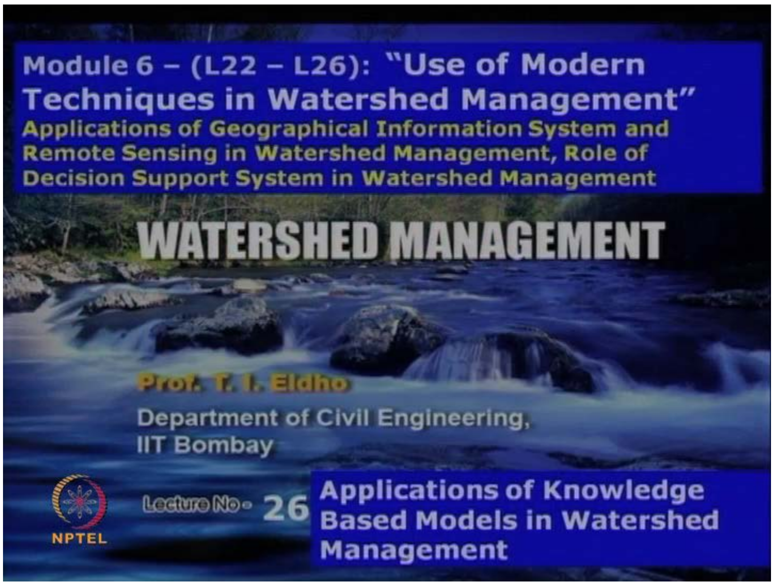
Watershed Management
Prof. T. I. Eldho
Department of Civil Engineering
Indian Institute of Technology, Bombay

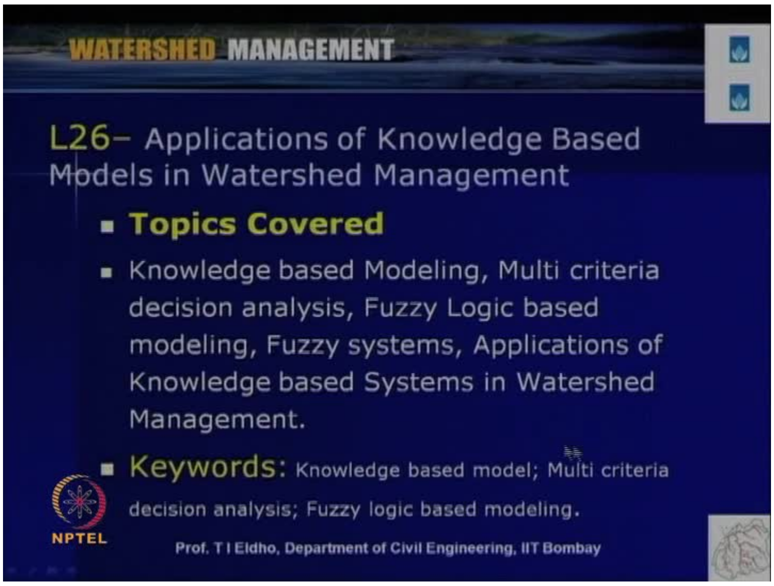
Lecture No. # 26
Applications of Knowledge Based Models in Watershed Management

(Refer Slide Time: 00:26)



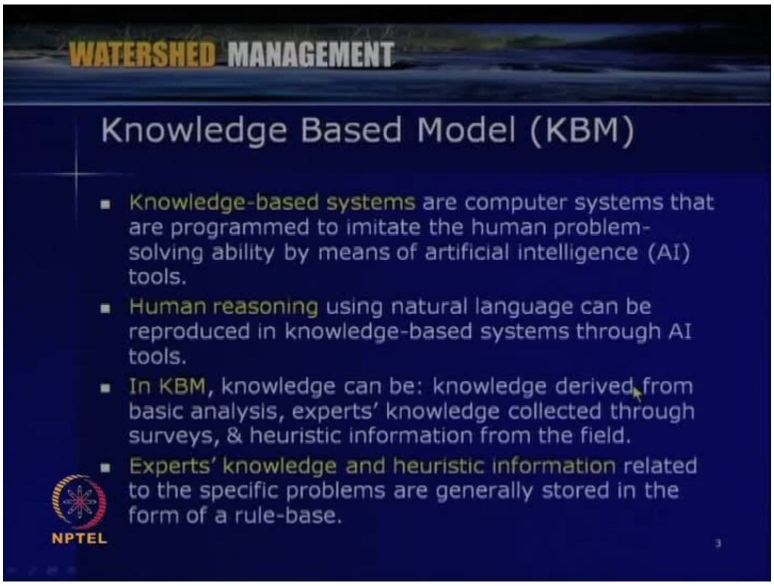
Namaste and welcome back to the video course on watershed management. In module number 6, on use of modern techniques in watershed management, in lecture number 26, today, we will discuss about the applications of knowledge-based models in watershed management.

(Refer Slide Time: 00:32)



So, in this lecture, some of the topics covered include Knowledge based modeling, Multi criteria decision analysis, Fuzzy Logic based modeling, Fuzzy systems, Applications of knowledge based systems in Watershed Management. Some other important key words - Knowledge based model, Multi criteria decision analysis, Fuzzy logic based modeling.

(Refer Slide Time: 00:55)



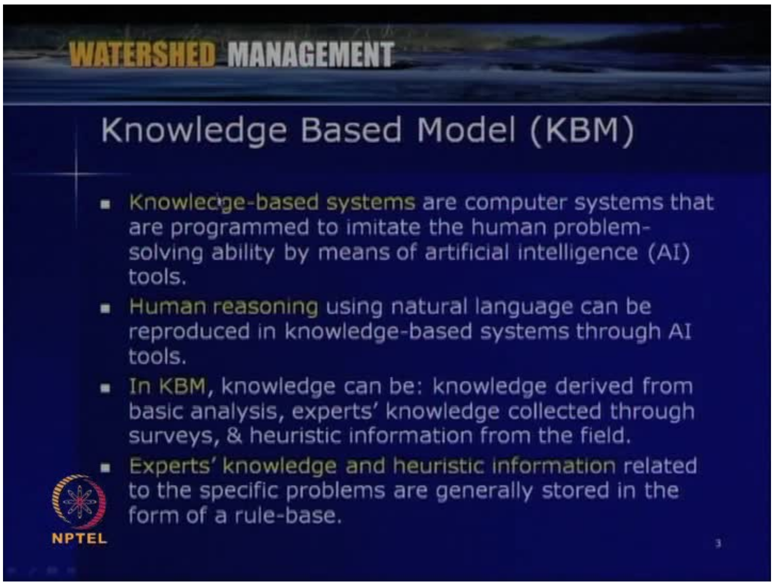
So, as we discussed earlier, say the modern techniques like geographical information systems, computer models, then remote sensing, then decision support system, all these things, all these models, all these modern models are very useful in the effective management of many engineering problems, say like watershed management or water resource management, etcetera.

So, we have seen the applications of computer models or numerical models, then the geographical information systems, remote sensing and decision support systems earlier. So, we can have some specified system for various specific types of problems like irrigation management or the land use management or crop management related to watershed. We can combine many of these modules together, and then, we can have a system called or a model called knowledge based models.

So, these knowledge based models are very useful to decide or to decide which way we have to do various management practices, which way we have to go for various plans as far as watershed is concerned.

So, actually these knowledge based models are also one way. They are also decision support systems or decision support models, but in the knowledge based models, we are using the artificial intelligence techniques like Fuzzy Logic or the techniques like genetic algorithm or Artificial Neural Network, etcetera. So, that is why these kinds of models are generally called as knowledge based models.

(Refer Slide Time: 02:47)

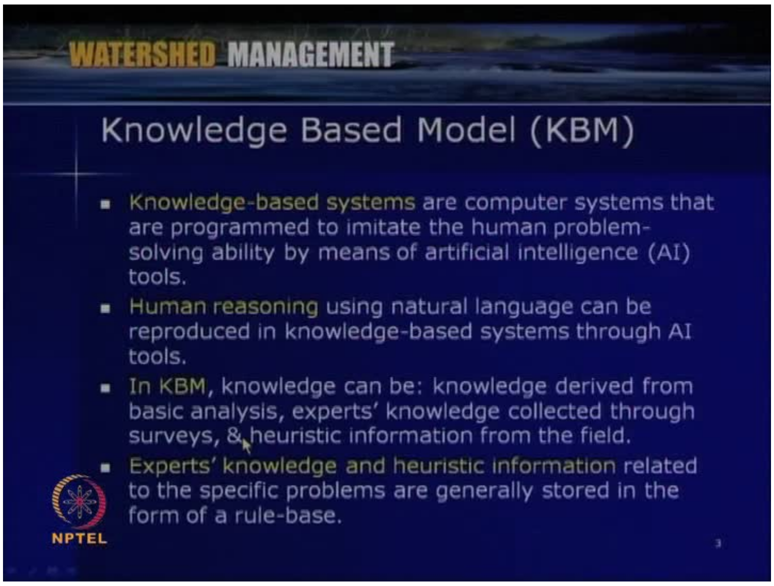


So, now, let us look into various aspects of knowledge based models. So, here, in this slide, I have given some information on knowledge based models. So, Knowledge based systems are computer systems; that are programmed to imitate the human problem solving ability by means of artificial intelligence tools.

So, actually, we can have a certain artificial intelligence tools like here Fuzzy Logic or the AI and or Artificial Neural Network or genetic operators or genetic algorithm very similar to the human intelligence type of systems. So, that can imitate the human problem very effectively. So, that way, the computer systems when models are made; that way, we called those kinds of models as knowledge based systems or knowledge based models.

So, human reasoning using natural language can be reproduced in knowledge based systems through various artificial intelligence tools like fuzzy logic. So, if this happens, what will be the outcome? So, like that or between good and bad, how the variation is it is not a very specific either good or bad, but between that, what can happen. So, like that, with these human reasoning kind of systems, we can have knowledge based models.

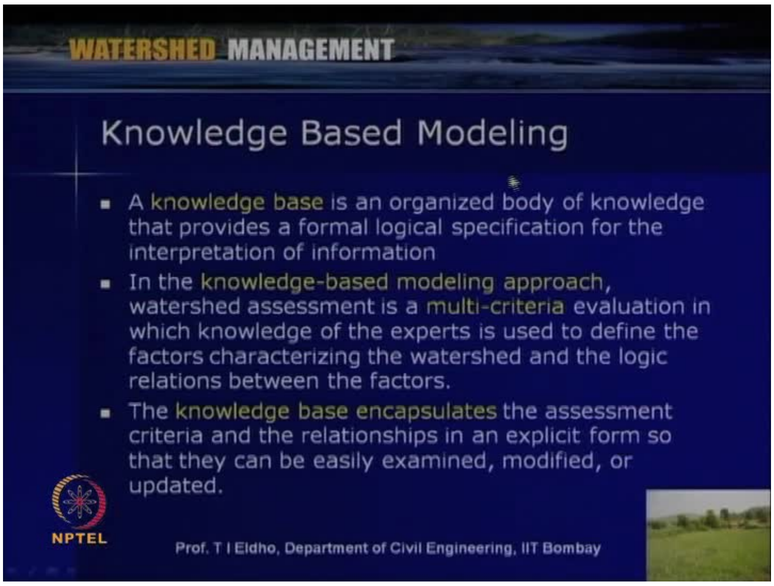
(Refer Slide Time: 04:17)



So, in knowledge based models, the knowledge can be derived from basic analysis or expert's knowledge collected through surveys and heuristic information from the field. So, these knowledge based models can be obtained from the basic data analysis or experts' knowledge or through heuristic information related to that particular problem.

So, experts' knowledge and heuristic information related to these specific problems are generally stored in the form of rule base. So, depending upon the problem, depending upon the watershed or area which we are dealing, we can generate specific rules and then we can store these rules in a rule base, and then, using those rule bases, we can generate scenarios or what can happen like if this particular thing is done, so, like that we can create various scenarios. So, those types of models are called knowledge based models.

(Refer Slide Time: 05:21)



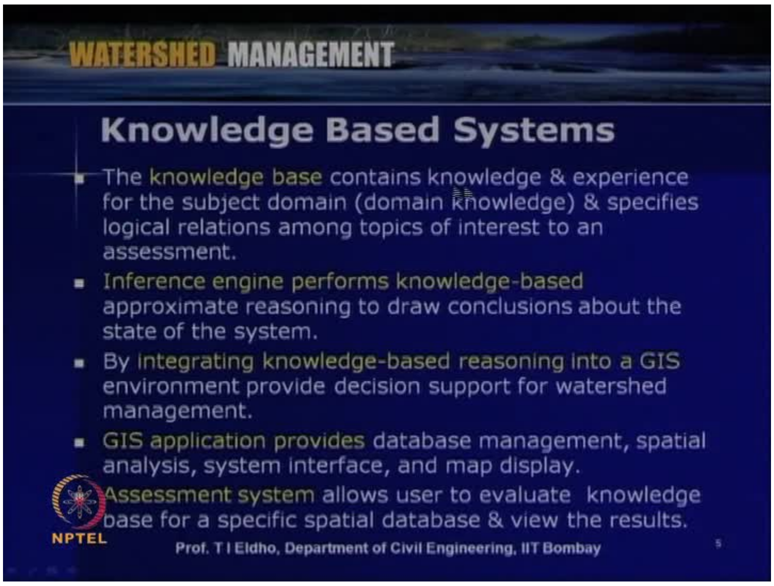
So, here, further on knowledge based modeling, knowledge basis an organized body of knowledge that provides a formal logical specification for the interpretation of information. So, for example, if, if the, the watershed, if, if land what is available, whether it is suitable for paddy cultivation or a millet cultivation or peas cultivation. So, like that, we can consider various information on the particular area and then we can generate the suitability of land depending upon the various details available.

So, in the knowledge based modeling approach, say for example, if watershed is concerned, watershed assessment is a multi criteria evaluation, in which, knowledge of the experts' is used to define the factors characterizing the watershed and the logic relations between the factors.

So, we can see when we deal with watershed assessment or watershed management, a number of criteria like the land used; then water availability; then the present cropping pattern; then neighborhood to the ponds or water bodies or neighborhoods to the transport systems. So, like that, we have to consider various criteria so called multi criteria, and then, based upon this, we can derive certain logical relationships using these factors and then we can develop a knowledge based model for the particular type of problem.

So, that way, the knowledge base encapsulates the assessment criteria, and the relationships in an explicit form so that they can be easily examined, modified or updated. So, depending upon the problems, so, we can created rule base based upon the database, and then, that rule base can be encapsulated within the systems which defines the various relationships and criteria, and then, based upon that, we can have a knowledge based model and that can be used to predict or to say that yes. This particular land can be used for this kinds of cultivation or what kind of supplementary irrigations to be generated for the cultivation of particular crop like that. So, that way, a knowledge based modeling can be done.

(Refer Slide Time: 08:08)



Now, let us look into various aspects of knowledge based systems. So, the knowledge base contains knowledge and experience for the subject domain. So, whatever we are dealing that subject is like domain knowledge and specifies the local relations among topics of interest to an assessment.

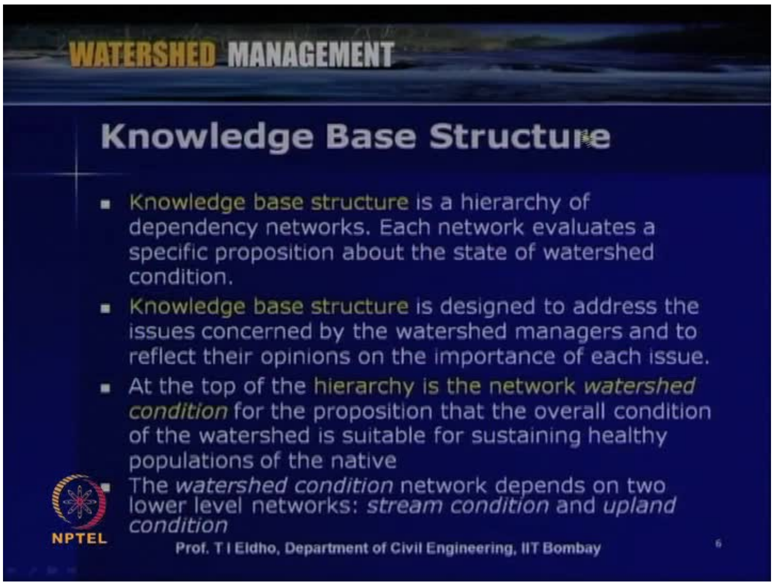
Say for example, if the assessment is whether particular crop is suitable for that particular land, so then we have to consider the type of soil; then the water availability; then various other factors which is required for that particular problems and then we can create the knowledge base.

So then, inference engine performs knowledge based approximate reasoning to draw conclusions about the state of the systems. So, we can generate the inference engines and these inference engines performs knowledge based approximations, and then, based upon that, we can generate particular scenarios or we can take particular decisions based upon these type of systems.

So, by integrating knowledge based reasoning into a GIS environment, provide decision support for watershed management. So, as we discussed earlier, for example, if a geographical information systems, say when we integrate this kinds of knowledge based models or knowledge based systems in a GIS environment, then we can see that what is happening within the systems or what is happening for that particular problem. All those with the given inputs and then generate output. We can easily visualize the various aspects and then we can go for particular decision according to the requirement.

So, that way, the knowledge based model process various relationships for those particular problems and then that gives certain decisions or scenarios. So, that way, as I mentioned, GIS applications provide database management, spatial analysis, system interface and map display. So, when we integrate this knowledge base system with GIS, we can have the database management, spatial analysis; like, a spatial variation, we can easily identify; then system interface, say GIS itself is system interface and then even we can generate various maps for display.

And then the assessment system allows users to evaluate the knowledge base for a specific spatial database and view the results. So, since when we integrate the knowledge base model or knowledge base systems within a GIS environment, so, we can easily see what is happening with the spatial variation or within the spatial database, and then, we can see within the GIS environment the results. So, that way, it is much easier and much useful for decision makers like if this is done, what will be happening. So, like that various decisions can be easily taken.



(Refer Slide Time: 11:26)

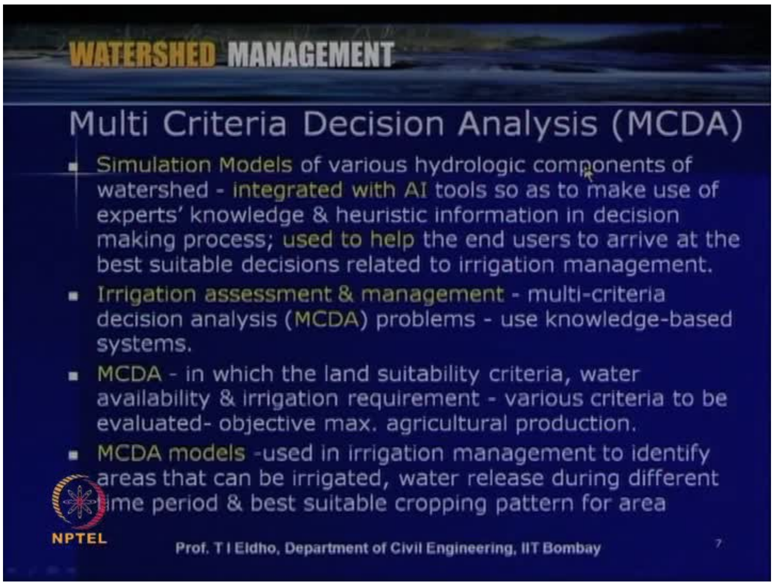
So, now, let us look into the knowledge base structure. So, what is the structure of a particular knowledge base? So, knowledge base structure is a hierarchy of dependency networks. So, depending upon the problems, say we have to go through various processes; various hierarchy of the various networks within the system.

So, each network evaluates a specific proposition about the state of, for example, watershed or watershed condition. So, if this particular watershed or particular area of the watershed, whether it is suitable for paddy cultivation or any kind of cultivation or that particular crop, then it has to go through a series of the various networks and then each network is evaluated, and then, we identify whether that is suitable or not.

So, knowledge base structure is design to address the issues concerned by the watershed managers, say for example, if you consider watershed and to reflect their opinions on the importance of each issue. So, in the knowledge base structure, we can consider various relationships, various issues, and then, we, say the, after effects if that particular thing is, then what will happens. So that if this is done, then what will happen. So, like that, it will be given. So, that is will be, that will be very useful for the watershed management or it will be useful for the decision makers.

So, at the top of the hierarchy is the network watershed condition. Say for example, if you consider watershed, then at the top of hierarchy is the network watershed condition, what is the condition of the watershed. For the proposition that overall condition of the watershed is suitable for sustaining healthy populations of the native. If you consider for the living condition of the particular watershed, then we consider the watershed condition whether it is deteriorated or it is very good condition or it is bad condition and then we can come up with various aspects related to particular decisions to be made whether related to cropping pattern land use or soil erosion or whatever type of problem we are looking for.

So, the watershed condition generally depends on two lower level networks like a upland or overland conditions. As we discussed earlier, watershed can be considered as an overland and then the stream or channel conditions. So, whenever we consider the watershed condition, so, the two lower level networks other than the overall watershed conditions, say two levels which we have to consider is how the overland condition and the stream conditions is so accordingly we can consider various aspects of the problem which we consider, and then, we can come with a solution or come with a scenario.



(Refer Slide Time: 14:51)

So, in all these aspects, when we deal with, say for example, watershed management, so, we have to consider as we discussed various criteria we have to consider in the analysis.

So, that way, we can see that these type of problems are very much multi criteria based. So, we have to do a multi criteria decision analysis. So, MCDA or multi criteria decision analysis very important in knowledge based models.

So, simulation models of various hydrologic components of a watershed, say for example, rainfall runoff or soil moisture or the water sharing, all these kinds of components. So then, integrated with the artificial intelligence tools like Fuzzy Logic so as to make use of expert's knowledge and heuristic information in decision making process; so, this is use to help the end users to arrive at the best suitable decisions related to irrigation management.

Say for example, if the watershed is concerned, if you are dealing with irrigation management, so, we can consider various hydrologic components of that particular watershed and then we can come with- Yes, this is the best irrigation management practice or this is the best cropping pattern or depending upon the requirement of the crops, this is the possible irrigation management schedule like that. So then, irrigation assessment and management as I mentioned, so, that way, is a multi criteria problem and then we have to go for multi criteria decision analysis.

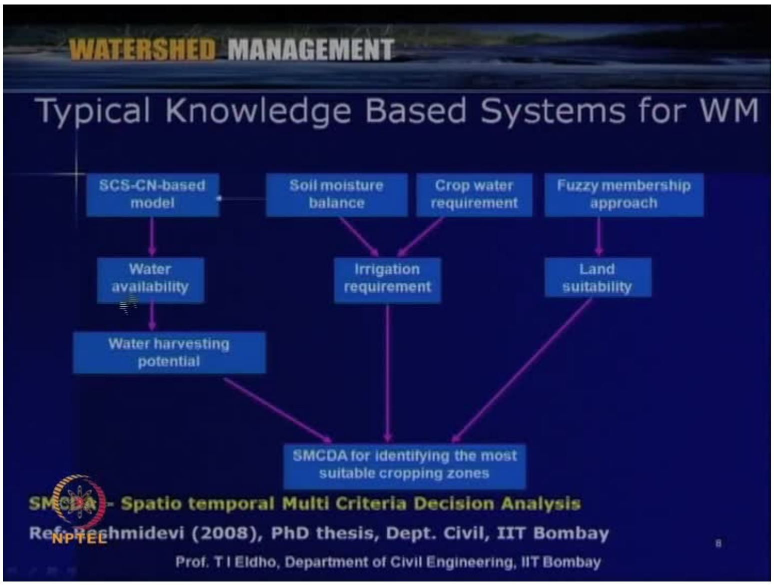
So, in this, we have to use the knowledge based systems. So, knowledge based systems are very useful for multi criteria decision analysis. So, MCDA or multi criteria decision analysis, in which, the land suitability, say for example, if land suitability criteria has to be consider, water availability irrigation requirement and various other criteria to be evaluated.

So, generally, the objective function can be or objective can be maximize the agriculture production when we are looking for irrigation management for the particular watershed. So, if you consider MCDA or multi criteria decision analysis, we can say our objective or objective function can be we have to maximize the agricultural production. So, accordingly, we can go for the irrigation management or the various scheduling.

So, that way, MCDA or multi criteria decision analysis models are used in irrigation management to identify areas that can be irrigated and then water release during different time periods and then best suitable cropping pattern for the considered area.

So, like that, when we deal with MCDA, - multi criteria decision analysis - we can identify the water release for different seasons of different time period, and then, what is the best suitable cropping pattern, and then, what is the irrigation schedule. So, like that MCD a is very much part of any kinds of knowledge base systems which we can develop for particular watershed management problem.

(Refer Slide Time: 17:49)



Now, let us look into a particular knowledge based systems for watershed management when we consider. So, this flowchart shows a typical type of knowledge based model for watershed management. So, if you consider watershed or water related issues within the watershed, then we have to go for hydrological modeling. Say for example, we can find out the rainfall runoff using soil conservation curve number based model, and once the runoff is determined, say this runoff also depends upon the soil moisture balance and then crop water requirement and then irrigation requirement.

So then, based upon that once the runoff is predicted, then we can identify how much water is available for that particular area, and then, if sufficient water is not available, then we can think over how we can go for water harvesting. So, what is the water harvesting potential for that particular area? And then, if you use a fuzzy membership approach which we will be discussing in the coming slides, what is fuzzy logic and all those things will be discussing detail.

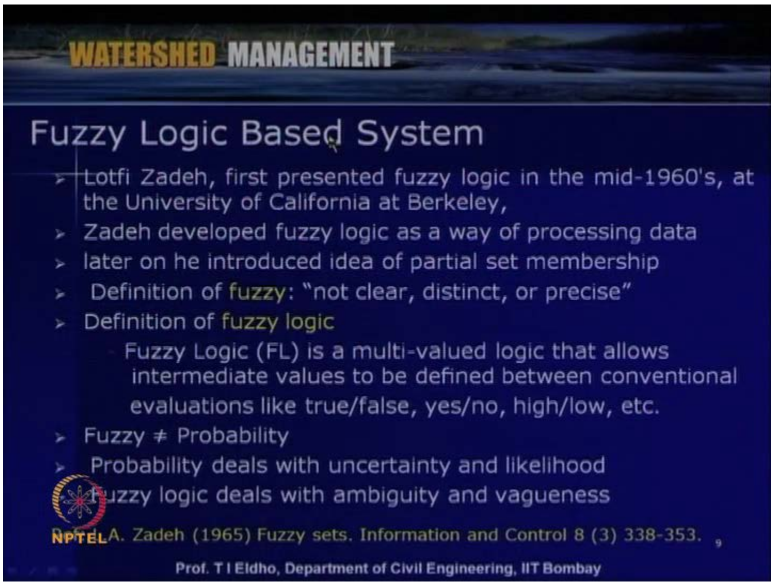
So, if we consider fuzzy membership approach, then we can use those approaches to identify what will be whether the land or particular area is suitable for that particular crop, and then, we will get a spatial temporal multi criteria decision system or multi criteria decision model for identifying the most suitable cropping zones for that particular area.

So, based upon this approach, one of my Ph.D. students Rashmi Devi, 2008 developed a model in Department of Civil Engineering, IIT Bombay - a specified knowledge based systems for watershed management and these results were published in the journal of Irrigation Drainage American Society of Civil Engineers.

So, this way a typical knowledge based systems consists various components for that particular problem, we have to, we may have to use sometimes some specified models, for example, rainfall to runoff model, and then, we have to consider the for example land suitability and then the water requirement and all those things we can combined together integrate together within a GIS environment, and so that, that becomes a knowledge base model, and that can be effectively utilized, say for example, for the land use, suitability analysis or the most suitable cropping zone identification for that particular watershed like that.

So, that way, as I mentioned these fuzzy logic systems which is used in many problems for the last two decades can be effectively utilized in watershed management also. So, let us now look into important aspects of fuzzy logic and fuzzy base system and then related modeling techniques.

(Refer Slide Time: 20:54)



So, these fuzzy logic systems - say it was first presented by Zadeh in the mid-nineteen sixties at the University of California in Berkeley and he developed the fuzzy logic as a way of processing data. So, by considering various problems, how to process this data between various variation within the parameters.

So, later on he introduced the idea of partial set membership. So, say if, within the one, if the variation is, for example, good to bad. If we cannot identify certain class is totally good or certain class is totally bad, in between what happens. Then that kind of partial set membership this doctor Zadeh introduced, and then, he defined the fuzzy systems as the system which is not clear or distinct or precise. So, a system which is not very clear or we cannot say that this is exactly this is the fashion or it is not so precise. So, that kind of system, we can call it as a fuzzy system, and then, he defined the fuzzy logic as a multi-valued logic that allows intermediate values to be defined between conventional evaluations like a true or false, yes or no, high or low, etcetera.

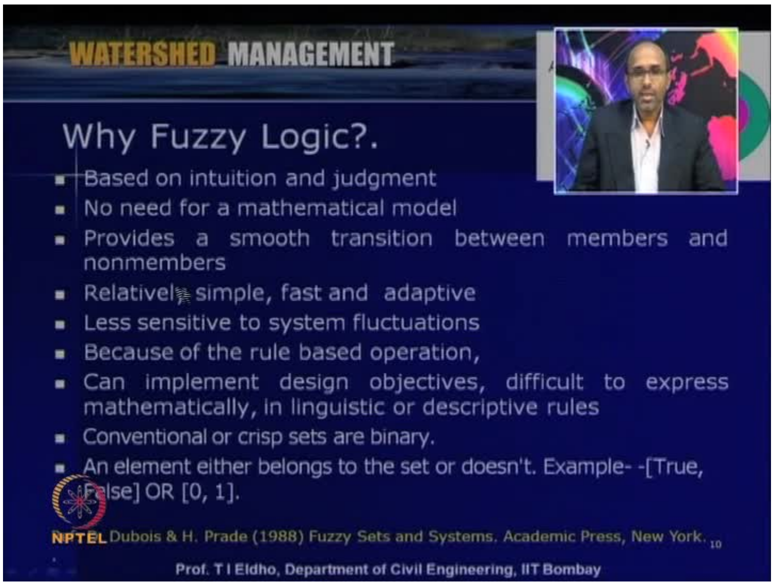
So, that way, Zadeh defined the fuzzy logic as an intermediate value or intermediate values between conventional evaluations like a say which is exact like a true false; between true and false, what is there, or between high and low, how is the variations. So, like that, so, system which is not so clear or distinct or precise that is defined within the fuzzy systems or fuzzy logic.

So, actually, that way, fuzzy we are not actually dealing with probability. So, probability generally deals with uncertainty and likelihood of various parameters. Say for example, if rainfall may or may not happens, so, it is uncertainty of that particular parameters, but in fuzzy logic fuzzy logic generally deals with the ambiguity and vagueness.

So, whether for example, if particular land is there, that land if say some particular land, we can specifically it is not at all useful for some paddy cultivation, but some land will be very suitable for paddy cultivation, but in between, if it is there, then how to identify. So, that kind of problems we can easily deal with the fuzzy logic based systems.

So, now, as I mentioned, this fuzzy logic is a system which we can utilize where vagueness or where we cannot exactly define what a situation is.

(Refer Slide Time: 23:45)



So, that way, the fuzzy logic is based on intuition and judgment. So, we have to see, the, what is the, say for example, for the when we deal with particular problem, what kind of intuition we are getting or what kind of judgment we are having.

So, that way, actually it is not based upon specified mathematical models, but we have to see that a with our intuition judgment, we have to come up with a methodology in fuzzy logic, and then, fuzzy logic provides a smooth transition between members and nonmembers.

So, if the member between member and non-member means if the what is the decision is - yes or no. So, what is there in between, so, that is we, that the transition between members and non-members or the between high and low, so, what is there; so, that kind of transition.

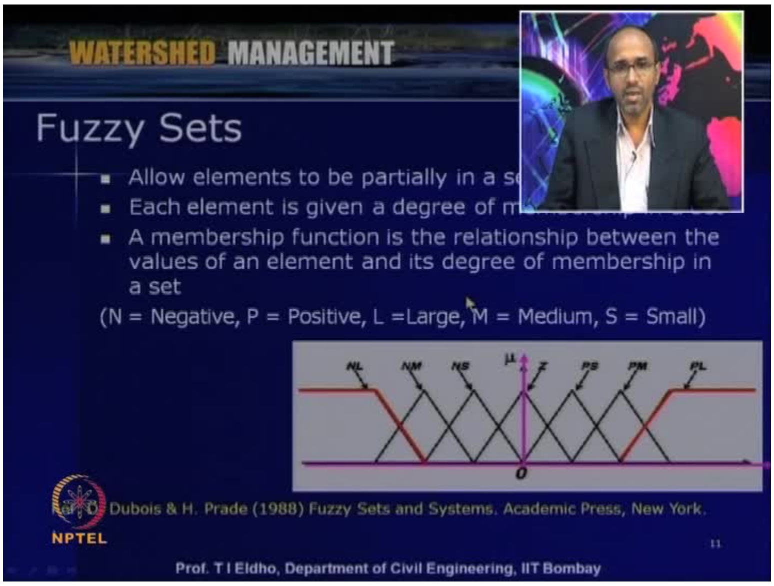
So, that way, it is relatively a symbol; this fuzzy logics is relatively symbol fast and adoptive and then it is less sensitive to systems fluctuations, and then, according to the problem, we can defined or design certain rules. So, that way, it is a rule based operation we can define, and then, it can be implemented for design objectives or like what is difficult to express mathematically in terms of linguistic or descriptive rules.

So, mathematically, if we cannot have precise type of rules or type of definition for that particular problem, then but it may be able, we can put it in terms of linguistic or descriptive rules. So, there fuzzy logic we can directly utilize. So, that way, if we consider for example conventional or crisp sets are binary, but fuzzy logic is the variation in between is considered.

So, now, an element either belongs to the set or does not. So, generally, crisp or the conventional set is particular thing is concerned, whether it belongs or it does not belong, but like a true and false. So, that way, if we assign true is zero, then we have for false; we can assign one, so, like that. But in fuzzy logic where for the type of problems, where it is not possible to specifically true or false but something in between; so, that means it may can vary from zero to one but it may not be exactly as zero or one depending upon the problem.

So, like that, if we consider the problem, so, now let us see here, you can see that in this figure, this a b c - these are all subsets of this particular problem. So then, if it is specifically the things are in this, then it is a or in this subset, it is b, or in this is c, but in between if then, what happens.

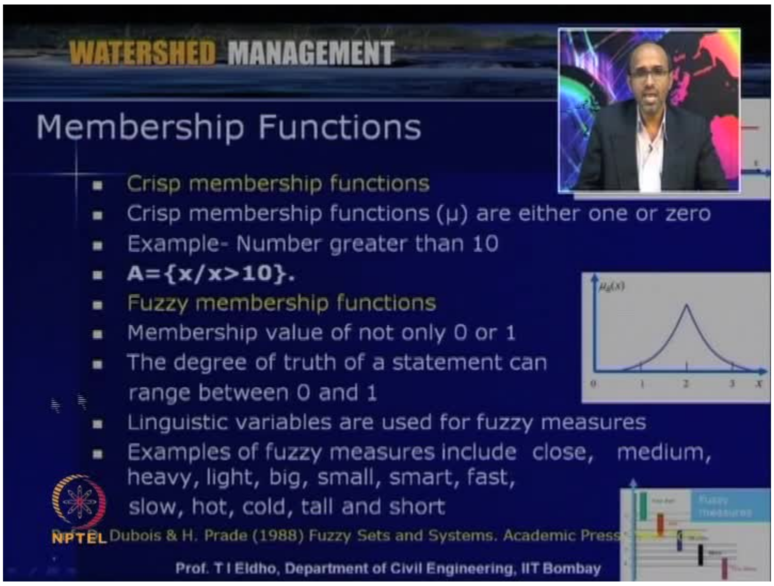
(Refer Slide Time: 27:14)



So, that way, fuzzy logic can be considered. So now, let us look what is fuzzy sets. So, fuzzy sets we have to consider set of details within the, for that particular problem. So, this allows elements to be partially in a set. As I mentioned here, this particular set which we considered, so, allows elements to be partially in a set. Each element is given a degree of membership in a set. Then a membership function is the relationship between the values of an element and its degree of membership in a set.

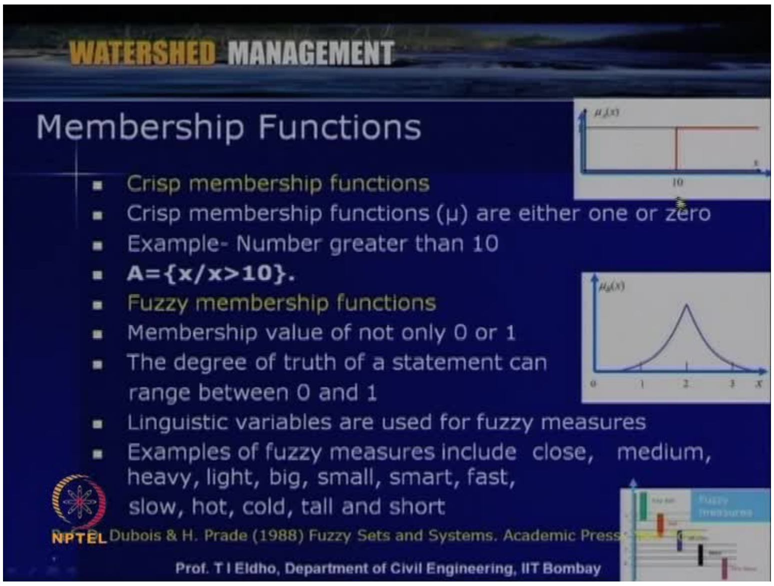
For example, if the variation is this particular function mu, so then this is negative and this side is positive. So then, a negative positive; then or large, medium, small. So, in between that how the variations are taking place. So, that way, we can consider for the particular problem which we consider.

(Refer Slide Time: 28:06)



So, that way we can consider the fuzzy sets. So now, in these kinds of problems, we have to consider the membership. Whether it is in which subset or whether between those sets, so, like that, we have to consider the membership functions.

(Refer Slide Time: 28:24)

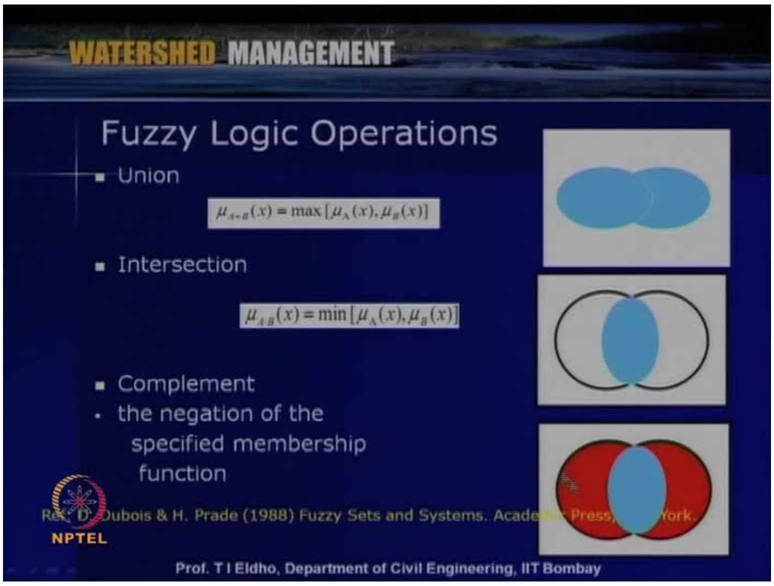


So, here, the details of the membership functions are given in this slide. So, the membership generally can be crisp membership functions. So, crisp membership functions, for example, this mu which we consider either one or zero; so, exactly one or zero. So, for example, particular number greater than ten so that we can define like this.

But as far as fuzzy membership functions are concerned, the membership value here is not exactly one or zero but it is varying. So, the degree of truth of a statement can range between zero and one, and the linguistic variables are used for to describe this fuzzy measure, what is happening.

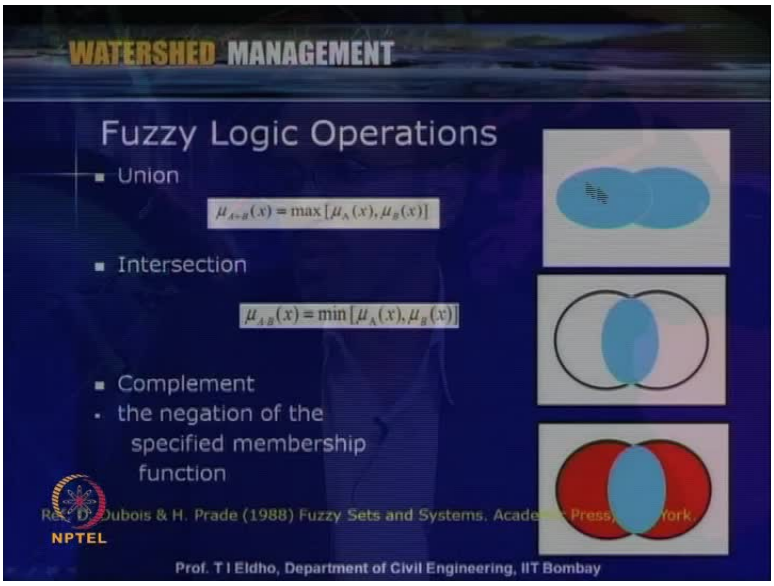
So, examples of fuzzy measures include the particular problem is close, say like a water bodies, close to the to the agricultural land or it is a medium, heavy; it is a heavy, light, big, small, smart, fast, slow, hot, cold, tall, short, like that. So, on linguistic terms linguistic variables, we can use between these parameters and then we can specify. So, that way, in the fuzzy membership functions, these values it is not crisp like a zero or one but it will be varying between, the, these parameters.

(Refer Slide Time: 29:51)



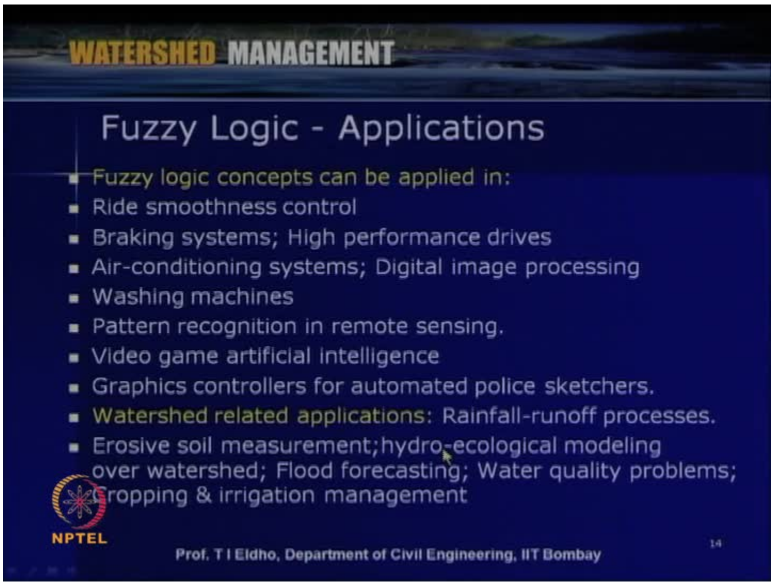
So now, we can see that that way we need to define the fuzzy logic operations. So, if we consider two sets whether how that sets are behaving, so, accordingly, we can design the problem. Now in the fuzzy logic operations, for example, we that the union, for example, if this is subset a subset b, then the union is maximum mu a x mu b x as shown in this figure.

(Refer Slide Time: 30:10)



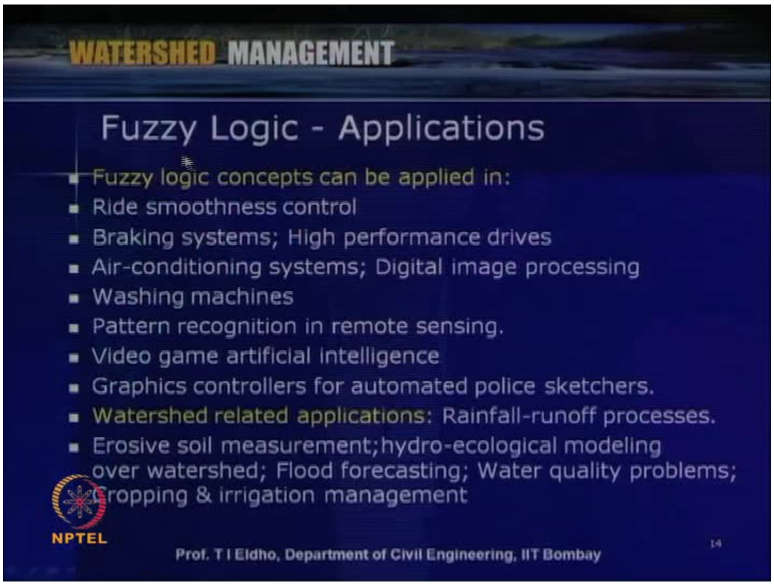
And then, if we consider only the intersection, so, for example, minimum of mu a x and mu b x, so, this is the intersection which we consider, and then, the complement, the negation of the specified membership function, so, we do not consider this area, but on the other two sides area if we consider when the compliment.

(Refer Slide Time: 30:52)



So, like that, fuzzy logic we can define particular fuzzy logic operations and then we can consider the particular problems which we are dealing. Now, this fuzzy logic, as I mentioned, in most of the natural problems which we consider like a, if we, if we consider the watershed management. So then, the particular area is concerned, crop suitability or irrigation management, so, like that, various problems, so, we cannot a specifically exactly, that is, this is the way but it can vary between yes or no, or false or right, or like that between these parameters vary.

(Refer Slide Time: 31:43)

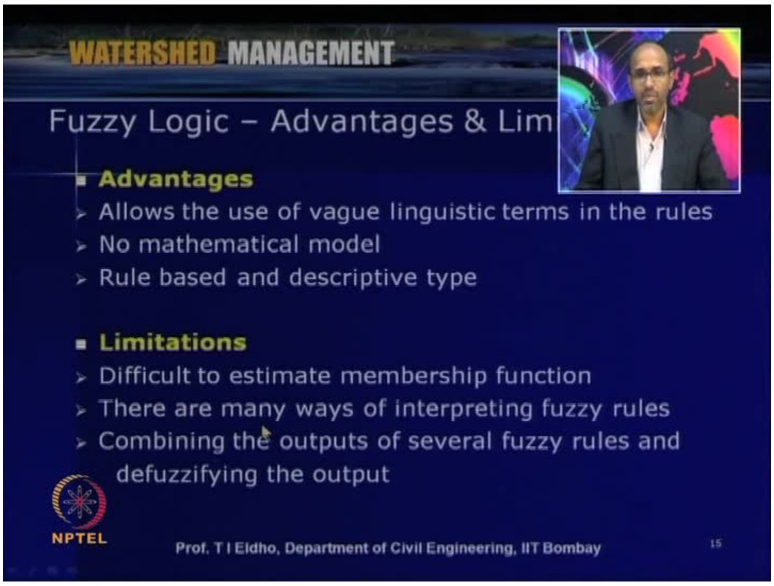


So, that way, fuzzy logic has got large number of applications, for example, in watershed management. Of course this fuzzy logic was developed for various other types of problems. Some of the applications I have listed here: like a ride smoothness control; then in all other kinds of engineering like electric engineering, electronics engineering mechanical engineering like that.

Then braking systems, high performance drives, air conditioning systems, digital image processing, washing machines, pattern recognition remote sensing, video game artificial intelligence, graphic controllers for automated policy sketchers like that. So, large number of applications we can see now in literature related to fuzzy logic. Now, since our main interest is here related to watershed management management problem, so, watershed related application also large number of applications, we can see in literature like in modeling rainfall-runoff processes.

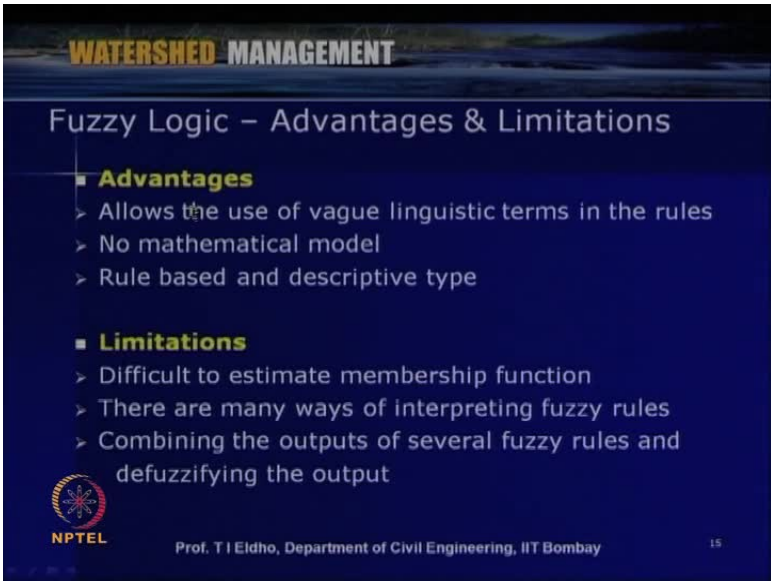
Then, erosive soil measurement, then hydro ecological modeling or watershed, then flood forecasting, then water quality problems cropping and irrigation management. So, like that, watershed related or watershed management related number of problems also we can utilize this fuzzy logic. Since many of these natural problems are related to watershed problems are very much fuzzy in nature. So, that way, we can utilize the this fuzzy logic or fuzzy sets or fuzzy based model for watershed management related problems.

(Refer Slide Time: 33:08)



So now, let us look this fuzzy logic the concepts we have now discussed. So now, let us look what are the advantages and limitations of fuzzy logic and with respect to applications what we are seen some there are certain advantages and some limitations.

(Refer Slide Time: 33:28)



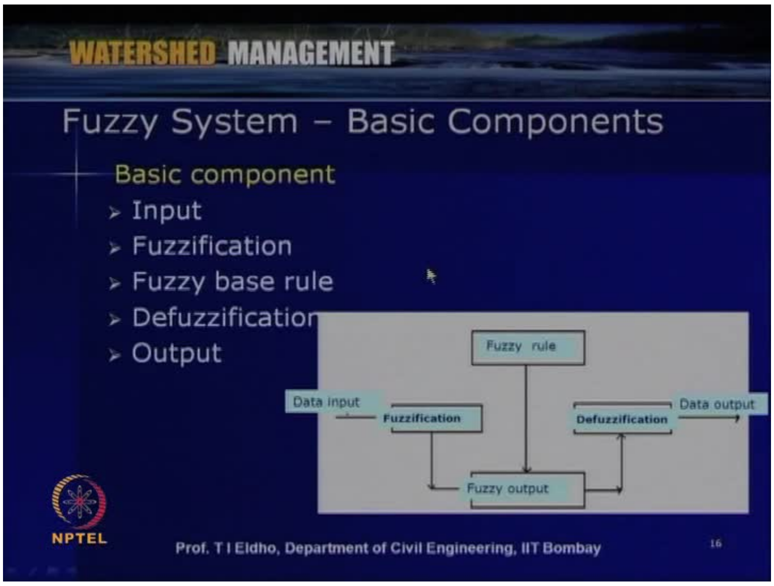
So here, some of the advantages are like, allow it, the fuzzy logic allows the use of vague linguistic terms in the rules. So that based upon that, we can come up with certain decision for the particular problem, and that way, we do not need any, the, excite mathematical models for that particular problem. So, based upon the linguistic variations, we can make decisions or make we can make modeling.

And these are rule based and descriptive type. So, most of the fuzzy logic systems are rule based, and then, some of the limitations include this is difficult to estimate membership function. So, most of the problems, say what kind of membership is there, accordingly, it is exactly to define, to estimate the membership is difficult.

There are many ways of interpreting fuzzy rules. So, say the time itself is fuzzy, so, we can interpret also in different ways. So, we have to the correctness of the decision or the, you have better decisions or better interpretation if we use the best possible kind of system.

And combining the outputs of several fuzzy rules and defuzzifying the output. So, we have to first see the fuzzification of the systems, and then, based upon the rules or, the, the, in terms of linguistic systems and then we have to again come back and defuzzify the output. So, that way, we have to go through certain procedure. So, these are some of the limitations as far as fuzzy logic types of systems are concerned.

(Refer Slide Time: 35:18)

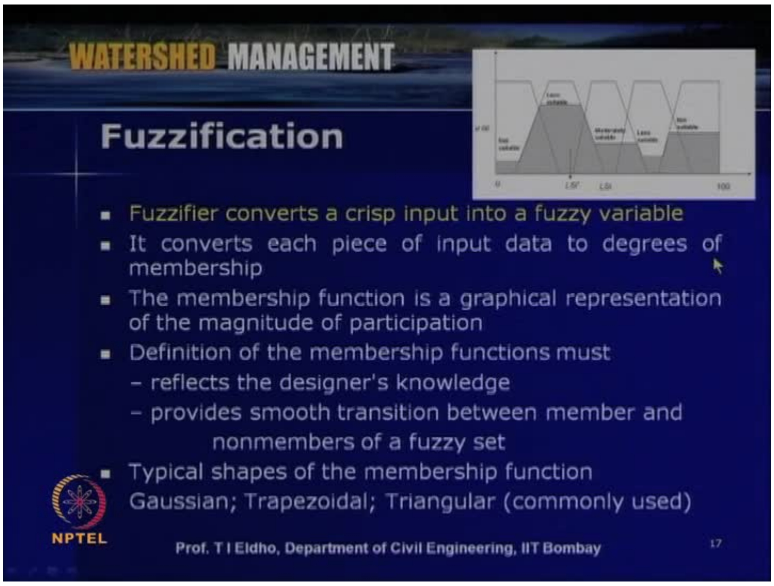


So now, let us look what are the important components as far as fuzzy logic is concerned. So, this slide shows the basic components of fuzzy logic systems. Here, first of all of course, data input is required based upon the available input only, we consider the particular problems and then come up with a certain decision.

So, first is the input. So, data input, and then, based upon the problem, we consider certain types of models to fuzzily the systems. So, that is called the fuzzification, and then, we consider the fuzzy rules, the base rules applicable for that particular problems. So, based upon that, we will be getting the fuzzy output, and then, since to the, to normalize and to for the understanding of the problem, again we have to do a defuzzification and then we will be getting the output.

So, this way, in a fuzzy system, the basic, there are five basic components, and that way, systematic modeling or systematic operation operations are possible in a fuzzy based modeling.

(Refer Slide Time: 36:27)

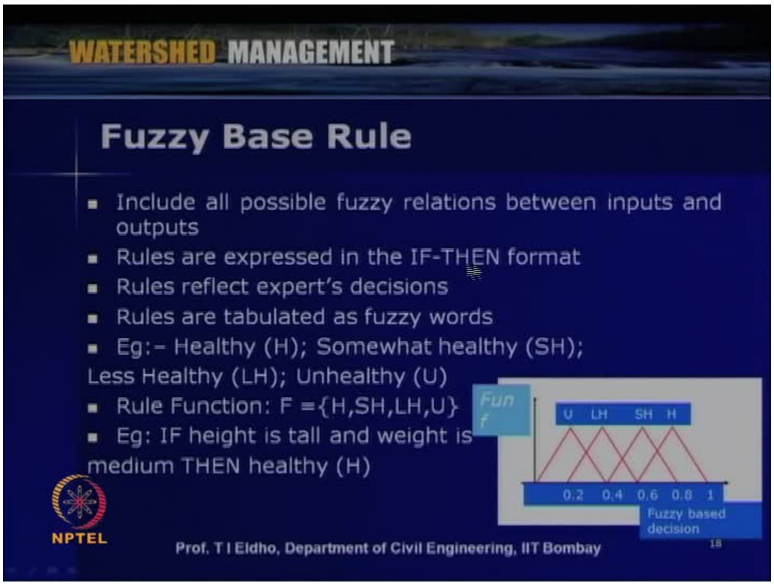


So now, let us have a look into the, three two, three components the fuzzification fuzzy based rule and defuzzifcation, some of the important aspects let us look into.

So, fuzzification means it is a fuzzifier; fuzzifier converts a crisp input into fuzzy variables. Say for example, if we consider the land use for particular crop, so, it is the possible crisp inputs are not suitable, then suitable. So, in between, we can have less suitable, moderate suitable, less suitable, so, like that.

So, that way, this fuzzifier converts each piece of input data to various degrees of membership. So, the membership function is a graphical representation as shown in this figure representation of the magnitude of participation. So, like the land suitability, it is suitable or not suitable; then in between, we can have less suitable, moderate suitable like that. Then the definition of the membership functions must reflects the designers knowledge; then provides smooth transition between member and nonmembers of a fuzzy set.

(Refer Slide Time: 38:22)



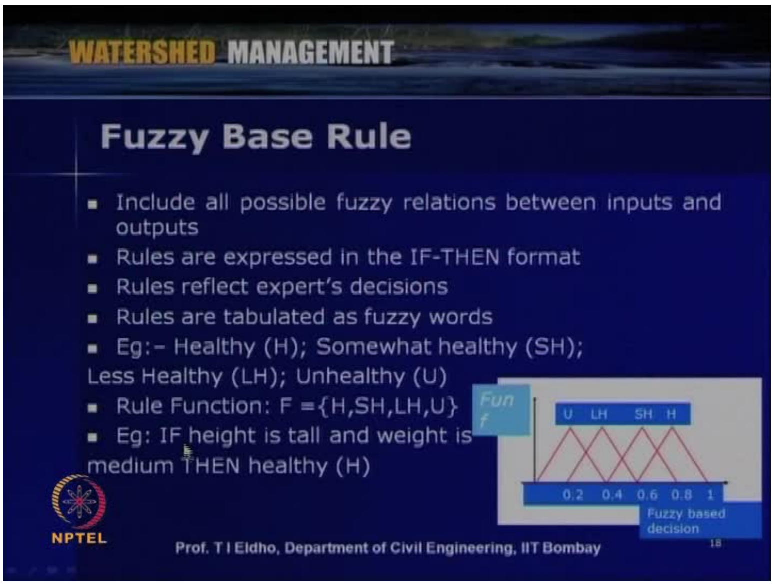
So, that way, we have to do this Fuzzification; so, it should provide smooth transition between member and nonmembers of the fuzzy set. Then typical shapes of the membership functions we can have a Gaussian variation, Gaussian variation like this, or we can have a trapezoidal variation as shown here or we can have a simple triangular variation also. That way, this kinds of variations we can use, in the, in the fuzzification processes.

Then the second one is the fuzzy base rule. So, this fuzzy base rule is actually the important component in any of these kinds of modeling. So, these fuzzy base rules include all possible fuzzy relationships between inputs and outputs. So, we have seen that inputs are there and then corresponding outputs will be there. So, this fuzzy relation, we can generate relations based upon this inputs and outputs.

So, this include all possible fuzzy relationships between this inputs and outputs. So, rules are expressed in the if-then format; that means if this done, if this particular check dam is constructed, then how much will be the flooding problem or how much is the area can be irrigated. So, like that, if this is done, then what will happen? So, if-then format, then we can the rules reflect experts decisions. So, this, the, whatever the rules which we generate, based upon that, the final decisions made. So, that way, they should reflect the expert's decisions and then rules are tabulated as fuzzy words.

So, like for example, if a particular person is there, we can by looking to that particular person, his actions or his conditions, we can say that weather he is healthy; then we can say that he is whether somewhat healthy, less healthy or unhealthy.

(Refer Slide Time: 40:08)



So, this can be based upon various conditions like a whether he is how much tall or whether he is a fat or he is thin or he is overall health conditions. So, for example, we can generate a particular fuzzy base rule, say for example, related to healthy or unhealthy, healthy is concerned.

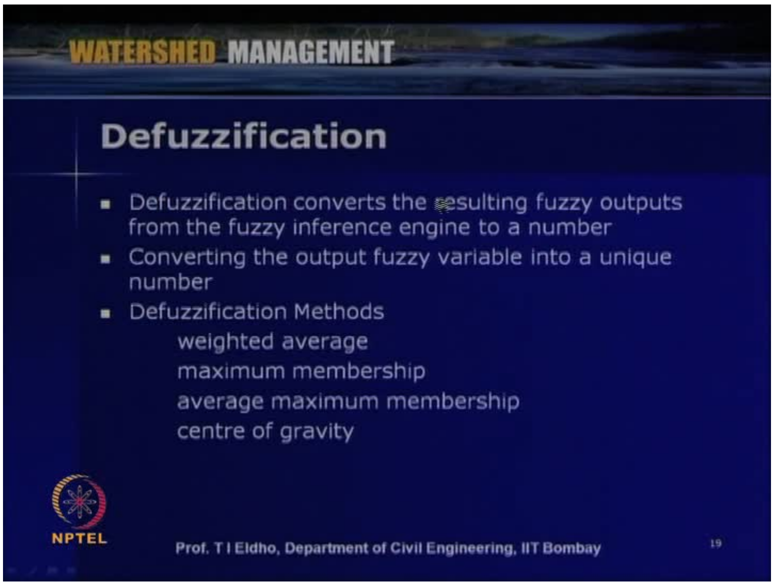
If height is tall and weight is medium, then we are healthy. So, like that, if-then relationships we can form, and for example, if height is small and then weight is more than unhealthy, so, like that, we can have a, we can generate various fuzzy base rules.

So, this is related to the health of a person, but for example, related to the crop suitability particular area or land suitability, we can consider various aspects like if water is available, then irrigation can be done so that this particular crop like a paddy is possible. So, like that we can generate the fuzzy based rules; so, that will be very useful in in this fuzzy based modeling.

So, that way, I have shown here we can have various conditions like a fuzzy based decision as shown in this slide. So, the fuzzy based decisions, we can give various weightages here and then function is shown here; so, this is related to unhealthy, less healthy, somewhat healthy or healthy, so, like that. So, most of this fuzzy based rules are based upon, if this is the condition, then what is the situation, so, like that.

So then, third component is the defuzzification. So, once the input is there and then fuzzification is done, then fuzzy based upon the fuzzy rules, we are now going getting a output which is in the not understandable for a normal person; so, we have to defuzzify the system.

(Refer Slide Time: 41:56)



So, defuzzification, as shown in this here converts the resulting fuzzy outputs from the fuzzy inference engine to a number. So, generally, in computer terms, it will be represented in terms of a number and this number will showing how the variations is taking place whether it can be between zero to one or what way it is.

Then converting the output fuzzy variable into a unique number, so, that unique number represent, whether that person is healthy, less healthy, somewhat healthy or that particular area is suitable, less suitable or more suitable, so, like that. So, numbers of defuzzification methods are available in literature, like weighted average conditions, maximum membership, average maximum membership or central gravity of that particular the area triangular or trapezoidal like that that variation. So, these different methods are there; anyway, we are not going into the details.

But the defuzzification is required when we use the fuzzy logic and that gives the particular output the system which we are looking for that particular problem. So, that way, defuzzification is also very important. So, now, what we are discussing is the fuzzy logic and then the structure of fuzzy logic systems and then how the fuzzy logic is working and then its applications. That is what we are discussing so far.

So now, today is our main topic is knowledge based model. So, related to watershed management, how we can develop a knowledge based, knowledge based, knowledge based model related to watershed management? So, that way, now further in the coming few slides, we will discuss a particular knowledge based model for related to watershed management.

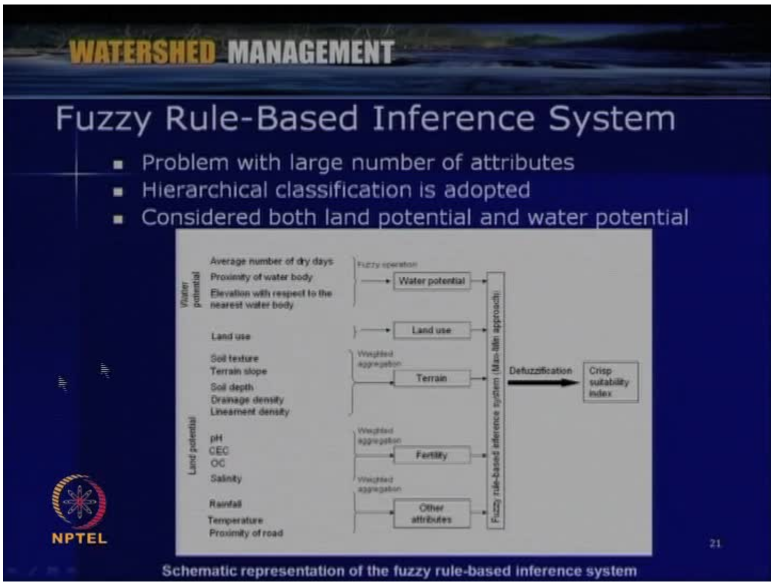
(Refer Slide Time: 43:52)

So, let us look into this particular model developed by PHD student Reshmi Devi and presented in her thesis knowledge based model for supplementary irrigation assessment in agricultural watershed. So, here, she developed a fuzzy rule based inference system for land suitability evaluation. So, for, if a particular land is a particular watershed for particular crops, how effectively that is suitable, less suitable or more suitable, like that.

And then she developed a spatial temporal multi creative decision analysis model for s m s MCDA model for identifying the scope for supplementary irrigation. So, based upon this fuzzy rule based system, she developed a model to identify whether if we consider the particular watershed and then its cropping pattern, its irrigation availability and so whether we have to go for supplementary irrigation and then how effectively we can do within the context of a knowledge based model. So, that way, model has been developed and then also she developed a graphical user interface for this particular model.

So, in this particular model for this knowledge based model, five steps are there in the model development - first one is the fuzzification of the attributes, then estimation of the intermediate land suitability index, then generation of the fuzzy rule based, then aggregation of the rules like a fuzzy output in terms of five suitability classes like a less suitable, suitable, more suitable, like that and then defuzzification. So, the basic steps - fuzzification estimation, intermediate land suitability index, then generation of fuzzy rules, then aggregation of the rules and defuzzification.

(Refer Slide Time: 45:44)



So, these were the essential steps for this particular model. Then fuzzy rule based inference system, so, here, the problem with large number of attributes. For example, if a particular watershed or particular area whether we want to identify whether that particular area is suitable for particular cropping, so, we have to consider various aspects like the average for the particular average number of dry days, proximity of water body. So, this is related to water related issues; then elevation with respect to the nearest water body; then land related issues like the land use, soil texture, terrain slope, soil depth, drainage density, lineament density. Then soil related issues like pH, then electrical conductivity, salinity, etcetera.

Then climate related like rainfall temperature, proximity to road. So then, based upon the fuzzy operations related to water related issues which is used water potential, and then, from this, the land use related issues; then the weighted aggregation related to soil; then related to terrain and weighted aggregation related to the soil use the fertility; then various other attributes also can be considered.

(Refer Slide Time: 47:47)

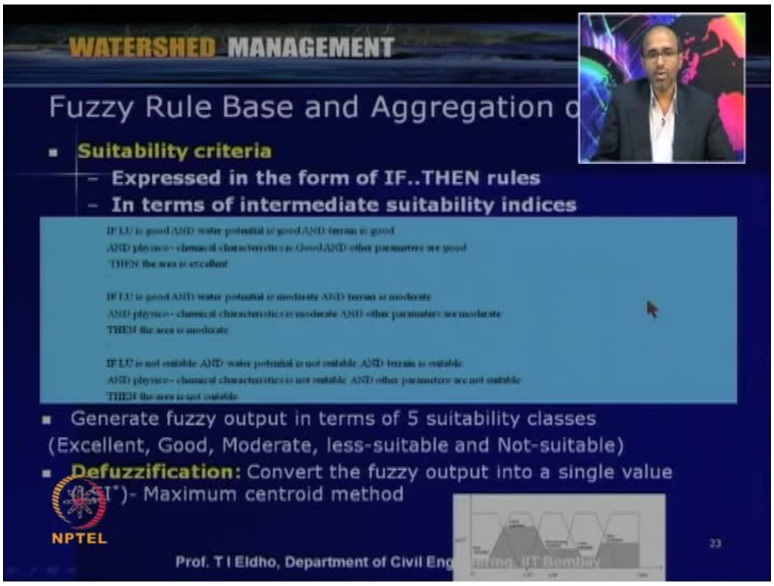
So now, based upon this fuzzy rule based, inference system has been developed and so this is the overall structure of the model and then defuzzification, and then, from that, we can get the particular the decision or particular suitability. So, the, here, she considered a hierarchical classification and then she considered both land potential and water potential for that particular problem. So, the main issues are related to land potential, water potential so that a suitable crop index or crop suitability or land suitability for that particular crop can be identified. So, this system was based upon the fuzzy rule based inference system.

So, as far as fuzzification is concerned as we discussed earlier, the attribute values are mapped between zero and one, and then, two types of attributes - like thematic attributes for land potential, unique membership value for each class, then continuously expressed attributes for land potential semantic import membership function, then asymmetric left or asymmetric right or optimal range.

So, more details of this, you can see in the journal of irrigation drainage a paper published. So, the reference will be given later by us. Then the next step is the intermediate land suitability index. So, here, the weighted aggregation of the attribute membership values are used, and attributes like a here, she used Saaty's relative importance scale to identify the intermediate land suitability index.

And then based upon that, relative importance is assumed based on literature, field observation and heuristic information, and then, this gives intermediate land suitability index in three suitability classes like good, moderate and not suitable based on the land and the water potential.

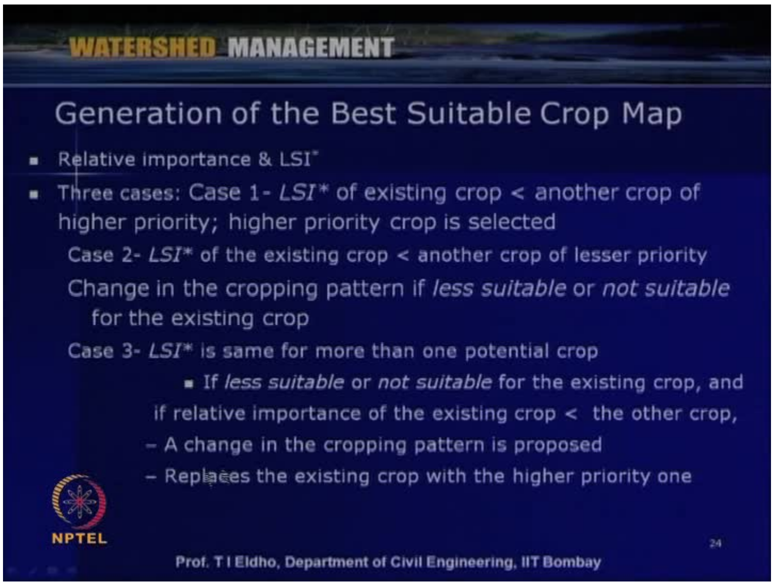
(Refer Slide Time: 49:09)



So this, these are the details as far as the intermediate land suitability index in this particular knowledge based model. Then the fuzzy rule based and aggregation of the rules are generated. So, suitability criteria is based upon in the form of if then rules in terms of intermediate suitability indices, like if land use is good and water potential is good and the terrain is good and chemical character is good and then other parameters are good, then the area is excellent. So, like that, the system is made.

And then another scenario, if land use is good and water potential is moderate and terrain is moderate, then and physical chemical characteristics is moderate and other parameters are moderate; then the area is moderate, and third one if land use is not suitable and water potential is not suitable and terrain is suitable and physical chemical characteristics is not suitable and parameters are not suitable, then area is not suitable.

(Refer Slide Time: 50:34)

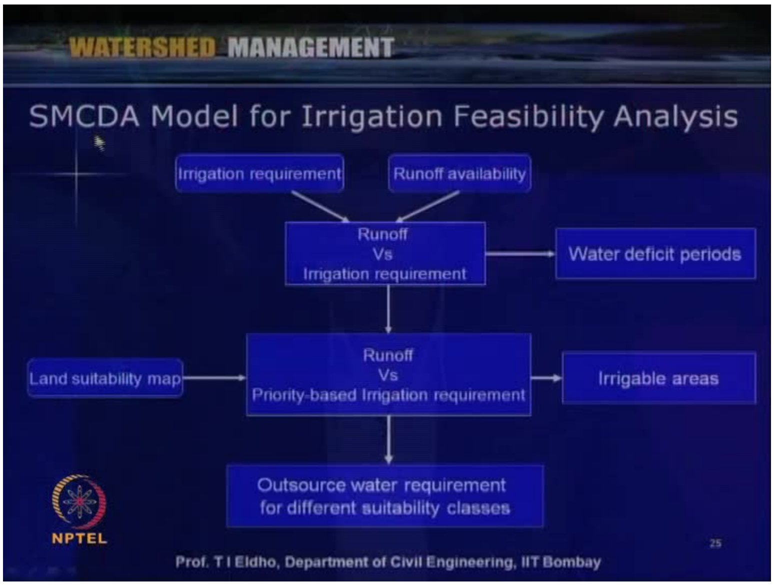


So like that, if then rules, fuzzy rule base we have generated. So, this we generated the fuzzy output in terms of five suitability classes for this model like excellent, whether the area is excellent, good, moderate, less suitable and a not suitable, and then, next step is defuzzification as I discussed earlier. So, this convert the fuzzy output into a single value land suitability index. So, here, maximum centroid method is considered so as shown in this figure.

So now, based upon this, using this model, we can generate the best suitable crop map. So, relative importance and land suitability index is given. So, three cases: case one is land suitability index of existing crop; so, that is less then another crop of higher priority. So then, higher priority crop is selected, so, this one case. Then case two is land suitability index of the existing crop is less then another crop of lesser priority. Then change in the cropping pattern if less suitability or not suitable for the existing crop.

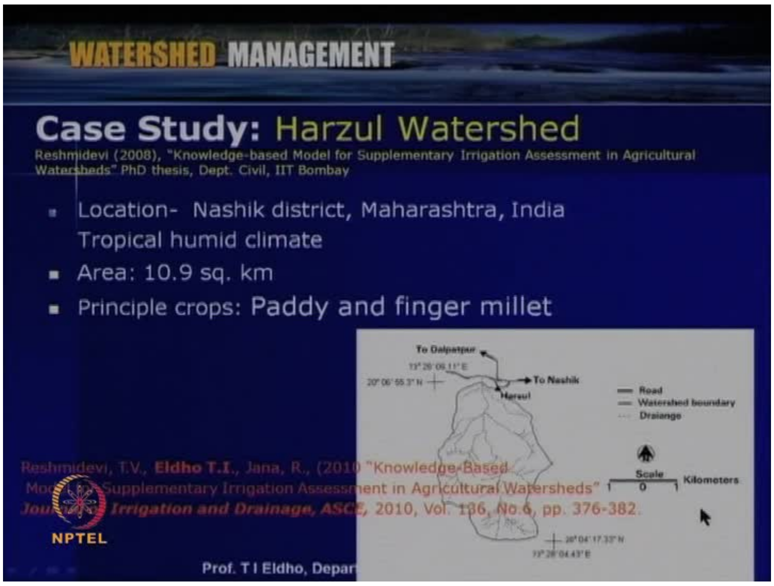
Then third case is land suitability index is same for more than one potential crop if less suitable or not suitable for the existing crop, and if relative importance of the existing crop, then the than the other crop. Then a change in the cropping pattern is proposed and then it replaces the existing crop with high priority one. So, like that various systems we are made in this particular models.

(Refer Slide Time: 51:37)



So, this model, the details are given in a flowchart. This is spatial temporal multi creative decision analysis model for irrigation feasibility analysis. So, here, first we have to assess the irrigation requirement and runoff availability, then runoff versus irrigation requirement; so, this gives the water deficit periods. Then land suitability - it is coming from the fuzzy logic. So, runoff versus priority based irrigation requirement. The irrigable areas, we can identify, and then, outsource water requirement for different suitability classes whether we have to go for the further the supplementary irrigation like that we can decide using this model.

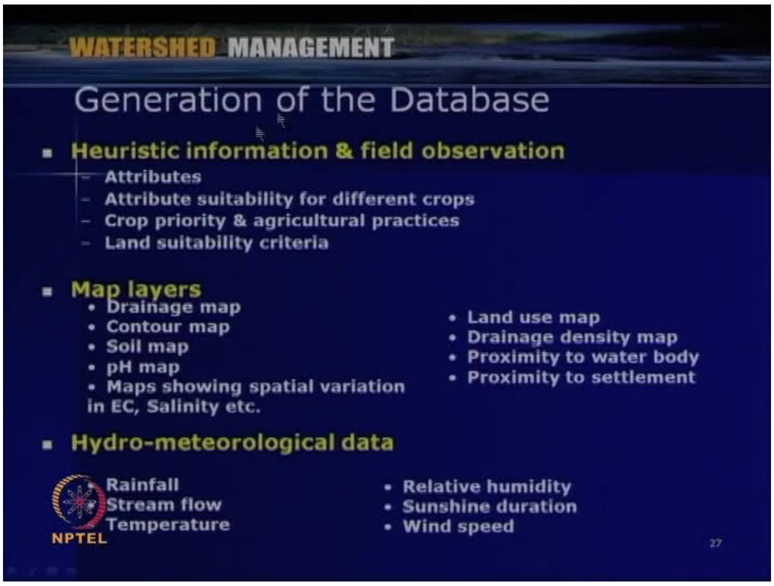
(Refer Slide Time: 52:11)



So, these details of these models are available by in this, you know, in the paper published in 2010 titled knowledge based model for supplementary irrigation assessment in agricultural watersheds journal of irrigation drainage ASCE 2010 volume 136 page is 376 to 82.

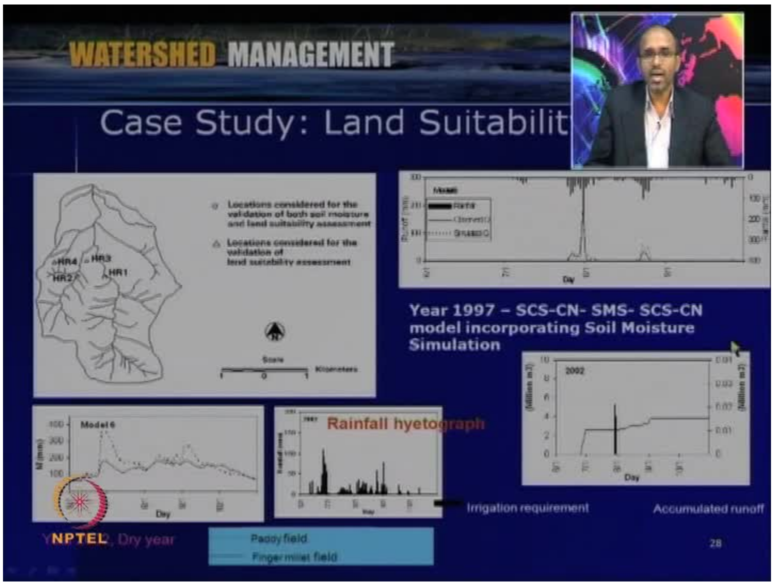
So, let us have a brief look into one case study related to this model which is done by Rashmi Devi in her thesis. So, location is the Harzul watershed and the area is 10.9 square kilometer and principle crops in this area are paddy and finger millet. So, this is the watershed area.

(Refer Slide Time: 52:50)



So, here based upon the various input data, various data based were generated like heuristic information and field observation related to attributes; attribute suitability for different crops, crop priority and agriculture practices, land suitability criteria. So, this is done in the heuristic information, and then, map layers related to drainage map, contour map, then soil map, pH map showing spatial variation electrical conducted salinity etcetera were generated.

(Refer Slide Time: 53:46)

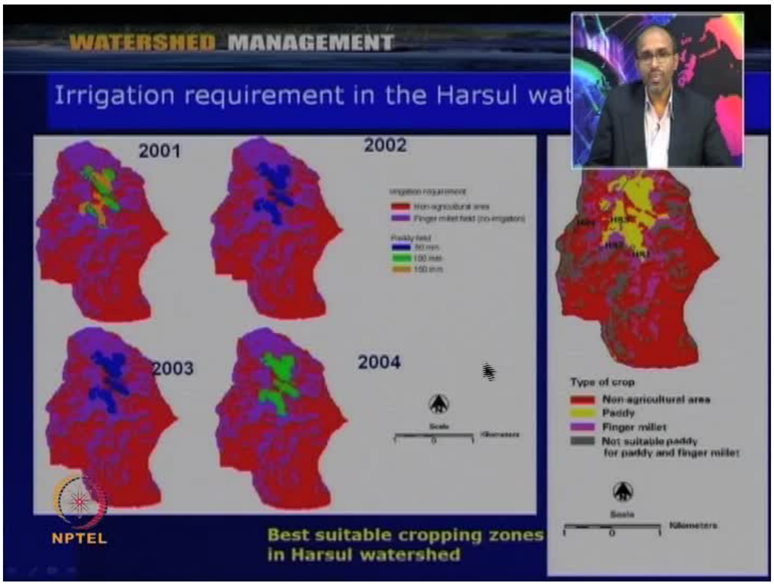


And then also land use map, drainage density map, then proximity to water body, proximity to settlement, so, all these details were generated in the data base so that this fuzzy based system modeling can be done.

And then hydro meteorological data related to rainfall, stream flow temperature, relative humidity, sunshine duration, wind speed, all these were collected, and then, using the earlier described knowledge based model, either modeling has been done, and so, the, for the land suitability related, so, for this watershed, for example the s c s c n soil moisture simulation model has been used for the runoff generation for the given condition; so, this shows the output.

And then for example year 2002 which is a dry year we can identify how much is the water available, and then, for paddy field or finger millet, how is water requirement, and then, this is the rainfall hyetograph and then we can identify how much is the irrigation requirement and then accumulation like that. So, that is these all generated using the particular model.

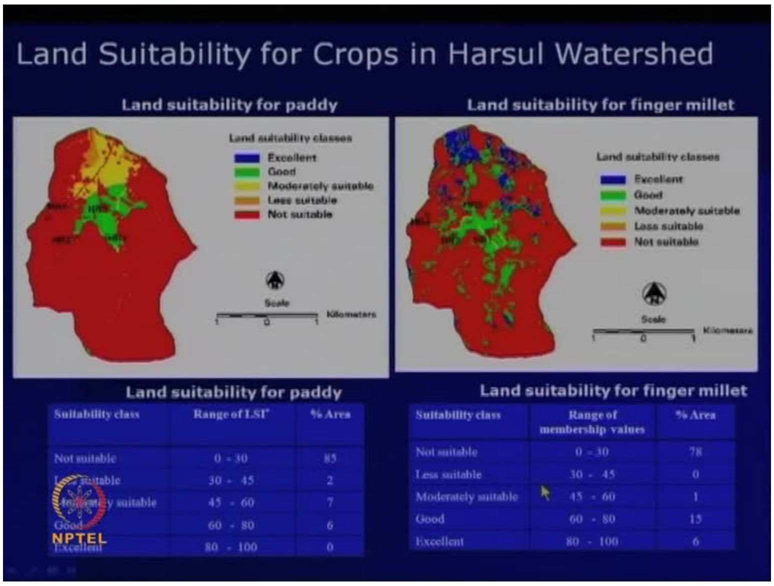
(Refer Slide Time: 54:31)



And then irrigation requirement harzul watershed, for example, four years – 2001, 2002, 2003, 2004 were generated. So, irrigation requirement, non-agricultural area, then finger millet irrigation, then paddy field, how with 50m requirement, 500m requirement, 150m requirement.

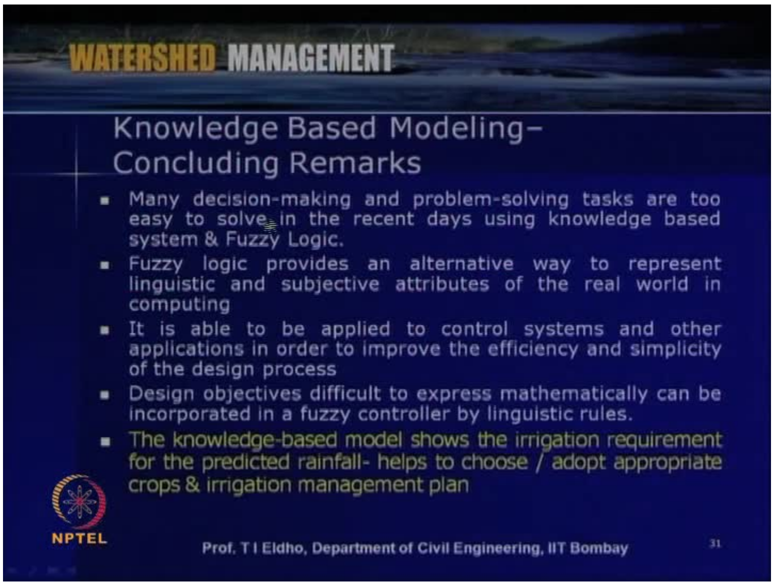
And then based upon that, best suitable cropping zones in harsul watershed has been generated. So, this yellow shows the area suitable for paddy field and then this red shows non-agricultural area and this violet this shows the finger millet suitable and not suitable for paddy or finger millet. So, this way, we can generate the best suitable cropping zones.

(Refer Slide Time: 55:16)



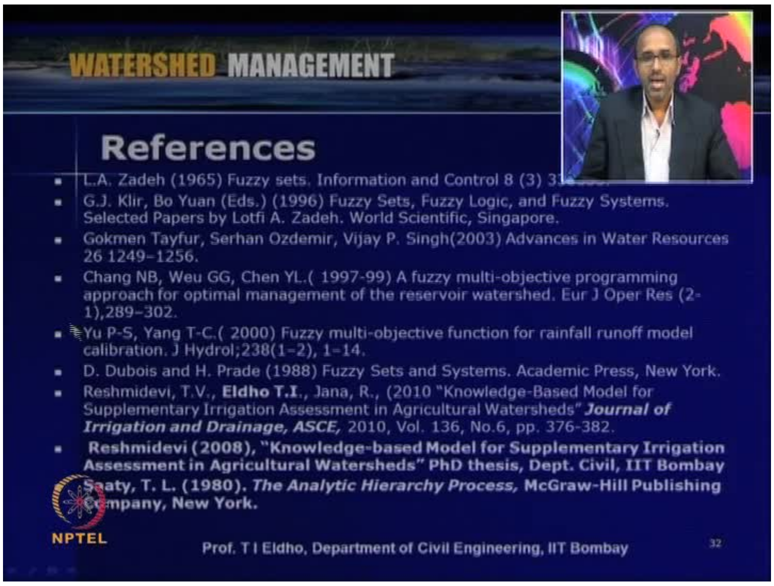
So, this shows the land suitability for paddy, land suitability for finger millet. The suitability classes and range of land suitability index is given here percent area wise related to paddy and finger millet. So, that way, we can generate the, using this knowledge based model, we can genera identify the land suitability for particular crop and then which of the area are most suitable, less suitable; so, like that, we can identify.

(Refer Slide Time: 55:52)



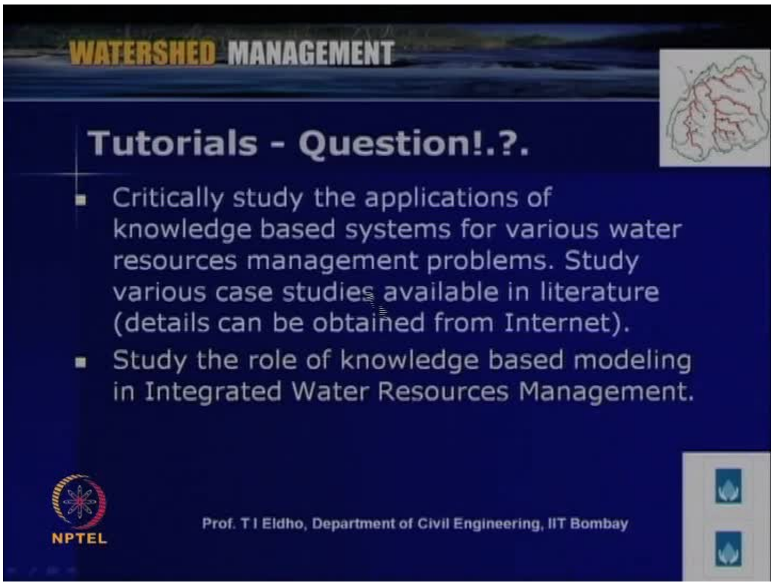
So, now, to, finally to conclude many decision making problem solving tasks are too easy to solve. So, this fuzzy logic can be used for this purpose and knowledge based models shows the irrigation requirement for the predicted rainfall and predicted rainfall helps to choose adopt appropriate crops and irrigation management plans for the given area.

(Refer Slide Time: 56:12)



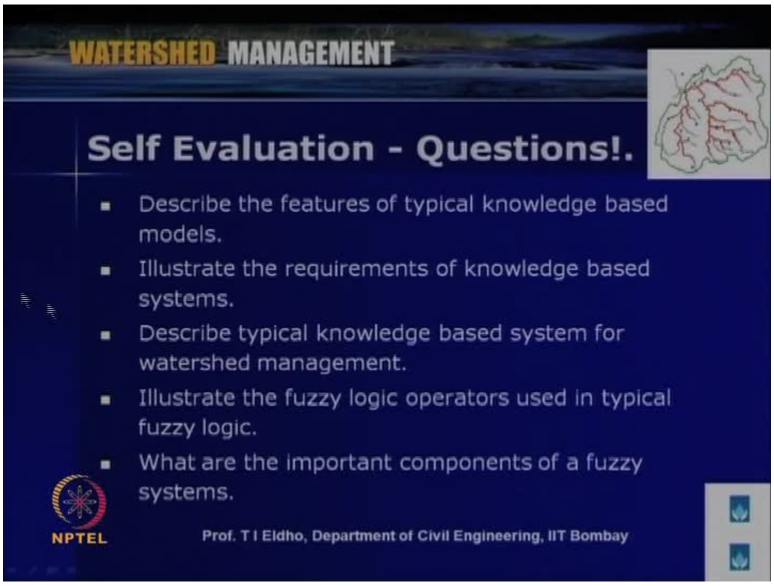
So, these are some of the important references used in a for today's lecture.

(Refer Slide Time: 56:19)



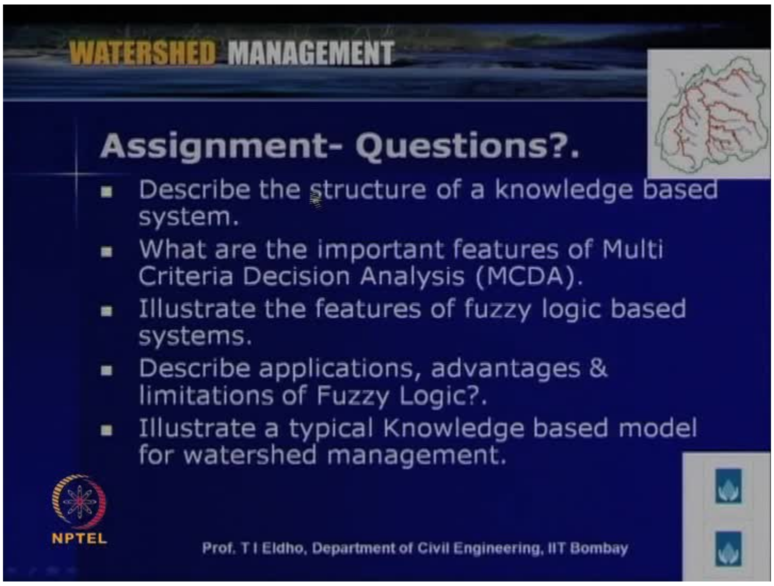
So then, before closing some tutorial questions, critically study the applications of knowledge based systems for various water resource management problems. Study various case studies available in literature. So, these details we can obtained from the internet. Study the role of knowledge based modeling in integrated water resource management. So, how we can effectively utilize knowledge based model?

(Refer Slide Time: 56:40)



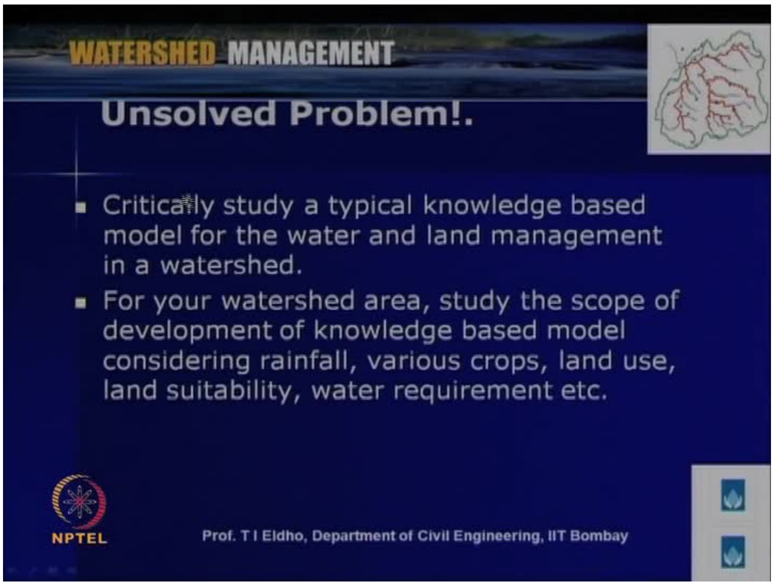
Then some self evaluation questions - describe the features of typical knowledge based models. Illustrate the requirements of knowledge based systems. Describe typical knowledge based systems for watershed management. Illustrate the fuzzy logic operators used in typical fuzzy logic. What are the important components of fuzzy logic systems? So, these all these questions you can answer by going through today's lecture.

(Refer Slide Time: 57:02)



So, few assignment questions - describe the structure of a knowledge based system. What are the important features Multi Criteria Decision Analysis? Illustrate the features of fuzzy logic based on systems. Describe applications advantages and limitations of fuzzy logic? Illustrate a typical knowledge based model for watershed management. So, all these questions we can answer by going through today's lecture.

(Refer Slide Time: 57:27)



And one unsolved problem - critically study a typical knowledge based model for a for the water and land management in the watershed. For your watershed area, study the scope of development of knowledge based model considering rainfall, various crops, land use land suitability, water requirement etcetera.

So, today we considered the knowledge based systems for watershed management. We discuss the fuzzy logic systems, and then, connecting to that, how we can generate knowledge based models. So, that way, we can see that this knowledge based models are very useful in watershed management.

So, with this lecture, the particular module on the modern systems for watershed management module number 6 is over. Now, we will discuss various other aspects of watershed management issues.

Thank you.