Air Pollution and Control
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Lecture 23
Emission Inventory for Agriculture Sector

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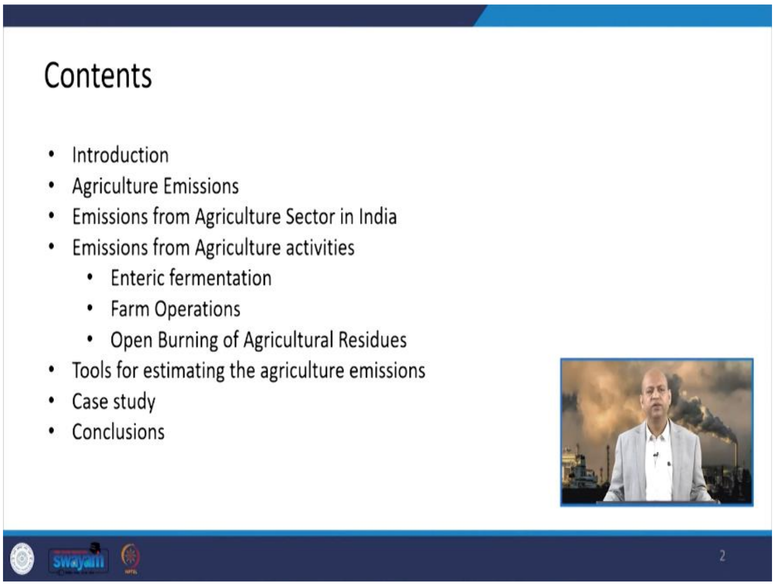

Hello friends. So, as we are discussing about development of emission inventory. For any city or for any country, if you want to develop total emission inventory, then we have to consider all the sources or all the sectors and with that perspective, we have already discussed like how to develop emission inventory for transportation sector, for industrial sector.

So, today we will discuss about agriculture sector means how to develop emission inventory for the emissions, which are emitted by the agriculture activities or agriculture sector. So, this would be the content list for today's lecture like briefly we will discuss in introduction, what are the emissions from the agriculture sector? What are the pollutants? What are the sources?

Then from Indian perspective means different emissions which are coming out of agriculture sector, that we will focus upon and later on we will see like what are the emissions from agriculture activities, like enteric fermentation or farm operations or open burning of agriculture residues, then we will see like what are the tools for estimating the agriculture emissions, because there are certain software or tools which have been developed by several agencies or countries for the estimation of agriculture emissions in their respective countries. Then we will have a case study and later on we will conclude.

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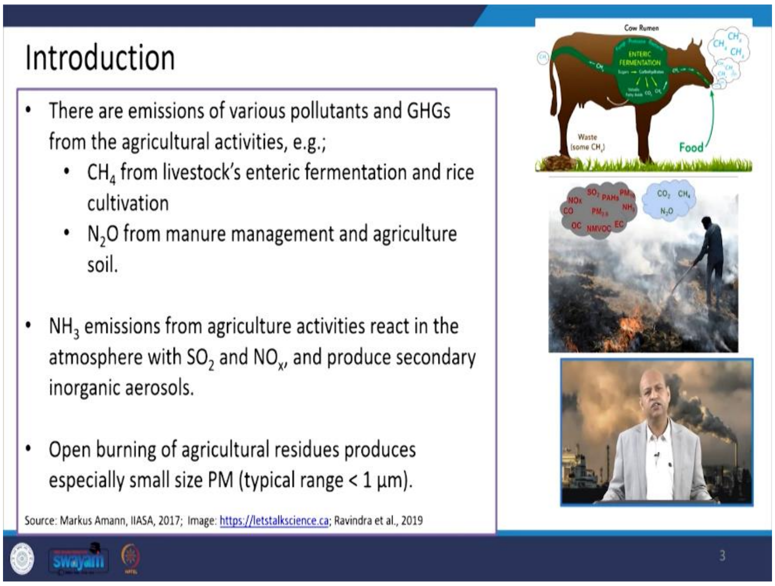

Now, if we look into like very brief introduction about emissions or sources of the emissions from agriculture activities or sector, so we can see like methane from livestock's enteric fermentation and rice cultivation is one predominant emissions you can see and nitrous oxide from manure management and agricultural soil also emitted in a lot of quantity. So, these are major greenhouse gases you can say.

Then ammonia emissions is also there and they can also react with the sulphur dioxide or these NO_x emissions, which are available or in atmosphere and they can create some secondary aerosols. So, that way also one contribution from ammonia emissions is also there. Then there are open burning of agricultural residues, which produce lot of small size particulate matter typically less than one micrometer and that again create a lot of smoke related problem in winter especially.

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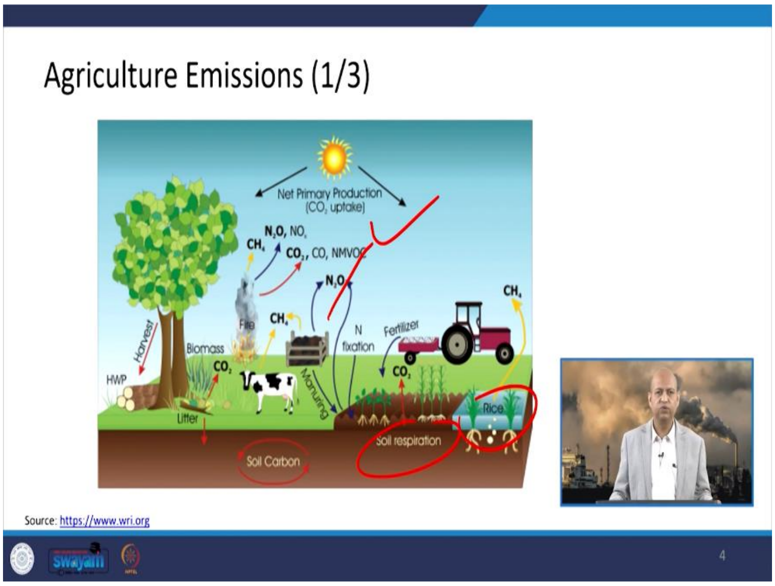

So, in this picture you can see the overall relationship of different agriculture related activities and the associated emissions or related emissions like you can see methane from this paddy fields and then CO_2 from soil respiration emissions and soil carbon of course, because of certain processes, then N_2 emissions are there, CO_2 emissions are there from different activities like fuel burning in tractors or even respiration systems. So, that is always there, this emissions and deposition of CO_2 or extraction of the CO_2.

And this NMVOCs are also there non-methane VOCs hydrocarbons, volatile organic compounds which are not of methane nature. So, those emissions are also there.

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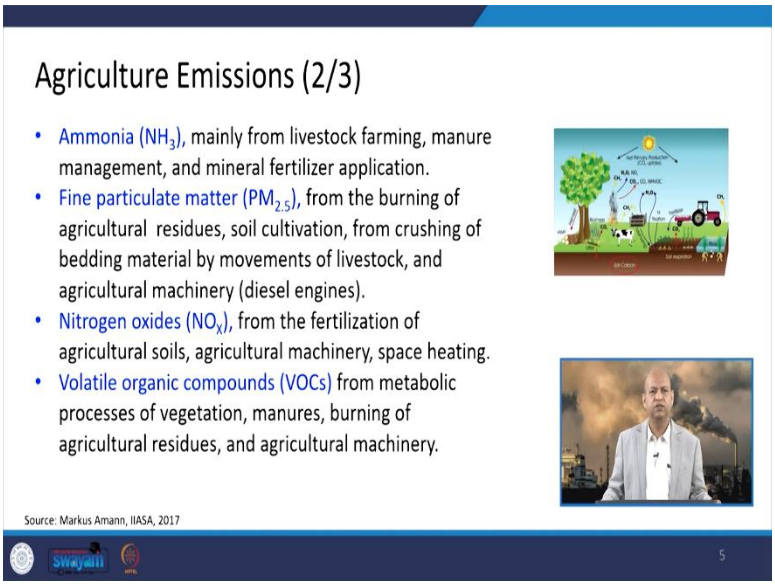

Well, so, if we summarize like what are the important emissions and their major sources, so if we talk about like ammonia which is mainly from livestock farming and manure management and the mineral fertilizer applications, this ammonia comes out of or is released in a lot of quantity. If you talk about fine particulate matter like $PM_{2.5}$, then this is from burning of agriculture residues.

Soil cultivation, because re-suspension of dust, so a lot of particulate matter is there or from the crushing of bedding material by movement of live stocks and agricultural machinery like diesel engines etc, tractors etc. Then nitrogen oxides are also their oxides of nitrogen from fertilization of agricultural soil, agriculture, machinery space heating, so oxides of nitrogen are from several activities related-activities of the agriculture.

Then volatile organic compounds those are VOCs from metabolic processes of vegetation, manures, burning of agriculture residues, agriculture machinery and then there are NMVOCs are also as we have seen in the last slide.

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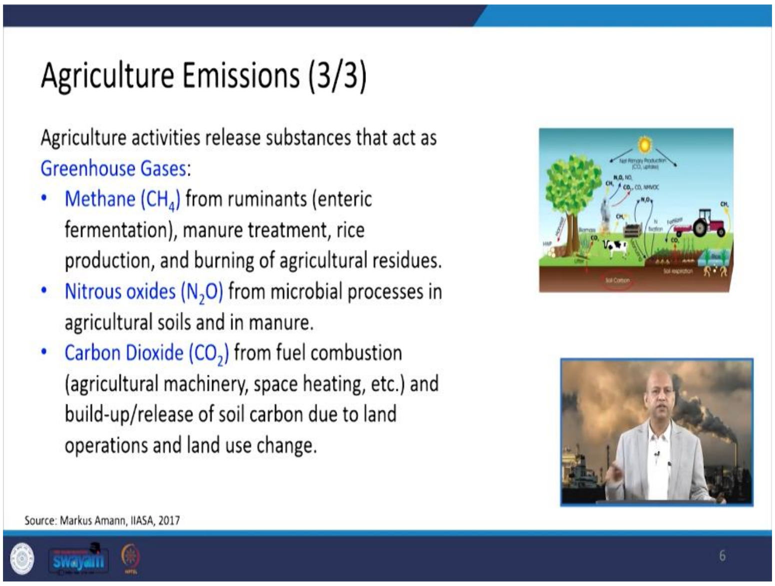

Then methane of course, like greenhouse gases if released, so methane and nitrous oxide and carbon dioxide are also there from all these different activities which we have just discussed.

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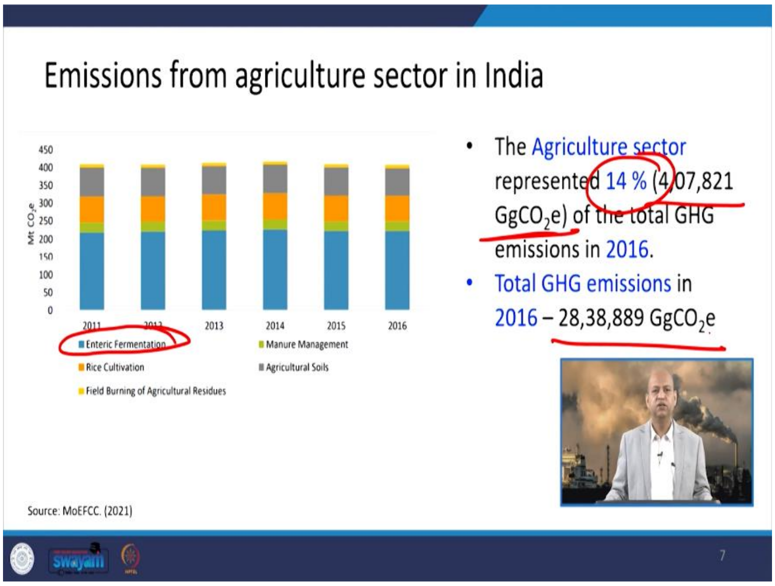

When we talk about emissions from agriculture sector from in India basically, then this chart, this bar diagram shows like enteric fermentation is the dominating source of CO_2, equivalent CO_2 means when we talk about greenhouse gases, we represent them as equivalent of CO_2 means we can convert them in the potential global warming potential or those kind of thing.

So, like this is the Giga gram CO_2 equivalent, this much of emission is there from agriculture sector and that is basically 14 percent of the total greenhouse gas emissions in 2016 and this was the total greenhouse gas emissions from the different sectors and agriculture sector was responsible for 14 percent.

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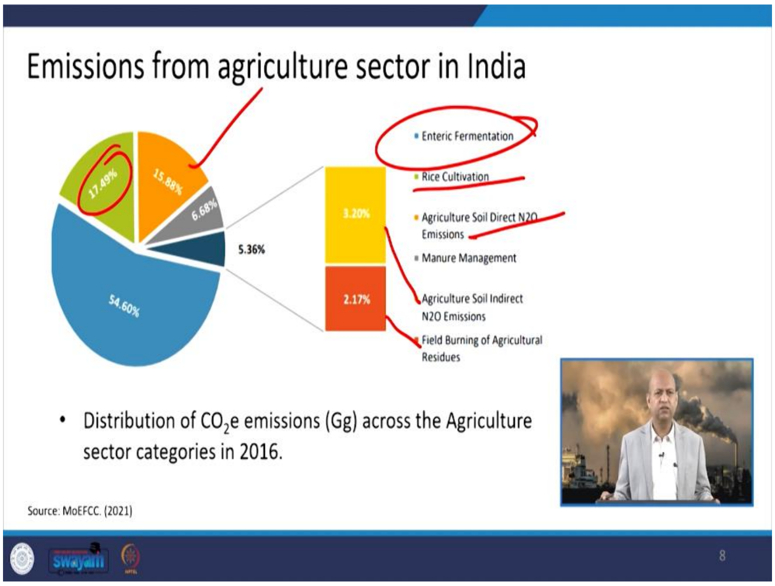

Well within that 14 percent or the emissions from agriculture sector, if we divide into different activities, then you can see 54.6 around 55 percent is from you can see this enteric fermentation alone. And the second largest that is around 17 to 18 percent, this is from rice cultivation. And the third largest emitter is this basically agricultural soil, direct end to emissions direct end to emissions are there. So, these are the three large basically activities from the agriculture sector.

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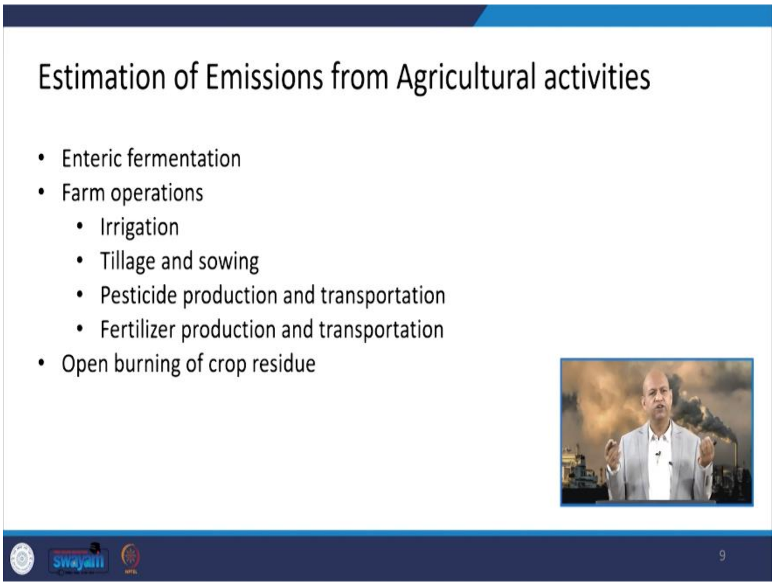

Now, if we discuss one by one like enteric fermentation or farm operations related to irrigation or tillage and sowing kind of activities or pesticide production and transportation, fertilization, fertilizers production and transportation or open burning of crop residues, these major activities of the agriculture sector, if we relate them to different kinds of emissions, then we can discuss them one by one.

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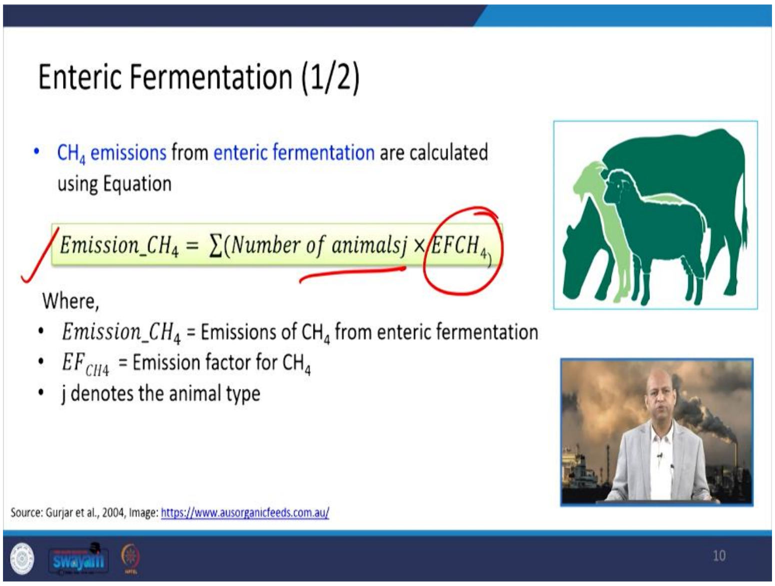

Like enteric fermentation, if you want to estimate emissions from that particular activity that is the digestion process of cattle's etc. These like sheep or cow those kinds of animals. So, this is the simple equation, which we use for estimation of emissions of the methane, like number of animals we go for and this emission factor of the methane for that particular species.

So, different species we again multiply that is a very simple way of calculation, then we add up all kinds of cattle's, because the different cattle different animals have different kinds of emission factors, which have been estimated with the help of different experiment, field experiment.

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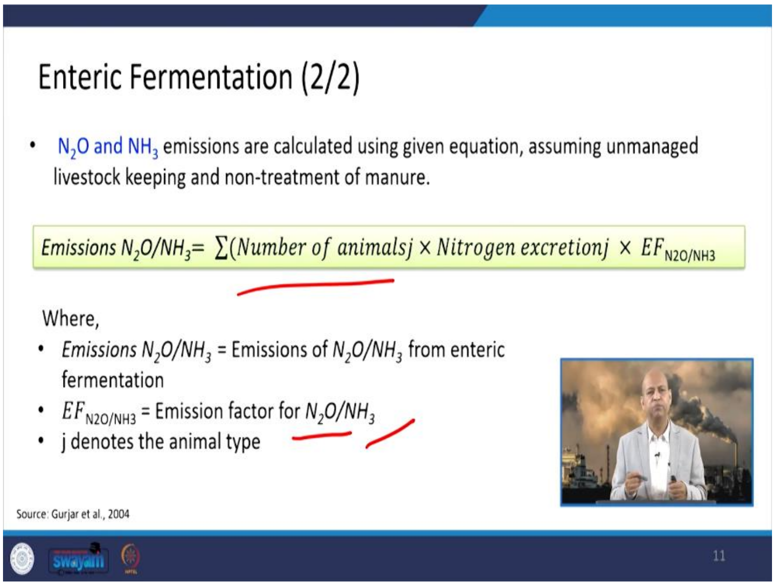

When we talk about like ammonia or nitrous oxide. So, those emissions again number of animals play role, because for per animal we have this emission factor like for N_2 or ammonia. So, that emission factor will be there and then we can multiply it with the number of animals and this j is the type of animal.

So, for each type of animal we have to calculate then again, we have to combine to get the total amount of N_2 or ammonia emissions.

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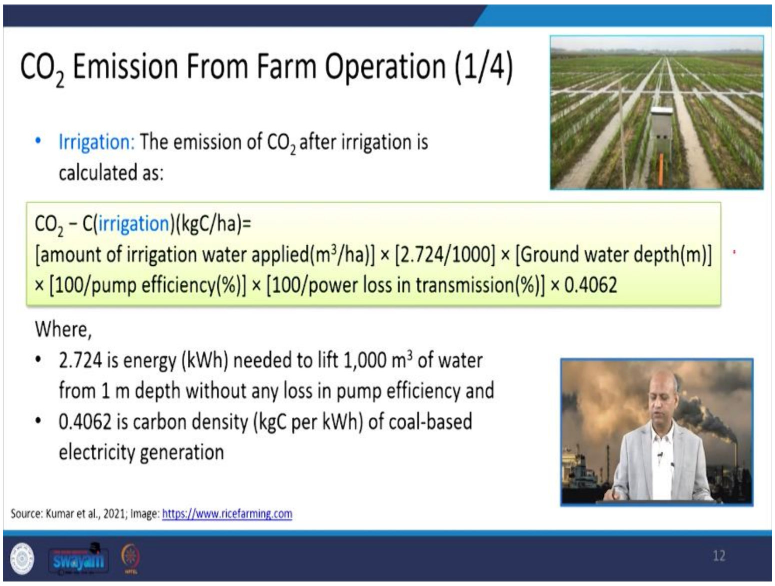

When we talk about CO_2 emissions from farm operations, so basically like if we know how much irrigation water has been applied in that much area of the field or agriculture field in that particular state or district and if we know that the electricity, which is being used for running the pump is from coal-based power plants, then this equation can be used for estimating CO_2 emissions related to that irrigation activity basically.

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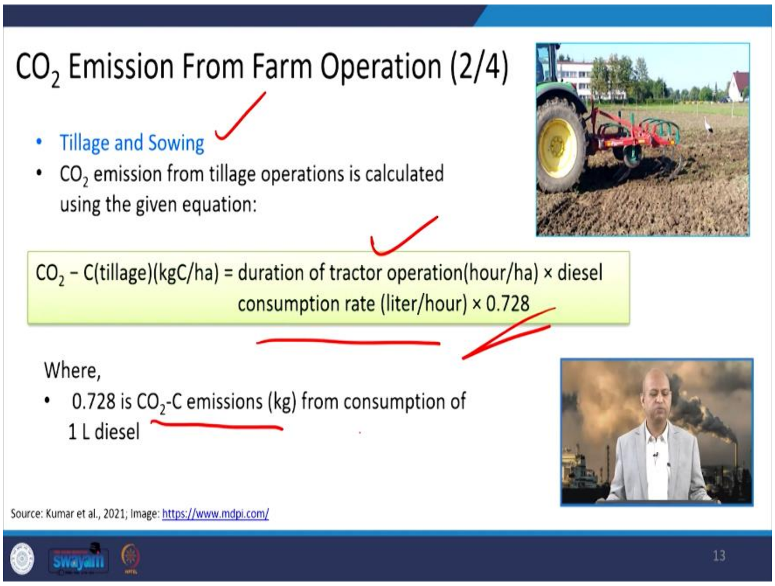

But if it is being irrigated by let us say from canal etc, then this equation will not be applicable. Then we talk about like this tillage and sowing kind of activities, when we use tractors, so again the duration of the tractor operation, because duration will determine, how much fuel is being burned and the diesel consumption rate liter per hour.

So, we can multiply that how much total diesel was consumed, and this is the one factor which can be known as CO_2 carbon emissions from consumption of 1 liter of the diesel. So, there are certain empirical relationships are there which can help us to estimate the emissions of different greenhouse gases.

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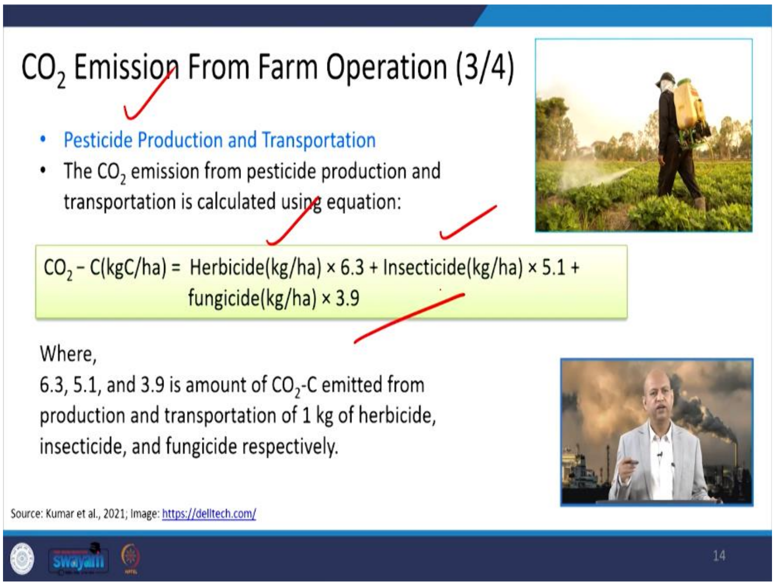

And now, if we talk about pesticide production and transportation, then again there are equations, so relationships so herbicide no application, insecticide application in how much amount of per hectare it is being applied and then again, you can use those values in this equation and you can calculate the equivalent of CO_2 carbon emitted by these activities.

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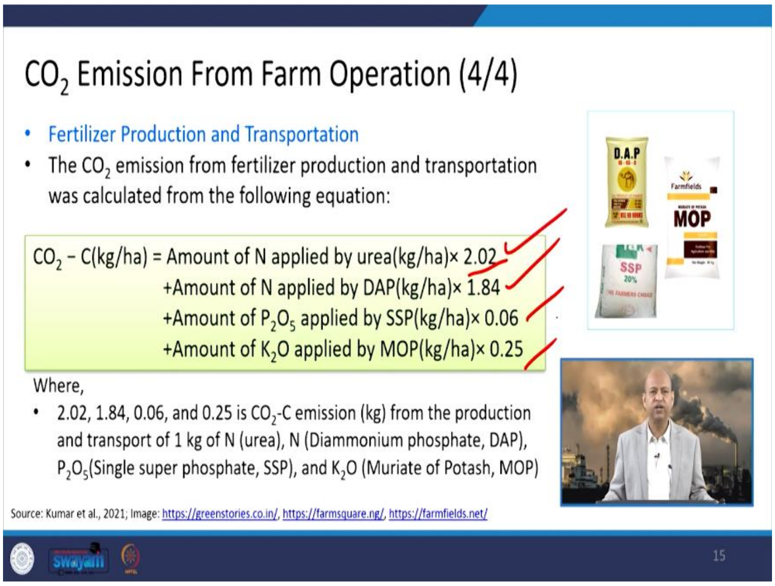

When we talk about fertilizer production and transportation, similar way like how much urea is being used, how much DAP is being used per hectare, and there are some emission factors. So, you can use those multiplication of those factors and you can calculate the CO_2 equivalent emitted by this application of different fertilizers.

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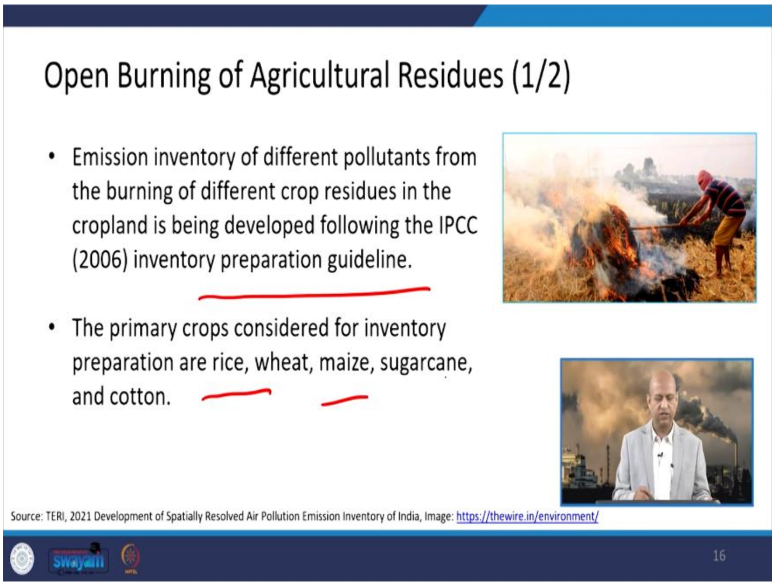

And now, if you talk about open burning agriculture residue, which is a big issue as you know in this time of winter when I am recording this lecture, the gravity of the situation is much more, because in northern India, this a lot of pollution plumes are there and they are related with not only local emissions, but also transportation of emissions from nearby areas like Haryana, Punjab, different kinds of agricultural residues are burned and particulate matters go by convection into the atmosphere and then they go by advection to downwind directions and they also add up into the poor air quality of that particular location or city.

Well, so, emissions from these agriculture residue burning is estimated by simple equations or relationships which has been developed and forwarded or recommended by IPCC, Inventory Preparation Guidelines are there. So, accordingly for different crops like rice, wheat, maize, sugar cane and cotton. So, different residues are having different kinds of emission factors and they are used for estimation.

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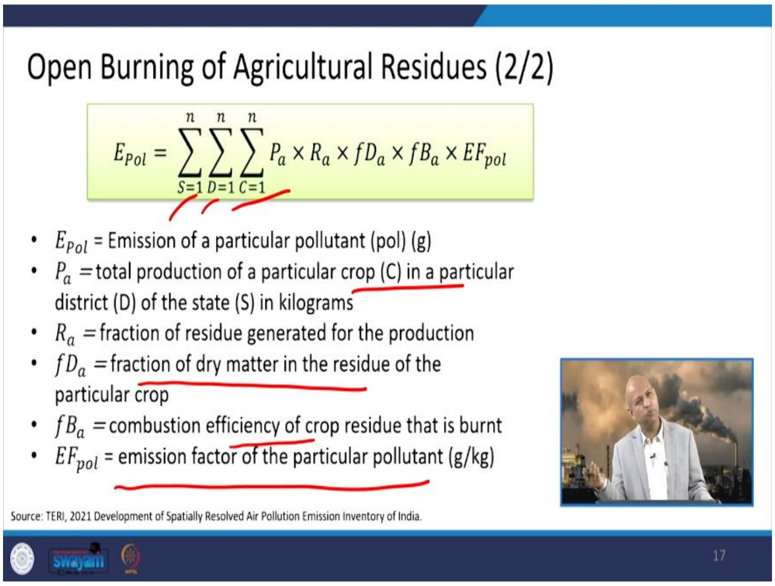

Like you can see here. So, crop type and then how much district type and then the state. So, these emissions for a particular pollutant you can calculate and then you can again you can integrate or combine all those emissions from different crops, like for each crop, there is emission factor which can be used this fraction of dry matter in the residue, because only the dry matter is burnt only means there may be other uses also, it is not that 100 percent of that residual material is burned. So, how much that residual material is being burned?

So, that is to be taken that amount and combustion efficiency is also a factor, then emission factor of a particular pollutant from that residual burning is there. So, all these are multiplied then we get the emission of that particular pollutant from that particular crop residue then for different crop residue, we repeat this and then we add up and calculate the total emissions.

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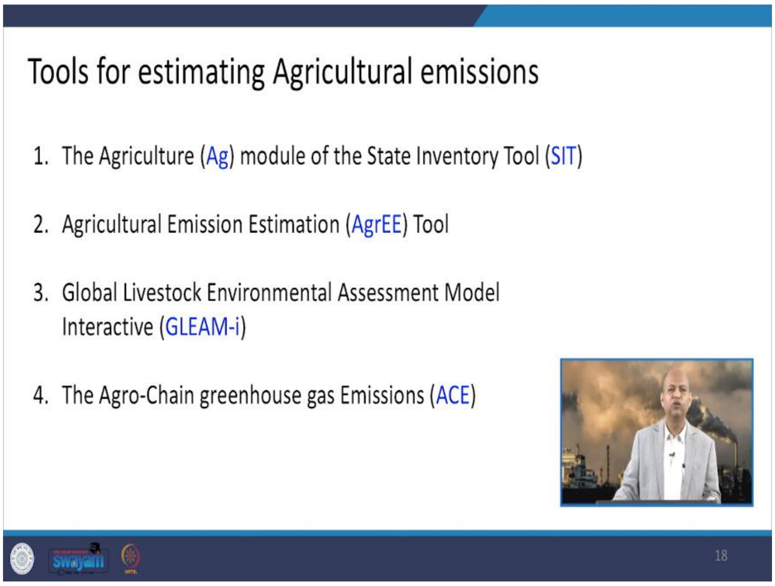

Now, we come to this, there are different tools or software, which have been like a spreadsheet related software or other programming language related software, which have been developed by different countries according to their needs and they are now much popular to fulfil their needs for estimating of emissions of greenhouse gases or pollutants in respective countries.

And these four major tools we are going to discuss like one is the agriculture module of the State Inventory Tool that is known as SIT and Agriculture Emission Estimation AgrEE tool. Then another is Global Livestock Environmental Assessment Model Interactive GLEAM-i, and the Agro-Chain Greenhouse Gas Emissions ACE. So, these are the four tools which we are going to discuss.

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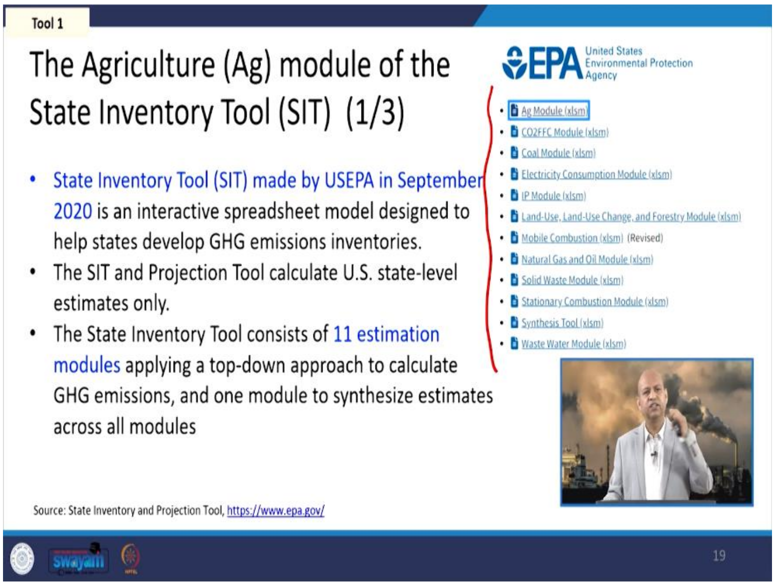

Well, the agriculture module this Ag module of the state inventory tool, it is shown here different modules are there basically, this has been developed by the United States Environmental Protection Agency in 2020. And this is interactive spreadsheet model. So, that is simple, it can be user friendly also, it is designed to help states develop greenhouse gas emissions inventories.

And this SIT and the production tool can calculate US state level estimates only, not for other countries basically, it is focused for the US states and the state inventory tool, which consists of 11 estimation modules you can see here and one is this synthesize module, which can estimate across all the modules, because the synthesizing is also needed for the total estimation of emissions.

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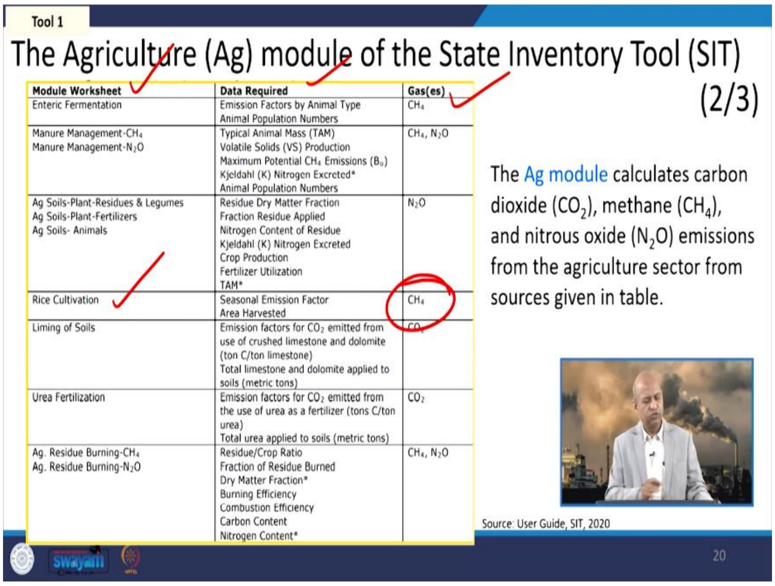

So, these are the module-related worksheets and the data required for using that worksheet is given here and what kind of gaseous or pollutants of greenhouse gases will be estimated by that particular module are given here. So, you can go through like rice cultivation, one module worksheet will be there. So, this is the data required is seasonal emission factor, area harvested and the emission of the methane will be calculated by this particular module. So, different modules are there, different data requirement is there and the gas emissions accordingly estimated.

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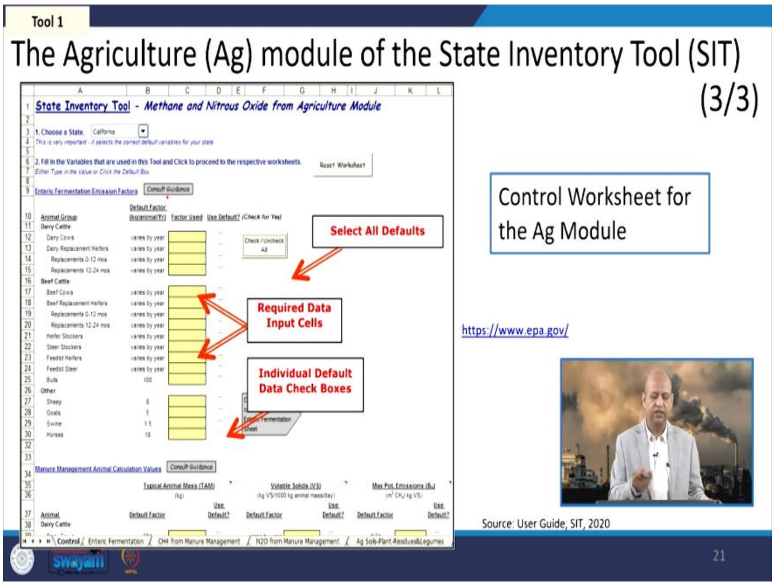

Well, this is basically the control worksheet for this Ag module, you can see here. So, some default values are there like required data input values you can select from here. So, this can have different categories basically and then default values may be there you can also put your own specific values and then calculation can be done very easily.

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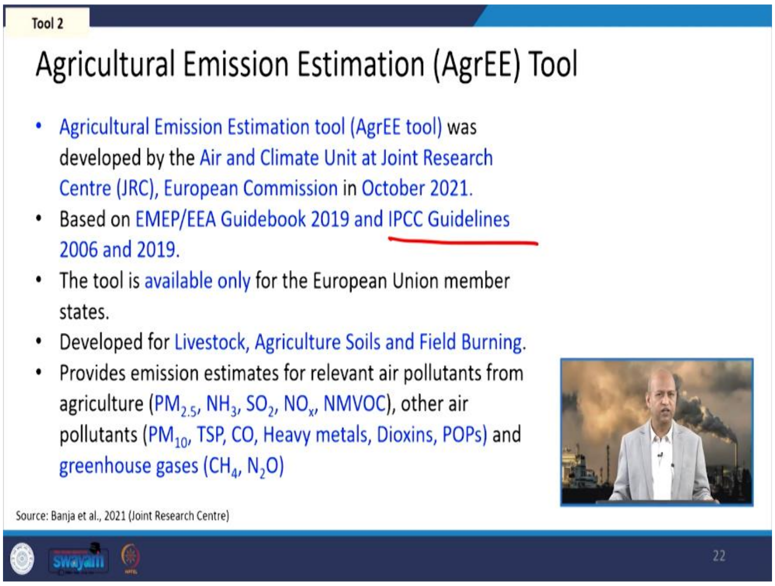

Well, when we talk about next tool, tool number 2, this is agriculture emission estimation, AgrEE tool. So, for example, this is available for European Union member states only. So, that Ag tool was for this SIT tool was for United States and this AgrEE tool is for European Union and this was developed by European Commission in October 2021 very recently, basically.

And this is basically based on old guidelines or guidebook up to 2019 and IPCC guidelines of 2006 and 2019. So, on the basis of that, this little more comprehensive tool has been developed by this climate unit at Joint Research Centre, JRC of European Commission.

Well this is developed for livestock activities, agricultural soils, field burning and this can estimate a number of pollutants like particulate matter, fine particulate matter $PM_{2.5}$, ammonia or sulphur dioxide or oxides of nitrogen, non-methyl VOC and then PM_{10}, TSP, carbon monoxide, heavy metals, dioxins, POPs, persistent organic pollutants, those are greenhouse gases like methane, nitrous oxide all those pollutants and greenhouse gases can be estimated. So, that way this is very versatile tool basically.

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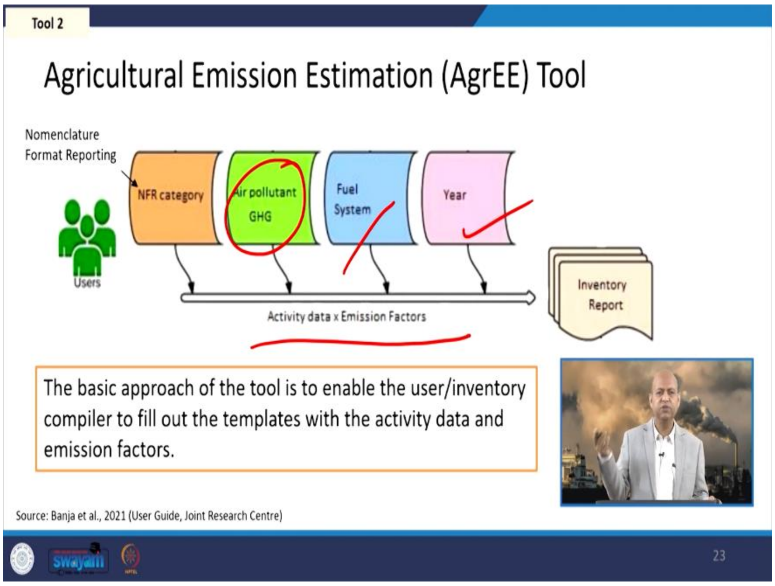

Now, you can see what is the way of estimating like there are certain categories, which you have to take care, then air pollutant or greenhouse gas, you want to estimate you have to select which fuel system you want to go for, then year which year you want to consider. So, activity data and emission factor basically, that is the fundamental thing for every kind of emission inventory you must remember, activity data and emission factor. So, those are the things which we really focus in all kinds of emission inventory development.

So, that you have to need to know and then inventory report is generated, because you put those activity data and emission factors, then this tool can calculate emissions of those particular pollutants and greenhouse gases.

So, the basic approach of this tool is basically to enable the user or inventory compiler to fill out the templates with the activity data and emission factors and after that, you run it and the emission, total emissions or depending upon what kind of result you want in which form like emission per activity or emission, total emission or emission per year something like that you can play with and you can get the results.

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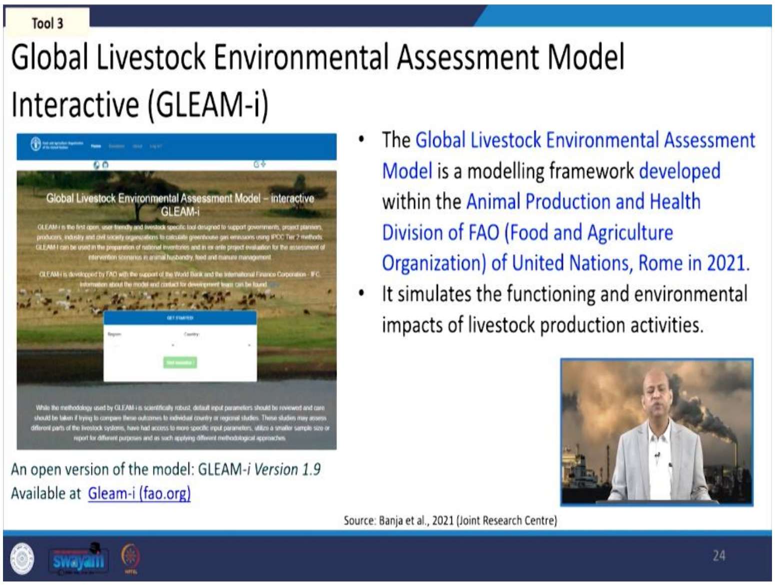

Now, we come to the tool number 3. So, this is global livestock environmental assessment model interactive, GLEAM-i and basically this has been developed by this Animal Production and Health Division of FAO, FAO is nothing but Food and Agriculture Organization of United Nations. So, in Rome, the headquarter, where in 2021, it has been developed and it simulates the functioning of environmental impacts of livestock production activities. So, that way it is very important.

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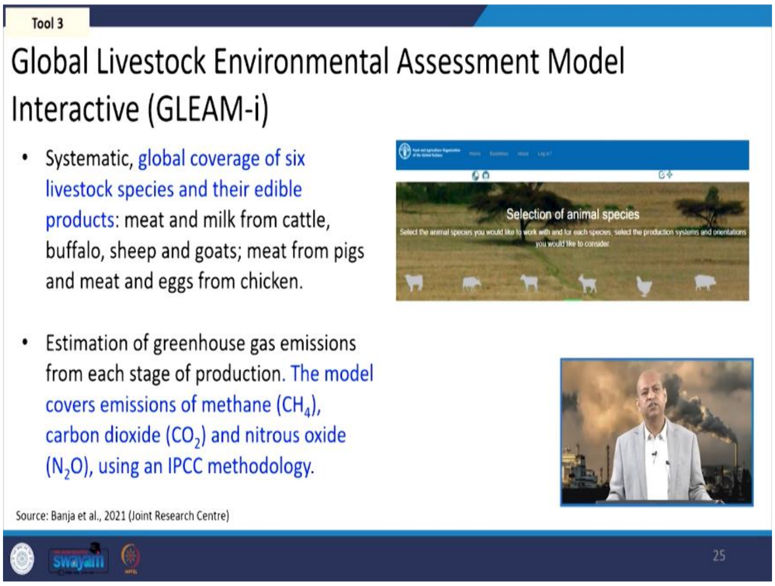

And you can see the systematic global coverage of the six livestock species is possible by using this particular model. So, like meat and milk from cattle, buffalo, sheep, goats, meat from pigs and meat and eggs from chicken, all those activities can be incorporated in this particular model or module.

Estimation of greenhouse gas emissions like methane, CO_2, N_2 etc. using IPCC methodology is the part of this particular model.

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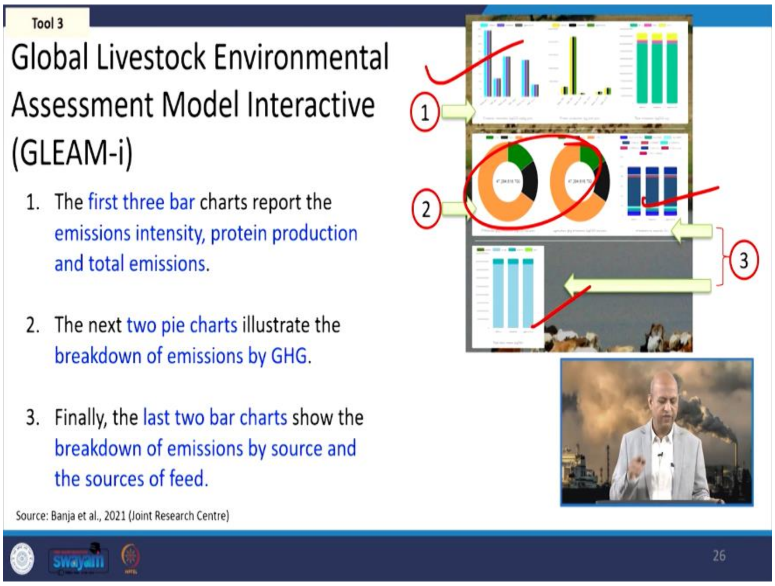

Well like you can see this working of this the first bar this these kind of three bar charts, report emission inventory and protein production and total emissions. And in second, the next two pie charts, they illustrate the breakdown of emissions by greenhouse gas. Then finally, you can see these two bar diagrams they show the breakdown of emissions by source and sources of the feed. So, different way of results you can calculate per field, per cattle.

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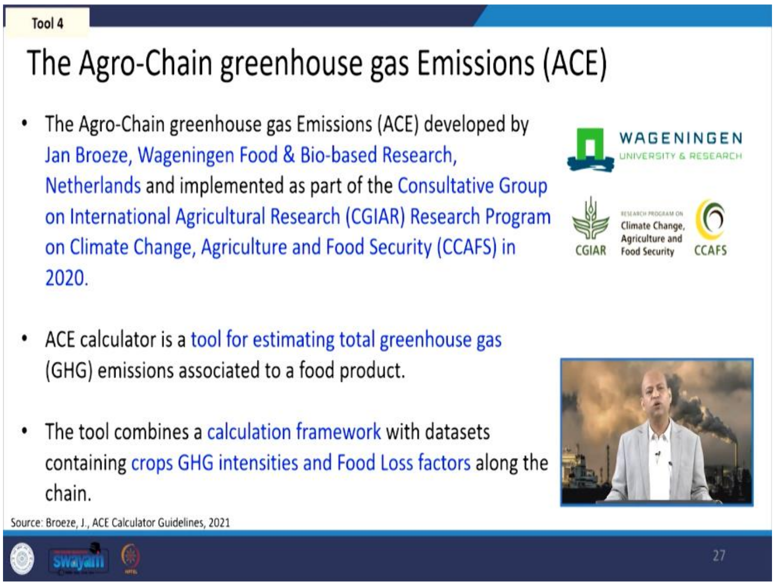

The fourth model is the agro-chain greenhouse gas emission, ACE and this has been developed by Jan Broeze by this particular institute in the Netherlands and it has been implemented as a part of this Cumulative Group on International Agriculture Research (CGIAR) research program on Climate Change, Agriculture And Food Security (CCAFS) in 2020. So, this has been the part of that particular program, this model development. And this calculator or module or model is a basically tool for estimating total greenhouse gas emissions associated to a food product.

So, this is specifically for food product and the tool which combines the calculation framework with data sets containing crop greenhouse gas intensities and food loss factors along the chain.

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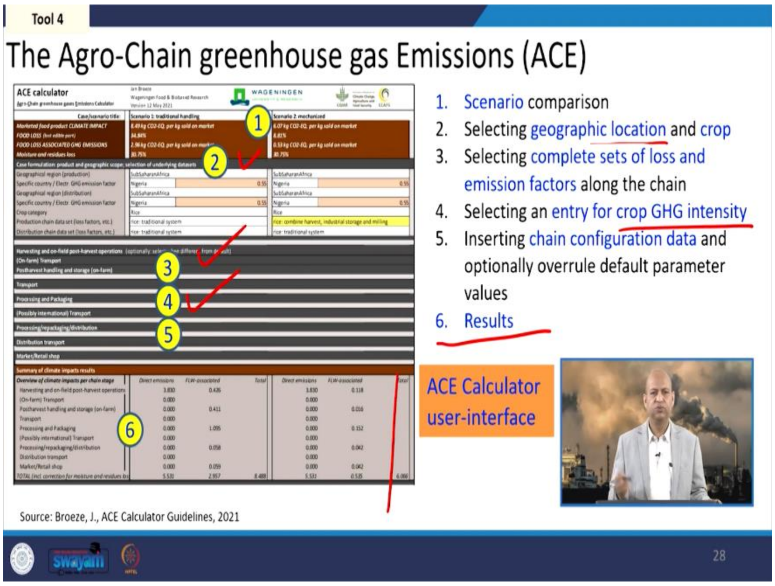

So, you can see this is the of course, this is very complex thing only in one picture, we are trying to give you the impression. So, there is a scenario comparison you can do basically different kinds of scenarios you can develop. Then in second step is like selecting geographical location and the crop. So, this is the basic second step, which can be used. Then you can go for complete sets of loss and emission factors along the chain, the third step.

Then selecting an entry for the crop greenhouse gas intensity, so that is the fourth step. In fifth you do like inserting chain configuration data and optionally overrule default parameter values. So, manually you can do that. And ultimately, you can get the results and results are in this form that is quite exhaustive and you can then take observation, you can analyze them you can present in different forms, so that you can have different inferences.

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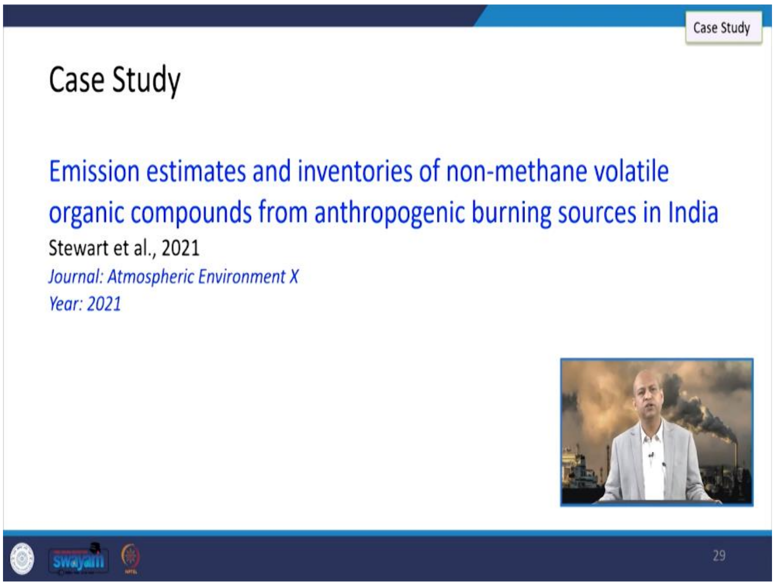

Now, we go for a case study, like how emission estimates and inventories of non-methane volatile organic compounds from anthropogenic burning sources in India has been developed. This is the latest study, which has been completed as a Indo-UK collaboration program.

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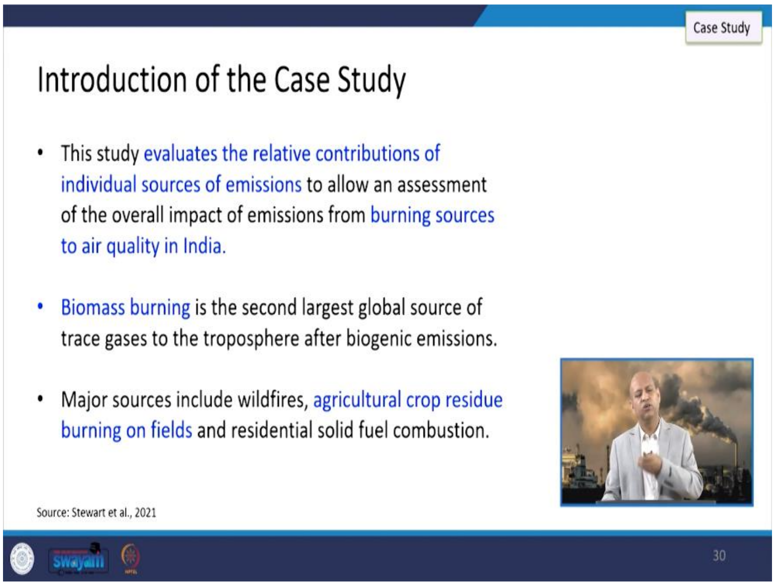

Well, so, a brief introduction about the case study is that this study evaluated the relative contribution of individual sources of emissions to allow an assessment of the overall impact of emissions from burning sources to air quality in India. So, that burning sources overall we have to see and within that biomass burning is the second largest global source of trace gases to the troposphere after biogenic emissions. So, that is why this is very important activity and major sources include like, wildfires or agricultural crop residue, burning on fields, residual solid fuel combustion or municipal solid waste kind of thing those kinds of things are there.

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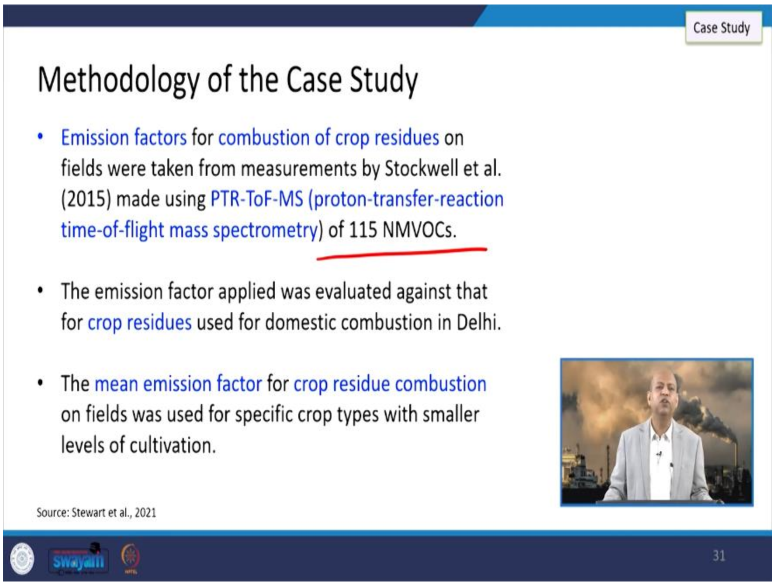

Well the methodology, which we are having in this particular case study is emission factors based emission factors for combustion of crop residues, different coppers residues, we have different emission factors and we use them on fields have been used and then measurements for this using particular, this proton transfer reaction time of flight mass spectrometry. So, this instrumentation has been used 115 non-methane VOCs. So, that is quite interesting to see what kind of species are there off and then VOCs or non-methane VOCs.

And the emission factor applied was evaluated against that for crop residues used for domestic combustion in Delhi. So, we could compare basically. Then the mean emission factor for crop residue combustion on fields was used for specific crop types with the smaller levels of cultivation. So, that these are the methodological important aspects basically.

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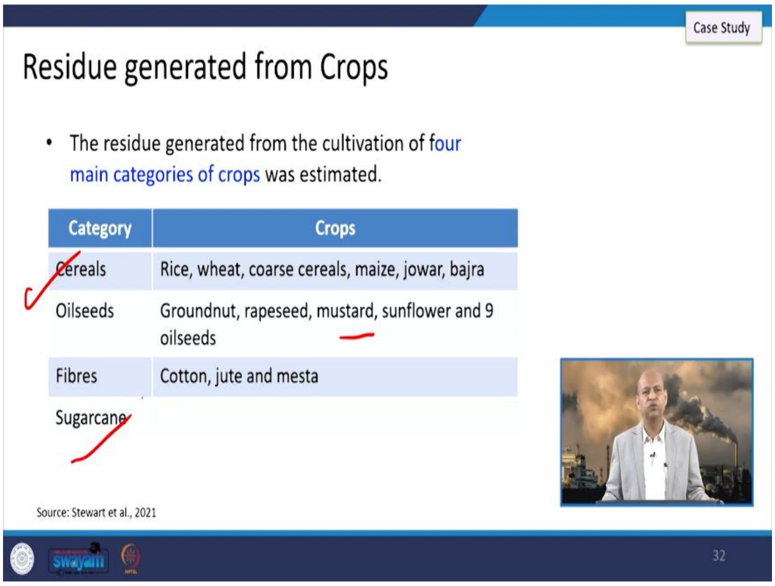

When we talk about residue generated from crops, the residue is generated from the cultivation of four main categories of the crops like cereals, like rice, wheat, maize, jawar, bajra etc. Oil seeds like ground nut or rapeseed or mustard sunflower etc. Then fibres like cotton jute and then the sugarcane, these kind of four crops related residues have been considered.

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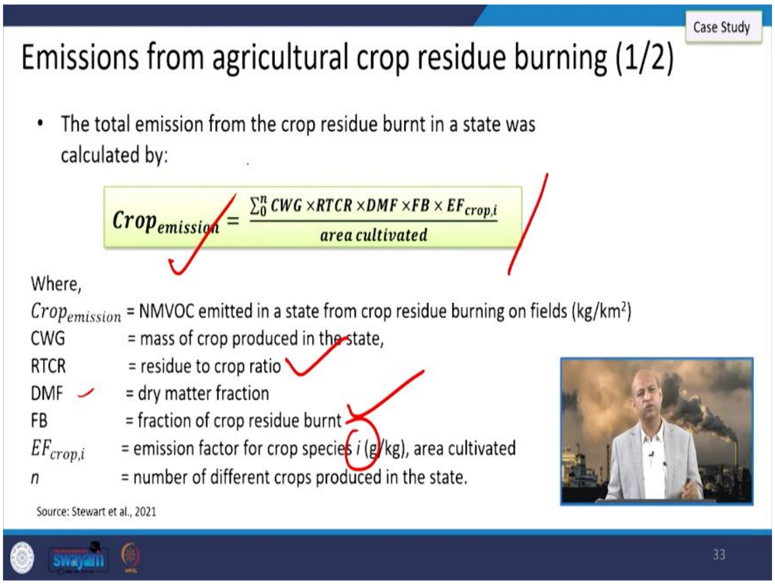

And this is basic equation, which have been used very simple. So, you can see here CWG is nothing but mass of crop produced in the state. Then RTCR residue to crop ratio, so that you can calculate the how much residue will be there, then dry matter fraction DMF is there, because all residue is not burnt only dry is being burned. Then fraction of the crop residue burned, because other things can be used for other portion can be used for other activities. Then emission factor for the crop species like wheat or rice are different crop species.

$$Crop_{emission} = \frac{\sum_0^n CWG \times RTCR \times DMF \times FB \times EF_{crop,i}}{area\ cultivated}$$

So, you can apply this equation per area cultivated and you can have the emission of that particular crop and then again summation you do for all kinds of crops.

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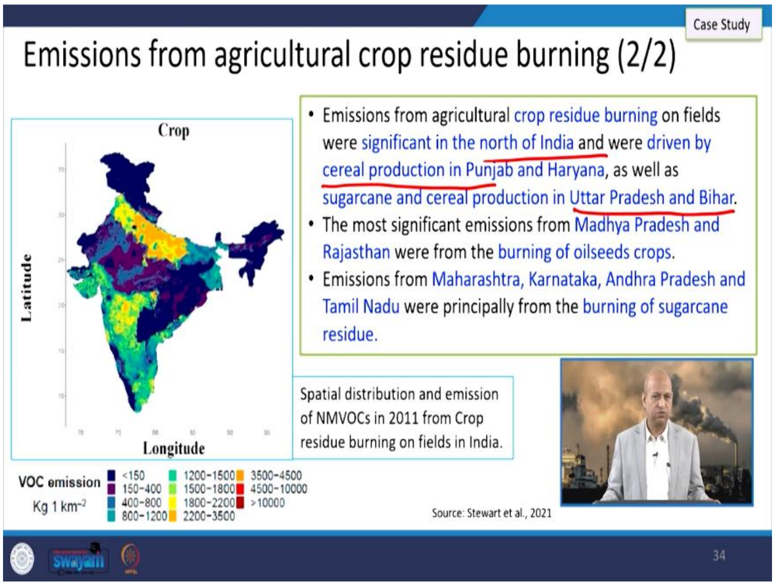

So, if you see entire India, you can see the emissions from agriculture crop residue burning on fields were significant in the northern part of India. So, these were like cereal production related estate like Punjab and Haryana and the sugarcane and cereal production in Uttar Pradesh and Bihar.

So, those have been considered and the most significant emissions from Madhya Pradesh and Rajasthan were from the burning of oil seed related crops like mustard or other kind of thing. Emissions from Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu were primarily from the burning of sugarcane related residues. So, these are area-related specific characteristics.

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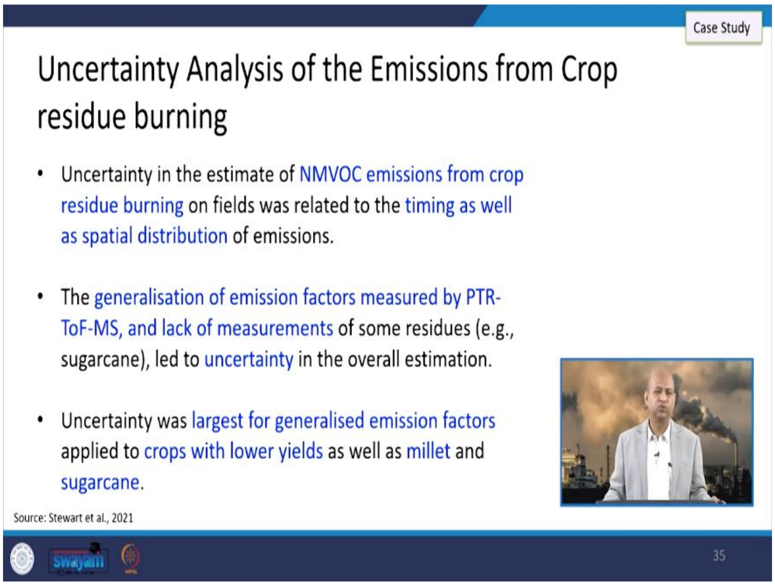

Well, there are certain uncertainties, because NMVOCs, which are emissions from different crop residue burning on fields, they are related to timing as well as a spatial distribution of emissions. So, uncertainties can be there as per their particular location, particular timing. And the generalization of emission factors measured by that particular instrument and the lack of measurements of some residues for example, sugarcane led to uncertainty overall estimation.

So, everything is not absolute this is kind of indicative you can say. Then there is uncertainty largest for generalized the emission factors applied to crops with lower yields as well as millet and sugarcane. So, those are the uncertainties in this particular case study.

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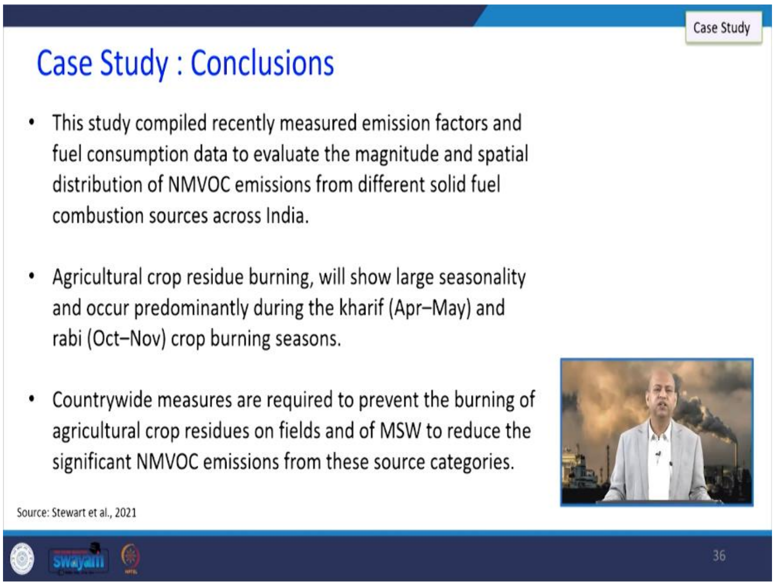

And if we go for conclusions of this case study. So, they are like the compilation has been there for recently measured emission factors and fuel consumption data to evaluate the magnitude and spatial distribution of known methane VOC emissions from different solid fuel combustion and sources across the India as we have seen different estates related activities.

And the agricultural crop residue burning, it will show larger seasonal and it occur predominantly during the kharif, that is the April-May season and the Rabi crops like October to November crop burning season, so different two seasons are there. And because October-November, this Rabi season is related to winter and this atmospheric dispersion is not very high in this particular duration. So, if a lot of burning activities are there, then within surrounding areas, pollution related problems may arise.

Then the country wise measures are required to prevent the burning of agriculture crop residues on fields and municipal solid waste to reduce, the significance of non-methane VOCs emissions from these particular source categories. That is the conclusion you can say with the help of this study.

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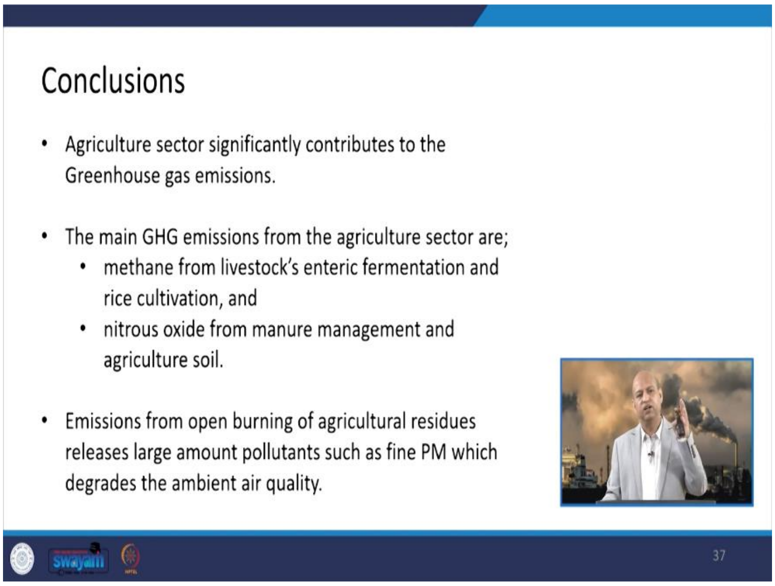

So, ultimately if we want to conclude, we can say that the agriculture sector significantly contribute to the greenhouse gas emissions, although there are other emissions like particulate matters and ammonia, nitrous oxide and methane are the greenhouse gases, but other pollutants are also there. And these greenhouse gases emissions are basically from these livestock's enteric fermentation and rice cultivation related activities and nitrous oxide is predominantly from manure management and agricultural soils.

And emissions from open burning of agriculture residues, releases large amount of pollutants such as fine particulate matter and that can degrade the ambient air quality, which every year we see particularly in northern part of India. So, that we means you can now appreciate agriculture related emissions are also very important, if we consider them how much they contribute to the greenhouse gas or how much they contribute to the regional air quality status. So, that is all for today. Thank you for your kind attention.

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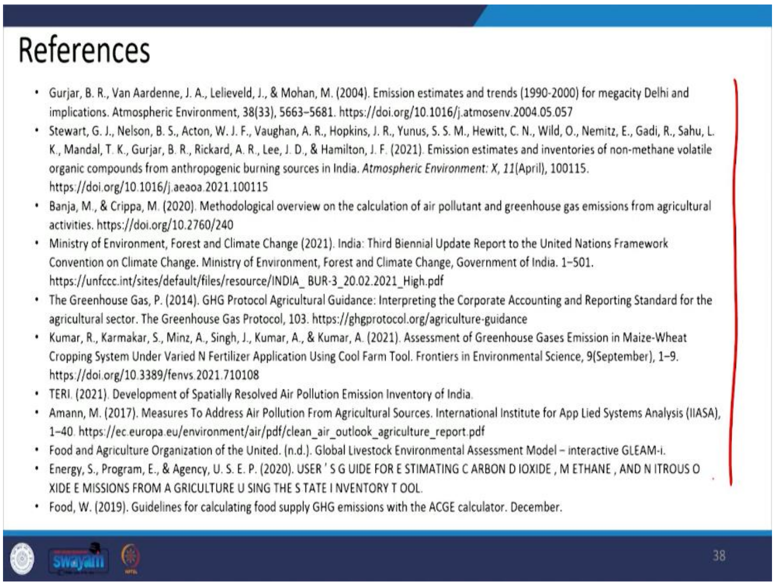

These are the references for your additional information, you can go through them. So, thank you again and see you in the next lecture. Thanks a lot.