The Monsoon and Its Variability
Prof. Sulochana Gadgil
Centre for Atmospheric & Oceanic Sciences
Indian Institute of Science - Bangalore

Lecture - 37
Monsoon Variability and Agriculture - Part 3

Today we are going to continue our discussion on monsoon variability and agriculture.

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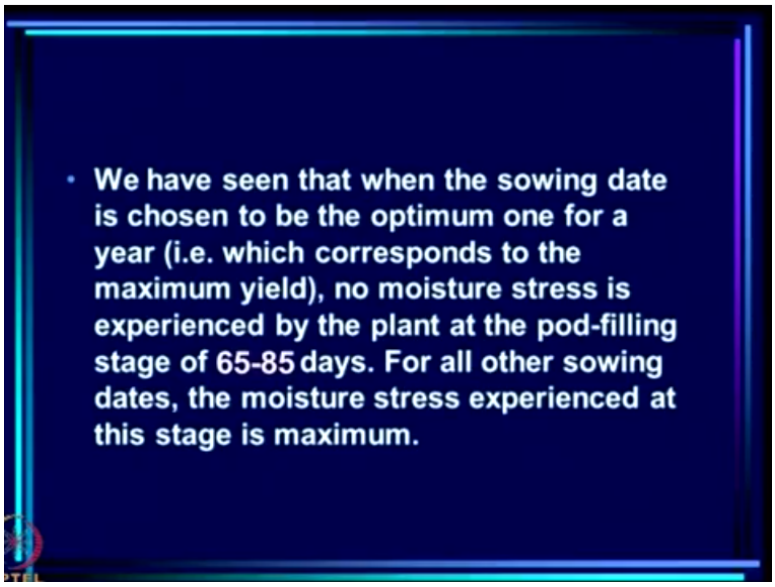

Last time, we have seen that when the sowing date is chosen to be the optimum one for a year, which corresponds to the maximum yield, no moisture stress is experienced by the plant at the pod-filling stage of 60 to 80 days after sowing.

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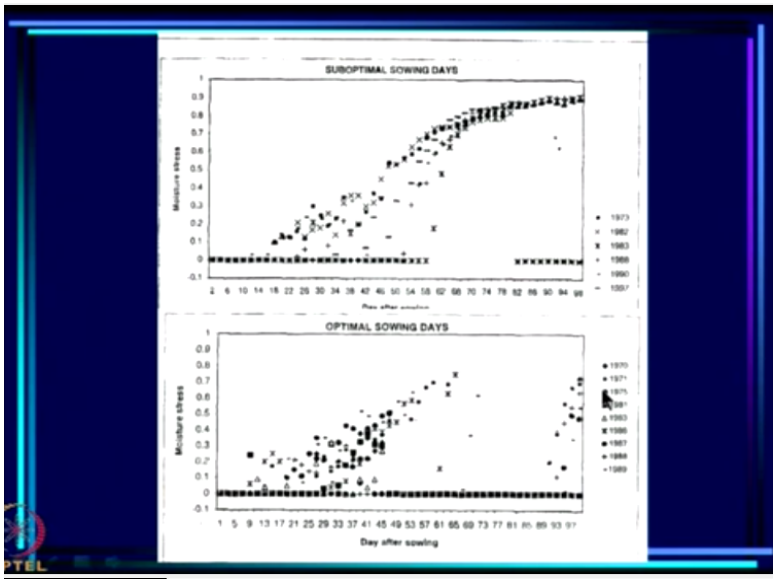

So for all the other sowing dates, the moisture stress in fact is maximum at that point. So these are the other dates suboptimal sowing that is when the moisture stress is maximum between 60 and 80 whereas here for the optimal sowing dates in fact the moisture stress is not at all there in this critical pod-filling stage.

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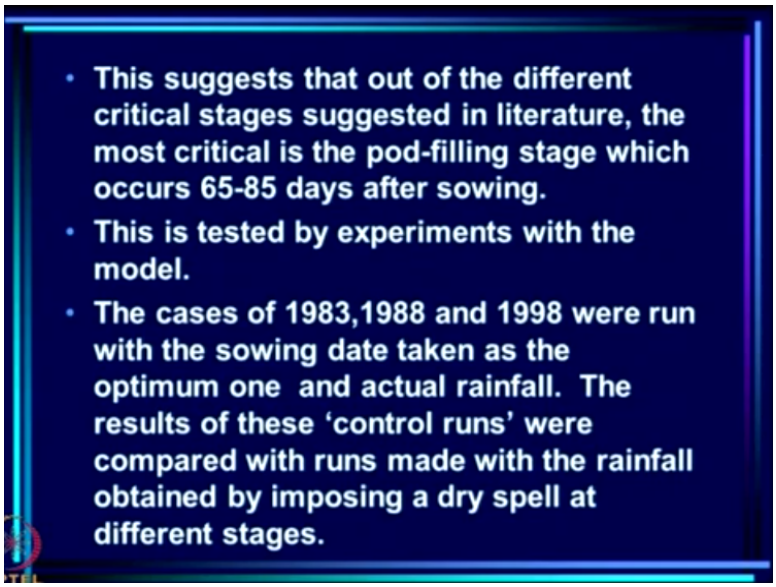

So this suggest that out of the different critical stages suggested in literature, the most critical is the pod-filling stage, which occurs about 60 to 80 or 65 to 85 days after sowing. Now this is tested by experiments with the model. See this is a result that we got that it appears that pod-filling stage is the most critical. So then we tested it with the PNUTGRO model. What we did was we run 3 years, 83, 88 and 98 okay.

And firstly we run them with the sowing date taken as the optimum one and the actual rainfall that occurred in those years. These were so called control runs. Now in addition to the control runs, we made runs by suppressing rain at different stages that is to say imposing dry spells at different stages.

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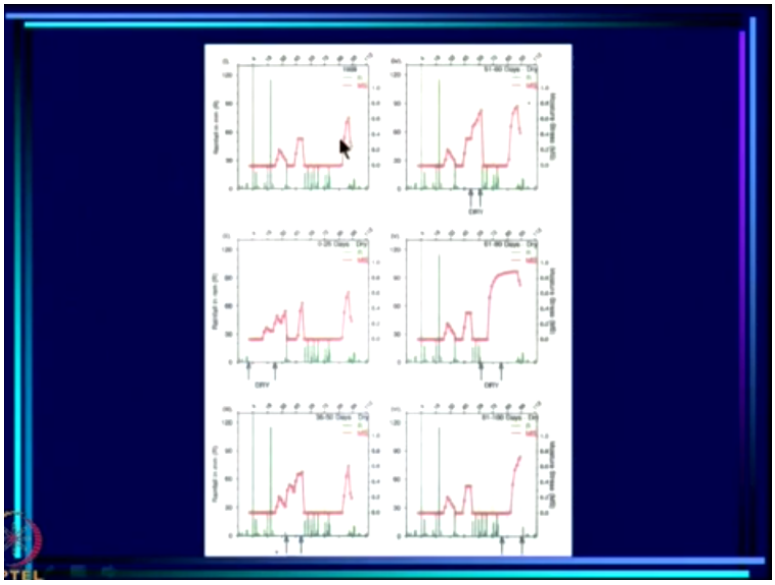

So you see here this is the control run for 1998 and see in this case there is a dry spell imposed in the first month after sowing. In this case, the dry spell is imposed at this stage, in this one it is imposed at this stage, in this one at this stage and in this one at the pod-filling stage. So we introduced dry spells at different stages and then asked the question that would of course no mean that the same amount of rain is suppressed.

Because as you can see the rain varies from day to day, so when you suppress this much more suppression occurs when you suppress this first part here. Then for example when you suppress this part because here not too much rain occurred and so on and so forth.

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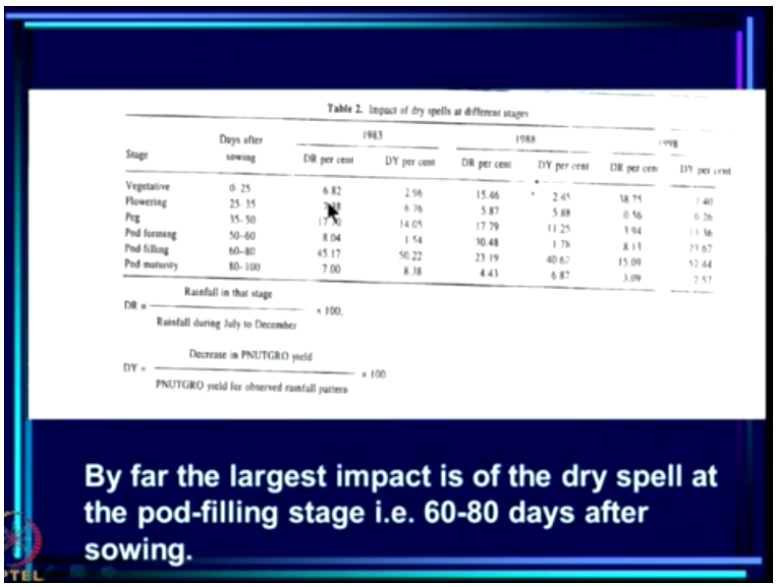

Now what are the results then? So at different stages, vegetative stage which is up to 25 days after sowing, flowering stage which is 25 to 35 then the peg formation stage 35 to 50, then

pod forming stage is 50 to 60, pod-filling is 60 to 80 and pod maturity is 80 to 100. So these are the main life-history stages of the plant phenological stages of the plant and by suppressing rain during these different stages how much of a difference did it make to the total rainfall?

So DR is the rainfall in that stage/rainfall during July to December*100. So what was the fraction of the total rain that occurred in that stage which we suppressed? So in 83 for example in vegetative stage, 6.8 or 7% got suppressed, same thing for flowering, but next stage more got suppressed 17% and pod-filling in 83 45% got suppressed okay and similarly here.

And remember that they are in fact optimum sowing date against, which we are looking at things okay. Now similarly in 88 also we see. In fact, in 88 it is the pod forming stage that had maximum suppression of rain and so on. Now we also calculate what is the difference in the yield produced by this dry spell? Because we know from the control run what the yield would have been with the actual rain.

Now we have suppressed part of the rain so what has been in the impact on the yield? That is the question you ask and for example for 98, which is the figure you saw, 7.4% yield got suppressed when it was in the first month, the dry spell was imposed. When it was imposed during flowering, it was very little suppression, then peg formation 13%, then 23% got suppressed when you had the pod formation.

But the maximum suppression in yield, which is 57% occurs when we impose a dry spell at pod-filling stage, which is 60 to 80 days. Remember we have already identified that as a critical stage. So we saw with the rainfall that we got suppressed, which was only 15%, 57% was the impact on the yield. Similarly, here also the rainfall suppression is only 23 and in fact rainfall suppression at the pod forming stage was 30%.

And the impact on yield was only 1%, but here the rainfall suppressed was 23% and impact of the yield is 40%. Similarly, here the impact on the yield is 50%, but there actually a lot of rain did occur in that stage, which got suppressed, 45% was the change in rain, but in any event for these 3 years what do we see? That amongst all the stages of the plant the impact of a dry spell is much larger than any other stage for the pod-filling stage of 60 to 80.

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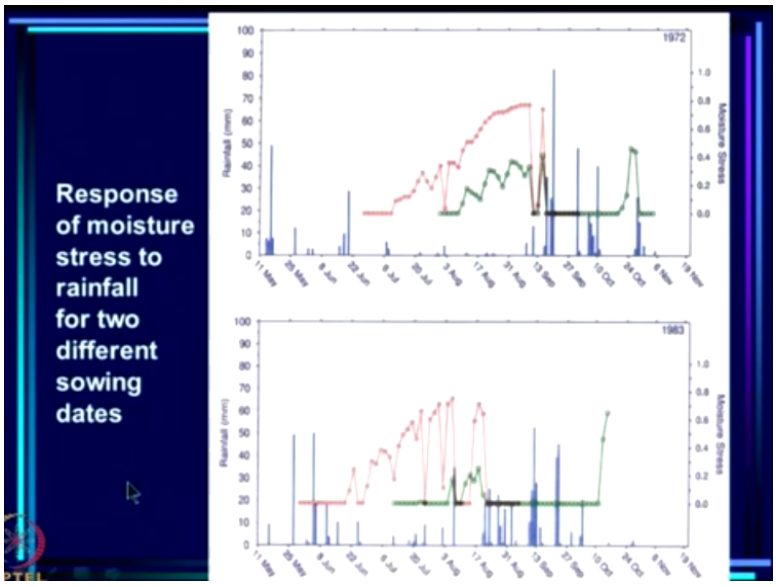

So by far the largest impact is of the dry spell at the pod-filling stage 60 to 80 days after sowing. Now in fact this is a picture again to make the case that when you sow makes a difference to what sort of moisture stress the plant will actually have and this is the case of 72 and when you have late sowing there is not much moisture stress here, but when you have early sowing huge moisture stress at the pod-filling stage.

Same thing here in 83, early sowing would have led to this kind of thing whereas optimum sowing leads to no stress at the critical pod-filling stage.

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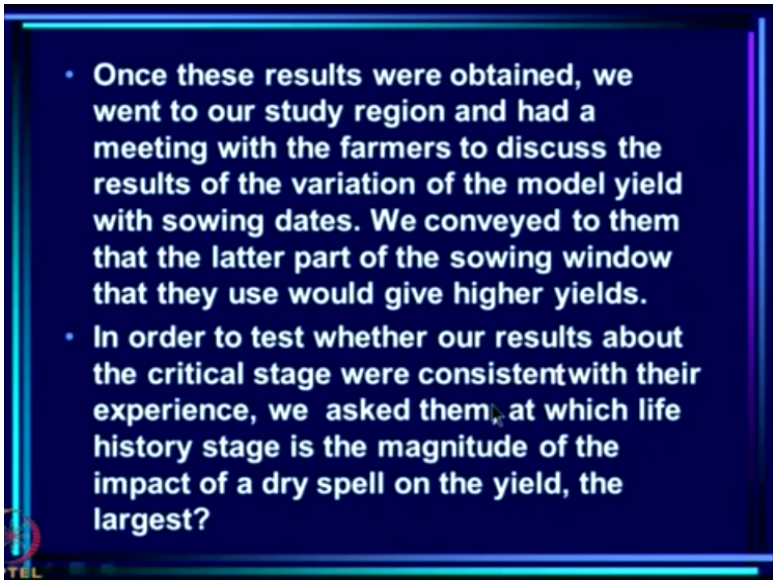

So once these results were obtained and I must say that these are not results that we expected because when we looked at the literature, there were separate papers saying every stage is

critical. Some would say the first month is very important, we should not get dry spell and so on and so forth. So we had no idea when we did this work that this pod-filling stage would be the most critical.

But once we found it out through the model then the question was to see if this was consistent with the experience of the farmers. So what were the results we wanted to convey to them? A, that the broad sowing window that they choose 22nd June to middle of August is very reasonable for avoiding crop failure, but within that sowing window if they could postpone the sowing to mid-July and after that they would get even higher yields.

This was the result from the model that we wanted to tell them and we told them this result and they were of course surprised because they did not quite expect it. See right now, they always sow at the first opportunity in Punarvasu, which is to say early July. That is what they prefer and we were trying to say that do not sow at the first opportunity, wait for a sowing opportunity a little later in the month in the next nakshatra.

And they were little skeptical about it. In any event, we thought let us also check with them about our result about which stage of the crop is more sensitive. So in order to test whether our results over the critical stage were consistent with their experience, we asked them at which life-history stage is the magnitude of the impact of a dry spell on the yield the largest?

So we are asking the same question that we ask the model and we wanted them to tell us on the basis of their experience. Which is the most critical stage where if a dry spell occurs you would get a huge loss in the yield?

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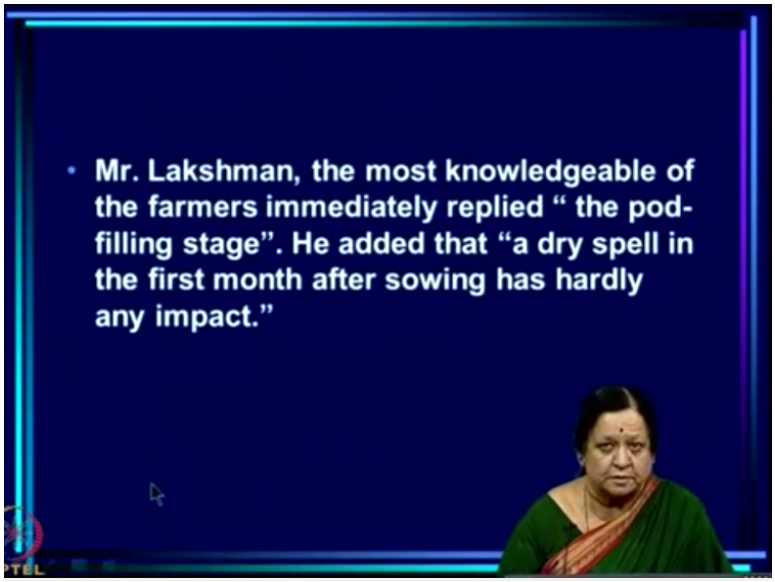

Now Mr. Lakshman whom I have introduced to you in the last lecture who is by far the most knowledgeable of the farmers that we had immediately replied pod-filling stage. He also added that a dry spell in the first month after sowing has hardly any impact.

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This again is totally consistent with our result; this is Lakshman again. So he is in fact the one who introduced TMV-2 this region the variety TMV-2 which everybody is growing and he is a very careful observer and he actually supported the result we had that pod-filling is the most critical stage.

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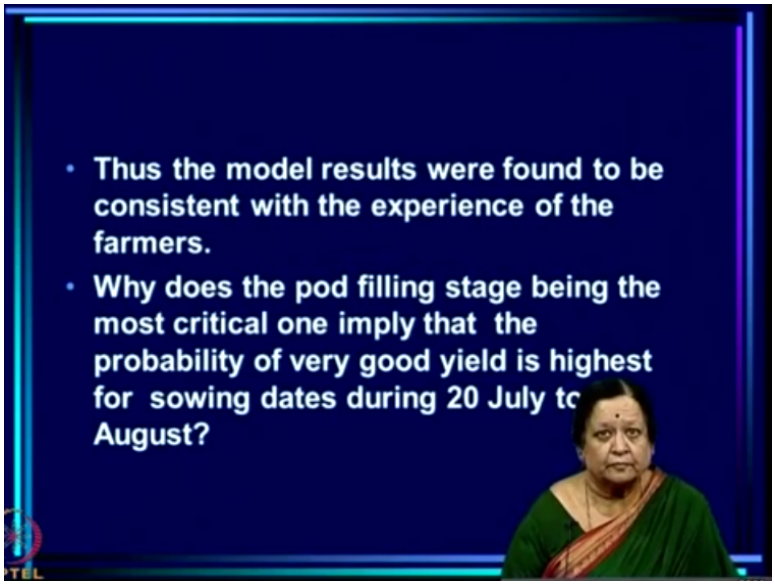

So the modeled results were found to be consistent with the experience of the farmers. Now the question is why does the pod-filling stage being the most critical one imply that probability of very good yield is highest for sowing during 20th July to 9th August. See we have to understand this. We have 2 results, 1 is that we get very high probability of good yields when the sowing date is between 20th July to 9th August.

And 2nd is pod-filling stage is most critical. Now is there a connection between the 2?

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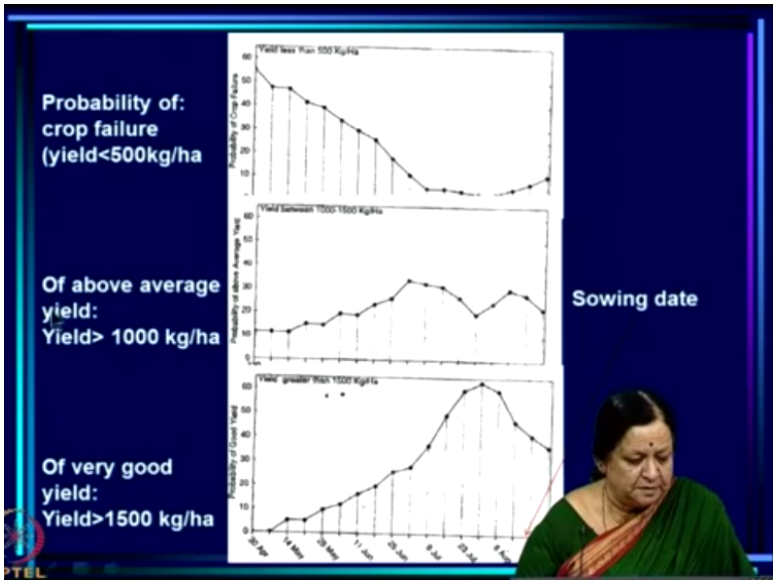

And let us just see here. These are the probabilities you know of crop failure. This is of reasonable yield that is more than 1000 and this is of more than 1500 and you see that right from 20th July onwards here onwards you get very good chance of getting very good yield, it is over 60% and already the chance of getting reasonable yield is 20, this means 80% chance

is there that you will make profit in this if you sow at this time if you get an opportunity to sow at that time.

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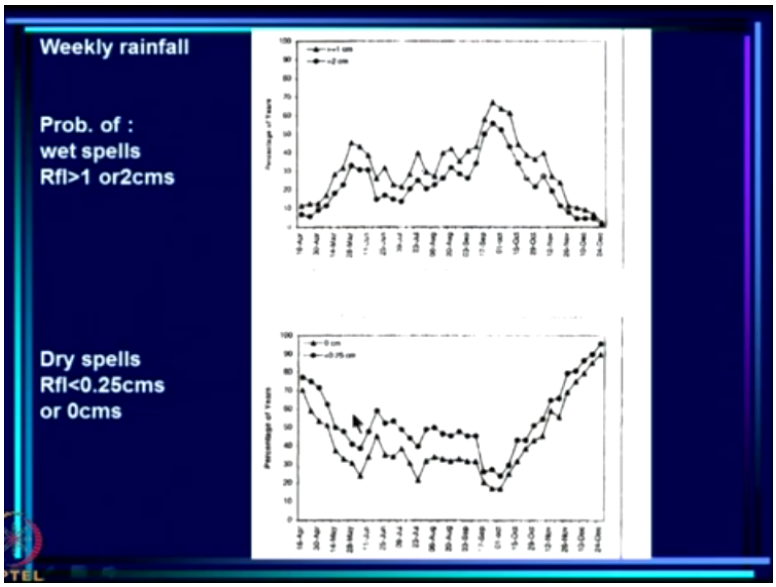

Now you remember these are the probabilities based on weekly rainfall. This is 88 years of data at Anantapur and on the basis of that we have derived what is the chance of rain > 2 centimeters or 1 centimeter in the week. This is wet spell likelihood and what is the chance of rain < 0.25 centimeters or 0. So this is the chance of 0 so this is the probability of a wet week, this is the probability of a dry week and what do we find?

We find that from around 20th September or so till early August is a huge peak in wet spells, which coincides with the huge trough in the dry spells. So probability of wet spells is maximum around here and probability of dry spells is minimum around here. So in some sense in terms of rainfall, this is the most favorable period for plants.

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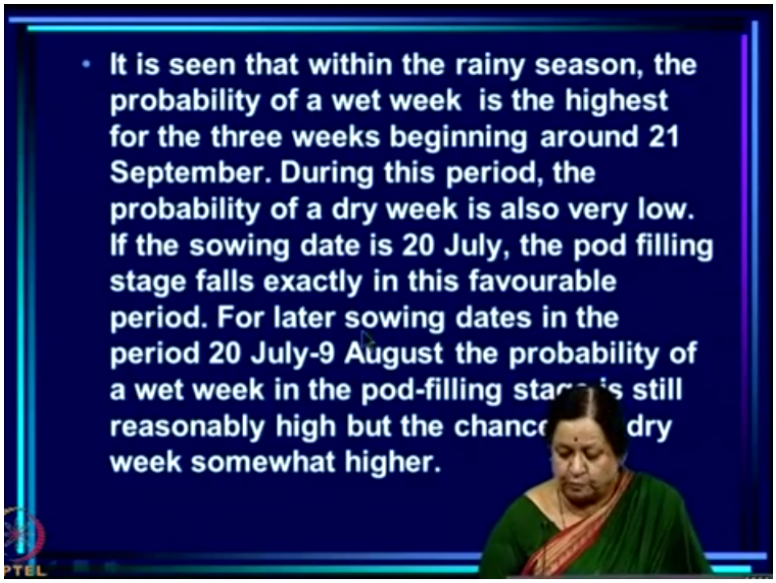

So it is seen that within rainy season the probability of a wet week is the highest for the 3 weeks beginning around 21st September. During this period, the probability of dry week is also very low. So if the sowing date is 20th of July, the pod-filling stage falls exactly in this favorable period 20th September onwards for 20 days so 20th September to 10th October.

So in fact if the sowing is done on 20th July, the pod-filling stage falls exactly in this favorable period. For later sowing days in the period 20th July to 9th August also, the probability of a wet week in the pod-filling stage is still reasonably high, but chance of a dry week somewhat higher. This is why for later dates you do not get as favorable as it is around 20th July.

So we had found that this is a good period 20th July and the few days beyond that for sowing that is when the yields are maximum. We also found independently that the most sensitive stage is the pod-filling stage and now we see that in fact the optimum sowing date is such that the most sensitive stage pod-filling stage occurs at a period when the probability of a wet week highest and probability of a dry week is lowest that is to say it is most favorable.

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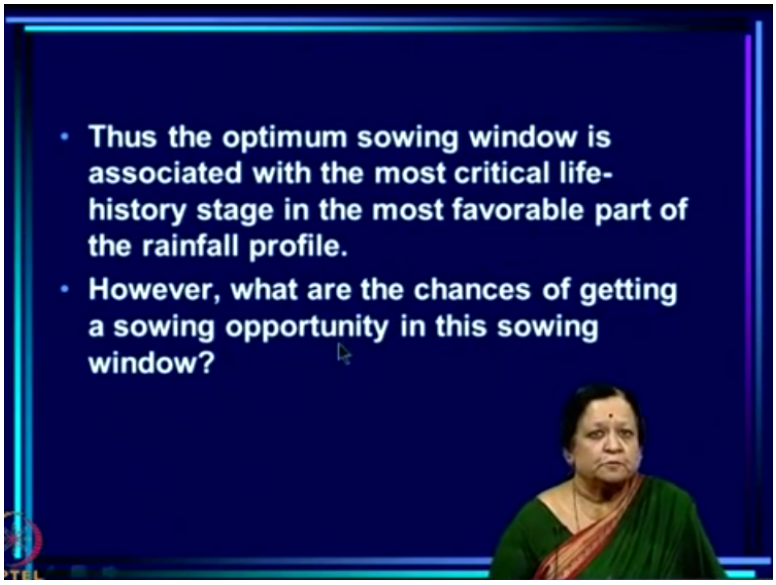

Thus the optimum sowing window is associated with the most critical life-history stage in the most favorable part of the rainfall profile okay. So this is what everything is now tying together nicely, we have found the optimum sowing window, we have also shown that pod-filling is the most critical stage and we have seen why the sowing window is optimum because if sown at that time, then the critical stage falls in the most favorable part of the rainfall profile of that region.

So now the question is the following that farmers look for opportunities to sow right from last week of June and they generally like to sow in Punarvasu, which begins around 6th to 20th July that is to say 15 days before or optimum. Now we tell them, no, no, no if you were only to wait for 2 more weeks, chance of you getting high yields is much higher okay.

Then they ask the question, suppose we give up a sowing opportunity earlier in July, what guarantee is there that we will get another opportunity in later July? This is a very, very valid question.

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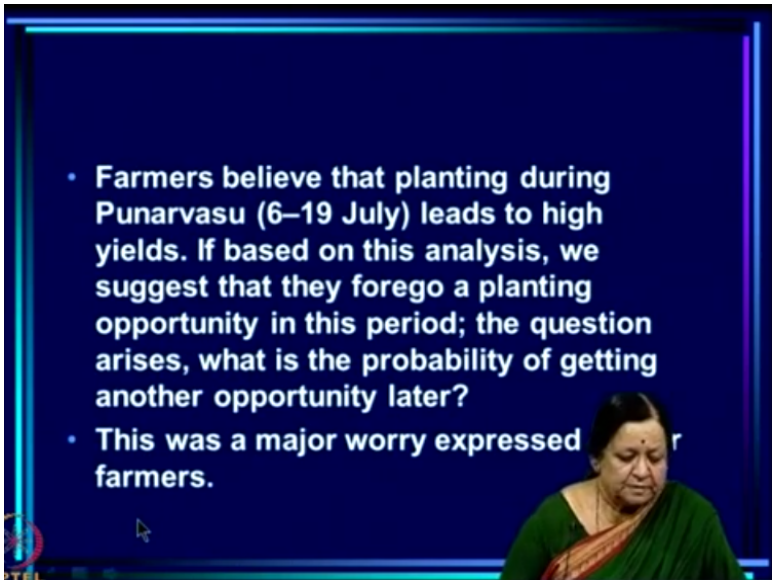

See farmers believe that planting during Punarvasu, which is 6 to 19 July leads to high yields if based on this analysis we suggest that they forgo a planting opportunity in this period. They do not sow although the sowing rains have occurred and the soil is moist enough. Then we said, no, no, do not sow at that time, just wait for the next nakshatra, which is Pushya and that begins on 20th July.

Then they ask the question what is the probability of getting another opportunity later because this is the major worry expressed by the farmers that based on your analysis if we forgo an earlier opportunity you know in early part of July and wait for an opportunity in latter part of July or early August and it does not arise then we will have lost the whole crop trying to get maximum yield.

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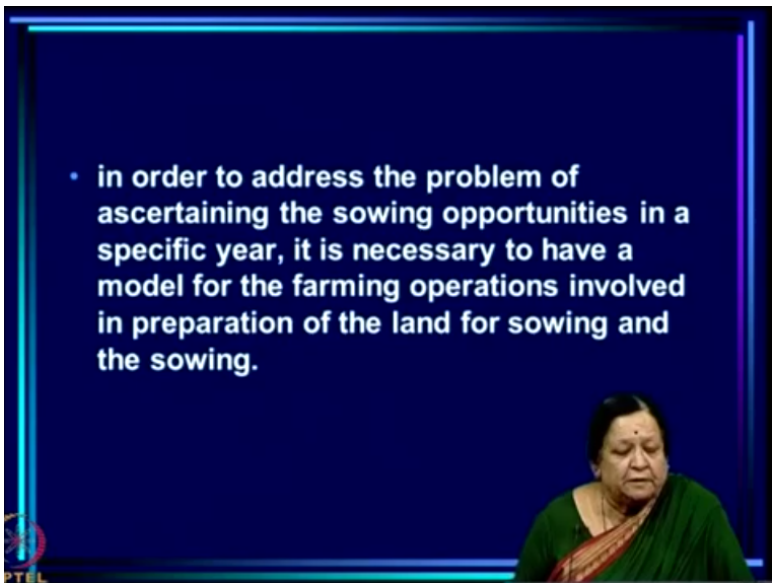

See this is not a risk that they would like to take. So in order to address the problem of ascertaining the sowing opportunities in a specific year what do we have to do? As I mentioned before sowing opportunities are decided by the soil moisture, only when the soil has adequate moisture and in fact farmers tested by making a ball of the soil in their hand and see you know if the soil is not wet enough you would not be able to make a good ball.

If you can make a good ball then they say okay the soil is reasonably wet, we can go ahead and so. So the important parameter is soil moisture, only if the soil moisture is adequate can we get sowing date. Now we want to know what are the opportunities for sowing? So what we need is the model for soil moisture because we do not have data on soil moisture like we have on rainfall.

We have data on rainfall, we have some data on meteorological parameters, but we do not have data on soil moisture. If the criteria for when a sowing rain will occur depends on soil moisture, then we have to have a model for this.

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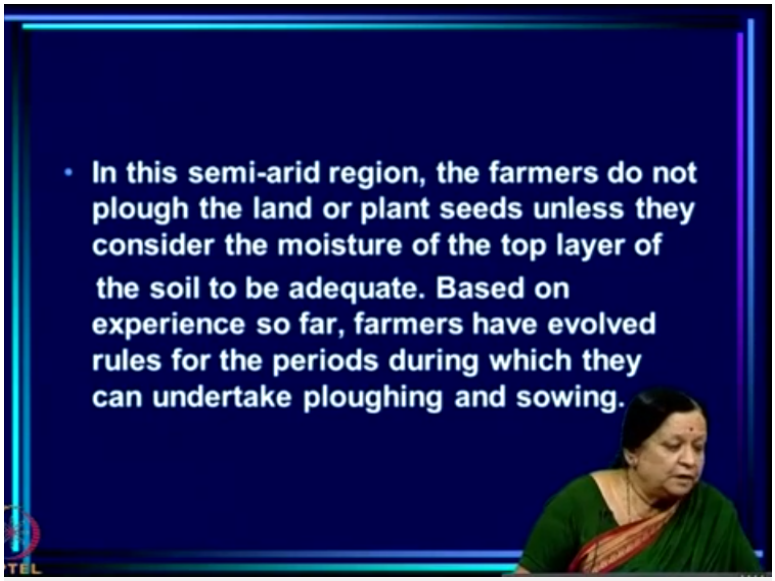

So in this semi-arid region, the farmers do not plough the land or plant seeds unless they consider the moisture of the top layer of the soil to be adequate. Not only has the soil moisture to be adequate for sowing, but before that there are operations, which involve land preparation. They involve ploughing and harrowing so on. Now only for those operations also the soil cannot be dry, it has to be sufficiently moist.

And they know how moist it has to be okay so what we need to do now is to generate a model, which will give us how the soil moisture varies in a year when the rainfall variation is given and given the variation of the soil moisture then determine when the farmer would be able to plough, when he would be able to harrow and when he would be able to sow. All this has to be done if we need to ascertain how many sowing opportunities arise in a year.

So based on the experience so far, farmers have evolved rules for the periods during which they can undertake ploughing and sowing.

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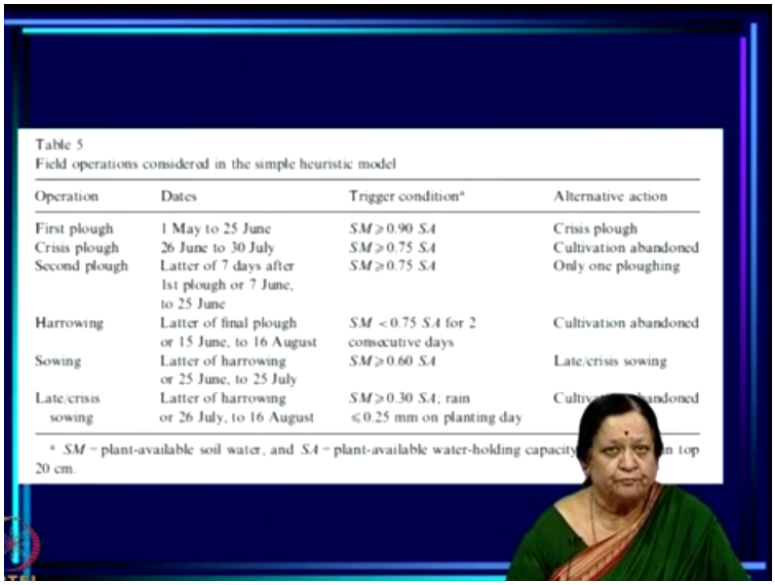
Table 5
Field operations considered in the simple heuristic model

Operation	Dates	Trigger condition[a]	Alternative action
First plough	1 May to 25 June	$SM \geq 0.90\ SA$	Crisis plough
Crisis plough	26 June to 30 July	$SM \geq 0.75\ SA$	Cultivation abandoned
Second plough	Latter of 7 days after 1st plough or 7 June, to 25 June	$SM \geq 0.75\ SA$	Only one ploughing
Harrowing	Latter of final plough or 15 June, to 16 August	$SM < 0.75\ SA$ for 2 consecutive days	Cultivation abandoned
Sowing	Latter of harrowing or 25 June, to 25 July	$SM \geq 0.60\ SA$	Late/crisis sowing
Late/crisis sowing	Latter of harrowing or 26 July, to 16 August	$SM \geq 0.30\ SA$; rain ≤ 0.25 mm on planting day	Cultivation abandoned

[a] SM = plant-available soil water, and SA = plant-available water-holding capacity in top 20 cm.

And these are the rules and SM stands for soil moisture and SA means when it is totally saturated okay and they have several rules that first plough will take place between 1st May and 25th June whenever the soil moisture exceeds 90% of saturation. Crisis plough, if till 25th June no opportunity arises then they will undertake what they call a crisis plough and that will require only 75% of saturation of soil moisture.

You see and if that does not come, then they had no opportunity to plough at all that year so cultivation is abandoned. This is what they do. Then they try second plough that would be latter of 7 days after and so on and so forth.

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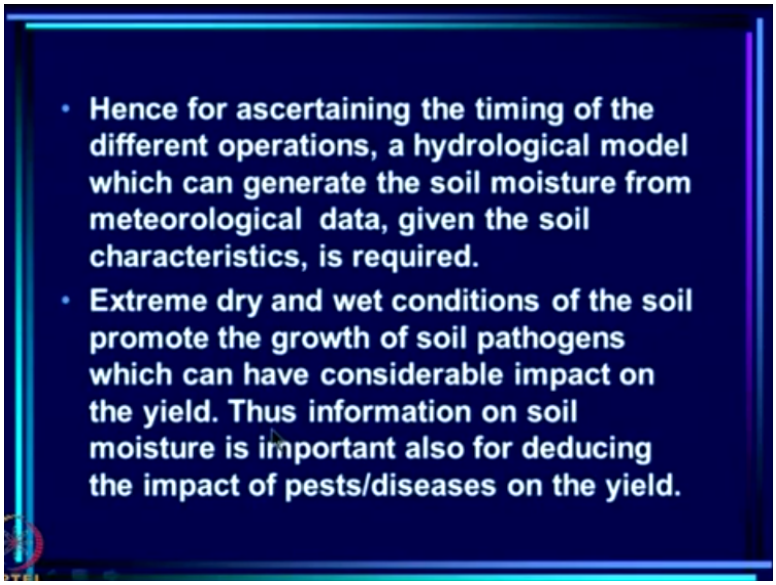

And we will get into details of what they do after we learn about how to get the soil moisture. So hence for ascertaining the timing of the different operations, a hydrological model which can generate the soil moisture from meteorological data given the soil characteristics is required. Now extreme dry and wet conditions of the soil also promote growth of soil pathogens, which can have considerable impact on the yield.

Thus information on soil moisture is important for did using the impact of pests and diseases on the yield. I must also mention that models like PNUTGRO have built in to it soil moisture model. So the growth of the plant in the model also depends on the soil moisture, which the model itself derives okay.

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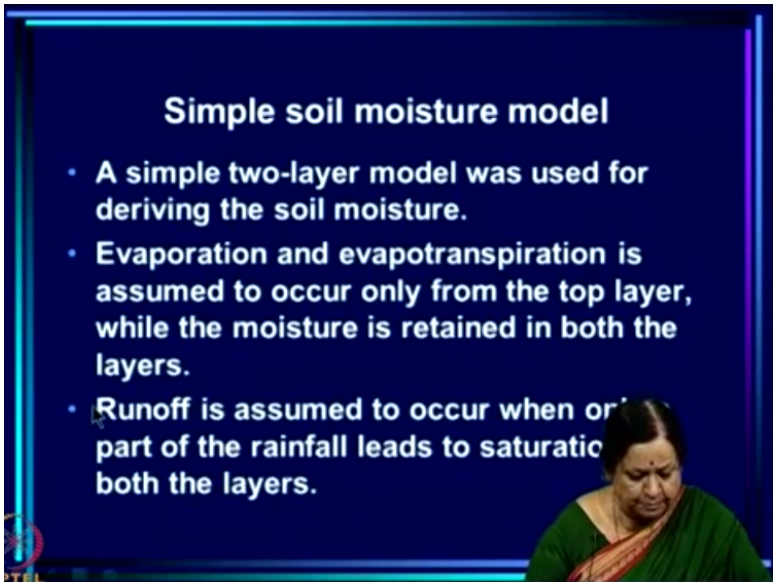

So now we look for a simple soil moisture model. So what we did was to develop a simple 2 layer models for deriving soil moisture okay. Evaporation and evapotranspiration is assumed to occur only from the top layer while moisture is retained in both the layers. Runoff is assumed to occur only when a part of the rainfall leads to saturation of both the layers.

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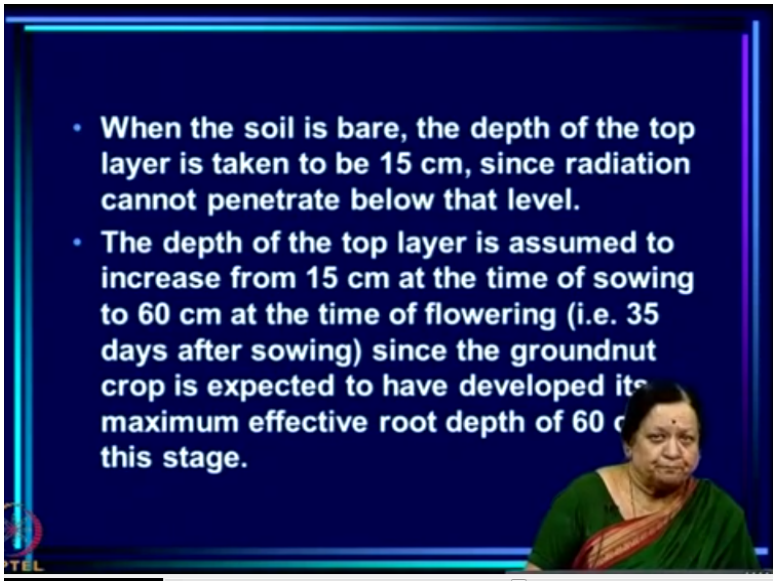

Now how deep are these layers? See when the soil is bare, the depth of the top layer is taken to be 15 centimeter because radiation cannot penetrate below that level. That is the top layer of the soil which gets heated on its own. So that is the layer that is going to take part in interaction with the atmosphere.

This is taken to be 15 centimeter. Now depth of the top layer is assumed to increase from 15 centimeter at the time of sowing to 60 centimeter at the time of flowering, which is 35 days after sowing because the groundnut crop is expected to have developed its maximum effective root depth of 60 centimeter by this stage. So initially the plant is developing its root and it is going deeper and deeper into the soil.

As it is going deeper and deeper into the soil, the soil moisture of the level to which the roots have reached is important, that is what we have to keep a tab on. So what we do is we increase the top layer from 15 centimeters to 60 centimeters as the roots grow.

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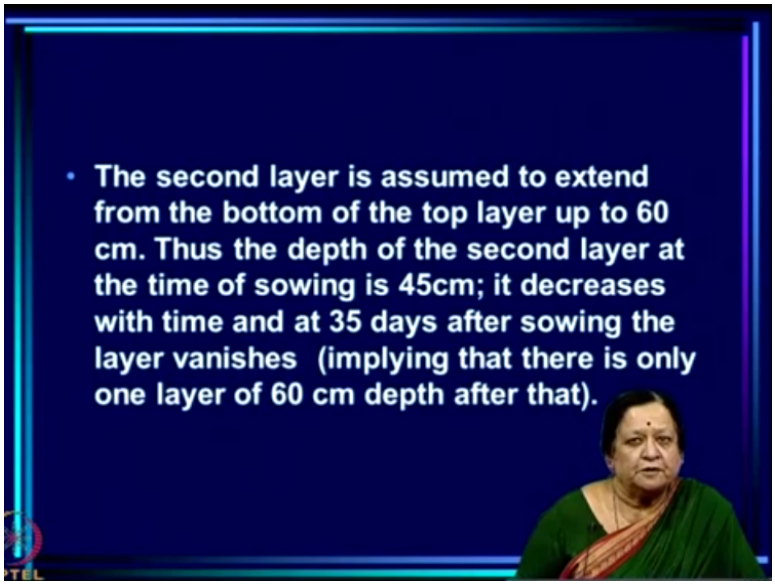

And the second layer is assumed to extent from the bottom of the top layer. Top layer is 15 centimeters to 60 so initially top layer is 15 centimeters, bottom layer is 45 centimeters. Top layer keeps on becoming deeper, bottom layer keeps on becoming shallower, till 35 days after sowing there is no bottom layer left at all, it is just 1 layer which is 60 centimeter deep okay.

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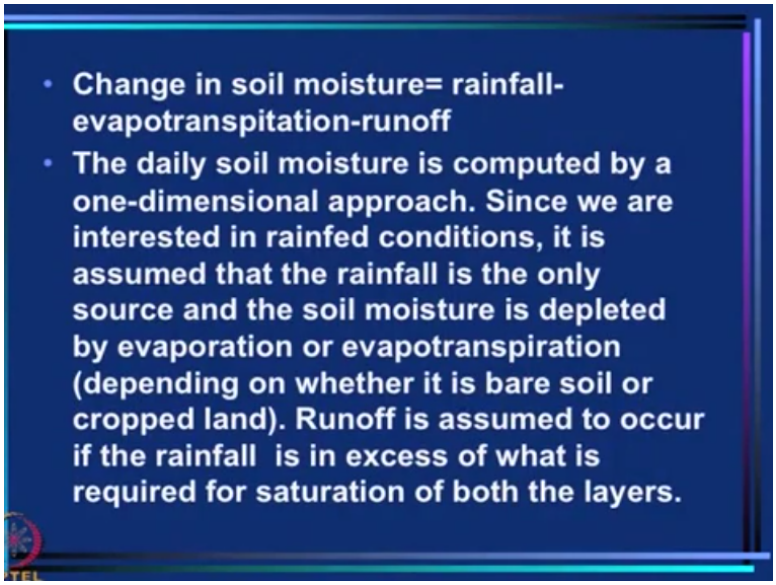

Now we are going to look at change in soil moisture in both the layers and what brings about the change in soil moisture? You know very well. This is the simple water balance approach okay. So change in soil moisture=rainfall which is the input of water evapotranspiration. See evaporation is what happens when there is bare surface, evapotranspiration why because when there are plants, plants also transpire.

So the net amount of water going into the atmosphere is the evapotranspiration when there are plants. So change in soil moisture depends on how much rain occurred above how much got evaporated okay. Now then there is also runoff so if we can calculate all these we can actually calculate what is the change in soil moisture. As I say we did it by simple water balance approach.

This is the model developed by professor Ramprasad at our institute, a very simple-minded 1-dimensional water balance approach. Now since we are interested in rain fed conditions, it is assumed that the rainfall is the only source and there is no irrigation obviously and the soil moisture is depleted by evaporation or evapotranspiration depending on whether it is bare soil or cropped land okay.

Now when does runoff occur? Now this is the big assumption that is made in most of the soil hydrological model that only when there is enough rain so that over and above the evapotranspiration, the soil moisture gets enhance to a level that it is saturated in both the layers only then whatever is left over will be sent off as runoff from the field. Now this is an assumption.

This is an assumption, which need not be valid. In fact, we know very well that in intense thunder showers that occur in our pre-monsoon season for example, there is a lot of runoff seen but deep layers of soil do not get saturated because the rainfall is so intense, you know runoff is a highly non-linear function of rainfall, which depends on rainfall irrespective of what is happening to the soil also.

So this is an assumption that is made and it has to be made because we do not have data on runoff. We can estimate evapotranspiration in some ways and I will show you how, but once evapotranspiration is estimated we know what is rainfall-evapotranspiration that water we take first to saturate the soil and only if any water is left over and above saturation then that is sent off as runoff.

So this is the basic assumption of the model that rainfall is the only source and soil moisture is depleted by evaporation or evapotranspiration and runoff is assumed to occur if there is excess rainfall above that required for saturation of both the layers. Evaporation from bare soil is assumed to occur at a rate proportional to the moisture content of the soil.

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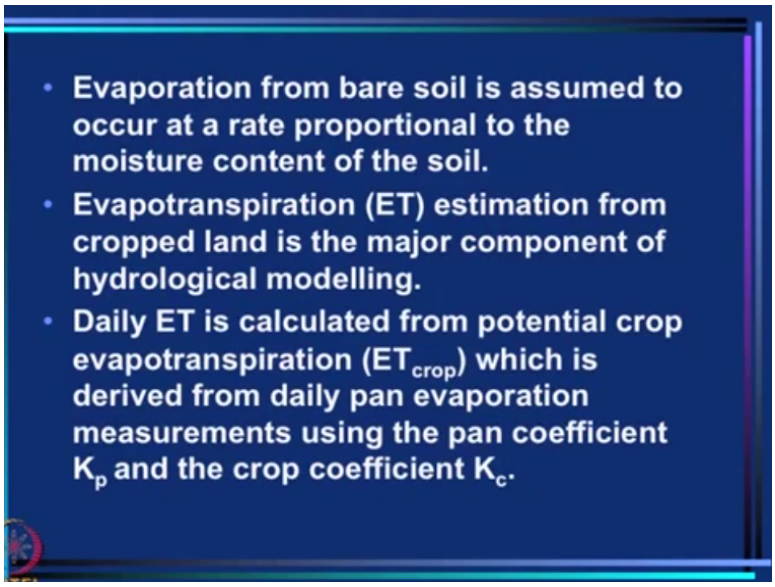

Evapotranspiration estimation from cropped land is the major component of soil moisture modeling. It is the one of the major unknowns here. So daily evapotranspiration is modeled and I am not going to get into details of that and actually evapotranspiration is calculated from what is a potential crop evapotranspiration. Potential means if there was plenty of water available to the plant how much would the evapotranspiration be?

That is the maximum possible evapotranspiration. Actually evapotranspiration is generally a fraction of that which we get by using daily pan evaporation measurements using the pan coefficient and crop coefficient okay. So there is a way of getting this.

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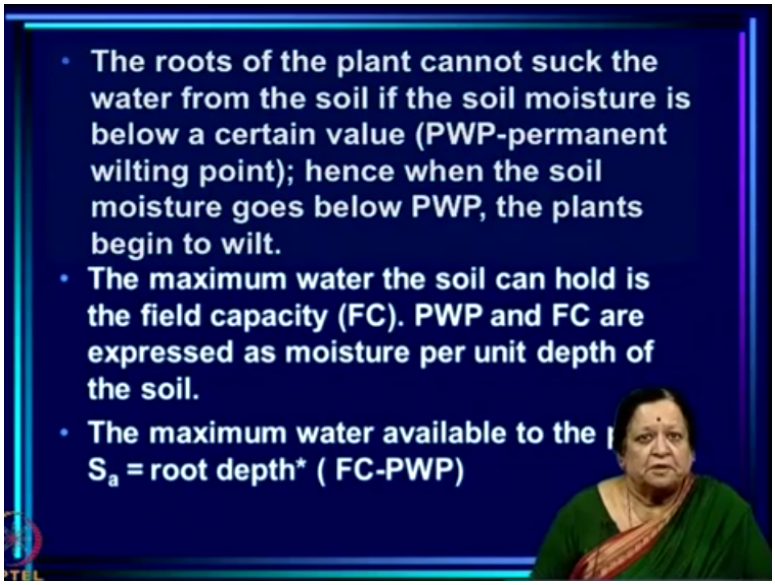

Now the roots of the plant cannot suck the water from the soil if the soil moisture is below a certain value okay. It does not have to be 0 for that even if it is below a certain threshold, the plant cannot suck it. This is called the permanent wilting point because when the soil moisture is below the critical value since the plant cannot get any moisture from the soil, it will begin to wilt.

So this is called a permanent wilting point. The maximum water the soil can hold is the field capacity. This again varies obviously from soil to soil and we know that for red sandy soils, the field capacity is less than clay or black soils that we get in other parts of our country. So PWP and FC are expressed as moisture per unit depth of the soil. The maximum water available to the plant is therefore root depth*FC which is the maximum field capacity-the wilting point.

Because it simply cannot take up water if it is below the wilting point, so FC-PWP is the available moisture per unit depth, you multiply it by the depth of the root you get what is the moisture available to the plant which is Sa.

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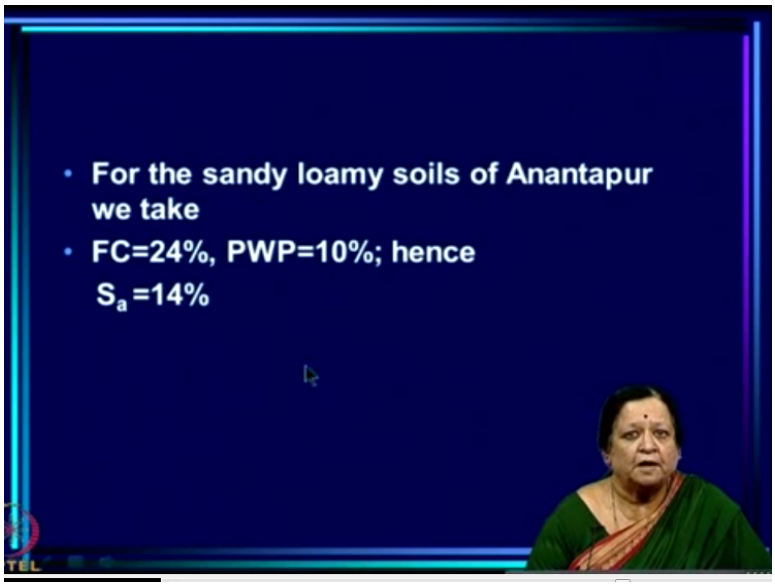

For sandy loamy soils of Anantapur, we take carrying capacity, this is per unit volume to 24%, wilting point is 10% so the maximum available soil moisture is 14%.

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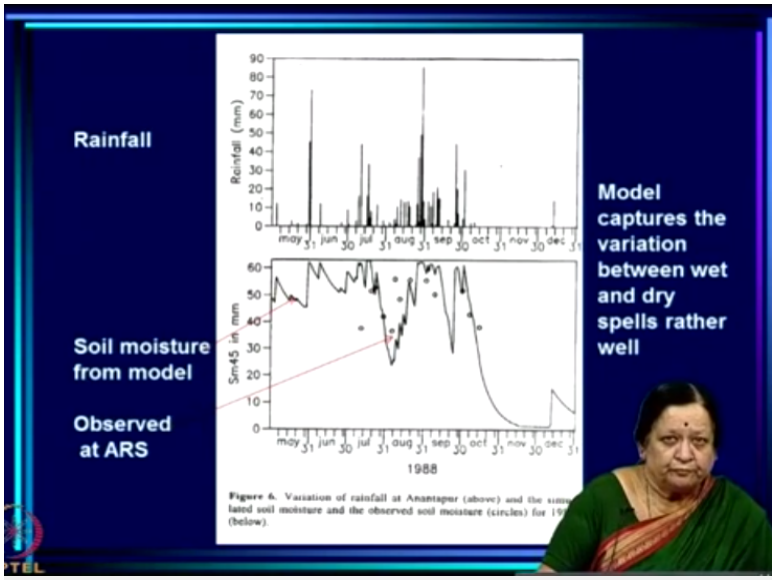

Now having built this model, having put in all the numbers that we could get from the literature and so on and the characteristics of the soil and so on we want to see how good the model is and it is extremely important to do so because any model one user has to be validated for the site you are using it for. So this is the validation that we did for 1998, up here is the rainfall pattern for that year.

And this is the soil moisture pattern simulated by the model and the circles are the observations and you can see that in the observations also there is a big dip here and then the moisture builds up here, then begins to decrease here, builds up here and is decreasing here, all of that is captured very nicely by the model. So the model is able to capture the variation between wet spells and dry spells.

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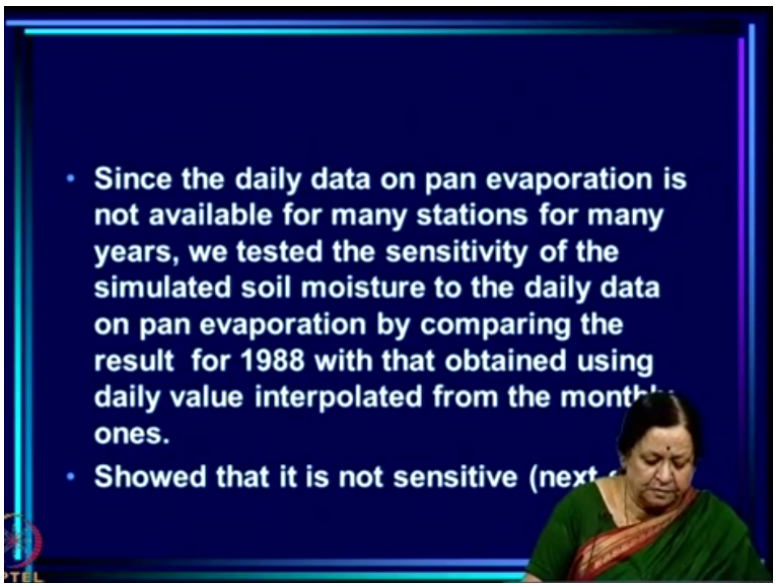

For our purpose, this model is good enough is what we concluded. Now there is another hitch that the daily data on pan evaporation is not available for many stations for many years; however, monthly data is available. So we tested the sensitivity of the simulated soil moisture to the daily data on pan evaporation by comparing the result for 1988 with that obtained using daily value interpolated from the monthly one.

See monthly is available we can always interpolate and generate daily values. These are fictitious of course, but the point is that this pan evaporation does not play a great role in deciding the variation of soil moisture. The key variable for that is rainfall and therefore you can get away with these kind of things.

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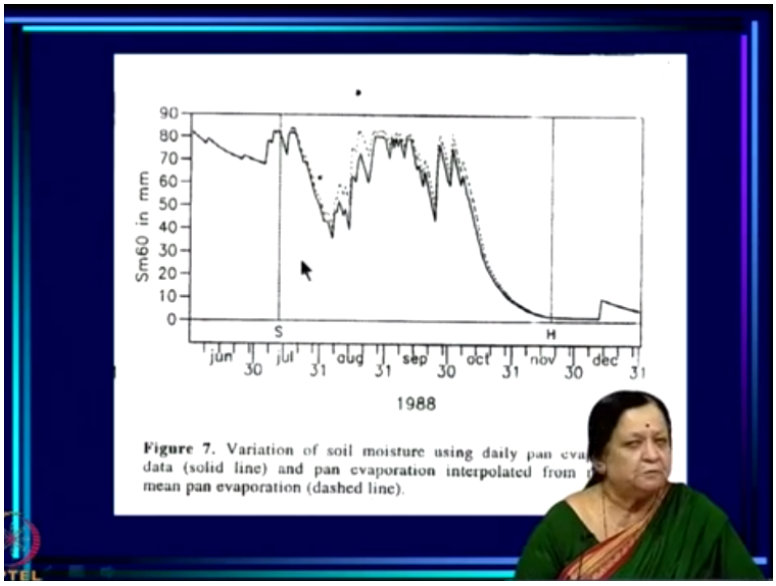

And we did this model experiment replacing the daily pan evaporation by interpolated monthly and what you see is the solid line is of course the one, which uses daily pan evaporation data, dash line is the one, which uses interpolated daily data obtained from monthly data and you can see that there is hardly any difference in the 2 patterns because what determines these huge fluctuations is really the rainfall.

So we do not have to worry even if we do not have daily pan evaporation, we can still generate soil moisture using this model.

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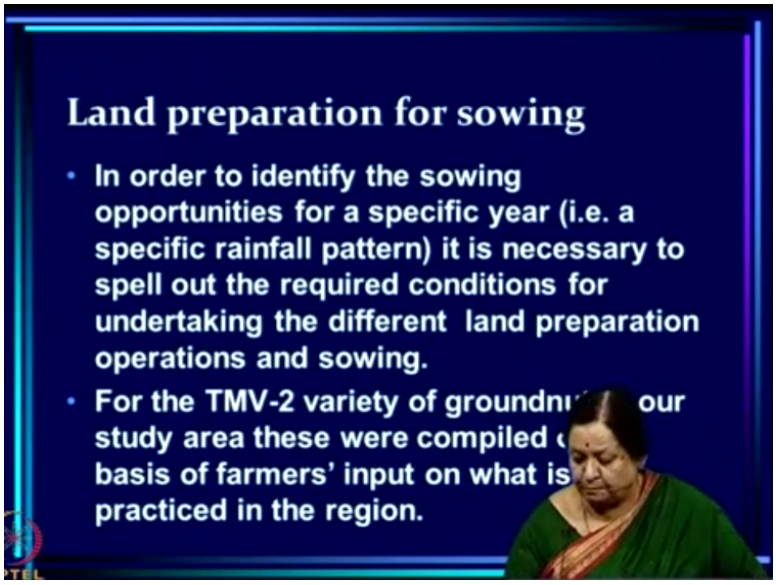

Now I was talking of land preparation for sowing. In order to identify the sowing opportunities for a specific year that is the specific rainfall pattern, it is necessary to spell out the required conditions for undertaking the different land preparation operations and sowing. For the TMV-2 variety of groundnut in our study area, these were compiled on the basis of farmers input on what is practiced in the region.

See I talked earlier about how critical it is if you want to get answers to scientific questions that you have a genuinely interdisciplinary group with interaction. This is another instance in which we would never have been able to model, you know occurrence of sowing dates in groundnut had we not got enormous input from the farmers in the region as to what are the criteria they use for deciding on different operations for land preparation.

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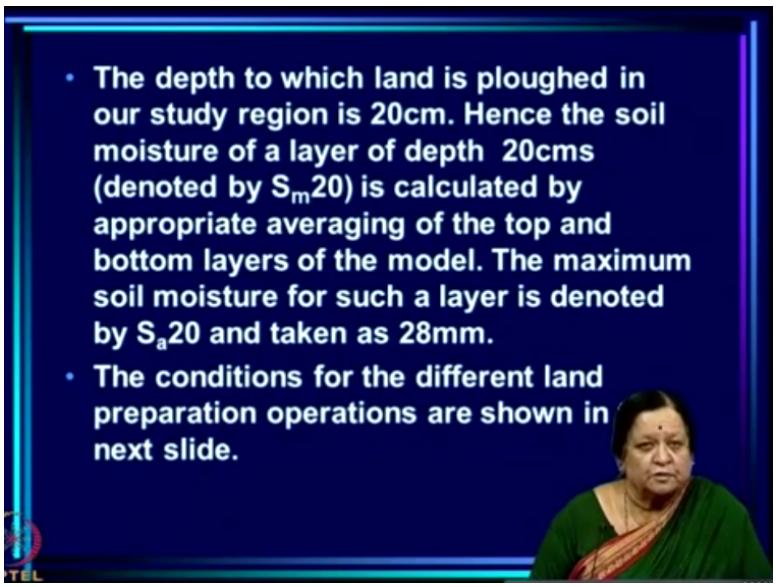

Now the first operation is ploughing as I indicated earlier. The depth to which the land is ploughed in the study region is 20 centimeter. Hence, the soil moisture of a layer of depth 20 centimeter, which we denote as SM 20 is calculated by appropriate averaging of the top and bottom layers of the model okay. The maximum soil moisture for such a layer is denoted by Sa 20 and taken as 28 millimeters.

This is consistent with the assumption we had made for the red sandy soil. So what we say is for this 20 centimeter layer, which remember is bare right now right. The land has to be ploughed in fact this is the situation that the maximum available soil moisture would be 28 millimeter. Now conditions for the different land preparation operations are in the next slide.

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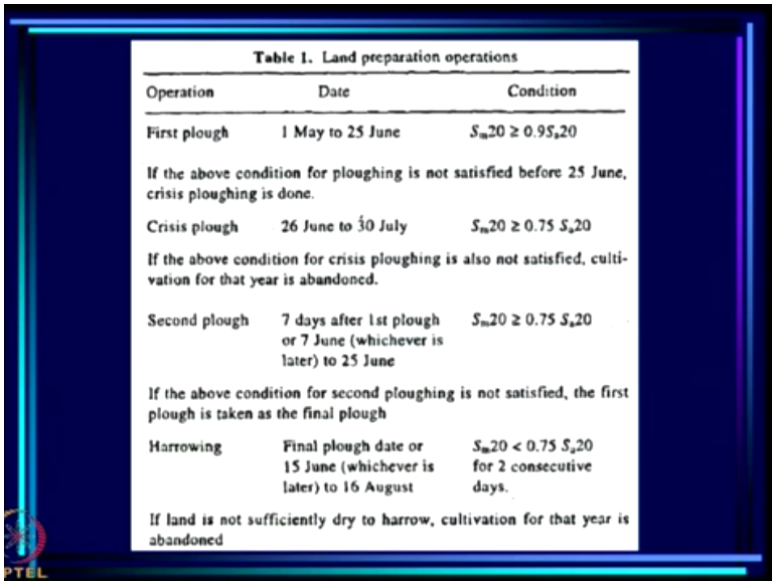

So what do the farmers do? If the soil moisture of 20 which means the top 20 centimeters of the soil is > 90% of this Sa 20, which we had taken as 28, see we had here Sa 20 is taken as 28 millimeters that is to say it is 2.8 centimeters 90% of that would be something like 2.7 centimeters little less than that. So if that much of moisture is available in that soil, then they will do the first plough somewhere between 1st May and 25th June whenever this moisture condition is satisfied.

If the above condition for ploughing is not satisfied before 25th June then they say okay now we cannot keep on waiting for the moisture to be enough for our regular ploughing, let us do crisis plough and so from 26th June to 30th July whenever the soil moisture exceeds 75% of the maximum possible, they immediately do a ploughing and that is called crisis plough.

If the above condition for crisis ploughing is also not satisfied, cultivation for that year is abandoned. So they take 2 chances, but if rain is simply not enough till end of July to even do crisis ploughing then there is no point in cultivating groundnut is what they say. Now the second plough, which is 7 days after the first plough or 7th June whichever is later till 25th June.

So they have to plough the field twice and this is the schedule for the second plough and for the second plough it is enough if the soil moisture is over 75% of maximum available. Now if the above condition for second ploughing is not satisfied, the first plough itself is taken as the final plough. So second plough in some sense is optional, they are not going to abandon the cultivation if they cannot plough second time.

This is the practice that they have. So if second plough is not possible then it is final plough, first itself is taken as final plough. Then they have a process called harrowing, which is done either final plough date or 15th June whichever is later to 16th August and here the condition is that the soil has to be sufficiently dry for 2 consecutive days for harrowing. If land is not sufficiently dry to harrow, cultivation for that year is abandoned.

Because they simply cannot prepare the land, see they may have ploughed it but if the land never gets dry enough to harrow they cannot carry on with the groundnut cultivation.

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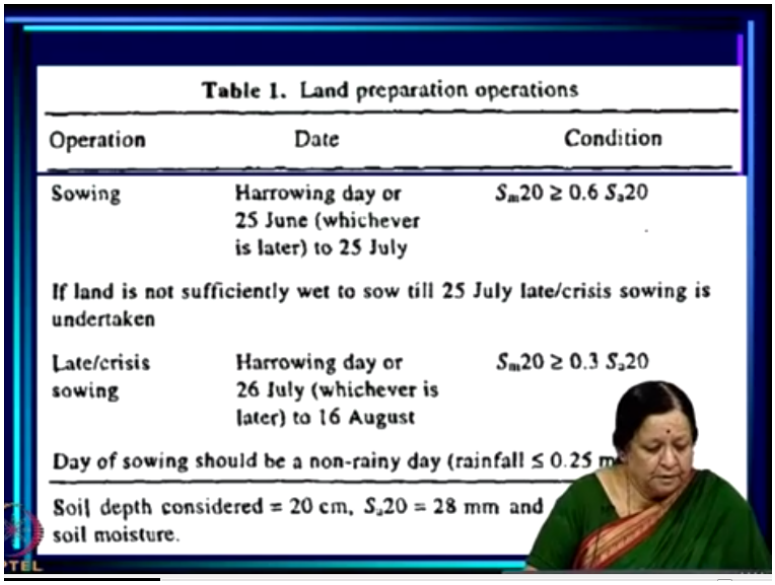

Now then comes sowing. So sowing can be done on the day of harrowing or 25th June whichever is later to 25th July. So they have a limit for every operation and the condition for

sowing is that the soil moisture has to be > 0.6 of the maximum available more than 60% okay. Now if the land is not sufficiently wet to show till 25th July, late or crisis sowing is undertaken. This late or crisis sowing is done either on harrowing day so this will not be done till almost end of July till 26th July whichever is later to 16th August. So due to different conditions then you may end up doing these different operations at different times.

Now day of sowing (()) (33:56) further conditions that we have to impose that they cannot sow on a rainy day. So day of sowing should be a non-rainy day and here we use the IMD definition of a non-rainy day that rainfall is < 0.25 millimeter. Now soil depth considered is 20 centimeters, the saturation is 28 millimeters and SM 20 is the available soil moisture. So this is what they practice.

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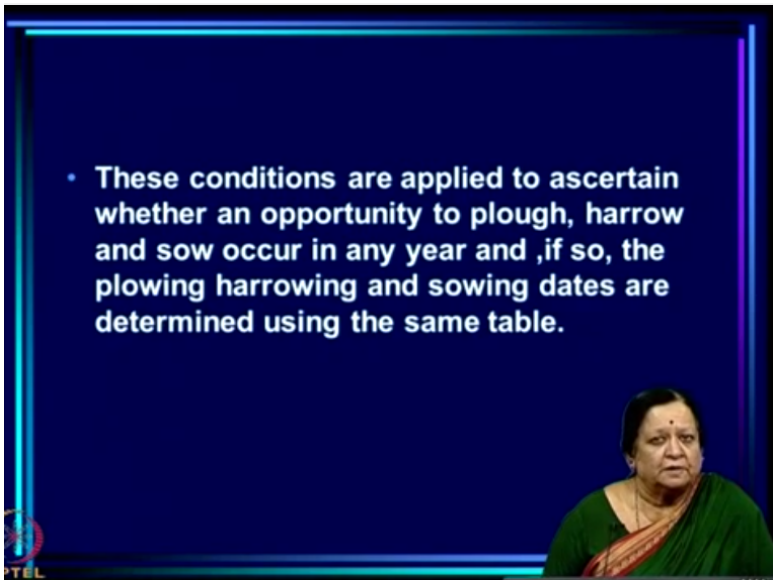

Now these conditions are applied to ascertain whether an opportunity to plough harrow and sow occur in any year and if so the ploughing, harrowing and sowing dates are determined using the same table. So now what have we done? We have collected from the farmers what are the conditions and criteria, which have to be met for them to undertake ploughing, harrowing, and sowing.

And these are all determined in terms of soil moisture, to generate soil moisture from rainfall we have a poor man's model, simple model of hydrological model, which seems to work reasonably well and from that model we get the soil moisture, then we check whenever those conditions that they have laid down are satisfied then we call that ploughing date, harrowing date and sowing date.

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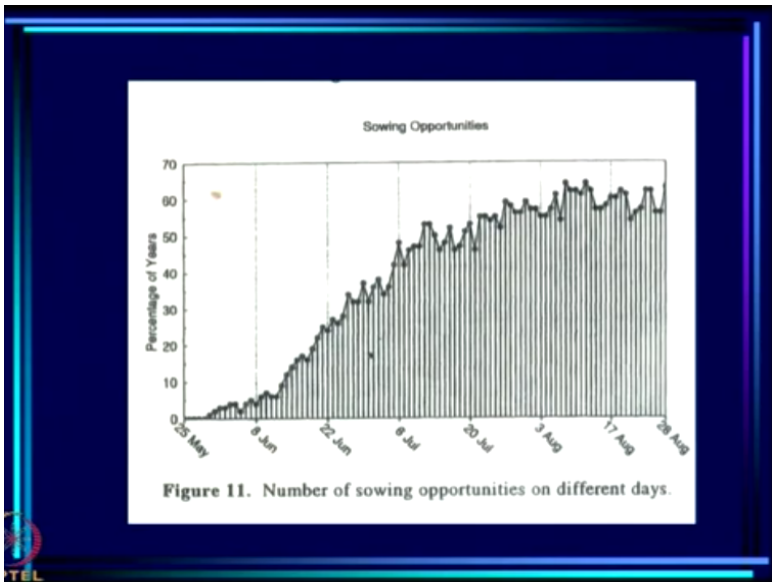

Figure 11. Number of sowing opportunities on different days.

And in case no such opportunity arises, we say the sowing got abandoned. So the cultivation itself is abandoned. Now how many sowing opportunities are there? This is clubbing all the 88 years; how many sowing opportunities occur on different days in percentage of years. So see around 6th July large number of years almost 50% of the years you will get sowing opportunity.

And it increases slowly to 60%, near 60% towards August and so on, so initially in May, June which is when the package of recommendation said you should do planting, the sowing opportunities are very, very small, up to June they are < 10% and even up to 22nd June this is the sowing window that they choose now. See after 22nd June, it has crossed 20%.

So it makes sense that if they feel like sowing, there is some chance of being able to do so because remember it is not a matter of only sowing, they have to have opportunities for ploughing, harrowing and so on after that okay.

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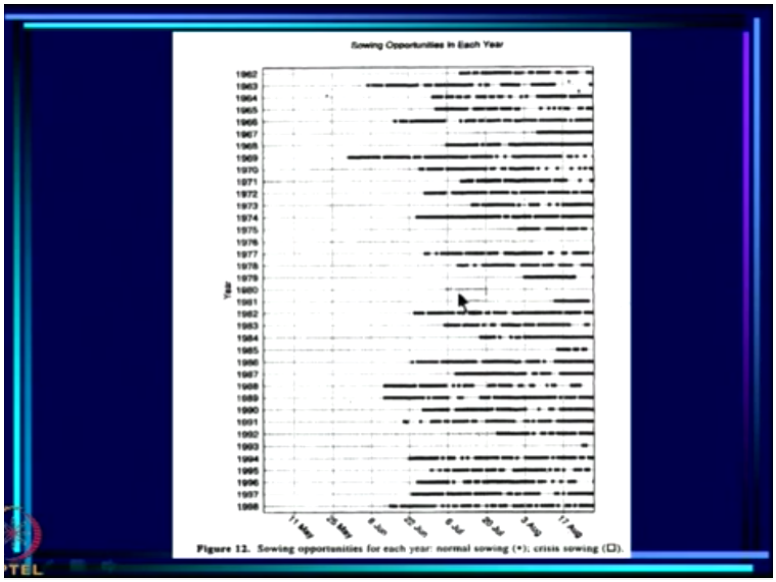

Now this is not a figure that you will be able to figure out, but for every year we have calculated what are the sowing opportunities and in which years crisis sowing was taken and in fact you will find that in some year's cultivation just had to be abandoned like this year here. No cultivation possible. This year no cultivation possible.

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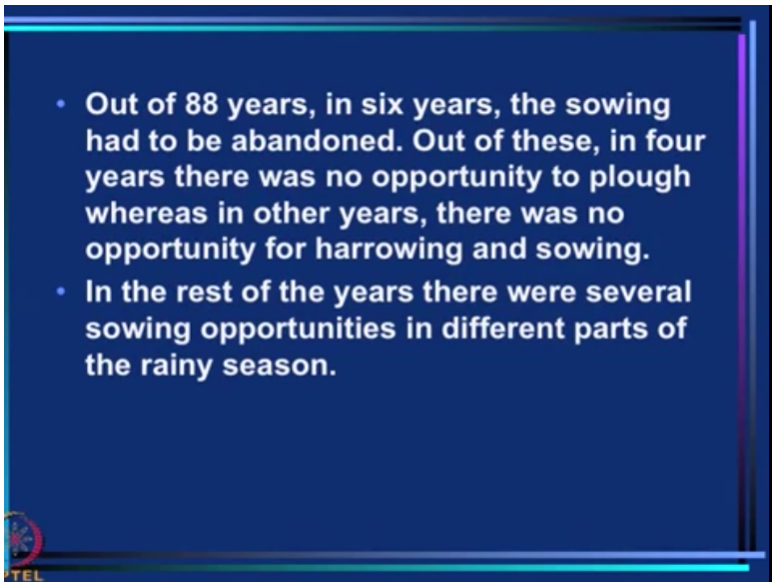

The rainfall was so poor that it did not happen. So out of 88 years, in 6 years the sowing had to be abandoned, out of these in 4 years there was no opportunity to plough whereas in other years there was no opportunity for harrowing and sowing. So in the rest of the years, there were several sowing opportunities in different parts of the rainy season.

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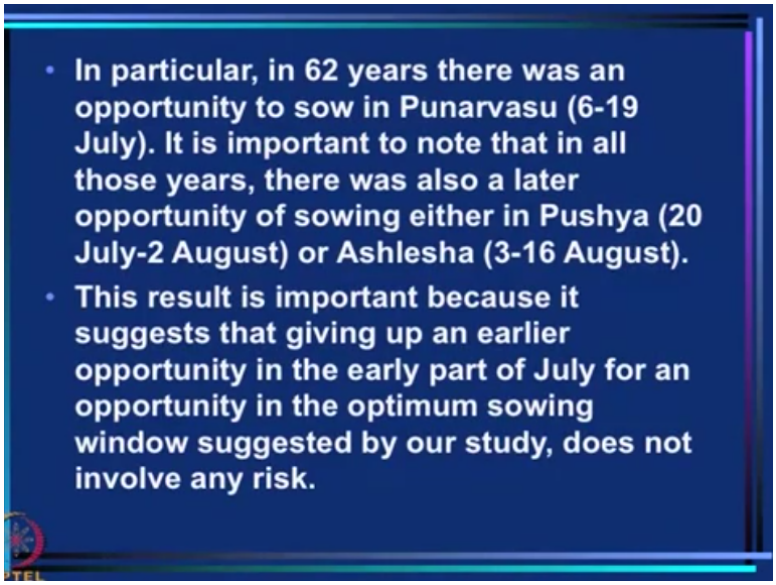

In particular, out of 88 now we are talking of in 62 years there was an opportunity to sow in Punarvasu which is the favorite sowing season for the farmers 6 to 19 July. It is important to note that in all these years in each of these 62 years there was also later opportunity of sowing either in Pushya which is the next nakshatra 20th July to 2nd August or Ashlesha, which is the nakshatra which follows which is 3 to 16th August.

So although they like to sow in Punarvasu if they decided to forgo that to you know maximize the chance of getting high yields in each of the years in which opportunity occurred in Punarvasu a later opportunity also occurred. This is a very, very important result because it suggests that giving up an earlier opportunity in the early part of July for an opportunity in the optimum sowing window that we have determined with our model suggested earlier does not involve any risk.

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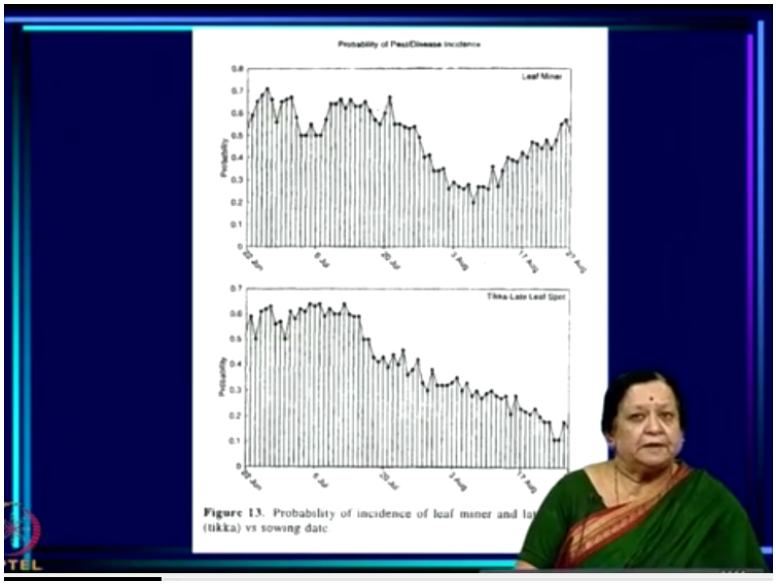

This is what we are saying that as far as our data is concerned there is no risk involved in this operation. Now this is something that I will come to when we talk of indirect impact of weather events. As I mentioned earlier you know wet spells and dry spells can also promote or trigger attacks by pests and diseases. Dry spells trigger attacks by leaf minor, wet spells trigger attacks by thing called late leaf spot or Tikka.

So this is the indirect impact of climate events or weather events. See so far through PNUTGRO model what we looked at was only the direct impact of rainfall, direct impact of rainfall on soil, on how it impacted on growth of the plant, on the yield and so on so forth. This is the direct impact, but there is also an indirect impact of wet spells, dry spells and so on which generates pests and diseases as I mentioned before.

Now we have very large areas of monocropping and because of that this pests and diseases in the region and in almost every rain fed region in India had become endemic. This means that a low level of low density of these is around all the time and if a favorable weather event occurs that is to say favorable for them pests or diseases immediately epidemic starts, you know pest population increases and they start attacking the plant.

And the losses can be quite high so one has to also think of going beyond the crop models, which are already developed and with us to think of how to take into account these indirect impacts of climate events and that is leaf minor and Tikka. I will not talk about how we determine this now because that will come when I talk about the model for these pests and diseases.

But this is only showing you the probability of incidence of leaf minor and late leaf spot depending on the sowing date and there was a belief amongst the farmers that if you sow late then the chances of pests and diseases are higher, but actually we find that is not true at all. Leaf minor after 20th of July it very rapidly decreases, chance of getting leaf minor and even Tikka or late leaf spot also decreases right from about mid-July onwards.

So as far as just the triggering of these attacks by weather events are concerned, the probability of incidence of this is going to decrease with late sowing window, but farmers tell us that you know actually if somebody cannot sow on time and sows late, the attack is much more on his field, but that has to do with the fact that what we have not taken into account in our model is that these pests move from one place to another.

Disease also spreads from one place to another so if you have patches in which crop is planted earlier lying side by side with patches and which it is planted later then diseases of plants, which attack the earlier sown crop can easily travel to the other field and attack it.

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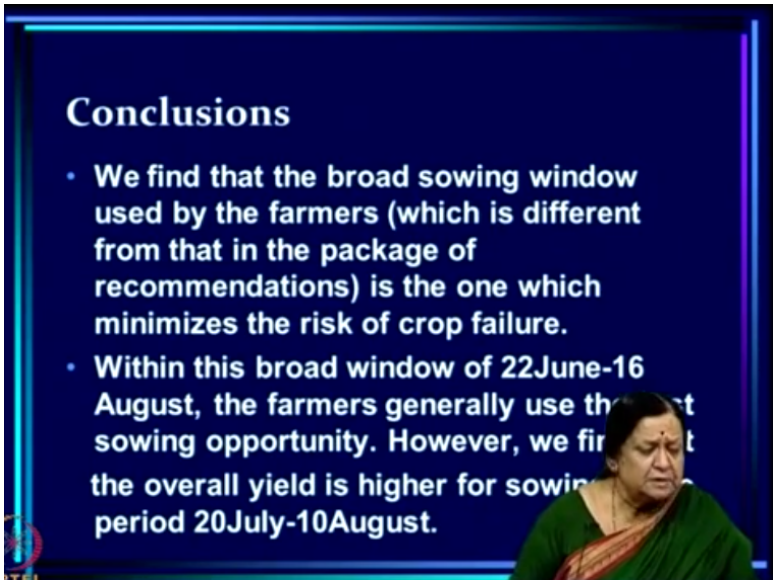

So this is something we have not taken and this could in fact lead to problems in having more pests and diseases when you do not have uniform sowing over large areas. So this is something we will have to worry about when we look at the model for pests and diseases. So what are the conclusions now? We have made a very detailed study in response to the question that farmers post to us.

What is the optimum sowing date of the region? Saying that what is in the package of recommendations is not right we have come up with another sowing window and how good is that and can you make suggestions as to how to improve the yields by changing the sowing window somewhat. Now as you know, we did this exercise by taking a lot of rainfall data, by taking a validated crop model.

And doing experiments to see how the yield changes with sowing date and what do we find? We found that the broad sowing window used by the farmers, which they have empirically hit on by trial and error they have come to this sowing window for this region over the 2 or 3 decades in which it is grown. So this is different from the one that was in the package of recommendation is the one which minimizes the risk of crop failure.

So it is a very rational choice. They have already come empirically on to a choice of sowing window, which is very reasonable in that it avoids the chance of crop failure. It minimizes the risk of crop failure. Now what we found was that within this broad window of 22nd June to 16th August, the farmers generally use the first sowing opportunity; however, we find that the overall yield is higher for sowing in the period 20th July to 10th August.

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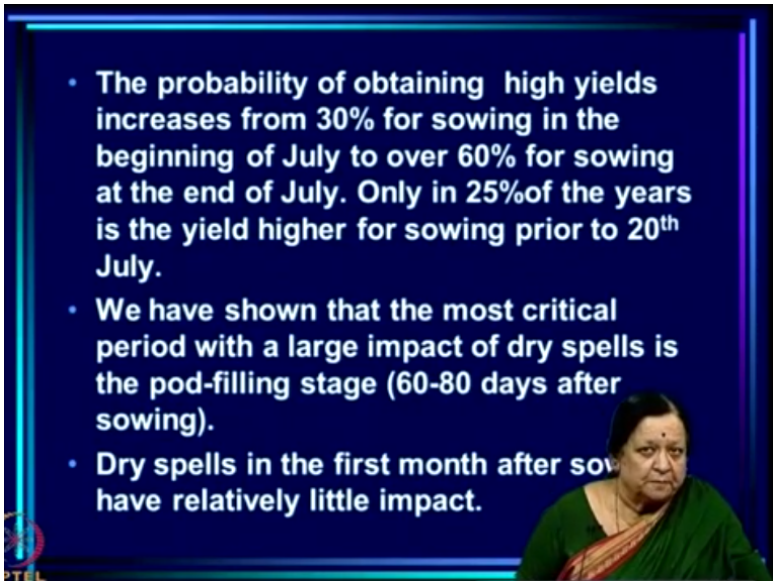

Again we had shown that the probability of obtaining high yields increases from about 30% for sowing in the beginning of July to over 60% for sowing at the end of July. Only in 25% of the years is the yield higher for sowing prior to 20th July. So 75% of the years, the yield will be higher if one can sow after 20th of July.

And again we have to note that if there is an opportunity to sow in early July, which is when farmers do like to sow when they have an opportunity in all the years in which such an opportunity occurred in early July, another opportunity did occur after 20th July also. So it is possible for them to forgo the first sowing opportunity and so in this window that we are suggesting that is the latter part of the sowing window that they have adopted.

Now this is something that we just found by running several years 88 years of the model, we found that this is an optimum sowing window, but then we also looked into why this is optimum? And we found that the most critical period with a large impact of dry spells is the pod-filling stage. So as far as the life-history stages of the plant are concerned, the most critical stage is the pod-filling stage, which is about 60 to 80 days after sowing.

Now dry spells in the first month after sowing have relatively little impact. This is also something that we showed in that experiment you remember that we did with 3 years.

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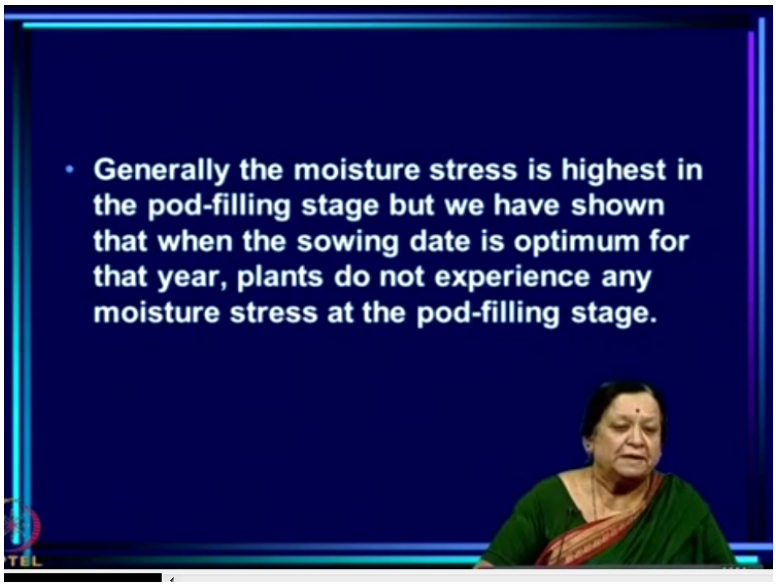

So we have found that the sensitive period, sensitive stage is the pod-filling stage dry spells in the first month after sowing do not have much of an impact. Now actually the PNUTGRO model also calculates the moisture stress experienced by the plant. So using that we could show that if you see in general you know the moisture stress is highest in the pod-filling stage because the moisture stress grows with the plant.

See as more and more leaves grow and the plant attains its maximum height then the need for moisture also becomes maximum and so when you have a dry spell, the moisture stress is

also maximum. So by 60 days the moisture stress generally is the highest at pod-filling stage, but we found interestingly enough that when the sowing date is chosen to be optimum for that year, then it turns out that the plant experiences no moisture stress at all in the pod-filling stage.

Now this is very interesting, this could be done only because of the model that we could show that in fact their optimum sowing dates, which we discovered by analysis of how the yield varies with sowing date actually implies that there is no moisture stress in the pod-filling stage of the plant when the sowing date is optimum.

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So this already tells us that we can do a lot with these results without actually having to run the model. You see what is it saying? Now we have to remember that in this region, the rainfall in any season you do not get continuous rain or heavy rain all the time like you do in rainy parts of the country. This is a semi-arid region so what happens every year you have some wet spells interspersed with dry spells.

The probability of occurrence of these spells varies in time right we have seen that also. So probability of wet spells is high and dry spells is low during this special window 20th September to 10th October for this region whereas reverse case occurs in the latter half of June.

So given any region and given the rainfall, we can easily derive you know what are the probabilities of wet spells and dry spells in different parts of the rainy season as we have done

here. Now what do we want to do? We want to maximize yield okay. For that we would like to avoid dry spells at the critical stage where dry spell can have a very large impact on the yield.

So if for maximizing the yield, the dry spells are to be avoided at some stage of the crop, the sowing date can be adjusted so that the probability of dry spell is least at that stage okay. So you can you know move the thing around we saw with the sowing date, move the rainfall pattern around we saw with the sowing date and thereby ensure that the probability of dry spell is minimum when the plant is at its most sensitive stage.

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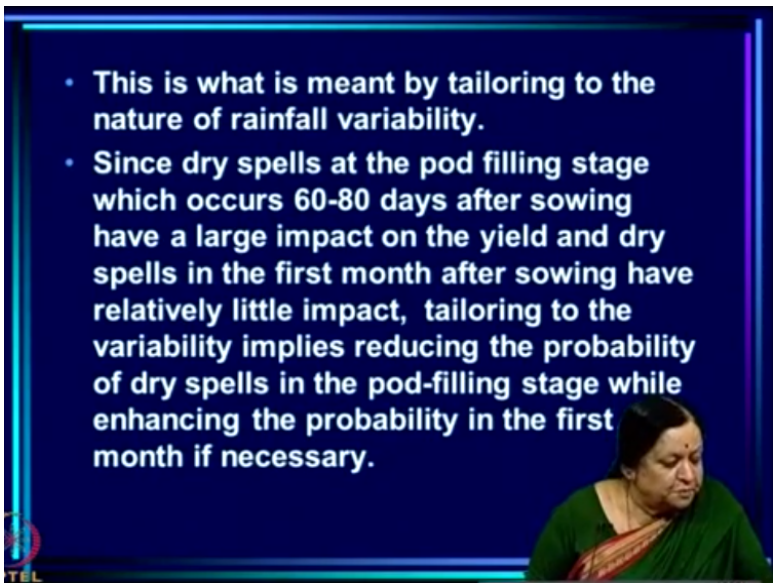

This one can do, but you know dry spells just cannot be wished away. So what you do is you can this is what means by tailoring to the nature of the variability. Now we are saying since dry spells at the pod-filling stage, which occurs as 60 to 80 days after sowing have a large impact on the yield and dry spells in the first month after sowing have relatively little impact. Both these results have come from our model work.

Then tailoring to the variability means that you should actually reduce the probability of dry spells in pod-filling stage that is how the sowing date should be chosen while if required enhancing the probability in the first month. In other words, as you are shifting the thing around you cannot just make do with no dry spells at all in any stage of the crop, dry spells will occur.

The point about tailoring is that you do not let them occur when the plant is most sensitive, most vulnerable to dry spells that is what one means by tailoring and that is how sowing date is used for tailoring.

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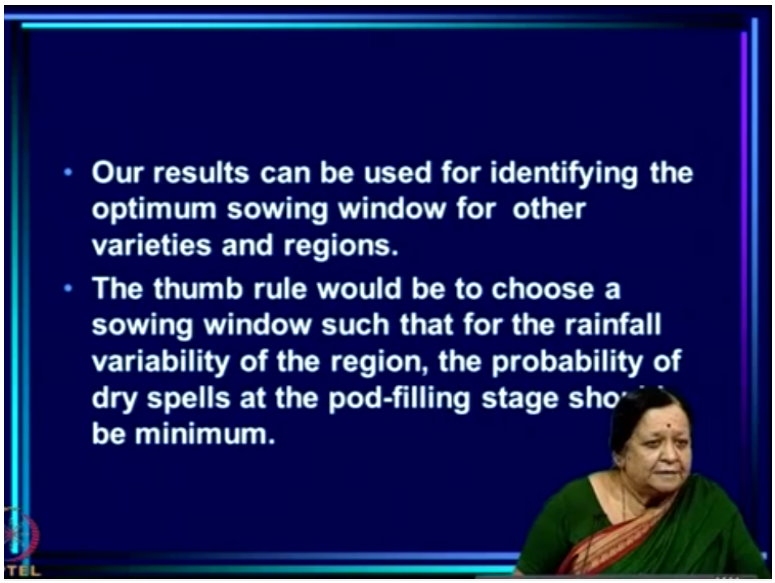

Now what is interesting about this study is it actually required a lot of modeling, it required modeling using of crop models, which were fortunately validated by some other group and it required getting the rainfall data and running the models, analyzing it and so on and so forth, but at the end of the day what we have learnt is that for groundnut pod-filling is the most critical stage.

And the way to get optimum sowing is to somehow match the pod-filling stage with the minimum probability of dry spells in the rainfall pattern of that region. That is what we have learnt. So this can be without running any models or anything if you have another variety of groundnut that you want to grow in this region for which the pod-filling stage is at a different stage not 60 to 80 days as it is for TMV-2 and so on.

Then it would be possible for us to right away conclude what the sowing date should be. So the thumb rule would be to choose a sowing window such that for that rainfall variability that the region experiences the probability of dry spells at the pod-filling stage should be minimum. See by using this kind of a thumb rule, we will do much better then in terms of choosing the sowing window.

Of course, if you had a model, it would help but having had the model the conclusions that we have come to are so reasonable and so consistent with the experience that we using the thumb rule we can derive and using this we can actually go ahead and determine the optimum sowing date okay. Now so far we have talked only of models as I mentioned before without pests and diseases.

And because of that actual model yield is much, much higher than what farmers get on the field, even then because the sensitivity of the yield to the sowing date is similar we could derive a lot of results about optimum sowing window using the PNUTGRO model, but eventually you would like a model, which mimics reality in terms of variability of yield on the farmer fields.

Now to do that we cannot omit losses that occurs due to pests and disease incidents. Now there are no models, none of the crop models incorporate pests and disease attacks. So what we did was that we developed a heuristic model in which using again the enormous experience and knowledge of the farmers we could develop a model in which we could actually calculate by means of using the model, what sort of pests and disease incidence will occur in any year and what would be the losses.

And thereby correct the yield generated by PNUTGRO by actually including losses that occur due to pests and diseases this is what I will talk about next time. Thank you.