Wild fodder plants are valuable because they provide an important livestock feed resource globally, especially for smallholder farmers, and have important roles in natural resource management. In-depth knowledge of wild forage plants can motivate local people for feed resource and habitat conservation of threatened herbivores such as Mithun (Bos frontalis). Mithun occur in small patches in the mountains of Dulongjiang, nearby villagers domesticated this animal but left animal to freely graze in the mountains. Many fodder plants occur in these mountains, however, little is known about their nutritional value. We conducted an ethnobotanical survey to document important wild fodder plants consumed by mithun in the Dulongjiang Township. The nutritional content of 21 highly mentioned wild fodder plants in an ethnobotanical survey was examined. Laboratory analysis showed that Fagopyrum dibotrys were the fodder species with the highest crude protein (CP) content (26.89%), followed by Polygonum molle (21.88%) and Hydrangea longipes (21.12%). Synthesis of relative feed value index and grey relational grade, P. molle, H. longipes and Tetrastigma obtectum were ranked the top three nutritional fodders. There was a significant difference between 21 species on their in vitro digestibility and the most highly digestible fodder species was Elatostema hookerianum. Linear model analysis on relationship between frequency of citation of 21 wild forage plants by local farmers and their nutrient composition showed that the frequency was significantly positively correlated with the nutritional value of the feed ($R^2 = 0.28, P < 0.05$). We concluded that these species have high nutritional values to improve mithun production in integrated crop-livestock systems. Fodder species or mixtures of species with useful nutritional characters could be cultivated to improve livestock productivity, habitat conservation including that of mithun and wild forage resource management.

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1. Introduction

The global livestock sector is one of the fastest growing agricultural sub-sector. Livestock are vital to the livelihoods and food security of almost a billion people and consumption of livestock products impacts the diet and health of these populations (Robinson et al., 2014). Livestock are also a source of organic fertilizer for the crops for many smallholder farmers in developing countries beside important source of meat and milk. The consumption of livestock products has been progressively increasing. In China, bovine meat consumption increased from 0.34 in 1961 to 14.32 g/capita/day in 2013 (FAO, 2015). Rapid growth in demand for livestock products has led to intensified competition between livestock and crop production for agricultural land and labor. At the same time, price of commercial feed for livestock is increasing and climatic stress such as heat stress is causing decline in the milk production (Ranjitkar et al., 2020). The declining availability of land for livestock, including that for grazing and high prices of commercial feed and recently growing climatic stresses threaten the sustainability of traditional smallholder livestock farmer in the mountains (Toth et al., 2017). In the light of limited land resources, it is important to find an environmentally sustainable balance between livestock and crop production, and good source of nutrition to the livestock.

Historically, forests have played an important role for livestock feeding in most parts of the world (Thapa et al., 1997; Paterson et al., 1998; Azim et al., 2002; Solorio and Solorio, 2002; Charlton et al., 2003; Pitta et al., 2005; Franzel et al., 2014a; Luske and van Eekeren, 2018). Since the middle ages, tree/shrub leaves as well as some wild grasses served as fodder in European countries, for example, cattle farmers relied on palatable evergreen shrubs and trees during winter when there is a shortage of livestock feed (Luske and van Eekeren, 2018). Tree species such as European ash (Fraxinus excelsior), lime tree (Tilia cordata) and elm trees (Ulmus spp.) were important source of fodder for livestock such as sheep, goats, horses and cows in Sweden and Austria (Slotte, 2001). Tree and shrubs are still an important source of fodder in developing countries (Maselli et al., 2011; Luske and van Eekeren, 2018). Fodder/forage plants are important source of nutrition for the livestock in the mountains particularly during dry season when other feed sources are in limited supply (Thapa et al., 1997; Maselli et al., 2011). The nutritive value of forage plants regulates optimal body size of herbivores thus knowledge of nutrient content is important to enhance livestock productivity and inform wild herbivore conservation strategies. However, nutrition is rarely considered as a part of ecological or conservation studies (Lee, 2018). Mostly forage diversity grows in the natural grasslands/rangelands, which is one of the most important natural ecosystems. At present, erosion of forage diversity is occurring in grasslands rapidly mainly due to land conversion from natural pasture and marginal areas to crop production area. Such rapid erosion of the important resources highlights the necessity for ex-situ conservation of forage genetic resources to provide nutritious livestock feed without damaging the natural source. Forage crops can be grown in mixed species cultivation to provide nutritional and environmental benefits (Capstaff and Miller, 2018). Proper knowledge of such resources is necessary for effective management and conservation planning.

Ethnobotanical knowledge of indigenous community on important resources can help to formulate planning for ex-situ conservation. According to ethnological records, mountain community has rich knowledge of fodder/forage plants (Thapa et al., 1997; Aumeeruddy-Thomas et al., 2004; Bahru et al., 2014; Geng et al., 2017). Ethnobotanical knowledge along with the known nutritive value of forage plants can guide ecosystem management strategies through forage species selection for ex-situ conservation as well as their habitat conservation (Lee, 2018).

Fodder species are grown in home gardens or croplands as an efficient way to improve sustainable livestock rearing and to change the free grazing style to stall feeding without damaging the environment. Agroforestry, the practice of integrating trees or shrubs with crop and/or livestock to maximize benefit from the resulting ecological and economic interactions (Mosquera-Losada et al., 2009), can address environmental issues, and provide ecological services as well as food for livestock. Agroforestry practice can help in ex-situ conservation of important forage resources, maintain and maximize the agricultural landscape. Tree and shrubs in the system could also help provide shade that is necessary for reducing heat stress effects (Ranjitkar et al., 2020).

In cattle or goat farms, fodder species reintroduced in or around could be a third crop in addition to main crop. Rao et al. (2015) called such integration of livestock, crop and trees-‘system intensification’. System intensification maximizes land use and promotes agricultural diversity, conserve biodiversity and ecosystem sustainability through environmentally friendly cultural practices. Compared with monocultural grain-based farming systems, system intensification have better resource utilisation in China (Zhen et al., 2014; Zhang et al., 2014). These benefits are drawing increasing attention and research emphasis to such integrated agricultural systems (Devendra and Thomas, 2002).

Achieving higher yields from livestock requires improvement in feeding programs. The aim of feeding programs is to meet the nutritional requirements of livestock through a balance of feed ingredients. For this purpose, it is essential to have access to detailed data regarding the nutrient content of feed ingredients. Understanding the nutritional requirements of the target ruminant is important for conservation efforts. In the investigation of fodder sources in different regions of the world, it is essential to document local knowledge as a valuable resource in the characterization of fodder plants (Nahed et al., 1997).

In this paper, we assess the nutritional value, diversity, distribution, and utilization patterns of 21 wild fodder species consumed by mithun (Bos frontalis) in Dulongjiang Township. We aimed to identify highly nutritious wild forage species that could be incorporated into agroforestry systems for maximizing land use. This work also explores the potential complementarity between indigenous and laboratory-based indicators of wild fodder species quality. Besides, we also discuss the potential contribution of crop-livestock integration to plant resources conservation.

2. Material and methods

2.1. Study site

Study area is in Dulongjiang Township (98°–98°5’E, 27°5’–28°N), Gongshan County, Yunnan Province, Southwest China, where an indigenous people group called the Dulong lived there for thousand years and had semi-domesticated mithun (B. frontalis) (Fig. 1). The area is inhabited by approximately 4000 people of the Dulong (or Drung) ethnic minority group. The Dulong are one of the least populous minorities in China (Li, 1999). The total land area occupied by the Dulong is only 1994 km² in which their population density is only 2.01 persons per km². Approximately 85% of this land area has slopes exceeding 35°. Swidden agriculture is central to the traditional livelihoods and culture of the Dulong people (Shen et al., 2010). The main crops of the Dulong area are corn, Chinese yam, and potato. The average rainfall is 3672.8 mm per annum. More than 2000 species of seed plants have been reported from the area (Li, 1994). Mithun is a rare semi-domesticated bovine species which is raised in mountain areas and is distributed only in India, China,
Myanmar, Bhutan, Malaysia and Bangladesh (Qu et al., 2012). In Dulongjiang Township, local residents report that the total population of mithun does not exceed 2000 individuals. It is an efficient grazer on steep hilly slopes, and local farmers just need to feed it with some salt weekly (Fig. 1). But due to rural transformation, Dulong people have moved to new countryside construction houses in low land areas since 2013. Therefore, the earlier mithun keeping activity is no longer efficient because of distance from farmers’ residence to mithun habitat. However, mithun are important in the economic, social and cultural life of Dulong people (Geng et al., 2017).

2.2. Nutritional analyses

From our ethnobotanical survey in 2015 and 2016, 21 most frequently cited plants stood out of 142 wild forage plants (Geng et al., 2017) (Table 1). In April 2016, we collected tender branches of frequently cited plants. In Dulongjiang Township, local residents report that the total population of mithun does not exceed 2000 individuals. It is an efficient grazer on steep hilly slopes, and local farmers just need to feed it with some salt weekly (Fig. 1). But due to rural transformation, Dulong people have moved to new countryside construction houses in low land areas since 2013. Therefore, the earlier mithun keeping activity is no longer efficient because of distance from farmers’ residence to mithun habitat. However, mithun are important in the economic, social and cultural life of Dulong people (Geng et al., 2017).

2.3. In vitro dry matter digestibility experiment

To assess the digestibility of 21 fodder species, in vitro dry matter digestibility experiment was conducted. Plant powder samples were randomly assigned into incubation bottles (nine replicates of each feed). 1.00 g of each sample was mixed with 50 ml of basal media and 25 ml of rumen fluid that had been obtained from three lactating Holstein dairy cows and cultured in vitro in an incubator for 72 h at a constant temperature of 39 °C. The residual samples from each bottle were collected, dried and weighed to calculate in vitro dry matter digestibility (IVDMD), where IVDMD = (residual weight (g)/1.0 g) *100 (%). The rumen fluids from three cows were collected 1 h before the morning feeding from different sites inside the rumen. These samples were squeezed through four layers of medical-use cheese cloth and mixed in equal proportions. The mixed rumen fluid was then transferred into a thermos pre-warmed at 39 °C and served as the inoculant for later batch cultures. All the animals were cared for and experimental operations were carried out under the Guidelines of the Beijing Municipal Council on Animal Care.

2.4. Statistical analysis

Grey relational analysis (GRA) was used to find the best mithun fodder species. According to the principles of grey relational method, 21 fodder species are regarded as a grey system, and each of them is regarded as a factor of the system. The optimal values of eight indexes, namely CP, NDF, ADF, EE, Ash, Ca, P and GE, are taken to construct a ‘reference species’, and the array of its various character indexes is taken as a reference X0. 21 fodder species are composed of the arrays of the evaluated species Xi (i = 1, 2, ... , n), and X0 = [x0 (1), x0 (2) x0(k)], Xi = [xi(1), xi(2), ... xi (k)], n is the number of species, k is the number of indicators. The grey relational coefficient εi(k) can be calculated as (Tosun, 2006):

\[
\varepsilon_i(k) = \frac{\xi_i(k) - \xi_0(k)}{\xi_0(k) - \xi_{i,min}(k)}
\]
Table 1

Nutritional contents and in vitro digestibility of 21 mithun feeds on a DM basis (%).

| Feed       | Scientific name | FC | DM | CP | Ash | NDF | ADF | Ca | P | GE | RFV | r_i | ME | NE | IVDMD(%) | Habitat     |
|------------|-----------------|----|----|----|-----|-----|-----|-----|----|----|-----|-----|-----|----|---------|-------------|
| Arundo donax | 27              | 95.94 | 13.10 | 1.44 | 8.11 | 67.91 | 41.17 | 0.34 | 0.13 | 19.35 | 77.84 | 0.64 | 8.29       | 4.83        | Lianas       |
| Carex baccans | 25              | 94.65 | 11.15 | 1.00 | 6.94 | 63.46 | 32.86 | 0.42 | 0.11 | 19.50 | 92.79 | 0.70 | 6.86       | 4.41        | Herb        |
| Carex rubiginosa | 18             | 94.86 | 12.88 | 1.59 | 8.83 | 63.62 | 36.37 | 0.35 | 0.23 | 19.23 | 88.56 | 0.63 | 8.56       | 5.03        | Herb        |
| Chimonolobus armata | 20           | 93.98 | 13.13 | 0.99 | 11.55 | 71.78 | 45.65 | 0.61 | 0.08 | 17.79 | 69.12 | 0.68 | 6.68       | 3.70        | Herb        |
| Debeccasia orientalis | 28         | 91.74 | 18.53 | 0.95 | 13.10 | 38.48 | 37.04 | 2.13 | 0.24 | 18.45 | 145.16 | 0.59 | 6.49       | 3.54        | Tree        |
| Dendrocalamus fungensis | 7          | 95.75 | 16.38 | 1.16 | 12.80 | 67.62 | 41.95 | 0.36 | 0.11 | 18.64 | 77.27 | 0.62 | 8.97       | 5.32        | Tree        |
| Elatostema hookerianum | 24           | 92.27 | 13.94 | 1.56 | 15.43 | 36.55 | 18.89 | 2.33 | 0.20 | 15.71 | 188.81 | 0.59 | 8.75       | 5.16        | Herb        |
| Eranthus longisetaus | 47            | 93.44 | 9.90 | 1.81 | 6.95 | 38.49 | 38.60 | 0.30 | 0.14 | 18.25 | 86.20 | 0.67 | 7.54       | 4.13        | Herb        |
| Fagopyrum dubitoxys | 20            | 93.44 | 26.89 | 2.64 | 10.15 | 39.35 | 23.66 | 0.86 | 0.38 | 18.98 | 166.59 | 0.74 | 8.14       | 5.20        | Herb        |
| Fragaria pentaphylla | 21            | 91.68 | 13.60 | 1.78 | 7.64 | 32.57 | 27.04 | 0.94 | 0.15 | 17.69 | 193.75 | 0.74 | 9.20       | 5.52        | Herb        |
| Hydrangea longipes | 8            | 93.98 | 21.12 | 1.50 | 10.70 | 38.70 | 35.46 | 1.63 | 0.37 | 17.86 | 147.29 | 0.87 | 9.28       | 5.54        | Herb        |
| Imperata cylindrica | 31           | 96.39 | 5.12 | 1.16 | 7.56 | 31.15 | 29.07 | 0.55 | 0.18 | 18.55 | 97.40 | 0.58 | 9.58       | 5.75        | Herb        |
| Isochne albens | 11            | 96.18 | 16.28 | 1.23 | 8.44 | 60.42 | 32.91 | 0.18 | 0.15 | 18.88 | 71.08 | 0.65 | 9.73       | 5.85        | Herb        |
| Ophiopogon compositus | 13         | 96.38 | 8.38 | 0.64 | 5.96 | 73.83 | 41.70 | 0.12 | 0.08 | 18.88 | 65.36 | 0.69 | 7.39       | 4.14        | Herb        |
| Phyllostachys manu | 37            | 96.14 | 14.41 | 2.13 | 9.10 | 68.66 | 41.06 | 0.36 | 0.08 | 20.23 | 77.11 | 0.61 | 7.56       | 4.32        | Herb        |
| Plantago asiatica | 6             | 93.47 | 13.84 | 1.57 | 16.22 | 40.21 | 38.54 | 1.81 | 0.33 | 16.61 | 136.21 | 0.83 | 10.04      | 6.07        | Herb        |
| Polygonum molle | 11            | 93.20 | 21.88 | 0.97 | 7.55 | 31.15 | 29.07 | 0.55 | 0.25 | 19.70 | 197.86 | 0.74 | 7.25       | 4.10        | Herb        |
| Rubus lineatus | 15            | 94.85 | 17.66 | 3.18 | 5.50 | 46.56 | 27.01 | 0.84 | 0.23 | 19.55 | 135.58 | 0.72 | 6.99       | 3.91        | Shrub       |
| Saccharum arundinaceum | 8           | 96.84 | 9.74 | 1.22 | 5.17 | 74.27 | 44.09 | 0.26 | 0.11 | 19.98 | 68.33 | 0.67 | 7.08       | 3.98        | Herb        |
| Sauraua polyneura | 20            | 91.98 | 9.52 | 1.50 | 6.56 | 42.70 | 42.07 | 1.11 | 0.10 | 19.46 | 122.84 | 0.78 | 8.03       | 4.65        | Herb        |
| Tetrastigma obtectum | 7             | 92.38 | 14.26 | 2.72 | 8.28 | 34.07 | 33.22 | 1.68 | 0.17 | 19.29 | 172.07 | 0.81 | 9.50       | 4.97        | Tree        |

Table 2

Attributes and their marks used for the analysis of the PUL.

| Preference (marks) | Distribution (marks) | Other uses (marks) | Availability (marks) | Nativity and Endemism (marks) | Status/Occurrence (marks) |
|-------------------|----------------------|--------------------|----------------------|-----------------------------|--------------------------|
| High (5)          | <500 m (5)           | 3 or >3.5 (5)      | Throughout year (5)  | Native and endemic (5)      | Rare (5)                 |
| Moderate (3)      | 500–1500 m (3)       | 2 (3)             | Two seasons (3)      | Native (3)                  | Occasional (3)           |
| Least (1)         | >1500 m (1)          | <2 (1)            | One season (1)       | Non-native (1)              | Common (1)               |

Note:
- IVDMD(%) = Indirect Voluntary Dry Matter Digestibility

Equations:

\[ r_i(k) = \frac{\min_{k=1}^{n} |X_0(k) - X_i(k)| + \max_{k=1}^{n} |X_0(k) - X_i(k)| \times \rho}{|X_0(k) - X_i(k)| + \max_{k=1}^{n} |X_0(k) - X_i(k)|} \]

where \( \rho \) is the resolution coefficient, the value of 0–1, usually 0.5. The higher value of the grey relational grade means that the corresponding fodder species is closer to optimal.
composition showed that the frequency was significantly positively correlated with the nutritional value of the feed \((R^2 = 0.28, P < 0.05)\). Among the nutritional indicators of wild forage plant resources, the percentage of DM and NDF were significantly correlated with the frequency of citation by the local Dulong people \((P\) value was 0.013 and 0.006, respectively). Taking the NDF content as an example, as the frequency mentioned by local farmers increased, the NDF content increased. After the NDF content was greater than 70%, the frequency was decreased as the NDF content increased (Fig. 3).

3.2. In vitro dry matter digestibility (IVDMD)

Digestibility determines the availability of nutrients in fodder to the animals that consume it. In vitro DM Digestibility (IVDMD) measurements have commonly been used to analyze feeds, because it is highly correlated to in vivo digestibility.

Based on in vitro digestibility, highly digestible fodder species included *Elatostema hookerianum*, *Tetrastigma obtectum*, *Carex nubigena*, *Isachne albens*, *Plantago asiatica* and *Fagopyrum dibotrys*. *Elatostema hookerianum* (IVDMD = 69%) could be an excellent source of fodder as it had the highest effective DM digestibility. There was a significant difference between species in their digestibility \((P < 0.001, \text{Table 1})\). The IVDMD of most of species was around 40% (Fig. 4).

3.3. Wild fodder distribution and utilization pattern and implications

Our ethnological study revealed Dulong people possessed rich knowledge on the wild fodder species, and they used such species to feed livestock including mithun. We listed 142 potential fodder species from Dulongjiang that consisted of 61 tree/shrub species and 81 herbaceous species (Geng et al., 2017). Most of the fodder species were available in the Dulongjiang area during two or more seasons around the year. Among the listed fodder species, tree species are distributed evenly across an elevation range of 500–1500 m and >1500 m, whereas herb fodder plants had different distributions (Fig. 5). That wild forage plants were gathered across such a wide span of elevation would indicate that mithun were fed with a wide variety of plants.
**4. Discussion**

### 4.1. Wild fodder evaluation

Most of the wild fodder species in the present study have high CP content and could be used either alone or as supplements to other feeds. From China Feed Database (http://www.chinafeeddata.org.cn), we could know that domestic alfalfa hay crude protein content is about 16 ± 2% in China, and *Fagopyrum dibotrys*, *P. molle*, *H. longipes*, *Debregeasia orientalis*, and *R. lineatus* could be comparable to it. The species with highest Ca was *E. hookerianum* (2.33%) and the species with the highest P was *F. dibotrys* (at 0.38%). According to Abdullah et al. (2013), the recommended ranges for provision of mineral nutrients in fodder for all classes of ruminants are 0.19–0.82% Ca and 0.12–0.48% P. Our nutrient analysis showed that some of the plant species contained an adequate quantity of crude protein, moderate levels of fiber and high contents of Ca and P. Thus these wild plant species would appear to be valuable for fodder.

The species with higher NDF (NDF > 70% of DM) were *Chimonobambusa armata*, *Opilsenus compositus*, *Saccharum arundinaceum*, and *Imperata cylindrica*. The NDF levels in fodder species are determined by the environmental conditions in the Dulongjiang area. The moderate temperatures and high precipitation in the study area tend to decrease cell wall fraction and reduce the soluble content of the plants (Boufennara et al., 2012). A certain amount of NDF is important for maintaining the normal rumen fermentation function, but overmuch NDF will have a negative effect on dry matter intake (Ma et al., 2015). The results of the laboratory nutrition evaluation showed that the local Dulong traditional feeding knowledge was highly credible and livestock keeping practices could be improved through the combination of local knowledge with mechanistic understanding of nutrient utilization in livestock (Thorne et al., 1997).

According to the definition of RFV value, if the RFV value is higher than 100, it indicates that the nutritional value of this feed is better overall, and the higher the RFV value, the higher the nutritional value of the feed (Rohweder et al., 1978). The biggest relative feed value can be seen in *P. molle* (197.36), thus it is the best feed among 21 wild fodders. However, the current RFV only considers the amount of NDF and ADF, and does not consider the digestibility of fiber. Therefore, the overall feed nutritional value could only be roughly judged and has certain limitations by RFV index (Wu et al., 2014). The grey relational analysis showed that 21 fodder species had a different ranking. Average ranking between the two methods could represent a more reliable assessment result.

### 4.2. Nature conservation and integrated crop-livestock systems

Fodder is one of the important livelihood resources for mountainous regions with limited access to modern infrastructure. Fodder resources from the forests are important source of food supply to domesticated or semi-domesticated herbivores. Villagers either collect fodder plants from forest or they took/release animals for freely grazing in the mountains. These mountain forest and rangelands grow many useful plant species and couple of them are already threatened due to human disturbance including haphazard grazing and destruction of natural habitat (Aumeeruddy-Thomas et al., 2004). Harvesting protected/threatened plants such as *F. dibotrys* may lead to local extinction of such species that could have a negative impact on mountain ecosystem. Fodder is derived from forests, and fodder development cannot be dealt with in isolation from forest development. Also, without the engagement of local people and the community, any protection goal could hardly be achieved (Pei et al., 2009). Proper utilization of all available resources, and coordination and cooperation between local authorities and farmers at the field level would ensure an increase in total fodder supply in the hills. This would eventually increase productivity of livestock, reduce dependency on forest resources, and help to develop crops, livestock and forests in harmony. A model, called integrated tree-crop-livestock systems or agro-silviapasture systems, could minimize fodder collection pressure to the forest, supply nutritious fodder to animal and help to minimize climatic stresses through fodder species/trees plantation (Capstaff and Miller, 2018; Ranjitkar et al., 2020; Shin et al., 2020).
Fodder trees are important feed sources for livestock in a wide range of agroforestry systems throughout the world. Since ancient times, farmers have used fodder species in traditional feeding systems (Azim et al., 2002; Solorio and Solorio, 2002; Charlton et al., 2003; Franzel et al., 2014a; Luske and van Eekeren, 2018). There has been a recent increase in interest in the use of indigenous fodder trees and shrubs as animal feed for ruminant animals in integrated farming systems (Thorne et al., 1999; Roothaert and Franzel, 2001; Odunsi et al., 2009; Gina et al., 2014). Agroforestry is important part of management system in many countries including China (Shin et al., 2020), while fodder trees are vital in the farming systems of mountainous countries like Nepal as well as to reduce the cost of meeting dairy cows’ protein requirements in Africa (Thapa et al., 1997; Franzel et al., 2014b). Also there has been growing interest to understand the functional role of trees for livestock as fodder in silvopastoral and agro-silvopastoral systems that include determining nutritional value of different tree species (Luske and van Eekeren, 2018; Shin et al., 2020). Bringing such trees/shrubs into agroforestry system could be an important approach to protecting environments, plant conservation and at same time providing nutritious feed to mithun.

Hanson and Ellis (2020) reviewed the challenges to the conservation of forage species and concluded that seed storage is the most cost-effective and efficient method for their conservation and sustainable use of forage resources for the immediate future. Ex-situ conservation of forage germplasm must be linked to use in forage. Conservation and management of wild fodder need a knowledge on cultivation, germination and harvesting for seed production of selected species and research need to be carried out to improve ease of cultivation (Hanson and Ellis, 2020). Understanding farmers’ perceptions about the value of wild fodder trees or shrubs and the constraints to introducing and growing native multipurpose fodder trees will also aid innovation of integrated farms. Ethnobotanical knowledge combined with scientific findings such as nutritional content in the important forage resources could help to prioritize species for beginning the integration practice. Based on our study, wild fodder species could be exploited and promoted into farming and livestock keeping, for example F. dibotrys, P. molle and H. longipes could be used as high protein food, and P. asiatica, F. pentaphylla and H. longipes could be used as energy food. If planted or managed properly, they can provide a valuable supplement to the otherwise limited diet of mithun during periods such as winter snow. As a starting point, farmers in Dulongjiang Township could try to plant high-quality wild fodder species in appropriate habitats. For example, they could plant E. longifolius in lowland fields, or R. lineatus along trekking routes for high protein supply to the mithun. The scope of this study did not extend to trialing such planting and cultivation of fodder plants. This would be a priority topic for future research. In recent times there have been significant movements of germplasm and increased cultivation of fodder plants in many areas (Franzel et al., 2014a). Understanding the elevation distribution range, farmers’ preferences, seasonal availability and nutritional content in fodder species provide valuable information on selection of fodder species from different habitats for cultivation (Geng et al., 2017; Luske and van Eekeren, 2018). This act will strongly support the conservation of habitat as well as wild plant resources. However, key challenges constraining the uptake of fodder species include limited species appropriate to different agroecological zones, availability of seed and skills of farmers needed to grow them (Franzel et al., 2014a).

5. Conclusion

Based on our results we conclude that wild fodder species can be important source of protein, macro and micro elements to livestock. Some trees/shrubs are higher in nutrient content than that in the herbaceous species, and some of them are comparable to commercial feed such as alfalfa hay. Productivity of mithun or livestock in general is chiefly determined by the availability of good quality nutritious fodder. Use of traditionally used or currently under-utilized fodder plants can help to cope with regional shortages of fodder crops. Our research documented 21 wild fodder species that had been identified through farmers’ traditional knowledge and laboratory assessment. Analyses of locally wild fodder samples provide insights in the nutritional value of fodder species. These results could help to select fodder species with high nutrient contents to improve the diet of livestock and thereby boost livestock health and productivity. The findings will also definitely help nutritionist, ecologist and policy makers to understand mithun’s needs and to take appropriate measures for conservation...
of mithun as well as mitigation of human-mithun resource competition. Proposed integrated crop-livestock systems could be regarded as a bold attempt of Applied Ethnobotany, which could contribute to the local nature conservation.

Declaration of competing interest

The authors declare that there was no conflict of interest in carrying out this work.

Acknowledgement

We are thankful to Jian Wang, Xin Zhang, Lu Ma and Lingling Sun from Institute of Animal Science, Chinese Academy of Agricultural Sciences for being helpful in lab work. Special gratitude is expressed to Dr. Fiona R. Worthy from ‘Centre for Mountain Ecosystem Studies’ at the Kunming Institute of Botany for English editing. This research was funded by the Chinese Academy of Agricultural Science and Technology Innovation Program (CAAS-XTCX20160111-01; ASTIP-JAS07), Talent Project of Guizhou University [J201806] and National Natural Science Foundation of China (31900275). We also acknowledge supports from CGIAR research programs on ‘Forests, Trees and Agroforestry’ (CRP6.2) and Strategic Priority Research Program of Chinese Academy of Sciences (No. XDA20050204, XDA19050303).

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