Chapter Four
Technologies for Land and Soil Management

Introduction

Without conservation measures and land management planning on extremely fragile terrain, as in the HKH region, the threat of land degradation and loss of fertile soil will exacerbate. Based on land-use patterns, land resources are generally classified into natural resources and farm resources. Conservation and development of both classes should evolve together for a sustainable mountain environment. Since both are inter-related, any negative impact on the health of one class is quickly reflected in the other. While planning for a long term, profitable mountain farming system, the parallel development of adjoining natural resources has to be taken into account.

Soil is the primary resource base for both classes of land. Loss of valuable soil due to wind and water erosion and depletion of soil fertility are emerging as the primary constraints to sustainable land use within the mountain ecosystem. HKH soils require scientifically based, site-specific soil and land management practices because of their shallowness (i.e., <20cm deep) with extensive colluvial slopes. Nizami (1996) described the characteristics of HKH soils. The soils have a well humidified, dark colour. The amount of organic matter is generally one to two per cent. The soil's organic matter content and thickness are generally greater on cooler and wetter aspects. HKH soils are mostly gravelly, coarse to moderately coarse in texture, and susceptible to erosion. The severity of erosion is linked with the gradient of the slope and vegetal cover at a particular location. Soils are calcareous, the content ranging from weak to strong, and the reaction to alkaline – with a pH range of 7.0 to 8.4 – is neutral.

The changing socioeconomic scenario of the HKH region is causing disturbances on rangelands and watershed areas, along with a rapid deterioration of chemical and physical properties and a declining fertility status of most soils. Thus, technologies included in this chapter will deal with natural resource rehabilitation, conservation, and improvement, as well as land preparation and means of improving the soil fertility of farm resources.

Range Improvement Using the Three Strata Model

Significance

The Three Strata Model (TSM) counts as a range improvement technology. It involves the rehabilitation and management of degraded ranges, as well as the improvement of relatively sustainable grazing areas, by

Plate 10: **The Three Strata Model for Range Improvement has Multiple Benefits**

Simply by incorporating a desirable shrub component into a range vegetation structure, the same range area can withstand stocking rates many times higher than usual.

constructing and harvesting the vegetal structure in a sequence of strata (i.e., grasses and forbes, shrubs and trees). TSM ensures increased and sustainable forage supplies to livestock, mainly during lean periods, and persistent supplies of firewood for domestic use. TSM creates a more pleasing environment, as some strata will remain green all year round.

Components

Many considerations must be taken into account when constructing a stratified plant community with multiple benefits on rangelands. These include biological, ecological, and cultural uses as well as socioeconomic factors. Plant species, which complement each other and are of multiple use, are extremely desirable. For example, mixing leguminous herbs with grasses in the lowest stratum would not only improve the nutritive quality of forage for animals, but would also increase yields due to improved soil fertility by legumes. Similarly, the inclusion of leguminous, non-leguminous and palatable shrubs in the middle stratum, and trees in the upper stratum, would improve the micro-climate for lower strata species that would result in their greater diversity, richness, and pronounced socioeconomic benefits. Thus, one of the crucial points for range re-seeding operations is the selection of proper species. For most of the HKH arid tract, the species to be seeded must be drought resistant, palatable, and salt tolerant. Among the grasses, *Lasiurus sindicus*, *Cenchrus ciliaris*, etc are recommended for this type of tract. Re-seeding by conventional means is likely to fail in low rainfall areas. Therefore, seeding of grasses coupled with water-harvesting techniques, such as spreading, pitting, contour trenching, and furrowing, is needed for the success of seeding operations.

From the existing native vegetation, it is evident that shrubs are capable of with-

standing the harshness of the arid climate as well as heavy grazing pressure. Shrubs provide good forage during winter when grasses disappear or dry up. Shrubs usually contain more protein than grasses. Certain trees and shrubs possess morphological and physiological elasticity in relation to drought. Fodder shrubs and trees possess a definite potential for resolving climatic, biological, social, and economic constraints encountered in arid and semi-arid areas. The following trees and shrubs are recommended for planting in the HKH belt, along with the above-mentioned grasses.

Acacia nilotica, A. modesta, A. tortilis, Prosopis cineraria, Tecoma undulata, Zizyphus mauritiana, Z. nummularia, Atriplex nummularia, A. polycarpa, A. canescens, Opuntia indica, and Tamarix aphylla.

Seabuckthorn - A Magic Plant for Dry Mountains

Significance

Seabuckthorn (*Hippophae* spp) is a deciduous shrub, widely distributed throughout the temperate zones of Asia and Europe, and the subtropical zones of Asia at high altitudes. It is commonly found throughout the countries of the HKH region. It has a highly developed root system, which is excellent for holding soils on a fragile slope. In seabuckthorn planted areas, loss of topsoil caused by seasonal monsoons can decrease to less than 30 per cent, and it is possible to hold more than 80 per cent of water in the ground. Seabuckthorn has the ability to take root even in poor soils, because it can fix nitrogen directly from air through the nodules in its roots. A natural seabuckthorn forest can yield 750 to 1,500kg of berries per hectare. Its fruit is a rich source of vitamins. Oil from the pulp and seeds is valued for its medicinal properties. It supplies palatable forage to all classes of livestock during most of the year.

Components

Seabuckthorn is described as the most appropriate multipurpose biological option for mountain areas. Its fruit can be used for making more than 100 products such as soft/hard/powdered drinks, jams, sweets, cosmetics, and medicines. Despite the scientifically proven potential of seabuckthorn for manufacturing several high-value products for human consumption, its harvesting is constrained by the lack of appropriate technologies and facilities for processing. China and several central Asian states used it effectively in industries related to food and medicine.

Use in the 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.

Use in the medicinal industry: About ten varieties of seabuckthorn drugs have been developed and are available in the form of liquids, powders, plaster, pastes, pills, liniments, aerosols, etc. These drugs are used for treating burns, gastric ulcers, chilblains, scales, oral mucosities, rectal mucosities, cervical erosion, radiation damage, skin ulcers caused by malnutrition, and other damage relating to the

Plate 11: ***Seabuckthorn in Mastung Area of Chitral, Pakistan***

Seabuckthorn is a 'magic' plant species and may be the best option when establishing a Three Strata Model for range improvement in arid mountain regions.

skin. The most important pharmacological function of seabuckthorn oil is in diminishing inflammation, disinfecting bacteria, relieving pain, and promoting regeneration of tissue.

Use in the cosmetic industry: 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. In China, it has been found that seabuckthorn products can cure 16 tropical diseases.

The use of leaves and residues: The leaves of seabuckthorn contain many nutrients and bioactive substances. Leaves and fruit residue used as supplementary food can promote growth of animals and poultry. There are no toxic or carcinogenic side effects.

Use 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, colour value, heat and light stability, and effect of pH and metabolic ions, make it a very useful food additive.

Role in 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. 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.

Use as fuelwood forest: In the HKH 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. The calorific value of dry seabuckthorn wood is 4,785.5 calories per kg. It is a good source of firewood. In a six-year old seabuckthorn forest, each hectare can produce 18 tons of firewood, equal to nearly 12.6 tons of standard coal.

Fourwing Saltbush - A Forage Shrub for Arid Highlands

Significance

This technology has been tested successfully in the arid highlands of Balochistan, Pakistan.

Fourwing saltbush can be established in cold and arid zones of the HKH region by using the proper techniques for soil moisture conservation. The most valuable characteristics of this plant include its tolerance for extreme drought, cold, and high quality browsing facility, especially during the autumn and winter months. This shrub is a perennial halophyte which continues to produce green leaves and twigs round the year. Fourwing saltbush is an excellent seed producer, with the seeds maturing from October to December. The seeds dry on the plant, thus allowing some flexibility in harvesting.

It can also be used as fuelwood in addition to forage for livestock. About 0.5 to 1.0kg of dry wood per plant can be obtained after an initial two years of plant growth and then each year. Fourwing saltbush can be promoted as a sustainable source of fuelwood and can help reduce the uprooting of local shrubs from already denuded rangelands.

Components

Atriplex canescens, commonly known as fourwing saltbush, is an evergreen shrub with dense foliage, 1.8 to 2.7m high. It

Plate 12: ***Sheep Grazing Fourwing Saltbush in Cold and Dry Mountains***

Fourwing saltbush is an exotic forage technology. By establishing forage banks on marginal lands, the ranges can be de-stocked for improvement and rehabilitation purposes.

bears male and female flowers on separate plants. The flowering period is from July to August. Fourwing saltbush has an extensive root system and is adapted to a wide range of soils and climates. It thrives in areas with a mean annual precipitation of 250mm. Below 200 to 250mm, additional water from runoff, irrigation, or the presence of a water table is mandatory for good production. Fourwing saltbush shows good adaptation to cold environments, withstanding temperatures as low as -20°C. On the other hand, it can survive at 35°C during hot dry periods in arid climates. It does better on shallower, silty soils, for example, soils having shallow lime crusts, etc. Fourwing saltbush has a good tolerance for saline conditions.

Normally, the seeds do not germinate under natural rainfed conditions, so direct seeding is not recommended. The best way to grow this plant is in the nursery. Germination takes place in about seven to 10 days in spring, summer, and early autumn.

Seedlings are transplanted at four to five months of age in the winter rainfall season. However, planting can be carried out throughout the year if irrigation is available. Under rainfed conditions, it is recommended that the first watering should take place at the time of planting to help the plants establish their roots deep in the soil.

Fourwing saltbush can be planted in holes (0.5m deep and 0.5m wide) to collect and store rain water. It can also be planted in ripped lines. For raising forage reserves, a 2 x 2m plant-to-plant distance is recommended that may be changed according to the type of plantation. Plants should be protected from grazing until they are about 18 months old and have woody stems and a well-developed root system. Plants can be grazed during winter without reducing the vigour of the shrub. However, heavy use in late summer or autumn could be detrimental to the plants. Sheep and goats would require an adaptation period of 10 to 15 days for grazing and then the farmer should increase their herbage intake over time. An average biomass of 1,200 - 1,600kg dry matter could be obtained per hectare, which is sufficient for six sheep to graze the area for three months.

Fourwing saltbush can withstand moderate to heavy grazing pressure and responds vigorously by re-sprouting the next spring. Plants become woody and less palatable if not grazed or pruned after two years of growth. Therefore, periodic grazing or pruning is required to keep plants highly productive and palatable. The quality of feed improves significantly after pruning, particularly the protein and carotene content of leaves. In addition, access for animals to graze the plant efficiently is also improved after periodic grazing and cutting.

Fourwing saltbush generally possesses a low energy value due to the high mineral content. The energy value is enough to supply the maintenance needs of sheep if they consume 1.2 to 1.5kg of dry matter (DM) per day. An important quality of this species is its high protein content, which can be as high as 15 to 20 per cent. The digestibility of dry matter and organic matter could be 60 and 50 per cent, respectively. The digestibility of nitrogen ranges from 50-55 per cent.

Kallar Grass for Biological Reclamation of Saline and Waterlogged Areas

Significance

Kallar grass (*Leptochloa fusca*) for biological reclamation of saline and waterlogged

Plate 13: ***Kallar Grass is a Biological Reclamation Tool of Waterlogged Areas Where Soils are Saline- Sodic and Supplies of Irrigation Water are Saline.***

Growing this species is a viable way to make optimum use of soil and water resources. On saline or sodic soils, this grass may be grown with good quality or sweet irrigation water and used to improve the properties of the soil.

areas is widely distributed in salt-affected areas of Australia, India, Pakistan, the USA, and other tropical arid and semi-arid regions of the world. It is easily propagated through seed, stem cuttings, or root stumps and exhibits excellent growth under saline, sodic, and flooded soil conditions. Kallar grass is amongst the few plant species that are well adapted to both waterlogged and saline conditions.

Components

Kallar grass is grown on salt-affected and waterlogged soils with peak yields during the rainy monsoon season. The stump planting requires regular flooding for good growth and survival. This vegetation can evaporate large quantities of groundwater. An added advantage of kallar grass under waterlogged conditions is that it reduces the salinity of groundwater and provides a better environment for other plants. The high tolerance of kallar grass to being waterlogged is obviously related to its ability to efficiently transport oxygen through its aerial parts to aerate the root system via internal air channels (parenchyma) in the same manner as rice and other wetland species. Similar to many other monocot species, this species is capable of producing numerous adventitious roots that emerge from the base of each node on the shoot when in water or wet soils.

The species does not grow without excessive salts and vanishes when salts are removed. This is an advantage because the grass cannot become a weed in non-saline and improved soils. Soils on which kallar grass is grown may improve sufficiently to support the growth of other field crops. Many farmers in Pakistan have reclaimed their salt-affected wastelands by growing kallar grass for three to five years continuously, until less salt tolerant and even sensitive plants could be cultivated. Farmers are now making a good living by

raising buffaloes, cattle, goats, and sheep on this reclaimed land. A large number of small farmers are now adopting this practice, thus reducing rural to urban migration.

Shoot foliage can increase organic matter, humus, and soil mulching; decrease surface evaporation; and improve physical properties of the soil. Thus, with the passage of time, this process of amelioration can improve problem soils.

Mesquite for Stabilising Desert and Degraded Areas

Significance

Mesquite wood is hard and heavy with a specific gravity of 0.70 or higher, is excellent for firewood, and makes superior charcoal. Because of its high calorific value, the wood has been called 'wood anthracite'. It burns slowly and evenly and holds heat well. The tree is also valued for shade, timber, and forage. Pods are eaten by livestock and can be ground into flour for human consumption. It is planted where other more valuable forest species cannot be grown (Table 17).

Stabilisation models for sand dunes using mesquite have been developed successfully in Balochistan, Pakistan. Mesquite seeds were raised in polythene bags filled with coastal sand and irrigated with good quality water. Six-month to one-year-old seedlings were planted in coastal sandy belts, spaced 2m apart. These were irrigated without any chemical amendment with sub-soil brackish water obtained from nearby wells. It is important to mention that during this work no chemical fertilizer, plant protection measures, mulching, or wind barriers were used.

Components

Mesquite (*Prosopis juliflora*) is a thorny semi-deciduous, large-crowned, and deep-

Plate 14: ***Mesquite Growing in a Sandy Area***

Prosopis juliflora inherits a strong defence mechanism which protects it from grazing and eventually lets it become a vigorous invader, with minor care and management, on abandoned soils.

Table 17: Beneficial Effects/Potential Uses of Prosopis Propagation in the Arid and Semi-Arid Areas of the HKH Region

Soil fertility	Environmental	Socioeconomic	Food/feed	Other products
Agroforestry systems	Improved C-sinks in the soil	Employment creation	Improved pasture	Charcoal
Control of soil erosion	Increased methane oxidation in soil	Diversification of food	Forage for ruminants	Gasification, electricity generation
Sand dune stabilisation	Sequestration of C in wood	Famine security (animal, humans)	Feed for domestic animals	Construction timber
Desalination	Alternative fuel (renewable resource; reduced use of fossil fuels)	Fuelwood for household use		Fencing materials
Prevention of salination		Cash flow	Supplements for meat/milk production from grass/crop etc. residues	Wood for furniture
N_2-fixation	Water runoff and quality improvement	Shade for humans and animals		Honey/hive products
Recycling of nutrients	Improvement of the micro-climate			Pharmaceutical products
Improvements in physical, chemical and micro-biological properties of the soils	Preservation of wildlife			Oil Gum (pods & bark)
	Landscape beautification (n.b. recreational areas to promote tourism)			Sugars
	Hedging			Non-starch carbo-hydrates
				Sweeteners
				Fibre source (food processing)
				Polyphenol resins (from heartwood)

Source: Muhammad 1996

rooted tree, which may grow up to 10m or more depending on the kind of site on which it grows. It was introduced into Pakistan in the early 1950s, mainly to stabilise dunes and for fuelwood. The tree grows on a variety of soils, but does especially well on sandy soils and can grow on rocky terrain, provided its roots do not face competition.

Mesquite has great potential for reclaiming desert and degraded lands. However, the following operations are a prerequisite for successful mesquite plantations:

- selection of genetically sound mother trees on inherently fertile soils;
- seed collection, cleaning, sorting, classification, and storage;
- nursery operations, maintenance, and transportation; and
- planting of trees with post planting care schemes.

Using rain-water harvesting techniques, mesquite has been planted successfully

on arid lands. Among rain-water harvesting treatments (sand dune slopes) mud and wheat straw plaster yielded maximum rain water. But in areas where sub-soil water is available and can be lifted with small diesel operated pumps, it is easier, and the outcome more successful, if the sand dune slopes are planted with different kinds of plants.

Medicinal Plants

Significance

Because of varying agro-ecological conditions, the HKH region is rich in medicinal flora growing under natural conditions. Farmers collect medicinal plants for their ethno-pharmaceutical uses and market the product for income generation. Proper propagation of important medicinal plant species would not only improve the ecological balance of natural resources but would fetch handsome prices in the market. Farmers may be encouraged to undertake unconventional cultivation of selected annual and perennial herbs as high-value cash crops.

Components

The *Ephedra* species grows widely on most rangelands of the HKH region. In fact, multi-national pharmaceutical companies have been producing the famous brand 'Ephedrine' from it. These companies are producing many other medicines from naturally growing plant species of this region. Because of the many socioeconomic factors and the ignorance of local inhabitants, the raw materials have been going to these factories at a nominal price, or free of cost. A list of important medicinal plants suitable to the region are given in Tables 18 and 19.

Plate 15: ***Ephedra Grows Widely in Cold and Dry Mountains***

The lack of awareness among local people, coupled with the overexploitation of medicinal plants (particularly the Ephedra species) by pharmaceutical firms, has endangered the highly valuable plant diversity. The cultivation of medicinal plants along scientific lines may change the economic scenario for local farmers.

Table 18.:Medicinal Plants Collected by Farmers in India

No	Drug Plants with high market demand	No	Drug Plants with moderate market demand
1	*Aconitum chasmanthum* (Bikh)	1	*Pistacia integerrima* Stewart (Kakar singhi)
2	*Aconithum heterophyllum* ,Wall. (Patis)	2	*Bergenia ligulata* Wall. Engl. (Pashan bedh)
3	*Aconitum violaceum*, Jacq. (Mitha patish)	3	*Punica granatum* (Desi anar)
4	*Berberis aristana*, *Berberis asiatica* and (Kemal or Rasaunt plant), *Berberis lycium*	4	*Terminalia belerica* Roxb. (Behera)
5	*Podophyllum hexandrum*, Royle. (Ban kakri)	5	*Terminalia chebula* Retz. (Harrey)
6	*Viola serpens*, Wall. (Banafsha)	6	*Centella asiatica* Linn. (Urban brahmi booti)
7	*Veleriana wallichii* DC. (Banafsha)	7	*Angelica glauca* Edgew (Cobra)
8	*Jurinea macrocephala* Benth. (Dhup)	8	*Taraxacum officinale* Wigg. (Dudhali)
9	*Saussusrea costus* C.B. Clarke (Kuth)	9	*Rhododendron campanulatum* Don. (Kashmiri Patha)
10	*Gentiana kurro*, Royle. (Kaur or Karu)	10	*Gymnema sylvestre*, R. Br. (Gurmar)
11	*Swertia chirayita* Buch. (Chirayata)	11	*Swertia angustifolia* Buch.
12	*Atropa acuminata* Royale ex Lindley (Indian Belladonna jharka)	12	*Onosma bracteatum* Wall. (Rattanjor or Ratta)
13	*Picrorhiza kruuoa*, Roule ex Benth. (Kutki)	13	*Withania somnifera* (Dunal)
14	*Salvia moorcroftiana* Wall. (Thuth)	14	*Thymus serphyllum* Linn. (Ban ajawan)
15	*Ephedra gerardiana* Wall. (Somlata)	15	*Cinnamomum tamala* Fr. Nees (Tejpat)
16	*Ephedra intermedia* Schr. and Mey	16	*Embilica officianlis* Gaertn (Amala)
17	*Colchicum luteum* Baker (Hirantutiaja or Suanjan-a-tallah)	17	*Mallotus philippinensis* Muell (Kasmal)
18	*Artemisia maritima* Linn. (Santonin plant)	18	*Orchis latifolia* Linn. (Salam panja)
		19	*Asparagus filicinus* Wall. (Satawar)
		20	*Dioscorea deltoidea* Wall. (Kniss)
		21	*Acorus calamus* Linn. (Bach)
		22	*Terminalia chabula* Retz. (Marcy)
		23	*Withania somnifera* Dunal (Ashjgndha)
		24	*Polygonatum multiflorum* Allioni
		25	*Polygonatum verticillatum* Allioni (Salam misri)

Source: Khosla 1997

Jojoba Cultivation in Tropical Aridlands

Significance

Jojoba tolerates extremely high temperatures. During summer, daily shade readings of from 35° to 48°C are common in its natural habitat. However, temperatures above 38°C appear to be of no advantage to the crop and may actually decrease its productivity because such temperatures cause stomata to close, thereby stopping vegetative growth. Jojoba is an exotic species and is successfully being grown in sandy deserts. It also has tremendous potential in arid mountainous regions.

Components

Jojoba (*Simmondsia chinensis*) is a woody shrub or small tree, multi-stemmed, and varying in height from 2 to 2.5m. It produces fruits after three to four years after plantation and is in full swing by nine to 10 years. Male and female plants are separate. Maximum production per unit area can be harvested if a male to female plant ratio is maintained at 1:8. These shrubs have a lifetime of over 100 years. The tap root of mature plants can be 15 to 25m below the soil, with substantial parallel lateral and secondary roots, which give jojoba the ability to draw moisture from a considerable vol-

Table 19: Important Medicinal Plants in the Western Mountains of Pakistan

Scientific Name	Local Name	Habitat/ Occurrence	Potential Uses
Acacia nilotica	Kikar	Plains	Used for diarrhoea, coughs, dysentery, diabetes, throat and chest complaints.
Alhaji maurorum	Jawasa	All habitats	Plant is a laxative, diuretic, expectorant, used as an aperient, and a blood purifier.
Calligonum polygonoides	Phog	Plains	Boiled roots in combination with catechu are used as a gargle for sore throats.
Capparis decidua	Karir	All habitats	Bark is laxative, diaphoretic, anthelminitic, acrid, used in asthma, cough, inflammation, boils and swelling.
Cenchrus biflorus	Lidder	Plains	The decoction of fruit is considered pectoral and a diuretic.
Crotolaria burhia	Sis, meimi	Plains	The plant is sold by medicinal herb vendors and is reputed to have cooling properties.
Cymbopogon jawarancusa	Khavi	Plains, hills	Plant contains essential oil (1%). Grass grown in Hazara contains 90% of d-piperitone and that from Sindh contains 44% Ketone.
Cynodon dactylon	Khabbal	Plains, hills	Plant is laxative, hamostatic haemostatic, demulcent, astringent, used in epilepsy, dysentery and opthalmia.
Desmostachya bipinnata	Dab	Plains	Gum is a stimulant and diuretic, used in dysentery and menorrhoea.
Euphorbia spp	Thor	Plains, hills	Used for snake bites, scorpion stings , is purgative, expectorant, also used in erruptions.
Indigofera oblongifolia	Jhil	All habitats	Purgative, used for rheumatic joints, has antisyphilitic and antiphelogistic properties.
Kochia indica	Bui	Fallow lands	Plant is a cardiac stimulant used in cases of weak and irregular heartbeat.
Peganum hermala	Harmal	Deserts	Seeds and fruits contain four alkaloids: harmine, hormaline, harmaline and pegamine.
Phoenix dactylifera	Khajoor	Deserts	Demulcent, nutrient, aphrodisiac, expectorant, laxative, used in cough, asthma, chest complaints and fever.
Prosopis cineraria	Jand	Deserts	Used for pregnant women, also for rheumatism, scorpion stings and to remove hairs from the skin.
Rhazya stricta	Senhwar	Plains, hills	Used as tonic, for skin erruptions, boils, sore throat, low fever etc.
Saccharum bengalense	Sarkanda	Flood, plains	Diuretic, demulcent, refrigerant, aphrodisiac and used for blood troubles and urinary complaints.
Salsola baryosma	Lani	Saline soils	Plant is used as a vermifuge and ash is applied to itches.
Salvadora oleoides	Wan	Desert	Purgative, to cure cough, aphrodisiac, vesicant and rheumatism.
Suaeda fruiticosa	Lana	Saline soils	Leaves are emetic, used as poultice in ophthalmia.
Tamarix aphylla	Frash	Plains	Galls are astringent, tonic and aphrodisiac used against eczema and other skin diseases.
Tribulus terrestris	Bhakara	All habitats	Plant is cooling, diuretic, tonic, aphrodisiac and aperient, used for mictorition, urinary disorders, impotence, cough and for kidney stones.
Withania coagulans	Paneer	Plains	Coagulant, alterative, sedative, emetic, diuretic and anodyne, used in chronic fever complaints, dyspepsia, intestinal affections and colic.
Zizyphus mauritiana	Ber	Plains, foot-hills	Used in diarrhoea, for purification of blood, digestion, wounds and ulcers.
Zizyphus nummularia	Mallah	Dry areas	Leaves are applied externally on boils and scabies. Fruit is astringent, cooling and used for bilious afflictions

Source: Muhammad 1996

ume of soil. This, combined with sclerophyllous leaves, which are rather hard, stiff, and remain on the plant year round, enables the plant to grow in arid regions.

The biggest and most vigorous jojoba plants are found on sloping, well-drained soils with silt and clay in the lower horizon. In cultivated stands, some plants are successful on sandy soils, others on silt-loam.

Plate 16: ***Jojoba is an unconventional high value resource for marginal lands***

The liquid wax, which is a clear, golden colour (known as liquid gold), is commercially called Jojoba oil and has a wide range of uses, including specialised lubricants, cosmetics, pharmaceuticals, and so on.

Jojoba oil can be used in alcohol and acid derivatives for the preparation of disinfectants, surfactants, driers, emulsifiers, resins, plasticisers, protective coatings, fibres, corrosion inhibitors, and in bases for creams and ointments. It can also be used in preparing hydrogenated waxes (solids), which in turn are used in polishing wax, protective coating for fruits and in smokeless candles. Additionally, jojoba foliage makes excellent browsing feed for deer, cattle, sheep, and goats.

Raising *Salicornia Halophyte* with Saline Water

Significance

Salicornia bigelovii, commonly called 'samphire', can be grown with sea water to a tolerance limit of 50,000 ppm without blighting. Non-potable well water can also serve as an irrigation supply source for *Salicornia*. *Salicornia* has also been grown successfully using labour-intensive techniques such flood irrigation, which means that it could also benefit farmers and consumers in low income countries.

A pilot farm of 150 hectares was planted in Saudi Arabia to raise it on a larger scale. The crop was harvested in September, 1994, and has been a success. The target at Ras al-Zawr is 4,500ha consisting of 90 pivot irrigation circles, each 800m across. Sea water is directly pulled in from the Gulf and is sprayed on the crop. One hundred tons of *Salicornia* crop were previously baled as forage for dairy herds, and the farmers are exploring the possibility of exporting the crunchy green tips to France as samphire salad ingredients. But the real value of the project lies in the oilseed which is now being processed. Suitable areas for *Salicornia* crop are places with saline groundwater. It has been successfully introduced in Balochistan, Pakistan.

Plate 17: ***Salicornia seeds produce high quality oil***

Salicornia crops have been grown successfully in the United Arab Emirates, Egypt, and Kuwait.

Components

Salicornia grows naturally along the sea coasts. Its seed has been developed selectively since the early 1980s at a test farm in Mexico's Sonora state, on the edge of the Gulf of California. It is an annual, succulent plant that is a member of the halophyte (literally 'salt plant') family. It has jointed, succulent stems and no leaves. These are common adaptations to a salty environment, since the stem helps the plant keep fresh water within the tissues.

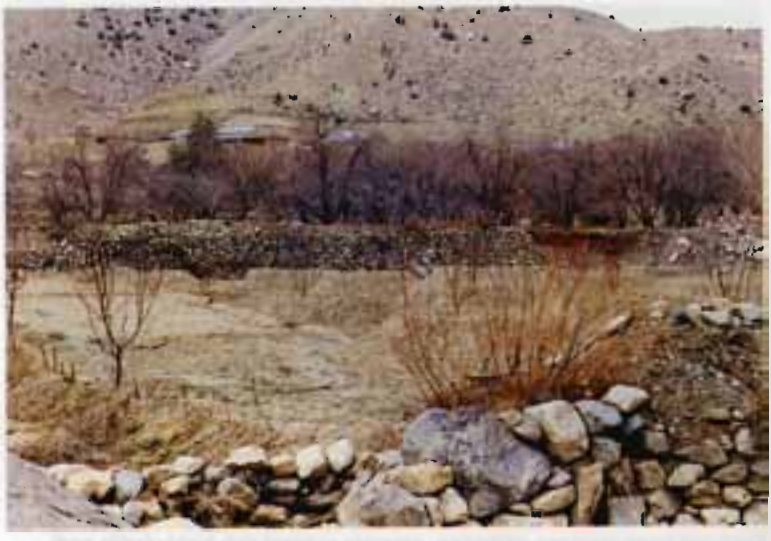
Salicornia is known for its oilseed as well as its straw. It produces as much seed per hectare as soybeans and more than sunflowers. It is a high quality crop with 30 per cent oil of its total weight compared to 17 to 20 per cent of soybean and 30 per cent protein. The oilseed is low in salt. The oil is extracted by conventional milling procedures. Although edible for humans, the oil can also be used in animal diets. The seed meal left after pressing out most of the oil contains 33 to 43 per cent of crude protein, depending upon the purity of the seed and how much oil is left behind after pressing. The meal contains saponin, which interferes with its use in poultry diets, but it can be substituted for cottonseed meal or other protein sources in ruminant diets at 10 per cent inclusion. Using the method of hexane extraction of the oil results in a meal with approximately five per cent residual oil, but other pressing methods yield meals with 10 per cent or greater oil contents. *Salicornia* oil also contains 72 per cent linoleic acid - a healthy polyunsaturated fat - levels are close to these found in safflower oil, and more than twice that of oil from soybeans. The *Salicornia* meal has been used with success as a poultry feed additive. Salicornia oil might also be used to produce pharmaceutical products and cosmetics.

Protection Spurs

Significance

Flash floods during the rainy season erode large amounts of precious soil mainly be-

Plate 18: ***Protection spurs in the highlands***



The effectiveness of these spurs could be increased considerably by planting soil-binding plant species along the spur, which is rarely seen in Balochistan.

cause of the uneven mountainous features of this region. Most of the time, flood waters take away agricultural fields, resulting in immense destruction. Farmers have begun to protect their fields, by constructing protection spurs.

Protection spurs are seen throughout Balochistan, Pakistan, and their role in protecting land from water erosion is great.

Components

A protection spur is a 0.9m wide and about 1.5m high wall of stones constructed on either side of a stream or any natural flood water channel. Traditionally, farmers used to protect their fields from flood damage by erecting tree trunks as wooden poles at a given distance and in a certain angle along their fields to protect against flood water. The gaps between the wooden poles were filled in with heavy stones. Farmers were able to protect their fields as well as divert flood water in a certain direction.

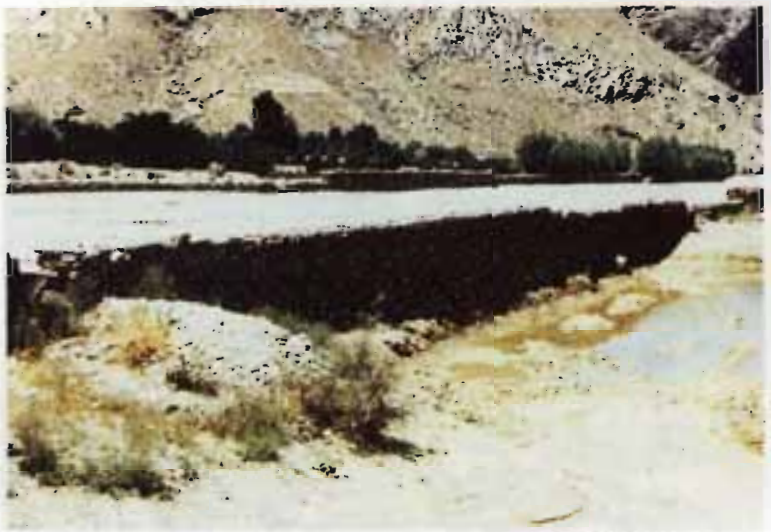
Scarcity of forest wood and awareness of modern knowledge have changed the raw material used in making protection spurs. Stones, roughly rectangular in shape, are put together to make a wall along a field and a wire net holds them together as a wall against flood water. These are used widely along hill torrent banks to control expansion of their basins.

Donga Soil Trap

Significance

Physiographically, the HKH belt is made up of high and low mountains and gravelly fans and terraces. Much of the surface of dry and cold mountain and hill slopes is comprised of bare rock and is without soil cover. Various patches contain shallow or very shallow, largely calcareous, gravelly, and stony loam soils. Soils of gravelly fans and terraces are shallow to moderately deep, heavily calcareous, with a lime content of about 30 per cent in stone or powdery form in the sub-

Plate 19: ***Donga soil trap in the western mountains, Balochistan***



Such soil traps increase infiltration, promote nutrient rich highly fertile sediment, and prevent widening of gullies and seasonal stream basins. Donga(s) slow down the velocity of runoff water, hence, prevent damage to adjoining land.

soil with a low water holding capacity. This phenomenon is peculiar to most of the western HKH zone. Desert varnished stones and coarse gravel, having thick lime coatings on their under parts, limit the use of these soils. Lack of good deep soil is an inherited and a major physiographic constraint of crop and orchard production. Traditional farmers developed this technology to collect eroded soil from flood water to construct agricultural fields and mainly for establishing orchards.

Components

A *donga* is in fact a dug-out pond measuring roughly 6 to 16m along the side of a seasonal tributary stream for trapping soil. It is always close to an agricultural field where soil is transported. A dyke keeps out the flood water from the *donga*. However, the pond is filled up by flood waters through a small inlet in the dike, which permits only muddy water to enter and prevents rocky materials from getting in. The water is stored there for two to three months.

Once the water dries up, it leaves behind fertile soil in the bottom of the *donga*, which is collected and taken to the fields to establish orchards. Some time later, a *donga* may become a field and a new *donga* is built next to it. Slowly and gradually, the wide bed of a stream is converted into fertile agricultural fields. The large scale apple orchards seen today in the Urak area of the Quetta Valley, Balochistan, are there just because of the *donga* technology used by local farmers over the past few decades.

Construction of Agricultural Fields by Transporting Soils

Significance

This technology is being used widely in the Balochistan province of Pakistan where agricultural activities (particularly orchard

Piate 20: ***Field being constructed by transporting soils***

The transported soils may be invariably deficient both in organic matter content or certain nutrients. Some farmers did complain about certain problems – apparently of nutrient deficiency. Soil samples from this kind of field should be analysed for a nutrient profile so that any nutrient deficiencies can be corrected.

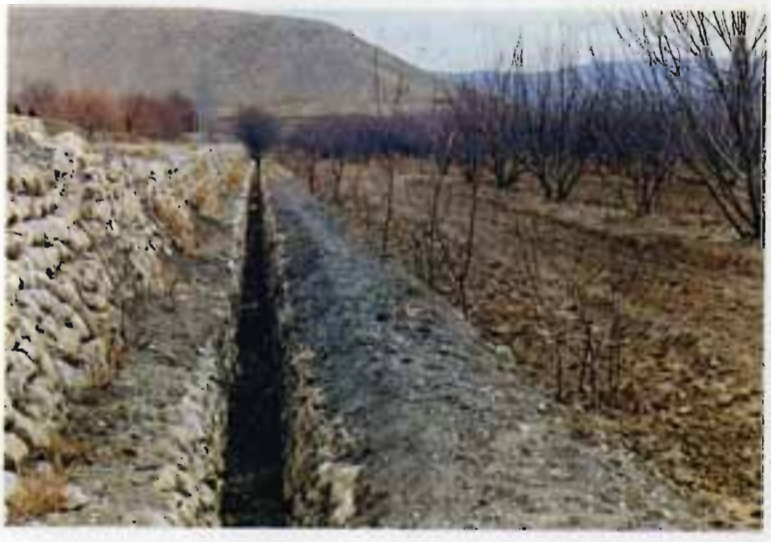
production) are largely linked to the practice. Lack of good and deep soil is the main constraint to the development of farm agronomy in this region. Native soils contain a lot of rock matter, which restricts the growing of crops and orchards. Since the invention of this technology, the cultivable area has been increasing gradually in the region. Until now, more than 90 per cent of orchards have been established by constructing new fields on agriculturally unproductive areas by using sediment soils brought from other places.

Components

A selected piece of land is levelled and an embankment is constructed all around it while levelling. Sediment, or any good soil, is collected mainly from delay action dams, riparian zones, check dams, etc and is transported to this piece of land. Tractor trolleys are a popular means of transport and are rented for the job. A layer of one metre thick fertile soil is laid over the levelled piece of land. Finally, the orchard is established.

This technology is labour intensive and requires a lot of cash investment. Farmers undertake this activity gradually and with lots of patience. Sometimes, a farmer does not have sufficient resources. Initially, he will prepare a site for this purpose. A selected piece of land is bulldozed or levelled by tractor blade. Heavy stones are picked up and used for constructing an embankment around it. The farmer will lay out the tree plantation and will import a number of soil loads equal to the total number of saplings to be planted (i.e., one soil load for one tree). Each trolley is unloaded as per the plantation layout. This method provides enough deep soil to each sapling to grow vigorously, meanwhile, the rest of the field is filled gradually by transporting more soil. Sometimes it may take years to construct a field fully.

Plate 21: ***Salinity control channels in the highlands of Balochistan***



Farmers need education about proper use of already scarce water resources.

Salinity-controlling Channels

Significance

The origin of this technology also lies in Balochistan, Pakistan, where agricultural fields are mostly terraced and are constructed by transporting soil from other places. Excessive irrigation of orchards and other cultivated fields is a general tendency among local farmers, as they believe that it improves productivity. They continue to flood their fields even if it is not required. The persistency of this practice has been causing salinity problems in most fields due to the saline water or soils. Local farmers have overcome this problem by constructing salinity-controlling channels along their terraced fields.

Components

Each terraced field is sloped to a certain degree. A salinity-controlling channel is actually a drain built on the sloping side. This drain is 0.6 to 1m deep, is about 0.6m wide, and runs parallel to the terraced field. Each drain is linked to a main drainage channel. Salts that have leached from the soil along with excessive water are collected in the first step channel and are taken to the main drainage channel.

Belcha Soil Tillage

Significance

In Balochistan; land holdings are small and terraced. The farm economy is heavily dependent upon orchard production. Farmers use small row to row and plant to plant distances in orchards to increase plant density per unit of cultivated land. This narrow plantation poses problems for tilling during intercropping. Farmers cannot undertake ploughing by tractors or traditional animal driven ploughs. Tillage is carried out manually using a tool called a *belcha*.

Components

A *belcha* is in fact a modified spade. It has multiple uses and can be used efficiently for many other field operations such as constructing and cleaning water channels,

crop residues, domestic residues, animal excreta, etc) and for improving overall soil fertility (Reijntjes 1992).

Farmers of the HKH, in general, and of Balochistan in particular, are marginalised, resource poor, and lack access to chemical fertilizers. Most farmers depend heavily upon compost as an indigenous fertilizer for improving the soil nutrient status.

Components

Composting is in fact the break down of organic wastes by micro-organisms and soil fauna, in order to prepare the material called 'compost' (Reijntjes 1992). This organic fertilizer also increases the resistance of plants to pests and various diseases.

Composting is normally done in heaps, however, local farmers have adopted a very simple method of preparing organic fertilizer. A dug-out about one metre deep, measuring roughly 4.5x9m, is constructed for this purpose. All kinds of home wastes, animal dung, ash, fallen leaves from the orchard, etc are dumped into it. Once filled, it is covered with a layer of soil. Sufficient water is added to it to moisten the material, and it is left to decompose for a few months or sometimes for a year. The farmers do not add any mineral such as rock dust, rock phosphate, or urea, thus compost quality is relatively poor. Later the compost is taken to the field as compost fertilizer. The same practice is repeated annually.

An improved version of preparing enriched compost could be popularised among the farmers. The procedure is as follows.

Construct a pit measuring 3x2x1m. Line it with a polythene sheet. Add a 30cm thick layer of organic waste and moisten it with water containing five per cent rock phosphate and two per cent urea fertilizer. Two such layers of organic waste should be laid above it in the pit. For aeration, PVC pipes could be inserted into the pit. Cover it with a 10cm thick layer of soil. After one month, turn over the organic waste and cover it again. The compost will be ready for use in three months.

Organic Manure

Significance

The organic manure content of a soil improves the sustainability of farming by promoting the nutrient index and soil life. The farmers of the Indian HKH region use manure to the fullest advantage for mountain farming. Manure is used extensively in wheat, paddy, millet, and maize fields. Local people are apprehensive about the use of chemical fertilizers as they believe that these fertilizers cause soil compaction which hinders other farming operations. In some areas, kitchen ash and manure are mixed together and are used for kitchen gardening and for improving the size of potatoes.

Component

Cows, sheep, goats, and donkeys are the main sources of manure. In some areas, human excreta and poultry manure are also collected. Traditional practices of collecting manure vary from area to area. Farmers of Lahaul and Spiti use an innovative means for collecting the excreta of small ruminants (i.e., sheep and goats). When flocks are taken out for grazing, each animal has a small bag covering the anal parts tied to it and faeces are collected in it. The faeces are later used to fertilize the extremely sandy, low fertility soils.

Plate 24: ***Organic manure is popularly used as cooking fuel***

In the Spiti Valley, manure is applied to the fields only once a year (i.e., September and October) after the crop harvest. This practice has traditionally been developed because of the monocropping pattern. Manure is broadcast over the entire field and is followed by ploughing for thorough mixing.

Human excreta, called *chaksa*, is considered to be the richest manure and is collected in a special dry latrine pit. Local people also crush the bones of dead animals and mix in the power, which adds phosphorus and calcium. Cattle dung is also collected, particularly during winter, from sheds and kept open in heaps for further decomposition until the next summer. The leaves and grasses used as bedding for animals get soaked with faeces and urine and are also collected periodically as manure. Some farmers believe that excessive use of sheep and goat manure is harmful to crops. Ass dung, though not preferred, is also used.

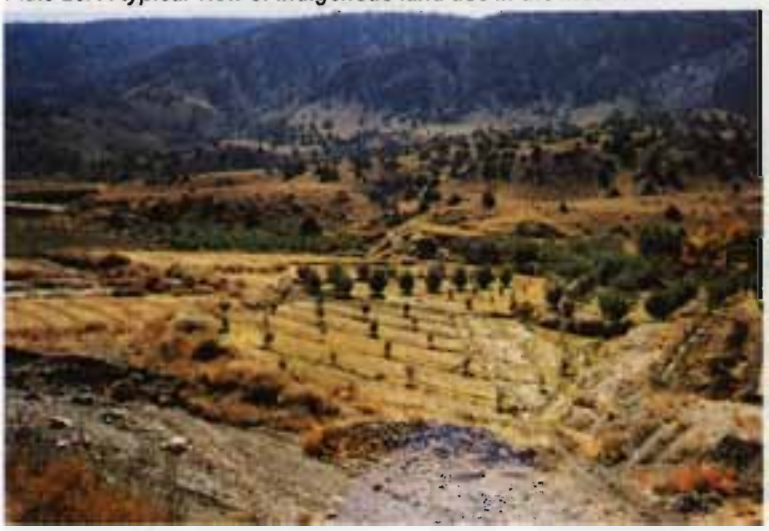
Organic manuring is the principal mode of improving soil fertility. Local inhabitants take every measure to arrange as much manure as possible for their fields. For this purpose, local pastoral tribes, such as the *Gaddi*, are paid for the animal excreta of their flocks. Thus, *Gaddi* grazers will camp with their flocks in particular fields.

Indigenous Land-use Systems

Significance

The indigenous knowledge of a community in a particular region is derived from the local people's farming experience and is handed down from previous generations to present generations. It entails many insights, perceptions, and intuitions, relating to local environment (Reijntjes et al 1992). The indigenous land-use systems in the Indian Himalayan region take into account ecological, social, and religious factors. Because availability of cultivable land is determined by fertility status and moisture regimes, fields are dispersed at different altitudinal zones. Land consolidation has occurred in such a manner that each family gets its share of the upper, middle, and lower reaches of the slopes.

Plate 25: ***A typical view of indigenous land use in the mountains***



Religious sanctity is also attached to traditional land distribution patterns.

Components

Land holdings have been consolidated to facilitate an intensive land-use system that yields maximum benefits to meet social and cultural needs. There are monastic lands (belonging to a monastery) and private lands. Both involve different types of tenancies in accordance with local social norms and extend opportunities for intensive land use by employing collective labour. Management of cultivated lands and grazing lands is undertaken as per the agro-climate, altitude, and terrain.

Cultivated land holdings are relatively small in size and are generally distributed at three altitudinal (i.e., lower, middle, and upper). Some of these are close to a settlement and others are far away from it and are isolated. These are called *kanda*. The permanent settlements are mostly located in the middle zone. A farmer usually makes a small, low-cost house at the *kanda* for periodic and secondary use. This is called *dogary*. The *dogary* is used temporarily during cultivation and harvest at the *kanda* and is also used for grain and hay storage. Cultivation at lower elevations takes place earlier due to the warmer climate. Sowing is mostly completed by mid April at lower elevations near the river banks and is followed by sowing in the middle zone. Sowing is, however, delayed for at least one month at upper altitudes.

Farmers move up and down from the centre for farming. During cultivation seasons, they leave their houses early in the morning and return by evening and carry a cooked meal with them. Sometimes they need to spend nights at the *kanda*(s) in order to complete the heavy work. In this situation they would take along provisions for a certain number of days.

Field boundaries are separated by erecting stone and mud walls, constructed mostly by women. Seabuckthorn and other thorny bushes are commonly used to keep animals out and earmark land ownership. Ploughing is generally carried out by *dzo*(s) and sometimes by horses on sandy soils.

However, all kinds of animals are put to work for draught purposes and for quicker completion of the job during a short growing season.

Major crops (i.e., barley and wheat) are harvested by uprooting them along with the roots. For this purpose, the soil is softened a day earlier by light irrigation. The person harvesting beats large handfuls of uprooted plants against his/her legs to shake off most of the soil from the plant roots. The harvested plants are then tied together in bundles which are piled upon a roof in such a skilled way that the ears of the lower row are covered and protected from birds by the roots of upper stacks.

The objective of leaving very little plant material in the soil indicates the farmers' strategy of maximising their dry hay storage for livestock during the winter. It may also help to prevent soil-borne diseases.

This region contains extensive grazing lands. Some are near settlements (i.e., villages) and others may be on high mountain ranges. The high mountain ranges are only accessible to sheep and goats in summer. Cattle graze in pastures close to villages along with small ruminants. The remote pastures are watched by hired shepherds who stay there with the flocks for several months during summer. *Dzo*(s) and yak, being very hardy, are allowed to reach the highest altitudes near glaciers for foraging.

Village grazing resources vary in size and also in number (i.e., one to four pieces). They are called *doksa*. This resource can be distributed over three altitudinal zones. A *doksa* near a settlement and the lower zones will have permanent housing for animals (i.e., yards and pens) with stone walls and roofs, while others will have circular stonewalls for temporary shelter.

The *doska*(s) are compatible with local ecological conditions and serve as buffer zones for grazing in early spring and late autumn when upper grazing lands are snow-covered. Rotational grazing is a common practice for sequential recovery of vegetation. Appropriate stocking rates are indigenously observed and livestock distribution and movement is controlled using an innovative manner of grazing management (i.e., the animal urge for mineral consumption).

Since winter is long (i.e., at least six months) and grazing areas are covered by snow, the peculiar climatic conditions necessitate sufficient dry fodder storage for animals. Farmers follow certain land-use schemes for growing grasses, meadow weeds, and other nutritious herbs. Steeper mountain slopes and ridges are protected for this purpose as hay fields. Hay fields are harvested and the harvest is sun dried. Hay is stored for winter use.

Indigenous Land Preparation Practices

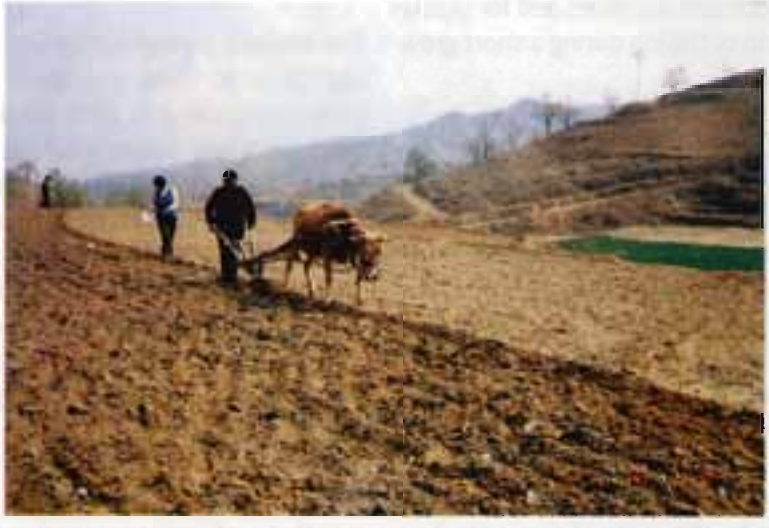
Significance

Local farmers in the HKH belt have developed various indigenous tillage practices through a process of informal research and development. These are compatible with the local agro-ecology, are local resource-based, and suggest advantages for their practical application on a given terrain.

Components

Fields are ploughed in a sword-like curved pattern to ensure proper land tillage at all corners. This pattern is successful in checking sudden runoff. Sloping lands are

Plate 26: ***Indigenous land preparation practice in China***



ploughed, following a bottom to top approach to avoid the soil losses that would occur otherwise.

The tillage tool is an indigenous plough with two extra flat pieces of wood attached to both sides of its iron blade. This plough is always preferred over the one available in the market, probably because of its two-fold function of saving labour and stabilising loose sandy stratum in one action.

The tillage operation is followed by the levelling of the field by using a *maddin* behind an animal. A *maddin* is a plain wooden plank. A heavy stone is put on the *maddin* to create a good levelling force. Sometimes, a person will also sit on it to increase pressure. Levelling of the ploughed field helps moisture conservation.

Cultivation practices are generally limited to plain and flat pieces of land to help reduce soil erosion. Fallow fields are irrigated in autumn to protect the surface layer of soil against heavy wind, which is a common feature of these cold deserts. The wet surface gets frozen during winter thus protecting it from being blown away. This practice also facilitates easy tillage operations during the next spring.