Demand, End-Uses, and Conservation of Alpine Medicinal Plant Neopicrorhiza scrophulariiflora (Pennell) D. Y. Hong in Central Himalaya

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Neopicrorhiza scrophulariiflora (Pennell) D. Y. Hong (Scrophulariaceae) (hereinafter referred to as Neopicrorhiza) has medicinally important rhizomes with high levels of trade. What factors drive demand for Neopicrorhiza in Central Himalaya is unknown. In this context, a nationwide comprehensive survey was conducted from September 2016 to March 2017 to assess demand, end-uses, and conservation of dry Neopicrorhiza rhizomes in Nepal. A total of 2313 herbal products were surveyed for Neopicrorhiza as an ingredient in 38 retailer shops. Processing industries of Neopicrorhiza in Nepal were interviewed using structured questionnaire. There were 23 herbal industries manufacturing 45 types of ayurvedic medicines as end-products containing Neopicrorhiza. The volume and value of annual demand for dry rhizomes of Neopicrorhiza in Nepal were found as 6076 kg and NRs 8573236 (USD 83235.30), respectively, in 2015/016 with average 264.17 kg/industry and NRs 1410.87 (USD 13.69) per kg. The major uses of ayurvedic medicines containing Neopicrorhiza were to treat a number of disease categories: cardiovascular system/liver (17), cardiovascular system/blood (6), nervous system (6), dermatological system (4), musculoskeletal system (3), digestive system (2), respiratory system (2), genitourinal system (4), and others (1). Despite changing legal regulation, trade and consumption of Neopicrorhiza exist in Nepal. It can be concluded that domestic consumption is not the major cause of resource depletion of Neopicrorhiza in Nepal.

1. Introduction

Neopicrorhiza scrophulariiflora (Pennell) D. Y. Hong (Scrophulariaceae) (hereinafter referred to as Neopicrorhiza) is a perennial alpine herb found in the subalpine as well as alpine zone of the eastern Himalayas comprising Sikkim, Nepal, Bhutan, and China [1–3]. It occurs in the wild in diverse habitat types: alpine grassland and gravelly areas, forests, shrublands, meadows, cliffs and screes, between 3600 and 4400 masl [4–6]. It prefers moist north-facing slopes with richer and partial shady soil [6]. Its Nepali name is Kutki, which is assessed as being vulnerable in Nepal [7]. Neopicrorhiza is prioritized by Government of Nepal for research and economic development among 30 medicinal and aromatic plants [8].

The long, creeping, and bitter rhizomes of Neopicrorhiza are used medicinally. Its rhizomes have been officially listed in the China's Pharmacopoeia for the treatment of fever, jaundice, hemorrhoids, and dysentery by Traditional Chinese and Tibetan Medicine [9]. In Nepal, a number of ethnomedical uses of its unprocessed rhizomes have well been documented to treat common cold, fever, sinusitis, headache, diarrhea, paralysis, hysteria, anemia, high blood pressure, sore throat, gastritis, intestinal pains, snake and scorpion sting, abdominal pain, indigestion, liver troubles, bile disorders, continuous pain in the chest and heart, increased heartbeat, difficulty in breathing, jaundice, cuts, wounds, and conjunctivitis [10–18]. Chemical constituents of rhizomes of Neopicrorhiza are well studied which comprise iridoid glycosides [19–21], triterpenoids [22], phenolic glycosides...
The herbal products for Neopicrorhiza can lead to pressure on the growing stock of Neopicrorhiza. The high levels of trade and unsustainable harvesting of long-lived species presents a particularly great challenge. Groundparts (rhizomes, roots, bulbs, or other storage organs) to premature harvesting. Sustainable harvesting of under-icantly smaller than those collected for health care, leading demand for raw materials, which hence could lead to rise. Ho lley and Cherla and Olsen which could foster demand for raw materials, which hence could lead to rise in harvest level of medicinal and aromatic plant species. So it has become important to understand what is driving the demand for Neopicrorhiza in Nepal. Understanding end-uses of plant species is essential for prediction of future demand for the species and planning for its harvesting sustainability. However, nothing is known about the industrial consumption and end-products of Neopicrorhiza. The aim of this paper is to contribute to the understanding of the end-uses of commercially important medicinal plants by exploring the industrial demand for rhizomes of Neopicrorhiza and its end-products, uses, and conservation in Nepal.

### 2. Materials and Methods

**Step 1. Telephone survey:** First of all, a list of herbal manufacturing industries in Nepal was compiled during September–November 2016 using a number of tools—web survey, online database analysis of Department of Plant Resources of Government of Nepal, database analysis of Department of Industry of Government of Nepal, analysis of directory of national census of manufacturing establishments (2069/2011), directories of herbal associations in Nepal, and stakeholder consultation. The output was a list of 246 herbal manufacturing industries.

Telephone interview adapted from Stanton and Futrell [35], Cooper and Schindler [36], and Boyd et al. [37] was conducted with representative of herbal manufacturing industries in November 2016 to find out the industries that process Neopicrorhiza. The main tool for the data collection with “telephone survey” was a structured questionnaire, finalized by expert panel and pretesting, and was composed of two major sections. Section 1 included introduction to the topic and researcher. Section 2 included categories of end-products the industry is currently producing, whether the industry processes Neopicrorhiza or not, name, location, and contact details of the industry.

**Step 2: Market survey:** The herbal products for Neopicrorhiza as an ingredient were randomly surveyed at 2313 herbal products at retailer shops in two big cities of Nepal, during November–December 2016 (see Table 1). We surveyed 1286 herbal products in Kathmandu city in 30 shops and 1027 herbal products at 8 retailer shops of Bharatpur city of Chitwan district of Nepal.

The main tool for the data collection in “market survey” was a structured questionnaire, finalized by expert panel and pretesting, and was composed of introduction, name of end-product containing Neopicrorhiza, form of product, manufacturers’ details, who mainly buys, basis of sale (prescription or without prescription), use of product, and retail price.

### Table 1: Details of herbal products surveyed for Neopicrorhiza as an ingredient in retailer shops (n=38).

| Herbal product categories* | Herbal products checked in Kathmandu | Herbal products checked in Bharatpur | Total herbal products checked |
|----------------------------|-------------------------------------|-------------------------------------|------------------------------|
| Ayurvedic medicine         | 405                                 | 725                                 | 1130                         |
| Herbal cosmetics           | 162                                 | 75                                  | 237                          |
| Incense                    | 67                                  | 26                                  | 93                           |
| Massage oil                | 67                                  | 59                                  | 126                          |
| Soap and shampoo           | 105                                 | 58                                  | 163                          |
| Unprocessed herb           | 84                                  | 0                                   | 84                           |
| Food additive              | 107                                 | 22                                  | 129                          |
| Vegetable oil              | 12                                  | 0                                   | 12                           |
| Tea                        | 277                                 | 62                                  | 339                          |
| **Total**                  | **1286**                            | **1027**                            | **2313**                     |

Source: Field survey (2015/16).

* Herbal product categories mentioned in Table 1 were adopted from Smith-Hallet al. [28].
Step 3. Industrial survey: A total of 23 industries processing Neopicrorhiza were identified in Nepal and visited during January–March 2017, and face-to-face interviews were conducted with representatives of these industries using structured questionnaire, finalized by expert panel and pretesting. The structured questionnaire was composed of three major sections. Section 1 included characteristics of respondents such as name, age, education, and number of years of experiences in processing of medicinal plants. Section 2 included characteristics of the industry such as name, year of establishment, and number of regular staff. Section 3 included name of end-product or end-product containing Neopicrorhiza, amount of its raw rhizomes needed, price paid for its raw rhizomes, and marketing channel of end-products. The information on end-products collected from market survey was also cross-checked and validated with this survey. Respondents were informed about the purpose of the research and their prior consent was obtained for interview. The research did not require approval of ethics from government of Nepal since it was a pure academic research mainly based on noninvasive and nondestructive methods (i.e., interviews).

The standard terminology for categories of diseases was adopted from Kunwar et al. [29]. Data analysis was performed using MS Excel and IBM Statistics SPSS 20. Descriptive statistics including frequency, percentage, mean, sum, and average were used. The information was presented in tables and explained.

3. Results and Discussion

3.1. Characteristics of Processing Industries of Neopicrorhiza in Nepal. Out of 246 herbal manufacturing industries, a total of 23 industries were found processing dry rhizomes of Neopicrorhiza in Nepal to manufacture its end-products. The number of Neopicrorhiza-processing industries in province three was the highest number of industries (n=13, 56.52%), while province four had the lowest number of those industries (n=1, 4.35%). The number of Neopicrorhiza-processing industries in provinces two and five was three (13.04%) and six (26.09%), respectively. There was not any Neopicrorhiza-processing industries in province number 1, Karnali province, and province number 7 (Figure 1). Out of the 23 Neopicrorhiza-processing industries recorded, 8 (34.78%) were
located in Kathmandu district, 6 (26.09%) in Rupandehi district, and two (8.69%) in each of Parsa, Lalitpur (8.69%), and Makawanpur districts, and one (4.35%) was located in each of Chitwan, Gorkha, and Dhading districts. Herbal processing and manufacturing are still in their infancy in Nepal, though herbal industries have a great scope of providing employment and developing new natural products that can fetch better prices in international markets [38]. Winrock International et al. [39] identified only 15 major companies involved in the processing of 205 non-timber forest products for making ayurvedic preparations and essential oils. Edwards [40] had projected that Nepal will find it difficult to compete with India’s highly complex, professionally managed herbal processing operations, which are on a considerably larger scale than may ever be developed in Nepal. We argue that there is a definite need for nation’s priority towards the expansion of ayurvedic medicine and herbal manufacturing industries and to create conducive environment for competitive functioning in Nepal.

Characteristics of the industries that involved processing rhizomes of Neopicrorhiza are summarized in Table 2. All industries were established between the periods of 1963 and 2013. Except Singha Darbar Vaidhya Khana, all were privately owned (n=22, 95.65%). Majority of the industries (n=20, 86.95%) were established after 1992. The industries had different number of regular staff ranging from 2 to 50. Most of the industries (n=11; 47.83%) had 2-11 regular staff. The scales of Neopicrorhiza-processing industries were of small (30.43%), medium (34.78%), and large (34.78%) as perceived and reported by the respondents themselves.

Our research shows that majority of the Neopicrorhiza-processing industries of Nepal emerged after 1992 AD, privately owned except one government owned Singha Darbar Vaidhya Khana, started during Rana regime for royal palace. The Industrial Enterprises Act of 1974 and its frequent amendments shifted the government’s emphasis on growth from the public to the private sector in Nepal [41]. Nepal entered into multiparty democratic system in 1990 after a nationwide successful revolution, which increased private sector development in the country, including industries. The Industrial Policy of Nepal came into effect only in 2010 that identified priority industries for Nepal, including forest based industries, and ayurvedic and homeopathic medicine manufacturing, as priority industries [42].

### Table 2: Characteristics of the Neopicrorhiza-processing industries (n=23).

| Variables                        | Categories | Frequency | Percentage |
|----------------------------------|------------|-----------|------------|
| Year of establishment of industry| 1963-1972  | 2         | 8.70%      |
|                                  | 1983-1992  | 1         | 4.35%      |
|                                  | 1993-2002  | 12        | 52.17%     |
|                                  | 2003-2013  | 8         | 34.78%     |
| Ownership of industry            | Privately owned | 22   | 95.65%     |
|                                  | State owned | 1        | 4.35%      |
| Number of full-time staff        | 2-11       | 11        | 47.83%     |
|                                  | 12-21      | 1         | 4.35%      |
|                                  | 22-31      | 3         | 13.04%     |
|                                  | 32-41      | 1         | 4.35%      |
|                                  | 42-51      | 7         | 30.43%     |
| Self-reported size of industry   | Large      | 8         | 34.78%     |
|                                  | Medium     | 8         | 34.78%     |
|                                  | Small      | 7         | 30.43%     |

3.2. Domestic Industrial Consumption (Volume and Value) of Neopicrorhiza in Nepal. The domestic industrial demand for Neopicrorhiza in Nepal was unknown for a long time. Industrial survey shows that the annual demand for dry rhizomes of Neopicrorhiza in Neopicrorhiza-processing industries (23) in Nepal was 6076 kg (6.076 tons). It is novel finding. The demand for its rhizomes ranged from 5 to 1000 kg/yr in different industries, with average of 264.17 kg/yr per industry. We compared our findings with that of India where the annual domestic consumption of Picrorhiza kurroa was 415 MT [43]. Rhizomes of Picrorhiza kurroa (found in western Himalaya) and Neopicrorhiza scrophulariiflora (found in eastern and central Himalaya) are morphologically similar and enter into trade without differentiation. The annual legal trade of Neopicrorhiza in Nepal in fiscal year 2015/016 was 61 tons [44] which is around ten times higher than the domestic industrial demand for this species (6 tons) in 2015/016 as found in this study. Olsen [34] indicated with no doubt that the annual harvested amounts far exceed the domestic demand for medicinal and aromatic plants in Nepal, and we also found similar results for Neopicrorhiza. Olsen [30] estimated 100–400 tons of annual Neopicrorhiza export from Nepal. Though the export figures vary, these data indicate higher levels of export of dry Neopicrorhiza rhizomes from Nepal than domestic consumption. Province-wise annual demand for Neopicrorhiza in industries of Nepal in 2015/016 is presented in Table 3, with highest demand in province three and lowest in province four. None of the herbal industries located in provinces 1, 6 (hereinafter referred as Karnali), and 7 were found using Neopicrorhiza as raw material.

The industries paid NRs 1150 to 1600 (USD 11.16–15.53) to purchase one kilogram of dry rhizomes of Neopicrorhiza in 2015/016, with average price of NRs 1410.87 (USD 13.69) per...
Table 3: Province-wise industrial demand of Neopicrorhiza in 2015/16.

| Districts    | Province 2 | Province 3 | Province 4 | Province 5 |
|--------------|------------|------------|------------|------------|
|              | Volume (tons) | Value (USD) | Volume (tons) | Value (USD) | Volume (tons) | Value (USD) | Volume (tons) | Value (USD) |
| Parsa        | 0.975       | 3375.72    | 1.721       | 19422.33    | 0.340        | 5048.54     | 2.090        | 24407.76    |
| Rautahat     | 0.200       | 2184.46    | 0.270       | 16669.90    | 0.050        | 792.23      | 0.030        | 1310.68     |
| Dhading      | 0.400       | 8388.35    | 0.400       | 8388.35     | 0.050        | 792.23      | 0.030        | 1310.68     |
| Chitwan      | 0.050       | 1310.68    | 0.050       | 792.23      | 0.050        | 792.23      | 0.030        | 1310.68     |
| Makawanpur   | 0.030       | 1310.68    | 0.030       | 1310.68     | 0.050        | 792.23      | 0.030        | 1310.68     |
| Total        | 1.175       | 5560.18    | 2.471       | 46583.49    | 0.340        | 5048.54     | 2.090        | 24407.76    |

Flat exchange rate: USD 1 = NRs 103; USD = United States Dollar, NRs = Nepalese Rupees.
kg. The latest royalty rate for one kilogram of Neopicrorhiza rhizomes is NRs 15 (USD 0.145) [45], indicating too much margin in trade to be paid by industries for Neopicrorhiza rhizomes. Olsen [30] reported that local traders paid NRs 87.9 (USD 0.853) in average to purchase one kilogram of dry rhizomes of Neopicrorhiza in 1997/98. Total annual value of dry rhizomes of Neopicrorhiza purchased for domestic industrial consumption in Nepal in 2015/016 was found NRs 8573236 (USD 83235.30) for 6.076 tons, which is much lesser than Olsen’s estimate of 1.5 million USD annual value of dry rhizomes of Neopicrorhiza from Nepal in 1997/98.

3.3. Availability of Neopicrorhiza for Industries and Its Substitutes. All the respondents reported that their industries had not faced any difficulty in obtaining quality rhizomes of Neopicrorhiza to fulfill their annual demand. In most of the cases (18, 78.26%), the traders themselves made contact with the industries and provided sample of dry rhizomes of Neopicrorhiza. Then the specialists in industries inspected the quality of the rhizomes and made decision whether to purchase or not. They did not depend on single trader for purchase of the dry rhizomes of Neopicrorhiza. Only 6 (21.74%) industries contacted traders from their list to purchase the dry rhizomes of Neopicrorhiza. In both cases, price of the rhizomes was also the major competitive factor while deciding the purchase from particular trader. All the Neopicrorhiza-processing industries did not use any substitute for Neopicrorhiza, indicating that their demand for its rhizomes were easily fulfilled, they did not require large quantities of Neopicrorhiza annually, and Neopicrorhiza was only used as an ingredient in end-products. Plants gathered in Nepal are used either for domestic consumption or for sale and manufacturing the end-products in Nepal, India, and third countries [46], as also found in this study. The lower levels of demand for Neopicrorhiza and government’s lifting of ban for collection and domestic trade might be the main reasons for ease in obtaining quality rhizomes of Neopicrorhiza by the industries.

Picrorhiza kurroa, of which India is a main consumer with annual domestic consumption of 415 MT [43], is open for trade in India. However, Olsen [30] argued that the majority of trade occurs in Neopicrorhiza from Nepal rather than Picrorhiza kurroa in India. Demand for Picrorhiza kurroa is continuously increasing in India; e.g., an annual growth rate of 12.9% was recorded for its demand for 220 tons in 2001-2002 and 317 tons during 2004-2005 [47]. China is apparently a major consumer of Neopicrorhiza [34]. This scenario indicates that there will definitely be pressure on supply status of Neopicrorhiza in future to industries due to this increasing regional demand. Multiple uses exert higher demand, leading to increased harvest, and such actions raise threats for medicinal plant species [18]. Regional level strategies will be necessary to keep balance between trade and conservation of Neopicrorhiza. Till date, population status of Neopicrorhiza in Nepal is unknown, without which any assumption of sustainable supply and trade of this species on long run might be misleading.

3.4. End-Products of Neopicrorhiza. We did not know before what end-products were manufactured from Neopicrorhiza. Market and industrial surveys revealed that Neopicrorhiza was used for manufacturing forty-five (45) herbal products in Nepal. A complete list of those end-products with description is presented in Table 4. All those end-products were ayurvedic medicines. Neopicrorhiza was used only as an ingredient in these products. The end use of Neopicrorhiza for production of only ayurvedic medicines can be explained by the presence of medicinally useful iridoid glycosides such as picroside I and II, and kutkoside in its rhizomes [48–52]. Out of 45 ayurvedic medicines containing Neopicrorhiza, 15 (33.33%) were classical (Classical Ayurvedic Medicine (CAM) is prepared by considering standard formulations from traditional Ayurvedic text books like Charaka Samhita, Sushruta Samhita, etc. Those formulations remain the same for specific medicines irrespective of the manufacturers.) and 30 (66.67%) were proprietary (Proprietary Ayurvedic Medicine (PAM) is prepared by industries using own formulations.) medicines. The forms of these medicines were different: 6 (13.33%) were in tablet form, 18 (40%) were in syrup form, 15 (33.33%) were in powder form, 5 (11.11%) were in gel form, and 1 (2.22%) was in capsule form.

The annual consumption of dry rhizomes of Neopicrorhiza for production of Hepadex (a liver tonic) was recorded as the highest (1000 kg). The annual consumption of dry rhizomes of Neopicrorhiza for production of particular end-product containing Neopicrorhiza ranged from 2 to 1000 kg. The average annual consumption of dry rhizomes of Neopicrorhiza for production of each product is 135.02 kg. The top three products, for production of which more than 500 kg dry rhizomes of Neopicrorhiza were purchased in a year, were Hepadex (a liver tonic), Rohitkyadi Churna (a liver medicine), and Hepagard DS (a liver tonic).

3.5. Production Rate of End-Products of Neopicrorhiza Adopted by Industries. The number of industries producing particular product and rank of production of each product is presented in Table 4. Rohitkyadi Churna, Neembadi Churna, and Arogyavardini Vati are the top three end-products containing Neopicrorhiza in terms of production by higher number of industries. Among these products, Rohitkyadi Churna enjoyed the highest production rate of 14.5%. Edwards [40] argued that the technology behind much processing of non-timber forest products was relatively straightforward and a wide range of ayurvedic preparations was already produced in Nepal, albeit on a small scale. Our findings on the data of annual demand for dry Neopicrorhiza rhizomes in domestic industries (6.076 tons) and their expense on these rhizomes (USD 83235.30) is consistent with Edwards’s general view of small scale production of ayurvedic medicines within Nepal.

Nepali and Indian manufacturers of Ayurvedic medicines available in the Nepalese markets are nearly equal in number, but the Indian products are dominating the Nepalese market [53]. It is interesting to note that, out of 45 Neopicrorhiza-containing ayurvedic medicines, only three of those medicines were produced by more than one industry (Table 4). It shows that industries of Nepal have not yet diversified the Neopicrorhiza-containing ayurvedic medicines in
| End product containing Neopicrorhiza | Form          | Number of processing industries | Consumption of dry Neopicrorhiza rhizomes (kg/yr) | Category of medicine | Disease category/use | Rank of production |
|-------------------------------------|---------------|---------------------------------|-----------------------------------------------|----------------------|----------------------|--------------------|
| Rohitkyadichurna Powder             | Powder        | 8                               | 619                                           | CAM                  | CVC (liver)          | 1                  |
| Neembadi churna Powder              | Powder        | 3                               | 259                                           | CAM                  | DER                  | 2                  |
| Arogyavardini vati Tablet           | Tablet        | 2                               | 250                                           | CAM                  | NVS                  | 3                  |
| Asthamarin                          | Tablet        | 1                               | 20                                            | PAM                  | RES                  | 4                  |
| Ayurved shakti churna Powder        | Powder        | 1                               | 2                                             | PAM                  | NVS                  | 5                  |
| Dardnasak oil Syrup                 | Syrup         | 1                               | 150                                           | PAM                  | MSK                  | 6                  |
| Diabeno Powder                      | Powder        | 1                               | 8                                             | PAM                  | CVC (blood)          | 7                  |
| Gastro Powder                       | Powder        | 1                               | 100                                           | PAM                  | DIG                  | 8                  |
| Glowderm Syrup                      | Syrup         | 1                               | 200                                           | PAM                  | CVC (blood)          | 9                  |
| Haridrakhanda Powder                | Powder        | 1                               | 7                                             | CAM                  | DER                  | 10                 |
| Hepadex Syrup                       | Syrup         | 1                               | 1000                                          | PAM                  | CVC (liver)          | 11                 |
| Hepagard DS Syrup                   | Syrup         | 1                               | 540                                           | PAM                  | CVC (liver)          | 12                 |
| Hepatop Syrup                       | Syrup         | 1                               | 50                                            | PAM                  | CVC (liver)          | 13                 |
| Heptogen capsule Capsule            | Capsule       | 1                               | 40                                            | PAM                  | CVC (liver)          | 14                 |
| Heptogen syrup Syrup                | Syrup         | 1                               | 90                                            | PAM                  | CVC (liver)          | 15                 |
| Jameda churna Powder                | Powder        | 1                               | 5                                             | CAM                  | CVC (blood)          | 16                 |
| Jatyadi ghrita Gel                  | Gel           | 1                               | 2                                             | PAM                  | DER                  | 17                 |
| Jeevan shakti prash Gel             | Gel           | 1                               | 30                                            | PAM                  | NVS                  | 18                 |
| Kasarin Syrup                       | Syrup         | 1                               | 70                                            | PAM                  | RES                  | 19                 |
| Kumaryasava Syrup                   | Syrup         | 1                               | 100                                           | CAM                  | GUS                  | 20                 |
| Kustadi danta manjan Gel            | Gel           | 1                               | 100                                           | PAM                  | OTH                  | 21                 |
| Lachhadi oil Syrup                  | Syrup         | 1                               | 20                                            | CAM                  | GUS                  | 22                 |
| Livergen Syrup                      | Syrup         | 1                               | 150                                           | PAM                  | CVC (liver)          | 23                 |
| Livherb Syrup                       | Syrup         | 1                               | 200                                           | PAM                  | CVC (liver)          | 24                 |
| Livorin Syrup                       | Syrup         | 1                               | 100                                           | PAM                  | CVC (liver)          | 25                 |
| Livosave Syrup                      | Syrup         | 1                               | 300                                           | PAM                  | CVC (liver)          | 26                 |
| Livotop Syrup                       | Syrup         | 1                               | 400                                           | PAM                  | CVC (liver)          | 27                 |
| Madhumeha churna Powder             | Powder        | 1                               | 100                                           | CAM                  | CVC (blood)          | 28                 |
| Maha sudarshan churna Powder        | Powder        | 1                               | 2                                             | CAM                  | CVC (blood)          | 29                 |
| Mahayogaraj guggul Tablet           | Tablet        | 1                               | 100                                           | CAM                  | MSK                  | 30                 |
| Mana Gel                            | Gel           | 1                               | 30                                            | PAM                  | NVS                  | 31                 |
| Megaferol Syrup                     | Gel           | 1                               | 300                                           | PAM                  | NVS                  | 32                 |
| MV Liv syrup                        | Syrup         | 1                               | 100                                           | PAM                  | CVC (liver)          | 33                 |
| MV Liv tablet                       | Tablet        | 1                               | 60                                            | PAM                  | CVC (liver)          | 34                 |
| Pilarin Tablet                      | Tablet        | 1                               | 90                                            | PAM                  | GUS                  | 35                 |
| Piles cure oil Syrup                | Syrup         | 1                               | 40                                            | PAM                  | GUS                  | 36                 |
| Pittghna churna Powder              | Powder        | 1                               | 60                                            | CAM                  | CVC (liver)          | 37                 |
| Sarivadlyasava Syrup                | Syrup         | 1                               | 90                                            | CAM                  | DER                  | 38                 |
| Shivastrini Powder                  | Powder        | 1                               | 5                                             | PAM                  | DIG                  | 39                 |
| Slim tea Powder                     | Powder        | 1                               | 50                                            | PAM                  | NVS                  | 40                 |
| Tonoliv Syrup                       | Syrup         | 1                               | 45                                            | PAM                  | CVC (liver)          | 41                 |
| Trinity Tablet                      | Tablet        | 1                               | 50                                            | PAM                  | CVC (liver)          | 42                 |
| Vata raktahar churna Powder         | Powder        | 1                               | 70                                            | CAM                  | CVC (blood)          | 43                 |
there production system. More processing of plants and the production of end-products in Nepal would greatly increase the value of the plants to the national economy [54]. Around only ten percent herbal industries out of 246 surveyed herbal industries in Nepal were found processing Neopicrorhiza rhizomes to produce the end-products. Hence, when issues emerge on resource depletion of Neopicrorhiza in Nepal, we here argue that it is due to export of Neopicrorhiza from Nepal than from domestic consumption, and regulatory measures should address the trade of Neopicrorhiza in terms of foreign export.

3.6. Uses of End-Products of Neopicrorhiza. We found that Neopicrorhiza is used to produce only Ayurvedic medicines. The major uses of the ayurvedic medicines containing Neopicrorhiza were recorded to treat a number of illness categories: cardiovascular, nervous, dermatological, musculoskeletal, genitourinal, respiratory, digestive, and others. The highest number of products (n=17, 37.78%) was reported to treat disease associated with liver. Previous studies had explored the use of the unprocessed rhizomes of Neopicrorhiza to treat various ailments such as liver disorders, fever, asthma, and jaundice and have pharmaceutical value for hepatoprotective, immunomodulator, and antiasthmatic activities [22, 55, 56] in Indian, Bhutanese, Tibetan, and Chinese traditional medicines. Mulliken and Crofton [57] argued that it is not inconceivable that in future the flow of Picrorhiza/Neopicrorhiza supplies could shift to the north (China), particularly if the efficacy of Picrorhiza kurroa in the treatment of liver disease is confirmed.

The information about major use (indication) of the ayurvedic medicine provided in the label of the medicines was cross-checked and validated during market survey and industrial survey and was found consistent with information of Table 5.

3.7. Legislation, Legal Trade, and Conservation of Neopicrorhiza in Nepal. Government of Nepal made a series of changes regarding the legal provisions for trade and conservation of the Neopicrorhiza (Table 6). In 2001, Government of Nepal banned for collection, utilization, sale, distribution, transport, and export of Neopicrorhiza [38]. In 2003, the government had revised the restriction based on Forest Act 1993 [59]. The government has set conditions for export of this species: (1) clear taxonomic identification of the Neopicrorhiza and its confirmation by the Department of Plant Resources are mandatory. (2) Department of Forest then permits the export after assessing the availability of the species.

Government of Nepal has changed the royalty rates of medicinal and aromatic plant products from time to time, including Neopicrorhiza [60]. In 2005, the royalty rate was NRs 10/kg [61]. The latest revision of the Forest Regulations was enforced in 2015 and it fixed a royalty rate of NRs 15/kg Neopicrorhiza [45]. In 2005, the government fixed NRs 500 as royalty for issuing CITES certificate for export of CITES listed species including Neopicrorhiza [61], which was increased to NRs 1000 in 2015 [45].

Despite the changes in legal provisions for trade and conservation of Neopicrorhiza from time to time, the trade of this species exists in Nepal. We analyzed the legal trade data of Neopicrorhiza of six fiscal years (2010–2016). The analysis of government data shows that 224.635 tons of Neopicrorhiza entered into legal trade during 2010–2016 (6 years period) in Nepal, with average of 37.44 tons/yr and the government collected a total of NRs 3360945 (USD 32630.53) from its royalty (Table 7). 33.652 tons of Neopicrorhiza was collected and traded from Humla district during the fiscal year 1999-2000 AD (2055-056 BS) [62]. The government’s official records show that the total volume of dry rhizomes of Neopicrorhiza exported to India, after receiving CITES certificate, from Nepal during 2015/016 period was around 28 tons [44]. Excessive and unregulated commercial harvest of medicinal plants (legally and illegally) has caused direct threat to the high value species [63]. Apart from unsustainable harvesting, other factors such as debris deposition at pasturale and cliff, deforestation, habitat encroachment, overgrazing, wildfires, shifting cultivation, and climate change contribute to species loss [4, 17, 18, 29, 64].

Looking at the province-wise trade, the legally traded volumes of Neopicrorhiza in provinces 3, Karnali, and 7 were 1.43, 15.91, 184.34, and 22.94 tons, respectively, with the highest in Karnali province (184.34 tons) and the lowest in province three (1.43 tons). In 2015/016, the legally traded volume of Neopicrorhiza in Nepal was about 61 tons [44]; our research showed that the domestic industrial consumption of this species was only around 6 tons in 2015/016. The remaining amount (61-28-6 = 27 tons) might be exported.
Table 5: Major use of ayurvedic medicines containing Neopicrorhiza as reported by industrial respondents and confirmed in market and industrial surveys.

| Ayurvedic medicines containing Neopicrorhiza | Use of ayurvedic medicines containing Neopicrorhiza to treat illness associated with | Number of ayurvedic medicines containing Neopicrorhiza | Percentage |
|---------------------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------|------------|
| Heptogen capsule, Pittgona churna, Rohitkyadi churna, Yakrit rasayan churna, Hepadex, Hepagard DS, Hepatop, Heptogen syrup, Livergen, Livherb, Livorin, Livosave, Livotop, MV Liv syrup, Tenoliv, MV Liv tablet, Trinity | CVC (liver) | 17 | 37.78 |
| Glowderm, Madhumeha churna, Vata raktahar churna, Diabeno, Jameda Churna, Maha sudarshan churna | CVC (blood) | 6 | 13.33 |
| Jeevan shakti prash, Mana, Megaferol, Ayurved shakti churna, Arogyavardini vati, Slim tea | NVS | 6 | 13.33 |
| Jatyadi ghrita, Haridrakhanda, Neembadi churna, Sarivadhasava | DER | 4 | 8.89 |
| Yuktadichurna, Dardnasak oil, Mahayogaraj guggul | MSK | 3 | 6.67 |
| Lachhadi oil, Pilarin, Kumaryasava, Piles cure oil | GUS | 4 | 8.89 |
| Kasarin, Asthamarin | RES | 2 | 4.44 |
| Gastro, Shivastrim | DIG | 2 | 4.44 |
| Kustadi danta manjan | OTH | 1 | 2.22 |

Source: Field survey (2015/16)
CVC: Cardiovascular, DER: Dermatological, DIG: Digestive, GUS: Genitourinal, MSK: Musculoskeletal, NVS: Nervous, OTH: Others, and RES: Respiratory (following [29]).

Table 6: Changes of legal provisions in trade and conservation of Neopicrorhiza by Government of Nepal.

| Government notice (source) | Enforced date | Remarks on Neopicrorhiza |
|----------------------------|---------------|--------------------------|
| Nepal Gazette, 2001        | 2058.09.16 (12.28.2001) | Ban of Neopicrorhiza for collection, use, sale, distribution, transport and export |
| Nepal Gazette, 2003        | 2060.08.01 (17.11.2003) | Lifted the ban of Neopicrorhiza for collection, utilization, sale, distribution, transport and export. Conditions for export requires clear taxonomic identification of the species and confirmation by the Department of Plant Resources. Department of Forest will permit the export after assessing the availability of the species. Otherwise, the export of this species is prohibited. |
| Nepal Gazette, 2005        | 2062.06.10 (11.25.2005) | Fixed the royalty rate NRs 10/kg for Neopicrorhiza. NRs 500 royalty for issuing CITES certificate for sale |
| Nepal Gazette, 2015        | 2072.07.17 (03.11.2015) | Revised royalty rate is NRs 15/kg. NRs 1000 royalty for issuing CITES certificate for export of CITES listed species, including Neopicrorhiza |

12.2 tons of Neopicrorhiza was traded annually from Gorkha district in 1994/95 [34]. Olsen [30] estimated 100–400 tons of annual Neopicrorhiza export from Nepal in 1998/99. These estimates seemed much higher when compared to legally traded volume of Neopicrorhiza in 2015/016 (i.e., 61 tons). This variation could hint for possibility of existence of illegal trade of Neopicrorhiza through Nepal. The main challenge will be how to regulate the export of this species outside the country while meeting the domestic demand and maintaining...
sustainable growing stock of this species. However, currently the domestic consumption of *Neopicrorhiza* cannot be entitled to be the root cause of resource depletion of this species.

4. Conclusions

This research presents a first exploration of domestic demand for alpine medicinal plant *Neopicrorhiza*, and its end-uses and manufacturers in Nepal. The annual domestic demand for dry rhizomes of *Neopicrorhiza* in Nepal was found around six tons in case year 2015/016 and this value is lesser than that of total traded volume and export. Forty-five end-products were found containing *Neopicrorhiza* as an ingredient and all those products were ayurvedic medicines. The major uses of the ayurvedic medicines containing *Neopicrorhiza* were to treat diseases associated with cardiovascular, nervous, dermatological, musculoskeletal, genitourinal, respiratory, and digestive systems. It can be concluded that the domestic consumption is not the major cause of resource depletion of *Neopicrorhiza* in Nepal. Regional consideration is necessary in setting priorities for conservation of *Neopicrorhiza* and sustainable trade in and from Nepal. In addition, growing stock of this species should be quantified throughout its habitat to set such priorities. Similar studies on end uses of *Neopicrorhiza* are recommended in countries (e.g., India) where this species is exported from Nepal.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon written request. The questionnaire used in industrial survey is available from the corresponding author upon written request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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| Fiscal year (BS) | Fiscal year (AD) | Quantity (Kg) | Revenue (NRs) | Revenue (USD) | Source (Provinces) |
|-----------------|-----------------|---------------|---------------|---------------|-------------------|
| 2067/68         | 2010/11         | 47218         | 710000        | 6893.301      | 4, 7, Karnali      |
| 2068/69         | 2011/12         | 21704         | 330810        | 3211.748      | 4, Karnali         |
| 2069/70         | 2012/13         | 10304         | 124215        | 1205.971      | 4, 7, Karnali      |
| 2070/71         | 2013/14         | 34019         | 489225        | 4749.757      | 4, Karnali         |
| 2071/72         | 2014/15         | 50432.9       | 788145        | 7651.893      | 4, 7, Karnali      |
| 2072/73         | 2015/16         | 60957.5       | 918540        | 8917.864      | 3, 4, Karnali      |
| **Total**       |                 | **224635.4**  | **3360945**   | **32630.53**  |                   |
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