Machine Learning and Soil and Crop Management
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Lecture 05
General Overview of ML and DL Applications in Agriculture (Contd.)

Welcome friends to this fifth lecture of week 1 and in this week 1 we are discussing the General Overview of Machine Learning and Deep Learning Application in Agriculture and in the past 4 lectures; we have discussed some basic overview of machine learning, artificial intelligence and deep learning methods. We have seen their interrelationship; we have seen the supervised, unsupervised reinforcement learning, semi supervised learning.

We have also seen some application of traditional uses of machine learning and traditional uses of machine learning. We have seen the machine learning structure and what is the difference in the structure between machine learning and deep learning. And also we have seen the some application of reinforcement learning.

And how this, there are different components of machine learning and how they are important? What is deep learning and what are the challenges in the modern agriculture? What are their consequences? What is precision agriculture? What are the major component of the precision agriculture? And what are the four pillars of smart farming, we have also discussed.

And then, what are the components of ICT in agriculture, we have discussed. And then we have seen the contribution of machine learning related studies from different countries all over the world. Also some of the most widely used machine learning application in the crop field and also their application. And also we have seen the best the features, most important features, which you use for machine learning application.

And when you started, and also we have started discussing about the machine learning application for yield prediction and I have showed you, how scientists are using fully connect different hierarchically connected different layers for predicting the crop yield. And they have used different deep learning networks, hierarchically connecting them together, to predict the tomato yield.

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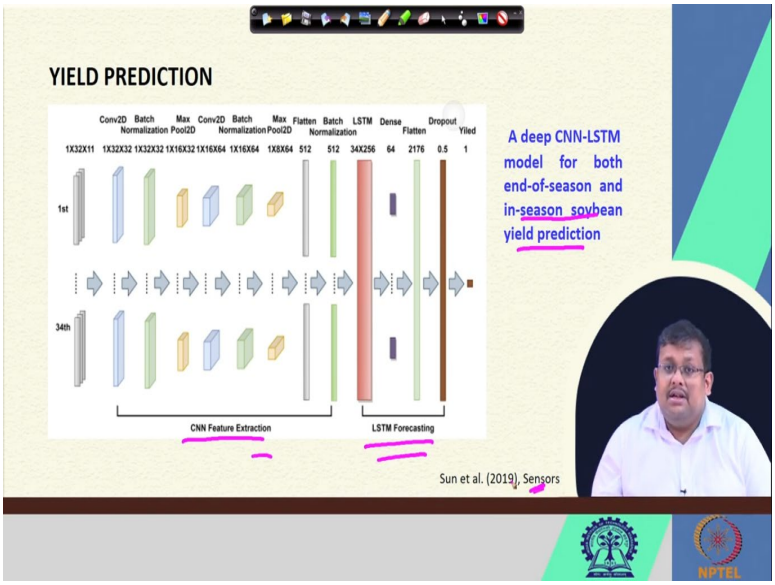

Now, let us start from here and we also can see another example, where scientists have used the deep convolutional neural network and long short-term memory model, for both end of season and in season soybean yield prediction. So, this is the structure of this deep learning algorithm, where you can see the CNN features extraction followed by LSTM forecasting. And ultimately, we are getting and this research was done by Sun et. al. in 2019 and it was published in the journal sensors.

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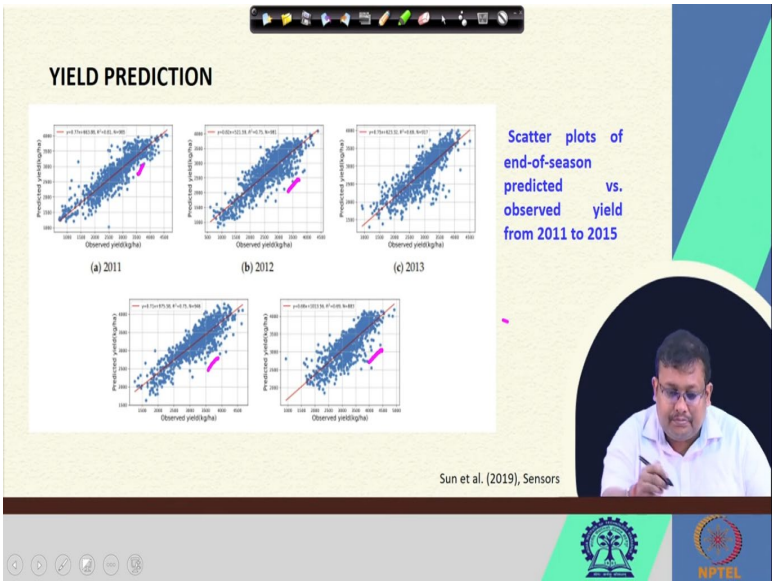

And ultimately, they predicted the yield of for 4-5 consecutive years, starting from 2011, 2012, 2013, 2014 and 15. And, you can see the scatter plot of end of the season predicted

versus observed yield. And so, this is for 2011, this for 2012, this 2013, then 2014 and 15. So, this is how using some advanced deep learning network, we can predict the yield of the crop.

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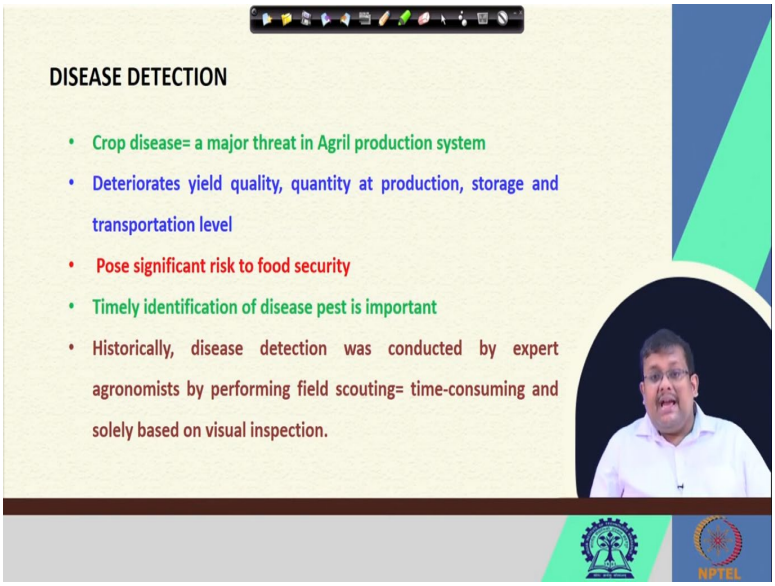

So, another important area, where machine learning is being utilized is, in case of crop management is a disease detection. This is a very important aspect, because crop disease is a major threat for agricultural production system. Because, when there is a disease in a crop, that deteriorates the quality of the crop of the produce and also quantity of the production is also reduced and also storage and transportation of the crop is also getting affected, adversely affected.

So, it ultimately pose a significant risk to food security. And as a result, timely identification of disease pest is very very important. Historically, disease detection was conducted by expert agronomist, by performing the field scouting, which is very much time consuming and solely based on visual interpretation, inspection. So, it is kind of qualitative in nature.

So, nowadays, by the adaption of modern tools in agriculture, like sensors and machine learnings and deep learning applications, it is now, pros possible to detect the disease, either by some sensory features or by using the image processing and subsequent machine learning.

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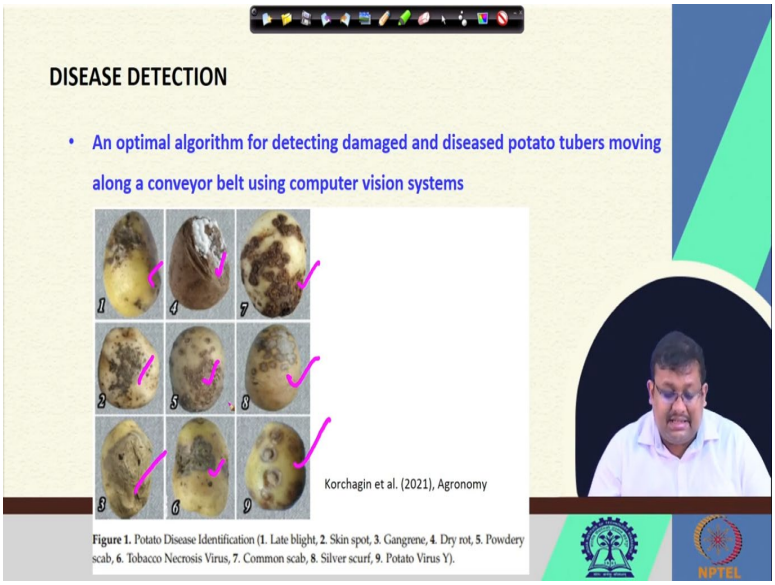

We can see one example from disease, potato disease detection. So, an optimum algorithm, so you can see here, an optimum algorithm, you know, was proposed by Korchagin et. al. in 2021, published in the journal Agronomy, for detecting the damage and disease potato tubers, moving along a conveyor belt using computer vision systems.

So, you can see here there are different types of crop potato diseases, starting from the late blight, which is one of the major diseases for potato and then there, this is the skins spot and then you can see this is a gangrene of potato. Then, it is the dry rot of potato and then powdery mildew of the potato, sorry, powdery scab of potato.

Then, tobacco necrosis virus, infection in potato. And also, you can see, this is a common scab and then silver scurf and potato virus 'Y', which is another viral disease. So, you can see different types of fungal and bacterial viral diseases of potato and when these potatoes are moving in a conveyor belt, using the machine vision and machine learning, can we detect these type of diseases?

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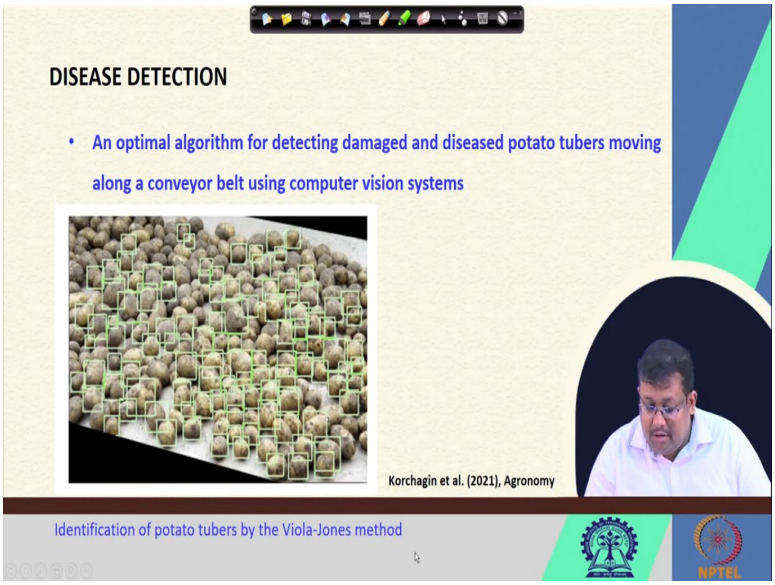

So, this was the challenging task and utilizing the machine learning methods, they have identified the disease detection, you can see, identification of the potato tubers by the Viola-Jones method, we will see this application in later part of our course in details, but here you can see that it is perfectly possible to identify the crop disease, using the machine vision, followed by and also utilizing the machine learning applications.

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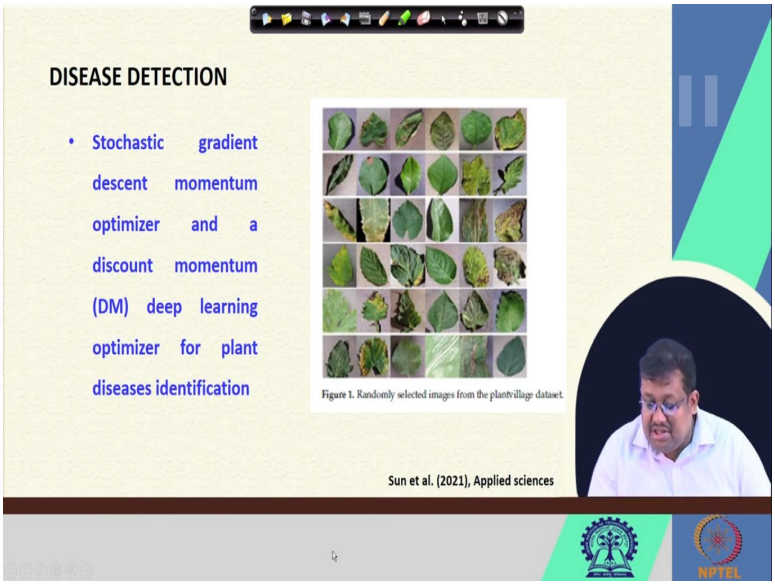

So, another application of disease detection, you can see, published by Sun et. al. in 2021, in the journal Applied Sciences and you can see here, they have used the stochastic gradient descent momentum optimizer and a discount momentum deep learning optimizer for plant

disease identification. So, they have collected image from planned village data set, which is a large data set repository.

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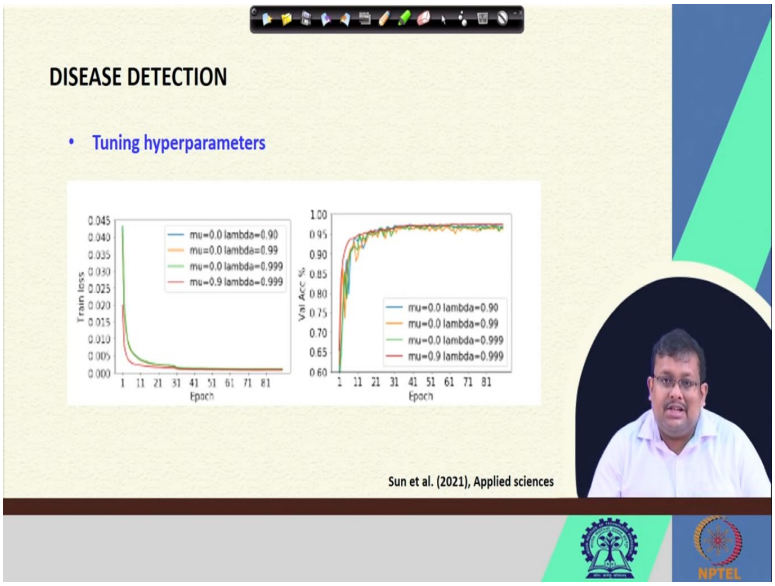

And data repository from there, they have collected the images and then they have tuned some of the parameters, as you can see, like alpha like lambda, like mu and lambda, these are the some of the tuning, these hyper parameters were tuned. Remember, in any type of machine learning or deep learning model, you need to apply; you need to first tune the parameters, so that you can get the desired results.

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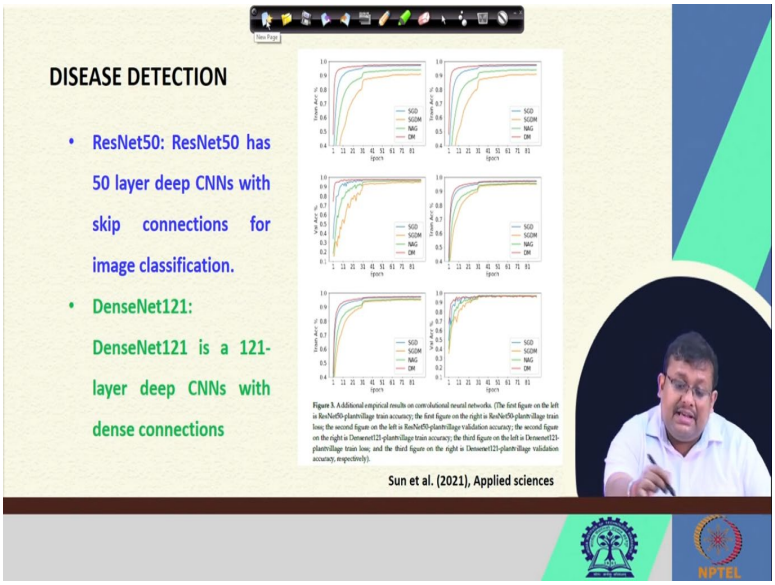

So, this tuning of the parameters were done, followed by the classification and they have used two different types of neural networks, one is called the ResNet50, which has 50 layer of

deep convolutional neural network with skip connection for image classification, and also they have used DenseNet121, which is having 121 layer deep neural, convolutional neural networks with dense connection.

And using these two methods, they have classified, you know, they have classified the disease or, that they have classifies the disease of the plant leaves based on the plant leave images. And these are some of the results train; they have shown the training accuracy and training laws testing accuracy and so on. So, that shows that how using the machine vision as well as the machine learning, deep learning can efficiently predict or classify the disease and also they can predict the crop yield.

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Another major aspect of crop management is weed detection. Application of machine learning has been found in case of weed detection, so remember, why weed is important? Because as a result of their prolific seed production and longevity, weeds usually grow and spread invasively, over large part of the field very fast, and competing with the crops for the resources, including space, sunlight, nutrients and water availability.

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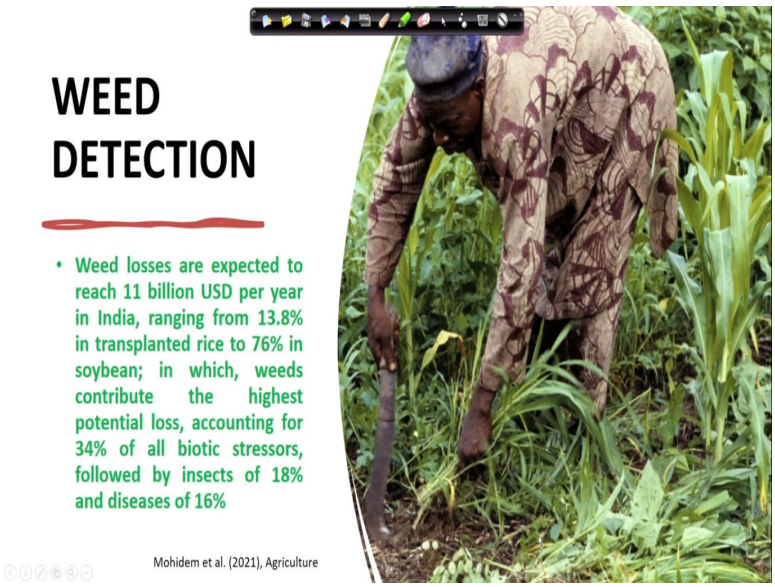

And weed losses are expected to reach around 11 billion USD per year in India, ranging from 13.8 percent in transplanted rice to 76 percent in soybean, in which, weeds contribute the highest protein potential loss, accounting for 34 percent of all biotic stressors. And it follows by the insects of 18 percent, diseases 16 percent. So, weed is known for the maximum loss in the crop.

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So, besides, weeds frequently arise sooner than crops, without having to face natural enemies, a fact that adversely affects crop growth. So that is why, weed control is utmost necessary for better growth of the crop. Without weed control, it is very very difficult to get the desired crop output.

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So, there are different types of control. One is mechanical control, as you can see here; this mechanical control is not that effective. It is ineffective in nature. A chemical control can be done with herbicides, but herbicides are costly and environmentally very hazardous. So, nowadays for environmental sustainability and environmental protection or agriculture sustainability, it is recommended that you should lower down your chemical application or synthetic chemical application.

So, nowadays, we cannot rely more on applying more herbicides. And also long term herbicides, when we go for the long-term herbicides application that also creates the crop resistance. So, in near future, those herbicides will not be useful again, useful enough, for those type of weeds. So, you can see that mechanical control and chemical control are not so much recommended nowadays with the advent of modern agriculture.

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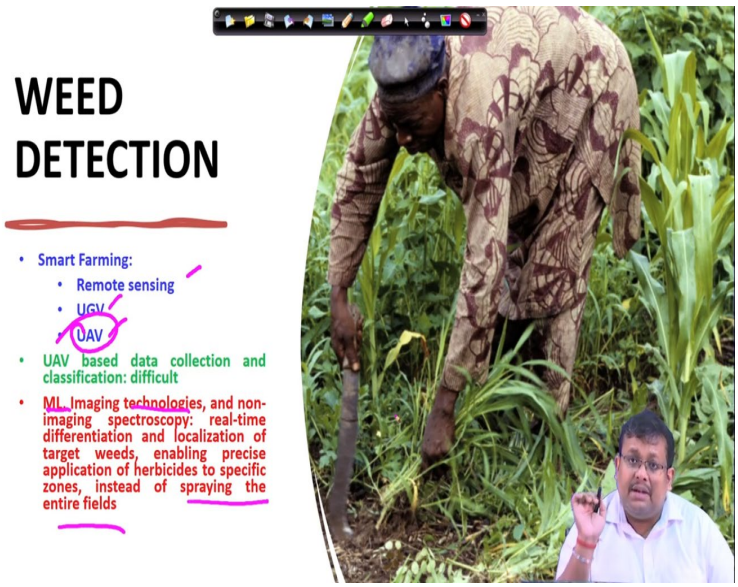

So, that is why the application of different types of tools, sensors and machine learning have evolved. So, in case of smart farming, we know that there are remote sensing and there are unmanned aerial vehicle and also unmanned ground vehicles. So, this UAV based data collection and classification is somewhat difficult.

However, machine learning and imaging technologies and non-imaging spectroscopy helps in real time differentiation and localization of the targeted weeds, enabling precise application of herbicides to specific zones, instead of spraying the entire field. So, we can use UAV for spraying the herbicides.

Also, you can use the machine learning and imaging technologies for weed detection. And then you can direct your operation to that particular area of the field also. So that you can utilize, you can save some resources.

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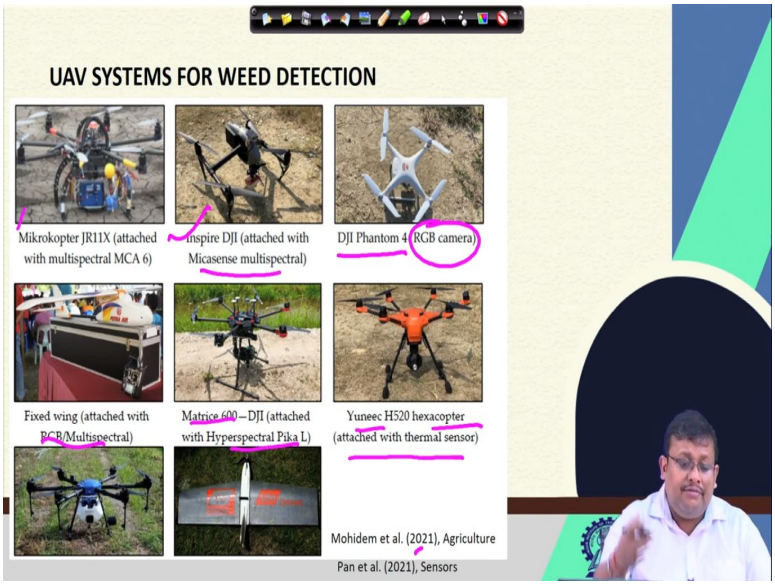

So, we can see here, one example here, Mohidem et.al, who has published in the journal Agriculture in 2021, he showed some of the UAV system for weed detection. You can see here mikrokopter JR11x, which is attached to a multi-spectral MCA 6 camera. Then Inspire DJI. Inspire DJI is a very widely used UAV system, which is attached to the Mica sense multispectral, which is another very widely used multispectral camera.

And also DJI phantom 4, which is attached with an RGB camera. You can see here, Fixed wing. Fixed wing UAV, which is attached with RGB multi spectral camera. Then Matrice 600 model, from the DJI, which is attached to the hyperspectral Pika L camera. Hyperspectral camera are more higher resolution, we will discuss it later on.

And then, Yuneec H 20 hexacopter, which is attached with the thermal sensor. And also sprayer, you can see, these are for use for weed detection. And also they are using the sprayer drone and also Unidrone. So, you can see here that shows the application of these UAV systems for weed detection. And for making for the proper application of proper detection of the UAV. Proper detection of the weeds, using the UAV system, is dependent on application of machine learning algorithms.

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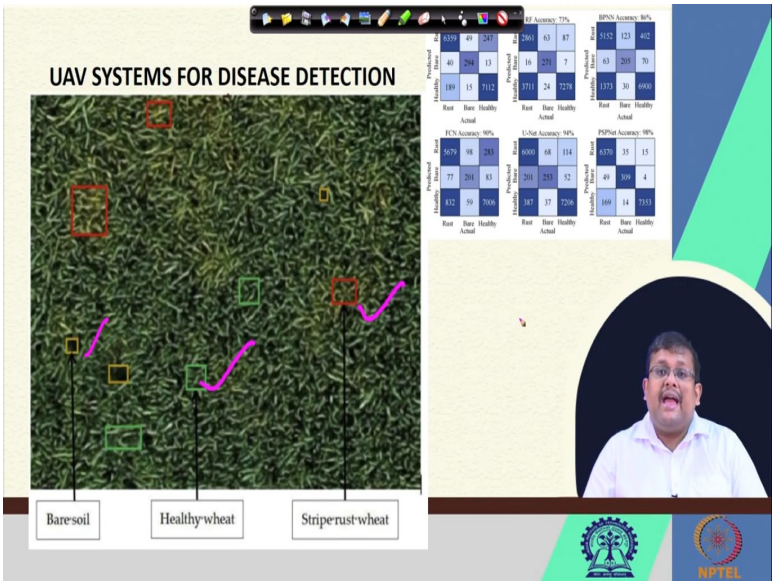

Also you can see here how another research by Pan et. al., which was published in the journal Sensors, they have used UAV systems for disease detection. You can see here, they have used the image detection for identification of the bare-soil as well as the healthy-wheat and also stripe-rust disease of the wheats, and followed by the classification.

And this confusion matrix shows the classification accuracy for using different types of machine learning approaches. We have already discussed the confusion matrix and remember that the diagonal values are showing the accurately classified samples.

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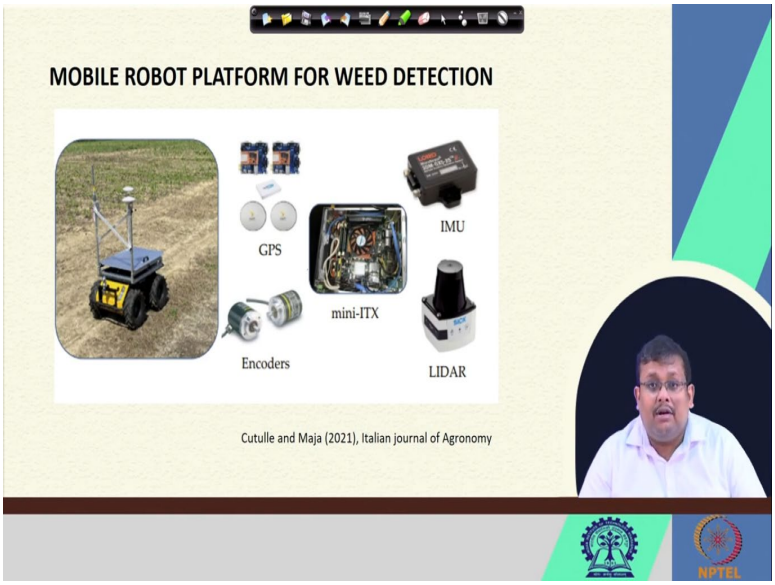

So that shows that how we can use this type of sensing approaches and machine learning approaches for identification of the weeds. Also UGV's, you know, unmanned ground

vehicles like mobile robots platform, are also being used for weed detection. One of this example was shown by this Cutulle and Maja, in the year 2021, which is published in Italian Journal of Agronomy, where they are using this mobile robot platform for weed detection.

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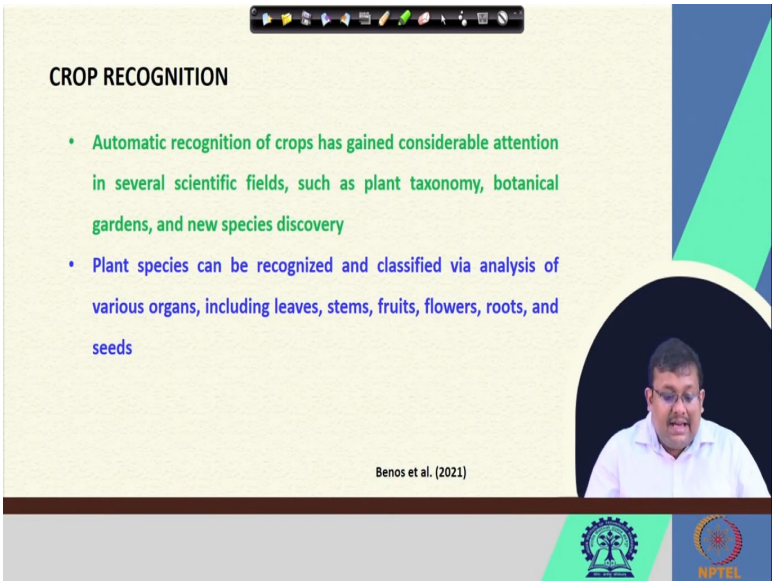

Crop recognition is another important aspect, which helps in the automatic recognition of crops, you know, which has gained a considerable attention in several scientific fields, such as plant taxonomy, botanical garden and new species discovery. And plant species can be recognized and classified via analysis of various organs including leaves, stems, fruit, flowers, and also by the seeds.

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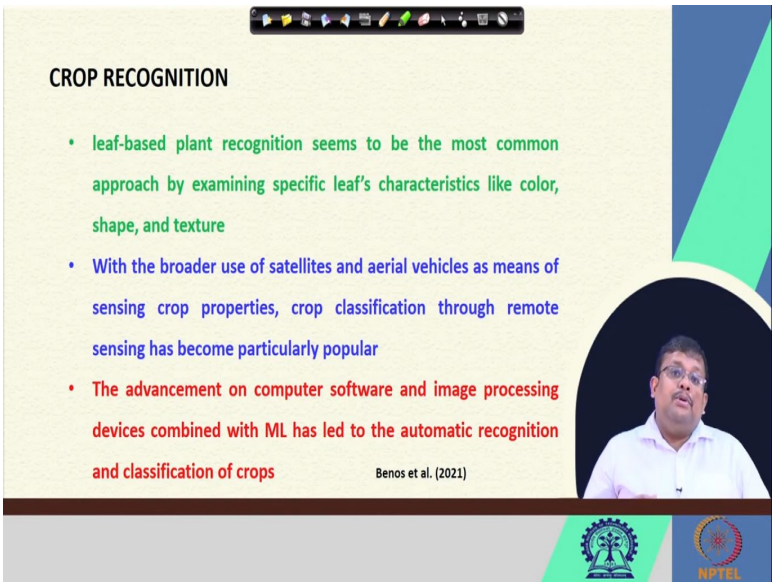

So, leaf-based plant recognition seems to be the most common approach by examining specific leaf's characteristics like color, their shape and texture. With the broader use of satellites and aerial vehicles and their images as a mean of sensing crop properties, crop classification through remote sensing has become a particularly very much popular. And the advancement of the computer software in image processing device with machine learning has led to the automatic recognition and classification of the crops.

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Also another important aspect is crop quality identification. So, it is very important for market and high quality produce can generate higher earning to the farmers, which is one of the objective of modern agriculture. So, developing decision support system can aid the farmers for taking appropriate management decision to increase the quality of their produce.

So, machine learning application can help in selective harvesting is a management practice that may considerably increase the quality. And also machine-learning application can identify the weeds and remove them, and also, so, this type of operation help in improving the crop quality.

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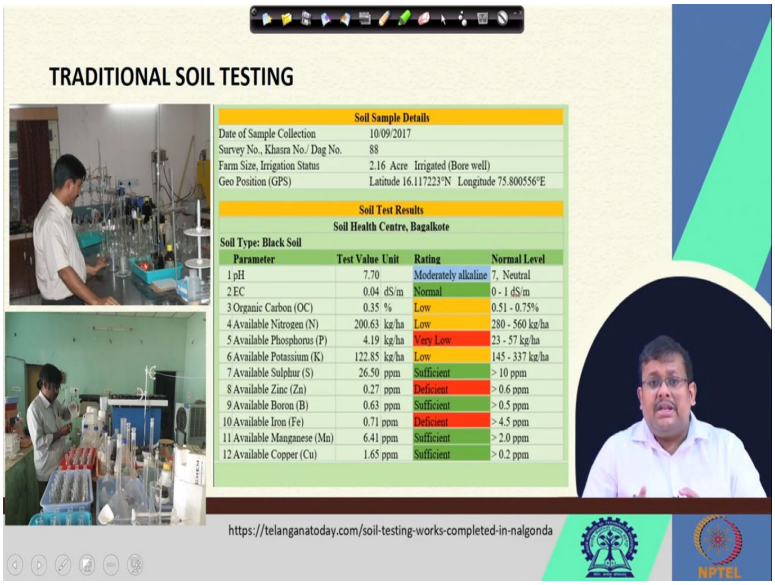

Now, let us talk about the soil testing. Now, soil testing, traditional soil testing, is very much time consuming affair, you need to collect the soil samples, you need to process the soil samples, and then you need to analyze the soil samples using the traditional wet chemistry method, for determining different types of soil parameters.

However, so this is a traditional soil testing labs, and these are the routine soil testing parameters like ph, electrical conductivity, then organic Carbon, available Nitrogen, available Phosphorus, available Potassium, available Sulphur, available Zinc, Boron, Iron, Manganese, Copper. These are some of the very common routine soil test parameters, which we generally use for testing the soil fertility.

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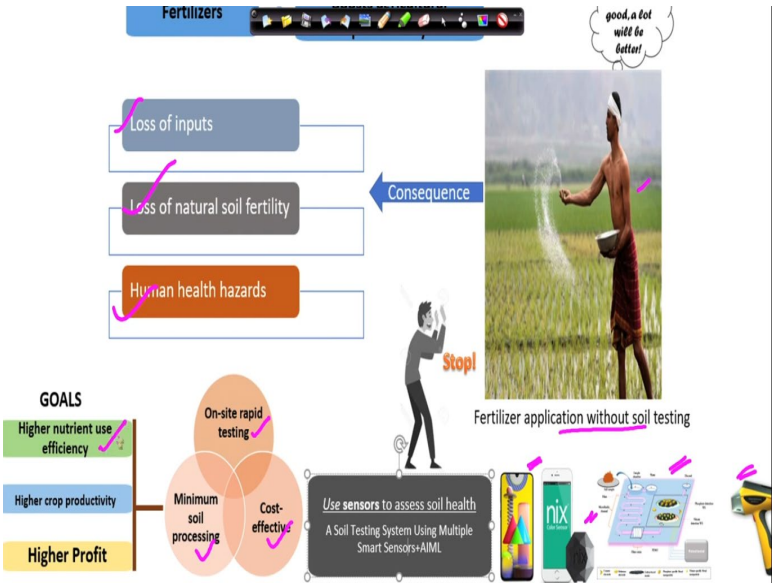

So but, the problem is, most of the soil testing facilities in our countries are not available to our farmers, so as a result, what happens, the farmers generally do not go. Because they are not aware of soil testing processes, and also they do not have access to soil testing. So, and also they apply the fertilizer indiscriminately without any soil testing.

And as a result what happened, loss of inputs and loss of natural soil fertility and also human health hazards. Because, these are chemical products, when they are mixed with the environment, that also for long term, that also creates some problem. So, these are some ill consequences.

So, to stop this kind of behavior, nowadays, scientists are using different types of sensors, portable sensors like you can see here, smartphones NIX pro color sensor and portable microfluidic sensors and also portable extra fluorescent sensors to judge or to test the soil as a rapid screening tool so that farmers can have at least an idea about their soil quality and they can apply the fertilizer in such a manner to reduce the environmental hazard and to increase their profitability.

Because, ultimately, this type of sensor application with machine learning will help in the onsite rapid testing. These are very much cost effective also, and also they require minimum soil processing. Ultimately, they will be helping to achieve the higher nutrient use efficiency and higher crop productivity and higher profit.

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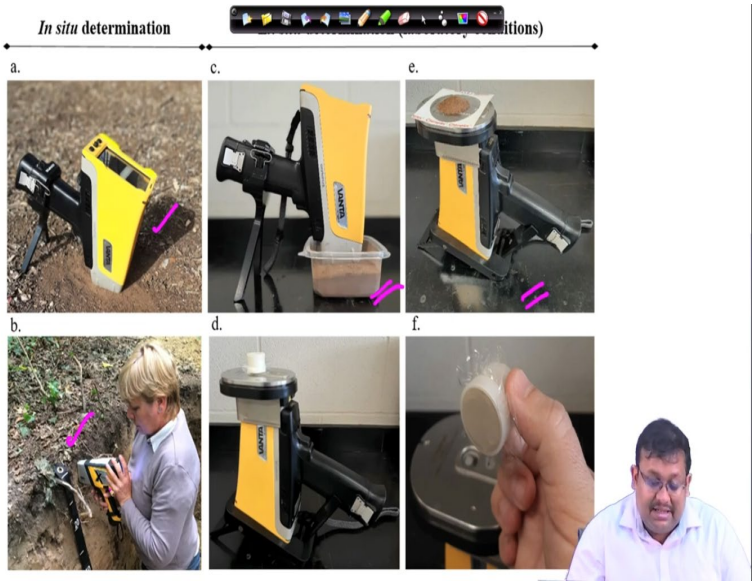

So, these are some of the impetus, which drives this application of the sensor for better for a machine learning for better soil management. As you can see here, this is another, this is a

specialized sensor called portable extra photo since we will discuss these details in our upcoming lectures. You can see, we can use this sensor directly in the field as scientists are using directly in the field. You can also use them in the lab condition also.

So, you can use them both in situ and out ex situ, for determining rapid determination of soil properties in a minute, using some calibration algorithms. And we will talk about, we will talk more about this instrument and their application, but remember this type of sensor using machine-learning algorithms, nowadays, it is possible to detect soil properties on site.

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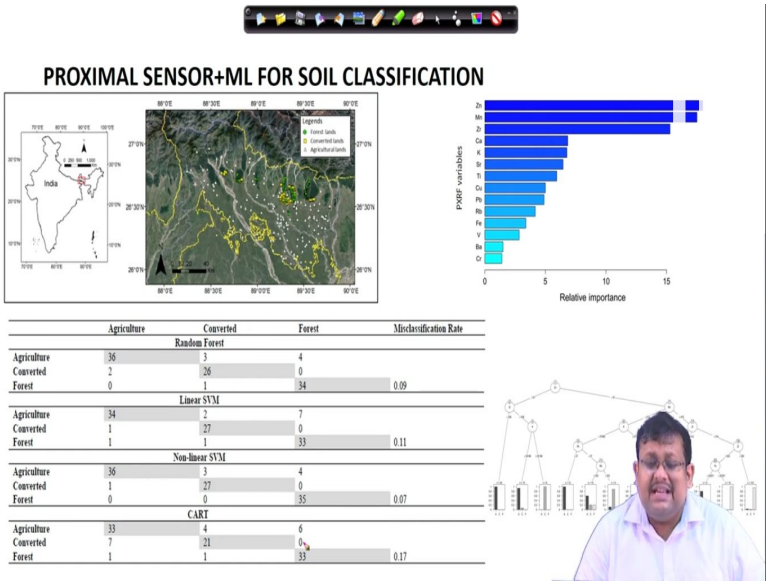

Some examples are given here, you know, one of our previous research, where we applied this tool, along with the machine learning, for soil type classification. So, we have used this tool for classifying the agricultural soil converted land, also the forestland with higher accuracy.

So, using the elemental report from this type of portable sensor, proximal sensor, we can classify the soil types. Because the soil types are dependent on these elemental values. We will go to discuss them in details in our upcoming lectures, but here just to show one example of classification using the elemental data, which we gather from the portable XRF.

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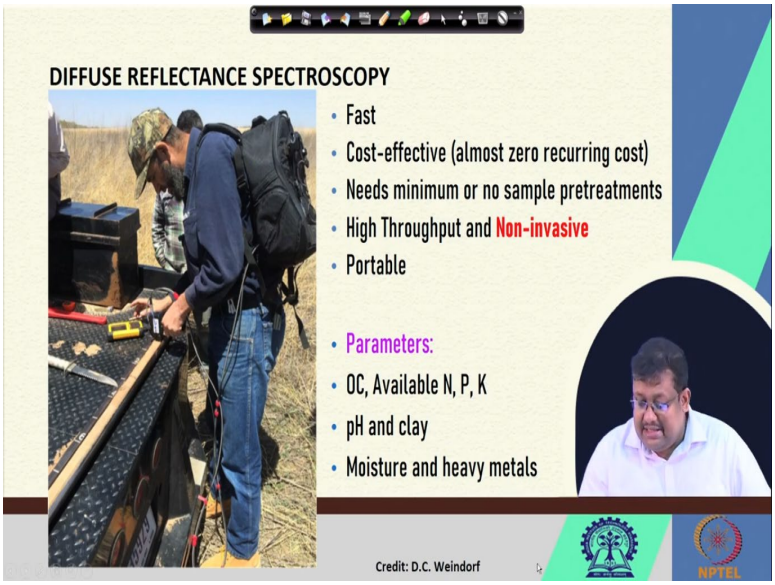

So, among other application, there is another method, which is widely used in the soil science discipline called diffuse reflectance spectroscopy. This diffuse reflectance spectroscopy is a very fast method. This is also a portable cost effective method. It requires minimum or no sample pretreatment. It is high throughput and non-invasive, you are not destroying the soil samples, and you can measure a multitude of soil properties using this sensor.

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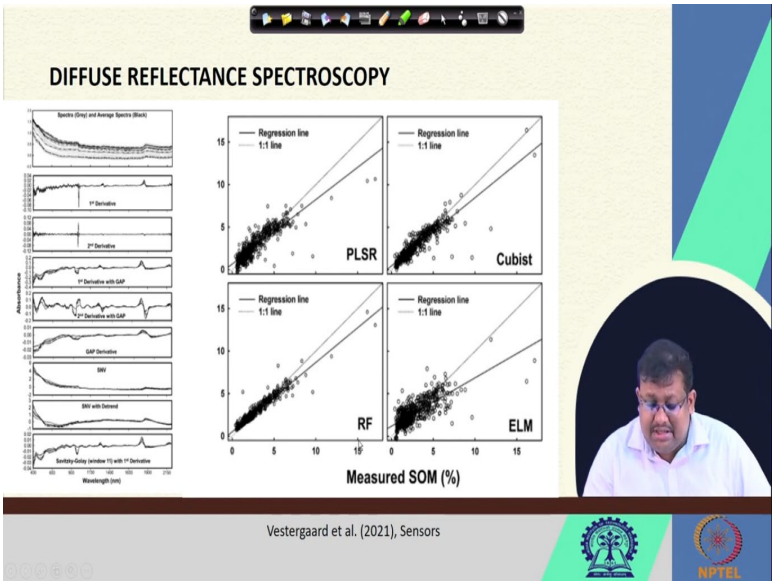

Now it is this sensor is very much useful and you can use this diffuse, scientists have used this diffuse reflectance spectroscopy and feature engineering like spectral preprocessing also in combination with different types of machine learning algorithms like you can see here, partial squares regression, cubist regression, then random forest regression, extreme learning

machine, all these are advanced machine learning approaches and deep learning approaches. They have used to predict the soil organic matter content.

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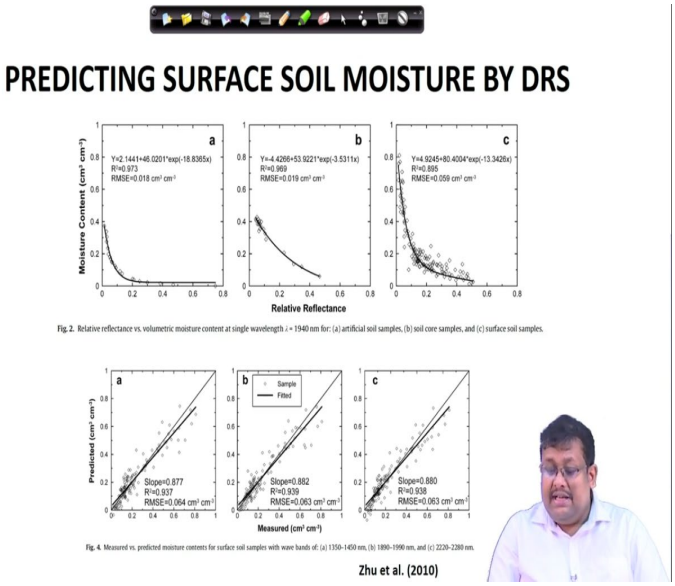

Also, this sensor has been used for predicting the surface soil moisture. So, you can see here, this grass shows the changes of the relative reflectance with the increasing moisture content, and then using this DRS spectra, scientists Zhu et. al., in 2010, they have predicted the surface soil moisture in three condition, in the wave band.

This is in the wave bands of 1350 to 1450 nanometer. They are using here the 1890 to 1990 nanometer and here another zone that is 2 2 2 0 to 2 2 8 0 nanometer of the spectral region of the diffuse reflectance spectroscopy to predict the soil moisture content, and this paper was published in Journal of Hydrology.

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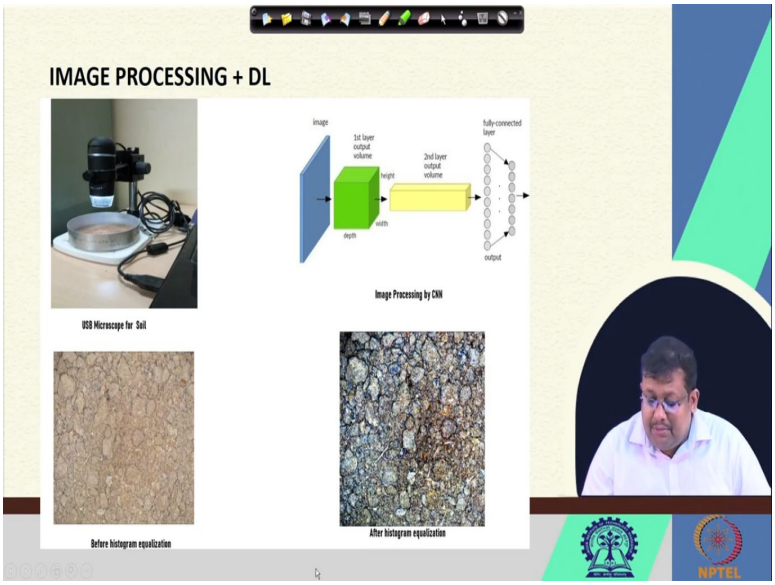

Nowadays, we are using new-new technologies for image processing and subsequent prediction of soil properties also. You can see here, it is a very handy tool that is USB microscope for soil. USB microscope, you can just, you can plug it in your laptop and you can take the images of the soil with high resolution.

And you can feed these images directly into the convolutional neural network to predict certain soil properties. So, this is one of the very you know good example of image processing plus deep learning based soil property identification.

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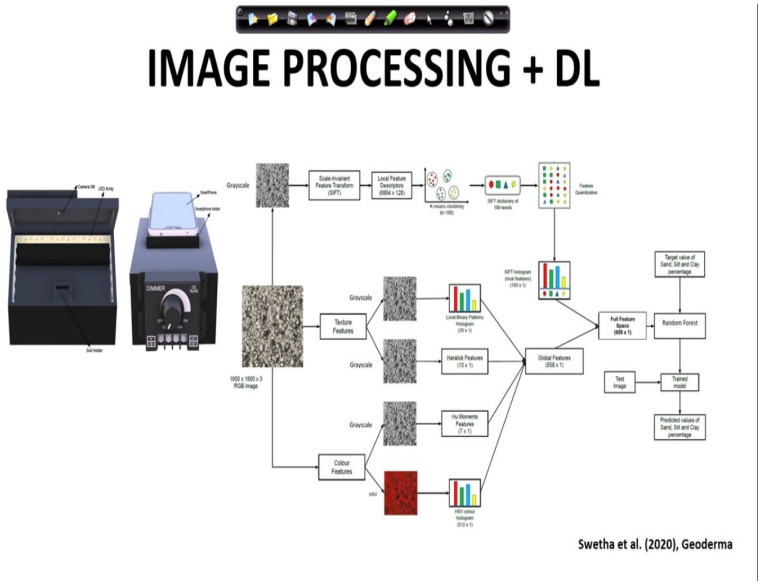

Also, nowadays, using the smartphone images and deep learning and machine learning algorithms, nowadays, it is possible to predict different soil properties. In an example of

Swetha et. al., which is published in their 2020 in the journal Geoderma, where they have used this smartphone setup for predicting the soil texture.

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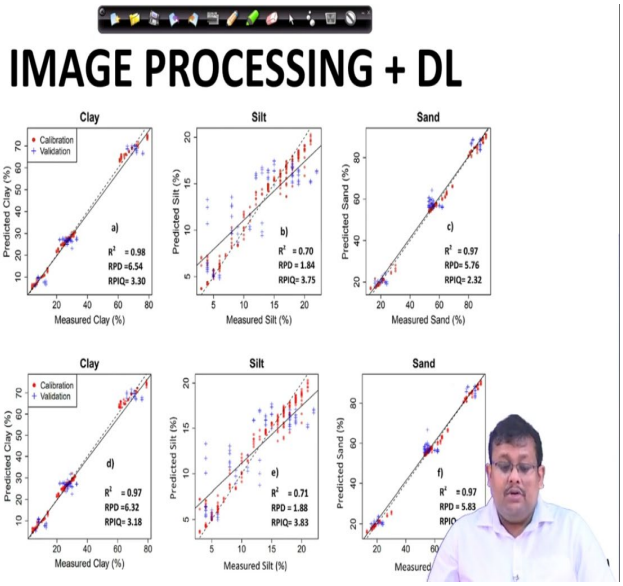

They have also used the convolutional neural network to predict the soil clay, silt and sand, as you can see in both this condition, they are getting very good 'r' square values, for clay, silt and sand. So, that shows the use of these advanced tools of deep learning as well as the smartphone images for better management of soil properties.

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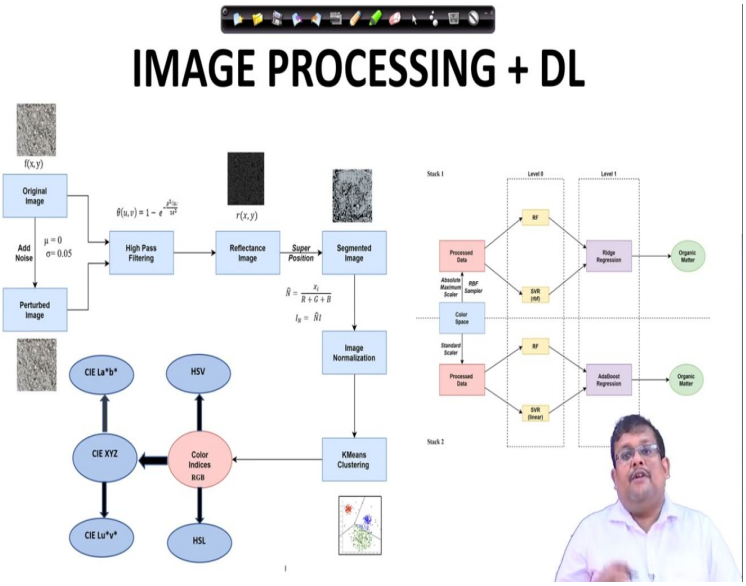

Also now it you know a recent paper from our group Gotheatol (())(26-36), which was published in Bio system Engineering in 2021, it has been proved that when we use the image processing and subsequent deep learning and machine learning method, it is possible to

predict the soil organic carbon in the field using smartphone. So that gives more support towards the application of machine learning and deep learning for rapid management of soil properties rapid prediction of soil properties.

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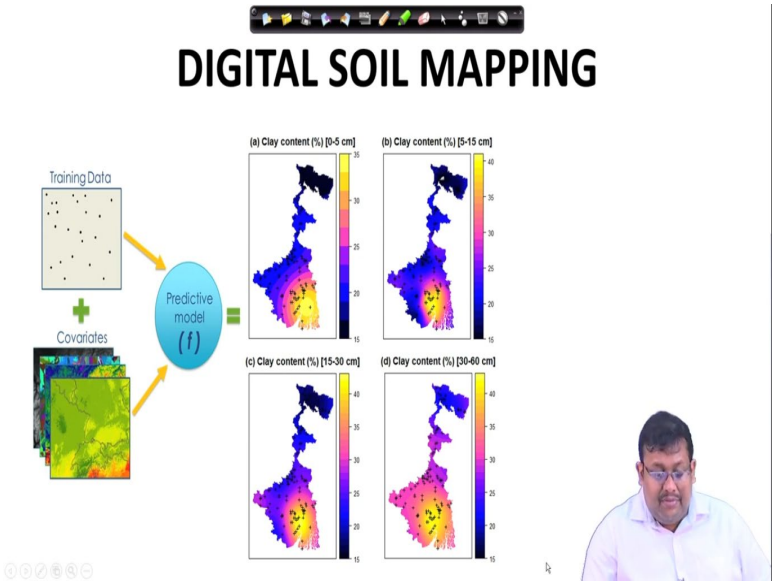

Digital soil mapping is another new area where the people have used different types of prediction models, so both deep learning model as well as machine learning model, where the training data has been you know training data, trading data, legacy soil data were combined with covariate data, easily available digital covariate data, and then developing a predictive model using machine learning or deep learning algorithm, to develop a high resolution soil maps, for different depth.

So, for different depth of the soil starting from 0 to 5 centimeter and it goes up to two meters. So, the digital soil mapping is a very you know booming area of soil science, and it has got a tremendous application of machine learning application, in for producing the high-resolution soil maps.

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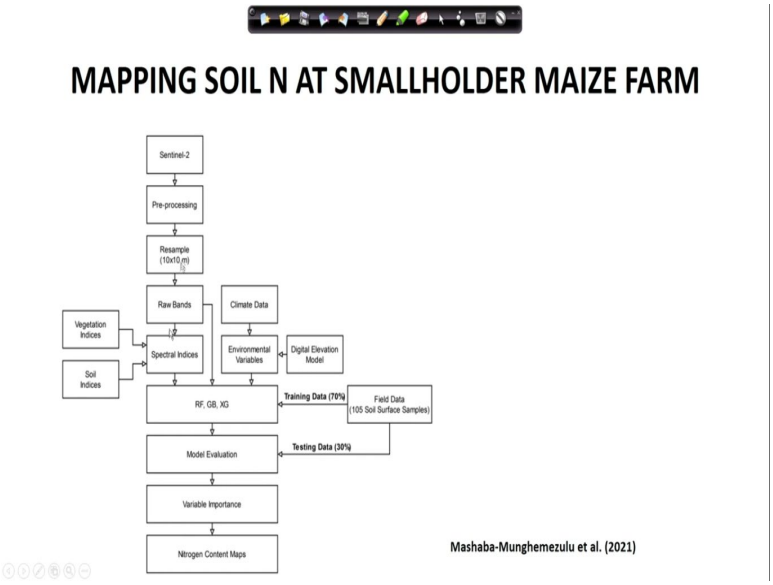

Also people have used different types of satellite data here you can see Mashaba Munghemezulu et. al., in 2021, they have used the Sentinel-2 data and which is a satellite and preprocess the data, resample the data and then combine with different types of vegetation indices and soil indices and also climate data and then digital elevation model as an auxiliary input.

And then they have identified some spectral indices and then they have run three different model like random forest model, gradient boosting regression and also exhibits regression and they have done a 70 30 training testing with the field data and then evaluated the model and then finally they produce the nitrogen content map.

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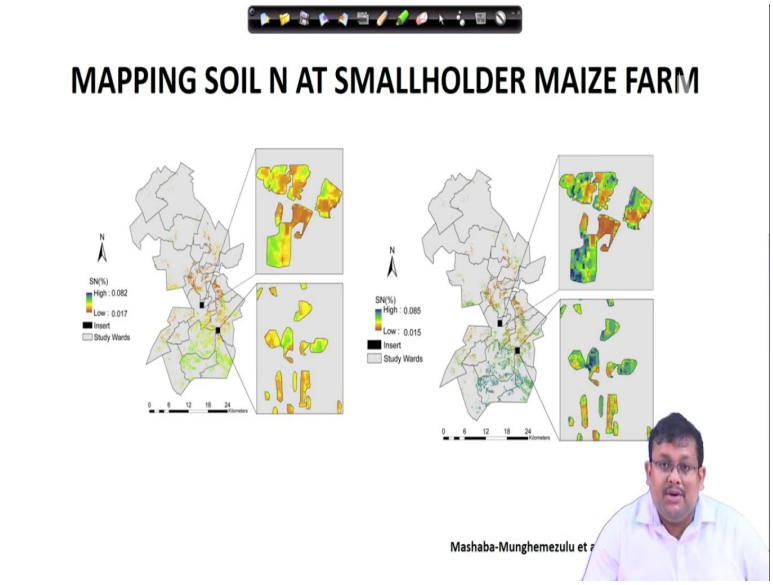

You can see these are the nitrogen content map in the small holder base form. So, not only machine learning helps you and tools like satellite images and also sensor data can help you to predict the soil properties, but also you can produce the high-resolution maps using those algorithms.

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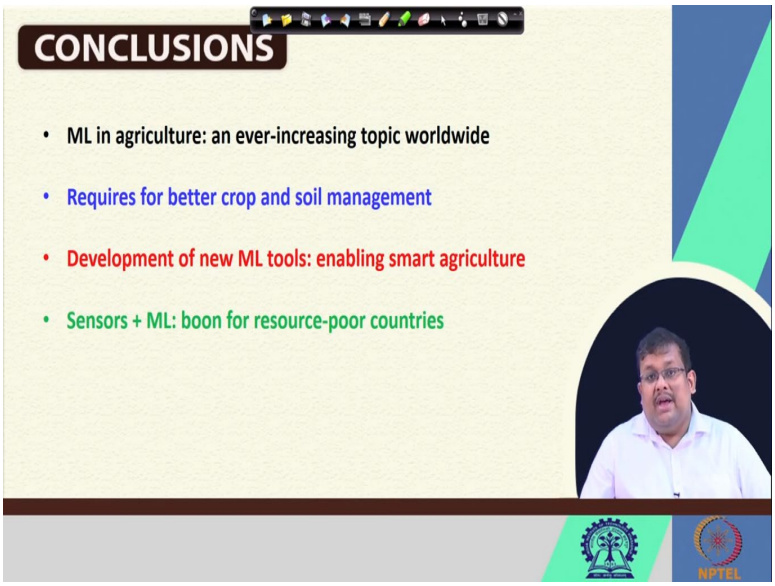

So, what is the conclusion? Conclusion of this whole chapter, these four first of all machine learning and agriculture it is become an ever increasing topic worldwide and it requires for better crop and soil management when we move towards modernization of agriculture especially in developing countries like India.

And also development of new machine learning tools are enabling the smart agriculture and of course for a resource-poor countries, this combination of sensors and machine learning,

appears as a boon, where the farmers do not have access to the traditional soil testing and crop testing. So, that makes the end of this first week of lectures. I hope that you have got some knowledge, new knowledge in this lecture.

And these are the references. Most of the references are coming from some published research papers. And if you have any doubts you can let me know and I will be more than happy to answer your queries. And let us meet in our next week, where we will be discussing, dealing, how to deal with the multivariate data.

Because how to deal with the multivariate data, it requires some type of data processing and this data processing will be learning in our second week of lectures. So, guys thank you for joining in this lecture. Let us meet in our second week of lectures to discuss these in details. Thank you.