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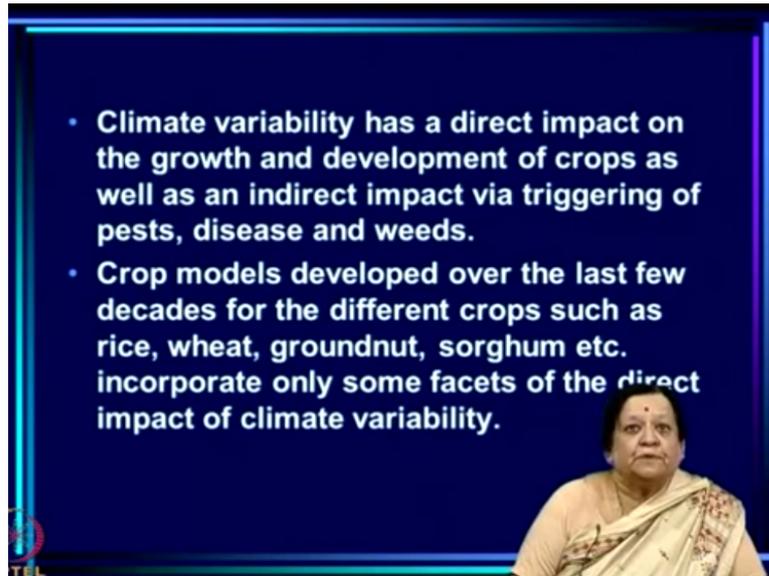**Prof. Sulochana Gadgil**
Centre for Atmospheric & Oceanic Sciences
Indian Institute of Science - Bangalore

Lecture - 38
**Monsoon Variability and Agriculture - Part 4**

So today I am going to continue talking about monsoon variability and agriculture.

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As pointed out, climate variability has a direct impact on the growth and development of crops. This we have looked at already as well as an indirect impact via triggering of pests, diseases and weeds. Now crop models developed over the last few decades for the different crops such as rice, wheat, groundnut, sorghum etc incorporate only some facets of the direct impact of climate variability.

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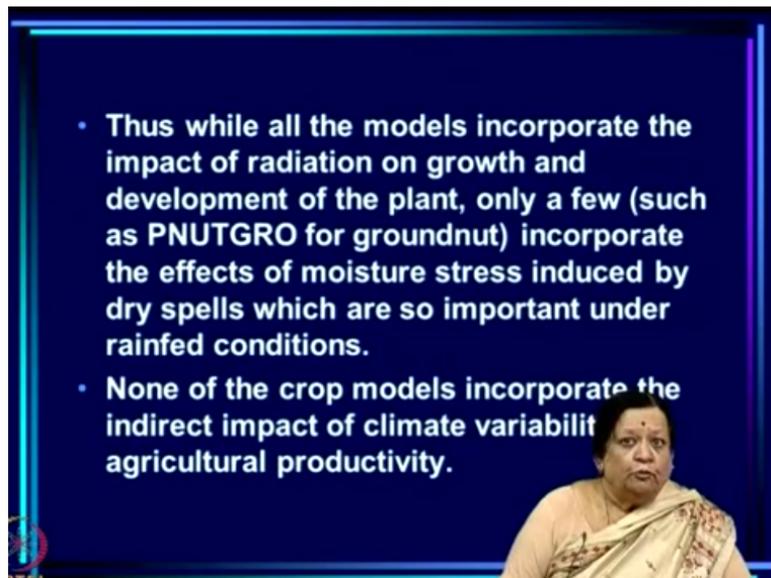
Direct impact is to say impact on growth and development of the crop. So for example, while all the models incorporate the impact of radiation on growth and development of the plant only a few such as the PNUTGRO model, which we looked at in the last class for groundnut incorporate the effects of moisture stress induced by dry spells, which are so important under rainfed conditions.

None of the crop models incorporate the indirect impact of climate variability on agricultural productivity.
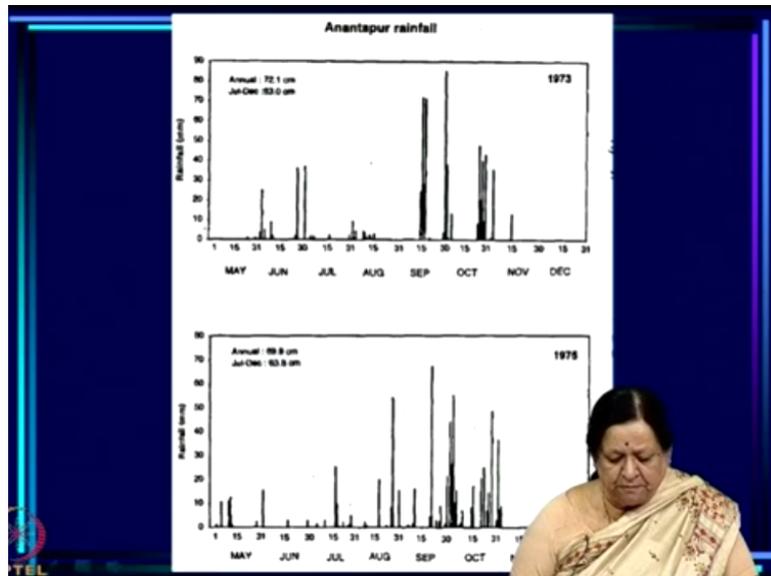
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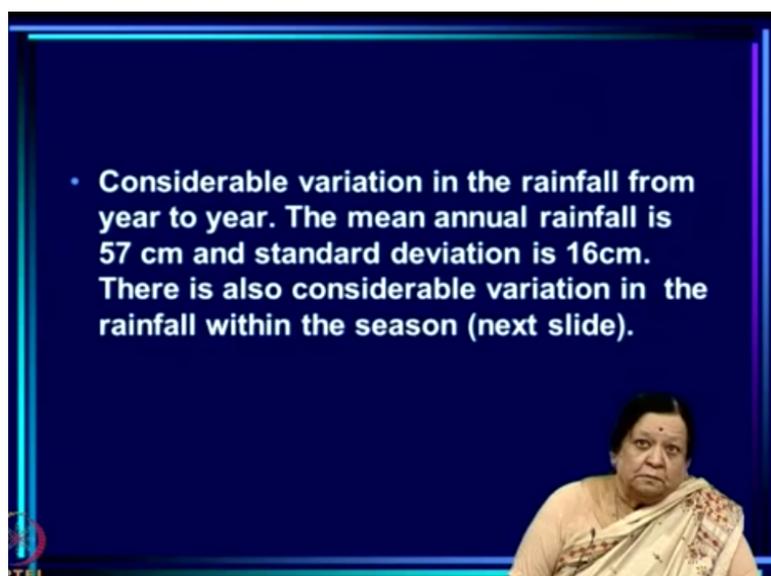
Now you know that there is considerable variation in rainfall from year to year in our study region in Anantapur and the mean annual rainfall is 57 centimeter and the standard deviation

is as higher 16 centimeter. There is also considerable variation in the rainfall within the season.

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So for example, in 1973 most of the rain fell from mid-September to mid-November. Hardly any rain in July, August, some rain in June and May. On the other hand, you look at 75 when there was plenty of rain in August, some rain in July and it continued to rain in September, October. So there is a lot of variation from year to year in the rainfall and in particular in the timing of wet spell such as these and timing and length of dry spells such as these.

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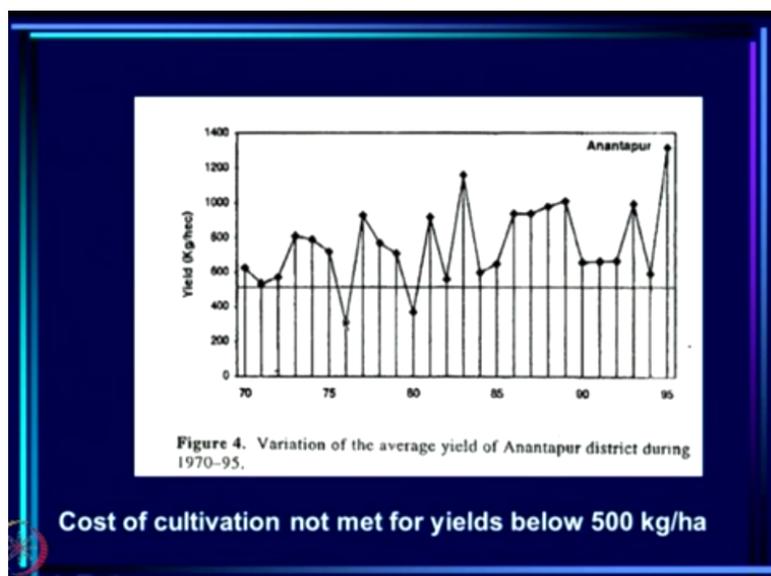
So there is a lot of variation from year to year and this leads to a very large variation in yield of crops like groundnut, which are rainfed crops. So they are very sensitive to the rainfall of the region. So this is the district yield for Anantapur region and you can see that it varies a

great deal. The maximum is very seldom more than 1000 only twice 1200 and 1300 or so it has come, but low yields are also quite frequent.

And in particular we had mentioned before that yields below 500 imply that even the cost of cultivation is not met so it should be considered as a failure.

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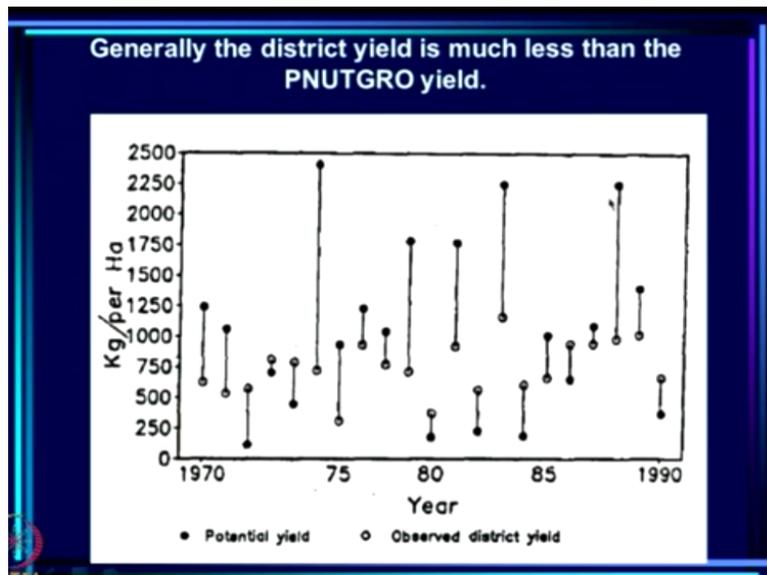
Now we have seen this before, generally the district yield is much<the PNUTGRO yield okay. So this is the PNUTGRO yield in solid and by and large particularly when the PNUTGRO is reasonable say above 1000 or so district yield is<the PNUTGRO yield and by very big margin when the yields are high of PNUTGRO so this we have seen.

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However, the yield at the agricultural stations is comparable to PNUTGRO yield.
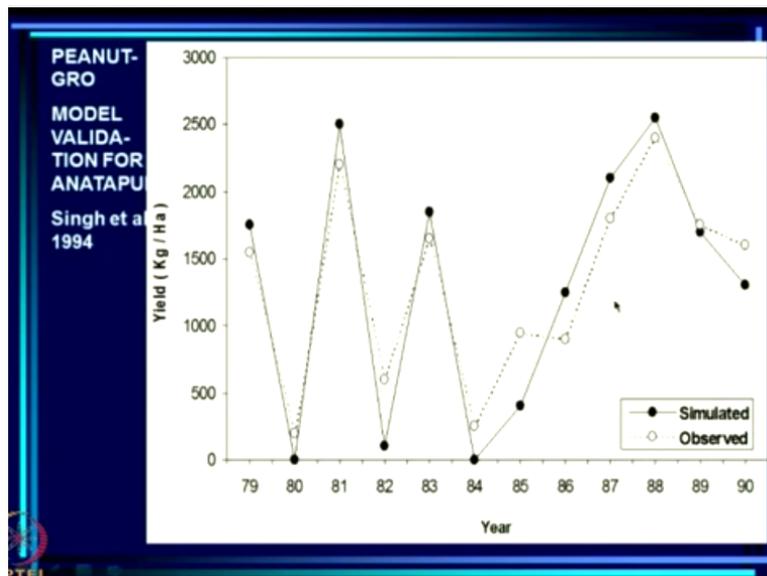
This we have seen that by and large PNUTGRO captures the variability of the yield at agricultural stations. So the yields on the farmer's fields and hence the district yield is less because generally farmers do not apply pesticides because they are not cost effective in poor rainfall years. We had also discussed this that the yields on the farmer's fields are much less because they do not think investment in application of pesticides is cost effective.

Because it is not cost effective in poor rainfall years and they do not know, which will be reasonable rainfall years so this is why they do not apply it. So we therefore expect that a large part of the difference between PNUTGRO yields and district yield is due to incidence and infestation of pests and diseases.
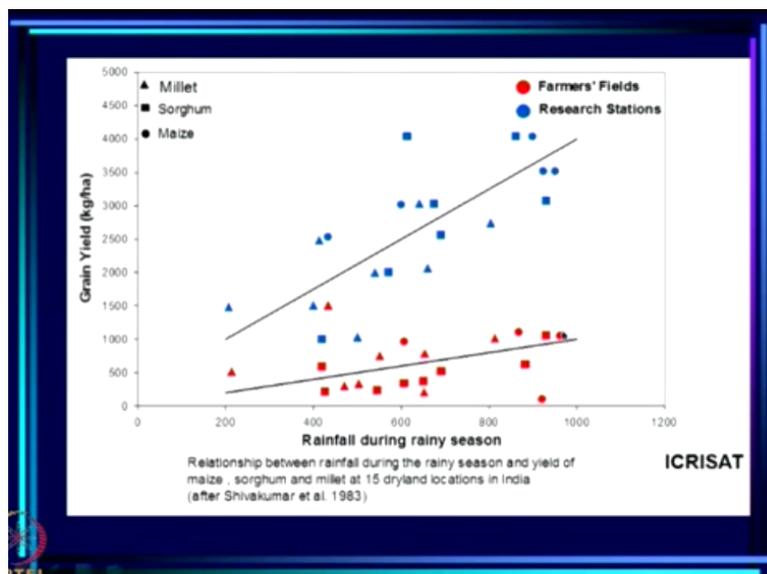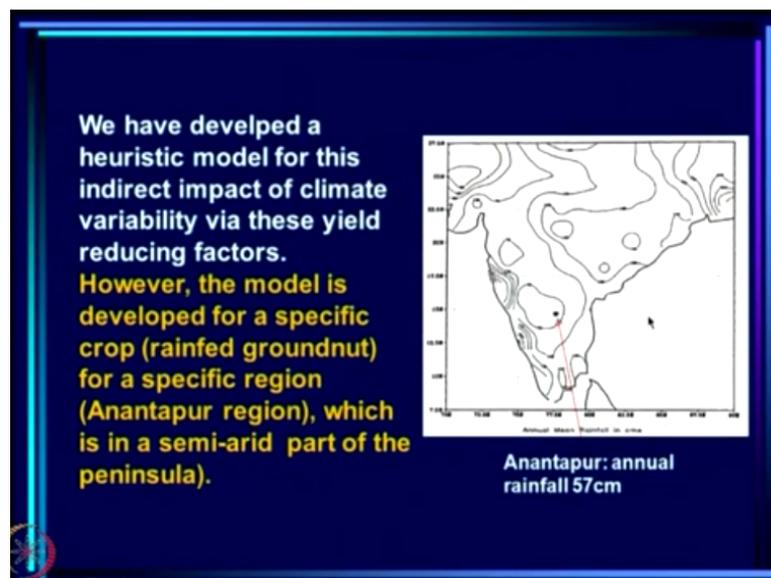
Now this is the large part of the difference has to be due to that and this is the difference between the agricultural research stations for different crops and the farmer's fields and as we have seen that particularly when the yields are high, there is a large difference between the farmers field and the agricultural research stations, which could also be looked at as the crop model yield and a district average yield.

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We have develped a heuristic model for this indirect impact of climate variability via these yield reducing factors. However, the model is developed for a specific crop (rainfed groundnut) for a specific region (Anantapur region), which is in a semi-arid part of the peninsula).

Anantapur: annual rainfall 57cm

Now what we have done is we have developed a heuristic model for this indirect impact of climate variability via these yield reducing factors. What are the yield reducing factors we are considering? Pests, diseases and weeds and we are incorporating in this model impact of events such as wet spells and dry spells on triggering of these pests and diseases. We all know that triggering of pests and diseases depends on weather events.

This is well known for example when we make pickles and the weather becomes very humid it is more likely to develop fungus, this is well known. So it is the same kind of thing triggering of certain diseases and pests by weather events. This is what we are looking at and it must be emphasized that the model I am going to talk about today is in fact for a very specific crop namely rainfed groundnut.

And the specific variety that they are cultivating TMV-2 and also specific to the Anantapur region, which I have shown on the map here and it is a semi-arid part of the peninsula and it receives only 57 centimeters of rain. So this model that we have developed is specifically for this, but obviously the model can be generalized for other crops and other regions as well okay.
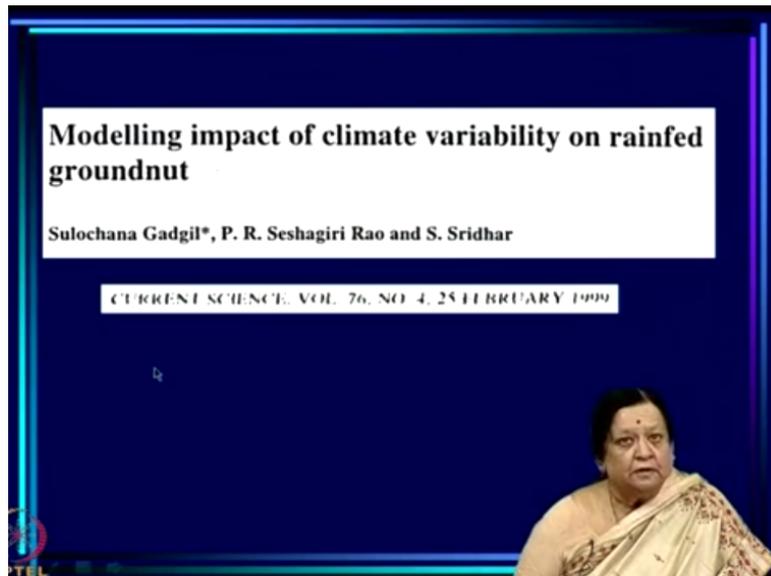
And this is published in a paper in current science in 1999. I will not talk about all the details of the model so if interested people can refer to the original paper.
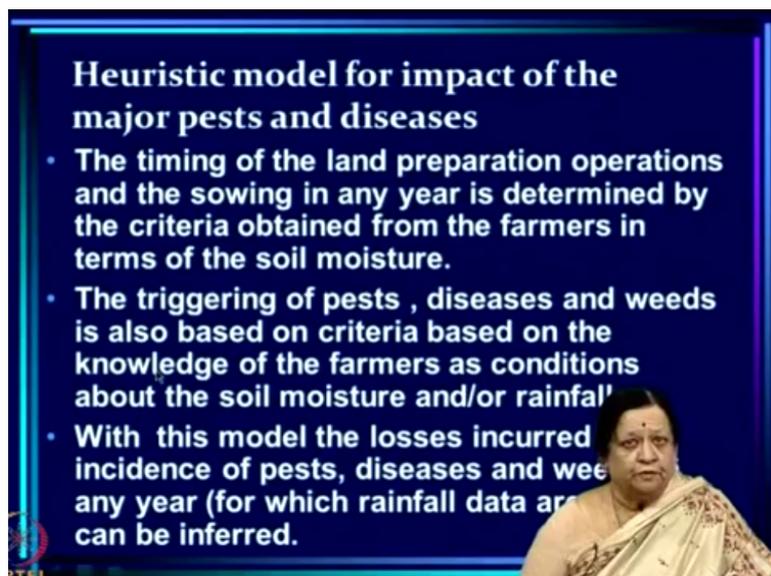
So now we are looking at heuristic model for impact of the major pests and diseases. For this the first thing we need is timing of the land preparation operations and the sowing in any year. How do we determine that given the rainfall pattern of the year? So this we have determined and I talked about the soil moisture model, simple hydrological model that we had used.

And the criteria that the farmers use for the land preparation operations had been incorporated and that is how we determine when the specific land preparation operations will take place.

Now the triggering of pests, diseases and weeds is also based on criteria based on the knowledge of the farmers as conditions about the soil moisture and or rainfall. So farmers have a lot of knowledge about when certain pests and diseases incidence will be triggered.

And on the basis of that we have actually developed the criteria. Now with this model the losses incurred from incidence of pests, diseases and weeds in any year for which rainfall data are available can be inferred.

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So now first of all this timing of land preparation and so on given the rainfall pattern of any year say 1965 then when would the first plough have occurred, when would the second plough has occurred and so on and so forth can be determined by this table, which I have

discussed earlier and based on the criteria that the farmers use. So we have put it in terms of soil moisture at a top layer depth of 20 centimeters.

And accordingly, the harrowing takes place ploughing and harrowing and sowing takes place again depending on the criteria.

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Table 1. Land preparation operations		
Operation	Date	Condition
Sowing	Harrowing day or 25 June (whichever is later) to 25 July	$S_m 20 \geq 0.6\ S_a 20$
If land is not sufficiently wet to sow till 25 July late/crisis sowing is undertaken		
Late/crisis sowing	Harrowing day or 26 July (whichever is later) to 16 August	$S_m 20 \geq 0.3\ S_a 20$
Day of sowing should be a non-rainy day (rainfall ≤ 0.25 mm)		

Soil depth considered = 20 cm, $S_a 20 = 28$ mm and $S_m 20 =$ available soil moisture.

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- These conditions are applied to ascertain whether an opportunity to plough, harrow and sow occur in any year and ,if so, the plowing harrowing and sowing dates are determined using the same table.
- It was shown that generally the sowing date so determined was within a few days of the sowing date at the agricultural station except when the sowing was not done at the first opportunity at the station.

Now since the input of this model for land preparation and sowing timing is from farmer's knowledge, it is also important to actually see if what we are getting is reasonable in terms of the actual sowing dates that were absorbed. Now because we are going to apply these conditions 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 because we are going to use it for this, it is important to check whether this model is working alright and what we did was to compare the sowing date at the agricultural research station with the sowing date that this model yielded and we found that by and large again the details are in the paper. The sowing date at agricultural research station was within a few days of the sowing date as determined by this model.

So the way the criteria have put in seem reasonable, only difference arose when at the agricultural station, they did not sow at the first opportunity, but the second one. Now here we have assumed as is practiced again in that region that farmers will sow at the first opportunity in their sowing window, which is already put in to the model.

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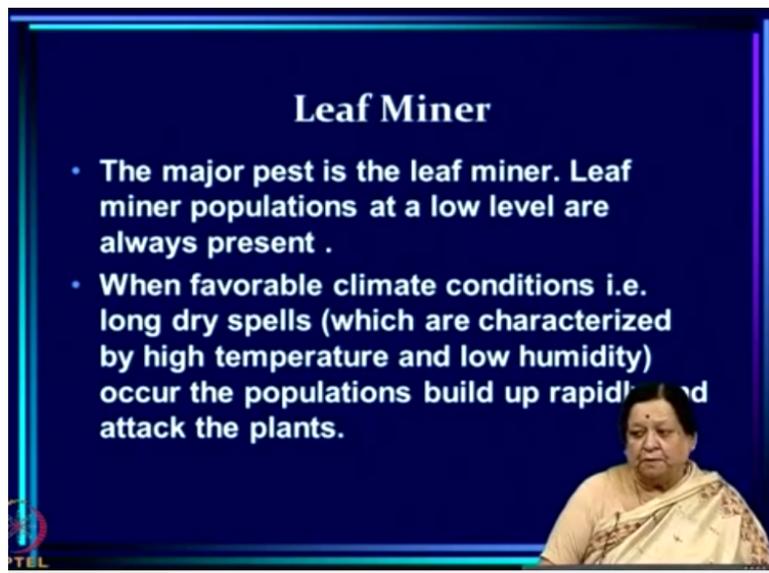
So we are fairly confident that the sowing date that the model yields is reasonable and consistent with what the farmers would have actually got. So one of the major pests of groundnut is leaf minor. Actually what has happened is as I mentioned earlier you know when we had the evolution from the traditional cropping system to the present cropping system, large tracks of land went under monocrop the same groundnut and same variety.

And furthermore very often the life history stages of the plant would also be same over vast regions because people would adopt the same sowing date and so on and so forth. So with this what has happened is that many pests and diseases have become endemic, you know this means that for example if we look at the pest leaf minor, always there is a small population of leaf minor present in these groundnut fields okay.

So there is always a small population present and when favorable climate conditions okay favorable for the leaf minor and adverse as far as the yield is concerned. So when these favorable climate conditions occur, then suddenly the population explodes and attacks the crop. So in particular for the leaf minor, the favorable conditions are long dry spells okay, which are characterized by high temperature and low humidity.

So when they occur, the populations build up very rapidly and attack the plants. So how do we define now?

- We define dry conditions which can promote leaf miner growth in terms of the soil moisture.
- Soil moisture less than 50% of the maximum value is taken as a dry day.
  i.e. $S_m < 0.5*S_a$
- A leaf miner day is defined as one on which the soil is dry (satisfies the above condition) and it is a non-rainy day. We use the IMD definition of rainy day as day with rainfall<0.25mm.
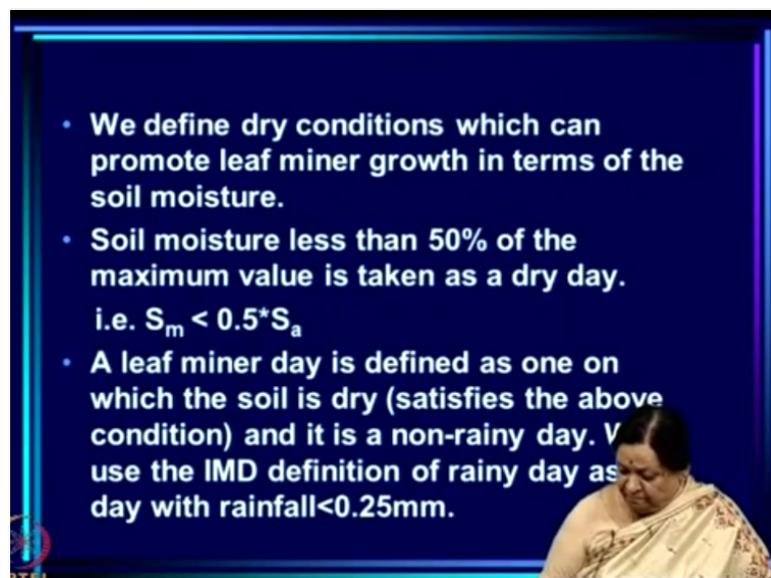
When the leaf minor population is going to build up? So what we do is we define dry conditions, which can promote leaf minor growth in terms of the soil moisture. Soil moisture < 50% of the maximum value is taken as a dry day. So you have soil moisture < 50%, remember Sa was the maximum value that is the total field capacity-wilting point.

So whenever the soil moisture is <50% of the maximum value we take that as a dry day and a leaf minor day is defined as 1 on which the soil is dry that is to say the soil moisture is < 50% of the maximum and it is a non-rainy day. So we use the IMD definition of rainy day as a day with rainfall < 0.25 millimeters. So we use the IMD definition of a non-rainy day as the 1 with rainfall < 0.25 millimeters.
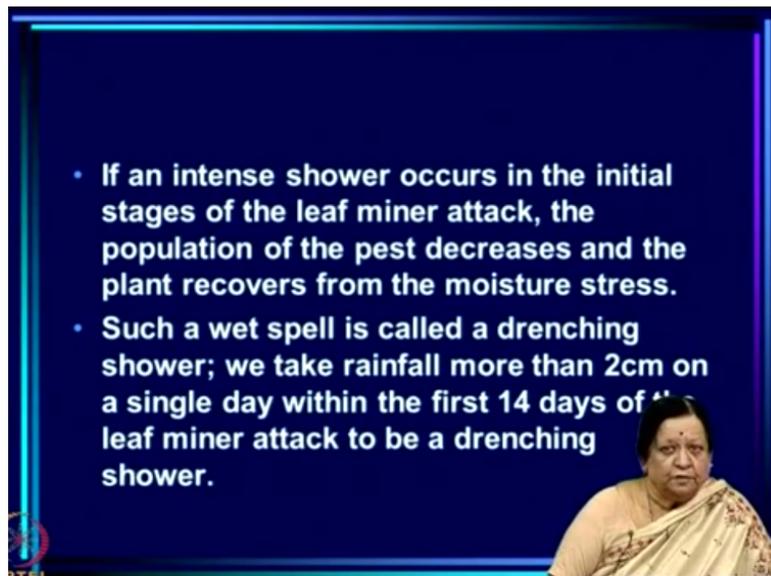
If an intense shower occurs in the initial stages of the leaf minor attack and this again is based on observations in the field by the farmers that in the early stages when the population of leaf minor are building up if there is an intense rain shower then the population of the pest decreases and the plant recovers from the moisture stress.

We should remember that when we talk of leaf minor days not only is it favorable for the leaf minor to grow, it is also unfavorable for the crop to grow because of the moisture stress because it is a dry day so what happens when we get intense shower? The population of the leaf minor decreases and because of the shower the moisture stress experienced by the plant also decreases so the plant recovers from the moisture stress okay.

So such a wet spell is called a drenching shower okay. Now again we have to define what we mean by a drenching shower. So we take the rainfall of more than 2 centimeters on a single day within the first 14 days of the leaf minor attack to be a drenching shower okay. This again is based on the experience of the farmers what should we call a drenching shower. So leaf minor population will start growing when there are leaf minor days.

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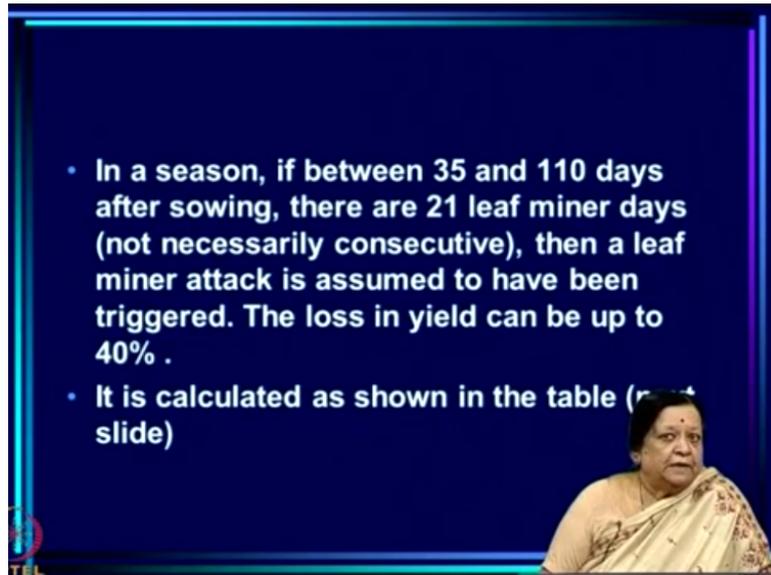
If in the early stages that is to say within first 14 leaf minor days, there is a drenching shower then the leaf minor population will decrease rapidly and we can say that probably there would not be much of a loss. In a season, if between 35 and 110 days after sowing, see 35 days is when the flowering occurs. So if between 35 and 110 days after sowing there are 21 leaf minor days and they do not have to be consecutive.

Then a leaf minor attack is assumed to have been triggered. The loss in yield can be up to 40%.

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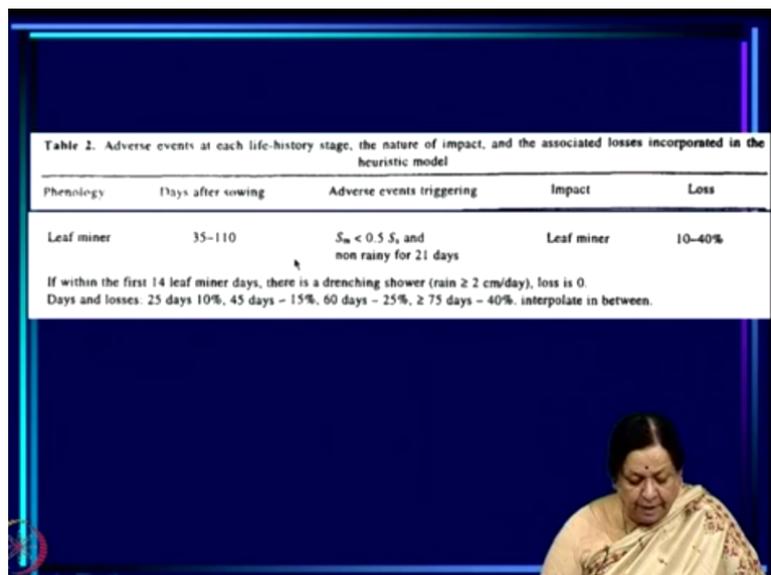
So how do we calculate the loss? We say leaf minor day is after sowing 35 that is when the thing begins to flower and the plant has grown and there are plenty of leaves around 35 days, from then up to harvest which is 110 days after sowing if whenever the soil moisture is<50%

of Sa and non-rainy for 21 days okay. This is the condition under which we expect a leaf minor attack and the loss can be 10 to 40%.

Now there will be an attack provided there is no drenching shower. So if within the first 14 leaf minor days there is a drenching shower that is rain>2 centimeter a day, the loss is taken as 0. Then days and losses so if there are 25 days of leaf minor then we take the loss to be 10%, 45 days 15%, 60 days which is a 2 months long dry spell is 25% and of course 75 days is 40%, but 75 days means the entire time almost after flowering has been dry.

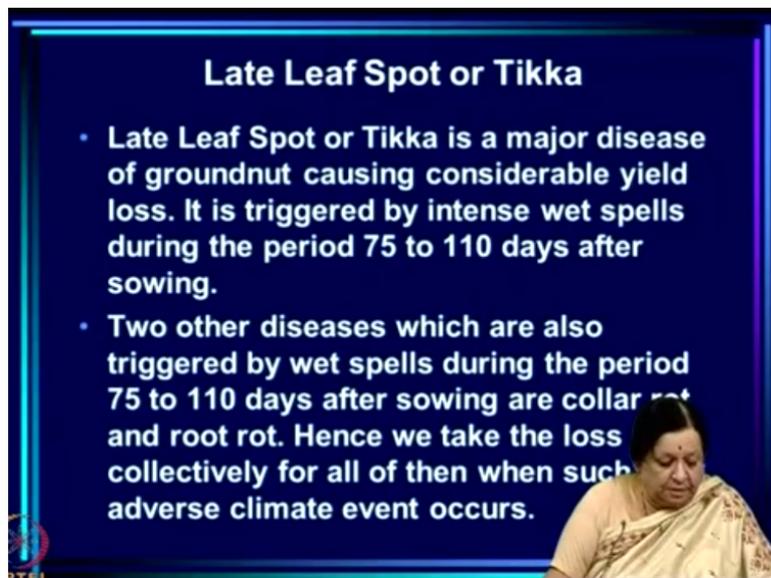So then the plant also is not going survive. So this is how we calculate the loss due to leaf minor depending on how many leaf minor days have occurred in the specific season.

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Now there is another important disease, which is called late leaf spot or Tikka. Late leaf spot or Tikka is a major disease of groundnut causing considerable yield loss. Now while leaf minor pest population increases when there are dry spells, this Tikka infers groundnut when there are wet spells. So Tikka is triggered by intense wet spells during the period 75 to 110 days after sowing.

I should mention that there are 2 other diseases, which are also triggered by wet spells during the same period and these are collar rot and root rot. So what we will do is we will take wet spells between 75 and 110 days to trigger all of them, Tikka as well as root rot, collar rot and then calculate the loss.

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- In the model for each set of three consecutive days with wet soil (i.e. $S_m > 0.9*S_a$), the loss is taken as 5% with a maximum of 20%. If in addition there are 10 more days of wet soil, an additional loss of 5% is assumed.
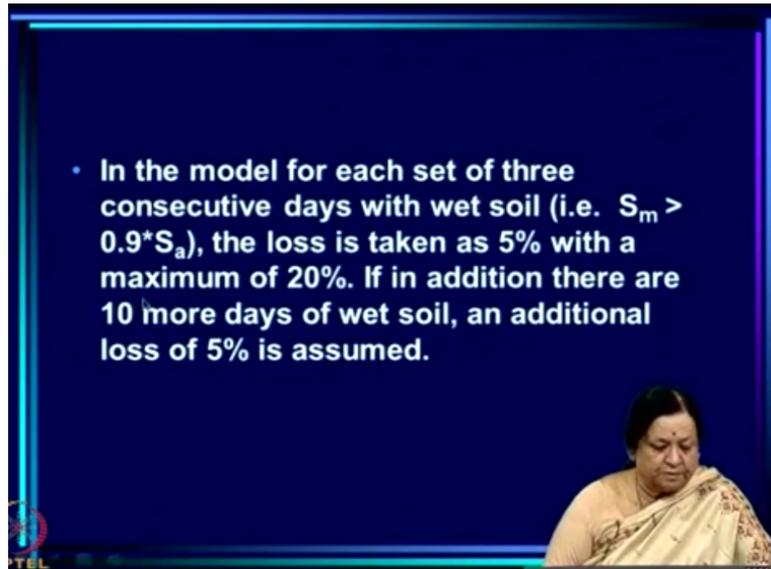
Now how do we calculate the loss? For each set of 3 consecutive days with very wet soil that is soil moisture > 0.9 of the maximum available, which is 90% of the maximum available, the loss is taken as 5%. So each set of 3 consecutive days, which are very wet, the loss is taken as 5% but with an upper limit of 20%. So that if there are more than 4 of these sets then we still take the loss to be 20% even for 5 sets like this.

If in addition to this, there are 10 more days of wet soil and additional loss of 5% is absorbed and this is in fact what is incorporated in the model.

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Validation

- The observations of the incidence of leaf miner or lack thereof as well as the infestation by Tikka or lack thereof simulated by the model were found to generally agree with observations at the agricultural research station.
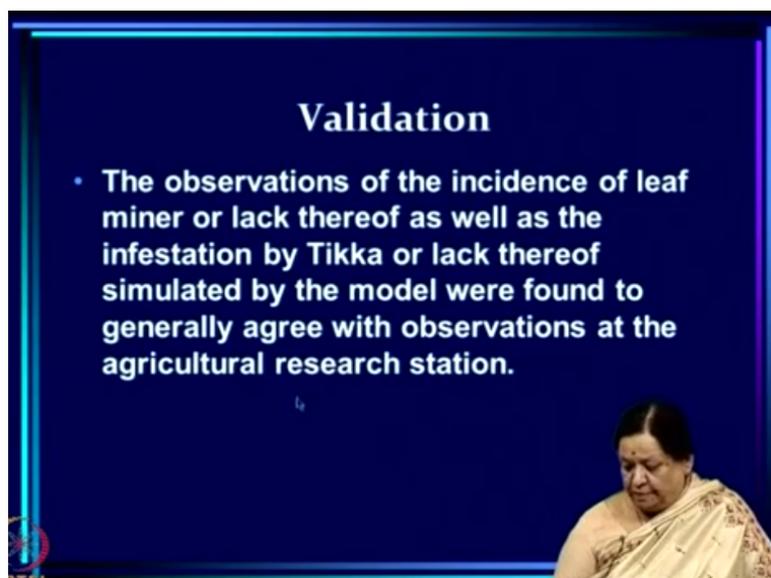
Now it is important again to validate this model because we have based the criteria on the knowledge of the farmers. So we went ahead and validated. There were observations at the Anantapur research station of the incidence of leaf minor and Tikka okay.

And we found that in general they agreed with the model, so whenever model predicted incidence of leaf minor or infestation by Tikka, it was also absorbed in the agricultural research station. So that gives us a little bit of confidence that we have translated correctly the farmers understanding of the triggering of pests and diseases into the criteria we have put in the model in terms of the soil moisture.

And what is the wet spell, what is the drenching shower so on and so forth. So we seem to be on a reasonable right track. See there is another factor that also causes loss of yield to the farmer and this factor is weeds. So generally farmers remove weeds once around 35 days after sowing. So weed grow during 35 to 80 days after sowing can have a very large impact on the yield okay.

So if the soil is very wet that is to say again the same criteria we had used for Tikka that soil moisture is>0.9 times the available soil for 7 consecutive days or rather wet, which is to say > 80% of those maximum available soil moisture for 14 days, a loss of 10% of yield due to the weeds is assumed. So there are 2 conditions either it becomes very wet for 7 consecutive days.

Or it is rather wet for 14 days, which are not necessarily consecutive. Then we assume 10% loss of yield due to weeds.

Table 2. Adverse events at each life-history stage, the nature of impact, and the associated losses incorporated in the heuristic model

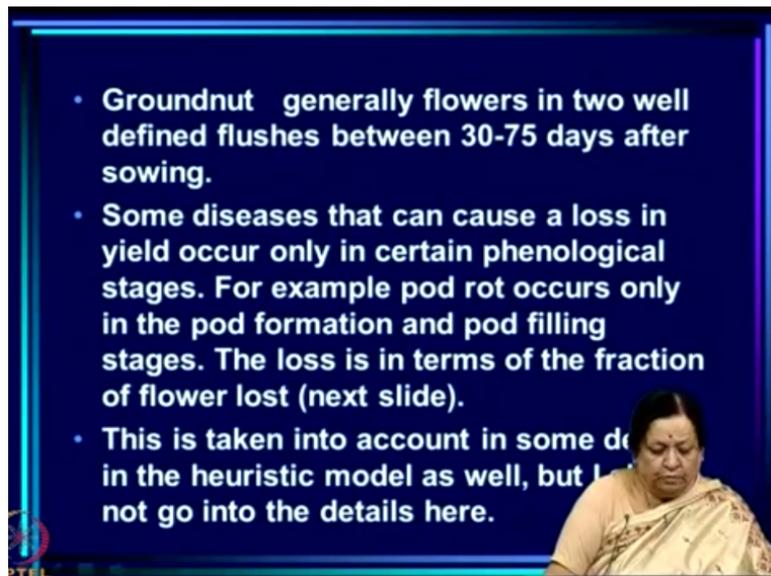| Phenology	Days after sowing	Adverse events triggering	Impact	Loss
Leaf miner	35–110	$S_m < 0.5\,S_s$ and non rainy for 21 days	Leaf miner	10–40%
If within the first 14 leaf miner days, there is a drenching shower (rain ≥ 2 cm/day), loss is 0. Days and losses: 25 days 10%, 45 days – 15%, 60 days – 25%, ≥ 75 days – 40%. interpolate in between.				
Weed growth	35–80	$S_m \geq 0.8\,S_s$ for 7 consecutive days or $S_m \geq 0.8\,S_s$ for 14 days	Weed growth	10%
Late leafspot (tikka)	75–110	$S_m \geq 0.9\,S_s$ for 3 consecutive days or $S_m \geq 0.9\,S_s$ for 10 days	Tikka/ collar rot/root rot	5–25%
For each consecutive 3 days set 5% up to a maximum of 20% + 5% for additional other 10 or more wet days				

So what is the final thing we take into account in this model? Leaf minor and leaf minor actually the adverse events, which trigger the leaf minor is soil moisture < 50% of the maximum available and non-rainy for 21 days okay and the leaf minor loss is taken as 10 to 40% and we have to remember that this loss occurs only if within the first 14 leaf minor days a drenching shower, which we define as > 2 centimeter rainfall in a single day does not occur.

If a drenching shower occurs within the first 14 leaf minor days, then the loss is taken as 0 because it is assumed that the leaf minor population has come down and the plant has become revitalized with this rain. Otherwise, the loss is 10 to 40% depending on how many leaf minor days there are. For 25 leaf minor days, it is 10%, for 45 days 15% and so on.

So we have assumed what is the loss going to be depending on the number of dry days for leaf minor. For weed growth, we have assumed that if soil moisture is great, if the soil is very wet for 7 days or rather wet for 14 days then we get a loss of 10% due to weed growth. Then we have late leaf spot or Tikka, which occurs often, which is triggered along with collar rot and root rot.

Because the same wet spell triggers this, so again we take it in terms of soil moisture that if the soil is very wet for 3 consecutive days or it is rather wet for 10 days okay then for each set of very wet days we take the loss to be 5% up to a maximum of 20% and we add 5% additional loss if there are 10 or more wet days in addition to these sets of 3 consecutive days. So this is how the losses are calculated now.

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- Groundnut generally flowers in two well defined flushes between 30-75 days after sowing.
- Some diseases that can cause a loss in yield occur only in certain phenological stages. For example pod rot occurs only in the pod formation and pod filling stages. The loss is in terms of the fraction of flower lost (next slide).
- This is taken into account in some d[...] in the heuristic model as well, but [...] not go into the details here.

So groundnut generally flowers in 2 well-defined flushes between 30 to 75 days after sowing okay. So far we have said that wet spells or dry spells within a certain period after sowing will trigger such and such pest or such and such diseases, but there are some diseases that can cause a loss in yield, which occur only in certain phenological stages okay. So for example, pod rot occurs only in the pod formation and pod filling stage okay.

And the loss in terms of the fraction of flower lost. So here now we have to do 2 things. We have to determine the phenological stage. When will this pod formation, pod filling occur? And if there was only one single instance of flowering, which we have taken as 35 days that is the first flowering. Then no problem we can actually knowing the stages of TMV-2 we can calculate which days pod formation occurs and when does pod filling occur.

Problem arises because you have 2 flushes of flowering, 1 in the early part 35 days or so and 1 in the latter part. So if we have to calculate the loss due to things like pod rot and so on, we have to do more complicated things. We have to take these 2 flushes of flowers into account and also then use farmer's knowledge to see what the loss will be.

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Table 2. Adverse events at each life-history stage, the nature of impact, and the associated losses incorporated in the heuristic model

Phenology	Days after sowing	Adverse events triggering	Impact	Loss
Germination	0 to 9	$S_m > 0.9\,S_s$ for 2 days	Seed rot	5–10%

5% loss for 2 wet days, 10% for 3 or more wet days

Phenology	Days after sowing	Adverse events triggering	Impact	Loss
1-Flower initiation	25–35	$S_m > 0.9\,S_s$ for 1 day	Flower loss	6–21%
2-Flower initiation	50–60			

	Good		Bad	
1-Batch 1-Flower fraction	$p = 0.7$		$p = 0.4$	
2-Batch 2-Flower fraction	Good / Bad		Good / Bad	
	0.3 0.24		0.45 0.39	
Total flowers (%)	100% 94%		85% 79%	

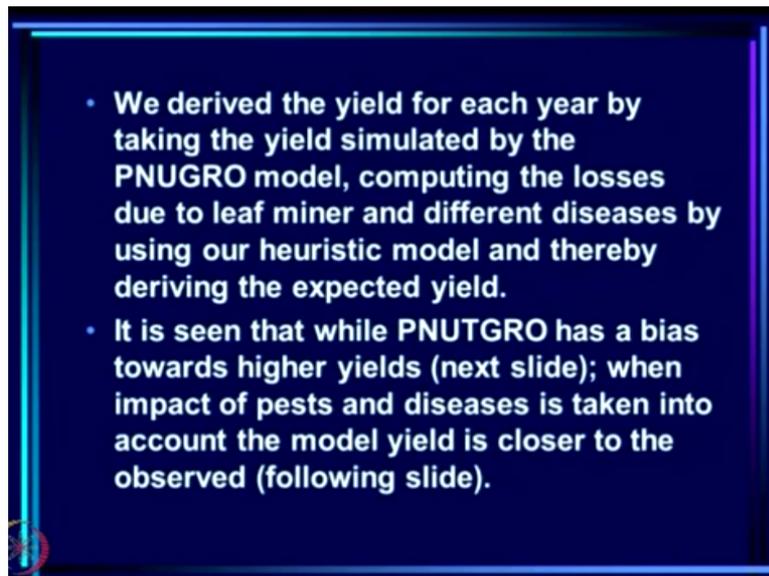| Phenology	Days after sowing	Adverse events triggering	Impact	Loss
1-Pod formation	50–60	$S_m > 0.9\,S_s$ for 3 consecutive days	Pod rot	30% of
1-Pod filling	60–80	$S_m > 0.9\,S_s$ for 5 consecutive days	Pod rot	
2-Pod formation	75–85	$S_m > 0.9\,S_s$ for 3 consecutive days	Pod rot	
2-pod filling	85–105	$S_m > 0.9\,S_s$ for 5 consecutive days	Pod rot	

And this is much more complicated and I am actually not go into details of this, but except to say that there is 1 more disease I did not mention, which is seed rot. So if we have wet spell for even 2 days within the first 9 days after sowing, seed rot can occur okay and this can lead to a loss of 5 to 10% depending on how wet it was and how long it was wet and so on and so forth.

Now let us come back to the pod rot problem. So what happens is that we have flower initiation somewhere between 25 and 35 days and whether it occurs, the conditions are given. Then we have the first batch of flowering and there is a relationship between the first batch of flowering and second batch because after all the plant is the same plant. So there are many conditions to be looked into.

And at the end of it what we find is that the total number of flowers okay. If the first one was good then it would be 100%, if the second one was good it would be 85% and so on. So there has to be a calculation done of the flower fraction that remains after the 2 batches of flowering and during pod formation and pod filling, which for the first batch would occur between 50 and 80 days and second batch between 75 and 105 days.

We have conditions of wet soil which give rise to pod rot and actually as I mentioned before the losses are in terms of what fraction of the flowering is destroyed by the pod rot okay. So this all has to be taken into account and in the full-fledged heuristic model that we had developed, all this was indeed taken into account, the loss of flowers and so on and so forth in calculating the final yield okay.

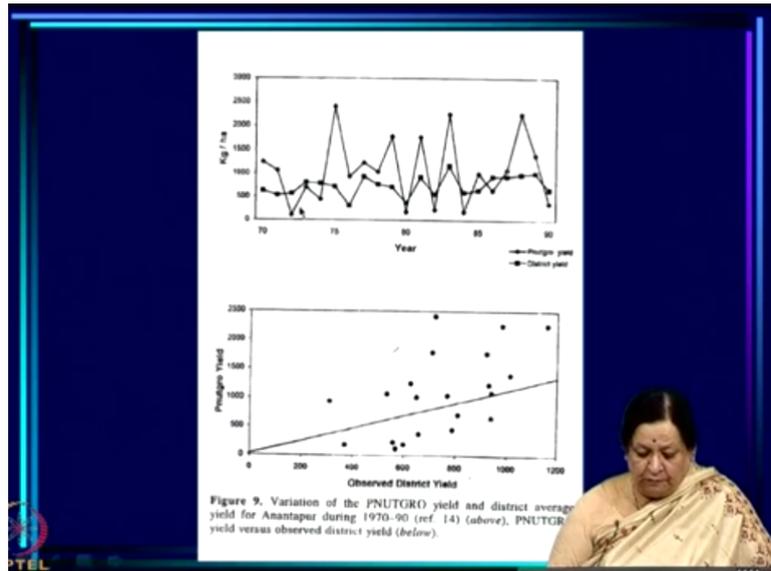So now we have the apparatus ready, the model ready to estimate firstly what sort of pests and diseases will attack whether leaf minor will attack, whether Tikka will attack and so on and so forth and if so what the loss would be okay? Now question is loss from what? We already know that the PNUTGRO model is a pretty good model for the direct impact of rainfall variability.

It captures the year to year variation in yields induced by rainfall that is to say PNUTGRO model actually is a good model for growth and development of the plant in the phase of rainfall variability. This we know, now what we want to do is add one more factor triggering of pests and diseases by rainfall variability and to do that we have developed this heuristic model.

So how do we now apply the heuristic model to get what would be the expected yield when pests, diseases or weeds do attack the crop? So what we do is that in fact we assume that the PNUTGRO model will give 100% of the yield. In other words, the yield obtained by PNUTGRO we take as 100% and from that did of the losses as computed by the heuristic model.

Figure 9. Variation of the PNUTGRO yield and district average yield for Anantapur during 1970-90 (ref. 14) (above), PNUTGRO yield versus observed district yield (below).
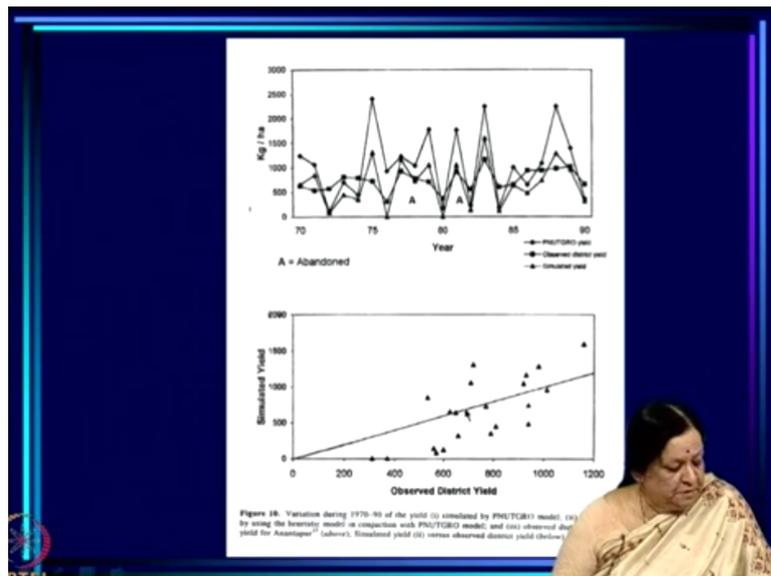
Let me just elaborate on this. First of all, let us see how does PNUTGRO look versus district yield? This is the time series we have already seen that when the PNUTGRO yields are very, very high. They are much higher than the district yields obtained. So a nice way to look at it is PNUTGRO yield versus district yield and what you find the buyers that I mentioned.

That in general PNUTGRO yields tend to be higher than district yield is very clear on this scatter plot of PNUTGRO yield versus observed yield where you know if it was a perfect thing it would have been on this straight line. In fact, there are some points at which PNUTGRO is<observed yield, but by far the larger number of points correspond to PNUTGRO more than the district yield.

So you can see the bias of PNUTGRO in over estimating the district yield. This is very nicely brought out in this slide.

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Figure 10. Variation during 1970-90 of the yield (i) simulated by PNUTGRO model, (ii) by using the heuristic model in conjunction with PNUTGRO model; and (iii) observed district yield for Anantapur[17] (above). Simulated yield (ii) versus observed district yield (below).

Now in the following slide you will see what happened when we applied the heuristic model, so here is the PNUTGRO model, here is what we get from the heuristic model and here is the observed district yield and you find that by and large in fact for example here we have got it on the dot. This is PNUTGRO which was over estimating and with the losses that we calculated from the heuristic model what we get is very, very close to the district yield here.

So what has happened now? We have corrected further yields in PNUTGRO by applying our heuristic model and estimating losses due to pests, diseases and weeds, which were not incorporated in the PNUTGRO model and have it appears got a better fit with the observed district yield and that is what you see here unlike the earlier one where there was a clear bias with more points above the line, which you saw here.

See here there are far more points above the line. In this case, in fact that does not happen and the line is sort of in between in the middle of the cloud of points. Of course, they will not be exact match between either of the models even with the corrected model with this because there are many other factors that come into play in determining the groundnut yield, but overall we seem to have removed the bias that was there in the crop model.

Because it did not take pests and diseases into account. Now you may ask the question okay so what? What is the use of doing this model?

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Application of such models

- Such models for the impact of pests diseases and weeds are useful in two kinds of decision support systems.
- (i) management operations after a specific variety is sown e.g. whether to spray or not spray a pesticide: important factor in this decision is the additional cost and expected benefit in terms of the enhanced yield. On the basis of probabilities of th attack of specific pests/diseases deriv from such models the cost/benefit o of the strategies could be estima

So let me talk a little bit on the application of such models. Such models for the impact of pests and diseases and weeds are useful in 2 kinds of decision support systems. Now eventually we are trying to do a study all this so that we can help the farmers to make a decision, which will be optimum so that he will get maximum yield or minimum risk of crop failure.

So how will these models help? They can help in management operations after a specific variety is sown okay. They may help in the decision whether to spray or not spray a pesticide. Important factor in this decision is the additional cost and expected benefit in terms of enhanced yield. On the basis of probabilities of the attack of specific pests and diseases derived from such models, the cost benefit of each of the strategies could be estimated.

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- For example, we find that the probability of a dry spell which promoted leaf miner is 93%. In about 30% of such years, a drenching shower occurs, implying that no spraying is necessary. Hence once leaf miner have started growing, the probability that a pesticide would be useful is about 65%. This information could be used in deciding the optimu strategy.

For example, we find that the probability of a dry spell which promoted leaf minor is 93%, this is on the basis of 88 years of data at Anantapur and we find that chance of getting leaf minor attack is 93%, but in about one third of these cases 30% of such years, there was also a drenching shower. Once a drenching shower occurs, there is no loss right. So hence once leaf minor has started growing, the probability that a pesticide would be useful is 65% right.

So on 65% of the occasions, a pesticide would be useful because you are going to get leaf minor growing in the crop. So this information could be used in deciding the optimum strategy and I will talk of bit a more about the optimum strategy in the latter part of the same lecture.

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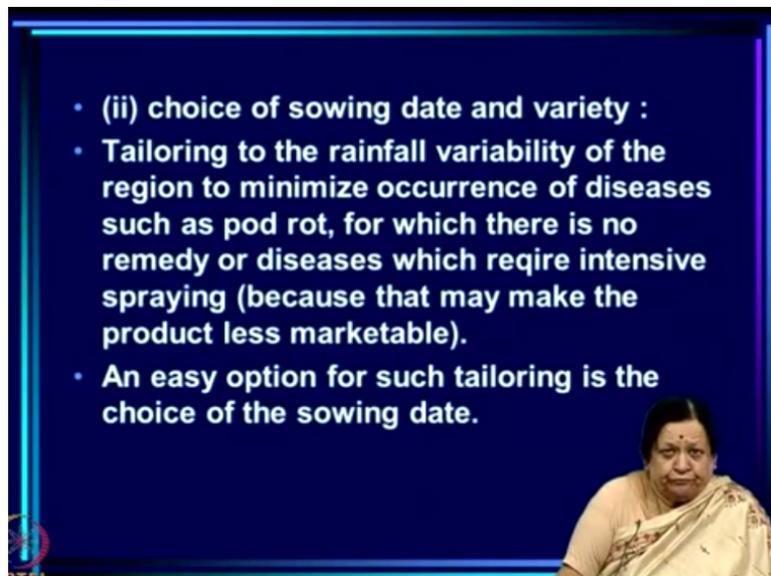
Now choice of sowing date and variety, see we have our earlier thinking that we are given the variety and it is already sown and we can see whether the model will give useful in push to decision making after that, but the question is how do we choose the sowing date and how do we choose the variety given the rainfall variability of a region?

For that tailoring to the rainfall variability of the region to minimize occurrence of diseases such as pod rot for which there is no remedy or diseases which require intensive spraying this model can be useful. Now why do you want to avoid intensive spraying because increasingly there has been a realization that one should not consume too much of pesticides, so spraying pesticides on crops is a harmful thing.

And there is a growing market now for what are called organic crops or crops which are grown without spraying pesticide. So given this kind of a demand, you may want to adjust your sowing date so that in the critical stages for attack of crops, you do not get adverse weather events. See this is another way by which one could do it and as I said easy option for tailoring is choosing the sowing window.
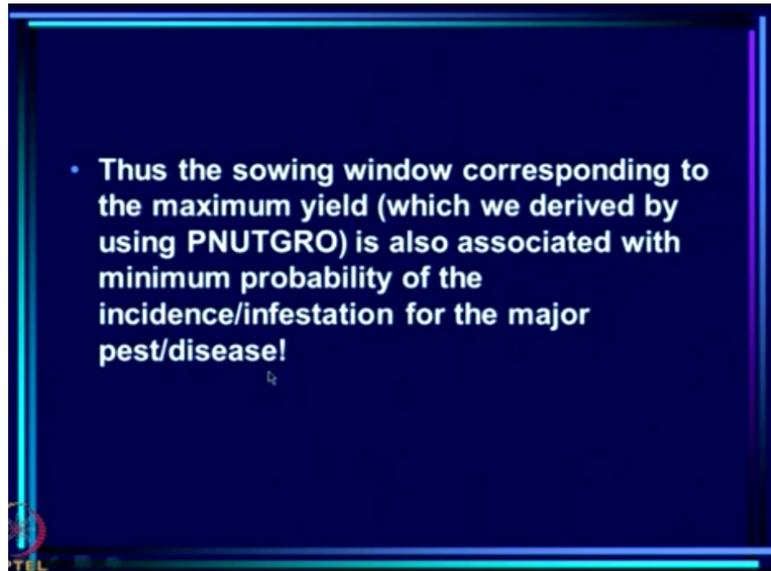
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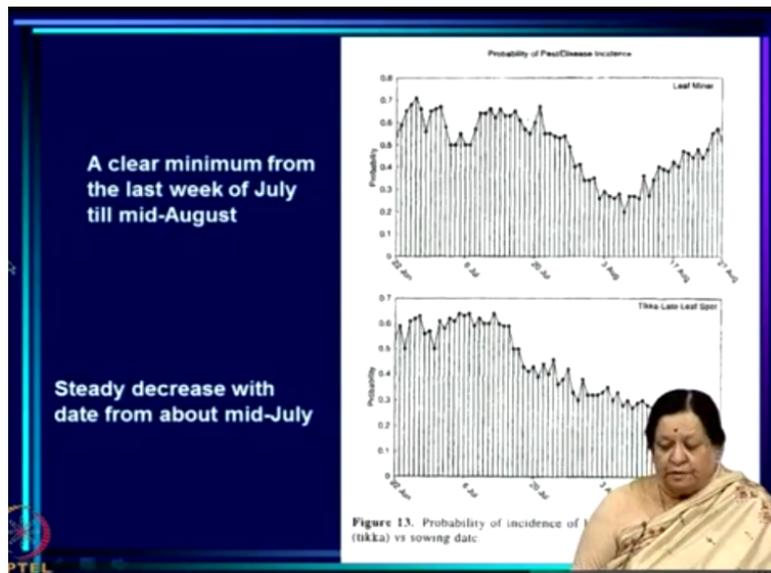
And when we use this same model that I talked about heuristic model and checked what is the probability of occurrence of leaf minor and of Tikka given a sowing date. This is the probability of leaf minor and you find that up to 20th July or so the probability of attack of leaf minor is very, very high. This is because there are a lot of dry days in July, August in this region.

Then this probability dips and it is rather low in this period here from about last week of July till about first week of August. So this is when the probability of leaf minor is low. Tikka also the probability of attack is very high for early sowing up to 20th July and then it decreases steadily okay.

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- Thus the sowing window corresponding to the maximum yield (which we derived by using PNUTGRO) is also associated with minimum probability of the incidence/infestation for the major pest/disease!
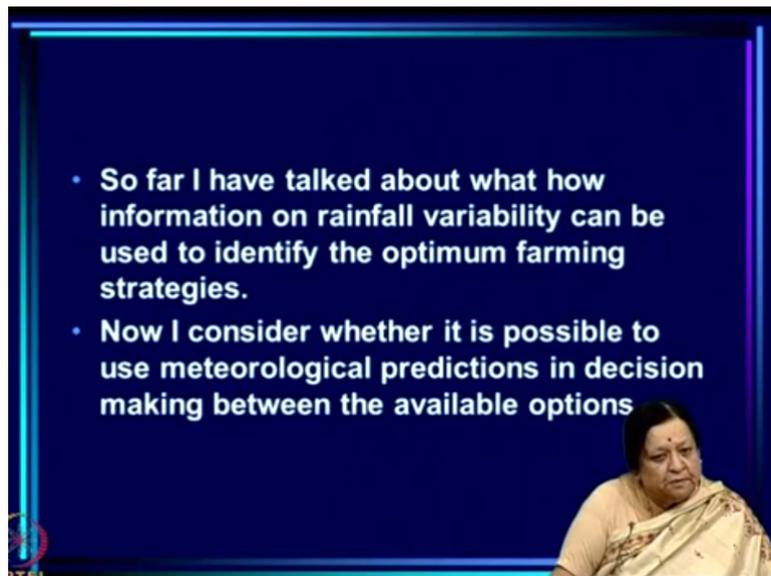
So this is very interesting because what is it saying? You remember that when we talked of what is the optimum sowing window for this region? We found that actually within the sowing window that the farmers have which is from 22nd June to about 17th August or so. We found that the latter part of the sowing window, which is from 20th July or so till mid-August is more favorable for maximizing yields.

Now it turns out that it is the same part, which is also more favorable if we want to avoid leaf minor. You see first part of that sowing window that the farmers use, the probability of leaf minor is very high and the probability of Tikka is also very high. So if we want to minimize losses due to Tikka or in leaf minor also, then it is very interesting that the same window is what is being recommended namely the latter part of the existing sowing window okay.

So this gives you an example of what we could do to get closer to reality in terms of district yields and how we could use this model to then help in making decisions.

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- So far I have talked about what how information on rainfall variability can be used to identify the optimum farming strategies.
- Now I consider whether it is possible to use meteorological predictions in decision making between the available options

Now so far I have only talked of how knowledge of rainfall variability can be used in decision making? How a choice of sowing window? You know how the optimum sowing window can be determined given the rainfall variability of the region and so on and so forth. Now remember all these prescriptions that depend on rainfall variability are the same year to year.

Because rainfall variability is summary statistics of how rainfall has behaved over the region over so many years okay, but now we have all heard of meteorological predictions that they are actually predictions of how the rainfall will be in the next few days or in the next week or within the next 2 weeks okay. Slowly meteorologists are improving the skill at which we can forecast these events even for larger time scale than 2, 3 days.

Two, 3 days already the forecast are pretty good. Now slowly they are beginning to make a head way into predicting things like wet spells and dry spells at much earlier that is to say few days in advance, 10 days in advance or so. So hopefully those predictions will improve. Now will it be possible to use these meteorological predictions also for decision support system?

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And as I said here I have been discussing dry spells and wet spells and we have considered probabilities of occurrence of these events for our study area and information about these climatological probabilities is an important input into the decision support system and the question is if we can predict these events can that actually improve the decision making?
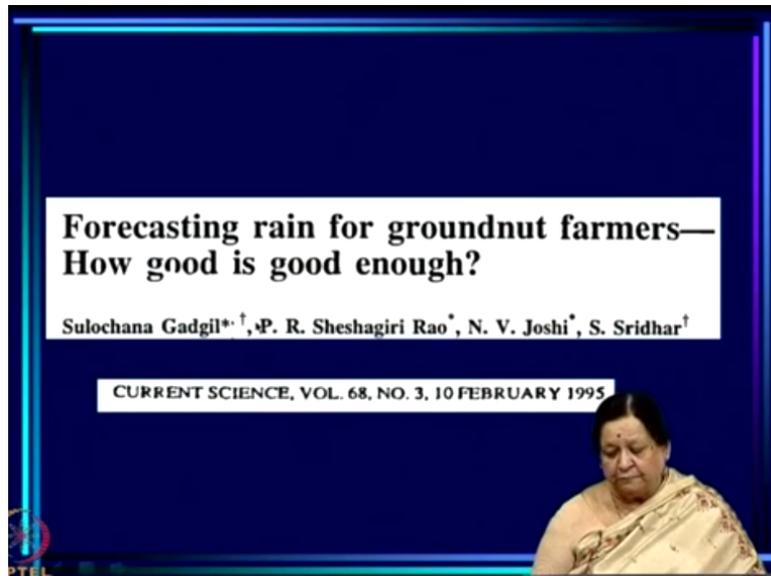
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So the first response would be-of course any additional input would be useful is not it? This is what one would think a priory because the more the merrier, the more input you get the more you know about the system the better of you will be in managing it. This is what would be one's gut feeling, but this response does not take into consideration the fact that forecast are never 100% reliable.
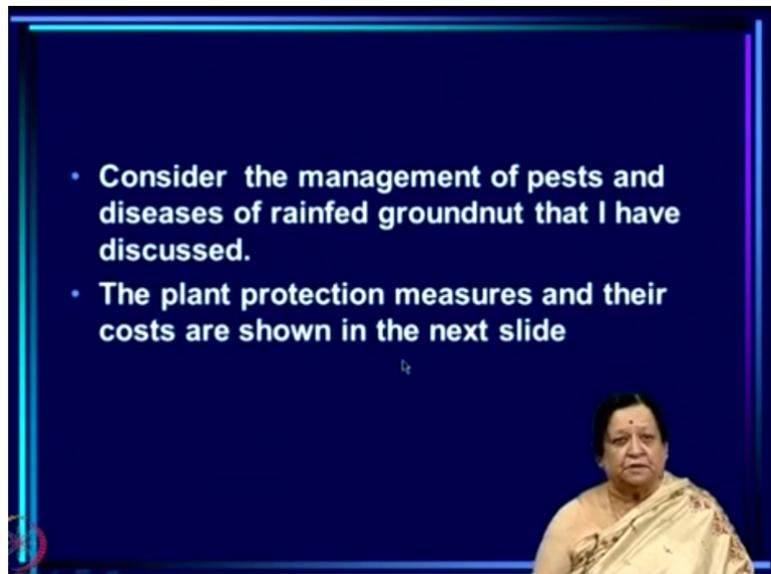
So given that there is a certain probability of the forecast being accurate one can derive for which decisions it would be useful okay

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Forecasting rain for groundnut farmers—How good is good enough?

Sulochana Gadgil[*,†], P. R. Sheshagiri Rao[*], N. V. Joshi[*], S. Sridhar[†]

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And this is very interesting and this is in fact one of the first problems we addressed as a group. This is forecasting rain for groundnut farmers-how good is good enough okay. How reliable and how much skill does the forecast have to be generated for it to be useful?

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- Consider the management of pests and diseases of rainfed groundnut that I have discussed.
- The plant protection measures and their costs are shown in the next slide

Now this is a very interesting concept so I thought I will discuss that here. So what are we doing? We are talking of management of pests and diseases of rainfed groundnut, which we have discussed and plant protection measures and their costs are shown in the next slide.

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Table 1. Cost-loss estimates for major pests/diseases

Disease/pest incidence	Cost of plant protection measure	Typical loss
Crown rot in seedling stage	Seed treatment by Dithane M-45 5 g/kg of groundnuts (40 kg seeds/acre) at Rs 36/acre	8–10%, i.e. Rs 320–400/acre
Late Tikka disease	Bavistein 1 5 g/l and 250 l/acre at Rs 345/acre	30–45%, i.e. Rs 1200–1800/acre
Leafminer in peg formation stage	Two sprays of Chloropyrephas at an interval of 15 days at 2 ml/l using 250 l/acre at Rs 750/acre	25–92%, i.e. Rs 1000–3600/acre

The estimate costs of the protection are based on the present prices ... emicals and labour.
Typical yield is assumed to be 4 quintals per acre at Rs 1000 ...

So we have crown rot in seedling stage, which is what we called seed rot and there is a cost of plant protection measure. This is a pesticide that you can use and the cost is given here and the typical loss is also given, it is only 8 to 10% okay. Similarly, we have talked of Tikka disease and what would you have to do to curtail it. So this is the pesticide you have to use and the typical loss is 30 to 45%, which is again translated in terms of rupees here.

Similarly, leaf minor, what would you need to control leaf minor? Two sprays of this one and this is the kind of intensity we need and this is the cost you will get, cost of spray and leaf minor can lead to a huge loss of 25 to 92%. So estimate of cost of protection are based on the prices of chemicals in 1999. Of course, they would have all gone up and typical yield is assumed to be 1000 okay.

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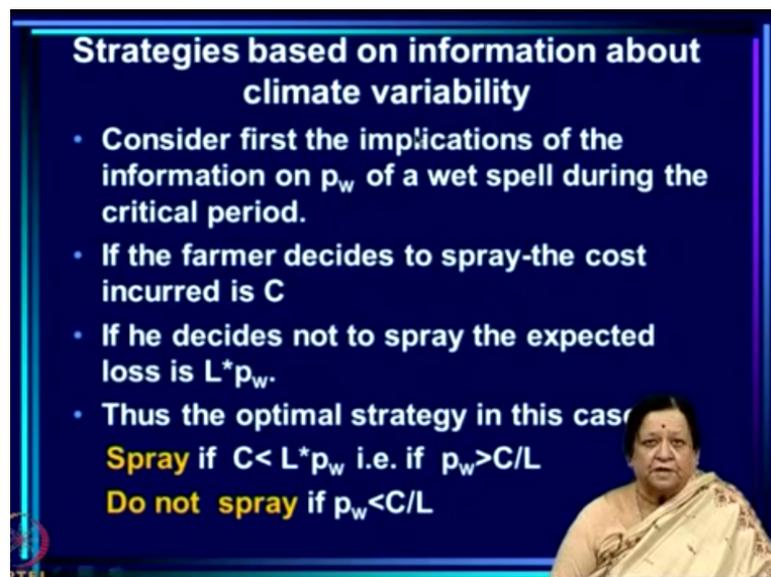

To spray or not to spray?

- Remedial measure cost C
- If not applied and if the adverse event (e.g. wet spell) occurs the loss in productivity is L.
- Let the probability of the wet spell be p_w.
- We take the optimum strategy to be one which maximizes the long-term average returns to the farmer by minimizing effective cost i.e. cost of remedial measure, or the expected loss as ... may be.

So the question is to spray or not to spray? That is the question before the farmer and he already has information on the climatological probability of dry or wet spells, which lead to the pest or disease okay and let us now to be concrete consider only a pest here okay. So that is why we are thinking of spray or not to spray a pesticide.

So remedial measure is cost C if not applied and if the adverse event example a wet spell occurs, the loss in productivity is L okay which is what we had seen in the earlier table. Now let the probability of the wet spell be p subscript w, pw is the climatological probability. We know what the wet spell is, we can derive from the rainfall data what is the climatological probability of the wet spell occurring in the critical stage let that be pw.

Now we take the optimum strategy to be 1, which maximizes the long-term average returns to the farmer by minimizing the effective cost that is cost of remedial measure or expected loss as the case may be and I will explain what I mean.

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So let us look at first strategies based only on information about climate variability, which is what we had looked at. So consider first the implication of information of pw, climatological variability of a wet spell during a critical period. If the farmer decides to spray then the cost incurred by him additional cost over and above is other cost is C and if he decides to not to spray, the expected loss is L* this pw.

Because pw is the probability of the adverse event occurring. So expected loss will be the product of the loss that would have occurred if the adverse event occurred times the

probability of the wet spell occurring. So it is L*pw. Thus the optimal strategy in this case has to be we want to minimize this effective cost, which is C or L* this. So if C is<this, if the cost is<the expected loss right then we should spray because if the cost is<the expected loss then clearly spraying is useful.

So we have if the probability of wet spell is>cost/loss then the farmer should spray and the farmer does not spray if the probability is<cost/loss okay. So this is how it works out that we are trying to minimize see we want to have minimum of C, L*pw okay. So if C is < L*pw we want to ensure that this is minimum right and therefore we want to have probability of wet spell > C/L.

If probability of wet spell is < C/L then one does not spray okay.

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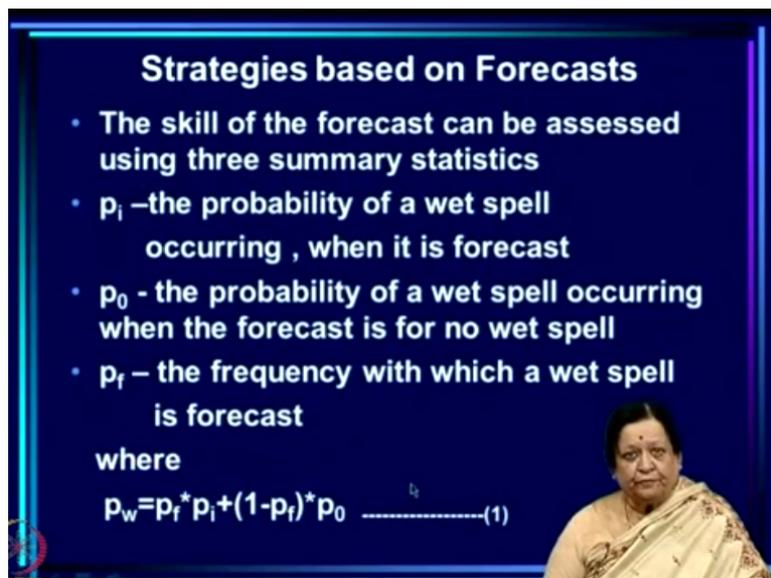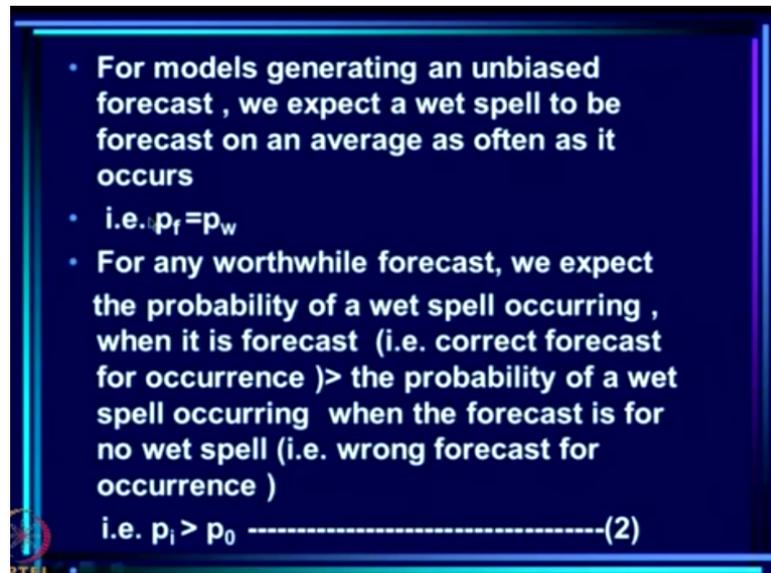

Now look at skill of forecast. Now skill of forecast can be actually assessed by using 3 statistics, pi which is the probability of a wet spell occurring when a wet spell is forecast, this means correct forecast of the wet spell, but there are also probabilities of wrong forecast, which is to say probability of wet spell occurring when no wet spell was forecast, this wrong forecast is po and pf is simply the frequency with which a wet spell is forecast right.

Now the 3 are related because probability of a wet spell occurring is simply the frequency with which a wet spell is forecast times how often it was correct, which was pi+1-pf is the frequency with which it was not forecast times the forecast turning out to be wrong right. So

if it was not forecast and the forecast was wrong this is the number that you get. If it was forecast and the forecast was right, then this is the number.

So totally the climatological probability pw is given by this.

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- For models generating an unbiased forecast , we expect a wet spell to be forecast on an average as often as it occurs
- i.e. $p_f = p_w$
- For any worthwhile forecast, we expect the probability of a wet spell occurring , when it is forecast (i.e. correct forecast for occurrence)> the probability of a wet spell occurring when the forecast is for no wet spell (i.e. wrong forecast for occurrence)
- i.e. $p_i > p_0$ ----------------------------------(2)

Now for models generating an unbiased forecast, we expect a wet spell to be forecast on an average as often as it occurs that is to say pf the frequency of wet spell forecast should be the same as climatological forecast. Now secondly for any worthwhile forecast we expect the probability of a wet spell occurring when it is forecast that is correct forecast for occurrence to be>the probability of wet spell occurring when the forecast is for no wet spell okay.

At least the probability of correct forecast of wet spell should be more than probability of wrong forecast of wet spell. This is for any worthwhile forecast. So we have pi > po.

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Now we can combine those 2 and get pi > pw > po that is to say the probability of correct forecast of wet spell is greater than the climatological probability of wet spell, which is greater than probability of wrong forecast of wet spell okay. For worthwhile forecast must be better than climatology. This is common knowledge to meteorology. See unless you can do better than climatology there is no point in generating forecast.
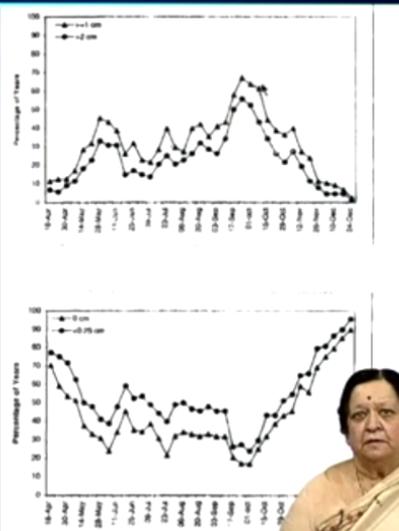
Now constraints on how large this correct forecast probability has to be and how small the wrong forecast probability has to be depends now on the climatological probability.
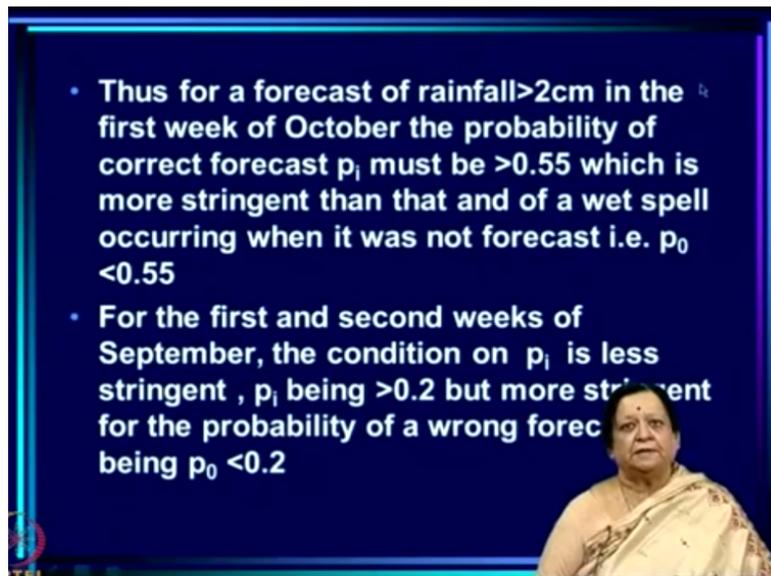
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So without dwelling on it if we are in this part first week of October.

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- Thus for a forecast of rainfall>2cm in the first week of October the probability of correct forecast p_i must be >0.55 which is more stringent than that and of a wet spell occurring when it was not forecast i.e. p_0 <0.55
- For the first and second weeks of September, the condition on p_i is less stringent, p_i being >0.2 but more stringent for the probability of a wrong forecast being p_0 <0.2
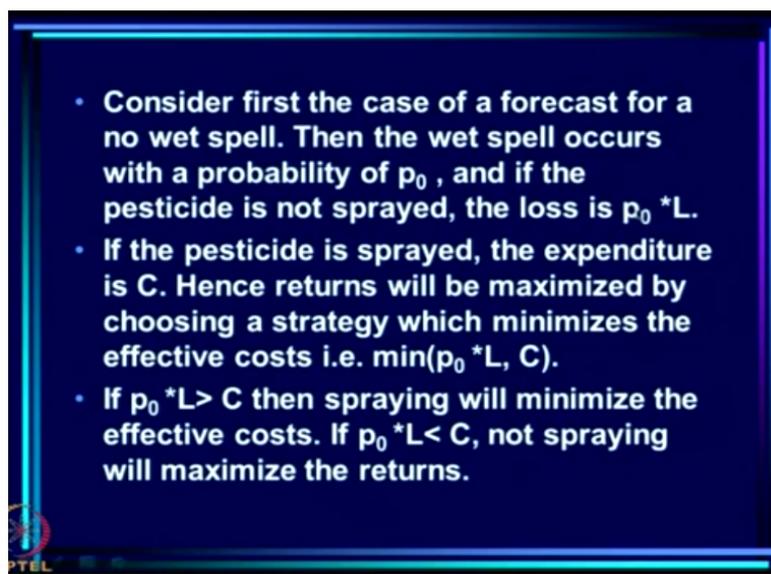
Then you know pw which is the climatological probability is high it is 0.55 which means that pi must be > 0.55, your probability of correct forecast has to be rather high more than 0.55, but the constraint is not so much on the wrong forecast because probability of wrong forecast has to be < 0.55, which is not a very strong constraint.

On the other hand, if we go back to the first and second weeks here of September then the number is more like 0.2 and so we get the condition on pi is less stringent because pi being > 0.2 correct forecast probability should be > 0.2, but wrong forecast probability should be < 0.2. So this is more stringent here.

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- Consider first the case of a forecast for a no wet spell. Then the wet spell occurs with a probability of p_0, and if the pesticide is not sprayed, the loss is p_0 *L.
- If the pesticide is sprayed, the expenditure is C. Hence returns will be maximized by choosing a strategy which minimizes the effective costs i.e. min(p_0 *L, C).
- If p_0 *L> C then spraying will minimize the effective costs. If p_0 *L< C, not spraying will maximize the returns.
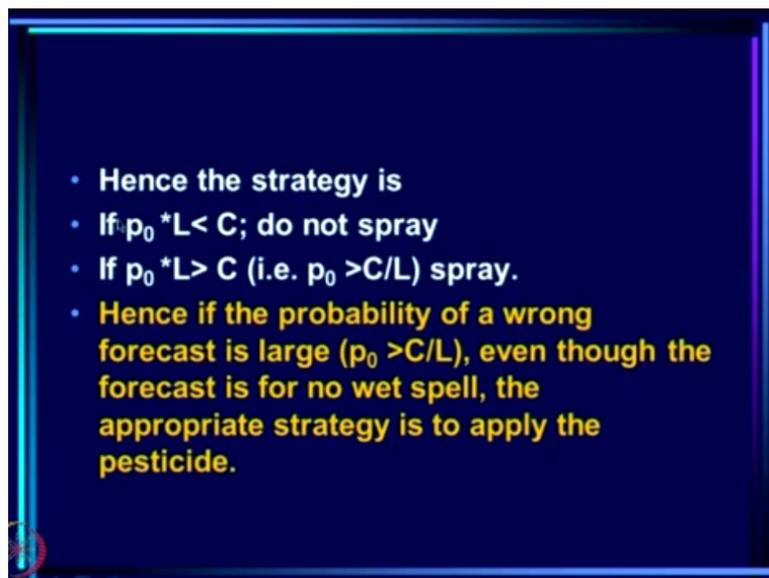
So it all depends on the climatological probability. Now consider first the case of a forecast for a no wet spell. Then the wet spell occurs with the probability of p0 because this is the

probability of the wrong forecast and if the pesticide is not sprayed okay. See the forecast is for no wet spell so the farmer decides not to spray the pesticide. So if the pesticide is not sprayed, the loss is p0*L.

Because p0 is the probability of the wet spell occurring despite the forecast so the loss is expected loss is p0*L. If the pesticide is sprayed, the expenditure is C right. Hence returns will be maximized by choosing a strategy, which minimizes the effective cost, which is the minimum of p0*L and C right. Now if p0L > C okay then spraying is better because this is large.

And therefore if p0L < C then not spraying is better because we want to minimize the 2. So you have to make sure that the higher one is not spent on. So if p0L > C then spraying will minimize and if p0L < C not spraying will maximize the returns.

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- Hence the strategy is
- If p_0 *L< C; do not spray
- If p_0 *L> C (i.e. p_0 >C/L) spray.
- Hence if the probability of a wrong forecast is large (p_0 >C/L), even though the forecast is for no wet spell, the appropriate strategy is to apply the pesticide.

So what is the strategy if p0L < C, do not spray or if p0L > C or that is to say if p0 > C/L then you spray that is to say remember now the forecast is for no wet spell right, but if p0 > C/L that is to say probability of wrong forecast greater than cost versus loss then the recommendation is to spray. That is to say if the probability of a wrong forecast is so large compared to C/L even though the forecast is for now wet spell, the appropriate strategy is to apply the pesticide.

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So it is saying that everything depends on the ratio C/L when a wet spell is forecast analogously we get expected loss as piL and the cost of spraying C and hence exactly like the before the returns can be maximized by strategy, which implies minimum of piL and C so it says if this piL < C, you should not spray. If piL > C, you should spray. That is to say you should remember the forecast is now for a wet spell.

So if were to go according to the forecast you should spray, but you should spray only if the probability of forecast being right is > C/L. So if the probability of correct forecast is small or of the wrong forecast is large, the strategy recommended is opposite to the forecast. So here if the correct forecast < C/L strategy recommended is not to spray even though a wet spell if forecast.
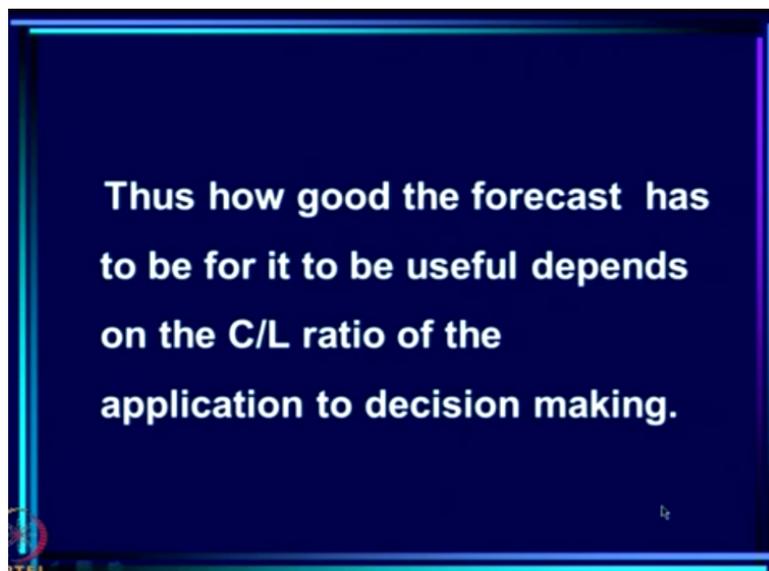
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And I will not get into too many details now except to say that since probability of correct forecast is>the climatological probability, which is greater than the probability of wrong forecast. When you have that the probability of correct forecast is < C/L then if probability of this itself is < C/L, then pw is < C/L. This means you remember our discussion on climatological info.

That if the probability of wet spell is small, so the probability of wet spell is < C/L so hence the recommended strategy of not to spray is the same. You would say probability of wet spell is small so do not spray and that is exactly what you get by recommendation. Same thing we can see if what happens when wrong forecast probability is > C/L that also implies that what you are doing then is going against what the forecast says.

But exactly what the climatological probability would tell you to do, so when we get a strategy depending on climatological probability we can add to that in terms of decision making only if probability of the correct forecast is > C/L and probability of the wrong forecast is < C/L. So use of forecast will yield a different strategy from what you would have got from climatological information only if probability of wrong forecast is < C/L, which is less than probability of the right forecast.

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Thus how good the forecast has to be for it to be useful depends on the C/L ratio of the application to decision making.

So the take home lesson is that how good the forecast has to be for it to be useful depends on the C/L ratio, C is the additional cost incurred and L is the expected loss due to the attack of the pest okay. So it depends on what application you have in mind for decision making. You cannot have a blank statement saying a forecast is good or bad for it to be useful in a specific

application you have to see whether the probability of correct forecast is actually larger than C/L.

And probability of wrong forecast of the same event that is to say event occurring when it was not forecast is < C/L. So it all depends on what applications you have in mind. You will be surprised to know how many meteorologists are in fact ignorant of this basic fact and talk of skill of forecast being good for the farmers or good for application without reference to the specific application you had in mind.

Or the specific decision that the farmer was going to make based on the forecast, so this is an important take home lesson and what we have learnt in these set of lectures is that there is a lot to be learned from analysis of the climate variability of the region, a lot can be achieved by tailoring either the crops, varieties or management practices such as sowing date to the rainfall variability of the region.

About that there is no doubt that one could get better yields by doing this, one can also get less losses by pests and diseases by tailoring to climate variability. Over and above that if we have very good forecast that is icing on the cake and those forecasts; however, have to be good for the application in mind.

The probability of correct forecast of that adverse event has to be > C/L, which is the critical ratio that comes out of here, critical parameter which has to be greater than the probability of wrong forecast. That is to say event occurring when it was not forecast only then forecast will add value and decision making of the farmer will gain because of the forecast and yields over rainfed regions which are so sensitive to climate variability will actually improve. Thank you.