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PARAMETER ESTIMATION FOR THE MATHEMATICAL MODELING OF THE CASE STUDY

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Parameter Estimation for the Mathematical Modeling of the Case Study

Modi Janak Kumar

Research Scholar

Abstract – This study is a part of my Ph.D. research and included in my thesis as chapter 5. The estimation of the following parameters is the required in the mathematical, kohonen Artificial Neural Networks (KANN) and multicriterion decision making (MCDM) modeling of Baja sagar project (MBSP). These are explained in the following sections.

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ESTIMATION OF CROP DIVERSION REQUIREMENTS

The water requirements of a crop is expressed as the depth of water needed to meet the water loss through reference Evapotranspiration (ET_0) of disease free crop, growing in large fields under non-restricting soil conditions and achieving full production potential under the given growing environment (doorenbos and Pruitt, 1977; pater, 2002).reference Evapotranspiration is determined monteith based on the meteorological data of Banswara station representing MBSP (table 3.3). CROPWAT software developed by food and agriculture (FAO) for penman monteith technique is used in the present analysis for computation of ET_0, there by crop water requirements (http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/cropwat.stm,Allen et al, 1998). Crop Evapotranspiration (Et_c) or crop water requirements are calculated by multiplying the ET0 by crop coefficient k_c.

$$Et_c = k_c \cdot ET_0 \qquad (5.1)$$

The crop duration and crop coefficients used in the present study are based on crop characteristics, rime of planting or sowing, stages of crop development or and general climatic conditions (Doorenbos and Pruitt, 1977; Allen *et al*, 1998; Singh *et al,* 2001) and interaction, personal discussion with project officials and experts (Krishna Rao, 2003; Palanisamy, 2004). ET_C for crop is determined by multiply the respective crop coefficients with ET0. The monthly values of the crop diversion requirements are shown in Table 5.1. Crop diversion requirements CWR_{it} used in the planning mokel is based on overall efficiency of 50% i.e. ratio of crop water requirements to overall efficiency (Bansal, 2003).

MONTHLY INFLOWS INTO THE RESERVOIR

Fourteen years of historical inflow data (MBSP) Inflows Record, 2000) is used to obtain the various dependability levels of inflow into the MBSP. These are computed based on Weibull plotting position formulae (Patra, 2002). Fig. 5.1 presents the inflow values from june to October for various dependable inflow levels (α') which were usedin the irrigation planning model. The inflows of other months are not significant and are neglected. It is observed from Fig. 5.1 that there is wide variation in the inflow values for various dependable inflow levels 50% (summation of inflow values from June to October are 5448.01 Mm^3) to 90% (summation of inflow values from June to October are 1160.36 Mm^3). In the present study, 75% dependable inflow level is employed for MBSP which is amounting to 2880.93 Mm^3 (Maji and Heady, 1980; MBSP Report on Status June 2002 at a Glance, 2002).

EVAPORATION LOSSES FROM THE RESERVOIR

Evaporation losses from the Mahi Bajaj Sagar Reservoir are estimated by Hydrology Directorate of Central Water and Power and Power Commission (Mahi Bajaj Sagar Report, 1978). These are presented in Table 5.2.

Table Monthly crop diversion requirements (meters)

MONTH	ET_0 (mm/day)	maize	paddy	cotton	pulses	Sugar cane	Zaid Crip	Wheat	barley	gram	Barseen	Mustard	Fruits & veg.
January	3.25	0.00	0.00	0.00	0.00	0.21	0.00	0.23	0.23	0.21	0.21	0.07	0.07
February	4.14	0.00	0.00	0.00	0.00	0.19	0.00	0.24	0.23	0.23	0.23	0.06	0.06
March	5.57	0.00	0.00	0.00	0.00	0.21	0.00	0.09	0.07	0.03	0.03	0.03	0.06
April	4.13	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.03
May	7.76	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June	6.81	0.15	0.25	0.08	0.09	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00
July	5.57	0.30	0.35	0.15	0.30	0.35	0.05	0.00	0.00	0.00	0.00	0.00	0.00
August	4.88	0.36	0.34	0.28	0.35	0.32	0.02	0.00	0.00	0.00	0.00	0.00	0.00
September	4.57	0.31	0.30	0.33	0.25	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October	4.39	0.11	0.24	0.33	0.01	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
November	2.09	0.00	0.00	0.13	0.00	0.13	0.00	0.05	0.02	0.03	0.03	0.01	0.02
December	3.07	0.00	0.00	0.13	0.00	0.20	0.00	0.19	0.16	0.13	0.13	0.03	0.05
Total	56.23	1.24	1.47	1.42	1.00	3.08	0.09	0.79	0.72	0.63	0.63	0.21	0.29

Table 5.2 Monthly evaporation losses EV_t (Mm^3)

(Source: Mahi Bajaj Sagar Report, 1978)

Month	Evaporation Losses
January	20.69
February	32.31
March	26.86
April	32.31
May	39.57
June	30.49
July	22.14
August	19.24
September	21.42
October	24.68
November	22.51
December	19.24
Total	311.46

UPSTREAM AND DOWNSTREAM REQUIREMENTS

An inter-state bilateral agreement is made between states of Rajasthan and Madhya Pradesh in the year 1961. Accordingly it was agreed to reserve 268.11 Mm^3 of Mahi water for upstream utilization in Madhya Pradesh. As the places of utilization are very near to the periphery of the Mahi Bajaj Sagar reservoir, it is expected that 84.95 Mm^3 water can flow back into the reservoir as regenerated water during the months of November, December and January (28.32 Mm^3 each) resulting in net sjare of Madhya Pradesh to be 283.17 Mm3 (Mahi Bajaj Sagar Report, 1978). Similar agreement is made between Rajasthan and Gujarat in the year 1966 regarding the sharing of Mahi water. It was agreed to release 1132.67 Mm^3 of water to downstream Gujarat through power house 2 (inclusive of evaporation loss). This includes actual requirements (12x81.14=973.68 Mm^3 as mentioned in Table 5.3) and evaporation losses. The monthly upstream requirements of Madhya Pradesh and downstream requirements to Gujarat are presented in Table 5.3.

Table Monthly upstream and downstream requirements from Mahi Bajaj Sagar Project (Mm^3)

(Source: Mahi Bajaj Sagar Report, 1978)

Month	Upstream requirement of Madhya Pradesh excluding Regeneration (Mm3	Downstream requirement of Gujarat excluding Evaporation Losses (Mm3)
January	94.39	81.14
February	0.00	81.14
March	0.00	81.14
April	0.00	81.14
May	0.00	81.14
June	0.00	81.14
July	0.00	81.14
August	0.00	81.14
September	0.00	81.14
October	0.00	81.14
November	94.39	81.14
December	94.39	81.14
Total	293.17	973.68

HYDROPOWER REQUREMENTS

The Mahi Bajaj Sagar Project includes a dam, a system of canals and two hydroelectric power houses, Power House I (*PH I*) located near Banswara with installed capacity of 2x25 MW and Power House 2 (*PH2*) near Lilvani of installed capacity 2x45 MW. In case of *PH I* average head has been taken as 40 m (Mahi Bajaj Sagar Report, 1978) and dischargeis calculated according to the power generation *WRI,* used in the planning model (Mahi Hydel Project Report, 2003) and is presented in Table 5.4. For example, power generation for the month of January is 13.32 MW. Discharge Q is computed from relation $P=\gamma QH$, where P=Power produced (13.32x10^6 watts); *γ=Unit* weight of water (9810 N/m^3) *Q* is the discharge requirements through turbines (m^3/sec); H= Average head (40m). From this, Q is computed and converted to 88.41 Mm^3 as per the procedure explained in Section 4.2.6. The share of Gujarat state is channelized through *PH 2* (http://www.rajirrigation.gov.in/4mahi.htm). In case of *PH 2*, monthly releases (*WR2,* used in the planning model) are 81.14 Mm^3 (Table 5.3) in the hydel canal, i.e, LMC (Mahi Bajaj Sagar Report, 1978). The project is basically planned to meet irrigation requirements and power heneration is incidental.

Table 5.4 Monthly power generation and corresponding discharge requirements for *PH 1* (Source: Mahi Hydel Project Report, 2003)

Month	Power Generation (MW)	Discharge (Mm^3)
January	13.32	88.41
February	14.30	94.41
March	10.80	71.68
April	9.52	63.18
May	8.80	58.41
June	8.24	54.69
July	7.44	49.38
August	7.82	51.90
September	10.68	70.88
October	14.70	97.56
November	15.30	101.55
December	15.55	103
Total	136.47	905.76

GROSS AND NET RETURNS FROM THE CROPS

The gross returns, seeds cost, fertilizer cost, irrigation charges for crops grown in the command area are obtained from MBSP Report on Project Estimate of Unit-11 (2001). Expenditure on hired labor and plant protection has been taken as Rs. 1070 per ha and Rs. 400 per ha respectively, for irrigated areas. These are presented in Table 5.5. The net returns of each crop per hectare are obtained by deducting the costs of seed, fertilizer, hired labor, irrigation and plant protection from gross returns.

Table 5.5 Net returns (B_t) of various crops grown in the command area (in Rupees)

(Source: MBSP Report on Project Estimate of Unit-11, 2001)

S.NO.	Crop	Gross Returns Per ha	Seeds Cost Per ha	Fertilizer Cost Per ha	Hired Labor Cost Per ha	Irritation Charges per ha	Plant Protection Charges Per ha	Net Returns Per ha
1	Maize (K)	9000	1000	1200	1070	90	400	5240
2	Paddy (K)	15750	750	1000	1070	200	400	12330
3	Cotton (K)	25500	400	1450	1070	180	400	22000
4	Pulses (K)	12800	350	900	1070	105	400	9975
5	Sugarcane (K)	30000	4000	2500	1070	100	400	21930
6	Zaid Crop (K)	14400	350	900	1070	290	400	11390
7	Wheat (R)	23400	2200	1400	1070	150	400	18180
8	Barley (R)	10400	1000	1000	1070	105	400	6825
9	Gram (R)	23340	900	1000	1070	25	400	19945
10	Barseen (RA)	12500	100	1800	1070	90	400	9040
11	Mustard (R)	15000	100	1500	1070	145	400	11785
12	Fruits & Veg. (R)	11200	200	2000	1070	115	400	7415

1. 8 WEIGHTAGE OF VARIOUS PERFORMANCE EVALUATION CRITERIA

A total of seven criteria (indicators) are evaluated for sixteen irrigation subsystems (denoted as ISI to ISI6) of MBSP to assess their performance and to rand them accordingly. This enables in selecting suitable irrigation subsystem that can be made a pilot subsystem to formulate guidelines so that the efficiency and performance of the other irrigation subsystems can be improved. The performance criteria chosen are Land Development Works (LDW), Timely Supply of Inputs (TSI), Conjunctive Use of Water resources (CUW), Participation of Farmers' (PF), Economic (EI), Crop Productivity (CPR) and Environmental Conservation (EC). A management expert was requested to act a decision maker due to vast experience in the field of Multicriterion Decision Making and allied fields and his acquaintance with the planning problem. The decision maker was requested to assess the relative importance of seven criteria using Analytic Hierarchy Process (AHP). The decision maker was provided with addition information such as Reponses from questionnaire in the form of summary, villages covered, and socio-economic conditions of the farmers' in MBSP. Opinion of the project officials are also explained to him as additional information.

The decision maker was requested to fill in the pair wise comparison matrix based on Saaty's name point scale of AHP (Saaty and Gholamnezhad , 1982; Saaty, 1990) and presented in Table 5.6 Maximum eigen value (λ_{max}) computed by the AHP methodology is based on the given inputs by the decision maker. The eigen vector corresponding to, maximum egen value (λ_{max}) is computed. Normalized Eigen vector values are weight ages of performance criteria. Maximum Eigen value (λ_{max}) and consistency index

(CI) are found to be 7,7637and 0.1273 i.e., [7.7637-7%7-1] as explained in the AHP methodology in Chapter 4. Consistency ratio (C_R) which is consistency index to random index (its value is 1, 32 for matrix size *N'* =7) is 0.0964. It is found that C_E is less than 0.1 indicating that judgments given by decision maker are satisfactory.

It is observed from Table 5.6 that weights of EI, CPR, CUW, PF, EC, TSI and LDW are 0.3554, 0.1928, 0.117, 0.0925, 0.0881 and 0.0362 respectively. The two criteria EI and CPR contribute approximately 55% to the importance that affects ranking where as other criteria contribute around 45%.

Table 5.6 Pairwise comparison matrix and resulting weights of criteria by

Analytic Hierarchy Process methodology

	LDW	TSI	CUW	PF	EI	CPR	EC	Weights
LDW	1	½	1/3	1/5	1/6	¼	1/3	0.0362
TSI	2	1	1/3	1/3	1/5	½	3	0.0881
CUW	3	3	1	1	1/3	½	1	0.1179
PF	5	3	1	1	1/3	1/3	½	0.1171
EI	6	5	3	3	1	3	5	0.3554
CPR	4	2	2	3	1/3	1	3	0.1928
EC	3	1/3	1	2	1/5	1/3	1	0.0925

λ_{max} = 7.7637, *N'* =7; *CI* =0.1273; *RI*= 1.32; C_R = 0.0964

FORMULATION OF PAYOFF MATRIX FOR PERFORMANCE EVALUATION SCENARIO

Sixteen irrigation subsystems of the Mahi Bajaj Sagar Project are considered in the present analysis. Payoff matrix is formulated based on the responses from project officials at various levels, interactions with farmers' and interviews with them using structured questionnaire and available project reports. Two matrices, namely, analyst (researcher) and farmer's payoff matrix are formulated.

Table 5.7 Payoff matrix formulated by the analyst

IS No.	Irrigation Subsystem	LDW	TSI	CUW	PF	EI	CPR	EC
IS1	Banka	35	75	40	65	40	45	65
IS2	Chhich	40	35	45	55	45	55	60
IS3	Gopinath	20	80	25	50	60	50	70
IS4	Parsoliya	40	40	55	55	65	60	80
IS5	Arthuna	65	45	50	45	50	50	65
IS6	Badliya	45	85	30	70	50	70	55
IS7	Udpura	65	85	45	35	50	30	35
IS8	Bhawarwad	50	75	55	60	70	45	70
IS9	Narwali	45	65	50	80	55	45	45
IS10	Jagpura	35	60	35	65	55	60	70
IS11	Karan Pur	50	75	60	70	40	65	60
IS12	Ganoda	45	80	50	70	65	60	45
IS13	Loharia	50	55	25	30	45	40	70
IS14	Badi Saderi	55	65	40	25	35	50	75
IS15	Asoda	35	60	45	50	40	60	35
IS16	Khodan	25	65	30	60	50	25	50
MAX		20	35	25	25	35	25	35
MAX		65	85	60	80	70	70	80
RANGE		45	50	35	55	35	45	45

Formulation of analyst (researcher) payoff matrix is based on his feedback of visiting the irrigation subsystems, interaction with farmers' and officials of the project and avaukabke reports, Eacg criterion for the respective irrigation subsystem was assessed subjectively based on numerical scale of 0-100 [Excellent (100), Very Good (80), Good (60), Fair (40), Average (20), Unsatisfactory (0)]. Payoff matrix is presented in Table 5.7. Flexibility is also provided to choose the intermediate values other than those marked on numerical scale to minimize subjectivety while assessing the criteria values.

It is observed from Table 5.7 that the payoff matrix values are ranging from 20to 85. The land development works are given a maximum vlue of 65 in Arthuna (IS5) and (IS7). Timely supply of inputs is given a maximum value of 85 in Badliya (IS6) and Udpura (IS7). Conjunctive use of water resources was given a high value of 60 in Karan Pur (IS11) and low value of 25 to Gopinath Ka Gra (IS3) and Loharia (IS13). It is also observed that participatory irrigation management is getting prominence as evident from their involvement in repair and rehabilitation work of the canals. Very good participation of farmers' is observed in Narwali (IS9) which is given a high value of 80.

Economic impact and crop productivity are given a high value of 70 for Bhawarwad (IS8) and Badliya (IS6) respectively and low value to Badi Saderi (35) and Khodan (25) respectively. High environmental conservation (80) is given for Parsoliya and less in Udpura (35).

Payoff matrix for each farmer is formulated based on the above mentioned numerical scale and their views about the irrigation subsystem to which they belong. The average of the total farmers' response for each irrigation subsystem for each criterion is presented in Table 5.8. Averaging of payoff matrix values gives by farmers' and analyst is made to consider both views in a holistic manner. Average payoff matrix presented in Table 5.9. Is used for grouping and ranking and ranking of irrigation subsystems.

Table 5.8 Average payoff matrix of farmers'

IS No.	Irrigation Subsystem	LDW	TSI	CUW	PF	EI	CPR	EC
IS1	Banka	37	74	38	67	45	44	63
IS2	Chhich	33	69	46	52	39	51	57
IS3	Gopinath	24	84	26	44	54	57	68
IS4	Parsoliya	42	42	57	56	63	54	74
IS5	Arthuna	63	52	44	49	49	51	65
IS6	Badliya	46	84	36	67	47	64	54
IS7	Udpura	69	63	43	41	52	34	36
IS8	Bhawarwad	55	78	48	55	57	52	66
IS9	Narwali	44	64	44	76	53	46	47
IS10	Jagpura	49	57	36	64	61	58	68
IS11	Karan Pur	47	83	51	52	37	62	62
IS12	Ganoda	53	77	47	69	59	59	49
IS13	Loharia	47	56	29	35	50	43	72
IS14	Badi Saderi	51	66	39	29	46	49	69
IS15	Asoda	33	58	46	47	53	58	39
IS16	Khodan	29	61	32	54	51	29	46
MAX		24	42	26	29	37	29	36
MAX		69	84	57	76	63	64	74
RANGE		45	42	31	47	26	35	38

Table 5.9 Average payoff matrix

IS No.	Irrigation Subsystem	LDW	TSI	CUW	PF	EI	CPR	EC
IS1	Banka	36	75	39	66	43	45	64
IS2	Chhich	37	52	46	54	42	53	59
IS3	Gopinath	22	82	26	47	57	54	69
IS4	Parsoliya	41	41	56	56	64	57	77
IS5	Arthuna	64	49	47	47	50	51	65
IS6	Badliya	46	85	33	69	49	67	55
IS7	Udpura	67	84	44	38	51	32	36
IS8	Bhawarwad	53	77	52	58	64	49	68
IS9	Narwali	45	65	47	78	54	46	46
IS10	Jagpura	37	59	36	65	58	59	69
IS11	Karan Pur	49	79	56	61	39	64	61
IS12	Ganoda	54	79	49	70	62	60	47
IS13	Loharia	49	56	27	33	48	42	71
IS14	Badi Saderi	53	66	46	27	41	50	72
IS15	Asoda	34	59	46	49	47	59	37
IS16	Khodan	27	63	31	57	51	27	48
MAX		22	41	26	27	39	27	36
MAX		67	85	56	78	64	67	77
RANGE		45	44	30	51	25	40	41

It is observed from the Table 5.8 that the payoff matrix values range from 24 to 84. It is noticed that timely supply of inputs is very good in Gopinath KaGara (IS3) and Badliya (IS6) whereas there is less utilization of conjunctive use of water. Conjunctive use of water resources is less evident in Gopinath Ka Gara (IS3) with a value of 26 and more in Parsoliya

(IS4) with a value of 57. There is a correlation of supply of inputs and less utilization of conjunctive use of water. Less use of conjunctive use of water may be attributed to the less requirements or more pumping cost. It is also observed that land development works are given low value of 24 for Gopinath Ka Gara (IS3) whereas these are given high value of 69 for Udpura (IS7) by group of farmers'.

Similarly, more participation of farmers' is observed with a value of 76 in Narwali (IS9) and less in Badi Saderi (ISI4). It is also observed that economic impact is more in Parsoliya (IS4) with a value of 63 and less in Karan Pur (ISII) with a value of 37. A similar trend is observed for crop productivity in Badliya (IS6) with a value of 84. Environmental conservation with a value of 74 is given for Parsoliya (IS4) and less in Udpura (IS7) with a value of 36. Payoff matrix values presented in Tables 5.7 and 5.8 represents the subjective opinion of the analyst and a group of farmers' based on a sample survey of 208. The objective of the present study is to understand the system characteristics to make the study more meaningful and develop a systematic and scientific methodology. The data used in modeling is obtained from various sources such as project, secondary sources such as discussions with project with project officials, experts and response survey analysis. The developed methodology can be further improved whenever updated and precise information is available.