

## ARABIA'S LAST FORESTS UNDER THREAT II: REMAINING FRAGMENTS OF UNIQUE VALLEY FOREST IN SOUTHWEST ARABIA

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Over the last three decades, vegetation surveys in southwest Arabia have documented the existence of a small number of valley forest patches. A well-known area is in Wadi Rijaf, Jabal Bura, a protected area which has recently been surveyed by the current authors. The other valley forest sites in southwest Arabia have not been surveyed for over 15 years. This paper presents a descriptive study of five of these important valley forest localities. To provide an assessment of conservation value, field studies recorded the extent, quality and composition of the vegetation and the presence of regionally rare species. The significance of these remaining patches of Arabian forest, and the immediate threats to their survival, are also discussed.

*Keywords.* Arabia, conservation, rare species, valley forest, Yemen.

### INTRODUCTION

Over the last three decades several studies have recorded the existence of rare forest vegetation in southwest Arabia. In a paper entitled 'Were there forests in the Yemen?' Hepper & Wood (1979) described the existence of the last remaining forest vegetation occurring in the wadi valleys of Jabal Melhan and Jabal Bura between 500 and 1500 m. They noted the rarity of this vegetation and found it dominated by the tree species *Combretum molle* R.Br. ex G.Don, *Terminalia brownii* Fresen., *Ziziphus mucronata* Willd. and *Piliostigma thonningii* (Schumach.) Milne-Redh. Al-Hubaishi & Müller-Hohenstein (1984) also recorded the existence of this tree-dominated wadi vegetation

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in narrow valleys in the Tihama foothills on the higher slopes between 500 and 1000 m. They observed that the best example of this vegetation was also in the Jabal Bura region, from where they described a closed canopy forest dominated by trees such as *Combretum molle*, *Tamarindus indica* L., *Trichilia emetica* Vahl, *Ficus populifolia* Vahl, *Mimusops laurifolia* (Forssk.) Friis and *Breonadia salicina* (Vahl) Hepper & J.R.I.Wood.

Later studies revealed that this vegetation was not confined to Jabal Bura and Jabal Melhan. Deil & Müller-Hohenstein (1985) recorded the existence of forest vegetation (which they called 'wadi woodland') in the At-Tur basin, near Wadi Mawr, between 450 and 900 m. This was dominated by *Combretum molle*, *Tamarindus indica*, *Berchemia discolor* (Klotzsch) Hemsl., with *Mimusops laurifolia* and *Ficus populifolia* also present. The tree layer of the wadi woodland was also described by Scholte *et al.* (1991), who recorded several large *Ficus* species, *Combretum molle*, *Tamarindus indica*, *Trichilia emetica* and *Mimusops laurifolia* as the main constituents. Their vegetation map of Yemen records five broad localities where this vegetation occurs:

- 20 km east of Zabid, centred on Jabal Qarazan
- On the western slopes of Jabal Raymah and Jabal Bura
- On the western slopes of Jabal Melhan
- 10 km southwest of Hajjah, centred around the At-Tur basin
- 45 km northeast of Hajjah, centred on Jabal Ash Sharafayn.

Wood (1997) broadly termed this rare vegetation 'valley forest', a type of forest only occurring between 500 and 1000 m on the western escarpment, dominated by *Combretum molle*, but with several *Ficus* species, *Tamarindus indica*, *Celtis toka* (Forssk.) Hepper & J.R.I.Wood and *Mimusops laurifolia* also characteristic. Wood (1997) noted that 'valley forest' only occurred at localities with locally high levels of orographic rainfall and with westerly or southwesterly aspects that trapped mist during the drier times of year. Wood (1997) provides the most detailed records for a number of fragmented valley forest localities (see Fig. 1):

- Above Alujah, below Hadiyah and around Suq ar Ribat, Jabal Raymah
- In Wadi Yur and Wadi Hillah, Jabal Melhan
- Above Hillah and in Wadi Rijaf, Jabal Bura
- At Rajamah and in Wadi Har, Haraz Mts.
- In Wadi Liyah, Khawlan Ash Sham.

The most recent survey of this vegetation in Yemen (Hall *et al.*, 2008) agrees that the term *valley forest* best defines this rare habitat. Such a definition is in line with the definition of forest as an area of land of more than 0.5 ha, with trees taller than 5 m,

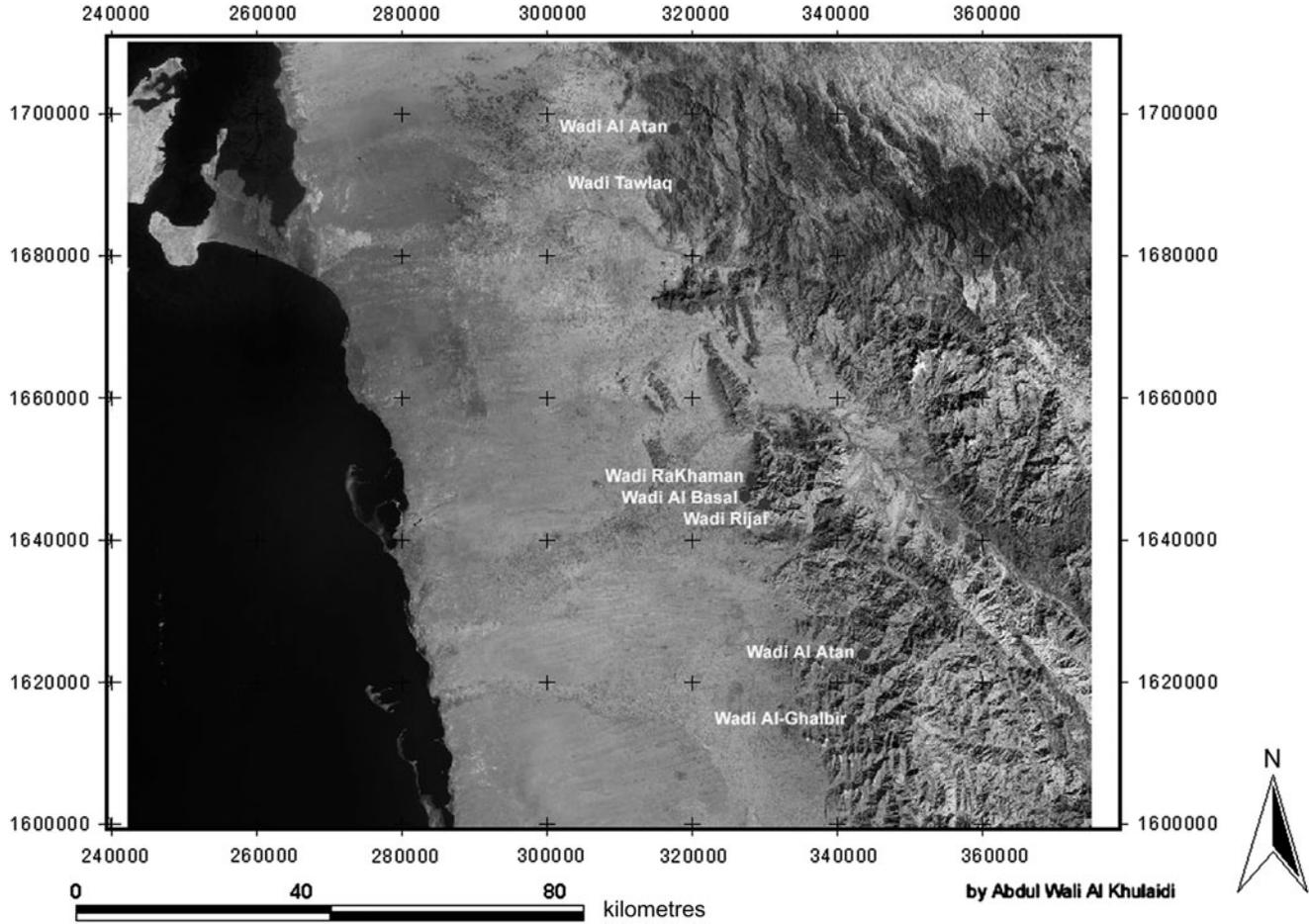


FIG. 1. The surveyed valley forest sites in the western escarpment mountains of Yemen. Map scale 1:1,000,000. Numbers along axes are UTM reference points.

which cover more than 10% of the land area (FAO, 2000). The density of this vegetation also qualifies it as forest under the criteria developed for Arabia by Scholte (2000).

The valley forest vegetation in Wadi Rijaf, Jabal Bura, measures some 80 ha, of which the densest areas are centred on the lowest slopes of the catchment, near the wadi channel between 400 and 800 m (Hall *et al.*, 2008). Widespread tree species are *Mimusops laurifolia*, *Phoenix caespitosa* Chiov., *Tamarindus indica*, *Terminalia brownii*, *Acacia asak* (Forssk.) Willd., *Combretum molle*, *Berchemia discolor*, *Ziziphus mucronata*, *Trichilia emetica*, *Commiphora kataf* (Forssk.) Engl., *Ficus sycomorus* L. and *Ficus ingens* (Miq.) Miq. The shrub layer was noted to be dominated by *Carissa spinarum* L. (syn. *C. edulis* (Forssk.) Vahl), several species of *Grewia* and *Maytenus*, and *Teclea nobilis* Delile. Hall *et al.* (2008) regard the valley forest in Jabal Bura as a 'relict forest' which has acted as a refuge for a number of tropical African tree species, with varying centres of endemism (White, 1983).

Hall *et al.* (2008) note that as well as being physiognomically rare, the valley forest in Wadi Rijaf is also home to 12 regionally rare plant species, including *Stereospermum kunthianum* Cham., *Antiaris toxicaria* Lesch. and *Nuxia oppositifolia* (Hochst.) Benth. (see Table 2). Most of these species are known only from a handful of localities and many are almost entirely restricted to the vegetation in Wadi Rijaf.

In terms both of uniqueness of habitat and the occurrence of rare species, Wadi Rijaf has been listed as a potential Important Plant Area in Arabia (GSPC, 2002; Plantlife International, 2004) and has recently gained legal protection, after much of Jabal Bura was designated as part of a Protected Area Management network (Environment Protection Authority, Yemen, 2005). The remaining areas of valley forest identified by Hepper & Wood (1979), Deil & Müller-Hohenstein (1985), Scholte *et al.* (1991) and Wood (1997) are also potentially important for plant conservation in Arabia. In particular, these areas of valley forest have the potential to contribute to targets (v) and (vii) of the Global Strategy for Plant Conservation, the conservation of important habitats and endangered species (GSPC, 2002).

#### AIMS AND METHODS

As the remaining fragments of valley forest had not been surveyed for more than a decade, the current study was undertaken in order to provide a basic assessment of their extent, quality, composition and ultimately their conservation value. Field studies were undertaken between April and October 2005 and in December 2007. As part of their general conservation goals, these surveys were also directed towards providing data for IUCN Red List assessments of the 18 regionally rare species that Wood (1997) lists as restricted to valley forest (see Table 1).

From the list of valley forest localities provided by Scholte *et al.* (1991) and Wood (1997) and from preliminary assessments on the ground, the following sites were selected as the most promising locations for surveying valley forest in the

western escarpment mountains. The areas of valley forest included in the field studies were:

- Wadi Tawlaq and Wadi Hillah – Jabal Melhan
- Wadi Al Atan (near Wadi Ar Ribat), Wadi Al Ghalbir (Alujah) – Jabal Raymah
- Wadi Al Basal – Jabal Bura
- Wadi Rakhman (above Hillah) – Jabal Bura.

The site at Wadi Liyah was discounted because of the current security situation in northern Yemen. The locality at Wadi Yur identified by Wood (1997) was not included in the present study as surveys by Scholte (unpublished field data) in 1988 revealed that the forest cover in the wadi had been severely degraded. Scholte noted that only isolated *Mimusops* individuals remained and no tree cover was recorded on the catchment slopes.

The specific aims of the surveys at the selected sites were to:

- 1 Assess the extent and quality of the vegetation.
- 2 Provide a basic, concise description of the vegetation.
- 3 Record any regionally rare species.

Basic floristic descriptions are based upon 26 vegetation relevés of 25 × 25 m conducted within these remaining valley forest fragments. These qualitative descriptions are intended to form the basis for a more detailed quantitative floristic study which will incorporate data from Saudi Arabia and northeast Africa. Qualitative description of the vegetation structure followed Scholte (2000). Each site was georeferenced and basic topographical information was recorded. Identifications were predominantly made in the field, but when required, voucher specimens were taken for identification at the Royal Botanic Garden Edinburgh. Specimens of rare and significant species were made, with duplicates deposited in the Taiz herbarium. The location of each rare species was recorded with a GPS and the number of individuals was recorded to assist future conservation assessments using IUCN Red List criteria (IUCN, 2001). Digital photographs were also taken for inclusion in a photographic database of Arabian plant species, to be used as a platform for photographic field guides (see Hall & Miller, in press).

## RESULTS

### *Wadi Tawlaq*

Wadi Tawlaq is a relatively open wadi valley on the southwestern side of Jabal Melhan (Table 2). The valley can be accessed via a rocky track leading from the Tihama. At the time of the field study (October) the wadi channel was flowing and there were numerous large standing pools of water. Despite the abundance of water,



FIG. 2. A patch of degraded valley forest in Wadi Tawlaq, Jabal Melhan.

the valley forest is in a degraded state compared with that found in Wadi Rijaf on Jabal Bura (see Fig. 2). The majority of the valley slopes are covered in an *Acacia* shrubland that is dominated by *Acacia ehrenbergiana* Hayne, the Arabian endemic *Acacia johnwoodii* Boulos and *Acacia tortilis* (Forssk.) Hayne. A relatively dense area of vegetation is found in a very narrow band alongside the wadi channel from approximately 400–750 m. The wadi channel is littered with large boulders and slopes gently at about 5% gradient.

The remaining valley forest in Wadi Tawlaq is very patchy, and is degraded to the extent that it takes the appearance of (open) woodland. It is interspersed with *Acacia* shrubs, and measures less than a hectare in area. Several tree species that are characteristic of valley forest are present, but the most predominant of these are the widespread riparian species *Trichilia emetica*, *Tamarindus indica*, *Combretum molle*, *Ficus ingens* and *Ficus sycomorus*, as well as *Acacia asak*. These are covered in the climbing species *Cissus rotundifolia* (Forssk.) Vahl and the parasite *Cassytha filiformis* L. By far the most abundant tree is the naturalised invasive species *Annona squamosa* L., which covers large parts of riparian vegetation in Wadi Tawlaq. The composition of the shrub layer also highlights the degraded nature of this valley forest. It is dominated by the invasive *Opuntia dillenii* (Ker Gawl.) Haw., *Acalypha*

*fruticosa* Forssk. and *Premna resinosa* (Hochst.) Schauer. The non-woody vegetation is relatively sparse and consists mainly of the grass *Dactyloctenium aegyptium* Boiss., *Aristolochia bracteata* Retz., *Ruellia patula* Jacq., *Boerhavia repens* L. and several species of *Commelina*.

Between 450 and 650 m, two mature individuals of *Mimusops laurifolia* and 13 mature individuals of *Diospyros mespiliformis* Hochst. ex A.DC. were found. These are the first records of these regionally rare species from this locality. The absence of any saplings or seedlings is perhaps an indication of the poor regeneration in Wadi Tawlaq.

#### *Wadi Hillah*

Wadi Hillah is a southwest-facing relatively narrow and steeply sloping valley on the western slopes of Jabal Melhan above the small village of Al Awda (Table 2). During the field visit, the wadi channel was flowing and there were abundant pools of water. The vegetation in the valley is less dense and extensive than that of Wadi Rijaf, but it is less degraded than at Wadi Tawlaq. The wadi channel is steeply sloping (up to 50% in parts) and between 450 and 650 m there are approximately 5–6 ha of vegetation that cover both the sides of the wadi channel and the slopes of the catchment. The wadi channel extends to approximately 900 m and although this area was not surveyed, local people indicated that the best quality forest could be found between 650 and 900 m. This vegetation could be characterised as open woodland that in patches (around 525 m altitude) becomes forest.

The tree canopy reaches about 12 m and is dominated by *Trichilia emetica* and *Diospyros mespiliformis*. Abundant tree species also include *Tamarindus indica*, *Phoenix caespitosa*, *Combretum molle*, *Terminalia brownii* and *Ficus ingens*. Less common tree species include *Acacia asak*, *Acacia johnwoodii* and *Berchemia discolor*. A notable absence from the tree layer is *Mimusops laurifolia*, the regionally rare species which is so characteristic of the valley forest in Wadi Rijaf.

At lower altitudes, many of the larger trees had been cut for wood and fodder. However, the vegetation in Wadi Hillah appears to suffer less from invasive species than other sites in Arabia. The naturalised species *Annona squamosa* is present but it is sparsely distributed. *Opuntia dillenii* also occurs, but it is far less abundant than in Wadi Tawlaq. The most common shrub is *Acalypha fruticosa*, but *Oncoba spinosa* Forssk., *Carissa spinarum*, *Grewia schweinfurthii* Burret and several species of *Maytenus* also make up the shrub layer. In places this can be very dense – to the exclusion of a developed herbaceous layer. Where gaps in the shrub layer occur, the herbaceous layer is not particularly rich but includes *Ruellia patula*, *Hibiscus deflersii* Schweinf. ex Cufod. and *Aristolochia bracteata*, as well as species of *Commelina* and *Anilema*.

The regionally rare tree *Diospyros mespiliformis* was particularly abundant in Wadi Hillah and more than 50 mature individuals were recorded. This species is valued for its particularly strong wood and the majority of mature trees showed signs

of cutting. However, unlike at other sites, *Diospyros mespiliformis* showed signs of regeneration in this locality. Another significant find in Wadi Hillah was the regionally rare tree *Antiaris toxicaria*. Two mature trees and several seedlings were recorded in the wadi – the first record of this species on Jabal Melhan. This species was previously known only from Jabal Bura and the Haraz Mts.

In a neighbouring wadi channel to Wadi Hillah, above the village of Bani Schraib at 1674 m (15°20'48"N, 43°21'01"E), we recorded four juvenile individuals of the extremely rare tree *Bucea antidysenterica* J.F.Mill. Although Wood (1997) describes these as being restricted to valley forest, they were growing in a deep shaded gully above coffee terraces. *Bucea antidysenterica* was previously only known in Arabia from two trees on Jabal Raymah (Wood, 1997).

#### *Wadi Al Atan (Wadi Ar Ribat)*

Wadi Al Atan is a very narrow, steep-sided wadi channel on Jabal Raymah (Table 2). This small valley connects with Wadi Ar Ribat, the main wadi in the Suq Ar Ribat area, identified by Wood (1997) as a valley forest locality. Surveys were conducted in Wadi Al Atan between 600 and 700 m. This site was chosen as it was the only locality in the Wadi Ar Ribat area with significant tree cover. Since Wood's surveys in the 1970s the valley forest in Wadi Ar Ribat has become almost completely degraded. The tree cover in Wadi Al Atan is extremely sparse and is little more than a very patchy scrubland. At the time of the study, there was no water in the wadi channel, and it appeared that much of the tree cover was interspersed with areas of abandoned cultivation.

Within the areas of patchy (sparse) shrubland there are very few tree species. The most common species is the naturalised *Annona squamosa*, but *Breonadia salicina*, *Ziziphus mucronata*, *Trichilia emetica*, *Phoenix caespitosa*, *Tamarindus indica* and *Terminalia brownii* are also present. The shrub layer is dominated by *Acalypha fruticosa* with occasional individuals of *Premna resinosa*, *Oncoba spinosa*, *Euclea racemosa* Murr. and several species of *Maytenus*. With such a sparse tree and shrub cover, the vegetation in Wadi Al Atan is mainly herbaceous. The most common species recorded were *Achyranthes aspera* L., *Becium filamentosum* (Forssk.) Chiov., *Pupalia lappacea* (L.) Juss., *Hibiscus deflersii* and *Ruellia patula*.

#### *Wadi Al Ghalbir*

Wadi Al Ghalbir is a wide, gently sloping valley located near the settlement of Alujah on Jabal Raymah (Table 2). The Alujah area was identified by Wood (1997) as a site for valley forest, but like the other sites on Jabal Raymah the tree cover in Wadi Al Ghalbir is not very extensive. The only vegetation resembling valley forest is open riparian woodland found immediately alongside the rocky wadi channel. Despite the abundance of water in the wadi, this open woodland occupies less than

1 ha between 500 and 600 m. It is heavily degraded, shows signs of being heavily utilised and is interspersed with areas of abandoned agriculture. Many of the trees show signs of being extensively cut.

Few tree species were recorded, but the most common trees in Wadi Al Ghalbir are *Breonadia salicina*, *Phoenix caespitosa*, *Pandanus odoriferus* (Forssk.) Chiov., *Diospyros mespiliformis*, *Trichilia emetica*, *Annona squamosa* and *Ficus ingens*. The shrub layer is dense and is dominated by *Carissa spinarum*, *Anisotes trisulcus* (Forssk.) Nees and *Acalypha fruticosa*. *Grewia villosa* Willd. is also present but in lower numbers. A very sparse herbaceous layer is restricted to species straggling over the many rocks in the wadi such as *Ipomoea cairica* (L.) Sweet and *Tridax procumbens* L., as well as the grass *Dactyloctenium aegyptium* (L.) Willd.

Several regionally rare species were observed including one record of the woody annual *Triumfetta pentandra* A.Rich. (which is known from only two other sites in Arabia; Hall, 2005), and more than 20 individuals of *Diospyros mespiliformis*.

#### *Wadi Al Basal*

Although Wadi Rijaf is well known as the least degraded, most extensive site of valley forest in Arabia, the neighbouring wadi system of Wadi Al Basal has received little attention. The only published description of the catchment (Herzog, 1998) records the area as an 'impoverished riparian forest' dominated by *Combretum molle*, and mentions that degradation of the vegetation has occurred as a result of human activity. Preliminary investigations revealed it to be one of the most significant areas of valley forest in Yemen (Hall, 2005).

Wadi Al Basal is a narrow, steep-sided valley, located to the northwest of Wadi Rijaf (Table 2). The wadi extends from the Tihama plain, at 300 m, to over 1000 m altitude, and has a rocky watercourse with a channel approximately 15 m wide. From the Tihama plain up to 450 m the vegetation is a sparse *Acacia-Commiphora* shrubland dominated by *Acacia mellifera* (Vahl) Benth. and *Commiphora myrrha* (Nees) Engl., with *Grewia schweinfurthii*, *Anisotes trisulcus* and *Adenium obesum* (Forssk.) Roem. & Schult. also common. From 450 m up to about 650 m, a valley forest exists in between the large boulders in the wadi channel and on the catchment slopes. As Figure 3 shows, this valley forest is less dense and of a smaller stature than in Wadi Rijaf, possibly due to the steepness of the valley.

The vegetation shows few signs of being degraded and it is estimated that c.30 ha of valley forest exists in the wadi channels and on the slopes of Wadi Al Basal. The dominant tree species are *Combretum molle* and *Terminalia brownii* with *Cordia ovalis* R.Br. ex A.DC., *Ficus sycomorus*, *Ficus vasta* Forssk. and *Trichilia emetica* also common. Notably, the regionally rare species *Antiaris toxicaria* and *Mimusops laurifolia*, and the Arabian endemic *Acacia johnwoodii*, are also present above 550 m. *Cissus quadrangularis* L. and *Cissus rotundifolia* climb over the tree layer, and *Cassytha filiformis* is also present. The shrub layer is also dense, with *Acalypha fruticosa*, *Grewia schweinfurthii*, *Grewia villosa* and *Teclea nobilis* the most common

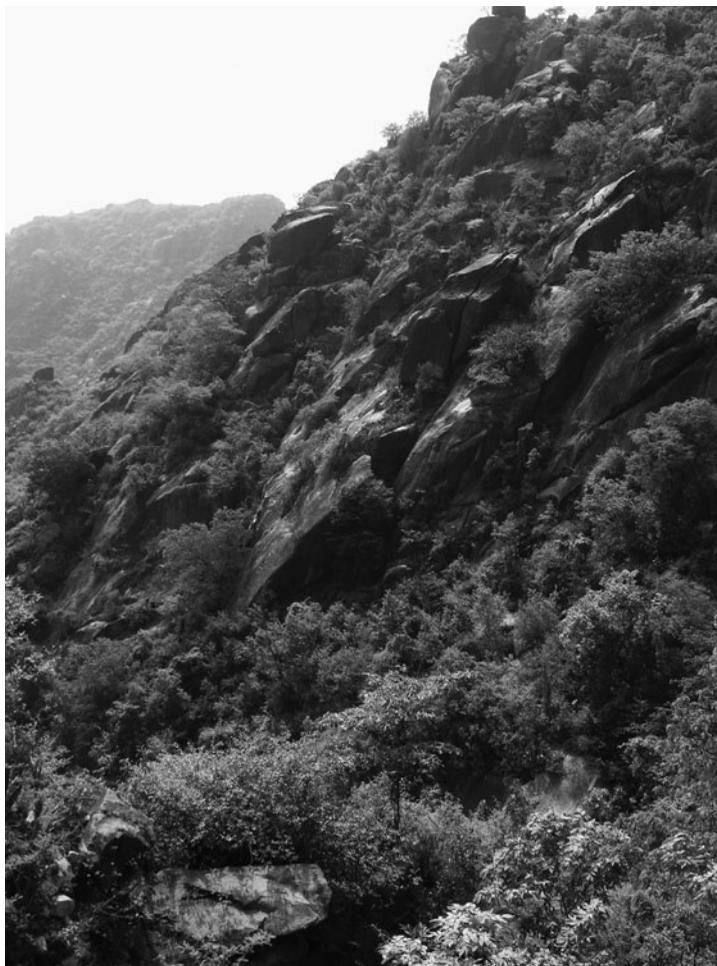


FIG. 3. The valley forest on the slopes of Wadi Al Basal, Jabal Bura. This newly surveyed area is the most extensive and intact area of valley forest after Wadi Rijaf.

species. At the time of the surveys (April 2005), the non-woody ground flora was sparse and consisted principally of *Commelina* spp., *Ipomoea* spp., *Jasminum fluminense* Vell. and, in damper sites, *Selaginella imbricata* (Forssk.) Spring.

In addition to its coverage and the presence of *Acacia johnwoodii* the vegetation of Wadi Al Basal is notable for the occurrence of several regionally rare species, previously unrecorded from the catchment. One mature tree and two saplings of *Stereospermum kunthianum* were recorded at 625 m. Six mature trees of *Antiaris toxicaria* were recorded between 435 and 650 m, with noticeable regeneration of this species. *Mimusops laurifolia* is relatively common in Wadi Basal between 570 and 650 m, and a single juvenile tree of *Nuxia oppositifolia* was found in the wadi channel. Due to time limits and difficult access, we were restricted to surveying the

TABLE 1. List of 18 species that are restricted in Arabia to valley forest habitat. Preliminary IUCN Red List assessments are provided for each species (CR – Critically Endangered, EN – Endangered)

Species	Family	Distribution outside Arabia	IUCN Red List regional assessment
<i>Antiaris toxicaria</i> Lesch.	<i>Moraceae</i>	Tropics	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Diospyros mespiliformis</i> Hochst. ex A.DC.	<i>Tiliaceae</i>	Tropical and Southern Africa	EN B1ab(iii), 2ab(iii)
<i>Triumfetta pentandra</i> A.Rich.	<i>Tiliaceae</i>	Africa and Asian Tropics	CR B1ab(iii), 2ab(iii), C2a(i,iii)
<i>Mimusops laurifolia</i> (Forssk.) Friis	<i>Sapotaceae</i>	Horn of Africa	EN B1ab(iii), 2ab(iii)
<i>Bauhinia tomentosa</i> L.	<i>Leguminosae</i>	Tropics	CR B1ab(iii), 2ab(iii), C2a(i)
<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	<i>Leguminosae</i>	Tropical and Southern Africa	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Bridelia scleroneura</i> Müll.Arg.	<i>Euphorbiaceae</i>	Somalia-Masai	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Meineckia phyllanthoides</i> Baill.	<i>Euphorbiaceae</i>	Somalia-Masai	EN B1ab(iii), 2ab(iii)
<i>Croton macrostachyus</i> Hochst. ex Delile	<i>Euphorbiaceae</i>	Tropical and Eastern Africa	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Bersama abyssinica</i> Fresen.	<i>Melianthaceae</i>	Tropical and Eastern Africa	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Allophylus rubifolius</i> (Hochst.) Engl.	<i>Sapindaceae</i>	Sudano-Zambezian	EN B1ab(iii), 2ab(iii)
<i>Ozoroa insignis</i> (Delile) Kuntze	<i>Anacardiaceae</i>	Sudano-Zambezian	CR B1ab(iii), 2ab(iii), C2a(i)
<i>Nuxia oppositifolia</i> (Hochst.) Benth.	<i>Buddlejaceae</i>	Sudano-Zambezian	EN B1ab(iii), 2ab(iii)
<i>Brucea antidysenterica</i> J.F.Mill.	<i>Simaroubaceae</i>	Somalia-Masai/Afromontane	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Gymnema sylvestre</i> (Retz.) R.Br. ex Schult.	<i>Apocynaceae</i>	Africa and Asian Tropics	CR B1ab(iii), 2ab(iii), C2a(i)
<i>Stereospermum kunthianum</i> Cham.	<i>Bignoniaceae</i>	Tropical and Eastern Africa	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Aneilema woodii</i> Faden	<i>Commelinaceae</i>	Yemeni endemic	CR B1ab(iii), 2ab(iii), C2a(i), D
<i>Endostemon gracilis</i> (Benth.) M.Ashby	<i>Labiatae</i>	Somalia-Masai	CR B1ab(iii), 2ab(iii), C2a(i), D

TABLE 2. Summary of the most important features of the surveyed valley forest sites in Yemen

Site	Location	Aspect	Altitude	Slope	Dominant tree and shrub species*	Rare species
Wadi Tawlaq	15°17'51"N, 43°19'19"E	SW	400–750 m	5%	<i>Trichilia emetica</i> <i>Tamarindus indica</i> <i>Combretum molle</i> <i>Ficus ingens</i> <i>Ficus sycomorus</i> <i>Acacia asak</i> <u><i>Opuntia dillenii</i></u>	<i>Mimusops laurifolia</i> <i>Diospyros mespiliformis</i>
Wadi Hillah	15°22'04"N, 43°18'54"E	SW	450–650 m	10–50%	<i>Trichilia emetica</i> <i>Diospyros mespiliformis</i> <i>Tamarindus indica</i> <i>Phoenix caespitosa</i> <i>Combretum molle</i> <i>Terminalia brownii</i> <i>Ficus ingens</i> <u><i>Opuntia dillenii</i></u>	<i>Diospyros mespiliformis</i>
Wadi Al Atan	14°40'51"N, 43°34'12"E	W	600–700 m	5%	<u><i>Annona squamosa</i></u>	None
Wadi Al Ghalbir	14°35'41"N, 43°33'12"E	W-SW	500–600 m	5%	<i>Breonadia salicina</i> <i>Phoenix caespitosa</i> <i>Pandanus odoriferus</i> <i>Diospyros mespiliformis</i> <i>Trichilia emetica</i> <u><i>Annona squamosa</i></u> <i>Ficus ingens</i>	<i>Triumfetta pentandra</i> <i>Diospyros mespiliformis</i>
Wadi Al Basal	14°53'05"N, 43°24'55"E	SW	450–650 m	10–60%	<i>Combretum molle</i> <i>Terminalia brownii</i> <i>Cordia ovalis</i>	<i>Stereospermum kunthianum</i> <i>Mimusops laurifolia</i> <i>Antiaris toxicaria</i>

TABLE 2. (Cont'd)

Site	Location	Aspect	Altitude	Slope	Dominant tree and shrub species*	Rare species
					<i>Ficus sycomorus</i> <i>Ficus vasta</i> <i>Trichilia emetica</i>	<i>Nuxia oppositifolia</i>
Wadi Rakhaman (above Hillah)	14°54'16"N, 43°25'07"E	SW	500–670 m	5–25%	<i>Ziziphus mucronata</i> <i>Acacia asak</i> <i>Trichilia emetica</i> <u><i>Annona squamosa</i></u> <u><i>Phoenix caespitosa</i></u>	<i>Aneilema woodii</i> <i>Ozoroa insignis</i>
Wadi Rijaf	14°52'39"N, 43°26'05"E	SW	400–800 m	5–15%	<i>Mimusops laurifolia</i> <i>Phoenix caespitosa</i> <i>Tamarindus indica</i> <i>Terminalia brownii</i> <i>Acacia asak</i> <i>Combretum molle</i> <i>Berchemia discolor</i> <i>Ziziphus mucronata</i> <i>Trichilia emetica</i> <i>Ficus sycomorus</i>	<i>Antiaris toxicaria</i> <i>Triumfetta pentandra</i> <i>Mimusops laurifolia</i> <i>Ptilostigma thonningii</i> <i>Meineckia phyllanthoides</i> <i>Croton macrostachyus</i> <i>Ozoroa insignis</i> <i>Gymnema sylvestre</i> <i>Stereospermum kunthianum</i> <i>Endostemon gracilis</i> <i>Nuxia oppositifolia</i> <i>Allophylus rubifolius</i>

\*Invasive species are underlined.

vegetation closest to the wadi bed and were unable to access the densest part of the vegetation at an altitude of 700 m.

#### *Wadi Rakhaman (above Hillah)*

Wadi Rakhaman is a narrow, sloping valley above the small village of Hillah, Jabal Bura (Table 2). The wadi channel is narrow and littered with large boulders, and slopes gently at about 5% gradient until the upper slopes which reach 25% gradient. Wood (1997) notes that this catchment was an important collecting locality for Schweinfürth, who recorded many of the regionally rare taxa that are restricted to valley forest in Yemen (see Hall, 2005). From the visit to Hillah in October 2005 it is clear that the valley forest is in a very degraded state, with the only significant tree cover occurring in a narrow band (less than 1 ha in area) along the wadi channel between 500 and 670 m.

It appears likely, from observations in the field, that degradation of the valley forest has occurred through extensive cutting and localised heavy flooding, which according to local reports destroyed many of the taller trees. Few tree species were recorded, but the most common were *Ziziphus mucronata*, *Acacia asak*, *Trichilia emetica*, *Annona squamosa* and *Phoenix caespitosa*. Although noted by Wood (1997), the regionally rare tree species *Mimusops laurifolia* was not recorded from Wadi Rakhaman. However, a single individual of the regionally rare tree species *Ozoroa insignis* (Delile) Kuntze was recorded at 670 m.

Within areas of tree cover, there is also a dense shrub layer. The shrub layer extends across much of the catchment and is dominated by *Carissa spinarum*, *Anisotes trisulcus* and *Acalypha fruticosa*, along with several species of *Grewia*. A very sparse herbaceous layer is restricted to species straggling over the many rocks in the wadi, such as *Ipomoea cairica* and *Tridax procumbens*, as well as the grass *Dactyloctenium aegyptium*. The most notable feature of the herbaceous vegetation in Wadi Rakhaman is the presence of *Aneilema woodii* Faden, an endemic perennial herb. Several individuals of this species, which is only known from above Hillah, were recorded in the present study (*Miller* 27163 (E)).

Like Wood (1997), we failed to find the tree species *Bersama abyssinica* Fresen. which had previously only been recorded from above Hillah by Schweinfürth. On account of the degraded nature of the valley forest we are in agreement with Wood (1997) that this species is now extinct on Jabal Bura. We also failed to find *Bridelia scleroneura* Müll.Arg. which was last recorded by Wood (1997) from Wadi Rakhaman and Wadi Ar Ribat.

#### DISCUSSION

The present study, although not exhaustive, is the first survey of southwest Arabia's valley forest fragments for over a decade. Although qualitative, it comprises the most comprehensive assessment to date of this regionally important vegetation. It is

intended that the current study will provide a platform for more quantitative floristic assessments of all the valley forest sites in southwest Arabia and northeast Africa.

Of the six remaining valley forest fragments surveyed, only three remain significant for plant conservation in Arabia, both for the quality of their vegetation and as the principal locations for the Endangered and Critically Endangered species listed in Table 1. One of these localities, Wadi Al Basal, is newly recognised as an important site for the preservation of Arabia's rarest vegetation. Wadi Al Basal holds up to 30 ha of reasonably dense valley forest that is home to three of these 18 regionally threatened plant species. This catchment deserves recognition as an important area for plant conservation because of the rarity of the habitat type and presence of several species threatened with extinction in the region (GSPC, 2002). Although currently outside the reserve boundaries, under the same criteria, Wadi Al Basal also deserves inclusion in the Jabal Bura protected area. Further fieldwork in the densest areas of valley forest may strengthen the case for its conservation.

Wadi Hillah on Jabal Melhan holds approximately 6 ha of valley forest vegetation which although somewhat degraded still represents one of the best sites in Yemen. This vegetation also contains two regionally rare tree species, including *Antiaris toxicaria* which is known from only three other sites in Arabia. For these reasons Wadi Hillah should also be recognised as an important site for plant conservation in the Arabian region. Due to the rarity of the valley forest vegetation, formal protection and conservation measures should be considered. In particular, action should be taken to mitigate pressures associated with resource use and the proliferation of invasive species such as *Opuntia dillenii*, a considerable conservation problem in large parts of Yemen (Al-Hubaishi & Müller-Hohenstein, 1984; Ellenberg, 1989).

Finally, the patchy and degraded valley forest of Wadi Tawlaq is one of a handful of localities for two regionally rare tree species. The wood of these species is valued by the local people for building and making tools, and all the individuals showed signs of cutting or pollarding. The relative rarity of these species and other large trees such as *Breonadia salicina* is most probably due to sustained overuse and overgrazing. Local people were adamant that there had previously been many more trees in the wadi, but that these had been felled for timber. To ensure the continuation of these species in Arabia, this site also deserves conservation recognition and action directed at both resource use and the management of the invasive alien species *Opuntia dillenii*.

Unfortunately, the sites of valley forest on Jabal Raymah are now in such a degraded state that they are currently of little value for conservation. Although the valley forest in Wadi Rakhman, above the village of Hillah, is similarly degraded, it is still an important site for conservation, being the only locality of the endemic *Aneilema woodii*. The loss of several tree species from the Wadi Rakhman catchment highlights the need for conservation initiatives to safeguard the existence of the remaining sites of Arabian valley forest.

As well as the sites surveyed above, the present study confirms the conservation importance of Wadi Rijaf as an outstanding example of valley forest in Yemen. Wadi Rijaf holds approximately 80 ha of valley forest, c.10 ha of which has a closed

canopy. It is also home to 12 of the regionally rare tree species listed in Table 1. In terms both of the extent and quality of the vegetation, and the number of rare species they hold, every valley forest site in this study was inferior to that of Wadi Rijaf. Following the work of Hall *et al.* (2008), this study confirms the need for the effective protection of the vegetation in Wadi Rijaf.

With this focus on conservation, we have completed regional IUCN Red List assessments (IUCN, 2001) for 18 species restricted to valley forest (see Table 1). Using IUCN Red List criteria, 13 species have been listed as Critically Endangered and five as Endangered in the Arabian region. Due to low population numbers, their occurrence in only a small number of fragmented sites and the continuing threat of habitat degradation, all these taxa are threatened with extinction in Arabia. Wadi Rijaf remains the most intact locality for the majority of these species (see Hall *et al.*, 2008).

The findings of the current study also highlight the importance of further field surveys of valley forest sites being conducted, both in Yemen and in Saudi Arabia. The current study was unable to survey the valley forest sites in the At-Tur basin and in the area of Jabal Qarazan and Jabal Ash Sharafayn. To gain a basic understanding of the conservation importance of these areas, any future studies should undertake to provide preliminary surveys of these localities. Valley forest sites in Saudi Arabia also require basic studies to determine their importance for conservation initiatives in the region.

In a Saudi Arabian study, Al-Turki (2004) reported the occurrence of small pockets of valley forest on the western slopes of Jabal Fayfa, dominated by the regional endemic *Acacia johnwoodii*, *Combretum molle*, *Trichilia emetica*, *Tamarindus indica* and *Mimusops laurifolia*. The vegetation was noted to be in a heavily degraded state as a result of poor land management practices, and Al-Turki (2004) reports that species such as *Mimusops laurifolia* are on the verge of local extinction. In Wadi Jawrah (close to Jabal Fayfa) there is a significant grove of 14 mature *Mimusops laurifolia* trees. These are to be incorporated into a new botanic garden in the region, which has the potential for *ex situ* conservation of regionally rare valley forest tree species. Future studies in Saudi Arabia should be directed towards determining the composition of the valley forest on Jabal Fayfa and to assessing the local abundance of regionally threatened species such as *Mimusops laurifolia*.

From a recent visit to Saudi Arabia, Miller (unpublished field data) recorded several individuals of *Mimusops laurifolia* on Jabal al-Qahar (an isolated mountain massif in the southern Tihama, northwest of Jabal Fayfa) in the Asir Governorate, at the confluence of Wadi Shi'ib and Wadi Tharb, and on Jabal Shada. These sites are potentially significant valley forest localities. They all require basic assessments of the extent, quality and composition of the valley forest in order to determine their importance for regional conservation initiatives. Similarly, on Jabal al-Qahar, particularly within Lejib Gorge, Miller (unpublished field data) noted the occurrence of valley forest patches. These patches also require further investigation to determine their extent, quality and species composition, particularly the abundance of regionally rare species. This will enable a complete, quantitative floristic analysis for Arabian valley

forest. With further work, all these sites could be recognised as important areas for plant conservation in the Arabian Peninsula.

The similarity of vegetation in southwest Arabia and northeast Africa has been emphasised by many authors (e.g. Schweinfürth, 1891; White & Leonard, 1991; Le Houerou, 2003). Descriptions of valley forests in northeast Africa, however, generally focus on higher altitudes (> 1800 m) where Afromontane species dominate, with a different botanical composition from the Arabian low to middle altitude valley forests (Friis, 1992; Hall *et al.*, 2008). Le Houerou (2003) argued that deciduous woodlands 'are the equivalent of the Combretaceae savanna of W, E and S Africa' (the closest to the Arabian valley forests; see Hall *et al.*, 2008). His wide-ranging survey of the Red Sea region notes that 'This type of woodland has become more or less vestigial and restricted to areas of rugged terrain and difficult access. In the area under study it has apparently been often replaced by *Acacia-Commiphora* woodlands and savannas, [but] the successional relationships between these two plant formations are far from clear' (Le Houerou, 2003).

None of the studies of Somaliland (Collenette, 1931; Gillett, 1941; Gilliland, 1952; see also Hemming, 1998) or of Djibouti (Audru *et al.*, 1987) have noted the existence of valley forests in the foothills of this region at altitudes of 500–1500 m. Instead, they have reported, at more humid locations at these altitudes, the existence of an evergreen *Buxanthus hildebrandtii* (Baill.) Tiegh. shrubland that is absent from the Arabian Peninsula. Interestingly, locally isolated *Mimusops* spp. occur at these altitudes as well (Gillett, 1941). The presence of winter rains in northeast Africa's coastal plains and low mountains (in contrast with the summer rains of southwest Arabia) may well explain these differences.

Only Schweinfürth (1891), with his first-hand knowledge of the Arabian valley forests (see above), reported the presence of valley forests on the eastern slopes of the Eritrean highlands, but he did not provide locations or altitudes. Schweinfürth (1891) emphasised the presence in both Arabian and Eritrean valley forests of *Ficus sycomorus*, *Phoenix reclinata* Jacq., *Cordia africana* Lam. (syn. *C. abyssinica* R.Br.), *C. ovalis*, *Ehretia cymosa* Thonn. (syn. *E. abyssinica* R.Br. ex Fresen.), *E. obtusifolia* Hochst. ex A.DC., *Nuxia oppositifolia* (syn. *N. dentata* R.Br. ex Benth.), *Carissa spinarum* (syn. *C. edulis*), *Diospyros mespiliformis*, *Mimusops laurifolia* (syn. *M. schimperi* A.Rich.), *Trichilia emetica* and *Tamarindus indica*. The absence of species such as *Combretum molle* and *Terminalia brownii* is, however, remarkable. Another significant difference between this vegetation and the southwest Arabian valley forests is the presence of the Arabian endemic *Acacia johnwoodii*. Until further research is done on the present state of the Eritrean valley forests, we are therefore inclined to emphasise the unique nature of the low to middle altitude valley forests in southwest Arabia.

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