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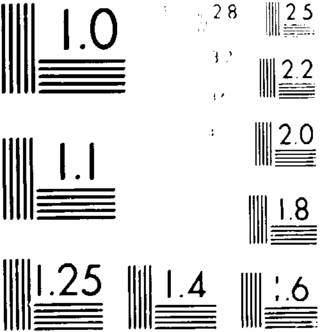
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on Mini Hydro Electric Generation Units

Kathmandu, Nepal, 10-14 September 1979

SEMINAR REPORT ON DEVELOPMENT OF SMALL SCALE HYDROELECTRIC POWER AND FERTILIZER PRODUCTION IN NEPAL*

by

The Asia Society
(SEADAG)
New York
U.S.A.

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REPORT OF MEETING

The National Council for Science and Technology of Nepal and the Society of New York co-sponsered a seminar in Pokhara, Nepal, from February 28 to March 3, 1977, on "Development of Small Scale Hydroelectric Power and Fertilizer in Nepal."

CONCLUSIONS AND RECOMMENDATIONS

(1) From the Standpoint of the national imperative to conserve the resource wealth of Nepal's revers and forests, and to increase agricultural productivity for the immediate well-being of all its citizens, small scale hydropower development is considered essential when coupled with a program of afforestation for a typical hill village of 250 persons, a 16-18 KW hydropower plant and a 30-40 hectare managed woodlet can provide significant irrigation, returns while having enormous social benefits.

(2) An appraisal of potential hydropower sites in the hills should proceed according to a scheme with the following elements:

(a) forest department identification of areas under most severe pressure of population on resources;

(b) electricity department use of existing aerial photographs and census data on population distribution to identify several major river valleys whose tributary valleys contain attractive sites; and

(c) deployment of trained and equipped field survey teams (10 men to work in field four months and survey 400 sites) to survey indentified sites by side gauging and utilization of local experience; this would require immediate implementation of a training program for the 10 team members to begin field work during 1977.

(3) Given the apparent high potential of the electric arc process for Nepal's needs for a small scale, low capital cost fertilizer unit, research and development work in Nepal should immediately be initiated. Collaboration with appropriate research and development institutes should be established.

(4) International aid agencies should support development of small electrolysis units for ammonia production and of compatible units for finished fertilizer production for plants of less than 10 tons of ammonia per day capacity. This work would include ammonia synthesis and finished product manufacture. Local suitability of CAN (calcium ammonium nitrate) based on limestone should be investigated from the standpoint of production technology and agronomic applicability.

(5) Development of indigenous manufacturing capacity for small water power units should be accelerated to include the entire hydropwer system. The Nepal Industrial Corporation and other agencies should investigate needs for extablishment of such production capability, particularly with respect to generators.

(6) A survey of existing waterwheel sites and their suitability for conversion to use of a modern prime mover should be initiated.

(7) Feasibility of using appropriate, less expensive materials and production techniques for local manufacture of hydropower units should be investigated, as part of a systems study to examine trade-offs between efficiency and cost for identification of hydropower technologies appropriate to Nepal's conditions, given its transport, skilled labor, and foreign exchange situation.

(8) It will be necessary to develop appropriate criteria for evaluation of alternative investments in energy supply and fertilizer production. Such criteria should include consideration of employment, income distribution, resource, and administrative impacts. They must also include careful analysis of the implications of flexibility, seasonality, and complementarity with other investments.

(9) Several (three or four) pilot projects could usefully be implemented in October 1977. Electricity generation and use aspects (for example, for irrigation water pumping) should be included.

(10) Reduction of cost of civil works is a priority matter. Specific suggestions presented at this seminar for dramatic decreases in costs should be followed up with installation of proposed designs in projects to be implemented in the near furture.

(11) The recently completed Nepal Energy Study provides a very useful base for energy planning. Work should continue with emphasis on energy inputs to the food production system, including human and animal labor.

SUMMARY OF DISCUSSION

Introduction

The seminar was inaugurated by Hon. Ratna SJB Rana, who welcomed participants and set the seminar theme within the Nepal planning context. Deforestation threatens the entire resource base of Nepal and it is imperative that action be taken to halt this drought-worsening and soil-devouring process. To this end all technologies must be examined but, for several reasons, small scale technologies might be especially appropriate.

First, required resources are most likely to be mobilized in relatively small units because of the scarcity of capital and transport difficulties. Second, the gestation period for large projects is invariably lond and thus unacceptable, given the immediacy of the problem. Third, the Plan emphasizes elimination of inequalities, participation of people in decisions and projects that affect them, and regional development. Each of these objectives is best achieved through small scale projects. Finally, it is essential for Nepal to mobilize local resources and talents to eliminate current dependence on other nations for finance and skilled talent.

This also would be most readily accomplished through small projects, some of which would serve an important skill development function.

Co-chairmen of the seminar, A.B. Shrestha and Roger Revelle, then explained the genesis of the seminar and emphasized that the purpose was to consider recommendations to the Nepal Government for a research and development program for energy supply and use.

Current Energy Situation in Nepal

The technical sessions opened with an overview presentation by Binayak Bhadra of the Centre for Economic Development and Administration, Kirtipur, on the energy situation in Nepal. The recently published energy sector report of the Energy Research and Development Group provided the background to discussions. Presentations were also made by D.R. Tuladhar, hydrologist, and B.M. Singh, engineer, on hydrologic knowledge and existing small scale hydropower projects in Nepal.

The extent and accelerating rate of forest encroachment was deplored by several speakers. It is estimated that, based on Forest Department statistics, only 12-13 years of accessible forest areas remain in Nepal. In the hill areas, a removal rate of 640 Kg/capita contrasts with a regeneration rate of only 70-80 Kg/capita. As a result 0.12 million acres per year of forests are being destroyed by overgrazing, firewood and fodder removal, and encroachment of agricultural land.

Although deforestation could be slowed by introduction of more efficient chulas and by fencing, the problem remains of formidable magnitude. Current forest productivities in the hills of about 0.6 ton/acre/year and a total fuelwood stock of 50 tons/acre imply an 80-year replacement time which necessarily must be reduced. Some trees can produce 50 tons/acre in 10 years although it was admitted that such species might not be suitable for hill areas. There was, however, general agreement that stabilization of forests through reforestation, productivity improvements, and fencing is an essential component of any resource development strategy. Hydroelectric development should complement, not replace, such a forest stabilization program.

The energy study was praised for its scope and information content and it was agreed the work should continue with emphasis on:

(1) animal and human energy, especially for agricultural operations, water drawing, and fuel gathering;

(2) the possibilities for wind, solar, and geothermal energy resource exploitation;

(3) space heating; and

(4) the critical role of women's energy in agriculture and the household and the effect of the overworking of women on the productive process.

Hydrologic Data for Small Rivers

Although Nepal has 170 gauging stations, very few of these are on small streams of interest for power development in the range below 100 KW. Limited data for four sites in the Kathmandu Valley and for eleven sites east of Kathmandu were presented for an assessment of low flow behavior. Unfortunately, topographic maps were available only for areas in the west so it was not possible to estimate accurately available heads and minimum discharges. It was felt, however, that a minimum gradient is 1,000 feet/mile and in most cases this is very conservative for the small streams.

It it is assumed that the eleven gauging stations for which data are available are representative, them their total flow of 2.61 m^3/sec (minimum recorded) from a 273 km^2 catchment area translates into a total flow in the hill area (100,000 km^2) of 940 m^3/sec. Given a total drop in the hills of say, 3,000 meters, this flow has a power potential of:

940 m^3/sec x 3,000 m x 9.94
= 28 million KW, or
3.7 KW per persons in the hills.

Small Hydro Projects in Nepal

There are few hydro projects in Nepal of less than 500 KW capacity so actual cost data are limited. The 120 KW, 200 meter Dhankuta project constructed twelve years ago cost Rs. 11,250/KW. The 345 KW, ... meter Surkhet project, now under construction, is expected to cost Rs; 30,000/KW, including costs for 7 km of transmission lines. It was revealed in discussion, however, that helicopters were used in order to expedite completion and that such costs might not be justifiable in most projects. Furthermore, over 40 percent of the costs of this project were for "civil works."

The electricity department has recently done a study of 10 small hydro plants designed to electrify remote administrative centers. These plants were designed for minimum flow and most had capacities of 200 - 260 KW with 20 - 30 meter heads, 1 - 3 km of canal, 2,000 - 4,000 persons per town, and a 3-year expected completion data. Costs ranged from 18,000 to 70,000 Rs./KW with most costs below Rs. 30,000/KW.

More detailed information was presented for the Chorajari 260 KW, 16 meter project which is expected to cost Rs. 18,000 per KW. Of this, civil works account for 46 percent, electro-mechanical for 37 percent, and transmission and overhead for the remainder. The project is 3 days' walk from the nearest airport; the 700 kg main unit will have to be airlifted.

It was noted in discussion that these projects are planned to provide electric lights to replace kerosene and candles, and may be irrelevant to the major overall energy problems of Nepal, in the light of the potential uses of electricity for irrigation and fertilizer production. It was further noted that the estimated civil works components of these projects are often unnecessarily large because of inflated reliability criteria.

The national company, Balaju Yantra Shala (BYS), is manufacturing crossflow (Banki) turbines that are suitable for heads up to 35 meters for the smallest units. BYS has performed feasibility studies of productive projects, of which a cheese factory two days' walk southeast of Kathmandu is an example. In his factory, 95 percent of the electricity would be used for heating purposes and would replace fuelwood. Electricity costs would be Rs. 0.84/kwh or 30 paisa per liter of milk (ignoring lighting cost). Investment would be Rs. 17,000/KW with a turbine (BYS) made in Nepal and a generator made in India. AC was used because of a 1.5 km transmission distance. Of the cost, 40 percent was civil wo.ks, 33 percent transmission (including transformers), 22 percent was generating equipment (of which 25 percent was governor cost), and the remainder was mainly transport cost. The design capacity was 40 KW for a 250 liter/second flow and a 30 meter head (with a 60 meter penstock). Minimum discharge is 40 liters/second for which power output would be 7 KW. Milk and electricity p oduction are highly correlated, with cows dry when streams are dry, so that the flow variability was not a constraint to effective project design.

Commentary on this project noted the complete absence of social cost analysis particularly with respect to the social cost of fuelwood. It was further noted that heating with electricity is an inefficient use of electric power.

Small Scale Hydropower: International Experience

International experience with small scale hydropower has been extensive, as participants from Japan, Norway, Switzerland, and the United States noted. Unfortunately for Nepal, this experience was accumulated many years ago and new installations are rare. Environmental and decentralist movements in the United States have combined, however, to produce a resurgence of interest in small units for farm/family use. These new units employ the latest technology (aluminium castings, epoxy coatings, solid state generators and inverters, and 2,000-cycle, deep discharge lead-acid batteries) to allow homeowner installation and maintenance-free operation.

Considerable discussion was devoted to the differences among turbine types with an impulse turbine suggested for heads above 27 meters and a propeller turbine (Nagler) for heads below 9 meters. For intermediate heads, a Banki cross-flow turbine or a modified impulse turbine are suggested. Choice of turbine is more complex than this, however, as it is necessary to consider: (1) ease of manufacture, (2) part-load efficiencies, and (3) sensitivity to trash and sediment load.

For U.S. applications it is recommended that below 18 KW, a turbine, DC generator/rectifier, battery bank, and inverter be used to produce AC. Above 18 KW a direct AC generator/governor system is recommended. In Nepal, however, a DC system would be acceptable for fertilizer manufacture, lighting, and powering of motors, provided transmission distances do not exceed several hundred meters. In practice it is likely fertilizer production would take place at the site of the hydro station and that electricity for other uses would be AC. A DC system above 20 KW would not require a governor but would require waterhammer protection which would not be expensive.

U.S. costs, for a high head installation (30-180 meters) in the range 1-20 horsepower, are about U.S.$.33 per watt for DC and U.S. $0.92 for AC with battery storage. Intermediate and low head systems could be expected to cost 15-20 percent more. Direct AC (with no storage) in the range 20-200 horsepower costs about U.S. $0.22 per watt for high head; U.S.$0.27 for heads of 10-30 meters, and U.S. $0.30 for low head. For a high head installation 12-15 percent of the cost is governor, for a low head installation the comparable percentage is 25. These costs are predicated upon a simple diversion structure in the stream and pvc pipe (about 60 meters) from stream to turbine.

Japanese experience with small scale hydropower is interesting for several reasons. In the initial stages during the 1920s, there were no streamflow data for small streams and siting was done by experienced engineers relying on local knowledge. With small, modular units, the risks of miscalculation of minimum flow are small as long as there is reasonable expectation of some flow during the driest days. The hydropower development of industrial New England also proceeded on this basis and it was suggested that Nepal's small scale hydropower development should not wait for good hydrologic data but should begin immediately based on local knowledge and technical experience.

The Japanese government gives tax and credit incentives to farmer cooperatives to install hydroelectric plants. Although this is an assist to Japanese agriculture, the industrialization of villages that is often expected to come from electrification does not always occur. Similar experiences were reported from India and Bangalesh were rural electrification powers irrigation pumps and the light bulbs of the rich, but rarely stimulates industrial development where none existed before.

In Japan, costs of 100-600 KW plants for current construction run from U.S. $875 to $1,400 per KW. Unmanned operation and equipment standardization are goals of programs to build run-of-river plants of small size for which a capacity of 2,000 MW exists in the country for untis of under 1,000 KW. As in the U.S., construction is ordinarily not feasible because of costs and environmental objections.

Mineral Resources of Nepal

A review of known mineral resources of Nepal reveals no deposits of coal, potash, or phosphates. Exploration for oil and gas is in the initial stages with the greatest potential considered to exist in the semi-arid region north of the Himalaya in western Nepal. Only low-grade iron ore has been found in mid-hill Nepal. Limestone is found in many parts of the country with high-grade deposits near Udaipur. Some iron pyrite deposits are known and magnesite (magnesium carbonate) is found northeast of Kathmandu and near Udaipur.

Use of chemical fertilizers in Nepal reached a high of 13,100 tons in 1973-74, and was 12,300 tons in 1975-76. The average nutrient composition was 69 percent nitrogen (N), 20 percent phosphorus (P), and II percent potassium (K). The price of urea per ton was U.S. $66 in 1970-71, $129 in 1972-73, and $360 in 1974-75. Comparable potash prices were $70, $77, and $240. About 57 percent of chemical fertilizers is used on paddy, 28 percent on wheat, 10 percent on maize, and 5 percent on other crops. Forty-eight percent was used in the Terai during 1975-76, 39 percent in Kathmandu Valley, and 13 percent in the Hills. Seventy percent went to the Central Region; 4 percent to the Far Western Region. No chemical fertilizer is manufactured in Nepal but use of organic fertilizer is widespread.

Electrolytic Production of Fertilizer

The economic feasibility of establishing an electrolysis plant for production of nitrogen fertilizer was investigated by the Government of Nepal in the early 1970s. This was based on an expected power surplus in the Central and Eastern Regions that has in fact never materialized. Large plants of 50,100, and 150 tons ammonia (NH_3) per day were considered for production of ammonium nitrate. Costs were compared with costs of production of urea based on imported naphtha and were revised in 1975 by a West German firm.

Production costs for a 100 tons NH_3 per day ammonium nitrate plant based on electrolysis were Rs. 1,790 per ton; for urea comparable costs were Rs. 2,420 per ton. Thus, in terms of nutrient, costs are nearly the same.

Although a number of questions were raised regarding the assumptions of these studies, the following issues were considered of most relevance to the seminar. First, with large power supplies, electrolysis is a definite competitor with urea. Second, use of naphtha prices at Calcutta port seriously understates the transport and political costs of naphtha movements over two different gauge Indian railway systems. In fact, there was considerable opinion that naphtha could not practically be transported to Nepal. With electrolysis no raw material transport is required. Third, no consideration in the analyses was given to the much longer gestation periods of naphtha-urea plants as compared to electrolysis-AN plants. Fourth, capacity utilization of electrolysis plants is consistently significantly higher than for the more complex urea plants.

For large and small electrolysis plants the following advantages were adjudge to be of particular interest to Nepal:

(1) simple operation and maintenance;

(2) high reliability;

(3) production rate flexibility;

(4) limited requirement for specialist labor;

(5) only water and air needed as raw materials; and

(6) almost no pollution effects.*

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* Technical details regarding electrolysis and costs of production of different fertilizer products may be found in two seminar papers: (1) Thomas Grundt, Norsk Hydro, Oslo, Norway, "Water Hydrolysis and Its Possibilities as Basis for Fertilizer Production;" and (2) O. W. Livingston; International Fertilizer Development Center, Alabama, U.S.A. "Potential Small Scale Fertilizer Processes for Developing Countries - Nepal Example."

There is little or no economy of scale in water electrolysis but moderate scale economies are present in ammonia synthesis. Of more importance to the seminar was the observation that small plants are readily available for the electrolysis and nitrogen liquefaction units but that design and development would be required for small ammonia synthesis plants that, even in China, are not regularly built below a capacity of 9 tons NH_3 per day.

For Project analysis purposes, Norsk Hydro assumes a total electricity requirement of 13,500 kwh per ton NH_3 and water requirement of 2 tons per ton NH_3. Current NH_3 production costs for an electricity price of 5 U.S. mills per kwh and 100 tons/day production capacity are estimated to be about U.S.$140 per ton NH_3. For a price of 10 U.S. mills per kwh, production costs are about U.S. $210 per ton NH_3. For higher electricity costs it was estimated the cost increases U.S. $100 per ton NH_3 for each 10 U.S. mills per kwh increase in electricity costs. To these costs must be added costs of producing a fertilizer product, which could be:

(1) ammonium nitrate which requires a nitric acid plant;

(2) calcium ammonium nitrate which requires a nitric acid plant and limestone, but which is stable compared with ammonium nitrate;

(3) ammonium bicarbonate which requires carbon dioxide;

(4) aqua ammonia;

(5) urea which requires carbon dioxide; and

(6) ammonium sulfate which requires sulfuric acid.

Each of these products has advantages and disadvantages in Nepal and careful study needs to be given to selection of the product appropriate to each situation. For example, in most situations ammonium sulfate would not be feasible but where iron pyrites exist and industrial use of sulfuric acid is attractive, ammonium sulfate would be a possibility. It was pointed out that China manufactures a great deal of crude ammonium bicarbonate and ammonium nitrate in small scale plants using relatively simple technology. The Chinese also use aqua ammonia which is simple to produce from ammonia and could be well-suited to use in Nepal hill villages applied directly to fields from plastic bags, metal tanks, or in irrigation water.

Because of the extreme variation of flow in Nepal streams it is likely that fertilizer production would be concentrated in the months of higher streamflows. Operation of electrolysis plant at full load for 8 months and shutdown for 4 months would involve no difficulties with catalyst maintenance as might arise from intermittent operation on a short-cycle basis.

Electric Arc Process

An alternative technique to electrolysis for nitrogen fertilizer production is direct nitrogen fixation by electric arc to produce nitrogen oxides, nitric acid, and with the addition of limestone, calcium nitrate which is a fertilizer that can be concentrate and solidified. Dissolved calcium nitrate can be added directly to irrigation water. An electric arc process was used in Norway in the early part of this century and was based on relatively plentiful hydroelectricity.

At present, the C.F. Kettering Research Laboratory in Ohio, U.S.A., is engaged in development of small electric arc units based on wind or water power. They perceive the following advantages of such a system:

(1) minimal transport costs;

(2) low capital investment (cell would be clay sewer pipe or new thermal plastics, electrodes would be iron);

(3) extremely simple technology requiring no import of foreign skills or sophisticated maintenance; and

(4) ready adaptability to modular design for incremental capacity expansion as demand grows.

Efficiencies as high as 10 percent have been reported for the process in historic installations. To date the Kettering Laboratory has achieved an efficiency of 2 percent. A 10 percent efficiency implies an energy input of 10,340 kwh per metric ton of fixed nitrogen. Two percent efficiency implies 51,680 kwh per metric ton.

One of the interesting aspects of the electric arc process is its compatibility with other power loads of varying demand. That is, if a turbine were installed for a flour mill, oil expeller, or rice huller, then with the addition of a generator the turbine could be running the electric arc and making fertilizer when not running the food processor. If it is assumed the food processor operates 40 percent of the year leaving 60 percent excess capacity for the electric arc unit, then a 3 KW turbo-generator would produce about 15,000 kwh that could be used for fertilizer manufacture. At 5 percent efficiency, this would produce 580 kg fixed nitrogen or enough for nearly 6 hectares of land.

Two separate extimates were made of the cost of a 3 KW installation under average conditions prevailing in hill Nepal. The first assumed:

(1) 2 1/2 inch pipe (2,000 feet to give 400 feet heat at U.S.$0.30/foot = $600

(2) siphon intake = $10

(3) screen = $5

(4) 7,200 v, 3 KW turbo-generator unit plus transformer = $900

(5) gate value = $25

(6) trench to cover pvc pipe ($36m^3$ at $1m^3$ per man-day and Rs. 15 per day) = $25

(7) sewer pipe for electric arc cell plus electrodes = $100

TOTAL = $1,690, excluding trensport from U.S.A. to site, about $ $2,500, including transpot

The second cost estimate was based on a larger unit one days' walk from a road with a 50 meter penstock and 200 meter canal (in other words a lower head unit). It was assumed that for this specific installation a 3 KW unit would cost about U.S. $3,000 including the electric arc equipment.

Amortized capital cost of $3,000 at 10 percent and 20 years is $350 per year while operating and maintenance expenses are negligible. Such a 3 KW unit could, at 2 percent efficiency, produce about one-half ton of fixed nitrogen for a cost of $700 per ton -- delivered to the village. Doubling process efficiency would halve this cost.

The electric arc process also produces a large quantity of heat that in many instances could be put to beneficial and productive use. Some uses mentioned were:

(1) crop and hay drying during monsoon;

(2) pottery kiln heating;

(3) dairy industry;

(4) heating of wash water for cleaning and dyeing of cotton and wool yarn and cloth;

(5) space heating;

(6) clothes washing in hot water to prolong clothes life;

(7) rice parboiling and barley flour roasting;

(8) leather tanning and processing;

(9) paper making; and

(10) crop yield increases with heated water irrigation.

Village Energy Balance

To pull together the above elements of electricity/fertilizer supply to a Nepal hill village, a typical village energy balance and an electrification scheme were outlined. The village has 250 people in 48 households with 28.8 ha. of cultivated land. There are 202 cattle and buffalo: 147 cows and 55 males. Crop production is 1.75 ton/ha. maize or paddy equivalent for a total of 50 tons. At 3.5×10^6 kcal per ton this implies a per capita daily caloric intake from maize/paddy of 1,920 kcal.

At 2.5 kg dry dung per animal per day the cattle produce 184 tons dry dug per year. If one-half of this ends up on the fields, a 1.7 percent N content gives 55 kg N per hectare from dung. This is a significant amount of fixed nitrogen transfer to the cultivated fields of the village.

Two kg wood per capita per day is the average fuel wood consumption. Total annual fuelwood use in the village is 183 tons so that there is four times the energy in wood for cooking than in the food. If it is assumed a sustainable yield of 2.5 tons/ha/year is attained, 73 hectares of woodlot would be needed.

Maize stalk produces 2.3 tons/hectare dry matter or 1.5 tons total digestible nutrients (TDN). Comparable figures for paddy straw are 2.2 tons and 0.9 tons. If the entire cultivated area is sown to maize there will be produced 43 tons TDN. Requirement is 1.2 tons/animal/year on the average for a total of 242 tons TDN. Thus about 200 tons TDN/year must come from pasture and forest.

If half of this comes from pasture and pasture productivity is 2 tons/hectare, then 50 hectares of pasture would be needed. Similarly, 40 hectares of forest would be required for animal feeding -- in addition to the 73 hectares needed for fuelwood extraction on a sustainable basis. Thus total land required in the village for crops, pasture, and forest is 192 hectares which gives a per capita land availability approximately equal to the hill Nepal average. It should be emphasized that in local and regional situations this amount of land is no longer available and that forests are not able to be operated on a sustainable basis. As a consequence, deforestation ensues.

Village Electrification

Phase One provision of electricity to this village might include power for irrigation, fertilizer production, and village water supply. Most village houses are assumed to sit about 350 meters above a relatively large, low gradient, north-south flowing river. Directly south of the village is a steep-gradient tributary flowing west-east. Of the total cultivated area of 28.7 hectares, 12 hectares are within 30 meters of the elevation of the major river. (That is, maximum static head to lift water from the river to these 12 hectares is 30 meters.)

Irrigation of winter wheat on these 12 hectares is assumed with a total irrigation requirement of 0.5 meter, or

$$12 \times 10^4 \times 0.5 = 60{,}000 \text{ m}^3$$

Motor-pump efficiency is assumed 50 percent and average total dynamic left 20 meters. Energy requirement will therefore be 6,600 kwh.

This wheat crop is fertilized at the rate of 100 kg N/hectare. The paddy/maize lands during the monsoon season will receive 50 kg N/hectare of chemical fertilizer in addition to the current dosage of organic fertilizers. Chemical fertilizer requirement is therefore:

$$\frac{(100) \times (12) \times (50) \times (28.7)}{1{,}000} = 2.6 \text{ tons N.}$$

If 20,000 kwh are required per ton of fixed N, energy requirement for 2.6 tons N of fertilizer is 52,000 kwh.

For water supply of 20 liters per person per day plus 25 liters per animal per day, and a total lift of 350 meters, energy needed for pumping is 7,100 kwh.

For these three energy uses of water supply, irrigation, and fertilizer production the total annual requirement is 65,700 kwh. At a 75 percent load factor the power requirement is 10 KW. The capital cost of a 10 KW turbogenerator unit is conservatively estimated to be about U.S.$.20,000 in Nepal. Cost of pumps and fertilizer production unit will be approximately another U.S. $20,000 for a total capital investment for the village of U.S. $40,000.

Direct production increases estimated as a result of this investment are as follows:

(1) winter wheat is a new crop, expected to yield 2.5 tons/hectare for total production increase on 12 hectares of 30 tons;

(2) winter wheat straw, 2.8 tons TDN/hectare or 33.6 tons TDN on 12 hectares;

(3) paddy/maize yields will increase with fertilization from 1.75 to 2.75 tons/hectare for a production increase on 28.7 hectares of 28.7 tons;

(4) maize stalk yields will increase by 2 tons TDN/hectare so that if maize is the monsoon crop over all the cultivated area the production increase is 57.4 tons TDN.

Thus foodgrain production increases are 58.7 tons and TDN increases are 91 tons. Valuing foodgrains at U.S.$120 per ton gives a benefit of $7,040 per annum from increased foodgrain availability alone. Moreover, the additional 91 tons of animal TDN will supply nearly half of the non-electrified village deficit thus effecting tremendous relief in the pressure on forests for animal feed. If, in addition, hay from pastures is properly dried with heat from fertilizer production, there should be no need for the village to exploit forests to feed animals or to expand cropped area. The social benefits of this reduced pressure on forests are incalculable. Furthermore, better nutrition and health will ensue.

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