Passive Solar Greenhouse – bringing better nutrition to the cold arid regions of Western Himalaya

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1. Context

Ladakh, Lahaul and Spiti lies in the northwestern part of India in the western Himalayas. The high altitudes (above 3,000 m) and low rainfall mean that fresh vegetables and other crops can be grown outside for only about 90 days in the summer. In winter, with temperatures falling below -25°C, vegetables would freeze and die. To supplement, fresh vegetables have to be imported by truck in summer or flown in by air during winter. The unavailability and high cost means that local people rarely eat fresh vegetables in the winter months, but instead rely on dried leafy vegetables and stored root crops.

Despite the sub-zero temperatures, the cloudless skies guaranty over 300 sunny days per year. Therefore, there is plenty of sunshine for crops to grow even in winter, provided that they can be prevented from freezing. There have been programmes to provide greenhouses to extend the growing season, but these have had limited success, because the greenhouses were not adapted to local conditions and the users were not well-trained to use them.

2. Technology (solar greenhouse)

Ten years ago the French NGO GERES (Groupe Energies Renouvables, Environnement et Solidarités) started working with Ladakh Environmental Health Organisation (LEHO), Ladakh Ecological Development Group (LEDEG), Leh Nutrition Project (LNP) and Society of Knowledge and Responsibilities for Culture, Health, Environment and Nature (SKARCHEN) and Spiti Trans-Himalayan Action Group (STAG) to develop improved greenhouses better adapted to the climate, which could help local people to substantially increase their crop production.

The improved greenhouse (IGH) is designed to maximize the capture of solar energy during the day, while minimizing heat loss at night so that the crops do not freeze. The greenhouse is heated by solar energy alone, and there is no supplementary heating. This is achieved using standard ideas from passive solar architecture, enabling solar heat gain, heat storage, natural ventilation, and reduced heat loss.

- Firstly, the greenhouse is orientated very carefully along an East-West axis, so that there is a long South-facing side. The transparent cover on the South-facing side is made from heavy duty polythene, which has extra stabilizer in it to resist the intense ultra violet (UV) light which penetrates the thin atmosphere. The polythene should last for at least five years. In particularly cold places a double layer of polythene is used.
- Secondly, the side and back walls of the greenhouse have a high thermal mass, so that they (and the soil) absorb heat from the sun during the day and release it at night to keep the inside of the greenhouse at a suitable temperature.
- Thirdly, to minimize heat loss, the side and back walls are cavity construction, and the 100 mm wide cavity is filled with insulation of either straw or sawdust. The back of the roof is sloped at 35° to avoid blocking any direct sunlight in winter, and it is covered with thatch to minimize heat loss. In addition a cloth or tarpaulin is used to cover the polythene at night in order to reduce heat loss.
- Fourthly, the inner atmosphere is controlled by natural ventilation through vents in the walls and roof, to avoid excess humidity and overheating.

The greenhouses are designed to be simple and robust. The walls are generally constructed of mud bricks, made locally, although in areas of high snow-fall more resilient walls of stone and rock are needed. Rammed earth is also used. Local masons are employed to build the walls and when necessary specialized training is provided. The roof is made from locally available poplar wood for the main frame, with willow for the struts and straw or water-resistant local grass for the thatch. The rear and west-facing walls are painted black inside to improve heat absorption, whereas the east-facing wall is painted white to reflect the morning sunlight onto the crops. There is a door in the wall at one end, and ventilators are incorporated into the roof, the door and the wall at the other end, to enable control of humidity and prevent overheating.

Two standard sizes of greenhouse have been developed. The normal domestic type is 4.5 m deep and 9.7 m long in the East-West direction. The larger commercial type has a similar depth (4.8) but is 27.3 m in length.

A wide range of vegetables is grown in the greenhouses. Local spinach and coriander is a very popular. Besides, garlic, radish, onions, lettuces and strawberries are also grown in winter. In spring the greenhouses are used for grow seedlings, and in autumn it is used to extend the growing season for crops like tomatoes, cucumbers and grapes. Some families also grow flowers and indoor plants.

How users pay

£1 = Rs 73 (Indian Rupees). US$1 = Rs 50 (April 2009)

GERES estimates that the total cost of a domestic IGH is about Rs 30,000 (£410 or US$600). Half of this is for materials sourced locally such as wood for the roof, mud bricks, stones and thatch. These can often be collected rather than purchased, and must be provided by the prospective owner. The owner is also expected to provide the labour to build the walls and roof, either directly or by paying a skilled mason. GERES pays for and provides the door, air-ventilators and the UV stabilized polythene, which represent about 25% of the total cost.

Item	**Rupees (INR)**
Ventilators	2,700
Insu lated Door	2,300
UV stabilised polythene	2,000
Labour	7,000
Materials (mud bricks, wood etc.)	16,000
Entire improved greenhouse	***30,000***

The timing of greenhouse construction is arranged carefully to fit in with the agricultural year. New owners are selected in the spring, so that they have the opportunity to collect materials, make mud bricks and bake them in the sun during the summer. At the end of the summer, when the main crops have been harvested, there is time available to construct greenhouses, and money from the sale of cash crops to pay for other materials and labour.

3. Community mobilization and implementation methodology

3.1 Training and support

Selection and training of greenhouse owners is one of the most important parts of the programme. It is coordinated by LEHO and managed by other local partner NGOs. GERES provides the methodology, design and development, monitoring, review and reporting.

Project partners have worked with the local community to select 64 greenhouse owners to act as local resource persons (RPs). Some are trained to supervise IGH construction, and others to advise owners on agricultural management. They receive some payment for their work and expenses, typically Rs 70/month per greenhouse. The other owners are supported by the RPs and also have direct access to their local NGOs, usually by phone. The phone number of a contact person is painted above the door of each greenhouse.

The selection of the people that own a greenhouse is carried out with care, in consultation with the local communities. Selected families must be living below the poverty level of US$1/day per person, and must have a suitable site to construct the IGH. The family must be motivated to demonstrate the use of greenhouse as a success story, and also to share the produce with the wider community through sale or barter. Potential owners are taken on an exposure visit of existing greenhouses before they make a final decision about owning one.

3.2 Management, finance and partnerships

In Ladakh, Lahaul and Spiti, GERES works very closely with the NGO network. GERES provides oversight and guidance for the overall project including IGH design and development, progress monitoring and reporting. Project partners are in charge of coordinating the implementation, which includes training for local resource persons (RPs) and other local NGOs, and it also manages discussions with local government. The local NGOs work closely with the 165 villages in the selection of IGH owners, and the RPs supervise the construction and advise on the agricultural site during running of the greenhouses. GERES

has a long-term commitment to Ladakh, but is gradually handing over responsibilities to local NGOS.

The work has been funded by the EU with co-funding from Fondation Ensemble. Although funding ends in May 2009, other sources of financial assistance have already been secured. Specifically the French NGO Solidarités and the Indian government's National Rural Health Mission have confirmed assistance, and the voluntary carbon credit trading organisation myclimate.org is providing carbon finance until 2013.

4. Result and Benefits

4.1 Numbers

A total of 586 improved greenhouses have been constructed since 2005, seven of them are large commercial size IGH and the remaining are for domestic and additional income use. Nearly all are still in use. A few minor problems have occurred, for instance some roofs have collapsed because of water damage.

4.2 Environmental benefits

Some of the vegetables which are grown in the improved greenhouses replace imported vegetables which were previously brought in by truck or airplane. This avoids the greenhouse gas emissions associated with transport. However, the main purpose and value of the IGH programme has been to improve the quality of life by increasing the quantity and variety of fresh vegetables, and not just substituting locally-grown produce for imports. It is therefore appropriate to estimate the greenhouse gas savings as what would have been obtained if all the vegetables produced had been transported to the region.

GERES assumes that about 28% of vegetable would have been transported by truck and 72% by air, for an average distance of 620 km. Using standard transport emissions per tonne of freight suggests a saving of about 0.835 tonnes/year of CO_2 per IGH, or 460 tonnes /year of CO_2 for the 560 greenhouses in use.

Additional environmental benefits have come from improved soil fertility, mainly by the use of better composting techniques pioneered by GERES, and in improvements in soil quality and organic content, which reduces soil erosion.

4.3 Social benefits

The provision of fresh vegetables in the winter months is a great benefit in the region. Surveys carried out by GERES suggest that about 300 tonnes/year of extra vegetables are produced locally, or about 0.5 tonnes/year per greenhouse. Studies have shown that consumption of vegetables during the winter has grown by a factor of eight for families who own an IGH, allowing fresh produce to be eaten two or three times a week in contrast to twice a month in the past.

The average greenhouse owner provides nine other families and exchanges vegetable through barter with a further six. Overall it is therefore estimated that the diet of over 50,000 people, or about 25% of the local population in the area, has been improved through the availability of vegetables. In some areas, such as Zanskar or Lahaul that are inaccessible in winter, it is the first time that fresh vegetable have been available at all in winter.

There is an increasing awareness of the health benefits of the improved diet which is also endorsed by local doctors. There is substantial anecdotal evidence and some survey evidence of improved health in those consuming the fresh produce.

Greenhouse owners gain social standing in their communities, by providing vegetables for the wider community for regular consumption and festive season. One of the aims of the project was to provide new opportunities for rural women. This is being achieved since the greenhouse owner is usually the woman of the family, and is responsible for providing nutritious meals to the members and the increased family income from the sale of produce. In the orthodox Muslim dominated region of Kargil, women were not only able to sell vegetables in the market, but also received encouragement from their Imams (religious heads) to do so. As a result of the improved financial position some families are able to afford to educate their children for the first time.

4.4 Economic and employment benefits

Locally produced winter vegetables are now available in markets at lower prices, typically Rs 35/kg to Rs 40/kg compared to Rs 60/kg for imported

vegetables. Surveys suggest that families save between Rs 500 - Rs 1,000 on vegetable purchases in winter. Because of the added nutrient value of the fresh green vegetables families have the option of not buying expensive non vegetable items and hence make further savings.

The Ladakh region has limited opportunities for employment, so any other alternative of generating additional income is welcome. The income from sale of produce varies between families, depending on how much is consumed by the extended family and neighbours, how much is bartered and how much is sold for cash. Surveys have found that the average increase in family income from the sale of vegetables and seedlings is Rs 8,250/year (US$1 65/year) or about 30%. This means that the time to pay back the entire cost of the greenhouse is less than four years. If a family has been able to gather construction materials and therefore provided only 25% of the cost in cash, then this cash investment is paid back in less than one year. In a few cases, 80% of a family's annual income can come from greenhouse produce.

There are a few commercial greenhouses in the scheme and the income from these is over Rs 35,000 (US$700) in a season. This is a substantial income in a region with limited earning opportunities, where the typical wage of labour is about Rs 150/day.

Locally 221 masons and 15 carpenters have received training and have benefited from the scheme, both through income and through the acquisition of the new construction skills.

5. Potential for growth and replication

GERES makes the greenhouse designs available free of cost, and this encourages replication by others in India and elsewhere. A community of practice has been launched through a website 'solargreenhouse.org'. Most of the materials and skills can be found in other similar locations. One component which needs to be sourced carefully is the polythene cladding material. This needs to be both mechanically tough and UV resistant. SILPAULIN, the Mumbai based manufacturer, made polythene with additional UV block for GERES, LEHO and partners.

GERES estimates that there is a potential demand for at least 3,000 IGH in Ladakh, and possibly 6,000 if provision of vegetables for the large military presence in the area is included. Many owners are keen to build a second greenhouse with their own financial resources. In the coming year LEHO will focus on promoting the commercial potential of the IGH with a target of 60 commercial units, including 30 in the Markha valley, a new area of activity.

The adoption of the IGH design by other organizations has been encouraged by GERES, and there is evidence of take up in other countries, notably Afghanistan, Tajikistan and China, as well as in other areas of India. The basic principles of passive solar gain, high insulation and high thermal mass have been incorporated in other domestic and public buildings in Ladakh.