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OASES OF OMAN

LIVELIHOOD SYSTEMS AT THE CROSSROADS

Al Roya Press & Publishing House

UNIVERSITY OF AGRICULTURE

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ANDREAS BUERKERT & EVA SCHLECHT

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The front cover of this volume shows the main terrace system of the 3,000 year old oasis of Biladsayt in the northern Al Hajar mountain range and the back page variation in irrigated wheat planting as a farmer strategy to cope with year-specific water availability during 2003, 2006 and 2007 in the agro-pastoral oasis of Maqta in the eastern Jabal Bani Jabir range of Oman.

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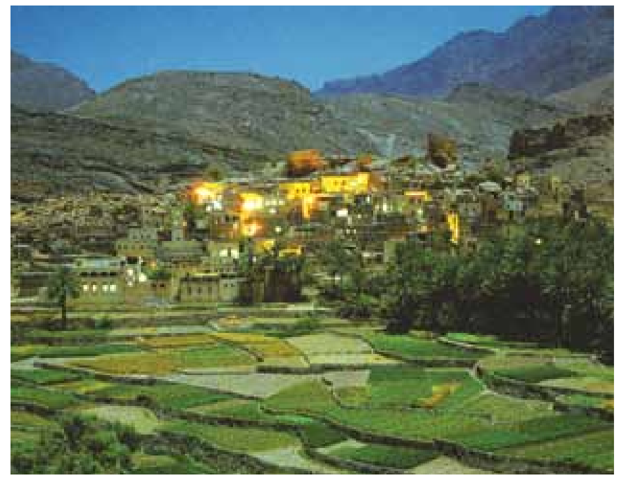
CONTENTS



FOREWORD

Omani oases are an integral part of the country's traditional land use system that have contributed to its cultural development since early historical times.

The oasis falaj system has made it possible to grow crops and fruit trees, such as date palm and citrus, nurturing the development of early settlements and civilisation throughout Oman's history. These unique circumstances have served to shape Oman's culture with its strong values and renowned cultural identity.

The continued existence of oasis settlements as attractive livelihood systems in the modern world will most likely require the generation of new income opportunities from the production of specialised high-value commodities and environmental services to cope with the increasing number of national and foreign visitors.

This book pays tribute to the development of Omani settlement structures that defied the bio-physical and climatic constraints characteristic of the harsh conditions on the Arabian Peninsula. It also highlights the threats that Omani oases face from the recent modernisation processes that have profoundly transformed their physical, cultural and economic basis.

Oman's journey into the future is linked to our understanding of our roots and this study aids us in developing sustainable strategies for the future of our traditional settlements.

H.E. Hamoud bin Faisal al Busaidi
Minister of the Environment & Climate Affairs

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INTRODUCTION

With its combination of short scientific contributions written for a wider public and a collection of unique photographs, this book has several aims. Firstly, to document the (agri-) cultural heritage of Omani farmers and their ancient agro-pastoral livelihood systems that reflect amazingly effective strategies with which to cope with the limitations of a harsh desert climate mainly characterised by highly unpredictable rainfall, seasonal water shortage, hot temperatures and very sparse vegetation.

Secondly, the book aims to draw the reader's attention to the fact that Omani oases systems that have survived for millennia are currently quickly vanishing as an example of sustainable livelihoods and a unique Arabian cultural heritage. While the many advantages of Oman's modernisation process have undoubtedly improved the lives of its population, it may also have diminished the memories of the seemingly less glamorous, but nevertheless most remarkable, achievements of Omani sailors, fishermen, farmers and herders who for centuries were renowned for their skills in maintaining their livelihoods along the coasts of the Arabian Sea and in Eastern Africa. This book, therefore, also seeks to encourage efforts in finding ways of how to reconcile the advantages of a modern lifestyle with preserving the roots of Oman's culture.

The authors would like to take this opportunity to thank their colleagues at Sultan Qaboos University (Muscat) for the support given to the Omani-German project studying 'Transformation Processes in Oasis Settlements of Oman' that was initiated by Prof. Dr. Heinz Gaube (Tübingen University, Germany), to Dr. Maher Nagieb and Dr. Stephan Siebert for their cooperation and advice, the Extension Center Al Jabal Al Akhdar of Oman's Ministry of Agriculture and Fisheries at Sayh Qutnah for baseline information, the Ministry of Defence for their trust, the Royal Air Force of Oman for several airlifts, countless farmers for their typical hospitality and open sharing of information, Helen Kirkbride and Hatim Al Taie of Al Roya Press and Publishing House for making this volume possible, Dhian Chand for skillful desktop editing, and Deutsche Forschungsgemeinschaft (DFG) for research funding.

The first edition of this book had been sold out within only a few months. We are therefore very thankful to Prof. Dr. Iqrar Khan, Vice-chancellor of University of Agriculture at Faisalabad, Pakistan, who had worked as a scientist for many years in Oman, for facilitating together with Al Roya Press & Publishing House (Muscat) this second, expanded edition of the volume.

Muscat / Witzenhausen, November 2010

Andreas Buerkert

Eva Schlecht

Iqrar A. Khan

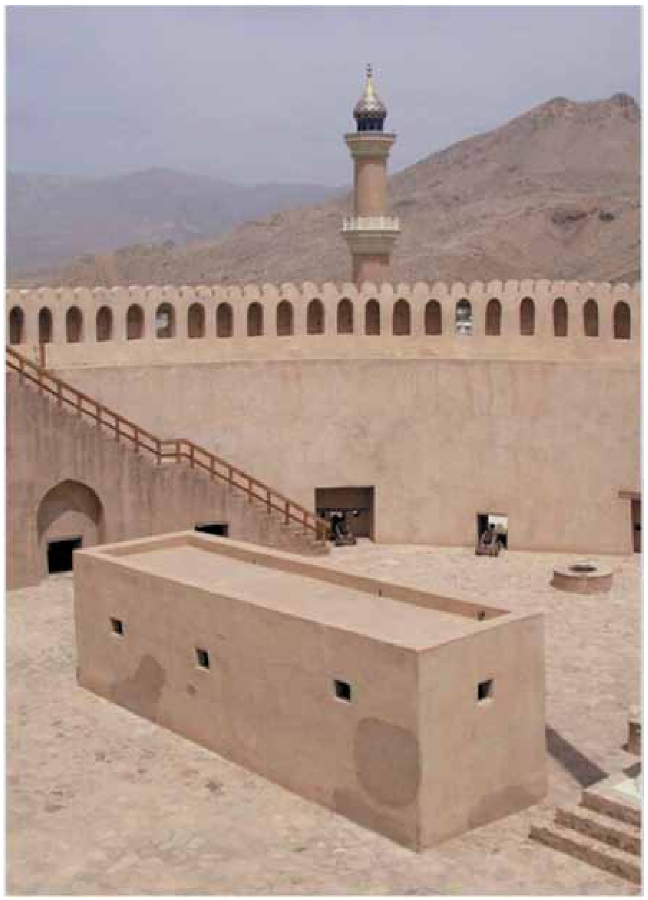
CHAPTER 1

INTEGRATED LIVELIHOOD SYSTEMS AND CULTURAL HERITAGE

ANDREAS BUERKERT AND EVA SCHLECHT

It has now been almost four decades that Oman has been under the dynamic leadership of his Majesty Sultan Qaboos bin Said. Facilitated by the rapid development of an increasingly flourishing oil sector, the country began to undergo a fundamental transformation process, changing from a millennia-old agro-pastoral-fishermen-trader society secluded from international politics to a respected nation with a modern physical and educational infrastructure. While these achievements themselves are remarkable, they also contributed to bridge the tribal divisions that had characterised the Oman Peninsula for centuries and kept foreign visitors and explorers effectively away, with a few exceptions such as Ibn Battuta (Gibb, 1939) and Thesiger (1959). The speed with which societal change occurred, however, distanced an increasing proportion of the Omani population from their unique history and cultural tradition based on oasis agriculture, sea-shore fishing and regional trading across the Arabian Sea and the Empty Quarter, the infamous Rub' Al Khali desert. As a consequence of this growing 'disconnectedness from history and tradition', many young Omani citizens and most

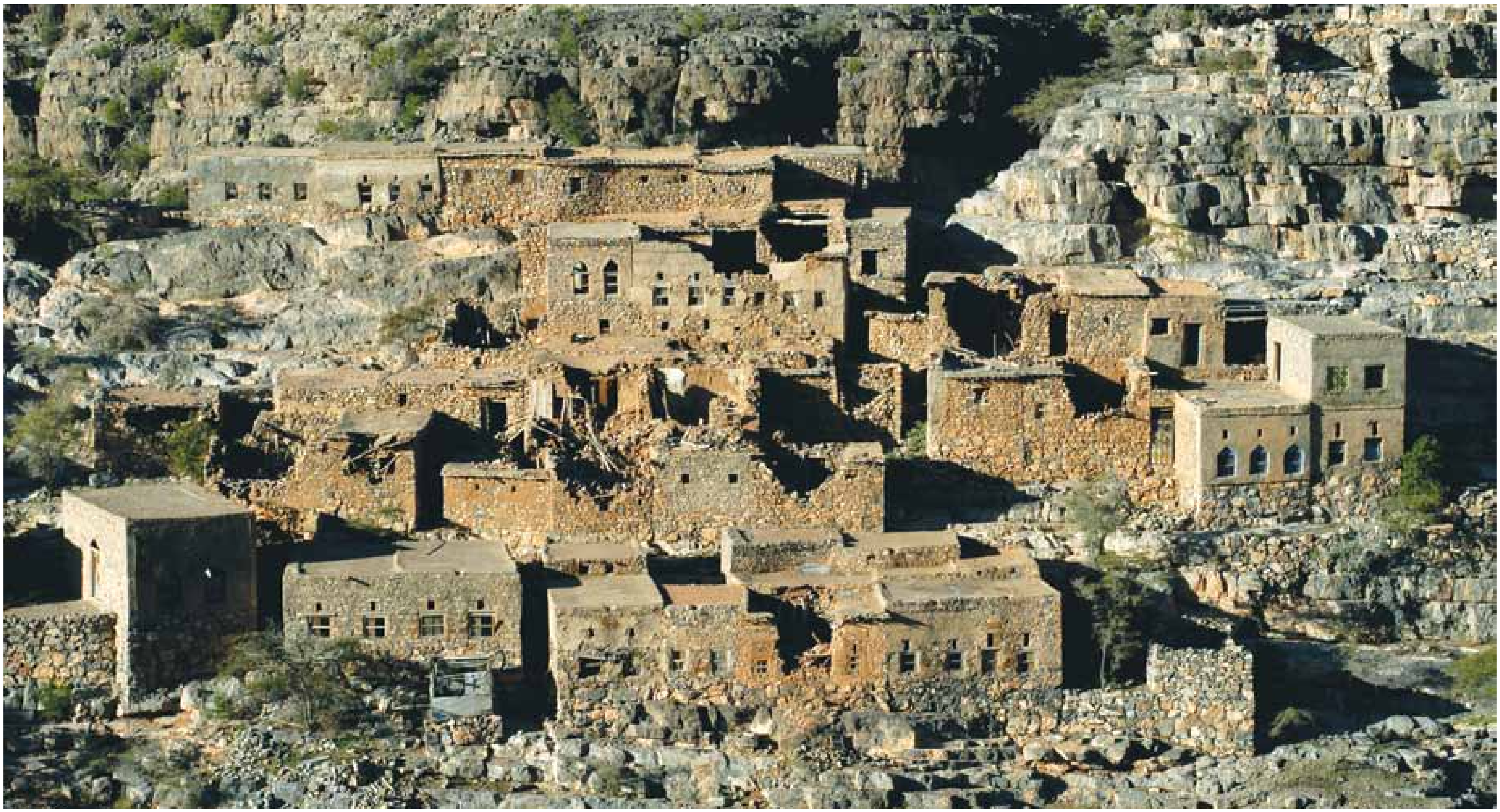
Figure 1. The embellished fort of Nizwa.



foreign visitors to the Sultanate appreciate well-preserved forts (Figure 1) in a beautified landscape and renovated *aflaj* irrigation systems. They tend to forget that these stone-built documents of Oman's cultural heritage are only an expression of a much more astonishing cultural and bio-physical achievement: the development of oasis agriculture as a livelihood system that overcame the hardships of a hyper-arid environment characterised by only occasional rainfall unpredictable in time and space.

As any land use within oases and their building structure reflect the socio-economic development of a society, both have profoundly changed in recent times (Mershen, 1998; Diener et al., 2003; Gangler, 2003; Ribbeck, 2005; Korn et al., 2004; Chapter 9). The texts and images in this volume show the unique cultural heritage that will be lost if Oman's oases are not perceived as integrated agro-pastoral livelihood systems that merit effective preservation based on an understanding of their functioning. The fact that during the last decades hundreds of oases have been abandoned and have fallen into ruin illustrates the socio-political urgency of the issue (Figures 2, 3 and 4). Oasis land use systems will only maintain the roots of Oman's rich cultural past, while offering reliable

Figure 2. The decaying oasis of Wadi Bani Habib, Al Jabal Al Akhdar .



income opportunities for at least some of their inhabitants (Buerkert et al., 2010) if they are properly maintained.

The efficient management of their water resources are obviously the most important factor for the bio-physical sustainability of Omani oases, regardless of their type (Chapter 5). Recent studies have shown that the multi-storey cultivation system, a careful mix of perennial and annual species and temporary fallowing of terraces leads to remarkably efficient water use of *falaj*-based flood irrigation systems that, at least in mountain oases, may average from 75%-79% (Norman et al., 1998; Siebert et al., 2007). The single most important component of Oman's irrigated oasis agriculture is the famous *falaj* system itself, which allows the harvesting of water resources that are otherwise hard to tap in the prevailing topographically and geologically difficult terrain. Its social organisation and effective basin-based distribution system (Wilkinson, 1977; Abdel-Rahman and Omezzine, 1996; Al Ghafri et al., 2001; Al Marshudi, 2001; Shahalam, 2001) enable a surprisingly uniform irrigation of fields. While debate about the origins of the *aflaj* irrigation system and the development of irrigated agriculture in the region is ongoing, archaeological and palaeo-climatic evidence indicates that the Oman Peninsula played a key role in it, as it did in the invention of *sarooj* cement (Al Rawasa et al., 1998). The latter allowed waterproofing of the complex canal system that

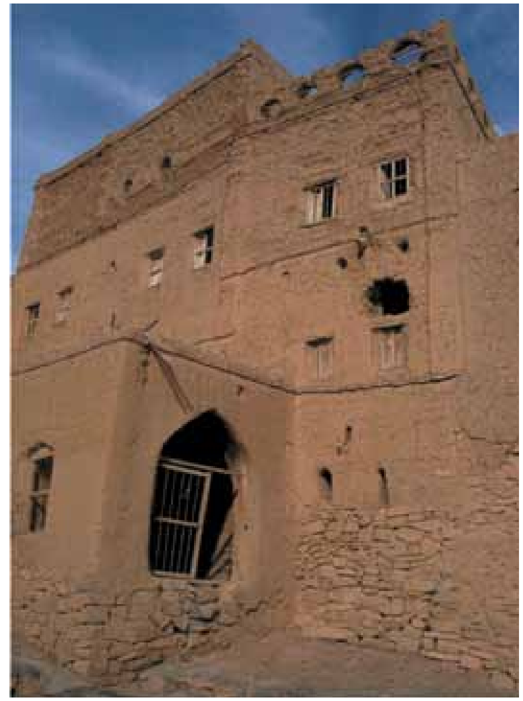
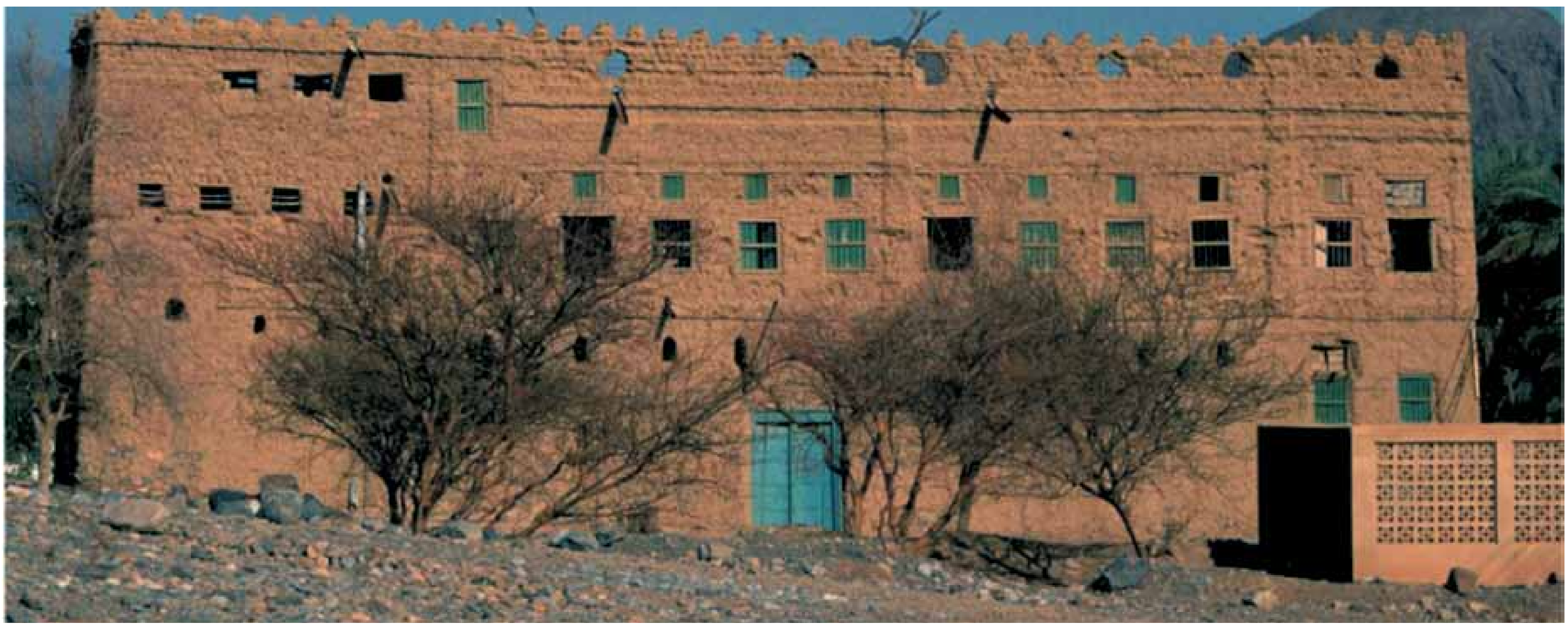


Figure 3. Old mud-brick houses in Al Hamra. Figure 4. Old caravanserai in Al Hamra.



conveyed water from a mother well or spring to the fields and the stabilisation of other stone-built structures, a milestone in the development of oasis agriculture (Chapter 3).

A second important component of oasis sustainability is the maintenance of soil organic matter on the man-made, silt-filled terraced fields. While year-round high temperatures and regular irrigation lead to high mineralisation of organic matter, as evidenced by large soil respiration rates (Wichern et al., 2004ab), these carbon losses are effectively balanced by annual additions of up to

Figure 5. Annual surface application of large amounts of composted goat manure (left) are the basis for the traditional productivity of man-made, irrigated terrace soils in the mountain oasis of Ash Shuraijah, Al Jabal Al Akhdar.

30 t ha^{-1} of composted animal manure (Figure 5). This illustrates that the structural stability of oasis soils, proper leaching and the unique avoidance of salinisation, on which soil productivity over time heavily depends (Luedeling et al., 2005), require the integration of (partly pastoral) animal husbandry (Chapter 8).

A third important component of the apparent stability of Omani oases is their diversity of crop germplasm, which in wheat (*Triticum* spp.) often results in the growth of mixtures of several bread and durum varieties on a single field (Al Maskri et al., 2003; Zhang et al., 2006; Al Khanjari et al., 2008). The diverse origins of this germplasm bear vivid testimony to the far-reaching trade relationships of Omani sailors (Chapters 4 and 6). Recent studies show that this remarkable between- and within-species diversity in cultivated plants is not only threatened by genetic erosion due to abandonment of cultivation (Hammer et al., 2009), but also — at least for some fruit tree species such as apricot *(Prunus armeniaca)*, almond *(Prunus dulcis)* and walnut *(Juglans regia)* in the famous high mountain oases of Al Jabal Al Akhdar — by a climatic change-induced reduction in winter chill hours, which inhibits fruiting (Luedeling et al., 2009).

Over long periods of time traditional knowledge codified in land use rights has avoided the overuse of pastures. With increasing livestock numbers in response to a higher demand for local meat, these land use codes are disintegrating, leading to a long-term destruction of the vegetation of pastures that are crucial for the agro-pastoral systems on which oasis agriculture is based (Chapter 7).

The use of oral history records (Chapter 10), in combination with a process-oriented understanding of the level of resilience of oasis systems, might allow the development of options for new livelihood strategies that reconcile the multiple goals of different stakeholders involved in the potential use of Omani oases. In some particularly attractive oases selected traditional houses could be converted into recreational facilities (small hotels and restaurants) for culturally interested tourists. Other buildings could be transformed into eco-museum displays and interactive units, where visitors could watch and join villagers carrying out traditional activities such as grinding grain, baking bread, or participate in making traditional handicrafts under the guidance of experienced village craftsmen. Offering guided tours through the ancient terraces or on treks along the ancient mountain trading routes might provide additional income opportunities. It is evident that such a reevaluation of culture would require the preservation of the physical infrastructure of oasis settlements. Equally important is the preservation of the millennia-old knowledge to maintain Omani oases as models for a sustainable livelihood system (Furze et al., 1995; Buerkert et al., 2010).

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CHAPTER 2

FROM BALLOONS TO REMOTELY CONTROLLED MODEL PLANES: USE OF HIGH-RESOLUTION AERIAL PHOTOGRAPHY TO DOCUMENT THE STATUS QUO OF OMANI OASES

ANDREAS BUERKERT AND WOLFGANG SCHAEPER

A little more than a century separates the Frenchman Arthur Batut, reported to have taken the world's first aerial image from a kite in 1889, and Google's efforts to make digital QuickBird® satellite images available to a global public via the Internet. However, until today simple technologies to obtain high-resolution aerial images of remote agro-ecosystems in order to study their structure or to measure plant biomass remain scarce. While the availability of digital cameras has fostered high-resolution kite-based aerial photography (KAP) around the world, its application obviously depends on local wind conditions, which are often sufficiently steady in open terrain such as steppes, deserts or altiplanos, but unstable in canyons, mountain valleys or around cliffs, which are typical topographies surrounding oasis settlements in Oman.

Figure 1. Helium-filled balloon (a), hot-air balloon (b) and kite system (c) used for the first low-altitude photographs of oases in Oman.

The aerial images of oasis agro-ecosystems in northern Oman that are featured in this volume, were taken between 2000 and 2008, initially from balloon and kite systems, which had been used earlier to monitor plant growth in the West African Sahel and in the Taklamakan desert of northwest China at altitudes of 150-750 metres above ground (Buerkert et al., 1996; Gérard et al., 1997; Siebert et al., 2004; Figure 1), and subsequently from a self-constructed, remote-controlled model plane from up to 1200 metres (Schaeper and Laemmlein, 2004; Schaeper, 2006). The cameras were an analog Nikon F-801S using Kodak Gold 100 ASA film for the balloon and kite systems and a 5.2 MegaP Olympus C 5050 or a 6.3 MegaP Fuji

Finepix F30 for the model plane system. The advantage of the latter was that it could be used in all wind conditions encountered in Oman allowing easy take-off and landing under the different infrastructural conditions of cities (parking lot) and remote villages (rocky cliffs).

Figure 2. Custom-made, remotely controlled plane equipped to take high resolution aerial photographs of different types of oases in Oman and detail of the digital camera system used.

Thanks to the trust of the Omani authorities, in particular the Ministry of Heritage and Culture and the National Survey Authority, we were able to cover all oasis types of Oman (Chapter 5) with these systems and could thus obtain high-resolution status quo documents of land use systems in rapid transition. We hope that these documents will stimulate the difficult on-going debate on how to further develop the sometimes millennia-old livelihood systems into entities that serve the multiple needs of future generations while preserving some of their agriculture- and trade-based architectural character and their role as cradles of a unique Omani identity.

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Chapter 3

From Hunter-Gatherer Communities to Oasis Cultures: Climate Change and Human Adaptation on the Oman Peninsula

Jutta Häser, Eike Luedeling, Eva Schlecht and Andreas Buerkert

Oases are a particular strategy of human adaptation to a desert environment, and they have played a crucial role in the history of man on the Oman Peninsula over the last five millennia. The origin of the oasis culture is still poorly understood but recent advances in the fields of palaeoclimatology, geomorphology, agriculture and archaeology have shed new light on the cultural evolution and survival strategies of human communities in this region during the post-glacial Holocene. These findings help explain the transition of the human population from hunter-gatherer and fishing communities to farming and herder societies. They also show that radical climatic and environmental changes in the region might be responsible for changes in the economic basis and adaptive social behaviour of these societies.

Early Hunter-Gatherer Communities

In the Early Holocene, until about 8,000 years before present (BP), Oman's climate appears to have been strongly influenced by the Indian Ocean monsoon, which delivered moisture during the summer, giving rise to a savannah environment that sustained hunter-gatherer communities. In spite of the monsoon influence, dunes developed in the area of the Sharqiyah Sands (formerly Wahiba Sands) during this time, indicating seasonal aridity. This implies that during this period the second main moisture source of the region, the Mediterranean system that supplies winter rainfall to northern Oman today, was not yet influential, and the region was characterised by people subsisting on hunting and gathering in the interior and on fishing at the coast.

The strengthening of the Mediterranean moisture source was probably a gradual process starting around 8,000 BP. Winter rains in Arabia, the Middle East and Pakistan are typically derived from frontal systems originating over the Mediterranean Sea. The cessation of sand dune accumulation in the Sharqiyah Sands around that time provides evidence that these frontal systems became a major climatic factor in Oman. Winter precipitation in Oman's interior apparently became abundant enough to allow for sufficient vegetation cover to stabilise the landscape and even allowed the existence of perennial lakes in the region between 8,500 and 5,500 BP (Radies et al., 2005). The lag of about 2,000 years between the onset of the monsoon rains and landscape stabilisation in the Sharqiyah Sands clearly indicates that the monsoon alone did not succeed in stopping dune development, pointing to the importance of winter rains to ensure year-round vegetation cover of the dunes.

Semi-Nomadic Pastoralism

Because the winter season gradually became less dry than in previous centuries, people turned from hunting and gathering towards a semi-nomadic lifestyle based on sheep, goat and cattle husbandry in the foothills of the northern Al Hajar Mountains. A vivid archaeological testimony of this was found at the Late Neolithic excavation site of Buhais 18 and in areas with a shallow water table like the Al Ain region, both in the United Arab Emirates (UAE, Figure 1). Since there are no wild sheep, goats and cattle on the Oman Peninsula, even in the archaeological record, they must have been introduced from outside the region, most likely from northwest Arabia. The presence of a now-desiccated spring at the ancient settlement of Buhais 18 suggests more favourable hydrological conditions at the time the site was used, supporting the hypothesis of a more positive regional water balance.

Around 6,000 years BP, the monsoon disappeared from northern Oman, leaving the population of the foothills and desert areas without their major moisture source. Reconstructions of water levels from the Dead Sea imply that the Mediterranean winter rains were not yet strong enough to allow rain-fed agriculture on the Arabian Peninsula (Migowski et al., 2006), though this could also be explained by the lack of knowledge of the population, which had not yet invented or imported elementary agricultural production techniques. The disappearance of perennial lakes in the central Sharqiyah Sands around 5,500 years BP indicates that by that time the weakened influence of the monsoon no longer allowed the semi-nomadic lifestyle that was previously practiced because of harsh and dry summer conditions. This is reflected in the archaeological record, which shows a major cessation of human life in the interior of the Oman Peninsula and an increase of coastal settlements.

Rain-fed Agriculture on the Oman Peninsula

Since approximately 5,000 BP, the Mediterranean moisture source gained strength and while, under modern conditions, precipitation from this frontal system is not strong enough to sustain rain-fed agriculture, the capacity of the Mediterranean system to supply moisture to the Arabian Peninsula might have been greater in the past. High water levels in the Dead Sea, lacustrine sediments in the UAE and high reconstructed flow rates of the rivers Euphrates and Tigris, all of which derive their moisture from the Mediterranean frontal system, support this hypothesis (Gebel et al., 1989; Migowski et al., 2006; Parker et al., 2006).

The cause for the rise of northern moisture may simply have been a southward shift of the influence of the monsoonal circulation, but events in the Mediterranean or North Atlantic have also been suggested as possible causes. The increase in winter rainfall from the northern moisture source around 5,000 BP — in the so-called ‘Bronze Age’ or ‘Hafit’ period (Figure 2) — appears to have enabled the population of northern Oman to start practicing rain-fed agriculture (Jorgensen and Al Tikriti, 2002). The paleolake ecosystems found in the Sharqiyah Sands required between 250 and 500 mm of precipitation per year (Radies et al., 2005). Provided that this rainfall was distributed over four months, the amounts of water are sufficient to support rain-fed agriculture. These winter rains, occurring during the season of lowest evapotranspiration, probably allowed the cultivation of short-duration cereals such as wheat (*Triticum* spp) and barley *(Hordeum vulgare)*, vegetables and date palms *(Phoenix dactylifera)* at locations with a shallow water table. Known oasis sites of the Bronze Age are located in the western foothills of the Al Hajar Mountains of Oman and around the modern town of Al Ain (UAE). Under the winter rain scenario described above, oases near the Omani foothills would have benefited from orographic rain falling from rising moisture-laden clouds of Mediterranean origin, while the region around Al Ain would have been a prime location for date palm cultivation because of its shallow water table (Jorgensen and Al Tikriti, 2002).

The oasis settlements appeared fully developed without known forerunners or obvious testing stages. The oldest one was found at Hili 8 in the oasis of Al Ain (UAE). Evidence recovered from this site shows that cultivated crops during this phase included emmer *(Triticum dicoccon)*, sorghum *(Sorgum bicolor)*, date and bitter melon *(Momordica charantia)*. At this site, and at most of the other Bronze Age oasis settlements, the main architectural features are large towers with an internal well.

Canals and small dams near the architectural remains of many early oasis settlements in Hili 8 (UAE), Maysar (M19 and M24), Al Khashbah, Bat, Tawi Raqi, Al Aqir and, maybe, Nizwa in Oman led to the assumption that agriculture at that time was already based on some kind of irrigation. Our postulation of rainfall as the main source of water supply for crops during this period is not contradictory to the findings of the canals and dams that might have been used to funnel the rainwater to the fields. Furthermore, one recent study on the palaeohydrology of Hili 8 indicated that well-based irrigated agriculture at the site is highly unlikely due to the labour requirements for lifting groundwater to the surface without the help of advanced technology (Jorgensen and Al Tikriti, 2002).

What is known is that these first steps to agriculture-based settlements on the Oman Peninsula, which were the economic backbone of the culturally famous Umm an-Naar period (Figure 3), were not made in isolation. Major components such as crops and irrigation techniques were probably introduced from outside, although it is still debated where the main impetus came from. Archaeological finds link the Oman Peninsula to Mesopotamia, east Iran and west Pakistan, however, until now there is no proof of how agriculture was introduced or from where. Regardless of these gaps in knowledge, the development of the social organisation on the Oman Peninsula during this period must have been ready to adopt new ideas and form the distinct cultural characteristics typical of early agriculture.

The Collapse of Rain-fed Oases and the Rise of the *Falaj* System

Around 4,200 BP, human settlements on the Arabian Peninsula started to suffer from sudden climatic change. On a regional and potentially global level, the so-called ‘4.2 ka Event’ caused a dramatic weakening of the Mediterranean moisture source, severely impacting human societies in the Mediterranean region and the Middle East. The sudden onset of dry conditions throughout the region, reflected by a drop of the Dead Sea level and the desiccation of Lake Awafi in Ras Al Khaimah (UAE), made rain-fed agriculture in northern Oman impossible. The population was apparently unable to cope with the impact of this climatic event, even though conditions probably turned more humid again between 4,000 and 3,500 BP, as indicated by high Dead Sea levels. Except for a few oasis settlements in the northern part of the Oman Peninsula, all known oasis sites in the foothills of the Al Hajar Mountains appear to have been abandoned during this time. Since the interior of the Oman Peninsula was not completely depopulated, as large cemeteries of the Wadi Suq period (Figure 4) prove, it seems likely that the population of this region reverted to a semi-nomadic lifestyle. After 3,500 BP, another dramatic drop in the strength of the Mediterranean moisture source aggravated climatic conditions to the degree that they became entirely unsuitable for rain-fed agriculture, and they remained the same ever since. Left without easily accessible sources of food and water, Oman’s interior desert had to be abandoned altogether, and even in the foothills and inner mountains, perennial settlement was no longer possible with the technological means available at that time.

In approximately 3,000 BP, at the start of the Early Iron Age period, a strong increase in settlement activities can be observed (Figure 5), although rain-fed agriculture was impossible. Under the given climatic conditions, this radical change was probably only feasible because of a fundamental technological innovation — the *falaj* system based on the break-through invention of sarooj cement (Al Rawasa et al., 1998), which was used to make canals watertight. This water management system, which has been continuously improved since then, has secured the agricultural basis of Oman and the neighbouring countries from the Late Iron Age Period (Figure 6) into modern times.

High Resolution Climate Records

To analyze climate change effects on specific socio-cultural developments of the Oman Peninsula high resolution records are required. Recent dendrochronological studies based on tree ring analyses of many centuries old juniper (Juniperus excelsa subsp. polycarpos) trees from the Al Jabal al Akhdar mountains showed that material from this species is unsuitable for climate research given the likely rainfall related formation of multiple rings per year and heterogeneous lateral stem growth (Sass-Klaasen et al. 2008). Fortunately, varved sediment records from the Pakistani shore of the Arabian Sea floor (von Rad et al., 1999), detailed stalagmite data from southern Oman (Burns et al., 2002, Fleitmann et al., 2003 and 2007) and most recently geochemical and charcoal records of a well dated, 20 m deep undisturbed soil profile excavated near the scattered, agro-pastoral oasis of Maqta in the Jabal Bani Jabir Mountains (Fuchs et al., 2007; Fuchs and Buerkert, 2008; Urban and Buerkert, 2009; Figure 7 and 8), enhanced our understanding of climatic variations over the millennia, particularly the last 4,000 years. This was the period during which Oman's cultural development - reflected among others by the building of the monumental stone tower tombs on the Shir plateau (Yule, 1992; Yule and Weisgerber, 1998; Figure 9) - led to the onset of the sea trade with Mesopotamia and Asia documented by the famous bitumen-sealed reed boats unearthed at Ras al-Jins (Cleuziou and Tosi, 1994) near the oasis of Maqta, the import of painted high-quality pottery from Iran for example found at Tiwi on the eastern Omani coast (Figure 10) and the acquisition of crop germplasm from neighbouring countries (see Chapter 4), and after 3,000 BP to the already mentioned development of the first aini-aflaj canal networks and underground falaj systems (Costa, 1983; Dutton, 1986; Wilkinson, 1974; Häser, 2004), which determine the survival of Omani livelihood systems based on oasis agriculture until today.

In the sediment archive of Maqta high charcoal frequencies in combination with geochemical data are indicative of an Early Holocene (‹ 9,800 BP) increase of rainfall. As supported by other data after 8,000 BP the climate apparently became drier followed by a few short relatively moister periods around 5,700 BP, 5,000 BP (giving rise to the famous Hafit and Umm an-Naar Periods on the Oman Peninsula), 4,400 BP and 1,500 BP as indicated again by high charcoal frequencies (Figure 11). These likely reflect regular burning of a denser woody vegetation cover by natural lightning and man-made fires; at shallower profile depths their increase is accompanied by occurrence of mollusc shells.

The absence of pollen from agricultural crops and Phoenix dactilifera until about 500 BP and the subsequent sudden appearance of pollen from wild olive (Olea spec.), ziziphus (Ziziphus spina-christi L. Desf.) and Fabaceae in this profile (Urban and Buerkert, 2009) probably reflect the harsh local ecological conditions enforcing a largely pastoral way of life. The advent of oasis agriculture in this inhospitable part of the Jabal Bani Jabir range corresponds well with similar developments in other areas like Wadi Bani Awf, Al Hamra or the large oases of Nizwa and Ibra where during this time period the ruling dynasties invested in increasing the size of arable land to enhance agricultural production and to strengthen their position.

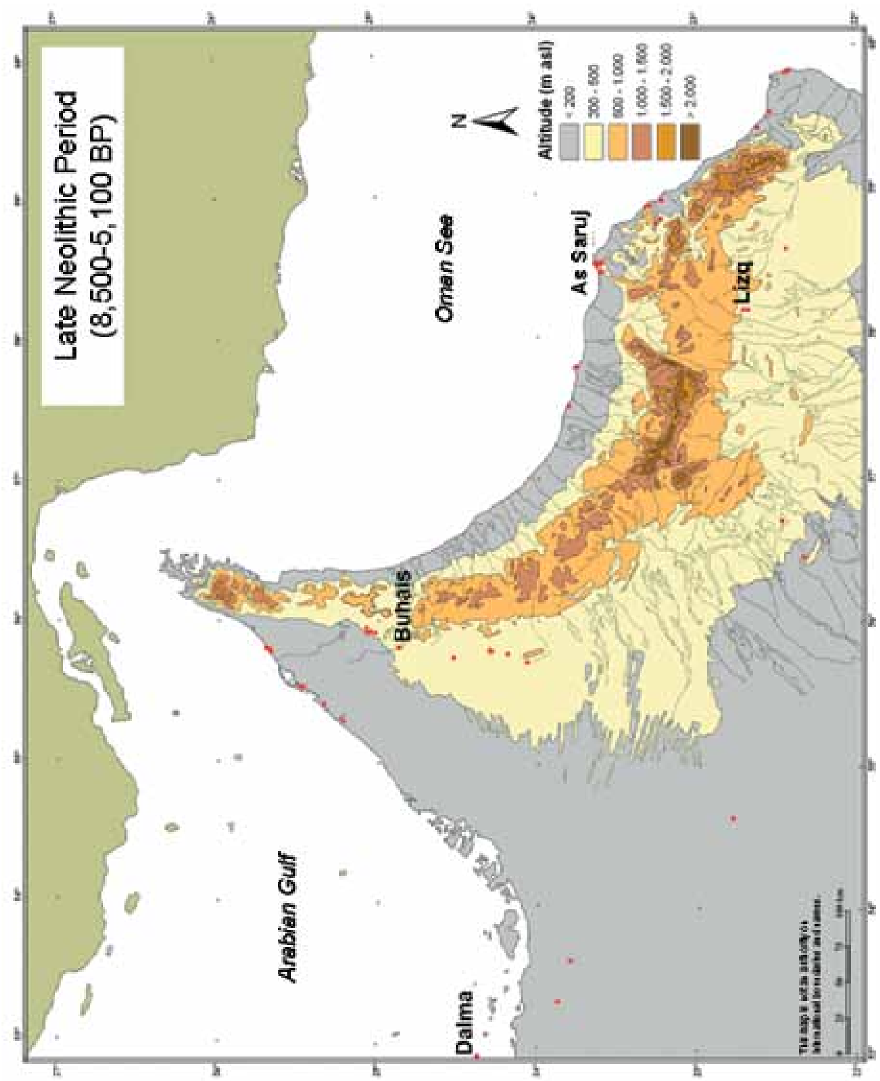

Figure 1. Settlement locations on the Oman Peninsula during the Late Neolithic period (Courtesy of Dr. J. Schreiber, DAI Berlin).

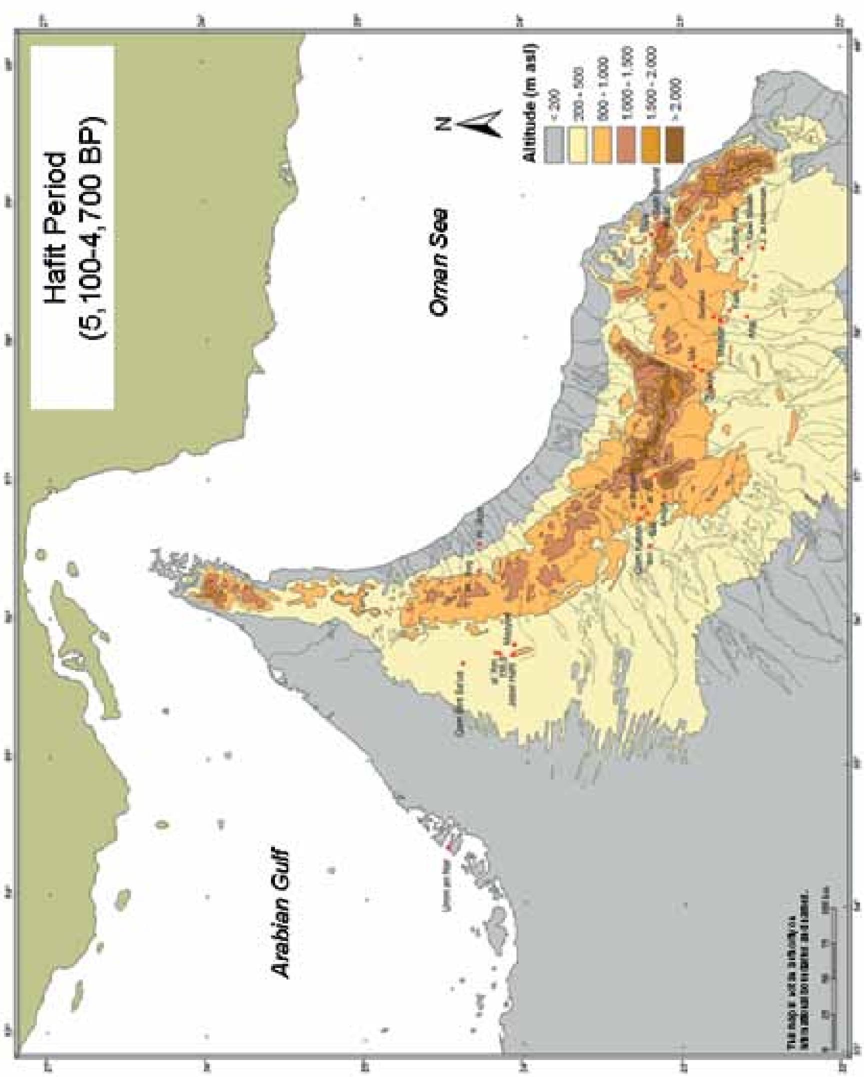

Figure 2. Settlement locations on the Oman Peninsula during the Hafit period.

Red dots indicate archaeological findings on all maps whereby underlined location names refer to settlements. Figures are based on TAVO, University of Tübingen, Germany and are courtesy of Dr. J. Schreiber, DAI, Berlin.

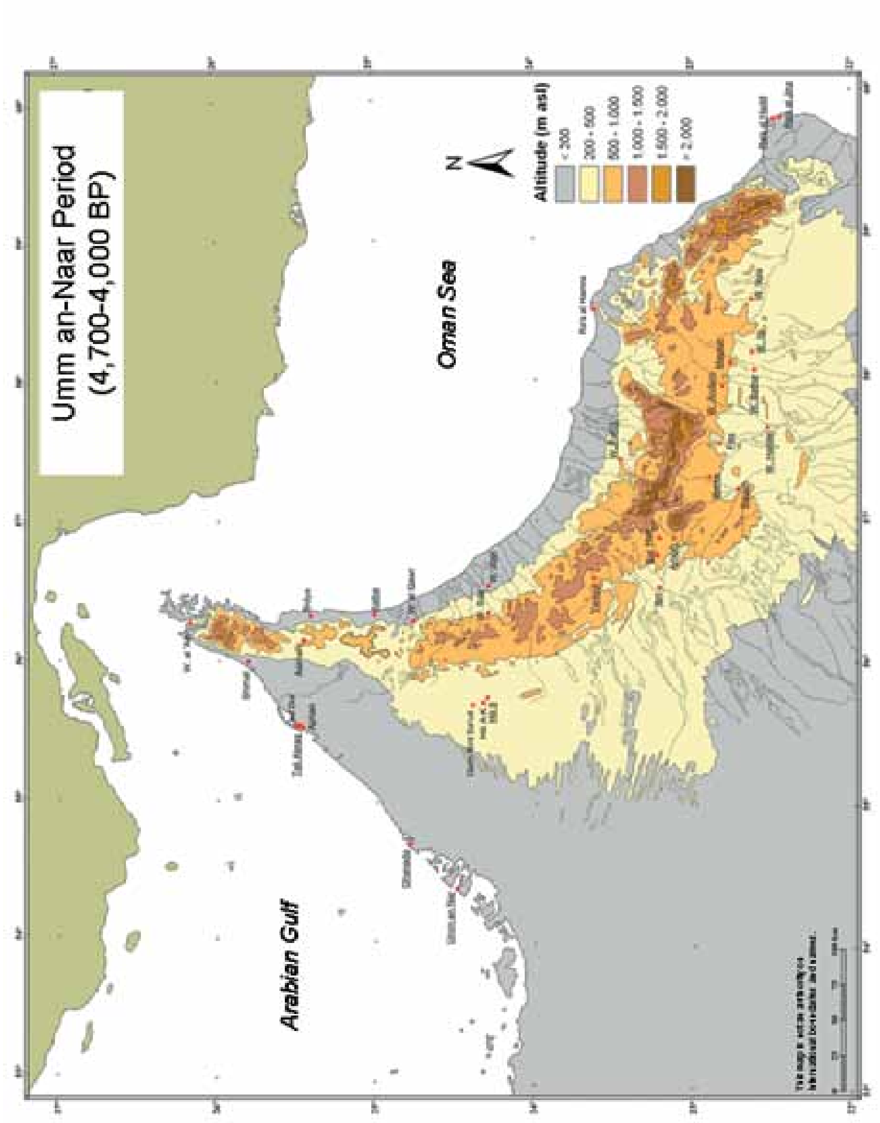

Figure 3. Settlement locations on the Oman Peninsula during the Umm an-Naar period.

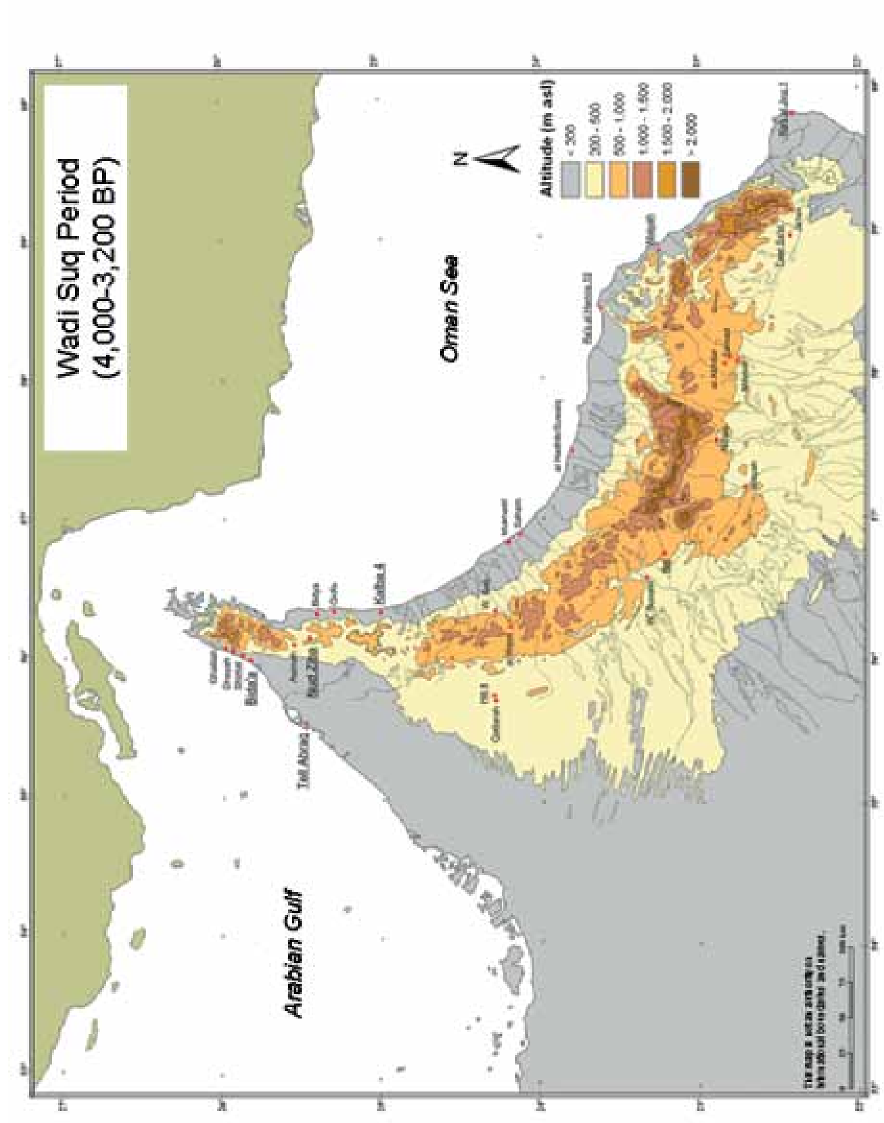

Figure 4. Settlement locations on the Oman Peninsula during the Wadi Suq period.

Red dots indicate archaeological findings on all maps whereby underlined location names refer to settlements. Figures are based on TAVO, University of Tübingen, Germany and are courtesy of Dr. J. Schreiber, DAI, Berlin.

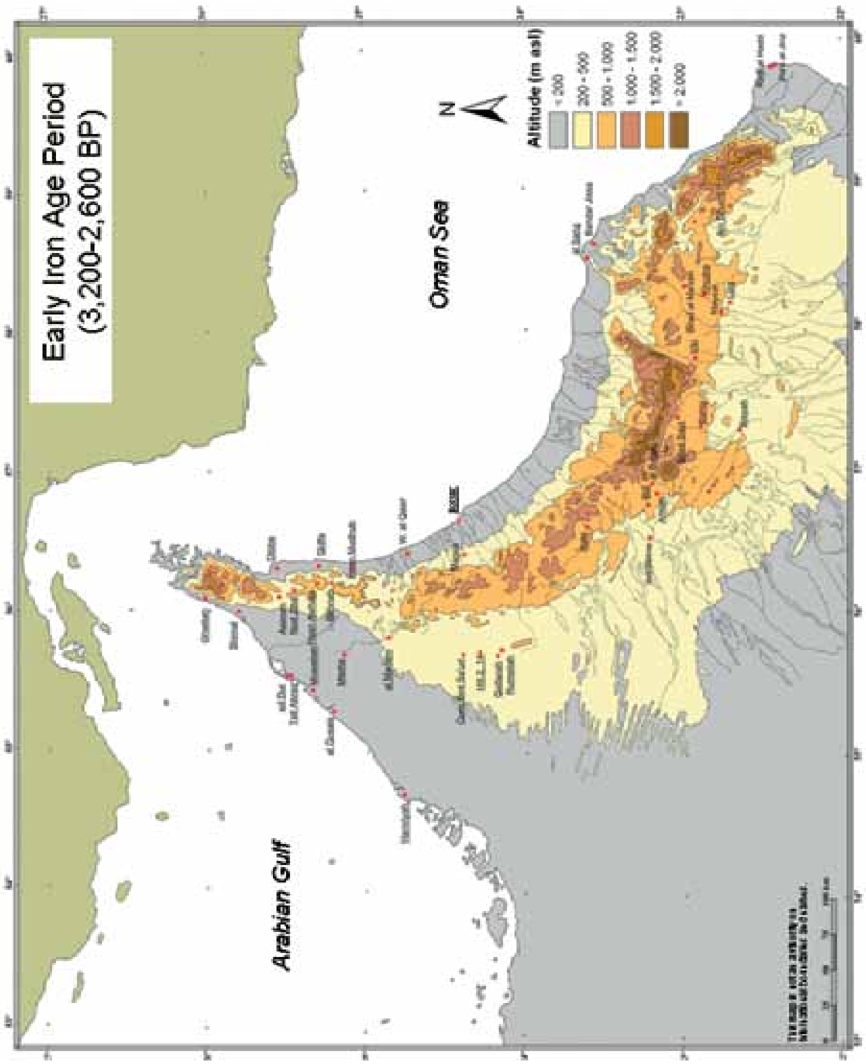

Figure 5. Settlement locations on the Oman Peninsula during the Early Iron Age period.

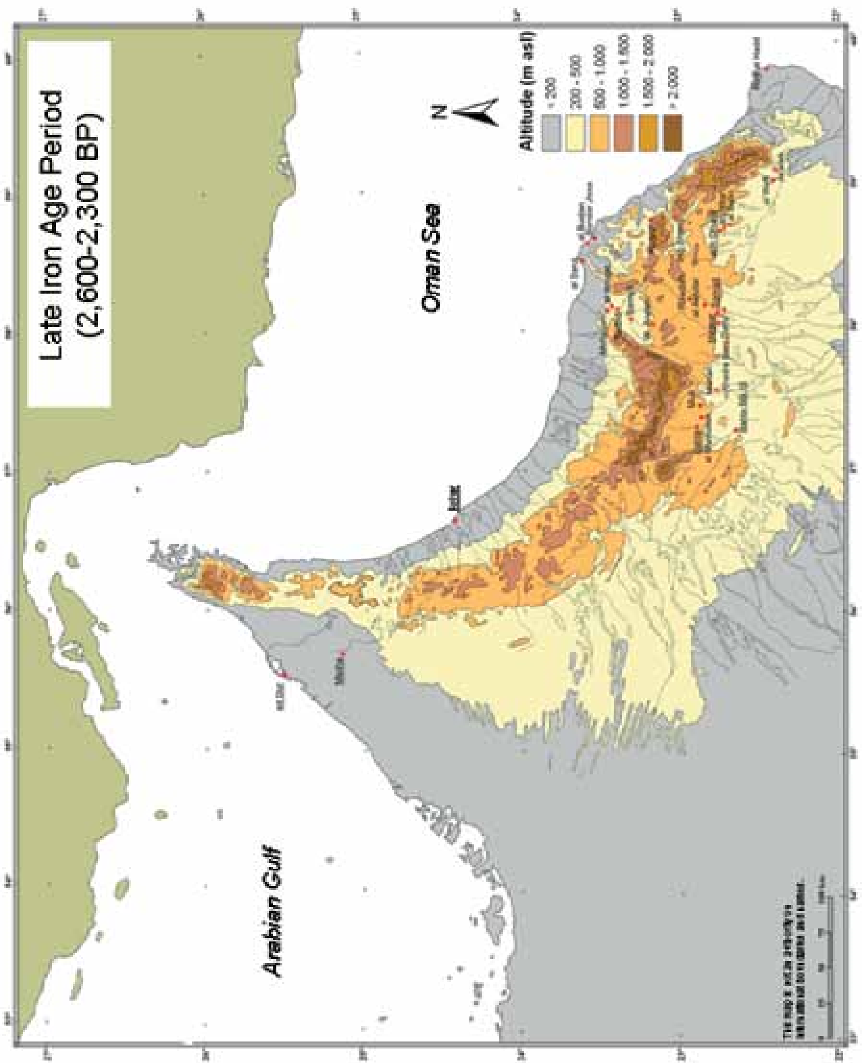

Figure 6. Settlement locations on the Oman Peninsula during the Late Iron Age period.

Red dots indicate archaeological findings on all maps whereby underlined location names refer to settlements. Figures are based on TAVO, University of Tübingen, Germany and are courtesy of Dr. J. Schreiber, DAI, Berlin.

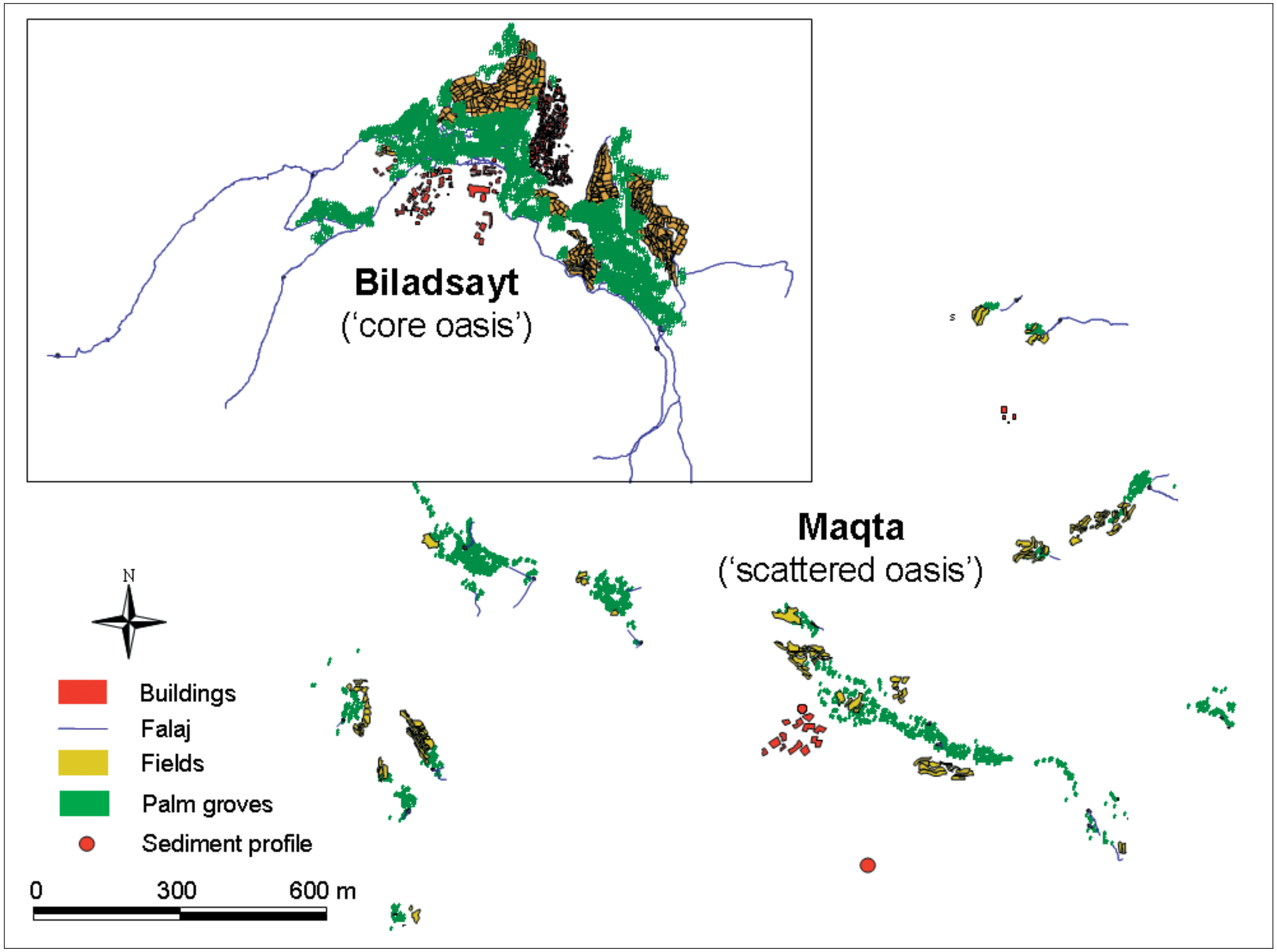

Figure 7. Typology of mountain oases in Oman: maps show the 'scattered oasis' of Maqta with 22 springs and 16 terrace systems on a total of 4.5 ha extremely adapted to scarce water resources and the 'core oasis' of Biladsayt with 12 springs feeding four major falaj systems that water 13.4 ha of land.

Figure 8. Rugged landscape between the oasis of Maqta and the Shir Pleateau of the Jabal Bani Jabir (Eastern Hajar Mountains) with the sediment filled depression from where the climate record was collected. The photographs shows the location vegetated with ancient indigo (*Indigofera tinctoria* L.) growing spontaneously after a rare sequence of winter rains in 2010.

Figure 9. Example of the famous up to 4,000 year old stone tower tombs above the oasis of Maqta on the Shir Plateau of the Jabal Bani Jabir, Eastern Al Hajar Mountains.

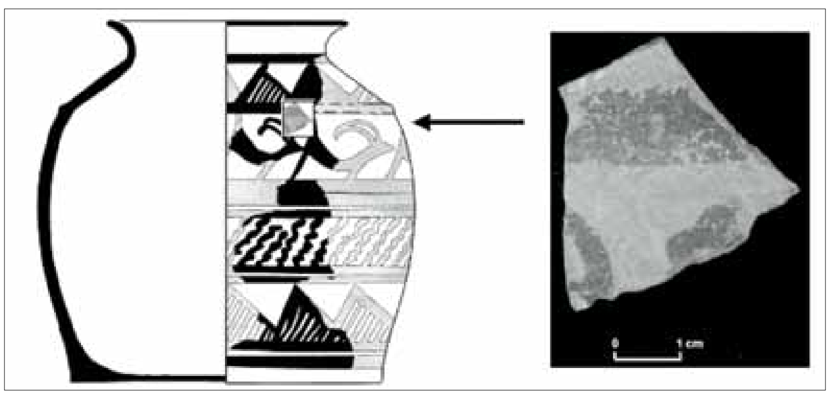

Figure 10. Painted black-on-gray pottery from a tomb at Tiwi showing ancient trade relationships between Oman and Iran.

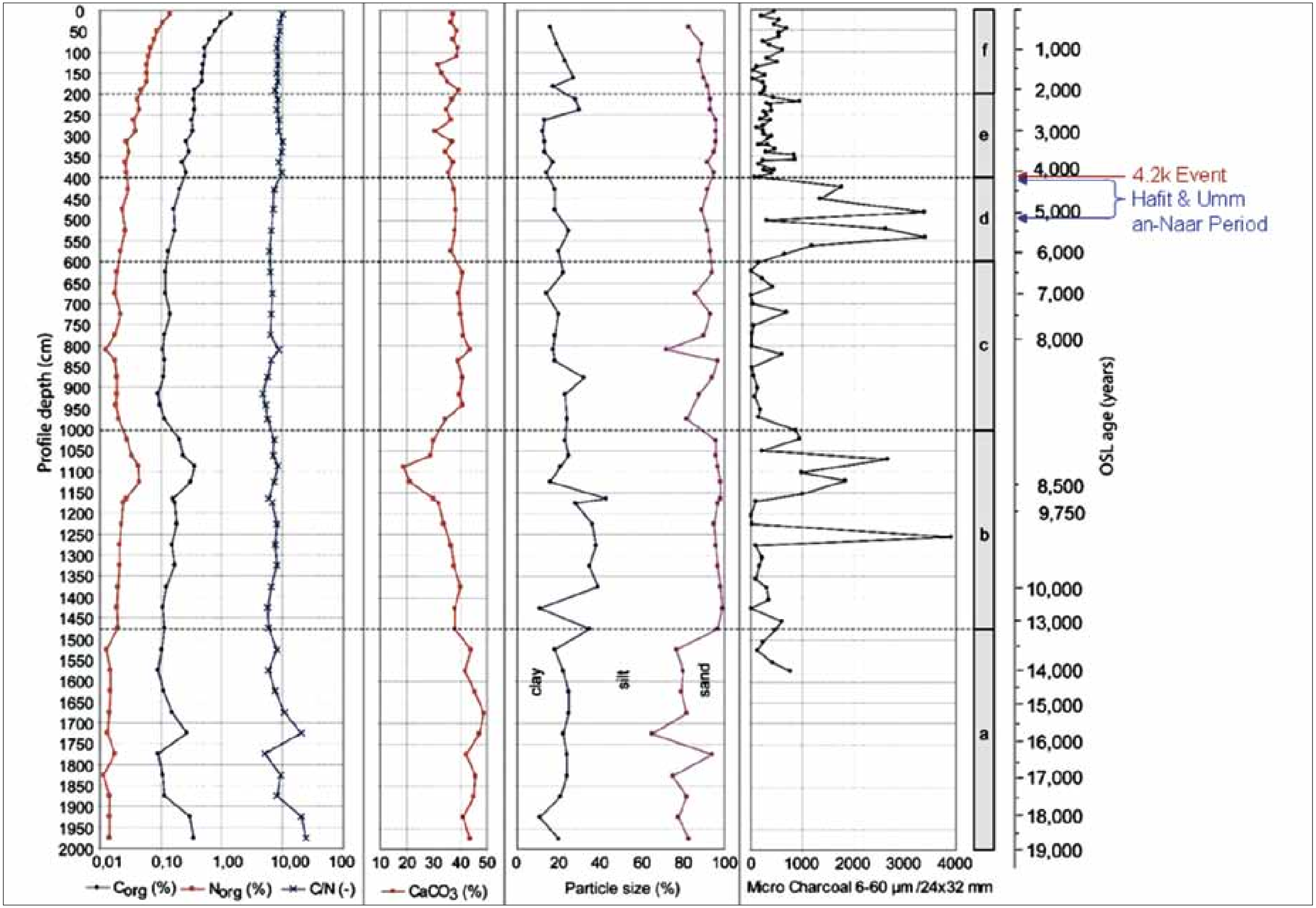

Figure 11. Organic carbon (Corg), organic nitrogen (Norg), C/N ratio, $CaCO_3$, particle size and micro charcoal distribution of the 20 m deep sediment profile at Maqta (Oman). The time scale (years BP) on the right y-axis is based on Optically Stimulated Luminescence (OSL) of quartz particles (Fuchs and Buerkert, 2008). Particularly note the increase of charcoal particles during the Haft and Umm an-Naar Periods and their sudden decline during the '4.2k Event' when Mediterranean winter rains ceased. Figure modified after Urban and Buerkert (2009).

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Chapter 4

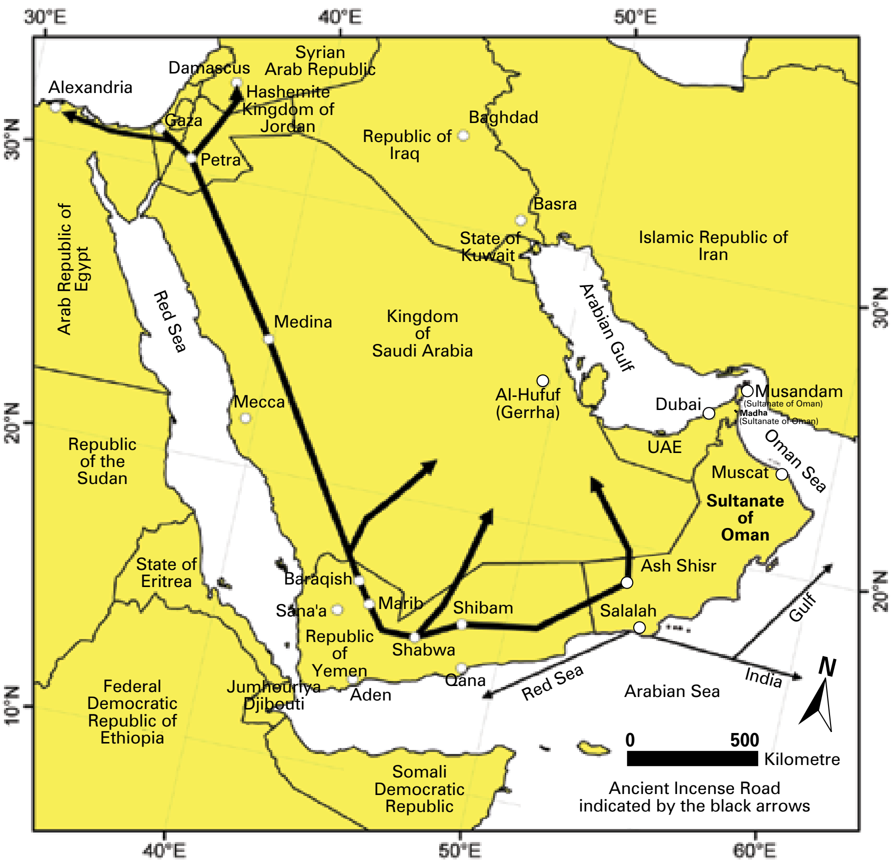
Plant Genetic Resources in Oman – Evidence for Millennia of Cultural Exchange in the Middle East

Jens Gebauer, Sulaiman Al Khanjari, Iqrar Ahmed Khan, Andreas Buerkert and Karl Hammer

Introduction

Famous as the origin of the best fumitory frankincense, a major copper producer and the birthplace of the legendary trader Sinbad the Sailor, Oman has maintained trade relations with all major countries in the region for millennia. Between the the late 4th millenium BP and the 19th century BP, frankincense was transported by domesticated camels from the production areas in southern Oman through Yemen, passing Mecca and Medina, along the famous Frankincense Road to the major markets in Mesopotamia and the Mediterranean (Böhlmann, 2006; Pickering, 2007; Figure 1). These trade relationships have certainly contributed as much to the diversity of crops in this country, as did its range of agro-climatic environments varying from irrigated agriculture in oases across the country, over rain-fed conditions in Musandam to monsoon-moistened land use systems in Dhofar. A particularly spectacular example of highly diverse oasis agriculture are the terraces on the Al Jabal Al Akhdar massif, widely known as 'hanging gardens' (Buerkert et al., 2007).

Figure 1. Ancient Incense Road (indicated by the black arrows) from 3,500-1,900 BP and today's country borders (altered from Böhlmann, 2006).



Origin of Oman's Plant Genetic Resources

Cultivated plants of a specific area can be classified into chronoelements and geoelements. Whereas chronoelements in Oman are of limited importance because of the relatively late arrival of agriculture into the area (there are only a few archaeophytes from 7,000-6,000 BP to the 14th century BP), geoelements play an important role. So far, 194 species of 133 genera and fifty-three families were identified and recently compiled in a checklist (Hammer et al., 2009). Among the families, Leguminosae (21 spp.), Gramineae (17 spp.), Rosaceae (13 spp.) and Cucurbitaceae (10 spp.) have the highest number of species.

Recent research reveals that agriculture was introduced into Oman first from the Near East and Eastern Mediterranean area with species that included important crop plants such as barley *(Hordeum vulgare)*, chickpea *(Cicer arietinum)*, lentil *(Lens culinaris)*, millet *(Pennisetum glaucum)* and wheat (*Triticum* spp.), of which wheat is of special interest as in traditional Omani landraces tetraploid and hexaploid wheat is often grown together (Al Khanjari et al., 2007ab; Zhang et al., 2006). It was only during recent years that studies have revealed the existence of a unique germplasm of *Triticum aestivum (T. compactum)*, of which ten varieties were new to science (Figure 2), of *T. durum* and of *T. aethiopicum* (Al Maskri et al., 2003; Al Khanjari et al., 2008). This wheat material was possibly introduced from Iran via the Musandam Peninsula (belonging to Oman). The occurrence of *T. aethiopicum* (morphologically similar to *T. aestivum*) suggests that this wheat reached Ethiopia from Iran via Oman and Yemen, and the occurrence of emmer wheat *(T. dicoccon)* supports the notion of Oman having historically been at the crossroads of cultural exchange in the Near East and Asia (Hammer et al., 2009). All traditional wheats, which have an evolutionary history of thousands of years in Oman, are now threatened by genetic erosion given the widespread conversion of oasis agricultural land to built-up areas.

Many tropical crops in Oman came from south and Southeast Asia, mainly from India, which was an important ancient trading partner. These include fruit trees, such as black plum *(Syzygium cumminii)*, mango *(Mangifera indica)*, Assyrian plum *(Cordia myxa, C. perrottettii* and *C. sinensis*), many *Citrus* spp. (Figure 3), vegetables like bitter gourd (*Momordica charantia)*, eggplant *(Solanum melongena)*, moringa *(Moringa oleifera)* and other crops such as sesame *(Sesamum indicum)*. After their introduction these crops experienced further evolution and in several cases came into interaction with local or naturalised Omani races leading to specific adaptations.

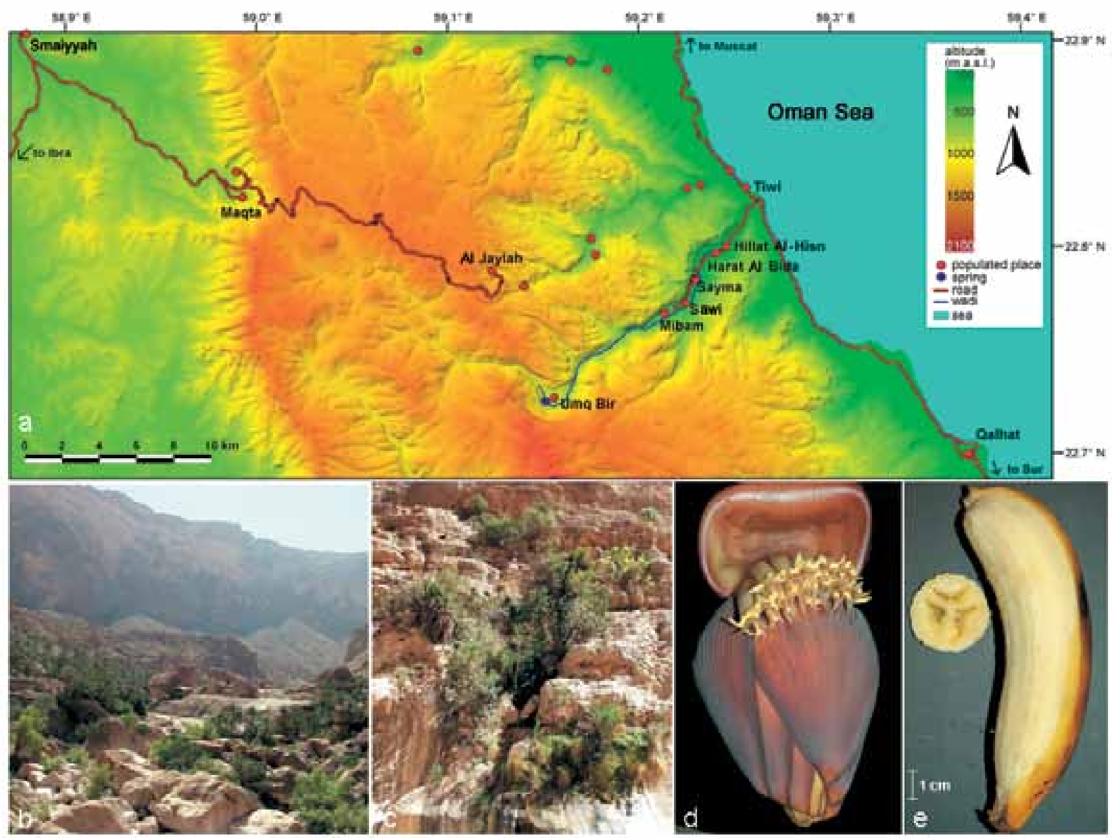
Figure 2. Newly discovered ancient botanical varieties of wheat (*Triticum* spp.) from Oman.

Figure 3. From left to right: citron *(Citrus medica)*, bitter orange *(Citrus aurantium)*, orange *(Citrus sinensis)*, sweet lime *(Citrus limettioides)*, lemon *(Citrus limon)* and lime *(Citrus aurantiifolia)* from mountain oases in northern Oman.

Bananas (*Musa* spp.), though they have no wild relatives in Oman, show an astonishing variation. Some clones likely reflecting old trade relationships to Southeast Asia where they may now have become extinct, being new to science (Buerkert et al., 2009; Figure 4). Obviously many different races have been introduced and maintained over the centuries.

Crops from Central and Middle Asia are apple *(Malus domestica)*, carrot *(Daucus carota)*, garlic (*Allium sativum*), onion *(Allium cepa)* and peach *(Prunus persica)*, which predominate in the mountains of northern Oman.

Figure 4. (a) GIS-based 3D map of the Jabal Bani Jabir mountains, Wadi Tiwi and the oasis of Umq Bi'r in northern Oman, (b) view of Umq Bi'r, (c) lateral spring area with a newly discovered ancient *Musa* clone, most likely from SE Asia, in its natural habitat, (d) male flower and (e) edible fruit of the ancient banana clone.



The big group of neophytes from Central and South America that arrived in Oman about 500 years ago includes chili pepper *(Capsicum annuum)*, corn *(Zea mays)*, field pumpkin (*Cucurbita pepo*), passion fruit *(Passiflora edulis)*, pineapple (*Ananas comosus*), sapodilla *(Manilkara zapota)*, soursop *(Annona muricata)*, sweet potato *(Ipomoea batatas)* and tomato *(Lycopersicon esculentum)*. Several of these crops show specific adaptations to the hot, dry conditions prevailing in Oman, and some of them have escaped from cultivation and are naturalised, such as Devil's trumpet *(Datura metel)* and tobacco *(Nicotiana tabacum)* in Dhofar. The naturalised populations are often the last evidence of a former cultivation in Oman.

A number of crops have been introduced, most likely via Yemen, from neighbouring northern and eastern parts of Africa, including Barbados aloe (*Aloe vera*; Figure 5), castor bean *(Ricinus communis)*, Mediterranean saltbush *(Atriplex halimus)* and mimusops *(Mimusops laurifolia)*. Tamarind *(Tamarindus indica)*, with many naturalised trees in Dhofar, may also have its origin in northeastern Africa.
The other geoelements are less important in Oman, with many of them having been introduced recently. They include germplasm from tropical Africa such as Egyptian sesban *(Sesbania sesban)*, from South Africa such as bottle gourd (*Lagenaria siceraria*), from Australia and New Zealand such as horsetail tree *(Casuarina equisetifolia)* and from Europe such as peppermint *(Mentha × piperita)*. Some species have been domesticated in Oman, while for others there is only some evidence, for example the famous frankincense

tree *(Boswellia sacra)*. Wild stands of this species have been found in Dhofar through millennia, and some plants were also introduced into the fields and gardens and even reached northern Oman (Gebauer et al., 2007), where under cultivation the process of domestication began. Frankincense, which was an important trading commodity, is still harvested from wild *B. sacra* stands in southern Oman, but it has recently lost some of its importance due to Somalia becoming a major producer and exporter.

Figure 5. Flowering Barbados aloe near the mountain oasis of Biladsayt in northern Oman.

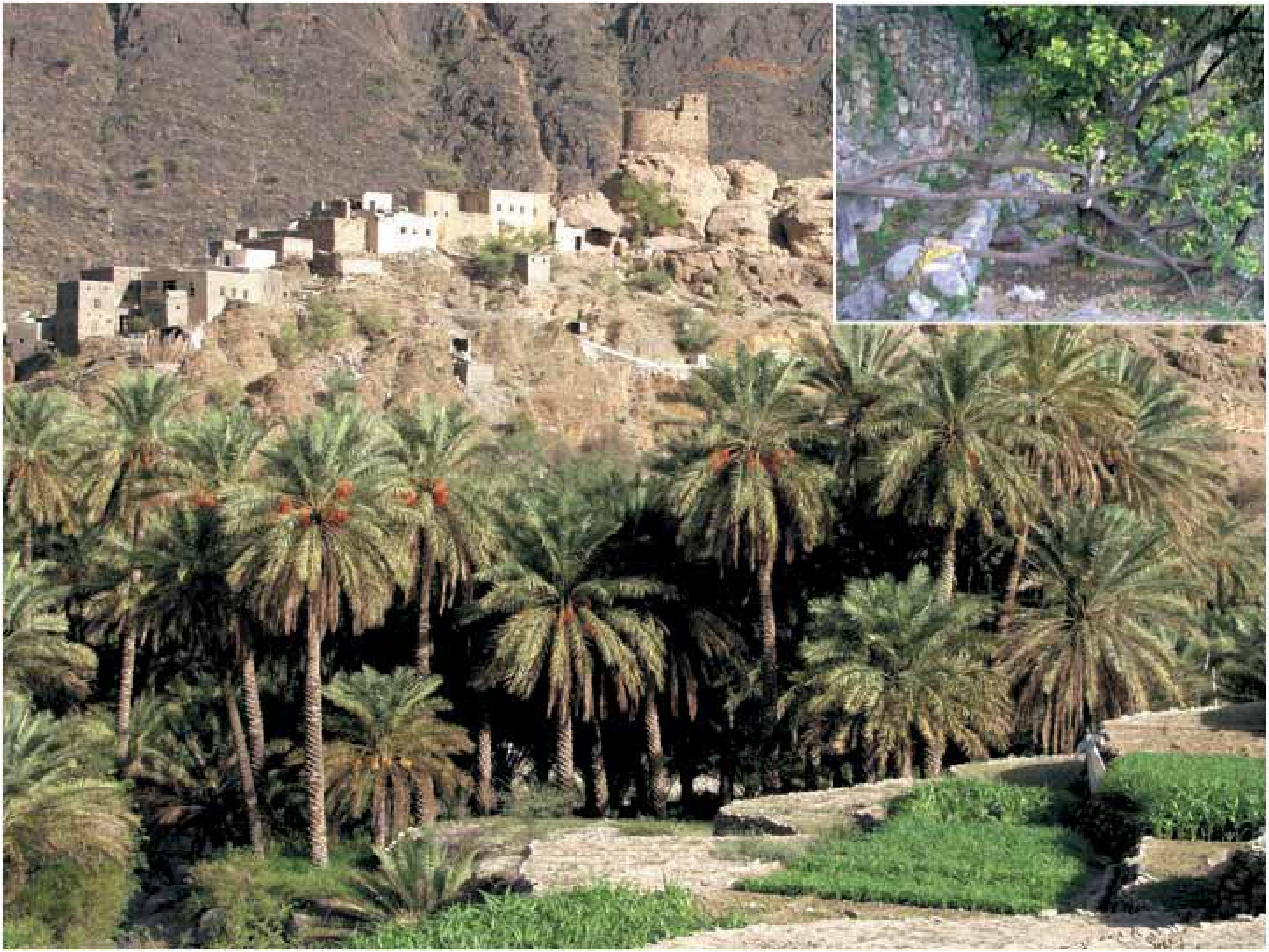
Decline and Potential Revival of Ancient Lime Production in Omani Oasis Agriculture

Since 1970s the Witches' Broom Disease of Lime (WBDL) has become a major problem for the production of lime *(Citrus aurantifolia)* in Oman which in fresh and dried form has been a major trading commodity of the country's mountain oases for many centuries. The disease is caused by *Candidatus phytoplasma aurantifolia,* a mycoplasma-like organism (similar to bacteria but without a cell wall), with the putative insect vector being the leafhopper *Hishimonus phycitis*. Once infected, trees survive a few years with poor yields and ultimately die off, which has left most oases without the traditional three-storey canopy structure of crops (fodder crops – citrus and banana – date palm; Figure 6). In recent years WBDL has also spread in neighboring countries, such as the United Arab Emirates, Iran, India and Pakistan. Given that lime is traditionally propagated by cuttings, the infected trees serve as parent trees allowing for large build-up of inoculum potential. Fortunately, somatic hybridization between a progenitor of lime *(Citrus micrantha)* and sweet orange *(Citrus sinensis)* can yield a lime-like fruit using sweet orange as a donor of disease resistance genes (Khan and Grosser, 2004). This offers new options for the re-introduction of lime into Omani oasis agriculture and at a more general level underlines the importance of conserving plant genetic resources to combat the rapid spread of novel diseases.

Conclusions

Oman's plant genetic resources have developed under traditional agriculture going back to 7,000 years BP. Oman's strategic position, at the crossroads of several important trading routes, provided a favourable pre-condition for the introduction of many crops. The evolutionary power of the area resulted from the easy availability of new plants from many parts of the world, and the conservation and evolution of plants in oases often isolated by steep mountains. In recent years strong genetic erosion has occurred in all traditional cultivated plants in Oman, requiring collection and conservation efforts to limit the loss of genetic plant resources, a valuable heritage to mankind.

Figure 6. Classical three-storey canopy structure of Omani oasis agriculture with the second storey (traditionally consisting of lime trees – in the insert a dying specimen) missing as a consequence of Wichtes' Broom Disease of Lime



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CHAPTER 5

TYPOLOGY OF OASES IN NORTHERN OMAN

EIKE LUEDELING AND ANDREAS BUERKERT

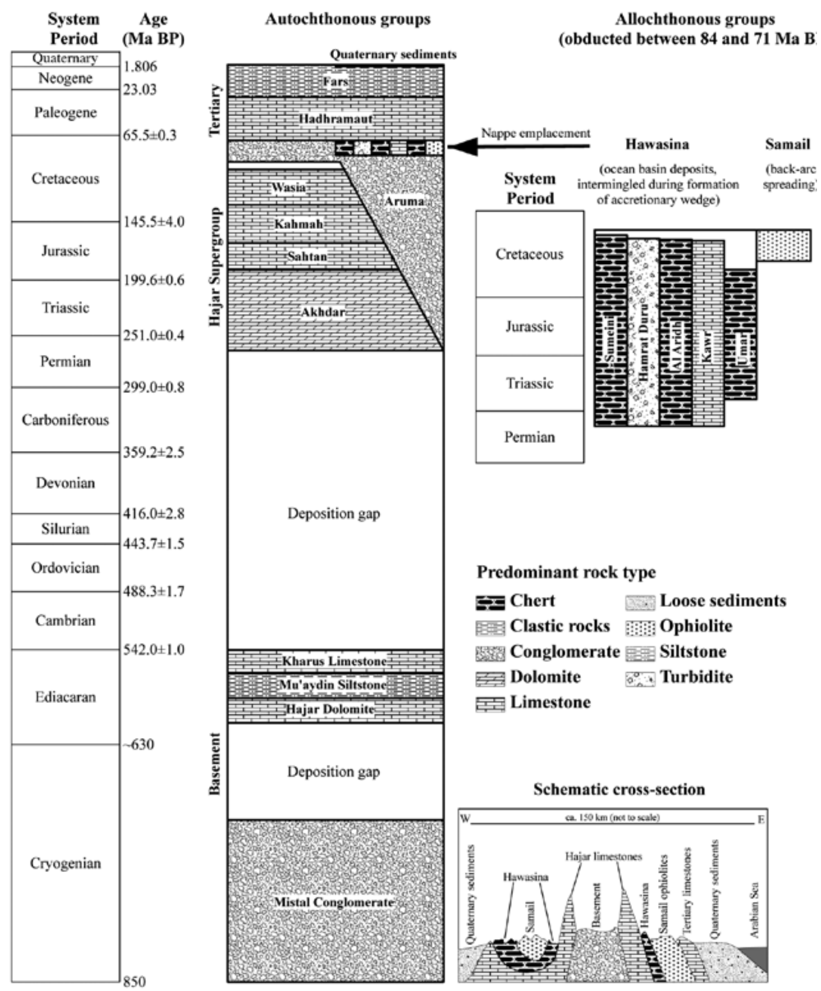
Introduction

Oasis agriculture has been the cultural and economic backbone of the Sultanate of Oman for thousands of years (Chapter 3). For much of this time, the country's cropping area has been restricted to sites where irrigation water for agriculture emerged naturally in springs or temporary streams, or could be easily accessed in shallow wells. It was only in recent decades that the introduction of modern pumping technologies has enabled farmers to expand the productive area beyond these favoured locations. Traditionally most northern Omani villages comprised at least one oasis with well-irrigated date palms (*Phoenix dactylifera L.*) and fields planted with crops such as wheat (*Triticum* spp.) and alfalfa (*Medicago sativa L.*; Siebert et al., 2007). However, until recently the exact number of oases in northern Oman was unknown.

There are also uncertainties about the types of oases that exist. While most oases on the plains rely on pumped groundwater, some plantations that are closer to the main natural drainage lines, such as Bilad Bani Bu Hassan or Nizwa, do not require such technology. Likewise, the geological formations and widely differing temperatures of the spring water between oases near to Nizwa, such as Nakhl and Biladsayt, which are both on the northern fringe of the Al Jabal Al Akhdar mountain range, provide vivid evidence of the variation in oases' geological frame conditions, which may hamper the extrapolation of scientific results on oasis agriculture from one valley to the next. Consequently, to date most research has focused on case studies of one or several oases, and more general studies are lacking.

In the following, an attempt is made to estimate the number of oases in northern Oman and to develop a typology allowing classification of

Figure 1. Simplified stratigraphy and cross-section of the Oman Mountains showing the main geological groups (Glennie, 2005; Rabus et al., 2003). Numerical ages are according to Gradstein et al. (2004).



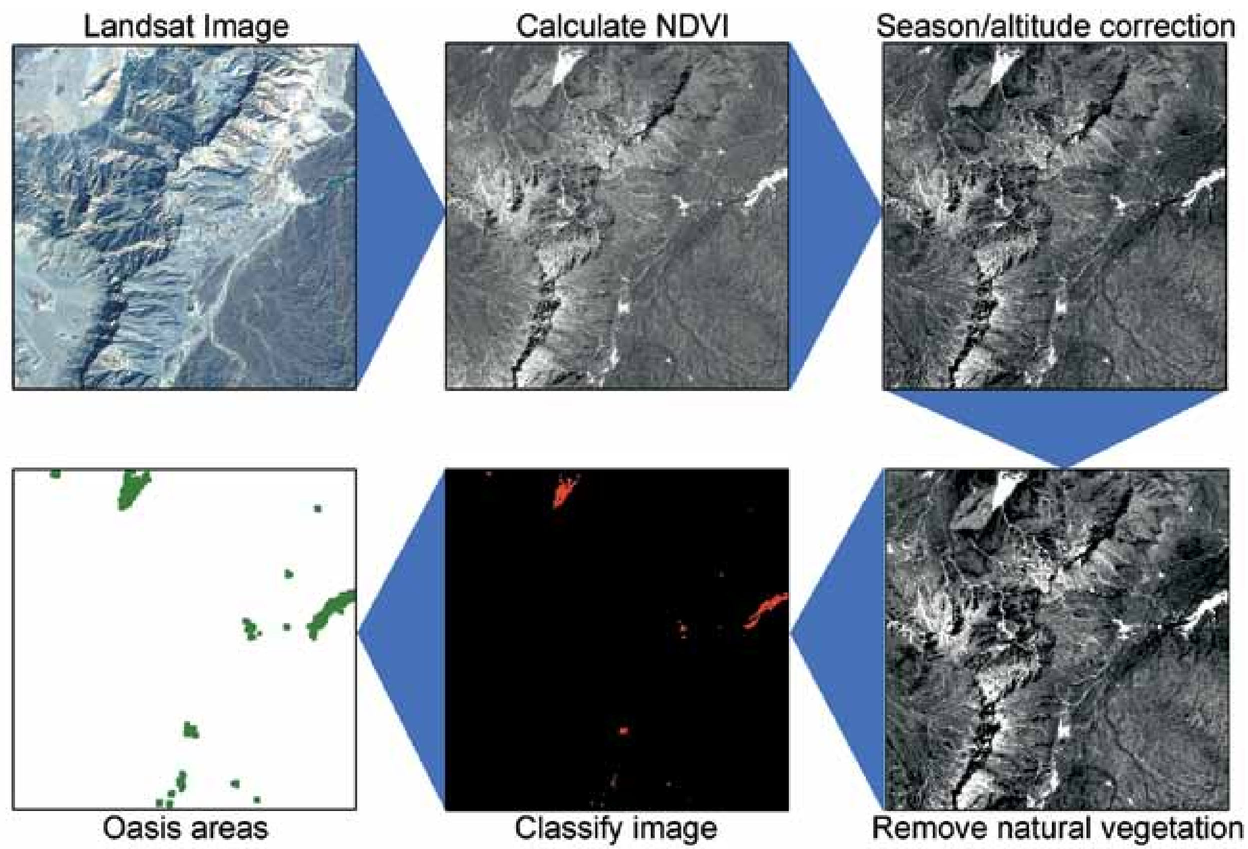
oases into well-defined categories. Since visiting each oasis in person would pose a serious logistical challenge, remote sensing techniques were used to determine oasis numbers and types based on satellite images, a digital elevation model and geological survey data. We hope that this typology will prove useful for future studies on oasis history and evolution (Chapter 3), the current state of the oases (Chapter 4) and for developing concepts for future management of Omani oases as integrated livelihood systems (Chapter 1).

Oasis Detection

To locate all oases that are scattered throughout the geologically complex landscape of northern Oman (Figure 1) multispectral images taken by the Enhanced Thematic Mapper Plus (ETM+) instrument aboard the Landsat 7 satellite were used. Such images contain information about the reflection of electromagnetic radiation at different ranges of wavelengths. Since vegetated areas reflect almost all incoming radiation in the near infrared region of the spectrum, while absorbing most of the red radiation, such areas can be detected through the Normalized Difference Vegetation Index (NDVI; Tucker 1979), which is defined as NDVI = (NIR-Red) / (NIR+Red). In this equation, NIR and Red are the reflections of Near Infrared and Red radiation by the ground surface, including the vegetation. After calculating this index, most vegetated areas in northern Oman became visible (Figure 2).

In order to clearly identify oases it was necessary to remove the effects of altitude, season and weather conditions on the level of apparent vegetation detected in the eleven images that were needed to cover the entire land surface of northern Oman. This correction was achieved by subtracting the average NDVI value within a surrounding rectangle of 303×303 pixels from each pixel of the NDVI images (Figure 2). To remove most natural vegetation that was erroneously classified as belonging to an oasis, each pixel was then replaced by the average of a surrounding rectangle of 3×3 pixels.

Figure 2. Illustration of the oasis detection procedure. From the Red and Near Infrared bands of the original Landsat image, the NDVI was calculated and subjected to a filter to reduce season and altitude effects. After removing most of the natural vegetation by another filter, the NDVI image was classified. Adding a buffer around each vegetated area subsequently yielded the oasis areas.



This step removed very small patches of vegetation, emphasising true oasis areas. NDVI images were then classified into five classes along natural breaks in the value distribution and the highest class was interpreted as an oasis area. After adding a buffer of six pixels around each delineated oasis and validating the procedure using Google Earth images, the number of oases could be estimated (Luedeling and Buerkert, 2008).

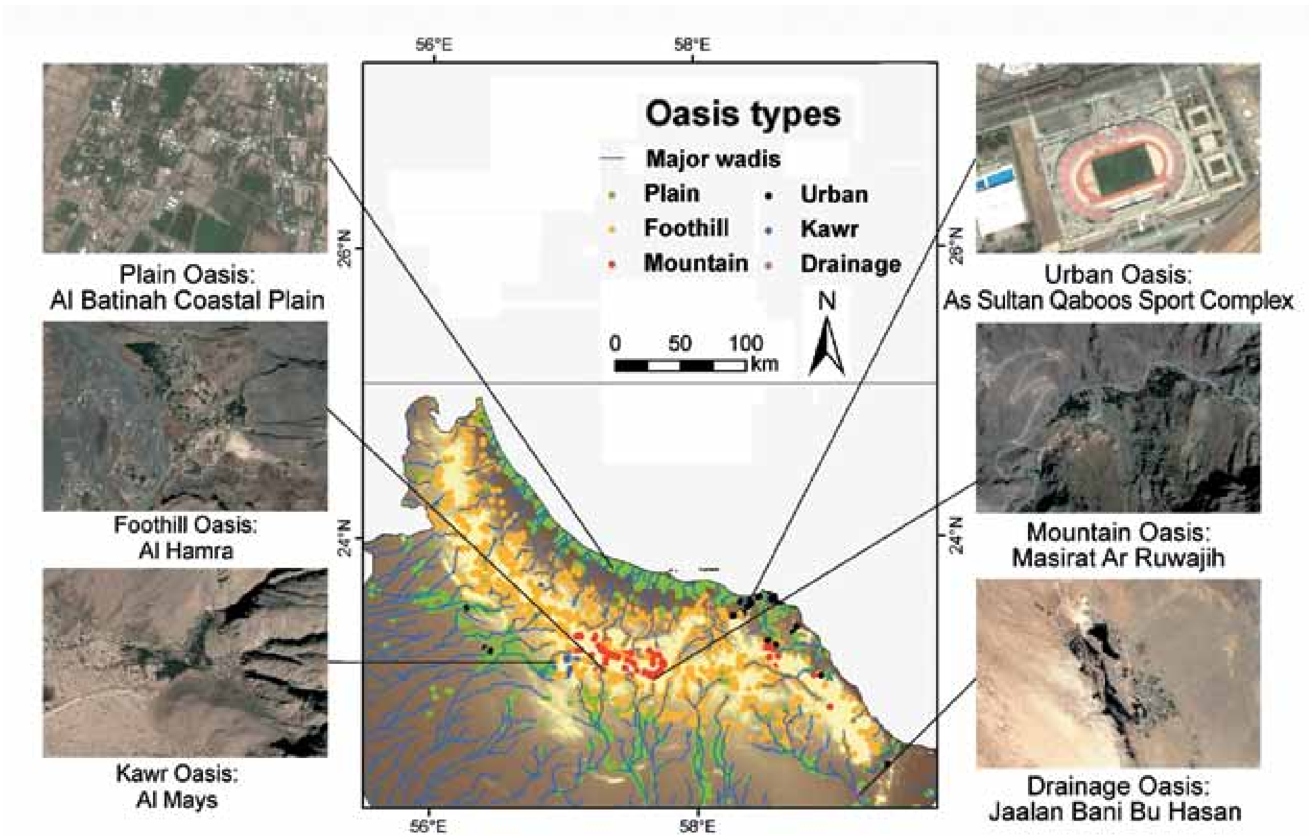
Overall, 2663 features interpreted as oases in northern Oman were detected, of which 2428 had vegetated areas larger than 0.4 ha, which was the minimum size that could be determined reliably with the procedure. The size of agricultural areas belonging to oases ranged between 0.08 and 718 ha. The overall largest oases were mostly contiguous areas of well-irrigated farms on the Al Batinah Coastal Plain, while the largest traditional oases were Bilad Bani Bu Hassan (436 ha), Samail (366 ha), Nizwa (337 ha) and Ar Rustaq (334 ha).

Oasis Classification

To characterise all oases and to classify them according to their site characteristics, elevation data from the Shuttle Radar Topography Mission (SRTM; Rabus et al., 2003) and geological survey data (Rabu et al., 1993) were used to examine their topographic, hydrologic and geologic setting. For each oasis, the average elevation and the height of the adjacent terrain were derived directly from the elevation model, which also yielded hydrological streams and catchment sizes. Subsequently, the distance to the major geologic formations that are present in northern Oman was quantified. Cluster analysis was used to group oases based on these attributes and discriminant analysis to interpret the grouping (Luedeling and Buerkert, 2008).

The classification yielded six distinct oasis types (Figure 3). ‘Plain Oases’ (48.5% of all oases) are mostly located on the Al Batinah Coastal Plain, as well as on the plains to the west and south of the Al Hajar Mountains.

Figure 3. Distribution of the six oasis types throughout northern Oman. The aerial photographs on the sides (extracted from Google Earth) show one representative of each type.



Agriculture in these oases is based on groundwater that is pumped to the surface. ‘Foothill Oases’ (46.2%), in contrast, are mostly traditional oases that lie along the eastern and western edge of the mountain range. Their water supply is ensured by water accumulation in large natural wadis, where it is channelled by the mostly impermeable rocks of the Samail and Hawasina geological units. ‘Mountain Oases’ (2.8%) lie in the interior of the mountain range and their water supply originates from natural springs that are fed by the extensive aquifers of the Hajar limestone formations. ‘Urban Oases’ (1.7%) lie far from settings that seem suitable for sustaining agriculture and are mostly represented by parks and sporting facilities that are irrigated using off-site water. ‘Kawr Oases’ (0.5%) are similar to ‘Mountain Oases’ in that they lie at the bottom of relatively steep cliffs of limestone where natural springs emerge. For ‘Kawr Oases’, however, the limestone pertains to the Kawr group, which is a remnant of an ancient chain of calcareous islands and thus differs from the Hajar limestone. Finally, ‘Drainage Oases’ (0.3%) are the largest traditional oases in Oman. They lie along the main wadi that drains most of the southern and western side of the mountain range, and their settlements are fed from an abundant supply of groundwater contained in the wadi sediments.

Conclusions

Northern Oman contains about 2430 oases that can be classified into six distinct types. ‘Plain Oases’ and ‘Urban Oases’ are non-traditional oases that can only be irrigated by modern techniques. ‘Foothill Oases’ and ‘Drainage Oases’ lie along the main wadi courses and rely on water accumulation in sediments. Finally, ‘Mountain Oases’ and ‘Kawr Oases’ lie at the bottom of extensive water-bearing limestone formations, which give rise to natural springs. The oasis typology developed in this study will hopefully contribute to better targeting of policies destined to preserve Omani oases as a heritage of unique cultural value.

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CHAPTER 6

PLANT COMMUNITIES, ENDEMISM AND CONSERVATION — HISTORY AND HERITAGE

ANNETTE PATZELT

Oasis Systems in Northern Oman: an Intricate Cultural Heritage

The agricultural systems in northern Oman are outstanding examples of sustainability, which have developed over millennia. They are complex, intensively irrigated desert oasis systems with terraced fields consisting of small man-made, silt and manure-filled stone structures built over many centuries on often very steep slopes. Typically, terrace size ranges from 2–100 m^2 and the fields carry a broad range of annual and perennial crop and tree species known to use the scarce water resources very efficiently (Gebauer et al., 2007; Siebert et al., 2007).

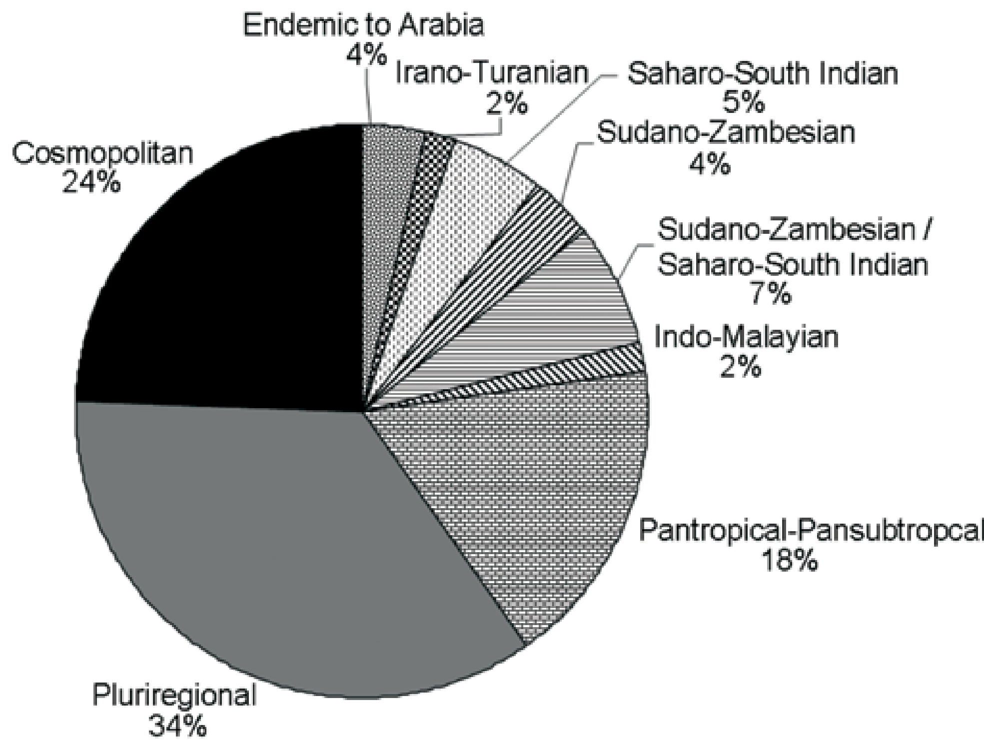
Diversity of Weeds

The diversity of the weed flora can be used as a criterion to assess the effects of management practices on the environment and on agroecosystems' sustainability (Marshall et al., 2003; Billeter et al., 2008). In Oman, the around two hundred indigenous weed species found in oasis systems represent 17% of the indigenous flora. This weed diversity largely depends on traditional management that uses little or no herbicides, pesticides or mineral fertilisers.

Phytogeographical Relationships of Weed Communities

In oasis settlements of the Al Hajar Mountains species composition is dominated by pantropical, pluriregional and cosmopolitan species (Figure 1). Pantropical species such as *Achyranthes aspera* and *Ammi majus* clearly indicate the former land connection of Arabia with Africa and Asia. Pluriregional species, such as *Andrachne*

Figure 1. Chorotypes of the weed community on cultivated terraces of the northern Al Hajar Mountains in Oman.



telephioides, Apium graveolens, Brachypodium distachyum and *Eragrostis papposa*, and cosmopolitan species such as *Anagallis arvensis* and *Euphorbia helioscopia* are weedy and ruderal, indicating human influence. The group of cosmopolitan weeds includes many that are equally successful in temperate climates and in the tropics.

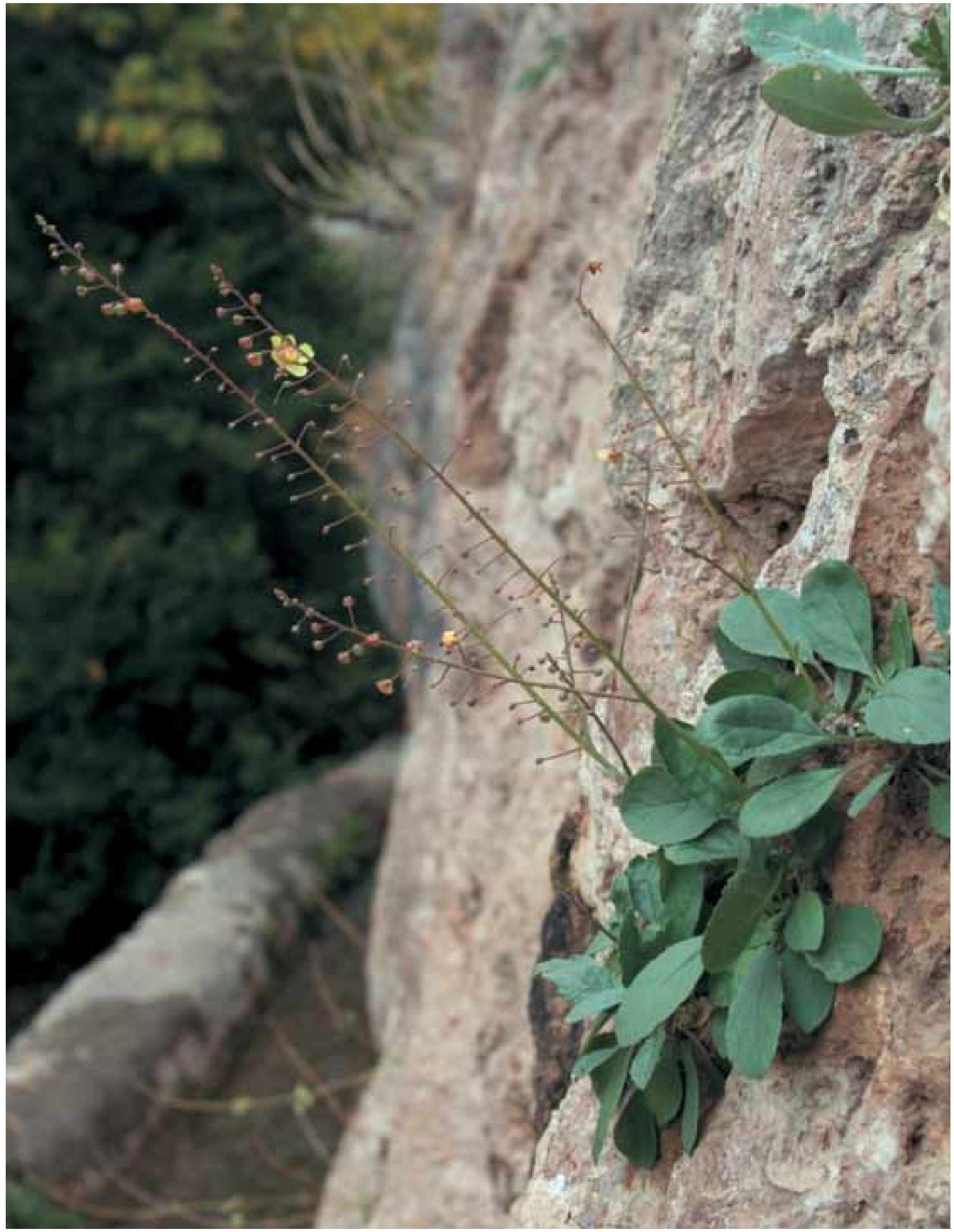
Although the origin of weed flora has so far not been investigated, it is likely that many came from Iran and adjacent countries, together with crops such as emmer wheat (*Triticum dicoccon*; Hammer et al., 2004) and coriander (*Coriandrum sativum*; Diederichsen and Hammer, 2003).

Conservation of Rare and Threatened Plants

The value of remote oasis systems for *in-situ* conservation of plant genetic resources needs to be emphasised. Several species endemic to northern Oman are found in oasis vegetation, such as *Campanula akhdarensis, Erucaria* sp. nov., *Orobanche perangustata* and *Verbascum akhdarense* (Patzelt, 2008; Figure 2). The delicate *Campanula akhdarensis* occurs on old stone walls in mountain villages much more frequently than in natural *Olea europaea-Juniperus excelsa* woodland vegetation, and in order to conserve them, these old structures need to be maintained.

The vegetation also holds species that are threatened on the national scale, such as *Epipactis veratrifolia, Gladiolus italicus, Gynandiris sisyrinchium, Ixiolirion tataricum, Muscari longipes, Pycnocycla caespitosa* and *Scandix pecten-veneris* (Patzelt, 2008). Modernisation, abandonment or careless 'beautification' often destroy the habitat

Figure 2. *Verbascum akhdarense* is a small herb endemic to the northern Hajar mountain range of Oman.



of these fragile species. One good example is the rare orchid *Epipactis veratrifolia* (Figure 3) that thrives in the proximity of old *falaj* systems, which therefore merit careful restoration. Massive application of cement to stabilise traditional *sarooj*-lined canals often causes the plants to disappear, and over recent years a number of populations have completely vanished.

Figure 3. The endangered orchid *Epipactis veratrifolia* is usually found in damp and shady locations of mountain oases in northern Oman.

Fortunately, Oman has adopted an active conservation policy and is leading conservation efforts in Arabia. Therefore, for fragile and endangered habitats like traditional and intact oasis vegetation, key representative areas need to be designated where existing regulations are strictly enforced to maintain Oman's rich native plant biodiversity.

The Threatened Wealth of Traditional Knowledge

Older people still have a wealth of indigenous knowledge about the uses of plants and traditional agricultural practices. However, the ongoing transformation process of these oasis systems leads to rapid loss of this knowledge and it is, therefore, of crucial importance to document existing information.

The abandonment of many terraced fields in the mountain oases needs to come to an end. The only way to maintain viable threatened plant populations is to get local people interested in preserving oasis agriculture as an integrated livelihood system. This may initially require help for improved marketing of local products and value-adding processing.

Finding a balance between biodiversity conservation and infrastructural development is a real challenge whereby often (short-term) benefits of the latter seem to outweigh the rewards of the former. However, Oman's unique cultural identity largely depends on oasis agriculture in which the maintenance of agro-biodiversity is an essential component.

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Chapter 7

Rangeland Vegetation on Al Jabal Al Akhdar — A Key Resource of Oasis Settlements

Katja Brinkmann and Annette Patzelt

Semi-arid rangelands in Oman have been valuable wildlife and plant habitats for millennia and still form a major feed source for livestock in most rural communities. The rangelands of Al Jabal Al Akhdar (the Green Mountain) belong to the WWF's Global 200 ecoregion 'Arabian Highland Woodlands and Shrublands' and are a local centre of plant endemism with a particularly high species diversity. Overall, about four hundred species of vascular plants are found in the *Olea europapea* subsp. *cuspidata* and the *Juniperus excelsa* woodlands above 1500 m asl, representing about 33% of the total flora of the country. Sixty-two species occurring in the Al Hajar Mountains are contained within the *Oman Plant Red Data Book* (Patzelt, 2008), representing 5.2% of the total flora of Oman and 15.5% of the flora above 1500 m. Botanically the highland flora has affinities with the montane flora of southwestern Iran, Baluchistan (Pakistan) and neighbouring territories.

The mountains of Oman have an only sparse vegetation cover, largely limited to runnels or small depressions where some sediments have accumulated in pockets. At higher altitudes most rangelands are characterised by semi-evergreen woodlands dominated by *Sideroxylon mascatense* growing in scattered mixed stands with *Dodonaea viscosa, Euryops arabicus, Olea europaea* subsp. *cuspidata* and *Sageretia thea* (Ghazanfar, 1991). Above 2000 m, the vegetation changes to juniper woodlands (*Juniperus excelsa* subsp. *polycarpos*), often co-dominant with *Olea europaea*, although there are only few locations that are well-developed. Most of the juniper trees are in poor condition and below 2400 m regeneration is minimal, which has been attributed to human disturbance, grazing pressure and climatic change (Fisher and Gardner, 1995). The patchy ground layer along the altitudinal gradient from 1100-2000 m is characterised by grasses and dwarf shrubs such as *Tetrapogon villosus, Chrysopogon plumulosus, Cymbopogon schoenanthus, Aristida adscensionis, Solanum incanum* and *Salvia aegyptiaca*, as well as the endemic species *Teucrium mascatense*.

The wadi fans consist mainly of gravel and sandy soil, and are bordered by plant communities of an azonal vegetation type, mainly dependent on the water regime. *Acacia gerradii, Ziziphus spina-christi* and *Ficus cordata* subsp. *salicifolia* are the major tree species present in the wadis and wadi fans. Occasional rainfalls in winter can lead to flash floods that rush through barren wadis. Typical of the narrow wadi outlets of the Al Jabal Al Akhdar range are shrubs such as *Dyerophytum indicum, Nerium oleander* and *Pteropyrum scoparium* (Deil and Al Gifri, 1998).

Environmental Effects on Diversity and Plant Species Composition

Various interacting factors determine the botanical composition of the rangeland vegetation and related species richness and functional diversity. Two of these key factors are altitude and topography, which control the (micro-) climate and have, therefore, a strong effect on the vegetation structure on the Arabian Peninsula. Grazing and browsing of pastoral rangelands results in changes of plant species composition, whereby some palatable species decline and those avoided by goats increase. To better understand and manage rangeland ecosystems, it is important to study such relationships between environmental factors and vegetation.

On Al Jabal Al Akhdar, the rangeland vegetation of Wadi Al Muaydin, near the central settlement Sayh Qatnah, shows different vegetation types along a steep altitudinal and grazing gradient. As such it mirrors the effects of altitude, grazing intensity, geology, landform and slope on plant species composition and diversity. Based on a hierarchical cluster analysis and a species indicator analysis, five vegetation groups can be defined and named after the most dominant species:

1. The *Sideroxylon mascatense - Dodonaea viscosa* group (Figure 1) occurs on grazed limestone derived soils at 2000 m. The most frequent species of the tree and shrub layer are *Dodonaea viscosa, Sideroxylon mascatense* and *Euryops arabicus*. The coverage of the tree and shrub layer is with 5-10% relatively low on plateau areas and gravel slopes. Additionally, the ground vegetation is sparsely developed with a plant cover ‹ 8%.

Figure 1. The *Sideroxylon mascatense - Dodonaea viscosa* group on disturbed places near Sayh Qatnah, Al Jabal Al Akhdar.

2. The vegetation on ungrazed sites can be characterised by the *Olea europaea - Fingerhuthia africana* group (Figure 2). *Grewia erythraea, Ochradenus arabicus, Ebenus stellata* and *Ephedra pachyclada* are frequent species within the shrub layer and the ground layer is well developed with a mean cover of 11%, a mean height of 35 cm and a high number of grass species (n = 11). *Fingerhuthia africana* and *Heteropogon contortus*, in particular, are characterised by high frequency and cover values.

3. At the intermediate altitudinal belt (1300-1700 m), the rangeland vegetation is characterised by the *Acacia gerrardii - Leucas inflata* group. *Euphorbia larica*, associated with dwarf shrubs such as *Leucas inflata, Aerva javanica, Blepharis ciliaris, Plectranthus rugosus, Abutilon fruticosum* and the endemic *Polygala mascatense* are dominant species in the ground layer.

4. On siltstone and shale at the upper altitudinal range (< 1300 m) the tree and shrub layer is dominated by *Moringa peregrina, Pteropyrum scoparium* and *Acridocarpus orientalis* and named as the *Moringa peregrina - Pteropyrum scoparium* group.

5. The *Ziziphus spina-christi - Nerium oleander* group is typically found on wadi sites. Wadi fans and plateau locations reveal the greatest variation in stand structure (Figure 3). The mean crown cover on wadi sites amounts to 44% (max. = 80%) with a mean tree height of 4 m and a stand basal area of 10 m^2 ha^{-1}, whereas on plateau sites the crown cover is less than 18% with a mean stand basal area of only 2 m^2 ha^{-1}.

Figure 2. *Olea europaea* associated with the grasses *Fingerhuthia africana* and *Heteropogon contortus* on a limestone plateau at Ras Al Kabul, Al Jabal Al Akhdar.

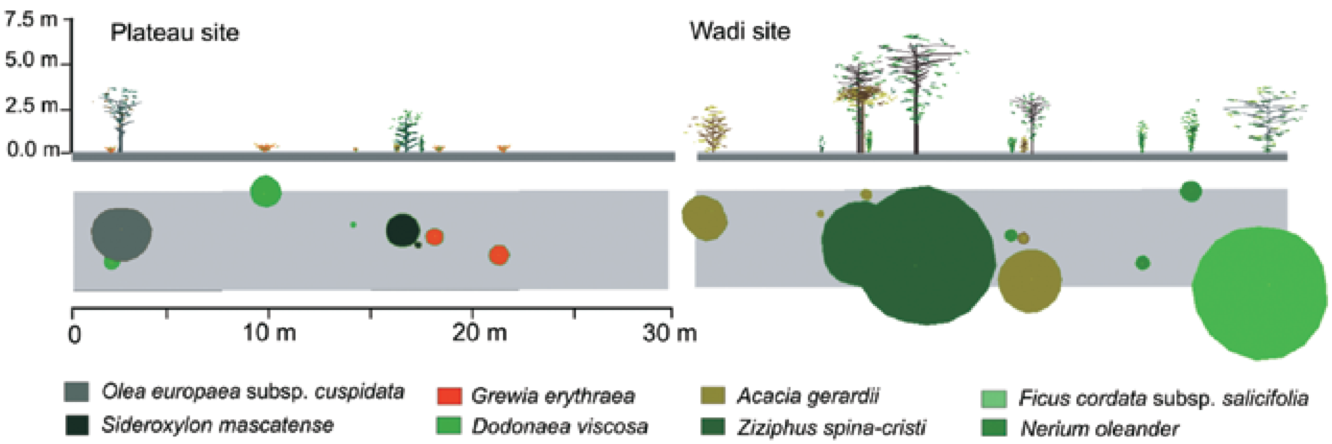

Figure 3. Stand structure of the rangeland vegetation on a typical wadi (right) and a typical plateau site on Al Jabal Al Akhdar (left) (Brinkmann et al., 2007).

Landform, altitude and grazing intensity seem to be the most important variables that distinguish between the different vegetation types of Al Jabal Al Akhdar, whereby plant species richness follows a unimodal distribution along the altitudinal gradient with the highest species number at 1400-1600 m (Brinkmann et al., 2009).

Recent Land Use Changes

In the past, the use of rangeland was regulated by rotational herding at selected locations, allowing grazing areas to regenerate. In some areas access was also controlled by the traditional 'hema' system whereby plants were cut for fodder when grazing conditions were poor. Today such conservation practices have been largely abandoned and, as a consequence, together with the increase in domestic livestock holdings, rangelands are over utilised. With the introduction of a well-developed network of roads since 1970, donkeys formerly used to transport merchandise across the mountain ridges, have been released into the wild and are now multiplying and grazing in uncontrolled feral herds. Overgrazing by goats and feral donkeys appears to be a serious problem, and many shrubs are now severely stunted. Altogether, the plants of 27% species at Al Jabal Al Akhdar show a high degree of browsing damage. The plant species most preferred by grazing animals (mainly goats and feral donkeys) are grasses, but trees and shrubs such as *Sideroxylon mascatense, Olea europaea* subsp. *cuspidata* and *Grewia erythraea*, as well as the dwarf shrubs *Leucas inflata* and *Polygala mascatense* are also popular. Dominant plant species in disturbed, overgrazed habitats are largely unpalatable; good examples are *Dodonaea viscosa, Euryops arabicus* and a few *Euphorbiaceae*.

Heavy grazing over a longer period of time will probably result in a decline of the diversity of plant species and the formation of monospecific stands of those perennial species most able to survive grazing pressure. Therefore, the conservation of wildlife and plant habitats at Al Jabal Al Akhdar will require the implementation of integrated conservation strategies for the agro-pastoral systems under transformation, including land use management plans.

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Chapter 8

Historic, Present and Future Role of Livestock on Al Jabal Al Akhdar Plateau in Northern Oman

Uta Dickhoefer and Eva Schlecht

Introduction

In the arid Sultanate of Oman, where most of the territory receives less than 100 mm of annual rainfall (FAO, 2008), water scarcity is the main constraint to people's livelihoods. The inter- and intra-annual variation in rainfall and the occurrence of drought periods severely limit the scope of irrigated oasis agriculture, due to their impact on the water flow from mountain springs (Siebert et al., 2007). Livestock husbandry is an opportunity to mitigate the drought-associated risk of cropping whereby goats (*Capra hircus*) and sheep (*Ovis aries*) can graze rainfed natural vegetation and provide meat, milk, hair, wool or leather to farmers. Until today the dung of livestock remains an important amendment in crop cultivation, maintaining fertility and preventing salinisation of the centuries-old irrigated oasis soils (Wichern et al., 2004; Luedeling et al., 2005). In other parts of the Arabian Peninsula such as in Yemen, donkeys (*Equus asinus asinus*), cattle (*Bos taurus*), camels (*Camelus dromedarius*) and horses (*Equus caballus*) are still used for draught power and transport services. Animals often also act as a savings account providing money when needed, and particular species, such as camels or horses, as well as the number of animals kept reflect their owner's social status and play an important role in cultural and religious contexts (Randolph et al., 2007). However, livestock husbandry can only be sustainable and continue to be beneficial to people's livelihoods if it is adapted to prevailing social, economic and environmental conditions.

The Historic Role of Livestock Husbandry on Al Jabal Al Akhdar

On the higher reaches of Al Jabal Al Akhdar mountains, an annual precipitation of up to 300 mm (FAO, 2008) results in a pasture vegetation characterised by open shrublands that gave the range its name 'The Green Mountain' (Chapter 7). In the past, two types of livestock keepers coexisted on Al Jabal Al Akhdar, the semi-nomadic pastoralists (formerly Shawawiya) and the sedentary farmers living in oasis settlements, combining livestock husbandry with crop cultivation (Scholz, 1976). Goats were and still are the main livestock in this region, because they are best able to climb the steep mountain slopes and access sparse vegetation growing on the cliffs. In contrast, the few sheep graze in the vicinity of settlements, while cattle are exclusively fed at the homestead.

Semi-nomadic Pastoralists

Since ancient times these semi-nomadic livestock keepers moved with their goat herds seasonally, upwards from the wadis during the winter and down into these valleys during the summer months. Besides their herds of sometimes up to three hundred goats, a few cattle and sheep were kept, as well as donkeys, as the primary means of transport for goods in Al Jabal Al Akhdar until the establishment of the road network in the mid 1980s. Moreover, pastoralists commonly owned small date palm (*Phoenix dactylifera*) groves and a few square metres of field crops in places with seepage of ground water or small springs. The seasonal movements of semi-nomadic herds covered only 2-12 km in areas < 80 km² (Scholz, 1976; Birks, 1978). At the seasonal campsites, goat herds were taken to the pastures in the morning and returned in the evening, when they were offered dried dates from the pastoralists' gardens as a supplement feed. Nevertheless, goat husbandry primarily depended on fodder provided by the natural vegetation. It was the key economic activity of the pastoralists, and the auto-consumption and sale of live animals and animal products in the mountain villages and on the lowland markets of Nizwa and Bahla provided the basis of their living (Birks, 1976).

Sedentary Oasis Farmers

The sedentary farmers in the villages of Al Jabal Al Akhdar traditionally combined livestock husbandry with the irrigated cultivation of food and fodder crops. Their herds of goats were smaller than those of the semi-nomadic livestock keepers and, therefore, mainly served for auto-consumption of livestock products. While the harvest from the gardens was the main commodity traded on the markets, only occasionally surplus livestock was sold (Scholz, 1984). The villagers' goats grazed on mountain pastures during the day (Figure 1), also partly used by semi-nomadic herders, but alfalfa (*Medicago sativa*), green barley (*Hordeum vulgare*) or maize (*Zea mays*) fodder cultivated in the terrace gardens and supplement feeds such as dates and dried sardines were offered to goats in the evening. Livestock manure collected from overnight enclosures was used as fertiliser (Figure 2) in the gardens (Scholz,

Figure 1. Herder accompanying village goats on their daily grazing itinerary on Al Jabal Al Akhdar.

1976). Since the semi-nomadic pastoralists owned more animals but cultivated smaller gardens, they increasingly sold their surplus manure to sedentary farmers.

Present Role of Livestock on Al Jabal Al Akhdar

Since 1970, Oman has undergone rapid economic and social modernisation based on the increasing exploitation and export of oil and natural gas. These changes have profoundly affected the traditional livestock husbandry both directly and indirectly, and Oman's population growth resulted in increased meat consumption and an increase in livestock numbers (WRI, 2003; Table 1).

Table 1. Population, annual meat consumption and livestock numbers in Oman (WRI, 2003).

Indicator	1992	2002
Population (1000 persons)	1,978	2,444
Annual meat consumption (kg per person)	37	50
Livestock numbers (1000 heads)		
Goats	800	1,018
Sheep	248	361
Cattle	180	320

Today, Oman's excellent road network and the availability of four-wheel drive vehicles has largely eliminated the role of donkeys for transport, which continue to be used only in a few inaccessible areas for the transport of harvested products and manure between gardens and homesteads. Improved mobility of people has also enabled an intensified exchange of goods between the markets of Nizwa and Bahla in the country's interior and the coastal regions and a great variety of goods has, therefore, become available to the mountain dwellers (Melamid, 1992). Imported, often cheaper, foodstuffs have reduced consumer dependency on locally produced staple crops such as wheat and vegetables but also lowered marketing opportunities for oasis farmers. Rising expectations have further contributed to the search for additional income and many men have migrated from remote mountain regions to urban centres in both Oman and neighbouring countries to seek employment. The absence of male household members, together with easier purchase and transport of supplement feeds, means that livestock husbandry in the mountains is less dependent on the natural vegetation and has, therefore, contributed to the sedentarisation of the semi-nomadic pastoralists, which started in the mid 1970s. Semi-nomadic pastoralists ceased their seasonal moves with their livestock and today, like the sedentary oasis farmers, frequent pasture areas in the vicinity of their homesteads (Birks, 1976; Scholz, 1976).

The increasing importance of non-farm income also poses a major threat to labour-intensive agriculture in mountain oases. Socio-economic interviews conducted in autumn 2006 in forty-one households of three oases (Ash Shuraijah, Al Qasha and Masirat Ar Ruwajih on Al Jabal Al Akhdar) revealed that thirty of them kept goats or sheep. In twenty-six of these, at least one member earned an off-farm income other than a pension or social-aid payment by the government. This means that men are often only able to work in gardens during weekends, and livestock husbandry has mostly been taken over by the women. The feeding, milking, cleaning of stables, harvesting of cultivated fodder in the gardens, as well as the collection of foliage and grasses in the mountains, can

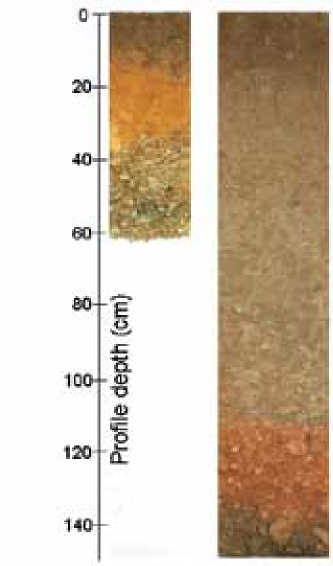

Figure 2. Soil profiles of the date palm-planted upper (left) and crop-planted lower (right) part of the Mazra terrace system in the mountain oasis Biladsayt at Wadi Bani Awf in the northern Hajar range. Note the difference between the brown-gray, silt-rich upper layers of this profile consisting of fine wadi sediments, of which an estimated 100.000 t were carried by hand over the centuries from the wadi bottom to the man-made terraces and enriched with large amounts of animal manure. The lower layers of the profile show a reddish, stony and rapidly draining structure (Luedeling et al., 2005).

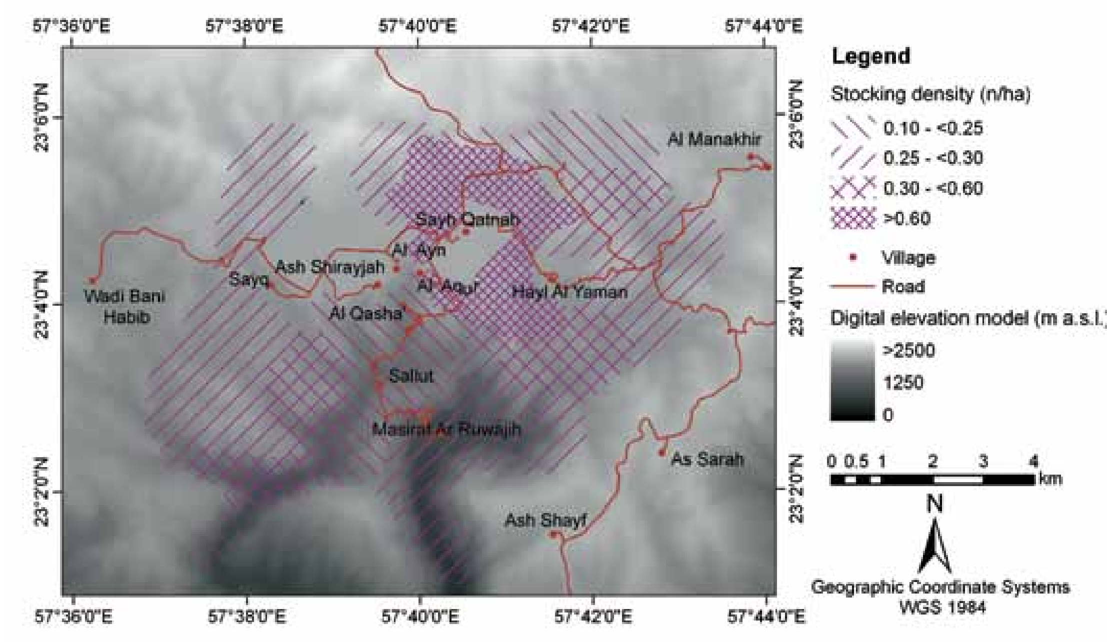

Figure 3. Map showing the stocking density of goats and sheep on the Saiq Plateau and in Wadi Al Muaydin, Al Jabal Al Akhdar, according to farmers' information and 2007 census data.

take up to six hours a day. Since household members may also spend up to eight hours a day with their goats in the mountains, current livestock husbandry practices are very labour-intensive.

Farmers are still offering cultivated fodder, dates and dried sardines as the traditional supplementary feeds, but Rhodes grass (*Chloris gayana*) hay from Batinah farms and wheat or rice (*Oryza sativa*) bran have become readily available as supplements in modern livestock feeding. Nevertheless, natural vegetation is the main source of fodder for goats, supplying 47% to 71% of their daily intake even after long dry periods, which shows the high reliance of goat husbandry on the natural resources. With 60% of goat herds consisting of less than fifteen animals in the households that were studied, oasis farmers still keep considerably less animals than the formerly nomadic livestock keepers of the Al Hayl region on Al Jabal Al Akhdar (Figure 3). However, despite the small herd sizes and the fact that the use of small ruminants for hair, wool or leather has lost its significance nowadays, livestock still fulfills several functions. The slaughter of cattle, goats and sheep on holidays and to honour guests remains an important part of Oman's religious and cultural heritage (Zaibet et al., 2004). Since livestock prices are high, the sale of goats can contribute significantly to a household's income. The modernisation of traditional terrace agriculture on Al Jabal Al Akhdar began with the introduction of mineral fertilisers and pesticides, and thirteen of the forty-one households interviewed in 2006 are now regularly using mineral fertilisers. However, even though these are applied to selected crops, livestock dung remains the main source of nutrients and the only source of organic matter in crop cultivation.

Future Challenges for Mountain Livestock Husbandry

Modernisation in the Sultanate of Oman did and will continue to affect the social, economic and environmental conditions for livestock husbandry on Al Jabal Al Akhdar. The decrease of Oman's rural population from 32% in 1992 to only 21% in 2002, due to migration from remote regions, such as Al Jabal Al Akhdar, to urban areas, has been accompanied by a reduced proportion of the total labour force working in the agricultural sector from 45% in 1990 to 35% in 2002 (FAO, 2008). Women, who mainly work in rural livestock husbandry, are increasingly seeking employment. This is reflected in the doubling of the number of economically active women from 63,000 in 1992 to 135,000 in 2002 (FAO, 2008). The diminishing availability of rural Omani labour will be a major constraint to traditional, labour-intensive agriculture in the mountains, and can only partly be compensated for by an increase in hired, mostly expatriate, labour. Even if agriculture persists under modified social conditions, the loss of traditional knowledge associated with the agro-pastoral systems may threaten its sustainability.

Depending on the gender and experience of the herder, as well as a family's or village's legitimate pasture area (Figure 3), today's goat herds may cover distances of 12 to 20 kilometres during a typical grazing day, resulting in high energy expenditure of goats for maintenance and locomotion (Schlecht et al., 2009). Since pasture vegetation as the main source of fodder is of low nutritional quality, the daily feed intake of goats just covers their basic requirements and, in particular during dry seasons, appears to be insufficient for animal growth. Although farmers are increasingly offering purchased supplements these are used inefficiently, resulting in decreasing returns-to-scale (Zaibet et al., 2004). Furthermore, farmers (n=14) interviewed in the winter of 2007/2008 mentioned diseases as a main problem in livestock husbandry, despite cheap veterinary services provided by the government. Apart from pathogenic infections, the causes for diseases seem to be linked to herd management and animal nutrition. Consequently, the productivity of goats is limited under current herd management and feeding practices.

Another constraint to goat husbandry is the rapid decrease in the area available for grazing due to the increased construction of roads and houses, especially on plateau areas. The main town on Al Jabal Al Akhdar, Sayh Qatnah, for example, has only developed in the last decade and already covers an area of about 180 ha. The rotational utilisation of pastures formerly spread grazing pressure more evenly across different areas, but today periods of pasture rest have been replaced by year-round grazing in the same areas, partly due to the sedentarisation of the semi-nomadic population and the reduced allocation of skilled labour to herding (Birks, 1976; Scholz et al., 1976). Increased grazing pressure, exerted by the goats as well as by the liberated donkeys that have multiplied well in the wild, has reduced the quantity and quality of available fodder and, therefore, the carrying capacity of the landscape. The lack of pasture fodder, particularly in dry periods when farmers also cultivate less fodder crops, is and will continue to be a major constraint to livestock husbandry on Al Jabal Al Akhdar.

Conclusions

Livestock husbandry has been an important activity of Oman's rural population for millennia, and was flexible enough to respond to highly variable environmental conditions. Its importance will persist in the future, which is reflected, for example, in the population's increasing meat consumption, high prices and consumer preference for Omani livestock and meat on local markets, and the continued use of animal manure in crop cultivation. However, simply increasing goat numbers or giving animals purchased feed can neither solve the main constraints of livestock husbandry nor improve animal production. In contrast, an effective management scheme adapted to seasonal fodder availability and the nutritional requirements of the animals is needed to improve animal production and the economic efficiency of goat husbandry. Under current management practices any increase in animal numbers to raise income from livestock husbandry would not only increase the labour demand beyond the available labour force, but also exceed the carrying capacity of already overgrazed natural vegetation. In contrast, an optimised herd management system that includes skilful herding and careful management of pastures will reduce overall labour demand, disease and mortality rates, and thus improve herd productivity. Pastoral management that is adjusted to the physiology of the local vegetation, and the demarcation of sufficiently large areas for livestock grazing would allow a rise in income from livestock without threatening the sustainability of the natural vegetation. Hence, only by social, economic and environmental fine-tuning, will livestock husbandry remain sustainable and continue to further benefit peoples' livelihoods. As such it will deliver income and food, enabling farmers to fulfill their religious and cultural obligations and maintain its role as an essential part of a unique mountain agricultural system that is a millennia-old cultural heritage of Oman.

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Chapter 9

The Architecture of Omani Oases: A Mirror of Social Structures

Lorenz Korn

Over the last thirty years Oman's infrastructural development has led to profound changes in the architecture and urban layout of most of the country's oases (Scholz, 1999). Some settlements have completely altered their appearance, so much so that a traveller from the 1960s would no longer recognise them. Constructions of reinforced concrete, houses with large mirror-glass windows, villas with balconies and sloped roofs, and shopping malls with illuminated boards determine the architectural impression but old structures have managed to survive too, though often hidden and sometimes partly in ruins. The appearance of old structures is marked by traditional building types and vernacular construction techniques as they were erected from locally available materials, reaching an optimum in adaptation to the climate whether on the coast, in the flat region of the Batinah, in the Al Hajar Mountains or in the wadi regions of the Interior. The traditional settlement architecture of Oman is very rich and varied, and a few classical publications have stressed the cultural heritage value of Oman's historical buildings (Dinteman, 1993; Al-Qila', 1994) with recent studies being undertaken to document and analyse the surviving structures in more detail (Damluji, 1993; Gaube, 2008 ab; Korn, 2008).

General Features of Settlement Structures

A marked difference in the overall structure of settlements can be noted between the larger cities on the coast and the oases of Oman's interior. Sohar in the northern area of the Batinah (Wilkinson, 1997; Kervran, 2004), Qalhat on the east coast (Bhacker, 2004) and Al Balid (today part of Salalah) in the southern part of the Sultanate (Costa, 1977) were places which played an important part in the history of the country. Their economic basis was mainly maritime trade that connected them with other 'Islamic cities' around the Gulf, the Indian Ocean and the Red Sea. With a population of several thousand each, they were densely built up and their perimeter was marked by an impressive city wall, at least in the cases of Qalhat and Al Balid. In the centre of these cities, a large Friday Mosque served for communal prayer, and market areas (souqs) served the local inhabitants.

The layout of typical oasis settlements differs from this pattern. Only in exceptional cases, such as the oasis of Al Hamra, does the built-up area of a large oasis constitute a unified single block (Figure 1); in most cases it is composed of several smaller settlements. Even in the largest oasis of Inner Oman, Nizwa, capital of the Imamate for centuries, there were (and still are) several settlement clusters distributed over the whole oasis. The central 'quarter' *(hara)* of Al 'Aqr stood out from the others because it was located next to the fort and its size was considerably larger. The walls of Al 'Aqr, with their projecting towers, were high, the gates firm, and the houses stately, thereby contributing to the image of a real city. However, the Friday Mosque of Nizwa was not built within Al 'Aqr itself but outside its walls, and mosques within its walls were no larger than those in other quarters.

Figure 1. In the oasis of Al Hamra at the southern foot of the Western Al Hajar Mountains, houses rise from the *falaj* at the border of the palm grove.

The distribution of settlement clusters across the territory of an oasis usually makes use of important features of the topography: the largest quarter of Nizwa is located on the banks of the wadi and takes a central position within the whole oasis. Obviously even more adapted to the topography is of course of the largest irrigation canal *(falaj)*. Finally, it can be observed that large *haras* occupy a slightly elevated territory, frequently at the foot of a hill or a mountain (Figure 1 and 2). This way the use of valuable arable soil for building residential areas was avoided and the fortification of important parts of the settlement became easier.

In the oasis of Ibra in Sharqiyah, the quarter of Al Qanatir shows these principles in a nearly ideal manner. The thoroughfares are laid out evenly along the foot of a steep hill, following the contour lines of the area. One street runs parallel to the wadi bordering it to the east and connecting Al Qanatir with the adjacent quarter of Ksham in the north, separated only by a sequence of gates. To the south, this street leads to the market *(souq)* and the Friday Mosque, both of which occupy a central position between different haras. Another main street runs in an east-west-direction. Over the junction of the two streets, a tower with large thoroughfares has been built, marking the centre of the *hara*. Quite naturally, the larger houses of the quarter are concentrated on the main streets (Figure 3), while the areas to the rear feature smaller houses built for the poorer population.

The neighbourhood of Al Qanatir, with the adjacent quarters of Al Dhaghshah and Ksham, was fortified with a continuous line of buildings positioned adjacent to each other against outside threats, with gatehouses to the north and south. The western side, where the houses offer little protection against the plain, is defended by a wall with a gatehouse and several towers. From the western gate northwards, the wall extends uphill in the direction of a freestanding tower that overlooks the whole oasis. On the southern side, the line of defence continues with weaker walls bordering the palm groves, and with two single freestanding towers. The fortification of the three neighbourhoods was integrated into the oasis-wide defence system.

Figure 2. In Al Hamra, houses of two and three storeys are built directly onto the rock's surface.

The oasis of Ibra has another important feature in common with other Omani oases: it is divided into 'upper' *(alaya)* and 'lower' *(sufala)* sections and named according to the settlement's position on the stream of the wadi. Each part had its own *souq* and a main mosque in the centre. Socially, the population was organised along tribal lines. Thus, upper Ibra was inhabited by the Masakira, while the quarters of lower Ibra were populated by the Hirth tribe. Likewise, the two large walled units that form the central part of the oasis of Izki were inhabited by two tribes, and in both cases, could be defended independently. The large open areas in between could be used for markets, but also functioned as buffer zones between the tribes. Similar layouts of urban and semi-urban settlements that mirror the structure of society can be found across the Arabian Peninsula (Gaube et al., 2008ab). It is of little surprise that the subdivision of the individual quarters *(harat)* within the larger parts of the oasis settlements followed the lines of kinship (Figure 3). Different families had clear majorities in one quarter, although no strict spatial separation existed (for Ibra see Le Cour Grandmaison, 1977; for Manah see Bandyopadhyay, 2004).

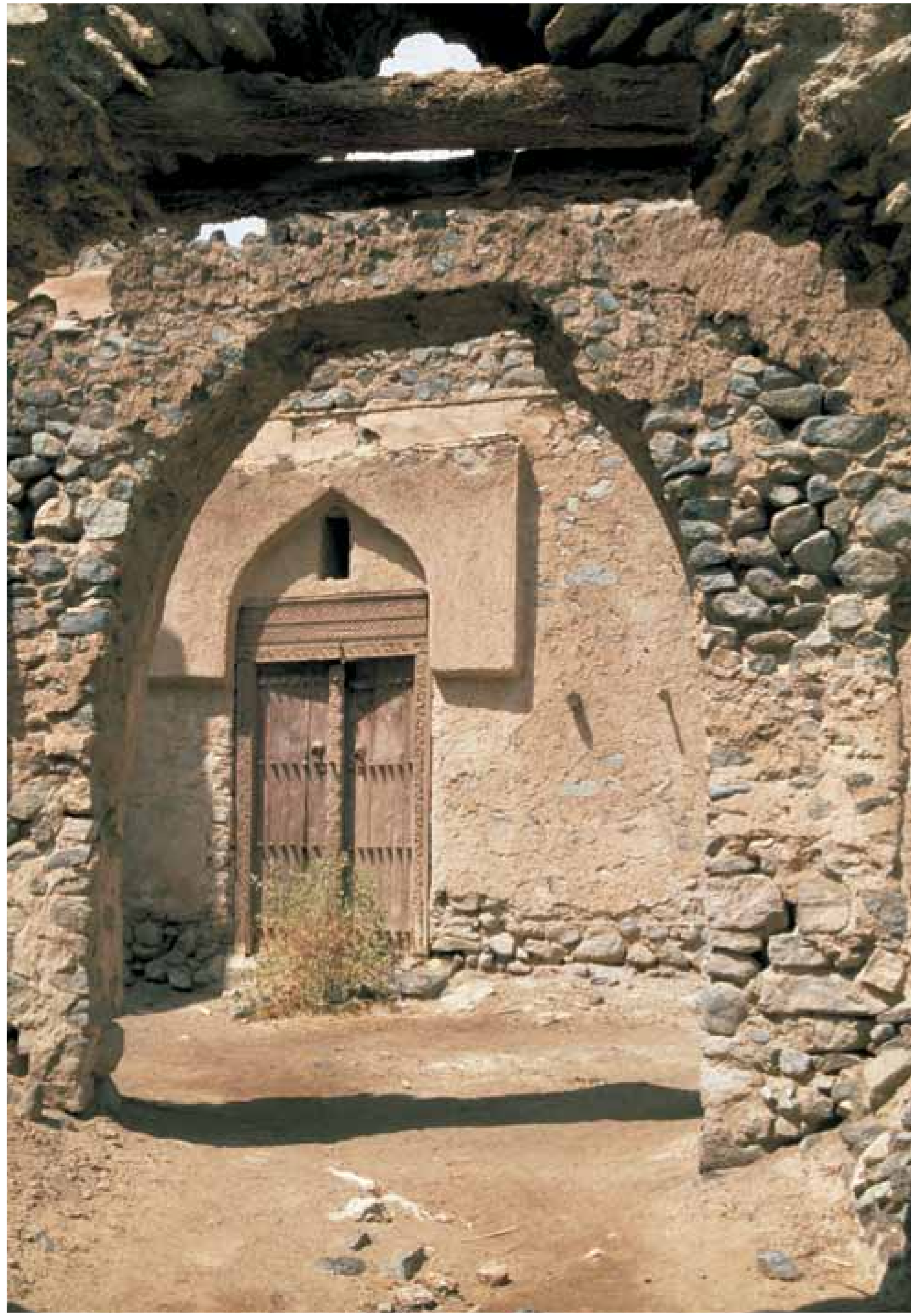
Even in the otherwise exceptional little coastal town of Tiwi, the bipartite structure can be clearly recognised in the division of the old town into the two parts of Al Ramla and Al Raf'a, inhabited by the Muqimi and the Salti tribes respectively (Korn et al., 2004). However, it is evident that the structural divisions and subdivisions of the settlement did not prevent the joint activities of their inhabitants. The building and upkeep of all mosques were common duties for the whole of the *hara*, and the same was true, at a higher level, for the main mosque of any oasis. In the case of the oasis of Bahla, there was also the common task of building and maintaining a defence wall that encircled the entire oasis and measured more than eleven kilometres long. According to local tradition, each quarter of this oasis had to care for the upkeep of a distinct section of the wall (Korn, 2008).

In contemporary times, it can be said that the administrative units of oasis towns continue to find their visible expression not only in traffic signs and office buildings for administrative purposes, but also in the building of major mosques. These may be located either at the site of a former Great Mosque, for example in Nizwa, or on 'neutral' territory, such as in Ibra, where the Sultan Qaboos Mosque occupies an area near the main road between the former tribal sections, or on a piece of land separate from the former central parts of the oasis, such as in Bahla or Tiwi (Gaube, 2008ab).

Residential Houses

Traditional housing structures in the oases of Oman had various shapes, depending on the owner's economic circumstances, social status and, more importantly, the characteristics of the location (geology, topography and climate; Damluji, 1993; Gaube, 2008ab). Such differences were expressed in the use of materials and construction

Figure 3. Access to individual quarters was regulated by walls and gates. Such as here in the Al Dhaghshah quarter of Ibra, large houses were normally located on the through road.



techniques as well as in the plan and height of the house. Throughout the regions of Oman, residential architecture also clearly shows regional differentiation, and the manner of constructing a house was very much determined by traditions and practices of experienced builders that were handed down from one generation to the next (Damluji, 1993).

In large oases, such as Nizwa and Al Hamra, at the southern end of the Western Al Hajar Mountains, houses were mostly constructed of mud brick; in Al Hamra the walls of the ground floor were erected directly onto the surfaces of bare rock (Figure 2). Rising to a height of nearly 15 m, the large houses of wealthy families had up to twenty rooms over three storeys. Towards the exterior, they formed a rather unified block, while the interior presented a complex arrangement. Courtyards are rare and were mainly used for improved lighting and ventilation. The ground floor, adjacent to the entrance area, was used for storage and as stables. The reception hall, family living rooms and kitchen were located on the first and second floors, and were connected with more than one stairway. While the ground floor had no windows except for ventilation slits high up under the ceiling, the upper storeys had numerous windows. The walls of living rooms featured high arched niches in which household items could be stored (Figure 4). The ceilings were normally constructed of quartered palm tree trunks with several layers of palm branches, palm fibre mats and clay over them. Decorative painting of the wooden beams, sometimes with inscriptions, can still be seen in many places. The exterior appearance of these houses featured carved wooden window grilles, which played an important role, as did the wooden doors with carved frames and leaves. Inscriptions on the central field of the door or the upper beam of the frame frequently contained the construction date and the name of the owner who commissioned the building of the house.

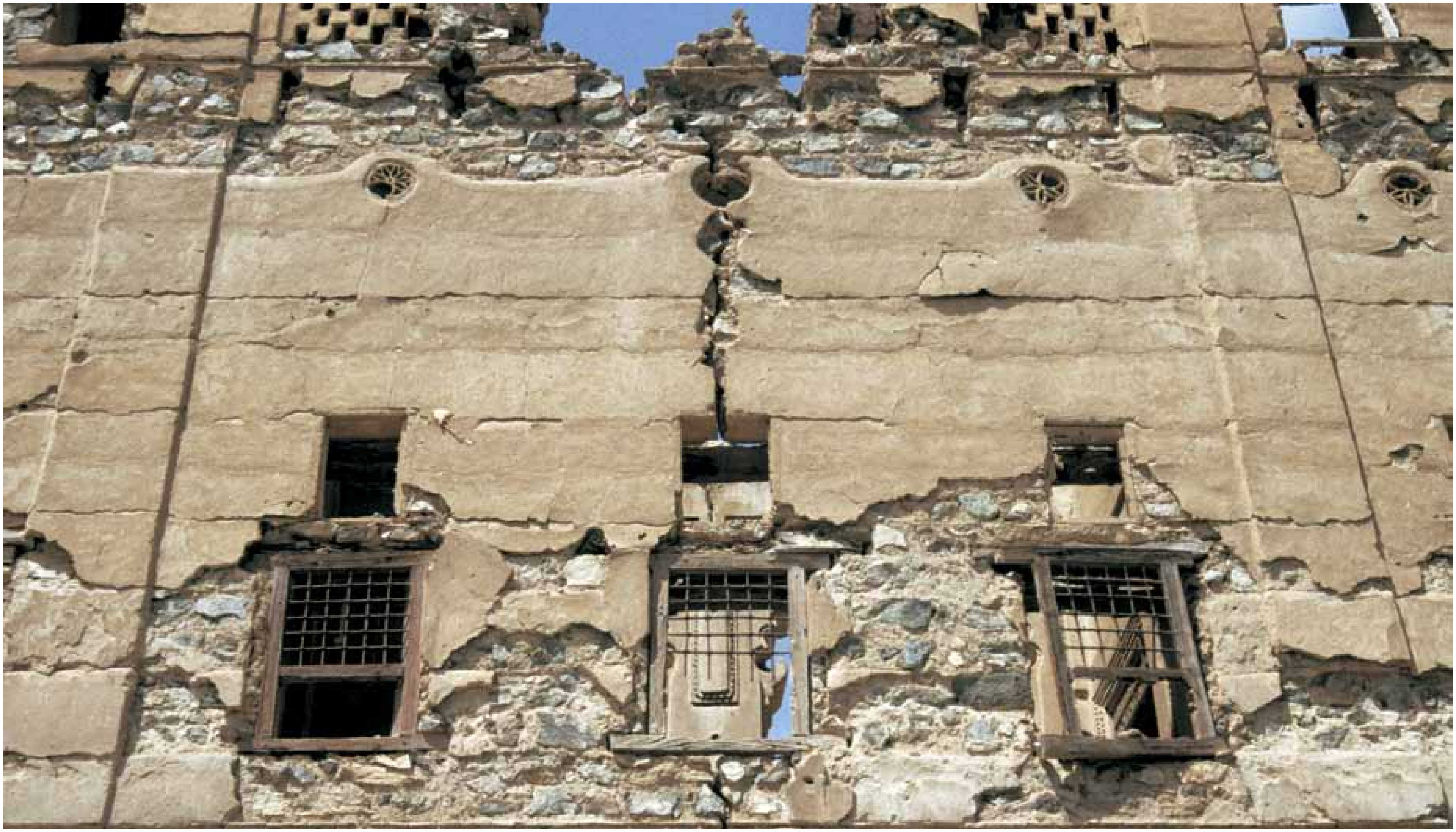
Several features helped to optimise the interior climate of the buildings. Apart from the thickness of walls to buffer temperature fluctuations, ventilation played a key role. Openings were placed high up in the walls under the ceiling, through which warm air could escape, and cooler air streamed through the windows or small openings slightly above floor level, leading to a chimney effect. In some houses of oases in the Sharqiyah region, arched loggias that open from the upper floor to the exterior still exist. Many buildings were erected within or directly adjacent to a palm grove so that the humid cool air evaporating from the irrigated land could be felt in some parts of the houses.

Houses in oases of the Sharqiyah were frequently built of stone with layers of mud used as mortar and a mud plaster coating (Figure 5). Arched openings were constructed with pre-fabricated frames of stucco and palm branches. The large houses in Upper Ibra were

Figure 4. The large Bait Husn Al Shubbak in the upper part of Ibra had once elaborate reception halls on the first floor.

built as unified blocks, with complex interior arrangements similar to those described above. The staircase from the ground floor typically led to a small courtyard, from which individual rooms could be reached. In the large houses of Al Mudayrib, rooms on the second floor opened out to the courtyard with arched loggias (Bonnenfant et al., 1977). The noble houses of Ibra - Al Manzafah, which were built during the 18th century by wealthy merchants with large properties in East Africa, follow a similar layout, but the courtyards tended to be larger and reached down to the ground floor. In these houses, the arched openings of the loggias were decorated with a polylobate profile, probably inspired by the Indian practice, which gave the interior facades a palace-like appearance. To the exterior, in some cases corner towers underlined the appearance of a fortified dwelling. In these houses the length of palm trunks used for the ceilings limited the size of rooms to a width of 3.5 m and arcades were used to support the ceiling in only very few cases, thereby creating a particularly large reception room.

Figure 5. In Ibra – Al Manzafa, residences of wealthy merchants were built in the 18th century.



The division of 'public' and 'private' zones within the house had its architectural expression in a spatial separation that was not always strictly observed. Reception rooms were usually on the first floor, very often located above the entrance, and directly connected with the vestibule on the ground floor and its waiting benches by a staircase. This way, visitors could enter without interfering with the space used by the family.

Figure 6. The built structure of the mountain oasis of Maqta is marked by simple constructions, huddled together for increased security.

Obviously, houses in mountain oases did not display the same level of sophistication as those of the rich merchant dwellings in flat land oases such as Ibra. Limited economic resources and space restrictions in an often-steep topography resulted in a different architecture (Figure 6). At Misfat Al Abriyin, the houses were built on and around huge boulders of rock, and rough stone was used as the main building material. It seems that the constructions were successively enlarged in an agglutinating manner with houses being built closely together, thus creating a complex that could be easily defended. Sometimes even walkways were spanned with beams on which rooms that connected the houses across the alley were built.

In the small town of Tiwi (Korn et al., 2004), located on Oman's east shore, the architecture of houses followed a scheme different to that of the oases in Oman's interior, although structurally this settlement is connected with the coastal cities of Sur and Sohar (Kervran et al., 1983). Despite the relative density of buildings in the old centre of the town, all houses were laid out around a courtyard in small modules of rooms. Most typical was the two-storeyed residential wing with large external windows: the lower storey comprised stables or storage rooms with an arched front portico, while the reception room or living room was on the upper storey with a terrace on the courtyard side. The large windows on the outside were designed to capture even the slightest breeze in the particularly hot, humid climate.

Modernisation and the Challenge of Heritage

The intense change that the Sultanate of Oman has experienced over the past forty years was bound to exert a deep impact on the architecture of all settlements. New sources of income, together with a growing population, created a need to build new residential houses and to expand settled areas, and this has profoundly altered the appearance and structure of oasis settlements. While kinship remains an important factor for the location of new house constructions, the typological change in architecture creates facts for social intercourse and social order. The detached individual house with a surrounding open space, separately fenced or walled, now appears to be the preferred way of organising family life in a spatial arrangement much different from that of densely built traditional oasis settlements, and in accordance with the ideal of motorised individual traffic. Modern construction techniques, and the training and visions of architect-engineers who have mostly migrated from Asia to the Sultanate, have resulted in the building of residential houses that dispense with the traditional experience and introduce new qualities. One major consequence of this building style is the high amount of energy needed for climatic conditioning, while another is the possibility of shaping the exterior facades according to new fashions, with previously unknown decorative elements including large coloured-glass windows over painted imitation brick surfaces to fancy columns, pediments and balustrades.

Meanwhile, the old oasis settlements have also experienced a variety of changes. In many places simple abandonment and partial destruction can be observed: with the fast decay of mud-based architecture, maintenance is abandoned inevitably leading to the loss of many traditional buildings and settlement structures. In other places, the construction of new houses as replacements for old buildings results in a loss of built substance but renews or preserves the overall structure of the settlement. It remains a major challenge for the future to preserve at least part of the heritage of Oman's unique millennia-old oasis settlement culture. Since technical and social change have already profoundly altered the needs and requirements for the design and architecture of residential structures, it is important to develop concepts for the possible use of restored traditional houses, and to establish a practice for their restoration and preservation, enabling coming generations to experience part of the fascination of the architectural heritage of Omani oasis settlements.

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CHAPTER 10

UNVEILING THE PAST: THE ROLE OF ORAL HISTORY IN UNDERSTANDING OASIS DEVELOPMENT

BIRGIT MERSHEN

Well into the mid-twentieth century, prior to the development of a modern educational sector that encompasses all areas of the country, and prior to the founding and publication of the first daily newspaper in Oman (Al Watan in 1971), the spoken word continued to be an important tool in handing down knowledge, skills, local history, folk stories from one generation to the next (Mershen, 2004a,b). This can be still appreciated when listening to a lengthy traditional Omani greeting, at the climax of which are questions about news and events (Carter, 1982).

Figure 1. Recording oral history on Al Jabal Al Akhdar.

'Oral history', as used in the social sciences, is commonly defined as the recording of people's memories and life experiences (Ritchie, 2003). As such it ideally reflects a person's own experience thus constituting an eyewitness testimony rather than a hearsay account (Figure 1). One of the great advantages of oral history is its coverage of historical events and of virtually all aspects of daily life; furthermore the fact that it operates independently from an educational background and other possible social or gender-related boundaries means that it does not exclude potential narrators.

Settlements abandoned some forty to twenty years ago provide a vivid testimony of pre-Renaissance ways of life. They are archives in mud-brick and stone that can tell tales and act as keys that open doors into a recent, yet distant, past. Many former inhabitants of these settlements for whom today's ruins were once home, place of work and area of social gatherings are still around to answer questions and provide information on all aspects of life at the respective sites. Oral history relating to these settlements provides an excellent opportunity to correlate spatial organisation, architecture and material culture, and the socio-economic, cultural and political processes that have shaped them or were shaped by them (Mershen, 1998).

For the documentation of and research on the development of oasis settlements in Oman, eyewitness accounts have been instrumental in understanding the spatial use and function on different levels; not only have they been crucial to finding out about the division and use of space within individual rooms or dwellings, but they have facilitated the interpretation of socially or seasonally conditioned use of buildings or particular parts of a dwelling (Al Harthy, 1992) or provided information on social stratification.

At the larger spatial level, oral history provides information on environmental and other conditions shaping human preferences and decisions about domestic architecture, settlement processes and land use, on migration patterns between seasonally occupied settlements, as well as on land use restrictions, such as those exemplified in traditional pasture reserves, for example the hamya system in Wadi Bani Awf (Insall, 2001). Also the specific functions and use of particular artifacts and structures in dwellings and in open communal spaces, such as a range of food-processing installations including subterranean ovens, date cooking facilities, communal mill installations or rock depressions for grinding, would often have remained unclear without the elucidations of local people. Based on informants' accounts, shallow depressions on a rock surface in Misfat Al Abriyin, for example, could be identified as an open-air 'workshop' where women extracted oil from the seeds of the shu' tree (*Moringa peregrina*), while depressions arranged in two rows on a rock surface in Wadi Bani Kharus could be identified as a 'game board' on which 'hawalis', a local game, was played, to cite but two examples.

Figure 2. Man-made agricultural terrace of enormous dimensions in Wadi Bani Kharus.

The use of oral history and traditions has also helped correct previous misinterpretations of some structures, and explain the function and history of an enormous terrace with walls of cyclopic dimensions in Mazra'at Sana'a, Wadi Bani Kharus (Mershen, 2001; Figure 2), as a man-made agricultural terrace rather than a huge water reservoir (Parry, 1998). In another case it enabled correct interpretation of an isolated building standing at the edge of a cemetery in Wilayat Ibra, which was littered with conspicuous amounts of ceramic sherds, as the town's old quarantine station, formerly used for epidemic control, particularly for sufferers of leprosy and smallpox (Mershen, 2004a; Figure 3).

Figure 3. Right: An old quarantine station standing at the edge of a cemetery that in the old days was used to accommodate sufferers of contagious diseases, such as leprosy and smallpox in Ibra. Left: Inside of same building with remains of pottery vessels, used to provide the sick inhabitants of the quarantine station with food.

The recourse to oral informants is indispensable when recording the spatial range of social exchange networks, such as those expressed in inter-marriage patterns or in trade networks, or when identifying and locating traditional footpaths and donkey tracks networks through the mountains (Mershen, 2002).

'Oral history' should be differentiated from 'oral traditions', which may consist of orally transmitted historical accounts, folk legends, genealogies and narratives. The latter refer to developments or events that are beyond the living memory of the narrator (Mershen, 2004b).

Toponyms that have been traded down through the generations can be a rich source of a settlement's history, as place names tend to be conservative and retain the names of events, individuals or groups of people who were once associated with it in one way or another, long after they have left the area. Thus in Misfat Al Abriyin, a particular section of the oasis' gardens is called Suwar Bani 'Amr, describing the gardens irrigated by a particular water gate (*suwar*) of the *falaj* channel (*saqiya*). The land does not belong to the Bani 'Amr and local informants had no explanation for the toponym, however, historical sources mention the role of Bani 'Amr in the context of the struggle for territorial hegemony in Al Hamra and thus point toward a plausible explanation (Wilkinson, 1987). Other power struggles thought to have taken place when the 'Abriyin were settling in the area and that are referred to in historical sources concern disputes with the Bani 'Adi (nickname for Bani Adawi) from Wadi Sahtan (Wilkinson, 1987). The name of a graveyard on the highland above Misfat Al Abriyin, and an oral tradition relating to it that is narrated in the village, provide an interesting anecdote to this dispute. According to the story, a feud between the two groups had reached a climax when the inhabitants of a village in Wadi Sahtan decided to raid Misfah during the time of the Eid prayer, when all the men would be out of the village in the musallat al Eid. A woman married and living in Wadi Sahtan, who originated from Misfat, is said to have learnt of the plan and secretly traversed the mountains during the night. She reached Misfah, warned her people and returned the same night without anybody in Wadi Sahtan noticing. The men of Misfah, who heeded the warning, took off into the mountains in the night before Eid, hiding behind the rocks. As expected the attackers arrived in the mountains and camped on the plateau above Misfah, so as to start their attack early the next morning. Their plan was destroyed by the nocturnal surprise assault by the men of Misfah, and the dead were buried on the spot. The graveyard was henceforth called *maqbarat Bani 'Adi* (Bani 'Adi cemetery).

Oral history has, without doubt, to be considered as a primary source for historical information, though it has to be acknowledged that the information obtained is not always accurate and unbiased. Distortions and deviations may further increase when dealing with oral traditions reaching beyond the realm of living memory.

Some of the limitations of oral history and traditions regarding the social and tribal history of abandoned quarters have been summarised by Bandyopadhyay (2004). These relate to the fact that fading memory makes detailed recollection of facts more and more difficult over the decades, when people who had formerly lived in particular houses had left, and when changes in the ownership of buildings were not known. Carter (1982) vividly describes how, due to the power associated with knowledge about tribal details, this knowledge is only reluctantly — if at all — shared with outsiders. Ultimately oral traditions referring to tribal issues will convey as Carter (1982) wrote, '... what the Omani tribesmen themselves say about their origins and tribal structures.'

It is evident that the verification of oral information will often depend on crosschecks with similar data from other informants, as well as with information from other sources, such as written historical references, documents, archaeological and material cultural data, or inscriptions.

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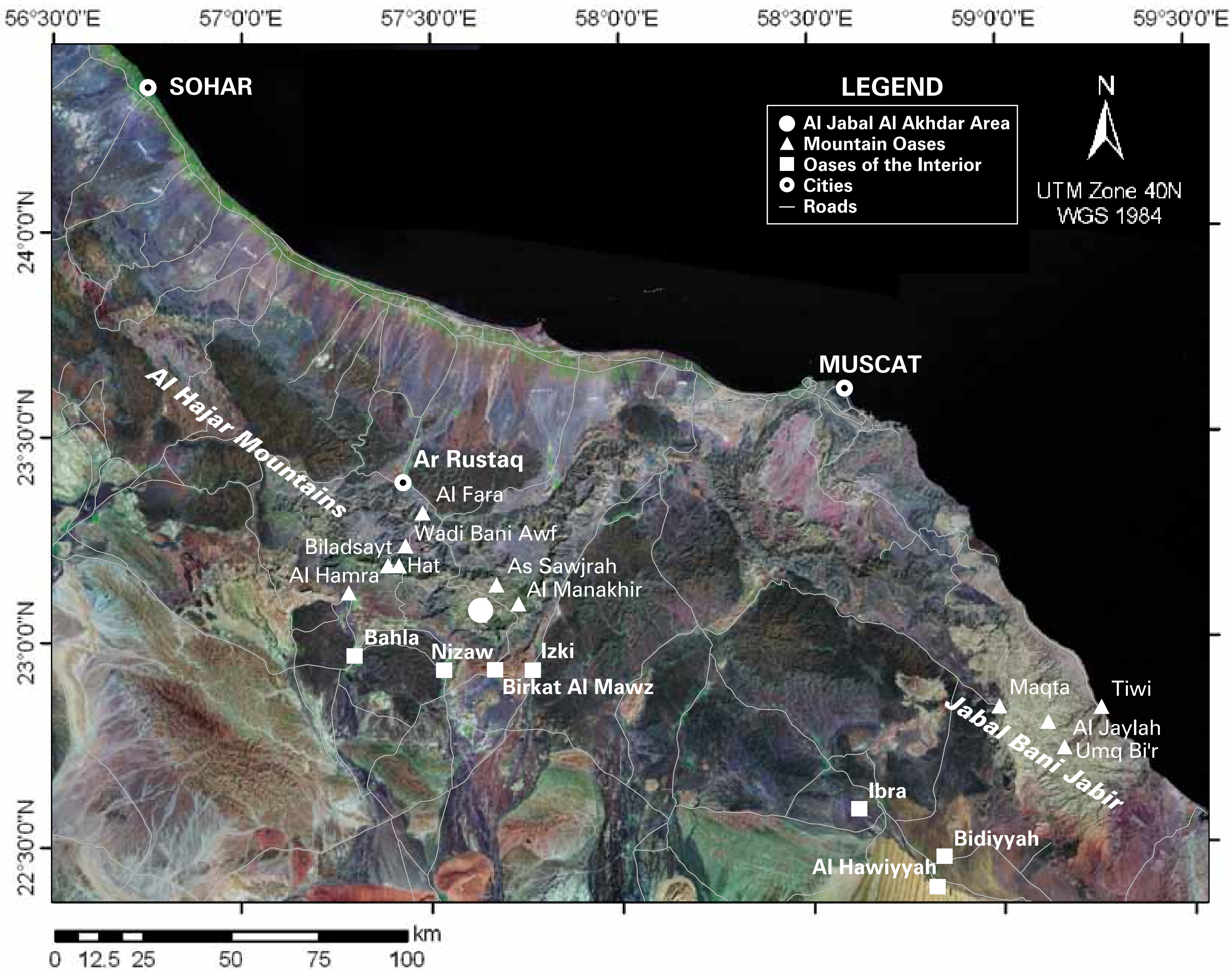
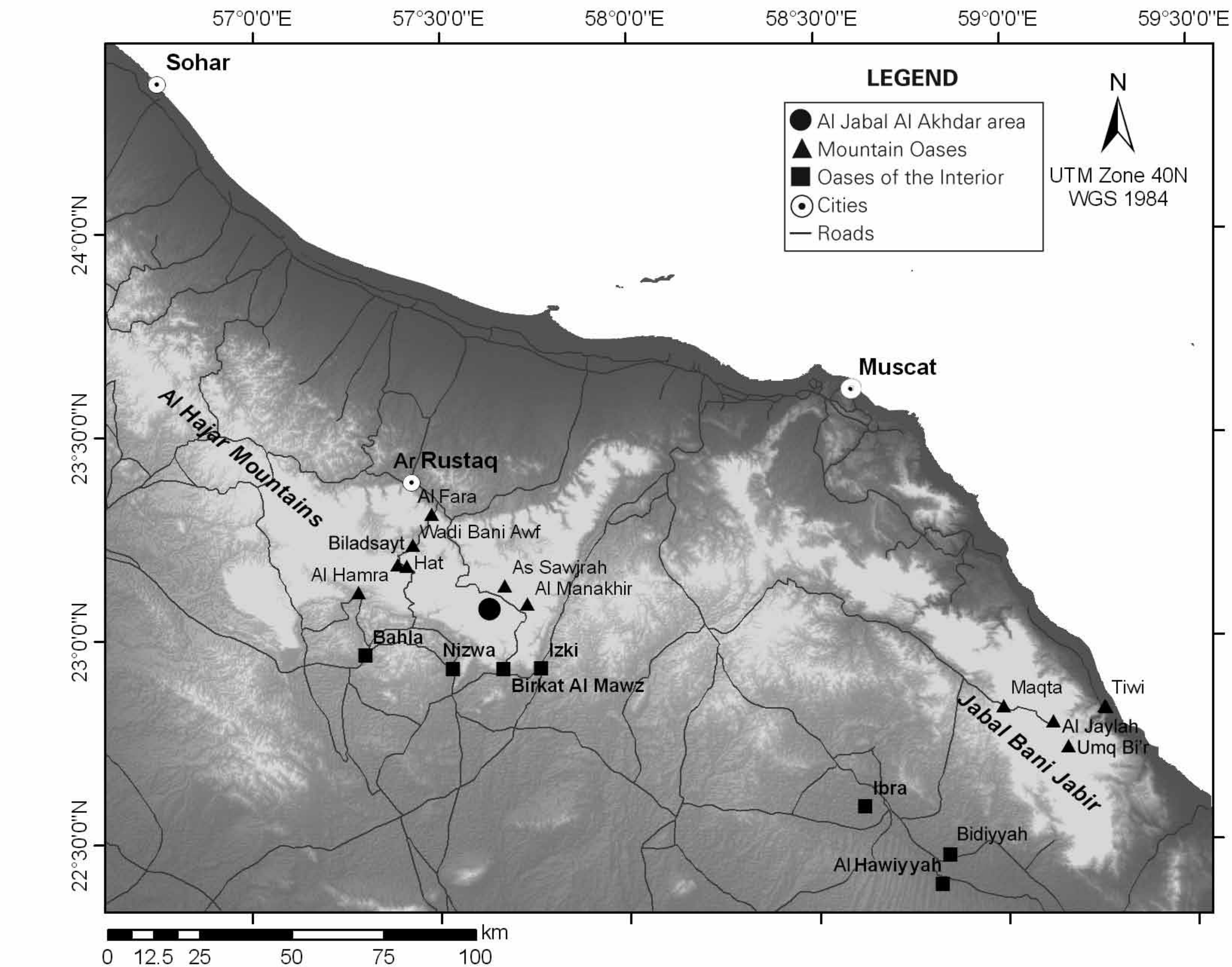
SATELLITE IMAGE OF NORTHERN OMAN

Locations in northern Oman where aerial images were taken in 2000-2007. Oases of the Interior and the southern Hajar range (Jabal Bani Jabir), mountain oases of the northern Hajar range and Wadi Bani Awf and oases of the central Al Jabal Al Akhdar area near Wadi Al Muaydin with the villages of Saiq, Ash Shuraijah, Al Ayn, Al 'Aqr, Masirat Ar Ruwajih and Wadi Bani Habib are marked. The locations are overlayed on a Landsat image of 2002.



MAP OF NORTHERN OMAN



SHARQIYAH SANDS

The Sharqiyah Sands form the north-eastern end of the Rub Al Khali the second largest desert of the world. The harsh beauty of wind-shaped sand dunes changes with the lush green of occasional ground water and well-based oases such as Hawija.

IBRA

Since the Umm an Naar period (4700-4000 BP) Ibra and Izki were two important regional centres. Large houses with interesting architectural features show the wealth of the merchants during the 18th and 19th centuries. Extended fortifications were constructed to protect these towns in this period. The dead date palms reflect the effects of a falling water table due to over-extraction of water in a drought year.


ALL STARS

IZKI

In Izki the remains of the old city centre (lower left and next pages) are still well preserved.

IZKI

BIRKAT AL MAWZ

As indicated by its Arabic name, which means ‘banana pool’, the typical foothill oasis of Birkat Al Mawz, the gate to Al Jabal Al Akhdar, fascinated early travellers such as Wilfred Thesiger. Its lush vegetation is based on a well-constructed *aflaj* system originating from a large wadi draining water year round from the mountain range. Even today, the carefully restored *falaj* with a major aquaduct merits a walk through the largely empty quarters of the old part of town that stretches along the uphill border of the palm groves.

BIRKAT AL MAWZ

The remains of double-storey mud houses reflect the former wealth of their owners.

NIZWA

Many remains of fortified wells and settlement features dated to the 5th millennium BP point to very good living conditions in the Nizwa area since ancient times. The 'plain oasis' was for centuries the country's religious and political capital. It is a particularly good example of how urban development changed old settlement patterns and increasingly encroaches on the date palm groves fed by Falaj Daris, which drains water from Al Jabal Al Akhdar.

NIZWA

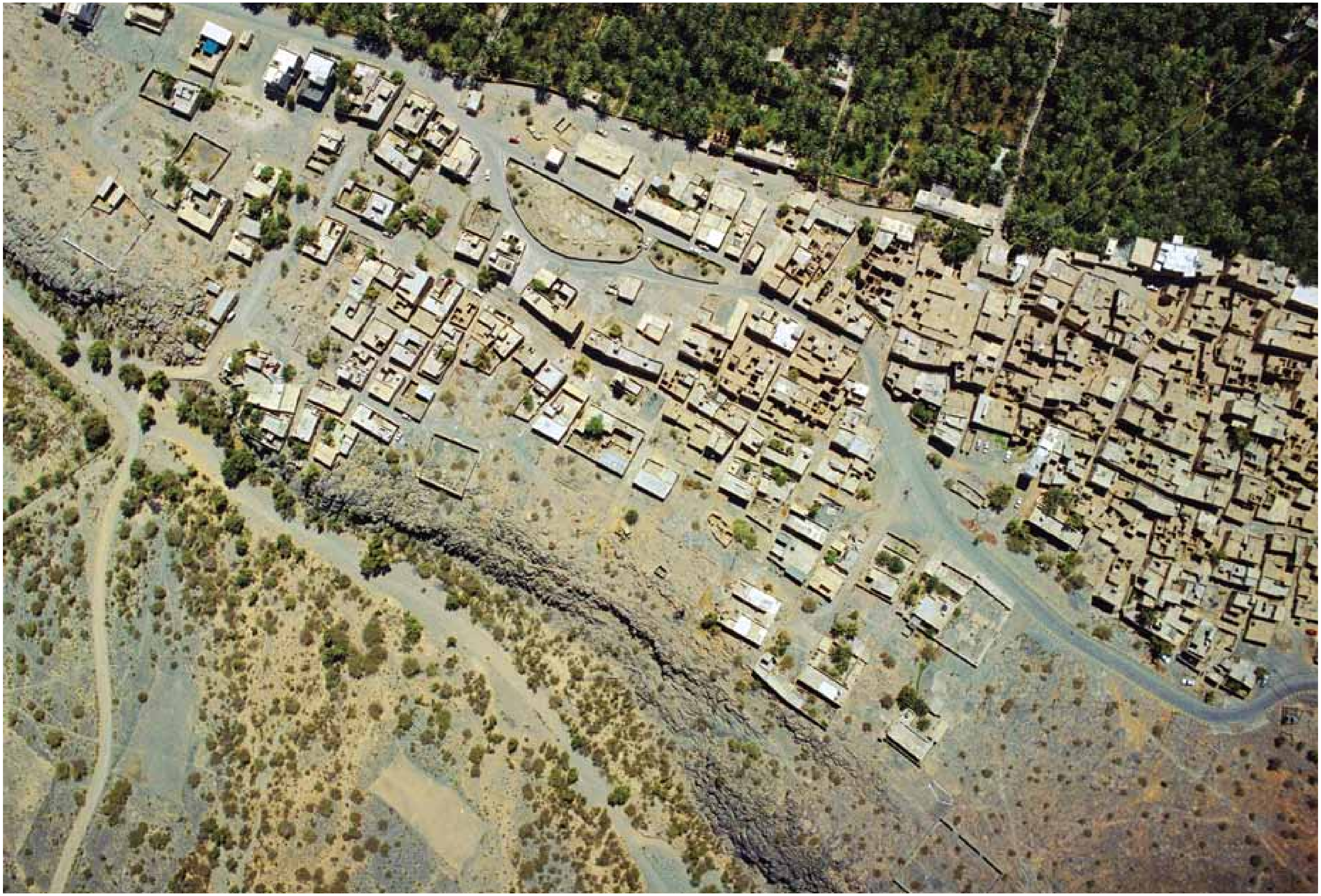
Close to the mosque and the old fort old mud-brick houses are mixed with the modern settlement structures.

NIZWA

NIZWA

AL HAMRA

While the origin of the name of the town of Al Hamra (The Red One) is unknown this small oasis with large date palm groves at the southern foothills of Al Jabal Al Akhdar played an important role as a local trading centre for centuries. As demonstrated by the recent discovery of handwritten letters from an 18th to 20th century archive perfectly conserved in pottery storage jars, the local sheikh of the Jabrin tribe was a powerful leader whose advice was sought throughout the country.



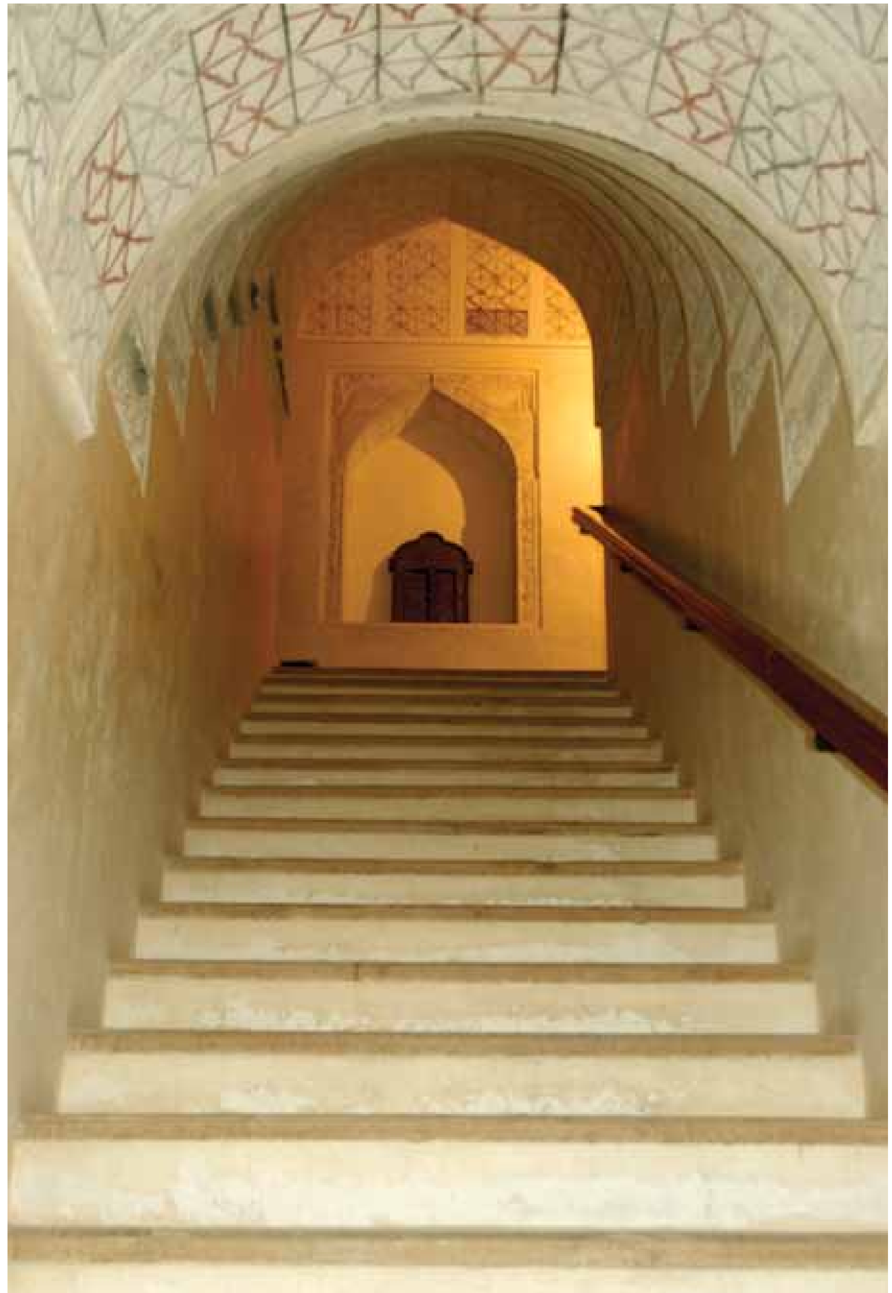
BAHLA

Bahla is one of the major towns at the southern foothills of Al Al Hajar Mountains, which, during the Middle Ages, was the capital of the Nabhani Dynasty. During the 17th century it was probably walled by a 12 km long mud-brick fortification with 15 gates and 132 towers. The town contains an important fort, which has been registered as a World Heritage site since 1987. Bahla was the most important pottery production centre in Oman and as such was praised for its green-glazed ceramics. The newly restored Jabrin Castle is situated approximately 5 km west of Bahla. With its fine decorations it once was a splendid example of Omani craftsmanship and of courtly life.

BAHLA

BAHLA

Jibrin Castle hosts spectacular remains of painted wooden ceilings.



THE NORTHERN COAST

Sprawling urbanisation in the coastal areas of the country pose a major challenge for sustainable infrastructural development, in particular the provision of water for human consumption and irrigation of green areas.

Aerial view of the the Sultan Qaboos Mosque in Muscat.

TIWI AND WADI TIWI

Due to year-round abundant freshwater resources from Jabal Bani Jabir, the ancient harbour town of Tiwi was of vital importance for Omani sailors on their way to East Africa, Zanzibar and India for many centuries. These inter-regional relationships have provided a heritage of rich genetic resources of banana of which varieties new to science have been discovered in upper Wadi Tiwi near Umq Bi'r.

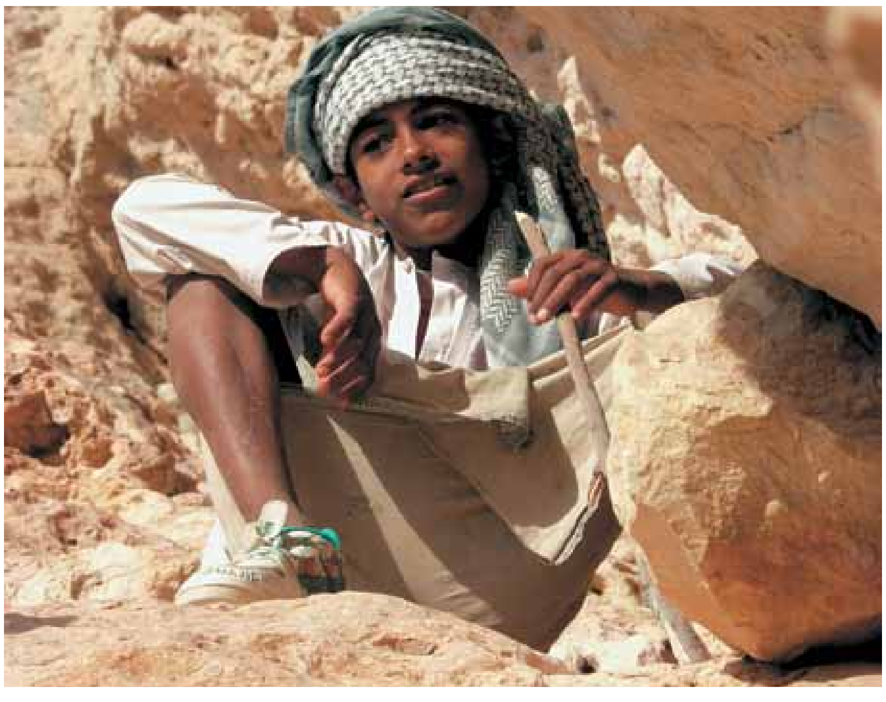
UMQ BI'R

This remote oasis in the midst of the spring watershed of Wadi Tiwi contains not only unique waterfalls but also ecosystems where ancient banana germplasm from Southeast Asia has survived for many centuries.

UMQ BI'R

Landscape and herdsmen near Al Jaylah, Jabal Bani Jabir, with its dozens of scattered stone-built tower tombs, of which some are estimated to be approximately 5,000 years old.

AL JAYLAH



MAQTA

The existence of Maqta, a remote 'scattered mountain oasis' depends on the outflow of twenty-two springs watering 4.5 ha on sixteen terrace systems of which 2.9 ha are planted to date palm groves, 0.4 ha to wheat landraces during the cooler winter months, 0.4 are left fallow and 0.8 h are abandoned. This oasis has few options for survival unless appropriate decisions are taken to bring development to its poor semi-nomadic population.

MAQTA

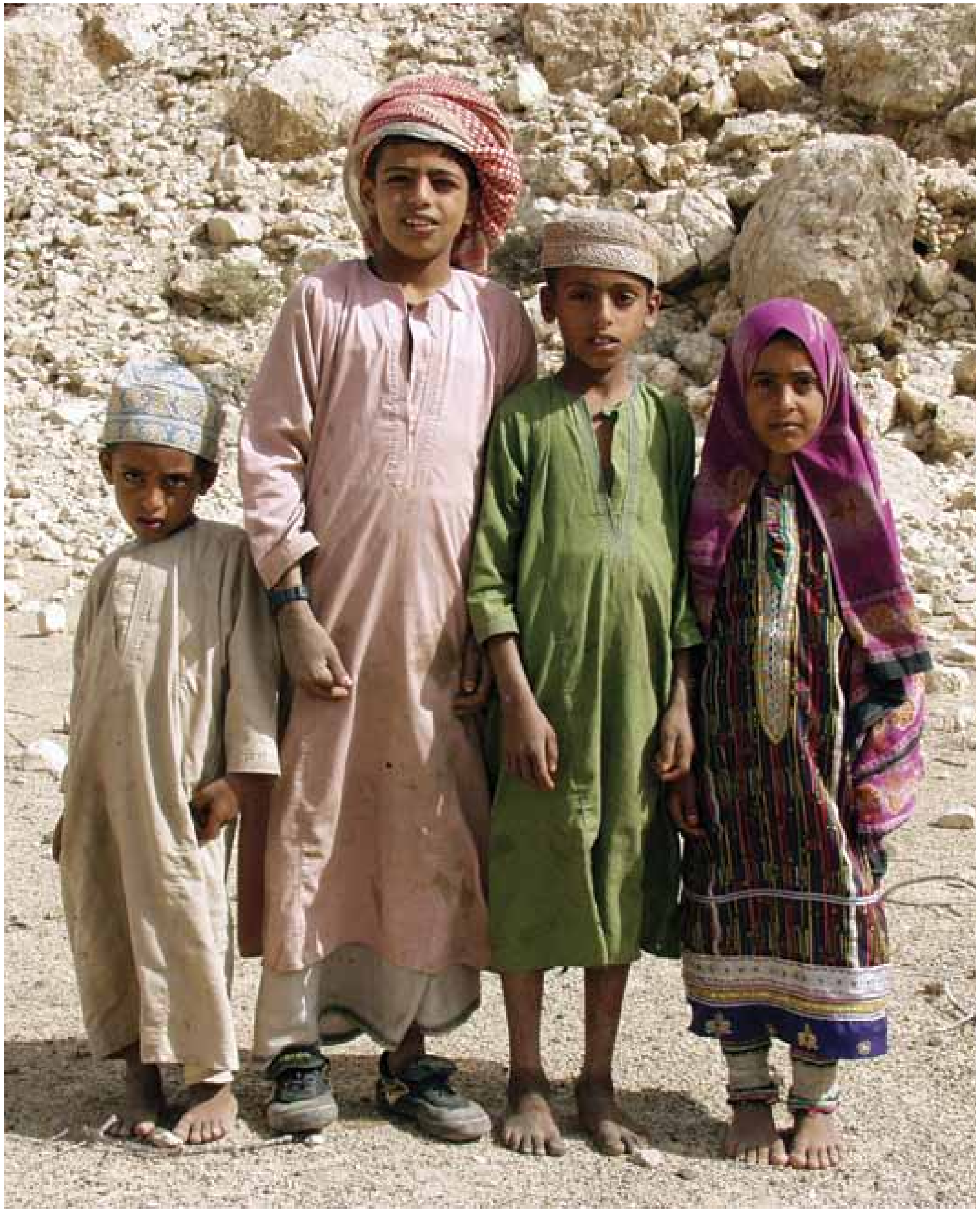
The find of new botanical varieties of wheat within farmers' landraces, which are related to wheat in Mesopotamia and Asia, provides further evidence of Oman's inter-regional trade and merits *in-situ* conservation of this rare germplasm.

MAQTA

Farmers harvesting traditional wheat landraces containing unique ancient germplasm.

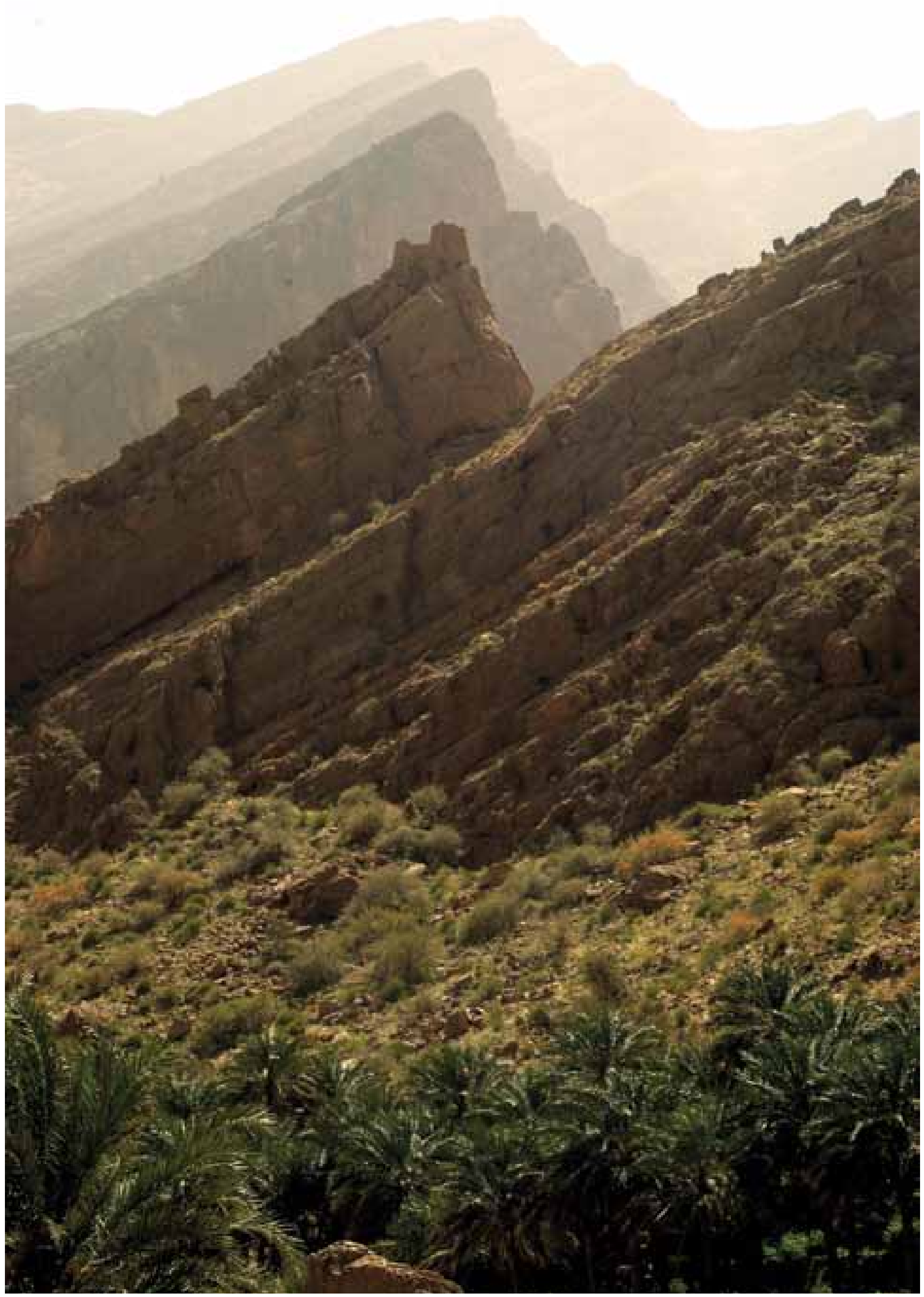
MAQTA

Maqta's children are lucky to be able to attend a local school, like all other young Omanis. However, creating enough off-farm employment opportunities for the rapidly growing population remains a major challenge in a country where farming is severely limited by harsh agro-climatic conditions.

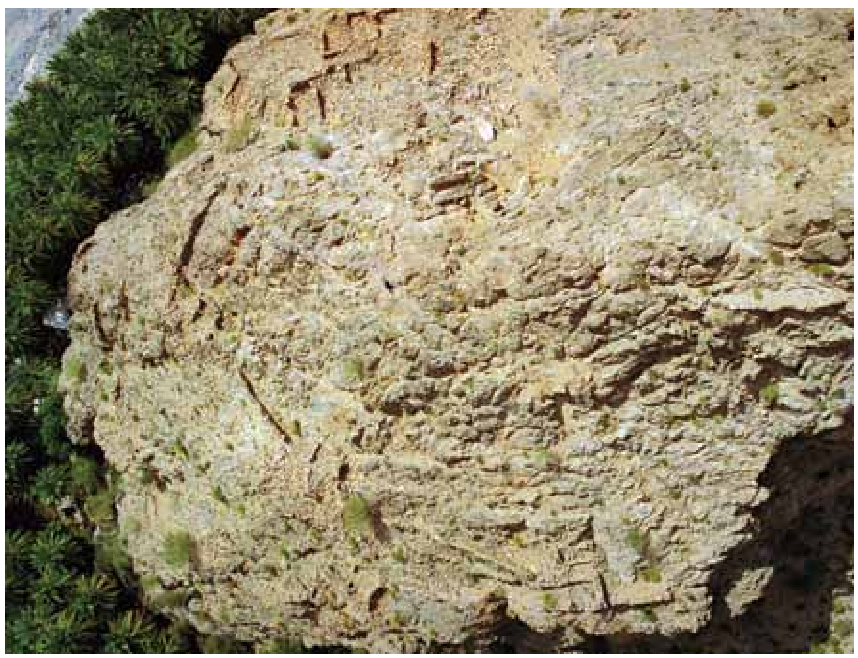


AL FARA

The fortifications of Al Fara reflect territorial boundaries in Wadi Bani Awf that link Ar Rustaq to the north of the Al Hajar Mountains to Al Hamra in the Interior.



The old settlement with the fort.



HAT

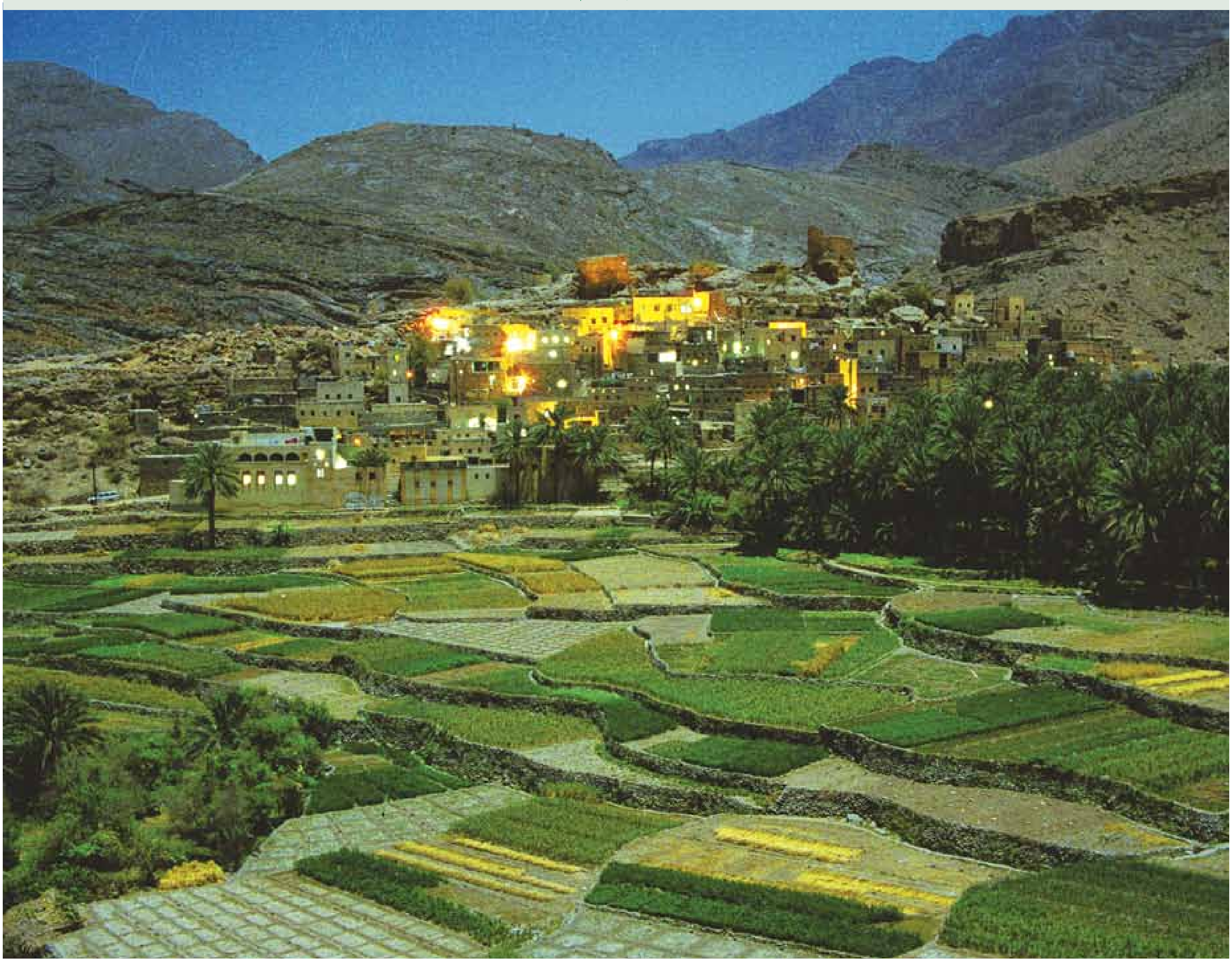
Historically the oasis of Hat in the upper Wadi Bani Awf was important as the beginning of a donkey track across Al Jabal Al Akhdar range to Misfat Al Abriyin and Al Hamra. Today it is characterised by intensive cultivation of date palms and garlic.

HAT

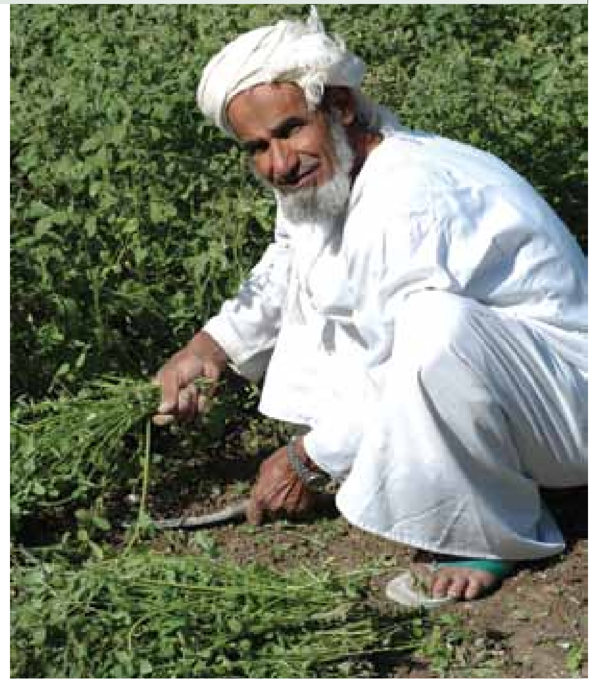
BILADSAYT

Biladsayt, a ‘core oasis’ in the upper part of the Wadi Bani Awf, probably owes its 3,000 years of continued existence to the stable flow of twelve springs originating from a 1,000 m thick Hajar limestone formation above the settlement. Its agricultural area is now covered by about 2,800 date palms comprising fourteen varieties on 8.8 ha of terraced land to which 385 fields totalling 4.6 ha have to be added. These are planted with wheat, alfalfa, barley, onion, garlic, banana, grape and other species.

BILAḌSAYT





AL JABAL AL AKHDAR AND ASH SHURAIJAH

With its rose gardens and Mediterranean tree crops such as pomegranate, walnut, apricot, almond and peach, the famous 'hanging gardens' of Al 'Aqr, Al Ayn and Ash Shirayjah on Al Jabal Al Akhdar are unique high-altitude agro-ecosystems (1750-1930 m asl) that are particularly vulnerable to the effects of sprawling modern settlements, road construction and climate change.

AṢH ṢHURAIJAH

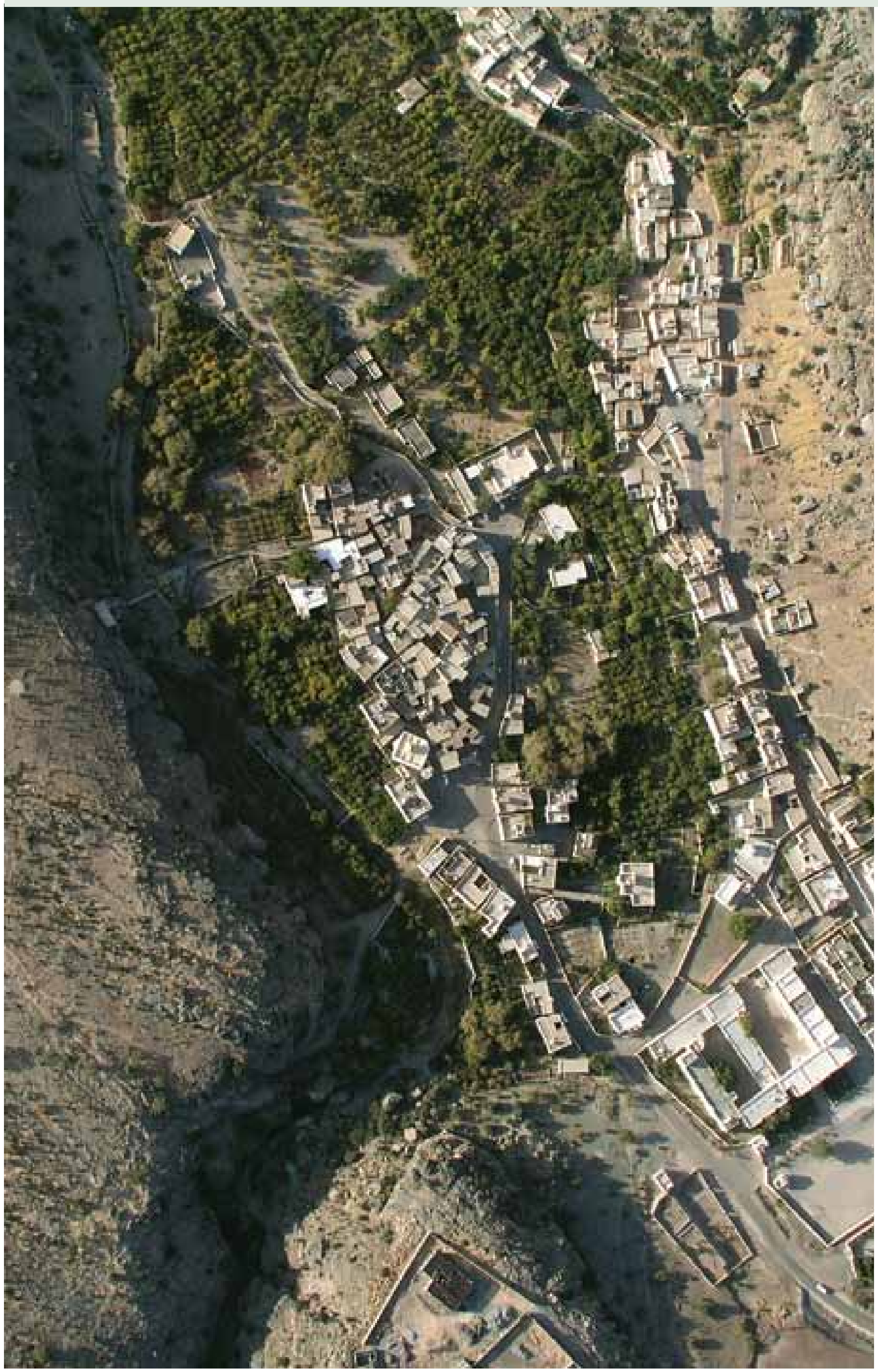
AL AYN, AL AQR AND ASH SHURAIJAH

AL AYN, AL AQR AND ASH SHURAIJAH

AL AYN, AL AQR AND ASH SHURAIJAH

SAIQ

The settlement structure of the oasis of Saiq on Al Jabal Al Akhdar has been completely modernised and most old building structures have vanished. This image shows the fruit gardens of Saiq.



MASIRAT AR RUWAJIH

At the bottom of Wadi Al Muaydin, at about 1050 m above sea level, the crops grown in the oasis of Masirat Ar Ruwajih are typical tropical species such as date palm, citrus and banana, complemented by fodder crops such as alfalfa and barley.

MAṢIRAT AR RUWAJIH

AL MANAKHIR

After being connected by a paved road, the mountain oasis of Al Manakhir has rapidly become modernised into a residential area.

AL MANAKHIR

AL MANAKHIR

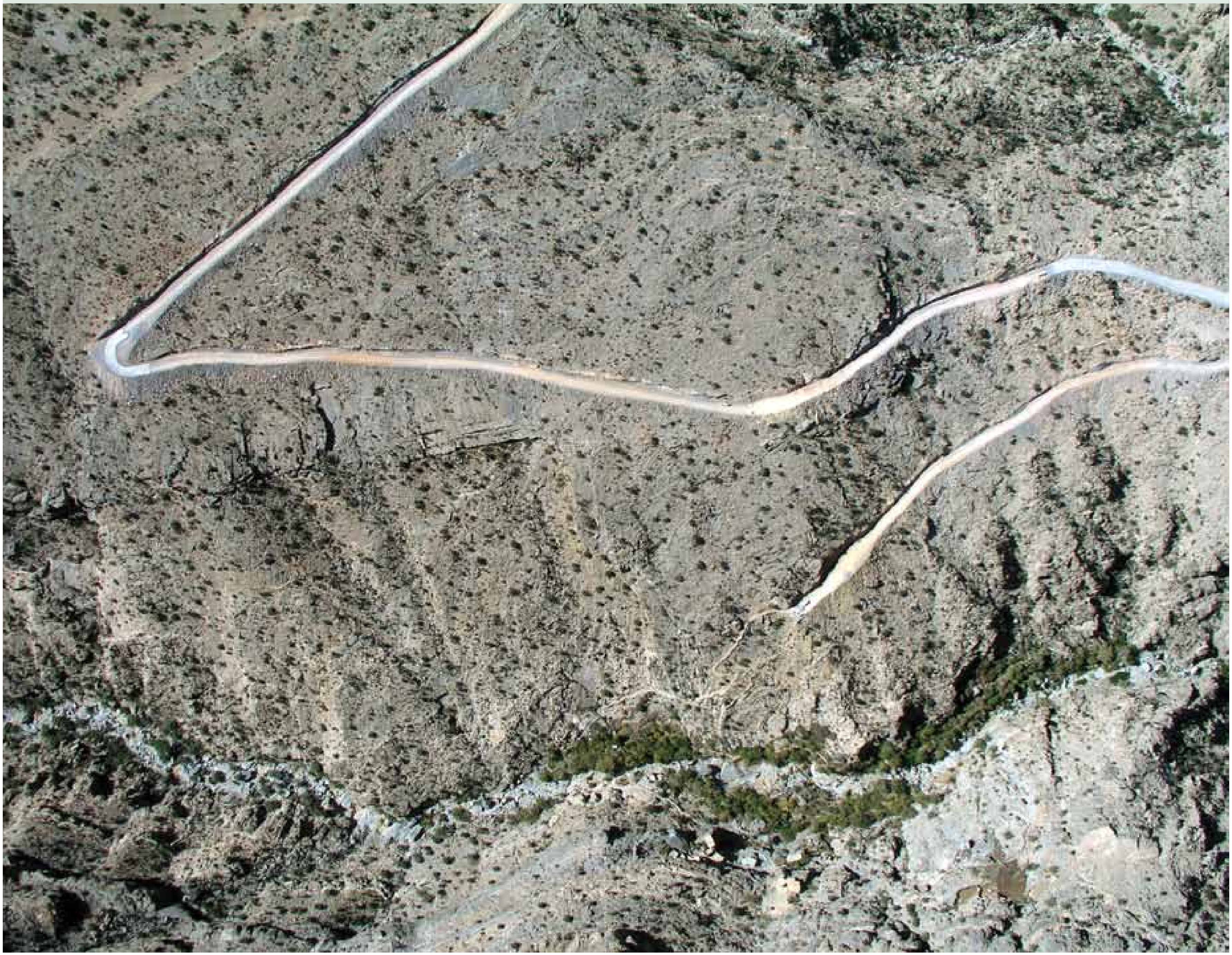
WADI BANI HABIB

Well separated from the modern settlement on the top of the plateau, the ruins of Wadi Bani Habib with its lush gardens of walnut and grapes, bear vivid testimony of agro-pastoral land use that adapted to a harsh climate.

AS SAWJRAH

It was only in 2005 that the tiny mountain oasis of As Sawjrah at the northern fringe of Wadi Bani Kharus was connected by a graded road to the modern infrastructure on Al Jabal Al Akhdar. It represents a particularly fragile settlement where eco-tourism may be a development option that can be explored in close cooperation with the local population.

AS SAWJRAH



WADI BANI KHARUS

Typical foothill oasis settlement in Wadi Bani Kharus at the northern fringe of Al Jabal Al Akhdar in Oman's northern Al Hajar Mountains.