The Monsoon and its Variability

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Lecture - 35
Monsoon Variability and Agriculture - Part 1

Today I am going to talk about Monsoon Variability and Agriculture.

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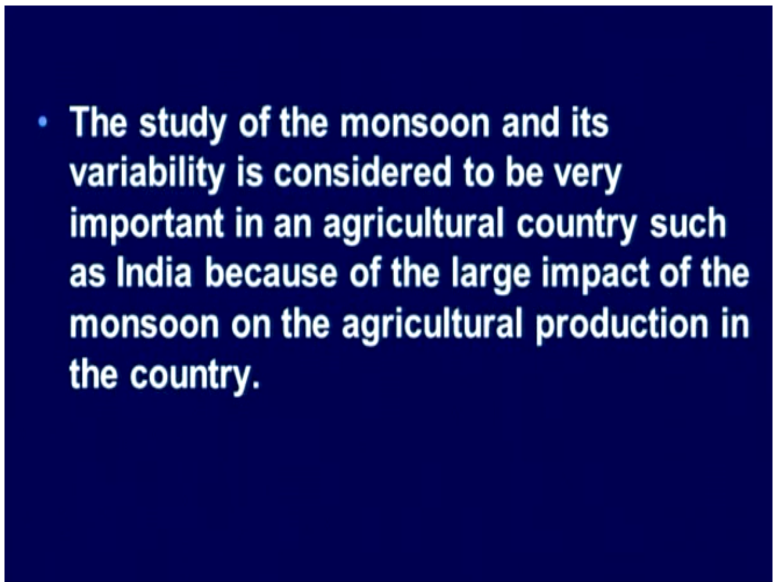

You know study of the monsoon and its variability is considered to be very important in an agricultural country such as India, because of the large impact of the monsoon on the agricultural production in the country, in fact a large number of papers on the monsoon begin with stressing the fact you know how important monsoon is in an agricultural country such as India.

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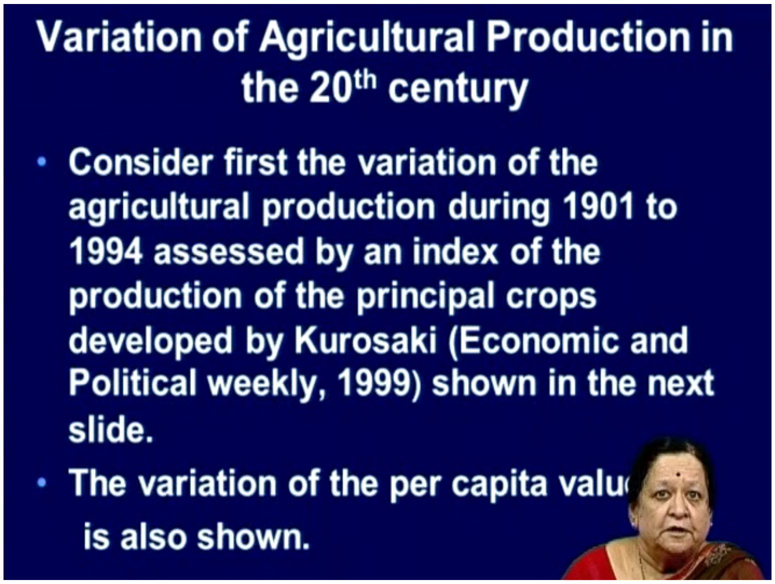

Now before we link monsoon to agriculture, let us first consider how agricultural production in the country has varied. And first we deal with the 20th century as a whole, so I consider first the variation of the agricultural production during 1901 to 1994 assessed by an index of production of the principal crops developed by Kurosaki shown in the next slide.

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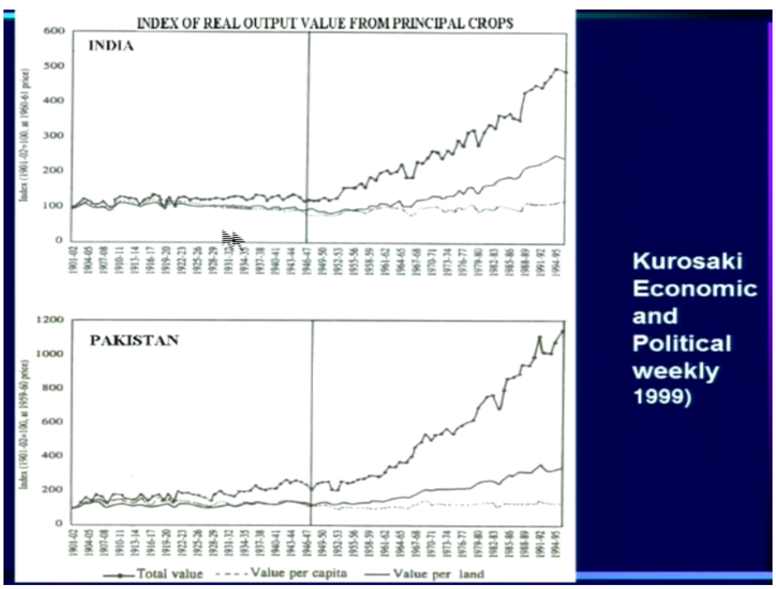

Now what you see here is very interesting graph this is India and this is Pakistan, and what you see is an index of production of principal crops, and from here to here you know this is when we got our independence 1947 independence from British rule. And what you see is that there is the marked difference in the 2 era, this is the colonial era in which the production has stayed more or less the same okay, but the population has increased a little bit.

So the per capita availability which is this one value per capita is the dashed line, so the per capita availability is slightly decreased in the colonial era, but with independence we will see very soon after independence from early 50s itself the production has begun to increase very much. And so even though the population is increased the per capita availability has remained reasonable. Interestingly, similar story for Pakistan as well.

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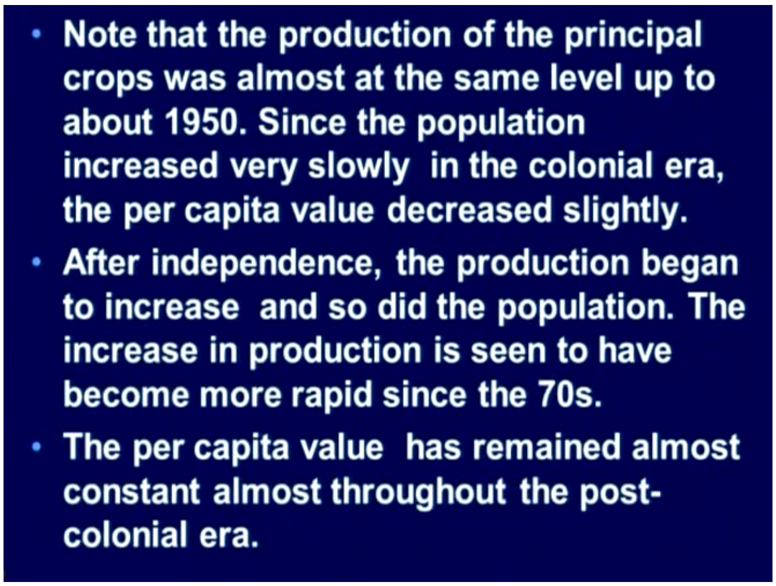

So this shows you that what did we see from here the production of the principal crops was almost at the same level up to about 1950, since the population increased very slowly in the colonial era, the per capita value decreased slightly. After independence the production began to increase and so did the population, the increase in production is seen to have become more rapid since the 70s that you will see here these are the 70s here.

And the increased seems to more rapid in this period here, after independence from colonial rule the production began to increase and so did the population the increase in production is seen to have become more rapids since the 70s. The per capita value has remained almost constant throughout the post-colonial era okay.

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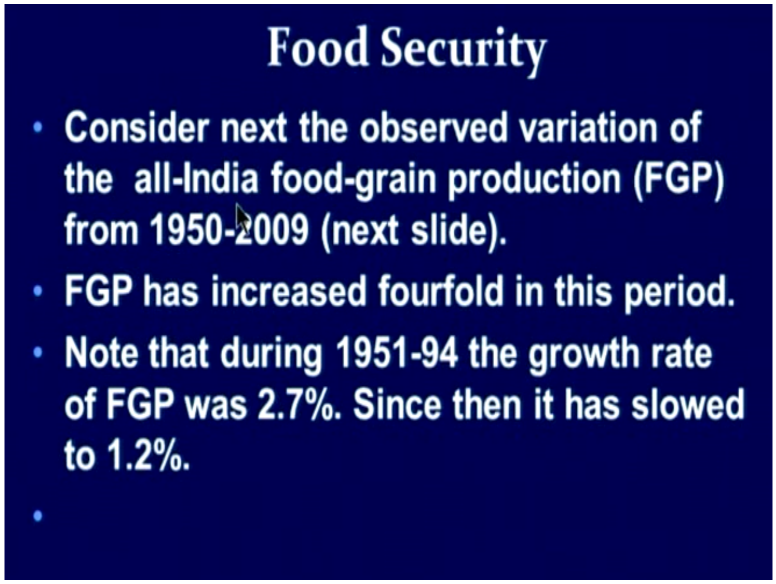

So now the next question to consider is food security, so we do not look at agricultural principal crops the totality of principal crops rather we look at food-grain production okay, this is the all-India food-grain production and let us see how that has changed.

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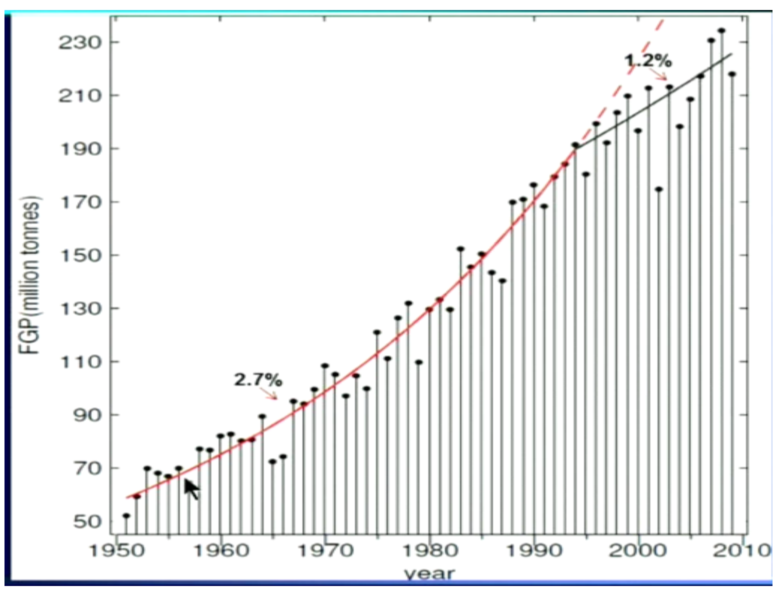

Now this is only post-colonial era only from after independence, and you find that actually the food-grain production has increased rather rapidly right from here you know right from post-independence and we will come to see why that happen. However, in the recent this is up to 2010 and mid-1990s the rate of growth has slowed down a bit, so earlier it was increasing the growth rate was increasing at a rate of 2.7%, now it has become only 1.2%. So the rate of growth has slowed down a bit.

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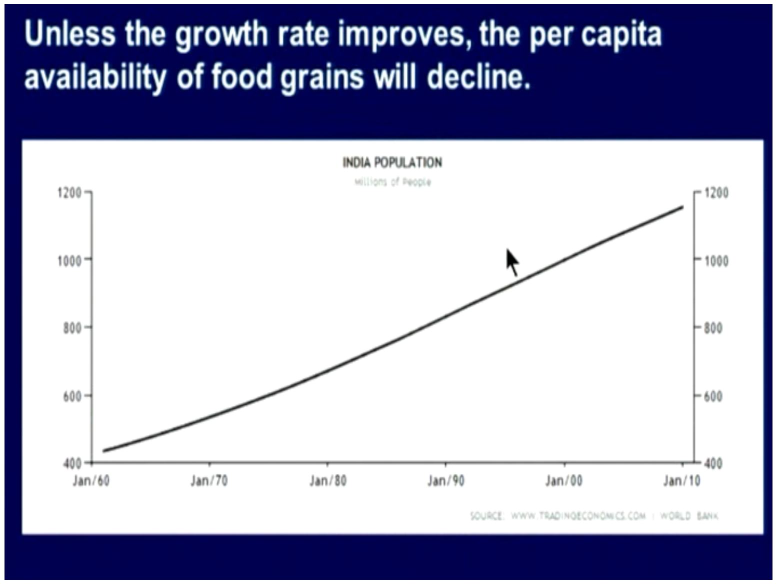

And unless this growth rate improve the per capita availability of the food-grains will decrease because if you look at the population that increases at rate of about 2%. Therefore, if we have here increase in food-grain production only at the rate of 1.2%, then slowly the per capita availability of the food-grains will decrease. So we have to do something about this okay.

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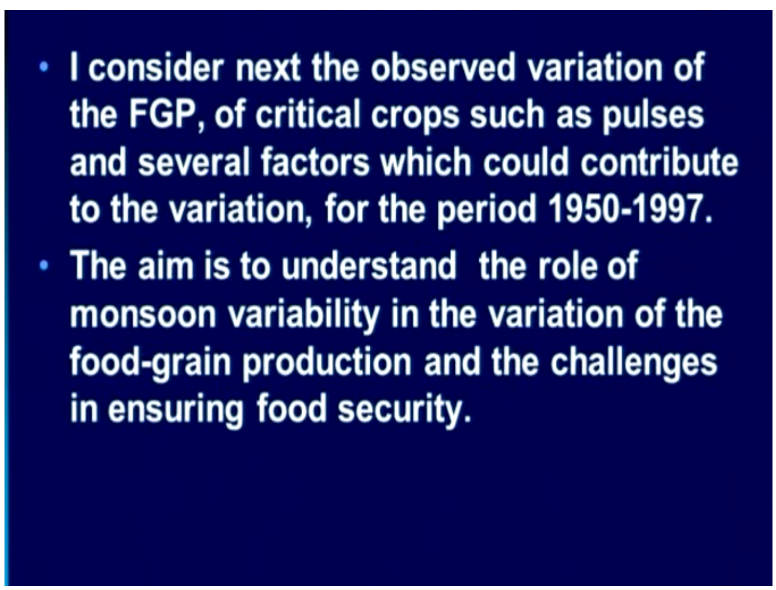

Now I want to consider in greater detail the observed variation of food-grain production of critical crops such as pulses and several factors which could contribute to the variation of these for period of 1950 to 1997 where I have a lot more data. Now the aim is to understand the role of monsoon variability in the variation of food-grain production, and the challenges in ensuring food security, okay.

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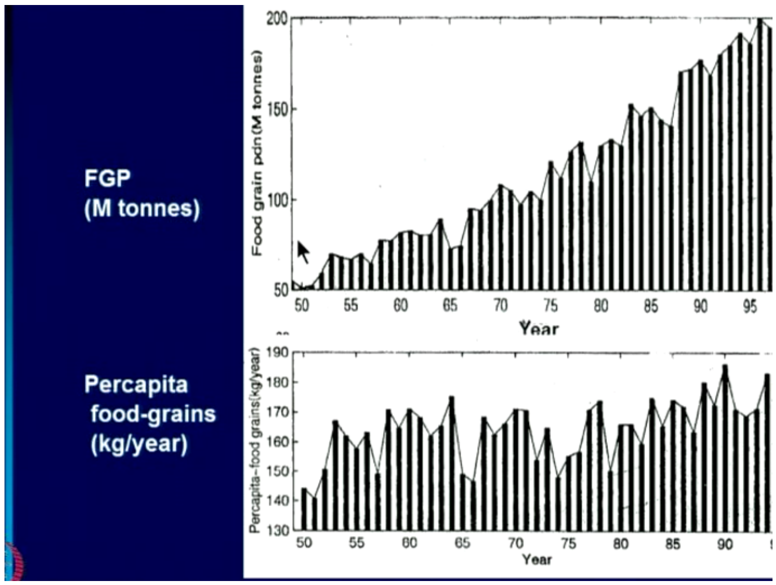

So now this is from 1950 to 1997 what you see here is the food-grain production which I called FGP in millions of tonnes, and what you see is that it has been increasing right from 50 onwards up to this point okay. And if you calculate the per capita food-grain availability this is in kilograms per year, then you find that by and large it has remained steady somewhat increased towards end here, but by and large it certainly has not decreased.

Of course there a big dip in the food-grain production as you will see here this is the 65, 66 droughts, and this is the 79 drought and so on and so forth. So big dips do occur in the food-grain production and associated with that you do get dips in the per capita availability, but on the whole the per capita availability has been steady.

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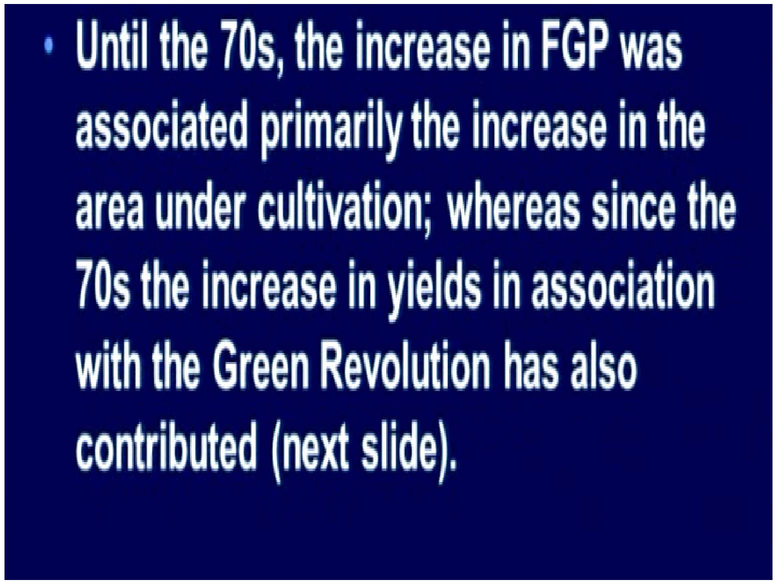

So until the 70s the increase in food-grain production was associated primarily with increase in the area under cultivation.

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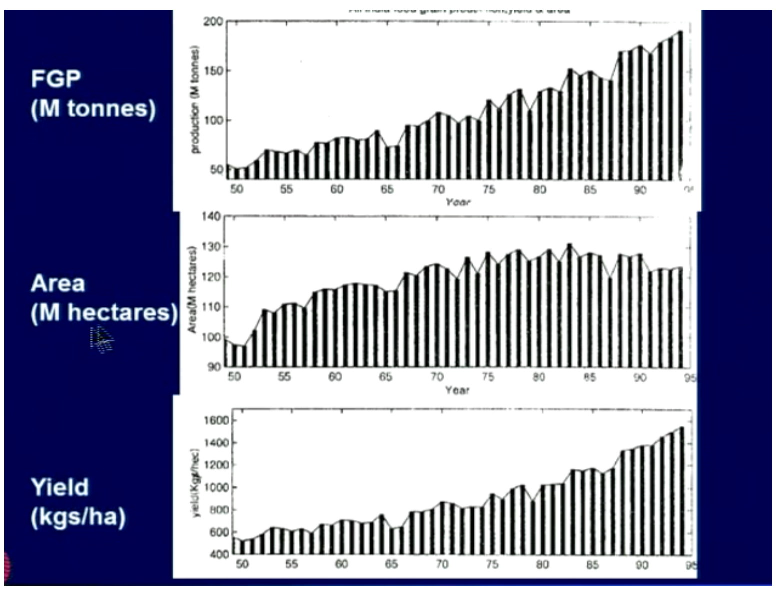

Now what you see is the same food-grain production that you saw before, then this is the area under cultivation in millions of hectares and this is yield of the food-grain production kilogram per hectare okay. Now you can see from 50 onwards up till the 70s mid-70s, the area under cultivation increases steadily okay, and this contributed a lot to the increase in production that you got here, this is post-independence.

Now yield on the other hand, you notice increased only very slowly, and it has begun to increase rapidly only from 70s onwards and this in fact is the green revolution which I will come too.

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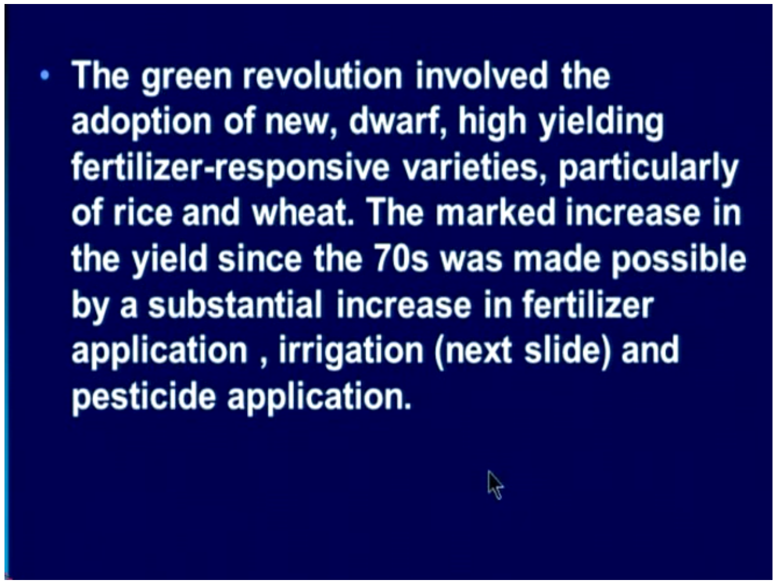

So in fact what was the green revolution? Okay. So until the 70s, the increase in FGP was associated primarily with the increase in the area under cultivation; whereas since the 70s the increase in yields in association with the green revolution has also contributed. So we have seen this that means 70s increase in yields has also become very rapid and that has contributed also to this, but initially it was primarily the area under cultivation.

Now what is this green revolution? See the green revolution involved the adoption of new, dwarf, high yielding fertilizer-responsive varieties, particularly of rice and wheat. Now the market increased in the yield since the 70s was made possible by a substantial increase in fertilizer application and remember these are fertilizers-responsive varieties. So they can make use of the fertilizer very efficiently. So they were the substantial increase in fertilizer application and irrigation, so in fact okay.

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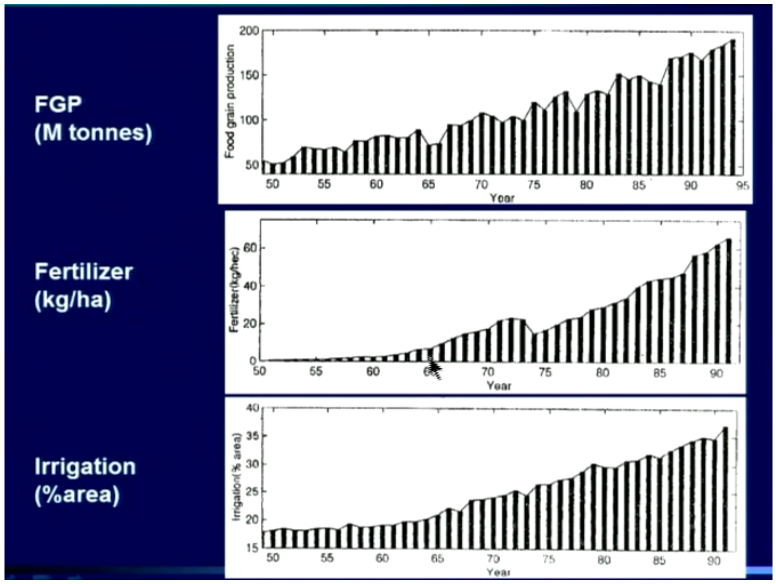

So this is the same food-grain production here, this is the fertilizers and you can see that this is until about 55 or so hardly any fertilizer was applied, it began to be applied in the 60s, and then increase very rapidly in the 70s okay. And irrigation see the government undertook projects to provide irrigation soon after independence, so irrigation has also been steadily increasing, so this is why the area under cultivation of irrigated lands has also increased.

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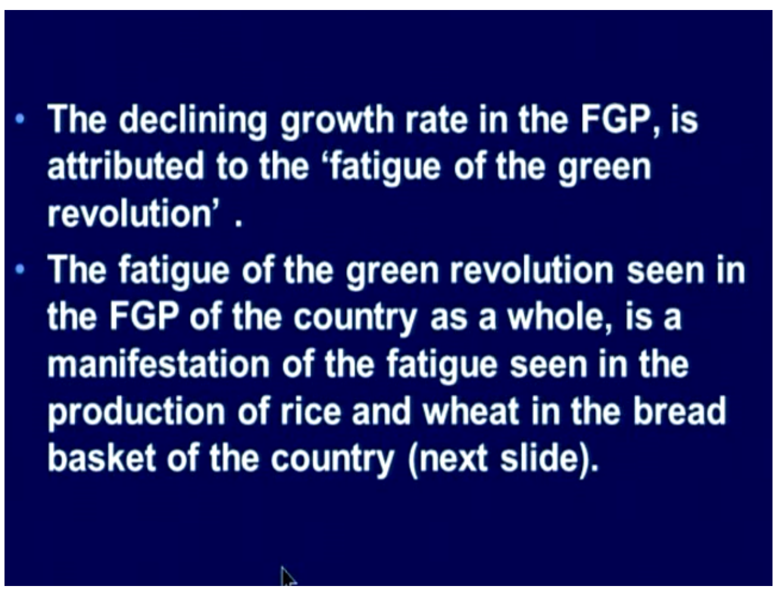

Now the declining growth of FGP, so to go back to where we were, so this is important to remember that the green revolution was made this marked increase in the yield since the 70s was made possible by a substantial increase in fertilizer application and irrigation. Whereas before

70s it was substantial increase in irrigation which is also contributed to the increase in food-grain production okay.

Now the declining growth rate in the FGP is attributed to the so-called fatigue in green revolution, now fatigue of the green revolution is seen in the FGP of the country as a whole and let me just remind you what it is, we have seen it here. See this is the fatigue of the green revolution, see with green revolution it was increasing very rapidly and suddenly the growth rate has decreased substantially it is less than half of what it was throughout the period from 50s, 2.7 and 1.2 %.

So this is the observed fatigue of the green revolution, and so this declining growth rate in the FGP is attributed to the fatigue of the green revolution, fatigue of the green revolution is seen in the FGP of the country as a whole is a manifestation of the fatigue seen in the production of rice and wheat in the breadbasket of the country.

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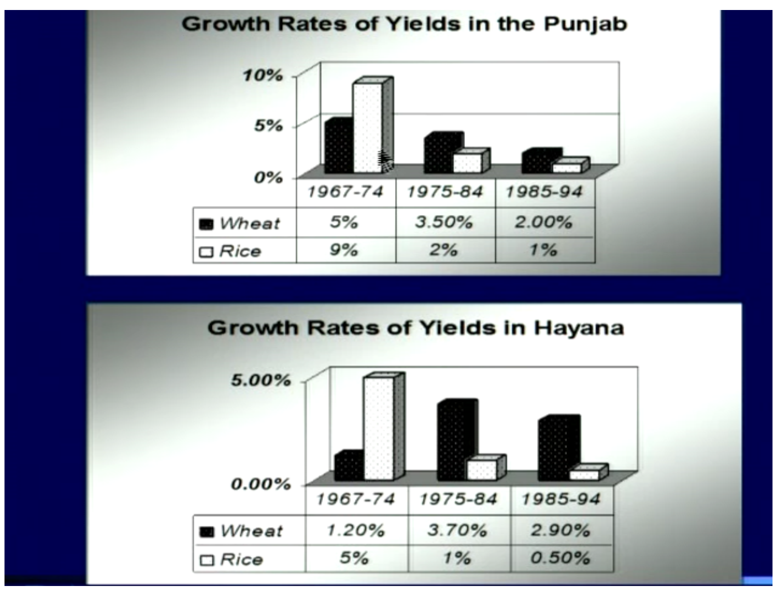

See places like Punjab and Haryana contributed enormously to the green revolution, and what you see here is growth rate of yields, we specifically saying yields and growth rates of yields in Punjab and Haryana and dark is wheat. You can see that the growth rate has dropped from the mid-60 to mid-70 it has dropped already to mid-70 mid-80 and even further from mid-80 to mid-90. Now rice also same story.

Haryana same story in rice, but Haryana for some reason I guess the green revolution technologies adopted somewhat later, so you get a very high yield here from 75 to 84, but that has also dropped here. So we are saying deepened growth rates as we go by.

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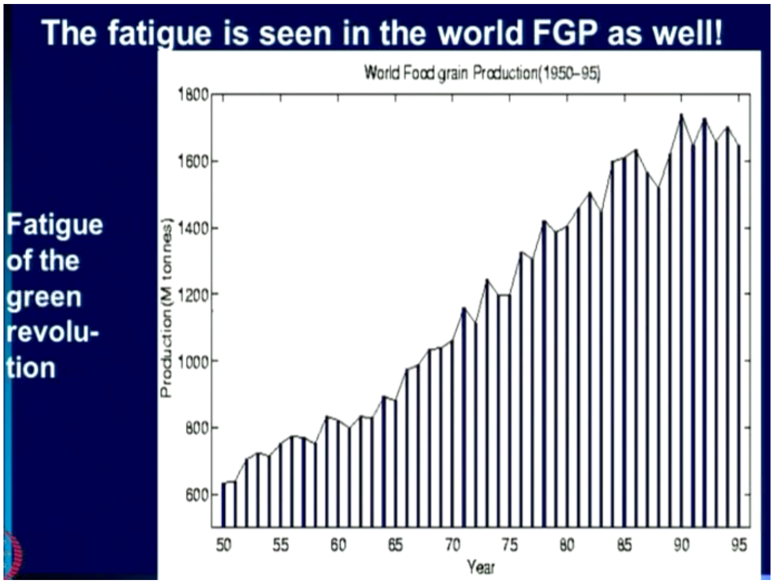

And in fact this fatigue of the green revolution is not special only to our country, even when we look at world food-grain production, we see a fatigue that here in the 60s and from the 50s onwards and particularly since the 60s there was a rapidly growth in food-grain production and now what you see is much lower growth if at all, and this is the fatigue of the green revolution that you see on the global scale.

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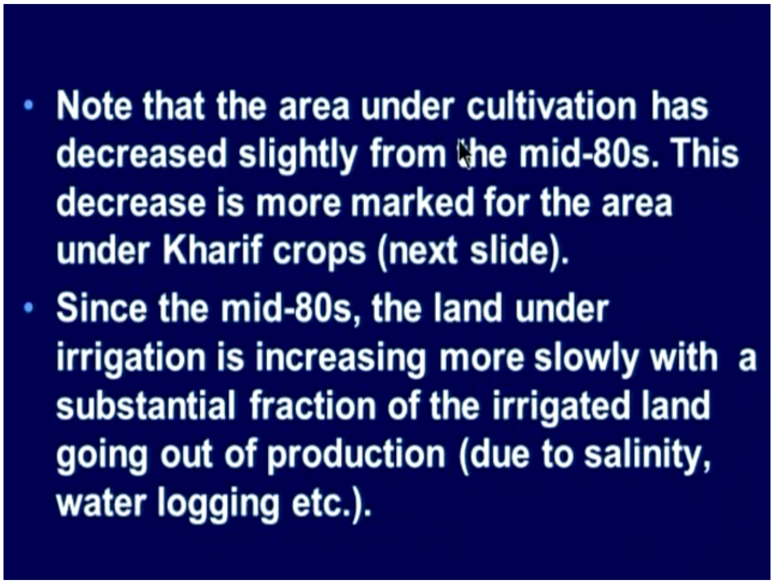

Now area under cultivation has decreased slightly from the mid-80s and it may be here, so this is the old graph that you have seen this food-grain production and this is the area under cultivation you can see that it reached the maximum from around here, and after that it has begun to decrease somewhat okay. So area under cultivation has decreased slightly from the mid-80s, this decreases is more marked for the area under kharif crops, okay.

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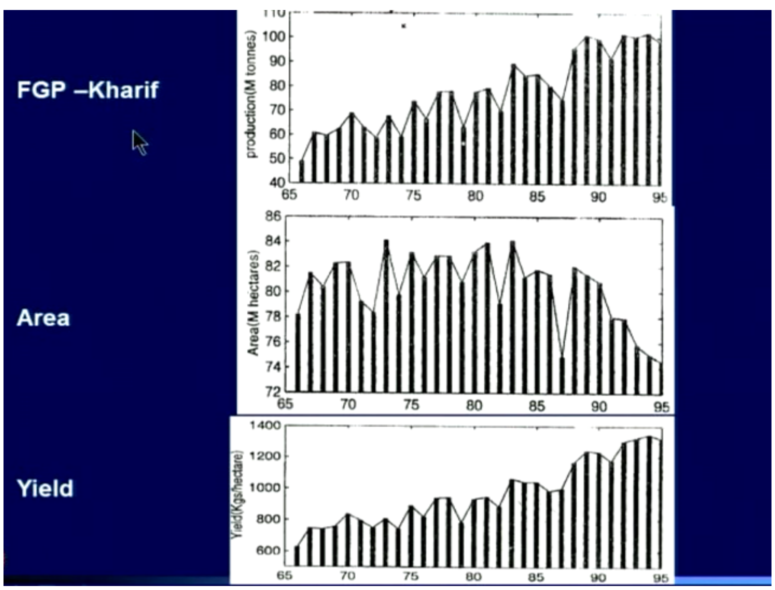

And so now this is kharif which is the summer monsoon season if you wish, and if you look at Kharif then you see the decrease in growth rate is even sharper, you see it has reached a plateau here, and it is not increasing at all. And the area under cultivation is decreasing very rapidly you see this. Whereas the yields have gone up to some extent. So since the mid-80s okay so area under cultivation has decreased slightly from mid-80s for the country as a whole and for both the seasons Rabi and kharif.

But the decrease is more marked for the area under Kharif crops, and since the mid-80s the land under irrigation is increasing more slowly okay then earlier with a substantial fraction of irrigated land going out of production due to salinity waterlogging etc. so there has been this kind of change that irrigated land is also not growing at the rate it was before.

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Now impact of the year to year variation of the Indian summer monsoon rainfall is large particularly for the droughts, and that you will see in the next slide.

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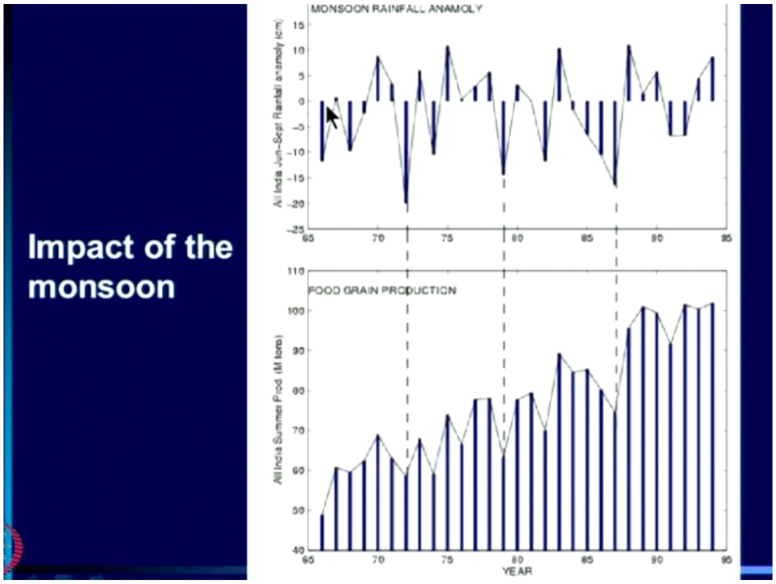

See this is the all-India summer monsoon rainfall, this is the ISMR anomaly, so that above 0 means the rainfall is more than average, below 0 means it is less than average. So these sharp dips are droughts, and what you see is associated with each of these sharp droughts you get dips here, this is the same Kharif food-grain production that you saw in the earlier slide, and corresponding to each and every drought you can see actually sharp dips in the food-grain production, okay.

So the decrease in the rate of growth of production since the 90s the fatigue of the green revolution is seem to be even more marked for the production of the Kharif crops with the rate becoming close to 0 leading to a plateau which you have already seen here, this is the rate has become almost 0 in this period, and this is the plateau the food-grain production for Kharif has become a plateau.

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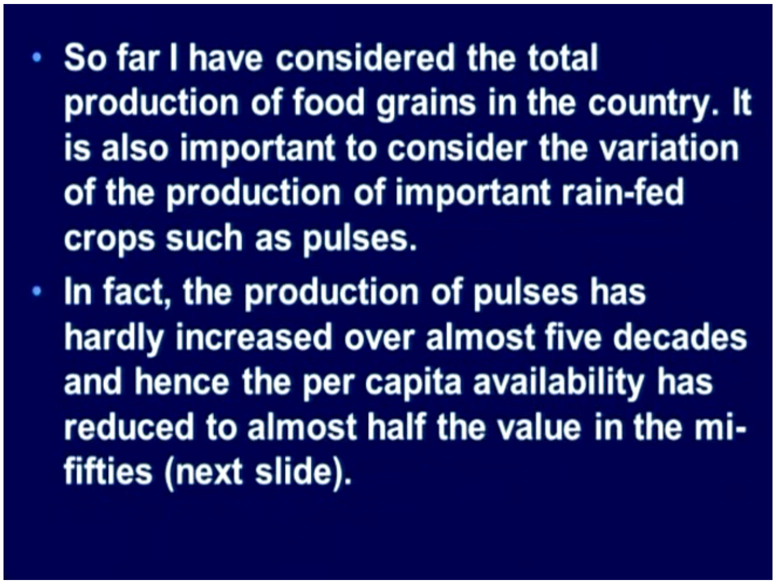

So far I have considered the total production of food-grains in the country, and what we have seen is that the rate of growth of food-grains has certainly dipped, and it is dipped below the rate of growth of population, so this is not a very good sign and we have to do something about it. Now let us look at some important rain-fed crops and see what has happened to their production okay. In fact, the production of pulses has hardly increased over the next decade.

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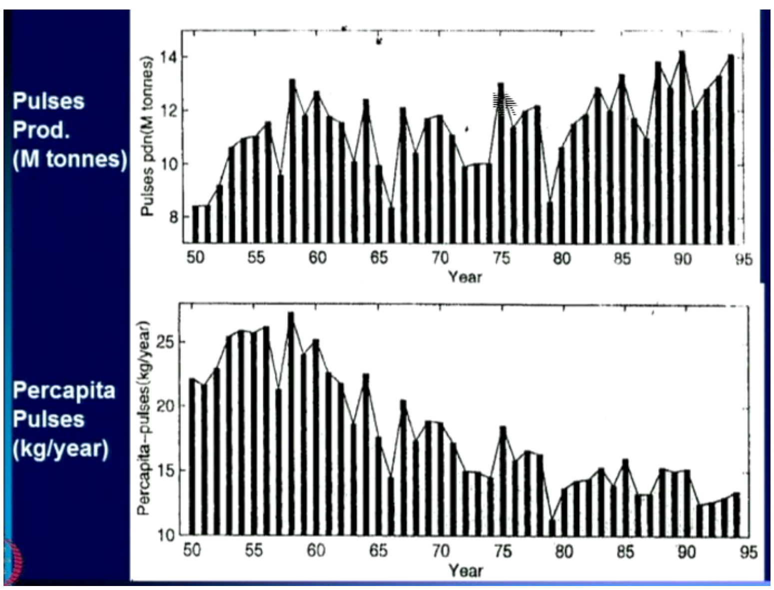

Now this is the pulses production again from 50 to 95 and what you find is that it has hardly increased, you remember the food-grain production of the country increased by a factor of 4 if you looked at the total food-grain production even here see it was around this is for Kharif it was around 50 here and for Kharif it has doubled. Whereas if you look at the non-Kharif the entire food-grain production then it has gone all the way from 52 almost 200.

So it has increased 4fold okay, in the period in which this FGP has increased 4fold when we consider both the seasons, and in which the Kharif has increased about by factor of 2, in the same period what you find is that the pulses have remained more or less the same level since about mid-50s. Why this increase occurred? I really do not know, but the pulses after that have remained more or less static since the mid-50s.

Now if you therefore, look at the per capita pulses is going to decrease with time simply because of the population is growing and the production is not growing, so you see a huge decrease in the per capita availability it has come down to almost half of what we had in the 50s, see this is the very bad thing that per capita availability of very critical crops like pulses which are one of the major protein sources in a vegetarian diet has come down so drastically okay.

So in fact the production of pulses has hardly increased over almost 5 decades and hence the per capita availability has reduced to almost half the value in the mid-50s.

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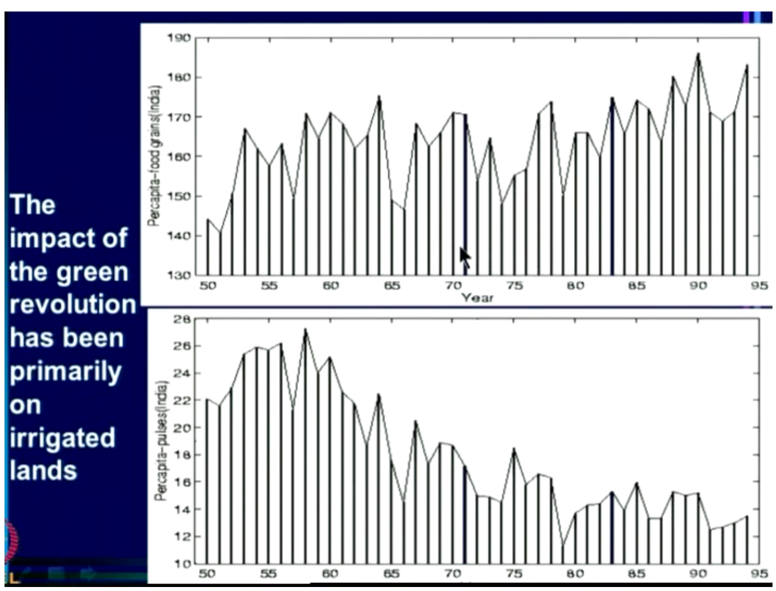

So now here what you see is the per capita availability of the food-grains on top, and per capita availability of pulses here. And what you can see is because of the green revolution per capita availability of food-grains was maintained very well, but per capita availability of pulses went down by a factor of 2. Therefore, the impact of the green revolution has primarily been on irrigated lands, you know in dry and crops in fact that has been hardly any increase in production.

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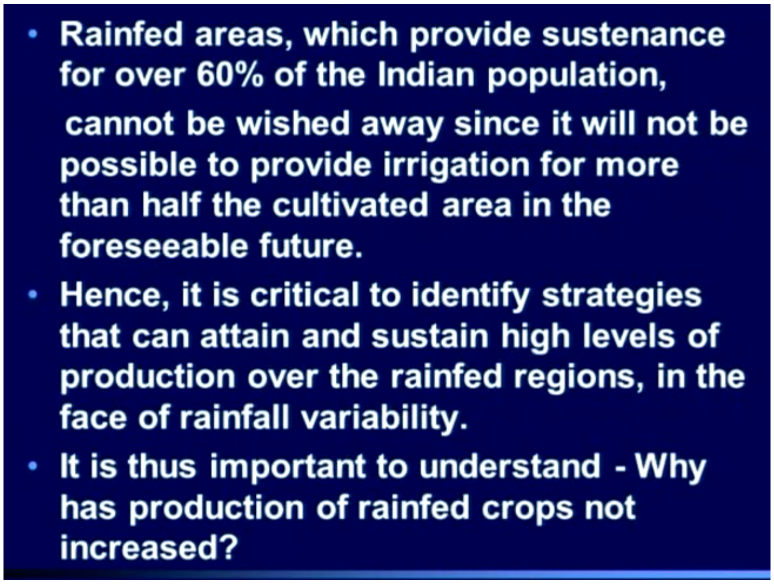

So rain-fed areas, which provide sustenance to over 60% of the Indian population cannot be wished away, because after all there is a limit to how much irrigation you can have it depends on the rainfall over the region, and it will not be possible to provide irrigation for more than half the cultivated area in the foreseeable future. So you cannot just say let convert all the rain-fed areas to irrigated areas and hence increase the production.

So we have to deal with rain-fed areas and see how we can increase the production of the rain-fed areas. Now therefore, it is critical to identify strategies that can attain and sustain high levels of production over the rain-fed regions in the face of rainfall variability. So it is important to understand-why has production of rain-fed crops not increased? You know we talk so much about the green revolution which came to our rescue. Now why is it that during the green revolution the production of the rain-fed crops did not increase?

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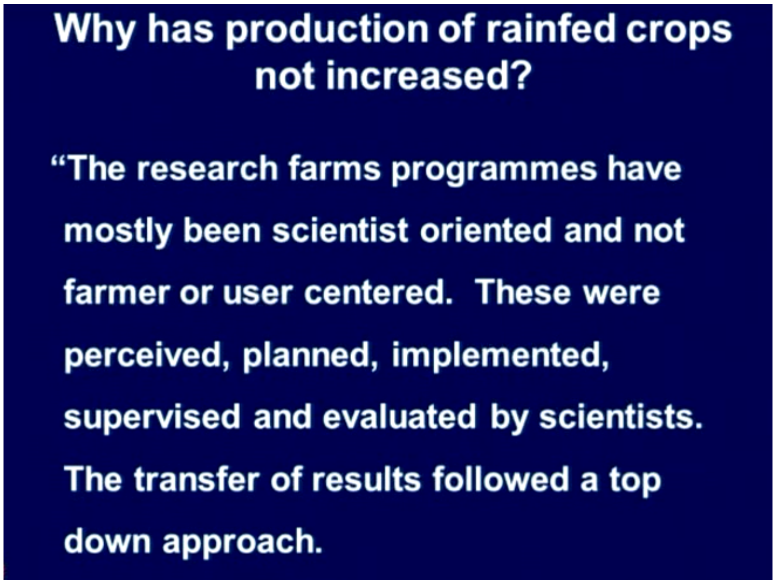

Now this question has been posed and answer by none other than M. S. Swaminathan the great agricultural scientist and what he finds out is the following, that the research farms programs have mostly been scientist oriented and not farmer or user centered. They were perceived, planned, implemented, supervised and evaluated by scientist. The transfer of results for a top down approach.

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In this, take it or leave it approach the farmer was at best a passive participant. Scientific findings which became the so-called technologies were born from small plots and short term research and were invariably not associated with critical cost benefit studies. So scientific findings really involved in a recommendation about how much fertilizer to use, how much pesticides to use, when should you sow a crop and so on so forth. These are all recommendations that are born out of the technologies which come from these short term research projects.

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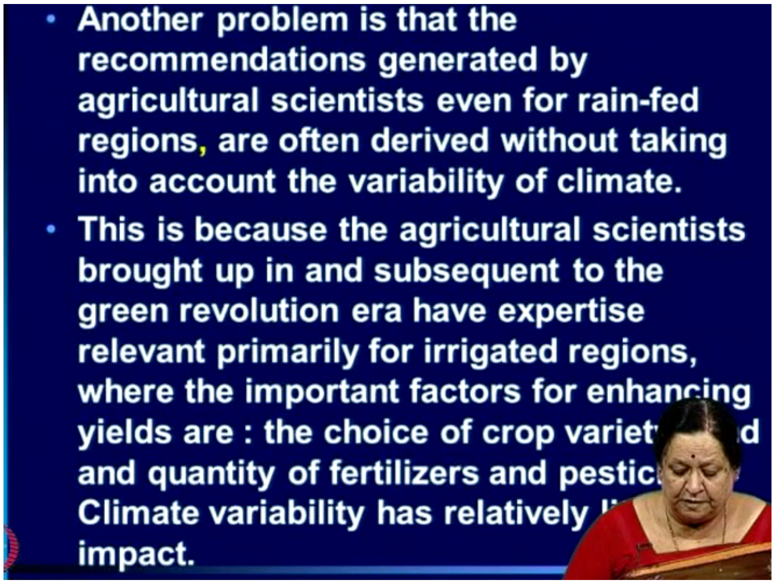

Now see another problem has been that the recommendations generated by agricultural scientist even for rain-fed regions, are often derived without taking into account the variability of rain or variability of climate. Now why does that happen? But that happens perhaps because the agricultural scientist sue a brought up in and subsequent to the green revolution era have expertise relevant primarily for irrigated regions.

Because remember green revolution occurred mainly over the irrigated regions, so these scientists also have expertise relevant primarily for irrigated regions where the important factors for enhancing yields are not trying to adjust to the climate variability at all, because climate is controlled now, rather it is the choice of crop varieties and the quantity of fertilizers, pesticides to be applied and so on. So climate variability has relatively little impact on the strategies over irrigated regions.

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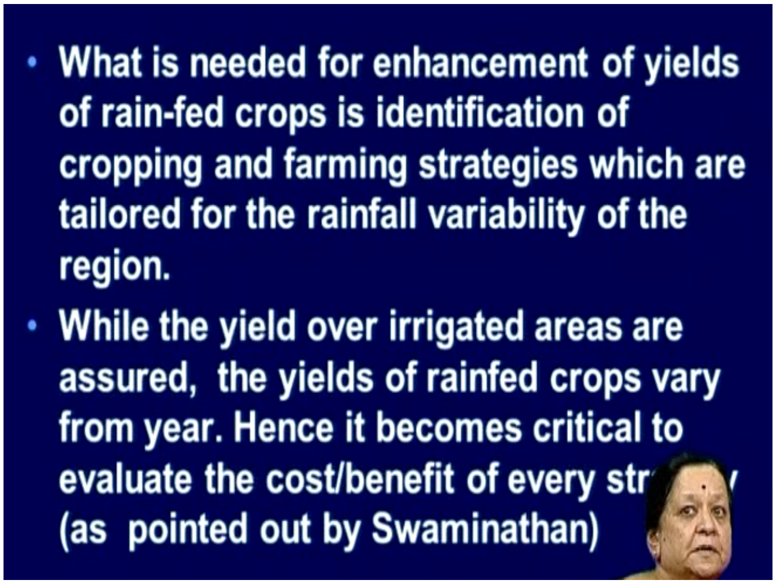

Now what is needed for enhancement of yields of rain-fed crops is identification of cropping and farming strategies which are tailored to the rainfall variability of the region. So what we need is to find strategies which are appropriated for the kind of rainfall variability experienced by the different regions, so they are also have to be location specific. Now while the yield over irrigated area assured, the yields of rain-fed crops vary from year to year.

Hence, it becomes critical to evaluate the cost benefit of every strategy as pointed out by Swaminathan, you see because the yields are not assured, the farmers do not have that much money to spare they do not make profits consistently. So they are much more worried about the cost benefit of every strategy that is recommended, and this is why Swaminathan pointed out that cost benefit assessments is absolutely essential.

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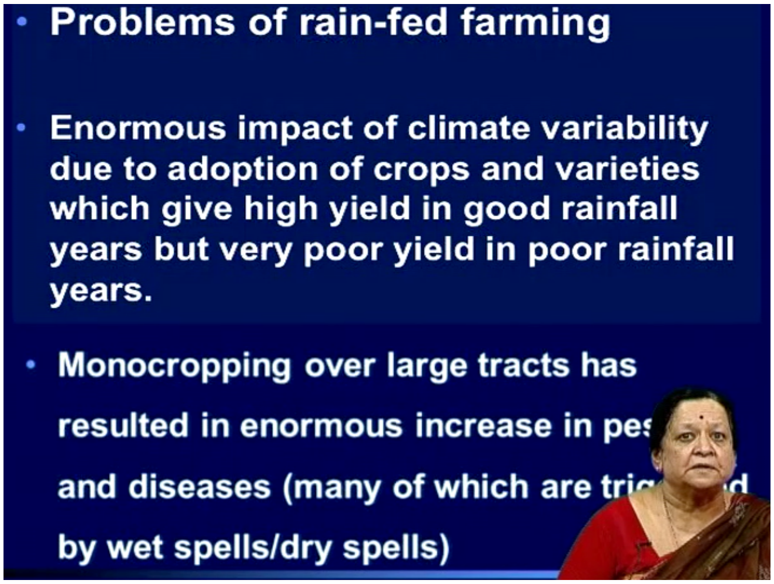

So what are the main problems then of rain-fed farming? That there is an enormous impact of climate variability due to adoption of crops and varieties which give high yields in good rainfall years, but very poor in poor rainfall years. See recently, there has been a change in cropping patterns which came up about with the green revolution even over rain-fed regions, and varieties and crops which give a very high yield in good rainfall years have become common now.

So but they do very poor info rainfall years you see. And so the impact of climate variability on these varieties is very large, also what has happened is unlike the diverse cropping system that was prevalent before the green revolution the traditional cropping system monocropping over large tracts has resulted in enormous increase in pest and diseases, many of which are triggered by wet spells and dry spells.

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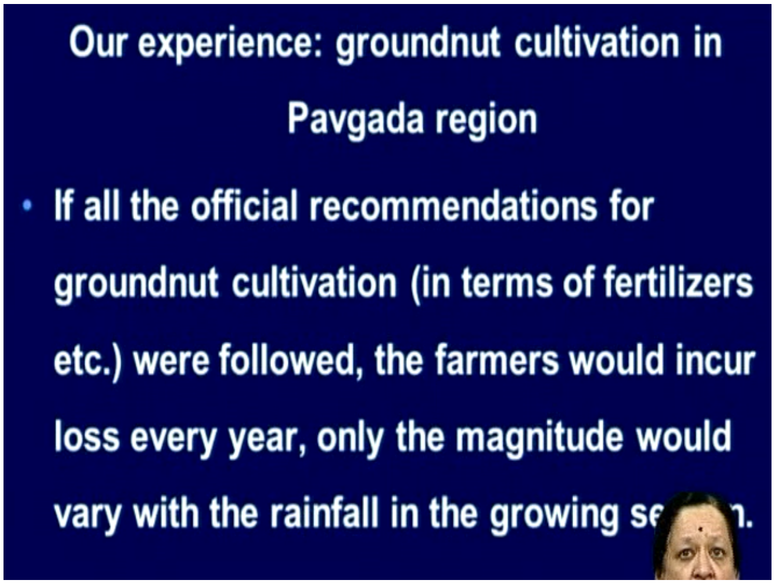

So in this situation one has to look make recommendations of strategies which will enhance the yields for the farmer. Now we actually have been working in this Pavgada region, Pavgada Anantapur region with farmers are right now cultivating groundnut. Now what we could do with the farmers help with actually assess what would be the cause if all the recommendations the official recommendations had to be implemented.

You know that our agricultural scientist through the University of Agricultural Sciences and so on actually generate recommendations for farmers of semi-arid regions for farmers of groundnut in this region also. Now what we found was and this was based on farmer's calculation that if all the official recommendations for groundnut cultivation was followed the farmers would incur losses every year only the magnitude would vary with the rainfall in the growing season.

So this is the problem that the recommendation generated by agricultural scientist are such that they are never going to be cost-effective for the farmer.

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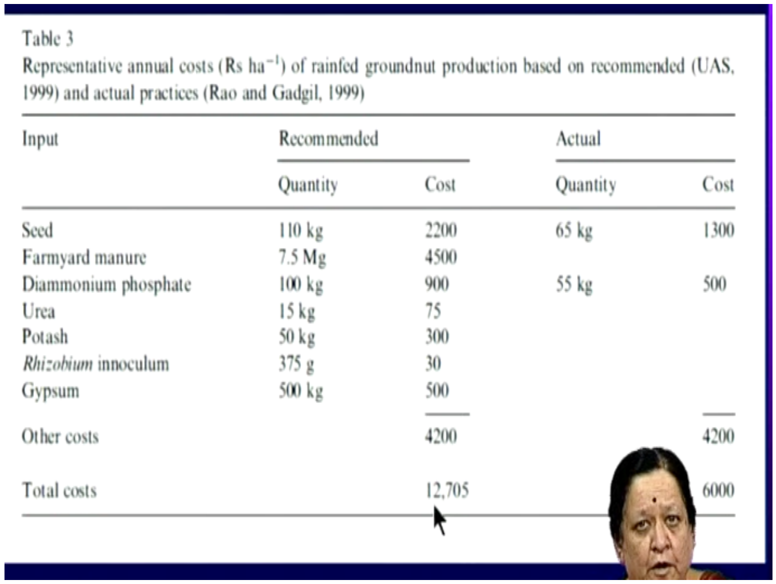

Table 3
Representative annual costs (Rs ha^{-1}) of rainfed groundnut production based on recommended (UAS, 1999) and actual practices (Rao and Gadgil, 1999)

Input	Recommended		Actual	
	Quantity	Cost	Quantity	Cost
Seed	110 kg	2200	65 kg	1300
Farmyard manure	7.5 Mg	4500		
Diammonium phosphate	100 kg	900	55 kg	500
Urea	15 kg	75		
Potash	50 kg	300		
Rhizobium innoculum	375 g	30		
Gypsum	500 kg	500		
Other costs		4200		4200
Total costs		12,705		6000

And this is just to give you an example I do not want to get into details, but this is the representative example of you know how much they recommend for seed etc. etc. this is all per hectare, and farmyard manure and various other things, by the way what we have not calculated here is pesticides. So actually they also recommend pesticides and that would mean the cost would go even higher in the event of attacking pest.

So now if they went according to the recommendation the cost per hectare would be 12705, whereas what the former does is he does not put too much fertilizers at all, and ends up spending something like 6000 so less than half of what would be the cost as per the recommended strategies.

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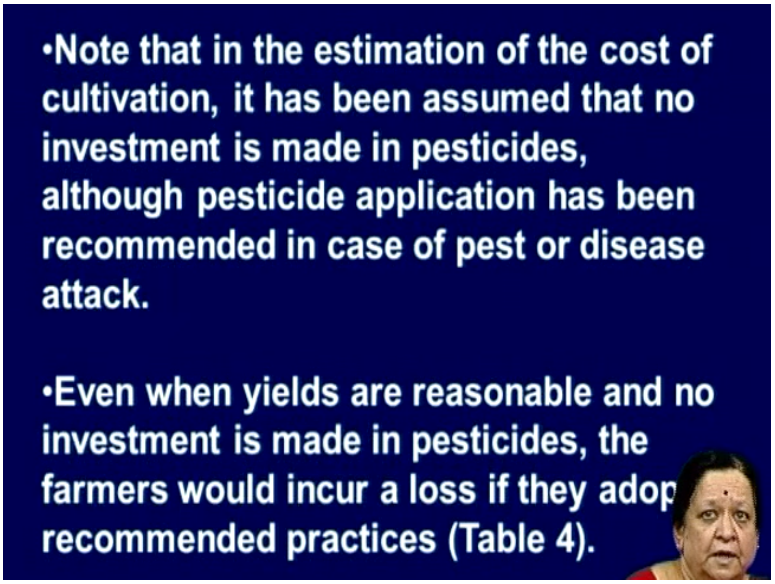

And we again note that in the estimation of the cost of cultivation, it has been assumed that no investment is made in pesticides, although pesticide application has been recommended in the case of pest or disease attack. Now even when the yields are reasonable okay, so suppose one were to spend in all this and you got reasonable yields okay, and no investment is made in pesticides.

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Table 4
Representative annual income (Rs ha^{-1}) from rainfed groundnut production based on recommended (UAS, 1999) and actual practices (Rao and Gadgil, 1999)

Yield	Gross income	Net income	
		Recommended	Actual
0.8 Mg ha^{-1}	9600	−3105	3600
1.0 Mg ha^{-1}	12,000	−705	6000

Even then what would happen is now this is an estimate of the yields okay, 0.8 and 1.0 this is the tonnes per hectare 0.8 and 1, so what you get is the gross income would be 9000 and 12000 here, and in that case the farmer had actually applied all the recommended strategies, then he would get a loss and he got only 800 per kgs per hectare he would lose 3000 rupees per hectare. And even when he got a good yield which was 1000 kg per hectare he would still lose 705 per hectare.

Whereas here the farmer would gain 3600 and 6000 okay. So what is happening is that even when the yields are reasonable no investment is made in pesticides the farmers would incur a loss if they actually adopt the recommendations, so this is the problem.

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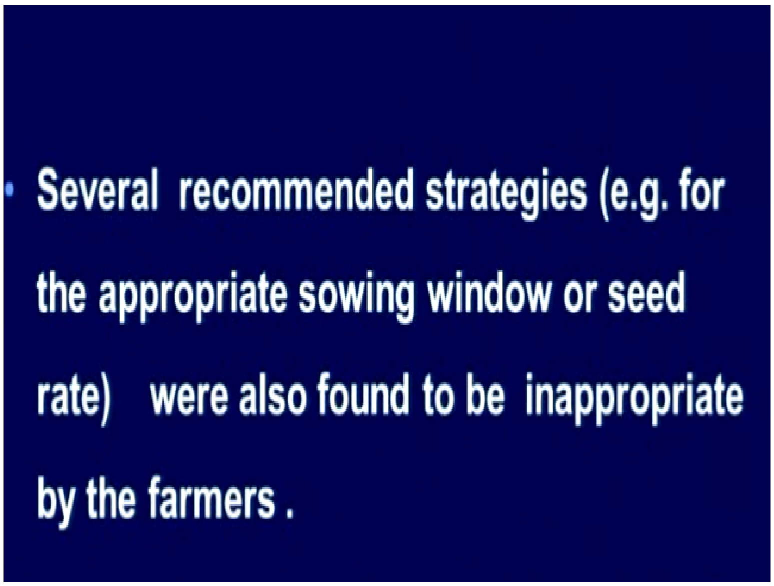

That the recommended strategies that are generated by the agricultural scientist cannot be applied by farmers, because they are not cost-effective. Now the farmers also told us that several recommended strategies for example, when should the groundnut be sown that is to say which is appropriate sowing window or how much seed should you put per hectare which they called seed rate. They were also found to be inappropriate by the farmers.

So I will come to this but for example it was recommended that if you do not get sowing rains till the end of July do not sow groundnut at all in the August, sow something else like soyabean and so on, but our farmers told as that often when they had to sow in August they get an extremely good yields. So clearly what the recommendation were not appropriate.

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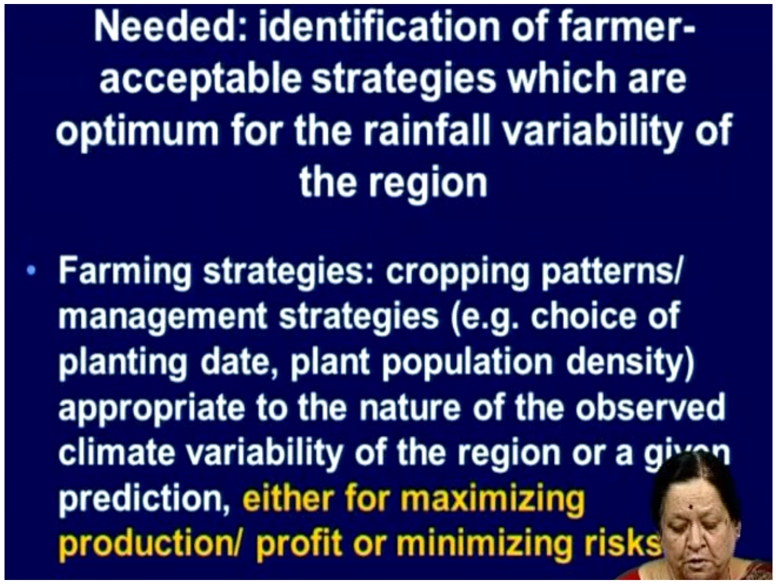

So what we need to do is if our aim is to enhance the production of the rain-fed regions, we need to identify former acceptable strategies which are optimum for the rainfall variability of the region okay. And so what are the forming strategies we are looking for? We are looking for cropping patterns, you know which crops would be optimum, in the crops which variety would optimum.

Management strategies which would means the choice of sowing date, plant population density and so on, appropriate to the nature of the observed climate variability of the region or a given prediction. So if you happen to have a prediction for the specific here that is fine, one should be able to even derive the strategy which would get maximum yield given that the prediction would be correct.

So what are these farming strategy is optimum for what is the final aim, either from maximizing production or profit or from minimizing risks that depends on the farmers, some farmers may want to minimize the risk particularly the marginal ones, whereas the people with large land holding would want to maximize profit because they can carried over to the next year, okay.

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In addition to this forming strategies one also needs coping strategies for extreme events such as droughts, vulnerability and so on. And I will come to that in this set of lectures what sort of coping strategies that these peoples adopt and could be adopted. One also needs sustainable strategies for irrigated and rain-fed regions. Now why has this fatigue of the green revolution come?

The fatigue of the green revolution in the irrigated area has come, because we have used the resources in an unsustainable manner, you know the soil nutrients have got depleted, so the soil has become less rich in nutrients and therefore, for the same field you need to add more fertilizers also because so many pests have grown with monocropping and so on, one has to also invest in pesticides.

In any event you know maintaining the soil health is absolutely essential if you want sustainable strategies. Obviously, right now we are taking more out of the system and got good production then we put into the system and this is why we are beginning to feel the effects of that.

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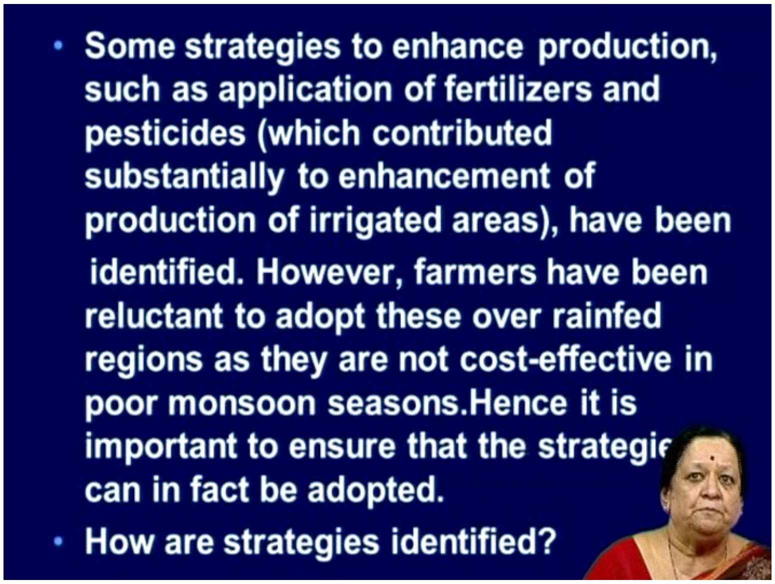

Now there are some strategies to enhance production such as application of fertilizer and pesticides and we already saw an example of this application of fertilizers specific recommendations were made about how much fertilizers need to be applied and so on. So application of fertilizer and pesticides which actually contributed substantially to enhancement of production of irrigated areas have also been identified for rain-fed regions.

However, farmers have been reluctant to adopt these over rain-fed regions as they are not cost-effective in poor monsoon season, hence it is important to ensure that the strategies can in fact be adopted. How are these strategies to be identified?

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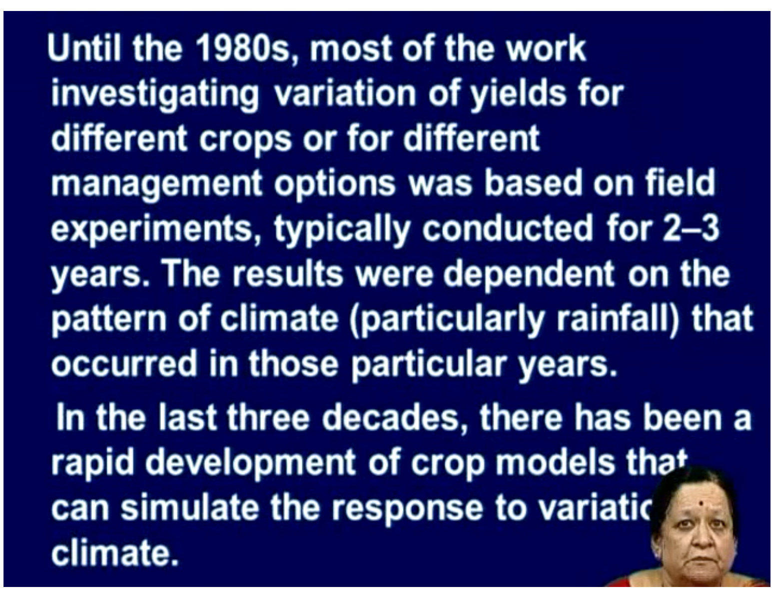

Now so the question is how do you decide what would be a good sowing window? And what variety would do better in a particular agro-climatic regime are given the soil and the rainfall variability of the region. Now until the 80s most of the work investigating variation of yields for different crops or for different management options, see what you want to do is use try and study what will happen if you sow a different date on different plots.

And see in which case you get maximum yield for example, so until 80s most of the work investigating how yields vary as you vary some strategy, it may be choice of sowing window or it maybe you know competition between different crops which crops would do better in terms of yields and so on. So all these strategies were identified on the basis of field experiments, and this field experiments are extremely time consuming and energy consuming and they were typically conducted for 2 to 3 years okay.

Now the results were dependent on the pattern of climate particularly rainfall that occur in those particular years, if you had a drought in those years you would get some result, if you did not have a drought at all you get some other results for example. So these were short-study this is exactly what Professor Swaminathan commented on that generally these technologies were born from these very very short experiments of 2 to 3 years okay.

Now we have another tool at our disposal which is being developed extremely well in the last 3 decades, and this is a thing called a crop model. So this is a model in a computer in which we specify the kind of seeds that there are, we specify what rainfall will occur, what is the kind of soil. And in the computer the plant actually grows and depending on various incidents that occur in a different stages and so on.

You know the computer calculates everything how the soil moisture was, how the plant grows, and eventually in the case of groundnut what is the kind of yield you get. So we have now this development of crop models that has taken place, and this is a very very interesting tool.

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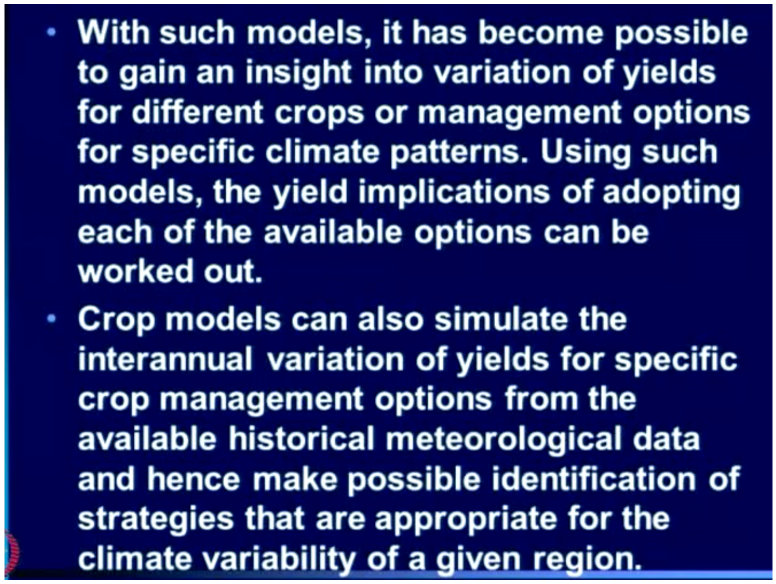

Because with this tools now we can get an enormous insight into the variation of yields either for different crops or management options, and because we can just run the model with different options that we are trying to look at, with different variety if we are choosing between different varieties, with different crops if you are choosing with different crops. And then see under what conditions is the yield maximized.

So crop model is an extremely important tool for identification of strategies, of course I must mention at this point it is extremely critical that crop models that we use are validated for the varieties we are going to explore and for the regions of interest this is extremely important. Because in the crop models there are many things specified about the physiology of the crop and so many other things.

And one should be able to give the parameters involved by using observations of the specific varieties in the field trials at agricultural station. And furthermore try and validate the extent to which the crop model can simulate the impact of say rainfall variability from year to year, so this is very important but given that we have good crop model, then it becomes possible to explore the different options available.

And crop models can also simulate the interannual variations of yields for specific crop management options from the available metrological data, so if you want to look at for example our problem that the former posed for us, what is the optimum sowing window for groundnut in the Anantapur region? Then for Anantapur we have almost 100 years of rainfall data and we can run the crop model for each of those years provided it is validated.

And that will give us insight on which is the optimum sowing window, so it becomes possible for identification of strategies which are appropriate for the climate variability or rainfall variability of the region.

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So this crop model is a very very important tool in the hands of scientist and with that we should be able to find strategies which can actually lead to maximizing our rain-fed production, but the approach to be adopted in that has to be very carefully selected. The approach has to be genuinely interdisciplinary, because you need people who are agricultural scientist, who know crop models.

You need meteorologist because they have to tell you what sort of rainfall variability occurs in that region or what sort of rainfall variability is expected in the next season and so on. Thirdly, farmers have to play a very very important, because eventually you are looking for an optimum strategy some amongst a slew of strategies, now you have to know from the farmer what are the options available to him in terms of cropping patterns, in terms of various other management options and so on.

It is also you need to know from him, what are the cost involved, and then you should be able to estimate the likely benefit of the strategy using your models crop models and so on. So what is needed is a genuinely interdisciplinary approach with participation of farmers, agricultural scientist and meteorologists on an equal footing top down, it is not a matter of generating recommendations and simply handing them to the farmers and asking them to obey that has not fail.

See this lab to land approach actually worked for the green revolution thing, because most of the technologies were actually discovered in the lab and then the farmers were given recommendations which worked in the field. In rain-fed areas it is very clear that the recommendations generated by the traditional methods by agricultural scientist are simply not working they are not farmer-acceptable.

And therefore, to generate recommendation, generate strategies, which are acceptable to the farmers we need this kind of genuinely interdisciplinary approach.

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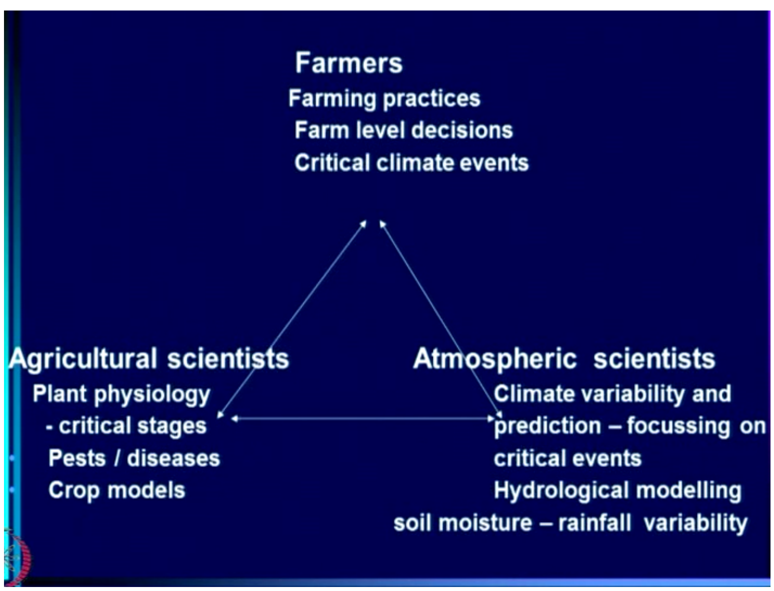

So what is it so we need a 3-way interaction, farmers should tell what the farming practices are, what are the farm level decisions to be made, for example the choices of sowing window as I said, and also what are the critical climate events, they will tell you that a wet spell at a certain stage will have a very large impact on the yield for example or on some pest or on some disease and so on.

So it is farmers who have the knowledge of the ecological system they are dealing with and they can give a lot of information on farming practices, on farming level decisions and critical climate events and so on and so forth. Now agricultural scientists have of course a very important role to play because they know the plant physiology of the crops we are growing, what are the critical stages? Then there are also pathologist people who work on pest and diseases.

And there are people who work on crop models, so all this know how the modern know how has to go into the system. And you also need atmospheric scientist and actually hydrologist as well, because you need inputs and the nature of rainfall variability and what sort of predictions are possible and they should generate for you predictions and the basis of historical data also, of what are the probably it is of the critical events occurring in a specific region.

They should be able to do hydrological modelling, so that they can see if the soil moisture can be predicted in a situation and for all this you need a back-ground in atmospheric science and hydrology. So all the science which you see in the bottom has to be put together along with the knowledge that the farmers have on the traditional ecosystem, before one can actually generate what are strategies which can be implemented.

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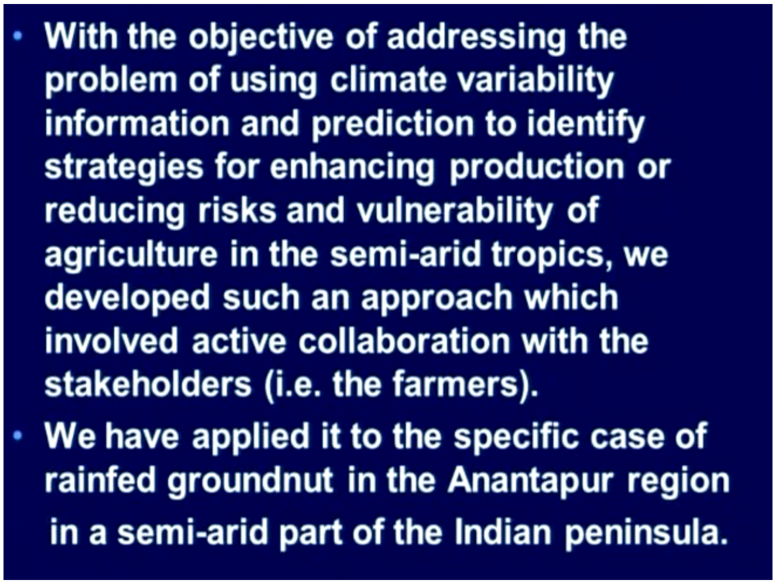

Now with the objective of addressing the problem of using climate variability information and prediction to identify strategies for enhancing production or reducing risk and vulnerability of agriculture in the semi-arid tropics, we actually developed such an approach which involved active collaboration with the stakeholders that is the farmers. Now we have applied it to the specific case of rain-fed groundnut in the Anantapur region in a semi-arid part of the Indian peninsula.

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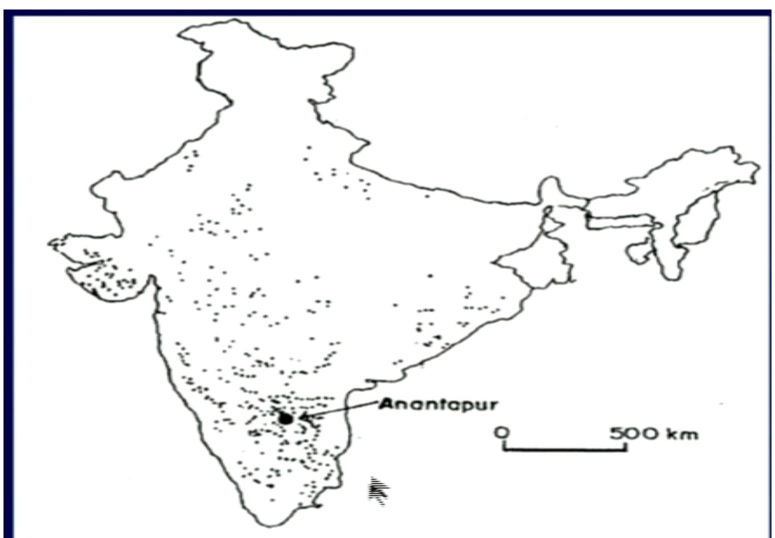

Figure 3. Groundnut growing regions of India.

So in fact this is the groundnut growing regions of India, all these dots are where groundnut are grown and Anantapur is right here in the heart of this dense packet here, I should also mentioned

Gujarat also has a lot of groundnut being grown. So Anantapur is a place here in the heart of the groundnut growing region of the Peninsula.

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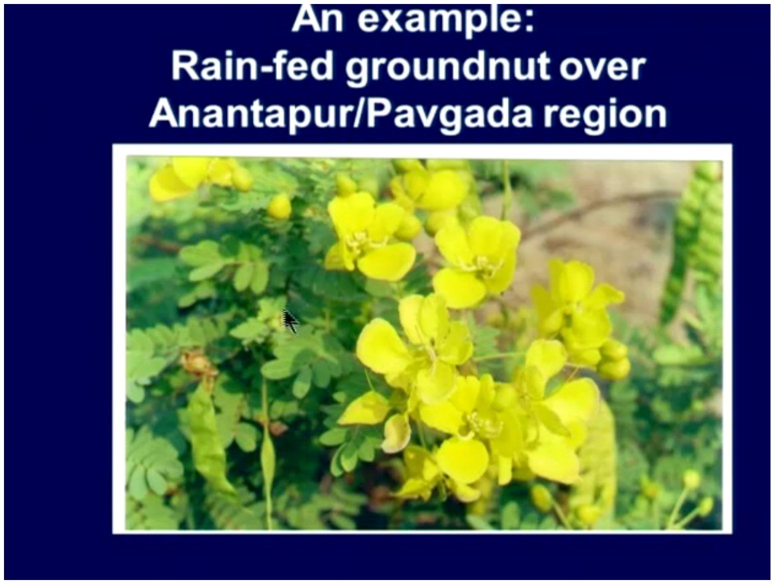

This is what we have chosen, and this what you see here is beautiful groundnut plant.

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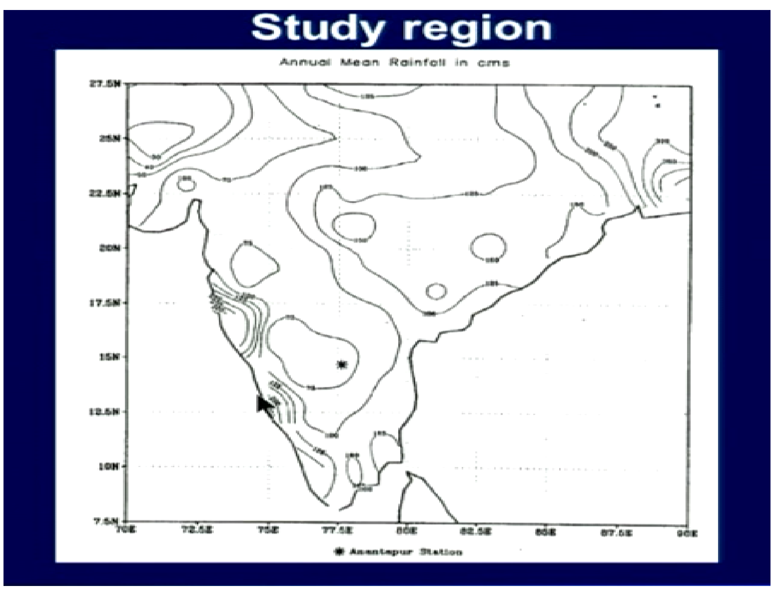

Now this tells you what the rainfall is like actually this is semi-arid region, it has rainfall of < 75 centimeters a year, so the rainfall is not much, and this is where Anantapur is located you can see that the rainfall is very high on the west coast, very high here. And also very reasonable in the monsoons zone here which we have seen earlier, but this is the part of semi-arid part of the region okay.

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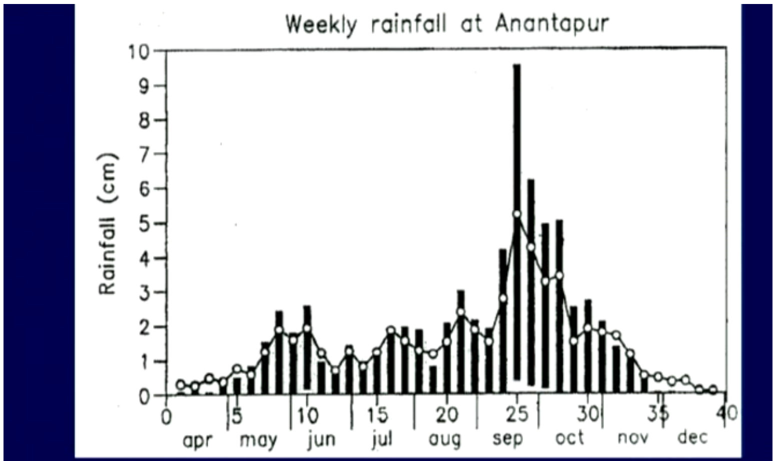

Figure 3. The circle represents the mean weekly rainfall and the bar covers 50% of years (75% of years below top edge and 25% below bottom edge): data period 1911 to 1990 (source: IMD).

Now what is the nature of the rainfall variability at Anantapur, I mean harping that the critical thing to look at is how much the rainfall varies from year to year, there is no point in assuming that the rain will be like the average rain it never is and this shows you how variable it is, so what this is weekly rainfall at Anantapur. And the circle here represents the average rainfall for that week, you can see the most of the rain there is a peak here around the April-May, which we called the pre-monsoon rain.

And after that most of the rain occurs from September-October and so on okay. So this is the little bit similar to Bangalore region and then this it decreases rapidly, so that by end of November there is hardly any rain. So this is the mean picture. Now what are these big sticks? These big sticks tell you how what is the variation of 50% of the years around the mean. In other words, see every year the rainfall will be different in a given week right.

Suppose this bar that you have covers 50% of the year that is 75% of years below the top edge and 25% below bottom edge, so 25% of the years are below this bottom edge of the thing, and 25% of the years are above this top edge okay, so in between the 50% years what is the range of variation that is shown. And you can see that the range of variation is extremely large particularly during the high rainfall.

Here, you can see the although the mean is reasonable actually 50% of the year will not get anywhere near the mean, it is much smaller and that is by and large true in the pre-monsoon events, you can see by and large the mean is above the 50% thing, and it is only here that you get some chance of getting more than the mean. And even then you can see that the variability is huge.

So here if the mean is about 5 or 6 centimeters you can see if you took only a 50% of the years near this thing then it can vary from anywhere near almost 0 to 9.5 centimeters, so this is the kind of huge variability that can occur from year to year, and we have to find strategies which can take this variability in its stride so to speak and still deliver the goods.

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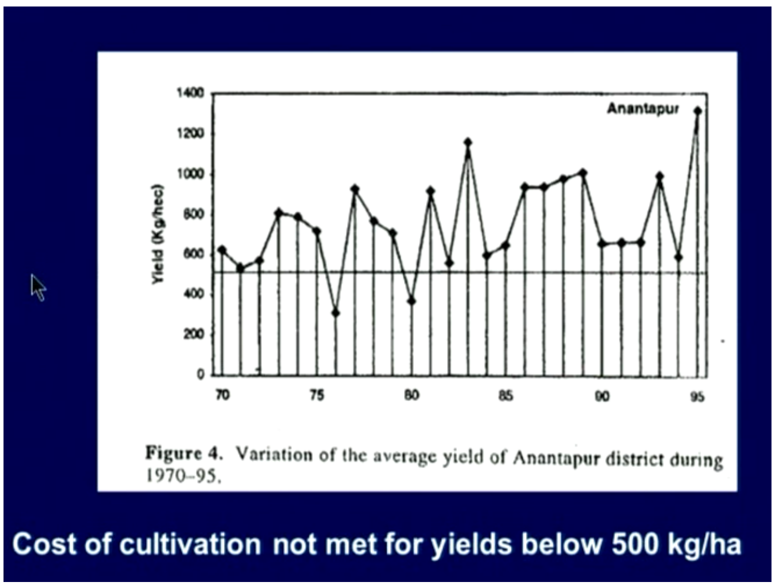

Now this is the yield for Anantapur this is the average yield for Anantapur district for groundnut again, and this is from 70 onwards. And what you see is this line is 500 kg is the minimum you need to meet the cost of cultivation, when you get < 500 that means it is a total loss, and that is what you got here and here. So there are years in which it is a total loss, there are years in which it is very close to a total loss very little profit.

Then there are some years in which you would make reasonable profit okay, so there is a lot of variations here and we have to see if we can derive strategies for adopting which they could make much more profit in then they are making here.

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Now as I said ours was not top down approach, we interacted with all the farmers, and here some working in the groundnut field you see groundnut field here.

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And this is the groundnut plant that you see, and you know this is the kind of soil it does not look like a very rich soil it is a sandy red, sandy soil in which groundnut is grown.

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And we were particular that we actually interact with the farmers. So these are my collaborators on this Dr Narari Rao, who worked on the crop model part, who was my associate in the Centre for Atmospheric and Oceanic Sciences. Seshagiri Rao, he is an ecologist farmer who was really one of the main people in this project, because he could talk to farmers as well as to us. And 3 of was found a team and did this work.

The people you see here are 2 farmers of whom this one Mr Laxman is particularly intelligent and one of the most successful farmers of that region. In fact, he is the person who brought the specific varieties they grow TMV2 from Coimbatore to this region. So this is the way we have interacted with them over the years.

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And had meetings not only with big farmers but also with the marginal farmers, we had a ne2rk of marginal farmers, farmers who own < 2 hectares of land, so that we come to know what are the options available to them also, what are the kind of strategies we should look for, so that they do not end up making losses year after year.

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This again is Mr. Lakshman about whom I told you and I will have occasion to talk about his contribution to our work, when I talk about the sowing window thing.

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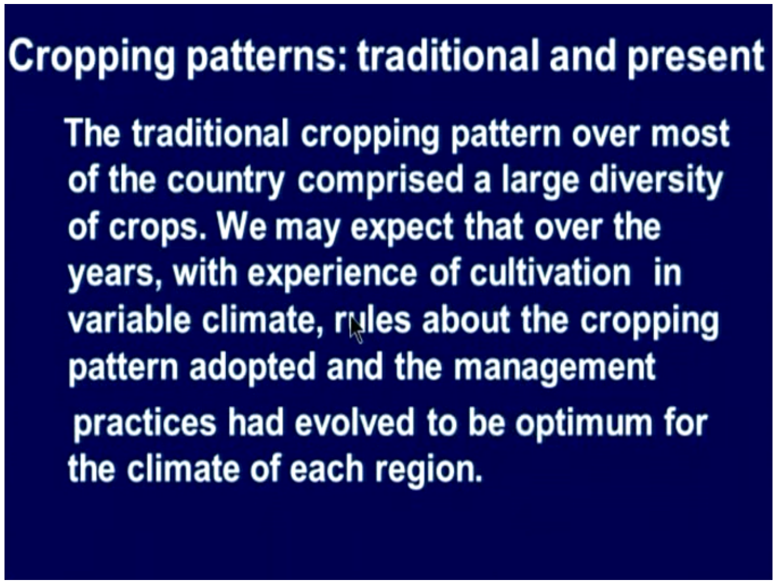

Now what has happened is that over this region the cropping patterns have changed enormously since the 70s okay, and the traditional cropping pattern over most of the country actually before the 70s comprised a large diversity of crops. See we expect that over the years with experience of cultivation in variable climate, rules about the cropping pattern adopted and the management practices has evolved to be optimum for the climate of the region.

What I am saying is that when you are growing a set of crops over a region for 100s and 100s of years, then by trial and error you would know when each crop should be planted in what succession they should be planted and so on, because of 100s of years' farmers would be trying out various things and eventually hit on the successful strategy for that region. See this is how natural selection takes place and this is how farmers would have identified the strategies for each region.

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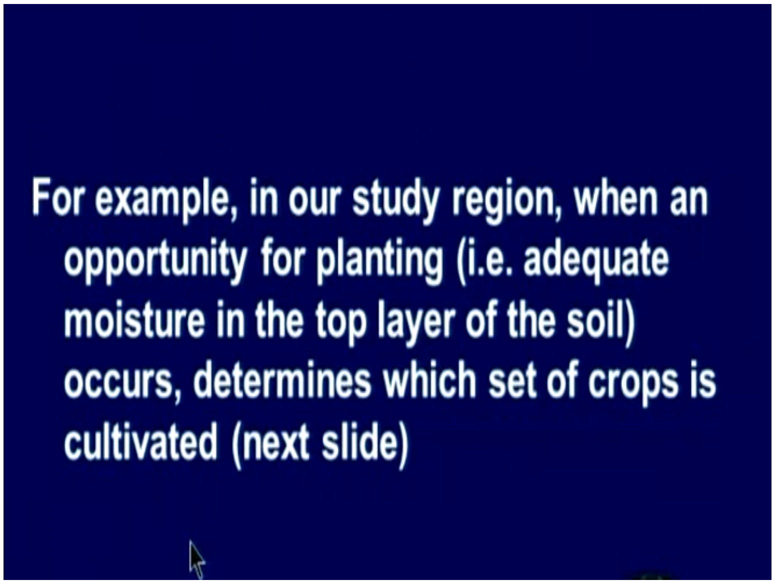

But now for example in our study region, when an opportunity for planting that is adequate moisture in the top layer of the soil occurs that determines which set of crops will be cultivated.

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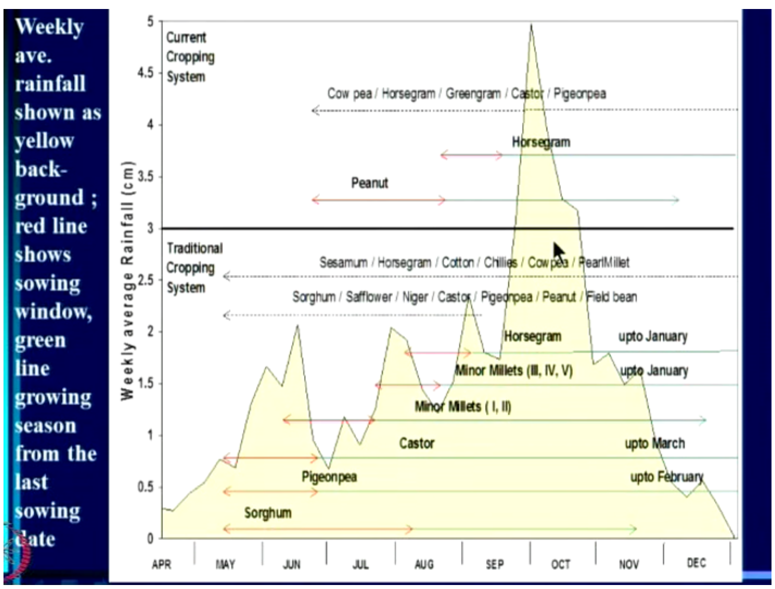

So what you see here now is again Anantapur weekly rainfall which you saw before, in May there is a peak and bigger peak occurring in October-November and so on, so back-ground hill is the rainfall okay. Now this is the traditional cropping system and you can see the enormous variety of crops, so depending on when the sowing window occurred you know they would plant Pigeon pea, Sorghum, Castor.

If the sowing window is somewhat later they would plant Castor, then if much later they would plant Minor millets and so on and so forth. So they had a whole variety of crops that they would plant depending on when the sowing date occurred. Now what has happened in place of these whole variety, now they are basically 2 main crops Peanut and Horsegram, and Peanut is planted somewhere during this period and Horsegram is planted here and that is it.

In addition, of course they have Coe pea, Horsegram, Greengram, Castor, Pigeon pea etc. over a very small portion of their land, so what has happened is from a very complicated system traditional complex diverse system which actually utilized the large part of the rain profile. Now we are getting a system which is much simpler which is actually does not use a part of the profile, and so there has been the transition from traditional cropping to current cropping.

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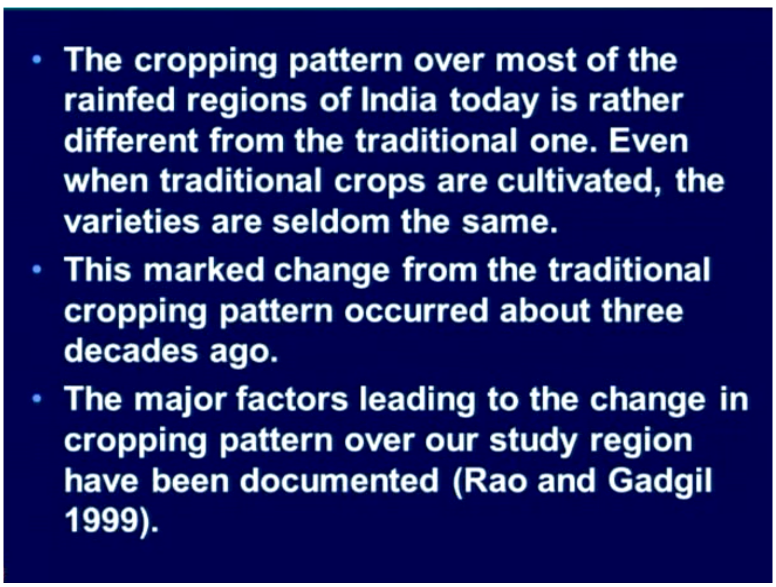

So the cropping pattern over most of the rain-fed regions of India today is rather different from the traditional one. Even when the traditional crops are cultivated, the varieties are also very rarely the same. So if the cropping patterns have changed a lot okay, and this marked change from the traditional cropping pattern occurred about 3 decades ago. Now I will continue in this and in fact share with you what are the factors that have led to this new cropping pattern.

But at this point let me say that what we need to do is given the current cropping pattern with try and find out, what are the problems faced by the farmers, and the current cropping pattern has been only for about 2-3 decades, so there has not been enough time for farmers by trial and error to find what are the optimum sowing windows, what is the optimum seed rate and so on and so forth. To some extent they know something about what may be the better variety on the basis of this experience.

So now with all the science at our command, we should be able to using the crop models and so on, try and identify for them what are the optimum strategies for the current cropping pattern, because those are simply not available from their experience. So I will continue with this and talk about this in the next lecture, how we go ahead and identify using the armory of the scientific tools that have been developed right up to now, how we identify strategies which will improve the production of rain-fed areas, thank you.

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