

Natural Resources Management (NRM)
Professor Sudip Mitra, PhD
Centre for Disaster Management & Research (CDMR)
Head, School of Agro & Rural Technology (SART)
Discipline - Agriculture Engineering
Indian Institute of Technology, Guwahati, Assam, India
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Lecture - 50
MCDA in Agriculture for NRM
Introduction

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MCDA in Agriculture for NRM

Multi-criteria Decision Analysis (MCDA)

- ☑ Part of operation research for comparative evaluation of the best alternative out of a number of the considered choices or to arrange them according to their importance for the defined purpose
- ☑ The use of the MCDM methods is based on integrating the criteria values and their weights for obtaining the standard of evaluation, which is the criterion of the process.
- ☑ Wide applications in economics, agriculture, resources management, engineering and science field
- ☑ Various types, depends upon the nature and types of the problem

The diagram illustrates the applications of MCDA in NRM and agriculture, categorized into four areas: Watershed and agricultural water management, Forest, wildlife other natural resources management, Disaster management, soil, water quality management, and Rural and urban planning, management. It also shows a hierarchical structure of criteria (C-1, C-2, ..., C-n) and alternatives (A-1, A-2, ..., A-m) leading to a final Decision.

C Criterion **A** Alternative

So this MOOC lecture we will be discussing about a very relevant topic, a technique which actually we can use for better natural resources management and this technique we call MCDA, multiple criteria decision analysis. Multiple criteria decision analysis is a tool which

you may be knowing that extensively applied in various fields, basically MCDA helps us to identify the best alternative for our any purpose.

We will be discussing the applications, the principles and the various aspects associated with this particular technique and its utilization in the field of agriculture for natural resource management. So, friends let us get into this particular topic, multiple criteria decision analysis in brief we say as MCDA, it is basically a part of operational research for comparative evaluation of the best alternative out of a basket of choices for alternatives or sometime it also help us to arrange them according to their importance for a particular purpose.

So what does this means, that if you have suppose more than one alternatives for a particular purpose, let us take the example of irrigation in agriculture field because in previous lectures also we have discussed many aspects with an example of irrigation, let us go for that because that perhaps would be easily understandable by participants coming from any discipline. Now irrigation we have also discussed in previous lectures there are various type of irrigation.

We have a surface irrigation, we can have utilizing groundwater, we can have irrigation through pump, we can have canal irrigation, we can have also drip irrigation, sprinkler irrigations, various ways of irrigation practices. Now when you have these so many alternatives in your hand then at times it become difficult to choose a particular one for your purpose at the particular site.

Now, MCDA is a tool which helps you, at least it helps to simplify this situation, so the use of MCDA methods is based on integrating the different values of different criterias and their corresponding weights for obtaining a standard of evaluation of those different alternatives that you have with you and these criterions actually help you to somehow rank them and obviously the top most rank options or alternatives you try to go for.

MCDA we will find that it is widely applied in the field of economics, agriculture, resources management, engineering and also sciences. So it has a diversified uses and different subject area and field, various types of MCDA techniques are available, which one you would like to use that depends on the nature and the types of problem that you have in your hand, so let us now look at a basic structure or skeleton of multi-criteria decision analysis tool.

Now we would be focusing as I said largely on natural resource management and in the field of agriculture as a case study. Now, application of MCDA in the field of natural resource management and agriculture how actually you can utilize this particular technique. So

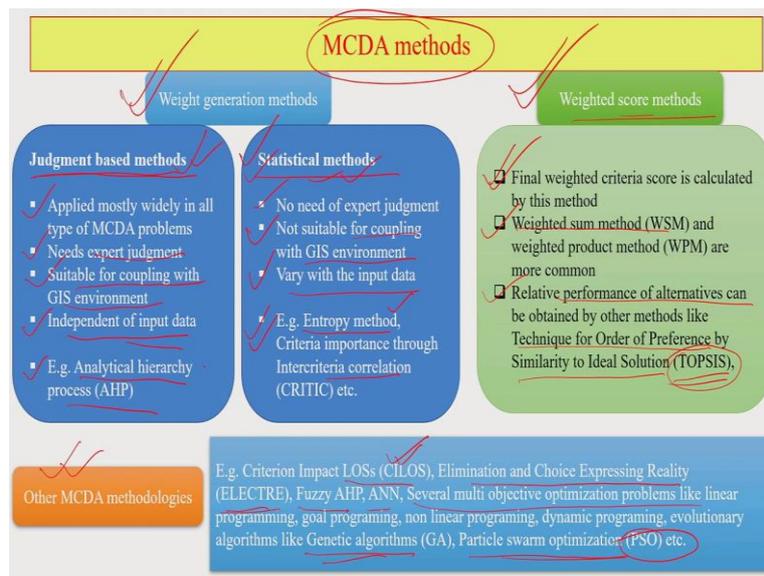
watershed and agriculture water management is one area where you can actually apply MCDA quite extensively, second is forest, wildlife and other natural resources management, disaster management, soil, water, quality management, rural and urban planning management.

So you see that how many different areas where actually MCDA can help us to reach a decision to identify the best alternative for our purpose. Now as I said that its basically helps in making decision now how it works actually is very simple so you try to make a decision and your decision is based on certain criteria, your criteria could be 1 to n number of criteria then in the second tier you have alternatives.

Alternatives can also be from 1 to m, any number, now each of these criteria can have interaction with all of these alternatives. Now, C1 can have interactions with A1, A2 to Am, C2 can also have interactions with A1, A2 so what actually is done that it basically tries mathematically for every criteria to find out that how the criteria and alternative interaction takes place, one by one you check all the criteria with all the alternatives and then you come up with certain rank and that rank helps you to identify the best alternative that is actually suitable for your purpose.

So this is a very systematic way of solving the confusion, the complexity that you may have because of more than one alternatives when you have in hand. But suppose in an area you are doing agriculture, suppose in an area where you have only one option of irrigation, no other options are available, then of course, you do not need MCDA. So, when you have more than one options and the number options when increases, number of alternative when increases certainly, the complexity also increases and then you need actually this kind of tool which can helps you to make a reasonable decision.

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Now, these MCDA methods how actually it is structured and how it works we need to discuss that. Now MCDA methods basically it is a weight generation methods, it also has a weighted score methods. Now as I said that there are various methods of MCDA you choose the one that is best suited for your purpose, now when we talk about the weight generation methods under MCDA what are those?

One is judgment based methods and another is statistical methods. In judgment based methods you actually applied mostly all type of MCDA problems that you in hand because judgment or giving a judgment on a particular aspect is almost common for any decision making process. This process or methods needs expert judgment, you need someone who has reasonable number of years of experience. You know in this kind of especially in kind of natural resource management field or agriculture water management field, experience plays a major role in making decision and right decision at right time.

Judgment based methods also suitable for coupling with GIS environment. It is independent of input data that is one good thing here, so this does not depend on your input data. And then you have one methods which many of you might have used knowingly or unknowingly in your profession or your study and that process is known as analytical hierarchy process (AHP). So that is basically a kind of a judgment base methods.

Then we have a statistical methods, statistical methods of MCDA it does not need expert judgment because from the name itself you can understand that it will be run by some data. This is not suitable basically for coupling with GIS environment unlike judgment based

methods, statistical method will definitely be regulated or controlled by input data. And what are the MCDA methods which are based on statistics are like entropy methods, criteria importance through inter criteria correlations, so these are some methods, some type of MCDA methods which are based on statistical methods.

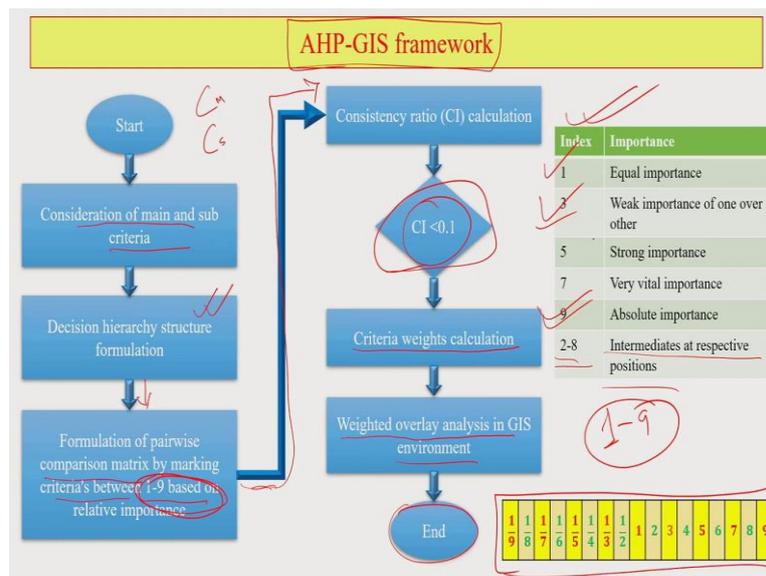
Then come here the other type of method of MCDA that is weighted score method, now in case of weighted score methods the final weighted criteria is calculated by this method. We will discuss in detail that how you actually calculate or score or give some value to the particular alternative, weighted sum method WSM you must be knowing it very common one and also weighted product method WPM are very common under these weighted score methods.

Relative performance of alternatives can be obtained by other methods like TOPSIS. TOPSIS means technique for order of preference by similarity of ideal solution, in brief we call it as TOPSIS, this is another MCDA methods. So see, that in under every MCDA methods we have certain types of MCDA methods which we can apply for. Now, let us see few other MCDA methodologies apart from those that I have just now mentioned.

We have CILOS, criteria impact loss, elimination of choice expressing reality which we call as ELECTRE, these also sometime used for decision making in different kind of engineering solutions. Fuzzy AHP, artificial neural network, several multi objective optimization problems like linear programming, goal programming, non-linear programming, dynamic programming, evolutionary algorithms like genetic algorithms and particles swarm optimizations known as PSO, these are various other MCDA methodologies.

So friends, so what you see here that MCDA methods decision making tool, there are plenty of options that we have different type of methods and this is up to us depending upon the purpose we can choose that which MCDA method will be suitable for our own work.

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Now let us look at another framework of MCDA in coordination with GIS, now for decision making and then projecting it is very important because of decision making process. Now AHP GIS framework, analytical hierarchical process and geographical information system framework is very efficient one which helps us to identify the alternatives, the suitable alternatives and also represent it in understandable manner. How it works?

Now, in this framework we consider main and sub criteria. First which are my main criteria, which are my sub criteria, so this I have to decide first. Once that is clear then I have to go for decision hierarchy structure formulation. Decision hierarchy structure formulation step leads me to formulation of pairwise comparison matrix by marking criteria between 1 to 9 based on relative importance of the choices.

So you give a value to those choices between 1 to 9 depending upon your understanding that which particular option is more suitable or less suitable accordingly the number will varies and these numbers or values which you attach to those choices ultimately will give you the ranking which will help you to make the decision to choose a particular alternative for your purpose.

Now once this ranking matrix is done then this goes into CI calculation. Now consistency ratio CI calculation is a very important step in MCDA methodology. Normally we accept any MCDA analysis if it gives CI less than 0.1 so CI less than 0.1 allows us to continue the MCDA analysis further, once you get this value then you continue with criteria weights calculation, the weightage that you give against your criteria, you start calculating that. Once

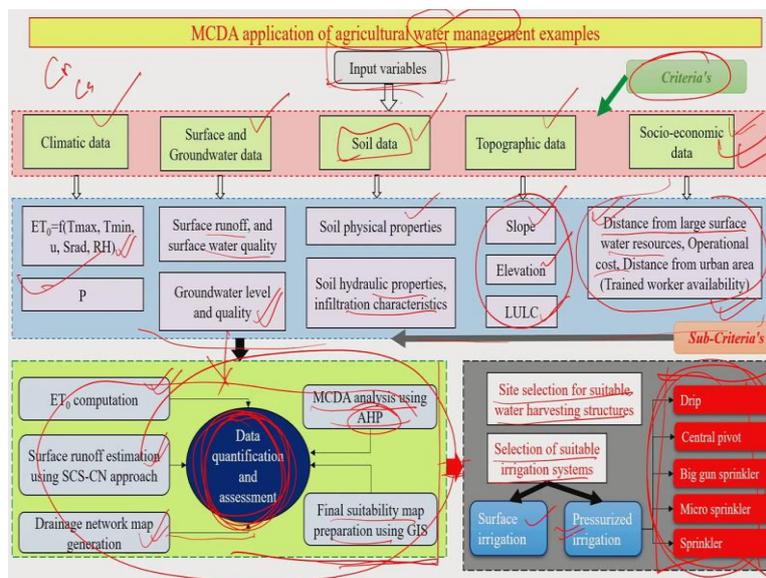
that is done then you go for weighted overlay analysis in the GIS platform. Now once you go into GIS platform then it becomes visible, easily understandable for researcher for also policy makers and there ends the process and you get the final outcome.

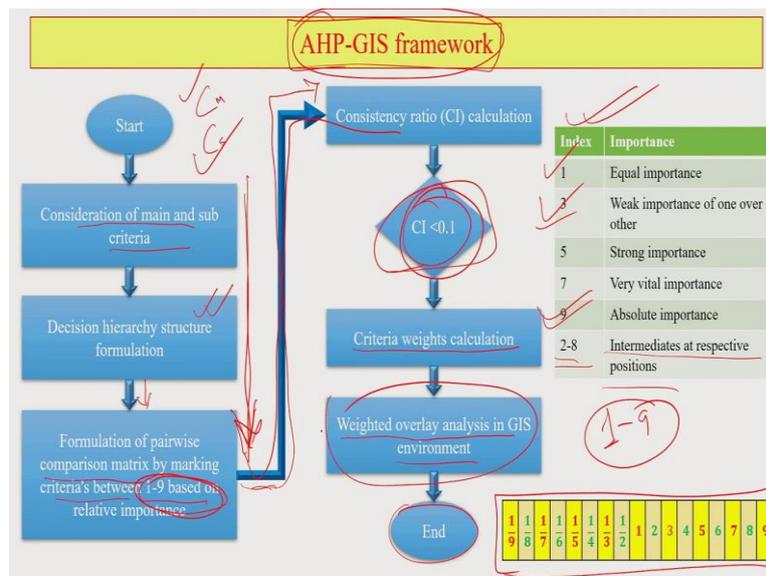
Now if you look at I said that some value between 1 to 9 that you give to those criteria and on the basis of that your calculation or ranking process works.

Now let us see that how these values particular 1 to 9 actually does mean? Now when you give 1 you mean equivalent importance between two alternatives, then 3 means weak importance of one over other when index is 5 strong importance, 7 very vital importance, 9 absolute importance and then 2 and 8 it is intermediates at respective position.

So these are the value 1 to 9 actually means in this exercise all right so this is important for us to know and this is the way that basically you give the marks between 1 to 9 and these are the meaning of those particular index values which you put against the criteria.

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Now MCDA and its application in the field of agriculture water management. So as you know that land and water these are the two most important natural resources on which the human civilization depends largely, significantly, but other natural resources are also important so we have considered land and water as the example to explain certain methodologies for resource management.

Now in case of MCDA application in the field of water management how it works so we have various input variables required for MCDA analysis or application in the field of water management and what are those variables? Climatic data, surface and groundwater data, soil data, topographic data and socio-economic, now these data basically are your criteria, okay. Now these data or the criteria actually you will be now analyzed through MCDA to find out that which one is most important for your purpose.

Now climatic data there are various calculations you do to find out the evapotranspiration, how water actually moisture from soil or plant surface going out into the environment. We have discussed in previous also lectures that evapotranspiration is a very key parameter which actually regulate the water circulation in the soil and plant or SPAC system. Surface and groundwater, surface runoff and surface water quality is important aspect within this particular variable, groundwater level and quality also is very important.

So then when comes soil data we need to know soil physical properties, soil hydraulic properties, infiltration characteristics; because these are the characteristics which are important and required for your best water management practices. Topography, so topography unit slope, elevation, land use land cover information, socio-economic data we

need information on surface water resources, operational cost, distance from urban area, availability of labor so these are the various us kind of information so from the socio-economic point of view.

Now once these are the data sets when it is with you then you go for the real MCDA analysis. Now these are your criteria and these are your sub criteria within each criteria you have set of sub criteria so you are ready with the main criteria and sub criteria. So, remember that we discussed here that main criteria, sub criteria and then you start your MCDA analysis, same here as an example in the field of water management.

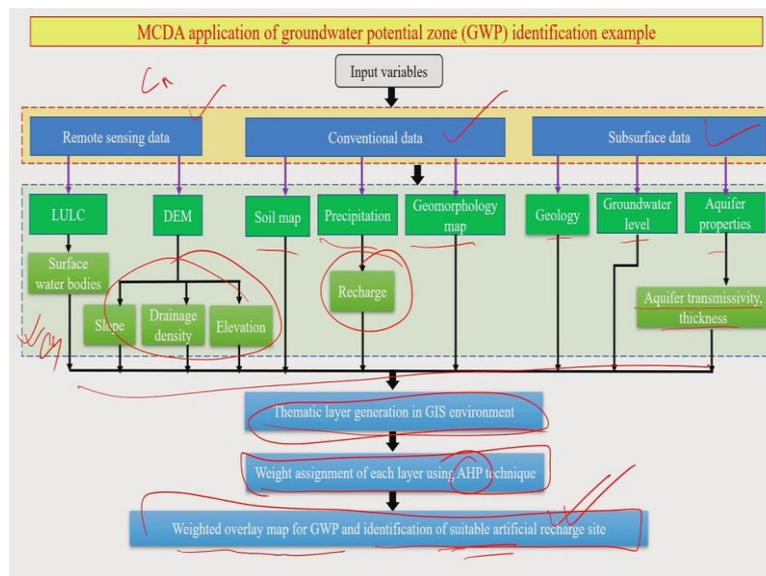
Now once these are ready, your sub criteria ready, you get into the MCDA analysis and here data quantification and assessment process is going on with the help of different calculation. You calculate ET, surface runoff, drainage network map generation so these information analysis will come your data quantification and assessments system.

And then this will also help you for MCDA analysis using AHP. Final suitability map will be created with the help of GIS which we just discussed here under AHP GIS framework how from your MCDA analysis the data goes there and then any value which is CI value less than 0.1 then you carry forward and then finally you get into GIS and develop map and ultimately present it.

Same way it will take place here once your MCDA analysis is completed then it goes here once GIS map is also created, site selection, now decision is ready in the form of a representable GIS maps then you go for your decision. Site selection for suitable water harvesting structures which area in which particular location you want to have a water harvesting structure that you have to decide, selection of suitable irrigation system as I said previously that you have to identify or choose the right one.

Now you have various set of options, so your this MCDA analysis basically will help you to choose one of these options because we cannot go for all the options available for irrigation. So the role of MCDA is to reduce the complexity of choosing your alternatives.

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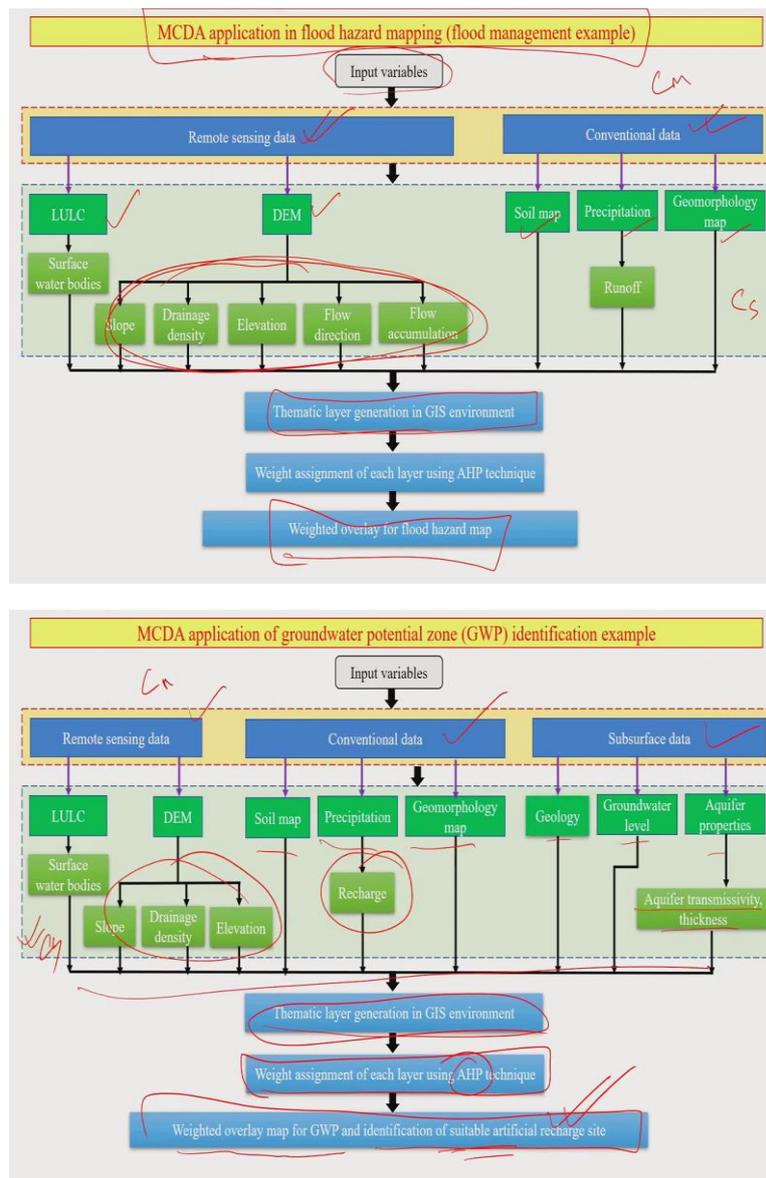


Now MCDA application of groundwater potential and how MCDA helps in managing groundwater. Now, here also we have certain input variable, remote sensing data, conventional data, subsurface data. Then we come here first is your main criteria and then we have sub criteria; we have LULC, DEM, surface water bodies, slope, drainage density, elevation under digital elevation model then soil map, precipitation, from precipitation you calculate recharge, geomorphology lab, under subsurface data we have geology, groundwater level, aquifer properties, aquifer transmissivity, thickness, all these information.

When these are available with you then you go for the thematic layer generation in GIS environment, weight assignment for each layer utilizing AHP technique and once that is ready then you get weighted overlay map of groundwater potential and identification of suitable artificial recharge site. Because that is the ultimate aim for you to enhance the ground water of a particular location so where you will be actually having your kind of intervention for enhancing the groundwater potential also will be decided by an efficient MCDA applications.

So you see that MCDA how it can help you almost all the critical functions of water management and also land management, in fact as I said that it can be used also for this decision making of even fertilizer applications. So, all the examples all the all type of examples and discussing it in this lecture, one lecture will be difficult but I hope that you understand that how MCDA can help in decision making for running the different practices within agriculture system for natural resource management. Similar way you can also apply this particular technique for other decision making processes.

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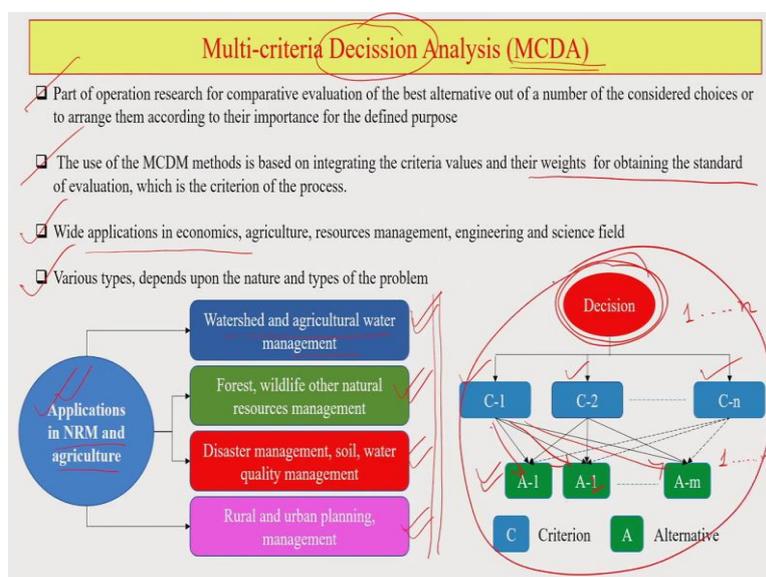
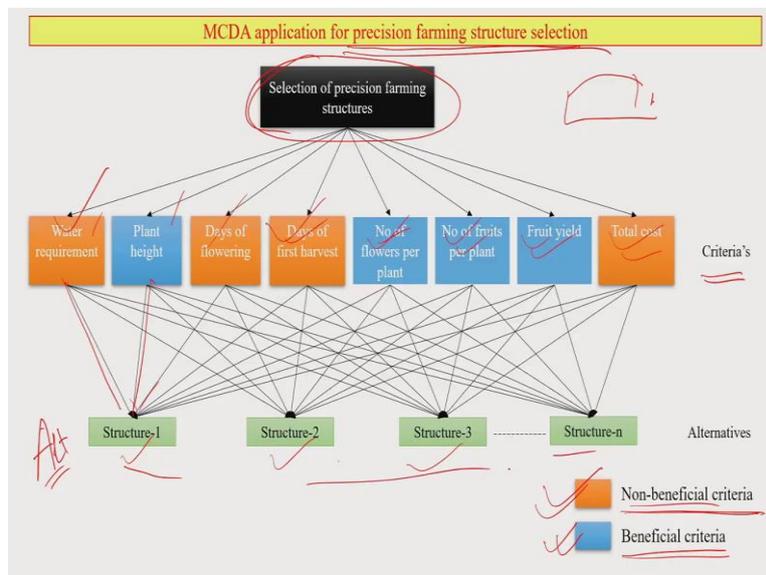
Now I let us talk about little bit on disaster as well because very recently you know that Assam had a terrible flood so we get the flood almost every year and many other parts of the country also get but when it takes place during the flood and also the after flood there are certain critical decision to be made. Now MCDA application in flood hazard mapping has also been attempted as a part of flood management; people have been using it.

So let us see that if you want to apply MCDA for flood management how it can actually work, first of all you need again some inputs, inputs variable before you start MCDA exercise. These days we have very good quality of remote sensing data and then we have conventional data, under remote sensing data you have LULC DEM data and under DEM you have these are the kind of data that actual information you get.

When you come to conventional data we have soil map, precipitation, geomorphology map, like the previous water management also you have seen so more or less a similar kind of data information we also need for flood hazard mapping.

So once your again main criteria and sub criteria are chosen then you go for similar way like ground water management, thematic layer generation in the GIS platform then you assign the weight for each layer using AHP technique that I have explained at the beginning of today's lecture. Once AHP technique is done then you get basically what the weighted overlay for flood hazard map finally you get a flood hazard map with weighted values for certain information, certain alternatives with you and which finally help you for better flood management.

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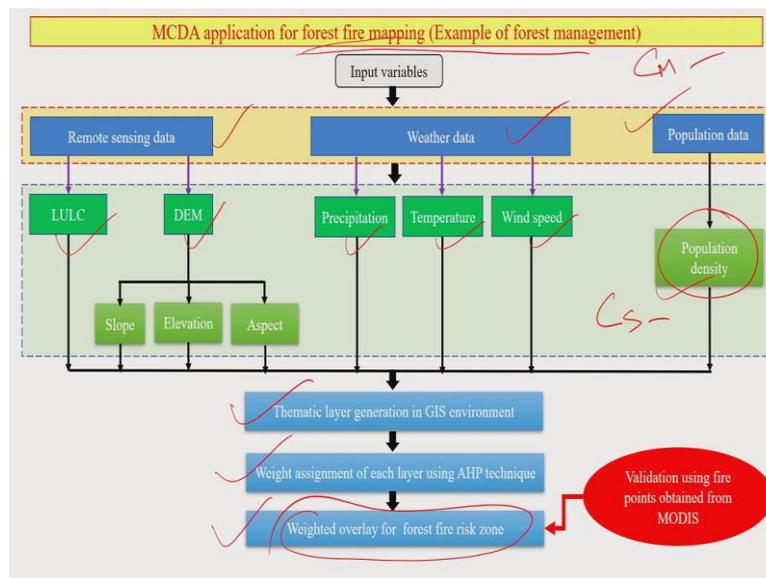
Another application of MCDA is getting very popular these days is in the field of precision farming. Precision farming we discussed in the previous lectures, so you are aware of what is precision farming is and how it is important for natural resource management. Today we will see that how multiple criteria decision analysis can also be integrated within precision farming structure and which particular precision farming structure you will select for your purpose.

I hope you also remember the various structures that we have discussed and also different type of farming like vertical farming, protected farming, various other things, options that which one you will go for. Now selection of precision farming structures if that is your challenge and that is your purpose to find out then you need to look at for water requirement, plant height, days of flowering, how many days it takes, days of first harvest, number of flowers per plant, number of fruits per plant, fruit yield, total cost.

Now these two colors blue and orange what does it mean. The orange color means these are non beneficial criteria, blue means these are beneficial criteria; beneficial criteria for your precision farming. But we need to look at the both the non beneficial criteria as well as beneficial criteria and then if you recall that we had a criteria versus alternative structure, this is that structure, similar are kind of thing criteria here, alternative here.

Now you see in the real example in the case of precision farming structure, these are your criteria and then you have different structure you remember the different greenhouse, net house structure also so one structures again third fourth and different structures you have. Now same way like each criteria with this alternative, these are basically alternatives, these are basically alternatives, so you will have a kind of a analysis with each criteria with all structure and then definitely you will come out with a score and finally ranking and then you choose one, two, three your priority of structural choices and then you go for that particular structure for your precision farming.

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Now another application of MCDA is forest fire mapping, very important we discussed at the very beginning of this course that forest is another important natural resources. So in today's lecture what I am basically trying is to give you certain examples of important natural resources how they can be actually managed with the help of MCDA. Now, here in case of forest fire mapping which are the main criterion sub criteria that you would normally choose.

Again remote sensing data, weather data and population data as your main criteria, then you have these information like the previous ones and some other also new variables or information you will have as your sub criteria. Once you have against main and sub criteria then you follow the same path like the previous examples go for mapping, then you go for giving weightage through AHP technique and finally then you get a map after giving weightage and the thematic layer, so you get finally a map which shows the ranking of options.

So this is again a very useful because forest fire is an a very important field or area which we need to look at for saving our natural resources and what you get actually if you observe it keenly that MCDA is not very complicated technique but it helps you to simplify a complex situation especially which is created by availability of more than one alternative. Having more alternatives in hand is good but not always because you might get confused which one to choose, which one is better for your purpose and that is the time multiple criteria decision analysis help us the most.