Natural Resources Management (NRM)
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Modeling and simulations applications in agriculture for NRM

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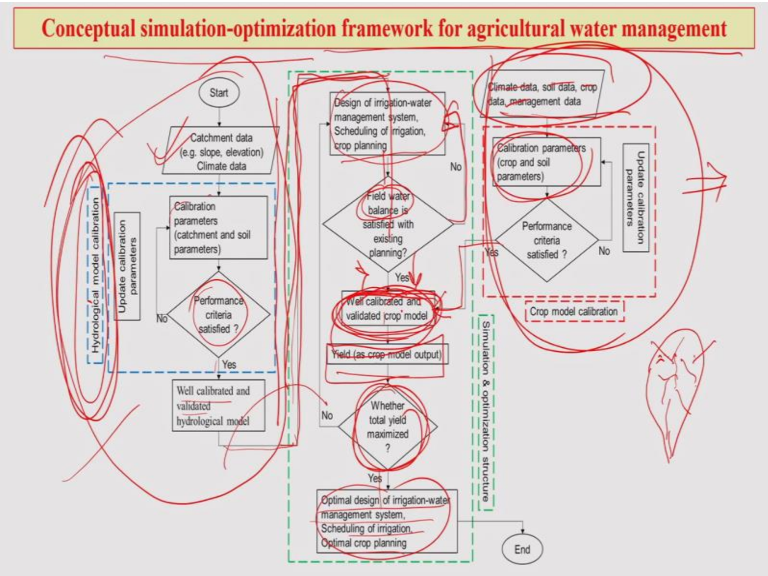

So, once again continuing our modeling and simulation applications in agriculture and NRM. In the previous lecture, we have discussed about the conceptual simulation-optimization framework for agriculture of water management. Here we discussed about how that hydrological model and crop model can work together in a integrated manner and how validation, sensitivity analysis, etcetera can be done in a integrated manner. Because that actually makes your computations modeling exercise much more robust.

So, with this kind of integrated framework at present time our modeling exercise has become much more convincing and also the gap between real condition in nature and the modeling system environment has gone significantly down.

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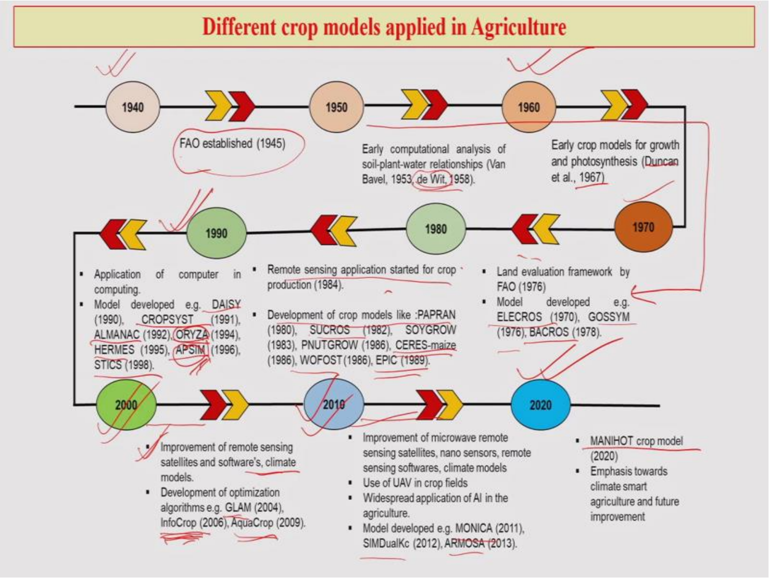

Let us now look at different crop models that has been applied in agriculture over last almost 60, 70 years or so. So, if you look at the history or chronology of the development of crop models in agriculture especially, you will see that one of the significant initiations of these modeling exercise started in 1940. 1945 food and agricultural organization established, 1950 in another one decade time the early computational analysis of soil, plant and water relationships has come into picture and the famous Van Bavel and de Wit, they were actually the pioneer of these computational analysis.

When you work in the field of crop model you will find the name of de Wit quite often coming in picture. Within another one decade by 1960 the crop models for growth and photosynthesis has been developed by Duncan et al. So, this particular slide actually I made it for you to be able to appreciate the speed or the rate at which the crop models has been developed, improved, and strengthened over the last almost 5 to 6 decades.

By 1970 land evaluation framework was announced or given by FAO. So, once that came into picture then land iterated modeling work also started with giving focus on the cropped production and crop growth. What are those? We got ELECROS in 1970 and GOSSYM in 1976 and then BACROS in 1978. So, you see the way between 1950 and 1970 or 80 within 30 years so much of development has taken place. This pace actually will be much higher when you go towards present time.

So, 1980s another decade remote sensing came into picture in a very significant manner. Remote sensing applications in crop production, crop growth also started. So, naturally the inputs of remote sensing exercises also started getting integrated into crop model. So, modelers started actually doing some kind of adjustment to bring in the remote sensing data into crop growth model.

Now, models like PAPRAN, SUCROS many of you might have heard these models, SOYGROW about soybean, PNUTGROW, CERES-maize, very famous WOFOST and EPIC. So, these model even today are being used. So, you can see that how in every 10 years the field of crop modeling is developing.

1990, application of computer, large computer, smart computer into computing started. So, once that started then of course the modeling functionality also got strengthen and further developed. So, models like DAISY, CROPCYST, ALMANAC, ORYZA, HERMES, APSIM, STICS they came into picture.

Now out of this many of you might have heard about APSIM, ORYZA these are very popular crop models and even today the models that we have with us many of them has wrote with this kind of models that came into picture in 1990s.

Then 2000, improvement of remote sensing in the last 10, 15 years between 1990 and 2000 that decade was quite significant for remote sensing, geographic information system and its application. So, naturally crop modelers took the benefit of that improvement in remote sensing satellite technology, softwares and also climate models. So, these all started getting as input into the crop model.

Now, the model also got change further strengthen and developed we got model like GLAM, InfoCrop from our own IARI Indian Agriculture Research Institute and I was as doing my PhD at that point of time when InfoCrop at IARI in front of me actually was being developed by a group of researcher and some of our students.

AquaCrop in 2009 came into picture. So, these crop models now can actually in 2000 they started actually somehow integrating or at least accommodating the outcomes of various climate model into that. So, naturally the predictions of these models will be much more convincing than the previous ones.

2010, within that 10 years again 2000 to 2010 was quite significant in the field of crop modeling exercises improvement of microwave remote sensing, and then smarter satellite, nano sensors came into picture. Then remote sensing softwares, climate models actually improved quite significantly between 2000 and 2010.

So, then we got unmanned different kind of UAVs into crop fields also. So, where people started using this kind of instruments to observe monitor the crop growth patterns. Wide spread of application of artificial intelligence started in 2010 and during those time and of course today almost every aspects now artificial intelligence is coming in to play a big role.

Now models which are actually developed post 2010s you will find that model like MONICA, SIMDualK, ARMOSA these are the models which are now applying various kind of latest technologies. Having said that still the old is gold. So, if you look at the models which were developed very early in 1980s, 70s, and 90s they are still what you call are the mother of our crop models like ORYZA, SUCROS. So, invention of technologies and then utilization of smart technologies into crop modeling exercises is a dynamic process.

Almost every day people in this community are working and trying to get the best benefit of existing technology. How are we now 2020 onwards? So, now of course we have very powerful artificial intelligence technology, fantastic machines we have with us. We have also nano chips, nano materials, nano sensors with us. So, we have lot of now smart technologies in hand.

Naturally we can expect that the models that will be developed further in this decade will be much more smarter. So, we have now got MANIHOT crop model and then the emphasis actually nowadays is giving towards the climate smart agriculture because today it is a fact that climate is changing, we cannot stay further in denial mode.

Now, sustainable agriculture we had been advocating, what is in climate smart agriculture is new is that the climate resilience or climate adaptation or mitigation component is also included where addressing the various aspect of sustainable agriculture. So, today's model today's crop model has to consider those aspect to remain what you call contemporary we must use those aspect into our crop models.

So, now it is 2022, so I hope that before the end of this decade. So, by 2029 you and me we would be able to see couple of more smarter models which includes various aspect and technologies and then allow us to handle the climate smart agriculture in really smart manner.

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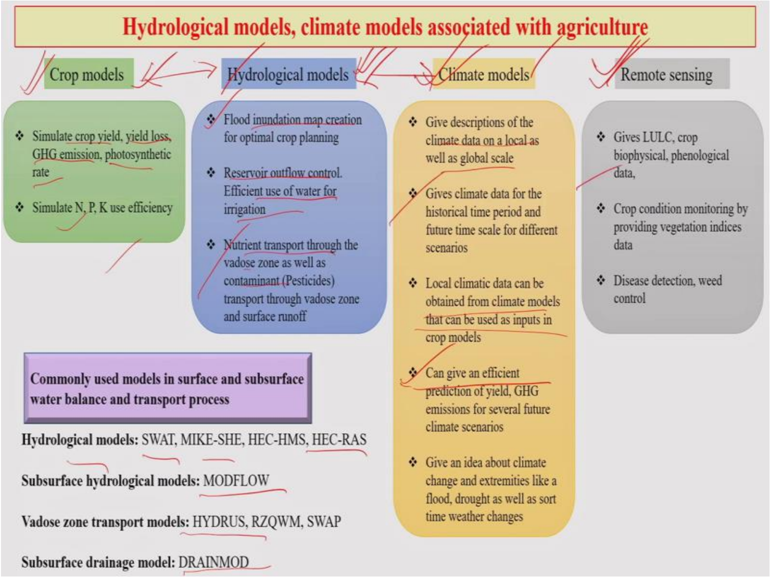

Now if you look at the various hydrological models and the climate models, how they can actually be utilized together or in a integrated manner especially for agriculture purposes. Now if we look at the crop models which actually being used to simulate the crop yield, yield loss, greenhouse gas emission, photosynthesis rate and also to simulate of course nitrogen phosphorus various nutrient use efficiency.

We have hydrological models I discussed in the previous lectures, that they also look at flood situation and then reservoir outflow control, efficient use of water, irrigation, nutrient transport, contaminant transport. So these things hydrological models are looking at.

Climate models as all of you know that they look at the various climate data local as well as global scale. So, we have GCMs Global Circular Models, and we have also LCMs Local Circular Models, regional model, also we have climate model. So, now this climate model actually gives climatic data for the historical time period and future time scale for different scenario. So, I will not go into detail because as per IPCC as you know that there are couple of scenarios on the basis of that how much percentage of greenhouse gases that any country can actually can regulate or commit to reduce.

On basis of those scenarios climate model can be run and accordingly the result or outcome of prediction that you may expect. Local climatic data can be obtained of course from climatic models that can be used as inputs as I said into crop models. Climate model can also give an efficient prediction of crop yield, then greenhouse gas emissions for several scenarios which have been given by IPCC.

So, sometime climate model also can efficiently give an idea about climate change and extreme events like flood, drought, as well as even a short time weather changes over a particular area. Now, remote sensing also, India is as you know that we are quite strong in the field of remote sensing very good quality of land use, land usage and different land capability classes also are being given by remote sensing data.

We also can get from remote sensing various crop parameters, phonological data, crop coverage or acreage. So, these data nowadays are coming with very high resolution. So, the accuracy of the information which we achieve from or which we obtain from remote sensing information on data is quite high.

Now, those data can actually help in crop condition monitoring by providing vegetation indices data. Disease detections, wheat control which are very important aspect of sustainable yield of various crops can also be actually detected or monitored by remote sensing technology.

Now, all these kind of instrument or what I call kind of power that you have in your hand then if you can somehow can integrate this kind of tools then you can imagine that how in a robust manner you can actually address the issues of climate change and its impact on crop productions or crop growth and also the emissions of greenhouse gases. So, entire those interrelationships can be studied in a very effective manner.

Now, the commonly used models in subsurface and subsurface water balance and transport processes that we have in case of hydrological models. SWAT, MIKE- SHE, HEC-HMS, HEC-RAS these are all very popular hydrological models that many people are using across the world.

Subsurface hydrological model, which is very popular some of you might have already used is MODFLOW many people in IIT system also are using MODFLOW. Vandose zone transport models like HYDRUS, RZQWM, SWAP these actually provide a lot of opportunities for researcher to study various transport phenomena.

Subsurface drainage model DRAINMOD, which also helps analyzing and studying various subsurface or drainage phenomena. So, in nutshell we have now in our hand many tools to study various aspects, which can actually impact the overall agricultural growth and productions in relations to water, climate, soil.

So, if we can integrate those things then definitely the outcome or the predictions of this simulation and modeling exercise will have much more robustness and that will definitely facilitate the process, decision making process in a much better manner. The loss due to some unseen event will go down. So, farmers, of course the loss of farmers income from various regions also will get reduced. So, there is multiple benefits that that we can achieve, if we can successfully integrate some of these very powerful tools.

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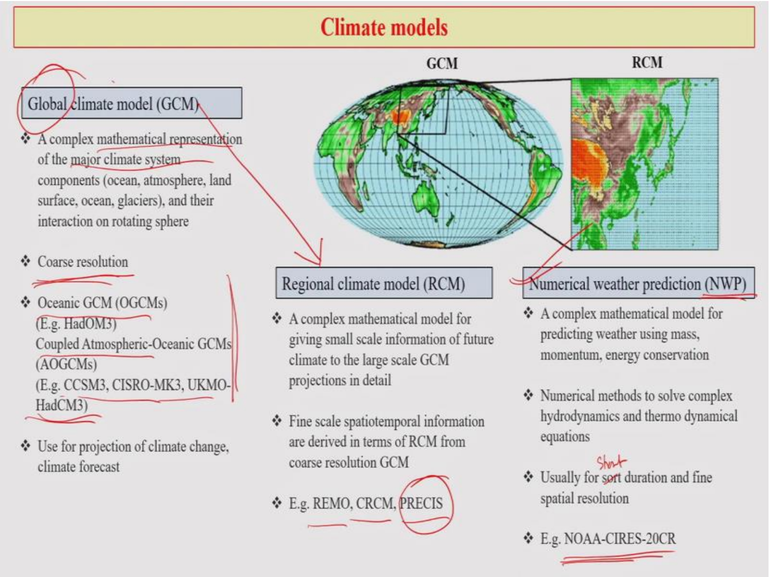

Now, climate models often you might have heard in the field of especially climate change. Now, just now I mentioned about global climate model (GCMs), and Regional climate model (RCMs), Numerical weather prediction model (NWP), now these all are actually quite powerful tools for studying the climate of our ecosystem.

GCM it looks is say some complex mathematical representation of our climate system. It takes care of ocean, atmosphere, land surface, all these interaction, and also they provide the various dynamics within those system. But the resolution of course as it is in global scale you can anticipate that it will be of relatively coarse resolution then we have various model for various systems. So, these are all actually quite popular and many of our researchers in India have been using HadCM3 quite frequently as well as some of the others that are mentioned in this slide.

These climate model uses actually are mainly for projection of climate change and climate forecasting as I said that this helps in preparations, decision making before an unwanted event takes place. So, you can avoid losses of life, economy and many other things. Now

Regional climate model, the resolution is little bit high. Once again it is also a mathematical model for giving relatively small-scale information for future climate and for a particular region. These are fine scale spatiotemporal information and these are derived in terms of RCM from coarse resolution GCM.

So, from entire Globe it looks into some region that is why it is known at Regional climate model and those models are some of them are REMO, CRCM, PRECIS. PRECIS actually a model also very popular among many of us. And then numerical weather prediction model (NWP). It is again a complex mathematical model for predicting the weather by using mass, momentum, and energy conservation. So, lot of principle of physics involved in this kind of modeling.

Numerical methods also used in this kind of model to solve certain complex hydrodynamics and thermodynamical equations. These models usually use for short durations and fine spatial resolutions. So, as an example we have NOAA-CIRES-20CR model, which is one of the numerical weather prediction model. These models are relatively complex in nature and it requires a little bit of experience in programming as well as modeling exercises. So, with strong knowledge in mathematics and physics and little bit of programming one can actually get trained very quickly to run this kind of very useful model.

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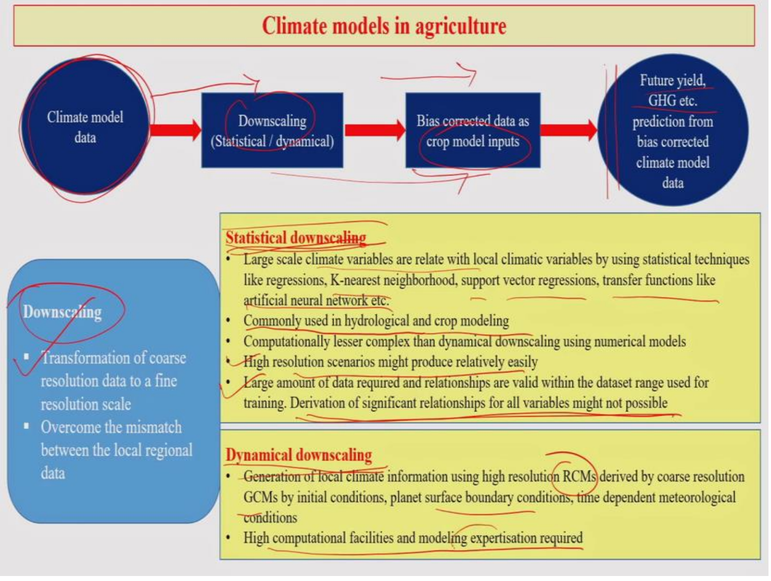

Now, let us see the use of this climate models in the field of Agriculture. You just saw in the previous slide that we have GCM, RCM, NWP from these models we will get certain outcome. So, the climate model data will be downscaled and then this down scale data will be corrected bias corrected or tried to reduce the error as much as possible and then they will get into the crop model as input, because we know that crop model requires the different weather parameters climatic information as well.

Now, once this comes then crop model can definitely capture the future scenarios, future different weather parameters on depth, this is the predictions of crop growth, future yield, greenhouse gas emissions will be much more robust than without having this climate model data into the system.

So, today's crop model can actually predict the future in a much more better way because we are getting the output from very powerful climate models and that output are being used as input for different weather parameters into the crop model. Now the down scaling exercise is critical of course because you are bringing in from a very high scale or huge region to a particular small region of data.

So, down scaling by transformation of course resolution data to a fine resolution scale is one of the important task and then it is also important to overcome the mismatch between the local regional data and the global data. So, this particular exercise it requires little bit of expertise and training to do it in an efficient manner.

Statistical downscaling is all also often done in case of this kind of model. Large scale climate variables which actually we get from GCMs, those climatic variables by different statistical technique like regression, K-nearest neighborhood, support vector regression, transport functions like artificial neural network are used to downscale this data or information. Some of the commonly used hydrological and crop modeling exercise use this kind of downscale data quite frequently.

These are actually statistical down scaling method computationally lesser complex than the dynamical down scaling using different numerical models. So, statistical down scaling one may find as I just said that little bit easier than the dynamical downscaling. High resolution scenarios might produce relatively easily the downscaling process, large amount of data are required and relationships are valid only within the data set range which are used for training.

So, derivation of on any significant relationships for all variables might not be possible. So, when you have certain benefits for statistical downscaling. So, this is one aspect which we need to keep in mind that, we cannot derive the significant relationships for all the variable that we want to. Now dynamical down scaling which I said that it is little bit complicated than probably statistical downscaling some people find it in that way.

So, in this downscaling generation of local climate information using high resolution Regional climate model RCMs derived from course resolution GCM which I just mentioned in the previous slide by some initial conditions then some boundary conditions. So, you try to now downscale it in a dynamic manner from GCM towards RCMs high computational facilities and modeling expertise is required for dynamical down scaling.

Yes, this is true that dynamical downscaling is much more fascinating and it also probably provides a better downscaling but at the same time you need little bit of extra expertise for doing such kind of dynamical downscaling.