Natural Resources Management (NRM)
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Week – 06
Lecture - 36
Modeling and Simulations Applications in Agriculture for NRM
Part 4

Well participants, we are continuing Modeling and Simulation Applications in Agriculture for Natural Resource Management.

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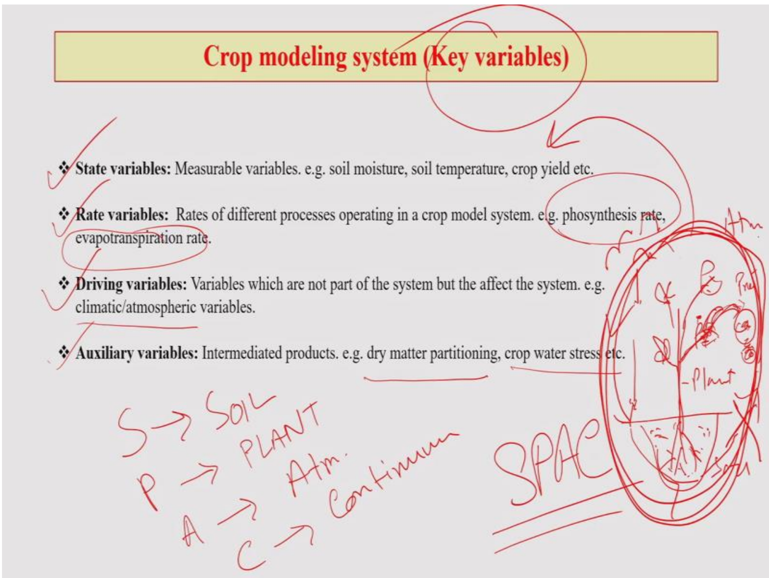

Today we will be discussing on another new topic that is crop modeling system. Now, crop modeling system is very important and very useful for agriculture purposes as well as natural resource management in agriculture sector. While discussing various other model I mentioned about also crop model. Now, today we will be discussing about the various aspects of crop modeling.

Now, in crop modeling system, why we do crop modeling? Crop modeling, basically, it is done once again, like any other model for some predictive exercise. Now, crop model help us on the basis of various input, data inputs, parameter inputs. It provide us an anticipatory result or outcome for certain package and practices and input parameters, it provides certain outcome, and the outcome is ultimately the production or the yield kg per hectare or whatever you need that you choose for.

So, the main purpose of crop modeling is to a kind of an anticipatory exercise, which helps you to establish or to prepare yourself towards some unseen, situation and especially these days when climate change, is getting manifested almost in everywhere in the world. So, in our country, crop modeling can play a very important role, this allows you to make certain decision well before the event takes place.

Crop modeling also now is a part of climate smart agriculture that these days we are often talking about. So, in crop modeling, what are the key variables that we actually consider? Now, one is state variables. State variables means the variables which we can measure, as for example, soil moisture, soil temperature, crop yield, etcetera, any variable that we can measure on the field.

Next is rate variables. Rates have different processes, which are operating in a crop model system. Now crop model system, whatever is being operated is actually trying to mimic the system what is happening in the nature with regard to the soil and plant system. Now, what are those one is of course, photosynthesis, evapotranspiration, and many other nutrient exchange also. So, these are the variables which are actually process based variable, call them rate variable.

Driving variables. Now these variables which are not part of the system, of the modeling system, but still it affect the system. What are those? Climatic or atmospheric variable. So, these variables, they may not be directly inside the system, but they can still influence the processes and also the outcome of this modeling exercise.

Next, auxiliary variables. Auxiliary variables, these are somehow intermediated products of the various system which is happening inside crop model, like dry matter partitioning, crop water stress and also moisture changes across the soil layer, transpiration taking place from the plant.

So, essentially, it tried to capture the system, which we call SPAC, where S stands for soil, P stands for plant, A stands for atmosphere and C stands for continuum. So, if suppose, this is your soil system and this is your plant, these are plant roots. So, this is your suppose plant system.

Now, this is your atmosphere, this is soil, this is plant. Now what happens is that from the soil you have also moisture here, because from the cloud precipitation is taking place, it is straightaway coming to the soil. So, from soil water, the water goes under capillary action through the plant stem up into the leaf and then outside in the atmosphere.

So, what happened is that, because of pressure deficit in the atmosphere and in the leaf here, so, when there will be low pressure the water will try to go out. So, in case of dry condition when outside atmosphere is dry, the transpiration of water will be more and it will directly go into the atmosphere. But when the weather is very humid, you will see that transpiration the water droplets sometime you will find on the top of the leaf, because the outside atmosphere is already saturated with moisture because of high humidity.

So, water coming from cloud into the soil, from soil it goes into the plant, from plant through transpiration it go into the atmosphere. So, this is the cycle which is continuously running and for any reason for any event, unwanted events say climate change or any other event in the soil or in the plant or atmosphere, if the cycle is broken, then there is an issue you will see definitely that is going to affect the plant overall growth as well as the yield.

So, this phenomena, these dynamics is also captured into crop modeling system and better the model which can capture this phenomena, SPAC phenomena in a better way, the outcome of the modeling exercise will also be better.

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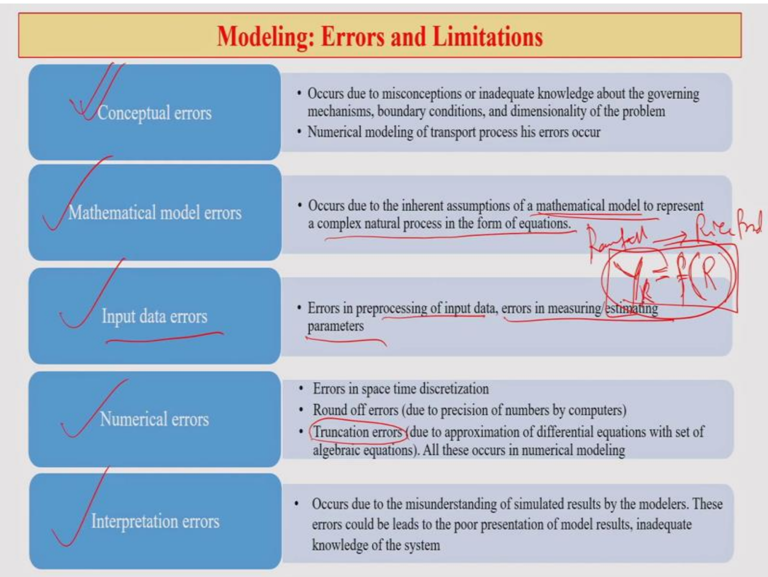

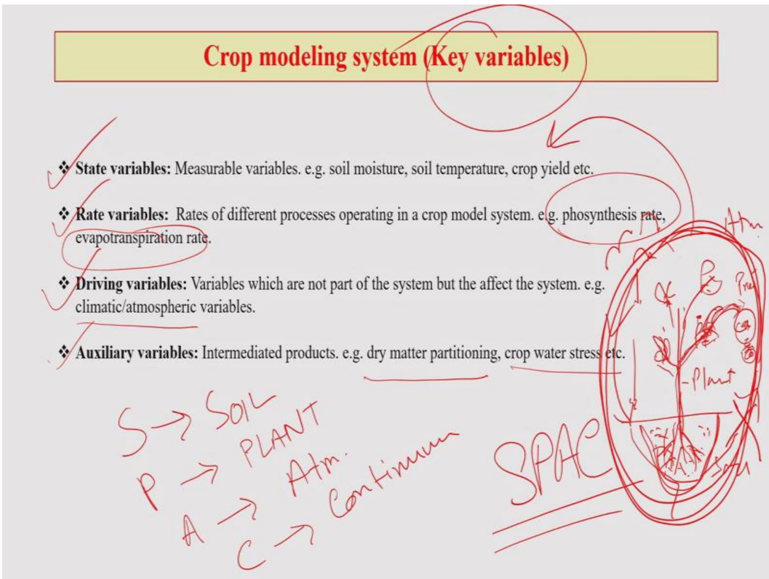

Now, in modeling case like any other model, in crop model also there will be errors and limitations. Now, there are various type of errors are associated with modeling exercise. Other day I discussed about certain limitation of modeling exercise. Of course, in modeling exercise the effort is always towards mimicking or copying the nature whatever is happening in the nature and our effort is to go as close as possible to the happenings in the nature, while doing so, during the process or during the exercise of modeling, we will end up with certain kind of errors, that is obvious.

Now, there are various ways also to handle those errors, minimizing the errors, but before that, let us know that what are the errors that we can anticipate in modeling exercise.

Conceptual errors, conceptual errors, it occurs due to certain mistakes or misunderstanding in the concept of the model or on the concept of the happening in the field. Suppose, you are working with a system, rice ecosystem and you are trying to model the rice ecosystem in a crop model. Unless until the rice plant in a better way and also the entire system of growing rice plant in the agricultural field it will be definitely very much error prone in the conceptualization state itself. And this error occurs as I said due to misconceptions or inadequate knowledge about the governing principle or the mechanisms or the boundary conditions. As I said for rice, if you think that example is the rice field, so, in the rice fields rice is standing there. So, if you do not know what is happening in the rice field, what are the different boundary condition, then it will be very difficult to run a model for that particular system.

So, various other aspects are also involved with conceptual errors, you will find that in case of numerical modeling if you try to do the transport processes may have a lot of errors. Now, when we talk about plant system, as I said that in the previous picture, I was showing you that continuously some activities are going on inside the soil and then remember any nutrient that is there in the plant system, almost all of them come from the soil.

Now, these nutrients are going under capillary action through root, through stem, into different parts of the plant. Now, if this transport process is not properly understood, how can we then be able to actually run a model successfully or develop a model. So conceptions about the processes, concept about the various condition under which a particular event takes place is must.

Next, mathematical model errors. Now if you go for some suppose mathematical model, what kind of errors you can expect. Here the error will occur due to the inherent assumptions of a mathematical model. For what? To represent a complex natural process in the form of equation. Suppose, you are trying to describe relationships between rainfall and rice production, rice production definitely depends on rainfall say there is a direct relation.

Now, if you want to express rice yield Y, YR as a function of rainfall. Now, this mathematical expression to represent a complex relationship between rainfall and crop production in the form of these equations can sometimes bring mathematical model errors. So, what is the way out? Way out is to understand the system absolutely clearly so, that when you make a mathematical expression of a particular relationships or of an event, you capture almost all the elements of that particular event.

Next is input data error. Very frequently this error takes place, while actually you are inputting the data at different parameters value into your model, you can end up with lot of errors, while actually inserting this into the system. Errors in processing input data, errors in measuring or estimating the parameters also in the field.

So, in different cases the error with related to input data can takes place. Either it can take place right in the field level while you are actually measuring or observing. Suppose, if you have observed or measured the data in appropriate manner, then next it comes that when you come into back to your lab and you insert those data which you have measured in the field, while inserting those data also there could be some kind of mistakes.

Numerical error. Now numerical errors can takes place in space, time, in case of space, in case of time and different types of errors can also can happen due to the precisions of numbers as recognized by your particular computer. And another error we can also find out is truncation errors with numerical data often it could happen, what happened is that due to the approximation of differential equation, suppose with the set of algebraic equation, you will find that there will be some kind of approximation which is automatically done by the system and that could also, insert some error inside the model. And all of these occurs largely during the numerical modeling.

Interpretation error after doing everything, then comes the issue of interpreting your analysis, interpreting your result. So, this occurs due to the misunderstanding of simulated result by the modellers.

So, what happened is that you have run the model, you have simulated nicely, you have got certain result, but you do not know how to interpret it. You do not know actually what this number means. So, that is where we will end up with interpretation error.

Even though our all previous exercises are correct, perhaps we also got the correct outcome, but we do not know how to interpret it. So, these errors could lead to the poor presentation of the model results. And sometimes, in fact, it could be completely incorrect representation of the happening or the analysis that you have carried out through modeling exercise.

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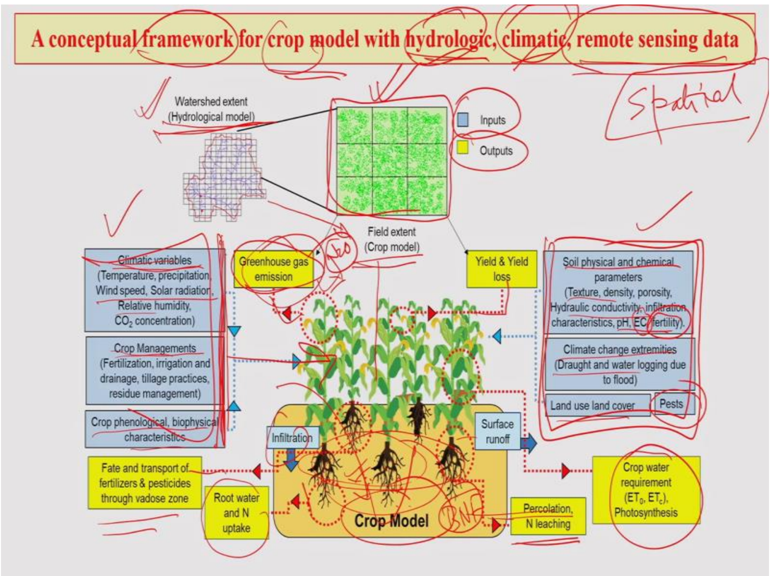

Conceptual framework for a crop model with hydrologic, climatic and remote sensing data. Now, in case of crop model, we often use hydrologic data, climatic data and of course, remote sensing data, that is to talk about the spatial aspect. So, you have a huge field and how the crops are actually located in that particulars grids that is being captured spatially through remote sensing and then you ultimately do certain analysis and then give the result or output through a tool called GIS, which is representable way to share your information or result outcome of your modeling exercise.

Now, this is a conceptual framework, which actually, we in our lab, myself and my students, we have been working on this aspect. So, as we see here that suppose a watershed, because watershed is the easiest way or administrative unit, where you can actually handle it much better way, whether it comes of managing any kind of resources or any administrative matters, anything. So, for any kind of practices watershed, it works very nicely not only as a unit for land and water management, but overall administrative management as well.

Now, if you consider suppose, watershed extend into a hydrological model, so, that model actually will give some output which output can be utilized by the crop model as input. Now, suppose here we have the crop model as you see here the crop model, crop model it works as I said, so, I will plant atmospheric continuum various actions inside the soil in the environment there are also these days issues with the greenhouse gas emission.

We have infiltration, surface runoff, many things. So, this is being captured inside a crop model, but for the crop model to run appropriately, you need certain inputs and those inputs could be the output of a different model, like hydrological model will give some inputs into the crop model for water related aspect.

Now, inside the crop model, these days we can have various climatic parameter, we can have various crop management parameter, crop phenological, biophysical characteristics, in fact, we can also have genetic coefficient of various crop. So, these are all inputs for your crop model. So, all the blue color that you see here, so, these are inputs and the yellow colors are basically outputs of this modeling exercise.

Now, what on the basis of this data you are getting you can estimate that how much greenhouse gas say methane, nitrous oxide can come out of this particular plant ecosystem. On the basis of these data sets and also these inputs, soil input, say soil physical and chemical parameters, texture, density, hydraulic conductivity, soil pH, EC, then fertility, you have also climate extremes like drought and water logging condition, flood condition, land use land cover, pests also because pests is another aspect which can affect your yield quite significantly even though your rest of all the parameters are perfectly fine for good yield, but because of pests your yield can go down significantly. So, that is also need to be looked at.

Now, what are the outputs we are getting after getting these sets of input into the crop model? We are getting greenhouse gases, yield or yield loss, we are getting fate of transport of fertilizers and pesticides in the vadose zone what is happening here, root, water and nitrogen uptake if you apply suppose nitrogen fertilizers or suppose BNF is taking place biological nitrogen fixation because of some organisms present here in the plant roots or soil in rhizosphere zone.

So, these all activities are happening here and you can actually almost predict that what could happen. Now, percolation and nitrogen leaching so, because you will be putting right here your fertilizer, amount of fertilizer that is applied like soil fertility also will go as an input. So, definitely we can calculate how much nitrogen is leached, how much nitrogen is going out as nitrous oxide into the environment.

Crop water requirement is another estimation which crop model exercise can give as an output. So, basically what we see that this is a conceptual framework proposed for a crop model, where you can actually bring in hydrological climatic model and also remote sensing data. So, today we have very powerful computing system. This is possible, probably 15, 20 years back this would have been beyond our imagination to integrate different models into another model.

So, what is this going to give? Instead of running crop model, hydrological climate and remote sensing all of them separately it takes a lot of time, if you integrate them, then in one run, you will be getting the outputs and which output can be also already in a very representative manner.

So, you can get out certain pictures and maps with different outputs already mentioned in those maps or for that particular area as it is represented here as a grid. So, this is how the modeling exercises or community is continuously working towards various type of improvement on the existing modeling system.

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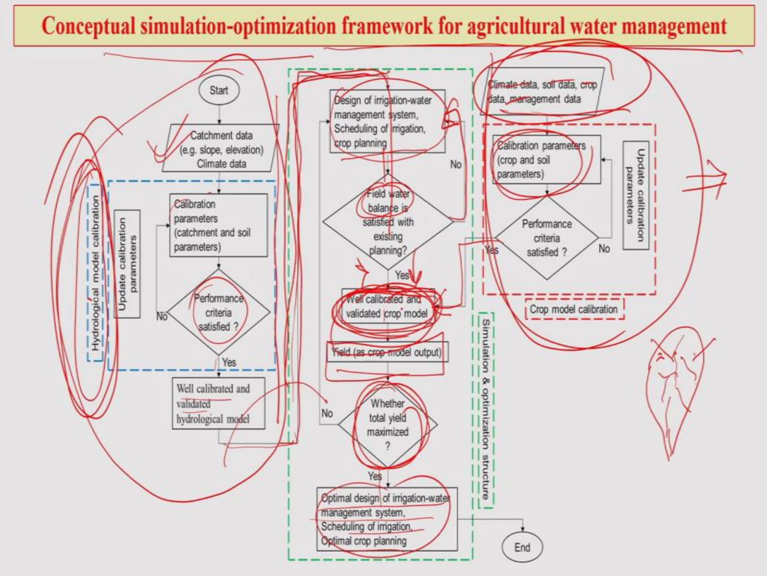

The next is another concept that we have proposed in one of our recent work. Conceptual simulation or optimization framework for agriculture water management. Water we know by now, that is another very important natural resources and without which, the agriculture system is very difficult to run.

Now, if you look at the concept that we are proposing for simulation optimization framework for water management. So, here on the left hand side as you see that this is a typical modeling system, you actually start a hydrological model with catchment data from a watershed suppose, this is your watershed.

So, from the catchment data you get actually slope, elevation, climatic take various kinds of data that is your input parameters in a model. And in that model, then you go for calibrating it, calibrating with what? catchment data, soil parameters. So, once your calibrated performance is good and you are satisfied, then you continue with validation. So, this we have already discussed. So, this hydrological model calibration and validation exercise once it is done, then this output of hydrological model will go here in the next phase where you actually try to optimize the conditions.

Now, our ultimate objective in case of agriculture for water management is that best use of or optimum use of water. Today everybody is talking about that crop per drop. So, that means, with minimum amount of water usage you get maximum output or yield. So, that is possible when your system is very efficient. And that can be done through this kind of exercise you can understand what are the things you need to do.

So, once the hydrological model is validated, then you try to do design of irrigation water management system or you try to schedule the irrigation system on the basis of the crop water requirement. Because this irrigation actually is one aspect, one practice where you actually need water for crop and if your irrigation management system is very efficient so certainly the water management also will be very efficient. So, the objective here is to try to figure out the best water management choice or optimization of water management.

Now, once your design thing is ready, then you go for field water balance. If field water balance calculation you are satisfied, then you progress if you are not satisfied, you go back again and again check it with your data and again do the analysis. But if your field water balance is fine and you are satisfied with your existing planning, you move ahead, you then go for well calibrated and validated crop model which is already in your hand. So, from hydrological model now we are getting into crop model.

Now, once crop model is already ready validated, so, you run it and you find out the output which is the yield how much yield you will get after designing a new irrigation schedule. So, that designing you can actually adjust to find out that this is the minimum amount of water that I can give to get yield without any loss. So, yield is not compromised. So, whether total yield is maximized.

So, if your yield is not affected, you are able to maximize in certain amount of irrigation water. So, that is the optimization you have to do, once it is done, then optimal design for irrigation management systems, scheduling and everything will automatically follow.

But before you get that there is another aspect apart from this hydrological model inside the crop model another aspect is your climate, which I said that external aspect which is happening outside the soil plant system. Climatic data, soil data, crop data, management practices data all this information can also come in the modeling exercise as a calibrating parameter. So, you can actually use this parameter, climate data, soil data, crop data for calibrating your model.

And if your calibration again performance criteria is satisfied, you are happy with the outcome. Then you straightaway go into this stage where we are telling that model is calibrated, crop model is calibrated.

So, this calibration exercise either you can carried out already before you start integrating your hydrological model data or you can do it parallelly you are running your hydrological model calibration validation and on the other side, you are trying to figure out your calibration of crop model itself. When it is done, then this data comes in and you run hydrological model plus into crop model and then you come out with a optimum irrigation design. Because, remember only hydrological model without the plant into the system you cannot actually design irrigation.

Irrigation for what? For crop production. So, the integration of hydrology along with crop model is required for a better outcome and better advisories for farmers or for end users. Because when hydrological information or result of hydrological model is integrated with the crop model, then actually you can ideally tell that this much water if I irrigate this much yield I can get. So, that is the beauty of integrating two different model, water model, crop model and come out with a kind of a optimization framework for agriculture water management for better yield with less or efficient use of water resources.