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NEW APPROACH FOR SUSTAINABLE AND PROFITABLE GRAZING SYSTEMS IN ARID OPEN LANDS OF THE NORTHERN NEGEV DESERT (ISRAEL)

ABSTRACT. In the past, most of the open lands of arid areas were used as rangelands because of the pivotal role of grazing in the life of the indigenous populace. Currently, because of the competition between grazing and other types of land management (crops' breeding, urbanisation, etc.) and the seemingly destructive effect of the grazing on the ecosystem, only a reduced part of the open lands is used for grazing. Even in the lands that are allocated to pasture, many restricting' legislations have been enforced by the authorities. Consequently, these policies have resulted in the dramatic reduction in the profits of the herd owners and a drastic decrease in the rate of grazing, which resulted by ecological catastrophes such as wide spread of fires and invasion of exotic species. In order to achieve a sustainable and profitable utilization of these open lands, we used an alternative approach, which based on the physical interactions of the animals with the ecosystem. This scheme takes into consideration the physical interactions of the bred animals with the ecosystem there, the statutory state of the lands, and the social patterns of the indigenous farmers, as parameters for a holistic solution for arid lands.

KEY WORDS: animals' physical interaction model, open lands, sustainable and profitable grazing system

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INTRODUCTION

Since ancient times, grazing play a very important function for the local population of the northern Negev. Grazing was their major source of employment and income. Scenes from the shepherds' lives are mentioned all over the holy scriptures of the main monotheistic religions (the Bible, New Testament, and the Quran) (Bodenheimer 1960; Stewart 1979). In these scriptures, the grazing and the animals serve, not only, as a food resource for the shepherds' families but also as an indicator of the shepherds' wealth, symbols of peace making, and treaties among people. In addition, herd management considered an educational tool for acquiring good manners. Nevertheless, the grazing areas were mostly frontier lands far from human settlements ('for every shepherd is an abomination unto the Egyptians') (Genesis chapter 46, line 34). Grazing restrictions were also legislated: 'It was prohibited to grow ruminants in the holy land' (Babylon Talmud, Baba Qama, chapter 70, page 2). In fact, the first murder mentioned in the Bible was due to the dispute between a crop breeder and a shepherd (Genesis, chapter 4). Such an attitude led to the destruction of ecosystems and an increase in the social alienation of the shepherds, particularly those whose major source of income was grazing. This attitude, which correlates grazing to ecosystem degradation, is still widely spread in the minds of politicians, land managers, researchers and the public, translated by the municipalities into over-regulation and restrictions on the herd owners, which causes a drastic decrease in their profits and a lack of wiliness by them to breed animals on pasture (Winter 2000). The reduced grazer density in the open lands has led to ecological catastrophes such as fires (Archibald et al. 2005).

Lately, several studies have demonstrated the positive impact of controlled grazing on the sustainable management of open areas, and even their rehabilitation efficiency in cases of degraded areas caused by inadequate agriculture practices such as intense tillage (Papanastasis 2009; Yurista 2012). Nevertheless, these data are partial, unorganised, and based mainly on theories. In order to suggest a substitutable grazing system, the existing grazing patterns of the northern Negev will be reviewed together with novel findings regarding the animal–ecosystem interrelations.

THE NORTHERN NEGEV AND ITS' CURRENT GRAZING SYSTEM

The basic terms that model any grazing system are the land statutory state, the bred animals on pasture, and the herd owners' social patterns.

The statutory state of the northern Negev open lands

Since the foundation of the state of Israel until 1978, the rangelands in the northern Negev were statutory defined as 'public' or 'private-undefined property', which allowed each herd owner to enter and use the land without limitations. This led to many disagreements on the use of these lands between the herd owners themselves and the municipalities. Ecologically it raised the overgrazing phenomena in a large part of the rangelands (Zeligman et al. 2016). Only after long legislation processes, parts of the lands were allocated to urbanisation, while the remaining were nationalised. Some of the open lands were leased to Kibbutzim (cooperative settlements), and others were given to KKL (Keren Kayemet L'Israel) for afforestation (from 1978, KKL leased a part of her areas for seasonal grazing). The remaining areas were defined as open lands, which were allocated to the Bedouin farmers, the local people of these areas) for yearly use. Parts of the allocated lands are used for rangelands, while others are used for rotational rain-fed cereals, breeding, and grazing, Fig.1. After the cereal seeds' collection season (defined from the end of summer until autumn, i.e. July–October), the straws are collected into buckets for sell or used for fallow grazing (Le Hougrou 2009; Ingram and Hunt 2015). In some cases, when the rainfall is not homogenous and inter-sessional forecasts claim that drought is predicted, the Bedouin farmers prefer to transport the herds to the fields even before the fallow season, a practice which was observed, as an example, in the summer of 2017. Altogether, the open lands are intensively cultivated for rain-fed cereals and used for grazing on a yearly basis, without a multi-year plan (Alassaf et al. 2012; Roncoli et al. 2012; Abdulrashid 2013).

Animals bred on pasture supply in the northern Negev

Historically, four animal species have been bred in the northern Negev, including the bulls, ruminants (cattle, goats, and sheep), and camels. The bulls mainly belong to the

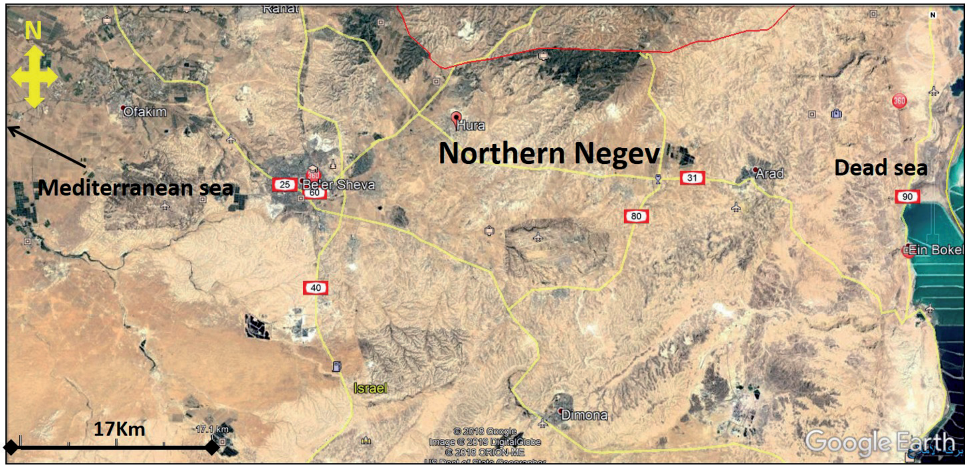

Fig. 1. The northern Negev open lands. A hilly and highly incised area due to long term and intensive agriculture utilization

species Bos Taurus with an estimated number of several thousand animals. A cattle herd contains 10–20 animals bred mainly for meat (data from Israel Grazing Authority, IGA). The ruminants are mostly goats (Capra hirctus mambrica) and sheep (Ovis aries musimon) that are mostly grazed together. Several herd owners have noted that their goats' role in the herd is to lead the sheep to the rangeland and back to their enclosure. The total number of ruminants in the northern Negev is estimated to be 250 000–300 000. The goats' ratio from the total grazed ruminants is 4% (Olsvig-Whittaker et al. 2006). The goats bred in Israel belong to the Negev-Baladi and Shami species' types and are bred mainly for the dairy industry. The sheep belong mostly to the Awasi species' type, and they are bred mainly for meat. The average ruminant herd contains 100–150 animals (Zeligman et al. 2016). The ruminant herds and the cattle are generally brought to the rangeland twice a day (early in morning: 06:00–10:00), and in the evening (16:00–19:00), mainly in the late spring and at the end of summer, i.e. April–September (personal data from local breeders). The fourth group of grazers are the camels, mostly belonging to Camelus dromedaries. As opposed to the other grazers, the camels are brought to the rangeland for several days or weeks before getting back to the enclosure. Their total number in the Negev is 3000 to 5000 herds; their herds are small, less than 10 in number, and they are bred for their milk and meat (Engelhardt et al. 1989).

The social patterns of the sepherds

In the past, most of the Bedouin families in the Negev relied on grazing as their main source of income. The adults were the herd managers, the women dealt with the milking and cheese making, while the young helped with the grazing and gained experience in herd management. Today, most of the herd owners are older than 50 years of age, while the women and young prefer more profitable occupations. Some herd owners rent illegal and inexperienced shepherds, which leads to additive ecological damage to the rangelands by improper practices. Others prefer to breed their herds in an enclosure or to limit open grazing only to the spring season only for the sake of convenience.

THE INTERACTIONS OF ANIMALS WITH THE ECOSYSTEM

The main models that are correlating the grazing intensity and the ecosystem are the compensatory, over grazing and the 'Intermediate Grazing Optimisation-IGO (Oba et al. 2001). The Compensatory model describes mostly ecosystem resist to grazing as ones settled with invaded species (Parker et al. 2006) (Fig.2). The steep decrease of the overgrazing model reflects species, which are highly sensitive to overgrazing (Villarreal-Barajas and Martorell, 2009). Nevertheless, the IGO model is been considered as the most

Fig. 2. The grazing animals in the northern Negev. A. Camels herd, Wadi Atir farm (31°16'16.64"N, 56°34'11.80"E), northern Negev, February 2011; B. Cattle herd, Ramot Menashe, March 2015. C. Ruminant herd (composed of goats and sheep), Eshtamoa Basin, February 2014. D. Ruminant herd dispatch linearly along the rangeland to reduce damage to the ecosystem, Eshtamoa Basin, northern Negev, February 2014, Photos: Amir Mor-Mussery

comprehensive one and includes both of them in its' different phases (Oba et al. 2001). Additional model is based on the physical effects of the animal on the ecosystem.

The IGO model

The correlation between the grazing intensity and the ecosystem's vegetation is been commonly described as a parabola. This scheme defines 'Intermediate Grazing Optimisation', which is composed of several phases (Oba et al. 2001; Doole and Romera 2013). Until the first turnover value, the grazing intensity does not affect the pasture edibility, which implies less edible species and reduced amounts. From the second turnover value, the increased grazing intensity causes an enhancement of pasture edibility. From the third turnover value, a negative effects are exists between the grazing intensity and the pasture edibility, as shown in Fig. 3.

The IGO model suffers from the following drawbacks, when applied to the study of the ecosystem states in the arid areas:

a. The meadows-oriented model is based on the studies of meadows with a mostly homogenous vegetal cover, while arid areas are characterised by patchy forms (shrubs or other ecosystem engineers that create small soil patches with low vegetal cover) (Mor-Mussery et al. 2015). Therefore, any scheme correlating the grazing and the vegetation in the arid areas must treat the patches and the matrices separately.

b. Wide parts of the open lands in arid regions have been defined as fragmented landforms because of the intensive erosion processes (Shi and Shao 2000). Thus, some of these landforms are more or less accessible to the animals, resulting in varying vegetation characteristics (Shi and Shao 2000).

c. Even under a given grazing intensity regime, the effects on the vegetation (and the whole ecosystem) may vary (for example, shrubs' browsing may accelerate the growth of fresh canopy parts, and the trampling may damage the patches' productivity; Schleuning et al. 2015).

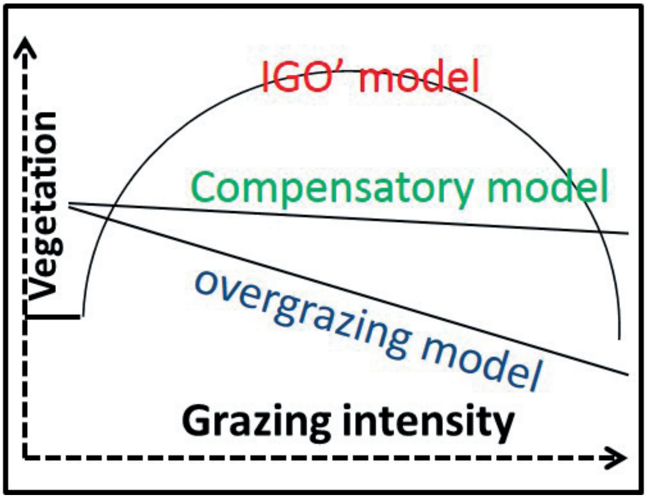

Fig. 3. Correlation between grazing intensity and vegetation patterns. The «Compensatory», «Overgrazing» and 'Intermediate Grazing Optimisation' models (Oba et al. 2001). 'Grazing intensity' denotes the number of the animals per plot, number of grazing sets in a year, etc.; 'Vegetation' defines the vegetation richness as amount, species biodiversity, etc

The animals' physical interactions model

Due to abovementioned drawbacks of the common scheme, in this study, we used an alternative scheme, which is based on the physical interaction modes of the animals and the ecosystem and analysed the factors that influence these physical interactions.

The main effects of the animals on the ecosystem are the trampling, vegetation harvesting, and excrement outlaying (Greenwood and McKenzie, 2001), as shown in Fig. 4.

These interactions influence the physical, chemical, and microbial characteristics of the soil in the rangelands (McNaughton et al. 1998; Sankaran and Augustine 2004; Savadogo et al. 2007). In turn, via feedback loops, these characteristics influence the productivity of the rangeland and its suitability for continuous use in cultivation. The factors that influence the intensity of these interactions can be grouped into animal, herd size, grazing timing and period, rangeland abiotic and vegetation state, and the herd owner's operations.

Animal: This group of parameters includes the species (Gamfeldt et al. 2008; Baker

Fig. 4. The physical effects of the animal on the ecosystem. A. Effect of flora harvesting on A. victoriae canopy, Chiran area, northern Negev, March 2015. B. Flora patches cut off due to ruminant trampling (B) as compared to the conserved area near the Chiran area (B*), northern Negev, March 2015. C. Reduced vegetation coverage due to concentrated ruminants' manure, Wadi Attir (31°16'16.64"N, 56°34'11.80"E), northern Negev, January 2017. Photos: Amir Mor-Mussery

et al. 2006(, type (Gamfeldt et al. 2008(, gender (Verdú et al. 2004), physiological state (Parsons et al. 1994), and travelling patterns (Duffy et al. 2003).

Herd: This group includes three parameters: herd size (Parsons et al. 1994), composition (Parsons et al. 1994), and travelling and distribution patterns (Duffy et al. 2003).

Grazing timing: This group includes three parameters: period (Fleischner 1994), duration, and intensity (number of grazing sets per unit time; Taylor et al. 1993).

Rangeland vegetation: This group includes three comprehensive parameters: vegetation composition (shrubs, perennials, cereals, broad leaves, etc.), physiological parameters (plant growth rate, blooming, drying out, etc.) (Tueller 2012), and the 'vegetation stability' — a parameter which defines the ability of the natural species to resist the invasion of exotic species (Clarke et al. 2005; Miki and Kondoh 2002).

Rangeland abiotic patterns: This group of parameters includes the climate characteristics (mainly the rainfall patterns; Kincaid and Williams 1966), landscape' patterns (Wondzell and Ludwig 1995), and soil properties (Wondzell and Ludwig 1995).

Herd owner's operations. The most important parameter of this group is the herd owner's personality; nevertheless, different social patterns such as origin, gender, and age may influence the operational grazing (preference of grazing vs. breeding in enclosure, grouped vs. spread, etc.) and consequently, the interactions with the ecosystem (Corner 1991; Fernandez-Gimenez, 1999).

The animals' physical interactions with the ecosystem in the northern Negev

In order to determine in the northern Negev open lands, the effects of the different grazing factors on the intensity of the animal' effects we interviewed 10 local Bedouin sheperds on the factors presented in Section Using Toma et al. (2016) methodology, per each factor the data from the herd owner translated into four conceptual intensity levels:

'H' (High effect): State which describes productivity change two folds higher (or lower) than the state in the previous year.

'M' (Moderate effect): State correlated to a productivity change of 50%–200% as compared to the previous year.

'L' (Low effect): State of productivity change of 25%–50% as compared to the previous year.

'Min' (Minor impact): State of productivity change of less than 25% as compared to the previous year.

One has to take into consideration that a factor's influence based on the existing state of the land in the northern Negev (climate, grazer species, etc.), therefore, elsewhere, the influence may be different. The findings are presented in the conceptual equation Eq. 1.

$$Trampling = Animal^{M-L} * Herd^{M-L} * Timing^{M} * \\ * Vegetation^{L-H} * Abiotic^{Min} * Social^{H}$$

$$V.harvesting = Animal^{L-H} * Herd^{L-H} * Timing^{M} * \\ * Vegetation^{L-H} * Abiotic^{Min} * Social^{M}$$

$$E.spreading = Animal^{L-M} * Herd^{L-H} * Timing^{M} * \\ * Vegetation^{L-H} * Abiotic^{Min} * Social^{L}$$

where X^{H} - high, X^{M} - moderate, X^{L} - low, X^{Min} - minor effect grades; V. harvesting - vegetation harvesting; E. spreading - excrement spreading.

SUSTAINABLE GRAZING SYSTEM OF THE NORTHERN NEGEV OPEN LANDS

In order to establish a sustainable grazing scheme in the northern Negev, we will refer to the land state and cultivation management, in-field management practices, and pasture enhancement practices. The data are based on recent publications and the unpublished data collected by the authors.

Land state and cultivation management Rangeland privatisation

As stressed previously, wide parts of the northern Negev open lands are 'public'. Nevertheless, in these lands, several privatisation schemes have been carried out along the years. In the 80's of the previous century, 59 areas in the Negev were allocated to private farmers for sustainable management as rangelands. The limitations of the privatisation terms, un-regularised state of the farms, and lack of supervision from the authorities led the farmers to rely on grazing as a secondary source of income, if at all (the main uses of the farmlands were tourism and medicinal plant cultivation). This state damaged in many cases the ecosystem productivity. An example is presented in Fig. 5.

Additional privatisation trials are conducted on seasonally or yearly rangelands' allocation to herd owners. Nevertheless, because of insufficient enforcement and lack of supervision on the existing state of the rangelands, wide parts of these privatised areas are continuously degraded (Olsvig-Whittaker et al. 2006; Hahazni-Cohen 2011).

Cultivation rotation

One of the most documented practices for long-term sustainable management of open lands in the northern Negev is the fallow period, years in which the land is not processed, neither grazed nor tilled. In the past, the recommended ratio between the grazing years and the fallow ones was 6:1, defined also by Shmita (Antal et al. 2016). However, currently, because of the global climate changes and the use of intensive cultivation, additional fallow years needed for a sustainable multi-year grazing set (Abubakar 1996). An example for the influence of conservation (prevention of grazing) on loess area in Project wadi Attir (PWA) presented in Fig. 6.

Recent studies that took place at the Wadi Atir farm in the northern Negev showed that four years of continuous fallow management caused an exponential growth of herbaceous biomass of up to two-fold as compared to the grazed area (Mor-Mussery et al. 2017). At the Oren-Aren family farm, after 20 years of partial conservation (1.1 ha per ruminant, preventing grazing at vegetation germination, etc.), the herbaceous biomass weight was nine-fold higher than that of the adjacent unsupervised area (0.09 vs. 0.01 Kg m^{-2}, Leu et al. 2014) (see Fig. 7).

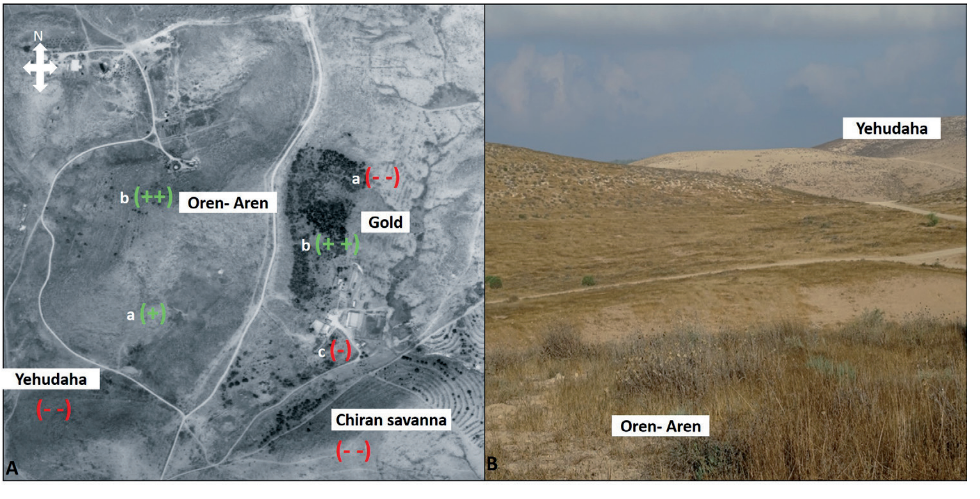

Fig. 5. Influences of privatisation on biomass in Chiran farms (31°19'17.46"N, 57°34'22.19"), northern Negev. A. Effects of land management on biomass production on Chiran farms, northern Negev: 'influence' levels: destructive (leads to degradation) '-', highly destructive '- -', and rehabilitative '++'. B. Differences in biomass cover between Oren-Aren and Yehudah farms, May 2016

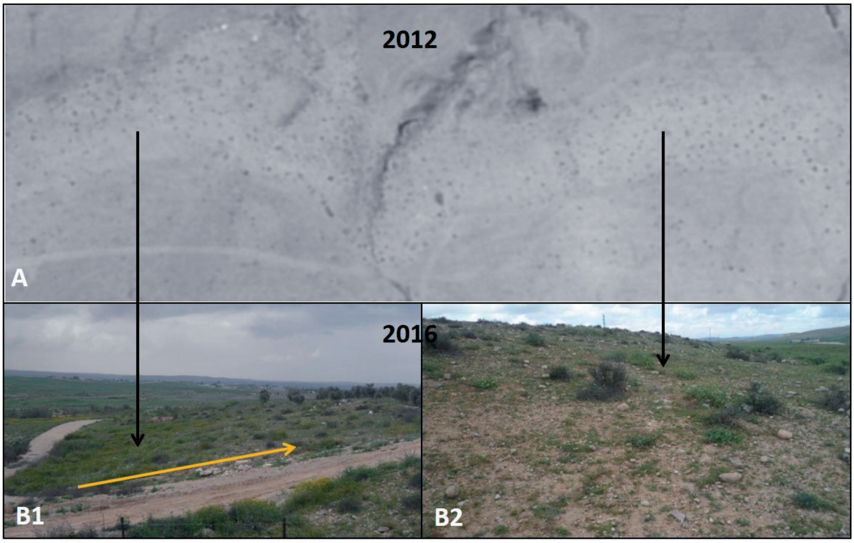

Fig. 6. Influence of continuous prevention of grazing on the vegetation state in the Wadi Atir area between 2012 and 2016 (31°16′16.64″N, 56°34′11.80″E). A. Air photograph from 2012, describing the degraded state of the rocky ground before conservation. B(1). A rehabilitation processes of the conserved rocky ground, expressed by a gradual increase in the vegetative cover downhill. B(2) Homogenous and low vegetation cover in the overgrazed rocky ground. Photo Amir Mor-Mussery

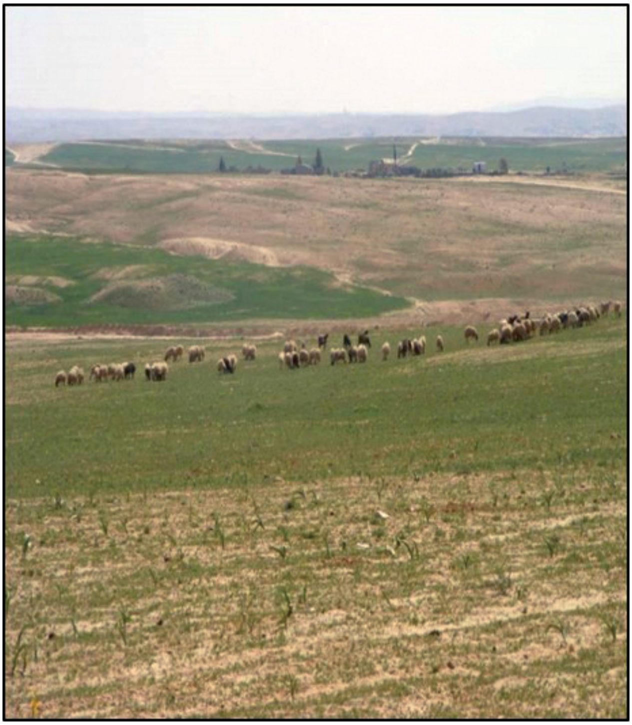

Fig. 7. Combined crop–livestock regime in the northern Negev (2016, Chiran area). The improper ruminant herding of crop fields (combination of multi-year monoculture wheat cultivation; ruminant herding during crop germination and after tillage) leads to drastic soil erosion and incision. Photo Stefan Leu

Most of the open lands in the northern areas are cultivated according to the combined stock-rain-fed cereals scheme (Perevolotsky and Seligman 1998) as follows: soil tilling in September–October and sowing in October–November. In case of the hay use as a feed it is produced from green wheat normally in April after the end of rainy season. In case when the grain is used it is harvested between May and June. During the fallow season, the animal herds are brought to the field for grazing. In drought years such as 2017, grazing starts as early as February–March without grain harvesting (Abdulrashid 2013; Ingram and Hunt 2015). The final decision on cultivation is based on the observed rainfall patterns or short-term meteorological forecasts and not on multiyear plans (Alassaf et al. 2012; Roncoli et al. 2012). The PWA (Project Wadi Attir) area is continuously cultivated with rain-fed wheat, except during the droughts. This cultivation scheme, which is repeated yearly, enhances degradation processes expressed by soil fertility, productivity decrease, and landform erosion (Sainju et al. 2011). The separation of the grazing sets from the crop cultivation reduces tillage and can thus enhance sustainability. For example, Thornton and Herrero (2001) described a decrease of 40% in the external nitrogen required for fertilisation once the combined scheme is applied. Descheemaeker et al. (2010) described a decrease of 25% in the need for additive irrigation (due to better infiltration of the rainfall, higher microbial activity, better CO2 fixation, and reduction in soil erosion). Nevertheless, comprehensive studies that will take into account the animals, soil, and climate need to be carried out in the Negev for increased pasture amounts (Herrero et al. 2010).

Possible sustainable practices

Based on the previously published data and our observations, the recommended guidelines for grazing in the Negev open lands are as follows:

a. Preventing or reducing the grazing intensities in the rangeland, when wide apart from the vegetation in the germination stage (Oesterheld and Sala 1990).

b. Spreading the animals in the rangeland or moving them rotationally between the pasture plots for preventing continuant grazing in the same locations, mainly during the vegetation growth period (Williams and Hall 1994; Encinias and Smallidge 2010).

c. Adjusting the animal to the pasture species' composition, for example, in the case of massive amounts of cereals, cattle may be preferred (Vesk and Westoby 2001).

d. Adjusting the grazing to the vegetation patterns. The main types of vegetation cover are grasslands and shrublands. In a shrubland, the shrubs establish soil patches with dense **biomass coverage**. These patches are the key factors for the vegetation growth in the whole area; therefore, any grazing scheme has to prevent severe damage to the patches (Butt 2010; Jakoby et al. 2010), while in the grasslands, this problem does not exist.

Pasture enhancement practices

Conservation

The state of almost all the open lands in the northern Negev is defined as 'degraded' because of continuous mismanagement by repeated tilling and grazing without fertilizer input, fertility, or grazing management (Helman et al. 2014; Weissmann and Shnerb 2014). The common way to increase the pasture amounts is based on conservation and leaving the land to restore its' vegetation coverage, processes that last 5–10 years (Leu et al. 2014). Nevertheless, the main drawbacks of this practice is its' long-term continuation and the reduced profits for the farmer in these years (Perrings et al. 2014). The Bedouins in Israel have a relatively low income as compared to the other populations; therefore, relying on conservation practices alone may not be practical for them.

Manure spreading

One of the common methods to increase rangeland productivity in the northern

Negev rangelands is the spreading of animal manure, obtained mostly from enclosures. The manure is dissimilated by microorganisms into soluble nutrients that are absorbed by the vegetation and enhance its growth and development (Ayan et al. 2010). Nevertheless, improper spreading can lead to the percolation of nutrients to the underground water (Madison et al. 2016), enhanced soil salinisation (Hao and Chang 2003), accelerated changes in the composition of the natural species such as enhanced propagation and growth of exotic species (Lu et al. 2010), and even accelerated soil erosion (Gilley and Risse 2000). The following parameters must been taken into account with respect to manure spreading (Williams 1999).

a. Manure source: The excrements of different animals and the enclosure beds have a considerable effect on the chemical composition of the manure and its assimilation rate (Kuepper 2000; Khan et al. 2008).

b. Timing: The most crucial factor for manure assimilation is the wetting. In rangelands, wetting is achieved artificially by irrigation, but in the northern Negev, it is mostly achieved by the rain water, which is highly heterogeneous. On the one hand, the long duration of unwetted manure may decelerate the vegetation development (Dewes 1996); on the other hand, massive amounts of manure, usually in the middle of winter, may lead to ground water contamination (Kuepper 2000). In general, the best timing for manure spreading is autumn or the beginning of the winter as during these periods, a low and prolonged assimilation of the manure into the soil takes place (Madison et al. 2016).

c. Soil thickness and landform patterns: In thick soils exposed to soil erosion and inclination higher than 12%, one has to use a thin manure layer to prevent its being swept away (MPCA 2012; Madison et al. 2016).
The effects of different manure spreading schemes presented in Fig. 8

Fig. 8(A) shows the differences between two rain-fed wheat fields. One of them was shallow tilled with a homogenous spread of cattle manure in autumn, while the other was cultivated without manure spreading. Fig. 8(B) shows improper manure spreading, which manifests in the lack of a vegetation cover due to the thin manure layer, which can lead to the leakage of nutrients into the low soil layers.

In the past, the herd owners in the Negev used to wander with their herds along the Negev rangelands and at night to establish temporary enclosures in the field. Based on the principles of these observations, several studies suggested the spatial location of these temporary enclosures in order to use them to fertilise the whole area (Verdoodt et al. 2010; Kigomo and Muturi

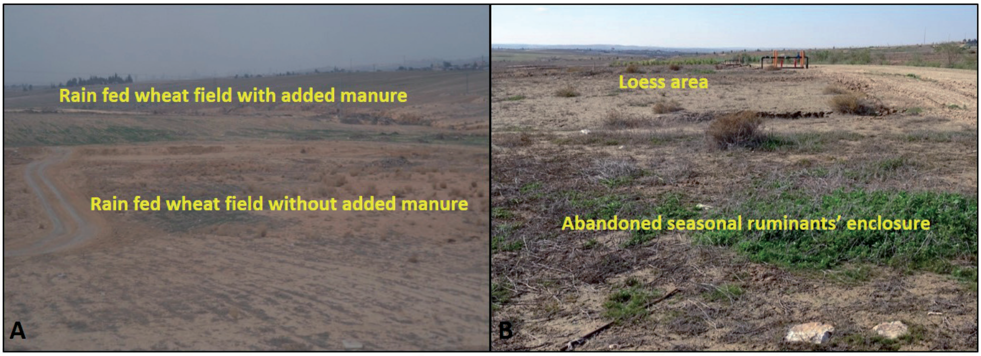

Fig. 8. Effect of manure spreading and abandoned seasonal enclosure on soil productivity. A. The impact of homogenous manure spreading on rainfed cultured cereals field, vs. un-spread one. Attir heals area (31o16'16.64" N, 56034'11.79"E), January 2017; B. The impact of abandoned seasonal enclosure on herbaceous cover vs. adjacent open area, Project Wadi Attir, February 2015. Photos Amir Mor-Mussery

2013). Nowadays, the reduced size of the rangelands, their fragmentation for other land uses, and grazing restrictions enforce the herd owners to take their herds from the permanent enclosure to the rangeland and return them at night. This makes the fertilisation based on the spatial location of the seasonal enclosures less practical.

Rangeland reseeding

An additional tool for enhanced herbaceous biomass is reseeding the rangeland with natural species of grazing importance (high edibility, rapid growth, etc.). The enriched seedbank creates a dense cover of the selected species (Grantz et al. 1997) in addition to enhancing pasture utilisation. For example, a herd owner from the Arzog Bedouin village claimed that a mix of *Triticum aestivum* and natural species in each reseeding set enhanced the ruminants' health, which resulted in increased profits for him. Examples for rangelands reseedings presented in Fig. 9.

This reseeding practice may also stabilise the landform by reducing the negative influences of monoculture cereal breeding (Vasta et al. 2008). Nevertheless, the selection of the seeds must be done with caution in order to prevent the spreading of exotic species (Rejmánek and Richardson 1996). In the northern Negev, several species have become invasive because of improper reseeding such as *Atriplex holocarpa F. Muell* (Dufour-Dror 2012) and Chloris gavana (Ng'weno et al. 2010; Dufour-Dror 2012).

Savanisation

Savanisation for enhanced pasture, defined additionally as 'silvi-pasture', has been documented in the northern Negev and other arid areas (Rai et al. 1999; Clason 1995). Several factors may influence the pasture amounts and properties, including the soil, landform, the animals, and the climate. The savanna trees affect the pasture in two ways: the canopy as the food source and the formation of understory vegetal patterns (mostly linked to the 'tree–grass' correlations; Dohn et al. 2013).

a. Tree canopy as pasture resource

The physiological state of the animals is also important; for example, milking animals prefer to consume vegetal parts enriched with nitrogen (Cabiddu et al. 1999). The accessibility of the canopy to the animal is determined by the tree and animal parameters, as shown in Fig. 10.

b. Trees' understory vegetation as pasture resource

Many parameters determine the effect of the tree on its understory vegetation (tree–grass interactions). The common theory, defined additionally by the competition/facilitation ratio (C/F ratio) (Dohn et al. 2013), claims that the tree–grass

Fig. 9. Influence of rangeland reseeding on herbaceous biomass. A. Reseeded rangeland with wheat for increasing pasture, Yattir farm, March 2016. B. Cultivated field composed from autumn wheat and natural flora seeds for better pasture (mainly Chrysanthemum coronarium), Arzog 2015 (31°24'39.12"N, 47°34'33.57"E). *The noticeable wheat crowns all over the Arzog fields are attributed to the enhanced ant nesting underneath. Photo Amir Mor-Musser

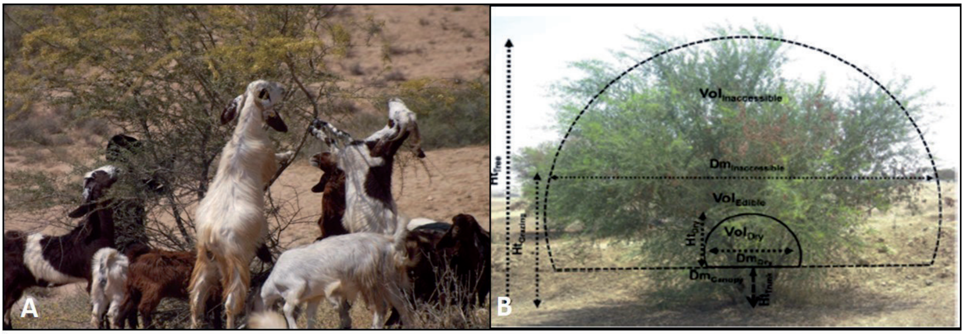

Fig. 10. Accumulation of available tree canopy volume for grazing. A. Goats eating the A. victoriae flowers. B. Scheme for evaluating the edible canopy part of a given savanna tree (based on Mor-Mussery et al. 2013). DmInaccessable- canopy diameter not accessible to the animal; VolInaccessable- canopy volume not accessible to the animal; DmDry dry part diameter surrounding the bole, which is not edible for the animal; DmDry- dry part volume surrounding the bole, which is not edible for the animal; HtDry- dry part height surrounding the bole, which is not edible for the animal; HtTrunk- trunk height; HtTree- tree total height; and DmCanopy- total diameter of the tree. Photos Amir Mor-Mussery

interactions are influenced by the ratio between two opposite processes. One is the 'competition' for resources, such as water, nutrients, or closeness to the roots, and the other is facilitation, which describes the ability of the tree to encourage the vegetation growth underneath its' canopy. The resulting understory vegetation patterns such as biomass weight and species biodiversity are determined by the ratio between these processes (Fig. 11).

The first and foremost parameter having effect on the C/F ratio is the stressor intensity. Anthropogenic effects such as dense tree plantings and a wide canopy may be considered as intense stressors that might reduce the understory vegetation (Sankaran et al. 2004; Dohn et al. 2013). Recent studies in the northern Negev have demonstrated that the C/F ratio theory is not comprehensive as the same stressor intensity may have different outcomes in the case of different species (Fig. 10A and B). In addition, dense planting may not only increase the understory vegetation but also affect the area between the trees' canopy (Fig. 10C). In summary, in many cases, the use of several savanna tree species, such as *Acacia victoriae*, may accelerate the vegetation growth and pasture usability of open lands.

PRINCIPLES FOR A SUSTAINABLE AND PROFITABLE GRAZING SYSTEM IN THE NORTHERN NEGEV

The current study describes a wide range of influences on the interactions of the animals and the ecosystem of the northern Negev open lands. In order to rehabilitate these lands and establish a sustainable and profitable grazing system, several groups must be involved, such as the authorities, the local herd owners, and scientific institutes. Nevertheless, the prerequisite for a successful grazing system in the northern Negev is a change in the attitude. Since the establishment of the state of Israel and even before it, the public and the policy makers viewed grazing as an 'unnecessary economic sector', because of the belief that grazing is destructive to the environment. This attitude led to a statutory change of many open lands from grazing to other uses and severe anti-grazing legislation. In turn, this attitude forced the herd owners to get imported food, which made the animal breeding, in many cases, unprofitable (Nevo 2013). The decrease in the animal grazing in the open lands (Zeligman et al. 2016) led to a decreased number of grazers, which in turn increased the unemployment in the Bedouin sector (Meir 1984). Besides the social effects, the decrease in the number of grazers in the open lands led to an increase in the number of fires (Perrings

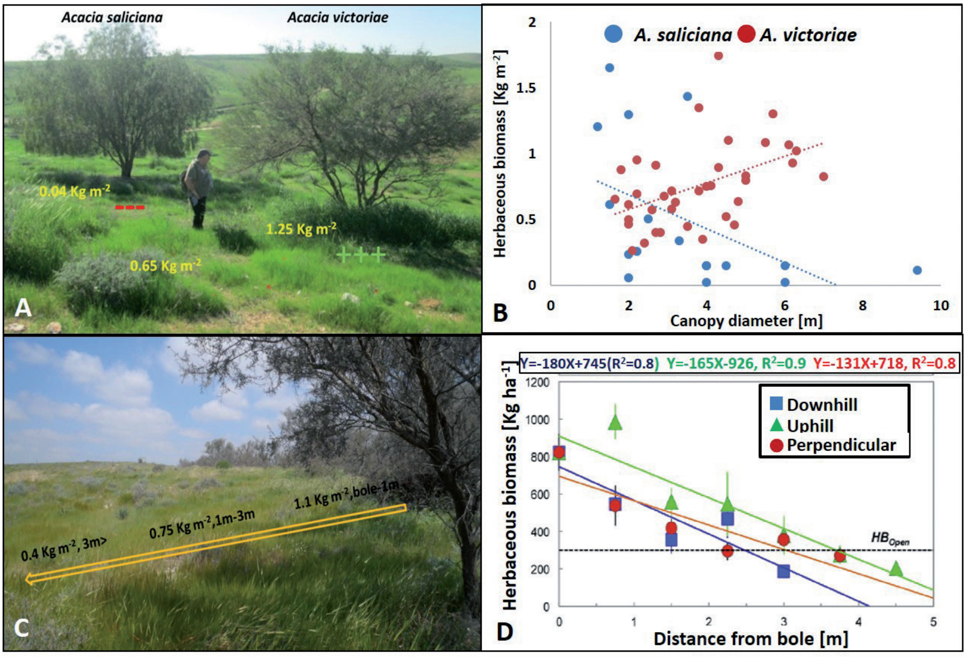

Fig. 11. Trees' influence on understory herbaceous pasture. All plots managed with the same grazing regime. A. Effect of different savanna tree species on the understory herbaceous biomass (March 2016) (Acacia victoriae accelerates the annuals growth underneath its canopy, while A. saliciana suppresses it). B. Effects of different canopy sizes on the understory herbaceous cover of savanna trees (Helman et al. 2017) (A. vicotriae canopy size is positively correlated to the understory vegetal cover, while that of A. saliciana is negatively correlated). C. Dense planting of Acacia victoriae encourages vegetal growth outside the trees' canopy area (photographed by A. Mor-Mussery in the Chiran area, 2016). D. The relative location of the tree trunk on the hill slope affects the vegetal biomass underneath (Mor-Mussry et al. 2017). Photos Amir Mor-Mussery

and Walker 1997) and the propagation of exotic species (Brunson and Tanaka 2011). The policy makers must realise that planned grazing is not only ecosystem friendly but also crucial for a sustainable and profitable management of open lands and will enhance the rehabilitation of the degraded ones (Papanastasis 2009; Yurista 2012). In order to achieve this goal, a collaboration among the authorities, local herd owners, and scientific institutes must be established on the basis of the scheme illustrated in Fig. 12.

CONCLUSION

In this paper, we presented a comprehensive view of the grazing system of the open lands in the Northern Negev, based on its' unique soil, vegetation, landscape and the indigenous farmers patterns. The scheme separates the interactions of the animal with the ecosystem, which enables better planning of adequate and sustainable utilization even in degraded open lands that are mostly been considered as 'edgy' and uncultivated. Nevertheless, the scheme requires a consistent cooperation among the farmers, municipalities and research institutes. Although the scheme studied on the northern Negev patterns, its' principles and its' suggested management plan could be adjusted for most of the open lands across the globe.

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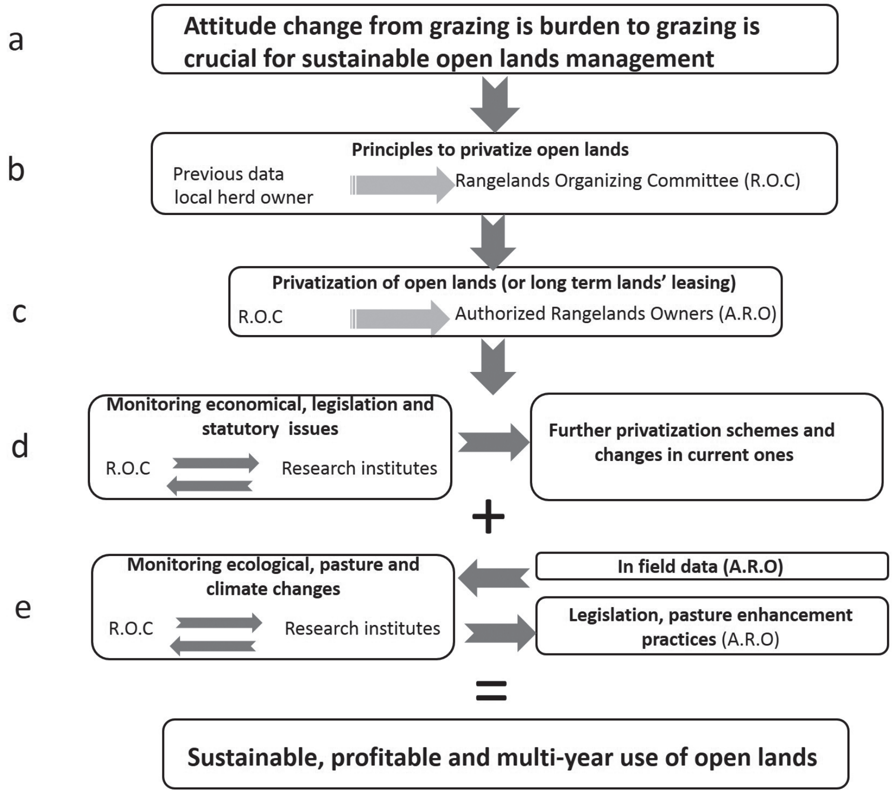

Fig. 12. Summarised scheme for sustainable rangeland management in the northern Negev open lands. A. Basic requirement of an attitude change from 'grazing is a burden' to 'grazing is crucial for successive open lands' functioning'. B. Determination of privatisation schemes for open lands on the basis of the social patterns of the local herd owners by the rangeland organising committee (R.O.C). C. Based on the determined privatisation schemes, the R.O.C allocates the open lands to authorised local herd owners (A.R.O). D. Continuous knowledge transfer between scientific institutes and the R.O.C, regarding economic and procedural issues and translation of the knowledge into further privatisation schemes or modification of the existing ones. E. Parallel to 'D', knowledge transfer of infield data from the A.R.O to the R.O.C, which will be analysed by research institutes and be translated into seasonal legislation and guidelines for the A.R.O. After several years of continuant implementation, it will lead to a sustainable and profitable utilisation of the open land.

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