Irrigation in Nepal: Opportunities and Constraints

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Abstract: Agriculture accounts for nearly two-thirds of the gross domestic product of Nepal, one of the least developed countries of the world. Thus, irrigation is important to sustaining the country's economy. While irrigation has been practiced for decades, there is considerable need both to expand the currently irrigated area and to improve the efficiency of existing systems. There is no question that for the future economic development of an agrarian country like Nepal, irrigation development and management must play an important part. This paper reviews the potential of large- to medium-size irrigation projects in the Terai, small-size irrigation projects in the hill areas, groundwater development, farmer-managed irrigation systems, and rehabilitation of existing irrigation projects. The role of irrigation as a means of expansion of production and income of the country and institutional implications is also discussed. It should, however, be noted that before major irrigation projects can be developed, treaties with India have to be negotiated for using the waters of international rivers. Thus, realistically, it is somewhat unlikely that major developments will occur before the year 2000.

Introduction

Nepal is considered one of the least developed countries of the world. In 1986, its population was 16,960,000, with an annual per capita gross national product (GNP) of $160. Currently its population is growing at the rate of 2.7% per annum. It is expected that the country's population will reach 24,480,000 by 2000, and 37,610,000 by 2020. Life expectancy at birth in 1985 was 47 years.

The total area of the country is 14,080,000 ha, out of which it is estimated that 2,320,000 ha are arable. Agriculture is the most important activity, accounting for nearly two-thirds of the gross domestic product. The general trend of total food production in the 1980s has been an increasing one. If the index of food production for 1979–81 is considered to be 100, it was 111.64 in 1986. However, if per capita food production is considered, it was only 97.17 in 1986.

Because of the importance of agriculture to the national economy, irrigation, both small- and large-scale, is essential for the country.

Irrigation

Information on the availability of water in Nepal for irrigation, in terms of its distribution over space and time, is somewhat fragmentary, and serious problems exist on the reliability and representativeness of some of the available data. As a general rule it can be said that more and better quality data exist for surface water as compared to groundwater, and on quantity of water available rather than its quality. Accordingly, the figures and estimates used

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TABLE 1. Irrigation in Nepal

	Area in Thousand Hectares		
(1)	Terai (2)	Hill (3)	Total (4)
Irrigable area	1,870	618	2,488
Area suitable for irrigation	1,246	250	1,496
Area having some irrigation	405	134	539

in this paper, for the most part, should be considered indicative rather than definitive.

Overall Situation

Since Nepal receives considerable precipitation, the country has abundant water available for irrigation, hydropower generation, and other related purposes. In an average year, the annual surface runoff is about 200 km^3, which, if fully utilized, can easily irrigate over 5,000,000 ha, and produce hydroelectricity far in excess of any of Nepal's foreseeable demands. Much of this rainfall, often nearly 80%, occurs during the monsoon months of June–September. This also means that 70–75% of the total annual flows in the rivers occur during this period. Accordingly, provision of perennial irrigation based on storage of water in the wet season and release in the dry season is an expensive proposition even in the Terai region, whereas in the hill region such storage sites are difficult to find because of topographic variations. Accordingly, a significant part of existing irrigation in Nepal is in reality what is called supplementary irrigation.

On the basis of the results available from the Land Resource Mapping Project (LRMP), funded by the Canadian government, some preliminary figures, shown in Table 1, are available on existing and potential irrigable areas in Nepal (Hildreth 1986; "Water" 1984).

Suitability of land for irrigation was considered on the basis of availability of water, type of soil in terms of texture and fertility, topography, including slopes and microrelief, groundwater potential, and drainage. These figures are preliminary.

Whatever the situation, one issue is quite clear. Nepal still has considerable land that can be irrigated, especially in the Terai region.

Irrigation is not new in Nepal: It has been practiced for centuries. What is remarkable, however, is the tremendous expansion of irrigation during the past two decades. The total irrigated area in 1960–61 was estimated to be 31,900 ha, which increased to 117,500 ha in 1969–70, and to 267,400 ha by 1979–80.

Irrigation Development in the Terai

Much of the land currently under some form of irrigation in Nepal is in the Terai region, which is in the foothills of the Himalayan mountains and thus comparatively flat. LRMP identified 405,000 ha of land as under some form of irrigation in the country, which accounts for 75% of the total irrigated land in the Terai. In terms of potential irrigation, LRMP found that a total of 1.246 billion ha of land can be irrigated in the Terai, which is nearly 83% of all irrigable land in Nepal. Thus, not surprisingly, most of the po-

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tentially new irrigable land can be found in Terai.

The Asian Development Bank (ADB) estimated ("Nepal" 1982) that only about 20% of the land in the Terai is under perennial irrigation, most of which was developed by the government. Thus, on much of the land (80%) in the Terai—as in the hill region—irrigation is really of a supplementary nature. Accordingly, in this section—unless otherwise stated—irrigation should be considered primarily supplementary.

If water balance is considered, generally June–September are the four months when precipitation is higher than Thornthwaite Et. The maximum water deficits occur in the premonsoon months of April and May when highest rates of evapotranspiration can be observed in the central and east-central portions of the Terai. While much variation can be observed in water deficits from location to location, LRMP estimated the deficit to be as high as 225 mm/month in May at Khajura, which is equivalent to 7.25 mm/day. Under these conditions, if 100 mm and 200 mm are assumed to be maximum soil-moisture storage capacities, the lengths of growing seasons for shallow-rooted and deep-rooted crops would be 4.5 months and 7.5 months, respectively. Naturally, the lengths of the growing seasons for shallow- and deep-rooted crops will vary in different parts of the Terai, depending on rainfall and soil characteristics.

In addition to the consideration of the length of the growing season, the other factor that should be noted is the unreliability of the rainfall. For example, in southern Terai, it is likely that, once every 10 years, there will be no rainfall in April or May (Hildreth 1986). Similarly, there are prolonged periods when rainfall is less than 2 mm/day. Under these conditions, even supplementary irrigation can produce considerable benefit to cropping patterns and yields.

Because of these climatic patterns, LRMP estimated that up to 9.69 mm/day must be planned in terms of crop-water requirements (Hildreth 1986). This translates to over 2,900 m^3/month/ha of crop-water requirements. Furthermore, since LRMP estimates are based on daily means of individual months, peak crop-water requirements will be much higher. If irrigation water requirements are to be considered, these naturally will be significantly higher than crop-water requirements. Thus, for irrigation planning purposes, and considering the present status of irrigation management in Nepal, water requirements of up to 7,500 m^3/month/ha may prove to be a good design criterion. This translates to a 39% water-use efficiency.

Enough water, however, is available in the Terai to provide for the irrigation needs. Four major river systems—the Koshi, Gondaki, Karnali, and Mahakali—four medium river systems—the Kankai, Bagmati, Rapti, and Babai—and numerous small rivers flow from the Hills to the Terai from a north-to-south direction. It is estimated that the average annual discharge of the rivers originating in Nepal to the Ganges river amounts to 224 billion m^3, which is equivalent to 7,100 m^3/s of continuous flow. While this total quantity of water is undoubtedly substantial, the river flows have significant seasonal fluctuations. An inadequate number of river-gauging stations and their improper allocation make it difficult to estimate the amount of land that can be properly irrigated in the Terai by surface water.

Preliminary estimates ("Water" 1987) indicate that 1,700,000 ha of main *kharif* paddy (summer), 163,000 ha of early paddy, and 480,000 ha of *rabi* wheat (winter) can be irrigated. It should be noted, however, that LRMP

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identified only 1,200,000 ha of land as suitable for irrigation in the Terai, as shown in Table 1. In addition, before such estimates can be taken seriously for planning purposes, other factors—such as the location of the water in relation to the land to be irrigated, cost and manpower necessary for large- and medium-scale irrigation development, and the possibility of bilateral treaties with India to utilize surface waters—need to be considered.

So far as groundwater resources of Nepal are concerned, systematic evaluation has not been carried out. Much of the data available are site-specific and were mainly collected to consider the feasibility of using groundwater for irrigation. In many places observation wells provide information only on static water levels. In the absence of pumping tests, proper interpretation of the data has to be considered more of an art than a science. Overall, however, more data are available for western Terai and very little for eastern Terai.

The Terai is basically a semiconfined or leaky aquifer system. The hydrogeological formation consists of coarse-textured alluvium originating from the Siwaliks and northern mountainous regions, interstratified with fine-textured clayey deposits of the Indo-Gangetic plain. Adjacent to the foot of the Churia hills is the Bhabar zone, which is thought to be highly permeable due to the presence of alluvial fan deposits mainly of gravels and coarse sands. It is generally believed that the Bhabar zone acts as a recharge area for the aquifer systems of the Terai through lateral flow. While it is possible that the importance of the Bhabar zone to recharge the aquifers of the Terai may have been overstressed, it appears to be a correct hypothesis.

On the basis of available data, it is not possible to estimate the annual recharge rate of the aquifer systems of the Terai. Using conservative figures, LRMP estimated that the minimum annual recharge of the Terai aquifer systems is 7,360 m^3/ha. Regardless of what may be a more realistic estimate, it is clear that the available lands in the Terai can be adequately irrigated with an appropriate combination of surface water and groundwater. Generally speaking, availability of water thus is not the limiting factor for irrigation development in the Terai.

For irrigation development in the Terai, drainage is an essential requirement. The combination of high monsoonal rainfall, shallow groundwater tables, and topographical features make provision of drainage critical for agricultural development, especially in flood-prone areas having poorly drained soils. Clearly, if *rabi* cropping is to be encouraged in poorly drained soils with high groundwater levels, substantial investments have to be made for drainage. Even for well-drained soils with relatively deep water tables, drainage will be necessary both to drain excess water from the fiels during the monsoon seasons and to drain off applied irrigation water. Thus, much of the irrigated area in the Terai will require on-farm drainage systems, the extent of which will obviously vary from one location to another.

Irrigation Development in the Hills

Because of topographical conditions, irrigation developments in the hill areas are highly site-specific and, accordingly, generalization may be misleading. Overall, except for floodplains, water from the large and medium-size rivers that flow through the hills cannot be used, since they cut deep through the area, which means that river water levels are at too low an elevation with reference to the fields to be irrigated for effective utilization.

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Consequently, irrigation in the hills is mostly dependent on smaller monsoon-fed streams, some of which have very limited baseflows, while others seem to dry up during the dry season. These streams are difficult to dam for many reasons, among which are: inadequate storage sites, extremely high seasonal monsoon flow, low water-retaining capacity of catchments, high sediment loads, and transportation of large boulders during high-flow season.

Current practices in the hill area to obtain water from small streams for supplementary irrigation include surface stream diversion, minor storage schemes on farm-pond types of impoundment, pumping where energy is available either in the form of electricity or diesel, water turbines driven by the hydraulic energy of streams, or conveying water by pipes. The choice of a specific irrigation method depends on a variety of factors and constraints, inter alia, overall economics of the scheme, subsidies available, accessibility of the site, quality of the soil, extent of irrigable land, and seasonal variation of available water.

Crop-water and irrigation requirements for the hill region cannot be estimated at present. Whereas lower temperature than the Terai may contribute to smaller evaporation and transpiration losses in the hills, wind and turbulent exchange tend to play a more important role in the higher altitudes, contributing to additional losses.

Very little information exists on the prevailing groundwater and the soil moisture conditions in the hills. It is clear that because of the topographical and soil conditions, deep percolation may occur, which means that the water is lost to the area if it percolates beyond the region. In the highly fractured Siwalik formation, water could percolate below the base levels of streams draining the areas, thus basically bypassing the flow downstream.

Whatever the general situation, there are bound to be localized pockets of groundwater. However, the locations of these pockets, estimates of volumes of water that can be extracted on a sustainable basis, and their potential exploitation for agriculture can only be considered when more detailed geological maps of the country are available.

Irrigation as Means of Expansion of Production and Income

Considering the present status of irrigation development and management in Nepal, it is likely that irrigation has considerable potential to further increase agricultural production and the income of people in the irrigated areas, both through construction of new projects and more efficient management of existing ones. While this view is likely to be correct, analysis of the existing situation indicates that if irrigation is to play a crucial role as an engine for further expansion of agricultural production, the management and organization of irrigation systems, including their institutional implications, must be substantially improved.

On the basis of existing data, it is not possible to assess what impact irrigation development alone has had on crop production in Nepal. An analysis of production figures of major crops for the last ten years (1976–87) indicates that, with the exception of paddy, the modest growth in production can be attributed to the increase in cropping area rather than increase in yields ("Report" 1985). Even for paddy the average annual growth in cropping area during this period was 0.6% compared to average annual increase

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in yields of 0.9%, a difference that may not be significant. For maize, the average annual crop yields during this period actually declined by 2.2%. In comparison, the average annual growth of population during the same decade was 2.6%.

It is evident that the introduction of irrigation is having only marginal impact on the overall crop yields. To a certain extent this finding is not surprising for the following reasons:

1. A significant percentage of cropping area in Nepal is under supplementary irrigation, as compared to year-round irrigation, and the management of both supplementary and perennial irrigation systems leaves much to be desired because of low irrigation efficiency.
2. Water is only one of several inputs for the agricultural production process. Even if a reliable water supply is available, which often is not the case, other inputs must be applied at appropriate times in desired quantities. Fertilizer and pesticide use in small-scale irrigation systems are still insufficient, and in most medium- and large-scale products, as observed in Narayani Zone Irrigation Development I Project, inputs are applied somewhat below the recommended level and not always at the right time or of the appropriate type. Under these conditions, it is not surprising that the crop yields are low.

Under the seventh plan (1985–90), His Majesty's Government of Nepal (HMGN) has proposed a total target of 235,493 ha of irrigation development, of which 180,451 ha will be in the Terai and 55,042 ha in the hills. Of this target, the Ministry of Agriculture will develop 100,000 ha of new irrigation, 60% in the Terai and 40% in the hills. Ministry of Water Resources (MWR) will handle an additional 135,493 ha, of which 106,003 ha will be continuing projects and 29,490 ha will be new projects, with an overall split of 89% in the Terai and 11% in the hills. Of this MWR target, 28,048 ha will be handled by district level projects under decentralization plan.

In terms of future developments in Nepal in the area of irrigation, the following alternatives can be considered. It should be noted that the alternatives are not mutually exclusive.

Large to Medium-Size Irrigation Project in the Terai

Harnessing some of the sizable rivers can produce some large to medium-size irrigation projects in the Terai, with command areas ranging between 1,000 and 60,000 ha. These schemes will require surface water storage, spillways, and a network of main, secondary, and tertiary canals and drainage systems. Investment costs are likely to be high ($3,000–$7,000/ha), with operation and maintenance costs around $20–50/ha. These schemes may be economical if irrigation benefits are combined with hydropower and flood control benefits. With such a multipurpose approach and efficient management, preliminary estimates by the World Bank indicate that the schemes can produce an internal rate of return (IRR) of around 12–25% ("Agricultural 1987).

If the overriding concern of HMGN is to increase agricultural production, such schemes are likely to be attractive, since they can irrigate large areas and provide year-round water to a large group of farmers. While such schemes will be capital-intensive, they will generate additional employment through linkage effects, especially larger ones which will undoubtedly influence the level of economic activities in a region. It is also easier to provide extension services to these schemes compared to a series of small projects spread all over the country.

On the negative side, these schemes will require higher levels of substantial technical and managerial expertise, long gestation and implementation periods (5–20 years), and higher environmental costs (submergence of valleys which will mean loss of land for agriculture and forestry, relocation of people from inundated areas, and effective handling of high sediment lands of the Nepalese rivers which shorten the life of reservoirs).

So far as technical aspects are considered, currently insufficient geological and hydrological data are available for planning and constructing large multipurpose dams and reservoirs. Additional data will be necessary on sedimentation rates, and how these may be influenced by the construction of dams. Seismicity would also be an issue. In the absence of seismic data, it is difficult to carry out a risk analysis and the potential impacts of seismic shocks of various magnitudes to the construction and management of dams and reservoirs.

The immediate problem facing HMGN is that all large and medium-size rivers of Nepal cross international borders, and are shared at least with India. Currently, only three treaties exist on the use of water of the Sapta Kosi, Gandaki, and Mahakali rivers between the governments of Nepal and India. While preliminary discussions have only been initiated between the two governments on some of these international waterways, so far HMGN, for internal reasons, has avoided discussion of these issues with the Indian authorities. On the basis of past experiences in that subcontinent, treaties on the development of international rivers take ten years or more to negotiate. If the long gestation and implementation periods for such schemes are considered, it is highly unlikely that Nepal will benefit from these development schemes any earlier than the year 2000 and, realistically, not until much later. In addition, multilateral and bilateral donors have always been reluctant to provide financial assistance for projects on international rivers until agreements have been signed.

During the seventh plan, among the major and medium projects which will be continued are Bagmati (32,000 ha), Koshi Western Canal and Pump Canal (24,280 ha), Khutia (3,500 ha), Kankwi second phase (3,000 ha), Mohana (2,000 ha), Sunsari Morang (2,000 ha), and Mahakali (1,900 ha). Current annual rates of development of these projects are between 4,000 and 6,000 ha.

Hill Irrigation Projects

As has been noted, hill irrigation in Nepal is not new; it has been practiced for many centuries. In terms of total area that can be irrigated, the potential for irrigation development in the hills is more limited than in the Terai. Substantial areas still exist, however, in the hills where new irrigation schemes can be developed or the existing ones can be substantially improved. LRMP estimated total irrigation potential to be 250,000 ha, of which 134,000 ha already has some form of irrigation. Hill irrigation is basically supplementary, which extends the growing period to just before and after the monsoon season.

Investment costs in the hills could fluctuate tremendously from project to

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project. For large projects of 50 ha and more, which are constructed and operated by the Department of Irrigation, Hydrology and Meteorology (DIHM), investment costs are approximately \$3,350–\$4,600/ha, with operational costs of around \$28–65/ha. IRR is relatively low—1–15%.

For small projects of less than 50 ha, the Farm Irrigation and Water Utilization Division (FIWUD), Ministry of Panchayat and Local Development (MPLD), and Agricultural Development Bank of Nepal (ADBN) provide financial support and some initial technical assistance, but generally do not get involved with their operation and management, which is left to the beneficiaries. It is difficult to get a general picture of the hill irrigation schemes, because conditions vary considerably from one project to another, and because of lack of systematic analyses. On the basis of the first 15 Small Farmers Development Projects (SFDP) projects that were implemented over the last five years, development costs per hectare have ranged from Nepalese rupees (NRs) 2,500 (\$1.00 = NRs 17.40) for the 55 ha, 25 beneficiary households in Khopasi to NRs 46,765 for the 10 ha, 10 beneficiary households in Jyamire. Of these, five projects had development costs of below NRs 5,000/ha, and 11 below NRs 8,800/ha. IRR for such projects is likely to vary from 20 to 40%.

For SFDP projects, annual operation and maintenance costs are approximately NRs 1,100/ha. But since damage to intakes and canals may be heavy in certain years, there could be significant fluctuations in year-to-year operation and maintenance costs. For example, for the 47 ha Raj Kulo project in Argali, one of the few projects for which data exist, labor mobilized per year for system maintenance varied from 1,162 to 2,642 person-days (Martin and Yoder 1987). Furthermore, because of factors, such as problematic access to these schemes, the sites being spread too thinly, and the lack of adequate professional manpower, these schemes often prove difficult to supervise during construction phases and to provide with extension and other associated agricultural services. Some progress has been made in recent years toward resolving these problems.

The annual rate of expansion of this type of hill irrigation is unlikely to exceed 1,500 ha in the near future, around 500 ha by DIHK and 1,000 ha by ADBN and FIWUD.

Groundwater Development

Overall, the potential for successful exploitation of groundwater in the Terai is far more promising, both technically and economically, than in the hills. However, tube-well developments require the simultaneous presence of favorable hydrological conditions and energy for sustained operation.

There are both advantages and disadvantages for tube-well development. The main advantages are

1. Topography is not a serious constraint.
2. Sedimentation is not a problem.
3. Tube wells are easy to install; one well can be installed within a two-week period.
4. Farmers who own them have access to reliable water supply.
5. Water management aspects for shallow tube wells are not complex and are relatively easy to handle.
6. Tube-well development processes can be tailored to funding availability.

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The disadvantages of tube-well development in Nepal are the following:

1. Tube-well operation needs energy. Most of the existing shallow tube wells (STW) are diesel-driven. Diesel is costly and its import and distribution are often erratic. Under the present plans, the NEA rural electrification program is expected to reach the first Terai areas by the early 1990s, however, the price of electricity and its continuous availability remain uncertain. While pumps can be energized from an electric grid, the potential impact of the pumping loads, especially if there is a proliferation of pumps in specific areas, can contribute to serious overloading problems. This has become a common phenomenon in India and Pakistan following widespread pump electrification. If tube-well development is to be a priority policy in Nepal, energy availability, requirements, and pricing in the Terai for this sector will require added attention, and probably some subsidy.

2. There is a suction head limitation for STWs, which is susceptible to groundwater table fluctuations. If the groundwater table is not sufficiently high, well failures will occur. The rate of failures of newly installed wells in Nepal is high—around 14%.

3. The operating costs for STWs are high. Thus, if cropping areas and yields are not up to expectation, farmers are known to stop irrigation and sell their pumps.

4. The capacity for well drilling and pump installation is limited at present in Nepal. The annual capacity for installation is likely to be approximately 2,500–4,000 STWs.

Currently there are 13,200 STWs and 190 deep tube wells (DTWs) in the Terai. While the target area for irrigation per STW is 4 ha, in reality it is about 2.5 ha. Typically, STWs are drilled to 40 m and fitted with a surface set of diesel-powered centrifugal pumps, then they produce discharges in the range of 6–25 l/s. Initial investment costs are around \$900–1,000 per well, which translates to \$360–400/ha. The operation costs, however, are high—around \$95–120/ha/yr. While shallow tube wells are likely to be economically attractive, very little data exist to make any general statement on IRR. At present, not surprisingly, it appears that farmers owning 3 ha or more of land have taken advantage of pump irrigation the most.

DTWs are typically drilled to a depth of 100 m and are equipped with deep-set pumps that provide discharges in the range of 30–120 l/s. Investment costs are higher than STWs, around NRs 1,534,000 per unit, with running costs NRs 36/hr for electricity and NRs 75 for diesel. One DTW can serve areas ranging from 30 to 120 ha. Assuming a 30-year well life and an interest rate of 15%, the monthly amortization payment over the life of the well comes to more than NRs 19,000. If the command area of the well is 100 ha, annual amortization cost comes to NRs 2,280/ha. These costs are substantial in view of the currently expected realistic crop yields. For smaller command areas, cost-benefit analysis of the DTWs will show an even less attractive alternative. Furthermore, DTWs require more complex equipment and technical know-how than STWs. Construction period per well is around 3–6 months. DTWs require better organization and water management practices and are more capital-intensive than STWs. Current annual installation capacity of DTWs in Nepal is estimated to be around 25–40.

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Accordingly, if farmers can be induced to use proper levels and types of fertilizers and pesticides, STWs are likely to be an attractive investment possibility in the Terai in the near future to increase food supply.

Farmer-Managed Irrigation Systems (FMIS)

FMIS are simple irrigation systems that are constructed and maintained by the beneficiary farmers, with limited or no involvement of government agencies. These systems mainly provide supplementary irrigation for monsoon paddy cultivation. There are many FMIS which also tap water from perennial sources. The performances of many of these systems are quite impressive since they enable farmers to achieve cropping intensities of 200% or more.

While much interest has been generated in FMIS among Nepalese institutions and foreign donors in recent years, following the Food and Agricultural Organization/United Nations Development Program/Agricultural Development Bank of Nepal (FAO/UNDP/ADBN) field action–cum–research pilot project initiated in two *panchayats* (lowest units of local government) in Dhanusha District in the Terai in 1975 and another two *panchayats* in Nuwakot District in the hills, it has to be admitted that only limited hard data are available at present on their performance or on the extent of their use. For example, current estimates of the total area receiving irrigation through FMIS in Nepal range from 100,000 ha to 400,000 ha.

From the viewpoint of HMGN, FMIS are an attractive proposition, since the initial investment of grant and loan to the farmers for individual schemes is low, and the follow-up expenditures are limited mainly to resolving serious problems occurring from accidents like landslides, boulder damage, etc. Nearly 8%–10% of FMIS sustain such serious damage each year. Farmers are responsible for the normal operation and maintenance of these schemes. Generally, the beneficiary farmers organize a committee that ensures that individual members contribute labor and resources as required. Normally, the systems are cleaned and maintained before the monsoon and the transplantation of paddy. Resource and labor mobilization is determined in proportion to the benefits received by the farming families. As would be expected under such conditions, the performance of FMIS varies tremendously from one system to another. Overall, however, they appear to succeed in their primary objective to provide supplementary irrigation for the monsoon paddy.

There is a tremendous variation in the extent of area irrigated per scheme, as well as in individual complexity. Depending on the type of work that needs to be carried, out, construction time of projects ranges from four months for simple schemes to about 24 months for more complex ones. It should be possible to expand FMIS at the rate of 7,500–10,000 ha/yr.

Investment and operating costs are difficult to estimate for FMIS, since farmers contribute their labor, the cost of materials used is comparatively modest, and the government institutions provide some supervision, technical assistance, grants, and loans.

Like any system, FMIS also have encountered some problems. They appear to perpetuate traditional systems, and improvement, though tangible, is somewhat limited. Crop diversification is often circumscribed, and so is the potential for incremental benefits. The desirability of or the necessity for the

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involvement of the public sector agencies and donor organizations after the initial credit, grant supervision, and technical assistance is still not clear. It is likely that FMIS—at least some systems—may continue to need financial and technical assistance for some years after their inception to obtain good operational results. That government institutions receive many requests from the farmers' organizations to repair and improve irrigation systems may indicate that the groups are unable to generate adequate resources to operate and maintain the existing systems. The other possibility, of course, is that the farmers know that the government is giving grants, and they are simply taking advantage of this free assistance.

While there is no question that considerable potential still exists to improve the overall operational and management performance of FMIS, hard facts and figures are urgently necessary for a reasonable number of projects covering some representative systems. This information will allow clear insight into their cost-effectiveness and long-term sustainability of the system. Additional steps that can be taken by all parties concerned to improve their performance should also be outlined.

Rehabilitation of Irrigation Systems

As a direct consequence of the overly ambitious irrigation development programs in the fourth, fifth, and sixth plans, most of the available resources were allocated to the construction of new projects, with only nominal amounts earmarked for the operation and maintenance of existing irrigation projects. Even with this lopsided emphasis, target achievement in the irrigation sector was less than 40% during the fourth plan (1970–75), 20% during the fifth plan (1975–80), and about 40% in the sixth plan (1980–85). In addition to starving the operation and maintenance budget, the government policy has had some repercussions, at least indirectly, on the completion status of the various projects. For example, an analysis of 18 completed projects in the Terai, which should have had a total command area of 129,500 ha, indicated that by the end of 1986, 103,000 ha (80% of the planned areas) were prepared for irrigation, but during *Kharif* season only 74,000 ha (57%) were receiving irrigation ("Agricultural" 1987). During *rabi* season only 28,200 ha (27%) were being irrigated. Lack of minor investments in the distribution networks has meant seriously reduced return from the major investments.

Rehabilitation and completion of existing irrigation projects are likely to be highly cost-effective, with IRR around 20–30%. Investment costs will be relatively low, around $400–$1,200/ha, and implementation periods likely to range from 8 to 30 months. While this is an attractive policy option, it would also necessitate that HMGN allocate an adequate operation and maintenance budget for the rehabilitated projects. One possibility is to aim for better cost recovery from the existing irrigation projects, which in the recent past has been virtually negligible for most projects. It will, however, require more assured delivery of water to the farmers concerned, substantial improvement of the inefficient collection system of user fees, and an appropriate legal framework for water development, including a legal framework to apply sanctions to the defaulters (Alhéritière 1983). Without a functioning cost recovery system, it is unlikely that a sufficient budget will be available for operation and maintenance on a regular basis.

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Irrigation Institutions

Four government agencies are involved with irrigation development in Nepal—the Department of Irrigation, Hydrology and Meteorology (DIHM) of the Ministry of Water Resources, the Farm Management and Water Utilization Division (FIWUD) of the Ministry of Agriculture, the Ministry of Local Panchayat and Local Development (MPLD), and the Agricultural Development Bank of Nepal (ADBN). While there is some rational basis for the type, extent, geographical distribution, and intensity of activities of the individual institutions, the overall responsibilities are still somewhat loosely defined. The implied national strategy appears to be parallel growth of project implementation institutions, presumably because of the perceived national need for fast expansion of irrigation all over the country. Coordinating mechanisms between the four institutions are still in their infancy, and accordingly, there is little synchronization of activities, planning processes, design standards, and feedback from the field problems to the designers and planners. Under these conditions, some duplication of activity between two or more of these four institutions is inevitable.

An analysis of the four institutions involved in irrigation development indicates certain common sets of problems, even though the magnitude of any specific problem may vary from one agency to another. Among these problems are the following:

1. Lack of well-defined and accepted criteria for project priority ranking and selection, resulting in misallocation of limited resources.
2. Weak planning capability, which to a certain extent can be attributed to inadequate data collection, processing, and retrieval.
3. Shortage of technical and managerial manpower which contributes to weak planning, implementation, and management of the irrigation systems.
4. Unsatisfactory monitoring and evaluation of projects by national and donor agencies.
5. Failure to integrate agricultural support services and facilities with the availability of irrigation water, which contributes to low crop yields.
6. Weak coordination between the four institutions mentioned earlier and the Water and Energy Commission Secretariat.
7. Absence of a reliable system of budget allocation and control.
8. Overemphasis on target-oriented development, without questioning whether such targets are achievable or whether dismal failures to achieve such lofty targets have an adverse impact on staff morale and performance.

While in the near future the parallel growth of the four institutions may not present serious problems, there are bound to be adverse implications over the longer term due to unnecessary duplication of activities, overhead, and competition between institutions for limited resources and manpower, thus exacerbating interinstitutional friction and uneven approaches.

Conclusion

On the basis of analyses and discussions of the various issues that are associated with the irrigation sector, it is evident that Nepal has several options or combination of options that may be pursued so that substantial growth

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in agricultural production can be generated, which will more than keep pace with population growth as well as contribute surpluses for export. The most suitable choice for the country's future will undoubtedly depend on the policies and strategies followed by the government. Whatever options are chosen by the government must be compatible with the available implementation capacity, resource availability, and management capacity.

Surface water and groundwater irrigation development targets, as outlined in the Seventh Plan ("Seventh" 1985), are most ambitious, especially when compared with the performance witnessed under the Fifth and Sixth Plans, and when financial, physical, and institutional constraints are considered. The Seventh Plan proposes to develop and improve a total of 295,600 ha of irrigated land. The government's long-term program projects further development of 226,500 ha of irrigation as proposed under the Eighth Plan (1990–1995) and 97,000 ha under the Ninth Plan (1995–2000). Naturally, such an ambitious long-term plan considers all potential forms of irrigation development options, even though their relative importance may vary from one plan to another during the 1985–2000 period. At present, three major options stand out for these three plans: completion and rehabilitation of surface water irrigation project in the Terai (98,900 ha in the Seventh Plan, 30,000 ha in the Eighth Plan, and 21,500 ha in the Ninth Plan, for a total 150,400 ha); farmer-managed irrigation schemes in the hills and Terai (corresponding figures 60,000 ha, 92,500 ha, and 16,500 ha, for a total of 169,000 ha); and shallow tube wells in the Terai (38,000 ha, 30,000 ha, 20,000 ha, respectively, for a total of 88,000 ha). While the relative importance of these three options appears to be correct, it is somewhat unlikely that these ambitious targets can be successfully achieved during the next 12 years. A more realistic and achievable irrigation program needs to be considered.

There is no question that for the future economic development of an agrarian country like Nepal, irrigation development and management must play an important part. This fact has now been clearly recognized by both HMGN and the various bilateral and multilateral aid agencies active in that country. Irrigation will undoubtedly be a priority activity during the 1990s. However, before major irrigation projects can be developed, treaties with India have to be negotiated for using the waters of international rivers. Currently, bilateral discussions between India and Nepal are taking place; but, as has been noted, it is somewhat unlikely that major developments will occur before the year 2000.

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