Machine Learning for Soil and Crop Management
Professor Somsubra Chakraborty
Agricultural and Food Engineering Department
Indian Institute of Technology Kharagpur
Lecture 04
General Overview of ML and DL Applications in Agriculture (Continued)

Welcome friends to this fourth lecture of week one of this NPTEL online certification course of machine learning for soil and crop management. And in this week, we are having a general overview of machine learning and deep learning applications in agriculture. In our past three lectures, we have discussed broadly some important concepts, we started with the machine learning and what is big data and then what are the different types of challenges we have in the big data storage.

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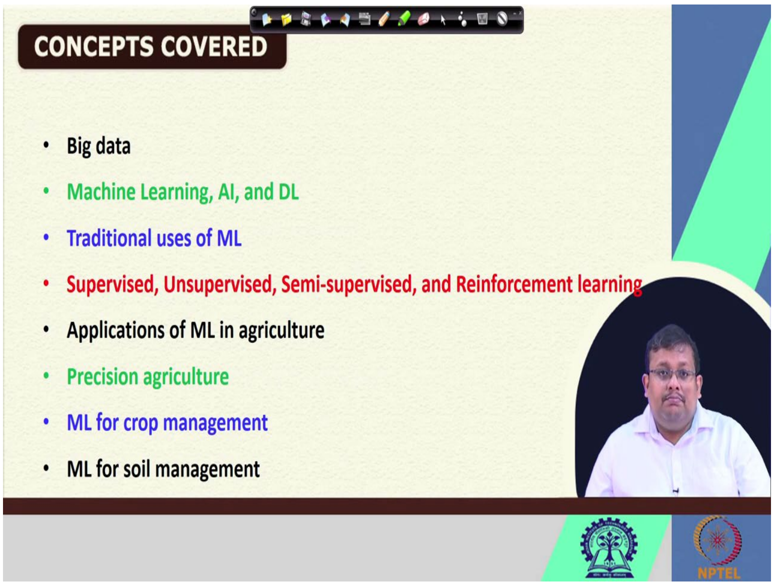

Also, we have seen the application, the basic overview of machine learning and then artificial intelligence and deep learning and their interrelationship, what is the difference between a basic computer program and machine learning program we have seen, we have also seen the supervised learning as well as unsupervised learning, then semi-supervised learning and reinforcement learning, we have seen some good examples of reinforcement learning and also we have started discussing about the deep learning.

So, today we are going to start from there, we have already covered this thing. So, let us go to the deep learning, and we will go from there where we left in our last lecture.

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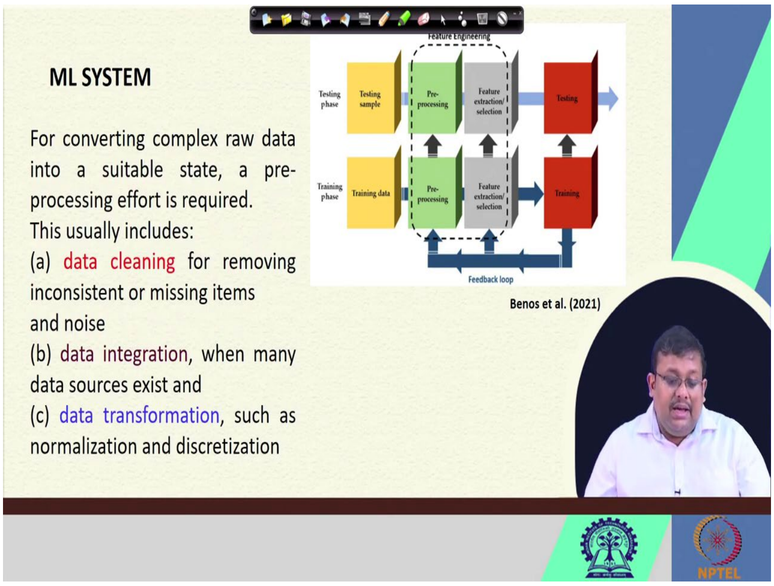

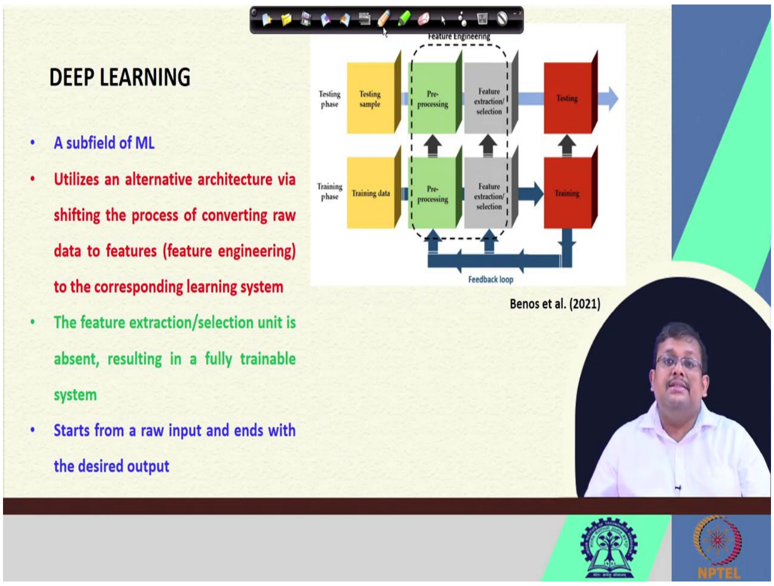

So, we have also discussed the basic structure of machine learning, why it require some pre-processing stage why it require some features selection or extraction step and what is the feedback loop, this type of discussion we have made in our last lecture. So, we have started with a deep learning. Remember, this deep learning is a subfield of machine learning as I have already told you and in this machine learning architecture the deep learning generally do not consider this feature engineering step.

And it presents a fully trainable system. And it starts from a raw input and ends with the desired output. So, just an example of deep learning, as I have told you, that convolutional neural network, this is an example of deep learning, it is a very common deep learning method. And suppose, there are some images and from these images, it learn the feature levels in scenes and then utilize this in the subsequent model development.

We will discuss their architecture and their application in our subsequent lectures, but at this point, just remember that they basically learn the feature levels in the scenes and then they utilize these for subsequent prediction or classification problems.

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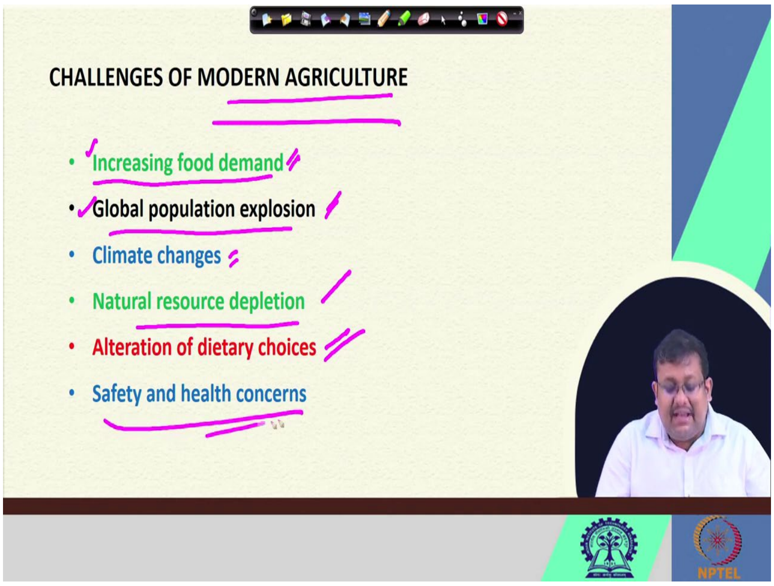

Now, let us see why we are talking about machine learning applications in agriculture. So, if we see some of the contemporary challenges of modern agriculture, these are some of the contemporary challenges of modern agriculture. First of all increasing food demand, so increasing food demand is a very important challenge of modern agriculture and at the same time there is global population explosion.

So, to meet the increasing food demand, which is proportionate to the global population increase rate, we need to increase the productivity of the crop and to improve the crop productivity, still maintaining the profit of the farmers, we require to add up some modern tools in agriculture otherwise, using the traditional methods it is getting difficult each and every day.

Simultaneously, there are some other challenges also like climate changes, climate changes has created some obstacles in performing some of the previous steps tradditional practices which you are used to adapt for example, burning of the stubble, this is a very important issue nowadays, specifically in Indian subcontinent, where farmers are burning their rice stubble after after harvesting their crop, wheat stubble after harvesting their crop and that creates a huge environmental impact.

So, this climate change effects are also very important which instructs the agriculture to add up new modern technologies. Also, natural resource depletion is another important thing as the time progresses natural resources are continuously depleting and as a result, there are exertions of the water resources.

So, we need to use some judicious management practices and these judicious management practices can only be done when you use some decision support system and these decision support systems are generally used in the modern agricultural practices. Alteration of the dietary choices another important issue.

Due to globalization, the human dietary choices are getting also changes and that is why modern agriculture should cope up with these changes in their dietary choices using some advanced tools. And also finally, there are some safety and health concerns. Earlier there were least health concerns, but nowadays, due to the safety and health concerns, the applicate the modern agriculture is is a is undergoing some drastic changes.

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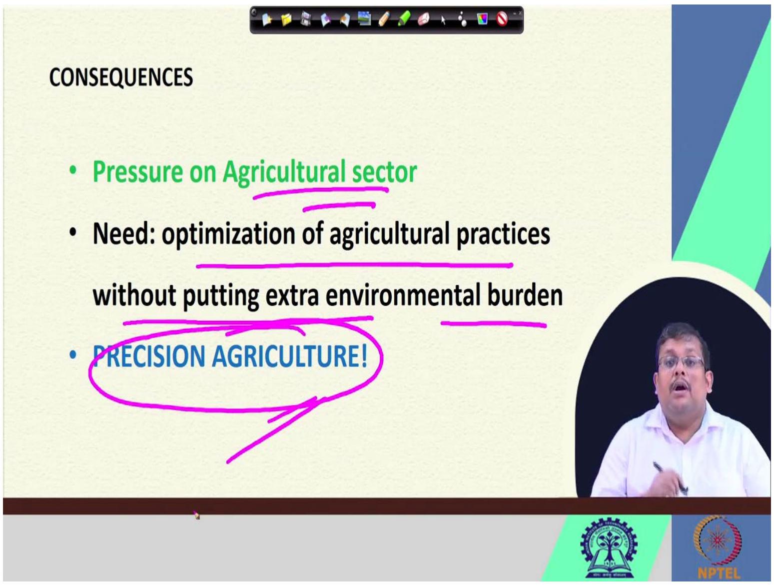

So, what are the consequences of these challenges? The challenges results in huge pressure in the agricultural sector, and also as a result of this pressure in the agricultural sector, there is a need for optimization of the agricultural practices without putting extra environmental burden, we cannot, we have to reduce these challenges.

But at the same time without putting any extra burden in the environment, because the environment is already stays by default anthropogenic activities and to reduce the environmental impact while maintaining or improving the crop productivity and profitability of the farmers is always a very-very challenging task.

So, that is why the concept of precision agriculture came. So precision agriculture is the management practice or it is a concept or philosophy that identifies, that addresses these challenges to improve the agricultural practices without putting any extra environmental burden. So, what is the definition of the precision agriculture?

The International Society of Precision Agriculture defines that precision agriculture is a management strategy that gathers processes and analyzes temporal spatial and individual data and combine it with other information to support management decisions, according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.

So, very important definition, and it covers a wide variety of sectors and aspects. First of all, it says about it analyzes temporal data, so not only the spatial data; it also encompasses the temporal data, spatial and individual data from different sensors and combine it with other information of support management decision. So, there are other information also not only the sensor information or sensor generated values, but also some auxiliary information suppose we want to develop a soil map or using digital soil mapping.

So, in case of digital soil mapping, we are not only using the legacy soil data, but also we are incorporating some correlated or auxiliary data from different sources like rainfall data, climatic data, also the topographic data. So these are the other sources, which we are incorporating and ultimately we are producing a high resolution sitemap through DSM practices or DSM methodology.

So it ultimately helps us for taking the management decision according to the estimated variability for improved resource use efficiency. Our objective would be to improve our resource use efficiency; we want to minimize the wastage of resources, at the same time we want to increase the productivity. So, when we improve the resource use efficiency and minimize the wastage that will increase our profitability and also the quality of the products and finally, sustainability of the agriculture production.

So, you can see that in this definition, it covers all the major objectives of precision agriculture and machine learning helps in achieving these objectives in the precision agriculture using artificial intelligence. So, machine learning is a small subset of precision agriculture, which is it uses to achieve these different types of goals.

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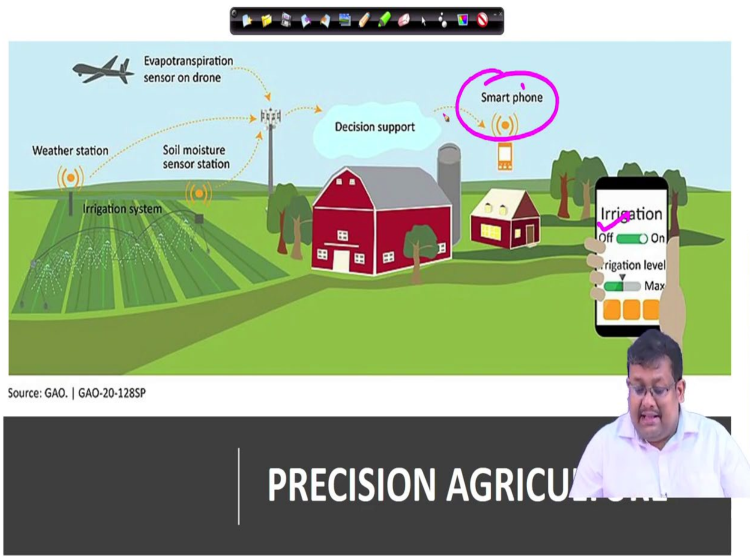

So, this gives a very broad structural overview of precision agriculture, you can see precision agriculture has their irrigation system, also it gathers the data from its weather station, it gathers data from soil moisture sensors station, also evapotranspiration sensors on drone, it uses the data and then process the data through a decision support system and ultimately, it sends the data into a smartphone and farmers can get the results of the required inputs in their hand in the form of irrigation and also some time nutrients.

So, this is the precision agriculture, once you have proper information of the spatial variability and temporal variability of the soil properties or properties, you can manage your resources in a better way and that is the ultimate goal of precision agriculture.

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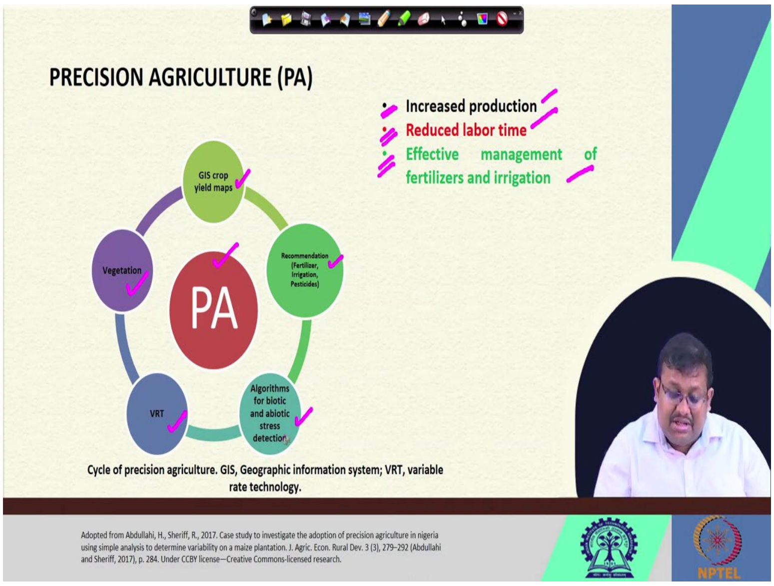

Now, if you see the cycle of precision agriculture, the cycle of precision agriculture has different components as we have, I have I mentioned in the slide you can see here, GIS and crop yield maps are there. And then fertilizer, irrigation, pesticide recommendations are their algorithms for biotic and abiotic stress and abiotic stress detection are there, variable technology or VRT is there, vegetation is another important part.

So, all these are important components of precision agriculture, and the objectives the major objectives of precision agriculture is to increase the production of the crop and then reduce the labour time and finally, effective management of the fertilizer and irrigation. So, these three are very important objectives of precision agriculture.

And as you can see, that this fertilizer recommendation, identification of the biotic and abiotic stress, VRT, GIS and cropping maps all these are having the application of machine learning and deep learning approaches.

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So what are the benefits of agricultural modernization? If you see the benefits of the agricultural modernization, as I have pointed out that there are three major benefits, one is environmental sustainability, so that we do not degrade the environment or we cannot put extra burden on the environment.

And then at the same time, we do the maximum productivity and to maximize the productivity and sustainability, because until the farmers are getting the profit from agriculture modernization, it will be difficult for them to add up these new new technologies in their field, because the agriculture sector is run through profit making.

So if there is no profit, then there will be problem of adoption of new technologies. So sustainability, maximum productivity and safe environment these are the three benefits of agricultural modernization.

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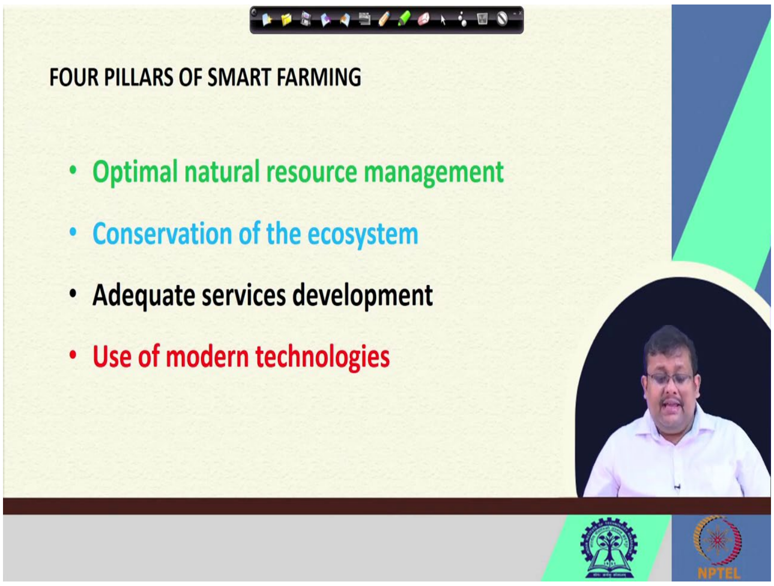

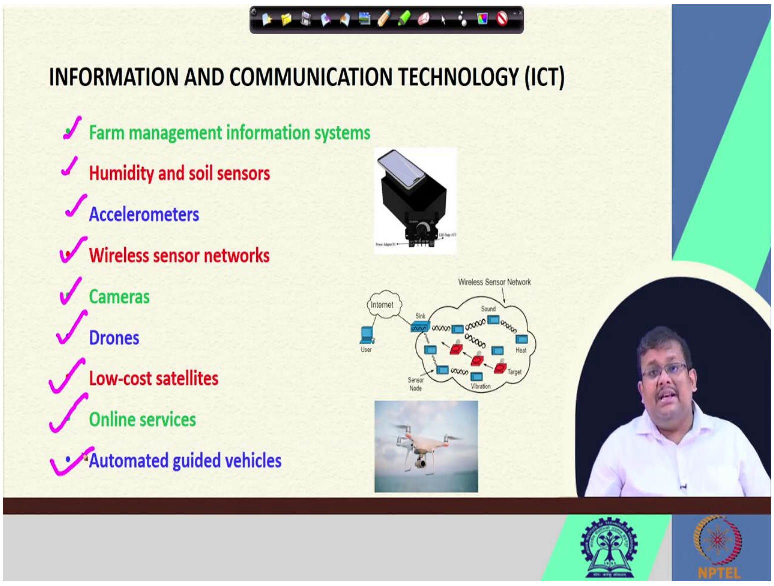

Now, what are the four pyieldars of smart farming? If we see the smart farming there are four major pyieldars. One is optimum natural resource management, and secondly is the conservation of the ecosystem; thirdly, adequate service development and fourthly, use of modern technologies.

So optimum natural resource management means when we are optimally using the natural resource, we are not over exploiting the natural resource, when we are irrigating, if we are irrigating based on the sensor records, sensor records and also some model output.

So, in that case we are doing the irrigation management and that is optimum natural resource management, we are reducing the wastage of the irrigation water, then we are conserving the ecosystem, then we are doing the adequate service deployment and finally, we are using modern technologies for achieving these goals.

So, these are the four pyieldars of smart farming and if we consider the information and communication technology or ICT, which is a very common word nowadays, they are especially in the agriculture sector; this ICT application in agriculture has different components.

For example, farm management information system is an important component, then humidity and soil sensors are very important component and then accelerometers, then wireless sensor networks. then cameras for taking the images, then drones also for taking the images, the low cost satellites, online services and automated guided vehicles all these are part of the information and communication technology.

Nowadays, automated guided vehicles have been used with machine vision for performing different types of field operation like weeding, like harvesting also, online services are there to provide the required information to the farmers doorstep, also there are some local service satellites, drones are being utilized for spraying and other operations and also to take the images for better image processing and management decisions.

Cameras are being used for for taking the images and developing the image based algorithms, wireless sensor networks are being used for IoT or internet of things. So you can see that a multitude of elements are there in the ICT especially when we talk about agriculture.

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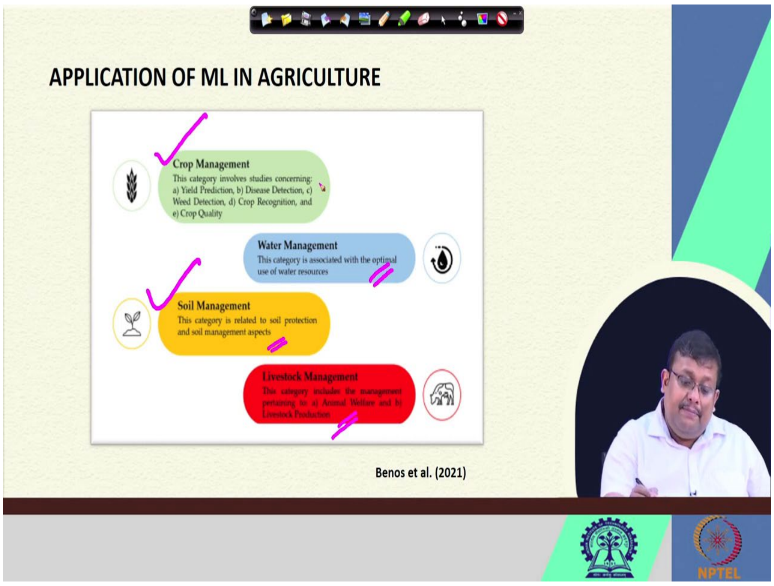

So, if we move ahead we will see that what are the major sectors under agriculture where machine learning has got their application? First of all the crop management, so machine learning has a huge application in the crop management and this category involves studies concerning with the yield prediction, then disease detection, then we detection, crop recognition and crop quality.

So, you can see that all these four to five categories are important and shows the application of the machine learning in the crop management sector. And then the second is the water management, water management this category is associated with the optimal use of natural resources or water resources.

Then soil management this category is related to soil protection and soil management aspects. And finally in the livestock management and this category involves the management pertaining to the animal welfare and livestock production. Now among all these all these four in this course, we are going to focus on crop management and soil management.

So, we are going to focus the application on crop management specifically focusing on yield prediction, disease detection, weed detection, crop recognition and crop quality and in case of soil management, we are going to discuss the application of machine learning for soil property prediction and rapid clustering of soil features for better management decisions. So we are going to discuss all these.

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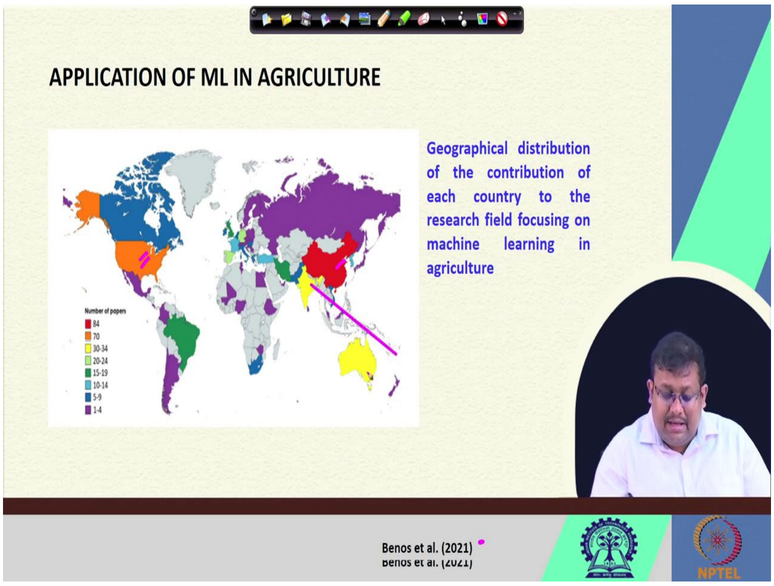

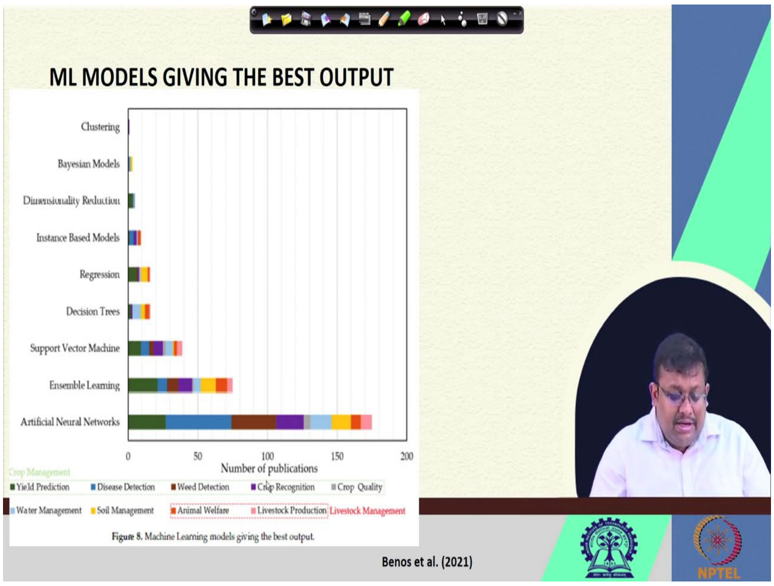

So there has been a review. There is a review done by Benos et al in 2021 to see the emergence of machine learning application in agricultural sector and they have found that, they have around 300 to 400 research papers, they have consulted and they have seen, this is the geographical distribution of the contribution of each country to the research field focusing on machine learning in agriculture.

And you can see here the maximum contribution of machine learning in agriculture is coming from China and also from United States. India is also contributing, India and Australia is also contributing a considerable number of studies in the field in the domain of machine learning application in agriculture. And secondly, we can see here machine learning models giving the best output.

If you see that artificial neural network is giving which is a deep learning method is giving best results in most of the crop related or agricultural sector related machine learning application papers followed by Ensemble Learning, Support Vector Machine, Decision Trees then Regression and then Instant based model then Dimensionality reduction, Bayesian model and clustering.

So, we can see and also the in which which area they are doing also are given here like you can see here these green indicates the yield prediction and then this blue indicates that disease detection and then this is weed detection, then crop recognition, and then crop quality. Finally, this is the water management and yellow is the soil management, then animal welfare and finally, livestock production.

So, you can see in most of the cases artificial neural network, which is an important and widely used deep learning method is giving the best result.

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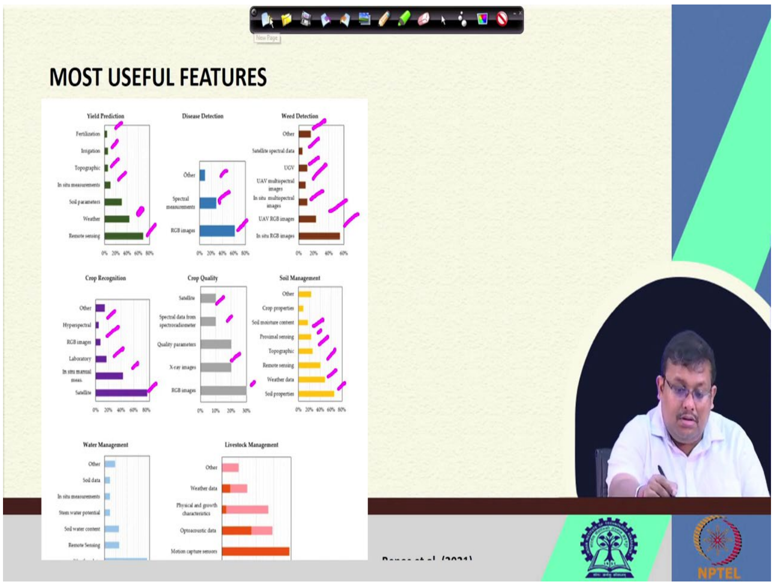

If you see the 10 most investigated crops using machine learning models will see that maize has been extensively studied by application of machine learning, you can see here yield prediction, then disease detection and crop recognition and small amount of crop quality studies have been done and also followed by wheat, rice, soy bean, tomato, grape, canola or rapeseed cotton, potatoes and barley.

So, maximum machine learning application related papers pertaining to the maize. So, the part of the reason is these maize is universally cultivated in all the countries specifically in the United States, in Europe and also in India and also in China, where we use this machine learning application for better crop management and decision support system.

Also, if we see the most useful features, which the users use from different types of machine learning application. So, in case of yield production, we can see the remote sensing is the most important feature for yield prediction in the machine learning model followed by weather and then soil parameters, in situ measurements, topographic variables, and also irrigation and fertilization.

So, these are the some of the important most useful features, while we use machine learning for yield prediction. When you go for the disease detection, RGB images, which you take using the RGB cameras are very much useful, followed by spectral measurements and others, when you go further weed detection in situ RGB images followed by UAV RGB images, in situ multispectral images, UAV multispectral images, then unmanned ground vehicles, satellite spectral data and others are very very important.

When you talk about crop recognition the satellites are very important; the in situ manual measurements are also very important, then laboratory measurements, RGB images, hyperspectral images, these are important consideration, these are important features for crop recognition using machine learning.

When you talk about the crop quality RGB images, X ray images and then quality parameters and then spectral data from the spectro radiometer and satellites data are very very important. When you talk about the soil management, the soil properties, weather data, remote sensing data, topography data, proximal sensing data, soil moisture content data, the crop properties, these are all important features.

And in case of water management we can see whether influences most in case of water management followed by remote sensing then soil water content then stem water potential and then in situ measurements soil data and others.

In case of livestock measurement, motion capture sensors are the most important sources for and followed by up to acoustic data, physical and growth characteristics weather data, these are the most useful features or variable which gives the desired outputs or in other way we can say that these are the most important features or variables which are necessary for developing a calibration model for trading model for yield prediction, disease detection, weed detection, crop recognition, crop quality identification, soil management, water management and livestock management.

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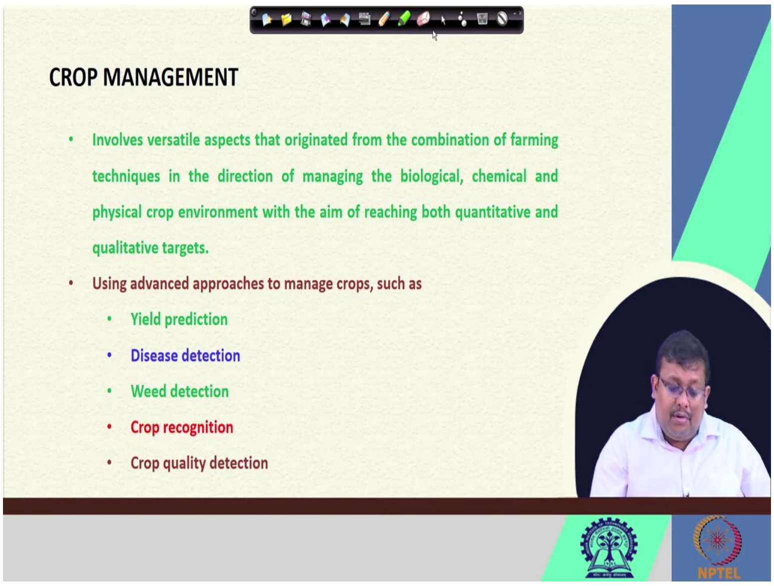

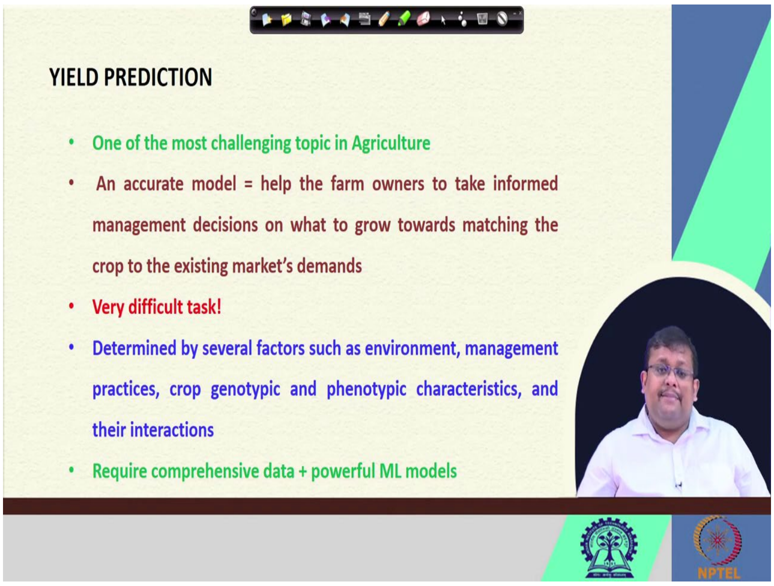

So, if we focus on the crop management, you can see that it involves versatile aspects that originate from the combination of farming techniques in the direction of managing the biological, chemical and physical crop environment with the aim of reaching both quantitative and qualitative goals.

So, if we see using advanced advanced approaches to manage crops, what are the sectors, as I have already told you yield prediction is an important sector followed by disease detection, weed detection, crop recognition and crop quality detection; all these are very very important approaches to manage the crops using machine learning.

So, first we will see that yield prediction. Yield prediction is one of the most challenging topic in agriculture, because an accurate model; we need an accurate model to help the farm owners to take, inform management decisions on what crop to grow towards matching the crop to the existing market's demand.

But this is a very very difficult task, because crop growth is a phenomenon which depends on several interconnected factors and it is not a simple model can do that. So, that is why we can say that it is a very important challenging topic in agriculture. So, it is basically determined because, why it is challenging, again it is determined by several factors, such as environment management practices, crop genotype and phenotype characteristics and their interactions.

And it requires, and to predict the crop it requires a comprehensive data and also powerful machine learning models. So, unless you have a comprehensive data set and also very powerful machine learning models, you cannot do the yield prediction.

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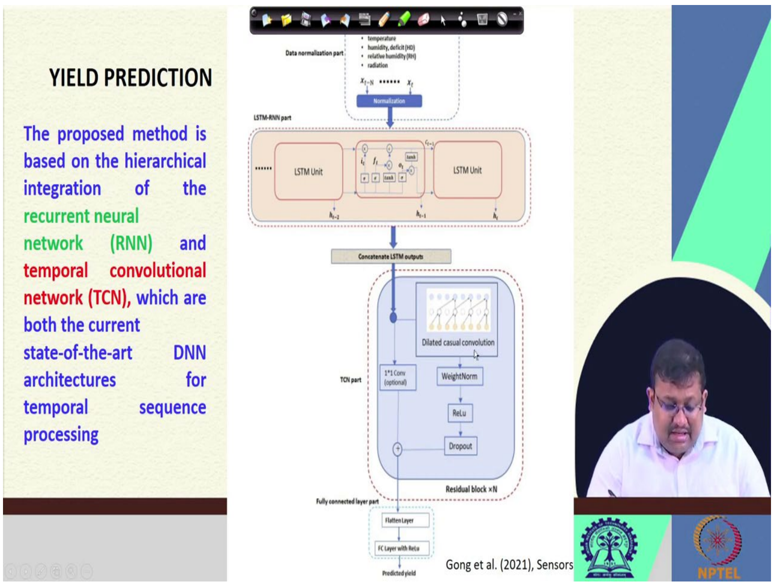

Now, some examples let us see some very good examples. So, here in this study Gong et al, which was published in sensors in the year 2021, you can see that they have used a novel neural network based methodology, novel deep neural network based methodology. They have proposed to predict the future crop will based on the historical yield and greenhouse environmental parameter.

What are those environmental parameters? You can see here, the carbon dioxide concentration is an important greenhouse environmental parameter then temperature, humidity, radiation etc. these are important parameters. You can see here they are doing the data normalization.

And once they are doing the data normalization, they are incorporating the data in the LSTM which is the long short term memory and RNN, recurrent neural network and then they are concatenating the LSTM outputs and finally they are incorporating in the TCM part and then finally they are getting the predicted.

So they are fully connected layer part and finally, they are getting the predicted yield. So, if we see these research, there are the proposed method is based on the hierarchical integration. As you can see, these are hierarchical integration starting from the normalization part, then this LSTM which is long short term memory and then RNN which is the recurrent neural network and temporal convolutional network neural network.

You can see here TCN part and which are the other state of art, DNN architecture for temporal sequence processing. So, ultimately, we are getting the, we are predicting the yield.

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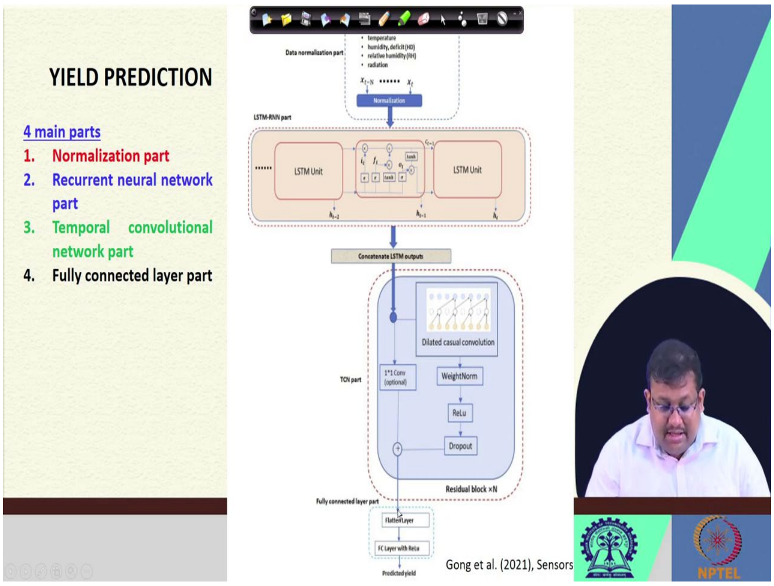

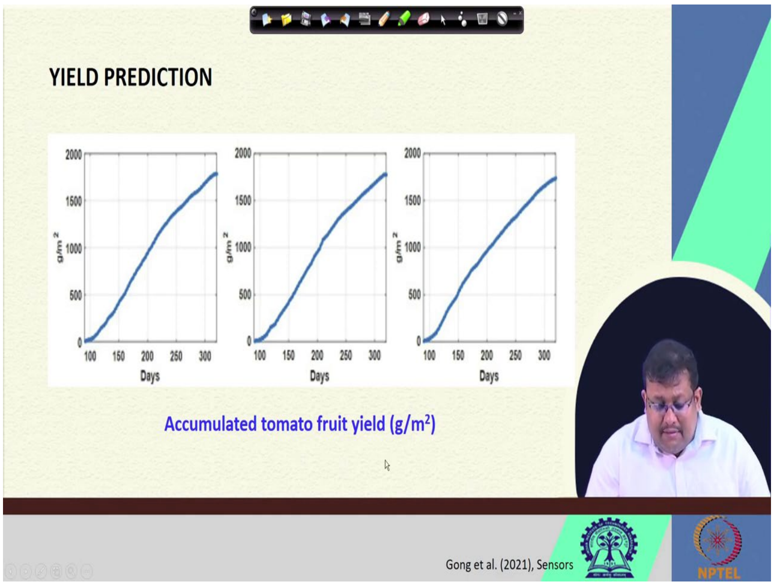

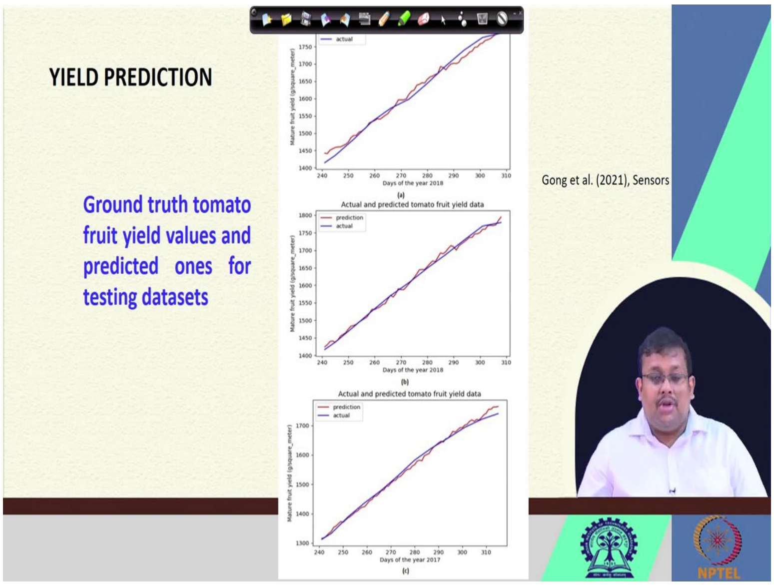

So, four major parts one is normalization part and other is recurrent neural network part, which we can see here, then temporal convolutional network part and finally, the fully connected layer part we can see here. Ultimately, when all these four parts are connected together, they are giving the predicted yield.

And you can see for three different data sets these are the accumulated tomato fruit yield with the passing of the days, so temporal changes in the fruit yield for three different dataset. Also we can see that ground truth tomato fruit yield values and predicted ones for testing the datasets we can see here directly.

So, days of year 2018 for three different datasets you can see that how the predicted values are matching with the actual values using the machine learning models. So this shows some of the good applications for machine learning in agriculture for yield prediction. Let us wrap up our lecture here, and in the next lecture we will start from here and we will see some more applications of machine learning algorithms for crop and soil management. Thank you.