Seabuckthorn (*Hippophae salicifolia*) Management for the Upliftment of Local Livelihood in Mustang District

Rajesh Rajchal

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Rajesh Rajchal

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Executive Summary

Seabuckthorn is a general term given to the deciduous shrub-tree *Hippophae Linn*. It is one of the most magical plant resources with higher value of economy and ecology. Its berry is very rich source of vitamins and it possesses a number of unique medicinal properties, which have a great potential to provide health foods and a variety of medicines. This plant is also equally important for firewood, fodder and serves as a soil binder species in cold deserts of Nepal Himalayas. Therefore, seabuckthorn should serve as a measure to safeguard medicinal and nutritional plants, to conserve biodiversity and environment and to generate sustainable income source for local people. However, this important bio-resource is largely understudied and underutilized in Nepal. Due to improper management, land degradation and lack of awareness, seabuckthorn is degrading from the higher Himalaya of Nepal. Nevertheless, Nepal is yet to harness the rich potential of seabuckthorn in producing foods, medicines, juices and other commercial products. Thus, this project has been started in 2006 in Mustang, Nepal to accomplish the two fold objectives. First was strictly a research about biophysical and socio-economic surveys to quantify the resource of seabuckthorn (*Hippophae salicifolia*), identify its contributions in livelihood and analyze current management systems so that appropriate management options could be recommended. Second was managerial aspect to build capacity of the local people to manage the seabuckthorn resource in a sustainable manner.

To estimate the biomass production of seabuckthorn i.e. wood, fruits and leaves, a total of 30 trees from 100 sample plots (10 m × 10 m) were harvested and the fresh weight of fruits and oven-dry weight of wood (stem + branch) and leaves were used to develop compartment biomass equations. The data were fed into the computer for identifying best model through the help of Statistical Package for Social Sciences (SPSS) programme. Among several models tested, the best-fit models were obtained as ln (Wood) = - 3.243 + 2.486 ln (Diameter), ln (Fruits) = -3.509 + 1.407 ln (Diameter) and ln (Leaves) = - 4.04 + 1.384 ln (Diameter) with adjusted coefficients of determination (adj. R^2) of 0.98, 0.64 and 0.84 for wood, fruits and leaves respectively ($p<0.001$). Using the biomass equations, an age-diameter model and the diameter distributions observed within the sample plots, the annual biomass production per hectare was estimated at 4200 kg for wood, 450 kg for fruits and 1800 kg for leaves.

For socio-economic data collection, discussions, key informant survey and household surveys were conducted. From the study, it has been found that seabuckthorn is a vital species for the rural poor of Mustang district that has contributed to both environment conservation and socio-economic well-being. As a multi-purpose species, this study reveals that the local people are using wood, fruits and leaves of seabuckthorn in a variety of ways as livelihood assets. The total income generated from seabuckthorn fruits in Mustang was estimated to be NRs. 585,000 (US 1 $ = NRs. 76). With regard to juice making, income from this species is harnessed more by the richer section of the society, especially tourist hoteliers, while the poor, who harvest the seabuckthorn fruits in the forests, are getting less. The major concerns are current inefficient harvesting practice and the low level of return from this species.

Thus, the local poor were needed to be empowered through awareness and capacity-building programme to manage the seabuckthorn forests in sustainable manner. For generating awareness, the utmost important part was to disseminate information about the importance of

seabuckthorn towards the local people. For this, brochure played an important role in sharing information about the species and provided a brief guideline to manage the forest. A community based seabuckthorn management committee was also formed and a participatory five-year operation plan was formed to manage the seabuckthorn in a sustainable manner. Training was also held in Mustang not only to share the information about the study but also to share the practical techniques of propagation, harvesting, extraction and utilization of seabuckthorn so that seabuckthorn forest could be managed in scientific, economic and sustainable manner. The training was held with the local people including women, poor, hotel owners, schoolteachers and school students.

The project has been successful and the objectives have been achieved because it has not only generate interest in and desire for community-based seabuckthorn management but also built capacity of the local people for the income generation from seabuckthorn and established the community based management system in Mustang district. Thus, the organized project supported from Rufford Maurice Laing Foundation, UK and Community Based Natural Forest and Tree Management in the Himalaya, Pokhara has hopefully added a cornerstone for building seabuckthorn industry in Nepal.

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Acronyms

ACAP	Annapurna Conservation Area Project
Adj. R^2	Adjusted coefficient of variation
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
CAI	Current Annual Increment
cal	Calorie
CF	Correction factor
cm	Centimeter
ComForM	Community Based Natural Forest and Tree Management in the Himalaya
DANIDA	Danish International Development Agency
DSCO	District Soil Conservation Office
F	Female
GIS	Geographical Information System
gm	Gram
GPS	Global Positioning System
HMG/N	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
INGO	International Non Governmental Organization
IoF	Institute of Forestry
kg	Kilogram
km	Kilometer
ln	Natural logarithm
M	Male
m	meter
m^2	Square meter
MAI	Mean Annual Increment
mm	Millimeter
n	number
NARMSAP	Natural Resource Management Sector Assistance Programme
NGO	Non Governmental Organization
NRs.	Nepalese Rupees
OP	Operation Plan
ppm	Parts per million
RADC	Rural Area Development Committee
RECAST	Research Centre for Applied Science and Technology
SEE	Standard error of estimates
SMC	Seabuckthorn Management Committee
SNV	The Netherlands Development Organization
Spp	Species
sq	Square
TISC	Tree Improvement and Silviculture Component
VDC	Village Development Committee
VIF	Variance Inflation Factor

CHAPTER 1: INTRODUCTION

1.1 Background

Seabuckthorn, found in the icy heights of the Himalaya, is a deciduous, thorny willow-like plant species native to Europe and Asia. It is a pioneer species and prefers to grow in low humid, alluvial gravel, wet landslips and riverside with brown rusty-scaly shoots (Lu, 1992). It is also a multipurpose fast growing species which is serving as a measure of biodiversity conservation, soil conservation, medicines, food, fodder and fuel wood. It has an extraordinary capacity to grow and survive under adverse conditions (-40 to 40º C) and has extensive subterranean rooting system with strong soil binding ability useful for soil stabilization, river bank control and water retention (TISC, 2001). Seabuckthorn berry is a very rich source of vitamins and is called treasure of bio-activity substance because of its over 190 bio-activity substances possessing unique medicinal properties (Maertz, 2006). For these reasons, it is also called a wonderful plant (Lu, 1992).

For the farmers living in the mountains, seabuckthorn offers the opportunity to maintain a sustainable livelihood – providing healthy foods, variety of medicines and protecting their land from soil erosion (Lu, 1992; Ansari, 2003). The use of seabuckthorn illustrates how low input costs and careful planning can lead to quite substantial benefits; a good example of mountain perspective-oriented sustainable development. It thus qualifies as a unique option for the simultaneous management of several problems emanating from the fragility, marginality, inaccessibility and diversity characterising mountain areas (Lu, 1992).

1.2 Rationale of the Project

Mountain areas show distinct signs of un-sustainability, decreasing soil fertility and a high degree of instability on one hand. On the other hand, the spectrum of poverty and a degraded resource base is the plight of mountain people, especially remote mountain people because their productivity is amongst the lowest and their quality of life amongst the poorest in the world (Jodha et al, 1992). The necessity of meeting increasing food, fuel wood, fodder and demands generated by market forces and public interventions are the most important factors, which accelerate the process of resource extraction both in forests and on farmlands (Jodha et al, 1992). Some 80% of the population of developing countries depends on non-timber forest products for their primary health, nutritional needs and income generation (FAO, 1995). The role and contribution of such plants are crucial and more so amongst the rural communities of developing countries. This is particularly true to a country like Nepal, where alternative economic opportunities are limited.

Seabuckthorn is of tremendous potential as it does and can play an important role in improving the living standards of mountain farmers and in maintaining ecological stability. This plant, important for its environmental value and use for various purposes, has become a concern of only a few people, industries and authorities, on one hand and the resource has not been exploited in its full extent on the other (Lu, 1990).

Though seabuckthorn is a multipurpose and vital species for mountain-rural poor, it is one of the least known, unexplored and underutilized plant species in Nepal Himalayas (TISC, 2001). The high mountain areas in Nepal, where seabuckthorn natural stands are gregariously found, face severe development problems (Hilbert, 1997) and the regeneration of the plant is poor (TISC, 2001) due to various factors, i.e. extreme cold, human interference, glacial flood

effect and high velocity wind. The seabuckthorn forest is also thought to be depleting due to fire and open access to grazing and cutting (Koirala, 2002).

Some initiatives in Mustang have been taken by various projects for the conservation and management of seabuckthorn and the livelihood upliftment from it. So far, studies regarding wood biomass production, fruit production, leaf biomass production and success performance of different organizations towards seabuckthorn management are lacking. Many studies (Hilbert, 1997; TISC, 2001; Koirala, 2002; Ansari, 2003; Baral, 2002) reveal that the local people are underutilizing the plant products, harvesting the fruits traditionally and over cutting woods leading towards the destruction of resource. The local people in Mustang district have so far reaped a small fraction of benefit from seabuckthorn despite the great potential of this species. One of the causes of these situations is the lack of adequate information of the local resources and their importance.

Therefore, a study is considered essential in the Mustang district in order to find the resource status and seek the role of a local resource in improving their lifestyle along with biodiversity conservation.

In Nepal, Seabuckthorn is among the leading species in the Himalaya, it has been used as wood, and there are ample opportunities to earn income from fruit and leaves as well. However, the biomass production of seabuckthorn has not been studied in Nepal so far and regression equations for fruit, leave and wood have not been developed. Thus, estimation of above ground biomass production is necessary, which is currently lacking for this species in Nepal.

Moreover, contribution of the species in the income generation of the local people has not yet been assessed. The present study has tried to explore the biomass production of seabuckthorn in Mustang and other biophysical and socio-economic information necessary to effectively manage the seabuckthorn forest that will be helpful for both the scientific and local community. The established regression equations and biomass tables will hopefully be helpful tools to manage seabuckthorn in other parts of the country as well.

Until and unless the local people are aware of the resource and able to generate income from it, research work alone would not contribute in the conservation and cannot uplift of the local people. Once the local people are aware of the resource and be capable to manage seabuckthorn for income generation, it can be hoped that a market for seabuckthorn products could be established in Nepal. Mustang itself is a popular site for national and international tourist because of heart touching landscapes, white snow capped peaks, attractive flora and fauna, deep gorge and eye catching panoramic view of Himalayan range. In this regard, it is important to remark that a market for health foods, seabuckthorn juice, jam and tea (from leaf and berry) could at least be developed locally and the seed and pulp could be sold at a reasonable price to international companies.

Thus, this project will provide necessary information for environment conservation and socio-economic well-being. It will also lift up the poor by increasing awareness level and capacity to manage their natural resources creating an independent resource mobilizer and thereby a model community. Moreover, the project outputs can be a cornerstone for formulating policies regarding seabuckthorn management.

1.3 Objectives

The general objective of this project was to manage seabuckthorn (*Hippophae salicifolia)* for the upliftment of local livelihood in Mustang district. Specifically, this project has four objectives.

1. To estimate the standing biomasses of wood, fruits and foliages of seabuckthorn (*Hippophae salicifolia*)
2. To identify the contributions of seabuckthorn to the livelihood of the local people in Mustang district, Nepal
3. To assess the current management systems regarding their techniques of propagation, harvesting, extraction and utilization of seabuckthorn to recommend the appropriate management systems
4. To form a seabuckthorn management committee (SMC), prepare five years' operation plan (OP), train the local people to the sustainable seabuckthorn management and disseminate the findings

CHAPTER 2: LITERATURE REVIEW

2.1 Name and Taxonomical Position

Seabuckthorn (also commonly written as sea buckthorn) is a general term used for the shrub-tree *Hippophae Linn.*, belonging to the family: Elaeagnaceae, Order: Elaeagnales, Super order: Celastraneae, Subclass: Rosidae, Class: Magnoliopsida and Division: Magnoliophyta. In ancient Greece, leaves of seabuckthorn were used as horse fodder for improving weight and shiny hair, thus gaining the seabuckthorn genus a Graeco-Latin name '*Hippophae*' (Hippo – Horse; Phaos – to shine) (Lu, 1992). It is called Oblepikha in Russia, Sanddorn in Germany, Argousier in France, Espino Armarillo in Spain, Finbar in Sweden, Tindved in Denmark, Rokitnik in Poland, Yashildoo Chatsargana in Mongolia and Sebu in China. It is a traditional component of herbal medicines in Tibetan where it is called Star-Bu or Dhar-bu. In Nepal, *H. tibetana* is known as Tserken kyun in Manang, Tora in Mustang, Torwa/Tirchuk in Dolpa and Bhuichuk in Humla and *H. salicifolia* is known as Tijicyun in Manang, Chichi in Thakali language in Mustang, Dalechuk in Dolpa, Tarachuk in Mugu, Jumla and Humla (TISC, 2001).

Classification within this genus is still controversial. A Swedish taxonomist Linnaeus for the first time recorded this plant distributed in Baltic Coast and established the genus *Hippophae* using *H. rhamnoides Linn* as a mode in the plant family Elaeagnaceae. After that, several other species were found and named by many taxonomists. In 1971, a Finish taxonomist Arne Rousi divided *Hippophae* into three species based on morphological traits: *H. rhamnoides Linn.*, *H. salicifolia D. Don* and *H. tibetana Schlecht*. *H. rhamnoides* was further divided into nine subspecies growing from Norway in Scandinavia to the Northwest of China: *carpatica, caucasica, fluviatilis, gyantsemis, mongolica, sinensis, turkestanica, yunnanensis* and *rhamnoides* (Rousi, 1971). In 1978, Chinese taxonomists, Liu Shengwu and He Tinnong, reported the fourth species – *H. neurocarpa* from the Qinghai Plateau, China. In 1988, Lian Yongshan upgraded *H. rhamnoides,* subsp. *gyantsensis* to an independent species. In 1995, Lian Yongshan again found one new species and two subspecies: *H. goniacarpa*, *H. goniacarpa subsp. litangensis* and *H. neurocarpa subsp. stellatopilosa* (Lu, 1999). Lian and Chen, in 2002 considered *H. litangensis* as an independent species. In 2003, Lian et al described a new subspecies *Hippophae rhamnoides wolongensis*. Therefore, based on these taxonomical studies, new taxonomic system should include seven species and eleven subspecies, which was also given in Species Records of *Hippophae*, Germplasm Resource Information Network (GRIN, 2007).

1) *H. goniocarpa*
2) *H. gyantsensis*
3) *H. litangensis*
4) *H. neurocarpa*
    i. *Subsp. neurocarpa*
    ii. *Subsp. stellatopilosa*
1) *H. salicifolia*
2) *H. tibetana*
3) *Hippophae rhamnoides*
    i. *Subsp. carpatica*
    ii. *Subsp. caucasica*
    iii. *Subsp. fluviatilis*
    iv. *Subsp. mongolica*

v. *Subsp. rhamnoides*
vi. *Subsp. sinensis*
vii. *Subsp. turkestanica*
viii. *Subsp. wolongensis*
ix. *Subsp. Yunnanensis*

The following table shows the distribution and the status of utilization of *Hippophae*:

Table 1: The Distribution and Status of Utilization of *Hippophae*

Taxons	The Areas of Distribution	The Status of Utilization
1. H. rhamnoides. Subsp. rhamnoides	Scandinavian countries, Baltic Sea countries, Germany, Belgium, Netherlands, Ireland, Poland, U.K., France, Russia	Many varieties are cultivated in some European countries and Canada
2. H. rham. Subsp. sinensis	The North, Northwest, Southwest of China	Wild resources are used for ecological restoration and berries are processed for products. Some new varieties are in tests.
3. H. rham. Subsp. yunnanensis	Sichuan, Yunnan, Tibet of China	Wild resources are used for ecological restoration only.
4. H. rham. Subsp. mongolica	Siberia of Russia, Mongolia, Xinjiang of China	More than 60 varieties are cultivated in Russia, Mongolia, many East European counties. Many West European counties, Canada and China introduced the varieties for test.
5. H. rham. Subsp. turkestanica	India, Pakistan, Afghanistan, Turkmenistan, Kyrgyzstan, Uzbekistan, Kazakhstan, Iran, Turkey, Xinjiang , Tibet of China	Wild resources are used for ecological restoration and berries are processed for various products on commercial level in India for the production of food, medicine and cosmetics.
6. H. rham. Subsp. fluviatilis	Around Alps Mountains: Germany, France, Switzerland, Austria, Czech, Slovakia, Italy,	Most of wild resources are protected as forest species. Some berries are collected for processing products
7. H. rham. Subsp. carpatica	The Carpathian Mountains, Transylvanian Alps, the valley and the mouths of the Danube and its tributary	Most of wild resources are protected as forest species. Some varieties are cultivated for processing products
8. H. rham. Subsp. caucasica	The Caucasus Mountains, Georgia, Azerbaijan, Armenia, Ukraine, Romania, Turkey, Bulgaria, Iran, Russia.	Most of wild resources are protected as forest species. Some selected varieties are cultivated for test.
9. H. goniocarpa	Sichuan, Qinghai of China	Most of wild resources are protected as forest species. Very few studies have been done.
10. H. goniocarpa Subsp. litangensis	Sichuan, Qinghai of China	Most of wild resources are protected as forest species. Very

		few studies have been done.
11. H. neurocarpa	Sichuan, Qinghai, Gansu of China	Most of wild resources are protected as forest species. Very few studies have been done.
12. H. neurocarpa Subsp. stellatopilosa	Sichuan, Qinghai, Tibet of China	Most of wild resources are protected as forest species. Very few studies have been done.
13. H. tibetana	Sichuan, Qinghai, Gansu, Tibet of China, Nepal, India	Most of wild resources are protected as grassland species. Very few studies have been done.
14. H. gyantsensis	Tibet of China	Most of wild resources are protected as forest species. Some berries are collected for producing Tibetan medicine.
15. H. salicifolia	The southern slope of Himalayan Mt. Tibet of China, Bhutan, Nepal, India	Most of wild resources are protected as forest species. Some berries are collected for producing products.

Source: pers. comm., Dr. Sanjai Kumar Dwivedi (Deputy Director, Defense Research and Development Organization, Delhi, India)

2.2 Plant Morphology

Genus *Hippophae* is a deciduous, usually spine scent, shrub-tree species. Depending upon the species and microclimate variation, morphological structure of seabuckthorn shows much variation. According to Lu (1992) and Ghaffar (1997), though seabuckthorn is a hydrophyte, yet it has developed some xerophytic features. *H. tibetana* is a dense much-branched shrublet with less than 90 cm tall (ANSAB, 2003b). *H. salicifolia* is willow-like small tree with height 6 to 10 m. However, tree of height 17 m tall was observed in Mustang. Its natural lifespan appears to be at least 60 to 70 years (Lu, 1992) and in Mustang, *H. salicifolia* with 64 years was observed to be fruiting with its heartwood of lower trunk slightly decayed. It is estimated that the age of seabuckthorn is more than 320 years and it is still bearing fruit (Lu, 1992).

Separate Male and Female Plants

Seabuckthorn is either male or female but the sex of the plant is not clear till the flowering stage. The males produce pollen, have flowers without petals and each flower contains four stamens. The females produce fruit and seed and have flowers, also without petals. Each flower contains one ovary and one ovule.

Flower

Seabuckthorn floral buds are mostly mixed with vegetative buds and are rarely pure. Floral buds appear mainly in the summer or the autumn and usually open in the following spring. Generally, the male floral bud consists of four to six flowers; the female floral bud consists of one flower and rarely two or three. The sex of the seabuckthorn cannot be judged until the first flower bud appears. In the precocious plants this may be in the third year, whereas in slow plants it may happen in the fifth or the sixth year (Lu, 1992). In Mustang, *H. salicifolia* was found to be fruiting at the age of five. The female flower depends almost entirely on the wind for pollination because both the male and the female flowers have no nectar and they rarely attract bees or other insects.

Fruit

Seabuckthorn bears a special fruit, which is different from other common fruits or berries. Morphologically it develops from an ovary and a calyx tube which is closely connected to the ovary. Actually the fruit is a combination of an unsplit, fleshy, expanded calyx tube and an ovary. In other words, the expanded, juicy calyx tube is the important part with economic value.

The time taken from flowering to fruit maturation is 12 to 15 weeks. Young fruits are hard and greenish, but turn soft and orange or orange-red as they mature. Unlike the majority of fruits that fall away from the maternal plant at maturity, the seabuckthorn berries remain on the branch for several months. This gives ample time to harvest them. In natural seabuckthorn forest, fruits can remain on the branches until the following spring. During this period, usually cold winter, the fruits gradually shrink but do not fall. Therefore they become the favourite food of animals, especially birds.

It has intense sour taste, sharp lemon flavor and contains 60 to 80% juice rich in sugar, organic acids, amino acids, tannins and vitamins and the fruit contains 3 to 5% of pulp oil and 8 to 18% of seed oil (Jasra, 1998). It cannot be eaten raw in any quantity, but makes an excellent juice, syrup or jam due to its strong acidity. It has also a unique aroma reminiscent of pineapple. Indeed, in Belarus the fruit juice is known as Russian pineapple.

The berries appear to be an unsurpassed natural source of vitamin A and several other carotenes, vitamin E and several other tocopherols and flavonoids. The vitamin C content of the juice ranges from 300 to 1600 mg per 100 gm of juice (Average 600 mg/100 gm juice) collected from Dolpa (Vaidya, 1999). Based on the studies, vitamin A is 3 times that of carrot and 20 times that of orange, vitamin C is 16 times that of Indian gooseberry and 30 times that of orange and similarly vitamin E is 6 times that of oil of the maize (Vaidya, 1999; ACAP, 2002). Biological studies suggest that the restorative action of the seabuckthorn oil may be in part due to its high content of essential fatty acids, carotenes, tocopherols and phytosterols, which are all important for the maintenance of a healthy skin. The essential fatty acids content in the seabuckthorn oil extract is 80 to 95 %. Among the carotenes found are alfa- and beta-carotenes, lycopene, cryptoxanthin, zeazanthin, taraxanthin and phytofluin. Tocopherols are mostly represented by vitamin E and gamma-tocopherol. Phytosterols of seabuckthorn include beta-sitosterol, beta-amirol and erithrodiol (Lu, 1992).

Table 2: Comparison of the Vitamin Contents of Seabuckthorn and Others (mg/100g)

Species	Vitamin A	Vitamin B1	Vitamin B2	Vitamin C	Vitamin K
Seabuckthorn	11.00	0.04	0.56	300-1600	100-200
Cilicrosa roxburghii	4.83	0.05	0.03	1000-3000	-
Kiwi Fruit	-	-	-	100-470	-
Hawthorn	0.82	0.02	0.05	100-150	-
Orange	0.55	0.08	0.03	50.0	-
Tomato	0.31	0.03	0.02	11.8	-
Carrot	4.00	0.02	0.05	8.0	-

Source: Lu, 1992

Seed

Seabuckthorn is a single seeded fruit. The seed is ovate-oblong with a length of 4 to 7 mm, a breadth of 2.5 to 3.5 mm and a thickness of 1.6 to 2.2 mm. The skin of the seed is greyish-brown or dark brown, leathery and lustrous. The seed is surrounded by a parchment-like ovarian wall. *H. salicifolia* seed is globose and seem fissured on one side with length 3 to 4.5 mm long, a breadth of 2.5 to 3 mm wide and 1.5 to 2 mm thick. It tastes sour. Seabuckthorn belongs to the group of thermophilic plants. Ideal temperature for germination of seed is 24º to 26º C (Ansari, 2003).

Photo 1: Seed of *H. salicifolia*

The seed represents only 10 % of the whole fruit. Major chemical composition of seabuckthorn seed are carbohydrate, lipid (fat) and protein. The seed contains 10 to 20 % of oil depending upon the species of the plant (Singh, 2001). *H. tibetana* contains 19.51 % oil which is highest among all the species of *Hippophae* (Lu, 1990). The seed oil contains 12 % to 20 % saturated fatty acids and 88.3 % to 89.1 % unsaturated fatty acids, particularly Linolenic acid (32.3 %), Linoleic acid (40.8 %) and Oleic acid (15%) (Schroelder and Yao, 1995). Other constituents of the seed oil included gamma and alpha Tocopherol (Li, 1999). Vitamins A, E and K present in seed oil are used in various fields of food, drug and cosmetics (Bernath and Foldesi, 1992; Vaidya, 1999). The chemical composition of the two species of seabuckthorn seed oil is given in Table 2.

Table 3: Chemical Composition of Seed on the Two Species of Seabuckthorn

Species	Oil Content %	Saturated fatty acid %	Unsaturated fatty acid %	Linoleic and Linolenic acid %
H. salicifolia	10.85	17.3	82.7	63
H. tibetana	19.51	11.7	88.2	64.9

Leaves

The leaves are small (usually 3 to 8 cm long and 0.4 to 1 cm wide), alternate, linear, lanceolate and covered on the backside with silvery stellate scales that reflect sunshine and reduce moisture loss (Lu, 1992). Leaves of seabuckthorn are used to manufacture various products because the leaves contain many nutrients and bioactive substances. Singh (1998) studied the fodder values of the foliage of seabuckthorn and found that the crude protein content in the leaves of *H. salicifolia* (21.6 %) was significantly ($p < 0.05$) higher than those of the *H. rhamnoides* biotypes. Fat content varies from 3.5 - 4.8 % in *H. rhamnoides* to 4.6 % in *H. salicifolia*. Natural detergent fiber value in the leaves of *H. salicifolia* was 32.7 %, which was significantly ($P< 0.05$) higher than the biotypes of *H. rhamnoides*. Ash content in *H. salicifolia* was 5.1 %. In general, the ash content increased in the leaves of both species (*H. rhamnoides and salicifolia*) in September. Total phenolics were 12.7 %, out of which 92 % were in the form of hydrolysable tannins (Table 2). The content of hydrolysable tannins was

Photo 2: Leaves of *H. salicifolia*

quite high, when compared to other locally available fodder species.

In the main seabuckthorn growing areas in northwest China, the average farmer can earn US$15 per year by selling seabuckthorn berries and leaves. In Burduliang village, Erduos city, Inner Mongolia, China, over a period of 20 days in 2002, each household increased its income by an average of US $ 144.6 by collecting leaves; some households earned up to US $ 253.

Wood/Stem

Depending upon the species, *Hippophae* is either shrub or tree. It is hard, woody, erect generally multiparous, cylindrical, perennial, spiny and waxy at young stage. The young stem is generally silvery white and smooth in nature covered with white scales and multicellular hairs, which disappear as stem matures. Secondary growth starts in the first year only, so it is very difficult to find out a stem without secondary growth (Dwivedi et al, 2006). Every branch of the stem terminates into a thorn.

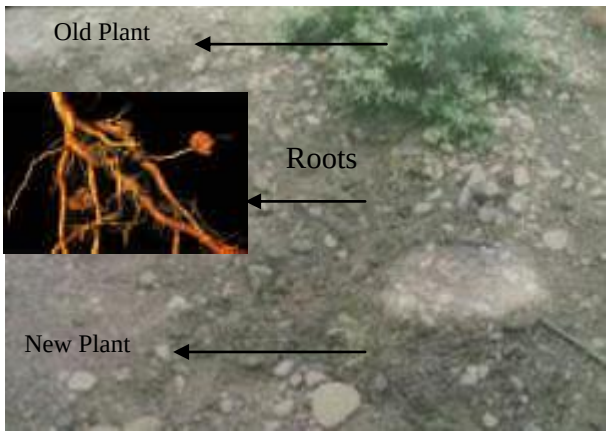
Thorn

Seabuckthorn, as the name indicates, is a highly thorny plant. Thorns are very hard and compound arising as appendages from stem. Each branch of the stem terminates into a thorn. On the stem, thorns are highly cutinaceous with a waxy outer surface covered with white and brown scales. The thorn intensity has been found varying from 1-5 thorns/cm^2 (Dwivedi et al, 2006).

Roots

Seabuckthorn has a mighty and well-developed tap root system, having primary, secondary and tertiary roots covered with root hairs, found more prominently in the apical portion (Dwivedi et al, 2006). Some 80% of its feeding roots are in the topsoil (0.2 to 0.8 m) helping to prevent erosion (Lu, 1992). Often young plants have twice the height of the plant and root widths three times wider than the crown of the plant above the ground. The seabuckthorn root system is so extensive that its roots can branch many times in a growing season and form a complex network of roots. Horizontal roots also have root turions (underground buds) which sprout and give rise to another plant. In this way, seabuckthorn bushes play an important role in protecting riverbanks, preventing floods and clogging mud, which would otherwise be washed away in floodwaters.

A symbiotic mycorrhizal fungus, which is identified as *Flank ia* (Actinomycetes), has been found on seabuckthorn roots. This symbiosis between the fungus and seabuckthorn results in root nodule formation that can fix the maximum amount of atmospheric nitrogen. It is estimated that the capacity of seabuckthorn roots to fix nitrogen is twice that of soybean (Lu, 1992). Besides fixing nitrogen, the perennial root nodule has the function of transforming difficult to dissolve organic and mineral matter into an absorbable state.



Shakya, 1992

Photo 3: Root System of 1-year-old *H. salicifolia*

2.3 Physical and Chemical Parameters

There are over 190 identified bioactive substances found in seabuckthorn and 60 unidentified (Maertz, 2006). The following table outlines the major constituents of seabuckthorn.

Table 4: Major Constituents of Seabuckthorn

Main Components	Contents
Fruits	
Colour	Yellow, orange to orange red
Shape	Round, oval, ovoid
Fruit weight	10-16 gm /100 berries;
Fruit juice extraction rate	64 – 75 %
Vitamin C in fruit juice	1161.1 – 1302.5 mg/100 gm
Vitamin A in fruit juice	0.75 mg/100 gm
Carotenoid in fruit juice	7.2 – 7.4 mg/100 gm
Soluble solids in fruit juice	15.92 – 17.66
Carotenoid in fruit residue oil	1570 mg/100 gm
Total flavone in fruit juice	365 – 885 mg/100 gm
Total flavone in fresh fruit	354 mg/100 gm
Protein in fruit	34.6 %
Total sugar	6.29 %
Organic acid	4.35 %
Sodium	41.28 mg/kg fruit
Potassium	1499.96 mg/kg fruit
Calcium	383 mg/kg fruit
Iron	11.68 mg/kg fruit
Magnesium	47.7 mg/kg fruit
Zinc	0.94 mg/kg fruit
Phosphorus	0.02 %
Seeds	
Seed	6.54 %
Oil in seed	10.37 – 19.51 %
Vitamin E in seed oil	101.5 – 277.6 mg/100 gm
Vitamin C in seed	149 mg/100 gm
Protein in seeds	21.66 %
Total sugar	5.84 %
Carotenoid in seed	3.3 mg/100 gm
Organic acid	0.94 %
Saturated fatty acid %	12 – 20 %
Unsaturated fatty acid %	88.3 – 89.1 %
Linolenic acid	32.3 %
Linoleic acid	40.8 %
Oleic acid	15%
Pulp	
Oil in fruit pulp	8.44 %
Carotenoid in fruit pulp oil	764 mg/100 gm

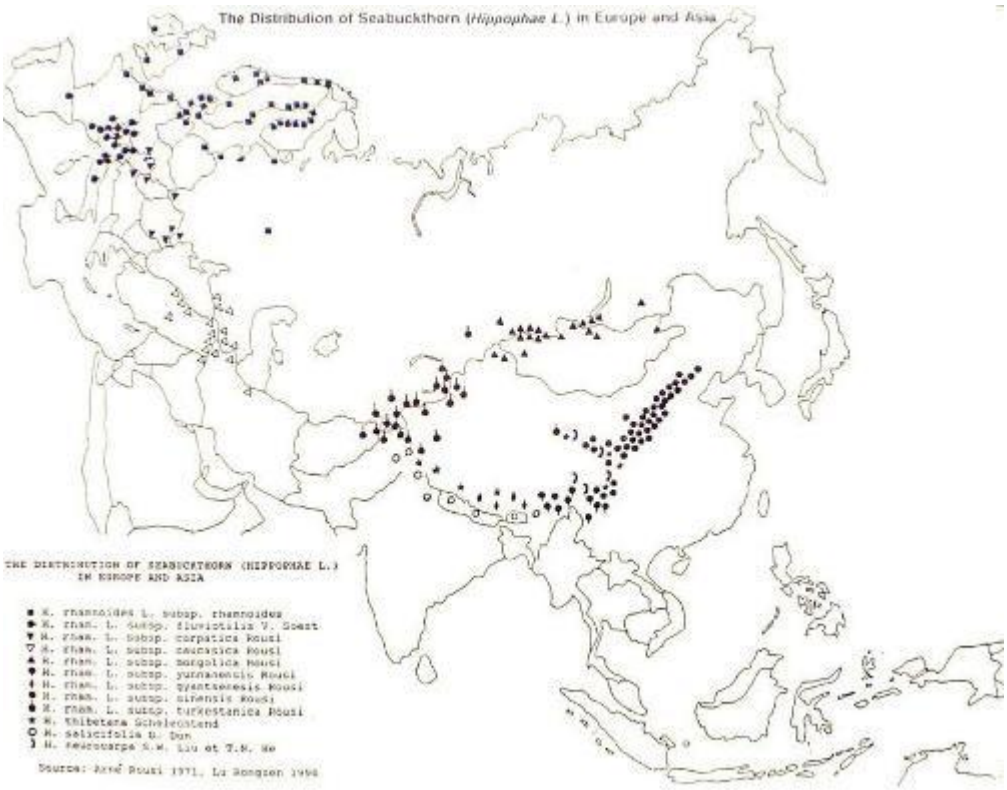
Vitamin E in fruit pulp oil	255 – 435 mg/100 gm
Vitamin C in pulp	780 mg/100 gm
Total sugar	7.17 %
Organic acid	4.4 %
Leaves	
Total flavone in leaves	876 mg / 100 gm
Protein in leaves	17.43 – 24.13 %

Sources: Schroelder and Yao, 1995, Li and McLoughlin, 1997, Vaidya, 1999, Lu, 2003, Dwivedi et al, 2006

2.4 Geographical Distribution

Many scholars and experts have certified that the genus *Hippophae* originated in the Himalayan mountain regions and then spread to southwest, northwest and northern China and eastern Inner Mongolia, as well as to the northwest regions of Eurasia where one route progressed west to reach the Alps via the Caspian and Black seas before finally arriving at the northwest shore of the Scandinavian peninsula and another route progressed northwest to reach northwestern Mongolia and southern Siberia in the Russian Federation via India, Nepal, Pakistan, Afghanistan, the Xinjiang Uygur Autonomous Region in China and several Central Asian countries of the former Soviet Union (Lu, 1990). In other words, seabuckthorn is a typical temperate plant of the Eurasian continent, widely distributed between 27º to 69º N latitude and 7º W to 122º E longitude (Rousi, 1971; Pan et al, 1989; Yu et al, 1989). It occurs at least in 38 countries including Afghanistan, Azerbaijan, Belarus, Bhutan, Britain, Bulgaria, Canada, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, India, Iran, Italy, Kyrgyzstan, Kazakhstan, Latvia, Lithuania, Moldova, Mongolia, Nepal, Netherlands, Hungary, Norway, Pakistan, Poland, Portugal, Romania, Russia, Slovakia, Sweden, Switzerland, Turkey, Ukraine and Uzbekistan.

The distribution throughout Europe and Asia shown in the map below shows that the species concentrates mostly in the Hindu-Kush Himalaya adjoining areas of China and parts of Europe and the former USSR as well as Scandinavian region. Considering the vertical range of elevations, seabuckthorn has a very strong ecological adaptability. It can grow from the seashore of the Baltic Sea in Europe to 5200 m above sea level in the Mount Everest in Asia. Generally, seabuckthorn grows in temperate regions of the world and it naturally occurs in the arid, semi-arid and high mountainous ecosystems. It grows well in the following climatic conditions: the monthly average temperature of the hottest month is 15 to 25°C and the maximum radiation on clear days in the vigorous growing season is 23500 to 26000 cal/cm²; annual rainfall ranges from 250 to 500 mm (Lu, 2002).



Source: Lu, 1992

Figure 1: The Distribution of Seabuckthorn (*Hippophae L.*) in Europe and Asia

Hippophae is the native plant of the mountain region of Nepal. The species is found within the altitudes ranging approximately from 2000m to 4500m (TISC, 2001) and has been reported from the mountain-areas of Baglung, Darchula, Dolakha, Dolpa, Humla, Jajarkot, Jumla, Kaski, Manang, Mugu, Mustang, Ramechhap, Rasuwa, Solukhumbu and Taplejung districts with altitudes ranging from 1950m at Dhunche of Rasuwa district to 4500m of Dolpa district. (Vaidya, 1999; Gupta et al, 2000; Baral, 2002).

As recorded by Gupta et al (2000), *H. salicifolia* has been distributed from 2000-3600 m from msl whereas *H. tibetana* is distributed from 3300 – 4500 m altitude in Nepal (Ansari, 2003).

Table 5: Distribution of *H. salicifolia* in Nepal

District	*H. Salicifolia* (m)	Geographical Locations
Manang	2100-3668	83º40'-84º34'
Mustang	2000-2880	83º30'-84º10'
Dolpa	2100-3850	82º24'-83º38'
Jumla	2100-3400	81º28'-82º18'
Mugu	2500-3400	81º44'-82º59'
Humla	2600-3500	81º12'-82º10'

Table 6: Identified Distribution of Seabuckthorn in Nepal

District	Distribution of *Hippophae*
Baglung	Dhorpatan
Darchula	Khandeshwori, Rapla, Sunsera, Ghusa, Pala Kutirau
Dolakha	Nagaon
Dolpa	Sahartara, Khanigaun, Chhala, Pahada, Dho, Laini, Chharka, Puwa, Dhargaunko Kot
Humla	Bargaun, Kalika, Mauberikhola, Melchham, Yari, Hilsa, Limi, Lare Khola
Jajarkot	Chuthari, Tumko
Jumla	Uthu, Tila valley, Depalgaun, Gariyangkot, Giri khola, Dillichaur, Chimara Lekh
Kaski	Bhainsi Kharka
Manang	Dharapani, Bagarchhap, Hke, Bhimat, Yak Kharka, Braga, Manang, Humden, Khbusar
Mugu	Karanbheg, Mugu Karnali Basin, Daura, Maha, Tirpa, Tharpa, Gambheg Talcha, Tobla, Pina
Mustang	Ghasa, Lete, Kalopani, Larjung, Jharkot, Manang, Charang, Ghemi Lomanthang, Chhoser, Chhanup Phuwa
Ramechhap	Species recorded from the district but sites not mentioned
Rasuwa	Dhunche, Langtang Valley
Sindhupalchowk	Species recorded from the district but sites not mentioned
Solukhumbu	Feriche
Taplejung	Ghunsa, Ramdang, Chha Khola, Nup, Yangma, Syabok, Nangama Khola, Lahpook, Khambachen, Nupchu Khola, Lonak, Teyang Khola, Jorkin

Source: Bhandari, 2003; Baral, 2002; TISC, 2001

2.5 Previous Studies and Activities

Two species viz. *H. salicifolia* D. Don and *H. tibetana Schlecht* have been reported in Nepal (Lu, 1990; Lu, 1992; Kharel, 1999; Vaidya, 1999). Another species *H. rhamnoides* was believed to exist in the country until 1994. National Herbarium, Department of Botany, Godawari, Lalitpur collected herbaria of seabuckthorn from Darchula, Jumla, Humla, Mugu, Jharkot, Baglung, Kaski, Rasuwa, Dolakha and Solukhumbu districts (Baral, 2002). Some specimens collected during 1963 were considered *H. rhamnoides* but there is no other single evidence showing that *H. rhamnoides* exists in Nepal and Hidelisa et al (1994) clarified the matter that only two species existed in Nepal (Hidelisa et al, 1994 cited in Vaidya, 1999).
Scientific exploration and study of seabuckthorn in Nepal dates back to 1990s when International Centre for Integrated Mountain Development (ICIMOD) started its activities concerned with these plants in the Hindu-Kush Himalaya region. In 1990 (April-May), ICIMOD trained three Nepalese members in China to study seabuckthorn resource, its development and possibilities of replicating successful experiences for initiating collaborative cooperation with Chinese authorities. CARE Nepal had also once worked in seabuckthorn in 1991. Both organizations – ICIMOD and CARE Nepal had been active to a certain degree with seabuckthorn in Mustang. CARE Nepal tried to grow plants in nurseries from seed at the mouth of the Lupra valley and Kali Gandaki valley along the Jomsom-Kagbeni road.

ICIMOD also established a nursery in Kalopani, Lete. However, both organizations had pulled out of the area in 1993 and the nurseries do not exist anymore (pers. comm. Mr. Lalit Ratna Shakya, Forestry Suppliers, Pokhara). Lu Rongsen also visited Nepal during ICIMOD working period and his reports published in 1990 and 1992 indicated the distribution of the two species in the laps of Himalaya in Nepal.

The HMG/Danida – Tree Improvement and Silvicultural Component/Natural Resources Management Sector Assistance Programme (TISC/NARMSAP), has started its activities in early 1996. The scope of the work was twofold. On the one hand, it sought to assist in conserving the existing seabuckthorn resources, especially in relation to the gene base. Besides, the programme had started activities in order to help inspiring and organizing the commercial exploration of the resource. This latter effort was done to increase the livelihood of the local population – the core of TISC's development objective. It also stemmed from the philosophy that a sustainable utilization of the species, appreciated by the local population, is in the long run the best guarantee for a preservation of the resource (use it or loose it) (Hilbert, 1997). It studied ecological distribution and state of Seabuckthorn, assisted training, extension and public awareness, raising seedlings in nurseries, plantation and marketing of seabuckthorn to protect environment and develop economy of high altitudes.

Rural Area Development Committee (RADC), Research Center for Applied Science and Technology (RECAST) and District Development Committees (DDCs) have worked in extension and awareness activities for manufacturing products like juice, squash, jam and powder. Asia Network for Sustainable Agriculture and Bioresources (ANSAB) has been working in non-timber forest products along with seabuckthorn management and utilization and has published a promotional material on seabuckthorn. Annapurna Conservation Area Project (ACAP) has also been conducting awareness programmes and training on juice making and has published a seabuckthorn booklet.

HimalAsia started working in 2003 in cooperation with RECAST. It established three seabuckthorn nurseries in 2003, in cooperation with two community-based cooperatives and a local Amchi family. The project aimed to establish additional nurseries and seabuckthorn forests in different communities of Upper and Southern Mustang in Nepal. HimalAsia began to collaborate with the Sushma-Koirala Hospital in the Kathmandu Valley in 2005 by starting a research-programme with extracted seabuckthorn seed-oil to treat patients with burns and scars more efficiently and at lower cost. This project is going on and it is planning to establish more nurseries in Mustang, train the local people, buy the seeds and establish seed pressing machine to extract seed oil.

Earlier studies were concentrated in the western and mid-western region of Nepal, especially in Jumla, Humla, Mugu, Manang and Mustang districts in Trans-Himalayan region. Later, they were extended to Rasuwa, Dolakha and Solukhumbu in the east. Though concentration has been on seabuckthorn for more than a decade, detailed information for individual species is still lacking. The following table lists the works, studies and activities of different organizations, researchers and conservationists.

Table 7: Work, Studies and Activities Concentrated in the Seabuckthorn in Nepal

SN	Works, Studies and Activities	References
1.	Seabuckthorn: a multipurpose plant species for fragile mountains	Lu, 1992
2.	Occurrence, use and potential in Mustang District	Thompson et al 1996
3.	Seabuckthorn – Chinese experiences	Hilbert, 1997
4.	Physio-chemical analysis of fruits	Vaidya, 1999
5.	Ethnobotanical uses in Rasuwa, Mustang and Dolpa	Banjade, 1999
6.	Monitoring report on the activities of the seabuckthorn programme	Pokharel and Thiels, 1999
7.	Ecological assessment in Jumla and Dolpa districts	Gupta et al 2000
8.	Market survey of juice	TISC, 2000
9.	Workshop on ecology and distribution of seabuckthorn	TISC, 2001
10.	Propagation techniques	Subedi and Adhikari, 2001
11.	Medicinal Plants of Dolpo: Amchi's Knowledge and conservation	Lama et al 2001 in Baral, 2002
12.	Ecology and distribution of seabuckthorn in Mustang and Manang district	Gurung, 2001 in Baral, 2002
13.	Monitoring and evaluation of seabuckthorn fruit processing training in Manang	Adhikari, 2001
14.	Germination and seedling growth of seabuckthorn	Pyakurel, 2001
15.	Assessment of seabuckthorn development activities in Mustang district	Koirala, 2002
16.	Present status and opportunity of seabuckthorn	Baral, 2002
17.	Multipurpose Plant: Seabuckthorn	ACAP, 2002
18.	Seabuckthorn (Medicinal Plant Extension Series-5)	ANSAB, 2003b
19.	Seabuckthorn: a potential resource for biodiversity conservation in Nepal Himalayas	Ansari, 2003
20.	Seabuckthorn: a multipurpose plant for mountain people	Lu, 2003
21.	Herbarium collection and recording from 12 districts (Darchula, Humla, Mugu, Jumla, Jagarkot, Baglung, Mustang, Kaski, Manang, Rasuwa, Ramechhap and Solukhumbu)	National Herbarium Department
22.	Establishment of demonstration plots	ACAP, TISC
23.	Awareness raising, juice making training and processing	TISC, ACAP, RADC (Rasuwa), ANSAB

Source: Baral, 2002, Bhandari, 2003 and other literatures as cited in the text

2.6 Uses

Due to its immense use, it has aptly been called a wonderful plant, magic plant, super food, functional food and bank of vitamins. The use of seabuckthorn has a very long history, especially on the Tibetan Plateau. In the 8^{th} century, the medical use of seabuckthorn was mentioned in the Tibetan medical classic the rGyud bzi – the four parts of pharmacopoeia, written by Yu Tuo Yuan Dan Kong Bu and completed during the Chinese Tang Dynasty (618 to 907 AD). The rGyud bzi gives 84 different set prescriptions for the preparation of

seabuckthorn medicines. During the 13th century, the rGyud bzi was disseminated through Mongolia and seabuckthorn began to be used in traditional Mongolian medicines. In the Qing Dynasty (1821 to 1850), the Mongolian scholar, Losan Quepei, wrote a 120-chapter book – A Selection of Traditional Mongolian Medicine, 13 chapters of which document the properties of seabuckthorn and its effects in clinical cases. There are 37 different set preparations based on seabuckthorn.

However, it is only in recent decades that people have had a better understanding of seabuckthorn. The scholars who are engaged in scientific research on seabuckthorn in various countries have revealed its importance to human beings by carrying out a large number of scientific experiments. Russian and Chinese scientists, in particular, have made a considerable contribution to the research and development of seabuckthorn. Inspired by ancient Chinese literature, scientists in the former Soviet Union carried out research on seabuckthorn from the 1930s onwards and developed many new varieties. They developed various medicinal preparations, including health products for astronauts and pilots. Since 1985, the Chinese Government has developed seabuckthorn production nationwide in a systematic manner and the total area of seabuckthorn in China is now 1 to 2 million ha, corresponding to about 40% of the total area (Hilbert, 1997). China develops over 200 types of industrial products with the annual turnover of approximately 37.5 million US $ (Bhatt et al, 1993). Encouraged by success stories from China, many South Asian countries, such as Nepal, Bhutan, India and Pakistan started their own seabuckthorn development programmes in the 1990s.

With the gradually worsening quality of the environment and the overriding poverty in many countries today, seabuckthorn has attracted a great deal of attention from scientists and engineers all over the world because of its concentrated ecological and socio-economical benefits.

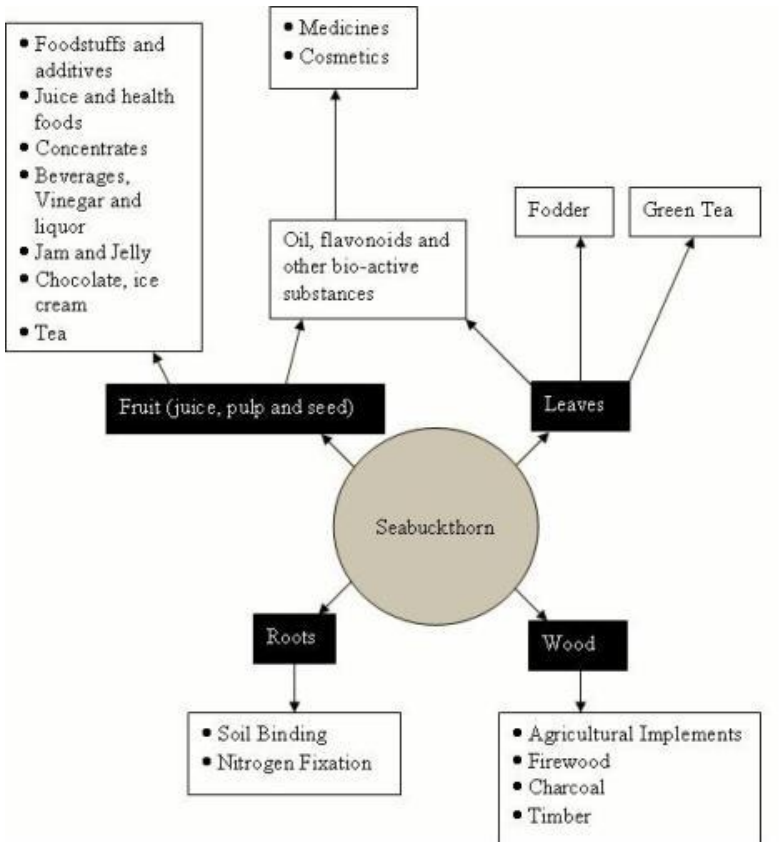


Figure 2: Use of Seabuckthorn Parts in Various Purposes

2.6.1 Ecological Uses

Due to its unique biological features, seabuckthorn has been used in various ways to maintain the ecology of the Himalaya.

Unique Biological Features of Seabuckthorn

- Strong root systems and the ability to propagating itself: A five-year plant has a taproot of 3 m and horizontal roots of 6 to 10 m (Lu, 1992). A three-year old plant can produce 10 to 20 new generation plants by root turions (Jasra, 1998).
- Nitrogen-fixing capacity: An 8 to 10-year old seabuckthorn forest can fix 180 kg of nitrogen/ha/year (Lu, 1992).
- Biomass production ability: A 6-year old seabuckthorn plantation can produce 18 tons of fuel wood. The heat value of seabuckthorn wood is 4785.5 cal/kg (Lu, 1992). One ton of seabuckthorn wood is equal to 0.68 ton of standard coal.
- Water and soil loss controlling ability: Compared to wasteland, 7-year old seabuckthorn forest can reduce 99% of runoff and 96% of soil loss.
- Soil fertility improving ability: Seabuckthorn is pioneer plant within a fragile and marginal context and forest can greatly increase the contents of nitrogen, phosphorus and organic matter in the soil.
- Ability to promote the growth of tree species: When pine and poplar were planted with seabuckthorn in mixed forests, it was found that seabuckthorn greatly promoted better growth of pine and poplar (Jasra, 1998).

Here discussion has been made on various topics mainly based on the discussion made by Small et al, 2000.

As Soil Enhancer: Seabuckthorn is useful in reclaiming and conserving soil, especially on fragile slopes, due to its extensive root system. Because it is resistant to drought and tolerates soil salinity and low temperatures, it is suitable for many situations that are simply too demanding for most plants. Riverbanks, lakeshores, steep slopes and other susceptible terrain can benefit from the establishment of seabuckthorn. Windbreaks made up of seabuckthorn are effective at preventing wind erosion in open areas. The spiny shrub has even proven to be beneficial in acting as a barrier to pedestrian traffic, preventing sensitive vegetation from being trampled. Not only does seabuckthorn prevent the loss of soil, but it also improves degraded soils due to its nitrogen-fixing capabilities. Thus, there is reduced need to add fertilizers, which results in less input costs as well as fewer ecological problems.

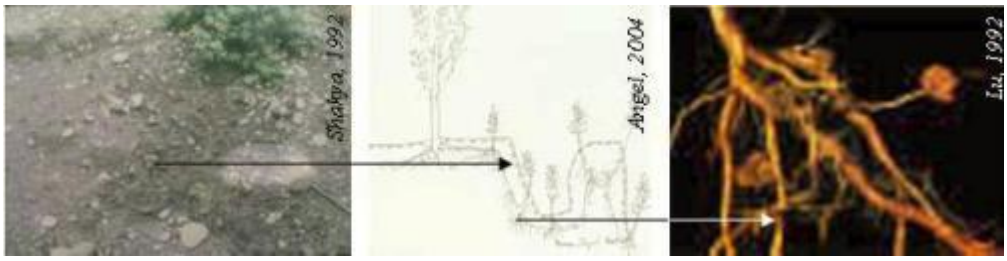


Photo 5: Sub-terrain Rooting System of Seabuckthorn

As Pollution Reducer: Seabuckthorn is useful in lessening pollution resulting from erosion of contaminated mine waste, since it can be used to re-vegetate a variety of mine spoils. Because seabuckthorn is naturally resistant to pests, it has limited need of pesticides that are

potentially damaging to the environment. In parts of North America, it has been planted as cover along highways where de-icing salt prevents growth of many other woody plants. Thus, seabuckthorn helps to prevent erosion and release of pollutants from roadsides.

Photo 4: Seabuckthorn Regeneration over Landslides Area

As a Landscape Management Tool: One of the most promising tools to control land degradation is re-vegetation and seabuckthorn is one of the species successfully used on a large scale. It can help to control desertification, conserve land, water resources, and integrate economic exploitation with ecological rehabilitation. A living windbreak is a linear arrangement of plants, primarily trees and shrubs, established to reduce harmful effects of strong winds, such as soil erosion. It also helps protect crops, manage snow accumulation and create wildlife habitat. Plants that serve as windbreaks must be resistant to the drying effects and physical injuries caused by wind and seabuckthorn is well suited to this task.

As Maintaining Ecological Balance: It has been observed that a number of wildlife species depend on seabuckthorn stems, leaves, flowers, roots, fruit and seed. In the Loess Plateau of China, 51 bird species are entirely dependent and 80 bird species are relatively dependent on seabuckthorn for their food (ICIMOD, 2006). In winter, the importance of seabuckthorn increases as it is almost the only food available for birds. Seabuckthorn provides long-term benefits in terms of maintaining the ecological equilibrium and improving the environment.

Photo 6: Bird Nest in Seabuckthorn tree

2.6.2 Socio-economic Uses

As food industry: At present, many factories are producing seabuckthorn food, beverages and other products such as jam, jelly, juices and syrup. Along with traditional foods, some new ones, such as condensed juice, mixed juice, seabuckthorn carrot jam, candied fruit, seabuckthorn cheese, seabuckthorn butter, tea and health protection drinks are also being produced.

As fodder and food for animals and birds: The leaves and tender branches of seabuckthorn contain many nutrients and bioactive substances and these are very good fodder for sheep, goats and cattle. Leaves and fruit residue used as supplementary food can promote growth of animals and poultry. There are no toxic or carcinogenic side effects.

As a food additive: The pigments of seabuckthorn are widely used as a food additive. Seabuckthorn yellow consists of flavours, carotene and vitamin E. Its physio-chemical properties, such as appearance, solubility, color value, heat and light stability and effect of pH and metabolic ions make it a very useful food additive.

As fuel wood: In the Hindu-Kush Himalaya region, plant biomass is the most important source of energy. Seabuckthorn has proved to be a popular green energy plant because of its quality biomass. It is a good source of firewood.

As medicine: About ten varieties of seabuckthorn drugs have been developed and are available in the form of liquid, powder, plaster, paste, pills, liniments, aerosols, etc. These drugs are used for treating burns, gastric ulcers, chilblains, scales, oral mucosities, rectal mucosities, cervical erosion, radiation damage and skin ulcers caused by malnutrition and other damage relating to the skin. The most important pharmacological function of seabuckthorn oil is in diminishing inflammation, disinfecting bacteria, relieving pain and promoting regeneration of tissue.

Seabuckthorn has been shown to have a potent antioxidant activity, mainly attributed to its flavonoids and vitamin C content (Rosch, 2004). Both the flavonoids and the oils from seabuckthorn have several potential applications (Li and Schroeder, 1996). Many health claims are associated with seabuckthorn. The berries seem to have preventive effects against, cardiovascular diseases, mucosa injuries, skin problems, cancer and immune system support. External uses of seabuckthorn include treating a wide variety of skin damage, including burns, bedsores, eczema and radiation injury. This section discusses the antioxitant, cancer, cardovascular, immunie system, skin and other treatments of seabuckthorn including cosmetic uses, which have mainly been taken from Anon, 2005.

Antioxidant: Seabuckthorn berries have high contents of natural, potent antioxidants including Ascorbic Acid (Vitamin C), Tocopherols (Vitamin E), Carotenoids, Flavonoids - isorhamnetin, quercein and kaempferol, Catechins, Proanthocyanidins and Chlorogenic Acids

Cancer: It has been estimated that 30-40 % of all cancers can be prevented by lifestyle and dietary measures alone (WCRF/AICR, 1997). Protective elements in a cancer prevention diet include selenium, folic acid, vitamin B-12, vitamin D, chlorophyll and antioxidants, such as the carotenoids (carotene, carotene, lycopene, lutein, cryptoxanthin) (Steinmetz, 1996). Drug metabolizing, detoxifying and antioxidant enzymes are important cellular defenses against carcinogenesis. Based on research findings, it is thought that due to the antioxidant proprieties of seabuckthorn, it may have chemopreventive and antitumorigenic efficacy. Research has also shown that the constituents present in the whole extract manifest radioprotection by several mechanisms, like free-radical scavenging, metal chelation, chromatin compaction and hypoxia induction (Goel et al, 2003; Kumar et al, 2002). It has also been reported to provide protection to whole body, various tissues, cells and cell organelles against lethal irradiation.

Cardiovascular: There is increasing evidence to support the hypothesis that free radical-mediated oxidative processes contribute to atherogenesis (Eccleston et al, 2002; Ivanov and Nikitina, 1973). Research (in vitro) has shown that antioxidant nutrients have the ability to affect cell response and gene expression. Seabuckthorn is a rich source of antioxidants both aqueous and lipophilic, as well as polyunsaturated fatty acids, which may provide cardiovascular benefits.

Immune System: Seabuckthorn contains several nutrients that may help to strengthen the immune system, by building immunity at the cellular level.

Skin Health: Seabuckthorn seed oil contains a high content of two essential fatty acids, linoleic acid and -linolenic acid, which are precursors of other polyunsaturated fatty acids such as arachidonic and eicosapentaenoic acids. The oil from the pulp/peel of seabuckthorn berries is rich in palmitoleic acid and oleic acid helpful for treating burns and healing wounds. This fatty acid can also nourish the skin when taken orally in adequate quantities of seabuckthorn or its oil are consumed; this is a useful method for treating systemic skin diseases, such as atopic dermatitis. Seabuckthorn oil is already widely used alone or in various preparations topically applied for burns, scalds, ulcerations and infections.

Cosmetics: Many kinds of seabuckthorn cosmetics have been developed and tested in hospitals. It is proved that seabuckthorn beauty cream has positive therapeutic effects on melanosis, skin wrinkles, keratoderma, keratosis, senile plaque, xeroderma, facial acne, recurrent dermatitis, chemical corrosion and inchthyosis, as well as freckles. Other seabuckthorn extracts can improve metabolism and retard skin maturation.

Others: Seabuckthorn has been shown to have additional health benefits for the liver, including treating liver fibrosis and providing a protective effect for liver injury. Research has shown benefits for gastric ulcer, treatment of chronic hepatitis, healthy mucus membranes and neurotoxicity protection.

CHAPTER 3: METHODOLOGY

3.1 Project Area

3.1.1 Mustang District

Mustang, one of the most important districts of Annapurna Conservation Area (ACA), which covers most of the north slope of Annapurna Himal complex and the Kali Gandaki valley, lies in the Dhaulagiri zone of western development region, which is surrounded by Tibet in the North, Manang in East, Myagdi in South and Dolpa in the West. It is semi-desert, Trans-Himalayan, rain shadow area. By covering an area of 3573 sq km (HMG/N, 2001), it extends from 28º24′ to 29º20′ N latitude and 83º30′ to 84º10′ E longitude. The altitudinal range varies from 1372 to 8167 m representing sub-tropical, temperate and alpine types of climate. Mount Dhaulagiri (8167 m) and Nilgiri (7060 m) are the major Himalayan peaks and Damodar Kunda and Muktinath are the places of holistic importance. Major River of Mustang is Kali Gandaki, major ethnic groups are Thakali and Bhotia and minor ethnic groups are Kami, Damai and Sarki. Major economic activities of the people are agriculture, animal husbandry, tourism, trade and labour.

Vegetation

Out of 3573 sq km, the forest coverage is only 145.85 sq km, which is only 4.05 %, and total grassland covers 1447.03 sq km (40.49 %) and total shrub covers 44.16 sq km (1.23 %) (DDC, 2003). Mustang district comprises 63 tree species and *Pinus roxburghii, Juglans, Aesulus spp, Acer spp, P. wallichiana, Cupressus spp*, *Taxus wallichiana*, *Rhododendron spp, Betula utilis* and seabuckthorn are the main species. Based on the climate and vegetation coverage, the area can be divided into five forest types (DDC, 2003).

1. Sub-tropical forest
2. Lower temperate forest
3. Upper temperate forest
4. Sub-alpine forest
5. Alpine forest

Wild Animals

Common leopard, snow leopard, Himalayan black beer, musk deer, jharal, ghoral, thar, barding deer, leopard cat, wild cat, jackal, porcupine, red panda, blue sheep are commonly found and important wild animals. Himalayan monal, satyr tragopan, kalij, cheer pheasant, koklass, red jungle fowl, dove, sparrow, pigeon, eagle, raven, yellow-billed chough, red billed chough, blue whistling thrush, demoiselle crane and vultures are the commonly found birds in Mustang.

Mustang district covers 16 VDCs that are divided into upper and lower Mustang. Upper Mustang consists of Chhoser, Chhunup, Lomanthang, Tcharang, Chhukang, Ghami and Surkhang VDCs, which cover much less forest areas. Lower Mustang consists Dzone, Kagbeni, Muktinath, Jomsom, Kowang, Tukuche, Lete and Kunjo VDCs. Total population of the district is 14981 (HMG/N, 2001).

As the population is concentrated in the lower parts of the district along the Kali Gandaki River, most of the seabuckthorn development activities are centered on these areas. Patches of natural seabuckthorn forest are found in those areas along the Kali Gandaki River. *H. salicifolia* in Mustang is found only in three VDCs i.e. Lete, Kunjo and Kowang VDCs. Out of these, most of the seabuckthorn forest is found in Lete and Kunjo VDCs.

3.1.2 Lete, Kunjo and Kowang VDCs

Lete VDC is situated in the southern part of the Mustang district and it is known as an entry point of the Mustang district. It starts from the Tallo Ghasa (approximately 2000 m), Kalopani to Kokhethati. It touches Kunjo VDC in the east, Myagdi district and Kowang VDC in the west, Kunjo VDC in the north and Myagdi district in the south. Total area of Lete VDC is 53 sq km and there are 174 households and 3 forest user groups. All together, there are 18 hotels in Lete VDC, which are listed in appendix 1. As the area lies in Annapurna trekking route, Lete is popular for tourist. For arriving Kunjo, there is a road to from Lete and this VDC is surrounded by Myagdi district in the east, Lete and Kowang VDCs in the west, Lete VDC and Myagdi district in the north and Tukuche and Kowang VDCs in the south. Total area of Kunjo VDC is 76 sq km and there are 162 households and 2 forest user groups. The Lete VDC is fallowed by Kowang VDC to Jomsom, which is the headquarter of Mustang district. Large patch of seabuckthorn forests are found in Lete and Kunjo VDCs. Kowang VDC, which is of 80 sq km, comprises seabuckthorn dispersedly along the Kali Gandaki River and seabuckthorn plants are regenerating at some areas.

3.2 Data Collection

3.2.1 Preparation for Field Visit

Discussion with Annapurna Conservation Officials and Getting of Permission: As Mustang lies in the Annapurna Conservation Area Project (ACAP) and this project has included research and participatory conservation approach, permission letter was necessary. So after discussion with the officials, permission letter was prepared for conducting project in Mustang district. The permission included research including destructive sampling seabuckthorn trees, other biophysical study and socio-economic survey and participatory nature conservation including training and seabuckthorn operation plan preparation.

Discussion with the Forest User Committees: It was necessary to get support of the local people to conduct the project activities. Several discussions were held with the forest user committees of the VDCs to make them aware of the importance of seabuckthorn tree and need of the study and management initiatives for the improvement of their livelihoods and the resources. With those discussions, local agreement and support were obtained to conduct the project.

Reconnaissance Survey: To get general overview of the project area and the distribution of seabuckthorn forest, socio-economic behaviour, reconnaissance survey was carried out along with the help of a local people.

Sampling Design: With the help of reconnaissance survey and aerial photographs, stratified systematic line plot sampling was chosen with plot size of 10 m × 10 m for the resource quantification of seabuckthorn. Altogether 100 plots (between plot distances – 100 m) was set in the map for resource inventory that would comprise approximately 2 % sampling intensity.

3.2.2 Biophysical Data Collection

GPS Locations: GPS locations of all the boundary of seabuckthorn patches were recorded. These locations were analyzed to find the distribution area of the seabuckthorn and to show the spatial distribution in the study area through GIS software. Aerial photographs were obtained from ComForM (Community based Forest Management in the Himalaya) project, Institute of Forestry, Pokhara, Nepal.

3.2.2.1 Data Collection for Regression Equations

Selection of Trees and Tree Measurements

Thirty seabuckthorn trees were selected following a stratified random procedure by choosing trees from each of nine diameter classes (5 cm). The diameters of the selected trees range from 1.4 cm to 43.2 cm at 30 cm height from the base. The dead, dying and malformed were avoided. Before felling, the direction of felling was fixed, the ground was cleared for shrub and other obstacles and a sheet of 20 × 10 m^2 size was laid along the direction of felling. After felling, measurements were taken for the height, diameter at breast height, crown diameter; bark width at 30 cm and growth ring at 30 cm. The height and crown diameters were measured to the nearest 10 cm and the diameters at 30 cm and breast height were measured to nearest 1 mm while bark width was measured the nearest 0.5 mm. The data collection sheet for regression equation has been given in appendix 2.

Fresh (green) Weight Measurement

The trees selected as mentioned above were cut first at 30 cm height and then at ground level. All the branches with leaves and fruits were separated and the trunk and branches were cut into short, manageable segments. All the leaves were clipped off and fruits were collected safely from the branches. The wood mass was divided into two categories – one with stem diameter equal to or greater than 3 cm and another dead and dry branches and stem with less than 3 cm. The wood parts were then freshly weighed separately to the nearest 0·1 kg using a spring balance and the leaf and fruits were weighed in-situ to the nearest gram by a battery-powered balance.

Samples Collection for Oven Dry Weight

Sections of stem (approximately 1 inch thick) from different parts of the tree were sawn off in the field and weighed to the nearest gram using a battery-powered balance. For leaves, 5 samples each weighing 100 gm were collected during various time periods of the days. These samples were kept in a shade dry place prior to final oven drying.

Dry weight measurement

The wood samples were oven dried at constant temperature of 105°C for 48 hours (FRI, 1986) to obtain constant weight (weighing to the nearest 0.01 gram). The leaf samples were oven dried at 70°C (Rayachhetry et al, 2001) until no further weight loss was obtained (took 12 hours). Then moisture content percentages were calculated for each tree (wood and leaves) to use in regression equations.

$$\text{MoistureContent} = \frac{\text{Wet Weight - Oven Dry Weight}}{\textit{Wet Weight}} X 100\%$$

$$\text{Oven Dry Weight} = \frac{100 X \textit{Wet Weight}}{\textit{Moisture Content} + 100}$$

3.2.2.2 Inventory

The literature regarding sampling intensity was not found to study *H. salicifolia*. For this study, stratified systematic line plot survey was chosen and the seabuckthorn forest was categorized into two strata – one is the area along the bank of the river and another is the sloppy, degraded and upper part of the river belt areas. Due to homogeneity of the seabuckthorn tree in the stratified areas, the distance between the plots was decided to be 1000 m. The size of a plot was fixed to 10 m × 10 m. The smaller plots would be too small to

survey the tree species and the bigger plots would be difficult to lie on the sloppy and difficult terrains. Based on these assumptions, sampling intensity was calculated.

The present stocking and biomass of wood, fruit and foliage per hectare were studied from 50 plots of size 100m^2 (10 m × 10 m) along the riverbank at a distance 1000 m between plots and 50 plots of the same size on the sloppy/degraded patches in a stratified systematic line plot manner. Data collection sheet for biomass calculation is given in appendix 3.

Photo 7: Field Assistants Surveying Sample Plots

The number of sample plots was calculated with the measurement of river distance. Lines were drawn on the map along the potential areas (riverbank, sloppy/degraded areas and upper belt of the riverbank) of seabuckthorn forest in Lete and Kunjo VDCs and it was measured to be approximately 92 km ≈ 100 km. The distance was crosschecked in both the digital and analogue map provided by ComForM.

So, number of sample plots was calculated by

$$Number\ of\ Sample\ Plots = \frac{Effective\ Length\ of\ the\ distributed\ Areas}{1000} = \frac{100000\ m}{1000\ m} = 100$$

After calculation of the distributed area of seabuckthorn, the sampling intensity was calculated to be 1.63 %.

$$Sampling\ Intensity = \frac{Area\ Sampled}{Total\ Area} X\ 100\%$$

$$= \frac{plots\ number \times\ plot\ area}{612300} X 100$$

$$= \frac{100 \times 100}{612300} X 100$$

$$= 1.63\ \%$$

Within the plot, number of trees, diameter at breast height, height, and number of regenerations, number of stumps and erosion and grazing status were recorded.

3.2.3 Socio-economic Data Collection

For the socio-economic data collection, following PRA and RRA tools were used by means of which the information regarding seabuckthorn like management, roles in livelihoods, poverty reduction, roles of different organizations, institutional arrangements, problems, prospects and

other important factors have been collected. Through direct field observation, extraction of fruits, utilization, their techniques of fruit harvesting and propagation were identified.

Household Survey: Household survey was carried out covering all the classes of people (including poor and rich) to identify the contributions of seabuckthorn to the livelihood of the local people and to assess the current management systems regarding their techniques of propagation, harvesting, extraction and utilization of seabuckthorn systems. Respondents in each VDCs were 20% of the total households. Questionnaire for social survey is given in appendix 4.

Focus Group Discussion: It was carried out with the members all the forest user groups members of Lete, Kunjo and Kowang VDCs, women groups and other groups (poor and Dalits). Checklist for group discussion is presented in appendix 5.

Semi-Structured Interview and Discussion with Key Informants: Some of the project officials, collectors, traders, Amchi and other knowledgeable personnel were consulted for taking data. Officials from ACAP, ICIMOD, CARE, DSCO, ANSAB and TISC were consulted for taking the socio-economic data.

Direct Sites Observation: The nursery, plantation sites, degraded areas and local juice and concentrate (chuk[†]) making homes (industries) were also visited to observe opportunity to initiate seabuckthorn product industries, the progress achieved in the past, production system and products.

3.2.4 Project Activities

3.2.4.1 SMC Formation and Participatory OP Preparation

For the formation of seabuckthorn management committee (SMC), several formal and informal discussions were made separately and jointly with Annapurna conservation officials, forest user committee, hoteliers, poor, dalit and women to form SMC. After forming SMC, date was fixed to prepare operation plan and participatory approach was applied to form 5 years' operation plan (2008-2012)

3.2.4.2 Training

For the adult training, local people (poor, women, dalit, and local hotel owners), committee members and schoolteachers participated in the five days' training. As school students can play important role in biodiversity conservation, a three days training was held to the secondary school students of Gyanodaye Secondary School in Lete, Mustang.

3.2.4.3 Brochure Preparation

Based on the different literatures and research experience, a brochure has also been published and distributed to the local people, local organizations and national organizations.

[†] A concentrate of juice; about 8 to 10 litre of raw juice is boiled to make 1 litre of chuk

CHAPTER 4: RESEARCH RESULTS AND DISCUSSION

In this chapter, some physical properties of seabuckthorn have been described, which are necessary for generating regression equations. With help of developed regression equations, biomasses production of wood, fruits and leaves have been estimated. Ethnobotinacal uses of seabuckthorn and existing and potential roles of fruits and leaves in income generation have also been described. Threats, current management practice, possible harvesting techniques and the opportunities to manage the seabuckthorn forest through community-based approach have also been discussed in this chapter.

4.1 Physical Properties of Seabuckthorn

Fruits

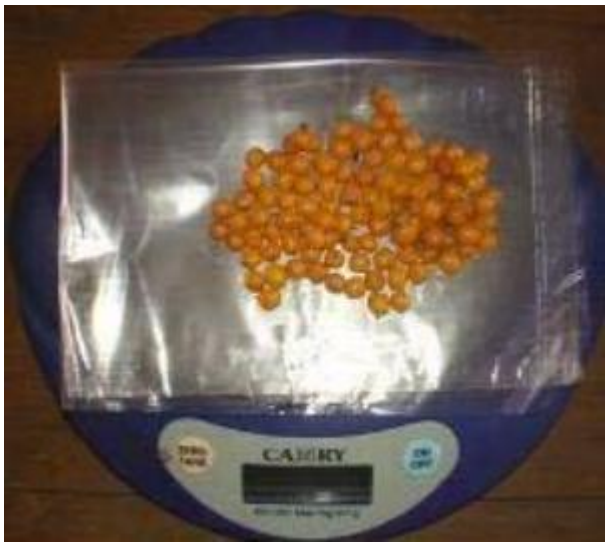


Photo 8: Fruits of *H. salicifolia*

In *H. salicifolia,* two distinct colours of fruits were noticed in Mustang. One was yellowish and another was reddish, which was slightly smaller in size. The berries are round (slightly oval) with 5.5 to 7 mm in diameter. In 100 gm fresh fruits, when measured by the means of an electronic balance with 0.1 gm accuracy, the number of berries counted from 630 to 676 (n = 10, σ = 15.84 and mean = 653), so the weight of 100 fruits was found to be 15 gm. The colours of juice also differed as the colours fruits. The fruit is soft, delicate and contains juice which is strongly acidic, i.e. its pH = 2.58 during lab test. When the fruits were locally squeezed, it extracted approximately 64.2 % juice. The density of juice was found to be 1.046 to 1.068 kg/liter (n = 10, σ = 0.01 mean = 1.055). Measurement was also done for seeds. The number of 10 gm air-dried seeds contained 16400 to 118000 (n = 5, σ = 6.54 and mean = 1168.6), when weighted by means of an electronic balance to the nearest 0.01 gm**.** So weight of 1000 seeds was found to be 8.56 gm.

Leaves

The size of the leaves varies from base to the apical part of the branches. The leaves are larger at the base of the branches and smaller at the apical part. The matured leaves were found to be 6.6 to 8.3 cm long and 0.8 to 1 cm wide. The number of *H. salicifolia* leaves was observed to be 12780 to 13280 per kg (n = five, σ = 9.66 and mean = 13020) and the moisture content of the leaves was found to be 186.19 %.

Photo 9: Leaves of *H. salicifolia*

Wood/Stem

The bark of the matured tree is dark grey with 7 to 14 mm bark width at the height of 30 cm

from the base of the tree. The colour of the heartwood is dark yellow and the sapwood is light yellow to white. The growth rings on the both heartwood and sapwood are distinct and the wider distance between growth rings indicated that seabuckthorn is a fast growing tree. The moisture content of the wood was found to be 137.44 %. From the study of 30 harvested trees, it has been found that a 21 years old seabuckthorn tree has its diameter 18 cm (at 30 cm from the base of the tree), height 8 m and bark width 8 mm.

4.2 Regression Equations

Many equations have been proposed to describe plant growth. Kiviste (1988) described 75 of them in a comprehensive two-volume monograph. Although only a few have proven useful, probably no biologist believes that one equation would suit all growth processes because biomass may be dependent on several factors including diameter at breast height, height of the tree, crown diameter, site index and several others. The current analysis is based on taking height and diameter at 30 cm from the base of the tree as dependent variables for estimating the models. Diameter at breast height was not taken for the current analysis rather diameter at 30 cm from the base was taken because of presence of many shrub species for which measurement was not possible at the breast height. The terminologies used in this analysis are:

- Diameter (D): Diameter at 30 cm
- Height (H): Total height of the tree
- Biomass (B): Biomass of wood, fruits or leaves of seabuckthorn
- Wood (W) = Oven dry weight of above ground biomass except reproductive parts and leaves
- Leaves (L) = Oven dry weight of leaf of seabuckthorn
- Fruits (F) = Fresh weight of seabuckthorn fruit
- VIF = Variance Inflation Factor
- Adj. R^2 = Adjusted coefficient of determination
- ln = Natural logarithm
- SEE = Standard error of estimates
- CF = Correction factor

A preliminary examination of the scattered plots of biomasses of wood, fruits and leaves against diameter and height indicated that there was non-linear relationship between biomasses and independent variables. Keeping view on this relationship, five linear and non-linear forms of model were generated and compared. These are:

Equation form 1: Those that incorporate only one independent variable, i.e. only diameter at 30 cm or height
Equation form 2: Those that incorporate both diameter and height as independent variables
Equation form 3: Those that incorporate diameter and height in the form of the products as the independent variables.
Equation form 4: Those that incorporate multiple sum and products of diameter and height as independent variables
Equation form 5: Those that incorporate diameter and/or height taken with natural logarithm as above cases.
In this analysis, different linear and non-linear models were formulated with varying parameter numbers and were fitted to the data. Only the following models covered well for regression analysis of the biomass and hence analysis is shown for these models.

Model 1: $B = a + b\,D$
Model 2: $B = a + b\,H$
Model 3: $B = a + b\,D + c\,H$
Model 4: $B = a + b\,D^2H$
Model 5: $B = a + b\,D + c\,D^2$
Model 6: $\ln B = a + b \ln D + c \ln H$
Model 7: $\ln B = a + b \ln D$
Model 8: $\ln B = a + \ln D^2H$

All statistical analysis to generate best fitted models was carried out by using SPSS 11.5 version. Comparison of all the forms was based on following criteria.

i. Adjusted coefficient of determination (adj. R^2): It can be expressed as

$$\text{Adj.}\,R^2 = (1 - R^2)\frac{(n-1)}{(n-p)}$$

Where, R^2 = coefficient of determination, n = total number of observations and p = number of parameters used in a regression model. The idea of using adj. R^2 criterion rather than R^2 to compare the fitted models with different parameter numbers was considered appropriate (Montgomery et al, 2001).

ii. Significance of parameter values, i.e. parameter estimates with 95% confidence band should exclude zero. This indicates that there is only non-zero value for the parameters.
iii. Homogeneity of residuals, i.e. plot of the residuals against the fitted values was made to highlight the deviation of homogenous variance assumption.
iv. Distribution of residuals, i.e. histograms of residuals were plotted to display the distribution (normal or abnormal) patterns of the residuals.
v. Standard Error of Estimates (SEE), which is considered one of the most important model evaluation criteria, was also used in this study. It can be expressed as:

$$SEE = \sqrt{\frac{\sum (Y - \hat{Y})^2}{n-p}}$$

Where Y = value of dependent variable, $\hat{Y}$ = estimated (or calculated) values from the estimating equation that correspond to each Y value

vi. Visual examination of the fitted curves overlaid on the scattered plots of the observed data.
vii. Variance Inflation Factor (VIF), the reciprocal of the tolerance, is the indicator of multicollinearity.

$$\text{VIF} = \frac{1}{\text{Tolerance}}, \quad Tolerence = 1 - R_1^2$$

Where, R_1^2 is the coefficient of determination obtained when independent variable(s) is/are used to predict the corresponding independent variable.

viii. Simplicity, practicability and cheap

4.2.1 Finding Best Fitted Regression Model for Oven Dry Weight of Wood

Various models were compared to ascertain the best model fit that do not indicate deviation from the general assumptions of linear regression and those show the best goodness of fit. The best relationship between wood biomass and diameter was obtained when the log of biomass was regressed against the log of diameter and height. Logarithmic allometric models are widely used in tree biomass studies (Whitesell et al, 1988; Claesson et al, 2001; Ter-Mikaelian et al 1997 and Ingerslev and Hallbacken, 1999) and it generally gives reliable results for many types of biomass prediction (Claesson et al, 2001), which explains their wide application in biomass studies (Claesson et al, 2001; Ingerslev and Hallbacken, 1999; Crown and Schlaegel, 1988 and kadeba, 1991). This transformation (log-log) also gave the best fit for the relationship between D^2H.

Both diameter and height are non-linearly related to wood and the relationships of diameter and height with wood biomass have been shown in figure 3. As is to be expected, biomass increased with the increase in diameter and height. Among several models tested, following two models were selected based on the adj. R^2, standard error of estimates and their residual plots.

Model 1: $\ln W = a + b \ln D$
Model 2: $\ln W = a + b \ln D^2H$

These equations are actually the transformed ones of the power curves, i.e. $Y = aX^b$ but such transformations, however, introduce bias to the results (Finney, 1941; Beauchamp and Olson, 1973 and Lee, 1982). Sprugel (1983) have given a correction factor (CF) which compensates for this bias.

$$CF = \exp(\frac{SEE^2}{2})$$

The parameters of the regression equations of the all forms are presented in table 8 for comparison. The above two equations have high adj. R^2, low standard error of estimates and significant at $p < 0.001$. Other models seemed to have poorer statistics of fits (adj. R^2), non-significant parameters, i.e. $p>0.05$ and/or high SEE and therefore they were considered incompetent and excluded from further analysis. Only, these two models seemed to have shown more attractive numerical statistics of fits and therefore they are qualified for further analysis to find the best one. Details of the two equations have been shown in table 9.
The table 9 shows that adj. R^2 and SEE value is better for model 2; however, when the estimated wood biomasses from two separate models, i.e. $\ln B = a + b \ln D$ and $\ln B = a + b \ln D^2H$ were tested by t-test, it showed that they were not significantly different at 95 % confidence limit. The estimated biomass from the two models was also compared with the actual biomass and it revealed that the first commits 6.6 % error while the second one commits 5.2 %. The residuals of the two models were found to be normally distributed and a visual examination and comparison of the residual plots of the two equations forms did not reveal any distinctive advantage of one over the other (Figure 4). The distribution of residuals, i.e. histograms of the residuals plotted to display the distribution (normal or abnormal) patterns of the residuals (Figure 5) also provide the similar results with mean = 0 and standard deviation 0.98 for the both. In the normal probability plot curves, the second model showed slightly better result (Figure 6).

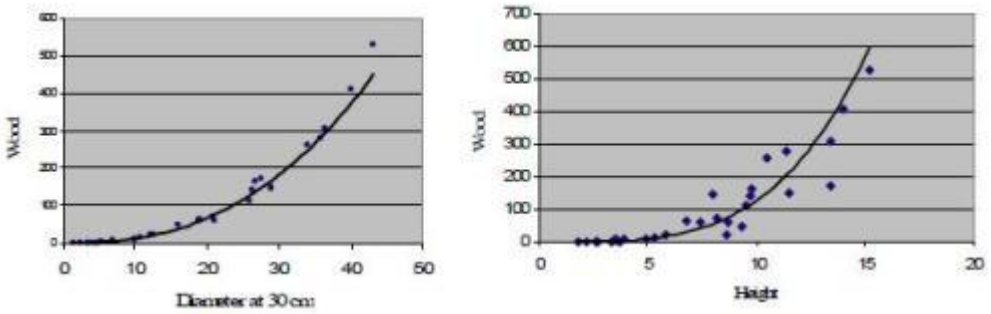


Figure 3: Relationships between Wood and Diameter and Height

(a) Allometric Relationships between Diameter and Wood biomass. (a) Allometric Relationship between Height and Wood Biomass.

Table 8: Regression Equations of Wood Biomass and their Parameters

Models	Parameter estimates			adj. R^2	SEE	VIF
	a	b	c			
1.	-74.15*	9.75*		0.830	55.619	1
2.	-114.50*	29.38*		0.737	69.109	1
3.	-70.65ns	10.29ns	-1.765ns	0.824	56.594	10.4
4.	3.61ns	0.01*		0.990	13.537	1
5.	21.51ns	-5.63*	0.38*	0.985	16.605	14.8
6.	-3.406*	1.948*	0.836ns	0.981	0.327	16. 5
7.	-3.243*	2.486*		0.978	0.348	1
8.	-3.424*	0.940*		0.981	0.322	1

*significant at $p<0.001$, nsnot-significant at $p \leq 0.05$

Table 9: Parameter Estimates, Adj. R^2, SEE, CF, VIF and p of the Selected Models

SN	Formula	Parameter Estimates		Adj. R^2	SEE	CF	VIF	p
		Coefficients	Std. Error					
1	ln W = a + b ln D	a = -3.243 b = 2.486	0.186 0.068	0.978	0.3476	1.06	1	0.000 0.000
2	ln W = a + b ln D^2H	a = -3.424 b = 0.940	0.176 0.024	0.981	0.3224	1.05	1	0.000 0.000

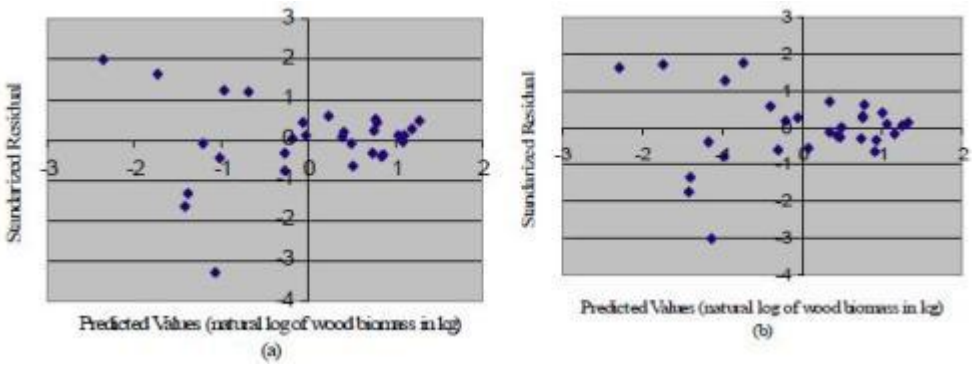


Figure 4: Results of Residual Analysis for the Biomass Equations
(a) ln W = a + b ln D and (b) ln W = a + b ln D2H

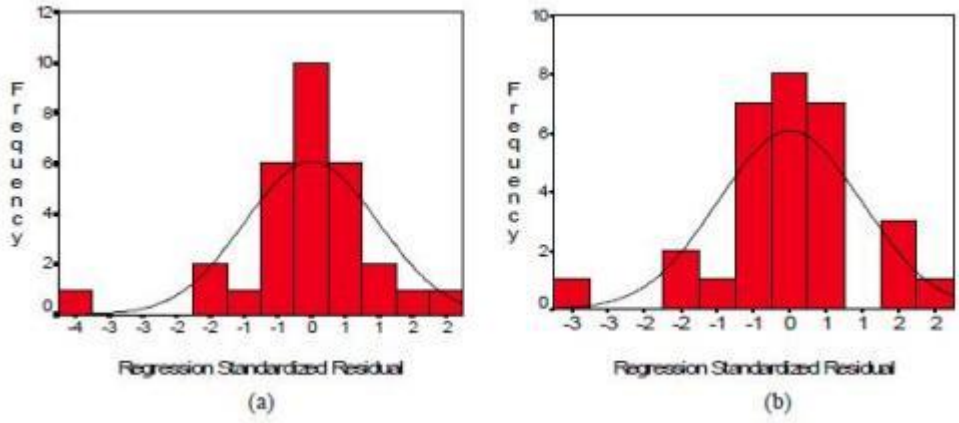


Figure 4: Residual Distribution Pattern with the Equations
(a) ln W = a + b ln D and (b) ln W = a + b ln D2H

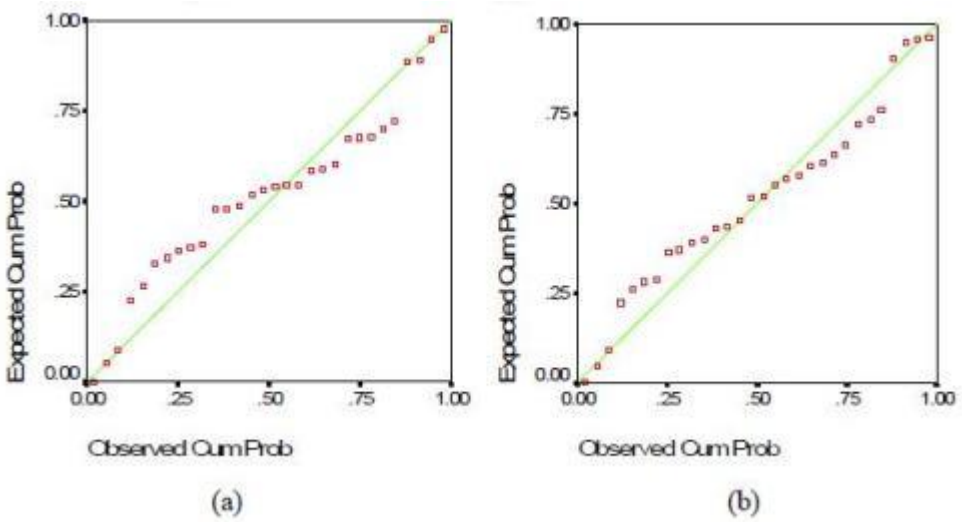


Figure 5: Probability Plot between Observed and Expected Cumulative Probabilities
(a) ln W = a + b ln D and (b) ln W = a + b ln D2H

Based on the above observations, the allometric model ln W = a + b ln D^2H seems to be better. However, the results reveal that diameter alone as independent variable explained a very high proportion of the variation in wood biomass. Including height as independent

variable did not result into a much better explanation of the variation in biomass as suggested by t-test. Although there was little improvement in the performance of the model by including height data in the model, the improvement was marginal. Considering the huge time invested in obtaining height data in the field, the associated measurement error and the fact that the inclusion of height did not significantly improve the performance of the model, the inclusion of height data in biomass models for *H. salicifolia* in the study area is of little significance. On the other hand, the inclusion of height data in biomass equations will reduce their practicality and use. This is because height data cannot be rapidly obtained for all trees over a relatively large area in the difficult terrains in Mustang. Furthermore, since diameter can easily be measured over a relatively large area and in difficult terrains within a short time with good accuracy and since diameter alone provides accurate estimates of wood biomass, the need of including additional variable does not arise. The advantage of such model (with only diameter as independent variable) is that it is simple, practical and easy to use, provides a more rapid and less costly biomass estimates and has low-data requirement (Wang, et al, 2000; Ter-Mikaelian and Korzukhin, 1997). Several researchers have concluded that tree biomass is primarily a function of diameter and is relatively insensitive to tree height and consequently have incorporated only diameter as independent variable in their biomass models (Verwijst and Telenius, 1999; Rapp et al, 1988; Wang et al, 2000; Naidu et al, 1988; Ter-Mikaelian et al 1997 and Kadeba, 1991). From the above considerations, the equation $\ln W = a + b \ln D$, i.e. $\ln W = -3.243 + 2.486 \ln D$ is the most appropriate for estimating wood biomass production for seabuckthorn in the study area and is thus recommended for use.

4.2.2 Finding Best Fitted Regression Model for Fresh Fruits

The scattered plot diagram (Figure 7 (a)) indicated that there was non-linear relationship between fruit biomass and diameter. For finding out the best fitted regression models, many different models were formulated with parameter numbers varying from one to five. As in the case of wood, the eight models were selected and were fitted to the data. The parameters of these selected regression model are shown in Table 10.

Table 10: Regression Equations of Fruit Biomass and their Parameters

Models	Parameter estimates			adj. R^2	SEE	VIF
	a	b	c			
1.	-1.12^{ns}	0.199^{*}		0.654	1.692	1
2.	-1.064^{ns}	0.483^{*}		0.362	2.2979	1
3.	0.558^{ns}	0.428^{*}	-0.212^{*}	0.788	1.324	7.5
4.	1.109^{ns}	0.000^{*}		0.529	1.975	1
5.	-0.200^{ns}	0.076^{ns}	0.003^{ns}	0.657	1.685	14.3
6.	-3.328^{*}	2.837^{*}	-2.116^{**}	0.701	0.727	10.5
7.	-3.509^{*}	1.407^{*}		0.640	0.797	1
8.	-3.424^{*}	0.508^{*}		0.599	0.841	1

*significant with $p<0.001$, ^{ns}not significant, **significant with $0.01<p<0.05$

The models 1 to 6 were considered unqualified for further analysis because of insignificant parameters. Regarding models 7 and 8, the figures of adj. R^2 and SEE showed that model 7 is better fitted. As in the case of wood, this model is also simple to use and practicable in the field. The residual distribution pattern showed that the deviations of the residuals are random (Figure 7(b)). The probability plot chart also showed that the expected cumulative probability

did not deviate much from the observed ones (Figure 8). The histogram revealed a near normal distribution pattern of residuals (Figure 9).

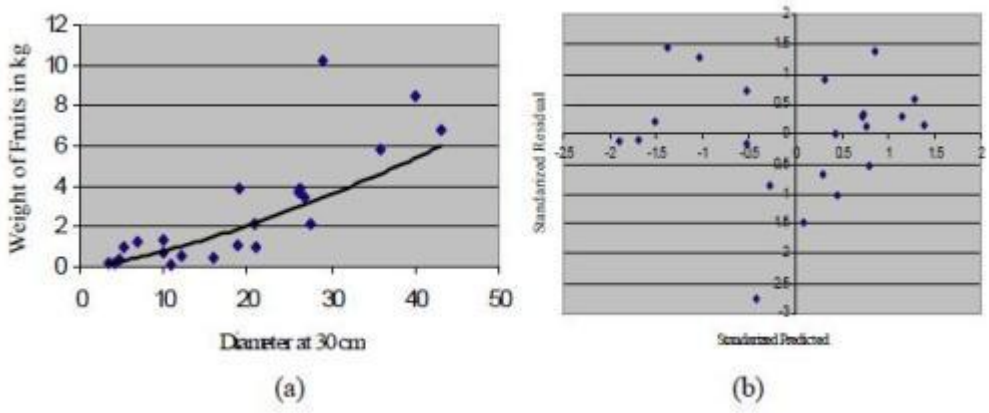


Figure 6: Relationships between Weight of Fruits and Diameter and Residuals

(a) Relationship between Diameter and Weight of Fruits (b) Residual Distribution Pattern with ln F = a + ln D

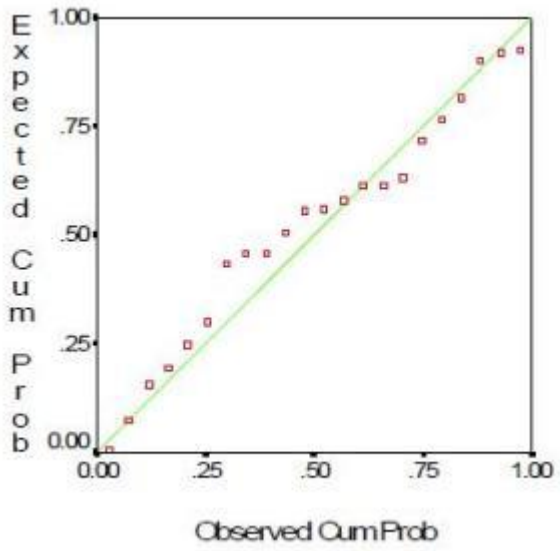


Figure 7: Probability Plot between Observed and Expected Cumulative Probabilities

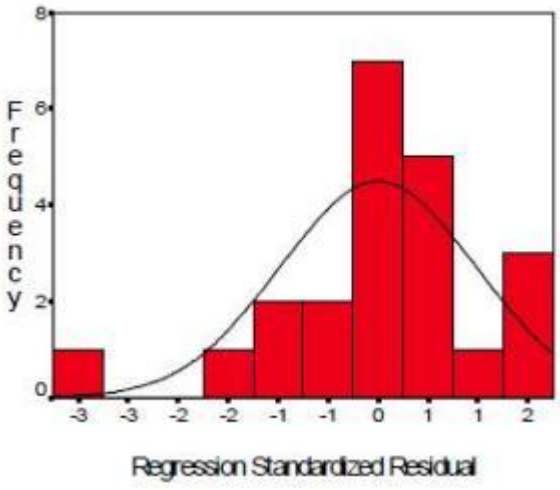


Figure 8: Residual Distribution Pattern with (a) ln F = a + b ln D

Although the result was not as good as that of wood, based on the observed results, it was clear that the best fitted model for fruits of the seabuckthorn was ln F = a + ln D. The details of the equation have been shown in table 11 below.

Table 11: Parameter Estimates, Adj. R^2, SEE, CF, VIF and p of the Selected Models

SN	Formula	Parameter Estimates		Adj. R^2	SEE	CF	VIF	p
		Coefficients	Std. Error					
1	ln F = a + b ln D	a = -3.509 b = 1.407	0.637 0.227	0.640	0.797	1.37	1	0.000 0.000

So the equation ln F = a + b ln D, i.e. ln F = -3.509 + 1.407 ln D has been selected as the best fitted model.

4.2.3 Finding Best Fitted Regression Model for Oven Dry Weight of Leaves

Similar to the wood and fruits, the scattered plot diagram (Figure 10 (a)) indicated that there was non-linear relationship between leaf biomass and diameter. For finding out the best fitted regression models, different models were formulated with parameter numbers varying from one to five. As in case of wood and fruits, eight models were selected and were fitted to the data. The parameters of these selected regression model are shown in Table 12.

Table 12: Parameter Estimates, Adj. R^2, SEE and VIF of the Selected Models

Models	Parameter estimates			adj. R^2	SEE	VIF
	a	b	c			
1.	-0.647^{ns}	0.110^{*}		0.746	0.805	1
2.	-1.224^{*}	0.347^{*}		0.734	0.823	1
3.	-0.949^{ns}	0.064^{ns}	0.152^{ns}	0.751	0.796	10.4
4.	0.223^{ns}	0.021^{*}		0.898	0.509	1
5.	0.333^{ns}	-0.048^{ns}	0.004^{ns}	0.857	0.603	14.8
6.	-4.109	1.157^{ns}	0.354^{ns}	0.832	0.583	16.5
7.	-4.040^{*}	1.384^{*}		0.837	0.575	1
8.	-4.137^{*}	0.523^{*}		0.838	0.573	1

*significant with $p<0.001$, ^{ns}not significant

The models 1, 3, 4, 5 and 6 were considered unqualified for further analysis because of insignificant parameters. The model 2 had relatively lower adj. R^2 and higher SEE, so this was also considered to produce poorer fitted curves and excluded from further analysis. Regarding models 7 and 8, the figures of adj. R^2 and SEE showed that these were similar. As in the case of wood and fruits, the model 7 is also simple to use and practicable in the field. The residual distribution pattern showed that the deviations of the residuals are random (Figure 10). The probability plot chart also showed that the expected cumulative probability did not much deviate from the observed ones (Figure 11) and the histogram revealed a near normal distribution pattern of residuals (Figure 12).

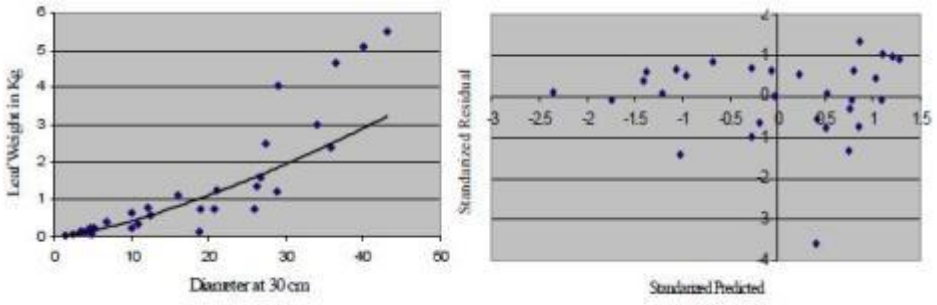


Figure 9: Relationships between Weight of Leaves and Diameter and Residuals

(a) Relationship between Diameter and Weight of Fruits (b) Residual Distribution Pattern with ln L = a + ln D

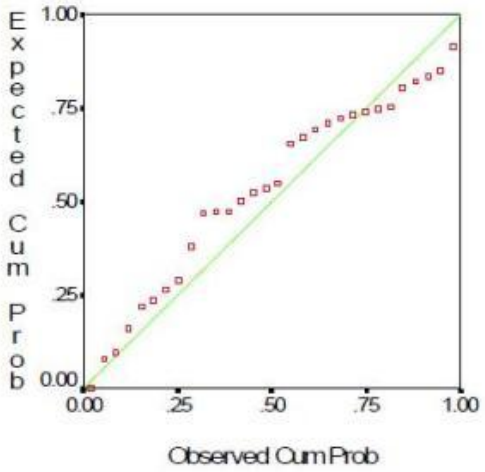


Figure 10: Probability Plot between Observed and Expected Cumulative Probabilities

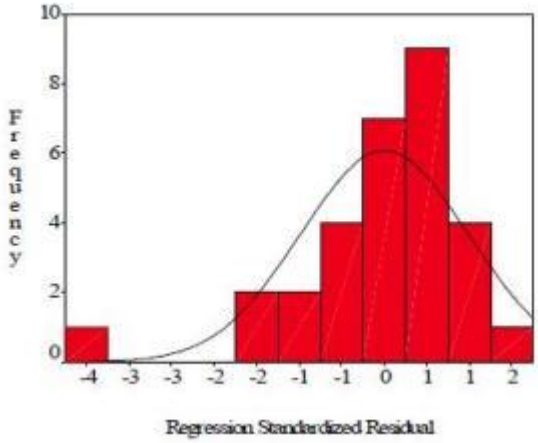


Figure 11: Residual Distribution Pattern with ln L = a + b ln D

The result was better as that of fruits although not better than wood. Based on the observed results above, it was clear that the best fitted model for leaves of the seabuckthorn was ln L = a + ln D. The details of the equation have been shown in table 13 below.

Table 13: Parameter Estimates, Adj. R^2, SEE, CF, VIF and p of the Selected Models

SN	Formula	Parameter Estimates		Adj. R^2	SEE	CF	VIF	p
		Coefficients	Std. Error					
1	ln L = a + b ln D	a = -0.040 b = 1.384	0.307 0.113	0.837	0.575	1.18	1	0.000 0.000

So the equation ln L = a + b ln D, i.e. ln L = -4.04 + 1.384 ln D has been selected as the best fitted model.

So, one can easily estimate the biomasses of wood, fruits and leaves of the seabuckthorn (*H. salicifolia*) using the equations below after measuring the diameter at 30 cm.

For Wood: ln W = -3.243 + 2.486 ln D (adjusted R^2 = 0.978, SEE = 0.348)
For Fruits: ln F = -3.509 + 1.407 ln D (adjusted R^2 = 0.640, SEE = 0.797)
For Leaves: ln L = -4.04 + 1.384 ln D (adjusted R^2 = 0.837, SEE = 0.575)

With the help of the developed regression equations, local biomass table has been developed for ease utilization by the local people in the field, which is given in appendix 6.

4.3 Distribution

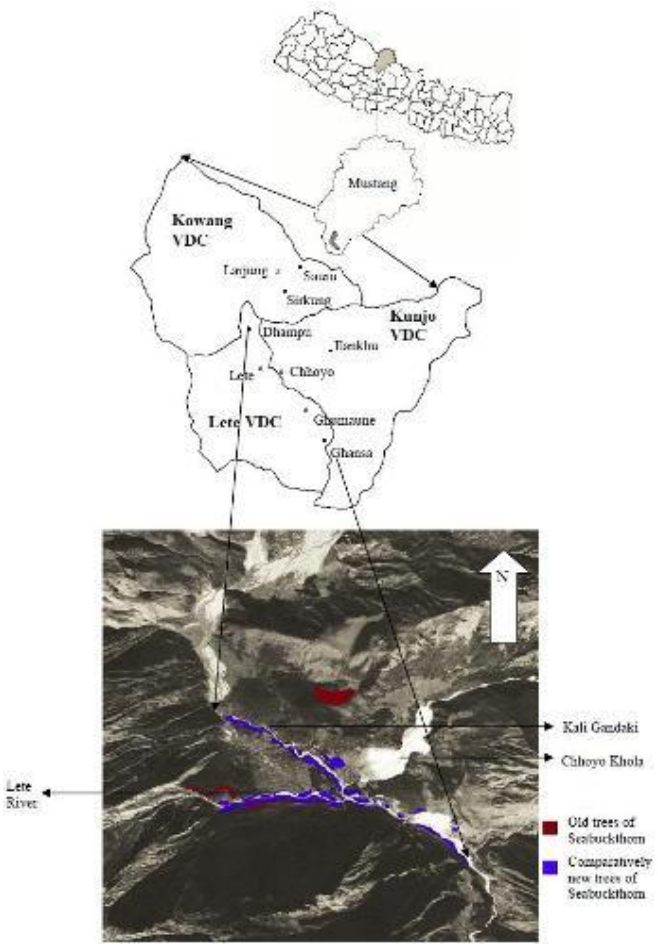


Figure 12: Distribution of *H. salicifolia* in Mustang and Project Area

H. salicifolia is naturally distributed along the riverbanks, booklet banks, flood plains, sloppy areas, alluvial soils and newly eroded colluvial deposits of Lete, Kunjo and Kowang VDCs of Mustang District. With the help of GPS locations and GIS software – ArcView 3.2, the area of the seabuckthorn forest was calculated to be 61 ha (hectare) in Lete and Kunjo VDCs of which maximum is distributed along Kali Gandaki River (see table 14 for detail). The locations, where seabuckthorn was gregariously found, were Kaiku Khola, Ghumaune, Kokhethanti, Dhampu, Ilankhu (Taglung), Larjung, Yamik Khola, Sauru and Sirgung. Along the Lete River, it has been found up to Thula Chaur at 2627 m (28.63ºN, 83.59ºE). Along Chhoyo Khola, very few matured species were found at the booklet bank and some regenerations were found on the flood plain. Considering the vertical range of elevations, it is found from altitude 2000 m near Ghasa (28.61ºN and 83.64ºE) to 2700 m at Ilankhu (28.64ºN, 83.62ºE) of Kunjo VDC.

Table 14: Distribution of Seabuckthorn in Lete and Kunjo VDCs

Location	Areas in Ha	Altitudinal Range (m)	Geographic Coordinates	Remarks
Ilankhu	11.42	2400-2700	28.64ºN, 83.62ºE	Northern part in Arial Map-Kunjo
Kali Gandaki River	23.71	2000-2500	28.61ºN, 83.64ºE to 28.65ºN, 83.60ºE	East-west
Upper belt	8.50	2450-2600	28.63ºN, 83.59ºE	Upper part of the Lete Khola (Southern –Lete)
Lete River	17.60	2400-2600	28.63ºN, 83.62E to 28.63ºN, 83.60ºE	Southern Blue Part-Kunjo
Total	**61.23≈61**			**61 Hectare of seabuckthorn forest**

Based on aspect, Gupta et al (2000) observed that *H. salicifolia* often makes its room on south, south-west or west facing slopes, of up to 80º but never recorded in north facing slope in Dolpa and Jumla district. Unlike the findings obtained by Gupta et al (2000), this species was frequently found on the northern slopes on the bank of the Kali Gandaki River, Ilankhu and Lete River. It was also observed on eastern, western and southern aspects.

Based on VDCs, seabuckthorn is distributed in approximately 41 hectares in Lete and approximately 20 hectare in Kunjo.

Table 15: Distribution of Seabuckthorn According to VDCs

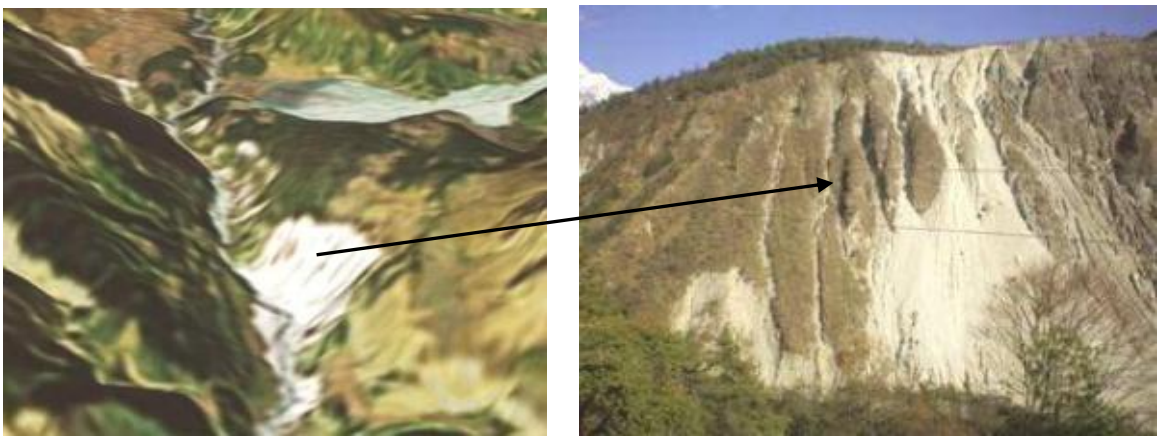
VDCs	Areas in ha	Places
Lete	41.33	Ghasa, Kaiku Khola, Ghumaune, Lete Khola, Kokhethanti, Dhampu
Kunjo	19.9	Chhoyo, Chhoyo Khola, Ilankhu, Larjung
Kowang	Data not available	Thak Khola, Tukuche, Sauru, Sirgung. Some regeneration areas over flood plains

Based on density (number of trees per hectare), it was relatively less (approximately 450) at Ilankhu and upper part of Lete Khola, which was at the higher elevations (above 2400m), while it was approximately 800 along the riverbanks and booklet banks at lower altitude. In addition, the upper belt areas were covered with over-matured seabuckthorn trees and the

regeneration of seabuckthorn was almost nil. On the flood plain along the Kali Gandaki River and Lete Khola, seabuckthorn was pioneering in a newly deposited soil. Maximum regeneration number observed was 82 per plot (10 m × 10 m).

Based on the production and use, the river belt areas – along Kali Gandaki and Lete River within one-hour distance to reach seabuckthorn forest – were found to produce relatively higher fruits and those areas were accessible. Therefore, people usually collect fruits and wood from those areas. However, there was good fruit production at the lower elevations of the Lete Khola; people were not found to harvest fruits and wood from those areas due to remoteness and inaccessibility. If there had been a trail to reach the seabuckthorn forest, they would have collected the fruits from those areas as well.

In 2001, seabuckthorn was planted on 0.5 ha in Thak Khola of Tukuche (2600m; 28.70ºN, 83.64ºE) in Kowang VDC with the support of HMG/DANIDA/NARMSAP. In addition, *Taxus*, *Pinus* and Seabuckthorn were planted in some areas of Lete VDCs in 2006. TISC (2001) calculated the potential area of seabuckthorn (*H. salicifolia*) in Mustang district at 57 ha. The current estimation shows that the seabuckthorn forest area in Mustang district is more than 61 ha because this calculation was strictly based on Lete and Kunjo VDCs only. This shows that the seabuckthorn forest area is increasing. There were several areas along the bank of the river and sloppy areas where seabuckthorn was regenerating. Riverbanks, sloppy areas and landslide areas were found to be potential sites for seabuckthorn regeneration and several such sites were observed to be regenerating seabuckthorn.



(a) (b)

Photo 10: Seabuckthorn Regeneration over Landslide Areas
(a) Image extracted from Google Earth that may probably taken during 2003/4 and (b)

Photograph taken during field visit, i.e. November 2006. In this photograph, seabuckthorn of age 1-2 years is regenerating over landslide area. The location is the same in both the photograph.

Morphological Variations in *H. salicifolia*

Morphological variations were noticed on *H. salicifolia* in Mustang district. During the collection of fruits, two distinct colours of seabuckthorn were observed – one was reddish and another was yellowish, reddish one slightly smaller. Gupta et al (2000) also observed the two morphologically different varieties of *H. salicifolia.* Their conspicuous variations were observed in the size of the thorn (long and short), frequency of thorns in stem, size of the leaves, colour of the leaves and taste of the fruit juice. As the reddish one is more attractive in colour, local people liked it more.

Species Association

The seabuckthorn occurred on the fragile lands with weak soil composition and infertile river fords. Newly emerging plants were grown abundantly along the fords where the associated species were lacking. This species grows and flourishes with a short interval of time and then other plant species invade the barren lands as the pioneering species of secondary succession.

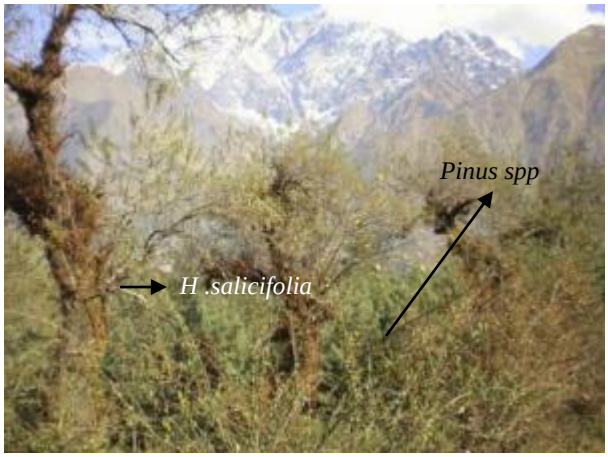


Photo 11: Colonization of *Pinus spp* at Ilankhu

The plants associated mainly with *Alnus nepalensis, Pinus wallichiana, Arundinaria falcate* and *Berberis aristata* at the lower elevations near Ghasa whereas it is mixed with *Pinus wallichiana, Abies spectabilis, Taxus wallichiana, Rhododendron spp* and *Tsuga demosa* at higher elevations. *Berberis spp, Sarcocca hookeriana* and *Sophora moorcroftiana* were the bushes and shrubs that occurred in association with *H. salicifolia.* Forbs and grasses on lower strata occurred in trace amount, however, *Girardinia diversifolia, Persicaria chinensis, Arisaema tortuosum, Artemesia vulgaris, Cannabis sativa, Ajuga spp, Gynura nepalensis* and *Inula cappa* were much common at higher altitude.

Based on the study of the associates, the species like *Pinus wallichiana, Inula cappa, Berberis spp* and *Pyracantha crenulata* seemed to be gradually invading the seabuckthorn area at higher altitude. Near Ghasa, *Alnus nepalensis* is gradually colonizing the area. At the areas of higher elevations like in Ilankhu, the regeneration of seabuckthorn is nil and *P. wallichiana* is gradually replacing the seabuckthorn. However, the seabuckthorn forest is almost pure along the bank of the river.

Various plant species recorded from various sites of the study areas as the associated species of *H. salicifolia* have been given in Appendix 7.

Frequency of Associate Species

Frequency of associated species studied on the sample plot survey was calculated by the formula:

$$\text{Frequency} = \frac{\text{Total Number of Quadrates in which a Particular Species Occurs}}{\text{Total Number of Quadrates Sampled}} X\ 100$$

Frequency of common associates of seabuckthorn has been shown in figure below and details have been given in appendix 8.

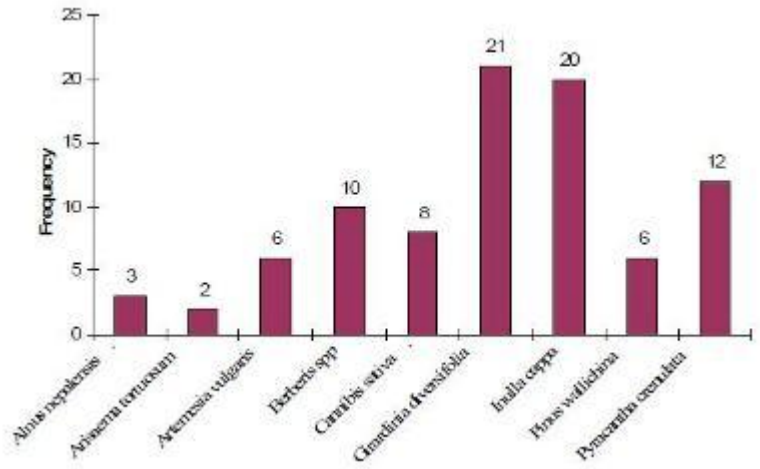


Figure 13: Frequency of Some Common Associates

4.4 Biomass Production

From the estimated regression models, biomasses of wood, leaf and fruits were estimated for each tree within the 10 × 10 m^2 plots. As leaves and fruits are produced annually, sum-total of the biomass of fruits and leaf per plot was considered as the actual annual production per plot. So by multiplying by 100, annual production per hectare of the fruits and leaves were estimated. Regarding wood, sum total of the biomass as calculated for fruits and leaves within the plot would give growing stock of wood. So to calculate the mean annual increment (MAI) and current annual increment (CAI), the relation between age and diameter was also estimated. Among several tested equations, the best fitted equation for the relationship between diameter as dependent variable and age as independent variable was:

$$\ln (Age) = 0.068 + 1.002 \ln D \text{ (adj. } R^2 = 0.903, p<0.001).$$

Table 16: Parameter Estimates, Adj. R^2, SEE, CF, VIF and p of the Selected Models

SN	Formula	Parameter Estimates		Adj. R^2	SEE	CF	VIF	p
		Coefficients	Std. Error					
1	ln (Age) = a + b ln D	a = 0.068 b = 0.002	0.165 0.061	0.903	0.309	1.05	1	0.000 0.000

After estimating age of the individual trees, the MAI was estimated by the formula

$$MAI = \frac{Total\ \ Wood\ Weight\ up\ to\ a\ \ given\ \ Age}{Estimated\ \ Age}$$

The current annual increment was estimated by the help of the relation Biomass = f (f (age). By differentiating this relationship, increment of the tree that puts on the given year was estimated. Based on these relationships, diameter at the given age was computed and CAI of wood was estimated.

4.4.1 Biomass Production of Wood

With the help of the developed regression model of wood, i.e. ln W = -3.243 + 2.486 ln D, an age-diameter model and the diameter distributions observed within the sample plots, oven dry

biomass of wood (growing stock) in kg was estimated at 44.5 tons per ha. This figure is actually the average growing stock per ha distributed over 61 ha of seabuckthorn land. When the plot data were analyzed by the ANOVA, there were not any significant differences between the growing stocks of the different plots of Kali Gandaki River, Lete River or upper part of the river belt.

Using the biomass equations, an age-diameter model and the diameter distributions observed within the sample plots, the mean and current annual biomass production of wood per ha was estimated at 2500 kg and 4200 kg respectively.

4.4.2 Biomass Production of Fruits

With the help of the developed regression model of fruits, i.e. ln F = -3.509 + 1.407 ln D, fresh fruit biomass of fruits in kg was estimated for each tree (female only) of the plots. Then the weight of total fruits within the plot was estimated and later converted for hectare. The result showed that total annual fresh fruit production per ha was 450 kg which was distributed over approximately 61 ha of seabuckthorn forest. It was estimated that there were over 15000 fruiting seabuckthorn trees in Lete and Kunjo VDCs. The result from the destructive sampling showed that a matured tree could produce up to 10 kg of fruits. The seabuckthorn trees produce fruits from the age 3-5 (Lu, 1992) but in Mustang, the trees of 5 years were found to produce fruits. The sex of the species could only be identified at the age of five in Mustang and the plot information showed that there were 60 % male trees and 40 % female trees.
It was not possible to compare the estimated biomass production of fruits with the production at the other areas because of the lack of such studies regarding *H. salicifolia*. However, there were some data relevant to the annual production of fresh fruits for *H. rhamnoides*, a shrubby natured seabuckthorn. Haq and Hughes (1995) reported the shrub to yield between 500-750 kg of berries/ha annually. Nizami (1996) also reported to yield between 750 to 1,500 kg of berries per hectare per year from a natural forest. In Germany, it was reported to yield 5 ton per ha from an orchard plantation and an orchard planting can yield up to 10 ton of berries of *H. rhamnoides* per ha (Oliver, 2001). So based on these data, the production in the study area was found to be less. The production was less probably because the ratio between male and female was 3:2. In general, the normal ratio between male and female in natural forest is approximately 1:1 (Lu, 1992). According to Lu (1999), one male tree is enough to fertilize 14 surrounding female trees up to 100 m apart. Therefore, for optimum production, about 7 % of male tree is enough for pollination. However, investigations have shown that as the distance from the female plant to the male plant (polliniser) increases (64 m or so), the yield of the female plant decreases. It was estimated that an orchard with 4,000 trees/ha and a 1:6 male and female ration, should yield approximately 10 t/ha (Li and McLoughlin, 1997). Hence, it was obvious to obtain lower production of fruits because the number of male trees in the study was comparatively very high. Moreover, there were almost 20 ha of land at the upper part of the river belt area where the annual production was approximately 300 kg/ha/year. This was much less in comparison to the river belt areas of Lete and Kali Gandaki rivers (approximately 500 kg/ha/year).

4.4.3 Biomass Production of Leaves

With the help of the developed regression model, i.e. ln L = -4.04 + 1.384 ln D and the diameter distributions observed within the sample plots, annual leaf biomass production per hectare was estimated at 1800 kg. The results of the biomass productions of leaves from the three areas – along the Kali Gandaki River, along the Lete River and at the upper parts of the river – showed that there were no significant differences in production among the areas at

confidence limit of 95%. There have not yet been any studies done regarding the production of seabuckthorn leaf, so no comparison was possible in this regard.

4.5 Socio-economic Characteristics

The ethnic composition comprises Thakali, Gurung, Brahmin, Lama and Dalit (Damai, Kami and Sarki). Thakalis are in majority and Gurung, Lama and Brahmin are in minority. Total respondents of the project area consists almost 55 % male and 45 % female. The ethnic composition and sex ratio of the project area have been given in figure 15 and figure 16 respectively.

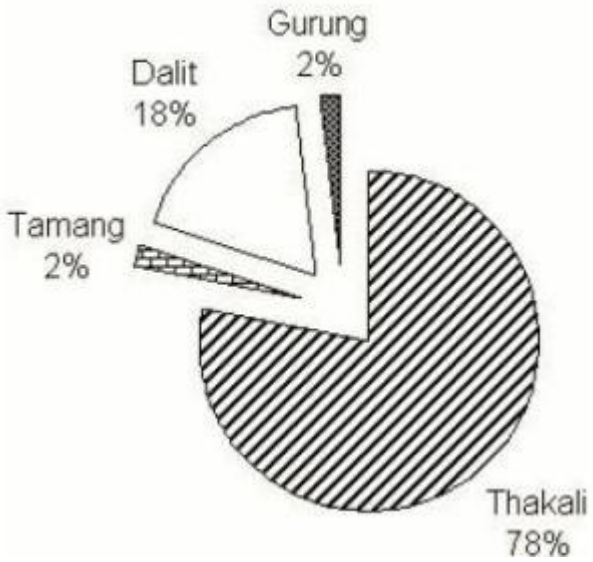


Figure 14: Ethnic Composition of the Respondent

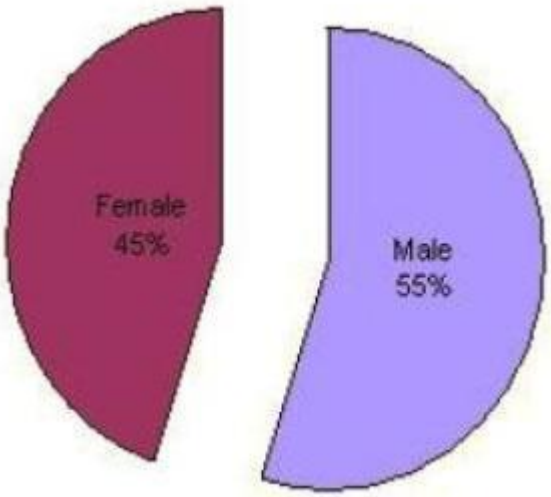


Figure 15: Sex Ratio of the Respondents

Thakalis are the main hotel owners in the project area. The Annapurna trekking route lies along the Lete and Kowang VDCs and almost all the tourist stays and rest in the hotels of the trekking route especially in Lete VDC. There are some hotels in Kunjo VDCs but these are not popular to tourists. Therefore, the hoteliers of Lete VDCs are mainly involved in activities of seabuckthorn juice marketing.

4.6 Ethnobotanical Uses

Seabuckthorn has been used by human beings of the Himalaya since the time unknown as food, medicines, fodder and fuel wood. It has been described as the most appropriate multipurpose option for mountain areas because it helps in reconciling high productivity through intensive land use in the mountains with land extensive usages dictated by the fragility and marginality of mountain slopes. It has potential to support high value-added products, which can be integrated within the market economy, as well as to support the rehabilitation and upgrading of marginal or fragile slopes through soil binding and building in mountain areas. However, local people in Mustang district have so far reaped a small fraction of its benefit despite the great potential of this species.

Used as Fuel Wood: The question of domestic fuel wood supplies in the developing countries has gained prominence in the past decades and it is more important in the Himalayas due to very low temperature and lack of alternative energy sources. For the mountain people, plant biomass is the most important source of energy. Resolving the problem of energy shortage in such areas is a big challenge. So, seabuckthorn tree has proved to be a popular green energy plant because of its high quality biomass. Before the knowledge of high cost of juice, the local people used the wood of the seabuckthorn in huge amount destructively. Blacksmiths and goldsmiths especially liked the charcoal. However, after the training of juice making, the local people have been quite aware of the resource and the people now use the dead and drying wood of seabuckthorn. The forest user groups of Lete and Kunjo have made provision not to collect the green seabuckthorn wood for fuel wood. Although the wood produces pungent smell, the people were found to be using its stem, branches and twigs in priority. They said the smoke keeps the fleas away. Because there are more male trees in the forest, they can use the male seabuckthorn tree as fuel wood and plant new seedlings in the felling areas.

Use of Leaves: The leaves of seabuckthorn contain many nutrients and bioactive substance. The leaves of either male or female plants have similar nutritive compositions but in the natural groves of seabuckthorn, it is often found that the quantity of male plants is larger than female plants (Lu, 1992). Because male plants do not bear fruit, their leaves can be used as forage, mulch, green manure and other commercial products. The local people were not found to use leaves as commercial products like oil and tea. During the discussion with the forest user groups and household survey, when the researcher mentioned that the leaves could easily be used as tea, the local people requested to teach making tea eagerly.

They were still not able to produce high value oil from the leaf. Regarding fodder, the local people was not found to prefer it owing to its thorn. However, dung in the seabuckthorn forests clearly indicated that the leaves, twigs and tender branches were being eaten by goats, cows, mules, donkeys and Himalayan yak. The local people were most likely found to use seabuckthorn leaves as mulch and green manure in potato farming. They had observed that the use of its manure produced high yield.

Use of Pulp and Seed: When the fresh fruit is squeezed and juice is extracted, many residues (seed and pulp) remains. The local people can extract approximately 65 % of juice from the fruits and they dry the remaining residues (pulp and seed). Just the past few years ago, these residues were of no use for the people and they used to leave them in the forest where they squeezed the fruit. Now, these were collected, dried and sold in Kalopani Guest House at the

rate of NRs. 85 per pathi (approximately 1.5 Kg). These residues are later collected by a foreigner probably for extraction of oil.

Photo 12: Seabuckthorn Wood as Plough

Use of Wood: Straight, sturdy and stems of bigger girth and height of seabuckthorn tree were found to be used in:

- Support or legs and frames of bed-stead, chair, door and window
- Axles of water-mills and wheels
- Planks for bridge construction and roofing; the wood can withstand moisture, i.e. it is durable in water.
- Plough and other agricultural implements, especially tool handles
- Wooden vessels to store and ferment milk; it was said that milk stored and curd fermented in the vessel made of male trees becomes tastier than that of the wood of the female tree
- Horse and mule saddles

Use of Fruit: The most important part of seabuckthorn is fruit, which has been used in various ways.

1. **Chuk:** About 8 to 10 litres of juice is boiled to make concentrate of 1 litre, which is called chuk. It is black in colour and its pH is 2.47 when tested in lab. Almost all the local people prepare and store it in a quantity of half to one kg and it can be stored for many years. The product has not been found to sell for fetching money, nor does it have any commercial value locally at present. It has been made for local household consumption only. It has been found to be used for the following purposes:
   i. **In Food Preparation:** Chuk is added in various food preparations, pickles, sauce and condiments. This not only makes the foods tasty but also reduces the bitterness of some wild and domestic foods.
   ii. **For Neutralizing the Effect of Poisoning:** Domestic cattle, while grazing mistakenly eat the poisonous plant species like *Arisima wallichiana* (Banko), with other palatable grasses, a mixture of chuk and salt dissolved in water is administered to the ailing animal. It was believed that the dose neutralizes the effect of poison and the animal gets relief from the trouble. This treatment was popular among the villagers and cattle owners. It is also used to neutralize the effect of poisoning in human beings.
   iii. **In Medicine Preparation:** The juice is very popular in Tibetan medicine to care edema, fever, furuncle, abscess, stomach tumor or growth, digestive problem, pain in the stomach, liver, chest, lumbar and menstruation problem. Similar to juice, chuk in the study area was used in:
      a. **Dental Problem:** Chuk and turmeric mixed or chuk alone is used as paste. Brushing teeth with it reduces pain as well as brightens the teeth.
      b. **Expectorant, Tonsillitis, Throat Pain or Vocal Problem:** Chuk is externally applied at the affected area. It is also mixed with hot water and drunk.
      c. **Joint Pain, Hurt, Muscular Pain and Swelling:** A mixture of black salt and chuk or chuk alone is prepared and daubed at the affected parts. They preferably cover the parts with a piece of Bhojpatra (bark of *Betula utilis*).
      d. **Appetiser, Gastritis and Asthma:** They use both chuk and juice mixed with food or water to increase appetite or to reduce gastritis.

e. **Menstruation Irregularity:** They mix chuk or juice with hot water and drink to regulate menstruation.
f. **Dyeing Wools:** Chuk is used to sharpen and fasten the colours in the wool.

Photo 13: Seabuckthorn Nursery, Lete

2. **Squash and Other Products:** As developed by RECAST, Kathmandu squash should be prepared with 25 % crude juice, 40 – 45 % sugar and rest water (Vaidya, 1999). Very few poor people were found to prepare and drink it; rather they sell the juice in raw to hotel owners. Only two dalits were found to prepare it in their households and they said that they finish the squash on the same day because of its sweet taste. During training by Nepal et al (2002), they were also taught to prepare jam, juice powder and fenugreek pickle. However, no people and hotel owners were found to prepare it. Very few people (approximately 5 %) were found to use fruit in alcohol and local beer (chhyang) preparation. A brief preparation process of these products as given in Vaidya (1999) has been given in appendix 9.

3. **Raw Juice as Medicines:** Similar to chuk, the local people were found to use juice for medicinal purpose. However, due to the problem in storage (huge in amount and fermentation in a short period), they were found to use it for short period in the year.

4.7 Current Management Practices

The cooperation in the management of forests was found to be good in Lete VDC. For every social work, the forest user group (main committee) of Lete VDCs calls meeting and performs discussions in a participatory manner. This meeting decides the works to be done in a specified way on a specific date. During the programme, one member from every household must participate in the work; otherwise, they would be punished monetarily. The way of discussion, decision-making and implementation seemed that they have good cooperation among gender and different castes. For the seabuckthorn management, they have been carrying out nursery management, plantation and harvesting in cooperative way. However, in Kunjo VDC, management of seabuckthorn is poor. They followed the date declared by Lete forest users group for harvesting and rules were similar to Lete. There was no nursery and had never planted seabuckthorn in Kunjo VDC.

Nursery Management

There is a nursery in Lete where several species including seabuckthorn (*H. salicifolia*), Pine (*Pinus wallichiana*) and Taxus (*Taxus baccata*) were propagated by seed. Despite the lack of technicians, the forest user groups of Lete VDC prepared soil in polypots by mixing 6.5 % of cattle manure, 43.5 % of seabuckthorn forest soil and 50 % of sand of the riverbank. From the experience of nursery management from China, the soil mixture in the polypot and plain bed should be prepared by mixing sand, humic soil and soil beneath seabuckthorn forest in the ratio 5:3:1 for the best propagation of seabuckthorn by seed (Huo et al, 1989). Despite poor management, the germination rate in the seabuckthorn nursery, Lete is 73 %, which can be considered good because even good nursery has the germination rate about 80 to 95 % (Lu,

2003). When asked with the local people about improving the nursery for seabuckthorn, they unanimously answered that they were willing to produce many seedlings but they lacked technicians and there were even no ACAP staffs in the Lete office. An illiterate old woman, Purna Kumari B. K. (a nursery staff from DSCO, Jomsom) was looking after the nursery for about 14 years, but she lacks technical knowledge about seabuckthorn and nursery management. The nursery conditions showed that even weeding was not done.

Plantation

There were two plantation areas in Lete VDCs. The local people got the idea of producing seedlings in seabuckthorn nursery in 2004 when TISC/NARMSAP provided a short training about nursery. In 2006, they had planted seabuckthorn along with *Pinus* and *Taxus* in two areas of Lete VDC with their own knowledge. The establishment rate of the seabuckthorn seedlings in the areas was found to be good (establishment rate is almost 95 %). Though there were many areas in both the VDCs, sufficient seedlings have not been produced. The aerial photograph shown here (Photo 14) is of Chhoyo River, Kunjo, taken during field visit and it was said that there was a dense seabuckthorn forest before 1994 and it was destroyed by flood of the year. In 2005, the local people had constructed a spur in the river and now few seabuckthorn regenerations have been found in the area. If seabuckthorn could be planted in this area, there is high possibility of rehabilitation by the seabuckthorn forest. This will not only produce fruits and leaf litter for their livelihood and income generation but also conserve soil.

Photo 15: A local Harvesting Seabuckthorn fruit

Weeding, Pruning and Thinning

These improvement practices in seabuckthorn forests were not found in the Mustang.

Harvesting Fruits

The time of harvesting fruits is declared by the forest user group, main committee from when the seabuckthorn fruit is permissible to harvest. The time of harvesting generally starts from November 15 to 20. On the first day, only one member of the households is permitted to collect the fruits and from the next day, everybody can go for collection. For harvesting fruits, all the people cut the branches down on the ground and then extract raw juice with naked hand in the field. So on the first day, the local people collect the fruits from higher productive trees and easily accessible places. Those people, especially the hoteliers, who could not send their own family member for collecting juice on the first day, could hire other local people at a cost of about NRs. 150. From the second day, the family members of the hoteliers were not found to go for collection juice

Photo 14: A Potential Area for Plantation in Kunjo

because of difficulty in harvesting, remoteness, business in their own hotel management and less income from seabuckthorn in comparison to hotels income. Although fruits could be collected by beating with stick, it was not found to be practiced in the field.

4.8 Income Generation

The most important part of seabuckthorn for the income generation of the local people was found to be fruits although there were several opportunities to generate income from leaves by making tea. Income from seabuckthorn leaves could not be estimated because of the fact that the local people were using the leaves only as green manure and mulch in the agricultural crops. In addition, the income from wood could not be estimated because only three households were found using it for furniture in the past although almost all the people liked its wood. As the agricultural implements, wood has been used in limited quantity for handles and plough, which once prepared would work for several years. Regarding firewood, they have been collecting dead and drying woods from the forest not only of seabuckthorn but also of other species. These products have certainly supported the local people for their subsistence livelihood but these did not seem to be supporting in the income generation and uplifting the livelihoods of the poor. So, in this part, only the income from fruits has been analyzed.

Income Generation from Fruits

The local people collect the fruits for 4 to 5 days during which they harvest almost every easy and higher yielding tree from the forest; however as the fruits remain in the branches for longer time, they could collect the fruits later from the difficult areas and less productive trees as well. On the first day, they collect up to 5-7 litres and then up to 2-3 litres from the next day.

In 2005, approximately 1800 litres of seabuckthorn raw juice was harvested in Lete and Kunjo VDCs; 1100 being collected in Lete and 700 in Kunjo. Out of the collected juice, almost 60 % was used at household level as chuk for sour additives and local medicines and the remaining juice was found to be sold to the hoteliers. The table 16 and table 17 shown below describe total raw juice collected, used for households, sold from the surveyed household, and then estimated for the total population.

Table 17: Utilization of Raw Juice in the Surveyed Households

Location	Household Number	Household surveyed	Raw juice collection in litre	Use of raw juice in chuk	Raw Juice Sold
Lete	174	35	215	125	90
Kunjo	162	33	143	85	58
Total	**336**	**68**	**358**	**210**	**148**

Table 18: Utilization of Raw Juice in the Project Areas

Location	Raw juice collection in litre	Use of raw juice in chuk preparation	Raw Juice Sold by the local people
Lete	1069	621	447
Kunjo	702	417	285
Total	**1771 ≈ 1800**	**1039**	**732**

Therefore, the raw juice collection in the project area was 1771 litres out of which 1039 litres was used for household purpose and 732 litres was sold. The juice was sold not only at the

local hotels but also at Larjung and Jomsom along the route of the Annapurna trek. The price of the raw juice in the areas was NRs. 100 – 120. Most often, the local people exchange one liter of raw juice with one liter of oil amounting NRs. 110. With this price, the local people of the areas were earning approximately NRs. 80,520 excluding the opportunity cost of collecting the juice.

The squash was being prepared only by the hoteliers for commercial purpose. There were altogether 18 hotels in the project areas (Appendix 1) and each collect/buy 20 – 30 litres of raw juice for a year. The hoteliers prepare 5 liters of squash from one liter with the addition of sugar of amount and some preservatives amounting approximately NRs. 100. It needs dilution with three parts of water before serving. Therefore, total drinkable juice becomes 20 liters from one litre of raw juice. One litre of juice can be served for 4 tourists, i.e. one litre contains four glasses of juice with an average of NRs. 65 per glass (NRs. 25 for Nepalese in some hotels). The juice is especially popular for foreign tourists and for the analysis of the income, tourist price of the juice has been considered, i.e. NRs. 65 per glass.

So total quantity the hoteliers buy = 18 hotels *25 = 450 litres
Cost of raw juice = 450*100 = 45,000
Cost of sugar and preservatives for squash = 100*450 = 45,000
Total cost of production = 45000 + 45000 = NRs. 90,000
Total glasses of juice produced = 450 litres of raw juice*20 = 9,000 glasses
Total price of the juice = 9000*65 = NRs. 585,000
Profit = price – cost = NRs. 495,000

From the estimation above, the hoteliers were getting maximum benefits of NRs. 495,000 from the juice of seabuckthorn. While the local people were getting only about NRs. 80,000 excluding the labour cost. Summing the both would be NRs. 575,000. These figures shows that the local people who harvest the fruits from the forest area were getting only 14 % of the total benefits that would again be less if cost for harvesting is included.

Regarding income generation from pulp and seed, the local people had started collecting residue only from two years back. Residues comprise about 36 % of the total fruit (Field Report, 2006). From the last two years, the local people have been collecting residues (pulp and seed) from the field and they would dry at their homes. These were found to be sold in Kalopani Guest House at the rate of NRs. 85 per pathi, which would later be collected by a foreigner probably for extraction of oil. Though the dried residues could be sold, some people were still found to leave the residues in the field due to ignorance. When asked with Laxmi Gauchan (the owner of Kalopani Guest House) about the quantity of residues she collected from the villagers, she told that she had collected of amount NRs. 10,000 last year. So, total income generated from seabuckthorn fruits was estimated to be NRs. 585,000 in Lete and Kunjo VDCs.

Though the local people have started generating income from fruits, it has not seemed sufficient, sustainable and appropriate. The biomass production of fruits showed that 450 kg could be annually harvested from 61 ha, i.e. 27450 kg could be collected annually but they were collecting only 1770 kg. It is true that many places are very difficult to access, if not impossible to get there, but the current fruit harvesting quantity showed that the local people have so far reaped a very small fraction of benefit from seabuckthorn fruits despite the great potential. The local people will be able to collect at least 50 % of the total fruits from the forests if some trails are established in the difficult areas. Therefore, there is a high

potentiality to promote seabuckthorn as an off-farm income generating resource. The local people, during the harvesting of fruits, cut the fruiting branches and dropped down on the ground. The branch cutting not only eases the users to collect the fruits on the ground but also helps them to harvest more. So, in most of the cases, two members from two households go for collecting fruits so that one can cut down the branches and another can extract fruits. Serious disadvantage of removal of the fruiting branches is that the destroyed branches would never be able to fruit again and since seabuckthorn sets fruits on second year branches (Lu, 1990), harvesting by cutting the fruiting branches means that a harvest can be obtained only every three year, which is not economically viable option for the farmers of the Himalaya. The supply of natural products is directly tied to the overall health of an ecosystem and natural product enterprise will not be sustainable unless it balances environment (ANSAB, 2003a).

No people were found to be using globes during harvesting of fruits which resulted scratches on their hands by the acidity of fruits. Moreover, there is loss of juice during picking of fruits from branches by hands and the collectors leave almost 20 % of the fruits on the cut branches because of the time expenditure to collect from fewer yielding branches. When measured the time and quantity collected by their local method, it was found that they were collecting only 70 % of the fruits from the cut branches and the remaining 30 % got lost in the branches during collection. The people left many fruits on the tree due to difficulty in access. A study in Ladakh (India) showed that only about 20 % fruits are being utilized and the remaining 80 % are wasted (Dwivedi et al, 2006). The time taken to collect fruits with knife from a tree as in the case of collecting fruits in destructive sampling took more than five times. The timing of the harvesting becomes important factor to complete harvesting.

On one hand, the destruction of forest was of major concern during the harvesting of fruits due to competitive collection and on the other hand, there was a frequent comment of addition by hoteliers of water in raw juice. The addition of water not only complicated the recipe of the juice but also damaged the raw juice during storage for longer time. Moreover, there was not any strict recipe of preparing juice. A woman from a hotel said that she used to mix more sugar and water to prepare higher quantity of squash. She said that if water and sugar is boiled for whole night, it gives a dark yellowish/reddish colour solvent similar to seabuckthorn squash and little addition of raw juice could produce more squash than general popular method.

The local people were also not using leaves although it has ample opportunities to generate income from the preparing nutritious herbal tea. This was because they have no technical knowledge of manufacturing it. The tea can be manufactured easily in a cost effective way and can be stored for longer time as well.

When compared with the income earned from the seabuckthorn fruits by the local collectors and the hotel owners, income has been harnessed more by the richer section of the society, i.e. tourist hoteliers. Whistle the poor, who harvest the seabuckthorn fruits in the forests were getting very less. The rich earn almost 6 times more than the poor although their contribution was less in harvesting. If opportunity cost was included in the income generation of the local people (not hoteliers), which is assumed to be NRs. 200 per day and they spent for 4 days to collect 10 litres fruits (NRs. 1100), the local poor are getting very less benefits in comparison to the rich. The rich, i.e. the hotel owners could buy the raw juice, prepare the squash within one hour and sell the tourists at a higher price. When analyzed with benefit cost ratio, the

value for the hotel owners is 6.5 while for the other local people, benefit cost ratio is 1.4. So, the local poor are not getting their real price of their labour.

There are several opportunities to manage seabuckthorn forests in Mustang for generating income from seabuckthorn forest but it seems there is a need of community based management approach to develop seabuckthorn nursery, organize plantation, tending operations and manage the resource in sustainable basis. With this community based approach, the local people may get higher return in equity basis. Detail of community-based approach is given in chapter 4.11.

4.9 Threats

For the sustainability of natural resources, balance of environmental, social and economic consideration must be assured. The existing and possible threats, if not assessed, cannot only lead to the deterioration of the resource but also raise question on sustainability of socio-economic development.

Environmental Threats
Though seabuckthorn is abundant in the areas, the current harvesting practice has been deteriorating the productive seabuckthorn forest. Every year they have been cutting fruiting branches leading to less production in the following years. Other significant threats to be discussed were the fragile soil, steep slopes, steep river system and glacial lake outburst flood in the areas. The vulnerable soil fallowed by steep slopes may lead to the landslides and soil erosion. The steep river system and glacier lake outburst flood may also wipe the regenerating seabuckthorn forest completely as in 1994 at Chhoyo flood plain, when all the matured trees were shifted away by the river. As seabuckthorn is a pioneering species, there is high possibility of eliminating the seabuckthorn forest by other competing species like *Pinus* in course of plant succession. Moreover, the regeneration of the species in the existing seabuckthorn forest was almost nil leading to the un-sustainability of the resource. The regeneration of the plants was found poor because of extreme cold, human and animal interference, glacial flood, high velocity wind (TISC, 2001) and pioneering behavior. Free grazing of cattle in the forest may also degrade the forests by feeding on the regenerating seabuckthorn.

Social Threats
As stated earlier, there was poor management regarding nursery and silvicultural treatments (weeding, pruning and thinning). The poor management was obviously due to lack of technical knowledge among the local people and unavailability of technician. The ratio of male and female trees could be maintained by proper silvicultural treatments. They also lacked equipment to harvest fruits, like globes, which was causing harm in their hands during squeezing the fruit juice. The local people were still not aware of the resource condition, importance and possible economic benefits from the species. There was lack of publicity regarding seabuckthorn produce and regarding the residues, there was no market confidence for oil extraction from seed and pulp. Regarding laws and policies, the local people have been utilizing seabuckthorn resource according to their own knowledge without transgressed by any laws. So, specific laws and policies regarding seabuckthorn have not been developed yet.

Economic Threats
The felling of green seabuckthorn has been banned to use as timber for construction and other purposes such as for agricultural implements. Hence, the local people are not able to use

seabuckthorn wood as fuel wood sufficiently (they are only using dead and drying wood). However, they are allowed to harvest branches during collection of fruits. This means that they are collecting only female trees and not male ones. This is leading to the increase in the number of male trees in the forest, which means less productive forest. Regarding export of possible produce, market linkages and channels outside Mustang has not been identified for juice, seed and pulp oil and green tea from leaves.

CHAPTER 5: SEABUCKTHORN MANAGEMENT

5.1 Propagation Technique

5.1.1 Environmental Requirements

In natural conditions, seabuckthorn is found growing profusely on a wide range of soil types, but does better in soils with a light physical structure, rich in nutrient compounds, with a pH near neutral. Best growth occurs in deep, well drained, sandy loam with ample organic matter. Under cultivation, seabuckthorn has been grown on various types of soils: on chernozems, brown soils, grey forest soils, turf carbonates, turf-podzols, peaty loams and peaty-swampy soils with various physical structures such as sandy, semi-sandy, semi-clayey and even clayey in all horizons. Keeping in mind, conditions that best fulfill the needs of seabuckthorn root system regarding water and air relationships and soil pH near normal. Very light, sandy soils have low water carrying capacity and are also low in nutrient mineral elements; so without the previous addition of organic matter, are not appropriate. Similarly inappropriate are clayey soils, with high density and water retention characteristics. However, environment conditions discussed below are supposed to make the seabuckthorn propagation idea.

Temperature

Seabuckthorn belongs to the group of thermophilic plant because it needs higher temperature to germinate seeds than those of apple and cherry which can germinate at 1 to 3°C. Seabuckthorn seeds germinate only 13.2% at 12°C over a period of 47 days but if the temperature goes up to 24 to 26°C, 95% of the seeds will germinate within six days (Lu, 1992). During a study of germination and seedling growth of *H. salicifolia* and *H. tibetana*, Pyakurel (2001) found 20°C to be the best temperature to germinate seeds (growth enhanced by application of 10 ppm of gibberellic acid). He found that lower temperature decreases the germination and at 35°C, the germination was almost zero. Seedlings of *Hippophae* grow proportionately to the seed germination (Pyakurel, 2001) and it is unanimous that seedling grows best at that temperature where the seed germinates well (Koller et al, 1962).

Notwithstanding, an adult seabuckthorn plant can withstand extremely low temperatures; during the winter season air temperatures of -10 to -13°C are common in its natural habitat. It has been reported that seabuckthorn can endure an extreme minimum temperature of -40.4° C (in Northern China) and -43°C (in the Gorky State of the former USSR) without sustaining long-term damage (Lu, 1992). It has been mentioned that *Hippophae* contains several species and sub-species that are widely distributed throughout various physical environment of Eurasia and Asia, therefore it is understood that they survive in different climatic conditions.

Moisture

According to Lu (1992) and Ghaffar (1997), though seabuckthorn is a hydrophilous plant, it has developed some xerophytic features. In its natural habitat, it thrives well on river banks, valleys and shady slopes of mountains where air temperatures and soil conditions do not suit many agricultural crops. Most natural population grows in areas receiving 400 to 600 mm of annual precipitation. Seabuckthorn plantation is not considered good in the sites where the annual rain fall is less than 400 mm, the underground water below 2 m and where there are no irrigation facilities. Natural seabuckthorn populations are widely distributed throughout the temperate zones of Asia and Europe and in the subtropical zone of Asia and higher altitudes. In the mountain areas, the most suitable altitudes are between 1500 to 2500 m where precipitation is about 600 mm and the mean annual temperature is 4 to 8°C, as a result of which plants grow well and produce large, good quality fruit (Lu, 1992).

Soil

In the natural environment, thriving seabuckthorn plants are found on sloping, well-drained soil with silt and on the banks of rivers, lakes and seashores. This is the reason why many researchers considered these soils to be most suitable to the biological characteristics of seabuckthorn. Indeed, these soils provide seabuckthorn with enough water, air and fertilizer, thus making it grow well and producing fine fruit. Some plants have proved successful even on sandy and stony soil. Heavy clay may be suitable in some areas but only if internal drainage is good. The plant cannot withstand soil with poor porosity. Excess water and lacking of air would kill the plant. Extensive measurements taken for wild seabuckthorn populations in north and north-western China have shown that the plants thrive in soils ranging from pH 6 to 7, but in other places, they have been found in soils ranging from pH 5.5 to 8.3 (Lu, 1992). This indicates that soil acidity and alkalinity are probably not limiting factors but the experiences on plantations have shown that the productivity of seabuckthorn can be increased greatly by providing enough water and fertilizer (Lu, 1992). Researches have shown that the best soil composition in the polypot and plain bed should be prepared by mixing sand, humic soil and soil from seabuckthorn forest in the ratio 5:3:1 (Huo et al, 1989).

Salinity

Seabuckthorn is also a salt-tolerant plant because it grows well on the soils of wastelands, deserts and dunes of the seashore that have highly concentrated salt contents. It can also be used to reduce the soil salinity. When tested in the laboratory, some varieties of seabuckthorn showed increasing growth of seedlings when about 0.15% of sodium chloride solution were added. Furthermore, before sowing, soaking seabuckthorn seeds in 0.15% of sodium chloride solution for 24 hours not only produced healthy seedlings but also increased the output of standard seedlings in nurseries (Lu, 1992).

5.1.2 Cultural Management

Drainage and Irrigation

Seabuckthorn can tolerate a little drought but it is a moisture sensitive plant especially in the spring when plants are flowering and young fruits are beginning to develop. Planting in arid or semi-arid areas, water must be supplied for establishment. For economic reasons, seabuckthorn plantings should be restricted to areas receiving a minimum of 400mm of annual precipitation, unless irrigated. It cannot tolerate over the crown, high water table or long-term inundation (two weeks), therefore situating plants on sandy loam soil on slight slopes with good drainage is best. The optimal soil moisture for mature, seabuckthorn, depending on soil type, is around 70%; inadequate soil moisture causes a reduction of leaf area and fruit set. Seabuckthorn has high requirements for nutrient mineral element content of the soil. The micro-element consumed in the highest quantity is phosphorus. It is indispensable for the normal life process of the nodules on the roots. The plant requires little nitrogen, and potassium is negligible.

Soil Testing

Results from a soil analysis are the most accurate guide to fertilizer and lime requirements. It is important to determine soil fertility and pH levels before planting, so that necessary lime and fertilizer can be applied to the soil.

Fertilizer Recommendations
Seabuckthorn, just like any other crop, requires adequate soil nutrients for a high yield of good quality fruits. Seabuckthorn responds well to phosphorus fertilizer, especially in soils low in phosphorus. Fertilizer recommendations should be based on the results of soil analysis.

Method of Fertilizer Application
There are various methods of fertilizer application. It can be broadcast on the soil surface and incorporated into the soil with tillage. Top dressing method can be used when seabuckthorn is growing.

Lime
Seabuckthorn can tolerate a wide range of soil pH, but a pH level between 5.5-7.0 is ideal. Soil acidity can be corrected by the application of lime. Use of some dolomitic limestone is recommended since it contains a significant quantity of magnesium which is an essential and often deficient plant nutrient. Quick lime, caustic lime, and burned lime are not recommended on agricultural land.

Manure or Compost
Manure or compost supplies plant food over a period of time; cow and poultry manures are commonly used. Maximum application rates of dairy manure should be about 45 tonnes/ha and poultry manure should be applied at no more than 20 tonnes/ha on cropped land.

Cover Crops
A cover crop before the land is to be planted with seabuckthorn is valuable in increasing organic matter in the soil and preventing nutrient losses and erosion by wind and water. Barley, oats or winter cereals such as winter wheat and fall rye at the rate of 80-150 kg/ha can be seeded in the fall and plowed under in the early spring to allow decomposition before seabuckthorn planting.

Nutrient Deficiencies and Corrective Treatments
There is very limited information in the literature regarding the nutrient deficiencies on seabuckthorn. Some of the information is based on other crops, fertilizer recommendations are quoted from other countries research institutes publications as follows:

Symptom	Deficiency	Treatment
Foliage is pale green or yellowish and later leaf senescence and dehiscence are accelerated, plants are smaller than normal, leaf area is reduced	Nitrogen and/or phosphorus deficiency	Nitrogen and phosphorus fertilizer should be applied early in the spring in the forms of ammonium nitrate around 20g/m2 and phosphate fertilizer (superphosphate) should be added in the fall at a rate of 20-30g/m2, the rates should be based on the results of soil analysis.
Pale leaf colour, marginal chlorosis, scorch, shortening of stem internodes, death of the terminal bud	Potassium deficiency	Potassium fertilizer should be added with the phosphorus at 20-25g/m2 of potassium chloride.
Terminal leaves normal, basal leaves marginal	Magnesium deficiency	As required Custom blend

chlorosis with V pattern, this symptom occurs when potassium is high or soil is acid, especially in young, vigorous trees and defoliation begins from the base of shoots and progressively affects the leaves above		
Delayed opening of flower and leaf buds in the spring, small chlorotic leaves, shortened internodes and little leaves along the shoot, reduced growth and small fruits	Zinc deficiency	As required Custom blend
Loss of chlorophyll and leaves become chlorotic, interveinal areas become yellow but the veins remain green, symptoms develop first on young leaves	Iron deficiency Iron deficiency can result when there is insufficient iron in the soil, sufficient but unavailable iron or sufficient and available iron that is not properly utilized in the plant	As required Custom blend

Other Symptoms caused by Physiological Factors

Symptom	Factor
Smaller crowns and lower yields	Result of shading effect. Seabuckthorn can only be grown on well-lit unshaded areas
Poor growth and beginning of rot at the root zone	Too much water or ground water level is too high. Plant seabuckthorn on slight slopes or sandy loam soil with good drainage
Small leaf area and low fruit set	Lack of adequate soil moisture. Seabuckthorn is a moisture loving crop which needs irrigation regularly especially in the summer
Die back of branches with late emerging small leaves	Winter or frost damage
Breakage of branches	Heavy damp snow clings to branches
Leaves wilt, turn yellow and drop	Lack of moisture

5.1.3 Planting

Sterilization and Fumigation of Soil

Normally soil fumigation is not needed before seabuckthorn planting unless the field is known to be infested with disease in previous crops, which may affect seabuckthorn; an example would be root type crops.

Land Preparation
Ideally, soil preparation should begin at least a year before planting. Planting site should be well cultivated, removing all the roots of perennial weeds. Depending on soil analyses, a good cover crop, such as rye or green vegetable, before planting is recommended to increase organic matter in the soil. Light sandy soil has low moisture retention capacity and may be improved by the addition of organic matter, manure or various composts. If the soil pH is too low, liming the entire surface is necessary; also clay and heavy loam without mineral improvements are unsuitable for seabuckthorn.

Propagated by Seeds
Propagation from seed is relatively simple and produces a large number of seedlings at low cost compared with other propagation methods. Seeds can be stored up to 3 years before lost viability.

Seed Treatment
For seabuckthorn, seed can be treated with hot water, some chemicals or bleaching solution before seeding for higher performance of seed germination.

Hot water
Prior to sowing, the seeds should be soaked in water for 48 hours and at this time seeds that are floating should be discarded. Soaking in cold water can also be done for three days prior to sowing. Other reports indicated that soaking seeds at a temperature of 70º C and stirred intermittently until the temperature drops to 10-15º C then leave standing 48 hours may improve germination rate. The results from experiment indicated that the water temperature did not show any significant differences for germination rates, but seed soaking before seeding shortened the days required to start and complete germination compared to non-soaking seeds.

Chemical
Experimentally, seeds were treated with GA_3 and KNO_3 (rooting hormone) for 48 hours before seeding which did not improve germination rate significantly among species tested.

Bleach Solution
To prevent fungal infection of cotyledon on emergence, it is recommended that soaking should be performed for a 20-minute in 10% bleach solution before planting. The ratio of 10 parts water to 1 part bleach is based on 5.25% sodium hypochlorite content, which is the normal concentration in household bleach.

Direct-Seeding Outdoors - Seed Depth and Germination
The results from experiments indicated that seeding at soil surface has significantly higher emergence rates than the depth of 1 and 2 cm. Soil should be irrigated (mist) periodically to prevent seeds drying out. If seeding in late spring, seeds should be covered with a very light layer of soil. Seeds should start to germinate within 5-10 days based on the condition of the seeds and the species of seabuckthorn. A number of seeds per planting site are recommended at spacing of 1 m within the row and 4 m between the rows.

Seeding Indoors and Transplanting
Seabuckthorn seeds can be seeded indoors in pots, in sterilized soil, in January or early February, one seedling per pot is allowed to grow for 3 months before transplanting in early

May. Manufactured tree seedling trays can be used for early greenhouse mass production. Size recommended is 2"-4" diameter - 12" deep. Spring is the best time for planting seabuckthorn. On light sandy soil, the root is buried 6-8cm deep to encourage the development of another tier of roots. They should be watered once every week after transplanting. In orchard planting, a spacing of 1 m within the row and 4m between rows is recommended, although high density planting of 1X1 m is being considered in Europe. Rows should be oriented in a north–south direction to provide maximum light.

5.1.4 Propagation by Cuttings

Cuttings produce rooted plants with the same genotype as the parent plant. The cuttings will bear fruit 1-2 years earlier than seed propagated trees. Seabuckthorn can be propagated using hardwood, softwood cuttings, layering or suckers.

Hardwood Cuttings

Hardwood cuttings should be chosen from healthy, well-developed plants in fruiting stage. Cuttings (15-20 cm long) should be taken from the previous year's growth during dormancy in the late fall or in the early spring. One week before planting, bundles of cuttings are soaked in water (room temperature and change once a day) and covering 2/3 of their length until the beginning of root formation. Cuttings can be transplanted when the roots are 1-2 cm long. Rooted cuttings can be directly planted outdoors in the field, but planting in pots, under a controlled environment for 1 to 2 months before transplanting will give better results.

Softwood Cuttings

The advantage of softwood cutting propagation is its high success rate. Softwood cuttings (15-20 cm long) are taken when shoots begin to become woody. Remove the lower leaves, leaving 2-4 leaves at the tip and dip into rooting hormone before rooting in media such as sand. Pay special attention to the moisture of the media (mist). Root cuttings should be planted in pots for 1-2 months before transplanting to the field.

Root Cuttings and Suckers

Root cuttings also can be an effective propagation method for seabuckthorn. Root cuttings are planted in pots in a greenhouse for 6-8 weeks before transplanting to the field in spring. Seabuckthorn easily produces suckers within a few years of planting, which is a good source for propagation, but sometimes do not carry the good genetics of the mother plant.

5.1.5 Male/Female Ratio

For economic reasons, the ratio of male to female plants is important, as the number of female trees in each planting directly affects the total yield. If seedlings of unknown sex are planted, it may result in an uneven distribution of male and female plants within each planting. There are two approaches to avoid this problem, remove male plants and replace with female plants, or vegetative propagation from mature plants of known sex. Recommendations for male and female ratio vary from 6 to 12%. A report from Siberian Institute of Horticulture in Russia indicated that one male: female mixed row for every two rows of female plants and in the mixed row every fifth plant is male. This design gave significantly higher total yield than other designs. It is estimated that orchard planting with 4,000 trees per hectare and 1:6 male and female ratio, should yield approximately 10 tonnes.

Pruning

The purpose of pruning seabuckthorn is to train branches, promote growth and facilitate harvesting. Moderate pruning will increase the yield and fruiting life of the plants. The crown

should be pruned to remove overlapping branches, and long branches should be cut to encourage development of lateral shoots. Mature fruiting plants should be pruned to allow more light penetration. Pruning is also recommended to eliminate thorns on the mature wood to facilitate harvesting.

Mulches and Row Covers

In an orchard planting, it is ideal to have row covers such as grass between rows to reduce loss of soil moisture. Mulches between trees within the row will reduce the cost of weed control and keep soil moisture and temperature to promote better growth. The use of black plastic during first 3-4 years from seed is ideal for moisture conservation and weed control.

5.1.6 Pest Management

Insects, Diseases and Others

At present time, seabuckthorn has relatively few pests and diseases. In tea production (leaves) the most damaging of insects is the green aphid (Capithophorus hippophae), which can be controlled with an insecticide soap. The most serious diseases in seabuckthorn is verticillium wilt, scab, damping-off and fusarium wilt. Mice and rats are other pests, which can destroy and girdle the trunk or chew up roots. Game birds, such as pheasants or grouse eat berries during the winter months, but ordinary birds do not touch. There are no insecticides and fungicides registered in Canada for seabuckthorn.

Weed Control

Weed control or vegetation management is very important in seabuckthorn plantings. Proper weed control promotes growth of newly planted seedlings. Only low concentration of herbicides should be used. Several chemicals are registered in Canada for weed control. As stated, black plastic may be used to control weeds during orchard establishment, also to retain standards for organic production.

5.2 Harvesting Techniques

As discussed earlier, the harvesting technique of the local people was the major concern in the sustainable management of seabuckthorn forest. The current harvesting practice seemed to be destructive and good harvesting techniques are necessary. The harvesting of ripe fruits of seabuckthorn is the most difficult and time consuming operation (Li and McLoughlin, 1997; Dwivedi et al, 2006) because it is highly thorny and fruit being soft, small, delicate and highly perishable and attached strongly to the plant poses difficulty in the operation. There are several techniques of harvesting fruits being practiced in the developed countries like Canada and China. The harvesting techniques have been discussed here and tried to find out the better options for the locality.

5.2.1 Hand Picking

Hand picking of fruits from the standing tree was not a general practice for seabuckthorn in Mustang because it is a time consuming process and as trees are tall, it is difficult. More than that while picking the berries by squeezing with the help of hand, some of the berries get ruptured resulting in the loss of juice. Some of the schoolteachers, officials and other interested people who want to ensure the hygiene of the juice may not like this method. It is a pretty time consuming method and requires better passion. Obviously, it is a labor-intensive method, so requires more investment.

5.2.2 Cutting of the Branches

Cutting or slashing of the branches / branchlets is not a legal approach in Mustang but due to difficulty in other methods, the local people were allowed to cut branches on the specified period of time to harvest fruits. This method is quicker and easier than hand picking. One person can harvest about 2 kg of ripe fruits per hour by this method (field study, 2006; Dwivedi et al, 2006).

5.2.3 Beating the Branches using Sticks

It has been observed that harvesting of fruits is comparatively easier and effective in early morning hours before sunrise when the air temperature is almost 0º C, since subsequently fruits develop turgidity and after sunrise it becomes difficult to harvest (Li and McLoughlin, 1997). Some of the people use sticks to shake the berries from the plant and drop down the fruits. The positive aspect of using shaking method to harvest the berries is that one does not have to suffer from the thorns and the picking becomes easy and quick. But the negative aspect of adopting this method is that all the dried leaves and other unwanted parts of the plants including the insects also get mixed along with the berries and the juice. The berries must be completely ripe to ensure the complete harvesting by this method. A greater difficulty with of this method is that as the temperature increases the fruits do not fall and all the branches are not accessible in the tree. Use of ladder has also been practiced to reach the height of the tree.

5.2.4 Mechanical Harvesting/Shaking

Except when frozen on the branches, fresh fruits mechanical harvesting method is still in the development stage. Principally, this is due to the difficulty in separating the stem (pedicel) from the berry (pericarp). Prairie Agricultural Machinery Institute, Partage La-Praire (Canada) has designed an individual branch shaker for harvesting fruits. The branch shaker shakes the branches with a frequency of 1200-1500 cycle per minute and amplitude of 1-1.25 inch and takes about 30 second to harvest approximately 70 % of ripe seabuckthorn fruits (Dwivedi et al, 2006). However, mechanical harvesting/shaking needs huge money and power and sufficient space, which is not currently possible in Mustang.

5.2.5 Using Forks

Forks, used in kitchen can be better in the sense that people have been using such equipments as they found it easier to work with (Nepal and Adhikari, 2003). More than that, the essence of using forks is that it can be used to get the berries from the plant without any loss of juice and without damaging the plant itself. Plus, in terms of hygiene, it is better than other options as it is used to collect the berries much selectively. It can be a bit more time consuming in comparison to some of the other options.

5.2.6 Using Mineral Water Bottle

In Manang, some local people are adopting using mineral water bottle direct from the plant (Nepal and Adhikari, 2006). The bottom part of mineral water bottle is cut in such a way that it looks like U-shaped fan. With the help of rope and a long stick, the berries can be collected without damaging the plants. For the conservation of resources, this method seems very nice but it is not economically feasible. Per unit time harvest of the berries is very low in comparison to the other methods tested (Nepal and Adhikari, 2006).

Easiness of the tools and technique is one aspect that draws more attention of the harvesters. No matter how efficient is the method; harvesters may not accept and use the recommended option if it is not user-friendly. There is no doubt that the local people are those who have

gathered lots of experiences from the history and modified themselves to meet the newer challenges by developing their own skills and knowledge's. In this context, it is imperative that the scientific verifications must analyze the local knowledge base and if possible, should add more innovations as to make the skills and tools locally used by the local people. Providing due respect to the local knowledge base and based on the scientific information shaking/beating could be better option. The local method of using mineral water bottle may also hold good. For the remaining berries, kitchen forks or modified bi-furcated hooks can be used. If some community based resource management options are used, these options may be practicable and sustainable and may reduce the branch cutting.

5.2.7 Post Harvest Handling and Storage

After harvest, the berries should be placed in shaded area in flats no more than 6 inches (15.24cm) deep. Pre-cooling for storage is advisable if high temperatures (20° C) at harvest, especially if breakage occurs at harvest and before cleaning. Fresh market berries, after cleaning, should be delivered and sold within five days. After cleaning, residue (burst berry etc.) can be included in fruit shipment for processing (jams, soils, etc.), where quick frozen, remaining at -18° C until required in processing plant. Seabuckthorn does store very well. Respiration is minimal in comparison to other berries such as saskatoons or raspberries. During storage at 20° C, the respiration rate comparison is saskatoons 100, raspberries 200 and sea buckthorn 50. If berries are to be transported to a processing plant, growers should build a pre-cooler on their property, relative in size to yield. A walk-in type cooler/wind tunnel is relatively inexpensive to construct. Maximum containment in cooler of ten days is recommended before shipment in cooler transport, to the processing plant. Transport should be contained (once fruit is cooled) in plastic wrapping, and then placed in cold storage at the processing plant at a temperature below freezing (-1 to -2° C) if processed within 30 days. Fruit can be frozen to -18° C for long-term storage (1 year) without further loss of ingredients.

5.3 Merchandise from Seabuckthorn

The basic processed seabuckthorn products are juice, beer, wine, jam, preserve, compote and tea (from leaves). Essential oil from seeds and berry pulp are the most valuable product, which has medicinal values. High contents of Vitamin C and carotenes are another valuable natural product. Considerable research is currently being conducted into the health foods, pharmaceutical, cosmetics and nutritional applications of seabuckthorn. Followings are some of the products, which can be manufactured locally and easily sold in the markets in a reasonable price.

5.3.1 Squash

The squash can be formulated with 25 % crude juice, 40 – 45 % sugar and remaining water. Sugar mixed with water is boiled and then juice is mixed. It is again boiled for a moment and squash is prepared. About 0.5 gm of potassium meta-bisulphide can be used for one litre of squash if it has to be stored for several months. It needs dilution with three parts of water before serving. The squash does not need any extra artificial flavors and colours as the juice contain its natural yellow and orange red colour and orange flavors.

5.3.2 Tea

Tea can be prepared from fruits and leaves. From leaves, the collected leaves can be quickly washed to sure the removal of dust particles. It should be fried for a while and twist it. Frying should be continued by stirring the leaves. It should be moistened after this frying. Second stir-frying should be continued and flutter it. It makes the leaves into dust particles and ready.

Now it can be packaged and sterilize to store for long duration. This tea can be used as commercial tea by mixing in hot water and serves with sugar if necessary. From the fruit, the juice of fruit can be used just as making lemon tea because the juice is very sour and nutritious.

5.3.3 Jam

Best quality jam can be prepared out of the fruit extract. The jam is prepared with 0.75 % pectin, 10 % juice, 70 % sugar, 1.14 % acid and remaining water. These are boiled until paste is prepared and then cooled.

5.3.4 Wine

The juice contained less amount of sugar and excessive amount of acid to make the wine, so addition of water and sugar is essential. The wine made with 10 kg sugar, 2 gm ammonium sulphate, 1.35 kg fruit juice and 38 litres of water should be mixed and heated to 60º C for about five minutes and then cooled. About 10 % of activated wine yeast should be added in the heated mesh and allowed to ferment for 3 – 4 weeks. Within that period, the fermented mesh produces a fine taste and flavour of wine. However, maturation for 6 – 8 months enhances fine aroma and clarity in the wine.

5.3.5 Juice Powder

The juice power can be prepared by mixing 100 gm of juice in a kilogram of sugar and 36 gm of acid and dried, preferably in electric oven at about 40 – 50º C and ground to powder. This powder easily mixes with water and gives a taste of seabuckthorn squash.

5.3.6 Fenugreek Pickles

Fenugreek is good for controlling blood sugar, Fenugreek seed and radish seeds should be roasted till dark brown in colour and grind to a fine powder separately. Other ingredients like, mustard seed, black pepper, cumin, ginger, turmeric, asafetida, salt powder and seabuckthorn juice and water should be mixed together in a steel vessel and boiled for 10 – 15 minutes. At the end, sodium benzoate should be mixed well and the mixture should be filled in a wide mouth previously boiled bottles. The lids of the bottle should be kept tight while hot.

5.4 Community Based Seabuckthorn Enterprise

Community based natural resource management programme, if successful, can be a model of local empowerment, imbuing communities with greater authority over the use of natural resources and bringing important benefits to poor people and poor community (Homes and Cooper, 2005). In Nepal, community based management of natural resources has conserved the forestry resources, created new jobs, including nursery staff, forest watchers, wage labour for tree planting and weeding and has produced commercial products exploring marketing channels to promote economic opportunities (Malla, 2000; Subedi et al, 2004). Community based seabuckthorn enterprise initiatives can be the best manifestation in the project areas to overcome the problems to manage and utilize the seabuckthorn forest. The community based enterprises have a scope for local economic development, harnessing social equity and conserving natural resources (Subedi et al, 2004).

The possibility of the success of community based seabuckthorn management for enterprise development has been assessed in relation to three concerned areas: the relationship between the community and the resource, the community's interest in collective management of the resource and the capacity of the community to carry out collective management (Woolcock,

1998). The relationship between the community and the resource is meant to document the community's use of and reliance upon the resource, in an economic or cultural sense. Based on this relationship, the community's knowledge of resource dynamics and understanding of sustainable management can be assessed. Community interest in management is a closely related concept. It documents the level of interest, in social and economic terms, that the members of the community express towards collective management. The capacity of the community to engage in collective management encompasses both the technical capacity of members to operate successful management institutions and the ability of community members to work together to achieve collective ends. Technical capacity referred to human capital, i.e. education and skill set that exists in the community and the ability of community members referred to as social capital, i.e. nature and strength of relationships between community members and between members and external actors such as people from other communities, organizations and government agencies (Woolcock and Narayan, 2000). These three aspects are crucial to the successful community based seabuckthorn management project and hence discussed below.

5.3.1 Relationship with the Resource

When assessing potential for collective management of a resource, it is important to understand the nature of the relationship between community members and the resource. Collective action theory postulates that the presence of several characteristics may aid in the achievement of successful management (White and Runge, 1994; Edwards and Steins, 1999). The first is that users have a comprehensive knowledge and understanding of the resource's ecology and environmental situation, so they can properly engage in sustainable management (Betts, 1998; Pomerory et al, 1998). This is generally facilitated by the users having a high reliance on the resource. A high reliance also provides a strong incentive for sustainable management over the long-term, rather than encouraging over-exploitation through free riding (Wade, 1987; Ostrom, 1999). Finally, users should have a shared image of the resource and agreed understanding of how their actions affect each other and the resource (Ostrom, 1999). These criteria are applied to situations in which the proposed members of the community management group are already users of the resource (Knowler, 2004). This was the case in Mustang. The local people of Mustang have been harvesting and using seabuckthorn since the time unknown for their household purposes and they have started using fruits and fruit residues in income generation. From the time when they knew that it has been playing crucial roles in soil and environment protection and that it could be used for income generation, they have strictly prohibited seabuckthorn to use as wood. Moreover, if there is a group endeavour, the poor people will get higher employment opportunities to harvest seabuckthorn fruits and the problem of cutting branches in competitive way will be reduced considerably and mixing of water in raw juice will be eliminated as well.

5.3.2 Community Interest in Seabuckthorn Management

Interest in and desire for community based management is one of the most important prerequisites for successful management situation (Knowler, 2004). If the people are not interested in managing resource then they will not invest the time and resources necessary for the development of an effective institution. Many collective action theorists have recognized this point and have identified two characteristics relating to the interest that a community may have in supporting collective management. First, there should be an enthusiasm amongst potential users for collective action. Enthusiasm is derived from a perceived cultural, political or financial benefit associated with collective action (Matakal and Duinker, 1991; Markey and Vodden, 1999). The second concern is that interests should be distributed in such a way that users with high political and economic influence are similarly affected by management

(Wade, 1998; Ostrom, 1999). This means that the economically and politically powerful should benefit from collective action because their support is necessary in overcoming potential barriers and facilitating the actions of common users. In these situations, it has already been discussed that the species has been in use culturally. By political enthusiasm, the local people have control over the seabuckthorn forests along with natural resources and they can use them in a constructive way on their desires. Of course, the ACAP officials have control over the resources but the relations between the local people and ACAP has been very good. Interview with Manish Raj Pandey (ACAP officer, Jomsom) and Lizan Maskey (ACAP officer, Hariokharka, Kaski) implicated that the decision making process is based on bottom up approach and they would always support for socio-economic well-being and bio-physical conservation. In response to the survey questionnaire, almost all of the people of Lete and Kunjo VDCs described their relationship with the park as good. Inevitably, in order to create interest in community based enterprise, the enterprise likely needs to be financially beneficial. The concern here is that the hoteliers are getting higher benefits from fruits than local poor and with this enterprise concept, it has to be assured that the financial return from seabuckthorn products from the new proposed enterprise should produce higher return than they have already been earning. There is no doubt that the poor will get employment during the fruit harvesting period. From the resource assessment, it was clarified that they have been harvesting very small quantity of fruits. With the development of enterprise, the group endeavor will establish trails and harvest fruits from all possible forest patches from one side or other. They do not have to compete during fruit collection and they will be able to collect more fruits in much less destructive way. Also, there are ample opportunities to get benefits from pulp, seed and leaves. The local hoteliers will get the first priority to buy squash and other products in reasonable cost. They will not have tension to send a member to harvest fruits on the first and next days. When the hoteliers were proposed this type of community based enterprise model, they agreed it and said that if this is possible, they will not have to worry about mixing of water in juice and they will get a common quality products. They agreed probably because the benefit they could get from squash is one of the many items in their hotels. It is, indeed, a consequence good relationship among the users as well. They are very convinced with the benefit sharing model of community based approach.

5.3.3 Community Capacity

As stated earlier, the capacity of the community to participate successfully in community based enterprise development is dependent on the availability of an adequate labour and skill set within the community, as well as on the presence of sufficient relationships among community members to facilitate cooperation and the production of joint benefits. The first of these concepts is called human capital and the second is referred to as social capital.

To successfully engage in collective management, participant must be able to accomplish a series of tasks. They must be able to run the management system, which includes the creation and implementation of rules that regulate protection, use and monitor the resource. They also must be able to meet the management harvesting, processing, marketing and administrative needs. Knowledge of the resource, the availability of labour, the ability to cooperate and the capacity to use monitoring, protection and harvesting technologies are the initial requirements. Dealing with the business side of the organization, the administration of funds, personnel and relationships as well as the marketing of products, requires a further set of more specialized skills.

Collective action theorists provide the following list of skills and community attributes that have been shown to exist in many successful collective action situations (Markay and

Vodden, 1999; Ostrom, 1999; Pinkerton, 1999; Pomeroy et al, 1998; Matakal and Duinker, 1991):

- The presence of leadership within the community that can draw upon local values and generate broad based support
- An entrepreneurial spirit within the community to develop new ideas
- Availability of labour and population education well enough to respond to the needs of the management system
- Some prior organizational experience in a range of community organization
- Some prior products

Lete, Kunjo and Kowang people appeared to measure up well supportive to these criteria. The community mobilization and leadership were satisfactory and the project area was likely to be able to meet the educational demands of the proposed strategy with little need for capacity building. Those who were illiterate, (approximately 50 %) have received informal technical trainings from NGOs like TISC, ACAP and HimalAsia. Only a few highly trained individuals are needed to provide administrative and marketing support that is possible by some capacity building programmes. In order to be successful, the local must be able to form relationships with outside actors and be able to take advantage of the opportunities provided by diverse social networks. ACAP, TISC, ICIMOD, ANSAB and HimalAsia are the possible external actors, which can support technically as well as financially. Therefore, there is high potentiality of developing a community based seabuckthorn enterprise to generate income and share it on equitable basis. Nevertheless, this involves tremendous active efforts on the part of government, supporting agencies, entrepreneur communities, which actually determine the genesis of the enterprises and the impact they have. Facilitating and ensuring service delivery in some crucial aspects such as marketing, resource management and technology development can trigger community to initiate the various dimensions of enterprises activities.

CHAPTER 6: PROJECT ACTIVITIES

Besides research about the biophysical features, this project carried out formation of seabuckthorn management committee, preparation of operation plan, conduction of training and publication and distribution of brochure.

6.1 Seabuckthorn Management Committee

The productivity of the seabuckthorn berry has remained stagnant and is even declining because of improper harvesting and management. The major problem in seabuckthorn production is that the local people are using the resources only for the subsistence basis, which can only support for the daily and short-term need and not for the improvement of the economic status. Therefore, a shift in paradigm from subsistence level farming to commercial is the must today. This can generate cash income, which ultimately contributes in health, education and social linkage of the household. There had always been a question, why the local people were poor despite the proximity to resources, accessibility of roads, facility of communications and adequate market and market value of the products. It is probably because local people were not using their natural resources in proper manner and unfair competition of the seabuckthorn. It is also because of the lack of technical knowledge and inappropriate financial resource allocation. To combat with this problem, SMC was necessary for group efforts, uplift the poor and commercial production of seabuckthorn produces.

Firstly, discussions were made with local people, women, poor, hoteliers, amchi and ACAP officials regarding the necessity of the SMC. Discussions were made separately as well as combinely with different groups. During the discussions, the respondents unanimously felt the need of the committee and were very excited if they could form it and operate some income generating initiatives. Finally, a committee was formed including poor, women, dalit, hoteliers and an ACAP official.

Photo 16: Discussions for the Preparation of SMC

The basic objective of the committee was to manage the seabuckthorn forest in proper manner so that they can conserve the resource and environment, higher production of the seabuckthorn and utilize it for income generation. The specific objectives are as follows.

1. To manage the seabuckthorn forest in proper way regarding harvesting of wood, fruits and leaves
2. To produce sufficient seedlings of seabuckthorn to plant on the bare areas and old seabuckthorn forest

3. To initiate the community based seabuckthorn management for income generation from seabuckthorn produces
4. To conserve environment and seabuckthorn forest by proper monitoring landslides areas, flood plains and erosion prone areas.

6.2 Operation Plan

This operation plan was prepared for what to do in which year and time. It was prepared anticipatorily and the committee and individuals in the training were committed to follow the plan.

Table 19: Plan of Action for Seabuckthorn Management

YEAR	ACTIONS	TIME
First Year (2008)	Built up capacity by training and field practices	January-February
	Build spur in the Chhoyo khola for flood control	February-March
	Land preparation for nursery	April-May
	Date fixing for fruit harvesting	October
	Management for fruits harvesting and collected at a place like cooperatives, prepare seabuckthorn produces and sell to the local hotels	November-December
	Encourage people for proper harvesting of fruit	November-December
	Prepare detail plan for the next year to utilize the income earned	December
Second Year (2009)	Selection of old unproductive seabuckthorn tree from Kujno and upper part of Lete Khola for cutting (according to necessity) so that plantation is easier	January-February
	Soil works for nursery	February-March
	Nursery raising by seed	March-May
	Land preparation in old seabuckthorn forest of Lete and Kunjo, see possible bare areas to plant seabuckthorn	June-August
	Date fixing for fruit harvesting	October
	Management for fruits harvesting and collected at a place as cooperatives, prepare seabuckthorn produces and sell to the local hotels	November-December
	Prepare detail plan for the next year to utilize the income earned	December
Third Year (2010)	Selection of old unproductive seabuckthorn tree from Kujno and upper part of Lete Khola for cutting (according to necessity) so that plantation is easier	January-February
	Look up for the spur of the Chhoyo khola for flood control and maintain if necessary	February-March
	Collection of cuttings (Hardwood cuttings, softwood cuttings and root suckers)	April-May
	Plantation in all possible areas including Chhoyo Khola	May-July
	Land preparation in remaining areas of old seabuckthorn forest of Lete and Kunjo and possible bare areas to plant	June-August

	seabuckthorn seedlings	
	Date fixing for fruit harvesting	October
	Management for fruits harvesting and collected at a place as cooperatives, prepare seabuckthorn produces and sell to the local hotels	November-December
	Monitoring the harvesting practice and encourage people for proper harvesting of fruit	November-December
	Prepare detail plan for the next year to utilize the income earned	December
Forth Year (2011)	Selection of old unproductive seabuckthorn tree from Kujno and upper part of Lete Khola for cutting (according to necessity) so that plantation is easier	January-February
	Look up for the spur of the Chhoyo khola for flood control and maintain if necessary	February-March
	Plantation in all possible areas including Chhoyo Khola and encourage plantation in their degraded home farm and waste lands	May-July
	Date fixing for fruit harvesting	October
	Management for fruits harvesting and collected at a place as cooperatives, prepare seabuckthorn produces and sell to the local hotels	November-December
	Monitoring the harvesting practice and encourage people for proper harvesting of fruit, monitoring about pests and diseases	November-December
	Prepare detail plan for the next year to utilize the income earned	December
Fifth Year (2012)	Selection of old unproductive seabuckthorn tree from Kujno and upper part of Lete Khola for cutting (according to necessity) so that plantation is easier	January-February
	Look up for the spur of the Chhoyo khola for flood control and maintain if necessary	February-March
	Pruning and mulching	March-April
	Plantation in all possible areas including Chhoyo Khola and encourage plantation in their degraded home farm and waste lands	May-July
	Date fixing for fruit harvesting	October
	Management for fruits harvesting and collected at a place as cooperatives, prepare seabuckthorn produces and sell to the local hotels	November-December
	Monitoring the harvesting practice and encourage people for proper harvesting of fruit, monitoring about pests and diseases	November-December
	Prepare detail plan for the next year to utilize the income earned	December

6.3 Training

The basic objective of the training was to impart Knowledge about seabuckthorn tree and to help the participants by its sustainable use to make local community an independent resource

mobilizer and thereby create a model community for seabuckthorn forest. The specific objectives are:

- Transfer the information about seabuckthorn and their resources
- Explain and demonstrate the techniques about the nursery, propagation, harvesting and processing of seabuckthorn produces
- Explain about value addition and marketing techniques of the seabuckthorn
- Prepare a work plan

Plenary discussion, lectures, group discussion and presentation by participants and practical observation were the major methodologies of the training. Meta card, brown paper, graph paper, marker, pencil, masking tape, cardboard paper, cartoons and flip charts were used as training materials. The training was delivered in participatory manner integrated by lectures, movie clips, individual discussion and group exercise on the aspect of propagation and harvesting. The presentation was packed with humors, jokes and relevant instances. According to the participants, the presentation style was interesting and impressive. The last part of the training was excised by construction of seedbeds, seed sowing and cutting plants for propagation. The information about all the topics given in session was taken from this report.

Table 20: Session Plan of Training

Day / Session	First Session	Second Session	Break	Third Session	Fourth session
First Day	• Registration • Opening • Introduction • Expectation collection • Goal and objectives • Norms setting	• Introduction and background of Seabuckthorn • Types of seabuckthorn • Local seabuckthorn species • Distribution		• Discussion about local uses of seabuckthorn (food, medical, others)	• Importance of seabuckthorn • Socio-economical uses • Environmental uses
	• Presentation by a participant about the first day training • Harvesting techniques	• Storage and packaging		• Field visit for harvesting techniques	
Third Day	• Presentation by a participant about the previous day training • Contribution in livelihoods of the local people • Linkage with millennium	• Teaching about preparation of squash, tea, jam, wine, juice powder and fenugreek pickles • Packaging and storage		• Practical preparation	

	development goal and tenth plan of Nepal Government				
Forth Day	• Group-wise presentation about the previous days' training and field visits	• Propagation techniques of seabuckthorn • Nursery management		• Field visit and practice of propagation of seabuckthorn	
Fifth Day	• Presentation by a participant about the previous day training • Need of community based management	• Market linkages of the products • Sustainability achievement		• Individual action plan preparation regarding seabuckthorn management •Commitment from the participants	• Overall paraphrasing • Closing

In the last session, the participants prepared a work plan to initiate plant propagation and marketing accordingly: The format example of the action plan was as follows.

SN	What action is necessary to improve seabuckthorn forest?	When to initiate?	Where to do?	Who to be involved?	How much to do?	How to do?	Source

It was happy to know that the participants were highly motivated and encouraged to do learn about seabuckthorn especially in propagation, harvesting, making commercial seabuckthorn produces and community based management system.

Photo17: Training Photograph

6.4 Brochure

The text and photo plate of brochure has been given below.

Seabuckthorn (*Hippophae salicifolia*) Management – An Introduction
Seabuckthorn, found in the icy heights of the Himalaya, is a deciduous, thorny willow-like plant species native to Europe and Asia. It has been distributed in over 40 countries of the world. It is a pioneer species and prefers to grow in low humid, alluvial gravel, wet landslips and riverside with brown rusty-scaly shoots. It is a multipurpose fast growing species which is serving as a measure of biodiversity conservation, soil conservation, medicines, food, fodder and fuel wood. It has an extraordinary capacity to grow and survive under adverse conditions (-40 to 40º C) and has extensive subterranean rooting system with strong soil binding ability useful for soil stabilization, riverbank control and water retention. Out of the seven species and eleven subspecies found in the world, two species (*Hippophae Salicifolia* and *H. tibetana*) have been thriving at high altitude areas of Nepal Himalayas. In Nepal, *H. salicifolia* has been distributed from 2000 – 3600 m from msl whereas *H. tibetana* has been distributed from 3300 – 4500 m.

Hippophae salicifolia
H. salicifolia is a dioecious tree species generally with 6 – 10 m in height. It is known as Tijicyun in Manang, Chichi in Thakali language in Mustang, Dalechuk in Dolpa, Tarachuk in Mugu, Jumla and Humla. The berry is round (slightly oval) with a single ovate-oblong seed. The leaves are alternate, linear, lanceolate and covered with silvery stellate scales on the backside.

Berry: 5.5-7 mm diameter
Seed: 4-7 mm long, 2.5-3.5 mm wide and 1.6-2.2 mm thick
Leaves: 3-8 cm long and 0.4-1 cm wide

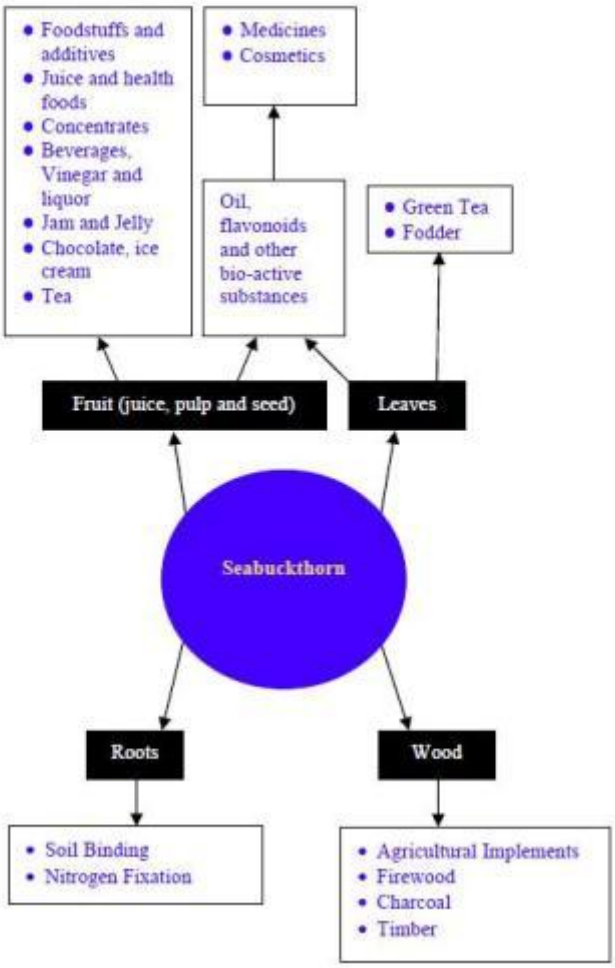
Comparison of the Vitamin Contents of Seabuckthorn and Others (mg/100g)

Species	Vit A	Vit B1	Vit B2	Vit C	Vit E
Seabuckthorn	11.00	0.04	0.56	300-1600	203
Cilicrosa roxburghii	4.83	0.05	0.03	1000-3000	-
Hawthorn	0.82	0.02	0.05	100-150	-
Orange	0.55	0.08	0.03	50.0	-
Tomato	0.31	0.03	0.02	11.8	-
Carrot	4.00	0.02	0.05	8.0	-
Oil of Maize	-	-	-	-	34
Soybean	-	-	-	-	7.5

Usefulness
Due to its immense use, it has aptly been called wonderful plant, magic plant, super food, functional food and bank of vitamins. Seabuckthorn berry is very rich source of vitamins and is called treasure of bio-activity substance because of its over 190 bio-activity substances possessing unique medicinal properties. Its leaves are also the important source of nutrients. China alone develops over 200 types of industrial products from the seabuckthorn.

Other Important Features of Seabuckthorn

- Regarding root systems and the ability to propagating itself, a 5-year old plant has a taproot of 3 m and horizontal roots of 6 – 10 m. A three-year old plant can produce 10 – 20 new generation plants by root turions.
- An 8 to 10-year old seabuckthorn forest can fix 180 kg of nitrogen/ha/year.
- A 6-year old seabuckthorn plantation can produce 18 tons of fuel wood. The heat value of seabuckthorn wood is 4785.5 cal/kg. One ton of seabuckthorn wood is equal to 0.68 ton of standard coal.
- Compared to wasteland, 7-year old seabuckthorn forest can reduce 99% of runoff and 96% of soil loss.
- If the seabuckthorn forest is managed properly, 750 to 1500 kg of fruits can be produced per hectare.



Uses of Seabuckthorn

Squash

The squash can be formulated with 25 % crude juice, 40 – 45 % sugar and 30 – 35 % water. Sugar mixed with water is boiled and then juice is mixed. It is again boiled for a moment and squash is prepared. About 0.5 gm of potassium meta-bisulphide can be used for one litre of squash if it has to be stored for several months. It needs dilution with three parts of water before serving. The squash does not need any extra artificial flavors and colours as the juice contain its natural yellow and orange red colour and orange flavors.

Quick Reference for Squash
Seabuckthorn Raw Juice: 1 kg (1 liter)
Clean Water: 1.4 kg (1.4 liter)
Sugar: 1.6 kg
Potassium Meta-Bisulphide: 2.4 gm (if necessary)

Jam
Best quality jam can be prepared out of the fruit extract. The jam is prepared with 0.75 % pectin, 10 % juice, 70 % sugar, 1.14 % acid and remaining water. These are boiled till paste is prepared and then cooled.

Tea from Seabuckthorn Leaves
The tender leaves of seabuckthorn are used for making tea. The processing procedure is as follows:

- Collect the green leaves preferably from male tree and wash with water
- Quick fry the leaves to remove moisture and twist them
- Stir-frying the leaves, twist them and moisten them with some water spray
- Continue stir-frying and fluttering them for a few minutes until it forms small tea leaves
- Remove the larger sized particles
- Tea is ready. You can package it and store

Wine
The juice contained less amount of sugar and excessive amount of acid to make the wine. So, addition of water and sugar is essential.

- Mix 10 kg sugar, 2 gm ammonium sulphate, 1.35 kg fruit juice with 38 litre of water
- Heat the mixture to 60º C for about five minutes and then cool it.
- Add 10 % of activated wine yeast and allow it to ferment for 3 – 4 weeks (within this period, the fermented mesh produces a fine taste and wine flavor)
- For maturation, allow it to ferment for 6 – 8 months (this enhances fine aroma and clarity in the wine).

Juice Powder

- Mix 100 gm of juice in a kilogram of sugar and 36 gm of acid
- Dry the mixture preferably in electric oven at about 40 – 50º C and ground to powder. This powder easily mixes with water and gives a taste of seabuckthorn squash.

The harvesting technique of the local people is the major concern in the sustainable management of seabuckthorn forest. The harvesting of ripe fruits of seabuckthorn is the most difficult and time consuming operation because it is highly thorny and fruit being soft, small, delicate and highly perishable and attached strongly to the plant poses difficulty in the operation. Hand picking, though easier, is very time consuming. Cutting of the branches, though convenient, is not a legal and sustainable. In some countries, use of mechanical shaker has been used. But it does not seem to be practical in Nepal due to steep slope and costlier. Using mineral water for harvesting fruits seems better for the conservation of the resource.

The bottom part of mineral water bottle is cut in such a way that it looks like U-shaped fan. With the help of a rope and a long stick, the berries can be collected without damaging the plants. It takes quite longer time.

It has been observed that harvesting of ripe fruits is comparatively easier and effective in early morning hours before sunrise when the air temperature is almost 0º C, since subsequently fruits develop turgidity. Harvesting of fruits is easy and quick at this time just by beating the fruiting branches with a stick and one does not have to suffer from the thorns. After sunrise it becomes difficult. Use of ladder has also been practiced to reach the height of the tree. Forks, used in kitchen can also be better in the sense that one can use such equipments for easiness, collecting berries without any loss of juice and for hygienic. Use of fork is a bit more time consuming in comparison to some of the other options.

Seabuckthorn Forest Management

Being a pioneer and the light demanding species, the seabuckthorn forest should be managed in proper way for its germination and higher yield of the fruits. For regeneration, the land should be cleared and the older, dried and dying branches should be pruned. During thinning, consideration should be made in such a way that male: female ratio becomes 1:6. Weed control, mulching, pest management and thinning operations are continuously necessary in the nursery, plantation sites and forest.

Local Biomass Table of Seabuckthorn (*H. salicifolia*)

Diameter at 30 cm in cm	Oven Dry Weight of Wood in kg	Fresh Weight of Fruits in kg	Oven Dry Weight of Leaves in kg
1	0.04	0.00	0.02
2	0.22	0.00	0.05
3	0.60	0.00	0.08
4	1.23	0.21	0.12
5	2.13	0.29	0.16
6	3.36	0.37	0.21
7	4.93	0.46	0.26
8	6.87	0.56	0.31
9	9.20	0.66	0.37
10	11.96	0.76	0.43
11	15.15	0.87	0.49
12	18.81	0.99	0.55
13	22.95	1.11	0.61
14	27.60	1.23	0.68
15	32.76	1.35	0.75
16	38.46	1.48	0.82
17	44.72	1.61	0.89
18	51.55	1.75	0.96
19	58.96	1.88	1.04
20	66.98	2.03	1.11
21	75.62	2.17	1.19
22	84.89	2.32	1.27
23	94.81	2.47	1.35
24	105.39	2.62	1.43

25	116.64	2.77	1.51
26	128.59	2.93	1.60
27	141.24	3.09	1.68
28	154.60	3.25	1.77
29	168.70	3.42	1.86
30	183.53	3.58	1.95
31	199.12	3.75	2.04
32	215.47	3.92	2.13
33	232.60	4.10	2.22
34	250.52	4.27	2.32
35	269.24	4.45	2.41
36	288.77	4.63	2.51
37	309.12	4.81	2.61
38	330.31	5.00	2.70
39	352.35	5.18	2.80
40	375.24	5.37	2.90
41	398.99	5.56	3.00
42	423.62	5.75	3.10
43	449.14	5.95	3.21
44	475.56	6.14	3.31
45	502.89	6.34	3.42

Propagation

Land should be prepared at least for a year before planting. Soil composition in the polypot and plain bed should be prepared by mixing sand, humic soil and soil from seabuckthorn forest in the ratio 5:3:1. The propagation of seabuckthorn is possible through seed, root sucker and branch cutting. Propagation through root sucker and branch cutting is more productive as one can choose male or female plant to produce but quite difficult.

Seed Treatment and Sowing

Soak the seed in clean water for three days or 48 hours at hot water of 70º C with stirring intermittently until the temperature drops to 10 – 15º C prior to the sowing in the polyplot or bed. Seeds will start germinating within 1 – 3 weeks based on the condition of the seeds and the species of seabuckthorn and will be ready to plant for the next year.

Propagation by Cuttings

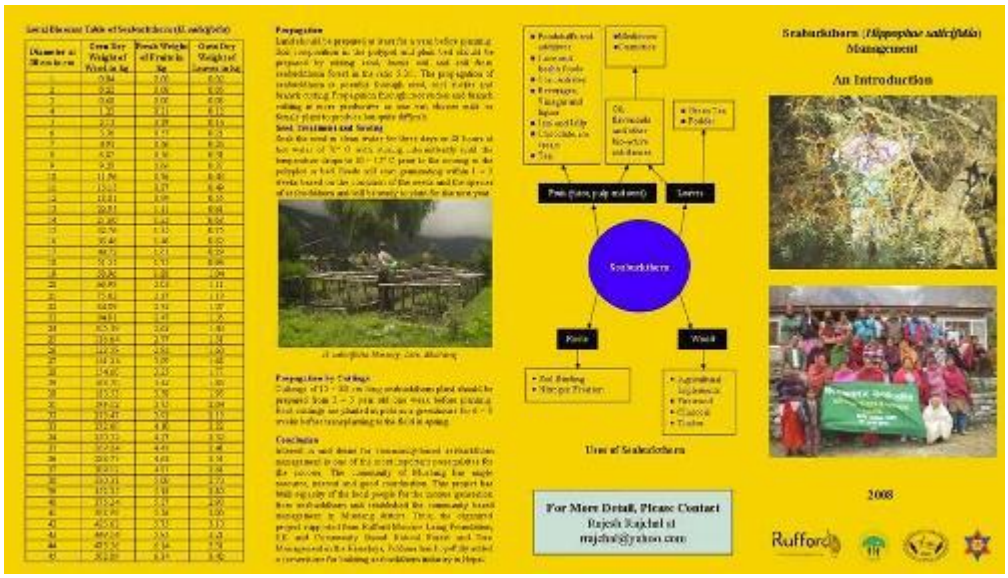
Cuttings of 15 – 20 cm long seabuckthorn plant should be prepared from 3 – 5 year old one week before planting. Root cuttings are planted in pots in a greenhouse for 6 – 8 weeks before transplanting to the field in spring.

Conclusion

Interest in and desire for community-based seabuckthorn management is one of the most important prerequisites for the success. The community of Mustang has ample resource, interest and good coordination. This project has built capacity of the local people for the income generation from seabuckthorn and established the community based management in Mustang district. Thus, the organized project supported from Rufford Maurice Laing Foundation, UK and Community Based Natural Forest and Tree Management in the Himalaya, Pokhara has hopefully added a cornerstone for building seabuckthorn industry in Nepal.

For more detail, please contact Rajesh Rajchal at rrajchal@yahoo.com

Brochure Photo Plates



CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Ethnobotanical Uses

As seabuckthorn is a multipurpose species, the local people of Mustang district have been using its wood, fruits and leaves in a variety of ways as subsistence livelihood. They have been using wood as fuel wood and timber as furniture and agricultural implements. The fruits have been used as food additives, dyeing wools and medicines for several diseases like poisoning, toothache, expectorant, tonsillitis, throat pain, vocal problem, joint pain, hurt, muscular pain, swelling, appetiser, gastritis, asthma and menstruation irregularity. The leaves have been used as green manure and a very few people were found to prepare squash for their drinking purpose. There was lack of adequate information in the community regarding the use and benefit of the species.

Income Generation

Fruit was the only used part for income generation despite high opportunity from leaves as well. The total income generated from seabuckthorn fruits was estimated to be NRs. 585000 in Lete and Kunjo VDCs. The local people, who harvest the fruits from the forests, are getting very less benefits in comparison to hoteliers. People are not getting the proper use of leaves, seed and pulp for income generation.

Distribution of Seabuckthorn Forest

Out of the two species found in Nepal Himalayas, *H. salicifolia* has been naturally found along the riverbanks, booklet banks, flood plains, sloppy areas, alluvial soils and newly eroded colluvial deposits of Lete, Kunjo and Kowang VDCs of Mustang district. In Lete and Kunjo VDCs, it has been distributed on approximately 61 ha. It has been found in Ghasa, Dhampu, Kaiku Khola, Ghumaune, Kokhethanti, Lete Khola, Dhampu, Chhoyo Khola, Ilankhu (Taglung), Thak Khola, Tukuche, Sauru and Sirgung areas of the three VDCs. Old and matured trees have been distributed at higher altitude while the young and matured trees have been distributed along the river belt and some seedlings have been regenerating over flood plains of Lete Khola and Chhoyo Khola. It was found to be associated with *Alnus nepalensis* in lower altitude and *Pinus wallichiana*, *Girardinia diversifolia*, *Inulla cappa, Pyracantha crenulata, Cannibis sativa* and *Berberis spp* at higher altitudes. The regeneration of the plants was found to be very poor.

Regression Equations

Among several model tested, the best fit model for wood was obtained as ln (Wood) = -3.243 + 2.486 ln (Diameter) with adjusted coefficients of determination (adj. R^2) of 0.98 and $p<0.001$. Similarly the best fit models for fruits and leaves were ln (Fruits) = -3.509 + 1.407 ln (Diameter) ($p<0.001$) and ln (Leaves) = -4.04 + 1.384 ln (Diameter) ($p<0.001$) with adj. R^2 0.64 and 0.84 respectively.

Biomass Production

Biomass production was estimated from Lete and Kunjo VDCs because the trees are matured and have frequently been used by the local people. The current annual biomass production per ha was estimated at 4200 kg for wood. The growing stock of wood was found to be 44.5 ton per ha. Regarding fruits, the annual production per hector was found to be 450 kg. In totality, non-fruiting trees were more than fruiting trees. There were about 15000 fruiting trees and the

female trees were found to start fruiting from the age of five. Similarly, the annual production of leaves was found to be 1800 kg per ha.

Opportunities

This species is a precious gift to the high fragile mountain because it has been contributing the locality in a unique way to both environment conservation and socio-economic well-being. There are ample opportunities to uplift the livelihood of the local people by managing, utilizing and marketing this kind of hidden treasure of the Himalayas.

Problems

As people have been harvesting fruits by cutting branches, the resource is liable to deplete sooner or later. Apart from inefficient harvesting other perceived threats to the species were grazing, landslides, glacier lack outburst flood, lowering streambeds. As a pioneer species, the regeneration of seabuckthorn in the forests was almost nil and there was high possibility of eliminating this species by *Pinus wallichiana* in course of plant succession. Regarding management prospective, there was policy constrains and lack of equipments. Another major problem was that there is not sufficient advertisement about the importance of seabuckthorn among the users which is hindering the seabuckthorn conservation and development.

Capacity Building

Besides research, the project has built up capacity of the local people to generate income from the previously unutilized species in participatory approach. From the field-based training, the local people were inspired to manage seabuckthorn forest in sustainable manner. The five-year operation plan was developed and the brochure, seabuckthorn produce recipe and management options for propagation, harvesting, extraction and utilization of seabuckthorn would certainly be helpful for the local people for the management. The local people are also seemed to be confident for managing seabuckthorn forest without further degrading the forest and biodiversity.

Income Generating Initiatives

Previously, local peoples were use to collect seabuckthorn fruits only for their domestic use. It was neglected and remained unused in its natural condition because of lack of awareness. Now, people are able to refine and preserve the seabuckthorn in the form of juice, jam, wine, juice powder, pickle and squash and these products are highly preferred by tourists. The poor, women and dalits have got the higher benefits from this project because they are now able to generate income from those produces.

Scientific Document

The final document is a very concrete one for managing the seabuckthorn forest. This can be a very prominent document for the local people, the students and the scientific community. The report contains management techniques, which the local people can understand and practice in their forest areas. The report is a manual for the local people for commercial produces and managing seabuckthorn forest. It can be important to students because of detailed compilation of information and to the scientific community because of scientific research with detailed analysis. Students from different universities of the world are getting benefits from this report and are requesting personal suggestions for the field based activities.

7.2 Recommendations

The rural people can play a vital role in the management and sustainable utilization of seabuckthorn. To facilitate and to harness the under exploited potential of seabuckthorn in the project areas, following steps are recommended for immediate attention from concerned quarters.

- **Regular Monitoring of Seabuckthorn Users Committee:** As this committee is new, they may face several inter-committee and external management problems like human resource management, seabuckthorn management (nursery, enterprise, and marketing) accounting, auditing, filing and marketing. To get rid of this problem, regular monitoring by ACAP officials or other concerned organization like CBEC is necessary for at least a couple of years.

- **Policy, Legislation and Management Plan:** Policies and legislation for seabuckthorn should be thoroughly analyzed and appropriate policies should be enforced. Appropriate management plan should be developed for the management of the seabuckthorn forest in the project areas.

- **Market Analysis:** Market analysis of potential commercial products of seabuckthorn is necessary in order to develop market confidence to the local people.

- **Further Studies:** Further in-depth studies are currently necessary to promote seabuckthorn development in the project areas. The studies should be focused on:
    - Innovation of advance harvesting and fruit processing technology
    - Market study for the products
    - Micro-enterprise development

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APPENDIX

Appendix 1: Hotels and Lodges of the Project Area

SN	Name of Lodge/Hotel
1.	Alpine Lodge
2.	Annapurna Guest House
3.	Baby Lodge
4.	Bimala Guest House
5.	Dhaulagiri Ice Fall Guest House
6.	Earth Lodge
7.	Everest Guest House
8.	Glacier Lodge
9.	Green Forest Guest House
10.	Hotel Mountain Top
11.	Kalopani Guest House
12.	Kasturi Cottage
13.	Lete Guest House
14.	Namaste Guest House
15.	Nepali Delicious Food
16.	New Horizon Guest House
17.	Pine Forest Lodge
18.	See You Lodge

Appendix 2: Data Collection Sheet for Regression Equations

1. For Shrub-Tree (RE)

SN	DBH at 1.3m (cm)	Height in (m)	Crown Diameter	Bark Width	Wood Biomass (kg)	Fruit Biomass (kg)	Leaf Biomass (kg)	Remarks
1. 0-5								
2. 0-5								
3. 0-5								
4. 5-10								
5. 5-10								
6. 5-10								
7. 10-15								
8. 10-15								
9. 10-15								
10. 15-20								
11. 15-20								
12. 15-20								
13. 20-25								
14. 20-25								
15. 20-25								
16. 25-30								
17. 25-30								
18. 25-30								
19. 30-35								
20. 30-35								
21. 30-35								
22. 35-40								
23. 35-40								
24. 35-40								
25. 40-45								
26. 40-45								
27. 40-45								
28. 45-50								
29. 45-50								
30. 45-50								
31. …								
32.								
33.								
34.								
35.								
36.								

Appendix 3: Data Collection Sheet for Biomass

Plot No: Aspect: Slope: Date:
Latitude: Longitude: Elevation: Surveyed by:

10m*10 m Plot Size

SN	DBH at 1.3m (cm)	Height (m)	Biomass (from RE)			Remarks
			Wood	Fruit	Leaf	
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						

Soil Type:

Erosion Level: Light: Medium: High:

Associate Species:

i.
ii.
iii.
iv.
v.
vi.

Stumps:

Grazing: High: Medium: Low: No:

Seabuckthorn Regeneration Number:

Appendix 4: Questionnaire for Household Survey

Name: Age: Date:
Education: Address: Occupations:

1. What are the activities you perform for seabuckthorn management? Number of days in year?

Activities	Seasons/Months	Days	Remarks
Plantation			
Cleaning			
Weeding			
Thinning			
Pruning			
Others			

2. How much quantity of seabuckthorn products do you collect?

Types	Seasons	Number of days per year	Quantity per day	Quantity per year
Fruit/Crude juice				
Fuel wood				
Timber/pole				
Fodder				
Bedding Materials for livestock				
Mulch				
Agricultural tools:				
Others				

3. How do you sell them?

Contract: Sell in open market:
Traders come: Sell in NTFPs based industries:
Others (specify):

4. How do you use the products of seabuckthorn?

Type	Quantity per year	Cost to collect /produce	Used in Quantity		Selling Price	Profit	Net Profit (NRs/unit)	Remarks
			Household	Commercial				
Crude								

Juice (Ras)								
Juice concentrate								
Pickle								
Juice								
Jam								
Wine								
Soft Drinks								
Food Additives								
Wood								
Oil								
Others								

5. Do you earn money from other sectors from seabuckthorn? How much you earn per day or per month?

Sectors	Days	Cost	Profit	Net Profit	Remarks

6. Which product of seabuckthorn is of more demand? (Ranking)

7. How do you harvest the seabuckthorn tree?
   For Wood: Selective: Random: Peculiar: Dead and Dying: Others (specify):
   For Fruit: Selective: Random: Peculiar: Dead and Dying: Others (specify):

8. What is the trend of the seabuckthorn forest?
   Progressing: Constant: Degrading:
   Reasons:

9. What are the problems in seabuckthorn management?

Harvesting:
Storage:
Processing:
Market:
Financial:
Technical:
Others (specify):

10. Have you got any support from any organizations? Which organizations? How did they help?

Training (Nursery establishment, Plantation, Propagation, Capability Building, IGA, Awareness, Others):
Juice Preparation:
Jam Preparation:
Other products preparation:
Financial:
Others (specify):

11. What are the benefits you have obtained from seabuckthorn?

12. In your opinion, what are the activities necessary for better management of seabuckthorn?

Training (for what):
Nursery establishment: Awareness: Financial Support: Others:

Appendix 5: Checklist for Group Discussion

- Nursery
- Propagation technique
- Harvesting system
- Extraction system
- Processing of fruits
- Storage system for fruits and juice
- Condition of seabuckthorn forest
- Market channels/trade
- Selling system and price
- Payment for collection (Wood, fruit, foliage)
- Cost of production for juice
- Income generating activities
- Income from seabuckthorn
- Benefits
- Labour
- Salary
- Loan system
- Infrastructure development
- Industry
- Participation
- Working organizations and their supports
- Training and tour
- Problems in seabuckthorn management
- Prospects
- Major events that has affected seabuckthorn forest viz. Fire, landslides, flood, snow
- Conflicts
- Community based enterprise development

Appendix 6: Local Biomass Table

Diameter at 30 cm (in cm)	Oven Dry Weight of Wood in kg	Fresh Weight of Fruits in kg	Oven Dry Weight of Leaves in kg
1	0.04	0.00	0.02
2	0.22	0.00	0.05
3	0.60	0.00	0.08
4	1.23	0.21	0.12
5	2.13	0.29	0.16
6	3.36	0.37	0.21
7	4.93	0.46	0.26
8	6.87	0.56	0.31
9	9.20	0.66	0.37
10	11.96	0.76	0.43
11	15.15	0.87	0.49
12	18.81	0.99	0.55
13	22.95	1.11	0.61
14	27.60	1.23	0.68
15	32.76	1.35	0.75
16	38.46	1.48	0.82
17	44.72	1.61	0.89
18	51.55	1.75	0.96
19	58.96	1.88	1.04
20	66.98	2.03	1.11
21	75.62	2.17	1.19
22	84.89	2.32	1.27
23	94.81	2.47	1.35
24	105.39	2.62	1.43
25	116.64	2.77	1.51
26	128.59	2.93	1.60
27	141.24	3.09	1.68
28	154.60	3.25	1.77
29	168.70	3.42	1.86
30	183.53	3.58	1.95
31	199.12	3.75	2.04
32	215.47	3.92	2.13
33	232.60	4.10	2.22
34	250.52	4.27	2.32
35	269.24	4.45	2.41
36	288.77	4.63	2.51
37	309.12	4.81	2.61
38	330.31	5.00	2.70
39	352.35	5.18	2.80
40	375.24	5.37	2.90
41	398.99	5.56	3.00
42	423.62	5.75	3.10
43	449.14	5.95	3.21
44	475.56	6.14	3.31
45	502.89	6.34	3.42

Appendix 7: List of Associated Species of *H. salicifolia*

SN	*Scientific Names*	Nepali Names
1.	*Abies spectabilis*	Talis Patra
2.	*Acer spp*	Kapasi
3.	*Achyranthes aspera*	Datiwan
4.	*Ajuga spp*	Ratopate
5.	*Allium wallichii*	Ban Lasun
6.	*Alnus nepalensis*	Utis
7.	*Arisaema tortuosum*	Banko
8.	*Artemesia vulgaris*	Tite pati, Pati
9.	*Arundinaria falcata*	Nigalo
10.	*Berberis spp*	Chutro
11.	*Bidens piolsa*	Kalo Kuro
12.	*Cannibis sativa*	Ganja
13.	*Caragana brevispina*	
14.	*Cirsium spp*	Dhada Kanda
15.	*Debregeasia salicifolia*	Dar, Tusare
16.	*Elsholtzia spp*	Ban Silam
17.	*Ephedra gerardiana*	Somlata
18.	*Girardinia diversifolia*	Allo, Thulo Sisnu
19.	*Hedera nepalensis*	Katha Lahara
20.	*Inulla cappa*	Kan Pate
21.	*Juniperus indica*	Dhupi
22.	*Makania nepaulensis*	Jamane Mandro
23.	*Persicaria chinensis*	Bakhre thotne
24.	*Pinus wallichiana*	Gobre salla
25.	*Populus spp*	Lahare papal
26.	*Potentialla spp*	Bajradanti
27.	*Pyracantha crenulata*	Ghangaru
28.	*Quercus spp*	Khasru
29.	*Ranunculus spp*	Brimomendo
30.	*Rosa spp*	Gulaph
31.	*Salix spp*	Bains
32.	*Sophora moorcroftiana*	
33.	*Taxus wallichiana*	Silangi, Dhegre salla
34.	*Thalictrum spp*	Dampate

Appendix 8: Frequency of Common Associates of *H. salicifolia*

SN	Scientific Names	Frequency	Remarks
1.	*Alnus nepalensis*	3	Distributed at lower elevations only
2.	*Arisaema tortuosum*	2	Along river belt and higher elevations
3.	*Artemesia vulgaris*	6	Along river belt and higher elevations
4.	*Berberis spp*	10	Along river belt and higher elevations
5.	*Cannibis sativa*	8	Upper part of the bank of the river
6.	*Girardinia diversifolia*	21	Along river belt and higher elevations
7.	*Inulla cappa*	20	Along river belt and higher elevations
8.	*Pinus wallichiana*	6	Upper part of the river bank and at higher elevations
9.	*Pyracantha crenulata*	12	At higher elevations