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INVITED REVIEW

Sustainable utilization and conservation of plant biodiversity in montane ecosystems: the western Himalayas as a case study

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• *Background* Conservation of the unique biodiversity of mountain ecosystems needs trans-disciplinary approaches to succeed in a crowded colloquial world. Geographers, conservationists, ecologists and social scientists have, in the past, had the same conservation goals but have tended to work independently. In this review, the need to integrate different conservation criteria and methodologies is discussed. New criteria are offered for prioritizing species and habitats for conservation in montane ecosystems that combine both ecological and social data.

• *Scope* Ecological attributes of plant species, analysed through robust community statistical packages, provide unbiased classifications of species assemblages and environmental biodiversity gradients and yield importance value indices (IVIs). Surveys of local communities' utilization of the vegetation provides use values (UVs). This review suggests a new means of assessing anthropogenic pressure on plant biodiversity at both species and community levels by integrating IVI and UV data sets in a combined analysis.

• *Conclusions* Mountain ecosystems are hot spots for plant conservation efforts because they hold a high overall plant diversity as communities replace each other along altitudinal and climatic gradients, including a high proportion of endemic species. This review contributes an enhanced understanding of (1) plant diversity in mountain ecosystems with special reference to the western Himalayas; (2) ethnobotanical and ecosystem service values of mountain vegetation within the context of anthropogenic impacts; and (3) local and regional plant conservation strategies and priorities.

Key words: Anthropogenic impacts, conservation, ecosystem services, montane ecosystems, plant biodiversity, sustainable utilisation, western Himalayas.

INTRODUCTION

Ecosystem ecology is a major part of the discipline of ecology (Barbault, 1997); the term ecosystem was invented by Sir Arthur Tansley (Tansley, 1935) for a community of organisms and their environment. Ecosystem ecology has become very important in the 21st century because of the highly accelerated rate of anthropogenic modification of natural systems. Human alteration of natural ecosystems dates back millennia to the use of fire, overexploitation and later to the introduction of agriculture. The more recent agricultural expansions in the past 200 years, however, linked to increases in population, industrialization and anthropogenic climatic changes, are recognized as the main causal factors of the massive degradation of natural ecosystems that we now experience (Billings, 1972; Odum and Odum, 1972; Macdonald and Service, 1996; Macdonald and Willis, 2013).

On a global scale, mountain, highland and plateau ecosystems above 1500 m, which cover approximately one-fifth of the earth's land surface (Geist, 2005), support a high and varied plant biodiversity due to their diverse landscape and climate, despite supporting about 12 % of the world's human population (Cincotta *et al.*, 2000; Loucks *et al.*, 2008). Mountain ecosystems do not just provide direct and indirect ecosystem services for the sustenance of human life; their influence is far more widespread because lowland ecosystems and human populations also depend on them for services. The western Himalayan region provides an example, where there is a long-established tradition of using plants directly for medicinal purposes and as a source of fodder for livestock. Here, as well as all over South Asia, the mountains are crucial for the resilience of lowland human settlements which depend on their major river catchments for both agricultural and domestic water supplies (Manandhar and Rasul, 2009; Xu *et al.*, 2009; Rasul, 2010). The Himalayas are the origin of ten of the largest rivers in Asia and the economies of several south Asian countries are mainly based on the flow of these rivers, which ensure food security by providing irrigation water for rice and wheat – the major staple foods (Adhikari *et al.*, 1995; Archer and Fowler, 2004; Rasul, 2010). The shrubby vegetation of high altitudes also regulates avalanche movements and protects soils from wash-out and erosion (Hester and Brooker, 2007). Unwise use of montane plant resources is a direct threat to biodiversity maintenance and the continued proper functioning of mountain ecosystems (Sharma *et al.*, 2010; Tarrasón *et al.*, 2010), as well as to the continuance of traditional livelihoods at both local and regional scales. High-altitude species and ecosystems are also potentially under threat of biodiversity loss from global warming – a consequence of both geographical range contraction and mountain-top ecosystem extinction risk (La Sorte and Jetz, 2010; Mondoni *et al.*, 2011, 2012).

Increasing awareness of human impacts on ecosystems has generated a growing appreciation of the wide range of benefits that biological resources and ecological processes provide to human societies in the past decade and a half, called ecosystem services (MEA, 2005). These are defined as 'conditions and processes through which ecosystems and species in them sustain and fulfil human life' (Deane, 1999) or as the 'components of nature used for human well-being' (Boyd and Banzhaf, 2006). Ecosystem services result from interactions between biotic and abiotic components of ecosystems (Adhikari *et al.*, 1995; Singh, 2002) and can be grouped into four categories according to the benefits that they provide for people – provisioning, regulating, supporting and cultural services (MEA, 2003). Plant species are the primary producers in every ecosystem and also the primary source of direct and indirect goods and services to humans (Fig. 1). Their direct provisioning services to humans are food, fodder, medicines, timber, fuel-wood and grazing, while regulating services include moderating air and water quality and erosion control. They also play a vital role in supporting services such as soil formation, and nutrient and water cycling and in cultural services, including traditional human knowledge systems. Maintaining a high level of plant diversity is connected to the maintenance of ecosystem services provision, even though the mechanisms may not yet be entirely clear, and it is widely believed that more species will be needed to provide ecosystem functioning under future environmental change scenarios (Haines-Young and Potschin, 2010; Isbell *et al.*, 2011). Thus, preserving as much plant biodiversity as possible across the widest range of ecosystems is generally seen as an indispensable approach to maintain the benefits that they provide to humans.

Ecosystems in high mountain regions are intricate and significant cost and time factors are involved in their study, particularly where they are remote. Conserving plant biodiversity requires consistent and sound qualitative as well as quantitative records of botanical data on a regular basis (Clubbe *et al.*, 2010) and robust phytosociological (quantitative ecological) techniques are essential to achieve this. Ethnobotanical methods can be linked to this, to describe and evaluate the nature and value of the ecosystem services that plant communities provide for local people. Data obtained through a combination of these techniques provides basic knowledge for conservation managers and biodiversity planners to evaluate the services provided by mountain ecosystems and to formulate sustainable management options.

This review provides an overview of ecological knowledge about montane ecosystems in a way which seeks to integrate the previously different approaches, drawing upon the authors' experience of the western Himalayas. Until our recent work undertaken there, no previous attempt had been made to combine quantitative and qualitative ecological (phytosociological) and ethnobotanical data in order to describe and assess plant communities and their associated provisioning services as a basis for plant conservation planning. These two methodological approaches are now described in more detail. The review addresses the application of phytosociological techniques to vegetation description and quantification and then goes on to review ethnobotanical approaches to the assessment of plant uses. It discusses how importance value indices (IVIs), derived from phytosociological data, can be combined with use values (UVs), derived from ethnobotanical studies, to provide a new

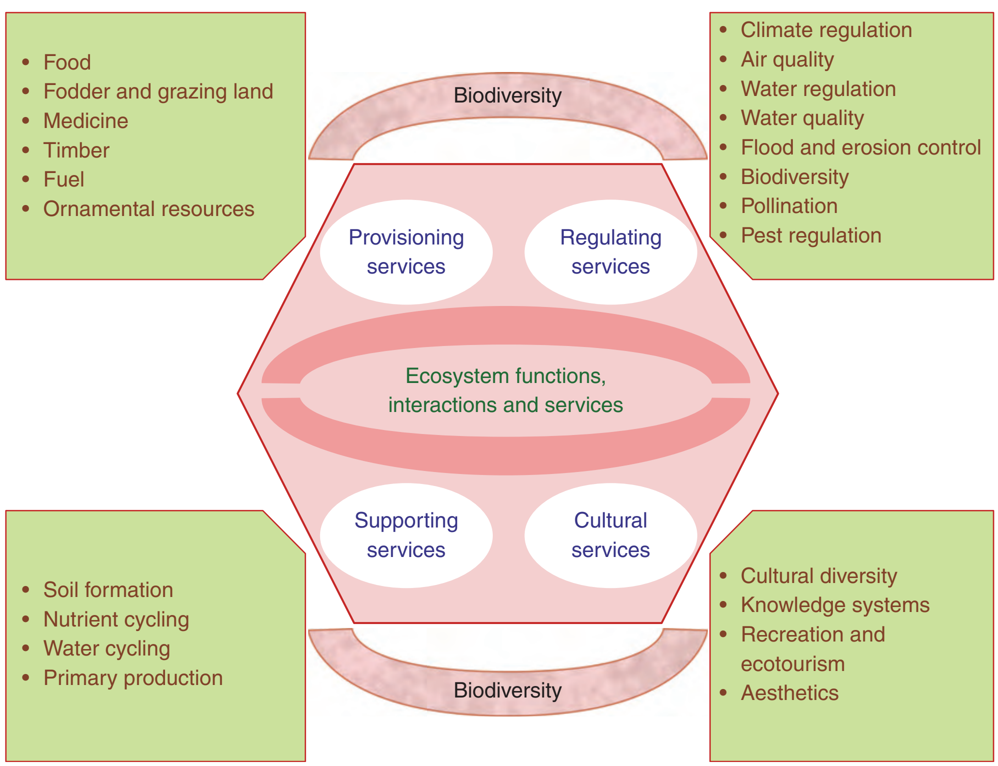

FIG. 1. Classification of ecosystem services in the western Himalayan region with modifications to the broad categories specified in the Millennium Ecosystem Assessment (MEA, 2003; Kremen, 2005; Wallace, 2007).

gateway to the assessment of anthropogenic pressures on plant biodiversity at both species and community levels. In the western Himalayas, there is well-established traditional ecological knowledge of plant use for human well-being, but this is at risk of loss alongside the growing threats to the species themselves as a result of a range of anthropogenic impacts.

PHYTOSOCIOLOGY AND ETHNOBOTANY USED TO IDENTIFY AND QUANTIFY VEGETATION-DERIVED ECOSYSTEM SERVICES

Phytosociology

The distribution of individuals of the same and different plant species in a community is a function of micro-environmental variations, time and biotic relationships. Plant species assemble in a community in a definite fashion and understanding this can be helpful during quantification and evaluation of ecosystem services (Daubenmire, 1968; Billings, 1972; Mueller-Dombois and Ellenberg, 1974; Rieley and Page, 1990; Greig-Smith, 2010). Phytosociology is the science of vegetation classification based on each species' co-occurrence and its relation to the surrounding environment. This has provided valuable methods for vegetation assessment that have been applied in vegetation mapping, ecosystem services quantification and biodiversity conservation (Rieley and Page, 1990; Ewald, 2003; Biondi, 2011). The health of ecosystems is closely allied to their plant biodiversity (Ruiz *et al.*, 2008; Schäfer, 2011) and thus vegetation classification is a vital first step towards ecosystem management and conservation. This knowledge is particularly important when studying rare or endemic species, for developing management strategies to protect them and/or reducing fragmentation of their habitats (Ewald, 2003; Aægisdóttir *et al.*, 2009).

Phytosociological field techniques allow ecologists to calculate diversity, richness and abundance of plant species in an ecosystem which not only helps them to decide on conservation priorities, but also their role as indicators of particular habitat types (Whittaker *et al.*, 2001; Greig-Smith, 2010; Tüxen and Whittaker, 2010). Moreover, IVIs can be calculated from such data by adding the relative values of species cover, density and frequency. In addition, frequency, constancy and fidelity analyses help to identify the most threatened species and those habitats needing protection (Baillie, 2004; Hester and Brooker, 2007; Zou *et al.*, 2007).

Phytosociology originated with the Swiss ecologist Josias Braun Blanquet (1884–1980) in Europe. A number of plant sociology schools developed subsequently at the beginning of the 20th century, two of which rapidly gained importance – the Zurich-Montpellier and the Uppsala schools. In 1915, Braun Blanquet defined the plant community as a plant group having characteristic (indicator) species and a stability with the surrounding environment (Rodwell, 1991–2000; Podani, 2006). The plant community of a region is a function not only of time but also of other factors such as altitude, slope, latitude, aspect, rainfall and humidity, all of which play a role in its formation and composition (Kharkwal *et al.*, 2005). The ecological diversity of vegetation communities is a measure of the strength of the whole ecosystem (Thompson and Brown, 1992; McGrady-Steed and Morin, 2000). The choice of sampling method used in any phytosociological study depends on the types of data desired, the objective of the study, the morphology of the vegetation, the geomorphology of the region, the available resources and time (Moore and Chapman, 1986; Biondi, 2011). The number of samples to be taken from a study area has to be enough to provide a good representation of the plant communities of that area.

The most common quantitative sampling methods are the quadrat and line transects. The quadrat method originated with Frederick Edward Clements (1874–1945) (Weaver and Clements, 1938, 1966). In its simplest form the quadrat is used to count the individuals and estimate cover of each species to determine their abundance, but it is also used to determine differences in the composition and structure of vegetation. It allows the user to define a fixed area, called a plot or relevé, within which plant characteristics are measured. This may be adapted in a variety of ways for analysing almost any type of vegetation. The line transect is typically used when there are apparent vegetation differences, such as along a gradient, from one point of interest to another within a sampling site. The two methods are often used together, especially when both quantification of vegetation and assessment of ecological gradients are desirable. Species composition, plant species density, cover and abundance are the most important characteristics for sampling with quadrats (Cox, 1996; Khan *et al.*, 2013*a*). Several scales for ranking vegetation cover have been suggested; two commonly used are the Braun Blanquet (1884–1980) and Daubenmire (1968) cover class scales (Braun-Blanquet *et al.*, 1932; Daubenmire, 1968). This is done by assigning cover class estimates for herbaceous and shrubby vegetation while diameter at breast height (dbh) is used for trees (Goldsmith *et al.*, 1986).

Once phytosociological data are collected, they need to be analysed in a statistical framework. Multivariate statistical techniques, which have emerged in the last few decades, help ecologists to discover structure in the data set and to analyse the effects of environmental factors on whole groups of species (Clymo, 1980; Bergmeier, 2002; Anderson *et al.*, 2006). Computer technology has revolutionized the field of community ecology, with a range of statistical programs available to help ecologists to understand and interpret ecological data in a more precise way. Software packages such as TWINSPAN, DECORANA (Hill, 1979; Hill and Gauch, 1980), CANOCO (ter Braak, 1989; ter Braak and Smilauer, 2002) and PC-ORD (McCune, 1986; McCune and Mefford, 1999; Grandin, 2006) are examples of packages used for vegetation classification and ordination in quantitative ecology (Gilliam and Elizabeth, 2003). Community data are summarized by constructing a low dimensional space, in which similar samples and species are placed close together and dissimilar ones far apart from each other by convenient and objective means (Gauch, 2010). Agglomerative cluster analysis (ACA), indicator species analysis (ISA), detrended correspondence analysis (DCA), principal components analysis (PCA) and canonical correspondence analysis (CCA) are the most widely used classification and ordination techniques to determine plant communities, their ecological gradients, indicator species, and the significance of the relationships between floristic and environmental data (Hill and Gauch, 1980; ter Braak, 1987; Dufrêne and Legendre, 1997). More recently the combination of field survey with remote sensing techniques for mapping vegetation and habitat types has increased (Sherrouse *et al.*, 2010; Kumar *et al.*, 2011; ten Brink *et al.*, 2013).

Humans have used the services of ecosystems, particularly the vegetation, for millennia, but in less than 100 years it has become increasingly obvious that our use is no longer sustainable and that many ecosystems are no longer functioning adequately. Phytosociological knowledge now needs to be combined with equally rigorous ethnobotanical analysis if humankind is to have any hope of restoring ecosystem services to their optima again.

The ethnobotanical approach for assessing plant-based ecosystem services

Natural vegetation provides basic needs for indigenous human communities and is often their prime source of livelihood, especially in the developing world. Plant–human relationships are as old as human history. In AD 77, the Greek surgeon Dioscorides published 'De Materia Medica', a catalogue of about 600 plants in the Mediterranean region, with information on how the Greeks used the plants, especially for medicinal purposes. The records from earlier cultures of Africa and China, the Nile and the Indus valleys have also revealed the use of herbal medicines by the inhabitants of those regions over several millennia (Baqar, 2001). The American botanist John William Hershberger used the term ethnobotany for the first time in 1895 in a lecture in Philadelphia to describe the scientific study of the relationships that exist between people and plants (Hershberger, 1895). Ethnobotany involves botany, anthropology, ecology, economics and linguistics. It can inform us about the present-day uses of plant species, including the development of new products such as drugs from plants, and their conservation status. Traditional botanical knowledge can be used in the assessment of economic benefits derived from plants, both at basic and at commercial levels. Such knowledge can be used as an analytical tool for the quantification of provisioning services provided by vegetation and can also maximize the value of traditional ecological knowledge. It can be applied in long-term management and conservation strategies (Pieroni and Giusti, 2009; Anthwal *et al.*, 2010; Tang and Gavin, 2010). The World Health Organization (WHO) has recognized the role that plants play in traditional healing systems and thereby their contribution to the provision of health services, particularly in the developing world. Moreover, plants have provided the models for 50 % of the present-day allopathic drugs in the developed world (Robbers *et al.*, 1996). Due to this immense value, some of the plants utilized for ethnomedicines are in decline due to over-collecting.

Ethnobotanical studies investigate the structural relationships between human society and the environment using socio-anthropological methods; these relationships can be social, economic, symbolic, religious, commercial and/or artistic (Aumeeruddy, 2003). Such studies can thus be a useful tool to quantify ecosystem services (Ford, 1994; Phillips *et al.*, 1994). Recently, in rapidly developing parts of the world, ethnobotanical studies have progressed from the production of inventories of plant species towards more practical quantitative approaches which place emphasis on sustainable use and the conservation of plant resources (Rossato *et al.*, 1999; Da Cunha and De Albuquerque, 2006; Uniyal *et al.*, 2006; De Albuquerque, 2009; Teklehaymanot and Giday, 2010).

Information on how indigenous people interact with the natural environment can be collected and analysed in a number of ways depending on the study objectives and research questions. Such analyses may range from laboratory analyses (e.g. to identify therapeutic compounds), to ethnobotanical surveys and assessment of priorities for conservation management. Whatever the analyses may be used for, one common requirement is that the information is obtained in a systematic manner (Martin, 2004; Thomas *et al.*, 2007, 2009) but, in contrast to scientific fieldwork, ethnobotanical surveys require that the researcher deploys additional skills such as calmness, patience, courtesy, empathy and keeping secrets (Ragupathy *et al.*, 2008; Miehe *et al.*, 2009) in their interactions with indigenous communities.

Ethnobotanical data have been analysed qualitatively to record plant uses and the plant parts that are collected, but more recently, quantitative ethnobotany has led to more rigorous hypothesis-based analyses of data sets (Phillips *et al.*, 1994; Rossato *et al.*, 1999; Da Cunha and De Albuquerque, 2006; De Albuquerque, 2009). Ethnobotanical data sets based on indigenous traditional knowledge can be tallied and analysed together with data from vegetation surveys to provide a better understanding and management of ecosystems (Moerman, 1991; Negi, 2010). One such approach, which will be described in more detail below, is the integration of plant UVs derived from ethnobotanical surveys with phytosociological data on the distribution and relative importance of individual plant species within a community, by dividing the number of uses of particular species in a region by the number of informants from that region (Phillips *et al.*, 1994; Mucina, 1997; Da Cunha and De Albuquerque, 2006).

BOTANICAL CONSERVATION IN ASIAN MONTANE ECOSYSTEMS

The unique topographic attributes of mountain areas, such as slope, aspect and altitude, provide characteristic spatial patterns for mountain ecosystems and processes (Radcliffe, 1982). Prominent vegetation zones are based mainly on altitudinal and climatic variations, while the variation in aspect enhances habitat heterogeneity and brings micro-environmental variation in to the vegetation pattern (Clapham, 1973). High mountains all over the globe are important locations for species-rich assemblages (Dirnböck *et al.*, 2001; Vetaas and Grytnes, 2002; Casazza *et al.*, 2005, 2008; Fu *et al.*, 2006; Nowak *et al.*, 2011) and endemic floras (Myers *et al.*, 2000; Halloy and Mark, 2003; Kazakis *et al.*, 2007; Khan, 2012). The Himalayas, the mountains of Central Asia, south-west China, the Caucasus, East Africa and the Andes are recognized as globally important biodiversity hotspots (Fig. 2).

Mountain biodiversity is, however, under threat and a number of endangered plant species are on the verge of disappearance because montane plant species respond in a very sensitive way to environmental change (Gordon *et al.*, 2002; Holtmeier and Broll, 2005; Miller *et al.*, 2006; Thuiller, 2007). This is, in part, a consequence of the narrow ecological amplitudes displayed by many montane and alpine species, but it also reflects

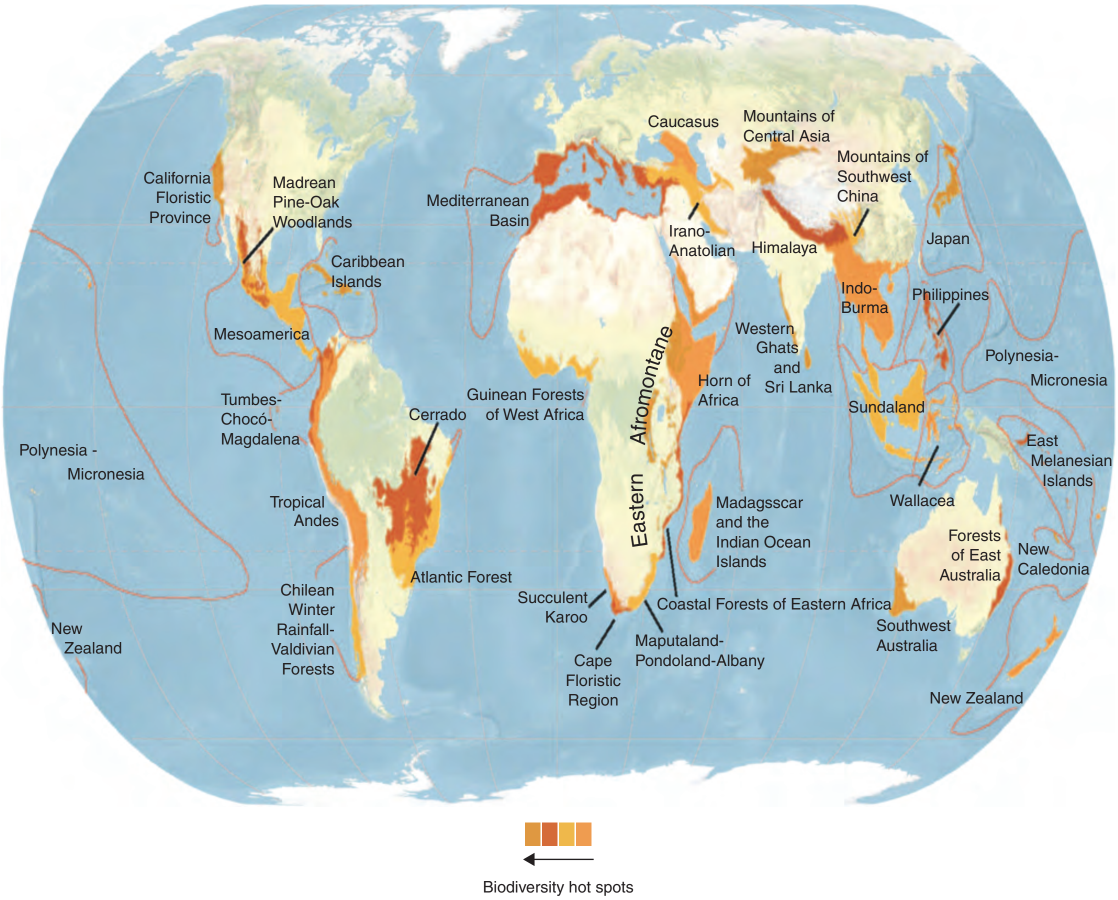

FIG. 2. Biodiversity hot spots around the globe (Myers *et al.*, 2000). Source: http://www.conservation.org/where/priority_areas/hotspots/Pages/hotspots_main.aspx)

increasing grazing pressure or collection for food or other uses (Hobbs and Huenneke, 1992). As a result, mountain regions are predicted to be locations for rapid species extinction, particularly under the threat of global warming (Kullman, 2010). Studies have already shown an upward elevation shift of habitat types and of alpine species over the recent past and the appearance of species from lower altitudes at higher elevations (Valley, 2003; Dobbertin *et al.*, 2005; Beckage *et al.*, 2008; Lenoir *et al.*, 2008; Walther *et al.*, 2009; Takahashi *et al.*, 2012), combined with the dominance of more resistant and vigorous species. Consequently, vegetation homogeneity has increased in some locations, enhanced by the selective utilization of plants by humans (Collins *et al.*, 2002; Kikvidze *et al.*, 2005; Srivastava and Vellend, 2005; Del Moral *et al.*, 2010; Grabherr *et al.*, 2011).

Montane ecosystems need proper management against these negative climatic and anthropogenic influences for their future sustainability (Kessler, 2000; Halloy and Mark, 2003; Holzinger *et al.*, 2008; Erschbamer *et al.*, 2011). Sustainable approaches to resource use are particularly urgent in less economically developed countries where there is a strong reliance by the indigenous people on plant resources. In the Himalayas, for example, there is widespread traditional use of species, often resulting in overuse, combined with a lack of botanical recording which makes the planning of conservation strategies a challenging task. The Himalayas differ from other mountain systems, for example the European Alps, in that in the former the people still possess an intact traditional healthcare system and ethnobotanical knowledge. Ethnobotanical knowledge has been largely lost in the Alps by contrast, and there is also a lower population density at high altitudes. The main land-use problem in the Alps at the current time is land abandonment, rather than degradation through over-exploitation (Gehrig-Fasel *et al.*, 2009; Niedrist *et al.*, 2009).

Bringing sustainability into the use and management of plant resources in mountain areas is a challenging task, especially in remote mountain ranges such as the Himalayas, Hindu Kush and Karakoram where there are both geographical and geopolitical constraints. These mountain ranges are also located in geopolitically immature and democratically young countries such as India, Nepal, Pakistan and Afghanistan where, in the majority of cases, policy-makers and politicians pay little regard to the scientific evidence on plant biodiversity and threats to its survival when taking decisions related to natural resource management. In addition, parts of these geopolitical territories have faced various political or tribal conflicts and unrest, e.g. the Hindu Kush mountains in Afghanistan. Such unrest reduces the opportunity for documentation of existing biodiversity and the implementation of conservation management.

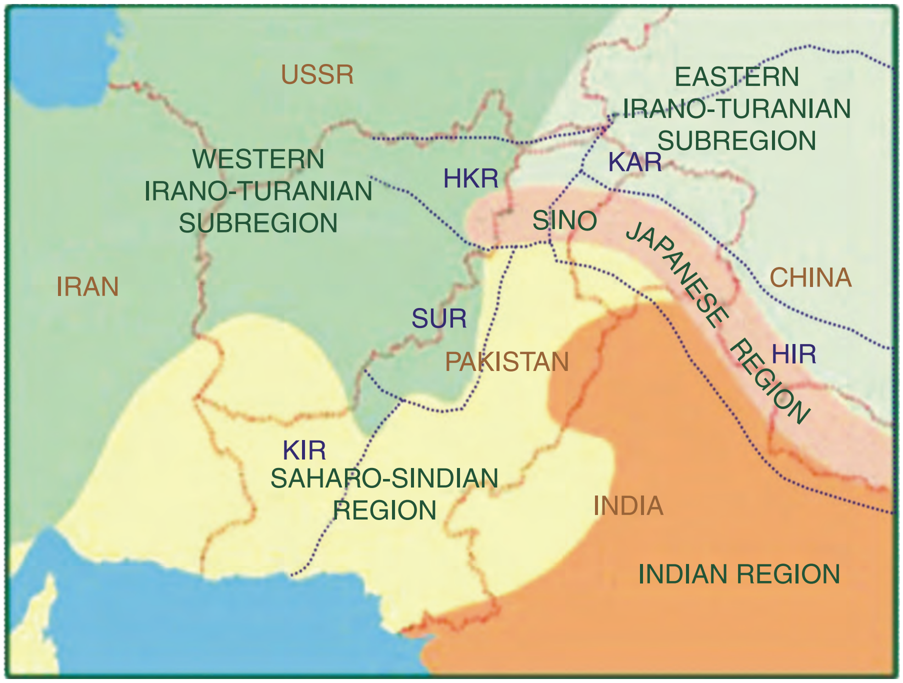

FIG. 3. Irano-Turanian region showing five of the world's significant mountain systems: the Himalayas Range (HIR), Karakorum Range (KAR), Hindu Kush Range (HKR), Suleiman Range (SUR) and the Kirthar Range (KIR). Source: http://botany.org/plantsciencebulletin/psb-2008-54-4.php

The plant resources and botanical importance of the Central Asian mountains – the three largest mountain ranges of the world

The Irano-Turanian region of the Tethyan sub-kingdom has a rich and significant floristic diversity due to the presence of several mountain ranges. This region, which encompasses Afghanistan, most parts of Iran and north-western Pakistan, a few central Asian states, southern China and northern India, supports diverse vegetation communities, owing to the diversity of geo-climatic zones and the presence of five significant mountain systems – the Kirthar and Suleiman with the world's largest three – Hindu Kush, Karakorum and Himalayas (Fig. 3). These mountain ranges meet together in north-western Pakistan where they hold a plant biodiversity of about 19 000 species (Champion and Harry, 1965; Dasti *et al.*, 2010).

The Kirthar mountain range commences at the Arabian Sea coast and extends about 300 km northwards to the Mula River in the east-central Baluchistan of Pakistan. Due to low rainfall, poor soil conditions, deforestation and grazing pressures these mountains are less rich in floristic diversity and are predominantly occupied by xerophytic plant species such as *Ziziphus nummularia*, *Salvadora oleoides*, *Dodonea viscosa*, *Grewia tenax* and *Capparis deciduas* (Enright *et al.*, 2005; Perveen and Hussain, 2007).

The Sulaiman Mountains are a major geological feature of the northern Baluchistan province; they extend westward to the Zabul province in Afghanistan and northward to the Hindu Kush. Their vegetation is sparse and scattered in the form of tufts of grasses and thorny plants; *Pinus gerardiana* (Chilghoza) forests are unique to this range.

The Hindu Kush mountain range stretches 800 km between the Suleiman range (in the south-west), the Himalayas (in the east) and the Karakorum (in the north-east) and forms the geopolitical boundary between Pakistan and Afghanistan. The forest areas of the Hindu Kush are characterized by *Cedrus deodara*, *Picea smithiana*, *Pinus wallichiana*, *Pinus roxburgii* and *Abies pindrow* especially in wetter areas that come under the influence of the monsoon. The eastern part of the Hindu Kush becomes increasingly similar to the adjacent Himalayas in terms of climate and flora, and thus most bio-geographers use the collective term Hindu Kush-Himalaya (HKH) for these ranges (Miehe *et al.*, 2009; Dong *et al.*, 2010).

The Karakorum mountain range, which is about 500 km long, connects the plateaux of Tibet and the Pamir and forms a part of the political border between Pakistan, India and China (Xiang *et al.*, 2002; Phartiyal *et al.*, 2005; Eberhardt *et al.*, 2007; Marston, 2008; Khan *et al.*, 2009). The vegetation is mainly xeric in nature due to the cold, arid climate. Vegetation zones can be categorized on the basis of humidity and elevation gradient from semi-desert, through montane shrub to alpine meadow. A few studies indicate the shrubby nature of the vegetation at lower altitudes (around 2700 m), with alpine pastures at higher altitudes (above 3500 m). Characteristic plant species of the Karakorum Range are *Salix karelinii* and *Juniperus semiglobosa*.

The Himalayan range of mountains is about 2500 km long and 400 km wide and occupies a comparatively small part of Pakistani territory but a larger part of India, Nepal and China. Important indicator species of the Himalayan range are *Pinus wallichiana*, *Abies pindrow*, *Rhododendron* species, *Fragaria nubicola*, *Viola* species and *Clematis* species. Floristically, the vegetation of the western and northern Himalayas becomes increasingly analogous, respectively, to that of the Hindu Kush and the monsoon belt of the Karakorum mountains in terms of species composition and richness, owing to geological,

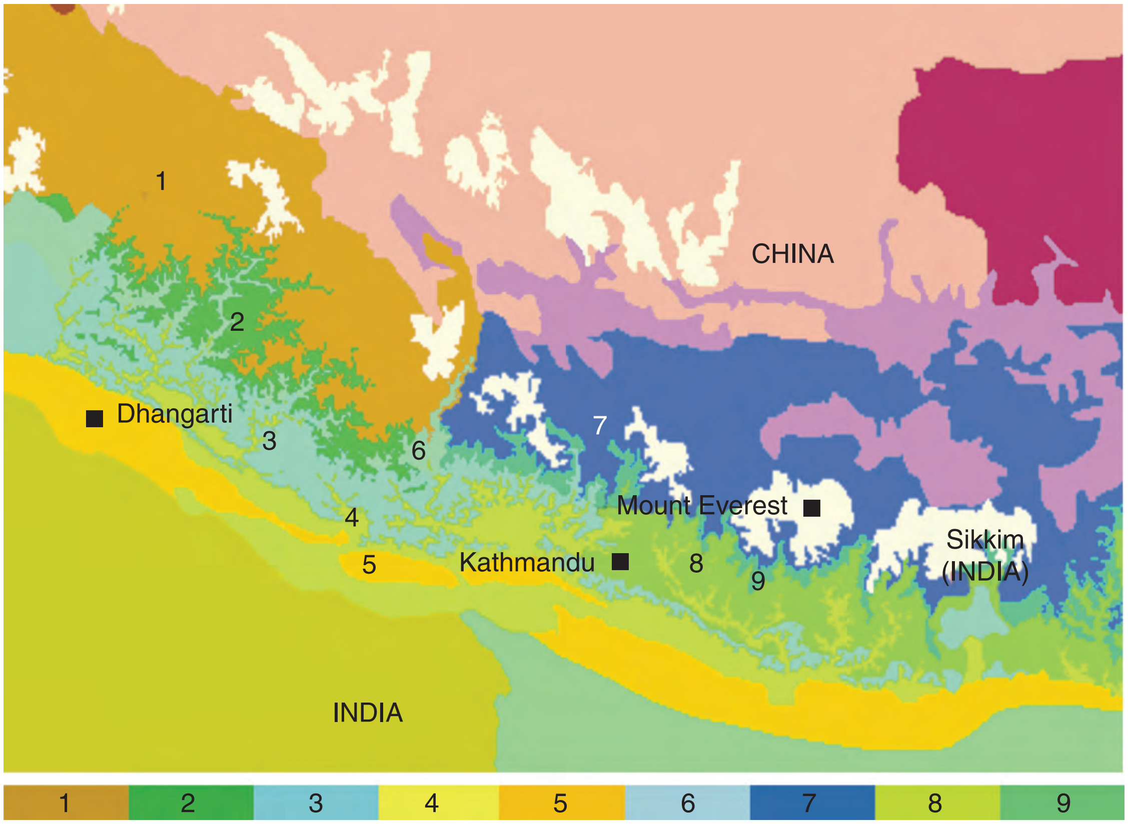

FIG. 4. Vegetation zonations in the Himalayas, using Nepal as an example. (1) Western Himalayan alpine shrub and meadows. (2) Western Himalayan subalpine conifer forests. (3) Himalayan subtropical pine forests. (4) Himalayan subtropical broadleaf forests. (5) Savanna and grasslands. (6) Western Himalayan broadleaf forests. (7) Eastern Himalayan alpine shrub and meadows. (8) Eastern Himalayan broadleaf forests. (9) Eastern Himalayan subalpine conifer forests. Source: World Wildlife Fund http://www.eoearth.org/article/Nepal?topic=49460

physiographic and climatic similarities. Alpine and subalpine habitats, where altitude becomes the most powerful limiting factor, further strengthen the floristic affinities with higher elevation vegetation of the Hindu Kush and the western Himalayas (Miehe *et al.*, 1996; Pei, 1998; Hamayun *et al.*, 2006; Eberhardt *et al.*, 2007; Qureshi *et al.*, 2007*a*; Wazir *et al.*, 2008; Ahmad *et al.*, 2009; Ali and Qaiser, 2009).

Plant diversity decreases with a reduction in the monsoon effect as one moves from south-east to north-west in the Himalayas. Other factors responsible for this decline are the increase in altitudinal and latitudinal gradients. In general the Himalayan vegetation ranges from tropical evergreen species in the south-east to thorn steppe and alpine species in the north-western parts (Behera and Kushwaha, 2007; Fig. 4). The dominance of an endemic flora in the western Himalayas, especially at high elevations, indicates the high conservation importance of these ecosystems (Dhar 2002); Dhar advocates that the timberline zones should be protected as priority regions. Throughout the Himalayan range, plants are threatened by the high anthropogenic pressures exerted by farming, herding, fuel, timber, and medicinal plant collection. In response, the mountain vegetation of this region has become a significant focus in recent ecological, conservation and ethnobotanical studies (Hamayun *et al.*, 2003; Parolly, 2004; Lovett *et al.*, 2006; Khan *et al.*, 2007, 2012*a*, *b*; Shaheen *et al.*, 2011, 2012).

Plant conservation efforts in the Himalayas

Despite possessing very diverse vegetation (Shrestha and Joshi, 1996), the plant resources of the Irano-Turanian region in general and the Himalayas in particular have not been examined thoroughly due to climatic, socioeconomic and geopolitical constraints. These mountains support approximately 19 000 plant species of which approximately 7500 are valued for their medicinal uses (Pei, 1998). Unlike the eastern Himalayas, where monsoon-driven vegetation predominates under higher rainfall and humidity (Behera *et al.*, 2005; Dutta and Agrawal, 2005; Roy and Behera, 2005; Chawla *et al.*, 2008; Anthwal *et al.*, 2010), the vegetation in the western Himalayas in general (Dickoré and Nüsser, 2000; Chawla *et al.*, 2008; Ahmad *et al.*, 2009; Kukshal *et al.*, 2009; Shaheen *et al.*, 2011), and in the Naran Valley in particular (Khan *et al.*, 2011*a*), has closer affinities with that of the Hindu Kush mountains, which have a drier and cooler climate (Noroozi *et al.*, 2008; Wazir *et al.*, 2008; Ali and Qaiser, 2009). Nevertheless, the vegetation in both these mountain systems as well as in the Karakorum (Miehe *et al.*, 1996; Eberhardt *et al.*, 2007) exhibits great similarity above the tree line (Miehe *et al.*, 2009), where climatic conditions are more comparable.

Only very few studies have used modern numerical/statistical techniques to quantify and model plant species, communities and environmental as well as cultural drivers of vegetation variation in this region, particularly in the more distant and least accessible parts of the mountains. In addition, plant community identification and classification using modern techniques has so far been restricted to the plains and low-altitude areas (Qureshi *et al.*, 2006; Dasti *et al.*, 2007; Perveen and Hussain, 2007; Saima *et al.*, 2009; Siddiqui *et al.*, 2009). The remote mountainous areas must now be the focus for vegetation studies due to their important phytogeographical location (Adhikari *et al.*, 1995). In addition to the scientific exploration of biotic and abiotic components of mountain ecosystems, there is also an immediate need for facilitation, social mobilization and education of the indigenous people of these remote regions. Education and awareness about habitat destruction, and decreasing biodiversity with increasing population and climate change are high priorities (Díaz *et al.*, 2006; Ma *et al.*, 2007; Hermy *et al.*, 2008; Giam *et al.*, 2010). The indigenous mountain people have a great deal of traditional ecological knowledge about vegetation ecosystem services, particularly provisioning services, which, in return, needs to be documented and incorporated into conservation and climate change adaptation strategies. Thus, there needs to be a three-way participatory flow of knowledge and information between vegetation scientists, local people and conservation managers.

In a recent review, Vačkář *et al.* (2012) pointed out that each aspect of biodiversity cannot be assessed using a single indicator and suggested the use of multiple indices and indicators for a better understanding of biodiversity in relation to human activities (Dolan *et al.*, 2011; Feola *et al.*, 2011; Vačkář *et al.*, 2012). In our study in the western Himalayas (Khan, 2012), we employed two different approaches to identify indicator species based on ecological as well as cultural analyses. ‘Ecological’ indicator species were identified as a result of extensive vegetation description and statistical analysis, while ‘traditional’ indicator species were recognized on the basis of ethnobotanical surveys amongst local people. The ecological component of this study was distinctive as our work identified indicator species based on their ecological fidelity and abundance. Other vegetation studies along environmental gradients in mountain ecosystems have merely compared the diversity indices among communities and treated all species equally without considering their ecological position and their meaning in those particular ecosystems (Carpenter, 2005; Oommen and Shanker, 2005; Gould *et al.*, 2006; Ren *et al.*, 2006; Dasti *et al.*, 2007; Crimmins *et al.*, 2008; Wazir *et al.*, 2008; Siddiqui *et al.*, 2009). We used species abundance data in PCORD to calculate the indicator values and thus at least one statistically significant indicator species was selected from each of the tree, shrub and herb layers in each of the plant communities using ISA. At the same time the faithfulness of these indicators was tested by their categorization in fidelity classes. Species with higher fidelity values were considered to have the maximum conservation priority, i.e. these were species having restricted distribution, and probably special or fragmented habitats and were at highest risk (Zou *et al.*, 2007; Pinke and Pál, 2008; Haarmeyer *et al.*, 2010). One of the individual aspects of our study was combining IVIs and UVs in their analyses to obtain residual values of plant species signifying anthropogenic pressure on them. Thus, this approach opens up a new way to study and manage ecosystem services and environmental sustainability (Layke *et al.*, 2011; Moldan *et al.*, 2011) and to prioritize special habitats and species of conservation importance.

Identification of traditional use patterns of plant resources in the western Himalayas; a step towards better conservation management

In the remote valleys of the Himalayas people exploit natural resources and vegetation according to their seasonal migration with livestock to summer pastures and they have valuable knowledge of the ecosystem services that can be derived from the vegetation. The use of plants for medicinal uses, grazing and fodder now imposes a high pressure on the plant biodiversity, with implications for longer-term sustainability; with some species under such continuous pressure they are likely to become extinct in the near future. Anthropogenic activities and biodiversity are in conflict with each other. People choose species only because of their own needs and hence put pressure on rare species (Ahmad *et al.*, 2002). The major social problems responsible for the enormous anthropogenic pressures on the vegetation in the region are the increased population, prevailing poverty, lack of awareness and poor education, which combine to increase the competition for and overexploitation of the natural plant resources.

In a study of the Naran Valley (Khan, 2012), we evaluated the knowledge of local people about recent trends in abundance of various plant species. There was a close coincidence between the findings from both ecological and ethnobotanical perspectives indicating a high extinction risk for plant species most valued (Khan *et al.*, 2012*b*). Many of the species recorded in this study (83 %) provide an array of provisioning services. Preference analysis showed medicinal use to be highest (56·9 % of responses) followed by grazing and food (13·1 and 10·8 %, respectively). The elevated priority given to medicinal use illustrates the depth of traditional knowledge about plants in the community and the lack of basic health facilities. It can also be attributed to the high market value of medicinal species (Khan *et al.*, 2013*b*).

Each medicinal species found in the region is noteworthy but a few have a pre-eminent importance in the local healthcare system. *Dioscorea deltoidea*, for example, is used to treat urinary tract problems, and as a tonic and anthelmintic. Local hakeems (experts in traditional medicine) use *Podophyllum hexandrum* in digestive troubles and for treating cancer. Powdered bark of *Berberis pseudoumbellata* is used for the treatment of fever, backache, jaundice and urinary tract infections whilst its fruit is valued as a tonic. Orchid species such as *Cypripedium cordigerum* and *Dactylorhiza hatagirea* are considered to be aphrodisiacs and used as nerve tonics. All of these species are listed by CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) (Fig. 5). We found 97 prominent remedial uses of medicinal plants, divided into 15 major categories based on ailments of specific parts of the human system. The largest number of ailments cured with medicinal plants were associated with the digestive system (32·76 % responses) followed by those associated with the respiratory and urinary systems (13·72 and 9·13 %, respectively) (Khan *et al.*, 2013*b*). There was considerable harmony between peoples’ own perception of the ecological status of each species when compared with the classification of the plant species according to the IUCN Red List criteria. Indigenous people reported a reducing trend in the availability and population sizes of 112 plant species (56·56 % of the total species), 32 of which fell in the IUCN category of Critically

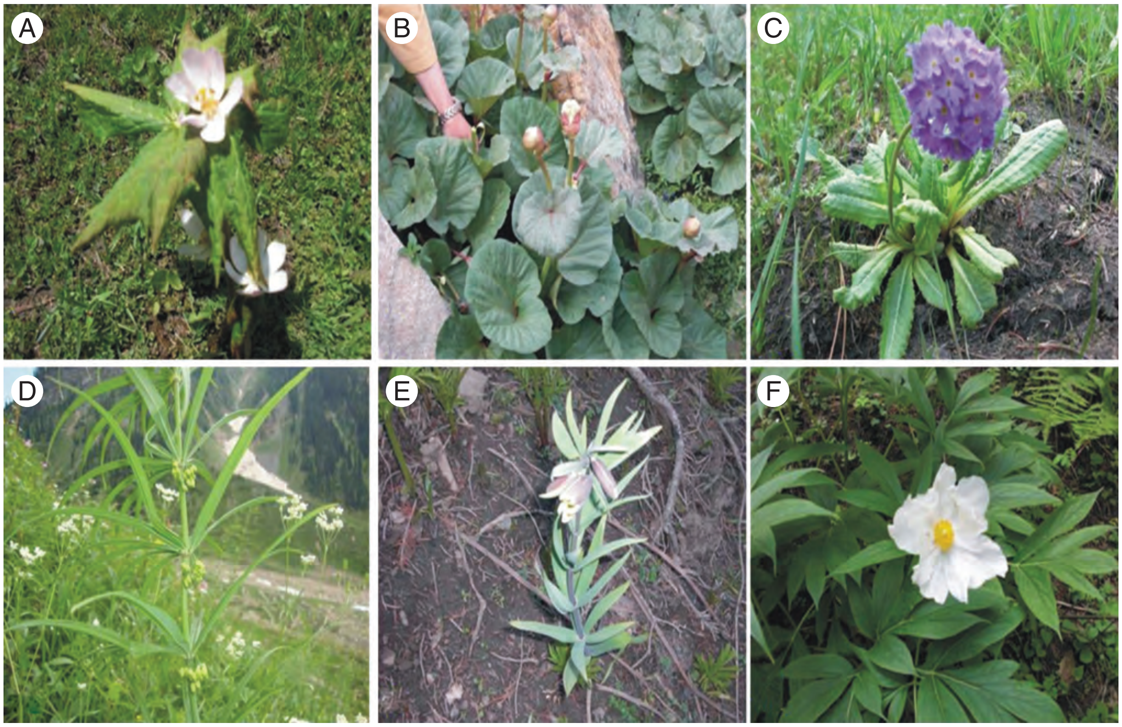

FIG. 5. Six of the more important plant species used for traditional medicine in the western Himalayas. (A) *Podophyllum hexandrum* (see Appendix, species no. 69 for details). (B) *Rheum australe* (species no. 79). (C) *Primula denticulata* (species no. 72). (D) *Polygonatum verticillatum* (species no. 70). (E) *Fritillaria roylei* (species no. 39). (F) *Paeonia emodi* (species no. 60).

Endangered, 22 in Endangered, 18 in Vulnerable, 24 in Near Threatened and only 16 in the category of Least Concern. Alarmingly, most of the species of conservation concern were classed as either endemic, indicator or faithful species with high habitat specificity, indicating that these species required specific conservation attention from all stake holders (Khan *et al.*, 2011*a*, *b*, 2012*a*, *b*, 2013*c*) (Fig. 6).

Integration of species' IV (abundance) with UV gave the pattern of use with high significance (Khan *et al.*, 2011*b*; Khan, 2012) and residual value analyses using linear regression statistics revealed that 93 species (50·8 % of the used and 46·9 % of the total species) had residual values greater than the standard deviation, signifying they are overused. The top 10 species with highest residuals were *Juglans regia*, *Polygonatum verticillatum*, *Origanum vulgare*, *Cedrus deodara*, *Malva neglecta*, *Rumex nepalensis*, *Rheum australe*, *Geranium wallichianum*, *Polygonum aviculare* and *Paeonia emodi*.

Reduction in vegetation-derived ecosystem services: a threat to sustainable utilization of plant biodiversity in mountain ecosystems

Plant resources are the most accessible source of products and incomes for economically marginalized societies, and are subsequently under extensive pressure to provide both provisioning and environmental benefits. Sustainable utilization and conservation of biodiversity are essential for the continuation of ecosystem functioning (Srivastava and Vellend, 2005; Kienast *et al.*, 2009); nevertheless, indigenous people give less attention to long-term ecosystem goods and services as they focus, of necessity, on marginal and short-term benefits. Local residents, especially of the older generation, prefer to live in the mountains because they can derive free benefits from accessing a range of plant-derived provisioning ecosystem services. In contrast, members of the younger generation tend to leave these rural spaces in search of education, facilities and an 'easy' modern life; thus, they are less aware of or dependent upon ecosystem services. Over time, the traditional ecological knowledge of the older generation will diminish or, at worst, be entirely lost.

Extensive use of natural vegetation in the past has decreased the provisioning services in montane ecosystems (Pereira *et al.*, 2005; Sharma *et al.*, 2008; Duraiappah, 2011; Khan *et al.*, 2012*b*). The consequence of the imbalance in supply of these services and the increasing human demands has been deterioration in the condition of the natural habitats and increasing rarity of plant biodiversity (Díaz *et al.*, 2006; Giam *et al.*, 2010; Khan *et al.*, 2012*b*). These effects are becoming exacerbated as indigenous people can neither access alternative services locally (e.g. healthcare services, which are either sparsely located and/or expensive) nor can they compete in urban societies. Linked with the imminent threat of species extinctions as a result of non-sustainable exploitation, the traditional indigenous knowledge of the people is at considerable threat of being eroded and ultimately lost.

Plant biodiversity can, however, be restored and the risks of ecosystem degradation may be combated, if measures such as reforestation, establishment of protected areas, greater awareness by the people and *ex-situ* conservation of rare species can be initiated (Brown and Shogren, 1998; Parody *et al.*, 2001;

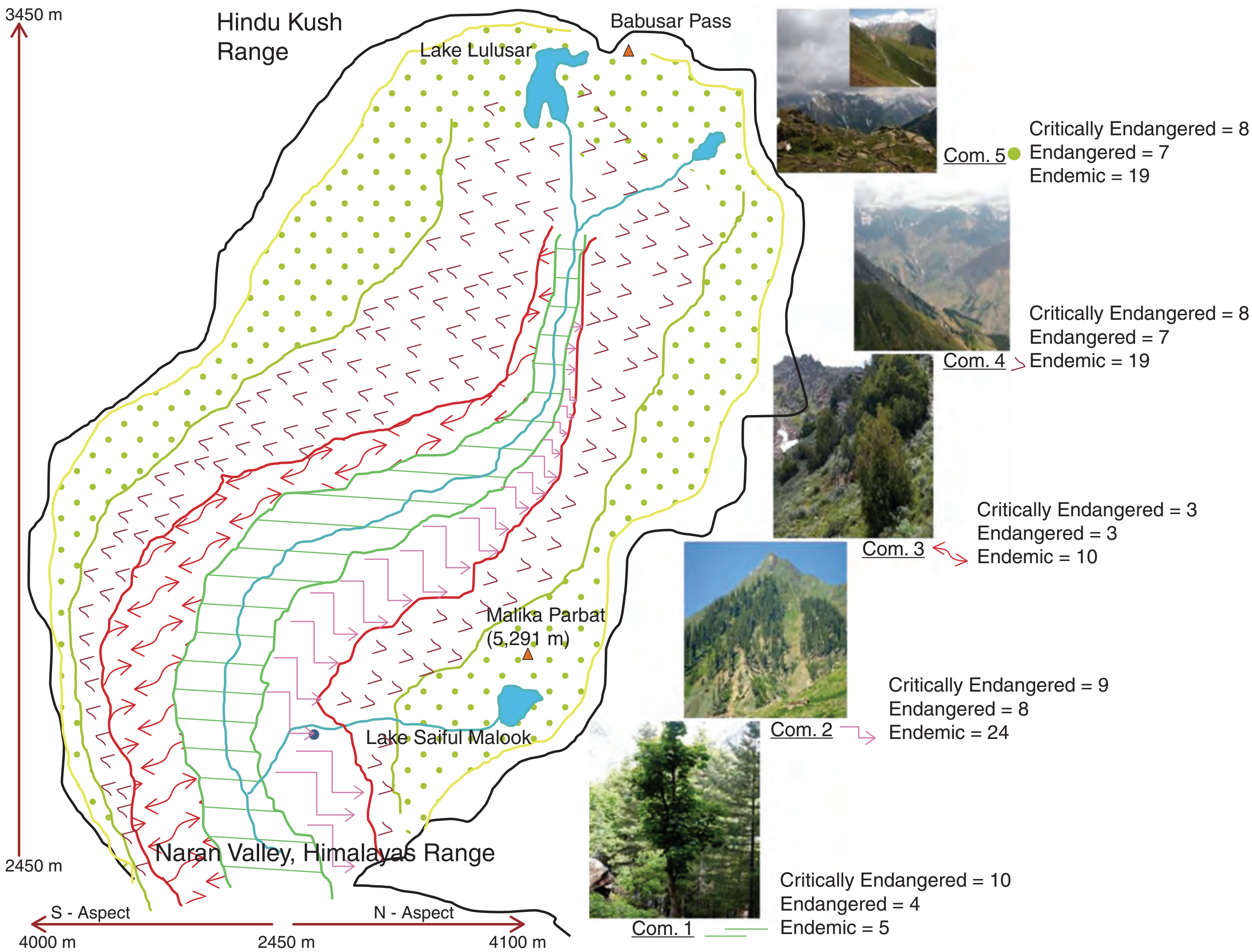

FIG. 6. Schematic map of the Naran Valley, western Himalaya showing its various vegetation zones (communities, Com.) and conservation status of endemic species. For area and communities details see Khan *et al.*, 2011*a*, *b*, 2012*a*, *b*; Khan, 2012.

Niemi and McDonald, 2004; Pereira *et al.*, 2005; Muzaffar *et al.*, 2011). Long-term management and conservation strategies might therefore have optimistic outcomes for both maintaining and restoring mountain biodiversity and ecosystem services, which would also have a positive impact on the lowland ecosystems by ensuring the flow of rivers for irrigation of agricultural land (Archer and Fowler, 2004).

Biodiversity conservation: the role of indigenous knowledge

In addition to the three most widely accepted biodiversity conservation criteria – rarity, threat and endemism – there are other important criteria that should be considered – historical, traditional and educational values. Traditional ecological knowledge in Asia in general and in the remote valleys of the western Himalayas and Hindu Kush in particular, can play a key role in the formulation and implementation of conservation strategies. Such knowledge reflects a life time's experience of the relationship between human cultures and the natural environment. Increasing urbanization and industrialization cause losses of traditional knowledge as the natural environment becomes degraded or as people move away from their native villages. Traditional ethnomedicinal knowledge is a particular and valuable form of indigenous knowledge; it is a cultural asset that can be used for the recognition and preservation of valuable species as well as the habitats in which they occur (Pieroni *et al.*, 2007; Jules *et al.*, 2008; Gaikwad *et al.*, 2011). In the Himalayas, population growth, prevailing poverty and expansion of agricultural land are the main causes of habitat and biodiversity loss and achieving the goal of sustainable resource use requires the management and collaboration of various governmental and non-governmental agencies involved in natural resources supervision and management together with the local communities (Gorenflo and Brandon, 2005). Apart from a number of other constraints, geopolitical barriers have always been hurdles in effective conservation measures and strategies and must be overcome for the betterment of sustainable future (Sandwith, 2003).

The need for an IUCN Red Data book for Himalayan biodiversity

There is no thorough work, such as a Red Data Book, on endangered plant species in the Himalayan region, despite its unique

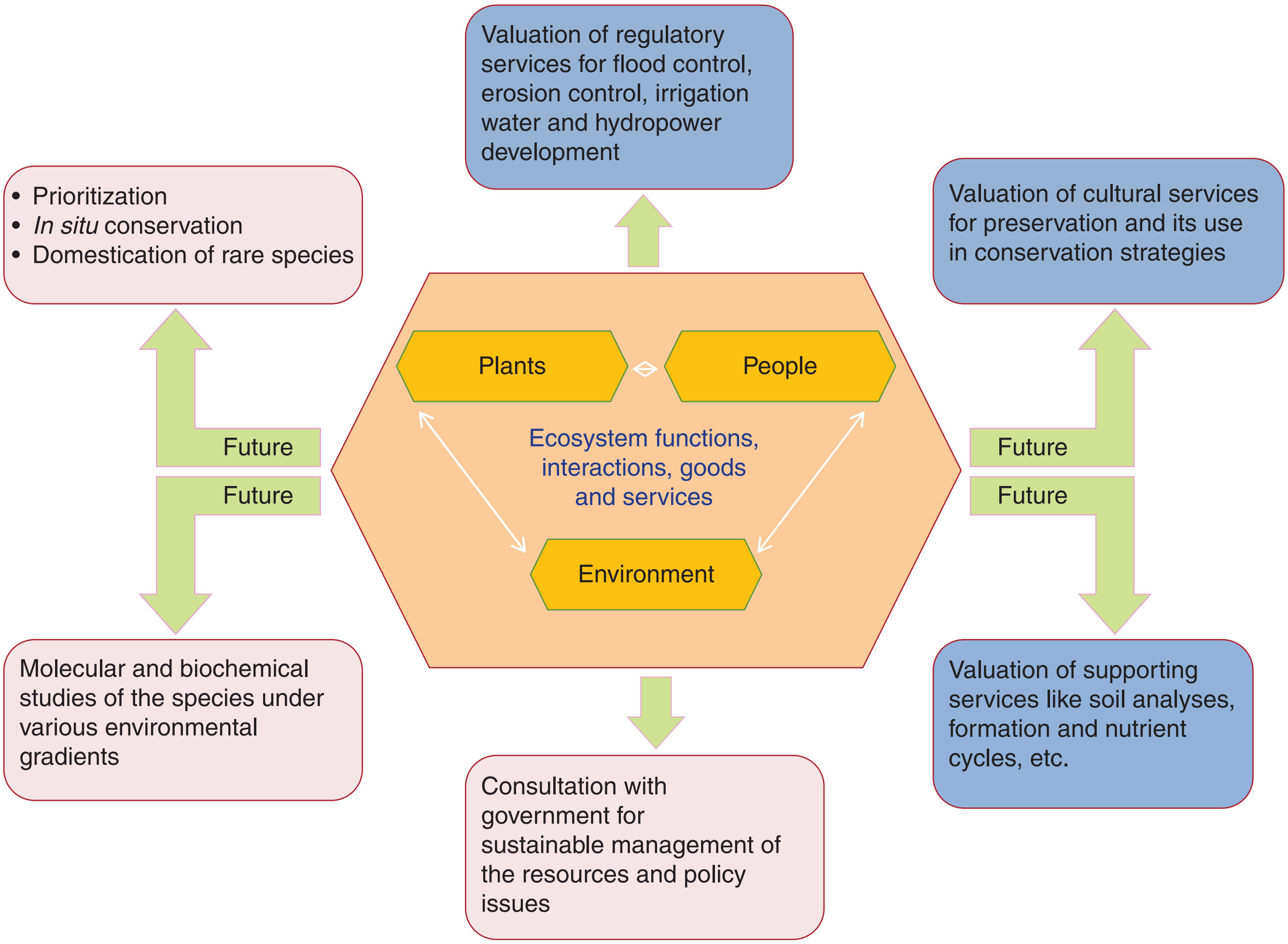

FIG. 7. The major topics for biodiversity conservation in montane ecosystem.

endemic flora. There has been very limited and fragmented published work on only a few IUCN Red List plant species (Ali, 2008; Alam and Ali, 2009, 2010; Ali and Qaiser, 2011), so one can find very few comparators to evaluate endangered and critical plant species at a national level (Ali, 2008). In part this is a result of the political conflict in this area over the last century (Hanson *et al.*, 2009). New efforts are, however, emerging and can be seen in a few publications over the last two or three years (Alam and Ali, 2010; Ali and Qaiser, 2011), although these provide descriptions of a very limited number of species. The case study by Khan (2012) can be compared with studies from other areas of the Himalaya, especially the eastern, in terms of the potential for linking endemism and ecosystem services (Samant and Dhar, 1997; Aumeeruddy, 2003; Kala, 2007; Qureshi *et al.*, 2007*b*) and could lead the way in developing a robust approach to critically evaluate the vegetation across the wider Himalayan region. In our study of the Naran Valley several plant species were recorded that are known to be endangered either globally or regionally and are listed by CITES. On the basis of IUCN criteria, several species were categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Near Threatened (NT). Only 39·4 % of the total species come under the IUCN criterion of Least Concern (LC) (IUCN Categories, 2001; IUCN Standards and Petitions Subcommittee, 2011).

The western Himalayas host a flora that is rich in endemic species, with 300 endemic species documented (Ali *et al.*, 1972–2009; Ali, 2008). Endemic species have an exceptional individuality and significance as their distribution is limited to a particular region, and hence ecologists and taxonomists always emphasize their quantification, documentation and conservation as a key priority. In 2002, the Convention on Biological Diversity agreed to protect 50 % of the significant regions for plant diversity and conservation based on species endemism, richness and ecosystem endangerment (Ma *et al.*, 2007). In our study of the Naran Valley, 64 plant species (32·32 %) of the total are endemic to the three mountain systems of the Himalayas, Hindu Kush and Karakorum. Twenty of these are endemic to the Himalayas alone, 29 are mutually shared by the Himalayas and Hindu Kush, while 19 are mutually shared by all three mountain ranges (reference: Flora of Pakistan). Applying IUCN Red List criteria at a regional level to these 64 endemic species, shows 20 as Critically Endangered (CR), 14 as Endangered (EN), 12 as Vulnerable (VU), 11 as Near Threatened (NT) and only seven as of Least Concern (LC). These results indicate that the Naran Valley is a hot spot for endemic flora, with three species being endemic to Pakistan (Appendix). The endemic species have a high fidelity level (fidelity classes 3–5), signifying the selective nature of the environmental conditions under which they grow (Khan, 2012). The highest numbers of endemic subalpine species were recorded in a northern aspect plant community at altitudes of between 2800 and 3400 m and in a timberline plant community (3300–4000 m).

We thus suggest that the use of IUCN Red List criteria should be given priority and that new government and corporate policies be implemented to allow for ecosystem services to be included systematically in economic decisions. Such concepts can also be applied beyond land and resource management, in broader government and corporate investment decisions that impact biodiversity. By building on the evidence and tools from past efforts, new solutions can be designed to maintain the critical plant resources that sustain both the mountain and the lowland ecosystems. A narrow range of habitats for specific indicator species and the presence of endemic vegetation in the region indicate that, once deteriorated, these mountain plant species would be extremely difficult to restore due to a number of climatic, edaphic and anthropogenic constraints. Our study emphasizes the importance of this fragile ecosystem for long-term environmental sustainability and ecosystem services management (Fig. 7).

SYNTHESIS AND CONCLUSIONS

This review emphasizes the need for sustainable utilization of plant biodiversity in order to maintain provisioning ecosystem services on the one hand and indigenous traditional knowledge which enables these uses on the other hand. The anthropogenic impacts on the vegetation require an assessment of the conservation status of all plant species and of the indicator, rare and endemic species in particular. We have demonstrated how an ethnoecological approach towards biodiversity conservation can be linked to quantitative ecology. This is a novel, integrative approach involving knowledge obtained from phytosociological classification, ordination, distribution, richness, diversity, ecosystem services and ethnobotanical perceptions of conservation. The findings from our case study from a remote Himalayan valley, located amongst three of the world's largest mountain ranges, illustrates how this approach can be used to identify the conservation status of plant species, from the perspective of both ecological criteria (i.e. endemism, endangerment and rarity) and the traditional knowledge of local people. Future work should address the long-lasting consequences of the loss of plant biodiversity for the sustainability of ecosystem services other than just provisioning services, i.e. also regulatory, supporting and cultural services.

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APPENDIX

Species of conservation priority from a case study in one Himalayan valley (Khan, 2012) based on their residual values (descending order), % constancy, perception of abundance (trend mentioned by indigenous people), IUCN criteria at regional level and data on endemism or other level of threat from the published literature.

Appendix

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
1	*Abies pindrow* Royle	3027	14·038	16	D	NT	
2	*Acantholimon lycopodioides* Boiss.	154	−14·114	2	NC	VU A4cd; B2bc(i,ii,iv); C1 + 2ab	
3	*Acer caesium* Wall ex Brandis	49	7·538	1·6	D	CR A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1 + 2ab; D	Vulnerable in the Himalaya
4	*Achillea millefolium* L.	364	−5·419	16·6	NC	LC	
5	***Aconitum heterophyllum* Wall.**	58	−6·4	3·4	D	EN A3cd + 4 cd; C1 + 2ab; D; E	Endemic to the Himalaya and Hindu Kush /Vulnerable species of Pakistan
6	***Aconitum violaceum* Jacquen ex. Stapf**	154	−5·977	8·4	D	VU A4cd; B2bc(i,ii,iv); C1 + 2ab; D	Endemic to the Himalaya also Vulnerable (Kumar *et al.*, 2011)
7	*Actaea spicata* L.	33	−8·362	1·4	D	**NT**	
8	*Adiantum venustum* D. Don	108	−4·828	9·2	NC	LC	
9	*Aesculus indica* (Wall. Ex Camb) Hook.	11	5·774	0·6	D	CR A3cd +4cd; C1 + 2ab; D	
10	*Alliaria petiolata* (M. Bieb.) Cavara and Grande	13	3·942	1·2	D	CR A3cd +4cd; C1 + 2ab; D	
11	***Allium humile* Kunth.**	155	−12·238	6·8	D	NT	Endemic to the Himalaya (Samant and Dhar, 1997; Pandey *et al.*, 2008)
12	*Alopecurus arundinaceus* Poir.	194	4·637	6	D	**LC**	
13	*Anaphalis triplinervis* (Sims) C. B. Clarke	132	4·023	6·2	D	**NT**	
14	***Androsace hazarica* R.R. Stewart ex Y. Nasir**	62	−11·543	4·6	D	CR A4cd; B2bc(i,ii,iv); C1 + 2ab; E	Endemic to Pakistan (Ali *et al.*, 1972–2009)
15	***Androsace primuloides* Duby**	133	−11·984	5	D	CR A3cd + 4; B2b(iii,v)c(i,ii,iv); C1 + 2a; E	Endemic to the Himalaya and Hindu Kush
16	*Androsace rotundifolia* Watt	456	−10·121	26·8	D	LC	
17	***Anemone falconeri* Thoms.**	155	−10·12	9·6	D	EN A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1 + 2a; D; E	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
18	***Anemone obtusiloba* D.Don**	143	−8·046	9·2	D	NT	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006; Rana and Samant, 2009)
19	*Anemone rupicola* Cambess	227	−12·307	8·2	D	NT	
20	*Anemone tetrasepala* Royle	304	−11·046	10·6	D	NT	Endemic to the Himalayas and Hindu Kush (Rana and Samant, 2009)
21	***Angelica glauca* Edgew.**	167	−4·195	6	D	EN A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1 + 2; D; E	Endemic to the Himalaya and Hindu Kush (Samant and Dhar, 1997; Rana and Samant, 2009)
22	*Apluda mutica* (L.) Hack	188	−10·325	8·6	D	LC	
23	***Aquiligea fragrans* Benth.**	29	−9·337	1·2	D	CR A3cd + 4cd; B2b(iii)c(i,iv); C1 + 2; D	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
24	***Arnebia benthamii* Wallich ex. G. Done**	107	−12·71	6	D	CR A3cd + 4cd; B2b(iii,v)c(i,ii,iii,iv); C1 + 2ab; D	Endemic to the Himalaya/Critically Endangered in the Himalaya (Shrestha *et al.*, 2006; Kumar *et al.*, 2011)
25	*Artemisia brevifolia* L.	4385	−18·552	40·2	I	LC	
26	*Artemisia vulgaris* L.	381	−8·524	6·4	NC	LC	
27	*Asparagus racemosus* Willd.	36	5·619	3·8	D	CR A3cd + 4cd; B2b(iii,v)c(i,ii); C1 + 2; D; E	
28	*Asperula oppositifolia* Reg. and Schmalh.	125	−12·934	4·8	D	NT	
29	*Asplenium adiantum-nigrum*	18	−12·269	0·6	D	NT	
30	***Aster falconeri* (C. B. Clarke) Hutch**	243	−13·667	11·6	NC	NT	Endemic to the Himalaya and Hindu Kush (Shrestha *et al.*, 2006; Rana and Samant, 2009)
31	*Astragalus anisocanthus* Boiss.	271	−4·841	12·8	NC	LC	
32	*Astragalus scorpiurus* Bunge	296	−13·996	13·4	D	LC	

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Appendix *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
33	***Berberis pseudoumbellata* Parker**	979	14·761	14·8	NC	VU A3cd + 4; C1 + 2ab; D	Near Endemic to the Himalaya (Samant and Dhar, 1997; Singh and Samant, 2010)
34	***Bergenia ciliata* (Haw.) Sternb.**	45	−6·437	2·6	D	VU A3 + 4cd; C1; D1	Endemic to the Himalaya (Shaheen *et al.*, 2011)
35	***Bergenia strachyei* (Hook. f. and Thoms) Engl**	958	−9·183	17·4	I	LC	Nearly endemic to the Himalayas and Hindu Kush also Vulnerable in the Himalaya (Ali *et al.*, 1972–2009; Singh and Samant, 2010; Kumar *et al.*, 2011)
36	***Betula utilis* D. Don**	2635	9·312	8·4	D	CR A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iv);C1 + 2a; D; E	Endangered species in the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
37	***Bistorta affinis* (D.Don) Green**	788	7·829	25·2	I	LC	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006; Rana and Samant, 2009)
38	***Bistorta amplexicaulis* (D. Don)**	180	13·625	11·4	NC	NT	Endemic to the Himalaya and Hindu Kush (Rana and Samant, 2009)/ Endangered species of the Pakistan
39	*Bromus hordeaceus* L.	279	3·109	11·8	NC	LC	
40	*Caltha alba* Jack. Ex Comb	182	17·712	10·4	D	NT	
41	*Capsella bursa-pastoris* (L.) Medic.	86	4·308	5·6	NC	LC	
42	***Cassiope fastigiata* (Wallich) D. Done**	49	−12·325	1·2	D	EN A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1 + 2ab; D;	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006)
43	***Cedrus deodara* (Roxb. Ex Lamb.) G. Don**	663	24·724	7·2	D	CR A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1	Endemic to the Himalaya and Hindu Kush; National tree of the Pakistan (Takhtadzhian and Cronquist, 1986; Ali, 2008; Singh and Samant, 2010)
44	*Cerastium fontanum* Baumg.	667	−7·338	21·8	NC	LC	
45	*Chenopodium album* L.	196	18·625	6·8	NC	LC	
46	*Clematis montana* Buch.-Ham. ex DC	110	−0·841	5·6	D	NT	
47	***Colchicum luteum* Baker**	261	3·221	9	NC	EN A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1	Endangered species of Pakistan (Ali *et al.*, 1972–2009)
48	*Convolulus arvensis* L.	57	0·489	3·2	NC	VU A3 + 4; C1 + 2a; E	
49	*Corydalis diphylla* Wall.	194	−3·363	9·4	NC	LC	
50	***Corydalis govaniana* Wall.**	130	−0·965	5·2	D	EN A3cd + 4cd; B2b(iii,v)c(i,ii,iv); C1 + 2ab; D;	Endemic to the Himalayas of Pakistan (Ali *et al.*, 1972–2009; Rana and Samant, 2009; Kumar *et al.*, 2011)
51	*Cotoneaster cashmiriensis* G.Klotz	79	−12·648	3·4	D	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D1; E	
52	*Cotoneaster microphyllus* Wall. ex Lindl	291	9·035	12	D	VU A3cd + 4; C1; D	
53	*Crataegus oxycantha* L.	10	−1·269	0·8	D	CR A3cd + 4; C1 + 2; D; E	
54	*Cynoglossum glochidiatum* Wall. Ex Benth	792	3·873	36·2	NC	LC	
55	*Cynoglossum himaltoni*	261	−0·915	12·8	D	LC	
56	*Cynoglossum lanceolatum* L.	7	−3·201	0·8	NC	LC	
57	*Cyperus niveous*	379	−14·512	16·6	D	LC	
58	***Cypripedium cordigerum* D. Don**	34	−5·369	3·2	D	CR A4cd; B2bc(i,ii,iv); C1 + 2ab; D	Endemic to the Himalaya (Ali *et al.*, 1972–2009)/Endangered/on CITES list
59	*Dactylis glomerata* L.	361	6·6	13·2	NC	LC	
60	***Dactylorhiza hatagirea* (D. Don) Soo**	29	−9·337	3·4	D	CR A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1; E	Endemic to the Himalaya and Hindu Kush/Critically Endangered (Singh and Samant, 2010; Kumar *et al.*, 2011)
61	*Dioscoria deltoidia* Wall.	30	−4·344	3·6	D	CR A3cd + 4; B2b(iii,v)c(i,ii,iv); C1 + 2; D; E	Vulnerable/on CITES list
62	*Draba oreads* Schrenk	85	−2·685	6·6	NC	LC	

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APPENDIX *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
63	*Dracocephalum nutans* L.	115	−4·872	4·6	D	NT	
64	*Dryopteris juxtapostia* Christ	147	14·929	7	D	NT	
65	***Dryopteris stewartii* Fras.-Jenk.**	791	−6·195	25·4	I	LC	Endemic to Pakistan (Ali *et al.*, 1972–2009)
66	*Eclipta prostrata* L.	49	−12·462	4·8	NC	LC	
67	***Ephedra gerardiana* Wall. Ex Stapf**	604	−0·91	8·2	D	EN A3 + 4cd; C1 + 2ab; D; E	Endangered species of Pakistan
68	*Epilobium angustifolium* L.	40	3·594	3·2	D	VU A4cd; B2bc(i,ii,iv); C1 + 2ab; D	
69	*Equisetum arvense* L.	84	−6·679	5·4	NC	LC	
70	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard	109	0·166	4·8	NC	VU A4cd; B2bc(i,ii,iv); C1 + 2ab	
71	***Eremurus himalaicus* Baker**	794	7·792	20·4	I	LC	Endemic to the western Himalaya (Ali *et al.*, 1972–2009)
72	*Erigeron multiradiatus* (Lindl. Ex DC) C. B. Clarke	48	7·544	2·6	D	EN A3cd + 4; C1 + 2; D; E	
73	***Erysimum melicentae* Dunn.**	57	−4·511	5	NC	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D1	Endemic to the Himalaya and the Hindu Kush (Nasir and Ali, 1971–1998; Shrestha *et al.*, 2006)
74	*Euphorbia wallichii* Hook. f.	165	7·818	7·2	NC	CR A3 + 4cd; C1 + 2ab; D	
75	***Euphrasia himalayica* Wetts.**	328	−2·195	16·4	D	NT	Endemic to the Himalaya and Hindu Kush (Shrestha *et al.*, 2006)
76	*Fragaria nubicola* Lindl. Ex Lacaita	1629	9·481	55·6	I	LC	
77	***Fritillaria roylei* Hook. f.**	24	−9·306	1·4	D	CR A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D	Endemic to the Himalaya and Hindu Kush/also rare and Critically Endangered (Ali *et al.*, 1972–2009)
78	*Gagea elegans* Wall. Ex D. Don	214	−13·487	9·2	D	NT	
79	*Galium aparine* L.	206	11·563	6	NC	LC	
80	***Galium asperuloides***	230	−3·586	7·6	NC	LC	Endemic to the Himalayas and Hindu Kush (Singh and Samant, 2010)
81	*Gentiana carinata* Griseb	421	−6·773	14·4	NC	LC	
82	***Gentiana kurro* Royle**	70	−9·592	3·4	D	CR A4cd; B2bc(i,ii,iv); C1 + 2ab; D	Endemic to the Himalaya and Hindu Kush/Endangered (Ali *et al.*, 1972–2009)
83	***Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw**	201	1·594	9·4	D	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D1; E	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
84	***Gentianodes argentia* Omer, Ali and Qaiser**	115	0·128	4·2	D	EN A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2; D	Endemic to Pakistan (Ali *et al.*, 1972–2009)
85	*Geranium nepalense* Sweet.	86	−6·692	3·4	D	VU A3cd + 4; B2b(i,ii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D1	
86	*Geranium polyanthes* Edgew and Hook. F	188	−4·356	10·4	D	LC	
87	***Geranium wallichianum* D. Don ex. Sweet**	154	18·886	9·2	D	EN A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)/ Vulnerable species of Pakistan
88	***Geum elatum* Wall. Ex G. Don**	74	−12·617	4·8	D	VU A3 + 4; D; E	Endemic to the Himalaya (Shrestha *et al.*, 2006; Rana and Samant, 2009; Kumar *et al.*, 2011)
89	*Gnaphalium affine* D. Don	453	−15·09	19·2	NC	LC	
90	*Gratiola officinalis* L.	9	0·787	1·4	D	EN A3 + 4; C1; D; E	
91	*Hackelia uncinata* (Royle ex Benth) Fischer	462	5·923	24·8	NC	LC	
92	***Heracleum candicans* Wall. ex DC.**	28	7·669	3·4	D	CR A3cd + 4; B2b(iv,v)c(i,ii,iv); C1 + 2ab; D	Endemic to the Himalaya and Hindu Kush (Nasir and Ali, 1971–1998; Pant and Samant, 2006)

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Appendix *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
93	*Hyoscyamus niger* L.	15	−9·251	0·8	D	CR A3cd + 4; C1; E	Near Threatened/Alien (Nasir and Ali, 1971–1998)
94	*Hypericum perforatum* L.	242	16·339	12·6	D	EN A3 + 4; C1; D; E	
95	*Impatiens bicolor* Royle	480	3·134	28·8	D	LC	
96	*Impatiens edgeworthii* Hook.f.	114	14·861	6	NC	LC	
97	*Indigofera heterantha* Wall. Ex Brand	17	8·737	0·8	D	CR A3 + 4cd; B2b(i,v)c(i); C1; D; E	
98	*Inula grandiflora* Willd.	31	−6·35	0·6	D	CR A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1; D; E	Near Threatened in Himalayas (Nasir and Ali, 1971–1998)
99	*Inula multiradiata*	30	−12·344	0·8	D	NT	
100	***Iris hookeriana* Foster**	1574	−14·979	30·8	NC	NT	Endemic to the Himalaya and Hindu Kush/Vulnerable species of the Pakistan (Ali *et al.*, 1972–2009)
101	*Juglans regia* L.	214	28·513	2·2	D	CR A3cd + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab	Vulnerable species of Pakistan
102	*Juncus membranaceus* Royle ex D. Don	198	7·613	4·2	NC	LC	
103	*Juniperus communis* L.	5505	−6·477	38·8	D	LC	
104	*Juniperus excelsa* M. Bieb	1063	5·935	21·4	D	NT	
105	*Juniperus squamata* Buch.-Ham. ex D. Don	1399	−14·848	11	D	VU A4cd; B2bc(i,ii,iv); C1 + 2ab	Native to the Himalaya and Karakorum
106	*Lathyrus pratensis* L.	14	8·756	2	D	LC	Alien (indigenous to Europe)
107	*Leucus cephalotes* (Roth) Spreng.	63	2·451	2·2	D	VU A3 + 4; C1; E	
108	*Malva neglecta* Wallr	669	22·649	38·2	NC	LC	
109	*Mentha longifolia* (L.) Hudson.	81	−2·661	2	I	LC	
110	*Mentha royleana* Benth. in Wall.	10	−4·219	0·8	NC	EN A3 + 4; C1; D; E	
111	*Minuartia kashmirica* (Edgew) Mattf	109	−8·834	5·2	NC	LC	Native to the Himalaya and Karakorum (Ali *et al.*, 1972–2009)
112	*Morina longifolia* Wall. ex. Dcs	36	−12·381	1·8	NC	LC	
113	*Nepeta laevigata* (*D. Done) Hand.-Mazz*	114	4·06	5·8	D	EN A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); D; E	Native to the Himalaya and Karakorum (Ali *et al.*, 1972–2009)
114	*Onopordum acanthium* L.	469	−16·071	32·2	I	LC	
115	***Onosma bracteatum* Wall.**	134	7·01	7·2	D	NT	Endemic to the Himalayas (Shrestha *et al.*, 2006)
116	*Origanum vulgare* L.	163	25·83	11·2	NC	LC	
117	*Orobanche alba* Stephen ex Wallid	24	−1·325	1·4	D	CR A3cd + 4cd; B2b(i,ii,iii,v,v)c(i,ii,iii); C1 + 2ab	
118	*Oxyria digyna* L.	383	10·463	18·6	NC	LC	Alien
119	*Oxytropis cachemiriana* Camb.	191	13·656	10	I	LC	
120	***Paeonia emodi* Wall. Ex Royle**	17	17·737	1·2	D	CR A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab;	Endemic to the Himalaya and Hindu Kush (Samant and Dhar, 1997)/ Vulnerable species of Pakistan
121	*Parnassia nubicola* Wall.	100	−5·834	4·4	NC	NT	Endemic to the Himalayas (Pant and Samant, 2006; Shrestha *et al.*, 2006)
122	***Pedicularis pictinata* Wall. ex. Benth**	112	3·147	2·8	D	CR A3 + 4cd; B2b(i,ii,iii)c(i,iv); C1 + 2; D; E	Endemic to the Himalaya (Kumar *et al.*, 2011)
123	*Pennisetum lanatum* Klotzsch	84	3·321	3·4	D	NT	
124	*Phleum alpinum* L.	63	9·451	4	NC	LC	
125	***Phlomis bracteosa* Royle ex Benth.**	60	8·47	2	D	LC	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006; Singh and Samant, 2010)
126	***Picea smithiana* (Wall.) Boiss.**	287	1·06	6·6	D	EN A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; C1 + 2a; E	Endemic to the Himalaya, Hindu Kush and Karakorum (Takhtadzhian and Cronquist, 1986; Singh and Samant, 2010)

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APPENDIX *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
127	***Pimpinella acuminata* (Edgew.) C.B. Clarke**	20	7·718	2·2	D	CR A3cd + 4cd; C1 + 2b; D; E	Endemic to the Himalaya (Ali *et al.*, 1972–2009; Rana and Samant 2009)
128	*Pimpinella diversifolia* (Wall.) DC	58	8·482	2·4	D	NT	
129	***Pinus wallichiana* Jackson**	2116	5·698	15·6	D	VU A3cd + 4; B2b(i,iii,v); C1 + 2ab	Endemic to the Himalaya, Hindu Kush and Karakorum (Takhtadzhian and Cronquist, 1986; Singh and Samant, 2010)
130	***Plantago himalaica* Pilger**	92	−3·729	4	D	CR A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii); C1 + 2b	Endemic to the Himalayas (Nasir and Ali, 1971–1998; Pant and Samant, 2006)
131	*Plantago lanceolata* L.	406	15·32	28	NC	LC	
132	*Plantago major* L.	287	16·178	19·6	D	EN A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; C1; E	Rare species of Pakistan
133	*Poa alpina* L.	1593	0·319	40	NC	LC	
134	*Poa annua* L.	61	8·464	4·2	NC	LC	
135	*Poa stewartiana* Bor in Kew Bull.	309	6·817	13·8	D	LC	
136	***Podophyllum hexandrum* Royle**	72	−3·605	4	D	CR A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2a; D; E	Critically Endangered/on CITES list; endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006)
137	*Polygonatum verticillatum* (L.) Allioni	386	−15·835	9·4	D	EN A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C2ab	Vulnerable in Pakistan/on CITES list
138	*Polygonum alpinum* (All.) Schur	641	17·861	17	NC	LC	
139	*Polygonum aviculare* L.	569	−11·338	14·4	NC	LC	
140	*Polygonum molle* (D.Done) Hara	351	−13·189	10·2	D	LC	
141	*Polygonum plebeium* R. Br	166	27·283	19	NC	LC	
142	*Poplus glauca* H. Haines	333	9·774	2·8	NC	LC	
143	*Potentilla anserina* L.	567	3·32	22·2	NC	LC	
144	***Potentilla atrosanguinea* Lodd.**	216	6·501	8·4	NC	NT	Endemic to the Himalayas and Hindu Kush (Rana and Samant, 2009)
145	*Potentilla nepalensis* Hook. f.	549	1·376	20·8	NC	LC	
146	*Primula calderana* Balf. F and cooper	82	−4·667	3·6	D	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1; D1	
147	*Primula denticulata* Smith	145	7·942	8·4	D	EN A4cd; B2bc(i,ii,iv); C1 + 2ab; D; E	
148	***Primula glomerata* Pax.**	58	−4·387	3·8	D	VU A3 + 4; C1; E	Endemic to the Himalaya (Shrestha *et al.*, 2006)
149	***Primula rosea* Royle**	223	−5·543	10·4	D	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii); C1 + 2ab; D1; E	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
150	*Prunella vulgaris* L.	71	16·072	4	NC	LC	
151	*Prunus cerosioides* D. Don	124	11·402	0·8	NC	CR A3 + 4; C1 + 2b; D; E	
152	*Pseodomertensia parvifolia* (Decne)	37	1·613	3·2	D	VU A3cd + 4; C1; E	
153	***Pseudomertensia moltkioides* Royle and Kazmi**	85	5·315	4·2	D	CR A3cd + 4cd; C1 + 2a; E	Endemic to Pakistan (Ali *et al.*, 1972–2009)
154	*Pseudomertensia nemerosa* (D. C) R. Stewart and Kazmi	79	4·352	3·6	D	NT	
155	***Pteris vittata* L.**	47	−12·536	5	NC		Endemic to the Himalaya (Ali *et al.*, 1972–2009)
156	***Ranunculus hirtellus* Royle ex D. Don**	180	−14·276	5	D	CR A3cd + 4; C1; E	Endemic to the Himalaya (Kumar *et al.*, 2011)
157	*Ranunculus laetus* Wall. Ex Hook.f. and Thoms	80	−13·654	4	D	VU A3cd + 4cd; C1 + 2; D; E	
158	*Ranunculus muricatus* L.	73	−13·611	3·4	NC	LC	

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Appendix *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
159	***Rheum australe* D.Don**	1320	20·406	31·6	NC	CR A3cd + 4cd; 2ab; E	Endemic species of the Himalayas, Hindu Kush and Karakorum also Vulnerable/Near Threatened (Samant and Dhar, 1997; Shrestha *et al.*, 2006)
160	***Rhododendron hypenanthum* Balf.f**	946	1·649	3·8	D	EN A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab;	Endemic to the Himalayas, Hindu Kush and Karakorum (Shrestha *et al.*, 2006; Rana and Samant, 2009) Vulnerable/ Near Threatened
161	*Ribies alpestre* Decne	98	6·234	2·2	D	CR A3 + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2b; D; E	
162	*Rosa webbiana* Wallich ex Royle	1943	4·648	28	D	LC	
163	*Rubus sanctus* Schreber	72	10·395	1·6	D	NT	
164	*Rumex dentatus* L.	632	12·885	42·8	I	LC	
165	*Rumex nepalensis* Sprenge	147	21·929	8	NC	NT	
166	***Salix flabellaris* Andersson in Kung**	1100	14·506	13·6	D	EN A3cd + 4; B2b(i,ii,iii,iv,v)c(i,iv); C1 + 2ab; D	Endemic to the Himalaya, Hindu Kush and Karakorum (Ali *et al.*, 1972–2009)
167	*Salvia lanata* Roxb.	88	−4·754	3·4	NC	NT	Alien
168	***Salvia moorcroftiana* Wallich ex Benth**	103	1·029	6	NC	EN A3 + 4cd; C1 + 2; D; E	Endemic to the Himalaya and Hindu Kush (Ali *et al.*, 1972–2009)
169	*Sambucus weightiana* Wall. Ex Wight and Arn	4926	−22·759	34·4	I	LC	
170	*Saussurea albescens* Hook. f. and Thoms	59	−12·524	4	NC	NT	
171	*Saussurea fastuosa* (Decne.) Schultz-Bip	29	−2·337	2	D	NT	
172	*Saussurea graminifolia* Wallich ex DC	85	−12·685	4	NC	NT	
173	*Scirpus polygenosa*	126	−12·033	5·8	NC	LC	
174	*Sedum album* L.	304	−15·133	17	NC	LC	
175	*Sedum awersii* Ledeb	195	−14·369	10·4	NC	LC	
176	*Senecio chrysanthemoides* DC	94	−12·741	2·6	NC	LC	
177	*Sibbaldia cuneata* O. Kuntze	1162	−8·221	31·2	NC	LC	
178	*Silene vulgaris* Garck	39	−2·4	4·2	D	NT	
179	*Sorbaria tomentosa* (Lindl.) Rehder	730	−12·692	8	D	EN A3cd + 4; C1; E	
180	***Stipa himalaica* Rozhev.**	72	−12·605	4·8	D	LC	Endemic to the Himalaya and Karakorum (Ali *et al.*, 1972–2009)
181	***Strobilanthes glutinosus* Nees**	59	−6·524	2·2	D	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D1	Endemic to the Himalaya (Ali *et al.*, 1972–2009)
182	***Swertia ciliata* (D. Don ex G. Don) B. L. Burtt**	82	11·333	7	NC	NT	Endemic to the Himalayas and Hindu Kush (Shrestha *et al.*, 2006)
183	*Swertia speciosa* D. Don	19	−12·275	1·4	NC	NT	
184	*Sysimbrium irio* L.	67	11·426	3·2	D	LC	
185	*Tamarix dioica* Roxb. ex Roch	195	−10·369	3·2	NC	LC	
186	*Taraxacum officinale* Weber	689	3·494	52·2	NC	LC	Alien
187	*Thymus linearis* Benth.	2333	4·964	64·2	NC	LC	
188	*Trifolium refens* L.	357	15·625	16·8	I	LC	Alien
189	***Trillidium govanianum* (Wall. Ex D. Don) Kunth**	48	−6·456	1·8	D	EN A3 + 4; C1 + 2; D; E	Endemic to the Himalaya (Rana and Samant, 2009)
190	*Tussilago farfara* L.	43	6·576	2·2	D	EN A3 + 4; C1 + 2; D; E	
191	***Ulmus wallichiana* Planch.**	21	5·712	0·6	D	CR A3cd + 4cd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab; D	Endemic to the Himalaya (Ali *et al.*, 1972–2009)
192	*Urtica dioica* L.	407	9·314	16·4	I	LC	Alien

Continued

APPENDIX *Continued*

Species no.	Name	IV	Residual value	% Constancy	Trend	IUCN criteria applied to our results	Endemic and Threatened status (IUCN) at regional and global level (from published literature)
193	*Valeriana pyrolifolia* Decne	185	12·693	10·6	NC	LC	
194	*Verbascum thapsus* L.	434	3·109	33·2	NC	LC	Alien
195	***Viburnum cotinifolium* D. Don**	163	12·83	6·2	D	EN A3 + 4; C1 + 2; D; E	Endemic to the Himalaya (Pant and Samant, 2006; Rana and Samant, 2009; Singh and Samant, 2010)
196	*Viburnum grandiflorum* Wall. Ex DC.	79	8·352	1·6	D	VU A3 + 4; C1; E	
197	***Vicia bakeri* Ali.**	43	−12·424	1·6	D	CR A3bcd + 4abcd; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2b; D; E	Endemic to the Himalaya/Pakistan (Ali *et al.*, 1972–2009)
198	***Viola canescens* Wall. Ex Roxb.**	1656	8·369	68·4	NC	VU A3cd + 4; B2b(i,ii,iii,iv,v)c(i,ii,iii,iv); C1 + 2ab	Endemic to the Himalayas (Rana and Samant, 2009) and Vulnerable species of Pakistan

The importance values (IV) and Constancy refer to the quadrat (phytosociological) data set; social perception (trend) refer to the questionnaires (ethnobotanical) data set whilst residual values refer to the combined analyses of both the data sets. Bold text indicates endemic species. These are endemics of the Himalayas, Hindukush and Karakorum.