**Local Agri-Clinics**

**Manual**

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# 1. Introduction

Climate stress on communities inhabiting the Indian Himalayas has been steadily on the rise. The changing weather patterns, increasing desertification and shrinking water resources, has led to declining land productivity, food insecurity, and associated disasters. The Himalayas is a geographically challenged region, and given its remoteness and variation from the mainstream, is marginalized in development. The limited technical manpower, lack of transport and communication facilities, inadequate financial support to the technology transfer creates a huge technological gap among the rural farming community. Smallholder Himalayan farmers in particular, need agricultural extension/support which is non-existent at high-altitudes, to help them improve productivity and adapt to climate change. Facilities for weather monitoring, soil testing/applications and crop advisory are limited in the high altitudes, and lack modes for dissemination, depriving the poor, smallholders most affected by climate change, of adapting through choice of crops, timing, etc. Non-availability of enhanced technological information to the farmers results in low and unstable agricultural productivity and creates food insecurity.

The agri-research and technology institutions in the country possess the necessary competence on agricultural technologies, and the weather monitoring stations have the climate information crucial for farmers, and are ready to associate for the development of Himalayan farmers.A*Mountain Agriculture Assistance Service* (MAAS) has been created by networking weather monitoring centers and agricultural support institutions to make availableagri-information/support to Himalayan farmers.

**1.1 Mountain Agriculture Assistance Service**

“Mountain Agriculture Assistance Service” (MAAS) is a network of Weather Monitoring and Agri Support Institutions created to enable the high altitude Himalayan small holder farmers to adapt to climate change and effectively deal with its impact on agriculture. The climate information and advisory services would augment agricultural productivity and improve the nutritional requirement of families. MAAS Network covers 5 districts in 3 high altitude states-Leh (Jammu & Kashmir), Lahaul &Spiti, Kinnaur (Himachal Pradesh), Chamoli and Uttarkashi (Uttarakhand). The launch of MAAS is set in a 3 modular approach to food insecurity, with specific steps envisaged under each module.

**Module1. Climate information and agri advice**

* Creation of MAAS by networking weather monitoring centers and agricultural support institutions for agri-information/support to Himalayan farmers.
* Organization of Local agri-advisory services:
* Educated local youth are developed as Agri-Advisors (AA: agricultural extension workers), for providing local, community-based agricultural extension services in the target districts.
* Local Agri-clinics (LACs) are set up tasked with supporting local farmers by providing climate advisory for farming, soil testing, precision farming advice, training on new technologies and facilitation/handholding for their adoption.
* The AAs along with the LACs deliver information and services and act as an agri-DSS (Decision Support System).
* Participatory farm-research for climate-adaptation through Farmer Expert Groups (FEG) carry out research on adaptation (arid-area crops, modified timing of farm-operations) to climate change, drought-resistant varieties of crops, cash crops, under guidance from MAAS.

**Module2.Agri-cooperatives and enterprises**:

* Formation of Farmer cooperatives in each district, to be empowered with linkages with government and financial institutions (e.g., NABARD, SIDBI), and facilitated to access support for facilities/equipment.
* Facilitation of agri-enterprises to assist Himalayan entrepreneurs to add value to the local produce, including processing/packaging/trading of the local agricultural produce.
* Creation of marketing linkages for producers in the Himalayan region to local/intermediate processing/trading hubs and national & regional markets.

**Module3. Nutrition improvement:**

* Farming of nutritive crops where Area-specific Nutrition-farming Packages [mix of crops based on their nutritive index] are developed in collaboration with MAAS and farmer groups.
* Education and community management of nutrition through educational sessions in villages and schools to generate awareness of family health & nutrition; and women’s groups on family nutrition, food budgeting and diet management.
* Training of educated women or village-level health workers as Grassroots Nutritionists to develop area/age/gender-specific dietary packages and run a ‘Hunger& Nutrition Watch’ program.

The Modular Approach to Food Insecurity is represented in Fig.1.

**Mountain Agriculture Assistance System (MAAS)**

**Module 3**

* Farming of nutritive crops
* Education & community management of nutrition

**Module 2**

* Farmer cooperatives & enterprises
* Facilitating agri-enterprises
* Market linkages

**Module 1**

* Institutional network of MAAS
* Local agri advisory services [Agri-Advisors AAs & Local Agri-clinicsLACs]
* Participatory farm research for climate adaptation (farmer expert groups)

**Fig. 1: Approach to Food insecurity**

The MAAS Secretariat is established at Gurgaon HO to facilitate collaboration with Agri-Support Institutions and Weather Information Providers and channelize their services to farmers. MAAS Secretariat would facilitate linkage between Agri- Support Institutions & LACs in informing farmers on weather variability, farm conditions, agri- technologies and farm level adaption research, viz a viz climate change and nutrient dense farming.

## 1.2. Structure of LAC Manual

The LAC Manual consists of 5 chapters, including this introductory chapter which explains MAAS,the Local Agri-Clinics (LACs) objective and composition, role of Agri-Advisors (AAs) and the services available. Chapter 2 on Land Development & Soil Management examines the newer methods that would help to prevent soil loss, increase soil fertility and conserve moisture such as Shelterbelts, Check dams and Gabion walls, Infiltration pits, Nutrient dense farming and Vermi-compost.Chapter 3 on Irrigation Technologies introduces appropriate technologies for Sourcing & Distribution of Water in the cold deserts such as Snow fences,Artificial glaciers and Snow reservoirs, Lift irrigation using Hydrams, Solar pumps,Drip Irrigation.Chapter 4 examines the measures for Agricultural Adaptation to climate change such as Cropping Patterns and Agro-forestry. The final chapter 5 discusses Precision Farming which is soil/ climate adapted farming, its Components and Technologies. Annexures include the formats for record and reporting of AAs at LACs.

**1.3. Local Agri-Clinics**

Local Agri Clinics (LACs) are a single window system which channelizes improved agricultural information and technology delivery across the 5 project districts of Leh, Lahaul &Spiti, Kinnaur,Chamoli and Uttarkashi. LACs set-up in different project locations enables small farmers to access agri-information, adapt to climate change, deal with climatic impacts on agriculture, whilst increasing their farm productivity.

LACs areset up to achieve the following objectives:

* Provide the farmers with information on weather variability and farm conditions
* Enable the farmers to improve their agri-technologies in use, adopt precision farming, and enhance their farm productivity
* Facilitate Farmer Expert Groups to undertake farm-level research related to climate/soil adapted farming
* Ensure such information and services will act as an agri-DSS (Decision Support System), helping small farmers undertake precision farming and response modeling to climate/soil variations. This includes timing for farm operations, irrigation and fertilizer schedules, choice of crops, towards optimizing crop-yields and reducing crop losses
* Provide LAC-services access to the small farmers in its operational area.

LACs are collectively managed by a groupof localeducated youth functioning as Agri-Advisors (AAs), as well as Farmer ExpertGroups and Pragya Staff. The extension services of LACs are rooted through AAs, whose functions are described in Section1.3. The 5 Project districts will have 10 LACs across 18 Blocks, classified further into 109 Clusters .One dedicated AA would serve one assigned cluster consisting of farmers within a range of 3-5 villages. In all, a total of 109 AAs are selected to operate the LACs and to offer extension services related to weather information and agro-farming.

**1.3.1LAC Functions**

The key functions of LACs are as follows:

* Maintain environmental data-recording related to weather, soil and moisture, crops, etc.
* Maintain knowledge base on improved agricultural methods.
* Maintain agriculture extension data and services derived from MAAS Network.
* Facilitate training and handholding support to AAs and farmers.
* Assistin offering handholding support to Farmer Expert Groups (FEGs), to undertake farm-level research related to climate/soil adapted farming.
* Facilitate in providing soil testing services (NPK, Organic carbon & pH) and weather monitoring-related services at farm level.

LACs are equipped with the following instruments for weather monitoring and soil testing:

* Weather Station
* Soil Moisture cum pH meter
* Snow Gauge
* Sunshine Recorder
* Soil Testing Kit
* Seed Moisture Meter

LACs facilitate in the dual function of providing weather-related information and soil-related services to the farmers. The AAs are trained in the use ofthese instruments placed at the LAC for weather monitoring and soil testing. Description of the Instruments and their use is given in Section 1.6.

**1.4Agri-Advisors**

The AAs play the role of grassroots Agri-Advisors (AAs) accessing the necessary information/technologies from the LAC,MAAS Secretariat and State Agri- Support Institutions and Weather Monitoring Stations and reaching it to smallholders in the target area. AAs play a critical role in bridging the gap between agri-technology institutions and weather monitoring stations and grassroots farmers. They are promoted as agri- entrepreneurs, are linked with the respective LAC and facilitate fee-based agri-services. They are equipped with agri-database (maintained at the LAC), and trained on use of weather informationand on soil-testing.

The specific role of the AA is as follows:

* Motivate local farmers in the cluster to become members of the LAC and access services of LAC.
* Draw seasonal weather forecasts, and related agricultural advice, from the regional/national linkages in MAAS Network, and interpret these at local scales.
* Provide soil-testing and weather-monitoring services to farmers interpret the data and offer customized agri-advise and handholding support.
* Inform farmers of weather variability and farm conditions, and enable them to improve their agri-technologies in use, adopt precision farming and enhance their farm productivity.
* Train farmers on newer methods/technologies that are resource-efficient, such as drip irrigation, lift irrigation, snow fence, snow harvesting, and help them to adopt these, providing close-touch handholding and problem-solving in the process of technology uptake
* Provide technical training/advice to small farmers, and help them adopt improved technologies for productivity enhancement, land & water management and post-harvest services, through assistance in procuring the necessary supplies/equipment.
* Facilitate farmer’s meetings, agri-conclave and Information Education & Communication (IEC) Materials.
* Facilitate formulation of area-specific nutrition-farming packages (mix of crops based on their nutritive index)
* Plan the calendar for specified activities in their respective cluster.

The AAs are trained in the use of the instruments placed at the LAC for weather monitoring and soil testing. They specifically offer weather-related information and soil-related services to the farmers.

## Weather-Related Information- AAs channelize the data gathered by MAAS and recorded by LAC for the farmers. They make use of the instruments placed at the LAC ~Weather Station, Soil Moisture cum pH meter, Snow Gauge, Sunshine Recorder, Seed Moisture Meter.AAsundertake weather monitoring services; interpret the data and advice farmers accordingly.

## Soil-Related Services- AAs are trained to provide soil testing services (NPK, Organic carbon & pH) at farm level. Spatial data and information on soil conditions gathered through MAAS and the soil-testing services at the LAC provide a comprehensive understanding of the local soil conditions.

**1.5 Mode of Operations**

As stated above, the AAs draw from information and advisory services through MASS.The information/services relate to Climate advisory & weather forecasting, Soil conditions, Conservation, Precision farming advice and new technologies. Fig.2 illustrates the MAAS InformationFlow Chart.



**Fig. 2:MAAS Information Flow Chart**

MAAS Secretariat at Gurgaon HO isa Liaison and Knowledge Hub Centre. MAAS Secretariat facilitates and channelizes the flow of information and services from Agri- Support Institutions tothe farmers. The information is routed through Pragya Project Office and shared with LACs, AAs and farmer communities. AAs receive the information through 2 modes, i.e., from MAAS Secretariat through LACs and directly from MAAS Secretariat. Similarly farmer communities also receive information from MAAS Secretariat through AAs and in specific case directly from MAAS Secretariat.The Secretariat also facilitates the process for farmer communitiestodirectlyaccess information from Agro-Support Institutionsthrough on line, email,voice and SMS services.

The LACs periodically record and monitor the local weather information/data and disseminate it to Farmers through AAs and also directly. The weather monitoring data with MAAS Secretariat is processed and shared with LACs, AAs and farmers. The AAs are the key contact person~ they share weather information and agri services with farmers and build their agronomic capacity. The AAs will undertake data collation on the following parameters: Name, Village, Soil texture (sandy/clay/loam), Area under cultivation, Crops cultivated, Season (pre-Kharif/Kharif/Rabi),years of experience, Commodity Value, Input Cost (Labor, Seed, Manure, Irrigation, and Pesticide), and linkage to govt. or other schemes. Field collection data by AAson set parameters will make use of Reporting Formats discussed in Section 1.5.1.

A site at every villageis identified as MAAS InformationCenter for the convenience of local farmers and a member of Farmer Expert Group acts as the contact. The mode of transferring data and information is presented in the Information Flow Chart.The periodicity of data sharing is as follows:

* Daily weather updates – daily
* Five day district level weather forecast – after every four days
* Weather warnings – whennecessary
* Agri advisory – separately for each crop season.

Annexure 1 documents the MAAS Information Flow Matrix for each of these data sources. The Matrix spells out the flow, frequency and channel of information from specific institutions to the MAAS Knowledge Hub and to the Field office.

**1.5.1 Reporting Structure**

The Reporting Structure cuts across various entities and functionaries-AAs, Team leader, Project Office and Head Office.

* One AA in the LAC is designated as the team leader under whose supervision the AAs work and report.
* Team leader is selected by the Pragya Field Office in coordination with all AAs on the basis of seniority (age), experience in technical aspects of farming, educational background.
* Team leader supervises and visits the farmers contacted by AAs on a regular basis to validate findings.
* AAs will maintain Base Line- 2015 Format (Annexure 2), Soil Testing Format (Annexure3), and Weather Monitoring Format (Annexure 4).A Tracker on the Base Line- 2015 will be inputted, post-season.
* Monthly Meeting of AAs is organized at the LAC along with PO to facilitate sharing,reporting coordination and planning.
* LAC maintains log sheet on weather monitoring, soil testing, crop advisories and database of local market and agri-business.
* A Log Register will be maintained at the village with the Contact Farmer. The Register will include the Monthly village/farmer group meeting minutes. The Minutes will include details such as~ Name of Farmer, Father's Name, Age, Sex, Issues discussed, Membership Fee. This Format will serve as the basis for effective formation of Farmer Groups.
* AAs submit reports on monthly basis to PO and share all the required information/data into the prescribed format (Annexure 5).
* Project Office compiles the AA reports and prepares LAC report on monthly basis with the assistance of the team leader by covering activities undertaken by each AgriAdvisor,on farm and off farm activities, action of farmer’s social groups, activities of LAC, liaison, training, village monthly meeting and resource mobilization.
* Project Office uses a prescribed format “PO Monthly Report Format” to report to HO within 5 days (Annexure 6).

**1.6 Instruments at LAC**

LACs provide facility of soil testing services (NPK, Organic carbon & pH)and weather monitoring on nominal charge. As stated earlier,LACs also have the following instruments to facilitate agro services:Soil Testing Kit, Weather Station, and Soil Moisture cum pH meter, Snow Gauge, Sunshine Recorder, Seed Moisture Meter.LACs act as an agri-DSS (Decision Support System) and are retrofitted with computer and online services.

**1.6.1 Soil Testing**

In most of the soil testing laboratories and kits in India, the soil pH, electrical conductivity, oxidized organic carbon, available nitrogen, phosphorous and potassium are determined by chemical analytical method within a short period. Soil testing is the rapid chemical analysis of a soil to estimate the available nutrient status, reaction and salinity of the soil.

**Objectives of Soil Testing**

* To evaluate the fertility status of a soil for providing an index of nutrient availability or supply in a given soil.
* To evaluate the fertility status of a soil on area basis by the use of soil test summaries.
* To estimate the available nutrient status, reaction (acidic/alkaline) of soil.
* To prepare a basis for recommendations for fertilizer, lime or gypsum.

Soil test summarizes the fertility status i.e., available nitrogen status, phosphorous and potassium status expressed as HIGH, MEDIUM or LOW. A soil fertility map showing such fertility status can be prepared and be used for -

* Delineating areas of nutrient (N, P, K) sufficiency or deficiency,
* Studying soil fertility changing pattern due to crop cultivation over a period of years,
* Determining nutrient (N, P, and K) requirement for the deficient areas.

**Soil Testing Programme**

A soil testing programme has **four phases**: Collection of soil samples; Chemical analysis of soil samples; Calibration and interpretation of the results of chemical analysis; Recommendation. Before giving the soil sample for chemical analysis, the collection and preparation of soil sample should be done with care.

**Collection:** Small portions of soil are to be collected up to the desired depth (0-15cm or more) by means of suitable sampling tool (described below) from at least 10-15 well distributed spots. Surface litter, if any, should be scrapped off. The soil collected should be thoroughly mixed by hand, on a clean piece of cloth or polythene sheet, and the bulk reduced by quartering and about 500gm of the composite sample retained.

**Preparation:** The soil sample should be air dried in the shade at room temperature. Later,40-50 gram of air dried soil sample, should be taken in pestle and mortar, and powdered by gently grinding. The sample should be sieved with the plastic sieve on clean polythene and stored in the given sample container with suitable description and identification mark. These samples would be ready for testing.

The soil testing kit consists of items such as Plastic Tube, Micro Tube, Glass Cylinder, Mortar and Pestle, Funnel, Spirit Lamp, Filter Paper, etc.

**Information:** Relevant Information on the soil should be collected such as Name, Village, Soil texture (sandy/clay/loam), Depth of soil sample ,Area under cultivation, Crops cultivated, Season (pre-Kharif/Kharif/Rabi),Years of experience, Commodity Value, Input Cost (Labor, Seed, Manure, Irrigation, and Pesticide), Linkage to govt. or other schemes. AAs will maintain this information in the Base Line-2015 Format presented in Annexure 2.

**Sampling time**

* Soil samples should be taken well before the sowing of the crop or establishing a new orchard.
* For agricultural crops, the best time of sampling is when the field is free of crops.
* For horticultural crops, the best time to collect a soil sample is during autumn.
* As a general rule, it is best to go for soil sampling a couple of weeks prior to the start of any seedbed preparation.
* In case of perennial crops like forage and fruit trees, soil sampling should be done prior to the beginning of a new flush of growth.

**Sampling Units**

To ensure the collection of representative soil samples, divide the areainto sampling units based on visual observations on: crop growth, appearance of the soil, soil colour, field slope, past crop management practices like manuring, fertilization techniques and cropping pattern etc. Collect one composite sample from each block or unit.

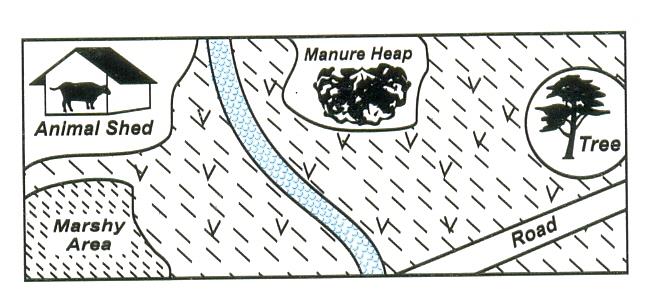


Fig. 3: Sampling example

**Rating of Soil Test Results**

On the basis of soil test results, the soils are grouped into different categorieswith respect to organic carbon, available P, K and N as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Categories** | **Organic Carbon(%)** | **Available N (kg ha-)** | **Available P (kg ha-)** | **Available K (kg ha-)** |
| High | Above 1.5 | Above 450 | Above 90 | Above 340 |
| Medium | 0.75-1.5 | 280-450 | 45-90 | 150-340 |
| Low | Up to  0.75 | Below 280 | Below 45 | Below 150 |

The categories of soils with respect to pH are as follows:

|  |  |
| --- | --- |
| **Soil pH** | **Categories** |
| Below 5.5 | Acid |
| 5.5-6.5 | Slightly acid |
| 6.5-7.5 | Neutral |
| 7.5-8.5 | Tending to become alkali |
| Above 8.5 | Alkali |

The categories of soils with respect to conductivity (total soluble salts) in mmhos/cm (dSm-1) followed are as follows:

|  |  |
| --- | --- |
| **Conductivity** | **Categories** |
| Below 1 | Normal |
| 1 - 2 | Critical for germination |
| 2 -.3 | Critical for growth of salt-sensitive crops |
| Above 3 | Injurious to most crops |

Thus, Soil Testing services at the LAC will conduct the soil analysis and report on pH, Electricalconductivity,Organic Carbon of the soil and Nitrogen, Phosphorous value as P in kg/hectare and Potassium value as K in kg/hectare.

**Significance of Soil Test Parameters**

The soil characteristic onpH, Organic Carbon,Nitrogen,Phosphorous and Potassium of all farms are not same, and they are vital in the selection of appropriate crops. The use of each parameter in agriculture is discussed here.

***pH***-A scale that chemists use to measure acidity. Values below 7 are considered acidic, values above 7 are alkaline (the opposite of acidic) and 7 is neutral. Most plants can tolerate a wide pH range in solution culture, but they cannot tolerate a wide range of acidity in the soil. When thesoil aciditychanges, solubility of the number of metal ions also changes. Plant growth is really affected by the varying concentration of these metals in solution rather than by the acidity itself.

Under acidic conditions, many soil minerals dissolve and increase the concentration of metal ions to toxic levels. The primary toxic metal is aluminum, but high levels of manganese and iron can also inhibit plant growth under these conditions. The nutrients phosphorus and molybdenum are less available in acidic soils and calcium and/or magnesium may also be deficient.

Under alkaline conditions, the solubility of minerals decreases to the point that nutrient deficiencies occur. Plant growth is therefore limited by deficiencies in iron, manganese, zinc, copper and boron. Phosphorus is also less available in alkaline soils and high levels of calcium may inhibit the uptake of potassium and magnesium.

The aim in managing soil pH is not to achieve a particular pH value, but to adjust the acidity to the point where there are no toxic metals in solution and the availability of nutrients is at its maximum. This condition is usually achieved when the soil pH is between 5.8 and 6.5; however some plants have special acidity requirements.

***NPK-***

* **Nitrogen**  
  Nitrogen is primarily responsible for vegetative growth. Nitrogen assimilation into amino acids is the building block for protein in the plant. It is a component of chlorophyll and is required for several enzyme reactions.
* **Phosphorus**  
  Phosphorus is vital for strong growth. Insufficient phosphorus in the soil will cause stunted, spindly crops. Phosphorus, when combined with water, breaks into separate ions that can be absorbed by the plant’s root system. The plant uses phosphorus for photosynthesis and energy/nutrient transport. The right amount of phosphorus can help crops yield more fruits and create healthier stocks and root systems; they may also mature much quicker than plants without phosphorus. Insufficient supply can cause green & purple discoloration, wilting, small fruits and flowers (if at all). When phosphorus is added to the crops when sowed, it can establish a strong root base and produce strong growth.
* **Potassium**  
  The role of potassium in the plant is indirect, meaning that it does not make up any plant part. Potassium is required for the activation of over 80 enzymes throughout the plant. It's important for a plant's ability to withstand extreme cold and hot temperatures, drought and pests. Potassium increases water use efficiency and transforms sugars to starch in the grain-filling process.
* **Organic Carbon**

Soil organic matter is important in relation to soil fertility, sustainable agricultural systems, and crop productivity. The amount of organic matter in soil depends on the input of organic material, its rate of decomposition, the rate at which existing soil organic matter is mineralized, soil texture, and climate. All four factors interact so that the amount of soil organic matter changes, often slowly, toward an equilibrium value specific to the soil type and farming system. Trends in long-term crop yields show that as yield potential has increased, yields are often larger on soils with more organic matter compared to those on soils with less.

Hence, the micro level soil testing services through LAC wouldpromotecultivation, crop production and high yield specific to the soil type and farming system. AAs will furnish the soil testing results in the Soil Testing Format given in Annexure3.

**1.6.2 Weather Monitoring**

As discussed earlier, the MAAS Information Center would transfer data and information to the farmers with the following periodicity: Daily weather updates,Five day district level weather forecast, Weather warnings – when necessary, Agri advisory – separately for each crop season. Annexure 1 documents the MAAS Information Flow Matrix, i.e., the flow, frequency and channel of information from specific institutions to the MAAS Knowledge Hub and to the Field office.

The LAC will also facilitate weather monitoring services using the Instruments: Weather Station, Soil Moisture cum pH meter, Snow Gauge, Sunshine Recorder, Seed Moisture Meter. The significance of each weather component and its use in agriculture is explained below:

**Weather Station**

The weather station facilitates information on Temperature, Wind Speed & Direction, Humidity, Air Pressure and Rain.

**Temperature**- Air temperature influences plant growth through photosynthesis and respiration, affects soil temperature, and controls available water in the soil.   Farmers use soil temperature and soil moisture to decide when to plant, what varieties of crops to choose, and to determine the likely development of key plant characteristics like flowering as well as emergence of insect pests and plant diseases.  The occurrence of freezing temperatures in winter generally heralds the end of the growing season. Temperature affects all of the biochemical reactions of photosynthesis. As the temperature increases, the plant respiration rates increase.

Plants are classified as either C3 or C4 plants (a classification of how they fix carbon) and their response to temperature is different. A C4 plant (such as corn) can photosynthesize and yield equally at any place in the range of 10 to 40 degrees C. Conversely, a C3 plant responds negatively to high air temperatures, and the yield declines as temperature increases. Most plants have a range of temperature at which growth occurs. Optimal temperatures are different from plant to plant, and can even be different within one species.

Air temperature can also affect the availability of some nutrients (phosphate is less available in the chloroplast of the plant at low temperatures), which in turn reduces the level of photosynthesis. Low air temperatures can also negatively affect plant growth. Growers of small fruit crops (strawberries) and tree crops (peaches) protect their crops when a damaging freeze is predicted. Sometimes they irrigate the crop so that a thin layer of ice forms on the crop (the act of water freezing actually releases energy that can raise the air temperature slightly). The farmers can cover the crop with plastic or cloth to protect the crop. Low air temperatures also affect soil temperatures and freezing soil temperatures can cause “frost heaving” of plants that overwinter in the soil.

* **Wind Speed &Direction**- Wind speed is significant for plantation, removing husk from grains, and for farmers who are using wind energy for irrigation. Wind direction is used for rainfall forecast, during spray of pesticides which should be in sync with the air direction. Wind speed is an important factor when using pesticides in fields. Pesticides increase yields and reduce the presence of foreign materials in some commodities. Some pesticides label directions specify the maximum wind speed for application.
* **Relative humidity-**It is the ratio of actual water vapor content to the saturated water vapor content at a given temperature and pressure expressed in percentage (%).Many plants can directly absorb moisture from unsaturated air of high humidity. Humidity affects the photosynthesis of plant leaves. Relative humidity (RH) directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield.

Photosynthesis is indirectly affected by RH. When RH is low, transpiration increases causing water deficits in the plant. The incidence of insect pests and diseases is high under high humidity conditions. High RH favors easy germination of fungal spores on plant leaves. Hence very high or very low RH is not conducive for high grain yield. The effect of very high Relative humidity reduces evapo-transpiration, Increases heat load of plants, Stomata closure, and Reduces CO2 uptake. Low RH increases the evapo-transpiration and influences translocation of food materials and nutrients. Moderately high RH of 60-70% is beneficial.

* **Atmospheric pressure-** Atmospheric pressure is an important parameter in monitoring the climate system specially rains & wind speed. In the atmosphere, if the air pressure is high, this generally means there is sinking air molecules and the weather will be clear.  These favorable weather conditions are good for field work and spraying, but can also be associated with periods of drought if they last a long time.  If the air pressure is low, this generally means there is raising air molecules and there is a chance of clouds and rain.  Pressure is also vital in the maintenance of hydraulic equipment, where internal fluid pressures have to be carefully maintained to prevent damage and maximize efficiency.
* **Rain-**LAC weather -monitoring stations generate information gathered from rain gauge to report how much rain a specific area has received, both at a single time-point and accumulation over time. Comparing current data to previous years helps to gauge if an area is receiving too much or too little rainfall and how that will affect plant life, food and water supplies. Rain gauge data are also useful to farmers for planting and harvesting purposes,e.g., manure application in field, water management, seed/plant sowing.

**Soil Moisture Meter**

By measuring soil moisture at regular interval and at several depths within the root zones, information can be obtained as to the rate at which moisture is being used by the crops at different depths. Measuring the moisture content of soil or compost pile allows analyzing whether we need to add more or less water. Water is important for carrying nutrients into plants and facilitates the composting process. Too much or too little water can cause problems and hence measuring with these meters can allow the farmer to get the water content just right. The farmers would be able to use less water to grow a crop, increase yields and ensure the quality of the crop by better management of soil moisture during critical plant growth stages.



Fig.4: Soil Moisture Meter

**Snow Gauge**

A snow gauge is used to gather and measure the amount of solid [precipitation](http://en.wikipedia.org/wiki/Precipitation_%28meteorology%29) (as opposed to liquid precipitation that is measured by a [rain gauge](http://en.wikipedia.org/wiki/Rain_gauge)) over a set period of time. The Himalayas depend on an accumulation of snow during winter that will melt gradually in spring, providing water for crop growth.



Fig.5: Snow Gauge buried in snow

**Sunshine Recorder**

Using the sun to dry crops and grain is one of the oldest applications of solar energy. Sun intensity measure is helpful for decision in plantation at local level. Sun intensity is helpful in electricity generation for agriculture purpose.

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Fig.6 : Sunshine Recorder

**Seed Moisture Meter**

Accurate moisture tests are important in every component of the grain industry from choosing seeds, to the harvest, to storage and sale of dry goods. The more accurate the moisture measurement, the more will be the yield and greater the profit. When storing seeds in airtight storage systems, it is recommended to use moisture meter to determine the seed moisture content before sealing the storage container.Grain that is too wet and placed in low temperature or open air drying bins will mold. Harvesting grain when it is too wet requires extra drying to keep stores from spoiling, while over drying grain can lead to a loss of quality, and wasted resources.

Hence, the farmers will receive weather monitoring information from multiple sources:

1. Direct micro level weather monitoring information from these instruments placed at the LAC.
2. Weather monitoring information from MAAS Secretariat.
3. Direct access information from Agro-Support Institutions through on line, email,voice and SMS services.

These services will enable them to decide on timing of cultivation, planting, harvesting based on the climate-soil mix of the farm.

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# 2. Land and Soil Management

Soil is vital for plants as it is not merely a support system, but a complex world from which the roots obtain water and other required elements. Soil is inhabited by small animals, insects, microorganisms (e.g., fungi and bacteria) which all influence the plant life.The major components of soil are solids (minerals and organic matter), liquids (water and dissolved substances), gases (mostly oxygen and carbon dioxide) and contains living organisms. Soil provides nutrients, recycles/filters water, stores water and is the basis of life on earth.

However, soil erosion is increasingly taking place,and large parts of the Himalayas suffer from erosion by wind and by water. The most important cause of soil erosion is destruction of forests and other vegetation from sloping lands. Vegetation acts as a protective cover against the forces of wind and water, protecting the soil from being washed or blown away and preserving the physical and-hydrographic balance of nature. When the protective cover of forests is destroyed, rainwater flows down the slopes unimpeded at great speed and carries with it large quantities of soil and their dense mat of undergrowth. Besides the destruction of forests, faulty land use practices such as overgrazing, failure to practice measures as ploughing along the contours on sloping lands, crop rotation and growing of cover crops are also causes of erosion. The cumulative effect is the reducing productive capacity and nutrient composition of farmlands.Therefore, management of soil entails 2 aspects~ a) restricting soil erosion- by wind and by water; b) enhancing the nutrients in the soil.

**2.1. Checking soil erosion**

The Himalayan region suffers from soil erosion by wind and water action. Furthermore, Glaciation, melting snow and rainfall in the mountains cause leaching of the nutrients (e.g., Iodine) from mountain soils and create deficiencies in micronutrients. Traditional methods such as contour bending, mulching, and terracing, contour farming have been in use to prevent soil loss and augment moisture conservation in Himalayan agriculture. Measures for Soil conservation would help to improve soils, prevent soil loss, conserve moisture and maintain the productivity of soil. These methods include use of shelterbelts and earth basins with infiltration pits and engineering measures as construction of check dams, gabion walls. This manual describes few of these methods, theirbenefits, design, steps for setting up and role in preventing soil loss and augmenting moisture conservation.

**2.1.1. Shelterbelts**

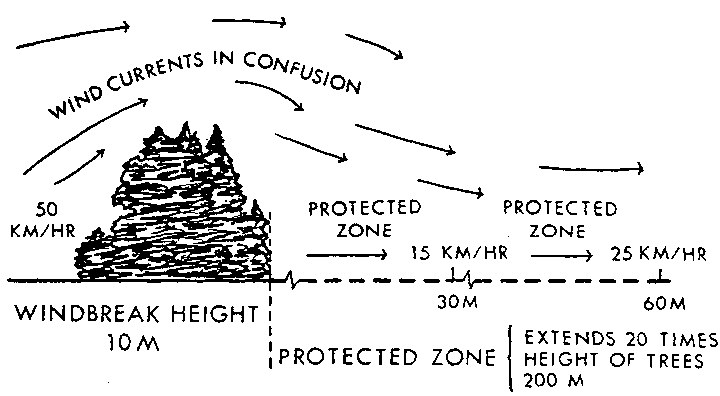
Description:**Windbreak** or **shelterbelt** is a [plantation](http://en.wikipedia.org/wiki/Plantation) usually made up of one or more rows of [trees](http://en.wikipedia.org/wiki/Tree) or [shrubs](http://en.wikipedia.org/wiki/Shrub) planted in such a manner as to provide shelter from the [wind](http://en.wikipedia.org/wiki/Wind) and to protect soil from [erosion](http://en.wikipedia.org/wiki/Erosion). They are commonly planted around the edges of fields on farms. Shelterbelts are vegetative barriers that are designed to reduce wind speed and provide sheltered areas on the leeward (the side away from the wind) and windward (the side toward the wind) sides of the shelterbelt. As wind approaches the belt, some goes around the end of the belt, some goes through the belt and most goes over the top of the belt. Air pressure builds up on the windward side and decreases on the leeward side. The denser the shelter, the greater is the difference in air pressure.

Benefits: Shelterbelts and [intercropping](http://en.wikipedia.org/wiki/Intercropping) can be combined in a farming practice referred to as [alley cropping](http://en.wikipedia.org/w/index.php?title=Alleycropping&action=edit&redlink=1). Fields are planted in rows of different crops surrounded by rows of trees. These trees provide fruit, wood, and protect the crops from the wind. Alley cropping has been particularly successful in India, Africa, and Brazil, where coffee growers have combined farming and forestry. Shelterbelts also provide a safe barrier for farm animals. They offer largely agronomic benefits,i.e., they reduce soil erosion by wind, increase moisture for crop growth, reduce wind damage to crops and can provide a potential source of income for farmers (e.g., plantation of timber along with medicinal species).

Design**:**There are several key elements to effective shelterbelt design. The elements that need to be considered are height, length, density, location, number of rows and the species to be used. It is important to maximize the height of a shelterbelt, as its height will determine the area over which the windbreak has a positive impact. Using the tallest suitable shelter species in at least one row of the belt will increase the eventual area over which a shelterbelt is effective. The species used for the taller row can be fast growing, to achieve maximum height rapidly.

Density is the proportion of solid material, such as foliage, branches etc. within a shelterbelt. Density can affect the extent and level of shelter provided. Wind turbulence is generally reduced with lower degrees of density. A high-density shelterbelt will provide a higher level of shelter over a shorter distance than a medium or low-density belt. Therefore very dense windbreaks may be used where a high level of shelter is required over a short distance. The design should aim for a medium density belt using shrubs and ground cover species as well as taller species. A shelterbelt consisting of 2- 4 rows using taller species that provide the benefits of a tall belt combined with shrub species that provide shelter lower down would offer an overall uniform density.

Field shelterbelts are used to shelter agricultural fields, while farmstead shelterbelts are planted around farmyards or livestock facilities. Trees and shrubs are also planted in blocks for woodlots or farm habitat. Field shelterbelts decrease wind erosion by reducing wind speeds for distances up to 20 times the height of the trees. They also trap snow for increased spring soil moisture, reduce wind damage to crops, and decrease evaporation of soil moisture and store carbon. Shelterbelts are most effective when planted across the prevailing wind direction. For increased sheltering effects, the shelterbelts can be spaced more closely together; for maximum wind erosion control, the rows should be spaced between 2 to 4 meters apart to allow the plants to grow relatively unrestricted.When considering shelterbelt planting, three zones can be recognized: the windward zone (from which the wind blows); the leeward zone (on the side where the wind passes); and the protected zone (zone in which the effect of the windbreak or shelterbelt is felt) (Fig.7).



**Fig. 7: Functioning of Shelterbelt**

Setting up, Operation and Maintenance:

The farmer should keep in mind the plant location, spacing within shelterbelts and the species selection while setting up a shelterbelt. Steep sided belts shelter a larger area because they provide a greater height barrier to wind flow and a lower density on the windward side. Sloping profiles on the windward side can actually reduce the distance over which protection is provided.

Taller species should be placed in the center of a belt. Lower growing species can be placed on each side. Medium to tall trees are usually spaced 3 to 4 meters apart. Large shrubs can be spaced between 2.5 to 4 metres while smaller growing shrubs are generally placed 1.5-2.5 metresapart. Plants should be placed closer together in belts with fewer rows to obtain the desired level of density.

The farmer should select the species to provide the height, growth rate and density characteristics suitable for the shelterbelt. The farmer should select locally native species which generally have higher survival and establishment rates. Species that will grow tall on the site, with an appropriate foliage density and growth rate should be considered. The farmer should use one species per row or species with similar or compatible growth forms. In the dry arid regions of the Himalayas, Species such as willows and poplar trees are most suitable. To get maximum benefit from shelterbelts, the farmer will need to design the belt, select species suited to the site, prepare the site for planting, control weeds for the first few years after planting, and do pruning, watering and other maintenance. Shelterbelts have to be managed for longevity; the trees would need to be replaced when damaged.

**2.1.2. Check Dams and Gabion walls**

Description: Check dams and Gabion walls are physical structures, such as walls against the flow of water or slope of land that can be used for decreasing run-off, reducing soil erosion and improving percolation of water into the ground.

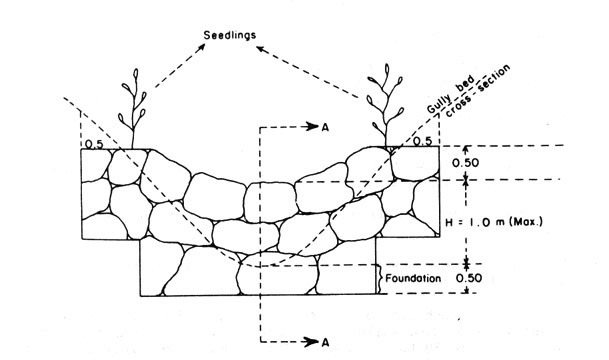
*Check dams:* Check dams are micro catchments that can be constructed on valley slopes to collect water and allow overflow into a narrow channel….controlling the speed of the run off. They are useful for slowing the movement of water, controlling erosion and allowing increased percolation into the soil. Soil and silt that builds up behind the dam is very fertile and can be utilized for farming. This land can be planted after the rains while it retains moisture. If the purpose of a check dam is to create good land for planting after the rains, a structure called a nala bund can be used. The earthen bund will lead to flooding of the upstream area and retention of moisture and silt. Check dams allow for overflow into a narrow channel over gently sloping stone pitching.

*Gabion walls:* Gabion walls are flexible, permeable and economical structures. They are constructed in places where stones are abundantly available. Their main function is to control soil erosion and retain the water so that percolation of water takes place which recharges the groundwater. A Gabion wall is basically wire mesh, filled with stones, where the size of stones filled is always greater than the mesh openings.

Benefits: *Check dams* are a highly effective practice to reduce flow velocities in channels and waterways. Check dams in contrast to big dams, have a faster implementation timeline, are cost effective, and are smaller in scope. Because of this, their implementation will not typically displace people or communities nor will they destroy natural resources if careful design considerations are undertaken. Moreover, the dams themselves are simple to construct , do not rely on advanced technologies and can be applied in rural and less advanced communities, as they have been in India’s dry lands.

*Gabion Walls* have several benefits as a measure of soil erosion. Gabion walls exhibit inherent**Flexibility,**when subjected to alternating forces of tension and compression. The Gabion structure enables it to deform rather than break, thus preventing loss of structural efficiency. Gabion walls display Strengthas it is bound together as a monolithic unit and the wire mesh is extremely strong under tension. The wire mesh shell is not simply a container for the stone filling, but a reinforcement of the entire structure. Additional strength is achieved by the use of vertical diaphragms. Gabion walls also have **Permeability**asthe spaces in the stone fill provide a great degree of porosity throughout the structure. The permeability eliminates the need for a drainage system and prevents buildup of hydrostatic pressure which would displace and crack concrete structures. Gabionwalls are highly **economical** with low construction costs and the graded stone fill is usually locally available. The structures may be built without any mechanical equipment, as pilings, underwater drainage systems and excavations are unnecessary. Gabion structures are virtually maintenance free and will take its full load immediately on completion - without the waiting period of up to one month normally associated with concrete structures.

Design: *Check dams* have traditionally been implemented in two main environments: across channel bottoms and on hilly slopes. Check dams are used primarily to control water velocity, conserve soil, and improve land.Theyslow down torrential flows along waterways by building small catchments on valley slopes. Check dams need to be adapted to the landscape, soil and slope. In the case of a plateau with permeable soil, a very slight incline and therefore relatively little runoff, the tillage should be on the flat area. At the top of a slope of an average gradient, with permeable soil that drains quite easily, there is a high risk of runoff and desiccation. The land here should be shaped into mounds and depressions in order to confine the water and force it to percolate. The stone section is built to hold back the silt and create a good area for planting. A series of such check dams conserve the water, collect the topsoil and halt its further loss, and also allow the percolation of water into the soil (Fig.8).



**Fig. 8: Check Dam Design**

*Gabion Walls:* There are various special designs of gabions to meet particular functional requirements and specific terms for particular forms have come into use. For example:

* Bastion: a gabion lined internally with a membrane, typically of nonwoven geotextile to permit use of a granular soil fill instead of rock.
* Mattress: a form of gabion with relatively small height relative to the lateral dimensions, very wide for protecting surfaces from wave erosion.
* Trapion: a form of gabion with a [trapezoidal](http://en.wikipedia.org/wiki/Trapezoid) cross section, designed for stacking to give a face that is sloping rather than stepped.

Setting up, Operation and Maintenance: *Check dams* require regular maintenance and should be inspected on a regular basis and after every large storm. Rubble, litter and leaves should be removed from the upstream side of the dam. Thisshould be done when the sediment has reached a height of one-half the original height of the dam.

*Gabion Walls* require vertical faces and have narrow depth .Gabion walls require extra support to give stability, which can be provided by using metal or concrete posts at regular intervals inside the mesh. The process for installing it involves clearing the area and making sure the surface is flat and tightly packed down. The mesh is placed into the desired position and a metal post is placed through the bottom of the mesh and set in cement for added stability. The mesh is then filled with rocks and metal fasteners installed to close off the mesh. This process is repeated as required.

**2.1.3. Earth basins with Infiltration pits**

Description: Earth basins are square or diamond shaped small collection areas, constructed to capture and hold all rainwater that falls on the field. Earth basins are suitable in arid and semi-arid areas, with annual rainfall amounts of 150 mm and above. They have proven especially successful for growing fruit crops, and the seedling is then planted in or on the side of the infiltration pit.

Benefits: Earth basins are easily constructed by hand and they help improve soil moisture and water availability for plants. Earth basins ensure that no rainwater is lost through runoff and the risk for erosion is reduced.

Design: The size of the basin is usually 1-2 m. In some cases basins of up to 30 m length are constructed. Sometimes grass is planted on the bunds for reinforcement. Manure and compost can be applied to the basin to improve fertility and water-holding capacity.

Setting up, Operation and Maintenance:Earth basins are constructed by making low earth ridges on all sides of the basin. These ridges keep rainfall and runoff in the mini-basin. Runoff water is then channeled to the lowest point and collected in an infiltration pit. The lowest point of the basin is located in one of the corners on sloping land. Soils should be deep, preferably at least 1.5 m to ensure enough water holding capacity. The slope can be from flat up to about 5%. Earth basins constructed on steep slopes should be made small.

Earth Basins have been successful in fruit growing areas, where the seedling is planted in or on the side of the infiltration pit.



**Fig. 9: Earth Basin used as fruit growing area**

**2.2. Managing soil nutrients**

The Himalayan region is affected by a high degree of soil erosion and leaching because of over-grazing, deforestation and intensive unsustainable agricultural practices. This leads to loss of soil fertility and valuable soil nutrients. Important nutrients in the soil like Phosphorous, Potassium and Nitrogen, secondary nutrients like Calcium, Magnesium, Sulfur, and micro nutrients like Iron, Manganese, Copper, Zinc, Chloride, Molybdenum, Boron, Selenium are lost from the soil. Nutrients lost through crop removal, erosion, leaching, have an impact on the land productivity as well as the nutritional value of the crop.

Apart from the methods described above to reduce soil erosion and run-off, the Application of Nutrient-dense farming, Vermi-composting and Soil-Improving Farm Practices could also be adopted towards increasing soil fertility.

**2.2.1. Nutrient Dense farming**

Description: Nutrient-Dense Farming (NDF) involves the cultivation of a suitable mix of crops based on their nutritive as well as soil-enriching value. These crop-mixes would include native crop species that possess nutritional and soil-enriching values while also ensuring the required nutrition for Himalayan households.

Benefits: Nutrient-Dense Farming (NDF) methods help to improve soils and produce crops that have high micro-nutrient content. It aims to create a highly functional soil ecosystem in which the crops that are harvested have a measurably greater quantity of minerals, vitamins, photo-nutrients, and antioxidants.NDF methods improve soil nutrients and prevent leaching, i.e., dissolving of minerals and organic matter in upper layers and carrying them to lower layers. Fruits and vegetables grown with these principles have more complex and intense flavor, longer shelf life, higher yield, and are more resistant to natural challenges.

Design: Nutrient components need to be in appropriate ratios to each other in order to maximize absorption and use by the body. NDF draws from cutting edge research and long proven techniques that build the ideal soil environment for crop growth and production and lead to high nutritive levels, greater yields, and better pest, disease and extreme weather resistance.

Cropping patterns based on their nutritive index have been suggested by Agri-support Institutions in MAAS .A combination of leguminous and cereal crops, deep and shallow rooted crops, and coarse grain and cereals should be promoted on the basis of their nutritive index. Area specific Nutri-Dense cropping options should keep in mind the landscape, altitude and weather conditions of the area, as well as the particular nutritional deficiencies in the resident population. For instance, Maize, rajma (kidney bean), tomatoes, peas and amaranths are suggested to meet the nitrogen deficiency in the soil for the entire Himalayan region.

Agri-support Institutions in MAAS recommend the following Area specific Nutri-Dense cropping options:

* Leh: Potatoes and barley are required to meet vitamin requirements.
* Lahaul and Spiti: Peas (off season), tomatoes and potatoes are required to fulfill vitamin deficiency.
* Kinnaur: Barley, Peas (Azad Pea3), apples, almonds and apricots would result in protein and vitamin enrichment of diets.
* Chamoli: Cabbage, cauliflower and mandua are suggested as they are rich in iron and vitamin A.
* Uttarkashi: Apples, uraddal (black gram), white rajma (kidney bean), tomatoes and mandua for enriching diet in proteins, iron and nitrogen fixing in the soil.
* Special crops that supplement nutritional requirement for children are Rajma, soyabean and maize, while for women mandua, rajma, soybean, foxtail and millets.

Setting up, Operation and Maintenance:

NDF draws from farm research and identifies crops that would lead to high nutritive levels, greater yields, and better pest, disease and extreme weather resistance. While a large variety of crops are grown across different regions of the Himalayas, some of them exhaust the soil nutrients whereas others help in enriching the soil. For instance in Kargil and Leh, Wheat, Oilseeds, Millets, Alfalfa, Cucurbits, Onion, Tomato, Sea buckthorn are cover crops that are also soil-exhausting; Pulses and Peas on the other hand, are Legume crops that are soil-enriching.NDF would draw from the inputs of farm research on the 'optimal' combination of leguminous and cereal crops, deep and shallow rooted crops and coarse grain and cereals which would fortify the nutrient content of the soil.

**2.2.2.** **Vermi-composting**

Description:Vermi-composting is the process of [composting](http://en.wikipedia.org/wiki/Composting) using various [worms](http://en.wikipedia.org/wiki/Worm), usually [red wigglers](http://en.wikipedia.org/wiki/Eisenia_foetida), [white worms](http://en.wikipedia.org/wiki/Enchytraeus_buchholzi), and other [earthworms](http://en.wikipedia.org/wiki/Earthworm) to create a [heterogeneous](http://en.wikipedia.org/wiki/Heterogeneous) mixture of decomposing vegetable or food waste, bedding materials and vermicast. Vermicast, also called worm castings, worm humus or worm manure, is the end-product of the breakdown of [organic matter](http://en.wikipedia.org/wiki/Organic_matter) by an [earthworm](http://en.wikipedia.org/wiki/Earthworm). These castings contain reduced levels of contaminants and a higher saturation of nutrients than do organic materials before vermi -composting.

Benefits:Vermi-compostisa nutrient-rich [organic fertilizer](http://en.wikipedia.org/wiki/Organic_fertilizer) and soil conditioner with several benefits for soil aeration, plant growth, environmental recycling and economic effect:

|  |  |
| --- | --- |
| **Soil aeration –**   * Enriches soil with micro-organisms adding enzymes such as phosphates and cellulose * Attracts deep-burrowing earthworms already present in the soil * Improves water holding capacity | **Plant growth-**   * Enhances germination, plant growth, and crop yield. * Improves root growth and structure * Enriches soil with micro-organisms |
| **Environmental recycling-**   * Helps to close the metabolic gap through recycling waste on-site * Reduces greenhouse gas emissions such as methane and nitric oxide * Bio-waste conversion reduces waste flow to landfills * Elimination of bio-wastes from the waste stream reduces contamination of other recyclables collected in a single bin | **Economic effect-**   * Creates low-skill jobs at local level * Low capital investment and relatively simple technology |

Design: A range of agricultural residues, all dry wastes, for example, sorghum straw and rice straw (afterfeeding cattle), dry leaves of crops and trees, pigeon pea (Cajanuscajan) stalks, groundnut (Arachishypogaea) husk, soybean residues, vegetable wastes, weed (Parthenium) plants before flowering, fiberfrom coconut (Cocosnucifera) trees and sugarcane (Saccharumofficinarum) trash can be converted into vermin compost. In addition, animal manures, dairy and poultry waste, food industry waste, municipal solid waste, biogas sludge and bagasse from sugarcane factories can also serve as raw material for vermi-composting.

The quantity of raw materials required using a cement ring of 90 cm in diameter and 30 cm in heightor a pit or tank measuring 1.5 m × 1 m × 1 m is given below:

* Dry organic wastes (DOW) 50 kg
* Dung slurry (DS) 15 kg
* Rock phosphate (RP) 2 kg
* Earthworms (EW) 500–700
* Water (W) 5 L every three days

The various ingredients are used in the ratio of 5:1.5:0.2:50–75:0.5 of DOW: DS: RP: EW: W. In the tank orpit system 100 kg of raw material and 15–20 kg of cow dung are needed for each cubic meter of the bed.Fig. 10 illustrates Vermi compost used as fertilizer in a Mid-scale worm bin (1 m X 2.5 m up to 1 m deep).



**Fig.10: Vermi compost used as fertilizer**

Setting up, Operation and Maintenance:Vermi-composting involves the following steps:

• Cover the bottom of the cement ring with a layer of tiles or coconut husk or polythene sheet.

• Spread 15–20 cm layer of organic waste material on the polythene sheet. Sprinkle rock phosphate powder if available (it helps in improving nutritional quality of compost) on the waste material and then sprinkle cow dung slurry. Fill the ring completely in layers ~ organic waste material, rock phosphate powder, cow dung slurry, as described.

• Paste the top of the ring with soil or cow dung. Allow the material to decompose for 15 to 20 days.

• When the heat evolved during the decomposition of the materials has subsided (15–20 days after heaping), release selected earthworms (500 to 700) through the cracks developed. Cover the ring with wire mesh or gunny bag to prevent birds from picking the earthworms.

• Sprinkle water every three days to maintain adequate moisture and body temperature of the earthworms.

• The vermi-compost is ready in about 2 months if agricultural waste is used and about 4 weeks if sericulture waste is used as substrate. The processed vermin-compost is black, light in weight and free from bad odor.

• When the compost is ready, do not water for 2–3 days to make compost easy for sifting. Pile the compost in small heaps and leave under ambient conditions for a couple of hours when all the worms move down the heap in the bed. Separate upper portion of the manure and sieve the lower portion to separate the earthworms from the manure. The culture in the bed contains different stages of the earthworm’s life cycle, namely, cocoons, juveniles and adults. Transfer this culture to fresh half decomposed feed material. The excess as well as big earthworms can be used for feeding fish or poultry. Pack the compost in bags and store the bags in a cool place.

•Prepare another pile about 20 days before removing the compost and repeat the process by following the same procedure as described above.

**Use of Vermi-compost**

• Vermi-compost can be used for all crops: agricultural, horticultural, ornamental and vegetables at any stage of the crop.

• For general field crops: Vermi-compost is used by mixing with seed at the time ofsowing or by row application when the seedlings are12–15 cm in height. Normal irrigation isfollowed.

• For fruit trees: The amount of vermin-compost ranges from 5 to 10 kg per tree depending on the age of the plant. For efficient application, a ring (15–18 cm deep) is made around the plant. A thin layer of dry cow dung and bone meal is spread along with 2–5 kg of vermi-compost and water is sprayed on the surface after covering with soil.

• For vegetables: For raising seedlings to be transplanted, vermi-compost is applied in the nursery bed. This results in healthy and vigorous seedlings. But for transplants, vermi-compost at the rate of 400–500 g per plant is applied initially at the time of planting and 45 days after planting (before irrigation).

• For flowers: Vermi-compost is applied at 750–1000 kg ha-1.

• For vegetable and flower crops vermi-compost is applied around the base of the plant. It is then covered with soil and watered on a regular basis.

**2.2.3. Farm Practices that improve soil performance**

Participants in the MAAS Workshop have identified various Farming techniques that would improve soil performance: green manuring, Integrated Nutrient Management, vermi-composting for soil management, micro irrigation, rainwater/ snow harvesting for water management, crop rotation, inter-cropping and cover cropping for crop management. Besides, other farm-management strategies, such as vegetation barriers using napier’s grass, or growing maize on bunds, and wild rose fencing, would also be beneficial. Select farm practices would help farmers in the Himalayan region to improve the soils, increase fertility and conserve moisture:

* **Adding organic matter** improves soil structure, enhances water and nutrient holding capacity, protects soil from erosion and compaction, and supports a healthy community of soil organisms. The organic matter can include residues and roots from the previous crops, animal manure, and cover crops.
* **Avoiding excessive tillage and soil compaction** by reducing tillage minimizes the loss of organic matter and increases the residue protecting the soil surface. Compaction, which is caused by trampling on wet soil or by heavy equipment, reduces the amount of air, water, and space available to roots and soil organisms.
* **Managing pests and nutrients efficiently** byapplying only the necessary chemicals, at the right time and place; testing and monitoring soil and pests; and adopting non-chemical approaches such as crop rotation, cover crops, and manure management.
* **Keeping the ground covered** as bare soil is susceptible to wind and water erosion, and to drying and crusting. Groundcover protects soil, provides habitats for larger soil organisms (such as insects and earthworms), and can improve water availability.
* **Increasing diversity** as each crop contributes a unique root structure and type of residue to the soil and helps control pest populations reduces weed and disease pressures.
* **Monitoring soil performance** by making systematic observations of the soil through the soil testing process which describes the composition and physical structure of the soil sample and the soil analysis.

# 3. Irrigation Technologies

Irrigation infrastructure in the Himalayan region is entirely different than other parts of the country due to the different geographic & topographic condition. In the hill region, Traditional systems for water harvesting in the Himalayas have evolved to address the particular constraints with respect to irrigation in the region. The most common source of traditional irrigation systems remains the small water channels locally called Kuhls, which intact accounts for 85.83 per cent of the total area under irrigation in hills. Kuhls and zings are the traditional irrigation infrastructure. Kuhls are essentially channels of great length that channel water from glaciers/streams/rivers to the agricultural fields and village tanks. Since water has to be brought from great distances, there is considerable effort required and cost invested to construct these long kuhls. Natural sources of irrigation in the region are Rivers, Natural streams, Glaciers, Lakes;Nalla etc.These traditional systems have proved successful from time immemorial. Howeverwith global warming and inadequate water availability, the storage and distribution infrastructure in the Himalayas often lies deserted once their only source of water turns dry.

Newer Appropriate Technologies for irrigation have been developed based upon engineering modifications of the existing water supplies. These technologies essentially deal with storage of water during a period of deficit or ensure transfer and distribution of water from the source to the field. They include new irrigation technologies as well as up gradation of traditional methods to make them more efficient. AppropriateTechnologies which could be adopted for farmers in the Himalayas for sourcing & distribution of water comprise the following: Snow Harvesting through Snow fences, artificial glaciers and Snow reservoirs, Lift irrigation using Hydrams and Solar pumps, Drip and Sprinkler irrigation; Upgraded Traditional Technologies as the open irrigation channels and zings.

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## 3.1. Snow Harvesting

Snow water harvesting has traditionally played an important role among the agricultural peoples of the Himalayan Mountains. Snow water harvesting through sustainable development initiatives alleviates the hardships for livelihood and habitation in cold desert regions .The development of Artificial Glaciers in the Western Indian Himalayas, a cold desert region that suffers from severe water shortage for both drinking and crop irrigation, is a form of snow water harvesting. Snow Reservoirs and Snow Fences are also examples of snow water harvesters. Harvesting snow water in cold desert regions rehabilitates the land for crop growth, brings life to cold deserts and renews traditional heritage as a means for long-term sustainability.

## 3.1.1. Snow Fences

Description: Snow fence uses the velocity of wind to transport snow from where it would normally fall through some distance to where it would be safely stored. The snow fence forces windblown, drifting [snow](http://en.wikipedia.org/wiki/Snow) to accumulate in a desired place.

Blowing snow particles resemble tiny grains of sand. Snow particles that are too heavy to be suspended in the air move by bouncing or intermittently jumping (satiating) along the surface. If they are too heavy to saltate, particles roll or creep along the surface, forming "snow waves," or "dunes." Snow fences restrain the wind, reducing wind speed. This reduces the force of the wind on the surface of the snow, allowing the creeping and satiating particles to come to rest. Some of these particles are deposited on the upwind side of the fence because of the reduced wind speed that occurs ahead of the barrier. Most of the snow deposit occurs on the downwind side of the porous snow fence.

Hence, Snow fences work by causing [turbulence](http://en.wikipedia.org/wiki/Turbulence) in the wind, such that it drops much of its snow load on the [lee side](http://en.wikipedia.org/wiki/Lee_side) of the fence. They are placed so as to cause a snow drift where it is beneficial for the communities.

Benefits: Snow fences restrain the wind, reducing the wind speed and ensuring snow and dust containment. Snow fences are cost-effective and have lowannual maintenance.

Design: Snow fences usethe velocity of wind to transport snow from where it would normally fall through some distance to where it would be safely stored. The factors that go into the design of a snow fence are typically:

1. Wind speed,
2. Direction of wind,
3. Relative humidity,
4. Porosity of fencing material,
5. Height of snow fence,
6. Ground slope,
7. Topography of land,
8. Expected precipitation
9. Amount of snow that would need to be accumulated.

The sources of data on Wind Direction, Snow Transport and Snow fall may be as follows:

* Wind Direction – Data can be found in meteorological records from weather stations, by examining drift features in area or aerial photographs, and by checking the orientation of vegetation, such as bent trees or snow-caused abrasion on wooden poles.
* Snow Transport – Data can be found from estimates from wind speed records in the area. The farmer should keep in mind that in winds of less than 20 mph, 90% of the blown snow stays below 4 ft. In winds of less than 45 mph, 70% of the blowing snow remains below the 4 ft. mark.
* Snow fall – Data can be derived from the snow fall records for past years and estimates projected for snow fall in the area.

The Design for snow fencing should take account the following aspects:

* Porosity refers to the open area of a fence. A porosity of 40-50% is recommended to form the largest drifts.
* Bottom Gap in the fence should be 10 - 15% of the fence height. The bottom gap should be left open so that snow does not settle directly under the fence, which would reduce its effective height. In rough terrain or snow covered areas the bottom gap may be higher, which makes the fence less likely to be buried.
* Anchoring the fence firmly is a necessity. In good soil, a six-foot fence post should be buried 2-1/2 ft.The other factors that need to be considered are the costs involved, safety & longevity and ease of fabrication at remote, difficult to reach areas away from normal human habitation for large parts of the year.

Fig. 11: Snow Fence

Setting up, Operation and Maintenance: Snow fencing is designed for snow storage andthere are 2Types of Fences. Fences may be supported by steel or wood posts set in the ground (post-supported), or by a surface-mounted framework, anchored or counterweighted to resist overturning in the wind ("truss type"). Snow Fences can be temporary or permanent. Temporary snow fences are usually one of two varieties: perforated plastic sheeting attached to stakes at regular intervals, or a lightweight wood strip and wire fence, also attached to metal stakes. A permanent snow fence consists of poles with horizontal planks running across them anchored on metal stakes in the fence area. Permanent snow fences can also consist of living snow fences of rows of closely spaced [shrubs](http://en.wikipedia.org/wiki/Shrub), trees or stalks.

Setting up Fencing: Use of Horizontal rails is the best. A porosity of 40-50% is recommended to form the largest drifts. There appears to be no great differences among materials having 40% to 50% porosity. There is a tendency for snow to be deposited close to the fence. With horizontal rails, even if the bottom gap does become plugged, the space between rails serves as gaps to slow the rate of burial. The small openings typical of most plastic fencing materials favor deposition near the fence. If the bottom gap remains open, however, there is little difference in snow storage capacity among materials having 40% to 50% porosity. Wood, metal, plastic, and woven fabrics can be used. If properly installed, all of these materials are equally good investments.

Points to remember:

1.The best fence porosity is 40% to 50%. Solid fences do not collect snow efficiently. 2. For effectiveness and economy, a single row of tall fences is always preferable to multiple rows of shorter fences.

3. One 6-ft. (1.8-m) fence = 2 rows of 4ft. (1.2-m) fence. One 8-ft. (2.4-m) fence = 5 rows of 4-ft. (1.2-m) fence

4. Although fences should be perpendicular to the prevailing wind direction, departures up to 25' are permissible.

5. Leave a gap equal to 10% of the total fence height under the fence.

Living Snow Fences: If properly designed, planting of trees and shrubs can make effective snow fences. These vegetative plantings are more pleasing in appearance than structural fences and require little maintenance after plants are full-grown. However, there are some disadvantages to living snow fences: On some sites, climate, soil type, and environmental conditions make growth of trees difficult; Several years are required before plants become tall enough to intercept snow; and Barrier height and porosity, and hence drift length and storage capacity, may change with time.

*Pragya has installed two snow fences in the villages of Kardang and Khinang in the district of Lahaul &Spiti (Himachal Pradesh).The snow fence in Kardang is located in a particularly arid and windy stretch of Lahaul valley. Above the village, there exists a large depression that is an effective spot for snow accumulation. Because the very high wind velocities do not allow the snow to settle on the ground, the technology of snow fences was adopted to accumulate snow. Snow fences 8.5 ft. high have been installed along the side of the depression to a length of 100 ft. and a gabion wall has been constructed at its lower end. The installation helps catch blowing snow and compact the settled snow, also prolonging its period of melting.*

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## 3.1.2. Artificial Glaciers

Description: **Glacier growing**, **artificial glaciation** orglacier grafting is a practice carried out in the [Hindu Kush](http://en.wikipedia.org/wiki/Hindu_Kush) and [Himalaya](http://en.wikipedia.org/wiki/Himalaya) regions aimed at creating small new glaciers to increase water supply for crops and in some cases to sustain [micro hydro](http://en.wikipedia.org/wiki/Micro_hydro) power. In order to encourage the growth of a glacier local farmers acquire ice from naturally occurring glaciers, and carry it to high altitude areas where the ice is put inside a small cave dug out in a [scree](http://en.wikipedia.org/wiki/Scree)-slope. Along with the ice other ingredients such as water, salt, sawdust, wheat husks and charcoal are also placed at the site. The use of glacier grafting is an old skill of the mountain farmers of [Baltistan](http://en.wikipedia.org/wiki/Baltistan) and [Gilgit](http://en.wikipedia.org/wiki/Gilgit), where it is used for irrigation purposes since at least the 19th century.

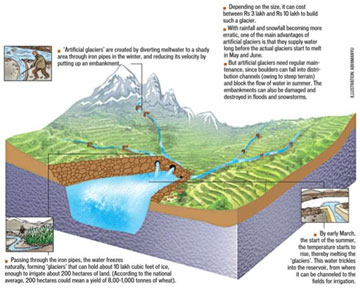
[Chewang](http://en.wikipedia.org/wiki/Chewang_Norphel)Norphel, Noted Engineer andArtificial Glacier Innovator, has helped construct artificial glaciers at Phuktse, Shakti, Sabo, Stakmo, Muth, Nang and Umla, and collectively, they provide water to 4000 people in 15 villages. The first artificial glacier Norphel built is near the village of Phuktsey. About 1,000 ft. (300 m) in length and 150 ft. (45 m) wide, it has an average depth of 4 ft. (1 m) and can supply irrigation water to the entire village of about 700 people, once the ice melts.These artificial glaciers, which are formed at comparatively lower altitudes, melt in the early summers and spring, when the natural high altitude glaciers do not begin melting, and thus fulfill the early cultivation season requirement.

Benefits: Artificial Glaciers attempt to manage the fluctuation in the amount of water available during the cropping season so that it can be uniformly distributed throughout the cultivation period. This technique developed and implemented in Ladakh, meets the early cultivation period water requirements of farmers. Artificial Glaciers are closer to the village and constructed at comparatively lower altitude. They make use of local resources and skills and enable communities to utilize water which would otherwise be wasted.

Design:The design for Artificial Glacier requires that a series of parallel stone embankments are built on mountain slopes and iron pipes drilled into the diversion channel at regular intervals, to help distribute the water over the slope. After the first dyke tops up, the water overflows into the next one and, when that one is filled, it goes into the third. In November, when the temperature drops, the trapped water begins to freeze, creating a series of glaciers.

The design for head work of the diversionchannel needs to be done in such a way that in the lean period i.e., November (when the discharge of the nalla reduces to the minimum level) it can enter the diversion channel by opening the head regulator gate, without blocking the main stream. Likewise, in summer , when the velocity of the water in the stream is at its highest the head regulator gate should be kept closed so that the diversion channel as well as other structures may not get damaged. The bed grade of the diversion channel should be steep enough as compared to normal channel bed grade. Through this arrangement the water does not block by freezing. First the water enters into the silting tank and after the silt settles down, the clean water will follow into the distribution chamber. In the distributing chamber iron pipes are fixedat an interval of 5ft so that there is smooth distribution of water. As soon as the water comes out from the pipe it starts to freeze.

The channel should be constructed on a north-facing mountain face that diverts water to a point from where the water can flow by gravity to the low lying settlements. The channel head is at a glacier point which enables water from the glacier as well as the huge snow reserve that would accumulate above the channel, to be utilized. There is a direct correlation between the length of the channel and the size of the glacier with the greater the length of the channel, the greater the size of the glacier formed. As the ice begins melting in summers, the channel diverts the melt water towards the desired point of use. The ice retaining embankments, stone masonry in the depression area need to be constructed. The melting water from the ice passes through the pores of the dry walls without damaging the structure.



**Fig. 12:Artificial Glacier Process**

Setting up, Operation and Maintenance: The first step involves looking for a suitable location. The preferred terrain, according to glacier growers in Baltistan and Gilgit, is in shadowed scree-slopes overlooked by steep [headwalls](http://en.wikipedia.org/wiki/Headwall).The sites should be located between 4,000-5,000 meters[above sea level](http://en.wikipedia.org/wiki/Above_mean_sea_level)and should be susceptible to snowfall and [avalanches](http://en.wikipedia.org/wiki/Avalanche) during winter and spring, creating an environment conducive to the accumulation of ice.This usually involves ascents from lower lying valleys (around 2,000-3,000 metres above sea level) up to the site selected for the glacier.

While the technique is simple involving local material and labor, the scale of the construction enhances the project cost (Phuktsey Glacier was built at a cost of about Rs.1 lakh).The channel may suffer damage and needs maintenance and repair each year just before the onset of winter. The technique is successful in locations with flatter slopes as in Ladakh, and may not be easily replicated in locations with higher gradients like Lahaul &Spiti.

*The first Artificial Glacier was constructed near the village of Phuktsey. About 1,000 ft (300 m) in length and 150 ft. (45 m) wide, it has an average depth of 4 ft. (1 m) and can supply irrigation water to the entire village of about 700 people. A series of parallel stone walls were built on mountain slopes and iron pipes were drilled into the diversion channel at regular intervals, to help distribute the water over the slope. After the first cavity got filled, the water overflowed into the next one and, when that one filled, it went into the third. In the month of November, when the temperature dropped, the trapped water in the cavity began to freeze, creating a series of glaciers. The glacier became 1000 ft. long and 150 ft. wide, with an average height of six ft. The artificial glacier melts in the early summer and spring, when the natural high altitude glaciers do not begin melting, and fulfills the early cultivation season requirement of the village.*

**3.1.3. Snow Reservoir**

Description: The snow reservoir is a technique developed on the model of artificial glaciers that has been constructed and implemented in Ladakh. In contrast to the early cultivation period water requirement in cold deserts such as Ladakh, lack of water is experienced late in the summers in locations such as Spiti, in the months of August-September. Snow reservoirs constructed in the shaded region in the highlands of the cold deserts are useful for meeting this late season water requirement, if the melting of the compacted snow in the reservoir could be delayed up till September. This would require covering the whole reservoir with charcoal, saw-dust or some insulating material, or by providing artificial shade, from April to end of August.

Benefits: Snow Reservoirs are a prime solution for Highlands of cold deserts and can be replicated for similar regions. The construct of Snow Reservoirs is an Easy to learn technology which is adaptable to the region's traditional methods of harvesting water.

Design: Snow reservoirs can be built in villages in the highland/steep bank settlement category. Snow reservoirs should be sited at an altitude of around 14000 ft. to ensure delay of the melt till late August. Snow reservoirs should also be sited in a shady area bound by a north facing cliff, and have a stream nearby for allowing water into the reservoir. An ideal site would be where the south sun is blocked till late in March and April, the most critical factor impacting the technology.

Setting up, Operation and Maintenance: Setting up the Snow Reservoir requires assessments during the pre-construct stage. Geological investigations will need to be done for an assessment of an appropriate site for the snow reservoir. Appropriate regulatory mechanisms for control of inflow into and outflow from the reservoir would need to be incorporated. Forthis in-depth assessment of the water requirements will need to be made for ensuring appropriate sizing of the reservoir.

The most limiting factor impacting this technology is the need for a site where the south sun should be blocked till late in March and April. To avoid the overhead sun after end of April and to delay the melting of the compacted snow in the reservoir till September, the whole reservoir needs to be covered with charcoal, saw-dust (both unavailable locally) and wild bushes or some insulating material on the frozen reservoir. The requirement for shading all over the reservoir becomes costly .If shading is not provided; the melting of water during April or May will worsen the situation downstream. Thus, huge physical effort and financial requirement are constraints for construction of such reservoirs.

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| *Pragya constructed a snow reservoir for the Demul community to enable them to harvest the abundant snowfall during winters and harness it for irrigation in the summer. Demul village (4289 district Lahaul &Spiti) is located atop a ridge, with an undulating topography and an inhospitable climate (5-months winters with temperatures that go down to -30 degrees C). The 65 households in the village grow subsistence crops and the only source for irrigation is the snowmelt that is accumulated and drawn to the fields through earthen channels. The snow reservoir is 2 km from the village at an elevation of 4389 m. The bed of the site is plain and flat, with a gentle slope towards the village, and a wall has been erected on this end of the site, thus allowing easy accumulation of snow. The reservoir wall is 59 m long, 2.5 m wide and 2.5 m high. The reservoir helps irrigate approximately 1sq km of agricultural land benefitting 100+ people while recharging the aquifers with infiltration as a result of the accumulated snow.* |



## Fig. 13: Snow Reservoir at Demul

## 3.2. Lift Irrigation

## Lift irrigation is a method of irrigation in which water is not transported by natural flow (as in gravity-fed canal systems) but is lifted with pumps or other means. Hydrams/Hydraulic Rams and Solar Pumps are 2 forms of lift irrigation suited to the high altitude Himalayas.

**3.2.1. Hydrams /Hydraulic Rams**

Description: Water lifting devices like hydrams would be effective for steep bank regions of cold deserts. A hydraulic ram, water pressure ram, or hydram, is a cyclic water pump powered by hydropower. A hydram is a unique device that uses the energy from a stream of water falling from a low head as driving power to lift part of the water to a head much higher than the supply head. It takes in water at one height, pressure and flow rate, and outputs water at a higher pressure, height and lower flow rate.

Benefits: The positive characteristics of the Hydram are its suitability for steep bank settlements, affordability with low investment, minimum operation and maintenance, eco-friendly nature, operation and maintenance by user groups. The source of the water determines whether the water can be used for drinking, consumption or irrigation. The system can deliver different quantities of water to irrigation tanks on the fields and makes continuous operation for agricultural water supply possible.

Design:

The Hydram operates according to well-known hydraulic principles, with the total force required to elevate a given volume of water being that which is greater than the sum of the forces created by the vertical distance which the water has to be elevated (or the static head) and the resistance offered to the flow within the suction and delivery pipes (or the friction head). With a continuous flow of water, a hydram operates automatically and continuously with no other external energy source.

The hydram is a structurally simple unit consisting of two moving parts: the waste valve and the delivery (check) valve. The unit also consists of an air chamber and an air (snifter) valve. The operation of a hydram is intermittent due to the cyclic opening and closing of the waste and delivery valves. The closure of the waste valve creates a high-pressure rise in the drive pipe. An air chamber is necessary to prevent these high intermittent pumped flows into a continuous stream of flow. The air valve allows air into the hydram to replace the air absorbed by the water due to the high pressures and mixing in the air chamber. The device uses the simple water hammer effect to develop pressure that allows a portion of the input water that powers the pump to be lifted to a point higher than where the water originally started.

By using a hydram, water can be delivered at a height 10 times the available supply head. Thus, for raising water to 100 m, a minimum of 10 m of supply head is required. The Hydram is used in remote areas, where there is both a source of low height water power and a need for pumping water to a destination higher in height than the source.

Setting up, Operation and Maintenance: A simplified hydraulic ram is shown in Fig.14. Initially, the waste valve [4] is open, and the delivery valve [5] is closed. The water in the drive pipe [1] starts to flow under the force of [gravity](http://en.wikipedia.org/wiki/Gravity) and picks up speed and [kinetic energy](http://en.wikipedia.org/wiki/Kinetic_energy) until the increasing [drag](http://en.wikipedia.org/wiki/Drag_%28physics%29) force closes the waste valve. The [momentum](http://en.wikipedia.org/wiki/Momentum) of the water flow in the supply pipe against the now closed waste valve causes a [water hammer](http://en.wikipedia.org/wiki/Water_hammer) that raises the pressure in the pump, opens the delivery valve [5], and forces some water to flow into the delivery pipe [3]. Because this water is being forced uphill through the delivery pipe farther than it is falling downhill from the source, the flow slows; when the flow reverses, the delivery check valve closes. Meanwhile, the water hammer from the closing of the waste valve also produces a pressure pulse which propagates back up the supply pipe to the source where it converts to a suction pulse that propagates back down the pipe. This suction pulse, with the weight or spring on the valve, pulls the waste valve back open and allows the process to begin again. A pressure vessel [6] containing air, cushions the hydraulic pressure shock when the waste valve closes, and it also improves the pumping efficiency by allowing a more constant flow through the delivery pipe.

A good site for a hydram demands a wide river with lowest possible slope on the banks. This is desired in order to avoid the effects of fluctuation in the river level on the supply head for the ram pump. In the absence of a good site available, construction costs might increase manifold. Hydrams installed by the IPH department have sometimes failed to operate because of the high silt load and high diurnal fluctuations in the water level in the river. The fluctuations are caused due to rapid variations in weather from cloudy to sunny, which in turn control the amount of snowmelt. The high silt loads in the rivers contribute to rising maintenance costs for civil works.

|  |  |
| --- | --- |
| 1. Inlet – drive pipe 2. Free flow at waste valve 3. Outlet – delivery pipe 4. Waste Valve 5. Delivery check valve 6. Pressure vessel | Hydraulic_Ram |

**Fig. 14: Working of Hydram**

## 3.2.2. Solar Pumps

Description: Cold deserts are rich in sun and receive more than 5000 W/sq. meter for a minimum of 6 hours (cloudy at other times). This enormous amount of solar energy can be tapped to lift water from the river. Solar power can be used with irrigation systems, such as solar pumps in basins where water needs to be lifted to a small height.

Solar pump runs on electricity generated by [photovoltaic](http://en.wikipedia.org/wiki/Photovoltaic) panels or the thermal energy available from collected sunlight as opposed to grid electricity or diesel run water pumps. The operation of solar powered pumps is more economical mainly due to the lower operation and maintenance costs and has less environmental impact than pumps powered by an [internal combustion engine](http://en.wikipedia.org/wiki/Internal_combustion_engine) (ICE). Solar pumps are useful where grid electricity is unavailable and alternative sources (in particular wind) do not provide sufficient energy.

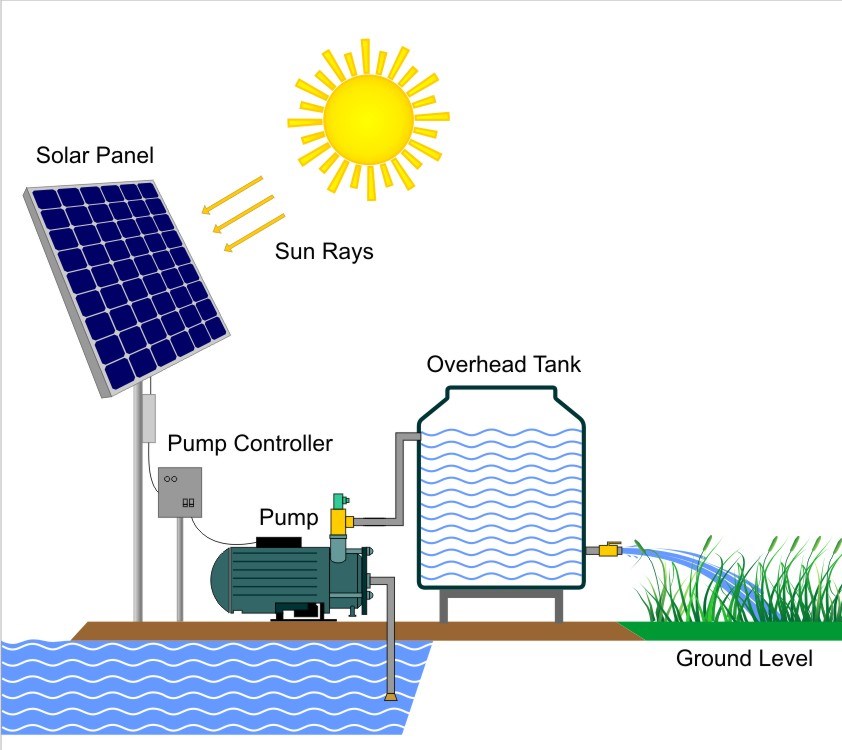
Benefits:Solar pumps can be placed in or next to the source of water and the water can be pumped where it is needed. Solar water pump system is clean and efficient and cuts down on waste because it is based on natural cycles. The [photovoltaic](http://en.wikipedia.org/wiki/Photovoltaic) panels provide the most pumping power on the sunniest days---when water is most needed. Solar pumps have almost no running costs associated with them, with batteries the only components that will need replacement. They run purely on the sun making them environmentally safe, add no poisonous gases into the atmosphere and actually help to prevent global warming.

Design: A solar pump system consists of a solar panel used to capture the suns’ rays, a deep cycle leisure or marine battery to get extended running potential, 12V pump and tubing in which to carry the water from the reserve, through the system to the farm. A photovoltaic solar powered pump system has three parts:

* the pump
* the controller
* [Solar panels](http://en.wikipedia.org/wiki/Solar_panel)

The solar panels make up most (up to 80%) of the cost. The size of the PV-system is directly dependent on the size of the pump, the amount of water that is required (m³/d) and the solar irradiance available.

The purpose of the controller is twofold. First, it matches the output power that the pump receives with the input power available from the solar panels. Second, the controller usually provides a low voltage protection, whereby the system is switched off, if the voltage is too low or too high for the operating voltage range of the pump. This increases the lifetime of the pump thus reducing the need for maintenance.



## Fig.15: Solar Pump Mechanism

## Setting up, Operation and Maintenance: Solar water pumps are specially designed to utilize DC electric power from photovoltaic modules. The pumps must work during low light conditions, when power is reduced, without stalling or overheating. Low volume pumps use positive displacement (volumetric) mechanisms which seal water in cavities and force it upward. Lift capacity is maintained even while pumping slowly. These mechanisms include diaphragm, vane and piston pumps. These differ from a conventional centrifugal pump that needs to spin fast to work efficiently. Centrifugal pumps are used where higher volumes are required. A surface pump is one that is mounted at ground level. Surface pumps work well when they draw water through suction less than 10 or 20 feet. A submersible pump is one that is lowered into the water. Most deep wells use submersible pumps. The pump controller (current booster) acts like an automatic transmission, helping the pump to start and keeps it from stalling in weak sunlight. With more hours of peak sun, a smaller pump and power system may be used, thus reducing overall cost.

Storage is vital, where 3-10 days' storage may be required, depending on climate and water usage. Most systems use water storage tanks and batteries are added to the system. Electrical energy from the solar modules is stored in the batteries so that the pump can run at non-sunny times.

Solar pump maintenance is focused on - PV cells and the pump. The cost of technology for amount of water lifted per day is high and the flow delivery rates are low (for 100 m delivery head) which may not always fit the irrigation requirements of the village.

*Pragya has installed solar pumps in the cold desert villages of Chuchot and Umla on Ladakh plateau. They were powered by 12-16 solar panel batteries and were used to lift subsurface water for converting huge barren land to agricultural use. Dug-outs along the infiltration zone facilitate infiltration, recharge aquifers and enhance subsurface flows. The submersible pumps with dynamic heads of up to 170ft and a capacity of 7,000 liters per day are being used to irrigate 2.06ha of land of the two villages benefitting 72 women farmers.*

## 

Example of Model suitable for small farmers:*Atom Solar Suntrolley* is a1 horse power portable solar powered water pumping irrigation system which can replace diesel irrigation pumps for small farmers. It is portable and versatile, can be assembled within 10 minutes, is suitable for country roads and can deliver 10,000 litres of water per hour. The bore well pump can be adapted for use in a lake and makes use of a 4 inch diameter submersible hose for irrigation. *Atom Solar Suntrolley* is practical in regions where electricity supply and distribution is unreliable. **(**[**http://www.greenpeace.org/international/en/news/Blogs/makingwaves/atom-solar-suntrolley-irrigation-pump/blog/48970/**](http://www.greenpeace.org/international/en/news/Blogs/makingwaves/atom-solar-suntrolley-irrigation-pump/blog/48970/)**)**

## 3.3. Resource-efficient distribution

## [Irrigation](http://en.wikipedia.org/wiki/Irrigation) is the artificial *exploitation* and *distribution* of water. Irrigation aims at *application* of water at *field level* to agricultural crops in dry areas or in periods of scarce [rainfall](http://en.wikipedia.org/wiki/Rainfall) to assure or improve crop production. Drip and Sprinkler Irrigation are 2 forms of distribution and management of irrigation water at field level.

## 3.3.1. Drip Irrigation

Description:. Drip irrigation systems deliver water and agrochemicals (e.g., fertilizers and pesticides) directly to the root zones of the irrigated plants at a rate best suited to meet the needs of the plants being irrigated. Drip irrigation equipment consists of a network of pipes, which is laid on the fields. The pipes have small holes at regular intervals for water to trickle down to the plants.

Benefits: Drip irrigation systems make efficient use of water, especially when compared to traditional methods of irrigation such as furrow, border, basin and sprinkler irrigation systems, which, under arid and drought conditions, suffer from a high rate of water loss and have a low degree of water use efficiency. Drip irrigation nourishes plants at the correct water level without supervision. Water and agrochemicals are delivered to plants at a rate, which is best suited to meet the needs of the plants being irrigated. These techniques are highly efficient water saving devices and can cut down water requirements by about 50%.

Design: Drip irrigation equipment consists of a network of pipes, with small holes at regular intervals for water to trickle down to the plants. The network of pipes is fed through a tank sited so as to supply a head of 1-1.5m to the network for irrigating about 1/2 bigha of land. This system helps in generating proper pressure for water to flow around the grid. The pipes are made from flexible vinyl or polyethylene and are hidden with a layer of mulch or soil, but the part that emits water should remain uncovered. As the plants grow, less and less of the network of pipes will be visible.

Setting up, Operation and Maintenance: The drip is to be kept at a steady water pressure level because an open spray will redistribute the soil and destroy the purpose of the drip system. The space/time between each drip is crucial for the proper distribution of water.

The capital costs involved in the establishment of a drip irrigation system are high compared to the costs of establishing conventional irrigation systems. However, the labor requirements and operational costs are low. The principle operation and maintenance requirements include the need for regular cleaning of the system and careful monitoring of the quality of the source water, as the drip irrigation systems are very sensitive to the clogging of the drippers. The systems also require a relatively high degree of skill to design, install and operate, and are susceptible to theft, damage and disruption by rodents that destroy the drip pipes and drippers.

Example of Model suitable for small farmers: Jain Drip Kitis scientific, durable and simple-to-operate irrigation system. Jain Drip Kit addresses the constraints of small farmers, majority of whom are without an independent water-source and electricity, having tiny holdings (< 1 acre) which are fragmented & located in more than one place. The Drip Kit empowers the small farmers with a "Drip Irrigation System which operates on gravity pressure". The Kit does not require electricity, is portable, can be easily shifted; and particularly suitable for kitchen gardens and Himalayan / hilly terrains where land holding is very small. It can be used for irrigation in open fields, green house and nurseries, is mainly suitable for cultivation of vegetables and can also be used for cereals, pulses and other closely spaced crops. Jain Drip Kit helps to maintain favorable soil moisture conditions to the plants which results in good growth & bumper yields. Drip Kit is available in 6 models and is affordable for small and tiny farmers. Pump options for the Jain Drip Kit include the Drip Kit with Solar Pump, with Foot Pump and with Hydraulic Ram Pump~Hydram.

[**http://www.jains.com/irrigation/drip%20kit/drip%20kit%20with%20solar%20pump.htm**](http://www.jains.com/irrigation/drip%20kit/drip%20kit%20with%20solar%20pump.htm)

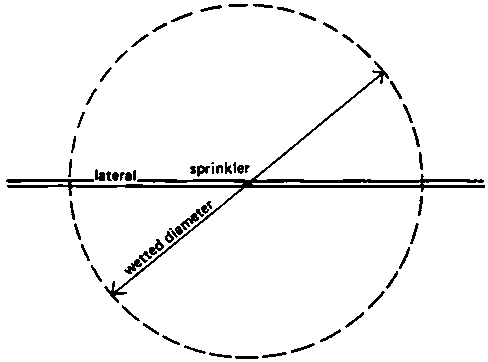
## 3.3.2. Sprinkler irrigation

Description: Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water. In South India, it is used in Karnataka and Tamil Nadu for the production of many crops.

Benefits: The sprinkler system irrigates the field drop by drop and thus it is widely used in sandy areas as it checks the wastage of water through seepage and evaporation. Sprinkler irrigation has less interference with cultivation and less land loss, coupled with higher application efficiency. Sprinkler irrigation makes for easy mechanization and automation where high and frequent application can be effectively accomplished.

Design: A typical sprinkler irrigation system consists of the following components: Pump unit, Mainline and sometimes sub mainlines, Laterals, Sprinklers. The**mainline** - and **sub mainlines** - are pipes which deliver water from the pump to the laterals. In some cases these pipelines are permanent and are laid on the soil surface or buried below ground. The water is distributed through a stationary sprinkler system, which evenly sprays water over crops and plants. In other cases when fields may be too large for stationary sprinklers; they are temporary, supported by movable trusses running across the fields. The main pipe materials used include asbestos cement, plastic or aluminum alloy. The **laterals** deliver water from the mainline or sub mainlines to the sprinklers. They can be permanent but more often they are portable and made of aluminum alloy or plastic so that they can be moved easily.

Setting up, Operation and Maintenance: The main objective of a sprinkler system is to apply water as uniformly as possible to fill the root zone of the crop with water. **Wetting patterns -**The wetting pattern from a single rotary sprinkler is not very uniform (Fig.16). Normally the area wetted is circular. The heaviest wetting is close to the sprinkler. For good uniformity several sprinklers must be operated close together so that their patterns overlap to the extent of at least 65% of the wetted diameter. This determines the maximum spacing between sprinklers.





**Fig.16: Schematic presentation of Sprinkler System**

The uniformity of sprinkler applications can be affected by wind and water pressure. Spray from sprinklers is easily blown about by even a gentle breeze and this can seriously reduce uniformity. To reduce the effects of wind the sprinklers can be positioned more closely together.

Sprinklers will only work well at the right operating pressure recommended by the manufacturer. If the pressure is above or below this then the distribution will be affected. The most common problem is when the pressure is too low. This happens when pumps and pipes wear. Friction increases and so pressure at the sprinkler reduces. The result is that the water jet does not break up and all the water tends to fall in one area towards the outside of the wetted circle. If the pressure is too high then the distribution will also be poor. A fine spray develops which falls close to the sprinkler.

## 3.4. Up gradation of traditional zing storage systems

Description: Zings are water harvesting structures found largely in Ladakh and Leh. They are large storage tanks, in which melted glacier water is collected. Essential to the system is the network of guiding channels that brings the water from the glacier to the tank. As glaciers melt during the day, the channels fill up with a trickle that in the afternoon turns into flowing water. The water collects towards the evening, and is used the next day. Zings are the age old water management structures adopted across different terrains in the cold deserts.

Benefits: Zingsare used to reduce seepage losses and addresses both sourcing of water from a distant spring and its storage for use in agricultural plots. They enable diversion of glacial water for irrigation in mountain regions.

Design: Channels are constructed to divert the glacial water into the Zing.However,all existing zings in these regions are made in dry stone masonry leading to frequent damages and hence repairs. The zings also remain unlined resulting in high seepage losses.

## http://www.rainwaterharvesting.org/Rural/img/Zing-img.jpg

## Fig. 17: Zing system

## Hence the zing storage systems need to be upgraded .The techniques for up-gradation can take various forms. The zings can be converted to permanent structures with cement lining. The size of the zing can be increased for raising their capacity. The zing can be lined with plastic film to reduce seepage; and focused maintenance and cleaning would improve their efficiency.

## Setting up, Operation and Maintenance:

Essential to the zing storage system is the network of guiding channels that brings the water from the glacier to the tank. Irrigation from the waters of melting snow is through long, winding streams from upper mountain reaches. At sowing time, the cold water from the snow-melt is limited; and owing to short growing period, all farmers need irrigation almost at the same time. Water has to be diverted from the streams with the help of guiding channels,towards the zing. Thuseach village should have a large network of canals and zings.A water official (called the churpun in the present system) shouldensurethat water is equitably distributed.

*Up gradation of Zing is seen in Pragya's intervention in Himachal Pradesh. Murtijais a small hamlet in Lahaul Valley, Himachal Pradesh,with 12 households.The natural springs available are located 1 km from the site. A zing, measuring 225 cubic meters, made in cement and poly-lined to reduce seepage losses and fitted with a guard-wall for safety considerations was constructed. A 1000-metre pipe lengthcontributed by the Forest Department helps to draw water from the distant springs to the zing. The zing addresses both sourcing of water from a distant spring and its storage for use in agricultural plots.*

Each of these Technologies: Snow Harvesting through Snow fences, Artificial glaciers and Snow reservoirs, Lift irrigation using Hydrams and Solar pumps, Drip and Sprinkler irrigation; Upgraded Traditional Technologies as the open irrigation channels and zings are effective in specific geo-climatic context.Finally the choice of the most effective irrigation method for a particular area depends on the wind speed, direction of wind, relative humidity, ground slope, topography of land, expected precipitation and amount of snow that would be accumulated.

# 4. Agricultural Adaptation to Climate Change

Climate Change, one of the most important global environmental challenges facing humanity, has implications on food production, natural eco-systems, fresh water supply and health. Regional changes in climate have contributed to various changes in physical and biological systems. These include the rise in air temperature leading to rapid melting of glaciers and increment of glacier lakes, changes in rainfall frequency and intensity, shifts in the growing season, early flowering of trees and emergence of insects, and shifts in the distribution ranges of plants and animals in response to changes in climatic conditions. Extreme climate events including flooding, heavy rainfall, droughts, heat wave and cold stream are also the consequences of climate change.

Adaptation to climate change in agriculture aims to minimize peoples’ vulnerability by improving their ability to cope with the impacts of climate change. Adaptive capacity is often limited, particularly in poor rural areas where people live on subsistence agriculture. The communities have to be provided with climate change-related information and new adaptation strategies and measures have to be integrated into existing capacities, assets and resources. Understanding the climatic changes is necessary in order to adapt to the climatic changes. Information is required on short-term and long-term impact of climatic changes so that farmers can use different strategies and measures.

*A study carried out on sorghum, helps to give an insight into the possible impacts of climate change. The study focused on winter and monsoon crops of sorghum in three different climate zones of India: central (CZ), south-central (SCZ) and south-west (SWZ). An increased temperature will most likely lead to an overall decrease in crop production. By 2020, monsoon sorghum production was predicted to decrease by 14% in CZ and SWZ and by 2 % in SCZ, whereas winter sorghum production was estimated to decrease by up to 7%. Low cost adaptation strategies, like changing variety and sowing date, could reduce the impact and vulnerability of winter sorghum and help maintain the productivity of sorghum under changing climatic conditions.*

Farmers can overcome the impacts of climate change by the following measures:

1. Cropping Pattern – Changes Observed and adaptations
2. Conservation Agriculture
3. Agro Forestry

**4.1. Cropping Pattern – Changes Observed and adaptations**

Due to Global Warning and changes in Climate in Nepal Himalayas, potatoes harvesting was shifted from Mid-March to Mid-January, while leafy vegetables was shifted by 15 days in July, August and September, respectively. The agriculture yield has been improved and the farmers reported a shift in growing time of vegetables. Similarly, change in flowering and fruiting patterns have also been noticed in recent years. There have been observations like decreased size of potatoes, due to seed decaying and extreme rainfall. Additionally, decreased apple harvest has been found to be due to reduced fruiting, early growing, dying and drying of apple plants, which had brought a huge loss to the farmers. The problem has also been due to the loss of agricultural produce by insect pests, like black flies, red flies, and white flies, and caterpillars, which were unknown to them few years back.

**Adaptation**

Adaptation of different practices by the farmers in the major settlements can be done to cope with impacts of climate change.

* Adopting agro-forestry to adapt to the reduction of forest resources for fodder and firewood.
* Adopting indigenous strategies to tackle change in cropping, harvesting, heavy rainfall or snowfall, such as:
* Covering vegetables with bamboo nets
* Cultivating before rainy season and after snowfall
* Digging deep for planting to protect from snowfall
* Spreading dry leaves over crops (millet, carrot and cabbage) to control the water losses due to transpiration
* Placing sticks to act as support to prevent crops from falling down due to heavy rainfall.
* Planting Pine and Juniper trees to protect agricultural land from river overflow or in case of extreme floods.
* Constructing stone dykes for fixing soil-surface nutrients, which otherwise could be washed away by runoff.

**4.2. Conservation Agriculture**

Conservation Agriculture is a method of farming that conserves, improves, and ensures efficient use of natural resources. It aims to help farmers achieve profits with sustained production levels while conserving the environment. Traditional methods of farming cannot cope with the increasing needs of the ever expanding human and livestock populations. Conservation actions stop and reverse land degradation, boost productivity and contribute to reducing land degradation and increasing food security. The steps and associated principles are outlined below.

**Principles:**

1. **Conservation Tillage with minimum soil disturbance:**

Disturbing the soil only where the seed, fertilizer and manure are to be placed ~

* Reduces destruction of the soil structure
* Does not expose soil to wind and water erosion
* Improves water infiltration rates
* Slows the rate at which organic matter is mineralized and oxidized, so organic matter build-up occurs
* Causes little disruption to the organisms that live in the soil
* Saves time, energy, and money because less land is tilled
* Reduces soil compaction because the crop plant roots are left undisturbed.

1. **Permanent Soil Cover:**

* Helps reduce direct raindrop impact and so reduces soil erosion
* Helps reduce runoff and aids water to seep into the soil
* Reduces evaporation and conserves moisture for the crop
* Suppresses weeds emergence
* Organic residues improve organic matter content and soil nutrient status
* Provides a beneficial environment for soil organisms, such as worms and millipedes, that are important for biological tillage
* Moderates soil temperatures.

1. **Intercropping and Crop Rotation:**

* Replenishes soil fertility: intercropping with nitrogen-fixing legumes adds ‘top-dressing Fertilizer’ to the soil
* Enables crops to use the nutrients in the soil more effectively
* Helps to control weeds, diseases and pests by breaking their life cycles through the introduction of a new crop
* Reduces the risk of total crop failure in case of drought and disease outbreak.

Conservation Agriculture improves yields, protects soil, increases soil moisture and restores soil fertility. Conservation Agriculture reduces production cost, cuts costs on labor and fertilizer while increasing their yields.

**4.3. Agro-forestry**

The use of trees for soil conservation and gully reclamation has been achieving good results in high altitudes across other parts of the world. These practices involve establishment of woodlots, protective hedges and live fences around homesteads and home gardens. Both food and non-food, including fodder tree species and trees for fuel wood and construction material, can be used.Agro-forestry systems has the potential to fight the aberrations due to climate change.

The selection of appropriate agro-forestry systems is usually based on existing practices, climate, soil conditions, the level of soil erosion, livestock population, availability of pastures, household food supply and nutrition, and fuel wood requirements. Features of the mountains to be taken care include the increasing land degradation and decreasing carrying capacity of the land, and the severely cold winters, often accompanied by strong winds, snow and frost. Since most fast growing tree and shrub species do not tolerate these conditions, there are few or no trees to shelter or protect livestock from the cold, and there is little in the form of fuel wood for the local communities to warm themselves.

The suggested measures are as follows:

* **Homestead gardens and orchards:** this system involves the establishment of small orchards or the scattered planting of individual fruit trees in the home garden, inter-planted with various vegetables. In the mountains, fruit species that can tolerate the climatic conditions can be used e.g. stone, pome fruit, and nut species.
* **Windbreaks:** establishing windbreaks in the mountains may be more difficult than elsewhere due to the very cold winters and the short growing season, and requires a long-term perspective. It may be preferable to establish windbreaks around homesteads and gardens rather than around fields, for protection of homes and gardens against cold, strong winds. Windbreaks may also protect the soil against wind erosion.
* **Hedges and live fences:** problems of trespassing are much higher in the lowlands than the mountains, but nevertheless, it is advisable to establish protective hedges and live fences around homesteads, especially against livestock kept within the village. Species that can be used in the production of medicinal products can be grown.
* **Fodder banks/trees on contour strips in cultivated fields:** this system is more applicable to the areas where grazing resources are poor. In arid and semi-arid lands, leaves and edible twigs of trees and shrubs can constitute well over 50 percent of the biomass production. At high altitudes, tree foliage may provide over 50 percent of the feed available to ruminants in the dry season, branches being harvested and carried to the animals. Even in regions of higher rainfall where grass supplies the major proportion of the dry matter eaten by ruminants, tree leaves and fruits can form an important constituent of the diet, particularly for small ruminants. These trees could be planted in rows intercropped with herbaceous annual or perennial fodder crops.
* **Gully rehabilitation:** the extent of soil erosion in the cold deserts is critical. Some erosion control and donga reclamation work has taken place in parts of these areas. A combination of tree, shrub, grass and herbaceous plant species may be used. Willows and poplars, amongst other species, can be planted on the gully floor where there is likely to be sufficient moisture to support tree establishment.

**4.4. Case lets of Farm Production Adaptations**

The different practices that can be adopted by the farmers also relate to Farm Production Adaptations such as Change in crops, Change in crop variety, Diversifying crops, Changes in timing of cultivation and Water Management. The case lets given below are specific examples of Farm Production adaptations to climate change.

**Changes in timing of cultivation**

Changes in the cultivation timing have been observed among the farmers in Africa who would nurse seedlings in the last two weeks of September and transplant them in the first two weeks of October. Faced with the problem of climate change (especially prolonged rains), the nursing period has moved from the last two weeks of September to the last two weeks of October with effective transplanting of seedlings in November. Due to the delayed rainfall in most zones, crop farmers are engaging in late planting by about a month and repeated planting of crops in response to the erratic rainfall. This is being practiced for maize, millet and Cucurbitaceous (*Cucumeropsisedulis*) and other cereal crops.

**Change in crops**

Farmers alter/replace the crop varieties in their farms with cultivars which are able to cope better with drought and other weather extremes. Crops with high yield variability (e.g. wheat or maize) are substituted by crops with lower productivity but more stable yields (e.g. fodder or sorghum). In Zimbabwe farmers have switched successfully to more drought tolerant crops in areas where the frequent recurrence of droughts has made agriculture production difficult using the traditional crop varieties.

**Water Management**

Water Management Techniques include altering amounts and timing of irrigation, improved irrigation technologies and structural measures. Under the Irrigation Ordinance of Sri Lanka, the Administrative Head of District Public Service (a government agent) is empowered to hold water management meetings prior to each season. During the meeting, farmers discuss the type of crop to be grown during the season and the timing of the first release of water and the final release of water. The final decisions reflect the extent of water in the main reservoir, and the probability of further rains as the season proceeds.

**Weather-related services at LAC**

These measures for Adaptation to Climate Change are possible when long-range and short-range weather forecasts are made available to farmers.The data gathered through MAAS and the weather monitoring services provided to farmers by the AAs in the LAC will enable them to interpret the data and advice farmers accordingly. The farmers can then overcome the impacts of climate change by taking these measures.

# 5. Precision Farming

Definition: Precision farming is weather/soil-adapted technique of farming and is the application of agricultural inputs based on soil, weather and crop requirement.

Precision Agriculture entails the following steps:

• The farmer looks at short and medium range weather forecasts and integrates them with his farming decisions. S/he is enabled to adopt crops and time farming operations, suited to the forecasts and thus adapt to climate stresses on agriculture.

• The farmer partitions the field into ‘grids’ based on soil pH, nutritional status, pest infestation, yield rates, and other factors that affect crop production. S/he accesses scientific real-time data on weather forecasts and soil testing (from weather monitoring stations and research institutes) and takes decisions based on the requirements of each grid.

• The farmer refers to agro-databases to generate cropping options suited to weather variationsand can experiment on drought-resistant varieties of crops.

## 

## 5.1. Components of Precision Farming

Precision farming (PF) is the use of information technology to support accurate application of agricultural inputs like water, fertilizer, manures etc. based on soil, weather and crop requirement to maximize farm productivity, quality and profitability. It enables response modeling to climate/soil variations in terms of timing for farm operations, irrigation and fertilizer schedules, and choice of crops.

The primary technological components of PF are:

* Information Technology [Remote Sensing (RS) and Geographical Information Systems (GIS)]
* Inputs-related [Irrigation and integration of fertilizer application (liquid fertilizer)]

***Remote Sensing (RS):*** Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

***Global Positioning System****(****GPS****):* The GPS is a space-based satellite system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

RS and GIS may be used to create highly accurate field maps that show the variation in soil quality and can then influence the mix of water and fertilizer needed for each specific part of the farm. When combined with a suitable irrigation and integrated system of fertilizer and water application, accurate amounts of water and fertilizer are delivered just when and where they are needed. In addition, weather information can enable accurate cropping decision, including type of crops, timing of seed sowing, and specific operations.PF is linked to agricultural adaptation to climate change since climate change has reduced crop yields, and this may be addressed through timely weather and cultivation advisories.

The steps in precision agriculture are as follows:

* The field is segmented into small zones also called ‘grids’ based on soil pH, nutritional status, pest infestation, yield rates, and other factors that affect crop production.
* The exact location for deficiency can be identified with the help of one of the main precision farming technology of Global Positioning System (GPS), while application on the exact location can be made with the help of advanced equipment’s available. To take care of this, the farmer must put a GPS receiver on the tractor/ system applying the chemical so that the equipment knows its location in the field.
* An in-vehicle computer is also required with fertilizer/pesticide need map which compares to the condition of the field position data recorded from the GPS receiver.
* In addition to fertilizer/pesticide requirements, the system can also monitor plant population and crop yield to maximize the absorption of soil nutrients and facilitate plant variety selection.

**5.2. Technologies used in Precision Agriculture**

Precision Farming requires a range of modern technological tools, i.e., hardware and software in order to collect and make use of information effectively.

**Mapping:**

* Preparation of Maps of the field with plots marked with variation in yield, pH and other parameters based on soil testing and specific location determined through GPS.
* The data collection occurs both before and during crop production using methods such as grid soil sampling, yield monitoring, RS and crop scouting.
* The data collection also makes use of sensing instruments such as soil probes, electrical conductivity and soil nutrient status.
* The mapping may be done by RS, GIS and manually during field operations.

**Signal Receiver System**:

* Global Positioning System satellites broadcast signals that allow GPS receivers to find their accurate location.
* This information is provided in real time; hence continuous position information is available. Having precise location information at any time allows soil and crop measurements to be mapped.
* GPS receivers, either carried to the field or placed on implements allow users to return to specific locations to sample or treat those areas.

**Yield monitoring and mapping system**:

* In highly mechanized systems, grain yield calculation is continuously measured and flow of grain is recorded in the clean-grain elevator of a combine.
* When connected with a GPS receiver, yield monitors can provide data necessary for yield maps. Yield measurements help to make better crop decisions.
* Soil, landscape and other environmental factors should also be weighed when interpreting a yield map.
* Used properly, yield information provides feedback in determining the effects of managed inputs such as fertilizer amendments, seed, pesticides including tillage and irrigation.

**Soil Sampling and Fertilizer application as per soil Factors:**

* Soil samples taken from random locations in the sampling area are combined and sent to a laboratory to be tested.
* Crop advisors make fertilizer application recommendations from the soil test information.
* PF makes use of Grid soil sampling which has the same principles of soil sampling but increases the intensity of sampling. For example, a 20-acre sampling area would have 10 samples using a 2-acre grid sampling system (samples are spaced 300 feet from each other) compared to one sample from 20 Acre Sampling area.
* Soil samples will be collected in a systematic grid and they also have location information that allows the data to be mapped. The goal of grid soil sampling is to generate a map of nutrient requirement.
* Grid soil samples are analyzed in the laboratory, and an interpretation of crop nutrient needs is made for each soil sample. Then the fertilizer application map is plotted using the entire set of soil samples.
* The application map is loaded into a computer placed on a variable-rate fertilizer spreader.
* The computer uses the application map and a GPS receiver to direct a product-delivery controller that changes the amount and/or kind of fertilizer product, according to the application map.

**Remote sensing**:

Remote sensing is collection of data from a distance. Data sensors can simply be hand-held devices, mounted on aircraft or satellite-based. Remotely-sensed data provide a tool for evaluating crop health, plant stress related to moisture, nutrients, compaction, crop diseases and other plant health concerns.

* Take decisions that improve profitability for the current crop.
* Remotely-sensed images can help determine the location and extent of crop stress. Analysis of such images can help determine the cause of certain components of crop stress.
* The images can then be used to develop and implement a treatment plan that optimizes the use of agricultural chemicals.
* Examples of Satellite remote sensing has provided a tool for acreage estimation one month in advance, with more than 95% accuracy ;In one crop area yield estimation with more than 90% accuracy ten days in advance.
* These images allow for mapping of crop, pest and soil properties for monitoring crop production stress and weed infestation within a field.

**Geographic information systems (GIS):**

* Geographic information systems (GIS) are Computer hardware and software that use feature attributes and location data to produce maps.
* Agricultural GIS stores information, such as yields, soil survey maps, remotely sensed images, crop reports and soil nutrient levels.

**5.3. Quantifying on Farm Variability in Precision Agriculture**

Since every farm presents a unique perspective, not all the tools described above will help determine the causes of variability in a field. An incremental approach is a wise strategy, using one or two tools at a time and carefully evaluating the results. It would be cost-prohibitive to implement all of them immediately.

**Soil Variation:**

* Soil variation is a spatial variable. Water-holding capacity or organic matter variation, along with topography, provides clear view of a field in which a producer places inputs or disturbs the soil.
* The role of variations on water use, plant growth, soil processes, yield, surface runoff, and groundwater has not been quantified for agricultural fields.

**Variability of Soil Water Content:**

* Soil water content in a field varies over time and location and this temporal and spatial variability in soil water content patterns has implications on Precision farming.
* Knowledge of the underlying soil water distribution could provide a useful basis for water management and lead to savings in energy, water, equipment cost, labor and improved production efficiency.

**Time and Space Scales:**

* Precision Agriculture gives farmers the ability to use fertilizers, pesticides, and tillage and irrigation water more efficiently.
* More effective use of inputs means greater crop yield and/or quality, without polluting the environment.

Precision Agriculture gives farmers the ability to use crop inputs more effectively including fertilizers, pesticides, and tillage and irrigation water. More effective use of inputs means greater crop yield and/or quality, without polluting the environment.

**5.4. Case-let on Precision Agriculture**

Application of precision farming has shown yield increases of 35-80% and even higher increases in gross margins of 67-165%, also because of the reduction in cost of inputs. A Precision Farming Project (by Tamil Nadu Agricultural University) in Dharmapuri/Krishnagiri districts (Tamil Nadu state, southern India) covering over 400 ha (one ha/farmer) has demonstrated high increase in crop productivity (e.g. ginger production 118 Qtls dry against 75qtl/ha and beans 20 Mt against 10 Mt/ha), and reduced water requirements by 30-40%. Savings in fertilizer and pesticide applications using Precision Farming Technology are around 5-30%. The total productivity difference between precision and non-precision farming of tomato was noted to be 63.86% and for brinjal 28.14%, with increase in gross margin of 165% and 67% respectively.