Natural Resources Management (NRM)
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Week - 06
Lecture - 33
Modeling and Simulation Application in Agriculture for NRM Part – 1

Today we will be discussing about a very important topic and that is on modeling and simulations application in agriculture for natural resource management.

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Now, we have already discussed a lot of technologies, a lot of principles, which we actually can apply for better natural resource management at the field level. Now, modeling or simulation exercises is another set of very important tool, which nowadays are extensively used for smart natural resource management.

So, today, I will be discussing about various types of model simulations, exercises and many other aspects which actually help these modeling or simulation exercise for better natural resource management. I am sure that many of you must be aware about the capacity or the power of modeling tool for various purposes. We have used lot of models of simulation exercise for climate change, its impact studies, crop production, soil, land use, even for that matter, some of the problems associated with the various natural resource management and other aspects, if you look at that role of modeling and simulations are very critical.

Now, having said that, before we start actually getting into details of this particular topic at the very beginning, I would like to share with you that there is also a group of communities who have certain amount of what I call conservation experts and many other natural resource experts; some of them have a little bit of doubt with some of the outcomes of modeling or simulation exercise. With due respect to those group of people, we must take they are also input and keep on developing further strengthening this modeling tool.

Yes, there will be certain cases or times when you may find that the result that you are getting out of your modeling or simulation exercise may not be the one that you are expecting. So, there could be some surprises and that is the beauty of this particular tool.

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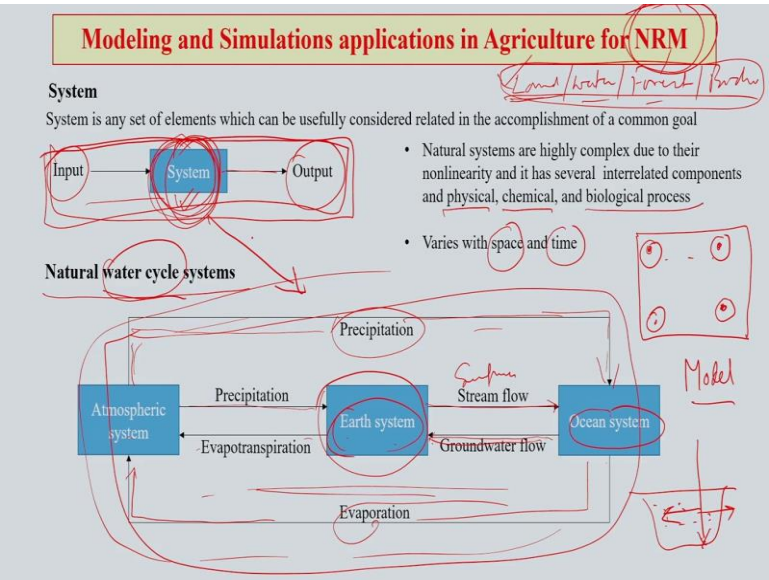

So, with that note, let us now get into the subject. Now, what actually modeling or simulation exercise when we say we mean? Is basically a system a kind of a composite system is a set of various elements, which can be usefully considered with relation to the accomplishment of our objective or goal. For any exercises here we are talking about NRM, so, in NRM, we know that many things come land, water, forest, biodiversity, what not. So, modeling tool, if you see the literature of reports in the public domain, you will find that extensively people are using for almost all of these aspects, which are basically part of natural resources.

Now, let us try to understand in a very simplistic manner, that how this system actually looks like. So, here, this very simple picture graphics, it shows what it does. You actually put certain sets of input into the system, which is suppose your model and these inputs when you

put into the system, there is something is happening within the system, which we will discuss later.

And after all those happenings, it also gives you some output. So, for users, this is important. For users what is happening inside the systems may not be that important, but for us, for you, who will be actually using this powerful tool, we need to know more about the system, how actually it works, when you provide a set of input, then what is happening there. And this system will have a set of equations, it could have set of different kinds of expressions, which are actually based on the field situations.

So, what actually we try to do is to mimic the nature and happening in the natures. Into this, having said that, I must say here that it is almost impossible to mimic or copy exactly what is happening in nature. So, our effort would be always to go as close as possible to the nature what is happening there and that is why this particular field is one of the most dynamic and progressive field every day something new is happening in this field.

So, natural systems as we know that when you work with natural system, it is very complex, and especially, when I say that you work with natural resources, then it become more difficult to work with because each one of these components of Natural Resources land, water, forest, they are so interactive, so dynamic every moment some changes is taking place. To capture that dynamics in a model system or simulate that happenings is not a easy task.

So, as I said that natural systems are highly complex due to their non-linearity nature and also several interrelated components are there. Suppose, you are working to find out a best management practices for land. Now, when you work on land, you cannot work land in isolation. So, what is happening is that inside the land, water system, forest, plantation, many thing? Different kinds of land use is taking place. So, all those things are basically impacting your calculations, your estimations for land.

So, that is why that to work with natural system is not that easy. Because in natural system one system is interacted, interacting with other and within each system, you have various physical, chemical and biological processes taking place. On top of that, a very steep challenge is posed by space and time changes. Almost for from one place suppose, this is your one area. So, from this point, if you move to this point or that point, you will find that the soil, the water, the organism, living in each place varies significantly.

So, to capture this kind of situation in a model environment becomes much more difficult. Now, so, let us take one simple example to understand that how this system can work. Say for, water cycle all of us during since our childhood we have been studying hydrological cycle, water cycle. So, what actually how you can actually capture even that phenomena. So, in water cycle basically what we see, we see the precipitation or rainfall it takes place.

So, rain it comes and then it goes to ocean system river and then from there evaporation takes place. Under the sunlight that evaporation it goes evaporated molecule moisture goes up to into atmosphere, then there are some processes takes place, condensations and other things and then again it precipitates.

But in between something is happening from oceanic systems it could go into groundwater flow also. If you remember that in watershed management classes we have discussed about different kinds of water flow. So, it could be horizontal flow, it could be vertical flow of water, So, from oceanic system groundwater flow can takes place and then it enters into the groundwater, which means a part of earth system.

So, try to see that how this simplistic system with an example of water cycle we are now discussing. Now, from oceanic system through groundwater flow water can come to the earth system from earth system through evapotranspiration it can go to the atmospheric system and then again the cycle continues.

But here from the atmosphere, sometimes what happens is that the precipitation can directly come to the land to the soil. It goes of course, into the water bodies, but it can also come to the earth surface and can straightaway go into the groundwater through implantation, or it can go through river as a steam flow, surface water can go into the ocean. So this is the basic water cycle which we can actually try to put in a simplistic system and which we can call as a model.

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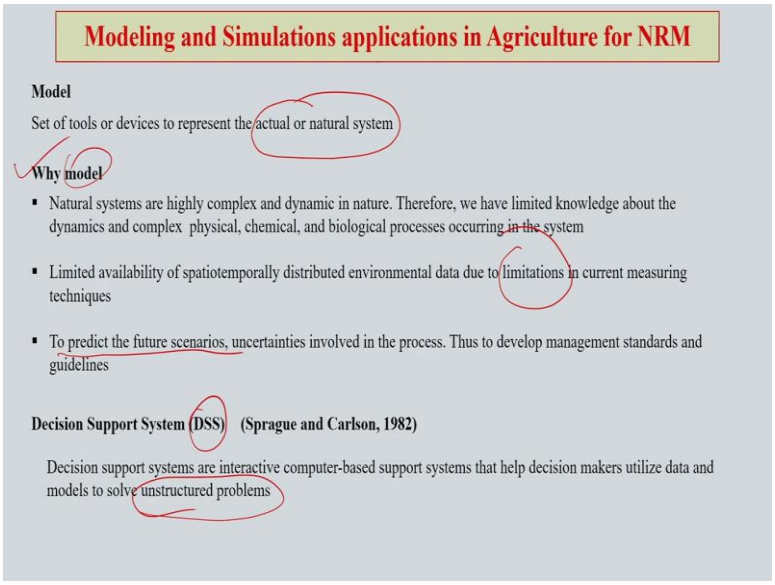

Now, let us get into the model. So, model is nothing but a set of tools to represent the actual natural system as I said just a minute ago. So, the challenge is this that how close you can actually make the system or the model that can mimic your natural system. But why do we need model? First of all, why do we need it?

Natural systems as we know highly complex and dynamic in nature. So, we have very limited knowledge about the dynamics and the complexity of the various physical, chemical and biological processes which are happening inside the soil, inside the water, interaction with forest and ambient environment. As I say that every moment changes is taking place, also, limited availability of data spatiotemporally spatial data distributed across the region is a great limitation for us.

Now, it is often very difficult to go for field level data collection for entire area suppose hundreds of kilometers of river or for a system or a suppose a particular land use system. A huge number of or huge volume of manpower system instrument you would be requiring, and that not only financially is quite difficult to arrange, but also otherwise logistic wise. And in such case model helps through model you can actually somehow capture those areas also, where you have not or you could not go, could not visit or could not carry out the field exercise. Because of various reasons.

Model also help us predicting future what would happen on the basis of what was happening in the past and what is happening now, you can also predict the future. Uncertainties which are involved in the process can also be captured. Thus, to develop a management standard and guideline modeling helps a lot.

So, these are couple of important aspect where modeling exercise or simulation exercise help us for better natural resources management. Now, when we talk about a modeling system or simulation system, the first thing that come in our mind is Decision Support System. In brief, we call them DSS.

Now, decision support systems are a kind of an interactive computer based support system, which help us to make decision on the basis of past data, past observations and models help us to solve sometimes even the unstructured problem. So, basically, decision support system, it is a modeling tool, which helps us to take certain decisions for certain area where for some reasons or other, you could not able to go physically.

But when you come out with this kind of decision, definitely, you need to carry out a very, very sound and robust modeling exercise and that robustness of a model, which can actually help you to take a decision for an area where you could not able to even visit depends on the quality of data, the past data of an area on the basis of what you are developing the model or validating it. So, developing model and validation model these are critically important exercise and that depend, the quality of that depends on the quality and quantity of your data.

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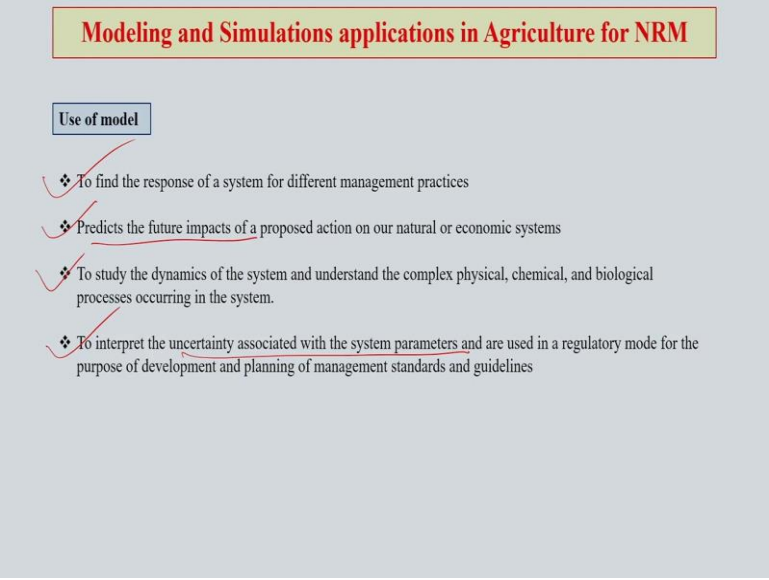

Now, what are the different ways that we can actually use these kind of models? Already some idea you have got, we need to find the response of a system for different management practices is one use of model. As I said, it helps in predicting the future impacts of a suppose any actions say today you have decided to carry out a particular practice suppose in an agriculture feed or in a forest.

Suppose, you have decided to utilize a certain practice says for example, take that you have decided to apply certain chemical fertilizer or suppose you have decided to utilize a particular instrument to prepare your land or manage your forestry. Now, what will be the impact of this particular practice on the land on the trees, plants and water that also model helps you to understand and also can give you a future impact if you take this decision what will happen. So, that also in another aspect of modeling exercise.

It also helps to study the dynamics of the system that couple of minutes back we were discussing, I was mentioning about the complexity and dynamics of natural system. But modeling help us to study those dynamics, help us to study the system mechanism, it also help us to study those complex phenomenon physical, chemical, biological processes continuously occurring in any system or their land or water, forest, even though they are complicated, they are complex. But models help us to understand that.

Modeling also help us to interpret the uncertainty associated with system parameters. Say for example, in an area people are very poor, farmers are very poor and they need to perhaps they are rice farmers say for example; now, all of us we know there is rice are transplanted from seed bait to the field, main field or it can be directly also seeded there are various other ways.

But one thing is important that every practice transplantation, fertilization, even for your suppose you want to apply pesticides, whether bio pesticides or chemical, you need to know about weather parameters. So, for agriculture, weather parameters are the most important aspect which actually regulate the entire production system. So, those parameters and the uncertainty associated with that also can be analyzed and to some extent, an anticipatory or precautionary mechanism can be developed by using the model outputs.

So, you see that modeling exercise can actually allow us to have some adjustment in our existing system. It allow us also to prepare our self for the unseen because it helps on the basis of the past history, past record to predict the future. Yes, I do agree that there will be chances in some cases, perhaps your modeling outcome or prediction does not match exactly what is happening, but even it is close suppose say 70 to 80 percent to the reality still it is helpful; because you are getting some kind of early warning before you lose everything.

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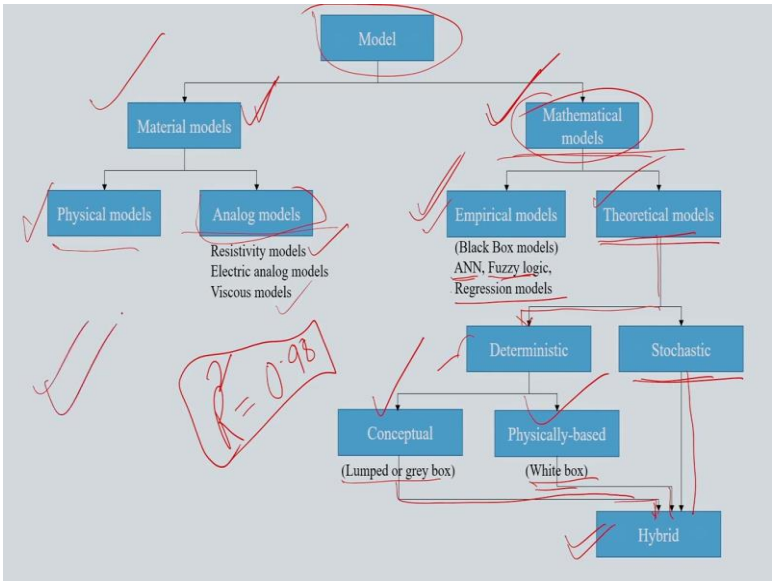

Now, let us discuss about a little bit about the structure how actually this kind of model looks like. So, model can be of different types and different nature to simplify it, we can have material models, where actually you have models working on a physical aspect or you can have analog models.

On the other side you have mathematical models, now mathematical model can be empirical or theoretical. I am just trying to give all of you a very simplistic manner to explain so that; because I understand that many of you may not be from modeling or simulation background or have experience on that.

So that is why I am trying to explain you as simple manner as possible. Now, these two sets mathematical model and material model. They have different purposes. So, on the basis of your purpose our purposes we decide which model to choose. Now, as you see here for analog models, we have resistivity model, electric analog models, we have viscous models, each one of them have different use.

Similar way when you come to the mathematical side, mathematical models, we have empirical models many of you might be using, and we have theoretical models. In empirical models largely black box models we say Artificial Neural Network, Fuzzy logic, Regression simple Regression model. So, remember that we come out with R square value something like this, and then we say that it is significant even that also a model, a mathematical model, regression model.

So, theoretical model can have again two different types, deterministic model and stochastic model. Now deterministic model again can have two conceptual and physically based. In

conceptual you can have kind of lumped or gray box type of model, in physically based you call it white box type of model.

Now, Stochastic model and then conceptual and physically based model all can, when come here in one place, we call it hybrid model. Certainly you can easily understand that this will be much more what you call complex, but this kind of hybrid model will definitely allow you to capture many things at a time. So, this is how a kind of a model the world, the world of model looks like which generally used for natural resource management aspect.

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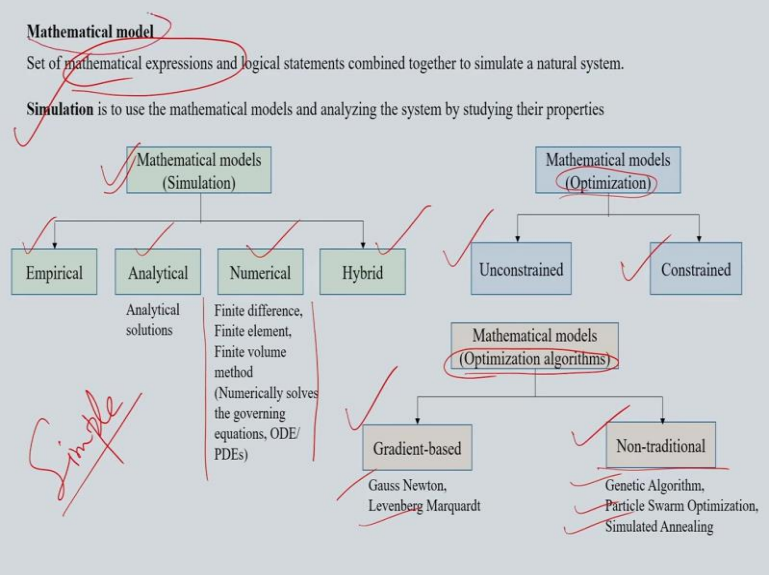

Now, let us spend some time on mathematical model aspect. Mathematical model basically it is a set of mathematical expressions and logical statements which are combined together to simulate a natural system. I repeat it again, mathematical model is a set of mathematical expression, various mathematical expressions and also logical statements these together they try to simulate a natural system.

Now, there are you might have heard that many scientists they argue that any kind of phenomena happening in our life can be mathematically expressed. Well, let us not go into that debate whether all of them can be possible, but majority of the phenomena are possible to be expressed mathematically. And when you club the logical statements along with the mathematical expression, then you actually reach very near or close to the natural system or happenings, this is what is the objective or target of mathematical models.

Now, simulations, simulations actually is to use these mathematical model or expressions and analyze the system by studying their properties. Suppose, you are going to study one natural resource say for water. Now you want to suppose in an area you want to, a pond system is there and you want to actually model it that how that pond system actually is working under certain sets of climatic conditions, if these changes then how the dynamics in the pond will affect you want to study that. You want to predict that what would happen if any changes takes place in one or many of the parameters.

So, in that kind of condition situation, you simulate it with the help of mathematical models and you try to study the System Properties of that particular pond; various aspects there will

be temperature issue, there will be rainfall issue, there will be various other things. So, that is how actually you begin and you try to simulate one natural particular system and then you come out that if I change A then what will happen, if I change B then what will happen.

So, this is the way it allows you, it gives a lot of opportunity for you to prepare yourself to the unseen something, some kind of changes that you have not seen, but you are prepared. So, that is a very very helpful inputs that modeling exercise can give to us in case of natural resource management.

Now, coming back to this mathematical models, so, simulation is one exercise that we do in mathematical model and the other is optimization very, very important. Now, in case of mathematical models, as I said that we have empirical, analytical, numerical and hybrid combination of all. So, largely many of you might have used numerical model quite frequently in your professional life, but the other model are equally also helpful.

Now, if you come to the optimization side of mathematical models, it can be done in two way, one is unconstrained approach, the other is constrained approach. Then optimization algorithms, this is also another aspect of mathematical model. Where we try to optimize the situation, optimize the conditions through various optimizing algorithms. Again, they could be of two types, one is gradient based and the other is nontraditional.

Now, in case of Gradient based you have Gauss Newton, Levenberg Marqaurdt. And then in nontraditional optimization of algorithms, you have Genetic Algorithm, Particle Swarm Optimization, you have Simulated Annealing, various techniques. So, this is again a very very simple way or simple representation of a very complex tool or phenomena which is involved in case of mathematical modeling.