Journal of Arid Environments 109 (2014) 92–102

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Traditional land use and reconsideration of environmental zoning in the Hawf Protected Area, south-eastern Yemen

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ARTICLE INFO

Article history:
Received 8 February 2014
Received in revised form
30 April 2014
Accepted 23 May 2014
Available online 19 June 2014

Keywords:
Anogeissus dhofarica
Deforestation
Grazing management
Cloud forest
Shifting cultivation
Subsistence agriculture

ABSTRACT

The Al Hawf area at the Yemen–Oman border hosts a unique fog-derived ecosystem which, due to its high diversity of plant and animal species, merits protection. Given the area's remoteness, poor infrastructure, high population growth and limited exchanges across the Omani border, the local livelihoods strongly rely on the exploitation of natural marine and terrestrial resources. Since quantitative data on the intensity of anthropogenic pressure on the terrestrial ecosystem are lacking, the present study analysed the impact of agricultural and pastoral land use on the vegetation of the designated Hawf Protected Area (HPA). To this end structured interviews, village walks and other rural appraisal tools were combined with vegetation surveys and GPS-based monitoring of pasturing livestock herds. The loss of traditional herding systems that regulated selective management of fragile grazing grounds along the altitude gradient in the HPA, particularly for camels, the overexploitation of woody perennials for construction purposes, and the resettlement of former migrant workers are major constraints for the successful implementation of the government-designed management plan. Implementation could be improved by better taking into account the vegetation composition in the area, current and traditional grazing schemes and local people's needs for off-farm income.

1. Introduction

Situated at crossroads between the Afrotropical, Oriental and Palearctic regions, Yemen has been identified as hosting globally important biodiversity (Mittermeier et al., 2004; Olson and Dinerstein, 1998). To address increasing pressure, the Government of Yemen has, since 1999, gazetted five protected areas: the Socotra Archipelago ('island of the dragon blood trees'), the cultural landscape of Outmah, the Aden Wetlands and the 'forgotten forests of Arabia' (Bura'a and Hawf), (Hall et al., 2008).

In Socotra, Aden Wetlands and Jabal Bura, conservation management with a strong involvement of local communities has been underway for several years (Hall et al., 2008; Scholte et al., 2011). These initiatives have been supported by the Global Environmental Facility (GEF), the United Nations Development Programme (UNDP), and bilateral cooperation (Hall et al., 2008). For the Hawf Mountains Forest, however, protection efforts are lagging behind and little is known about the agro-ecological and social settings of this remote area in the south of the Arabian Peninsula that is bordering the Sultanate of Oman. In an attempt to follow the pattern of the traditional *Mahjur* (grazing reserve management) system, the 'Sustainable Community-Based Protected Area Management Plan' of 2005 proposed to divide the Hawf Protected Area (HPA) into three zones (MWP/EPA, 2005). In a high altitude 'Core Zone' (800–1400 m asl) all human activities are meant to be strictly prohibited, while limited use of forest resources is allowed in most of the mid-altitude parts of the forest classified as 'Buffer Zone' (>400–800 m asl; Fig. 1). The low-lying 'Peripheral Zone' (0–400 m asl) is meant to remain open for settlement and other activities of the local community (MWP/EPA, 2005). While the proposed Peripheral Zone mostly comprises degraded and cleared land, the Buffer Zone is predominantly populated by large trees such as *Anogeissus dhofarica* A.J. Scott, *Acacia* sp., *Commiphora* sp., and a mixed vegetation of shrubs and grasses. The Core Zone is characterised by open shrub land and populations of *Acacia* sp.,

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http://dx.doi.org/10.1016/j.jaridenv.2014.05.016
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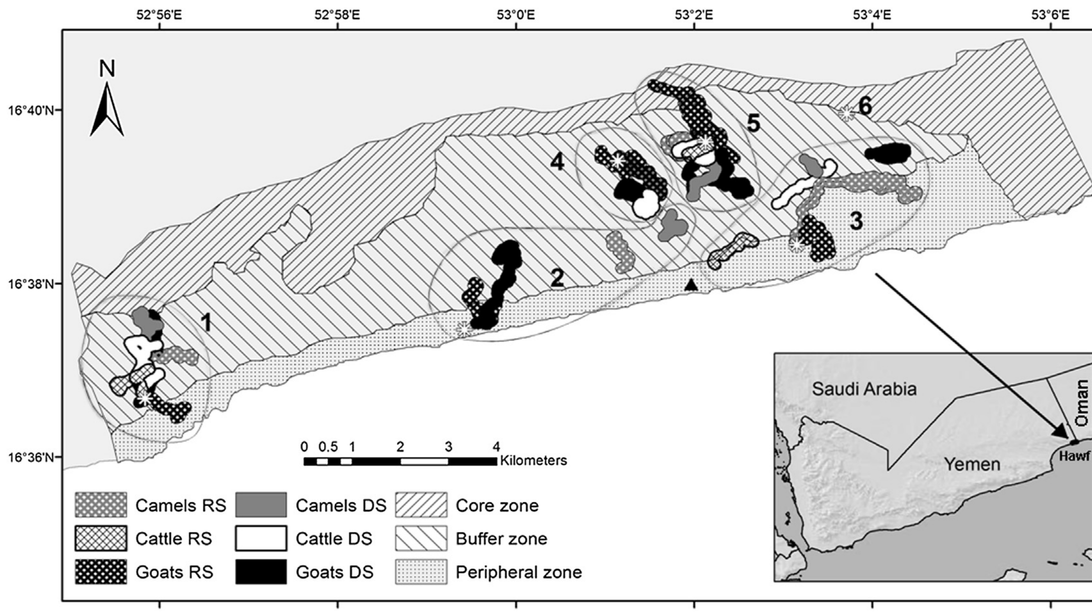

Fig. 1. Location of Hawf Protected Area in SE-Yemen (small inset) and map of the area with delineation of the designated Peripheral, Buffer and Core Zone, the location (white stars) of the study villages Ka'ab (1), Jadeb (2), Shanu (3), Kasset (4), Thenaik (5) and Qoon (6), and the major settlement Hawf (black triangle). Depiction of the dry season (DS) and rainy season (RS) grazing areas of cattle, goat, and camel herds of five of the six studied villages, as well as manual delineation (ovals) of the larger year-round village grazing areas.

Jatropha dhofarica Radcl.-Sm., *Dodonaea angustifolia* L.f., and *Commiphora* sp.

To facilitate the implementation of this management plan together with the local population and to alleviate human pressure on the natural vegetation, the plan proposes various income-generating initiatives for the regional population, such as bee-keeping, dairy farming, and fish processing (MWP/EPA, 2005). However, until today none of these elements are implemented, despite the growing pressures and the importance of the area not only for biodiversity conservation and local livelihoods, but also for water provision to communities in the arid coastal zone (Hall et al., 2008).

Given its infrastructural remoteness, the only solid information about the region besides the MWP/EPA (2005) report is a general IFAD (1999) report about the larger Al-Mahara Governorate. The unique biophysical aspects of Al Hawf and especially the neighbouring Dhofar region in Oman such as climate, geomorphology, flora, and fauna have received wide attention (Hildebrandt and Eltahir, 2006; Kilian et al., 2002; Meister et al., 2006, 2007; Oberprieler et al., 2009). However, whether the information on traditional land use patterns and land use intensities are comparable on both sides of the border is doubtful given the major socio-economic changes accompanying the modernisation processes in Oman since 1970 (Janzen, 2000).

Experience with natural protection elsewhere has shown that successful implementation of natural protection efforts requires that (i) people's needs of access to vital resources in the protection area are taken into account from the planning stage, (ii) they obtain tangible benefits through the protection efforts as compensation for foregone land use options, (iii) the target setting leads to an overall strengthening of people's livelihoods and (iv) they themselves are involved in the management of the conservation efforts (Gadd, 2005; Wambuguh, 1998; Western and Waithaka, 2005; Western and Wright, 1994). This may either be achieved by including tourism activities or by enhancing their resource base providing additional options for fulfilling subsistence or reap market niches (Dold and Cocks, 2002; Walpole and Leader-Williams, 2002; Young et al., 2005).

For the unique ecosystem of Hawf in one of the most remote and poorest areas of Yemen, this underlines the need to (i) determine the spatial extent and the intensity of current land use patterns and traditional resources management practices and (ii) assess the potential effects of conservation efforts such as park boundaries or restrictions on access to resources for current and new users. For HPA information is thus mandatory to analyse the functioning of the present land use system, its (in)-efficiencies and role in people's traditional livelihood strategies and how these will be affected by the zoning proposed in the Management Plan. Our study aimed at contributing to filling these knowledge gaps using a combination of interviews, surveys on agricultural land use and animal grazing orbits, and vegetation assessments.

2. Materials and methods

2.1. Characteristics of the study area

Located at 52°42′–53°04′ E and 16°32′–16°41′ N, the Al Hawf district in Al Mahara Governorate, south-eastern Yemen, covers 30,000 ha of rugged mountains with a maximum elevation of 1400 m asl. Oriented west to east these mountains separate the Rub-al-Khali desert from the Arabian Sea, extending for about 60 km from Ras Fartek in the west to the border with Oman in the east (MWP/EPA, 2005; Fig. 1). Crowned by a dry plateau at the top and traversed by a narrower one at approximately 450 m asl, the mountains consist largely of limestone with occasionally overlying granite outcroppings. *Wadis* (valleys) of 800–900 m depth dissect the range along most of its length. Inland the mountains gradually give way to gravel hills and desert along their entire length, but towards the sea they form steep escarpments.

During the south-westerly monsoon (June–September) the steep coastal range is often covered in clouds; the annual precipitation is around 500 mm to which up to 1000 mm of fog- and cloud-derived precipitation may add during the rainy season (Hildebrandt and Eltahir, 2006). However, exact rainfall data for the Hawf region is not available. Temperatures are highest during mid-March to mid-June, and lowest in January and February. The particular climatic conditions, especially the relatively high precipitation, result in a unique flora of dry (relict) deciduous monsoon forest that continues into the neighbouring Dhofar mountain range of Oman (Hildebrandt and Eltahir, 2006; Meister et al., 2006). In Yemen this forest, covering about 90 km^2, is dominated by the tree *A. dhofarica* – often associated with *Jatropha* and *Commiphora* species – and comprises >250 plant species. The fauna includes about 65 species of birds, more than 12 wild mammals and several reptiles, while most of the naturally occurring wild herbivores and many carnivores are close to extinction or extinct (MWP/EPA, 2005).

The most frequent plant species in the coastal plain are *Adenium obesum* (Forssk.) Roem. & Schult., *Calotropis procera* (Aiton) Dryand., *Ziziphus leucodermis* (Baker) O.Schwartz, *Grewia villosa* Willd., *Euphorbia hadramautica* Baker, and *Acacia tortilis* (Forssk.) Hayne. Further inland, along the base of the mountain escarpments, the vegetation is dominated by xerophyte shrubs such as *Commiphora* sp., *Grewia* sp., *J. dhofarica*, *Croton confertus* Baker, and the succulent creeper *Cissus quadrangularis* L. The riparian woodlands, common in the dissecting wadis, include *Tamarindus indica* L., *Ficus sycomorus* L., *Ficus vasta* Forssk., and *Ficus lutea* Vahl (Kilian et al., 2002; Kürschner et al., 2004; Miller and Morris, 1988). From the first plateau at 450 m asl upwards, the semi-evergreen woodland is increasingly dominated by *A. dhofarica*, *F. vasta*, *Ziziphus spina-christi* (L.) Desf., *Acacia nilotica* (L.) Delile , *Rhus somalensis* Engl., as well as *Commiphora* sp. and *D. angustifolia*. A rich herbaceous layer containing many legumes, grasses and ferns flourishes beneath these ligneous species. The leguminosae *Cadia purpurea* (G.Piccioli) Aiton and *Senna obtusifolia* (L.) H.S. Irwin & Barneby are frequent as well, the latter on patches where land has formerly been cleared for agriculture and abandoned since.

2.2. Local population and governance structures

HPA comprises 10,000 ha and hosts 41 small hamlets scattered across the mountain range plus three larger coastal settlements which altogether are inhabited by about 3200 people in 800 households (MWP/EPA, 2005). Of the villages scattered across the mountain range 18 are occupied throughout most of the year except during November to January (winter), and 20 are seasonal settlements (16 winter villages and 4 rainy season villages). Only the three larger coastal settlements have permanent housing structures with a semi-urban character; they are close to an asphalt road leading from Al-Ghaydah in the east to Salalah (Oman) in the west. The other settlements are typically inhabited by 2–5 families with 10–20 family members who are living in round stone huts with wooden roofs made from *Anogeissus* trees (MWP/EPA, 2005). Livestock husbandry is the major livelihood activity (37% of the population), followed by crop farming (32%) and fishing (29%; MWP/EPA, 2005).

2.3. Household interviews

Our study was carried out during August–November 2007 and departed from a spatially explicit database that contained physiographic and topographic features of HPA, set up within a Geographic Information System (GIS) based on ArcView 9.1 (ESRI, Redlands, CA, USA). To this end, maps containing the respective information were digitised from a series of colour printouts obtained through the Yemeni authorities from Consulting Engineering Services India PV. Ltd. and Ghayth Aqua Tech Ltd., Sa'dah, Yemen. Based on key informant interviews at Hawf municipality and the local market place plus a five-day reconnaissance tour on foot through HPA, three study villages (Table 1) and the adjacent areas used by their inhabitants were selected between 0 and 700 m asl, and three between >700 and 1400 m asl (Fig. 1). In the following these will be referred to as the 'lower zone villages' Jadeb (2 m asl), Ka'ab (280 m asl), and Shanu (180–433 m asl) comprising 2109 ha of village territory altogether, and the 'upper zone villages' Qoon (878 m asl), Thenaik (738 m asl), and Kasset (740 m asl) covering 6038 ha of village territory.

After pre-testing, a detailed structured questionnaire containing a mixture of closed and open questions was administered to the heads of 38 households (8 in Jadeb, 7 each in Shanu and Kasset, 6 in Ka'ab, and 5 each in Thenaik and Qoon) who were identified using a snowball sampling approach. Questions addressed household characteristics (location, tribe, sex, and age structure), family labour (age, sex, skills, and specialisation), employment (on-farm and off-farm), external labour (seasonal and permanent), cropping systems (30 HH only; crops grown, cultivation and fallowing practices, autoconsumption and marketing of crops, and problems in cropping), livestock husbandry (species kept, feeding and health care, purchases and sales, home consumption and marketing of products, and problems in livestock rearing), use of forest resources (grazing, fodder, fuel, construction material, ethno-botanical purposes, rationale of resource use, and alternatives), and attitude towards the conservation endeavours and Management Plan of HPA.

2.4. Assessment of cropping practices

Since there was no precipitation record available for HPA, we installed one rain gauge at sea level and one at Thenaik. Measurements for the month of September 2007 registered 7 mm of precipitation in Hawf village (0 m asl) and 20 mm in Thenaiek

Table 1
Characteristics of the six study villages in Hawf Protected Area (SE-Yemen), number of inhabiting households (HH), household structure, and livestock holdings (data show means and ±one SD).

Village	Jadib	Shanu	Ka'ab	Qoon	Thenaik	Kasset
Character	Urban	Rural	Rural	Rural	Rural	Rural
Road access	Yes	Yes	Yes	No	No	No
Winter migration[a]	No	Yes	Yes	Yes	Yes	Yes
Pipe water	Yes	No	Yes	No	No	No
Electricity	Yes	No	Yes	No	No	No
Total HH (*n*)	300	27	30	5	5	8
Sampled HH (*n*)	8	7	6	5	5	7
Adults (n HH^{-1})	5.6 (2.97)	6.3 (2.29)	5.8 (1.94)	6.6 (2.79)	3.4 (2.19)	5.6 (2.76)
Children (n HH^{-1})	5. (2.49)	4.0 (2.58)	6.8 (5.76)	5.2 (3.11)	7.0 (2.16)	6.4 (2.51)
Camels (n HH^{-1})	2.0 (3.89)	15.9 (17.73)	7.5 (10.50)	2.0 (1.87)	7.6 (5.03)	8.4 (9.20)
Cattle (n HH^{-1})	3.6 (4.14)	34.7 (31.14)	4.0 (5.69)	27.8 (8.87)	6.6 (6.27)	24.9 (10.25)
Goats (n HH^{-1})	14.3 (9.07)	6.9 (11.41)	22.8 (13.23)	2.4 (5.37)	25.8 (14.17)	10.9 (18.76)
Total TLU[b] (n HH^{-1})	6.7 (7.39)	47.5 (40.97)	14.5 (12.87)	24.9 (5.53)	17.0 (7.35)	31.1 (13.32)

[a] To an urban settlement.
[b] TLU: Tropical Livestock Unit, a hypothetical animal of 250 kg live weight; 1 camel = 1.2 TLU, 1 cattle = 0.8 TLU, 1 goat = 0.1 TLU.

(738 m asl). This corroborates the claim that precipitation in the mountain range exceeds that of the coastal plains by an average ratio of 2.5:1 (Miller and Morris, 1988). To characterise cropping activities, the agricultural fields, home gardens and recent fallows were mapped with a hand-held Global Positioning System (Trimble® Pathfinder Pro XR), differentially corrected at the sub-metre level by data from a Trimble® base station installed at Hawf village, and entered into the GIS data base. The current use and use history during the past 30 years of all mapped plots was recorded through interviews.

During the survey grain yield, straw yield, and total dry matter yield of sorghum were quantified as follows: First, the bundles of sorghum plants harvested per field were counted. Depending on the size of the cultivated field, 4–10 randomly chosen bundles were subsequently weighed individually to obtain average bundle weight per field; this was multiplied by the total number of bundles harvested from the field. Grain yield was determined after heads of sorghum had been cut from the rest of the plant. Straw yield was quantified by subtracting grain from total yield. Finally, one representative sample of grain and straw per bundle was kept to determine residual moisture (Naumann et al., 2004).

2.5. Grazing areas and forage selection of livestock

To determine spatio-temporal patterns and intensity of livestock grazing, the daily grazing itineraries of the goat, cattle and camel herds of all but one village (Qoon) were tracked using two GPS collars (one for camels and cattle, one for goats; Vectronic Aerospace, Berlin, Germany), which recorded the geographical position of one animal per herd during daytime at an interval of 10 s (Buerkert and Schlecht, 2009). Tracking periods lasted for one week per village and two days per species and village, respectively, with the first period scheduled during the rainy season (August) and the second during the cool dry season (October). To extract information on the seasonal location and extension of grazing areas, the collar data was overlaid on the land use maps. Additionally, livestock owners were shown a map of the area to discuss seasonal variation in species-specific grazing management.

The time that goats, cattle and camels grazed on the herbaceous layer and browsed the shrub and tree stratum along their itineraries was recorded through direct observation parallelling GPS tracking. For each tracked herd (goats: 15–150 animals per herd; camels: 5–45 animals per herd, cattle: 4–25 animals per herd) the visible number of animals grazing each stratum was recorded every 3 min during 3–5 h per day (Schlecht et al., 2011); whenever possible the plant species selected by the animals were recorded. From this information the percentage of grazing time spent per stratum and plant species, respectively, was calculated, and served as indicator for the seasonal grazing preferences of the three animal species.

2.6. Assessment of pasture resources

In the end of November 2007 the vegetation of the study area was mapped along the altitudinal gradient. To this end three transects of 5 km length each were defined in the eastern, central and western part of the study area, running perpendicular to the mountain ridge from its top (1400 m asl) to the coast (sea level). Vegetation units were defined based on the abundance and ground cover of the five dominant ligneous species; for the herbaceous layer, only total canopy cover was determined. The starting and end point of each transect as well as the starting point of every vegetation unit was recorded by GPS. Every time a new vegetation unit was encountered, but at least every 0.5 km along the transect line, the following variables were determined in 1 m^2 plots: centre coordinates, topographic aspect (plain, slope or wadi), present strata (herbaceous and/or ligneous), overall crown cover, and grazing intensity. The latter was classified as very high, high, moderate, low, and no grazing based on visual appreciation (Brinkmann et al., 2011). Plant species were determined with the help of a classification guide (Miller and Morris, 1988), and botanical names and authorities were updated using the JSTOR Global Plants online data base (http://plants.jstor.org/).

2.7. Data analysis

Data gathered in the interviews, the vegetation survey and the livestock monitoring were analysed using descriptive statistics. Crop and soil data were tested for normal distribution using the Kolmogorov–Smirnov test. Spearman's rank correlation was used to determine the effect of seed rate, amount of manure used, age of cultivated field and cultivated field surface on grain and total dry matter yield. One-way analysis of variance (ANOVA) was employed to test equality of means of sorghum yields across altitudes and distance to settlements. Dummy variables were attributed to nominal data for crop management such as legume association and sorghum sowing date. The differences in yield related to these practices were assessed by the Kruskal–Wallis test. All statistical analyses were performed using SPSS software 12.0 for Windows XP (SPSS Inc., Chicago, USA).

3. Results

3.1. Economic activities of HPA inhabitants

At the time of study, HPA was inhabited by 594 HHs with an average of 10.6 members (SD 4.67). Of these, 517 HH settled in the lower zone, whereas the upper zone hosted 77 HH.

Of the 38 HH surveyed, 53% stated to rely mainly on agricultural activities for income generation; yet, whereas in the upper zone agro-pastoral activities provided the major income for 80% of the surveyed HH, in the lower zone this was only true for 29.4% of the HH. For 84% of the interviewed HH animal husbandry contributed the major share of on-farm income, while the remaining 16% claimed to gain more money from crop production. Crop husbandry was mainly subsistence-oriented and farm products were only commercialised in case of surplus harvest or urgent need for cash. In all households agro-pastoral activities were complemented by off-farm economic activities of some of the members, which included employment as teachers (53%), civil servants (20%) and nurses (7%) as well as other forms of employment (13%) and commercial activities (7%). To these added short-term occasional opportunities for earning monetary and non-monetary income. None of the surveyed households employed external labour for cropping activities. However, for herding their goats, the inhabitants of Jadeb hired the services of shepherds. Another form of external labour prevalent in the coastal settlements was the employment of house maids to assist in cleaning duties.

3.2. Subsistence cropping

In HPA a new crop field can only be established with the agreement of the chief of the tribe controlling the area. The 30 HH surveyed for crop production managed 33 crop fields and 7 home gardens with a total surface of 20 ha, plus 14 fields that lay fallow at the time of the interview. However, the surface actually cultivated in the rainy season 2007 amounted to only 5.25 ha, whereby the ratio between non-cropped and cropped land within a farm increased with altitude ($r = 1.0$; $P \leq 0.01$). Whereas at

200–400 m asl cultivated surfaces accounted on average for 87% of the total farm surface, this proportion decreased to 25% at 400–600 m and to 22% at 600–800 m. The average size of the actually cultivated plots was similar across altitudes (0.13 ha, SD 0.066, $n = 40$).

Rain-fed crop production was practiced by all surveyed HH, while irrigated cultivation was restricted to fruit trees in home gardens of Ka'ab and Jadeb, the only surveyed villages with year-round access to piped water. Typically only one or two banana (*Musa* sp.), papaya (*Carica papaya* L.), and lemon (*Citrus aurantifolia* [Christm. et Panz.] Swingle) plants were found in the home gardens at Ka'ab, Jadeb and Shanu, as well as in three compounds at Kasset and Thenaik.

The major crop in HPA is sorghum, which is mostly grown on crop fields but also in home gardens (Table 2). Small areas of maize (*Zea mays* L.), cucumber (*Cucumis sativum* L.), and cowpea (*Vigna unguiculata* (L.) Walp.) were frequently found on crop fields, whereas okra (*Abelmoschus esculentus* Moench), aubergine (*Solanum melongena* L.), and chilli (*Capsicum annmum* L.) were planted in home gardens. Tomato (*Solanum lycopersicum* L.) grew wild in some fields and home gardens. Intercropping or crop rotation was not systematically practiced, and even sorghum–cowpea associations that were reported for 27 fields were not perceived as an explicit strategy to improve land productivity, but reflected the desire for fresh pulses.

With the arrival of the first monsoon clouds in mid-June, sorghum and accompanying species were sown by one person (usually a man or a physically-strong woman) making holes with a pointed stick and a second person (usually a woman or child) was burying the seeds. Seeding holes averaged 10 cm in depth, distance between holes ranged from 15 to 20 cm, and seed rate was 10–20 seeds per hole. Sowing was not done in rows, but in an irregular pattern. Pre-sowing seed treatments included the soaking of sorghum kernels overnight to enhance sprouting (7 HH) and a traditional ritual involving chants that is thought to alter seed physico-chemical properties (8 HH). Seeds of annual crops were saved from the previous harvest (29 HH) or obtained from relatives (1 HH); papaya seeds and banana corms and offshoots were purchased in Al-Ghaydah. Lemon tree cuttings were bought at Wadi Marara from where the first lemon tree had reportedly been introduced to HPA by the army in the 1980s. Except for two cases of melanose (*Diaporthe citri*) in lemon, which were treated with agrochemicals provided by extension officers of the Yemeni Ministry of Agriculture, there was no evidence of fungal or viral diseases affecting crops during the study period. Locusts, ants and other insects were combated occasionally with smoke of small fires light at field borders, while weeds in fields were removed manually.

3.3. Soil fertility management

Prior to sowing the crops, all HH removed stones from the fields in early June, followed by cutting and burning of brushwood that had accumulated on the fields during overnight corralling throughout the dry season (October–May). Around 40% of the households purposefully applied farmyard manure to agricultural fields whereby the applied amount depended on the availability of a vehicle and the accessibility of the field. Close-by home gardens either received manure that could not be transported to crop fields ($n = 3$) or droppings from goats and young cattle that were penned inside the garden for some part of the year ($n = 4$). Fallow use was not reported as an explicit strategy to restore soil fertility. Rather, it seemed to occur incidentally as a result of (i) lacking labour force for field cultivation, (ii) high precipitation at the beginning of the rainy season, and (iii) lack of material to renew the fence that protects a field from grazing livestock.

3.4. Sorghum yields

According to the local agricultural calendar, crops should be – and were – preferably sown between 18–30 June. If rainfall during this period is insufficient, sowing may take place during the following two fortnights. Surveyed HH viewed the 2007 rainy season as very low in precipitation, which led to delayed sowing on 9 out of the surveyed 40 plots. On the 31 plots where sorghum was sown in the second half of June as indicated in the agricultural calendar, grain and straw yields averaged 669 kg DM ha^{-1} and 9244 kg DM ha^{-1}, whereas delayed sowing (between July 1–26) yielded only 226 kg DM ha^{-1} of grain, but 10,865 kg ha^{-1} DM of straw per hectare. Overall, sorghum dry matter yield was higher ($P > 0.05$) on fields ($n = 31$) than in home gardens ($n = 9$), averaging 628 kg ha^{-1} of grain and 11,651 kg ha^{-1} of straw on the former compared to 291 kg ha^{-1} of grain and 10,352 kg ha^{-1} of straw in the latter. Sorghum grain and straw yields did also not differ significantly between sorghum–cowpea associations and sorghum monocultures. Surprisingly, manure application rate and sorghum biomass, straw and grain yields were not correlated, except for two cases where grain yield increased significantly with higher amounts of manure applied ($r = 0.35$, $P < 0.05$, $n = 30$; Fig. 2a). Likely as a consequence of the rainfall gradient, sorghum grain yield also increased with altitude ($r = 0.51$, $P < 0.01$; Fig. 2b), but there was no effect of the distance between homestead and field on sorghum grain or biomass yield.

Table 2
Size of fields and home gardens, number of associated crops grown in addition to sorghum, sorghum seed rate, manure application rates and sorghum grain and straw yields in the six study villages of Hawf Protected Area (SE-Yemen). Data show means and ±one SD.

Village	Plots (n)	Plot size (ha)	Associated crops (n)	Years of cultivation	Sorghum seed rate (kg ha^{-1})	Manure application (kg DM ha^{-1})	Sorghum grain yield (kg DM ha^{-1})	Sorghum straw yield (kg DM ha^{-1})
Fields								
Jadeb	6	0.11 (0.06)	0.7 (0.8)	15 (17.7)	185 (108)	89 (217)	345 (285)	10,597 (7044)
Ka'ab	1	0.06	1.0	35	218	0	0	12,200
Shanu	5	0.20 (0.06)	2.2 (1.1)	28 (17.5)	51 (14)	147 (328)	179 (296)	6046 (1357)
Qoon	4	0.10 (0.07)	3.3 (0.5)	14 (8.2)	139 (78)	2772 (2710)	1063 (712)	9137 (1761)
Thenaik	6	0.19 (0.09)	0.8 (0.8)	15 (8.3)	126 (85)	326 (397)	797 (522)	7613 (3102)
Kasset	11	0.13 (0.04)	0.5 (0.5)	15 (16.4)	72 (41)	1305 (1470)	792 (817)	11,240 (4508)
Home gardens								
Ka'ab	2	0.06 (0.02)	8.5 (0.7)	25 (21.2)	155 (29)	0 (0.0)	0 (n.a.)	11,375 (7601)
Kasset	5	0.10 (0.05)	2.0 (1.4)	9 (2.6)	60 (19)	575 (745)	408 (265)	10,352 (6870)

DM = dry matter.

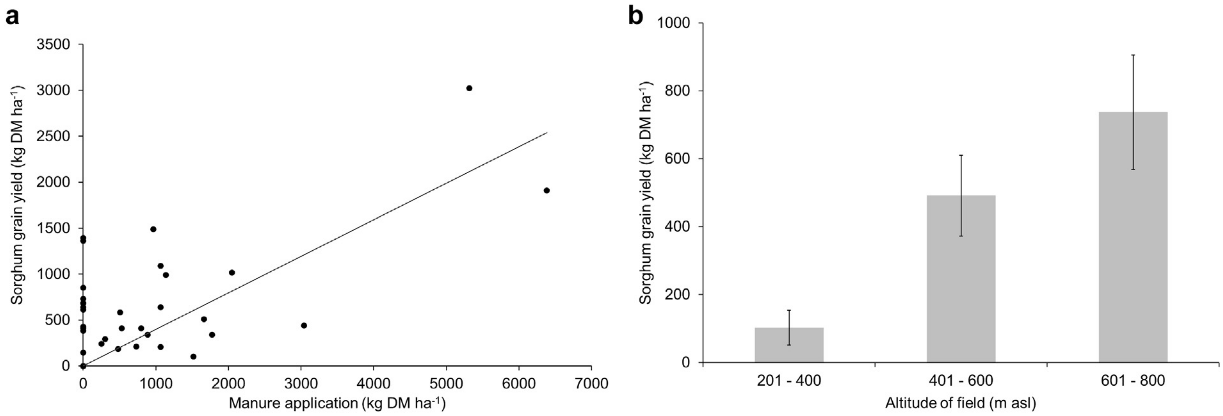

Fig. 2. Relationship between sorghum grain yield and manure application to the field (a) and altitude of the field (b). Note the different scales of the vertical axes. DM = Dry Matter.

3.5. *Recent changes in cropping practices*

Over the past 30 years HPA farmers declared to have abandoned traditional anti-erosive practices such as utilisation of organic debris for mulching and construction of stone bounds, which both were practiced in former times. Reportedly in the past a larger variety and volume of crops was grown including the staples finger millet (*Eleusine coracana* Gaertn.), pearl millet (*Pennisetum glaucum* L.), and pigeon pea (*Cajanus cajan* L.). Maize, which was found at very small quantities in a few home gardens only, was more abundant then. Since the asphalt road to Al-Ghaydah made rice and wheat flour more easily available and affordable, the size of crop fields had reportedly declined, and even the 2007/2008 world-wide increase in food prices did not trigger a re-introduction of formerly grown crop species given the scarcity of labour, loss of traditional knowledge, and the perceived increasingly unreliable rainfall.

3.6. *General aspects and economic importance of livestock husbandry*

In the three studied lower zone villages, 1805 goats, 297 camels and 477 cattle were kept, while in the three upper zone villages livestock numbers summed up to 678 goats, 733 camels and 833 cattle. The 38 HH interviewed in detail on livestock husbandry reported that the main reasons for keeping livestock (multiple answers were possible) were income generated by the sale of animals ($n = 34$) and milk production for home consumption ($n = 33$). Meat ($n = 14$), butter ($n = 8$), and heritage/tradition ($n = 6$) were other reasons. Live animals were sold to intermediaries from Al-Ghaydah and to traders from Oman. Only on the occasion of weddings, religious holidays, and other special events ruminant animals were slaughtered and consumed in the study area.

Households with no other on-farm or off-farm source of income than livestock ($n = 6$) kept an average of 38 TLU[1] (SD 54.0), equivalent to 4.9 TLU (SD 4.85) per family member, while HH with one ($n = 4$) and two ($n = 12$) additional sources of income kept 35 (SD 13.8) and 12 TLU (SD 10.3) per HH, equivalent to 3.0 TLU (SD 1.37) and 1.0 TLU (SD 0.6) per member. In HH having three ($n = 16$) additional sources of income the average number of TLU was 24 (SD 13.1), equivalent to 2.7 (SD 2.15) TLU per member.

Camels, cattle, and goats greatly varied in importance. While 38% of the livestock keepers kept all three species, 28% kept only two and 35% only one species. Across livestock keepers, cattle contributed most to the livestock-based family income (stated by 63% of HH keeping all species, 66% of HH keeping camels and cattle, and 50% of HH keeping cattle and goats), followed by goats (stated by 36% of HH keeping all species and 50% of HH keeping cattle and goats), and camels (stated by 33% of HH keeping camels and cattle). None of the farmers who owned all three species mentioned camel as the species that contributed most to the livestock-based income.

3.7. *Recent changes in livestock numbers*

The majority of livestock keepers (82%) reported that animal numbers in HPA had declined in the past years; only 13.2% perceived that numbers had increased and 5.3% had not observed any change. According to 3% of the farmers, accidents and attacks of leopards and wolves were the main reason for livestock losses and during our field research period seven such attacks on cattle and three on goats were reported. Yet, while various carnivores still inhabit HPA, the presence of leopards remains unconfirmed (Pittet, 2011).

The large majority (>90%) of the livestock keepers believed that animal production will remain important in HPA even for the next generation, while the few remaining expected that in the near future alternative income opportunities may replace livestock husbandry.

3.8. *Feeding practices*

Livestock freely grazed the entire area. For 78% of the livestock keepers the availability of naturally growing forages determined the size of their herds, while the remaining 22% did not relate herd size to forage availability. Animals had daily access to pastures, only few farmers in the low-lying urban settlements kept lactating animals at home. In the rainy season, lactating camels were kept in a hut overnight, so as to avoid accidents on the then very slippery paths, whereas pregnant camels were always grazing on their own. Milking cows were often kept at home during day in the rainy season, to protect them from flies and other insects, but they grazed freely during evening and night hours.

Feed supplements offered to non-lactating animals in addition to grazing were dried sardines, collected grasses, and sorghum stover while wheat flour, wheat bran and collected grasses were given to lactating and young animals. For 27% and 47% of the HH, respectively, livestock feeds constituted the first and second most

[1] TLU Tropical livestock unit: animal of 250 kg live weight; 1 camel = 1.2 TLU, 1 cattle = 0.8 TLU, 1 goat = 0.1 TLU.

important expenditure right before and just after food for the family.

3.9. Vegetation characteristics and grazing intensity within the HPA

The low altitude (0–500 m asl) was largely deforested, and only in the region close to the Omani border the original forest remained. The deforested areas were dominated by *Jatropha dhofarica* followed by *Commiphora* sp. At the mid altitude (500–900 m asl) in most cases *Anogeissus* was associated with *Commiphora* sp., while abandoned fields were dominated by *D. angustifolia*, accompanied by *J. dhofarica*. The highest altitude (900–1400 m asl) was likely receiving less precipitation than the mid-altitude since forest stands were dominated by an association of *Acacia* sp. and *Commiphora* sp., whereas the number of *A. dhofarica* trees was lower than at mid-altitude. Since our vegetation survey was conducted at the start of the dry season, the whole region had already been grazed to different extents. Of the surveyed vegetation plots, 36% were exposed to a very high grazing intensity, 28% to a high grazing intensity, 26% were grazed at medium intensity and 10% showed little signs of grazing, whereby the western and central region were more affected by high and very high grazing intensity (53% and 93%, respectively) than the eastern region (38%) bordering Oman (Fig. 3a). Across the three transects, wadis, plains and slopes accounted for 15.4%, 56.4% and 28.2% of the surveyed area; grazing intensity varied substantially across these terrain components. Of the slopes, 50% were affected by a high or very high grazing intensity and 30% by a moderate or low grazing intensity. The plains and wadis, on the contrary, were affected to >77% and 80%, respectively, by a very high and high grazing intensity (Fig. 3b). In consequence, average vegetation cover across the herbaceous and ligneous strata was 36% (range 5–80%) on the plains, 63% (20–100%) on the slopes and 57% (40–80%) in the wadis.

3.10. Spatio-temporal aspects of livestock grazing

In the rainy season goats from the lower zone villages were herded at altitudes <500 m asl, while in the upper zone herds were guided to graze above 900 m asl. Camels were herded in the vicinity of settlements during the rainy season, while in the dry season they were taken to grazing areas further away (Fig. 1). Presence of camels in the designated Core Zone was not observed throughout the study period. Due to the abundance of fodder, cattle were not herded but stayed close to the settlements in the rainy season; however, even during the dry season they did not move far away from the homesteads.

The allocation of the animals' grazing time to different vegetation units reflects the importance of these feed resources for the different livestock species across altitudinal zones and seasons

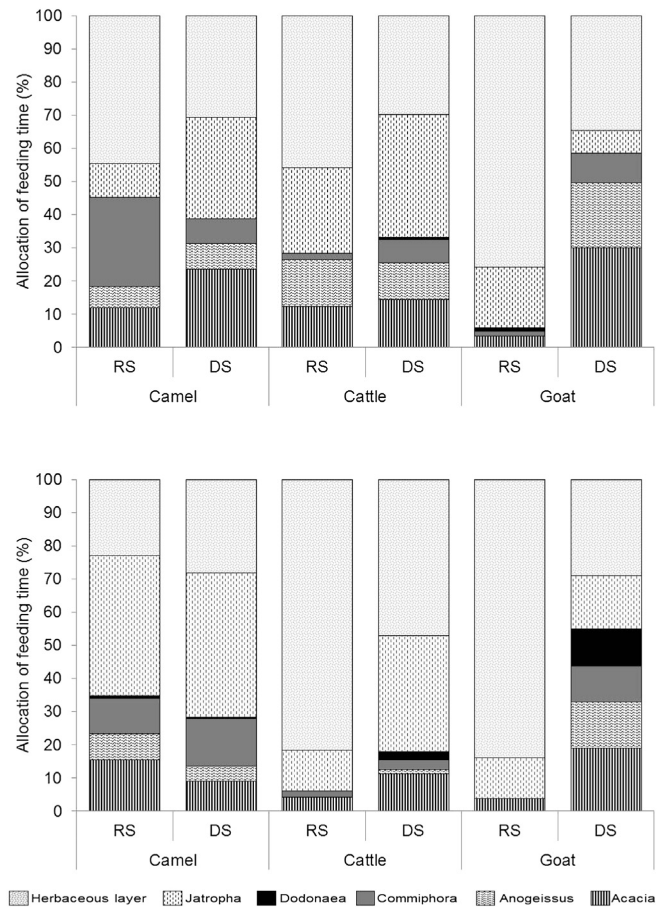

Fig. 4. Average rainy season (RS) and dry season (DS) feeding time allocated to the herbaceous layer and to individual trees and shrubs by camel, cattle, and goat herds of the lower lying villages Jadeb, Shanu and Ka'ab (below) and of the villages Qoon, Thenaik and Kasset located at higher altitudes (above) in the Hawf Protected Area. Full botanical names of ligneous species: *Anogeissus dhofarica* A.J. Scott.; *Dodonaea angustifolia* L.f.; *Jatropha dhofarica* Radcl.-Sm.. Of *Commiphora* and *Acacia* genera, various species were present and grazed in the pasture areas.

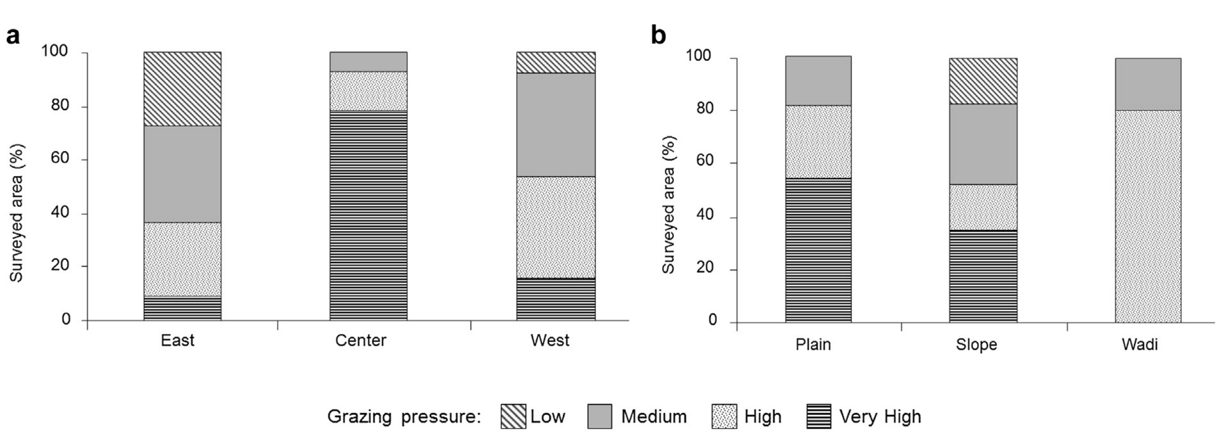

Fig. 3. Livestock grazing pressure in the western, central and eastern region of Hawf Protected Area (a) and on plains, slopes and in wadis of the mountain ridge (b).

(Fig. 4). Our data clearly show the low utilisation of the ground vegetation by cattle during the rainy season, when they spent 82% and 46% of their grazing time on herbaceous swards and fallowed fields in the lower and the upper zone, respectively. However, grasses and forbs were not their only source of fodder – during the dry season shed tree leaves, especially of *A. dhofarica*, played an important role for cattle nutrition. In the rainy season, camels of the upper zone villages spent 45% of their grazing time on the herbaceous layer, and of the 10% grazing time devoted to *Jatropha* stands mostly was also spent grazing the herbaceous understorey; browsing of *Anogeissus*, *Acacia* and *Commiphora* stands accounted for 6.5%, 12% and 27% of daily feeding time, respectively. Similar values were obtained for browsing time in *Anogeissus* and *Acacia* stands by camel herds from the lower zone villages (Fig. 4).

Goats avoided *Anogeissus* and *Commiphora* stands during the rainy season and spent only little time in *Jatropha* dominated areas (13% and 19% of goats' grazing time in the lower and upper zone) and *Acacia* stands (3.7% and 3.5% of grazing time in the lower and upper zone). Most of their time was spent on the herbaceous layer (84% and 76% of grazing time in the lower and upper zone) of fallowed areas. This changed substantially during the dry season, when the proportion of time spent on herbaceous plants decreased and the time spent browsing *Acacia* (30%, upper zone), *Anogeissus* (20%, upper zone) and *Commiphora* stands (11%, lower zone) increased.

As a consequence of livestock foraging behaviour, the three vegetation strata were affected differently by livestock grazing: the herbaceous vegetation was predominantly grazed by cattle (54% of total time that herbaceous vegetation was grazed), followed by goats (32%) and camels (14%). Trees were mainly grazed by camels (95% of total grazing time observed for trees), rarely by goats (5%) and not by cattle, and shrubs were predominantly grazed by camels (50% of total grazing time observed for shrubs) and goats (49%), but hardly by cattle (1%).

3.11. Other uses of the natural vegetation in HPA

Apart from being grazed by livestock, ligneous plants in the HPA were used for timber and lumber. Firewood was used for cooking and illuminating, to keep insects away from cropped fields and prevent snakes from nesting in the roofs of the traditional houses; *Premna resinosa* (Hochst.) Schauer and *Flueggea virosa* (Roxb. ex Willd.)Voigt were preferred for these purposes. Sometimes wood (often of *A. dhofarica*) was burnt to produce charcoal; crushed charcoal mixed with salt, cardamom and cloves was used as toothpaste. *Croton confertus* Bak., *Cadia purpurea* (Picc.) Ait. and *D. angustifolia* were used for fencing fields and home gardens. However, fences surrounding fields and dwelling compounds were either completely constructed from small trunks and branches (as was the case of fields managed by households from Thenaik and Ka'ab) or consisted of metal wire nets (only one farm from Shanu); most frequent were mixtures of metal fence and wood (the latter especially used to cover patches of damaged wire fences). The major use of *A. dhofarica* was for roof construction of the traditional round stone houses – according to the interviewees 100–150 fully grown *Anogeissus* specimens are required for one roof. In addition to the sporadic utilisation of their wood for construction, the edible fruits of *Tamarindus indica* L. and *Z. spina-christi* were extensively collected as food supplements. Whereas all surveyed households reported using traditional methods and materials for the construction of animal corrals, only those of Thenaik, Qoon and Shanu fenced the round stone houses within their dwelling compounds. In contrast, more modern houses, such as the ones prevalent in Jadeb, Ka'ab and Kasset, were constructed with cement blocks and imported wooden beams.

Medicinal plants used included *Rhamnus leucodermis* Baker to treat snake bites; stomach aches were cured with *Cadaba baccarinii* Chiov., and various birth-related calamities were treated with several plants, amongst them *Suaeda fruticosa* Forssk. The sap of *Aloe dhufarensis* Lavranos and *J. dhofarica* was used to treat wounds and ulcers, and the fresh stems of *J. dhofarica* as a body deodorant. The resin of the frankincense tree (*Boswellia sacra* Flueck.), apart from being a popular air-refresher, was sometimes used in the traditional pre-sowing treatment of sorghum kernels: Wrapped in cloth, a handful of seeds were placed in a pouch of frankincense while songs were chanted to secure a good harvest. Plants that once were part of people's diets, but are no longer consumed today, included corms of *Gladiolus ukambanensis* (Baker) Marais, tubers of *Dorstenia foetida* (Forssk.) Schweinf., *Ceropegia bulbosa* Roxb. and *Remusatia vivipara* (Lodd.) Schott. Other important non-edible plants such as *Aerva javanica* (Burm. f.) Juss. provided stuffing material for pillows and cushions. Leaves of *Acacia oerfota* (Forssk.) Schweinf. were used for tanning hides. The fibre of dry *Luffa acutangula* (L.) Roxb. fruits served as scrub for kitchenware, and *Phoenix* sp. leaflets were formerly used to wave mats, fans, baskets, bird traps and other traditional artefacts which are increasingly replaced by plastic items. Although weaving was still practiced by a few elderly women, leaflets of date palm (*Phoenix dactylifera* L.) are brought in from Al-Ghaydah today since there are only a few isolated specimens of palm trees left in the region.

3.12. People's attitude towards the HPA concept

Asked about their level of information regarding the status of the HPA, half of the interviewees acknowledged to be aware of the existence of Governmental Decree No. 260 establishing the protection area; one person 'had heard about it, but did not know it was official', and two got to know about it from the various signposts positioned along the main road that rise awareness among inhabitants and travellers. The other part (= 19) (n = 19), however, were unaware of the concept. Only one of the respondents who reported being informed about the HPA status declared herself acquainted with the zoning suggested in the Management Plan, but did not know of the measures proposed in order to achieve the aims stated there. All interviewees considered the protection of the Hawf Mountains Forest as paramount to secure the future subsistence of the local population, and recognised the felling of trees as a major problem. Interviewees who acknowledged that the area's natural resources needed protection also pointed out that this could only be achieved if alternative resources were provided which help sustain their livelihoods. In consequence, the interviewees proposed that the government should provide construction materials for houses, corrals, and fences to counteract the felling of trees. Further suggestions included a decrease in livestock population and access to cheaper staples and livestock fodder, as well as to quality education. Respondents acknowledged that formal education was important for their future but does not automatically secure livelihoods. Sending children to school means loosing farm labour force and involves considerable costs which for many families seemed unaffordable. Another perceived threat of formal education was the disappearance of the *Mehri* language to the Arab mainstream as learning Arabic at school is currently the only way to become literate. For the interviewees, the loss of *Mehri* was connected to the loss of local culture and traditions, among them land use practices and rules. These trends were perceived to have aggravated by emigration and repatriation of male family members, who had been working in neighbouring Arab countries in their youths, as a consequence of the 1990/91 Gulf War. Respondents perceived an increasing wealth in the area as the result of (former) remittances, and more possibilities for earning off-farm income as compared to the situation three decades ago. This increased wealth was, however, also blamed of having created an over-abundance of livestock with adverse consequences for water and vegetation resources.

4. Discussion

4.1. Cropping practices and land use

The interviewees' comparisons between their life thirty years ago and today indicated that emigration and repatriation may have severely deteriorated their agricultural skills. The abandonment of traditional land use practices was attributed to population growth, more easily available and affordable food, immediate cash needs, and labour shortage. However, determining the extent to which re-migration contributed to the recent erosion of traditional agricultural practices would require a profound analysis of the agricultural system prior to the political changes that occurred since the 1960s and the related implications for land use. However, it seems as if the people of HPA had never been very experienced agriculturalists. This is evidenced by the uncoupling of livestock keeping and manure production from its erratic application to crops and low cropping intensities leading to low, fodder-focused yields. Although the use of stone bounds along slope contours was reported as a previous erosion control measure, there was no remaining physical proof to confirm this claim. Shifting cultivation in the mountain range likely allowed to sustain its inhabitants over a long period of time without causing major damage to the natural resource base as long as numbers of humans and livestock remained low. However, after tree cutting abandoned crop fields are not restoring to natural (secondary) forest because the discontinued capture of cloud water by tree canopies (horizontal precipitation) together with heavy grazing makes the regeneration of trees and shrubs very difficult (Hildebrandt and Eltahir, 2006). Abandoned fields therefore thus easily develop into monocultures of *D. angustifolia* and *Senna obtusifolia* (MWP/EPA, 2005).

Although long-term rainfall data for the Hawf – Dhofar region is scarce, available information indicates that the mean annual precipitation in the coastal plain is 100 mm, while annual means on mountain slopes and plateaus average 200–500 mm, mainly intercepted from clouds and fog (horizontal precipitation; about 34–35 mm per day during the rainy season at 4.9 m above ground; Kürschner et al., 2004; Miller and Morris, 1988). Interviewees claimed that precipitation had declined over the last three decades, and particularly during the past five years. Because vegetation density varies according to altitude and land use intensity, it is important to stress the role it plays in condensing moisture (Miller and Morris, 1988). The destruction of the natural vegetation in the cloud zone with its closed canopy may thus dramatically reduce effective precipitation and in consequence also affect grazing and agricultural activities.

4.2. Livestock husbandry and environmental conservation

The beneficial role of livestock for smallholder mixed farming systems is widely accepted (Schiere et al., 2002; Scoones, 1995; Silanikove, 2000). Among the reasons for keeping livestock, milk production and income generation were of major importance in HPA. During the rainy season, the availability of food is reduced in the hard to access upper zone. The limited offer of regionally grown fruits and vegetables makes milk a very important component of the household diet and source of vitamins and protein. The income generated from livestock keeping is certainly important for families without any other source of income. The fact that also families with one or more sources of off-farm income kept livestock indicates that livestock serves as an important savings account and defines a person's social status – the latter applying in particular to camels.

Across HPA, the climatically and edaphically most favoured altitude ranges from 300 to 900 m asl. The *Anogeissus*-dominated woodland found here is the most diverse and dense on the Arabian Peninsula, with approximately 90 tree species per 1000 m^2 (Kilian et al., 2002). Two main constraints affect the future of the native vegetation in the HPA: Deforestation triggered by wood use for house construction and repair every 20–25 years and livestock grazing, especially on mountain plains and fallowed cropland (MWP/EPA, 2005). Low availability of forage and high grazing pressure in the dry season may trigger floristic changes, including the disappearance of palatable grasses (Shelton, 2004). In HPA, the encroachment of areas with unpalatable plants such as *Senna, Dodonaea* and *Jatropha* in heavily grazed areas is a clear sign for overgrazing. The improved prosperity of families during the 1970s–1990s triggered considerable investments in livestock and worsened the pressure on natural resources. Negative effects of livestock overgrazing have been reported from various semi-arid and Mediterranean countries (Qarro, 1986). In the mountains of Greece (Zervas, 1998) and on islands such as Santorini (Giourga et al., 1998) or Sardinia (Santini et al., 2007) overgrazing and soil erosion at hillsides are prevalent. In the Mediterranean grasslands of Spain grazing cattle caused a decline in plant abundance (Leiva and Fernández-Alés, 2000), and in the south of Spain large areas of woodland and shrubland have been transformed to semi-open oak parklands by a systematic combination of pastoral, agricultural, and forestry uses. Today these *dehesa* parklands are among the most prominent and best-preserved low-intensity farming systems in Europe, and the successful integration of traditional land use and biodiversity conservation in these systems is considered an example for judicious ecosystem management (Bienal and McCracken, 1996). Yet, livestock husbandry is accused of being one of the main reasons for the insufficient regeneration of the vegetation in this system (Plieninger, 2005). In HPA, the densest and most diverse tree stands are found on very steep slopes and in wadis. Such difficult to access areas help to preserve the original structure of the forest, as their topography prevents the entry of large numbers of livestock, and humans prefer to cut down trees in areas where wood harvest is easier.

4.3. Future development of the designed HPA zones

Until the 1990s, the traditional land management system and its perpetuation by the socialist government of what was then South Yemen has preserved the region's unique ecosystem of global importance (Mittermeier et al., 2004; Olson and Dinerstein, 1998). The traditional *Mahjur* rangeland management system was governed by spatially and temporally explicit grazing rules for livestock. According to the latter, goats, sheep, and camels were to be removed from the low and the mid-altitude ranges (that is, the designated Buffer Zone), where ligneous vegetation is dense and dominated by *Anogeissus*, and had to be taken to the less vegetated plateau (>1000 m asl, the designated Core Zone) during the monsoon time. Cattle were allowed to remain in and around the villages throughout the year. The aim of this system was to rotate grazing and reserve forage for the dry season, since vegetation was densest in the designated Buffer Zone. As shown by our livestock monitoring, this system is still respected in the case of goats: herders in the upper villages take their goats to the higher altitudes and the ones at lower altitudes stay there with their goats. When the rainy season is over and the fodder in these drier areas is consumed, the herders from the upper villages descend and start to graze the mid-altitude ranges. Similarly, the herders from the lower altitudes also take their goats to the mid-altitudes. For camels, today's situation is different. Although some herders take their animals out of the Buffer Zone to the Core Zone (high altitude) or to the Peripheral Zone (low altitude), this is not a general herding strategy. Many camels stay at mid-altitude range (Buffer Zone) during the rainy season and the herders lop off branches of *Anogeissus* trees to feed them. These practices can be sustainable in cases that such pruning is well spread across trees (Miller and Morris, 1988); however, frequently very intensive pruning of individual trees was observed by the authors. Such practice was formerly punished by the tribal system, and in Yemen's socialist past, by a strong government. Since the reunification of Yemen in 1990, lacking control of natural resource use and lack of governmental presence in the region resulted in a situation where such destructive practices are not sanctioned any more.

The Management Plan suggests preserving a Core Zone at HPA's high altitude, but the prohibition of grazing in this area would further increase rainy season grazing pressure in the ecologically most valuable mid-altitude range beyond the pressure already exerted by camel husbandry. It has been demonstrated that repeated heavy grazing pressure during the growing season has about three times stronger (negative) effects on the persistence of key species compared to grazing when plants are senescent (Hyder et al., 1975). In HPA negative effects of heavy grazing are further accentuated by the often considerable slopes and may in the long run result in intensive soil degradation (Evans, 1996). In contrast to the provisions of the current Management Plan, allowing or rather enforcing grazing of camels and goats in the high altitude range during the rainy season would benefit the livestock and the conservation of the area as a whole. The pressure exerted by livestock would thus be shared between different areas and the negative effects on the vegetation would decline. The success of the traditional *Mahjur* system demonstrated for the Hawf area that rigorous rangeland management should concentrate on defining specific times for grazing instead of totally excluding livestock from grazing a certain area and therefore increasing the grazing pressure on adjacent zones (Kessler, 1995).

5. Conclusions

Traditional farming practices in HPA were reportedly never very elaborate, and if the agricultural land use system was formerly able to sustain its population, this was mainly due to the low numbers of humans and livestock. Limited use of soil amendments, particularly manure, for crop production reflects a widespread uncoupling of crop and livestock husbandry. While the basic principles of traditional herd management are still practised for goats and cattle, they are nearly abandoned by camel herders. Implementation of the HPA Management Plan as designed in 2005 would require major modifications in traditional herding practices and would likely lead to a higher concentration of livestock in the particularly biodiverse and vulnerable areas of the *Anogeissus* forest, designated as Buffer Zone. In addition, increasing abandonment of crop fields and deforestation for construction and house renovation purposes continues to open new treeless areas for grazing livestock. Even though livestock keeping is not the only reason for forest degradation in the HPA, it is a major reason for the failure of forest regeneration. To effectively protect the most endangered vegetation communities in HPA, the current zoning concept must be revised and take into account the traditional livestock herding schemes. In addition to a re-establishment of the principles of deferred grazing, successful ecosystem protection in the HPA region will require the identification and establishment of viable alternative income sources to strengthen local people's fragile livelihoods by allowing them to purchase resources such as bricks and cement for house construction rather than relying on the exploitation of large amounts of woody species. Apart from generating shared revenues from eco-tourism, which at present is not feasible for security reasons, value addition within the local fishing industry and dairy production, and niche marketing of medicinal plants within the region are potentially promising.

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