Assessing sustainable use of wild medicinal plants: a case study in the Naban River Watershed National Nature Reserve (NRWNNR), Yunnan/China

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Research

Abstract

Background: Commercially harvested wild medicinal plants are often subject to overharvesting. This study aims to examine the ecological requirements, collection status, harvest practices, sustainability of harvest and trade chain of five medicinal plant species and assesses the socio-economic importance of these medicinal plants for local households.

Method: We studied the abundance of five selected medicinal plant species in the surrounding areas of five selected villages. Harvest and trade related information was recorded by interviewing plant collectors and middlemen as well as pharmacies in Germany. For the ecological analyses concerning the occurrence of plants we performed ANOVA followed by LSD Post-Hoc tests. Correlations between profit from collection of medicinal plants and income per household in the five villages were calculated with the Pearson Correlation Coefficient.

Results: The results showed that (1) harvest practices are destructive for individual plants, (2) economic contribution of plant harvest varies between villages and species and (3) the amount of cash earned is negatively related to average per capita income in the village.

Conclusion: A management plan for sustainable harvest or cultivation is recommended to ensure the future existence of the plant species as well as the sustainability of market supply.

Keywords: Non- Timber Forest Products (NTFPs), wild collection, household economics, Traditional Chinese Medicine, sustainable harvest

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Background

Traditional and herbal medicine is getting more important and popular all over the world (Lee et al. 2008). According to the World Healthcare Organization (WHO), more than 80% of the world’s population rely on the use of traditional medicinal products for their primary health care (Hamilton et al. 2003; Sun et al. 2007). In China for example, 30-50% of all health care delivered is in the form of Traditional Chinese Medicine (TCM; Lee et al. 2008; Li et al. 2008b). Globally, the use of plants as medicines represents by far the biggest use of biodiversity in terms of species numbers (Schippmann et al. 2003).

The World Bank expects the trade of medicinal plants to grow up to a trading value of five trillion USD by 2050 (Bopana & Saxena 2007).

China is the world’s biggest exporter of medicinal and aromatic plants (MAPs) and likewise an important importer (Cunningham et al. 2008). In 2013, China (without Hong Kong) exported 201,788 tons of MAPs equivalent to 1196.6 million USD, conversely it imported 99,175 tons of MAPs during the same period with a total value of around 212 million USD (UN COMTRADE; http://comtrade.un.org/db/default.aspx). Over the last ten years, the quantity of medicinal plants obtained from just one province in China (Yunnan) has increased tenfold (Hamilton 2004).

However, increase in the demand and consumption of medicinal plants puts more pressure on wild populations as large numbers of medicinal plants traded are collected from the wild (Hamilton 2004; Leaman 2006). For instance, of more than 11,000 medicinal plant species used in China, only 492 species (approximately 4%) are under cultivation (Hamilton 2004; Ji et al. 2004; Leaman 2006).

Medicinal plants are the main source of income for many people in rural areas. In some communities, 40-63% of household income originates from the trade of so-called Non-Timber Forest Products (NTFP) often encompassing medicinal plants (Boesi 2014; Rodríguez et al. 2006; Schippmann et al. 2003). Since prices for medicinal plants paid to the collectors are generally low, people tend to “mine” plant resources to generate more income in the short-term instead of managing their resources to achieve sustainable collection (Bopana & Saxena 2007). Today, many species already show a decline in availability in natural habitats (Boesi 2014; Botha et al. 2004; Cunningham 1994; Delgado-Lemus et al. 2014). The vulnerability of a plant population under harvesting pressure depends on the plant parts being harvested and the quantity, intensity and frequency of harvest (Schippmann et al. 2006). When whole roots of herbaceous plants are reaped the harvest is entirely destructive and may put the population itself at risk of overharvesting (Cunningham 1994; Cunningham 2001). It is important to conserve and properly manage medicinal plant resources, not only to maintain biodiversity but also in order to improve rural economy and welfare of the local people, who depend on these plants for income and subsistence (Boesi 2014; Cunningham et al. 2008; Hall & Bawa 1993; Lee et al. 2008; Martin 1992; Shanley & Stockdale 2008; Sher et al. 2014).

The present study aimed to assess the ecological requirements, harvest practices, processing and trade chain of five commercially harvested medicinal plant species. Furthermore, the sustainability of current collection practices is tested in the Naban River Watershed National Nature Reserve in Yunnan province, P.R. China as well as the impact of collection on local livelihoods and its socioeconomic role in the area.

Materials and Methods

Study area

The study was conducted in the Naban River Watershed National Nature Reserve (NRWNRR), which is part of the Xishuangbanna Dai Autonomous Prefecture, Yunnan province, located within the Southeast Yunnan-Western Guangxi Centre of endemism (Ji et al. 2004; Yang et al. 2004). The climate of Xishuangbanna represents a transition between the subtropics and the tropics. Geographically it belongs to the East Asian Monsoon Region (Cao et al. 2006; Guo et al. 2002). Consequently, it is characterized by a rainy season from May to October and a dry season from November until April (Cao et al. 2006).

The tropical rain forests of Xishuangbanna are presently undergoing drastic changes. By the year 2003, the tropical seasonal rain forests lost 67% of its former size and nowadays only covers 4% of Xishuangbanna (Guo et al. 2002; Li et al. 2008a). More than 5280 plant species are documented in Xishuangbanna which equals 34.8% of total plant species in Yunnan and 14.9% of the Chinese flora (Fu et al. 2006). Almost 1000 of these species, mostly those growing in fallow land and forests are used by people (Liu et al. 2006).

The NRWNRR is located north of Jinghong township, covering an area of 267 km² (see Fig. 1). The Nature Reserve was established in 1991 and became a “National Nature Reserve” in 2000. The Reserve is managed according to the “Man and the Biosphere” program of the UNESCO (Dyer & Holland 1988). This study was conducted in five villages in the NRWNRR, namely Bengganghani, Danuoyou,
Manxinglongdai, Shijiazhai and Xiaonuoyoushangzhai. These villages were selected based on a previous study in which extensive collection of medicinal plants has been shown (Ghorbani et al. 2011).

Figure 1. Location of the Research Area within China. Yunnan province is located in the south-west of China (a) and the Xishuangbanna Dai Autonomous Prefecture is located in the south of Yunnan (b). The selected villages within the Naban River Watershed National Nature Reserve are highlighted within the area (c).

Selected plant species
We selected five medicinal species for assessment based on their intensive collection and their economic importance in the region (Ghorbani et al. 2011; Ghorbani et al. 2012a; Fig. 2). These species are Asparagus filicinus Buch-Ham. ex D.Don, Asparagus subscandens F. T. Wang & S. C. Chen, (both Asparagaceae), Paris polyphylla Sm., (Melanthiaceae), Stemona tuberosa Lour., (Stemonaceae) and Tacca chantrieri André,
(Taccaceae), the nomenclature follows the International Plant Names Index (2012). All plants are part of the Traditional Chinese Medicine (TCM) system and local folk medicines.

*A. filicinus* and *A. subscandens* (Fig. 2) are used as one ethno species in TCM, meaning they are not separated into two species and both are traded as “Tian-dong” or “Asparagi Radix” (Bucher et al. 2011). *A. filicinus* is distributed in the Himalayan region whereas *A. subscandens* is endemic to Yunnan and listed as threatened in the Red List book of China (Wang & Xie 2004). The roots of both species are tuberous. *A. filicinus* is used medicinally in India, Nepal, China and Vietnam (Joshi & Joshi 2000; Rajbhandari et al. 2009; Sharma & Thakur 1994).

*P. polyphylla* (Fig. 2) is one of the most potent and valuable plants in TCM and is traded as “Rhizoma Pari” (Long et al. 2003; Madhav et al. 2010). It is a perennial herb with annulate rhizomes which are used medicinally. It is listed as vulnerable in the IUCN Red List (Baillie et al. 2004). It is found in Bhutan, India, Laos, Myanmar, Nepal, Thailand, Vietnam, Taiwan and China. It grows at elevations between 100 and 3500 m a.s.l. mostly in moist, shaded habitats and forests (Long et al. 2003).

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Figure 2. Pictures of the aboveground parts of the selected plant species. *P. polyphylla*, *T. chantrieri* and *A. filicinus* show erect growth form whereas *A. subscandens* and *S. tuberosa* are climbers. Although *Asparagus* spp. are regarded as an ethnospecies their leaflets display different width and are easily distinguishable in the field. All photos taken by S.F. Bucher.
S. tuberosa (Fig. 2) is a perennial herb growing as a vine and has tuberous roots which are used in TCM as “Stemonae Radix” (Greger 2006). S. tuberosa is distributed in Bangladesh, Cambodia, India, Laos, Myanmar, Philippines, Thailand, Vietnam and China. It grows in forest margins, thickets, mountain slopes and besides trails at elevations between 300-2500 m a.s.l. (www.efloras.org).

T. chantrieri (Fig. 2) is a perennial plant with rhizomes. It is also used in Vietnamese and Thai traditional medicine (Huai & Pei 2004; Lemmens & Bunyapraphatsara 2003) and is listed as vulnerable in the Red List book of China (Wang & Xie 2004). It is distributed in the subtropical regions of South East Asia and occurs especially in humid areas between 200 and 1300 m a.s.l., mainly in forests, valleys and along rivers (www.efloras.org).

Data collection and analysis
To record abundance and ecological requirements of selected species (elevation and canopy cover) we conducted transects in the forest areas surrounding the target villages and along riverbeds within the forest. Each transect was 500 m long and 4 m wide (a central line and two m distance to each side). All transects ran in parallel within a forest area being 100 m far from each other. A total of 29 transects at five study sites in the area were conducted (Fig. 1c). Directions were selected prior to fieldwork with the help of satellite images to cover as much of the forest area as possible. In each transect, the occurrence of individuals of selected plant species, their height, the distance from the starting point of the transect and its central line as well as forest canopy cover and elevation was recorded using a measuring tape, GPS devices and visual estimations.

Interviews were conducted in Chinese with 29 villagers from the selected villagers who are active in medicinal plant collection and trading. The average household income differed between villages from RMB 1474 year\(^{-1}\) in Shijiazhai to 1681 in Maxinglongdai and Danuoyou. Bengganghani had an average income of RMB 1537 year\(^{-1}\) and in Xiaunuoyoushangzhai the average income per household was 1667 year\(^{-1}\) (Wehner 2011). Before conducting interviews, permission was asked from informants. Information about the current harvest methods, annual harvest volume, places and time of collection, processing of harvested plant parts, sale prices, trade routes and annual income generated from collection of medicinal plants and local uses of the selected plant species were recorded following a standardized questionnaire (see supplement 1). In addition to that, a wholesaler in Menghai, five pharmacies in Jinghong town, a market for medicinal plants in Kunming (the capital of the province) as well as three pharmacies in Germany (the “end” of the trade chain) were visited and information regarding trade of target medicinal plants, further processing and prices were recorded. Income generated from medicinal plant collection was compared to annual per capita income for each village to determine the contribution of medicinal plant harvest to the household cash income. Plants are traded as dried plant parts, therefore all information about weight is displayed as kilograms of sun-dried plant matter. Prices are given in Chinese Currency RMB (1 RMB equals USD 0.161 or EUR 0.144 on 11.05.2015).

To assess the amount of plant individuals needed for 1 kg of dried plant material, ten individuals of A. subscandens and A. filicinus were excavated, tubers were processed as described by collectors (boiled, peeled and sun-dried) and dry weight was recorded. Based on this information and the information on plant population size around the selected villages, we calculated how long the current populations would last in the different villages, if the harvest amounts would remain constant and 25% of all households are engaged in the harvest as it is currently the case. Since no information on regeneration and dispersal of these species was available, it could not be included in our calculations.

Ecological analyses concerning the occurrence of plants (elevation, forest or river transect and canopy cover) we performed ANOVA followed by LSD Post-Hoc tests. For mean values the standard errors are indicated. Correlations between profit from collection of medicinal plants and income per household in the five villages were calculated with the Pearson Correlation Coefficient. For all statistical analyses SPSS 13.0 was used.

Results
Plant population sizes and ecological requirements
The occurrence of plants in the forest depended strongly on elevation and canopy cover at specific sites and varied largely between forest areas surrounding the selected villages (Table 1). S. tuberosa was scarce in the region as were P. polyphylla and T. chantrieri. The latter ones were restricted to rather moist areas within the forest whereas A. subscandens was quite frequent and tolerant concerning the species-specific ecological requirements studied. The average elevation of the species was significantly different (\(p<0.001\); Table 1). Asparagus filicinus occurred at two sample sites only and seemed to be restricted to higher elevations, growing in areas above 1700 m a.s.l. A. subscandens was not limited to certain light conditions and occurred in areas ranging from 0-100% canopy cover with a mean of 69 ± 19%.
Asparagus one individual of species yield The numbers of individuals necessary to obtain such knowledge is absent for name a medicinal use for availability. Surprisingly, only nine villagers could name a medicinal use for Asparagus spp. whereas all villagers could name at least one medicinal use for P. polyphylla indicating that especially for the Asparagus species, the traditional ethnobotanical knowledge is absent.

The numbers of individuals necessary to obtain such yield volumes (Fig. 3) also varied depending on species. Up to 30 kg dried root can be obtained from one individual of S. tuberosa (pers. comm. from villager), whereas for one kg of dried plant root of Asparagus spp. on average 71 individual plants have to be collected [54 (45-68) individuals of A. subscandens and 88 (57-185) of A. filicinus, respectively]. Based on this information, we found that assuming collection practices remain unchanged, the amount of Asparagus spp. will suffice for another 0.31 to 0.86 years of collection in Bengganghani, 0.82 to 1.43 years in Danuoyou, 0.069 to 0.562 years in Manxinglongdai, 0.27 to 0.64 in Shijiazhai and 4.97 and 38.08 years in Xiaonuoyoushangzhai. Due to the fact that we had to exclude regeneration, which will happen, these numbers are no reliable estimations but serve to indicate future trends and the current collection pressure on natural populations and are rather to be interpreted as a comparison between villages.

Prices for one kg of dried plant material varied vastly along the trade chain (see Fig. 4). In villages, one kg of Asparagus spp. was traded for RMB 22.26 (USD 3.58) in average, one kg of P. polyphylla for RMB 96 (USD 15.46), S. tuberosa for RMB 7.18 (USD 1.16) and T. chantrieri for RMB 6 (USD 0.97; Fig. 4). In between villages and markets there was no further processing of the plant parts that could justify the increase of prices. In pharmacies specialized in TCM in Germany, one kg of Asparagus spp. was 45 times of its price at the villages in China. The price difference for P. polyphylla was 21 times and for S. tuberosa it was 117 times of the price in the villages in China. T. chantrieri was not available in Germany.

The contribution of medicinal plants to the total household income varied between villages (1.14 % of household income in Danuoyou and 25.44 % in Shijiazhai). The harvest amount (kg year\(^{-1}\)) of S. tuberosa was significantly negatively correlated to average income per capita in each village \((r = -0.611, p<0.05)\). Similarly, the amount of P. polyphylla collected was highly significantly related to the average income per capita \((r = -0.995, p<0.005)\) as was the collection of Asparagus spp. \((r = -0.653, p <0.005)\), that is poorer villages collected more intensively.

### Harvest volume and economical importance

Underground parts are used medicinally for all species selected. The collection is mainly carried out between November and March. Fresh roots or rhizomes are boiled, peeled (in the case of S. tuberosa and Asparagus spp.) and sun-dried before being traded.

Harvest volumes of plants (here expressed as dry matter), collected during one year, varied depending on plant species and site (Fig. 3). On average 24.0 ± 9.9 kg year\(^{-1}\) of Asparagus spp., 12.3 ± 9.4 kg year\(^{-1}\) of P. polyphylla, 33.1 ± 14.9 kg year\(^{-1}\) of S. tuberosa and 0.2 kg year\(^{-1}\) of T. chantrieri were harvested per collector. Asparagus spp., P. polyphylla and S. tuberosa were mainly collected in winter, which is the dry season (November-March) whereas T. chantrieri was collected all year round and was mainly used for subsistence rather than sale. In general, harvest volumes were highest in Shijiazhai and lowest in Danuoyou and Manxinglongdai (Fig. 3). Most of the villagers reported decreasing plant availability.

Villagers collect plants mainly on the way to and from fields. The collection was intensified in winter during the dry season when labour in the fields is reduced and thus income is low. About 83% of collectors interviewed reported the collection of Asparagus spp. for sale, whereas almost no one had collected T. chantrieri during the previous year. P. polyphylla was also collected sparsely due to scarce availability. Surprisingly, only nine villagers could name a medicinal use for Asparagus spp. whereas all villagers could name at least one medicinal use for P. polyphylla indicating that especially for the Asparagus species, the traditional ethnobotanical knowledge is absent.

### Table 1. Average elevation and distribution of species studied

| Species         | Elevation (m a.s.l.) | Canopy cover (%) | Beng Gang Ha Ni 1800 m | Da Nu You 1200 m | Man Xing Long Dai 1700 m | Shi Jia Zhai 1400 m | Xiao Nu You Shang Zhai 1500 m |
|-----------------|---------------------|------------------|------------------------|-----------------|--------------------------|---------------------|-----------------------------|
| A. filicinus    | 1819 ± 24           | 77± 10           | 106 ± 43               | 0               | 2 ± 2                    | 0                   | 0                          |
| A. subscandens  | 1502 ± 231          | 69 ± 19          | 9 ± 4                  | 40 ± 21         | 6 ± 3                    | 77 ± 12             | 37 ± 9                     |
| P. polyphylla   | 1759 ± 122          | 80 ± 11          | 32 ± 14                | 0               | 39 ± 21                  | 3 ± 3               | 5 ± 4                      |
| S. tuberosa     | 1622 ± 170          | 71 ± 13          | 5 ± 2                  | 4 ± 3           | 3 ± 1                    | 1 ± 1               | 0                          |
| T. chantrieri   | 1092 ± 196          | 76 ± 15          | 0                      | 23 ± 18         | 0                        | 17 ± 12             | 0                          |

Canopy matter (volume)
Figure 3. Harvest volume in kg per year and household in the selected villages. Grey shades are giving species identity; whiskers indicate the standard error. *Asparagus* spp. \( n = 24 \), *P. polyphylla* \( n = 4 \), *S. tuberosa* \( n = 10 \), *T. chantrieri* \( n = 1 \).

Figure 4. Prices per kg dried plant matter in RMB. Grey shades indicate location (dark= village, light= markets), whiskers give the standard error.
Discussion

During the interviews, most of the villagers reported a decrease in plant availability, which seems to be a global issue (Boesi 2014; Botha et al. 2004; Cunningham 1994; Delgado-Lemus et al. 2014). Households with less assets and poorer families tend to collect more medicinal plants for cash generation than others which is also true for bamboo shoots (Dendrocalamus sp.) which are collected as food in the area (Ghorbani et al. 2012a). In Shijiazhai collection was highest and income lowest (RMB 1474 year\(^{-1}\)) of the selected villages. An explanation for this might be in the accessibility of plant sites that is good at Shijiazhai besides the fact that there is less agricultural land available compared to other villages. Although plant abundance was also high in Bengganghani, overall collection was much lower and the household income was higher (RMB 1575 year\(^{-1}\)). In Danuoyou and Manxinglongdai, the household income was highest (RMB 1681 year\(^{-1}\)), whereas collection was lowest. Paumgarten and Shackleton (2009) documented a similar pattern between NTFP collection and household economic status. Evidence from Boesi (2014) shows that gathering and especially trading of NTFPs has become more important and a crucial activity for the economy of whole villages or even towns during recent years. Our finding that collection of medicinal plants occurred mainly in winter supports this hypothesis. In our area, the collection of NTFPs generated up to 25.4% of the households' income, which underlines their economic significance for the region. The plant with highest economic value in our study (P. polyphylla) showed the strongest correlation of harvest volume (kg year\(^{-1}\)) to average per capita income. Asparagus spp. was second and S. tuberosa showed the weakest yet still significant correlation to the per capita income of the household. The lack of traditional knowledge regarding uses of medicinal plants - especially for Asparagus spp. - points to the fact that collection practices were brought to the area by outsiders. It illustrates that these medicinal plants are not the main components of local folk medicine, which exists in parallel to TCM, but instead are important in TCM. For Asparagus spp. we also found that if current collection practices remain unchanged, the populations are at high risk of going extinct at least in most of the villages. The use frequency of 0.017 (based on citation of species in free-listing interviews divided by the number of informants, varying between 0 and 1) has been reported for A. filicinus and 0.014 for A. subscandens in the study area (Ghorbani et al. 2012a). However, there was no difference in collection between the two Asparagus species (Bucher et al. 2011; Ghorbani et al. 2012a). The former species was proven to contain medicinally active compounds; however, no study has been conducted to test the medicinal effectiveness of the latter species (Bucher et al. 2011; Joshi & Joshi 2000; Rajbhandari et al. 2009; Sharma & Thakur 1994). A. filicinus is distributed in the whole Himalayan region and is therefore much less susceptible to overharvesting than A. subscandens with limited distribution to Yunnan. This makes A. subscandens a priority species for conservation and further research on its medicinal properties and effectiveness is needed (Bucher et al. 2011). The use frequency reported for P. polyphylla is 0.05 and 0.09 for T. chantrieri (Ghorbani et al. 2012a). Considering the low harvest volume of T. chantrieri but high use frequency, it seems that the plant is only used locally by villagers and it is not collected commercially. Local people did not use S. tuberosa at all albeit the highest volume of dried plant matter harvest per household were recorded for this plant. According to a rapid vulnerability assessment (RVA, based on literature data, indigenous knowledge and field observations), all species (except T. chantrieri on which no data was available) are moderately vulnerable to overexploitation in the area (Ghorbani et al. 2012a).

Ecological and biological information on these plants are needed to fully understand harvest impacts on the population demographics (like regeneration, seed dispersal or propagation). However, this kind of data is scarce - not only for the species selected in this study but also for most medicinal plant species harvested from the wild (Cunningham et al. 2008). In our study we tried to reduce this gap of knowledge by collecting information on ecological requirements of the species. For P. polyphylla and T. chantrieri a sustainable collection is more likely to be realized since these species possess rhizomes instead of tuberous roots. Regeneration from rhizomes is possible and therefore modified collection practices in which only some parts of the rhizomes are harvested are recommended. However, this still needs to be tested scientifically and a way of transferring this knowledge to local people needs to be established.

In our study we detected exceptionally large increments in prices for plant material along the trading chain. For example, for Asparagus racemosus a 100% increase of price was recorded (Bopana & Saxena 2007) a number which is easily outstripped by our target species. Other studies showed that the collectors' urgent needs of cash are one of the reasons why prices are especially low at the villages (Sher et al. 2014). Since no further processing of plant material is required for these species, this increase in value is only generated by costs of transportation, storage and especially profit-making by the middlemen along the trade chain and
of natural plant populations is important to sustain household economics and livelihoods of people in the area. In the long term, mainly poor people are affected by unsustainable harvest of NTFP practice, as medicinal plants are one of their important income sources.

Declarations

List of abbreviations: medicinal and aromatic plants (MAPs), Non-Timber Forest Products (NTFP), Traditional Chinese Medicine (TCM).

Ethics approval and consent to participate: The study did not involve animals or the export of plant material. The benefit was shared by translating and publishing Bucher et al. 2011 in Chinese.

Consent for publication: The pictures were taken by SFB.

Availability of data and materials: The data is made public with this manuscript.

Competing interests: There are no competing interests.

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Authors’ contributions: The research was designed by all authors. Data collection was carried out by SFB and AG. The analysis was done by SFB with the help of all co-authors who also critically discussed the manuscript. All co-authors agreed on this version.

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Literature cited

Baillie J, Hilton-Taylor C, Stuart SN. 2004. 2004 IUCN red list of threatened species: a global species assessment. IUCN, Gland, Switzerland and Cambridge, UK.

Boesi A. 2014. Traditional knowledge of wild food plants in a few Tibetan communities. Journal of Ethnobiology and Ethnomedicine 10:75.

Bopana N, Saxena S. 2007. Asparagus racemosus - Ethnopharmacological evaluation and conservation needs. Journal of Ethnopharmacology 110:1-15.
Botha J, Witkowski E, Shackleton C. 2004. The impact of commercial harvesting on Warburgia salutaris (‘pepper-bark tree’) in Mpumalanga, South Africa. Biodiversity & Conservation 13:1675-1698.

Bucher SF, Ghorbani A, Langenberger G, Küppers M, Sauerborn J. 2011. Asparagus spp. in Traditional Chinese Medicine: wild collection and its sustainability. TRAFFIC Bulletin 2

Cao M, Zou X, Warren M, Zhu H. 2006. Tropical Forests of Xishuangbanna, China. Biotropica 38:306-309.

Cunningham AB. 1994. Integrating local plant resources and habitat management. Biodiversity & Conservation 3:104-115.

Cunningham AB. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan Publications Ltd., London, UK.

Cunningham AB, Shanley P, Laird S. 2008. Health, habitats and medicinal plant use. Human Health and Forests A Global Overview of Issues, Practice and Policy People and Plants. International Conservation Series:35-62.

Delgado-Lemus A, Casas A, Téllez O. 2014. Distribution, abundance and traditional management of Agave potatorum in the Tehuacán Valley, Mexico: bases for sustainable use of non-timber forest products. Journal of Ethnobiology and Ethnomedicine 10:63.

Dyer M, Holland M. 1988. UNESCO's Man and the Biosphere Program. BioScience:635-641.

Fu Y-N, Guo H-J, Chen A-G, Cui J-Y. 2006. Household differentiation and on-farm conservation of biodiversity by indigenous households in Xishuangbanna, China. Biodiversity & Conservation 15:2687-2703.

Ghorbani A, Langenberger G, Feng L, Sauerborn J. 2011. Ethnobotanical study of medicinal plants utilised by Hani ethnicity in Naban river watershed national nature reserve, Yunnan, China. Journal of Ethnopharmacology 134:651-667.

Ghorbani A, Langenberger G, Liu J-X, Wehner S, Sauerborn J. 2012a. Diversity of medicinal and food plants as non-timber forest products in Naban River Watershed National Nature Reserve (China): implications for livelihood improvement and biodiversity conservation. Economic Botany 66:178-191.

Ghorbani A, Langenberger G, Sauerborn J. 2012b. A comparison of the wild food plant use knowledge of ethnic minorities in Naban River Watershed National Nature Reserve, Yunnan, SW China. Journal of Ethnobiology and Ethnomedicine 8:17.

Greger H. 2006. Structural Relationships, Distribution and Biological Activities of Stemona tuberosa. Planta Medica 72:99-113.

Guo H-J, Padoch C, Coffey K, Chen A-G, Fu Y-N. 2002. Economic development, land use and biodiversity change in the tropical mountains of Xishuangbanna, Yunnan, Southwest China. Environmental Science & Policy 5:471-479.

Hall P, Bawa K. 1993. Methods to assess the impact of extraction of non-timber tropical forest products on plant populations. Economic Botany 47:234-247.

Hamilton AC. 2004. Medicinal plants, conservation and livelihoods. Biodiversity & Conservation 13:1477-1517.

Hamilton AC, Pei S-J, Kessy J, Khan AA, Lagos-Witte S, Shinwari ZK. 2003. The purposes and teaching of applied ethnobotany. WWF Surrey, UK.

Huai-H-Y, Pei S-J. 2004. Medicinal plant resources of the Lahu: A case study from Yunnan Province, China. Human Ecology 32:383-388.

The International Plant Names Index. 2012. http://www.ipni.org., 2015.

Ji H, Pei S-J, Long C-L. 2004. An ethnobotanical study of medicinal plants used by the Lisu people in Nujiang, northwest Yunnan, China. Economic Botany 58:S253-S264.

Joshi AR, Joshi K. 2000. Indigenous knowledge and uses of medicinal plants by local communities of the Kali Gandaki Watershed Area, Nepal. Journal of Ethnopharmacology 73:175-183.

Leaman DJ. 2006. Sustainable wild collection of medicinal and aromatic plants: development of an international standard. Frontis 17:97-107.

Lee S, Xiao C, Pei S-J. 2008. Ethnobotanical survey of medicinal plants at periodic markets of Honghe Prefecture in Yunnan Province, SW China. Journal of Ethnopharmacology 117:362-377.

Lemmens RHMJ, Bunyapraphatsara N. 2003. Medicinal and poisonous plants 3. Backhuys Publishers, Leiden, The Netherlands.

Li H, Ma Y, Aide TM, Liu W. 2008a. Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics. Forest Ecology and Management 255:16-24.

Li S, Han Q, Qiao C, Song J, Cheng CL, Xu H. 2008b. Chemical markers for the quality control of herbal medicines: an overview. Chinese medicine 3:7.

Liu H, Gao L, Zheng Z, Feng Z. 2006. The impact of Amomum villosum cultivation on seasonal rainforest in Xishuangbanna, Southwest China. Biodiversity & Conservation 15:2971-2985.

Long C-L, Li H, Ouyang Z, Yang X, Li Q, Tranmer B. 2003. Strategies for agrobiodiversity conservation and promotion: a case from Yunnan, China. Biodiversity & Conservation 12:1145-1156.
Madhav K, Phoboo S, Jha PK. 2010. Ecological study of *Paris polyphylla* SM. Ecoprint: An International Journal of Ecology 17:87-93.

Martin GJ. 1992. Searching for plants in peasant marketplaces Sustainable harvest and marketing of rain forest products Island Press, Washington, DC, 212-223.

Meinshausen F. 2006. FairWild Standards. Version 1. Zurich, Weinfelden and Munich, Swiss Import Promotion Programme (SIPPO), Forum Essenzia Institute for Marketecology (IMO).

Paumgarten F, Shackleton C. 2009. Wealth differentiation in household use and trade in non-timber forest products in South Africa. Ecological Economics 68:2950-2959.

Pilgrim SE, Cullen LC, Smith DJ, Pretty J. 2008. Ecological knowledge is lost in wealthier communities and countries. Environmental Science & Technology 42:1004-1009.

Rajbhandari M et al.. 2009. Antiviral activity of some plants used in Nepalese traditional medicine. Evidence-Based Complementary and Alternative Medicine 6:517-522.

Rodríguez LC, Pascual U, Niemeyer HM. 2006. Local identification and valuation of ecosystem goods and services from Opuntia scrublands of Ayacucho, Peru. Ecological Economics 57:30-44.

Schippmann U, Cunningham A, Leaman D. Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. In: Biodiversity and the ecosystem approach in agriculture, forestry and fisheries. Proceedings, Rome, Italy, 12-13 October 2002., 2003. Food and Agriculture Organization of the United Nations (FAO), 140-167.

Schippmann U, Leaman D, Cunningham A. 2006. A comparison of cultivation and wild collection of medicinal and aromatic plants under sustainability aspects. Frontis 17:75-95.

Shanley P, Stockdale M. 2008. Traditional knowledge, forest management, and certification: a reality check. Forests, Trees and Livelihoods 18:55-67.

Sharma S, Thakur N. 1994. Furostanosides from *Asparagus filicinus* roots. Phytochemistry 36:469-471.

Sher H, Aldosari A, Ali A, de Boer HJ. 2014. Economic benefits of high value medicinal plants to Pakistani communities: an analysis of current practice and potential. Growth 1.6.

Sun J, Liu BR, Hu WJ, Yu LX, Qian XP. 2007. In vitro anticancer activity of aqueous extracts and ethanol extracts of fifteen traditional Chinese medicines on human digestive tumor cell lines. Phytotherapy Research 21:1102-1104.

Wang S, Xie Y. 2004. China species red list, vol. 1 Red List Beijing, China.

Wehner S. 2011. Transformation of rural space from an institutional perspective. Socio-economic development and land use change in Xishuangbanna, Southwest China.. Der Andere Verlag, Uelverstäubl.

Yang Y, Tian K, Hao J, Pei S, Yang Y. 2004. Biodiversity and biodiversity conservation in Yunnan, China. Biodiversity & Conservation 13:813-826.
Annex 1. Questionnaire

Village:                                                             Date:
Researchers:                                                        Number:

Name:  
Age:  
Sex:  
Occupation:  
Education:  
Ethnic group:  
Household number:

Name of plant:

How does the plant look like?

What are the needs of the plants/ where is it growing?

Where do you collect the plants/ how many plants are there?

How are the plants collected and how are they selected?

Are there fewer plants than in former times?

Are the plants grown in home gardens?

Which parts are used:

In which way they are used:

Who is collecting the plants:

How much is collected:

How often are the plants collected:

When the plant is collected, how does it grow for the next year?

Is there a processing of the plant material and who is processing them?

Is it sold?

If yes, to whom and for how much?

How much is sold?

is it possible to ask for more money, if the quality is better?