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Fuzzy Logic in Reservoir Operation Modelling

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ABSTRACT:-In this paper, an efficient and profitable flood control method by Scientific regulation of a multipurpose reservoir based on fuzzy rules is developed. The main purpose of this study is to establish the relationship between the inputs - storage and inflow and the outputs - drinking water supply, irrigation water distribution, release for power generation and spill from the reservoir. Allocating the surplus in *non-irrigation period* (rainy season) to maximize power generation helps not only in reducing the spill and consequent flooding, but also for earning a substantial income. Due to the temporal variation of inflows and multipurpose demands, the task of allocation of available water becomes more complex. The aim of this paper is to develop a Fuzzy Inference System (FIS) model for flood controlling.

KEYWORDS: Mamdani Fuzzy Inference System (FIS), Membership Function (MF), MATLAB, Fuzzy Rule Base (FRB), Reservoir Management (RM)

I. INTRODUCTION

Flood Hazard remains the most devastating hazard globally, despite substantial investments in flood prevention and management in recent decades. In spite of the scientific knowledge now available, great uncertainty concerning the application of the knowledge to actual problem still remains, primarily due to the uniqueness of each design problem, and the use of subjective judgment and relevant “rules of thumb” is unavoidable. This is why reservoir managers so quickly found a strong affinity with fuzzy set theory. The reservoir management system is a control system that manages the spillway gate in a Dam to increase or decrease the amount of discharge of water.

Drinking water demand remains more or less same throughout the year. Also, irrigation period starts by November and ends by May in a water year. Generally during rainy season (non-irrigating period) from June to October there is no irrigation requirement. The inflow resulting from heavy rains during this season could not be stored as the storage capacity of reservoirs are usually limited. If the surplus can be diverted for power generation and if the tailrace gets discharged to another basin, the flood in the parent basin can not only be mitigated but also the power deficit can be compensated with a substantial income.

A reservoir operation or release plan is a set of rules for deciding how much quantity of water can be made available for each purpose, under various conditions for meeting the conflicting demands and to control flood. System analysis models help to evaluate the operating plans of existing reservoir systems, govern the water allocation systems involving water rights and agreements between water suppliers and users, forecasting management strategies and operation plans, perform real-time operations etc.

It is proven by the experts that the fuzzy concept is a useful tool and can be effectively applied for the real problems in order to arrive at the optimal solution. Yeh (1985) observed that, despite considerable progress, the research relating to reservoir operation has been very slow in finding its way into practice. The managers and reservoir operators are often uncomfortable with the sophisticated optimisation techniques used in the models, which are made much more complex by the inclusion of stochasticity of hydrologic variables. The fuzzy logic approach may provide a promising alternative to the methods used for reservoir operation modelling, because, the approach is more flexible and allows incorporation of expert opinions, which could make it more acceptable to operators. Panigrahi and Mujumdar [1] developed a fuzzy rule based model for the operation of a single purpose reservoir. The model operates on an ‘if – then’ principle, where ‘if’ is a vector of fuzzy premises and the ‘then’ is a vector of fuzzy consequences. This study concludes that by fuzzy based reservoir operation model the complex optimization procedure can be avoided, linguistic statements based on expert

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knowledge can be incorporated and the operators feel more comfortable in using this model. Suryanarayana T.M.V., Mihir Kemkar[2] developed a Fuzzy Rule Based (FRB) model for obtaining the optimal reservoir release. The results obtained shows that the release obtained from the FRB model are satisfying the demand completely for the period of study and there is significant amount of water saving, when compared with the actual release.

The application of fuzzy sets theory can provide a viable way to handle situations when problems with objectives are difficult to define due to imprecision. Out of the two types of Fuzzy Inference System (FIS) named Mamdani type and Sugeno type, the fuzzy inference process named Mamdani's fuzzy inference method has been adopted as it represents the output more realistically.

1. RESERVOIR OPERATION MODELLING WITH FUZZY LOGIC

In modelling of reservoir operation with fuzzy logic, the following distinct steps are planned with the aid of MATLAB package.

In modelling of reservoir operation with fuzzy logic, the following distinct steps are followed: (a) Fuzzification of inputs, where the crisp inputs such as the inflow, reservoir storage and release, are transformed into fuzzy variables, (b) Formulation of the fuzzy rule set, based on an expert knowledge base, (c) Application of a fuzzy operator, to obtain one number representing the premise of each rule, (d) Shaping of the consequence of the rule by implication, and (e) Defuzzification. These steps are discussed in the following paragraphs for a general reservoir operation problem. Some basic concepts of fuzzy logic relevant to the present work are given in Appendix. The application is demonstrated through a case study in the subsequent section.

2.1. Fuzzification of the inputs

The first step in building a fuzzy inference system is to determine the degree to which the inputs belong to each of the appropriate fuzzy sets through the membership functions.

The input is always a crisp numerical value limited to the universe of discourse of the input variable and the result of fuzzification is a fuzzy degree of membership (generally between the interval 0 and 1). The problem of constructing a membership function is that of capturing the meaning of the linguistic terms employed in a particular application adequately and of assigning the meanings of associated operations to the linguistic terms. The general scenario within which construction of a membership function takes place is as follows. The scenario involves a specific knowledge domain of interest, one or more experts in that domain, and a knowledge engineer. The role of knowledge engineer is to elicit the knowledge of interest from the experts, and to express the knowledge in some operational form of a required type. In the first stage, the knowledge engineer attempts to elicit knowledge in terms of propositions expressed in natural language. In the second stage, the knowledge engineer attempts to determine the meaning of each linguistic term employed in these propositions. The methods employed for constructing a membership function, based on experts' judgement, can be classified as direct methods and indirect methods. In the direct method, experts are expected to give answers to various questions that explicitly pertain to the construction of a membership function. In the indirect method, experts are required to answer simpler questions, easier to answer and less sensitive to various biases of the subjective judgement, which pertain to the construction of membership function only implicitly. Both the methods may involve one or more experts. A detailed discussion on construction of membership functions and assigning membership values may also be found in Ross (1997). Civanlar and Trussel (1986) and Devi and Sharma (1985) provided methods of constructing membership function from statistical data. Useful discussions related to construction of membership function may be found in Dombi (1990) and Klir and Yuan (1997). Figure 1 shows the transformation of the storage variable, as an example. For a storage of 300 M m³ the membership value of the variable storage is 0.7, as seen from the figure.

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Vol. 7, Issue 12, December 2018

2.2. Formulation of the fuzzy rule set

The fuzzy rule set is formulated based on expert knowledge. A fuzzy rule may be of the form: If the storage is low, and the inflow is medium in period t , then the release is low. The expert knowledge available on the particular reservoir should always be used for formulating the rule base.

2.3. Application of fuzzy operator

Once the inputs are fuzzified, the degree to which each part of the premise has been satisfied for each rule is known. If the premise of a given rule has more than one part, then a fuzzy operator is applied to obtain one number that represents the result of the premises for that rule. The input to the fuzzy operator may be from two or more membership functions; but the output is a single truth value. The fuzzy logic operators such as the AND or OR operators obey the classical two valued logic. The result of the 'AND' (min) operator

2.4. Implication

The fuzzy operator operates on the input fuzzy sets to provide a single value corresponding to the inputs in the premise. The next step is to apply this result on the output membership function to obtain a fuzzy set for the rule. This is done by the implication method. The input for the implication method is a single number resulting from the premise, and the result of implication is a fuzzy set. Implication occurs for each rule by the AND method which truncates the output fuzzy set, or the prod method which scales the output fuzzy set. In applying the implication to a set of rules, weightages may be attached to different rules to distinguish them from each other based on priorities.

2.5. Aggregation

Aggregation is the unification of the output of each rule by merely joining them. When an input value belongs to the intersection of the two membership functions, fuzzy rules corresponding to both the membership functions are invoked. Each of these rules, after implication, specifies one output fuzzy set. The two output fuzzy sets are then unified to get one single output fuzzy set.

2.6. Defuzzification

The result obtained from implication is in the form of a fuzzy set. For application, this is defuzzified. The input for the defuzzification process is a fuzzy set and the result is a single crisp number. The most common defuzzification method is the 'centroid' evaluation, which returns the center of area under the curve. Other methods for defuzzification include 'bisection', which returns the bisection of the base of the output fuzzy set; 'middle of maximum', which returns the value of middle of maximum of the aggregation of the truncated output fuzzy subsets; 'largest of maximum', which returns the value of largest of maximum of the aggregation of the truncated output fuzzy subsets; and 'smallest of maximum', which returns the value of minimum of maximum of the aggregation of the truncated output fuzzy subsets. For a general discussion on defuzzification, see Hellendoorn and Thomas (1993). The defuzzification methods of maximum membership like largest of maximum (LOM), middle of maximum (MOM) or smallest of maximum (SOM) are derived from the probabilistic method of maximum likelihood. The maximum membership defuzzification scheme suffers from two fundamental problems. First, the mode distribution of the output fuzzy sets is not unique. For continuous membership functions this leads to infinitely many modes. Second, the maximum membership method ignores the information in much of the output fuzzy set. In practice the output fuzzy set is highly asymmetric. Therefore infinitely many output distributions can share the same mode. Yager and Filev (1993) have shown that the selection problem can be implemented by converting the output fuzzy subset into a probability distribution and use this probability distribution to select the element either via performance or by calculation of an expected value. In 'centroid' method of defuzzification we directly compute the real valued output as a normalized combination of membership values.

2. FORMULATION OF MODEL

In this study a water year from June to May is divided to two periods and two distinct set of rules are formulated.

- 1) irrigation(dry) period and

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Vol. 7, Issue 12, December 2018

2) non-irrigation(rainy) period.

Out of the various demands- drinking demand, irrigation demand, power generation demand, the drinking demand is to be satisfied to its 'medium' range and not allowed to fall to 'low' range. Though the Irrigation demand in irrigating (dry) season varies, as far as possible the same is kept in its 'medium' range. Power generation, which is the tertiary aim to control flood, that is allowed to range from 'low' to 'maximum' depending on water availability. As the surplus in non-irrigating season with the high rain runoff to the reservoir is diverted for power generation and its tailrace gets discharge to another catchment/stream, the surplus water during non-irrigating period and the effect rain runoff in the catchment/stream under consideration is highly reduced. and of flood due to the rain in In the present study the following two and four variables are taken as input and output respectively.

Inputs

- Storage (ranges from 0-700 mcm)
- Inflow (ranges from 0-1200 m³/sec)

outputs

- Drinking water release (ranges from 0-150 m³/sec)
- Irrigation water release (ranges from 0-700 m³/sec)
- Power generation (ranges from 0-300 m³/sec)
- spill from the reservoir (ranges from 0-800 m³/sec)

Input

Membership functions are traced to 'low', 'medium', 'high' of storage and inflow.

Output

The prime importance is given to supply drinking water, secondary to irrigation and tertiary to power generation in the *irrigation (dry) period*. In *non-irrigation(rainy) period* importance is given to drinking water supply and for Flood Control by Power Generation. In both the cases the Spillage is to be limited to mitigate Flood.

Knowing the storage, inflow ('low,' 'medium' and 'high') appropriate fuzzy rule is invoked. The fuzzy operator, implication and aggregation together yield a fuzzy set for drinking water supply, irrigation, power generation and spilling. A crisp release is then obtained using centroid of the fuzzy set.

Table 1: fuzzy rules- **irrigation period** (l=low, m=medium, h=high)

Rule No.	Input		Output			
	Storage	Inflow	Drinking	Irrigation	Power	Spill
1	l	l	m	l	l	l
2	l	m	m	l	l	l
3	l	h	h	m	l	l
4	m	l	h	m	l	l
5	m	m	h	m	l	l
6	m	h	h	h	m	m
7	h	l	h	m	l	l
8	h	m	h	h	m	m
9	h	h	h	h	h	h

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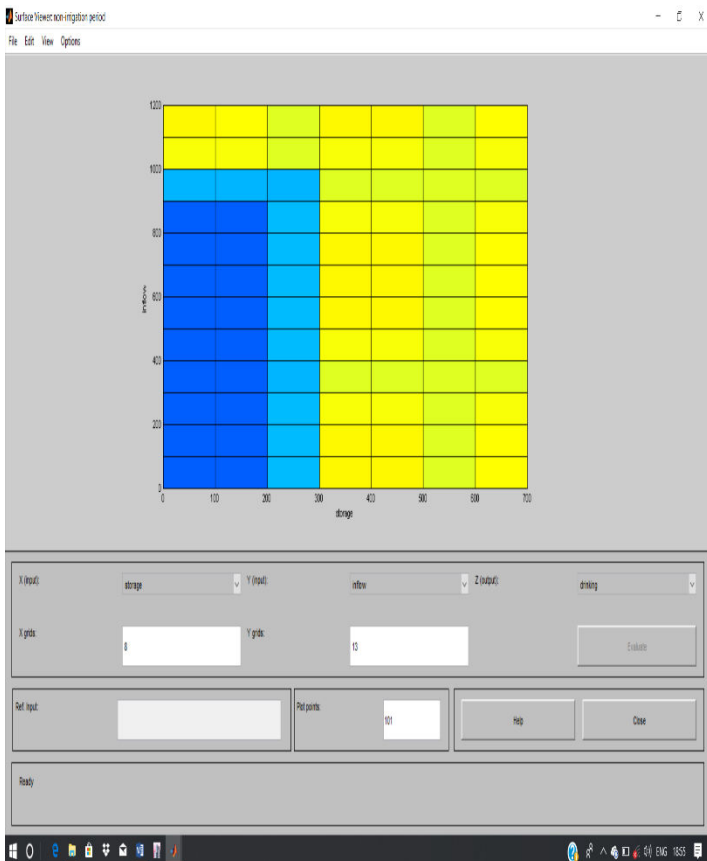
Vol. 7, Issue 12, December 2018

Table 2: fuzzy rules- non irrigation period- rainy season (l=low, m=medium,h=high)

Rule No.	Input		Output			
	Storage	Inflow	Drinking	Irrigation	Power	Spill
1	l	l	m	l	l	l
2	l	m	m	l	l	l
3	l	h	h	l	m	l
4	m	l	h	l	m	l
5	m	m	h	l	m	l
6	m	h	h	l	h	m
7	h	l	h	l	m	l
8	h	m	h	l	h	m
9	h	h	h	l	h	h

2.1 COMPARING OUTPUTS OF IRRIGATING AND NON-IRRIGATING PERIOD

Irrigation period



Non-Irrigation period

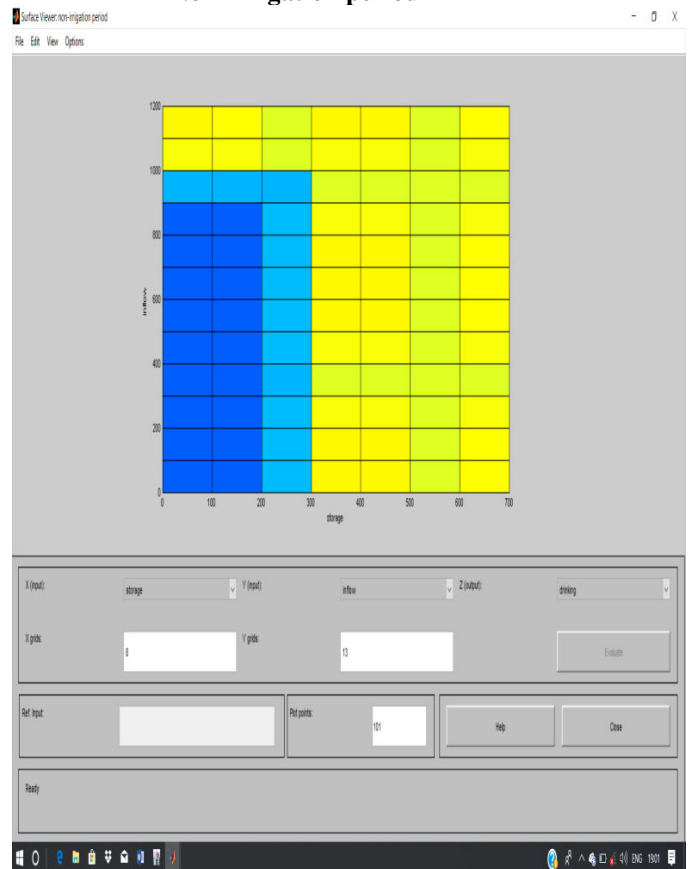


Figure 1: drinking water supply

Irrigation period

Non-Irrigation period

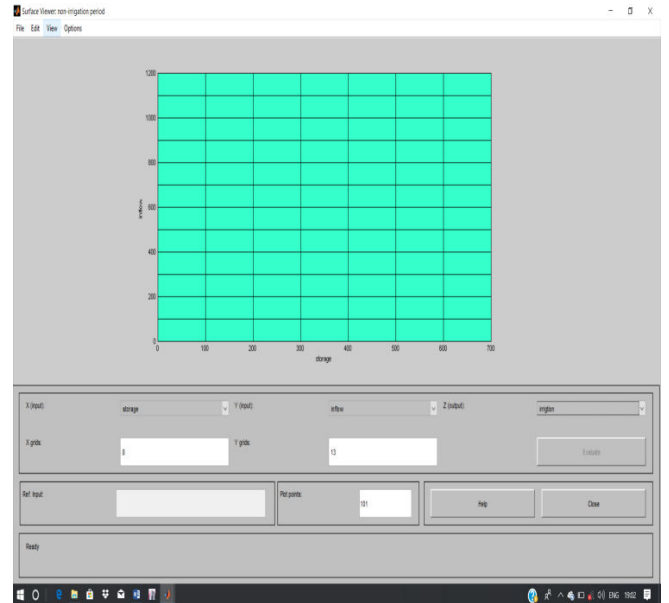
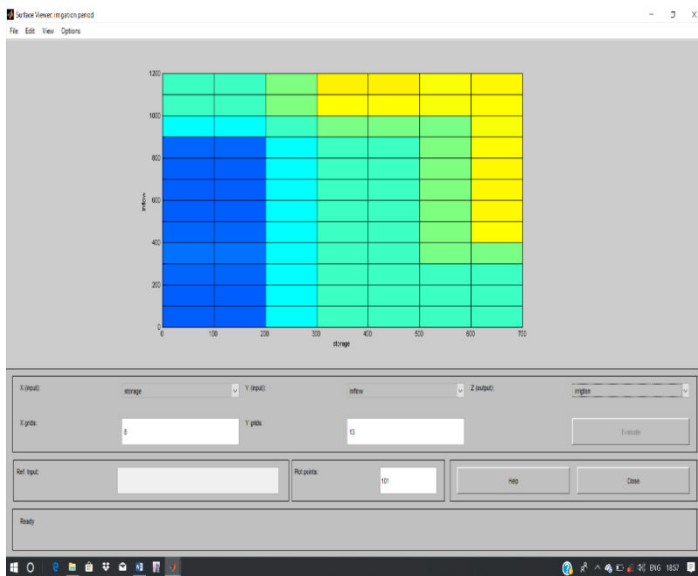


Figure 2: irrigation release

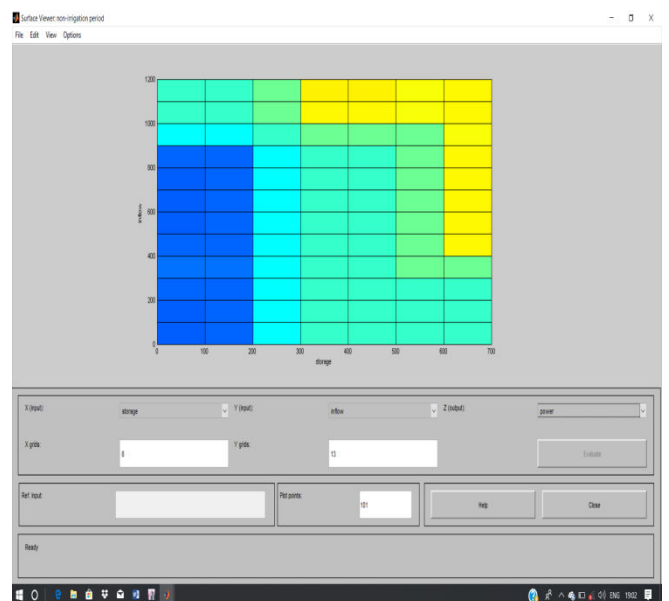
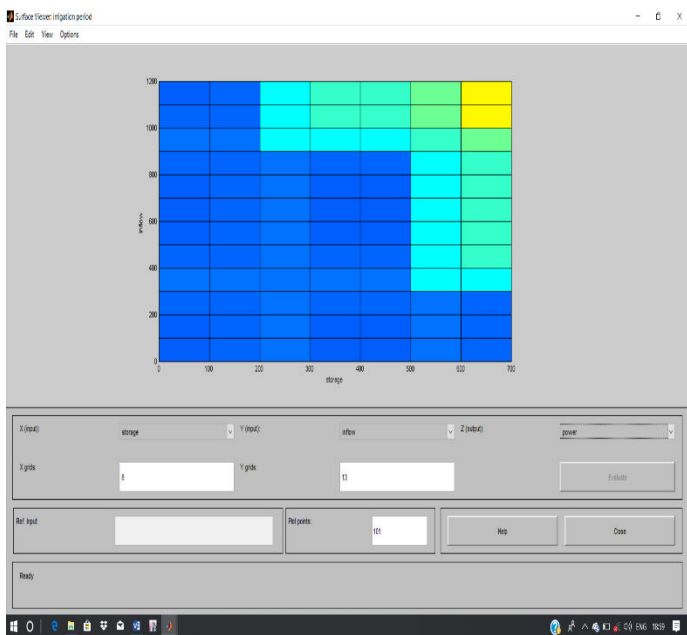


Figure 3: power generation

Irrigation period

Non-Irrigation period

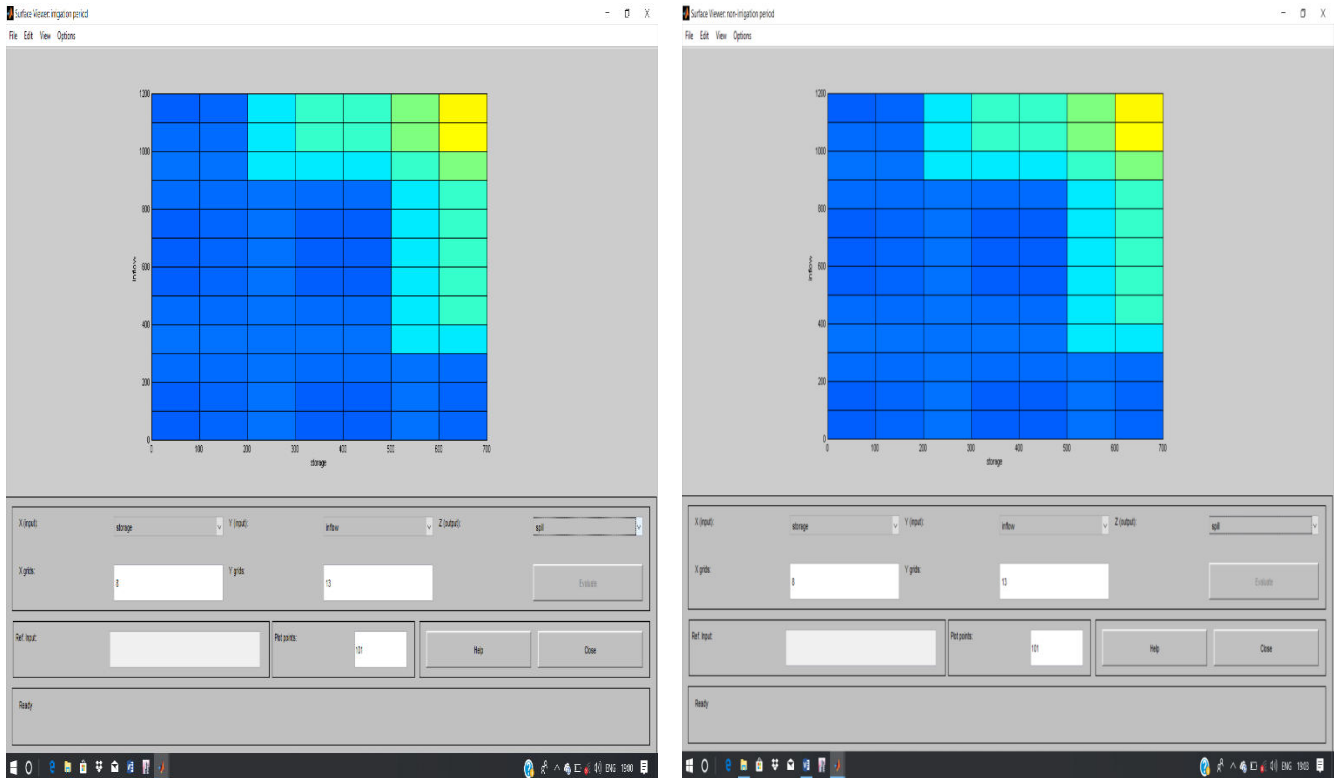


Figure 4: spillage

IV. RESULTS AND CONCLUSION

- Drinking water supply and spillage remains more or less same in both cases. Though there is increase in inflow, it is allocated for power generation and hence flood is mitigated. (fig1&4)
- There is considerable increase in power generation when the storage and inflow increase beyond 300mcm and 1000m³/sec. respectively.
- Spill quantity goes to its peak when storage goes beyond 600mcm and inflow goes beyond 1000m³/s.

V. FUTURE SCOPE

The evaluation of current operating rules of existing reservoirs or forming operation rules, in case it is absent, is very important to control flood. Non power generating reservoirs are to be modelled for power generation as a secondary/tertiary means to mitigate flood hazards.

REFERENCES

- [1] Panigrahi D.P. and Mujumdar P.P. (2000), 'RESERVOIR OPERATION MODELLING WITH FUZZY LOGIC' Water Resources Management, 14 P 89-109.
- [2] Suryanarayana T.M.V., Mihir Kemkar (2014), 'Fuzzy rule based model for optimal reservoir release', International Journal of Modern Engineering Research, 4(6) P 29-32.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 12, December 2018

- [3] Mynepally, Anjaneya Prasad, S.Mohan, (2005), Fuzzy logic model for multi –purpose multi-reservoir
- [4] Li, Y. P., and Huang, G. H. 2009. Fuzzy Stochastic Based Violation Analysis Method for Planning Water Resources Management Systems with Uncertain Information. Inform. Sci., 179(24): 4261-4276.
- [5] Regulwar, D.G. and Gurav, J.B. (2010) Fuzzy Approach Based Management Model for Irrigation Planning. Journal of Water Resource and Protection, 2, 545-554.
- [6] M. Abbas, M. Saleem Khan, Nasir Ali (2011) Fuzzy Logic Based Hydro-Electric Power Dam Control System, International Journal of Scientific & Engineering Research Volume 2, Issue 6, June- 1 ISSN 2229-5518
- [7] R. U. Kamodkar, and D. G. Regulwar (2013), Multipurpose Reservoir Operating Policies: A Fully Fuzzy Linear Programming Approach, J. Agr. Sci. Tech. Vol. 15: 1261-1274

BIOGRAPHY



P.S. KOSHY completed his B.Tech. degree in Civil Engineering from Mahathma Gandhi University, Kerala with Second Rank in the year 1994. He completed his M.Tech. degree in Structural Engineering and Construction Management and presently working as an Executive Engineer in Kerala State Irrigation Department. He has been working as an Irrigation Engineer for the past 20 years and he has a good track record in managing multipurpose Irrigation Dams/Barrages, Irrigation water distribution, canal construction and maintenance. A part from this, he published many technical papers in national and international journals.