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NEWS UPDATE

Singapore International Water Week 2010

3rd Singapore International Water Week themed "Sustainable Cities: Clean and Affordable Water" was held in Singapore from 28th June to 2nd July 2010. The workshop was focused on the need of efficient and cost effective solutions to address water problems amidst a constantly changing environment. Water leader summit, Water convention, Water expo and Business forum were the key events on the Water Week. Similarly, a special workshop on "River basin and Delta Management" was organized to discuss on Integrated Water Resource Management issues in context of river basins and deltas. Over 14,000 participated the summit from around 85 countries/regions .Mr. Balkrishna Khand, Hon Minister, Ministry of Irrigation, Er. Uma Kanta Jha, Secretary, Ministry of Irrigation, Er. Anil Kumar Pokharel, DG, Department of Irrigation and Executive Director, Mr. Pramod Raj Sharma, Ground water Development Board participated on behalf of Government of Nepal.

During Water Leader summit, responding to the question or "how government of Nepal is responding to the effect of climate change in irrigation development." Minister Khand explained that adoption of integrated water resource management by the government will take care of the effect to some extent. He further stressed that the government has emphasized the development of ground water (20000 shallow tubewells per year) for irrigation on ground water resource are lesser affected by the record climate changes.

Seminar on Agricultural Irrigation Management for Developing Countries

Mr. Narendra Raj Sharma, Joint Secretary MOI, Er. Rama Nand Prasad Yadav, Chief SMTP, DOI and Dr. Kishor Kumar Bhattarai, Coordinator NITP, DOI attended seminar on Agricultural Irrigation Management for Developing Countries from June 15 - July 05 organized by China Agricultural University, Beijing, People's Republic of China.

Seminar was focused on water use management in Agriculture and its multi functional roles. Similarly, other issues responsible to boost agricultural production like fertizers, machinery and soil conservation were also discussed. Field visit to the Three George Dam was the highlight of the seminar.

IWMI Nepal day

The Nepal Office of the International Water Management Institute (IWMI) organized an IWMI-Nepal Open Day, celebrating IWMI's 25th anniversary on 08th June 2010 by highlighting its long and fruitful work in Nepal.

The program started with a welcome note by Dr. Colin J. Chartres, Director General IWMI followed by his presentation on IWMI research priority areas focusing on food security for Nepal. IWMI Nepal Office Head Dr. Dhruba Pant presented a brief overview on IWMI 25 years of activities in Nepal. Similary, Dr. Bharat Sharma, Senior Researcher and head IWMI- India presented the impact of IWMI Nepal's work.

The Secretary Er. Umakant Jha, Ministry of Irrigation viewed that past IWMI work has been helpful in policy formulation and appraised the need for research on better irrigation water management. The Secretary, Water and Energy Commission Secretariat, Er. Kishore Thapa opined that there is need for research at basin level and informed that government is preparing Water Resources Policy which will come out very soon. Following that, Dr. Vladimir Smakhtin, Theme Leader, IWMI highlighted the key research niche for future IMWI work. Associate Professor John Janmaat from University of

Highlights of the Issue

Editorial

Fertigation "An integral and modernized effort to increase water & fertilizer productivity"

Fertigation,a new concept in irrigation technoloy for saving water and fertilizer at a time , is the process in which fertilizers are being applied with the irrigation water: Fertilization+ Irrigation. Fertigation has many advantages over other fertilization methods and when properly used, it saves time and labor, fertilizers application is more accurate and uniform, and nutrient uptake by roots is improved. When using fertigation, fertilizer solutions are prepared in advance in stock tanks and the solution is then injected into the irrigation water. Effective fertigation requires knowledge and proper management. In fertigation, fertilization is an integral part of the irrigation system and therefore the irrigation-fertigation system has to be properly designed. Not all fertilizers can be used in fertigation only water soluble fertilizers are appropriate. Different fertilizers differ in their solubility.

Fertigation is an effective & efficient for production of cash crops. It reduce the pressure from high price of fertilizer and help to increase in yields by 15-28% for vegetables & 10-14% for fruits and also increase in quality both externally and internally. Some studies in China revealed that it save in fertilizer by 25-35% in orchard , 20-30% in green-houses and also save in water 2250M^3/ yr.ha for fruits & 1500M^3/yr. ha for vegetables thus increasing water and fertilizer productivity both in a same time. Also it allows to absorb up to 90% of the applied nutrients, while granular or dry fertilizer applications typically result in absorption rate of 10-40%. Thus the benefits of fertigation over traditional method of fertilizer application includes increased nutrient absorption by plants, reduction in fertilizer and chemicals needed, reduced leaching to water table ,reduction in water usage due to the plant's resulting increased root mass being able to trap and hold the water and also the application of nutrients at the precise time they are needed and at the rate they are utilized. Hence this concept of fertilizer application along with irrigation water may be of great importance like our country having fertilizer deficit in space and time both.

Columbia, Okanagan, Canada gave a small presentation on their role in water storage project. Dr. Luna Bharati, Researcher IWMI briefed about the Launch of new project on water storage.

57th Irrigation Day Celebration

57th Irrigation day was celebrated at Department of Irrigation 0n 25th of Chaitra,2066(7th April,2010). Mr. Balkrishna Khand, Irrigation Minister graced the celebration as the chief guest Er. Uma Kanta Jha, Secretary, Ministry of Irrigation, Er. Kishor Thapa, Secretary, Water and Energy Commission and Er. Shital Babu Regmee, Secretary, Ministry of Peace and reconciliation were the special guest of the ceremony. Er. Anil Kumar Pokherel, Director General(DG), Department of Irrigation was the chairperson of the celebration.

He gave token of love to the 43 retired personal appreciating their contribution in Organization. The chief guest also gave prizes to Best Water User Association and Best Employee of the Year selected in this fiscal year. Shreengi Ghat Irrigaiton system,Kapilbastu and Surya Patuwa Irrigation System combinely won the Best Water User Association prize these year. Likewise, Er. Sudhir Man Baisyet,Deputy Director General, Er. Krishna Belbase, Senior Divisional Engineer(SDE),Bijay Chandra Khatiwada,Senior Divisional Engineer(SDE),Mr. Santosh Kumar Dahal, Section Officer, Mr. Surendra Raj Shrestha, Hydrogeologist, Mr. Hari Parajuli, Account officer, Mr Narayan Prashad Satyal, Computer operator, Ms. Susan Bhandari, Computer operator, Mr. Durga Kumar Shrestha, Association Organizer, Mr. Parsuram Kamat and Mr. Nar Bahadur Thapa, Driver were honoured for their work.

In addition to it, Blood Donation Program facilitated by Nepal Red Cross Society also held on that day and 101 people donated blood in that program.

JCKGP-Meeting

Fifth Meeting of Nepal India Joint commitee on Kosi-Gandak Porject (JCKGP) held on June 17-18, 2010, Kathmandu. The Nepalese team was led by Er.A.K.Pokharel, Director General, Department of Irrigation and the Indian team by Mr. Ajay Nayak, Principal Secretary, Water Recourses Department, Government of Bihar, India.

Bangladesh Study Tour

The ADB funded Emergency Flood Damage Rehabilitation Project (EFDRP) organized a 7-day study tour for high officials of Nepal. The tour, which transpired May 29-June 4, 2010, was sponsored by ADB and Nepal Government as part of EFDRP's program for sharing the knowledge of flood rehabilitation works. The participants of this tour comprised of 15 senior officials from Government of Nepal. Er. Prakash Chandra Pokhrel, SDE, Er. Narendra Bahadur Lama, SDE; Er. Pramod Kumar Shrestha, SDE represented on behalf of Ministry of Irrigation.

During seven day tour, participants visited Institute of Water Modeling, Disaster Management Bureau, Bangladesh Water Development Board, Roads and Highway Department of Bangladesh where they interacted with high officials of Bangladesh on different aspects of flood. They also visited Flood Rehabilitation works site at Bogra, Gaibandha.

TRAININGS/WORKSHOPS/SEMINARS

National Irrigation Seminar

National Seminar themed "Challenges in Irrigation Development and Management" was held on July 11-12, 2010. It was organized jointly by Department of Irrigation, IWMI- Nepal & INPIM-Nepal. The Seminar was inagurated by Hon Minister Mr. Balkrishna Khand, Ministry of Irrigation and was participated by 66 experts and intellectuals from different field of water and irrigation development and Management. In the two day irrigation seminar 13 technical papers were presented by the experts on the prominant key issues; Year Round Irrigation, Federalism and Resource Distribution, Climate Change, Participatory Irrigation Management and Commercialization and Professionalism in Irrigated Agriculture in the respective five technical sessions.

The chief guest Hon Minister Mr. Balkrishna Khand, Irrigation Minister highlighted on the need of Multipurpose projects for the ensuring the availability of water at the field level on time. He also emphasized on installation of Shallow Tubewell which are cost effecient and managable by the farmers especically in the Terai region. Likewise, Er. Uma Kanta Jha, Secretary, Ministry of Irrigation, stressed on proper management of Irrigation infrastructures and added issue of water management in the government managed irrigation systems. Er. Sheetal Babu Regmee, Secretary, Ministry of Peace and reconciliation and Mr.Ram Prashad Meheta, Chairman, NFIWUAN express the success of the seminar and hope the outcome of the seminar will give a guideline for the further irrigation deveopment and management.

Er. Bhuwanesh Kumar Pradhan, Chief Guest of closing ceremony highlighted on appropriateness and relevancy of the recommendations of the seminar. Er. Anil Kumar Pokherel, DG, Department of Irrigation was the chairperson of both Opening and Closing Session. He ensured that Department will try its best to implement the recommendations of the seminar for the betterment of irrigation development and management.

Technical Staff Training

In close collaboration with Department of Agriculture(DoA), National Agriculture Research Council (NARC) and Agriculture Development Bank (ADB), Department of Irrigation (DoI) is operating Integrated Crop and Water Management Program (ICWMP) to get maximum productivity from the selected irrigation systems.

To review the development of works, discuss technical and non technical hinders, 3 days long Technical Staff Training(TST) was held in Sauraha, Chitwan from 21-23, May and Lumle, Kaski from 26-28 may, 2010. The participants were the District Technical Team(DTT) members comprising Engineer, sub-engineer & Association Organizer (A.O.) from Irrigation office and Subject Matter Specialist(SMS) & Junior Technician (JT/JTA) from Agriculture Development office.

The Director General Mr. Bijay Kumar Mallik, Director Dr. Suraj Pokharel from DoA; Deputy Director Genaral Er. Uttam Raj Timilsina, Chief, SMTP Er. Rama Nand Prasad Yadav from DoI and Senior Scientist Dr. Ek Raj Bhattarai, NARC were involved as resource persons and the participants got direct exposure to the related high level officials to interact with the problems faced in the field during implementation. The officials jointly assure the support and necessary help to the program execution from the central level.

FEATURE ARTICLES

Adoption of Lay Flat Thin Polythene Tubing (LFTPT) in Shallow Tubewell and Small Lift Irrigation Schemes

✍ **Shreemat Shrestha**

Background

In the irrigation system the conveyance loss and water application loss is one of the major factors for the low water use efficiency in irrigation system in Nepal. During the design of surface as well as ground water irrigation system, the construction of field channel is not considered. Because of lack of field channel, farmers irrigate by using plot to plot (cascade type) check basin method. Hence, because of lack of field channel low water application efficiency is obtained. Previously, almost in all the cases of shallow tube wells as well as small lift irrigation system in Nepal, water is conveyed through earthen channel which results high conveyance losses. Because of high conveyance and low water application efficiency, less area is irrigated in winter and spring season. Similarly in the case of shallow tube well the cost of irrigation is significantly increased. In this context lay flat thin wall polyethylene tubing (LFTPT) is available in the market for easy conveyance of water. Because of low cost and easiness in handling, farmers have started adopting this LFTPT for conveyance of irrigation water mainly in the case of small lift irrigation and shallow tube well irrigation system. In this context a study was conducted by Nepalese Society of Agricultural Engineers (NSAE) in Kavre and Chitwan on the efficacy of LFTPT with the support of Department of Irrigation (DOI) in 2010.

Major Findings

It is found to be adopted by the small farmers (with land area 0.15 ha) to medium farmers (with land area 2.7 ha) to irrigate their crops (potato, rice, maize, vegetables) in the study area. The farmers in the study areas are adopting LFTPT in small lift and shallow tube well irrigation to save water and irrigation cost. The farmers realized that about 20-40 percent irrigation water is saved and in average about 24 percent of irrigation cost (mainly the energy cost) is reduced after adoption of LFTPT. Portability (light weight and foldable), low cost and easiness in handling irrigation water are the major characteristics of LFTPT that attracted the farmers for its increased adoption in the study area. Hence, significant water saving as well as energy saving is found after the adoption of LFTPT by the farmers for small lift irrigation and shallow tube well and small lift irrigation scheme.

After the comparative test of LFTPT and earthen channel on conveyance efficiency it is found that the conveyance efficiency is about 99 percent in LFTPT where as in earthen channel it is at the range of 76 percent. Even though the discharge of the pump is reduced due to frictional head loss of LFTPT, it is found that more than 13% water is saved by LFTPT in comparison to earthen channel.

In the study area, LFTPT is found to be supplied to the farmers by different types of shops viz. home appliances and plastic goods shop, pump shop and hardware shops. Due to availability of LFTPT in nearby market shops of villages farmers are having easy access to LFTPT. In Chitwan and Kavre, LFTPT is found to be supplied under 3 brands, Kisan Surya and Trishakti brand from Biratnagar and Maruti brand from Birgunj.

Average sales of LFTPT by the surveyed shops in current year is 659 kg (625 kg in Kavre and 692 in Chitwan) where as in last year it was only 319 kg (115 kg in Kavre and 522 kg in Chitwan). It shows that there is quantum jump in sales of LFTPT by more than 100 percent in average. Hence it is evident that LFTPT is getting popularity in the study area.

The LFTPT of different diameters 1.5, 2, 2.5, 3, 4 and 5 inch are available in the market. LFTPT with 3 inch and 4 inch diameter are found to be popular in the study area. The average cost of LFTPT in present market ranges from Rs. 150 to 200 per kg that means the average cost of per meter length of 3 inch and 4 inch diameter LFTPT is Rs. 24 and Rs. 30 respectively. With respect to length it ranges from 30m to 180 m. It is found that LFTPT works successfully at the range of 100-300 m long. Beyond this range the backpressure on the pumps is too large to handle. The life of the thin wall LFTPT is found to be 1-3 years. It is prone to damage due to weathering and puncturing.

Recommendations

After the study following recommendations are made regarding the promotion of LFTPT

- Since, LFTPT is found to be adopted by the farmers and getting popular among the farming communities for conveying water of shallow tube well and small lift irrigation schemes with out the notice of government as well as development organizations, the importance this low cost appropriate technology for small holder is to be recognized by the Department of Irrigation (DOI)and Department of Agriculture (DOA).
- Due to significant reduction in conveyance loss and reduction of irrigation cost by the adoption of LFTPT, it should be considered as an integral part of promotion of shallow tube well and small lift irrigation system by DOI and DOA.
- Since there is lack of information to the users as well as suppliers regarding the efficient utilization of LFTPT for irrigation, clear information is to be provided to the user and supplier for the different quality LFTPT and its efficient use as well as handling and storage to increase its life.
- The life of ordinary LFTPT ranges from 1-3 years and it is prone to damage due to weathering. UV (Ultra Violet) stabilized silpoline

made LFTPT is found to be resistant to damage due to weathering, but it is costlier (1.5 to 2 times) than ordinary LFTPT. To benefit the farmers by the increased life of LFTPT, silpoline made UV stabilized LFTPT is to be promoted by exemption of value added tax and with the provision of subsidy.

- There is also need for regular monitoring of the quality and price of LFTPT so that the farmers can get quality LFTPT at reasonable price. Similarly, there is need of quality testing and standardization of LFTPT so that the user can select the quality product from the market.
- According to the supplier there is 13 percent Value Added Tax in LFTPT. Since it is used for agriculture and conserves water and energy the tax should be waived to make further cheaper so that the small holders can adopt this appropriate technology.
- This LFTPT is found to be used to reduce the conveyance loss (about 13% for 100 m pipe). It is not found to be commonly used to reduce the water application loss by shifting the outlet end systematically. As action research is needed to use it for reducing application loss along with conveyance losses.

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Crop and Irrigation Planning of Kosi (Distrubution) Irrigation System

Madan Mohan Jha

Introduction

Population increase in many developing country needs an increase in agricultural production to meet their increasing food and nutritional demand.The goal to meet these demands can be achieved through irrigated agriculture but rapid expansion of new irrigation schemes will not continue in the next decades due to many reasons e.g. scarce resource, economic and environmental conditions. Poor performance of irrigation system in these countries requires greater attention towards planning, management and development of resources of these systems. Efficient resource utilization is the central issue. Conjunctive use of surface and groundwater resources has now been recognized as a significant strategy for the optimum utilization of regional water resources. Conventionally, irrigation planning and management problems have been approached mainly from the economic and engineering feasibility point of view. But, there usually exist multiple considerations, which should be followed in irrigation development. For example, in Nepal, an updated working policy on irrigation development for the fulfillment of the country's basic needs of food and nutrition requirement has been in effect (IP, 2003).

For developing countries, based on the United Nations Industrial Development Organization (UNIDO) guidelines, Goodman (1984) also indicated that the objectives of a water resources project may be expressed as the economic sector development, balanced regional development, engineering and economic feasibility, and financial viability. However, only in a few cases have multiple criteria or objectives been explicitly considered in irrigation planning.Therefore, the purpose of this article is to address the following integrated issues involved during the planning phase of an irrigation project in a developing country: (1) determining alternative irrigation development plans; (2) devising an appropriate cropping pattern; (3) finding optimal surface and groundwater allocation; (4) deriving optimal system capacities of project components; and (5) selecting the most satisfactory development strategy considering multiple objectives.

The study area

Distribution System of The Kosi Irrigation System is chosen for the study area. The Distribution Canal System of the Western Kosi Main Canal irrigates gross command area of 14,125 hectare, however, present command area of it is 11,300 hectares, which can be extended upto total cultivated area of 13500ha. Highlighted part shown on Figure1 is command area of the system. Rice is the main crop, and other important crops are wheat, oilseeds, pulses, maize and vegetables. Immense scope exists for intensification through higher cropping intensities and crop yield. This is possible only by means of effective (reliable and timely) irrigation delivery and crop planning.

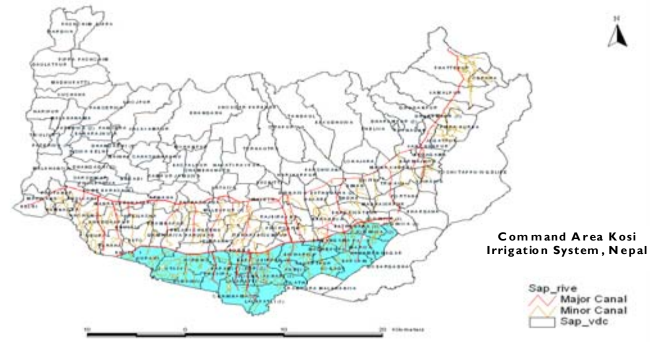

figure 1 : map of command area

Assessment of water resources and water requirements

The water allocation of the Distribution System is 320 cusecs. Annual safe yield of the shallow groundwater system that can be effectively utilized was computed to be 34.27 X 10^6 m^3. Net irrigation-water requirements for major crops were computed using reference crop evapo-transpiration values obtained by the FAO-56 Penman Monteith method for the agro-climatological data of the study area by using CROPWAT software.

Goal programming and agricultural planning

Goal Programming is one of the oldest multi criteria decision making techniques. The objectives of goal programming are defined as a) maximization of profit, b) maximization of protein and calorie requirements and c) maximization of area.

Model Formulation

There are two types of constraints i.e. goal constraint and non goal constraint.

Goal constraint

1st Goal : Maximization of the total net economic benefits from agriculture less the costs of production,

$$-\sum_{i=1}^{12} Si*Cs - \sum_{i=1}^{12} Gi*Cg - n_1 + p_1 = \text{Total Net Return} \quad \text{------} \quad (1)$$

2nd Goal : Maximization of protein value

$$\sum_{i=1}^{N} Ai*Yi*Pi - n_2 + p_2 = \text{Total protein value} \quad \text{--------} \quad (2)$$

3rd Goal : Maximization of calorific value

$$\sum_{i=1}^{N} Ai*Yi*Ci - n_3 + p_3 = \text{Total Calorific value} \quad \text{--------} \quad (3)$$

4th Goal : Maximize the total irrigated cropped Area

$$\sum_{i=1}^{N} Ai - n_4 + p_4 = \text{Total area} \quad \text{------} \quad (4)$$

Where, A_i= Area under i th crop activity
R_i= Net return per hectare (excluding water charges) from ith crop activity
N= Total number of crops = 1, 2,……………7
S_i= Optimal surface water releases
G_i= Optimal ground water release
Cs= Cost of unit volume of surface water
Y_i =Yield of ith crop activity.
C_i= Calorie content of ith crop activity.
P_i= Protien content of ith crop activity.
C_g= Cost of unit volume of ground water
n,p=negative, positive deviation from goal

Non goal Constraints

1. Crop water requirement:
The water utilization by any crop in any month should not be more than the surface and ground water available in that month .

$$\sum_{i=1}^{N} I_{it}*Ai \leq d" S_t + G_t \quad \text{------} \quad (5)$$

Where ,
I_{it} =Gross irrigation requirement in excess of effective rainfall for the i th crop in t th month in meter .

2. Maximum area availability constraint:
Area under various crops during any month can not exceed the cultivable command area (CCA) of the study area. Hence total area under monsoon crops can not exceed the CCA. Similarly, total area under winter crops and spring crop should be less than CCA.

$$\sum_{i=1}^{N} Ai \; J \leq AA \quad \text{------} \quad (6)$$

Where ,
AA = Total available land (CCA)
A_{ij} = Area allocated to the ith crop in jth season.

3. Agricultural production requirement:
In order to avoid excessive transportation of various food grains like paddy, pulses, cereals, oil seeds etc. and to fulfill the minimum requirement of the inhabitants of the study area as per their food habits and nutritional requirements, a minimum area for each crop is considered and maximum area for vegetable crop due to limitation of storage

$A_i \geq T_i$ (min) ------ (7)
$A_i T_i$ (max) ------ (8)
Where, T_i = area allocated to i th crop

4. Surface Water availability Constraint:
The maximum surface water utilization by crops during any month can not exceed the net surface water available in that month for utilization or conveyance capacity of canal which ever is minimum.

S_t Q_{st} ------ (9)
Where,
S_t = Surface water requirement in tth month
Q_{st} = Surface water Available in tth month

5. Ground Water availability constraint:
Ground water withdrawal for irrigation in any month should not exceed the 20% of utilizable balance annual ground water recharge.
The constraint equation may be given as;
Gt Qgt ------ (10)
Where,
Gt = Ground water requirement in tth month
Qgt = Ground water Available in tth month

6. Ground water availability: groundwater pumping cannot exceed the safe yield *(SY)* of the ground water safe yield
Gt ≤ SY ------ (11)

7. Non-negativity of the decision variables:
St, Gt,Ai,AA ≥ 0 ------ (12)

Weighted Goal Programming (WGP)

WGP considers all goals simultaneously within a composite objective function comprising the sum of all respective deviations of the goals from their aspiration levels.The deviations are then weighted according to the relative importance of each goal, w_a.The model minimizes the sum of the percentage deviations from the targets. So, in the problem that is under consideration, the composite objective (achievement) function has the following form:

$$\text{Min} = w_1 \times n_1 + w_2 \times n_2 + w_3 \times n_3 + w_4 \times n_4 \quad \text{------} \quad (13)$$

subject to
Eq (1) – Eq (12)
nj,pj = 0 (j = 1,2,…4)

Three different policy scenarios are examined by assigning a diverse set of weights in each case (Table1). Namely, a farmers' friendly (economic) scenario, health friendly and environmental welfare and finally, a compromising scenario are analyzed in order to infer the trade-offs among these.

Gross return, Protein & calorific value and total irrigation water consumption are considered as the most important objectives in the economic, health and environmental scenario respectively, while equal weights are assigned to all objectives in the compromising scenario.

Model application: results and discussion
Individual optimal solutions

As the first step in modeling, the four objective functions were treated separately by solving the single objective LP problems using LINDOsoftware. Individual optimal solutions for the four maximization problems are presented in Tables 2, 3 and 4. Table 2 shows the 'ideal' agricultural development plans while Table 3& Table 4 shows the corresponding 'ideal' cropped area and water allocation policies respectively.

For the first optimization PLR1 (i.e. maximization of net economic benefits) problem, the maximum net annual agricultural benefit is NRs 2563.79 x10^3. The development plan is quite intensive as indicated by a high cropping intensity (295.38%), which is the ratio of total irrigated cropped area (33378 ha) to net irrigated land area (11300 ha). The cropping strategy is oriented towards crops with more gross margins (e.g. Maize, Oilseed). The surface and groundwater utilization rates on an annual basis are 48.96% and 20.49% respectively.

For the second and third optimization PLP1/PLC1 (i.e. maximization of protein and maximization of Calorific values of projected population of the area) subjected to the same set of inputs and constraints have shown same optimal solution.

Table 2: Optimal system variable of individual maximization model

Attributes	PLR1	PLP1	PLC1	PLA4
Total net agri return (10^3 NRs)	2563.79	1693.51	1693.51	2196.49
Protein (x10^8 gm)	73.85	91.18	91.18	75.8
Calorie (x10^9 cal)	2434.12	2984.02	2984.02	2504.01
crop area (x 10^3 ha)	333.78	333.78	333.78	350.45

Table 3: optimal crop area ('00 ha) of individual maximization model

Crop	PLR1 Area	PLP1 Area	PLC1 Area	PLA4 Area
Paddy	113	113	113	132.556
Wheat	0	109	109	13.22
Oilseed	109	0	0	60.46
Pulse	0	0	0	41.52
Vegetable	4	4	4	4
Maize	107.78	107.78	107.78	87.56
Spring paddy	0	0	0	11
Tatal Area	333.78	333.78	333.78	350.316
CI(%)	295.38	295.3805	295.3805	264.27

Table 4: optimal water allocation (x 10^6 m^3) of individual maximization model

Month	PLR1		PLP1/PLC1		PLA4	
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
January	4.58	0	6.67	6.85	7.35	0
February	21.57	0	22.23	0	23.33	0
March	19.18	0	3.06	6.85	23.33	0
April	23.33	0.17	23.33	0.17	23.33	0
May	23.33	6.85	23.33	6.85	23.33	4.91
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	10.283	0	10.283	0	12.06	0
November	19.89	0	19.89	0	23.33	0
December	3.47	0	14.48	0	6.57	0
IWU	125.633	7.02	123.273	20.72	142.63	4.91
Utilize %	48.96	20.49	48.04	60.48	55.58	14.33
Total water use	132.65		143.993		147.54	

For the fourth optimization PLA4 (i.e. maximization of irrigated cropped area) subjected to the same set of inputs and constraints, the maximum total cropped area is 35031 ha with a cropping intensity of only 264.27%.

It is clearly seen that the three solutions are in conflict with each other and a trade-off among them should be made by using weighted goal programming. Weights are allocated as per table1 and results are as follows;

Comparison of WGP result

Table 5 depicts the results of all the scenarios of weighted goal programming. More precisely, it displays the goal values, the deviation of attributes from goal and final values of each attributes to assess the results in a better way. It is clear from result that economic scenarios end up to highest optimal value in terms of total net return and total cropped area but there is deviation of each attributes from its goals.

Table 5: Optimal system variables under different scenario

Attributes	Economic scenario	Health scenario	Environmental scenario	compromise
Total net return goal (x10^3 NRs)	2564	1694	2196	2196
Protein goal (x10^8 gm)	74	91	76	76
Calorie goal(x10^9 cal)	2434	2984.	2504	2504
crop area goal (x 10^3 ha)	334	334	350	350
N1	319	0	0	0
N2	0	10	0	0
N3	0	315.47	0	0
N4	0	0	0	0
P1	0	324.20	0	0
P2	4.07	0	0	0
P3	141.25	0	4.69	0
P4	23.40	22.70	1.05	0.25
Total net return achieved (x10^3 NRs)	2245	2018.2	2196	2196
Protein (x10^8 gm)	78.07	81	76	76
Calorie (x10^9 cal)	2575.25	2668.53	2508.69	2504
crop area (x 10^3 ha)	357.4	356.7	351.05	350.25

Again, environmental and compromise scenarios would have the most satisfactory solution with minimum deviation from the 'ideal point'. But all other attribute values are less than economic scenarios, but protein and calorific values are lowest among all. Similarly, health scenario has highest protein and calorific value but total net return is lowest among all.

It is also clear that economic scenario maintained existing cropping pattern which is not possible earlier in PLR_1 plan (benefit maximization).

Among the entire tested scenario, economic scenario would have the most satisfactory solution.

This plan gives maximum net return Nrs 2.245 million. Total cropped area and cropping intensity are 35739 ha and 270% respectively. Calorific and protein values are also more than demand of the population of the area. Annual surface and ground water use efficiencies are 55% and 24% respectively.

Finally, comparing attribute of most satisfactory economic scenario with existing one. Table 6 compare different attribute of most satisfactory economic scenario with existing scenario. It is seen total net return in economic scenario is more than three times as compare to existing scenario. Similarly, values of other attributes in economic scenario are also higher than existing one. Comparison with the existing cropped area indicates that the model seems to favor maize crop at the expense of spring paddy and wheat, basically from water supply considerations.

Table 6: comparison of different attributes under economic and existing scenario

Attributes	Economic scenario	Existing
Total net return (x10^3 NRs)	2564	675.12
Protein (x10^8 gm)	74	38
Calorie (x10^9 cal)	2434	1517
crop area (x 10^3 ha)	334	188

This significant difference in coverage of the main crops (e.g. main paddy and wheat) raises two questions. The first is on the effectiveness (i.e. intensity of irrigation) of the existing as well as the proposed crop plans under prevalent conditions. The second question is on the practical viability of the model cropping plans themselves.

Summarizing the optimal values of the system attributes obtained from the planning model for various alternatives show that in consonance with the objectives, the development areas increase as relative preference shifts from maximization of net benefit toward maximization of protein and calorific value and cropped area maximization. Both the maximum monthly surface and groundwater allocations which provide indicative system design capacities (canal capacity and installed well capacity) also increase. Similarly, the annual surface water and ground water utilization increases from individual optimal value. All these figures provide good guidelines for appropriate levels of irrigation development.

Concluding remarks

According to goal programming results, it is important to point out that the economic scenario may not satisfy the health and environment goals, but they end up to better numbers than the status quo. The planning model presented in this article is a versatile mathematical tool for generating and evaluating alternative irrigation development plans based on the conjunctive use of surface and groundwater. The multi-objective framework of the model provides more insight to the decision-making process than conventional use of optimization models. Trade-off possibilities identified between different objectives help in decision making with optimal balancing of different interests. Sensitivity analysis of the solution to changes in important input data can also be carried out to see the effect of uncertain parameters.

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INPIM - Talk Program on: "Demonstrating Enhanced Productivity of Irrigated Agriculture System through Multifunctional WUA: Findings from the RETA Research Case Studies".
20th August, Hotel Himalaya, Kathmandu.
Contact: Er. Suman Sijapati, Chairman, INPIM/Nepal

International Training of Trainers on Wetland Management: "A course focusing on the facilitation of multi-stakeholder processes and curriculum development"
6 - 24 September 2010, Netherland
Website : http://www.cdi.wur.nl/UK/Courses

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12 October 2010, Yogyakarta, Indonesia.
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6th Asian Regional Conference on "Improvement of irrigation and Drainage efficiency under the small land holding condition"
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World Aqua Congress Seminar on: "Emerging Technologies in the Water Sector- Present Status and Need for the Future".
Dec. 8-10, 2010 Indian Habitat Centre, New Delhi, India http://www.environmental – export.com

NPIM - Talk Program on: " Transbasin water transfers in Nepal "
Last week of October, 2010
Kathmandu, Nepal
Contact: Er. Suman Sijapati, Chairman, INPIM/Nepal

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