Introduction

BACKGROUND

The northern parts of the Hindu Kush and Himalayan ranges are mostly cold desert lying between 2500 and 5000 metres above sea level. This area, often called the trans-Himalayas, stretches from Tajikistan in the west to Bhutan in the east, with the Tibetan Plateau in the centre. The environment is very harsh: the winter temperatures frequently fall below -30°C and precipitation – both rain and snowfall – is low (less than 300 mm per year). The natural resources are very limited and the lack of trees and forests results in a very low population density. Even so, some of the highest villages in the world can be found here.

During the short summer season, communities devote their energy to stocking up for the winter. Women spend two months a year on average collecting cow dung from the pastures for cooking and winter heating. The whole way of life is geared towards surviving the long harsh winter. Subsistence farming is limited in most of the area to one crop per year and is focused on barley and wheat with some peas, potatoes, and occasionally other vegetables. The average agricultural landholding is small, less than 0.5 ha per household. The inhabitants of the high altitude plateau depend almost entirely on cattle rearing. Poor transportation infrastructure limits the supply of fresh food in all parts of the region. In winter, snowfall blocks the high passes and the roads are mostly closed; foodstuffs are flown in to the major cities at high cost; in rural areas they are simply not available. At the same time it is very sunny, especially in winter. The solar radiation offers great potential for improving people's lives. It can be used not only to warm the interiors of houses, schools, dispensaries, and handicraft centres, it can also be used as a basis for developing off-season agricultural activities such as composting, production in greenhouses and trench greenhouses, and poultry farming.

In the following, we focus on the design and construction of greenhouses for the trans-Himalayan region.

Figure 1: View of a high valley in Mustang, Nepal

What is a Greenhouse?

A greenhouse is designed to provide an environment suitable for growing fruit, vegetables, flowers, or others, at a time when the outside conditions are not favourable for the specific purpose. In the trans-Himalayas, the emphasis is on vegetables. Vegetable growing depends on two main factors: solar radiation and climate. Vegetables need solar radiation for photosynthesis, and the interior environment (temperature and humidity) must match the vegetable requirements.

Solar Greenhouses for the Trans-Himalayas

A passive solar greenhouse, or solar greenhouse for short, is a greenhouse heated entirely by sunlight, with no additional fuel-based heating. In the trans-Himalayas, the temperature inside these greenhouses can be kept high enough to grow vegetables throughout the year, even in winter, if the greenhouse is built efficiently. Thus greenhouses can be of great use, particularly in those areas where there are continuing concerns about food security and economic development. The main benefits of solar greenhouses are

- vegetable production in winter;
- fulfilment of basic subsistence needs in remote areas; and
- income generation in peri-urban areas.

The model proposed in this manual is an efficient greenhouse constructed almost entirely with local materials (apart from the polythene and some minor parts like nails and hinges). The initial model was tested, developed, and improved by farmers in Ladakh, India, working together with the non-government organisation (NGO) LEHO (Ladakh Health and Environment Organisation) to reduce the investment cost, facilitate construction, and increase the life span. The improved version was further developed and adapted to the specific local conditions by farmers and NGOs in Lahaul & Spiti and Ladakh in India; Qinghai province in China; Mustang in Nepal, and Badakshn, Hazara Jat, Lowgar, and Parwan in Afghanistan. The designs presented in this manual reflect the experience gained and lessons learned in all these areas. Greenhouses of this type are suitable for use in other areas of the Hindu Kush, Himalaya, and Pamir ranges with a similar climate and socioeconomic situation, such as the high valleys of Sikkim and Arunachal Pradesh in India; Humla, Simikot, and Dolpo in Nepal; the Tibetan Plateau in China; Bhutan; other parts of Afghanistan, Tadjikistan, and Kirghizstan in Central Asia; and Chitral and Baltistan in Pakistan.

Vegetables can be grown in mid-winter even in extremely cold climates where outside temperatures fall below -15°C. In very cold climates like that of Leh at 3500m (minimum temperatures in January of around -15°C) vegetables like spinach,carrots, and onions can be grown in winter. The greenhouse is even more efficient in less cold areas like Kabul in Afghanistan at 1800m (minimum temperature -5 to -10°C) where tomatoes (actually a fruit) can be harvested until January. The average growing efficiency of fresh vegetables is 0.8 kg/m^2 in very cold climates and 1.4 kg/m^2 in cold climates. Table 1 shows the typical crops that can be grown in these greenhouses during the year in different climates.

Table 1: **Greenhouse crops in different seasons**

Season	Cold (min. >-10°C in winter)	Very cold (min. -10°C to -15°C)	Extremely cold (min. <-15°C)
Winter	Tomatoes if planted in the autumn Root vegetables	Root vegetables if planted in the autumn Leafy vegetables	Leafy vegetables
Spring	Seedlings Root vegetables/tomatoes	Seedlings Root vegetables/tomatoes	Seedlings Root vegetables
Summer	Exotic vegetables	Exotic vegetables	Exotic vegetables/ tomatoes
Autumn	Tomatoes	Tomatoes	Root vegetables

Typical examples of vegetables are spinach (leafy), carrots (root), and tomatoes (actually a fruit).

Figure 2: Constructing a greenhouse in Qala-e-Panja village, Wakhan district, Afghanistan

Figure 3: Solar greenhouse built in Leh, Ladakh, India

To be useful in development, a solar greenhouse must be **adapted to the local context**. In other words, it must be financially and physically viable for local people to construct and run without outside support. The following criteria were used to assess whether this need was being met, and to guide development where it was not:

- the materials are locally available (mud, wood, straw, stone), except for the transparent cover sheet;
- it can be constructed by local builders;
- the cost can be recouped in less than three years if the production is well-managed and the products sold.

Solar greenhouses can contribute to **human development** in a number of ways including empowering women, since they are often in charge of the production and the selling; helping overcome nutritional deficiencies by enabling more diversified food production all year round; and providing a means of income generation.

However, a greenhouse is only efficient if it is constructed in the right place and used properly. Past experience has shown the importance of **planning the dissemination method** to ensure that the maximum benefit is gained. Points to consider include the following

❖ Stakeholder selection – focus on
- communities with poor families
- innovative and dynamic farmers

❖ Site selection – consider
- availability of water (river, wells, canals, snow)
- availability of direct and abundant sunshine
- need to adjust dimensions and materials to the site
- minimising waste of land at the back of the greenhouse

❖ Setting up of facilities – plan for
- training builders
- training farmers in greenhouse cultivation methods
- developing networks for the supply of seeds, tools, and polythene, and for vegetable marketing

This manual focuses on the guidelines for **design and construction** of an efficient greenhouse. The economic feasibility, dissemination methodology, and agricultural use will be covered in other booklets (in preparation). The manual is divided into two parts: a description of the theoretical principles, which provides the basis for understand the concept of using passive solar greenhouses in cold areas and knowing how to select a suitable site and design; and a description of the practical elements of construction with detailed instructions on each step and the points to consider to ensure that the greenhouse is efficient.