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Fuzzy Logic and Statistical Based Modelling to Predict Rural Solid Waste Generation of West Bengal

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Abstract: ***Waste generation prediction is a vital component to planning of rural solid waste management. Based on the past statistical data mathematical model can be develop but incorporation of new data cannot be done. In this situation advance model need to be developed, which can predict. Fuzzy logic may be one option for develop such model because dynamic and linguistic date can be used as an input parameter. A mathematical model has been developed to predicting the total. Rural waste generation using fuzzy logic if west Bengal study area. House hold, population, per capita income, district wise domestic product, literacy rate were considered as an independent variable for predicting rural solid waste generation. To described the dependent and independent variable triangular and trapezoidal shaped membership function are used. To described the defuzzification centroid method has been applied.***

Initially two input variables have been used to identify the correlation with rural solid waste generation Finally all input variable considered for the mathematical model. Per-capita waste generation in rural west Bengal average 150 to 300 gm/day. The statistical analysis rebuilds that age group wise population and income model is the best fitted model.

Keywords: ***Rural solid waste generation, per capita, fuzzy logic, modelling.***

I. INTRODUCTION

Rural Solid Waste Management (RSWM) is an important environmental issue and subject in rural development works. A robust RSWM system consist of the house hold collection, transportation, treatment material recycling, compost and disposal of RSW. It is very much necessary to employ mathematical model to assist decision makes sufficiently in operating such a multi-process RSWM system. Some studies have applied deterministic mathematical model for MSWM. However, there is not any type of study already done on the rural solid waste Management. Significantly successful modelling depends on selection of waste stream. (Kolekar, 2016). Monthly MSW generation can be predict reliably using machine learning algorithms by training with waste generation time series (Abbasi ,2016).

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Waste generation generally is related to demographic, economic, and other social factor. (Younes, 2015). Suitable waste disposal area can be identified by using satellite image and to integrate fuzzy logic modelling and with help of GIS Remote sensing (Lotfi, 2007)

II. METHODOLOGY

A. STUDY AREA: West Bengal is located in the eastern part of India between the Himalayas and the Bay of Bengal. The latitude of West Bengal is 22.978624^{o} N, and the longitude is 87.747803 ^{o} E of India shown in Figure 1. The area of West Bengal is 88.752 km^{2}. The states are near sea level, with the average elevation being 5.18 m. As the states are starts from the Himalaya to near the sea the states have a temperature variation uniform throughout the year. The temperature ranges from 14 to 25 ^{o} C in the winter and 23 to 36^{o}C in the summer. Annual rainfall is around 1600 mm. The humidity level is very high during the summer season.

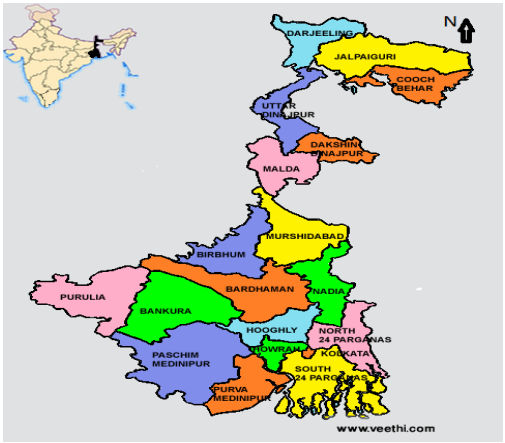

Fig :1 Map showing the study area of West Bengal

B. FUZZY LOGIC: The reasoning of fuzzy logic is approximate not fixed and exact value. Generally, four steps are followed in the fuzzy logic a) Fuzzification b) fuzzy rule c) fuzzy interface and d) defuzzification In fuzzification process crisp values transform into grade of membership function as per fuzzy sets. (u) is a membership function which defines the input space of each point between 0 to 1 in the universes.Membership function of fuzzy logic shows the degree of truth as an extension.
In this present study triangular and trapezoidal shaped membership function has been used.

To described the dependent and independent variables in MATLAB triangular membership function is use to collect three vertex point (a, b, c) Trapezoidal membership function has the flat top and straight lime membership function have the advantage of simplicity.

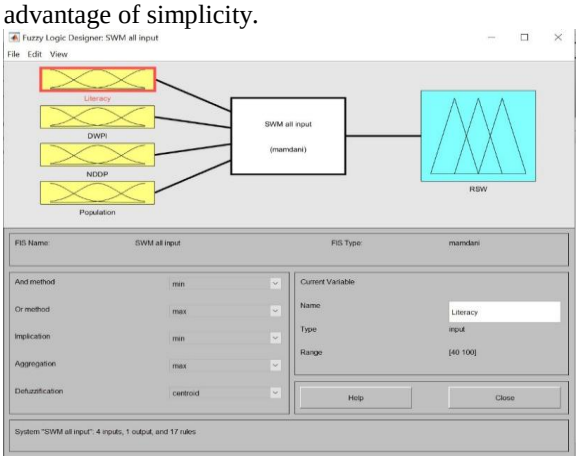

Fig 2 Fuzzy interface modelling for rural solid waste

Identify and selecting the independent variables: Identification of independent variable is the vital role for the model development. These variables were identified based on the literature review. The independent variable may be classified mainly in two part as socio economic condition and demographic condition related.

Socio economic condition related to variables are income, gross domestic product (GDP), Expenditure, tax, employment, retail sales, material consumption, energy consumption, gas consumption power demand. These variables are directly or indirectly affecting the RSW generation. Income is the most wisely and significant component in RSW generation prediction for the rural West Bengal. For this reason, per capita annual income, was used in the study after saving portion a significant income portion indirectly related to waste generation that also taken in to account in this study as a expenditure, buying capacity of consumer.

On the other hand, total population age literacy rate are the most commonly used demographic parameter affecting RSW generation for rural West Bengal.

The total population is most widely and significantly use variable affecting RSW generation followed by age and literacy rate. However, the primary objective of the study is to prediction the factor that affecting the solid waste generation. Therefore, total population was considered as a input parameter along with the age group and literacy rate.

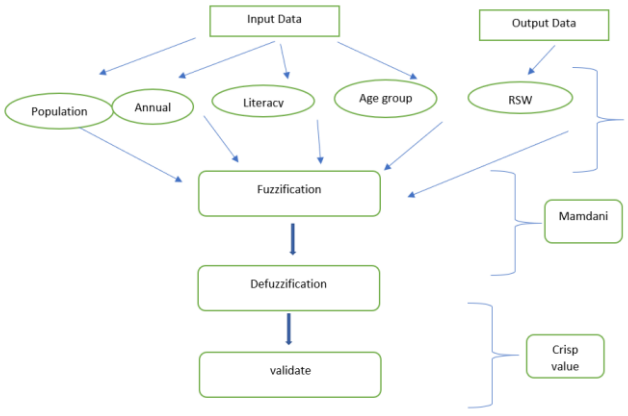

Fig: 3 Diagram of proposed fuzzy model

Detail description of selection of input variables were presented in Kolekar et al. (2016). Finally, most commonly used five input variables were shortlisted 1. Total population 2. literacy rate 3. ODF status 4. Monthly Income/Expenditure 5. District wise net domestic product 6. Population density.

C. Design of survey Instrument: Solid waste generation and socio-economic characteristics data were collection by these survey instruments. Collecting data of population, literacy rate NDDP, Per capita income was used to calculate of SW generation of the study area.

D. Collecting and analysis of data: The primary data were collected by the help of survey. due to unavailable of rural area in Kolkata, at present 17 number of districts has been considered in this experiment. House hold census data are unavailable normality understand the socioeconomic characteristics random sampling approached are used. All the randomly selected 100 house hold of different topographical zone of rural west Bengal were selected for this study. Based on the 100 random sampling 17 data set has been prepared which represent the total population of rural west Bengal in terms of income ,domestic product ,literacy rate of district.(State domestic product report 2013-2014)The weight of solid waste from rural house hold were measured by portable mechanism for accurate data of solid waste.

E. Development of model: The data analysis were done by the fuzzy interface modelling. The MATLAB toolbox use for fuzzy logic system. Their input variable foe fuzzy system, house hold population, per-capita income (PI), district wise gross domestic production (DGDP). Rural solid waste generation indirectly depends on the socio economic, income, expenditure, domestic produce, literacy rate, population. Previous research paper significantly shows that income is directly corelated with prediction of RSW generation.

The house hold consumption also can be related with more waste generation. In first stage 2 type of input variable and output variable were considered for RSW generation. In 2nd stage all variable will be considered for prediction the RSW generation.

F. Fuzzification:

In this fuzzification process two input variable model are used. In this fuzzification Number of rules were planned by using formula mi × nj (where m is the number of levels of ith variable and n is the number of levels of jth variable). The rural are decided based on the all input variable model formula $\Pi mini$=1 where mi is the number of levels of the ith variable. Since by providing input variables several numbers of rules can be generated, which is quite impossible to handle even with software. Hence only general applicable rules on intuition and literature were considered during model development. Based on the inbuilt fuzzy inference of software rule editor and a set of 'If-Then' rules were formulated based on the training data to achieve the desired output.

If necessary, these rules were further modified at the time of testing

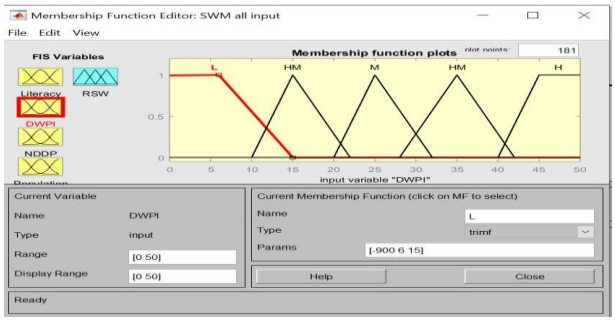

Fig 4 Membership function for district wise per-capita income

a) Total Population: As per census report a place with of 0.1 million was divided in to four groups as low, low medium, medium and high for model development. In this study the total population considered in lakh for defining the membership function.

b) Per capita income: House hold level monthly income of the family are considered income.

c) Literacy rate: Literacy rate of the total population of west Bengal was classified into three categories low, Medium and High (Planning commission of India 2011). Literacy rate was classified in six categories as very low medium high medium high very high for this specific model.

d) Age group: West Bengal planning commission report has classified the percentage of the population of the rural west Bengal in to four groups 0 to 4 5 to 14 ,15 to 59 and 59 to 60 and above. Each and every age group was considered individually and also categorised as low medium and high. This individual categorised age group data are used to identify the SWM generation.Daily RSW generation: As per present study regarding the generation of rural solid waste lies between 50 to 150 gm per day per person. Solid waste generation was classified very low, low, low medium, high medium, low high and very high to predict future generation of RSW for both modelling and design period function were and member ship function were assigned to the data range.

G. Fuzzy rule: In this model development the input and the output function were formulated if and then rules using the and operator. The rule has been presented in the following figure:5 along with the name.

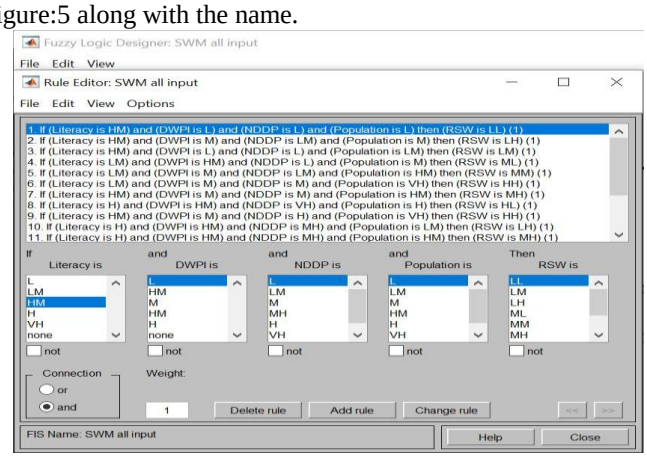

Fig 5 A part of the formed rule editor

H. Fuzzy inference: Using of Mamdani method is a very common process in fuzzy interface system. In fuzzy interface system equal weightage for all the rule and minimum implication for results are considered. Maximization and minimization also applied for aggregation system.

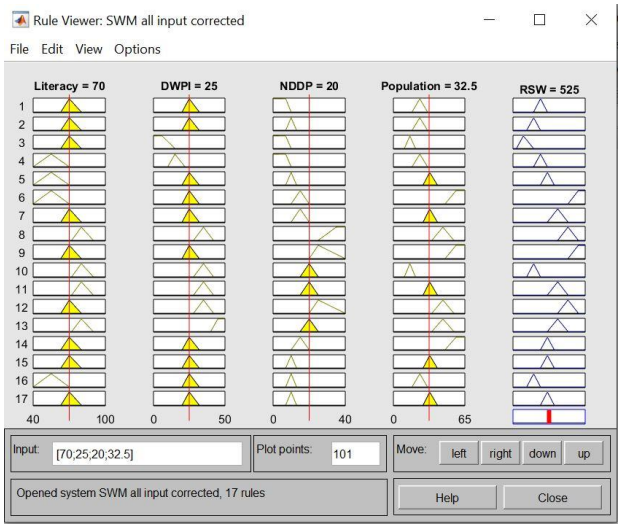

Fig 6 Opened system membership function for district wise SWM

I. Defuzzification: After providing proper input data, the output data were also collected form the fuzzy set. Generally, defuzzification is a essential to convert the crisp output values from the fuzzy model. The accuracy of the defuzzification is depends on the centroid method. Detail schematic diagram of proposed model shown in the figure.

J. Validation of the model: The value of rural solid waste generation obtained from each model was compared with the actual data of rural solid waste generation obtained from the training and testing process and rules applied for each model. The model was validated with renaming data RSW generation. The modelling period related to input variables obtained from best fitted curves. In this modelling 40% data were used for training and 30 % for testing and remain 30 % for validation of model. The developed model was used for future prediction of RSW generation for a specific design period.

III. RESULT & DISCUSSION:

In this research collected data and acquire output values from the model were developed based on the actual values. Average per capita waste generation 20 gm to 150 gm per day per person.

In this fuzzy logic model coefficient of determination (R2) values, adjusted coefficient of determination(R2) and root mean Square error (RMSE) values of four different model were shown in the table 2

It is observed in the table 2 that R2 value range between 0.7478 to 0.9579 for different combination of input values.

Model-1 gives the highest values “0.9579“.

However, Model-1 was best fitted model to predict rural solid waste generation. It can be concluded that input variable literacy rate has been considered lesser accuracy to predict rural waste generation by fuzzy logic. Graphical diagram shown the relationship between input variable and rural waste generation fig 6 from the graphical diagram and output data it is clear that (DWPI), (NDDP), (POP), (LR) directly relation with rural solid waste generation (RSW).

In model 2 (DWPI, POP) and Model 3(DWPI, NDDP, POP) the values shows the similar trends. Since every type of model population values increasing and proportional to the rural solid waste generation also increases It can be sad that rural population is dominant variable for solid waste generation.

Table: 2 Results of statistical analysis for evaluating model

Fuzzy Model	Coefficient of determination (R2)
M1 (DWPI, NDDP, POP, LR)	0.9579
M2 (DWPI. POP)	0.7478
M3 (DWPI, NDDP, POP)	0.8802
M4 (NDDP, POP)	0.8896

In this experiment it can be concluded that model 1 is the best model to calculate the waste generation.

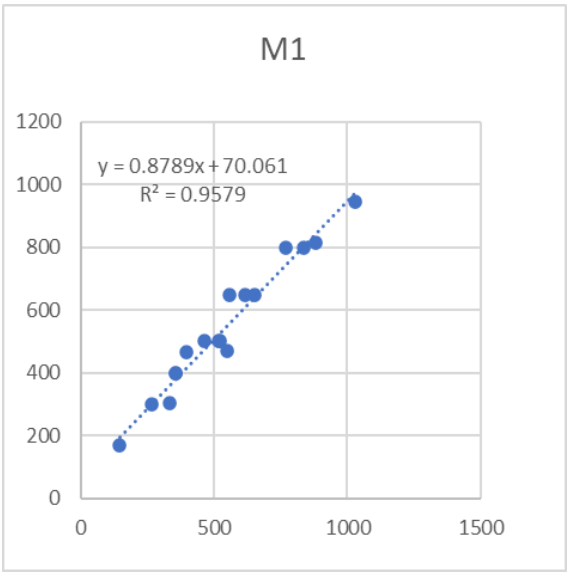

Fig:7 Experimental values

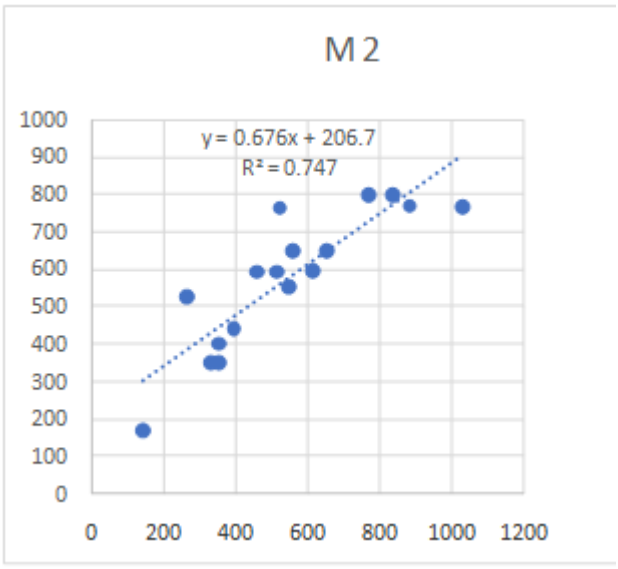

Fig:8 Experimental values

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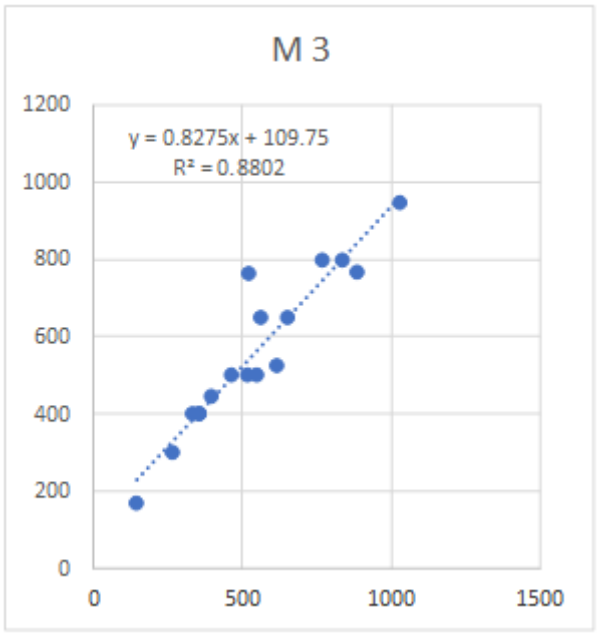

Fig :9 Experimental values

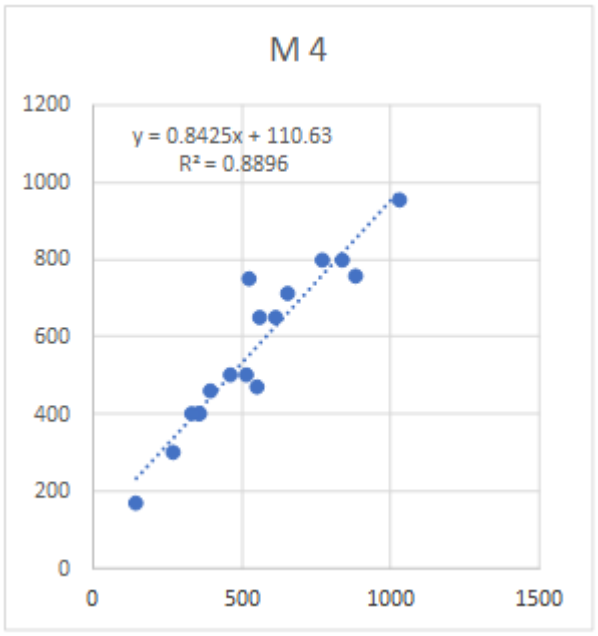

Fig: 10 Experimental values

IV. CONCLUSION

In this research process prediction of rural solid waste generation based on the fuzzy logic model has been evaluated. In this study four type of input variable considered for develop the model. The input variable is age wise population, literacy rate, per-capita income and domestic gross production. Combination of all four variable was applied for the evaluation process. In this process district wise all input are provided for this model. All input variable were considered to find out the general correlation between RSW generation and input parameters.

Fuzzy logic modelling is very much effective to predict the RSW generation. As per experiment results RSW generation has a strong relation with four other variables of the experimental R2 values.

ABBREVIATION

SWM	Solid waste Management
RSW	Rural solid waste
Fig	Figure
CPCB	Central Pollution control Board
MOEF	Ministry of Environment and forest
PRDD	Panchayat and Rural Development Department
GDP	Gross domestic product
NDDP	Net District Domestic Product
DWPI	District wise per-capita Income
POP	Population
LR	Literacy Rate

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