Sustainable agricultural practices and technologies in Nepal

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Some practices that could be sustainable in the Nepalese context – such as water usage, biogas programme, gravity ropeway and resource conservation technologies are mentioned. Similarly, technologies – possibly helpful to the small & marginal farmers (such as maize planter, millet thresher, coffee pulper, and dryers for paddy, cardamom and perishables) and potential technical partners involved in up-scaling sustainable technologies – are also described. Finally, strategies for the development of sustainable agricultural practices and technologies are listed out for policy formation by the government, for research and development, and for promotion.

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Introduction

Hill farmers in Nepal have developed traditional practices and indigenous technologies over generations of trial and local adaptations. In the past, these practices have been in harmony with the ecosystem and hence sustainable. Rapid increases in population, food and fibre demand, and cropping intensities, as well as changes in food habits, demographic trends and land use have led to exploitation and imbalance in the agro-ecosystems. An integrated approach involving various technological practices is required to ensure the sustainability of farming, especially in the mid-hills. There is ample scope and opportunity for this to be executed in collaboration with government agencies, non-government organizations (NGOs) and community-based organizations (CBOs) to initiate or support local participatory development, research or training programmes in areas related to management and farming.

Most of the agricultural technologies that have been promoted for the last 20 years or more were imported from the West, where they were developed for agricultural systems with minimum farm size of 50 acres. Even the technologies imported from countries such as Japan or Taiwan-China, where plot size are smaller, are designed for systems where capital is cheap and labour is expensive. For the small farmers in Nepal, the opposite is true – labour is cheap and capital is expensive. Thus, we have been taking inappropriate technologies and imposing them on the wrong agricultural context. The results have been a high percentage of failure and technologies that tend to create larger gaps in income distribution. Appropriate technologies targeting the poor and marginal farmers (70 per cent) need to be those that: promote agricultural or post-harvest productivity; generate cash income through either cash crops or other means of income generation; focus on dry land farming; are appropriate for plots of 0.17 ha[1] or less; and costs an individual farmer less than Rs 2,000 (US$25).

Selective semi-mechanization, however, has become a necessity of the country, as agricultural operation is found to be completely dependent on the old and female labourers. Large numbers of young people are migrating to Malaysia and Gulf countries due to lack of employment opportunity. Mechanization could help complete farm operations in time; time saved from agricultural activities could be utilized in other income generating activities, child health care, education and recreation. Human/women drudgery and farm work load could be substantially reduced with quality farm operations, resulting in higher crop yields and cropping intensity. Environmental degradation could also be minimized by using selected agricultural machinery.

Sustainable agricultural practices

Water harvesting

Nepal is gifted with many mountains in its northern belt from west to east. Water from melting snow in the mountains in the summer flows down as a river towards the south. It crosses many hills and valleys to move to the Terai region and finally enters India. Rainfall, mainly from June to September, brings more water. However, large quantities of rainwater is wasted as runoff, which also causes soil erosion as well as landslide in hilly tracts. If the wasted rainwater were to be appropriately harvested at various hills, higher hills, and even rural and inner Terai areas, it would not only reduce hazards of soil erosion and landslide but also provide supplementary irrigation to the winter crop during the dry months. As about 80 per cent area of the country is covered by hills and mountains, water harvesting for supplementary irrigation of hill crops and vegetable crops would be a sustainable practice.

Farmer-managed irrigation system

Nepal is estimated to have 20,000 farmer-managed irrigation systems (FMIS). As about 74 per cent of irrigation command area is covered by FMIS, farmer's organizations have been playing a key role in irrigation development and management. Farmers in each FMIS have developed an organizational structure that fits the local needs of the system. FMIS ranges from a few hectares to 15,000 hectares. Most of these systems are not registered (informal), but these need-driven systems are running properly with clearly defined roles and functionaries. Usually, the FMIS with high resource mobilization requirement would be the most developed organization.

Use of solar energy

Bulk of fruits gets deteriorated due to the lack of market near the production sites or the facility to take the produce to the city or needy areas. Farmers do not get remunerative price if the commodities are transported by air. In addition, prices of commodities like potato, onion, tomato, capsicum and cucumber sometimes go very high. Consumers had to meet this incredibly higher prices for their daily needs, such as when vegetable traders and dealers imported onion from countries other than India.

Solar energy is reported to provide a simple and economical method for dehydration of perishable products at production sites to reduce spoilage. Therefore, development of solar energy technology could be encouraged for drying fresh fruits, vegetables, fish, meat and mushroom; for cooking food and boiling water; for room heating and electrification; and for linking up communication facilities. Designing improved technologies, like smokeless and firewood-saving improved cookers, is possible. When electricity is produced, any machine – including mills and grinders – could also be installed in rural areas. Traditional water mills could also be improved for use.

Biogas Support Programme

The Biogas Support Programme (BSP), which started in July 1992, is currently implementing BSP Phase IV (July 2003-June 2009) after successfully completing the first three phases. Recently, BSP has been working also to promote rainwater harvesting system to address the problem of safe drinking water in water-scarce areas, besides promoting the use of biogas plants in such areas. So far, it has supported the construction of three rainwater harvesting tanks – one tank of 60,000 l and two of 25,000 l – in schools in Kaski and Syngja districts. By December 2005, BSP had constructed 140,549 biogas plants in 66 districts and more than 2,500 Village Development Committees (VDCs). Of the total plants constructed, 66.05 per cent are connected to toilets. BSP-Nepal was awarded the first prize in the 2005 "Overseas Award for Welfare" category from the Ashden Awards for Sustainable Energy, the United Kingdom, in recognition of the "outstanding achievement in using sustainable energy to improve quality of life and protect the environment."

Micro-irrigation programme

Treadle pump

Treadle pump is easy to operate, fabricated locally, recovers the investment in a short period and costs less. It can lift water up to 6.7 m and can irrigate up to 0.32 ha. It was initially developed in Bangladesh, and had been tested in the Terai region of Nepal during 1993/94. IDE/Nepal is providing technical support for pump fabrication, marketing and installation. To date, 100,000 farmers have benefited from the use of treadle pump in irrigating various crops and generating income. Currently, six private companies are fabricating the pump and distributing it through local dealers.

[1] Local measure: 3.4 ropani or 5.1 katha

Drip irrigation technology

Through research and development (R&D), IDE/Nepal has developed an easy-to-use and low-cost drip irrigation technology for Nepal. The technology has been used by about 5,000 farmers to successfully generate income through vegetable cultivation. As fields can be irrigated with less water, drip irrigation is more effective in areas having water scarcity. It has been very successful in hilly regions and the north belt of Terai region.

Improved Water Mill Support Programme

The Improved Water Mill Support Programme has been honoured by the prestigious London-based "Ashden Award 2007" for upgrading more than 2,400 traditional water mills in the Himalayas of Nepal and improving the livelihood of millers and mill users, besides stemming the rise in diesel-powered mills. It is being implemented through 16 service centres and eight Ghatta Owner's Associations in 16 hill districts. By end of June 2007, it had helped install 7,767 improved water mills: 2,473 are of short shaft used for efficient grinding and 294 units are of long shaft used for other purposes such as rice mill, sawmill, oil expeller, etc. It has replaced diesel-powered mills, thus directly contributing towards the reduction of carbon dioxide emissions and hence global warming.

Gravity ropeway

Practical Action/Nepal began its transport programme in 1998. It improved and promoted innovative transport systems such as cable river-crossing bridges known as "twin"; gravity rope way for hilly and mountainous regions and bicycle ambulance/trailer for the Terai region. Gravity ropeway technology was transferred from Northern India to Nepal, in collaboration with the International Centre for Integrated Mountain Development (ICIMOD) and a private manufacturer/supplier. Demonstration ropeways were installed in the Marpha and Tukche VDCs of Mustang district to facilitate apple transportation from orchards to road heads. Later, the Janagaon/Bishaltar ropeway was installed in Benighat VDC, the Hadikhola-Chiraudi ropeway in Kalleri VDC of Dhading, and the Torisawara-Bishaltar ropeway in Jori Sawara VDC of Gorkha, with financial support from the donors.

An initial study showed that the transportation cost of agro-based products decreased by at least 50 per cent after being served by the gravity ropeway system. It provided confidence to the villagers to supply their products in larger amounts, to enter the competitive market in cities. It also improved their socio-economic status and health, education and community awareness. In addition, it created employment opportunities and supported businesses of local service providers and manufacturers. There could be other places where this technology would be applicable.

Resource conservation practices

Nepal is experiencing deficit of food grains for the past 10-15 years. Manual seed broadcasting and delayed planting are some of the reasons for poor crop yield. Late wheat planting causes 30-50 kg/day/ha yields reduction, and this cannot be reversed with better crop management and application of inputs. Main causes of delayed wheat planting are excess or depleted soil moisture and long turn-around time. Besides these, there are other factors such as manual rice harvesting and unavailability of labour for rice harvesting. As the temperature drops rapidly, the delayed sowing results in delayed germination and hence low yields.

- Tillage is the major farm operation that consumes more energy and time. Usage of traditional tillage delays wheat sowing by 2-3 weeks (turn-around time in rice-wheat system) or longer for heavy soils, as power availability for agricultural purposes is low (0.74 kW/ha) in Nepal when compared with India (1.25 kW/ha) and Indian state of Punjab (3.5 kW/ha). It is estimated that 0.16 ha of land can be prepared with a pair of bullocks and a wooden plough in a day.
- After paddy harvest, significant crop residues (1.5-2.0 tonnes/ha) are left in the field. For preparing good seed beds, farmers have to resort to excessive tillage, which results in increased cost of cultivation, accelerated soil erosion and compactness of sub-soil.
- Traditional wheat sowing is done through broadcasting seeds on the prepared surface (mainly by animal power) and manipulating them into the soil through tillage operations (ploughed 4 times and planked 5 times). Poor tilth and manual seed broadcasting cause poor plant stand.

Hence, resource conserving technologies (RCT) – such as minimum, reduced or zero tillage – are recommended to reduce input costs and to secure long-term sustainability, economic and environmental benefits of agriculture.

One Village One Product (OVOP) System

This programme was started during 2005/06 for the first time in Nepal. A few agricultural crops were selected by the OVOP Committee organized for the purpose (Table 1).

Co-operatives for sustainable commercial agriculture

Nepal's entry into the World Trade Organization (WTO) in April 2004 has opened for its farming community an avenue of marketing opportunities for agro-based products in the international arena. In order to compete in the world market, Nepal has no alternative but to lower the cost of cultivation and reduce the price of agricultural commodities through mechanized commercial farming. Commercial agriculture would be better implemented for the small and marginal farmers through the consolidated effort of co-operatives, which can help in quality input supply on time and dialogue with the government for infrastructure (rural roads, rural electricity) and supportive policy on agricultural mechanization, provide proper technical back-up and well established market links, facilitate access to other countries for exporting agricultural produces, and assist in competitive marketing. Co-operative farming also helps mobilize limited

Table 1: Products and districts/VDCs selected under OVOP

Products	District /VDC
Junar - sweet orange *(Citrus sinensis)*	Ramecchap (Okhreni & Sukhajor), Sindhuli (Ratanchura & Basheshor)
Bel - Bengal quince *(Aegle marmelos)*	Siraha (Lahan), Bardiya (Guleriya)
Lapsi - Hog plum *(Choerospondias axillaris)*	Bhaktapur (Changunarayan, Jhaukhel, chhaling, Bagesori, Nagarkot, Sudaal, Taathali, Chitpole, Nakhel, Sipadole, Dadhikot, Gundu)
Fish (Rainbow trout)	Nuwakot & Rasuwa (3/5th VDCs)
Agro-tourism	Kaski (Lekhnath Municipality)
Orchid	Lalitpur (Badikhel, Godawari)
Note: Words in parenthesis are VDCs	

financial resources of individual farmers for the betterment of the group, mobilize labour, and lower possible risk in cultivation, thereby helping to increase profit. Co-operatives would be helpful also in introducing OVOP concept so that the crops are grown on commercial scale in reality.

For small land holdings, there are two options for mechanization: land consolidation and service co-operatives. With land consolidation, it would be easier to operate the equipment but with co-operatives, there are many other advantages as well. Agriculture Perspective Plan of Nepal also urges further consolidation of the land use policy and a system of co-operative farming. The government and/or the private sector should play a role for strengthening the economics of the small land-holding farmers.

Vegetable seed production

Nepal has varied climatic conditions from north to south. One can get subtropical climate in the Terai to Alpine climate in the Himalayan region. For example, commercial-scale production of both summer and winter vegetables is carried out in hilly areas such as Sinduwa in Tehrathum district. These vegetables have an export market in India. Hence, vegetable seeds offer a potential to fetch good foreign currency earnings. Quality production of seeds, however, is a major challenge for the Nepalese farmers. The production technology for this needs to be imported from countries such as Japan, The Netherlands and Italy, as climatic conditions akin to those of Nepal do not prevail in the neighbouring countries like India, Bangladesh, Pakistan and Sri Lanka. Thus, foreign collaboration would be needed to produce good quality guaranteed seeds and that is a very costly proposition for the poor farmers.

Mechanized model farm concept

Establishment of a model farm that successfully demonstrates sustainable technologies will be helpful to promote the recent approaches, such as OVOP or commercial-scale production. The model farm operated by the farmers' group from one sector should be able to attract the farmers from other sectors of the country for adoption of sustainable technologies. Prior to establishment, the technical feasibility and economic viability of the model farm need to be studied. From the very beginning, all the process of establishment should be documented so that proper monitoring and evaluation of the farm establishment can be carried out later on. This will also help conduct impact assessment in future.

Exchange of live animals/fish programme

Heifer International/Nepal started this programme for the first time in Nepal in 1950 with sheep, pig and cow. Since 1993, it is working with Bakhrapalan in Chitwan district through women's groups. Live animals are provided to the needy farmers. When off-springs are grown, they have to be passed on to other needy farmers.

Sustainable agricultural technologies

Manual seed-cum-fertilizer jab planter

For maize planting in hills and mountains, germination is found to be poor due to loss of residual soil moisture by tillage operation. Soil erosion takes place in rainy season and conservation practices are lacking. The Agricultural Engineering Division (AED) of the Nepal Agricultural Research Council (NARC) designed a jab planter for simultaneous manual seeding and fertilizing. It is lightweight (5 kg) and can seed more than 0.05 ha of land in an hour. It costs around Rs 2,500 (US$31.25), and has following advantages:

- It can be used in untilled land;
- Residual moisture is conserved;
- Offers better germination; and
- Ensures increased fertilizer use efficiency.

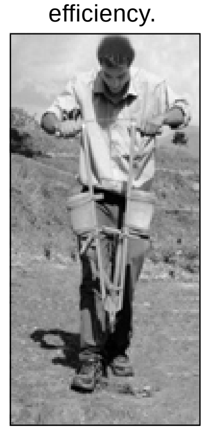


Figure 1: Jab planter

Figure 2: A pedal thresher/pearler

Pedal millet thresher/pearler

A pedal-operated millet thresher-cum-pearler was designed, fabricated and tested by AED/NARC to reduce the drudgery of women farmers in millet threshing and pearling. After successful testing of prototypes, seven units of this thresher was replicated and distributed to the farmers in Humla through different agencies. The millet thresher-cum-pearler has a capacity of threshing and pearling of 40-50 kg/h. It has a threshing efficiency of 97 per cent and pearling efficiency of 98 per cent. The unit weighs about 50 kg.

NARC signed a memorandum of understanding with Trishul Agri Tools in 2007-08 for the commercial fabrication of the machine.

Coffee pulpers

Coffee is cultivated in steep, marginal and shaded land at 800-1,600 m altitude in 22 hill districts in Nepal. It is an attractive cash crop for small and poor farmers in mid-hills. There has been significant increase in coffee export from negligible amount in 2002 to 112 tonnes in 2007. To enhance the quality of coffee for international export, wet processing technology was introduced. As pulping is one of the important processes, more than 350 coffee pulping centres were set up. An example of a coffee pulper introduced in Nepal is the AED roller-type hand-operated coffee pulper.

Figure 3: A coffee pulping machine

The weight of the pulper with stand is about 25 kg. Operating capacity of pulper is 60 kg/h with a pulping and cleaning efficiency above 99 per cent and 96 per cent, respectively. Broken parchment and loss are less than 0.33 per cent and 0.44 per cent, respectively. It is robust in construction and maintenance cost is negligible. It costs about Rs 8,000 (US$100).

Minimum till drill

Minimum tillage by power tiller drill

RCTs save time, input (fertilizers, fuel and labour) and natural resources (soil and water). They reduce drudgery and are environment-friendly. One of the RCTs, minimum tillage by power tiller drill (PTD) is popular among small to medium-scale farmers, as the drill performs three operations – soil tilling, seed sowing and planking – simultaneously. Data on the extent of its adoption, area covered and grain yield are provided in Tables 2 and 3. Grain yield from minimum tillage by PTD was more when compared with traditional farmers' practice. It was very economical and showed a mean net return of Rs 25,755/ha (US$322) compared with Rs 18,060/ha (US$ 226) when traditional farmer's practice was employed. Reduced, zero and minimum tillage are the sustainable options of tillage and crop establishment in rice-wheat system in flat land/ Terai.

Table 2: Effect of adoption of resource conserving technologies on wheat grain yield

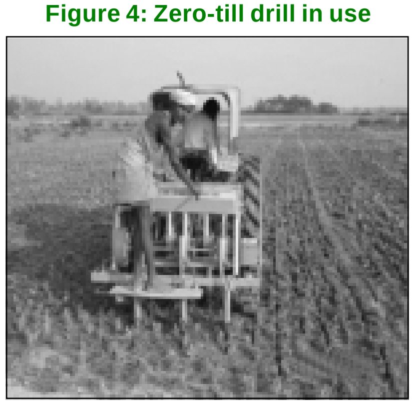
Parameter	Minimum tillage by PTD	Zero tillage by zero till drill	Farmer's practice (FP)
No. of machines used	9-14	5-9	
No. of beneficiary farmers	225-585	30-136	5-71
Area covered (ha)	103-221	76-179	
Average grain yield (kg/ha)	2928	3161	2314
Change over F.P. (per cent)	26	37	

Table 3: Economic returns of resource conserving technologies for wheat at farmer's fields

Particulars (Rs/ha)	Minimum tillage by PTD	Zero tillage by zero till drill	Farmer's practice (FP)
Gross return from grain and straw	45,983	38,507	38,500
Land preparation+ sowing cost	797	1,475	2,775
Other costs (seed, fertilizer, chemicals)	18,995	17,892	17,665
Total production cost	19,792	19,367	20,440
Net return	25,755	18,832	18,060
Change in net return over FP (per cent)	42 ↑	4 ↑	-

Zero tillage by zero till drill

Figure 4: Zero-till drill in use



Zero-till drills (ZTD) are used on untilled soil after rice harvest; furrows are opened in which seed and fertilizers are uniformly deposited. Optional planking, depending on the type and moisture content of the soil at sowing, is performed by tying a lightweight plank behind the drill. Data relating to ZTD are given in Tables 2 and 3.

Impacts among farming community

The concept of "better the soil pulverization, higher the wheat yield" has been changed among the farming communities of few Terai districts of Nepal. They have become confident on RCTs for wheat cultivation. Hence, some farmers have started to purchase seed drills operated by power tiller, while some others have tractor-operated zero-till drills. Custom hiring system of the drills is gaining popularity among the farmers.

Mini SRR dryer for paddy

Sundrying is the predominant method for rice seed (paddy) at farmer level. However, early rice is harvested during the rainy season and hence needs a dryer. Adoption of dryer allows not only the conservation of product but also its storage that would enable the farmers to await better prices. It would also help reduce women's drudgery, as they are mainly involved in crop drying. Adoption of dryer would help in saving at least the seed grain. Few years back, in Chitwan district, the farmers could not harvest early rice due to continuous rain at harvest time. Hence, it should help encourage the farmers for higher coverage of early rice, which was the target of Community Groundwater Irrigation Sector Project to manage Nepal's food deficit situation.

Mini SRR (simple, small, low-cost dryer in Vietnamese) dryer consists of a cylindrical bin; an electric blower with an inverted funnel and a cylindrical support frame with fine wire net on its outer periphery; a rice husk stove; and two metallic pipes connected in L-shape. One end of the pipe (vertical) rests on top of the stove and the other end of pipe (horizontal) is attached to the blower. The exit of the blower is attached to the top of the inverted funnel, which is tightly attached to the top of the inner cylindrical frame. The inside of the frame serves as a plenum chamber. The inner cylinder supports the funnel along with the blower. The grain is loaded between the cylindrical bin and the inner support frame along with wire net, and the top is covered by a plastic sheet.

SRR dryer is simple to assemble and easy to operate. The rice hull stove used in the dryer is also simple in design and could easily be operated. As it dries the rice at an air temperature limited to 43.3ºC, it could be used to dry paddy. During the test installation at AED/NARC, the initial investment of dryer was found to be around Rs 10,000 (US$125), which is affordable for the small farmers. The dryer was found adequate for about 250 kg of paddy per batch. The average grain-drying rate was found to be 0.45 per cent per hour with the initial grain moisture content variation from 20.9 per cent to 23.5 per cent (25.7ºC to 31.6ºC ambient temperature and 71 to 91 per cent relative humidity). Rice husk use varied from 5.4 to 8.6 kg/h. The study, aimed at enhancing cultivation of early rice to partially fulfill food deficit situation of the country, has shown encouraging results. Average power consumption was found to be about 6.1 kW, which includes 3.3 kW equivalent of rice husk (»6.5 kg).

Improved dryer for large cardamom

Large cardamom (*Amomum subulatum* Roxb.), extensively cultivated in the eastern hill districts of Nepal, is spreading to other hill districts too; 12,636 ha in 2001/02 with a production of 5,581 tonnes. Farmers often consider it as an additional source of income, as land utilized for cardamom cultivation is not suitable for any other food crop. The cop can be grown in moist, sloppy land, with protection against landslide and soil erosion. Farmers use traditional batch dryer, known as *bhatti,* in which cardamom usually becomes black/smoky. Statistics show that cardamom export is decreasing since 1986/87 mainly due to inferior quality.

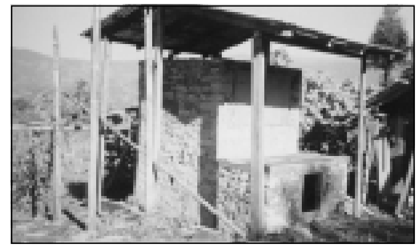
Traditional method of drying

The dryer has a rectangular structure, with mud-mortared stonewall 1.2-2.5 m high and 1.5-6 m^2 in area. On one side, an opening of about 60 cm × 80 cm is provided to facilitate firewood feeding. The dryer has a thatched roof 20 cm above the wall top. Cardamom is spread in about 20 cm thick layer on a loosely woven bamboo mat. Smoke passes through bamboo mat, heating and drying the crop. As it is dried by smoke, water is often sprinkled on the burning logs to avoid flame. It takes 24-48 hours to dry one batch of cardamom. Fuel wood consumption is 1-3 kg to dry 1 kg of wet cardamom. Moreover, the dried cardamom is of blackish colour, with a smoky odour that precludes a good market price.

Improved dryer Model-2

AED/NARC modified the traditional dryer in different steps, tested and developed a new dryer (Model-2) in close association with growers and the Cardamom Development Section. The improved model has a small chamber with grate for efficient combustion of air-dried fuel wood, a conical drying chamber and air intake facility for diffusion of hot air. The height of drying bed from firing place is increased to avoid contact with flame, and openings are provided just below the drying bed to reduce the drying temperature. The bamboo-drying tray of Model-1 is replaced by removable wooden trays fitted with wire mesh. The dryer has a cabinet type-drying chamber with doors at the sides and a platform. It has provision to dry 6 trays of cardamom in 3 layers, with a capacity of 240 kg wet cardamom per batch. Removing the trays for stirring has become easier. Dryer Model-2 has incurred an additional cost of Rs 1,500 for grate and drying trays, but it saves about 10 hours per batch.

Figure 5: Improved cardamom dryer Model-2



Low-cost solar dryers

Development and dissemination of horticultural technologies have significantly contributed in enhancing the socio-economic status of the farmers of Nepal. However, fruits and vegetable growers are on high risk due to fluctuating market price. At times, the farmers have to throw away their products because of low price resulting from suppy-demand mismatch. Moreover, farmers in remote areas cannot benefit from the modern agricultural technologies because of poor market access and high transportation costs of bulky agricultural produce.

Promotion of small-scale income-generating technologies, including post-harvest technologies, could play a crucial role in empowering rural women. Difficulty in transportation and unavailability of construction materials hamper the adoption of solar dryers in remote rural areas. To address these issues, a low-cost solar dryer was developed. Comparative testing with wooden and metallic solar dryer was performed for mushroom drying in AED/NARC. The metal (GI sheet) solar dryer costs about Rs 6,000 (US$ 75), while the wooden one costs only

Figure 6: Low-cost solar dryer

Table 4: Comparative energy/performances of rice husk stoves

Energy/related performance	Unit	Vietnamese model	Traditional model
Fuel	-	Rice husk only	Compressed husk & small fuel wood
Burning the stove	-	Easy with piece of paper	Easy but needs some kerosene
Smoke emission	-	Less than traditional	Smoke emission
Removal of ash	Manual	Manual (tapping)	-
Average heat input	MJ	12.81	14.17
Average heat output	MJ	3.00	2.28
Average efficiency	Per cent	23.61	16.15
Average power	kW	1.37	1.55

Rs 2,500 (approximately US$31) in Kathmandu.

The low-cost solar dryer is constructed using locally available materials. It has stone or brick wall, with mud mortar, inclined 10º and facing south. It is a rectangular box of 12 cm height, and length and width as required. For air intake, small bamboo pipes are inserted and for the exit of the moist air, slots were made on the edge of walls. Mud plaster is applied on both sides of the walls and at the top. Once the mud dries, black paint is applied on the drying chamber. The wooden/bamboo tray and the wooden frame for UV plastic cover are fabricated according to the dryer's size. This dryer costs about Rs 500 (US$ 6.25).

This dryer has a capacity to dry 3 kg of mushroom per batch, when the size is 0.8 m × 1.5 m. It will dry the mushroom to less than 10 per cent moisture content within 2 days – from about 90.4 per cent (wet basis) to 9.0 per cent in 1½ days in all three dryers. But, the rate of moisture removal from mushroom by the GI dryer is more than those of wooden and low-cost mud dryers. This is mainly due to higher temperature that the GI dryer attains comparative to the other two.

Rice husk stoves for cooking

Traditional energy forms predominate in the energy sector in Nepal. Major share of energy consumption in the domestic sector is contributed by fuelwood (81 per cent). Forest resources are under increasing threat from the burgeoning human and livestock populations and their need to meet annual requirements for fuelwood, fodder, timber and other minor forest products. Reforestation compensates for only nine per cent of the annual forest loss. Women's drudgery in firewood collection is on the increase, while family health is on the decline owing to smoke inhalation. Dung cake, another extensively used fuel, results also in declining agricultural productivity, mainly in Terai.

Nepal produces around 833,000 tonnes of rice husk annually, which is mainly used as bedding material for poultry and livestock. It is used also as energy source in some industries. There had been some attempts on the production of rice husk briquette. In the domestic sector, rice husk has limited use owing to the tedious process of compression needed in the traditional stove. In this context, AED/NARC conducted a study on rice husk stoves.

Performance related to energy input and output and operational performance are in Table 4. It indicates that the Vietnamese model is superior to traditional stove in terms of efficiency. But, with respect to power, it is a bit inferior to the traditional stove.

In the Vietnamese model, burning is easy and smoke emission is less. Also, there is no need for compaction of rice husk which makes it easier for the users. However, in the Vietnamese model, the ash needs to be removed by tapping.

Poly-house technology

In poly-house technology (environment covered with transluscent or transparent plastic sheets), a barrier between plant microclimate and the ambient conditions helps to increase temperature within the poly-house for plant growth, retain soil moisture and make vegetable cultivation possible

Figure 7: Vietnamese model rice husk stove

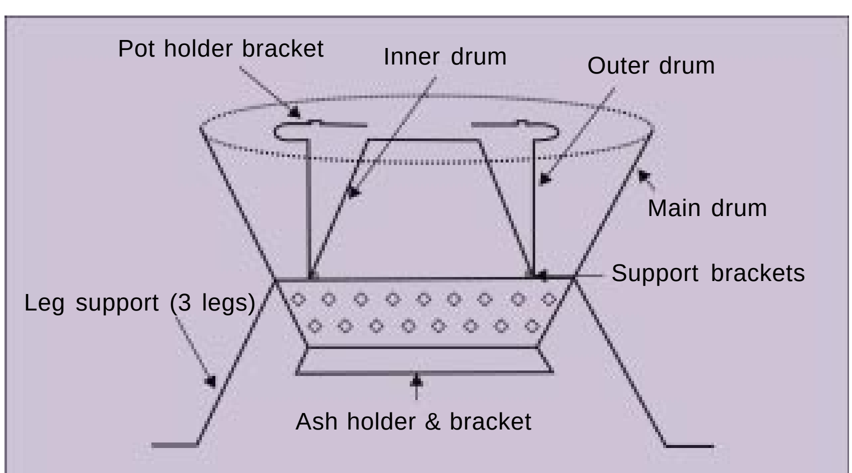


Figure 8: A poly-house

during rainy or winter period. The technology modifies natural environment, creating a favourable micro-climate for crop production in adverse situations also. It protects the plant from heavy rain and cold injury, and has the effect of enhancing reflex light, prolonging the effect of light, improving photosynthesis and strengthening crop functions. It is reported that the plastic film technology enables various crops to mature 5-20 days earlier than normal, and increases the yield by 30-50 per cent.

Consumption pattern of vegetable is changing/increasing in Nepal due to: improvement in people's dietary habits; realization of the nutritional importance of vegetables; and also the increased per capita incomes. In general, net return from vegetable farming is higher than from any other agro-enterprises. Nevertheless, demand for vegetables in Nepal is being fulfilled by importing from India and other places.

Off-season vegetable cultivation in hills is a category specified in the Agriculture Perspective Plan. Commercialization of the existing farming practices with wider adoption of off-season vegetables production technologies can improve the livelihood of the small farmers of Nepal. It can enhance quality and productivity, secure favourable market prices, and offer an additional source of income and employment opportunities for the growers.

A study on poly-houses was conducted at AED/NARC by constructing one with a bamboo frame, posts, rafters and purlins, all secured using plastic ropes. The bamboo frame was covered with plastic sheets of different types, as needed. Results were encouraging:

- When compared with open field conditions, poly-house was found to increase the marketable yields of tomato and cucumber by 16.0 kg and 5.8 kg, respectively, per plot.
- Economic analysis based on 5 m × 30 m area showed that using 120 gsm UV-stabilized Silpaulin in the poly-house gives maximum net annual income on tomato and cucumber cultivation. The sheets lasted for about eight years without tear or other damage (occasional minor repairs were done).
- Tomato and cucumber were found to mature about 5 days and 6 days earlier, respectively, compared with open field conditions.
- Average marketable yield in cucumber was found to be about 25 per cent more for August planting than that for March planting.
- Maximum temperature recorded inside was 25.6ºC during Aug-Dec and 25.8ºC in Mar-Jul planting time.
- Average maximum relative humidity recorded inside was 86.6 per cent during Aug-Dec period and 87.1 per cent during Mar-Jul crop period.

Plastic mulching in vegetable plots

Initially, the vegetable growers in the Kathmandu Valley used to produce in small areas of land. Now, they have increased the scale, and some have started growing vegetables also during the off-season. Still, the country is importing a lot of vegetables from neighbouring countries. Much wider adoption of production technologies for off-season vegetables and commercializing farming practices would help address this issue and improve the livelihoods of the small farmers. A study was conducted in open field and inside poly-houses on the use of mulching with black, 200-gauge polyethylene sheet. Overall effect of mulching was found to increase the marketable tomato, cucumber and capsicum yields by 9.6 tonnes, 9.3 tonnes and 2.5 tonnes, respectively, per hectare.

Magnetized irrigation for vegetable cultivation

A study on the effect of magnetized irrigation on vegetable cultivation was carried out, first on cauliflower. A yield increase of 20 per cent was observed. In view of this, the method was again tried for tomato, cucumber and capsicum crops. Comparisons were made of mulched and non-mulched plots, which were irrigated with ordinary water and magnetized water. Magnetized water was produced by fixing/connecting a magnetizer around the polythene pipe close to its discharge end. During planting time, ordinary water was provided to all pits made for the purpose. Marketable cucumber (0.75 t/ha) and capsicum (0.5 t/ha) yields were found to be increased. Marketable tomato yield was found to be increased only slightly.

Other sustainable agricultural practices

- Community management of forest resources;
- Small-scale development projects run by local communities;
- Drinking water projects and purification methods;
- Community contribution (cash or kind);
- Modification of soil conservation practices making them environmentally sound;
- Encouraging adoption of reduced or minimum tillage;
- Identifying the socio-economic and site-specific conditions for determining suitability of practising new techniques;
- Technology transfer – making technology more accessible to farmers and co-operatives;
- Farmer–manufacturer-researcher approach;
- Furrow-irrigated raised bed;
- Solar village concept, wind mill, biomass gasifier, etc.; and
- Hydraulic ram.

Sustainable technologies for women development

The contribution of women in agriculture is very significant, because they participate as workers, supervisors,

Table 5: Equipment that could be improved for women participation

• Seed planting machine • Seed treatment, cleaning/grading machine • Transplanter • Manure/fertilizer applicator • Manual rice drum seeder • Manual rice transplanter • Rice weeder	• Weeding/hoeing tool • Harvesting tool • Threshing machine • Cleaning machine • Rice mill • Four mill • Oil expeller • Solar dryer • Winnowers	• Loading and unloading equipment • Metal storage bins & storage techniques • Coffee pulper • Chaff cutter • Rice hull stove • Milk processing equipment • Pedal thresher
For animal production:	• Feeders, waterers, small milking machine	
For horticulture:	• Pit digging, watering, fruit/vegetable harvesting • Cleaning, sorting, grading, packaging	

as well as decision makers. Except tillage and marketing activities, all farm activities (like transplanting, weeding, harvesting, threshing, winnowing, transportation, shelling/decortication and milling) have 40-64 per cent contribution from women farmers (using traditional tools and equipment that cause lot of drudgery). The share of women is found to be even higher in areas where male household members move to urban areas and abroad in search of job opportunity. However, their contribution is rarely recognized and their drudgery is not addressed.

Nepal's R&D institutions need to develop several gender-neutral or women-specific, ergonomically comfortable, women-friendly, simple devices/equipment for crop production and processing, which could be easily adopted/operated by rural women. As women's earnings are reported to have a positive correlation with children's health, education and nutrition levels, this strategy may lead to overall growth and development of the country. Possible equipment for improvement for women involvement are listed in Table 5. Apart from these, the women could be involved in many post-harvest and processing activities.

Potential technical partners

Blacksmiths

Blacksmiths and rural artisans residing almost in all rural areas are the primary suppliers of basic hand tools and bullock-drawn (BD) implements for small and marginal farmers. It is estimated that more than 85 per cent of the tools and implements used by farmers, especially in the hilly areas, are made by blacksmiths/rural artisans. The work is low-earning but stable provided the blacksmith has adequate raw materials and remains healthy to work. The knowledge of blacksmiths can be used even for making some parts of power-operated machinery and equipment.

Blacksmiths, however, need financial and institutional support, appropriate working tools, high-quality raw materials and knowledge of improved techniques. Helping blacksmiths would reduce the pressure of under-employment and unemployment in the agricultural sector, as it would help develop labour-intensive industries. Slight modification or addition in their workplace, tools, equipment, etc. will improve the efficiency of their work.

Equipment fabricators/ manufacturers

Private workshops and manufacturers in urban areas fabricate agricultural equipment and machinery. However, most of their products run on electric power. Production of manual tools, equipment and BD-implements is limited. Out of 18 private manufactures surveyed few years back, only two were fabricating hand tools. There is a possibility of co-ordinating farmers and manufacturers in cities and all Terai areas, so that manufacturers would accept to take order for small tools and equipments. It also provides an opportunity for the nation to save money spent on import of agricultural implements and machinery.

Extension organizations

The Department of Agriculture Extension has initiated and implemented extension activities on agricultural mechanization. Similarly, AED/NARC and Agricultural Implement Research Centre too have been engaged in on-farm demonstration of agricultural machinery. NGOs, machinery suppliers and manufacturers do organize agricultural fairs. Leading farmers in the villages bring in improved implements markets on the India border and also act as service providers.

Marketing agents

The following sectors are mainly involved in promotion and development of agricultural mechanization in Nepal: the private sector (tractor and power tiller dealers, suppliers and importers), and the quasi-government sector (National Trading Limited, Agri Inputs Corporation [reformed], etc.).

Strategies for developing sustainable agricultural practices/technologies

Need of government policy

- Institutional support to upgrade knowledge and efficiency of blacksmiths;
- Facilitate the formation of farmers' groups or co-operative societies;
- Initiation of a pilot programme on identified commercial crops;
- Inclusion of a policy on agricultural mechanization in the future plans;
- Establishment of an Agricultural Machinery Testing and Evaluation Centre at AED/NARC;
- Assistance to agri-businesses and guarantee for purchase of produces to encourage growers;
- Support to agricultural engineering workshops/agriculture-related industries;
- Initiation of custom hiring schemes on equipment and machinery;
- Selection of similar micro-climatic pockets/areas for selected crops;
- Utilization of cultivable and non-cultivated farming land; and
- Utilization of river transportation, wherever feasible (successful ex-

ploration from Melamchi to Bay of Bengal).

Sustainable technologies recommended for application in R&D

- Low-cost lift irrigation system, hydraulic ram, water-saving irrigation practices & technologies, farmer-managed irrigation systems;
- Wastewater reuse for agriculture, groundwater recharging;
- Moisture conservation practices/ technologies, including usage of plastic mulch;
- Forage and fodder cultivation on degraded land;
- Soil conservation and terrace improvement;
- Value addition of fruits and vegetable products;
- Cottage-scale processing of herbs and medicines;
- Biofuel (biodiesel & bio-ethanol);
- Documentation of all indigenous technologies and successful cases related to agricultural engineering and technology;
- Utilization of the knowledge and skills of local community in rural areas;
- Inclusion of legumes in the cropping system;
- Government priority for agricultural research; and
- Value addition of milk products.

Strategy for promotion

- Water harvesting practices/technologies and low-cost water lifting devices/technologies;
- Zero tillage/minimum tillage cultivation for rice and wheat;
- Cultivation of vegetables in polyhouses;
- Renewable energy technologies, specially water mill, micro hydro plant, wind mill and biogas plant;
- Environment-friendly transport systems, including gravity ropeway, chargeable battery-operated three-wheeler for agricultural purpose;
- Community forest approach for further up-scaling, or at least, for maintenance; and
- Value chain approach – need for government help to farmers, input suppliers, enterprises and institutions in marketing channels.

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