IV. A Plant for Upgrading Marginal Mountain Lands

For fragile and marginal lands in mountain regions, the environmental gains of seabuckthorn reflected through resource upgrading, i.e., building/binding of soil on steep slopes and conservation of moisture for productive use, may far exceed the commercial benefits discussed in the preceding section. The root system, rapid prolification, nitrogen fixation, adaptation to harsh environmental conditions, and other attributes of this plant discussed earlier, amply equip seabuckthorn to play a conservation role in the fragile and marginal mountain lands. We discuss this by briefly summarising the Chinese experience. The case of the Loess Plateau is discussed in detail.

Use in Controlling Loss of Water and Soil

Harsh Situation

China is a country that lacks sufficient forest area. Its forest coverage is only 12 per cent of its total area, and the per capita of timber is 0.02 m^3. In China, 60 per cent of 800 million farmers experience a shortage of firewood for 3 to 5 months each year. In northern and north-western China, particularly,there is less vegetation cover and the land surface is always exposed. Rainfall is below 400 to 500 mm and it is extremely uneven. Ecological conditions are so poor that soil erosion persists throughout. On the Loess Plateau, for example, the soil erosion modulus generally exceeds 5,000 tons/km^2/year, and in some areas, it reaches 30,000 tons/km^2/year (Li Min et al. 1989). The sediments carried each year by the Yellow River to the lower reaches is 1.6 billion tons, mostly from the Loess Plateau.

Severe loss of soil and water has devastating effects on farming, forestry, stock-breeding, and on the ecology and environment of the area concerned. It also influences use of water, land, and mineral resources. Huge quantities of sediment deposited in the lower reaches have rendered the river "suspended" above the adjacent land surface, seriously menacing life and increasing poverty in the North China Plains. To control soil erosion is the most urgent task in this region. Seabuckthorn has a lot of advantageous characteristics over other trees and shrubs and, since the rainfall in this region cannot meet the requirements for tree afforestation, but can for seabuckthorn and other shrub afforestation, it has often been chosen as a pioneer species in afforestation. Since the 1940s, seabuckthorn has been cultivated as the plant for soil and water conservation in northern and north-western China and much knowledge and experience have been accumulated regarding it. The local inhabitants are now mobilised to make good use of the advantages of growing seabuckthorn on a large scale to conserve water and hold soil so as to improve the ecology and environment in this region. This has become an important task and much attention has been paid to this by the Chinese Government.

Ecological Benefits of Seabuckthorn Forest

One of the most successful regions that has used seabuckthorn as a water and soil control plant is the Western Liaoning Province which is located in northeastern China. With a total area of 50,111 sq.km., of which the mountain lands account for over 70 per cent, the vegetation cover rate is 15 to 30 per cent, and the forest cover rate is only 12 to 15 per cent. The climate here falls into the semi-arid and semi-humid climate ranges. The annual rainfall is 350-600 mm, of which 70 per cent is concentrated in July and August. The existing eroded area is 33,188 sq.km. and the modules of erosion are 2,500-8,000 tons/km^2/year. Therefore, the environment is seriously imbalanced and natural disasters such as drought, sandstone, and floods occur frequently. These severely hamper the development of agriculture, forestry, and animal husbandry. As a result, this region has become one of the ten poverty-ridden regions of China.

In order to bring soil erosion under permanent control, to improve the environment, and to promote agricultural development, several species of tree and shrub were planted in this region. Among them seabuckthorn had the strongest competitive ability both in pure and mixed forests. Hence, it was sown over large areas and soon several seabuckthorn forests were established. Since 1984, a lot of information

about the integrated use of seabuckthorn in different fields was accumulated, the single ecological benefit of seabuckthorn also gradually expanded into economic returns.

Thereby seabuckthorn planting reached a climax. The seabuckthorn forest area was 266.77 sq.km. in 1984, but it reached 1,133.33 sq.km. in 1988, of which the mixed seabuckthorn forest accounted for 30 per cent. The artificial seabuckthorn forest area in western Liaoning has become the largest one in the country and Jianping County has the largest seabuckthorn forest area in this region. The total area of seabuckthorn plantation in Jianping County has reached 520 sq.km., of which 400 sq.km. has borne fruit with an annual output of 15,000 tons.

The Effects on Water Retention, Soil Conservation, Wind Control, Sand Fixation, and River Bank Protection. The growth of a five year old seabuckthorn plant can reach up to 1.69 m with 1.7 m of crown diameter. When it occurs in pure stands the canopy density can reach 0.9 m. This canopy layer plays an important role in reducing soil erosion caused by the kinetic energy of rainfall and intercepts much rainfall. Based on the determination of a five year old seabuckthorn forest in Luofu Gully, Jianping County, the interception rate of rainfall by the canopy was calculated at 8.5-49.0 per cent. In a ten year old seabuckthorn forest, the litter thickness was 1-3 cm, capable of absorbing 1.8-2.2mm of rainfall. Therefore, the canopy and litter can regulate surface runoff and increase the soil infiltration capacity effectively. Judging by the measurements taken of runoff plots in this forest, 94.20 per cent of runoff and 77.63 per cent of sediment reduction were obtained against those in waste mountain lands which were taken as the control. In seven year old seabuckthorn forests, 99.6 per cent of runoff and 96.6 per cent of sediment reduction against those in the control were obtained (see Table 13).

Table 13: Comparison of Runoff and Soil Loss Observed between Waste Mountain Land and Seabuckthorn Forest Land

Items	Waste Mountain Land	Seabuckthorn Forest Land
Plant cover (%)	25	90
Annual Rainfall (mm)	380.6	380.6
Runoff (m^3/ha^{-1}/annum)	1672.20	7.49
Soil loss (kg/ha^{-1}/annum)	314.25	10.80
Runoff reduced (%)	-	99.6
Soil loss reduced (%)	-	96.6

Source: Li Quanzhong et al. 1989

The artificial seabuckthorn forest built along river banks had remarkable effects on wind control and sand-fixation. For example, the windbreak provided by seabuckthorn built along the banks of the Laohahe River, Jainping County, prevented sand drifts and formed a natural sand wall to protect the river banks and fields of crops.

In Xiangyang and Taiping townships, seabuckthorn wind-breaks intercepted the sand drifts reaching 13,708-23,370 m^3/km^2/ year, thus reducing the sand dust in the air. Poplar forests mixed with seabuckthorn had better protective effects than pure poplar forests. The thickness of the captured sand by a nineteen year old mixed forest increased 33.3 per cent compared to pure forests of the same age. The thickness of the deposited soil layer in mixed forests increased 89.3 per cent compared to that of pure forests (see Table 14).

The Effects on Soil Fertility. Seabuckthorn plants have a dense crown and a strong, well-developed root system. A five year old seabuckthorn plant has a root system with an extension of 4.5m and a tap root with a depth of 2.5m. The total weight of the root system is 0.777 kg/m^2. The seabuckthorn plant produces a great deal of biomass both above and underground through its metabolism. This biomass is transformed into organic and mineral materials by the activities of microbes in the soil. All organic and mineral materials can improve the soil's physical and chemical properties and raise soil fertility (see Table 15).

Table 14: Comparison of Amounts of Soil Deposited in Pure Poplar Forests and in Poplar and Seabuckthorn Mixed Forests in the Laohahe River

Items	Pure Poplar Forest	Poplar and Seabuckthorn Mixed Forest
Forest Age (year)	19	19
Movable Sand Thickness(cm)	62.5	83.7
Increased (%)	-	33.9
Deposited Soil Thickness (cm)	10.1	100.3
Increased (%)	-	893.1

Source: Li Quanzhong et al. 1989

Table 15: The Physical and Chemical Properties of Soils on Different Types of Land*

	Waste Mountain Land	Pure Chinese Pine Forest Land	Pure Seabuck-thorn Forest Land
Forest age	-	5	5
Canopy density	-	0.5	0.8
Total nitrogen (%)	0.060	0.067	0.074
Total phosphorus (%)	0.055	0.096	0.064
Organic matter (%)	0.952	1.092	1.300
Bulk density ($9cm^{-3}$)	1.43	1.32	1.29
Porosity (%)	47.04	51.11	52.22

Source: Li Quangzhong et al. 1989

* Sampling depth is 40cm.

Table 15 shows that the total nitrogen, the total phosphorus, and the organic matter contents in pure seabuckthorn forests are respectively 0.014 per cent, 0.009 per cent, and 0.384 per cent; more than the amounts contained in waste mountain land. The soil bulk density is 0.14 g/cm^3 less and the soil porosity of seabuckthorn forest land is 5.18 per cent higher than waste mountain land.

The Role of Seabuckthorn in Mixed Forests. For a long time, Chinese pine (*Pinus tabulaeformis*) and poplar (*Populus simonii*) were used for afforestation in western Liaoning. It was proved that pure Chinese pine forests and pure poplar forests were low yielding forests. When the poplar or the Chinese pine were mixed with seabuckthorn, both grew much better than pure forests. For example, based on the survey of a 23 year old seabuckthorn and poplar mixed forest, the average height of poplars in mixed forest was found to be 4 times higher than in pure poplar forests, and the average chest diameter was 3.75 times larger (see Table 16).

Table 16: Comparison of Seabuckthorn, Poplar Mixed Forest, and Pure Poplar Forest

Growing Diameter Place	Type of Forest	Age of Tree	Sample Numbers	Height (m)	Mean Chest (cm)
Middle Slopes	Poplar mixed with seabuckthorn	23	30	6.5	9.0
Lower Slopes	Poplar only	23	30	2.7	2.4

Source: Li Quangzhong et al. 1989

This result is particularly due to the contribution of seabuckthorn to the improvements of the soil moisture and soil fertility. For example, during the growing season from April to September, it was found that soil moisture in the 0.20cm soil layer of mixed forest was 0.2-1.7 per cent more than that of pure poplar forest. The nitrogen content of the cultivated layer (0-20 cm) and the organic matter content in the mixed forest increased by 11.5 per cent and 26.6 per cent respectively (see Table 17).

Seabuckthorn not only increased the nitrogen content of the soil but also improved the nitrogen level in the plant. After careful tests of plant organs, it was found that the total amount of nitrogen in the leaves of poplar in the mixed forest increased by 33.63 per cent compared to leaves in the pure poplar forest. This indicates that seabuckthorn can promote better growth of other trees and that it is a desirable accompanying shrub for plantation in the mixed forests of semi-arid regions.

Table 17: Comparison of the Total Nitrogen and Organic Matter Contents of Pure Poplar Forests and Poplar and Seabuckthorn Mixed Forests

Soil Profile Horizons (cm)	Total Nitrogen (%)			Organic Matter (%)		
	Pure Forest	Mixed Forest	Increase	Pure Forest	Mixed Forest	Increase
0-10	0.0848	0.0953	0.0105	1.520	1.943	0.421
11-20	0.0673	0.0680	0.0070	1.070	1.356	0.286
21-30	0.0580	0.0592	0.0012	1.120	1.220	0.100
31-54	0.0545	0.0555	0.0010	-	-	-

Source: Li Quangzhong et al. 1989

Example of the Loess Plateau, China

The Loess Plateau covers an area of about 600,000 sq.km. and is located in Northern China. The altitude of most parts of it is between 1,000-2,000 masl and the climate is semi-arid to semi-humid. The annual rainfall ranges between 400mm to 600mm, with a large annual variation. There is low vegetation cover, and the percentage of natural forests is only 4.4 per cent. Poor natural conditions and primitive production methods have caused it to be one of the poorest areas of China and lack of fuel, animal feed, and fertiliser are the problems that many districts here have to face.

General View of Water and Soil Loss on the Loess Plateau

The eroded area of the Loess Plateau is estimated to be 430,000 sq.km. (it is almost equal to the area of Iraq or 3 times that of Nepal), and the total annual surface soil loss amounts to 1,600 million tons. Calculations revealed that the fertility loss from the soil exceeded the total chemical fertiliser output produced in the entire country in 1973. Downstream from the Yellow River, the annual accumulation of sediment averages 400 million tons, causing the river bed to rise about 10cm annually. This not only endangers the life and property of the people but also compels the Government to spend vast sums of money in strengthening and increasing the height of the embankment.

Since the 1950s, organised control over soil erosion on the Loess Plateau has been carried out and about 100,000 sq.km. of eroded area have been primarily improved. Thus more than 200 million tons/year of sediment washed down into the Yellow River have been reduced. Among the various control measures, biological measures are predominantly used and have been adopted in 64 per cent of the total area controlled. Among the areas using biological measures, soil and water conservation forests have been established on more than 70 per cent of the area.

For many years, because of the irrational selection of tree species; irrational decisions regarding the location of afforestation; and a variety of other reasons, the survival rate, preservation, and growth of the forests have been unsatisfactory. Therefore, one important subject of research work relating to soil and water conservation in the Loess Plateau is the identification of appropriate tree species and the location of suitable afforestation areas.

After many years of investigation and study, it was found that the local species of seabuckthorn has wide ecological adaptations. It is distributed extensively throughout grasslands, forest-grasslands, and deciduous forest zones of the Loess Plateau, especially on the mountains and hills of the forest grassland zone.

As described earlier, seabuckthorn has many special characteristics that cannot be found in other trees; it can fix nitrogen, improve soil fertility, has a strong ability to sprout from its roots, resulting in individual as well as community plants at a rapid rate, and it can accumulate more biomass in a short period, thus forming dense woods. Table 18 gives a comparison of the biomass accumulation of seabuckthorn and other shrubs on the Loess Plateau.

Table 18: Comparison of the Biomass Accumulation of Seabuckthorn and Other Shrubs on the Loess Plateau

(10,000 kg/ha)

Species	Soil	West Shaanxi		East Gansu	
		Age (years)	Biomass (fresh)	Age (years)	Biomass (dried)
Seabuckthorn	red	15	1.98	9	1.69
Caragana korshinskii	red	15	1.39	6	0.79
Rosa xanthina	red	15	1.78	-	-
Vilex chinensis	red	20	0.39	-	-
Amorpha fruticosa	red	20	0.83	6	0.45

Source: Li Min et al. 1989

Investigations showed that a three-year old seabuckthorn plant can sprout up to 10 turions and a five-year old plant up to 51 stems. On one abandoned wasteland, seabuckthorn forests expanded their borders by 2m or so each year.

Seabuckthorn plants can multiply to form dense, bushy woods over a short period of time and the bushy woods intercept rainfall and protect the soil from erosion. It is reported that in Youyu County, Shanxi Province, 74km of seabuckthorn forest planted on the banks of the Changtouhe River protected the river banks, and the sediment discharged into the Yellow River decreased by 3-5 million tons each year (Li Min et al. 1989).

Seabuckthorn has long been known as a soil and water conservation plant. Why does it now play an even more important role in harnessing the Loess Plateau? A reasonable explanation is that the implementation of any project should mobilise the people (especially farmers) to participate in the project. Before realising the economic value of seabuckthorn, farmers did not care about afforestation because they did not get direct cash income. Now, as the comprehensive benefits have become visible, the farmers have begun to accept this plant. To sum up, seabuckthorn has a high economic value; from each hectare of seabuckthorn, 4,500 kg/year of dry firewood and 1,500 kg/year of leaves, with high nutritive value, are produced. Seabuckthorn also enhances soil fertility by fixing nitrogen, and its fruit is used in the food, medicine, and cosmetic industries. In recent years (1986-1988), extensive exploitation and use of seabuckthorn resources have been carried out on the Loess Plateau. The production value of

seabuckthorn fruit-processing has reached more than 100 million *yuan* (21.2 million US$) altogether, and the products have been offered to both domestic as well as international markets. Therefore, popularising seabuckthorn in poor areas like the Loess Plateau, where fuel, feed, and fertilizer are lacking, has a lot of significance.

Concrete Results and the Long-term Programme

According to statistics, during the period 1986-1989, 53.3 thousand hectares of land were planted annually with seabuckthorn and a total of 213.0 thousand hectares was established on the Loess Plateau. Because seabuckthorn can survive more easily than other trees and bushes, the area of seabuckthorn forest accounted for more than 10 per cent/year of the total forest area treated for water and soil conservation in the region.

To take a case in point, Wugouxian of Zhangyaan County, Gansu Province, is located in the hill and gully area of the Loess Plateau. It has an annual precipitation of 460mm and is one of the poorest areas. During the 30 years before 1982, many tree species, such as apricot (*Prunus armeniaca* var. *ansu Maxim*), poplar (*Populus davidiana*), willow (*Salix matsudasa*), sophora (*Sophora japonica*), elm (*Ulmus laevis*), were tried and the total reforested area reached 2,333 ha. Because the natural condition in the area was very poor and not suitable for these species, only 400 ha of forest, accounting for 17 per cent of the total area, remained. Even those remaining trees did not do well and looked small and weak. From 1983 onwards, the farmers began to plant seabuckthorn on a large scale. With the guidance and help of the local government, by 1988, they planted about 20 million saplings which covered 4,000 ha of mountain slope. More than 80 per cent of the seabuckthorn forest survived and more than 27 per cent of the total area in this township was covered by this forest. The per capita area of seabuckthorn forest was about 0.3 ha and this provided the farmers with enough fodder and firewood.

Yike Zhau in Inner Mongolia is situated towards the edge of the Mu Us Desert. In the total area of 80 thousand sq.km., 47 thousand sq.km., accounting for 58.8 per cent of the total area, are prone to severe water and soil losses. Each year about 0.19 billion tons of mud and sand are washed away from this area into the Yellow River, out of which about 0.15 billion tons are arenite. The modules of soil erosion reach 15,000-30,000 tons/km^2/year. Because most of this area geologically consists of arenites that are characterised by their loose structure, easily breakable by water, and covered with sparse vegetation, when the downpour comes, this kind of arenaceous land quickly disintegrates. Surface soil and water rush down swiftly and many gullies are left. Therefore, the local people call this area the "Valley of Death" and the "area of maximum water and soil loss".

From 1986 onwards, under the leadership and financial support of the Conservation Committee of the Yellow River, the local officers and farmers have jointly worked on the trial, demonstration, and extension of seabuckthorn. Within 5 years, more than 6,666 ha of seabuckthorn forest were established in this area. Now the four-year old seabuckthorn saplings have grown well, reached up to 2m in height, and have begun to bear fruit. Because of the massively sprouting turion seedlings, the canopy density of seabuckthorn forest has exceeded 90 per cent of the planted area on the shady and semi-shady slopes where there is more moisture.

In areas with an altitude of 1,500m, more than 600 ha of mixed forest, consisting of Chinese pine, apricots, and seabuckthorn, have been established. Apparently because seabuckthorn provides more moisture and nitrogen, Chinese pine trees grow much better in mixed rather than in pure forests.

On the Loess Plateau, most parts of the forest-grassland zone and a part of the grassland zone are the areas where extremely severe soil and water loss occur. According to the divisional forest plan of China, the afforestation here, because of moisture limitations, should be carried out with shrubs as the principal species. Seabuckthorn, as a native shrub, has characteristics that have advantages over other shrubs, e.g., it grows faster, it helps soil and water conservation, gives more significant economic benefits, and is more readily accepted by the people.

The total area of this region is about 160,000 sq.km. According to the divisional plan of the Ministry of Forestry of China, the forest cover rate of this region should be 40-50 per cent. Of this, if 70 per cent is shrubs, and seabuckthorn accounts for 60 per cent of it, then with the deduction of 5 per cent of the area already covered, there will be 1,890-2,560 thousand hectares of land on which seabuckthorn should be planted. This equals 2.7-3.6 times the seabuckthorn forest area that currently exists. Extensive development of artificial seabuckthorn forests in this region will result in economic benefits as well as effective improvement of the soil and water loss over a relatively short period of time.

Seabuckthorn Afforestation by Air-seeding

Seabuckthorn has some positive biological features, e.g., the germination rate of seeds is high and the emergence of seedlings is fast, it has a strong root system, and it has the powerful capacity to form root turions. All these features make seabuckthorn suitable for air-seeding. Once it is sown and grown, rational cutting and improvement establishes the mass groves that will survive for many years.

Successful Examples of Seabuckthorn Air-seeding

Since the 1950s, seabuckthorn afforestation through air-seeding has been carried out in the mountain areas of northwestern China. Some successful experiences are discussed below.

1. In December 1959, on the Niangniang Mountain, Datong County, Qinghai Province, where the altitude is between 2,800-3,100m and the area falls into the cold alpine region and receives 576.4mm of precipitation, about 1,333 ha of slopy mountain land were afforested with seabuckthorn by air-seeding. According to investigations carried out in late July, 1960, 8,385 plants per hectare had survived and the area covered with seabuckthorn seedlings accounted for 45 per cent of the total air-seeded area.

2. In 1982 (July 20-22), the Lanzhou Civil Aviation Bureau and the Lanzhou Forestry Bureau jointly conducted experimental air-seeding in the Gaolan Mountain, Lanzhou, Gansu Province. This air-seeding covered 78.4 ha of wasteland with seabuckthorn seeds, totalling 7.5 kg per hectare. According to investigations made in October, 1982, there were 1475.7 seedlings per hectare on this mountain and the area covered with seedlings accounted for 75 per cent of the total air-seeded area.

3. From 1977 to 1979, the Northwestern Institute of Soil and Water Conservation, Academia Sinica, carried out an air-seeding experiment on 1,240 ha of mountain land in Wuqi County, Shanxi Province, a typical semi-arid, Loess Plateau Region. In 1983, a sample investigation made in the area showed that there were 21,905 to 40,960 seedlings per hectare remaining and most of the air-seeded area was covered with massive forests of seabuckthorn.

4. In 1982, air-seeding, using mixed seeds of Chinese pine (*Pinus tabulaeformis*), spruce, and seabuckthorn, was carried out in Xihe County, Gansu Province, and in 1987 another air-seeding operation, using mixed seeds of Chinese pine, Chinese arborvitae (*Platycladus orientalis*), and seabuckthorn, was carried out in Qingshui County, Gansu Province. The air-seeded areas of those two counties amounted to 1,714 ha. Investigation carried out in the autumn of the same year showed that the survival ratios were 30,015 and 18,000 seedlings per hectare respectively in those two counties (the survival ratio included 3 species of plants) and that the average height of the seedlings in the air-seeded area had reached 4.3cm.

To summarise the experiences above, it may be said that in lands that are characterised by large areas and sparse populations, serious soil and water losses, and annual precipitation of more than 400mm, such as the hill-ravine area of the Loess Plateau, China, seabuckthorn afforestation by air-seeding is an effective measure of accelerating and recovering vegetation, as well as of enhancing seabuckthorn forest and promoting the development of agriculture, forestry, and animal husbandry in these areas.

Many years of experience with seabuckthorn air-seeding have proved that it is a very promising method. The following are some of the advantages: generally, the seed quantity per hectare is only 0.4-0.5kg, but if an aeroplane (in the Chinese case, a small aeroplane, Yun-5, is used) flies 5-7 flights per day, it will cover 1,334 ha. Leaving aside the cost of seeds, the expense of air-seeding is 60-75 *yuan* (1.27-1.59 US$) per hectare which is one-third of the cost involved in artificial afforestation. Furthermore, compared to the artificial afforestation of seabuckthorn, air-seeding has some special advantages, such as speed, more effectiveness, a wider range, and low cost. It seems that the technology of air-seeding can be popularised in the vast mountain areas (Wang Zhengmin 1990).

In order to speed up vegetation recovery to control soil and water loss, an experiment in the air-seeding of seabuckthorn and other herbs and shrubs was carried out in Wugi County, a semi-arid region of the Loess Plateau, China, from 1977 to 1979. Air-seeding of seabuckthorn has been successful and also popular in large areas of north, northwestern China. It is believed that air-seeding is an effective way to accelerate the control over soil and water loss and to exploit seabuckthorn. The results of the experiments from 1987 to 1988 are summarised in the following passages.

The Natural Conditions of Seabuckthorn Air-seeded Areas. The experimental air-seeded areas are located in the northwestern part of Wugi County, at an elevation of 1,365-1,650 masl and belonging to the loess, hilly, gully regions where the Luohe River originates. The annual mean temperature is 7.5°C, the minimum temperature -27°C, and the maximum 35.5°C. The annual rainfall is about 380mm. The experimental areas, according to vegetation zonification, fall into the shrub-steppe region of temperate pastures. Forty years ago, there were some seabuckthorn shrubs as well as other species, but currently the natural shrubs are almost totally destroyed and the existing natural vegetation is composed of herbaceous communities of Bunge Needlegrass (*Stipa bungeana)*, Mongolian Thyme (*Thymus mongolicus*), Fringed Sage brush (*Artemisia frigida*), Stemless Cinguifoil (*Potentilla acaulis*), and Wormwood (*Artemisia gmelinii*). The lands were not treated before air-seeding and the seeds of seabuckthorn were sown on the natural vegetation, young plantations, and derelict lands. In the three-year experiment in air-seeding, two years were successful. Many tracts of air-seeded seabuckthorn forests can currently be seen in this area.

The Results of Air-seeded Seabuckthorn and the Main Constraints. In order to determine the most appropriate air-seeding time, artificial sowing experiments were carried out during different times in 1975 and 1976. The results indicated that from the last ten days of June till the 20th of July was the right sowing time. Thus, seabuckthorn air-seeding was carried out during the three years from 1977-1979. It was observed that the emergence of seabuckthorn seedlings by air-seeded area and the density of seedlings were quite different during different years. The survival rate of seedlings in the year sown was about 1 to 25 per cent, and 60 per cent of the young seedlings died during the following winter. However, after the third year, the percentage of the area and the plant numbers increased each year because the plants by then began to sprout seedlings from the roots.

Despite the low survival rate of air-seeded seabuckthorn, there was one plant per $10m^2$, on average, on the air-seeded land. After several years, the air-seeded land was covered with close stands of seabuckthorn. In other words, air-seeding of seabuckthorn can be successful.

The rainfall situation after air-seeding is a major constraint influencing the air-seeding results. Surveys showed that the seeds sown on the earth's surface germinate well when there are 6 to 8 continually cloudy and rainy days and more than 50 to 60mm of precipitation. If the seedlings form three pairs of microphylla in the 50 to 60 day growing period, their survival chances are better during winter. The seeds cannot germinate well unless there is enough rainfall after sowing. If the continuous rainfall is too late, or the frost comes in too early, the seeds germinate late and the seedlings cannot survive through the following winter. In addition, seabuckthorn seedlings are sensitive to high temperatures, the unlignified young seedlings are easily scorched and die in temperatures of 40° to 50°C. In most regions of the Loess Plateau, the rainy season is concentrated in July, August, and September and the amount of rainfall in these three months accounts for 60 per cent of the total annual rainfall. Thus, this provides a favourable condition for air-seeding. The experiments also showed that when the seeds were sown on loose earth, such as derelict land or young artificial woodlands, the young seedlings emerge faster and are stronger, but on dry and hard land, germination could not take place easily and the seedlings did not emerge well. In fact, most air-sown seabuckthorn forests were distributed on shady slopes and on loose land.

The Establishment and Nurturing Process of Air-sown Seabuckthorn Woodlands

According to observation, the air-sown seabuckthorn plants began to propagate through the root turion from the third or fourth year onwards. The seedling area and density then increased year after year. The more the soil moisture, or the lower the density, the more and earlier the sprouting. When the density of plants reached 2 plants/m^2 and the canopies clustered together, the topmost leaves and branches rose higher for want of light and excess absorption of soil moisture occurred, therefore some plants began to wither and die. This is the reason why, after about seven years, the density of the plants in the air-sown forests began to decrease.

Air-sown seabuckthorn forests can be transformed or nurtured for different uses according to their site types. Their special uses are discussed below.

A. For Soil and Water Conservation. On steep and broken slopes, a high density of air-sown seabuckthorn forests should be maintained in order to control soil and water loss. After 5 to 6 years, the crown density of seabuckthorn woodlands can increase up to 80 per cent from the previous 20 to 30 per cent, and, in seabuckthorn forests, litter can accumulate up to a

thickness of 2-6 cm and it can hold twice as much water as the weight of the litter. In addition, compared to natural mountain slopes, the nitrogen-fixing ability of the root tubercles of seabuckthorn can increase the nitrogen contents and the organic matter of the soil, in 10cm depth, by 1.7 and 2.1 times respectively. Thus, herbaceous plants in seabuckthorn forests grow luxuriously, and they enhance the conservation efficiency of the soil and water.

B. For Orchards. On gentle slopes, air-sown seabuckthorn forests can be transformed into orchards. Thinning out male plants, maintaining the male and female ratio at 1:8-1:10, and spacing the rows 3-4m apart and the plants 1m apart, seabuckthorn forests can be transformed into orchards. By using fertilisers and pruning the withered and diseased branches, the fruit yield of seabuckthorn orchards can be improved. Investigations carried out in 1987 showed that the fruit yield of a transformed forest reached 1,100kg/ha, whereas the untransformed forest only yielded 420kg/ha.

C. For Timber. Straight, sturdy seabuckthorn plants can be selected or nurtured into small pole-like stands by thinning and pruning. These micro-phanerophytes can be used to make farm tools and furniture.

D. For Firewood and Grazing. Air-sown seabuckthorn woodlands provide lots of firewood after thinning and strip-cutting. The leaves of seabuckthorn are rich in nutrients and they can be used as animal feed. After strip-cutting, rich herbages can be grown along the row or beneath the seabuckthorn plants. This kind of woodland can become good grazing land (Li Daiqiong et al. 1989).

The Role in Maintaining an Ecological Balance

Benefits for Mankind and Animals

Once seabuckthorn forest has been established on a large scale (e.g., in Jianping County there are 56,000 ha of seabuckthorn forest covering mountain slopes which used to be bare and arid), it can bring about enormous environmental changes and form special natural landscapes in the concerned area. Seabuckthorn forests not only improve the microclimate, control loss of water and soil, and provide fuelwood, but also give added dividends. According to investigations made in Lougu Gully, after the seabuckthorn forest coverage reached 57 per cent, wildlife returned to the forest. This benefits both the farmers as well as the wildlife. Attracted by a suitable habitat and seabuckthorn fruit that cling to the branches right through winter to the following spring, 8 animal species and 25 bird species have inhabited this forest and are recovering their numbers. Every year, from seabuckthorn forests, the local farmers collect about 30,000kg of wild edible fungi which is worth 8,000 US$ and they trap about 25,000 rabbits worth 38,000 US$. From these items, the farmers in Loufu Gully make an annual cash income from seabuckthorn forests of 16-30 US$ per household.

Ecological Balance

A survey on the interaction between seabuckthorn and some birds and beasts conducted by the Shanxi Institute of Biology and the Northwestern Plateau Institute of Biology, Academia Sinica, revealed a wide ecological significance. For example, in the Loess Plateau Region, among over 360 known living bird species, there are 51 species that are entirely dependant upon seabuckthorn as a food and 80 species that are relatively dependant upon seabuckthorn. As mentioned before, the ripe seabuckthorn fruit cling to the branches for several months. In winter, the importance of the fruit increases as it is almost the only food available for the birds perched there. Especially for the rare bird, *Crosoptilon manchuriam*, seabuckthorn fruit accounts for 48.1 per cent of its food and for *T. alaschanicus* it accounts for 58.4 per cent. Thus, it can be seen that seabuckthorn is of vital importance to birds. In the Loess Plateau Region, among about 60 known living animal species, 29 species have been found to inhabit seabuckthorn bushes and for 27 species seabuckthorn stems, leaves, flowers, roots, fruit, and seeds serve as food. Carnivorous animals, such as *Canis lupus, Felis pardus, Vulpes vulpes, Felis bengalensis,* etc often seize their prey and take shelter in seabuckthorn bushes. There are indications that the number of beasts increase as seabuckthorn bushes increase and become forests.

However, for seabuckthorn that are producing fruit it causes damage when the seabuckthorn is eaten by birds and animals, but despite this it is an effective way to transfer seeds through the digestive tubes of birds and beasts. Results of experiments have shown that the rate of germination of seeds from the stool of *Turdus ruficollis* is 65 per cent and that from the stool of *Lepus capensis* it is 35

per cent. Due to the ever- increasing scope of human activities, the natural habitats of birds and animals are decreasing, resulting in extinction and a substantial reduction of certain species. The protection and development of seabuckthorn resources are in many ways beneficial to the existence of birds and animals. Therefore, seabuckthorn forests provide long-term benefits in terms of maintaining ecological equilibrium (Ma Zhiben et al. 1989).

Seabuckthorn as Fuelwood Forest

Importance of Fuelwood

The question of domestic fuelwood supplies in the developing countries has gained prominence in past decades. In the HKH Region, by far the most important source of energy is plant biomass in one form or another and hardly anything else is of any significance to most farmers. According to the Forest and Soil Conservation and Agricultural ministries in Nepal, forests constitute 37 per cent, bushes, 5 per cent, and grassland 12 per cent of the total cover in the country. In the central hill region of Nepal, the biomass from forests, including shrublands, supplies approximately two-thirds of the total annual fuel supplies produced rurally. The rest (one-third or so) comes from private land in the form of agricultural crop residues, tree fodder residues, and some other forms (Mahat 1987).

As has been previously mentioned, in China 60 per cent of the 800 million farmers face a shortage of fuelwood for 3 to 5 months each year. In the rural areas of the arid and semi-arid regions, because of lack of fuelwood, a number of farmers have only two meals per day. Unfortunately, Chinese farmers in this area are less lucky than Nepalese farmers, because the latter can at least collect fuelwood from rich resources of forest, bush, and grassland. In some areas of the Loess Plateau, especially during spring, the farmers have to dig up even the roots of weeds for cooking fuel because the stock of crops has already been consumed. For example, in Wugouxian, Zhengyuan County, Gansu Province, every year the households have to spend 70-140 mandays to dig turf and roots for fuel, and these too are very sparse and scattered throughout the area. Furthermore, an average of 170 kg of dry dung/annum/person is consumed as fuel and this in turn leads to the degradation of the soil because of lack of dung for the fields.

Potential of Seabuckthorn as Fuelwood

Resolving the problem of energy shortage in the rural areas is a big challenge both for the Government as well as for the farmers. Seabuckthorn has proved to be a popular green energy plant because of its high quality biomass. Based on this knowledge, a programme for the purpose of establishing fuelwood forests of seabuckthorn has been carried out in Luofu Gully, Jianping County, Liaoning Province. During the seven year (1982-1988) period, more than 4,000 ha of seabuckthorn seedlings were planted in Luofu Gully and more than 20,000 ha of the same were extended over the whole county. Experiments and calculations carried out in a six-year old artificial seabuckthorn forest in Luofu Gully, revealed that each hectare can produce 18 tons of fuelwood. As the average calorific value of dry seabuckthorn wood is 4785.5 calories per kilogramme, which is more than that of most species of trees, one ton of seabuckthorn wood is equal to 0.68 of a ton of standard coal. It is estimated that, if the farmers grow seabuckthorn for fuelwood, every household may save four tons of standard coal per year. Based on the experiment, it is recommended that the proper planting density of seabuckthorn is 6,600-9,999 plants per hectare and the first harvest (cutting) time should be when the plant is six years' old, the time when it can produce the maximum biomass. The best cutting time is from December to March when the plant is in the dormant period. After the plant above the ground is cut, from about 94,000 to 95,000 root turion seedlings (new plants) per hectare will emerge in the next growing season. This means that seabuckthorn can provide a lot of fuelwood in a short period and can be used sustainably over the long term (Jiang Shumao et al. 1988).