 eq r = 5%	SCC*(ΔSOC +ΔAGC)/(1+r)^t
2011...	6.4	6.4	0	0	8	0
2015...	5.9	6.3	0.12	0.02	9	1.1
2020...	5.6	7.2	0.18	0.002	9	1.5
2030...	5.0	7.2	0.06	0.001	12	0.5
2035	4.7	7.2	0.06	0	14	0.5
Total by 2035	4.7	7.2	2.5	0.11		21.5 JOD/ha

Implementation, management, and opportunity costs of Hima restoration

On the basis of the above analysis showing the significant societal benefits associated with Hima restoration, one may question why use of the Hima system within the Jordanian Badia remains low. The reason is found in a multitude of interlinked cultural, technical, political, and economic factors that discourage individual communities from managing rangeland resources optimally. Specifically from the economic side, there are implementation, management, and opportunity costs associated with Hima restoration.

Implementation costs refer to costs directly associated with starting land restoration activities. For example, to create momentum around the establishment of the Bani Hashem Hima, and enable community buy-in, the IUCN Regional Office for West Asia organised several community based focus groups. In the Bani Hashem community, equipment was also purchased to process dried medicinal plants collected in the Hima sites. Once vegetation begins to recover on a Hima site, it becomes more attractive to livestock owners who may cross into protected Hima units. It may therefore be necessary to construct an observation tower or purchase donkeys or vehicles for surveillance purposes.

Actual surveillance activities (e.g., personnel time) fall under community **management costs** in the case where the community has management rights over the land. In Bani Hashem, illegal intrusion to the Hima site often happens during the night, showing that it is therefore necessary in any Hima system to remunerate or compensate some of the time spent on surveillance[15] (Madat 2014, personal communications). The surveillance requirement should not be socially undermined, in terms of necessary community mobilization, especially in the early stages of Hima development when pastures are being converted from open-access to community managed areas. Herders from other communities will need to learn to respect boundaries that do not exist at present. As revealed in the household survey, some herders travel up to two hours by truck with their sheep and goats to reach green pastures. In the discussion we debate the impact that government policies and land tenure have on Hima management cost structures.

Other **management costs** relate to the technical expertise that may be needed to conduct vegetation biomass studies and establish the animal carrying capacity of Hima sites, as these vary according to a complex set of highly variable climatic and agro-ecological conditions (MoA, 2001).

The **opportunity costs** of Hima restoration, namely the known forgone benefits of continuing grazing, are already incorporated in this cost benefit analysis, since the benefits earned in the baseline scenario were subtracted from those of the restoration scenario (*Equations 3.5 to 3.9*). Total cost per 400 ha of a Hima site may thus be expressed as the sum total of implementation costs (IC), in the first year and recurrent management costs (RMC) as seen in *Equation 8.1*.

[15] While community members in the Bani Hashem area do not have the right to fine infractions made by outside intruders, according to their own-defined tribal charter, they can call upon an MoA employee to deal with significant violations (MoA 2013).

On the basis of a series of expert interviews and IUCN's experience, a table with examples of possible implementation and management costs of a 400 ha Hima site has been compiled (*Table 10*).

To provide an initial estimate associated with large-scale Hima restoration (*Equation 4.7, Table 10*), it was assumed that implementation costs will be about 3,000 JOD per 400 ha Hima site for the first two years, and management costs will be 3,000 JOD/yr (4,200 USD/yr) per 400 ha for the first 5 years of the Hima restoration project, and 2,000 JOD/yr hereafter.

As shown in *Table 11*, scaling up to the whole of the Zarqa River Basin the present value recurrent and implementation costs were assessed to be in the order of 10.1 million JOD or 14.1 million USD/yr (for r = 5 per cent). Although based on expert opinion and existing evidence, the cost estimates remains hypothetical. In particular, this figure is expected to be an upper estimate of maximum potential restoration costs. Large-scale rotational Hima restoration is likely to be associated with economies of scale, for example related to the informal transfer of knowledge, capacity building, and the evolution of other Hima self-enforcement mechanisms.

$$PV\ Cost\ of\ hima\ system = \sum_{t=0}^{1} \frac{IC_t}{(1+r)^t} + \sum_{t=0}^{10} \frac{RMC_{BIOMASS\ STUDY_t}}{(1+r)^t} + \sum_{t=0}^{24} \frac{RMC_{SURVEILLIANCE_t}}{(1+r)^t}$$

(Equation 4.7)

TABLE 10

Implementation and recurrent management costs associated with Hima restoration

Type of cost	What	Monetary estimate per 400 ha of Hima in JOD	Source
Examples of upfront implementation cost	Community workshops, awareness rising and expert advice	1 000 JOD for the first 2 years	Haddad (2014) personal communication
	Construction of observation post or tower	1 500 JOD one-off	
	Two donkeys to facilitate surveillance	150 JOD one-off	
	Motorised surveillance equipment	1 000 JOD one-off	
	Medicinal plant drying equipment	500 JOD one-off	
Examples of yearly management cost	Paid labour to contribute to community surveillance activities	2 000 JOD/yr for the first 5 years, 1 000 JOD/yr hereafter.	Al-Satiri (2014) personal communication
	Yearly biomass study and recommended stocking density - 5 days full time by a rangeland expert	1 000 JOD/yr for the first 5 years after which it may be assumed that sufficient capacity was generated in the community to manage stocking rates	

TABLE 11

Present value implementation and management costs of large-scale Hima restoration over a 25 year time horizon

Hima restoration costs, r = 5%	
per 400 ha	For entire Zarqa River Basin rangelands (109,093 ha or 273 Hima sites of 400 ha each)
37,072 JOD	10.1 million JOD

Cost and benefits of large-scale Hima restoration

Discount rates

The discount rate is a critical parameter in cost-benefit analysis and a subject of much dispute. Approaches to selecting real discount rates may be characterised as 'prescriptive' – an approach that derives from ethical views about intergenerational equity, and 'descriptive' – an approach which is based on the opportunity cost of drawing funds from the private or the public sector (Harrison, 2010). Due to the relative short time horizon of the changes evaluated in this paper, the descriptive approach was adopted. Accordingly, the cost of investing a Jordanian Dinar in a Hima restoration project today is the value that the Dinar would have produced in its alternative use. Therefore, for the Hima restoration to be socially or commercially worthwhile, the invested capital should grow more than the extra Dinar invested elsewhere. This expectation is reflected through the use of positive interest rates when evaluating Net Present Values (NPV).

Three discount rates were used to estimate returns to Hima restoration: 2.5, 5, and 8 per cent. The 5 per cent rate approximates recent benchmark interest rates for Jordan, which has fluctuated between 4.2 and 5 per cent over the last five years (Trading Economic, 2014). The benchmark interest rate is the minimum rate of return investors will accept for buying non-treasury (non-government) securities. An interest rate of 8 per cent was used to reflect that some investors will demand a higher rate of return in order to trade present for future consumption. Hima restoration projects could also be feasibly supported by the public sector, because a large share of the benefits from Hima restoration accrues to the public (water infiltration, sediment stabilisation, carbon sequestration, etc.). Private discount rates are generally considered to be upper bound for federal projects because rates of return to public sector projects are lower than private sector projects. A discount rate of 2.5 per cent was also therefore used as a lower bound rate of return on investment, in accordance with a recently issued US guaranteed Eurobonds leveraged to finance Jordanian government spending in vital sectors at this rate (Petra, 2014).

Net present value estimates and benefit cost ratios

On the basis of above benefit and cost estimates, the true returns of Hima restoration to pastoral communities, Jordanian society, and globally was estimated, considering that the benefits of carbon sequestration pertain to the world as a whole. In doing so, the present value net benefits of Hima restoration (in terms of natural forage, carbon sequestration, water infiltration and soil stabilisation) over and above the benefits achieved in the baseline scenario for different discount rates was calculated. Finally, the management and implementation costs associated with Hima restoration were deducted to derive the NPV of Hima restoration (*Equation 4.8*). The benefit-cost ratio, is simply total discounted benefits over and above the baseline benefits, divided by the total discounted costs.

Table 12 shows that to NPV benefit to pastoral communities is 12 million JD (17 million USD) at a benchmark discount rate of 5 per cent. The benefit cost ratio is 2.1, indicating that pastoral communities will enjoy 2 JOD of benefit for every JOD they invest in implementing the Hima system.

Because of the significant societal benefit associated with enhanced groundwater infiltration, net-benefits to the Jordan society are estimated to be in the order of 144 to 190 million JOD (165 - 200 million USD), depending on the discount rate used.

When including the benefits associated with carbon sequestration, the net benefits increase by a further 144 to 327 million JOD depending on the discount rate used.

$$NPV_{\text{OF HIMA RESTORATION}} = \sum_{t=0}^{24} \frac{(\text{Benefits}_{t,\text{HIMA}} - \text{Benefits}_{t,\text{BASELINE}}) - \text{Costs}_{t,\text{HIMA}}}{(1+r)^t}$$

(Equation 4.8)

TABLE 12

Present value benefits and costs associated with large-scale Hima restoration over a 25 year time horizon

	r = 2.5%	r = 5%	r = 8%
Present value benefits of large-scale Hima restoration in million JOD			
Welfare economic value of natural forage	30.3	21.1	14.2
- Of which the present value benefit of avoided forage purchase is	24.5	16.8	11.2
Present value of additional groundwater infiltration	260.7	188.5	132.7
Present value benefit of avoided reservoir sedimentation	10.4	7.6	5.3
Present value benefits to the Jordanian society	**301.4**	**217.2**	**152.2**
Present value benefit of enhanced carbon sequestration	37.7	6.9	*
Present value benefits to the global society	**339.1**	**224.1**	**152.2**
Present value costs of large-scale Hima restoration to the Jordanian society in million JOD			
Present value implementation costs	0.8	0.8	0.8
Present value management costs (upper bound)	11.6	9.3	7.5
Total present value costs	**12.4**	**10.1**	**8.3**
Net present value of large-scale HIma restoration in million JOD			
To pastoral communities in the Zarqa River Basin if they bear the management costs	**18.7**	**11.8**	**6.7**
Benefit cost ratio	**2.4**	**2.1**	**1.7**
To the Jordanian society	**289.0**	**207.1**	**143.9**
Benefit cost ratio	**24.3**	**21.5**	**18.3**
To the global society	**326.7**	**214**	**143.9**
Benefit cost ratio	**27.3**	**22.2**	**18.3**

*The interagency Working Group on Social Cost of Carbon (EPA, 2014) do not report SCC estimates using discount rates above 5%. At discount rates of 7% or higher conservative models such as FUND find SCC estimates that are zero or even negative (Murphy, 2013; Anthoff et al., 2009). With lack of any consensus as to whether it is justifiable to discount the value of carbon emissions at 7%, and in that case, what model to rely on, authors refrained from attempting to do so here.

05 Discussion

Over the past five decades, indigenous plant species have disappeared and rangeland productivity in Jordan has more than halved due to overgrazing, declining rainfall, high run-off, changes in tenure regimes, and the abandonment of natural water harvesting and Al-Hima practices (Al-Jaloudy, 2006; Al-Tabini et al., 2012; MoA, 2013). To reverse this tendency, there is a growing interest in reviving Hima systems within pastoralist systems in the Arabian Peninsula. This interest spans across all levels of society, from governmental, community, civil society, and even to the Royal society as recently witnessed in the Hima Forum presided over by Jordanian HRH Prince Hassan. While it is recognised that rangeland Himas have the potential to provide diverse economic and environmental benefits, this study is the first of its kind to demonstrate both the market and non-market economic values associated with rangeland restoration.

The study has shown that large-scale adoption of the Hima approach piloted by IUCN, based on improved local level governance to enable pastures to be grazed and rested systematically within the Zarqa River Basin, may deliver between 144 and 290 million JOD worth of net-benefits to Jordanian society, using discount rates between 2.5 and 8 per cent. Whilst some benefits of improved rangeland management will be directly captured by producers, it would be worth exploring options to compensate pastoral communities for other benefits that are enjoyed by the wider society, including for example carbon sequestration. The benefits associated with carbon sequestration within the Zarqa river basin are estimated at a value of up to 38 million JOD (53 million USD) over a 25 year project cycle

Other regulating services provided by rehabilitated rangelands benefit the Zarqa River Basin as a whole. For example on average 307,500 m^3 less sediment per annum will be deposited in the King Talal Dam, thereby safeguarding provision of hydroelectric power to the heavily industrialised town of Zarqa. Moreover, a very significant benefit is associated with ground water infiltration, increasing annual safe yield abstraction rates within the Zarqa River Basin by 13 to 14 per cent, at an estimated value of 189.5 million JOD to society over a 25 year time horizon. While the benefit estimate may seem very significant, it reflects what pastoralists are willing to pay for access to water (2 JOD/m^3) on one hand, but also what the Jordanian government is willing to pay as reflected in the upfront costs of creating water storage capacity through dams. Comparatively, it is shown that rangeland restoration through the Hima approach is a cost-effective way of responding to water demands. As such, a strong case can be made for establishing payments for ecosystem service (PES) schemes, with public water utilities compensating pastoralists and farmers upstream for reduced soil erosion. Examples of PES schemes and how they can be established can be found in Landell-Mills and Porras (2002) and Aylward et al. (2005).

Results show that even without capitalizing on ecosystem services such as carbon sequestration or sediment stabilisation, it is still in the interest of rangeland communities to use the Hima system to manage their rangelands, provided they have adequate tenure system and rights. The net present welfare economic value to pastoralist communities of avoided forage purchase is in the order of 16.8 million JOD/23 million USD (at r = 5 per cent), assuming that the communities themselves bear the management costs of the Himas.

It is important to note that the implementation of effective Hima system requires clarity over rights of access and management of rangeland resources; for example, the ability to exclude grazing during designated periods of resting the land (The Declaration, 2014). IUCN's experience has been that the process of developing Hima sites can also initiate a process of strengthening these rights, as the outcome of extensive negotiation between communities and between the community and government. This is consistent with work in a wide range of countries to strengthen common property regimes as a means of reviving effective rangeland management strategies (Ostrom, 1990; Herrera et al., 2014).

Pastoral communities are often referred to as the contemporary substitute for the traditional tribal authority that can prevent the trespassing of flocks from outside communities onto prime grazing land (MoA, 2013; Bounejmate et al., 2004). Supporting this argument, Al Karablieh and Jabarin (2010) show that rangeland cooperatives have lower feeding costs compared to communities grazing in open access areas and governmental reserves. However, cooperatives are not considered sufficiently effective in excluding access in Jordan; a situation that is compounded by the central government's reluctance to assign sufficient responsibility to pastoral communities and allow them to exercise full land tenure privileges (Bounejmate et al., 2004).

Research has shown that local institutions are often an important interface between government and communities for effective rangeland management, but frequently need professional upgrading to play this role. Government employees also need capacity building to adapt to a significantly different role as facilitators of governance processes rather than simply rangeland technicians (Herrera et al., 2014).

Furthermore, the reintroduction of the Hima system cannot take place in the absence of effective common property regimes achieved through a delegation of long-term management rights to local communities. Improvement in long-term tenure of rangeland communities was proposed in the 2001 Jordanian Rangeland Strategy (MoA, 2001). The strategy however has not been effectively implemented due to the absence of a national consensus over suggested legislation (MoA, 2013). In this document, emphasis was placed on the promotion of pastoral communities (MoA, 2013), although little attention was given to land tenure related issues. The research found in this paper provides compelling evidence that the Rangeland Strategy should be implemented through widespread support for community based rangeland management with the al Hima approach, while addressing potential significant obstacles over land rights.

This valuation was conducted based on a rather simple form of rangeland management, using well defined periodic exclusion of grazing to rest pasture on a small scale. International research on rangeland management (e.g., Vetter, 2005; Briske et al., 2008) suggests that much more innovation is possible in rangeland management and that one could anticipate greater pasture productivity and faster rates of recovery using improved knowledge of grazing cycles and timing, improved use of herd movements for selective seed dispersal, and concentrated herd impacts for rapid soil formation. Whilst this valuation shows that rangeland restoration is highly cost effective, the study may also underestimate the true potential for rangeland rehabilitation. Other technologies and approaches have been demonstrated as useful for rangeland rehabilitation, including planting nutritious, drought-tolerant shrubs such as *Salsola vermiculata* (saltwort) and *Atriplex spp* combined with water harvesting structures (Al-Tabini et al., 2008; Karrou, 2011) which need to be evaluated according to their relative costs and benefits.

The high numbers of livestock currently managed in the Zarqa Basin depend upon high levels of imported fodder input, which come at a high cost to the national treasury. As such, in order to generate viable capital for investing in Hima restoration, one could contemplate a cross-compliance scheme where feed subsidies to pastoralist communities are conditional on improved rangeland management; for example, rotation of pastures, land resting or development and respect of grazing protocols. Indeed, this paper has demonstrated that with a change in management practices, the total contribution of rangeland fodder can appreciably increase. This should be used to incentivise a change in management practices, with livestock grazed for appropriate periods according to fodder availability and then removed from the rangelands during the recovery period. This could be accomplished either by partitioning herds into range fed or fodder reared, which could ultimately lead to differentiation in breed characteristics, or it could follow a hybrid system in which large numbers of stock use the rangelands for a finite period of time and are then removed to feed lots for fattening. These scenarios are plausible only if rangeland managers have management rights in order to directly capture the benefits of improved rangeland management.

While the benefits associated with more biodiversity rich plant fodder were valued, the authors have not attempted to value other kinds of biodiversity such as the potential return or increase in number of invertebrates, mammals and birds (such as partridge) that depend on healthy rangelands. Unfortunately, not enough data was available to make an accurate assessment of how rangeland restoration through the Hima system will affect fauna as a whole. However, it is known that biodiversity would be positively affected as a whole and our benefit estimates of Hima restoration within the Zarqa river basin should therefore be considered as lower bound. Communities in Bani Hasham and other Hima sites in the Zarqa River Basin already exploit the value of biodiversity through production of medicinal infusions which have a ready market in Jordan. Further options have been suggested, including controlled bird shooting and ecotourism; the latter might be more of an option in other parts of the Jordanian Badia, such as those adjacent to the Dana Biosphere reserve.

The multi-sectoral nature of the benefits of rangeland management pose a potential challenge to ensuring all affected stakeholders engage in the rangeland rehabilitation process. Rangeland management in Jordan currently falls under the mandate of the Ministry of Agriculture, yet the benefits of rangeland management include improved hydrological cycles and reduced sedimentation, which benefit the Ministry of Water and Irrigation and the Ministry of Industry and Trade respectively. Ensuring cross-sector collaboration may require engagement with a higher level of government, to enable decisions that are made in the interest of Jordan as a whole, rather than narrow sectoral interests. In Jordan this has been advanced by the recent endorsement of the Hima approach to rangeland rehabilitation by HRH, Prince El Hassan Bin Talal, who has signed a declaration of support to Hima.

06

Recommendations

In conclusion, this research enables us to make the following recommendations:

1. Increase public investment to strengthen management rights and governance for community-based rangeland rehabilitation, through revival of Hima

- **Strengthen communal management rights over rangeland resources through appropriate legal mechanisms and greater willingness within the public sector.** Hima is only viable and cost-effective in the long term if communities are able to develop and enforce rules over rangeland use. For this, they require both the consent and the support of government through land reform. However, at the same time, allocation of such rights will be a powerful incentive for communities to engage in the Hima approach.

- **Identify appropriate investments in support of Hima approaches.** The community based Hima approach has proven to be acceptable to both communities and government, and has proven to be a technically feasible option. This study demonstrates the long term economic advantages of the approach. Further insight is needed on how public and private investment can most effectively contribute to scaling up experiences.

2. Strengthen awareness of the economic values of rangeland rehabilitation and develop market-based incentives

- **Develop market-based instruments to incentivise the environmental benefits of Hima.** Options include PES, linking fodder subsidies to sustainable pasture management through cross-compliance schemes, discouraging the expansion of irrigated agriculture into rangelands through distortionary water pricing policies, and developing niche markets that capitalise on the environmental credentials of rangeland products and ecotourism.

- **Use economic valuation to validate further up-scaling nationally and regionally.** The Jordanian Badia is representative of the vast dry environments found in West Asia and North Africa (Karrou, 2011). As such, Jordan could position itself as a front-runner within the region using innovative financial mechanisms and regulatory policy reform to reverse desertification, whilst promoting both climate change adaption and mitigation.

3. Build institutional capacity and awareness to implement and monitor Hima processes, to provide suitable rangeland management advice, and to stimulate innovation in rangeland management

- **Strengthen awareness and capacities in the public sector and communities for implementing Hima processes.** Hima is low-cost, but demanding of human resources as it is a process-dependent approach that depends on negotiation and conflict resolution skills, which are not strong within current extension services. Public investment should be oriented towards developing these skills in existing extension officers, raising awareness country-wide, and promoting future skills-development through university curricula.

- **Develop protocols for linking technical rangeland extension services with Hima development.** Rangeland science is central to effective use of Hima, but it cannot replace local and indigenous knowledge if Hima is to be successful. Rangeland science must therefore be introduced to community dialogue sensitively, ensuring that communities, rather than scientists, lead in strengthening rangeland governance, and are empowered to draw on technical advice when appropriate.

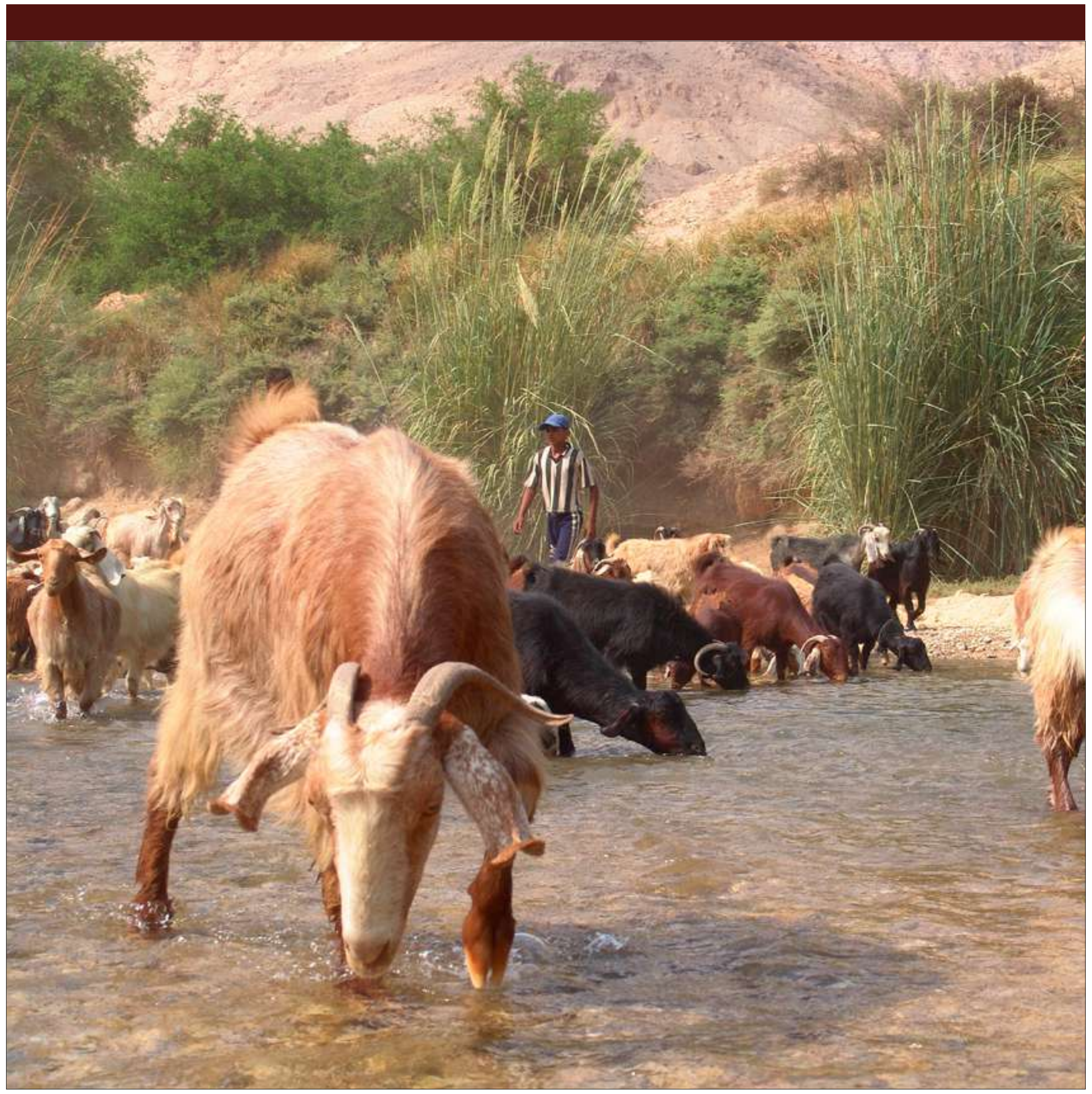
- **Promote innovation in rangeland management** and incorporating herder-led innovations, such as improvements in grazing patterns and maximisation of herd benefits, with scientist-led innovations around vegetation improvement.

- **Invest in appropriate rangeland surveillance for improved monitoring and decision making,** and explore options for incentives and sanctions for sustainable rangeland management.

4. Create an enabling policy and institutional envinronment for sustainable rangelands management

- **Establish mechanisms for improved coordination of government planning across sectors** that impact on the rangelands. Improved coordination will help ensure greater consideration for the diverse externalities of rangelands management, which may be felt in a number of sectors (e.g. agriculture, water, environment etc.).

- **Explore options to differentiate policies and investments for livestock sub-sectors.** The economic potential of Hima and of the rangelands in general is contingent on change in livestock production practices. Further work is required to explore suitable livestock sector policies, e.g., to differentiate range-based production from import-based production.



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Appendices

Appendix 1 - Background note on the biophysical analysis

The following describes the methodology used to study the hydrological impacts of the SLM interventions that were valued. The flow-chart in *Figure A.1* summarises this process and is further explained in the following paragraphs:

Present land use and cover data were created using Landsat-8 2013 images. Landsat is an American Earth observation satellite launched in February 2013. It has a two-sensor payload, the Operational Land Imager and the Thermal Infrared Sensor. Landsat images are subsequently segmented to create spectrally homogeneous and spatially contiguous group of pixels using the K mean algorithm based on the mean spectral similarity. 12 different land use types were identified based on the spectrally homogeneous and spatially contiguous image segments during a two day field visit of the entire case study water basin. The field visit duration was two days for verification of land use and land cover with respect to image segments. These image segments are classified as the present land use scenario map.

Detailed field observations and documentation and/or detailed interpretations of Google Earth Professional Images (when field visits are not possible) were essential processes to classify image segments into information classes for present land use scenario data. Future land use sceneries were created based on multidisciplinary discussions with local experts from national and international institutes, land use policy, and biophysical and climatic suitability of selected plant/tree species for restoration.

Soil is an integral part of the biogeochemical cycle in the ecosystem process. FAO/UNESCO Soil Maps were used, as they provide comprehensive and homogeneous attributes for the analyses. It is also important to know the elevation and slope of land cover in order to predict direction of the movement and accumulation of water throughout the landscape. SRTM DEM from NASA was used to retrieve elevation and slope parameters In conjunction with these data sources, weather data was used to evaluate the climatic suitability of species and the maintenance of hydrological cycles. Precipitation is major source of water for the landscape. Weather data was accessed through Texas A&M University (http://globalweather.tamu.edu). As future weather patterns cannot be predicted with any certainty, authors evaluated how hydrological impacts change as a result of land management interventions using weather data from the past 20 years.

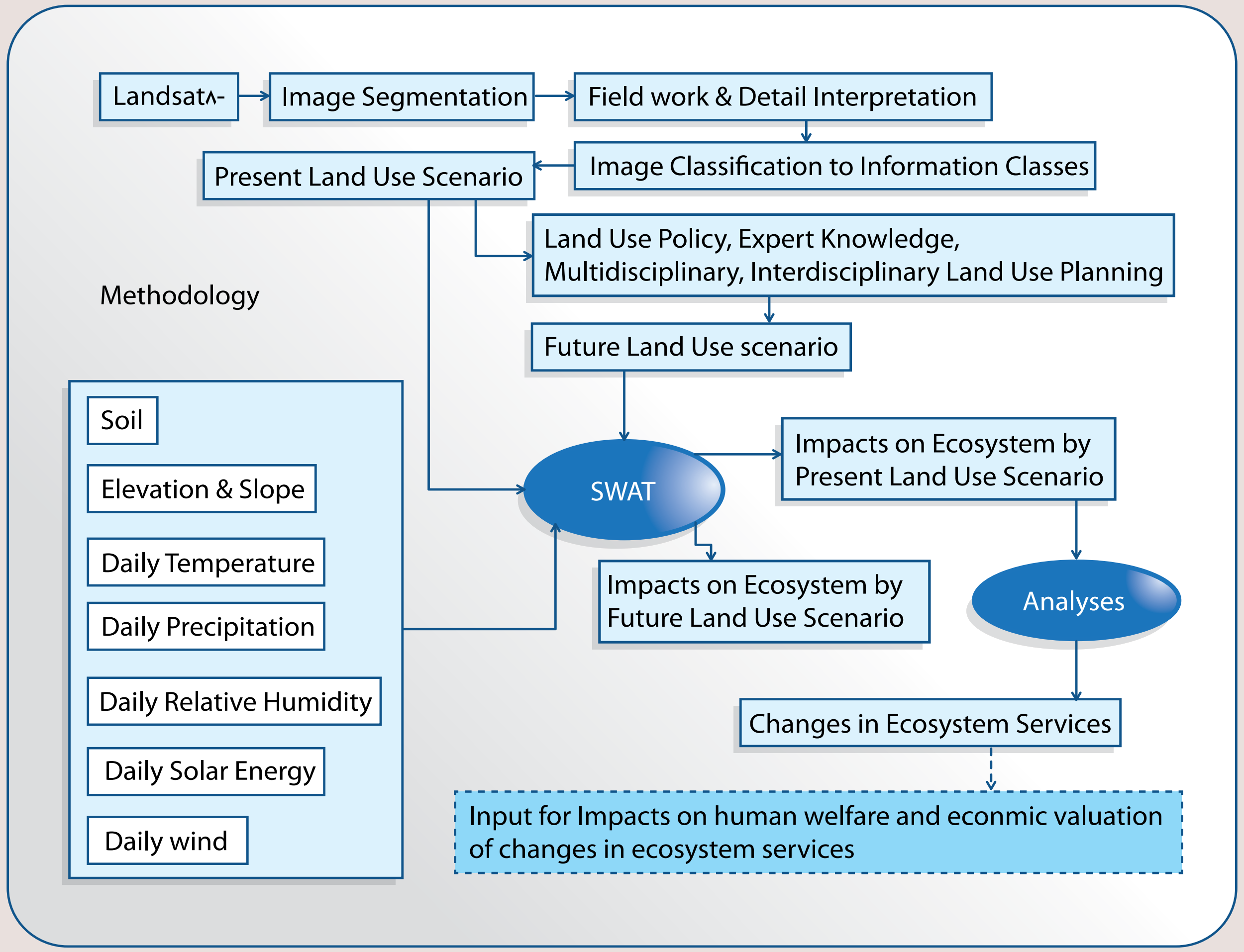
Finally, soil, elevation, slope, and time series data on daily temperature, rainfall, relative humidity, solar, wind, and present and future land uses were used as input variables for SWAT tools. SWAT is a river basin or watershed scale model, developed to predict impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long time spans. The model is physically based, computationally efficient, user friendly, has available inputs and enables users to determine long-term impacts. ArcSWAT ArcGIS extension is a graphical user interface for the SWAT model. The interested reader is referred to the SWAT theoretical document[16] for detailed physical interactions of aforementioned input parameters.

SWAT model outputs include daily, monthly, and yearly precipitation, snow fall, snow melt, sublimation, surface runoff, shallow and deepwater aquifer recharge, water availability from shallow aquifer to soils and plants, total water yield, percolation, evapotranspiration, potential evapotranspiration, transmission losses, and total sediment loading as the impacts to ecosystems by the present and future land uses. In this study, these ecosystem service impact values were determined for the whole basin, which defined the boundaries of the case study. Ecosystem services were estimated for the baseline and future SLM restoration scenarios. The average of the year-by-year differences between the scenarios for a 20 year time horizon were subsequently fed into the 25 year economic valuation exercises in order to determine the net benefit of proposed SLM interventions.

[16] SWAT 2009 Theoretical Document is downloadable from: http://swat.tamu.edu/documentation/

FIGURE A.1

The underlying biophysical assessment framework



Appendix 2 - Present and future land use and land cover

The present land use and land cover spatial data (*Figure A.2.1*) was created based on the Landsat TM 8 August 2013 dated satellite image. Through additional detailed field visits in the whole of the water basin, standard image processing procedures were undertaken.

The suitable area for Hima development was defined as existing rangeland found within an area receiving between 100 to 200 mm annual rainfall. The annual rainfall spatial data was produced based on the daily rainfall (1990-2010) data sourced by Texas A&M University and the National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR). CSFR data was collected over a 32 year period, from 1979 through 2010. Daily temperature and rainfall data was derived from 224 weather stations in and outside the watershed. The reliability of the rainfall estimate for the Zarqa River Basin is 80 mm at a 95 per cent confidence interval. *Figure A.2.2* show the suitable Hima restoration area based on the rainfall criteria and the rainfall confidence interval.On the basis of the rainfall criteria and the identification of existing rangeland areas, the future land use and land cover scenario was elaborated. It is illustrated in *Figure A.2.3.* The total suitable areas for Hima development that meet the criteria is 109,093 ha.

FIGURE A.2.1

Present land use and land cover

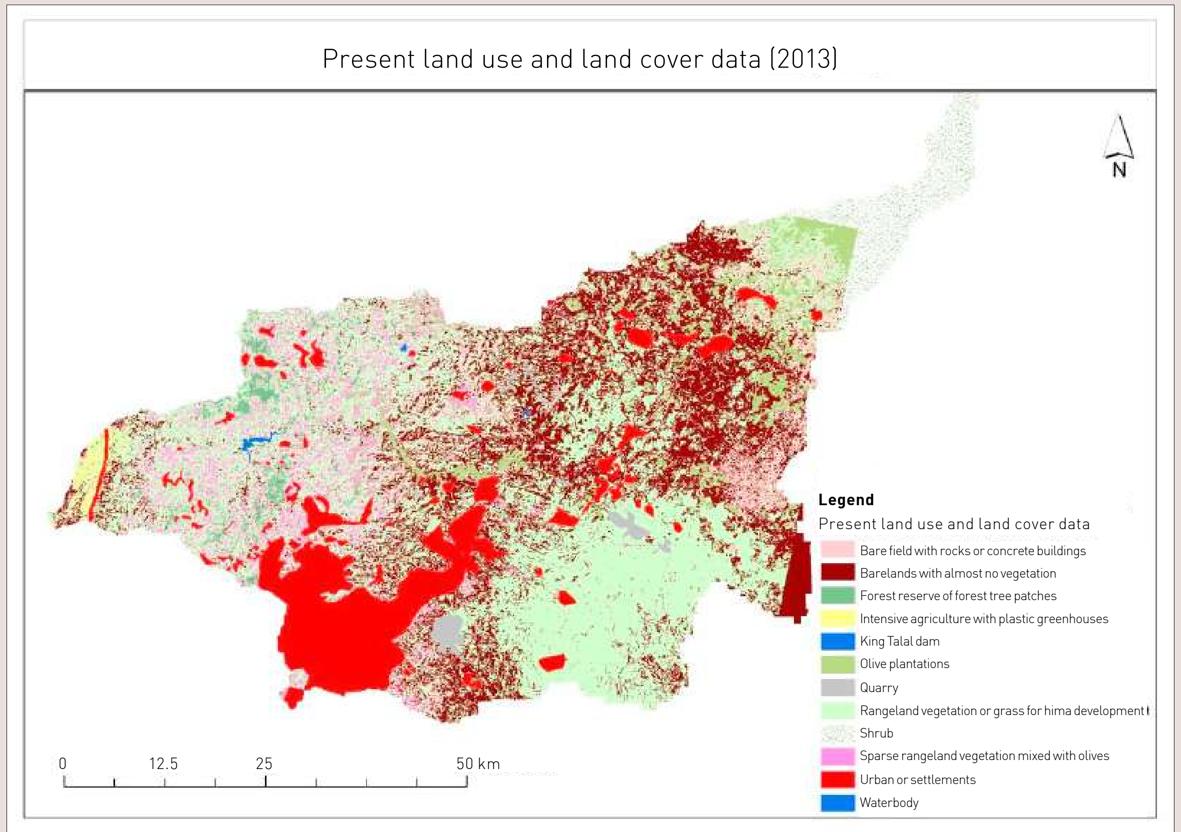


FIGURE A.2.2

Areas considered suitable for Hima restoration based on rainfall criteria

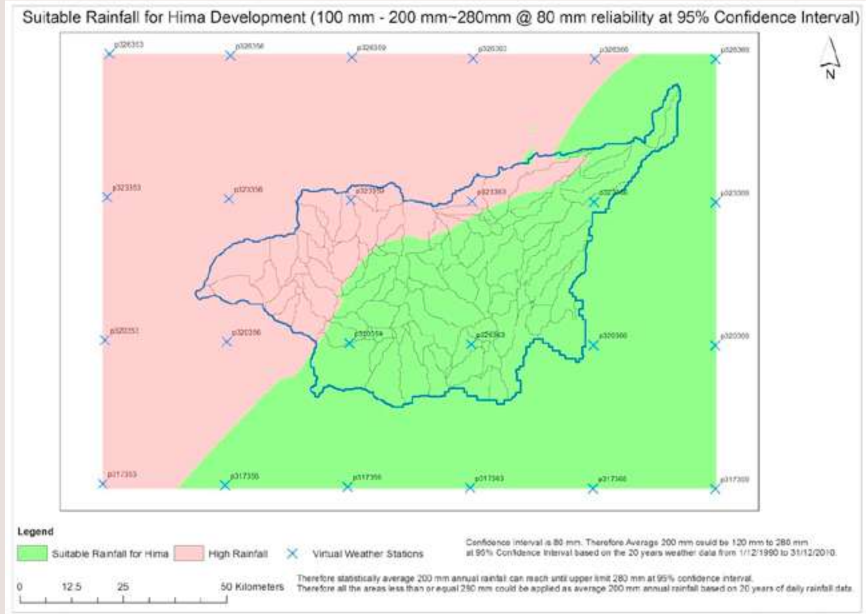
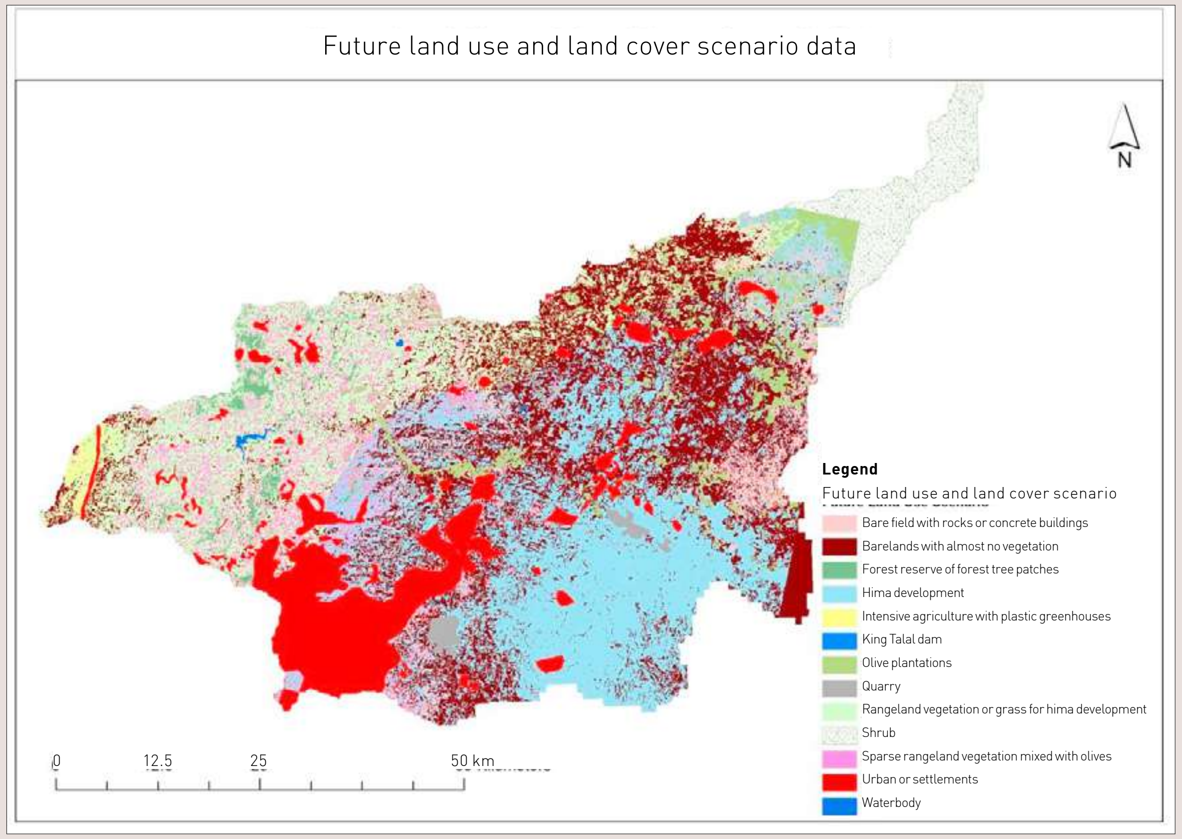


FIGURE A.2.3

Future land use and land cover scenario



Appendix 3A - Summary statistics from 2013 rangeland biomass study undertaken in the Bani Hashem Hima

Table A.3 shows the biomass per hectare estimates recorded in May 2013 for each of the Hima units in Bani Hashem after two years of exclusion of grazing.

The sensitivity analysis based on Al-Satiri (2013) and personal communication with Yehya Al-Satiri.

TABLE A.3

Estimation of fresh to dry biomass and biomass (kg/ha) for Hima and neighbouring open access rangeland

	HBH1	HBH2	HBH3	HBH-All	Open	Remark
Area (ha)	19	30	51	100	100	
Allowable Dry Yields (kg)	2557	2735	5715	11007	457	
Dry Biomass (kg)/ha	134.5789	91.16667	112.0588	110.07	4.57	
Dry Biomass (kg)/m²	0.013458	0.009117	0.011206	0.011007	0.000457	
Dry Biomass (g/m²)	13.45789	9.116667	11.20588	11.007	0.457	Transform from kg to g to validate with field measurements
Lower Limit Fresh weight (g/m²)	73.57	55.71775	61.84007	70.92178	5.463126	
Upper Limit Fresh weight(g /m²)	120.696	92.07325	105.2429	93.92178	10.76487	
Ratio (d/w) for Lower Limit	0.182926	0.163622	0.181207	0.155199	0.083652	Ratio (d/w) for open access is very low, so authors used the (d/w) ration HBH which is statistically constant
Ratio (d/w) for mean	0.138537	0.123372	0.134136	0.134038	0.056322	
Ratio (d/w) for Upper Limit	0.111502	0.099015	0.106476	0.117193	0.042453	
Lower Limit Fresh weigh(g/m²)	73.57	55.71775	61.84007	70.92178	5.463126	
Mean Fresh weigh (g/m²)	97.143	73.8955	83.5415	82.1188	8.114	
Upper Limit Fresh weight(g/m²)	120.696	92.07325	105.2429	93.92178	10.76487	
Lower Limit Fresh weigh (kg/m²)	0.07357	0.055718	0.06184	0.070922	0.005463	
Mean Fresh weigh (kg/m²)	0.097143	0.073896	0.083542	0.082119	0.008114	
Upper Limit Fresh weight (kg/m²)	0.120696	0.092073	0.105243	0.093922	0.010765	
Lower Limit Fresh weight(kg/ha)	735.7	557.1775	618.4007	709.2178	54.63126	
Mean Fresh weight (kg/ha)	971.43	738.955	835.415	821.188	81.14	
Upper Limit Fresh Weight (kg/ha)	1206.96	920.7325	1052.429	939.2178	107.6487	
						New estimate for Open Access
Lower Limit Dry weight (kg/ha)	134.5789	91.16667	112.0588	110.07	4.57	8.478725137
Mean Dry weight (kg/ha)	134.5789	91.16667	112.0588	110.07	4.57	10.87580408
Upper Limit dry weight(kg/ha)	134.5789	91.16667	112.0588	110.07	4.57	12.61570257
Lower Limit Dry weight (kg/ha)	114.18	86.47347	95.97526	110.07	8.478725	
Mean Dry weigh(kg/ha)	130.2081	99.04769	111.977	110.07	10.8758	
Upper Limit dry weight (kg/ha)	141.4476	107.9036	123.3376	110.07	12.6157	
Lower Limit weight (kg/ha)	98.87625				8.478425	
Mean Dry weight (kg/ha)	113.7442	Final Estimate for Hima			10.8758	Final estimate for Open Access
Upper Limit dry weight (kg/ha)	124.2296				12.6157	

Appendix 3B - Maximum stocking rates of rangeland within the Zarqa River Basin assuming all pastures are converted to rotational pastures under the Hima regime

In order to calculate the maximum stocking rate (the number of animals allotted to an area for a given length of time) under large-scale strict Hima restoration within the Zarqa River Basin, authors proceeded as follows:

Based on the management regime in Bani Hashem:

- One cell out of three is closed off to grazing in any one year. Hence, there is zero biomass offtake for one third of the Hima area at any one year, and;
- In the two cells opened to grazing, only 50 per cent of available edible dry matter may be grazed, to ensure sufficient regeneration next year.

Moreover, it is known that:

- Every kg of edible biomass is equivalent to 0.8 kg of barley in energetic value (Al-Jaloudy, 2001), and;
- A mature sheep or goat eats 1.5 kg of barley equivalent nutrition per day for 360 days.

On the basis of the Noy-Meir model of forage growth and the parameters estimates provided in *Chapter 3*, authors found that the annual steady-state edible dry biomass production fluctuates between and 224 and 310 kg/ha (of which only 50 may be grazed). This means that for every hectare subject to Hima restoration (in the Zarqa River Basin), the following amount of barley equivalent nutrition can be extracted in the steady state:

0.5*310 kg/ha + 0.5*224 kg/ha + 0 kg/ha = 89 kg/ha

This result is within an expected range. Nabulsi et al. (1992) found that open access Jordanian rangelands (range and steppe) yield between 20 and 40 kg of barley equivalents (40 food units)/ha, assuming 50 pe cent utilisation of vegetation.

Given that 109,000 ha of land would be under Hima restoration the total edible biomass would be equivalent to: 89 kg*109,000 hectares = **9,732,224 kg.**

Hence, if all the forage was to come from Hima managed rangeland in the Zarqa river basin the maximum number of sheep that could be fed exclusively through Hima managed pastures would be equivalent to: 9,732,224 kg / (360 days *1.5 kg per sheep) ≈ 18,000. This result presumes there would be no additional pasture seeding or use of irrigation or fertilizers, which would obviously increase the lands carrying capacity.

This implies that the carrying capacity - *the maximum stocking rate possible while maintaining or improving vegetation or related resources* - under strict Hima management is equivalent to 6 hectares per sheep per year.

Appendix 4 - ArcSoil and Water Assessment Tool (SWAT) inputs and process

SWAT is a river basin, or watershed, scale model developed to predict impact of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions over long time. The ArcSWAT model developed for Jordan has not been calibrated to actual flow data, as the models had not converged by the time results were needed for this study. Fortunately however, authors are interested in the relative values differences in biophysical outputs between the baseline and future restoration scenarios (not absolute values). Therefore, the non-calibrated relative estimates work perfectly for the economic valuation study undertaken here. As the inputs are of high quality and a rigorous land use and land cover map was made, there is strong confidence in the SWAT outputs used for the economic valuation studies.

Weather station data is based on the 224 virtual weather stations from the NCEP CFSR. It was completed over the 36-year period of 1979 through 2014. The CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period. The current CFSR will be extended as an operational, real time product into the future. The weather data was downloaded from http://globalweather.tamu.edu. which is hosted by the University of Texas A&M. Daily temperature (C), daily precipitation (mm), daily wind speed (m/s), daily relative humidity (fraction) and daily solar (MJ/m^2) energy were derived from the weather station data and applied as the weather data input to the modelling process. The input weather data could predict the periods and amount on availability of snow within the study area basin.

The FAO soil map was selected as the soil data source. Although decades old data, it has homogeneous comprehensive soil attributes throughout the world, an excellent piece of work of FAO. Its attributes are more comprehensive than newly available soil data sources for ArcSWAT modeling. The FAO soil data is downlaoded from the following web link: http://data.fao.org/map?entryId=446ed430-8383-11db-b9b2-000d939bc5d8.

The present land use digital map and future land scenario digital map are created using recent Landsat-8 satellite data (30 meter spatial resolution) with ground truth verification. The Landsat 8 data is downloaded from http://earthexplorer.usgs.gov/ from the United States Geological Surveys (USGS).

The NASA SRTM (Shuttle Radar Topographic Mission) digital elevation data, produced by NASA originally, is a major breakthrough in digital mapping of the world, and provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. The 90 Meter Resolution STRM Digital Elevation Model (DEM) was downloaded from http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1, hosted by the CGIAR Consortium of Spatial Information.

The weather data, land use data, soil data and digital elevation models are input data to create the hydrological response units for modelling.

The ArcSWAT Spatial Datasets used in the analysis were:

1. Present and future land-use cover (*Appendix 2*).
2. Monthly or daily Temperature (C), Precipitation (mm), Wind speed (m/s), Relative Humidity (fraction) and Solar (MJ/m^2) energy. The global weather data from Texas A&M University and the NCEP CFSR was applied for the analyses. The detail of the climate data metadata is described in *Table A.4*. Rainfall pattern simulated from 80 weather stations in Bani Hashem is shown in *Figure A.4.1*.
3. The SRTM Digital Elevation Model obtained from USGS EROS Data Center (http://dads.create.usgs.gov/SRTM/) and National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).
4. An FAO soil map was selected as the soil data source. Although decades old, it has homogeneous comprehensive soil attributes throughout the world. Its attributes are more comprehensive than newly available soil data sources for ArcSWAT modelling. There are five types of soil are found within the study area.
5. The SCS Curve Number equation (1972) was used to estimate the amount of run-off for the soil use profiles for the soil types in the Zarqa River Basin and rangeland cover status (under the baseline and restoration scenarios).

On the basis of these input a water balance equation (*Box A4*) was derived for the basin and illustrated in *Figure A.4.3* for the Zarqa River Basin. A summary of the impact of restoration on yearly soil and water balance parameters is provided in *Table A.4*. The model reproduces the weather pattern observed over the last 20 years for the next 25 years.

Figure A.4.4 illustrates the extent to which ground water infiltration is affected by Hima restoration, assuming that the weather pattern observed over the last 20 years is reproduced. It shows that the percolation of water in soil will increase in the future land use scenario associated with Hima restoration (PERCmm_FLU).

TABLE A.4.1

Climatic data collected

Location	Area (ha) South Latitude: 28.8; West Longitude: 34.5 North Latitude: 33.21 East Longitude: 39.5 Number of Weather Stations: 224
Period	Start Date: 12/1/1990 End Date: 12/31/2010 Starting Hour of Day: 12:00 AM
Data Collected:	Temperature (C) Precipitation (mm) Wind (m/s) Relative Humidity (fraction) Solar (MJ/m^2)

BOX A.4

Water-Balance Equation

$$Sw_t = Sw_{t-1} + \{R_t - Q_t - E_t - GWQ_t\}$$

Sw_t	Available water at time, t (today)
Sw_{t-1}	Available water at time, t-1 (yesterday)
R_t	Rainfall (today)
Q_t	Runoff (today)
E_t	Evapotranspiration (today)
W_t	Seepage loss (today)
GWQ_t	Groundwater runoff (today)

FIGURE A.4.1

Rainfall (in mm) in Bani Hashem

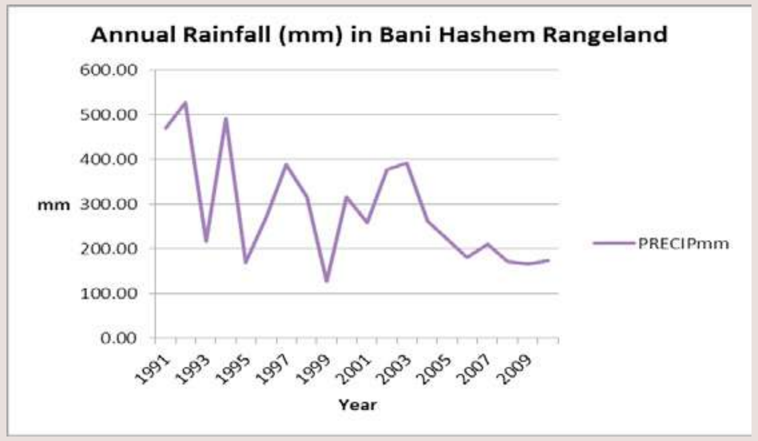
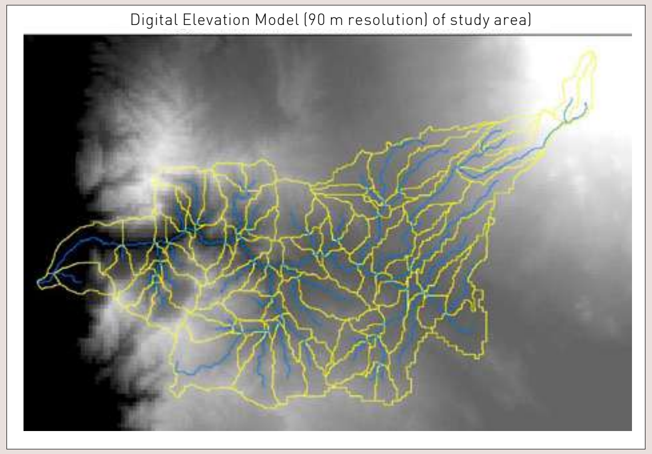


FIGURE A.4.2

Digital elevation model of the Zarqa River basin



FAO soil classes in the Zarqa River basin

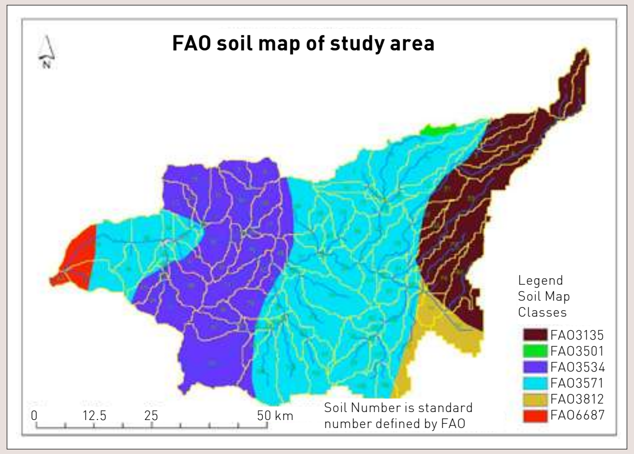


FIGURE A.4.3

Zarqa River basin and sub-water basins with Bani Hashem highlighted as 71

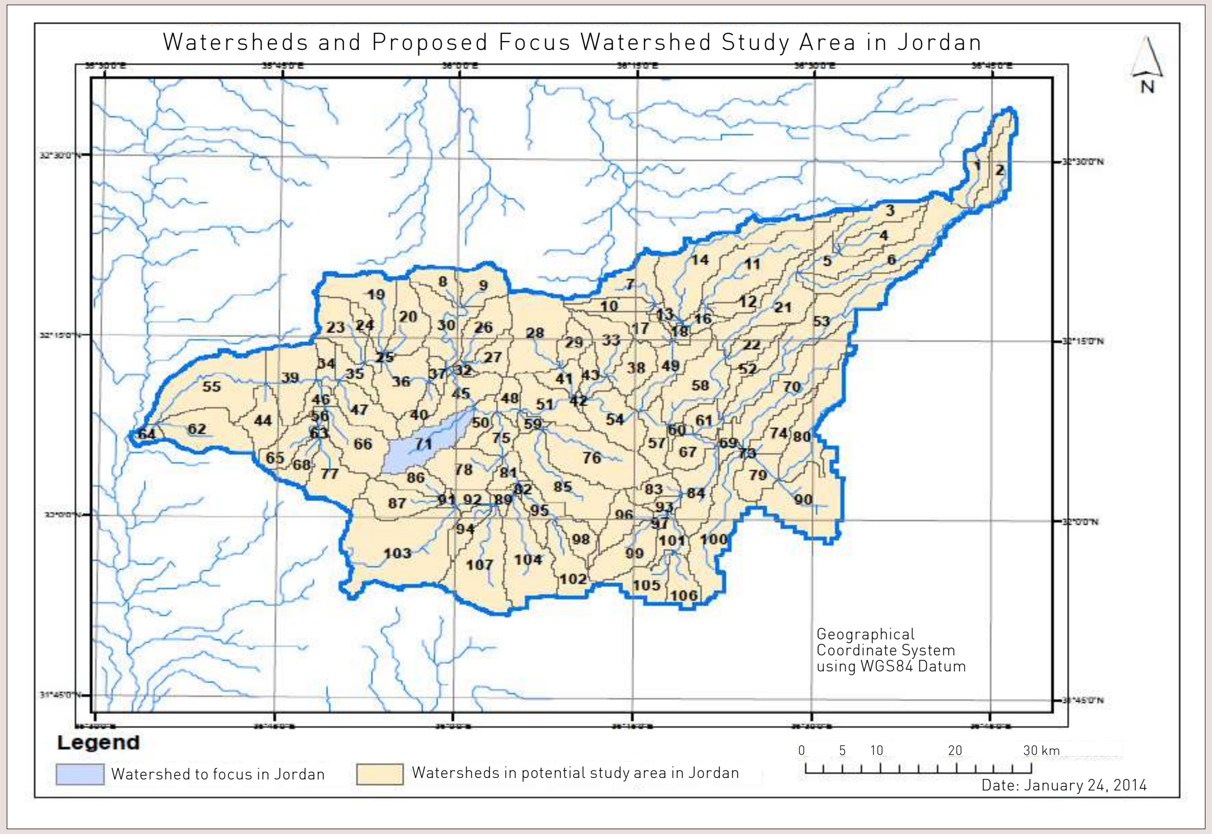


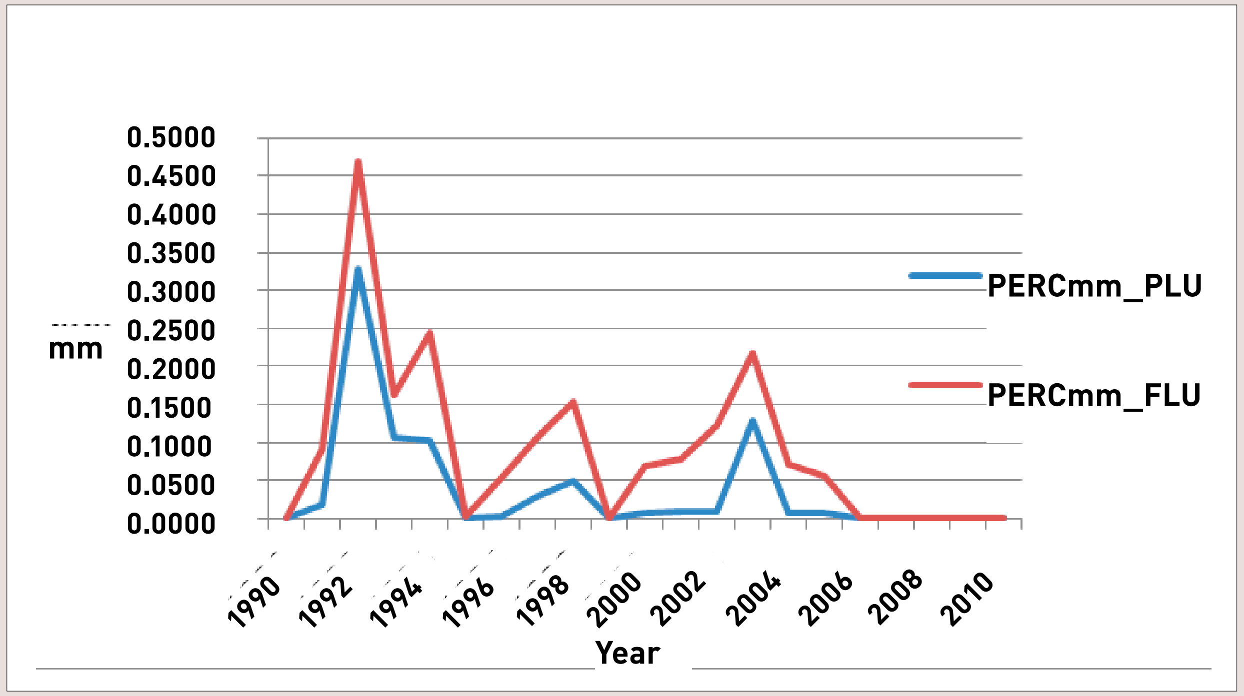
TABLE A.4.2

Summary of the impact of Hima restoration on yearly soil and water balance parameters

Average Annual Basin Values		Remark
Future Land use scenario	Present Land use scenario	
8.911 Tons/ha	9.489 Tons/ha	Lower sediment loading
20.11 mm	17.08 mm	More percolation
1.47 mm	1.67 mm	Less transmission loss
0.57 mm	0.56 mm	More lateral flow to the stream
18.48 mm	16.06 mm	More shallow aquifer flow
2.05 mm	1.78 mm	Soil and plants will get more water from shallow aquifer
1.08 mm	0.94 mm	More water will flow to deep aquifer
21.58 mm	18.75 mm	More water will be available to aquifer than surface runoff
39.46 mm	44.79 mm	Less surface runoff due to more percolation, groundwater and acquifer recharge
57.03 mm	59.74 mm	Although total water yield is low, it seems more balanced hydrology

FIGURE A.4.4

Percolation impact by the two land use scenarios (PLU = present land use scenario, FLU = future land use scenario)



Appendix 5 - Bulk density calculations for soils in the Zarqa river basin

TABLE A.5

Bulk density calculations for soils in the Zarqa river basin

FAO Soil type	Area (ha)	BD(g/cm³)	BD(t/m³)	Conversion factor
3135	64719.37	1.40	1.4	1 g/ cm³ = 1 ton/ m³
3501	1485.30	1.60	1.6	
3534	110462.17	1.40	1.4	
3571	198839.76	1.40	1.4	
3612	14690.51	1.50	1.5	
6687	8107.42	1.40	1.4	
	339.1	224.1	152.2	
		Average	1.45 t/m³	
		Weighted Average	1.40 t/m³	

Appendix 6 - Descriptive statistics of Bani Hashem household survey respondents

TABLE A.6

Statistics from Bani Hashem household surveys

Variable	Mean (Std.dev)	Variable	Mean (Std.dev)
Number of households	42	Declared spending on fodder per month	380 JOD/month
Average age of household head	50 (13.9)	Kg of fodder purchased per month (a combination of barley, wheat, straw, and bread, but in Majority Barley foddder)	1700 kg/month
Average number of children per household	7 (4.4)	Number of sheep per household	31
Literacy of household head	51%	Number of goats per household	30
Household born in same governorate	49%	Price per ton of Barley to livestock owner (subsidised)	175 JOD
Yearly gross income (JOD)		Price per ton of Barley paid by the Jordanian government	223 JOD
←2,000	30%		
2001-2500	15%		
2500-3000	0%		
3000-3500	5%		
→3500	27%		
Don't know	24%		
Used Hima system for grazing last year	5%	Price per head of sheep	180 JOD
Livestock: Main livelihood activity	25%	Price per head of goat	220 JOD
Secondary livelihood activity	32%		
Agriculture: Main livelihood activity	3%		
Secondary livelihood activity	40%		

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