The Monsoon and Its Variability
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Lecture - 39
Indian Summer Monsoon, GDP and Agriculture

Monsoon is not only one of the challenging problems in atmospheric science, it is also a very important subject to study because of the very large impacts it has on the economy and food grain production, agriculture of the monsoonal regions of the world. So today, I am going to talk about Indian summer monsoon, GDP and agriculture.

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In fact, a couple of years back, the opening remarks by our then finance minister, Pranab Mukherjee in the budget speech to the Indian parliament said "I seek the blessings of Lord Indra to bestow on us timely and bountiful monsoons." So this is how important the monsoons are to the finance minister of India.

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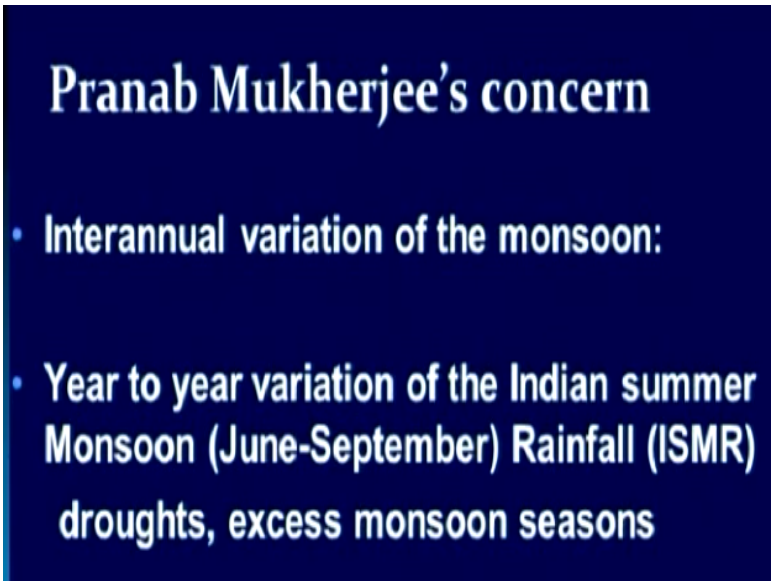

In fact, what was Pranab Mukherjee's concern it is about year to year variation of the monsoon, interannual variation of the monsoon, all India scale that is to say Indian Summer Monsoon Rainfall what we used to call ISMR and whether it will be a drought, whether it will be an excess monsoon season or what.

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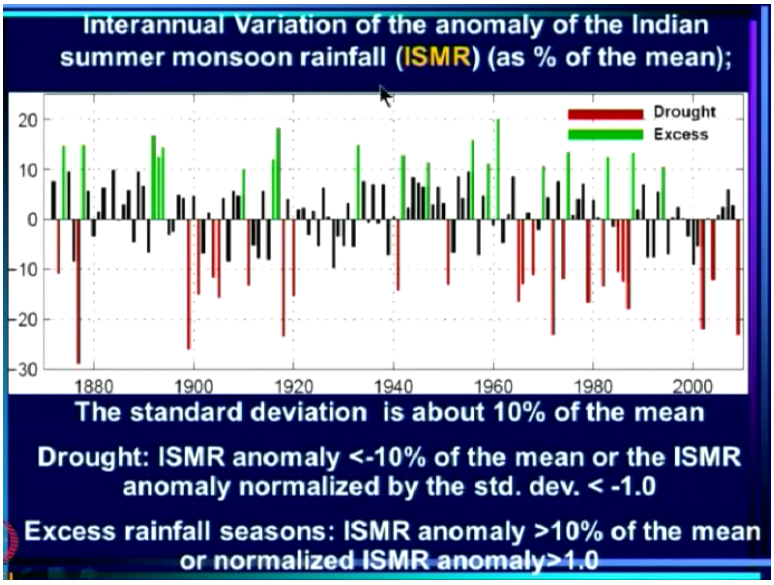

Now this is a figure which shows how the ISMR or the Indian Summer Monsoon Rainfall has varied from the time data are available 1876 to now and as I mentioned before the standard deviation, the mean is about 85.4, the mean is given here. The standard deviation is about 10% of the mean and because it is about 10% of the mean, we define a drought as a season in which the deficit is larger than 10% or the ISMR anomaly is negative in magnitude larger than 10%.

When the ISMR anomaly is positive in magnitude larger than 10%, we call it an excess monsoon year. It can also be defined by anomaly normalized by standard deviation, ISMR anomaly normalized by standard deviation to be < -1 for drought and > 1 for excess monsoon seasons.

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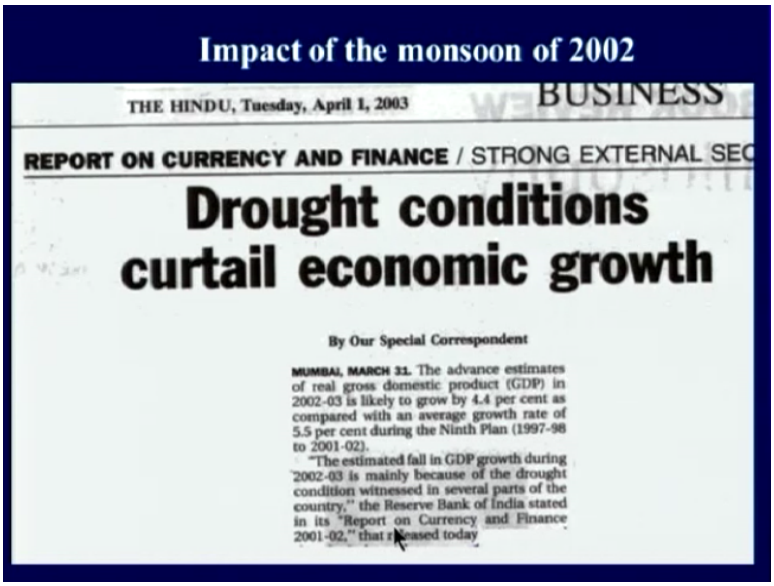

Now as far as the impact of the monsoon on economy is concerned, we often read about it in the newspapers. Although we could not find a single systematic study before the one I am going to present today to give quantitative assessment of the impact. So for example, the impact of monsoon in 2002 was felt of course in 2003 and there is headline in Hindu, which has drought conditions curtail economic growth.

That it is now likely to grow at only 4.4% as opposed to last year's growth of 5.5% because of the drought. As you know, 2002 was a major drought. This is 2002, a very major drought and it had impacts.

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Similarly, another report from a newspaper saying GDP growth slips to 2.6% in the third quarter. This is the way we read about the impact.

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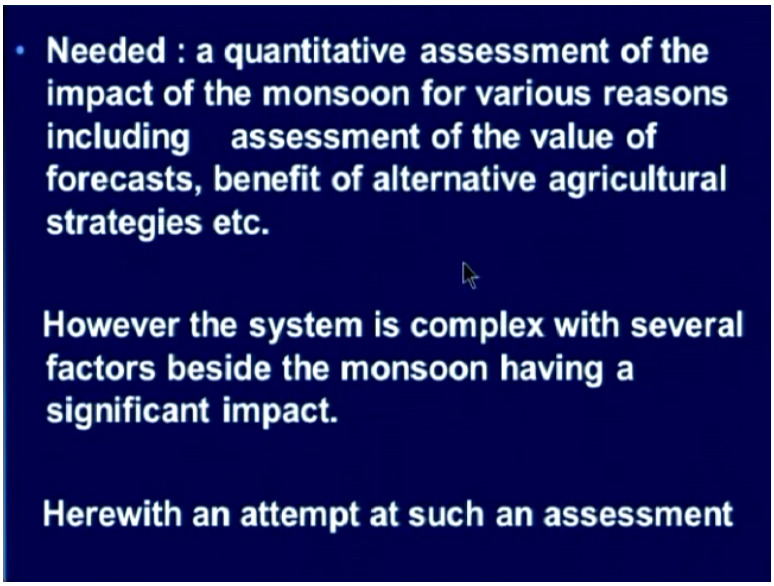

But it is important to have a quantitative assessment of the impact of the monsoon for various reasons including assessment of value of forecast, benefit of alternative agricultural strategies, etc. However, the system is complex, with several factors beside the monsoon having a significant impact. So now I will talk today about an attempt at such a quantitative assessment.

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And this is from a paper we published called Indian Monsoon, GDP, and Agriculture in economic and political weekly in 2006.

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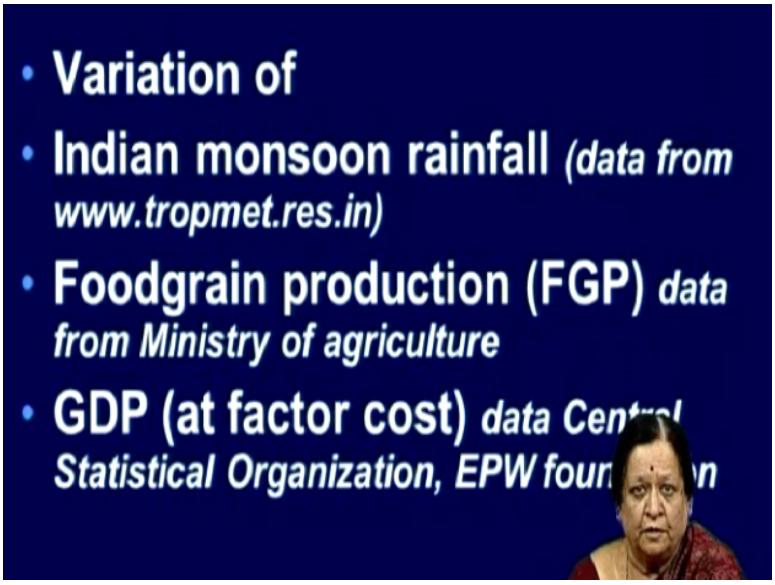

Now what are we concerned with. We are concerned of the basic data. The basic data is on variation of course Indian monsoon rainfall, which are readily available from the IITM website.res, food grain production data from Ministry of Agriculture and GDP at factor cost data from Central Statistical Organization, EPW foundation.

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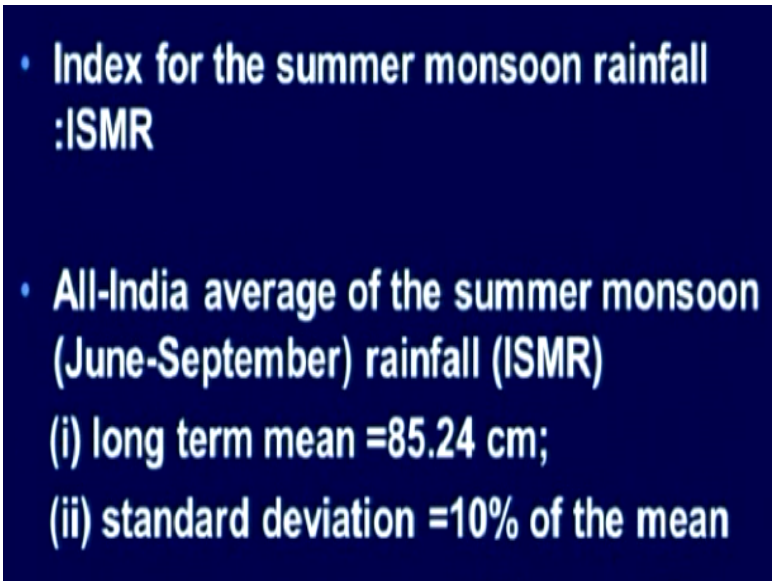

Now as I said the index for the summer monsoon rainfall is all India summer monsoon rainfall ISMR. So all India average of the summer monsoon rainfall, ISMR long term mean is 85.24 cm, standard deviation is 10% of the mean.

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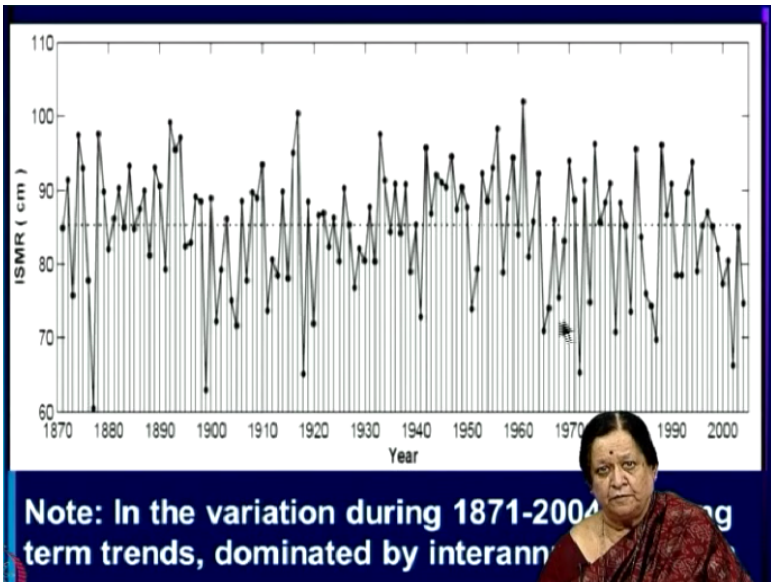

And this is a plot showing the actual ISMR what you saw earlier were the anomalies from the mean and what you see is that there are a lot of fluctuations, these are the major drought years, including 2002, which appears here, but there is no trend. Basically the mean rainfall has remained the same. There are epochs in which it is above normal for a long time, below normal for a long time and so on. But by unless the rainfall has remained the same.

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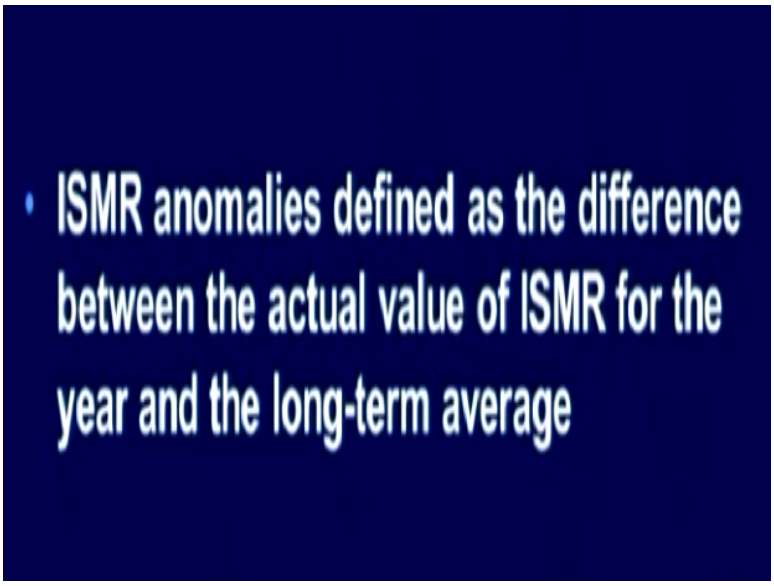

There are no long period trends. Now ISMR anomaly we define as the difference between the actual value of ISMR for the year and the long term average.

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So ISMR anomaly can be considered to be representative of most parts of the country only when there are droughts or excess rainfall seasons, because during normal monsoon, quite a few parts of the country may have above normal, substantial part may have below normal. So it is only when we have droughts that a very large part of the country actually has deficit rainfall and similarly only when we have excess ISMR, then we have large parts of the country having above normal rain.

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We have already seen how ISMR has behaved and by unless the mean has remained constant and there are wide fluctuations around the mean. Now this is how GDP has behaved and you can see that it has grown since independence in a remarkable way, very large growth of GDP that we have registered. This is the Indian economy growth.

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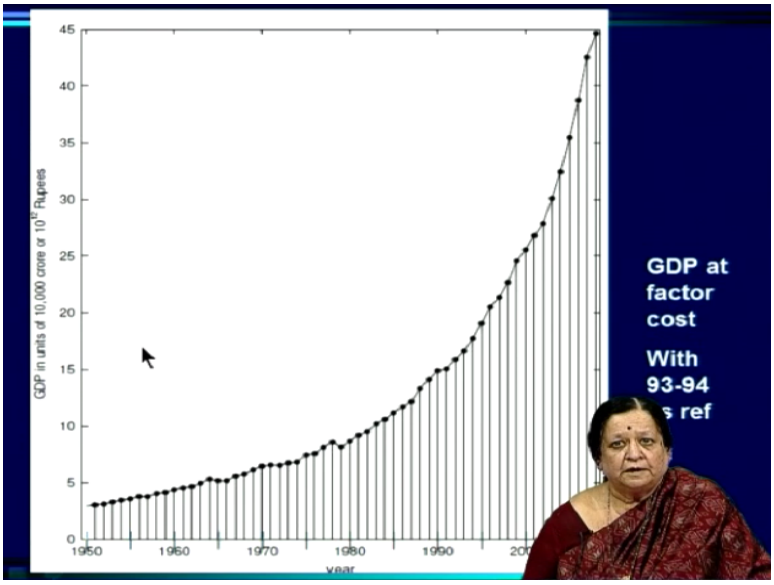

Now this is the food grain production, all India food grain production of the country. That has also increased substantially from the 50s to now, the increase has been more than by a factor of 4. So from 52 to 2010, you have enormous increase in both.

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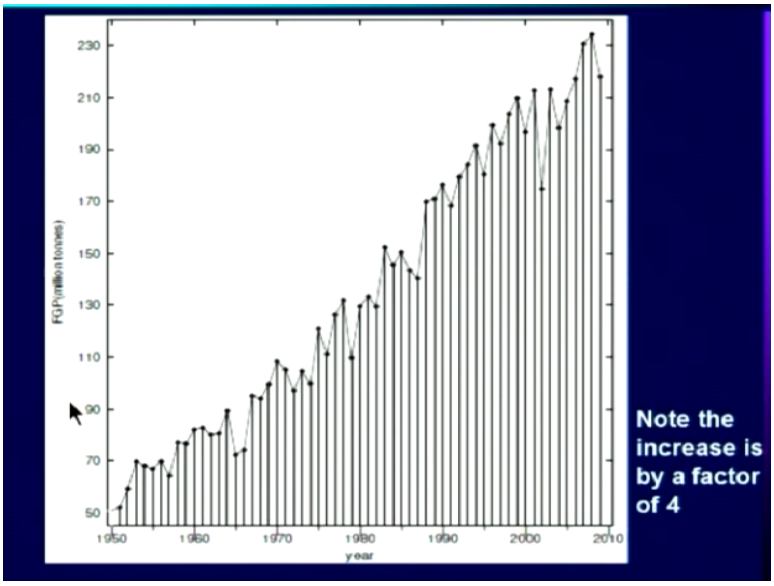

Now what is the relationship between the 2, up there is ISMR anomaly and down here is the same food grain production and what you see is that large dips in ISMR, in fact give rise to substantial dips in the food grain production, that is what you are seeing here including this one year 2002, also gives a substantive dip in the food grain production.

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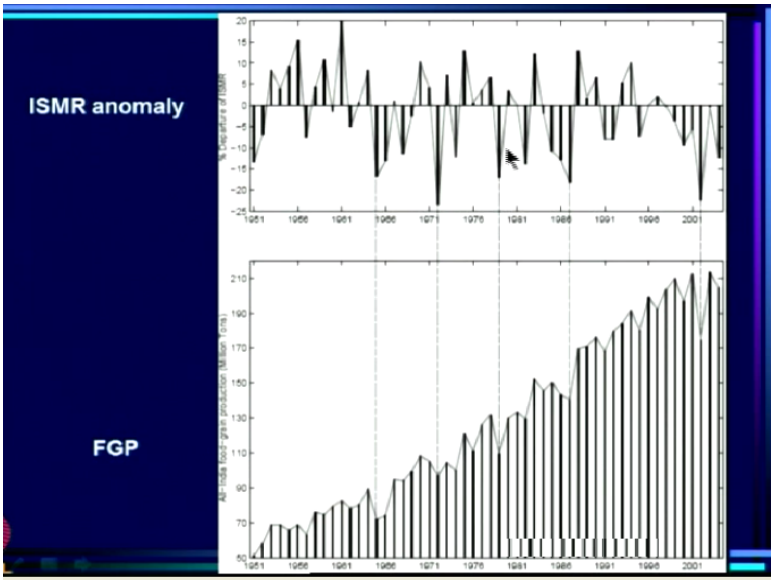

FGP is the total of the production over different agro climatic zones, which will depend on regional rainfall and its subseasonal distribution. Only when there are large deficits or excess in ISMR, most of the country experiences anomaly of the same sign that is drought or excess rain and we expect similar anomalies for food grain production.

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Now how do we go about quantitatively assessing the impact of monsoon on food grain production or GDP. While the monsoon and the factors are dependent on the monsoon, fluctuate from year to year, the other factors leading to the change in growth of agricultural production GDP, etc., vary on a much longer time-scale. We are seeing right from 50s to now, there has been a sustained growth of GDP, so this is in a time-scale of decades that it is changing.

Food grain production also has this kind of a long term trend. We expect deviations from this long term trend to be related to the impact of the monsoon of that year.

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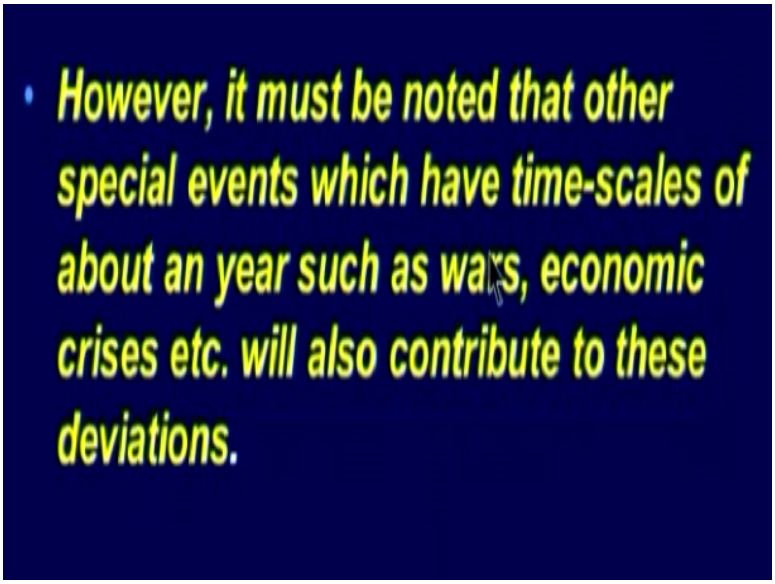

However, it must be noted that other special events which have time-scales of about a year, such as wars, economic crises, etc. will also contribute to these deviations. So what we are doing is quantitatively assessing if you wish, the impact of the events of a specific year. Now a major event of a specific year is a monsoon, but there can be a major event in other years, such as wars and financial crises and so on, which can also have an impact and we will come to that.

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Now we expect the growth rate of GDP to be proportional to the value of GDP. That we expect the growth of GDP to be exponential because the more GDP you have, the better growth you get. So it is proportional to GDP. Now Parthasarathy who is in fact to be given credit for generating this ISMR data at Indian Institute of Tropical meteorology had shown that an exponential function is also good fit for the trend of the growth of food grain production.

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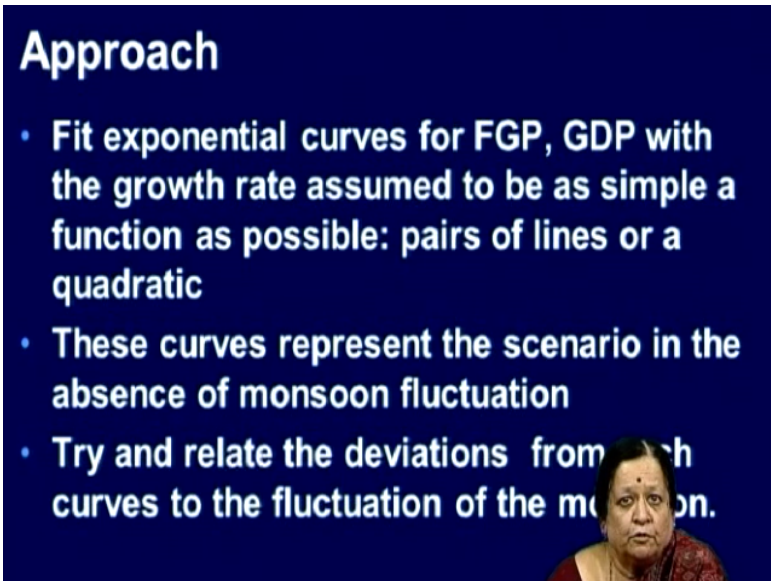

So approach is that if we fit exponential curves for FGP and GDP with the growth rate assumed to be as simple a function as possible. So we do not want to complicate our life. We will in fact fit curves, which are as simple as possible for the growth rate, pairs of lines or quadratic and so on. These curves represent the scenario in the absence of monsoon fluctuation. Now we try and relate the deviations from these curves to the impact of the monsoon.

So this is the GDP and you can already see here. There are some dips here that occur and these are in fact the impact of the monsoon. So since we know that we are going to fit an exponential what we have here is the log of GDP and log of GDP versus year and that means we can fit straight line. This is a line with a certain slope and then we find that after 1980s, we have to fit another line with a much sharper slope.

That is to say the rate at which GDP grew exponential rate is in fact somewhat smaller up to 80, then it is beyond 80 and this is because of the impact of the economic reforms since the 80s. Now had we continued along the same path, we would have gone along the green curve and would not have reached as high as GDP as we have seen. So what are the best fits for GDP now.

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Log GDPi, this is just the growth rate here and it is about 3.5% per year up to 1950 and beyond 1950 it has increased to 5.5% per year. So this is the actual GDP. What we saw in the earlier figure was the log GDP and you can see it is growing exponentially, it would have come only up to here, had we continued along the same path, but since the 80s, the growth rate has picked up and we have gone on a much deeper slope here.

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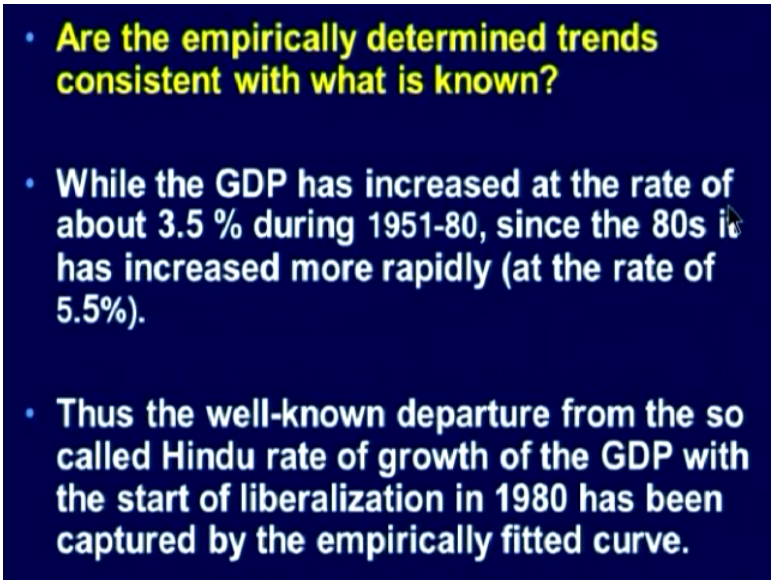

Are the empirically determined trends consistent with what is known? While the GDP has increased at the rate of about 3.5% during 51-80, since the 80s it has increased more rapidly at the rate of 5.5%. Now, this 3.5% was known as the Hindu rate of growth of GDP and only with

the start of liberalization in 1980, we have had a higher growth rate and this has been documented in literature.

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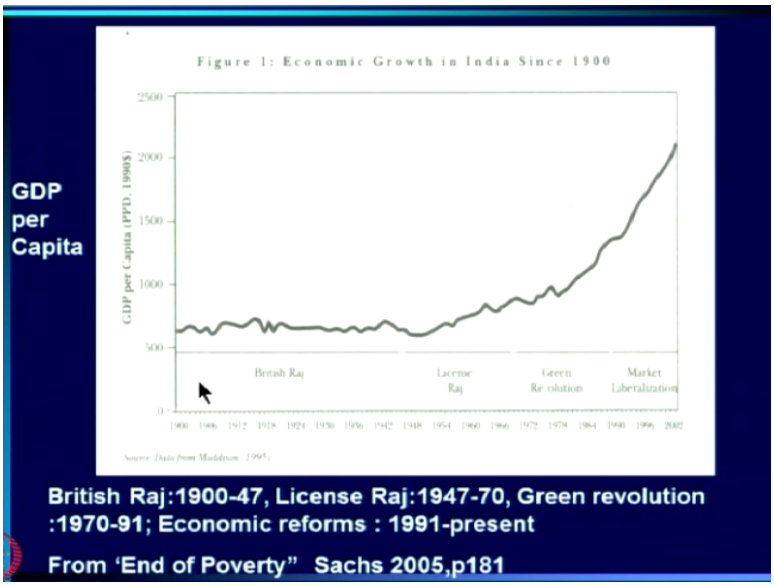

So what we have found by fitting the curves is consistent with what is known. This is from a book End of Poverty by Jeffrey Sachs and he has a picture of the GDP of India and you can see this is British Raj colonial era, the GDP did not grow at all because we were being exploited and now, then there is one rate here and another rate here. So what we have found is very consistent with what other people have also found.

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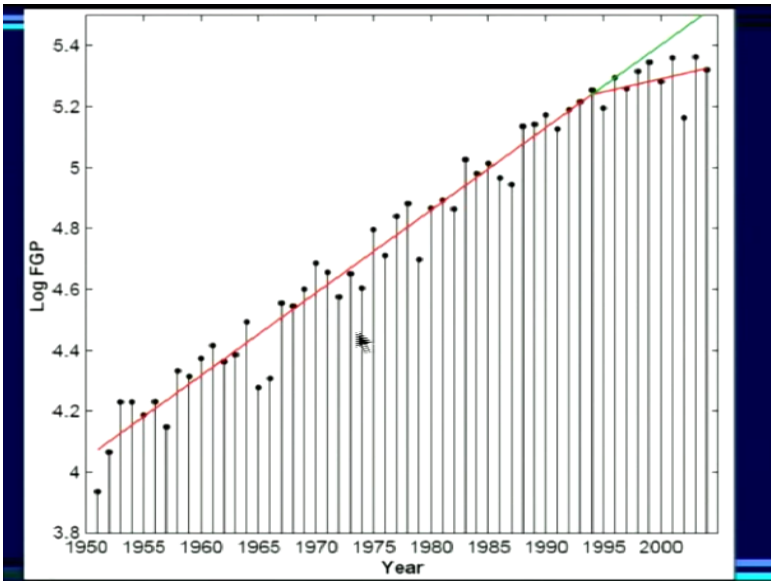

Now we look at the food grain production, again we fit curves, but this time what has happened is while the GDP grew faster than the earlier one, the food grain production, the growth rate has actually dipped since the 90s. So had we continued, we would have been much better off, but actually there has been a dip in the thing.

So what are the trends, from 51-94, it has grown about 3.7% a year and notice that the growth is right from 51, even from before the green revolution of the 70s and this is because a large investment was made by the free government after the end of the colonial rule in many things, which promoted growth of food grain production such as irrigation, making fertilizers available and so on and so forth.

Now from 94-2004, actually the rate of growth of food has dipped very much to < 1%. This is very, very worrying and see it here in actual food grain production that you have this kind of flat, very slow growth rate in this period as opposed to what you had earlier.

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So the growth rate of FGP has increased steadily at about 2.7% from the early 90s consistent with the analysis up to the early 90s. So this is consistent with the analysis of Kurosaki, who also showed this.

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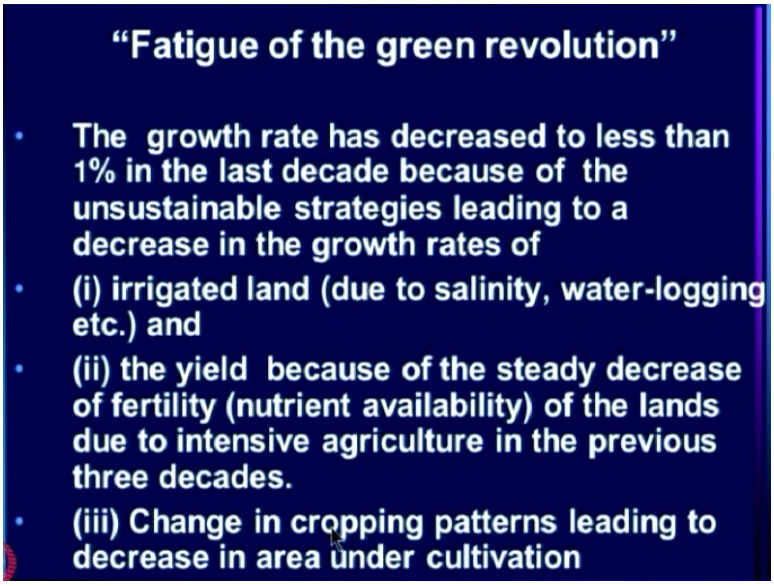

Now the growth rate has decreased to < 1% in the last decade because of the unsustainable strategies leading to a decrease in the growth rates of irrigated land. See irrigated land quite a bit of it has fallen out of cultivation due to salinity, water-logging, etc. and decrease of growth rate of yield because of the steady decrease of fertility that is nutrient availability of the land due to intensive agriculture in the previous 3 decades.

Change in cropping patterns leading to decrease in area under cultivation.

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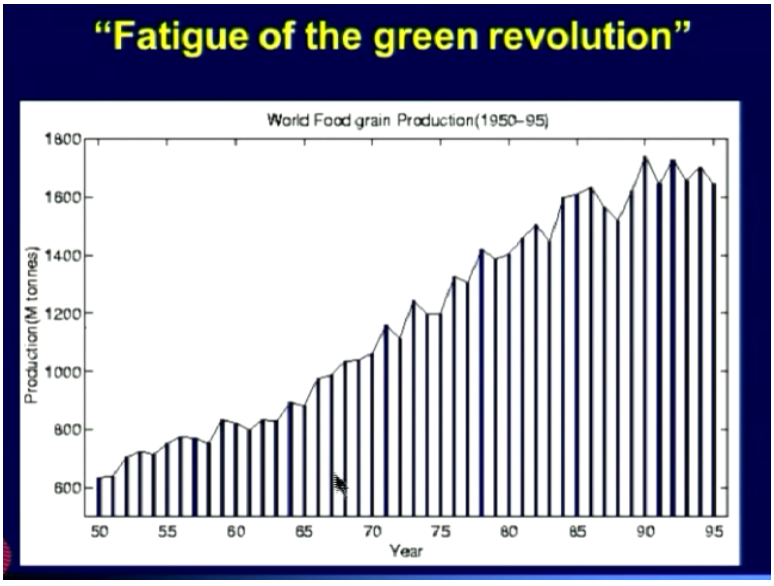

So because of all this, the growth rate has decreased and it is a reflection of what has happened the world over. Even if you look at the world food production, then you find that there is a

fatigue of the green revolution. This is the very fast growth rate that was achieved during the green revolution. Now there is a fatigue and we are also experiencing it.

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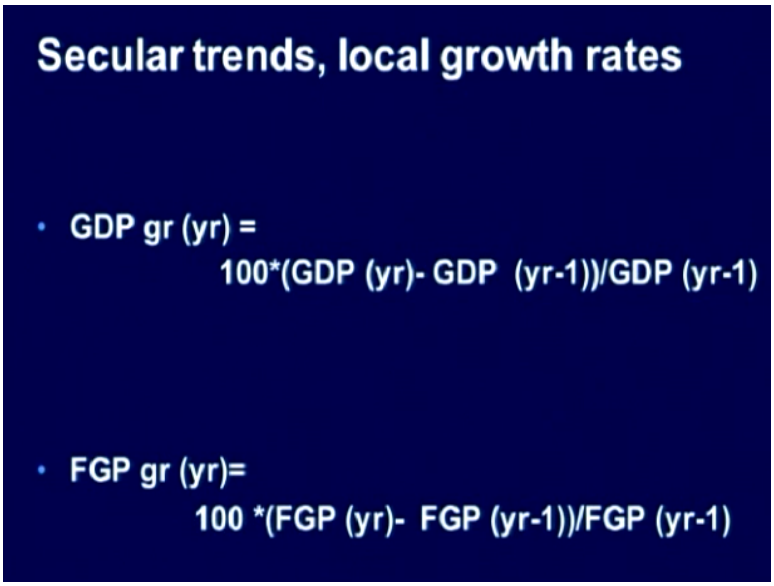

So what are we saying now. There are long term trends, which are exponential and there are also local growth rates. This is what most economies report on. This is what we hear on the radio or TV and this is what we see in the newspapers. The GDP rate coming down from 5.5 to 4.4 that was in the newspaper cutting that I showed earlier. Refer to this growth, which is called the local growth.

So this local growth rate is simply how much the GDP change from last year to this one, normalized by last year's GDP multiplied by 100. Similarly, we can have a local change of FGP. So when it is negative, it means that GDP has decreased. When it is positive, it means GDP has increased from last year to this year.

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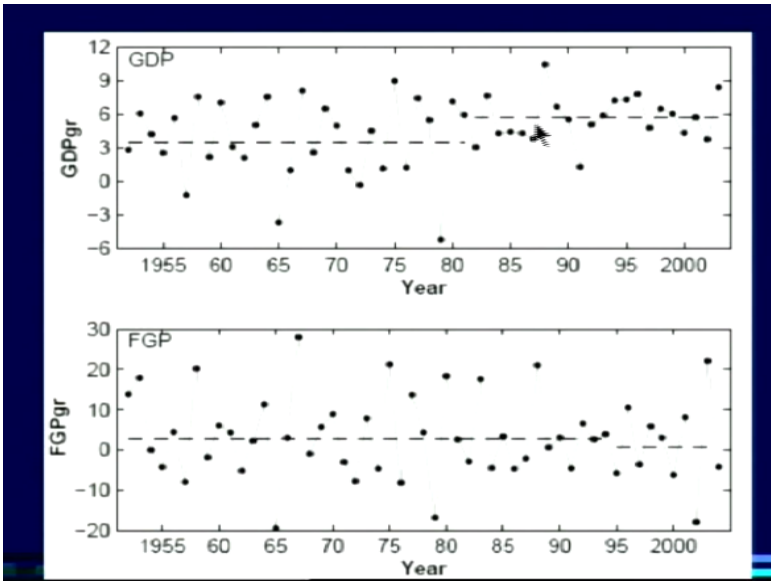

So this local rate looks like this and this is FGP and this is GDP. Basically, it fluctuates a great deal. Now this is the GDP that we had seen and this is the fitted curve and now what we are looking at is deviation from the fitted curve. You can see it is higher than the fitted curve here and lower than the fitted curve here and here and so on. Now this is the FGP and here the deviations are more spectacular.

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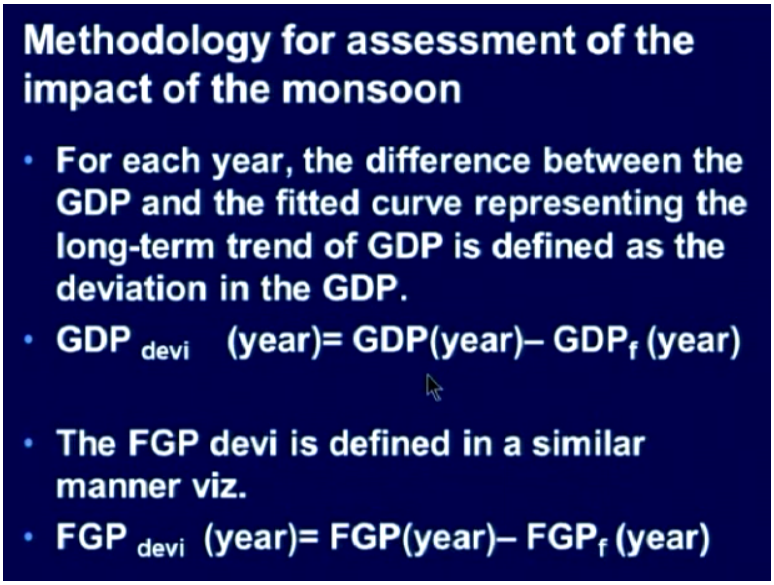

Now how do we assess the impact on the monsoon. For each year, the difference between the GDP and the fitted curve representing the long term trend of GDP is defined as the deviation in the GDP. So what do we say, GDP deviation is the GDP of that year. For example, we take this

point here. So if the GDP of this year – the fitted curve, which is the red one, so the GDP deviation is positive for this and it is actually negative for the next point here.

So that is what we define it. We say GDP deviation in a year is the GDP of that year – GDP fitted at that year and similarly FGP deviation is defined as the value – the fitted value.

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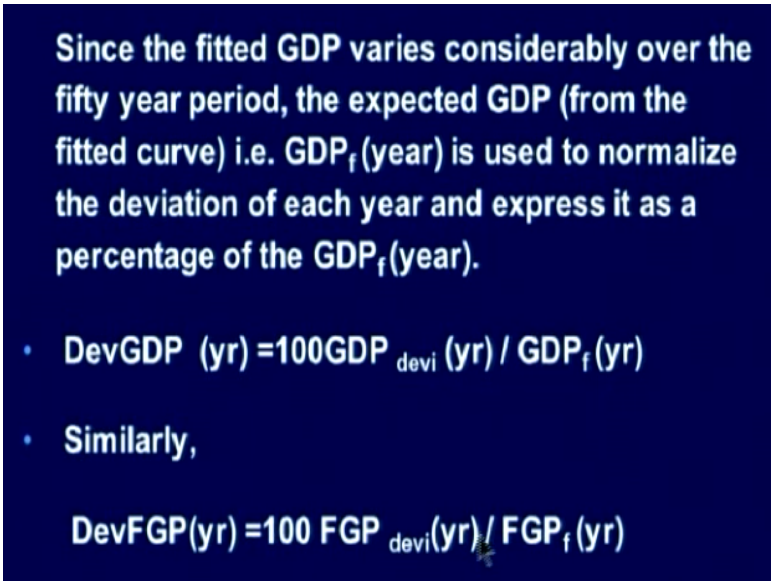

Now the fitted GDP varies considerably over the 50-year period, the expected GDP from the fitted curve that is GDPf year is used to normalize the deviation in year and express it as a percentage of GDP. So this is the minor point. We have to normalize it to express it as a percentage. So deviation is expressed as a percentage using the fitted curve and the same thing with FGP.

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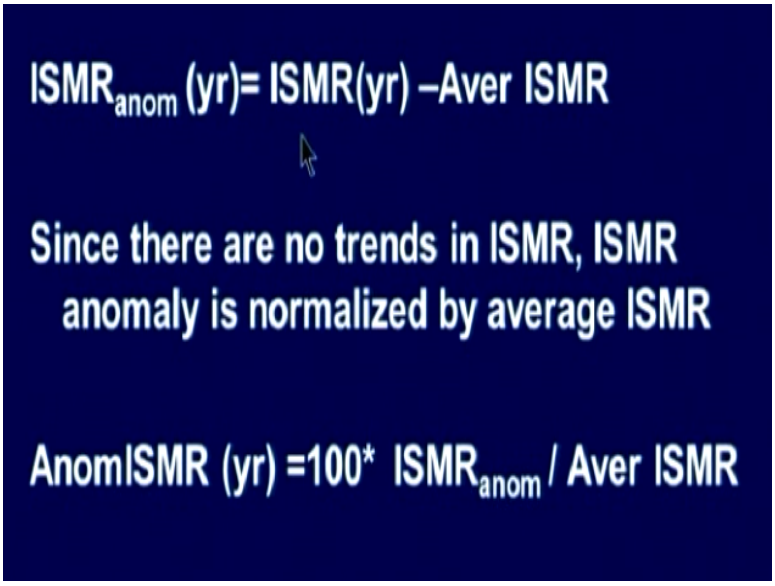

But for ISMR, there are no trends at all. So ISMR anomaly is simply defined as the ISMR of that year – average ISMR and it is normalized by the average ISMR itself. We do not have to worry about special fitted values in this case.

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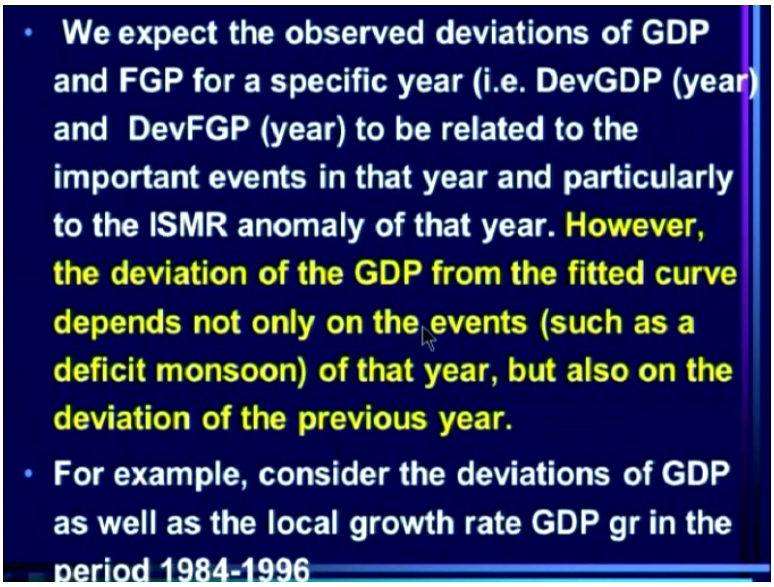

Now we expect the observed deviations of GDP and FGP for a specific year, which we have just defined to be related to the important events in that year, particularly the monsoon rainfall. That is to say the ISMR anomaly of that year. So what are we saying. We expect the extent to which the actual FGP of that year, food grain production of that year differs from the fitted curve, which is the expected food grain production given the long period trend.

Or how much the GDP of that year differs from the expected GDP, which is obtained from that curves that we had of whatever it was, 5.5% growth or whatever. So we expect these deviations to be related to events in that year and particularly the ISMR anomaly. However, the deviation of GDP from the fitted curve, we found depends not only on the events, such as the deficit monsoon of that year, but also on the deviation of the previous year.

This is what made the computation a little more complicated. We could not simply call deviation of GDP as the impact of the events of that year and to show what the problem is, consider the deviations of GDP as well as the local growth rate GDP gr in the period 84-96 and that is what is shown here. Now this is the local growth rate. So this just relates to this year – previous year kind of thing and what you find is that after the drought of 87, the growth rate was positive.

In 88, the local growth rate and so on and so forth. Notice that there was a huge dip in 91 and we will see later this dip had nothing to do with the monsoon, this had to do with the financial crisis. So this is the GDP dip due to the financial crisis, which occur in 91 and notice that after that in fact, the GDP has been increasing steadily from year to year. There is no negative growth, but in spite of that, when we look at the actual GDP which are the expected long period trend, then we find that this dip that occurred in 91 could not be made up till 5 years later.

So the curve remains below the fitted curve for several years because of this particular dip that occurred in 91. So we cannot simply blindly now relate this deviation from the fitted curve to impact of that year.

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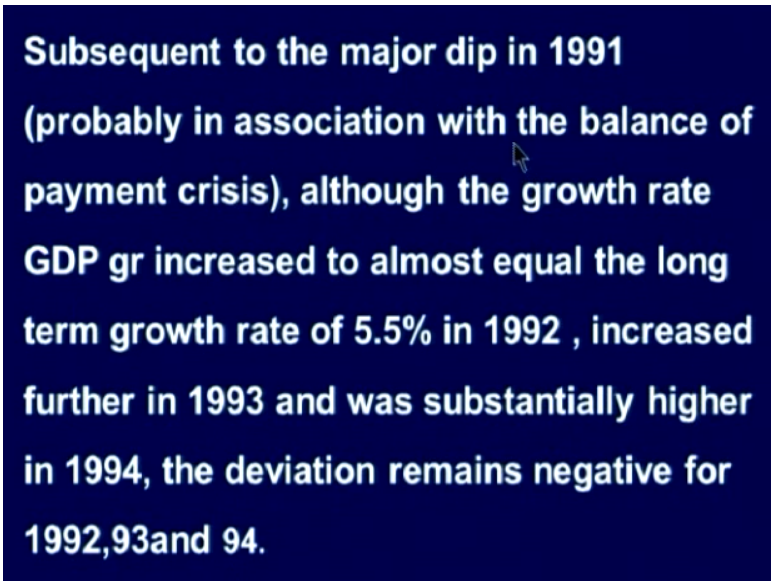

Subsequent to the major dip in 1991 (probably in association with the balance of payment crisis), although the growth rate GDP gr, this is the local growth rate now, increased to almost equal the long term growth rate of 5.5% in 1992 increased further in 1993 and was substantially higher in 1994, the deviation remains negative for 92, 93, and 94.

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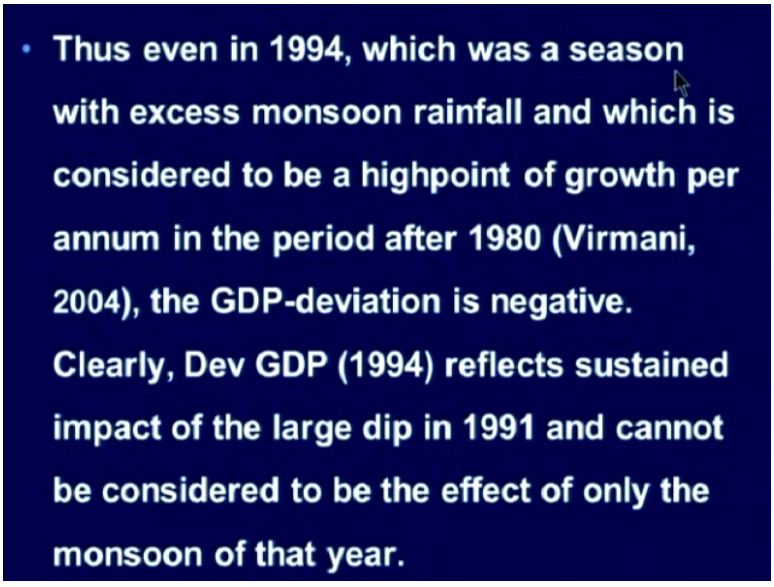

Thus even in 1994, which was season with excess monsoon rainfall and which is considered to be a highpoint of growth per annum in the period after 1980, the GDP-deviation is negative. Clearly dev GDP reflects sustained impact of the large dip in 1991 and cannot be considered to be the effect only of that year, so what do we do?

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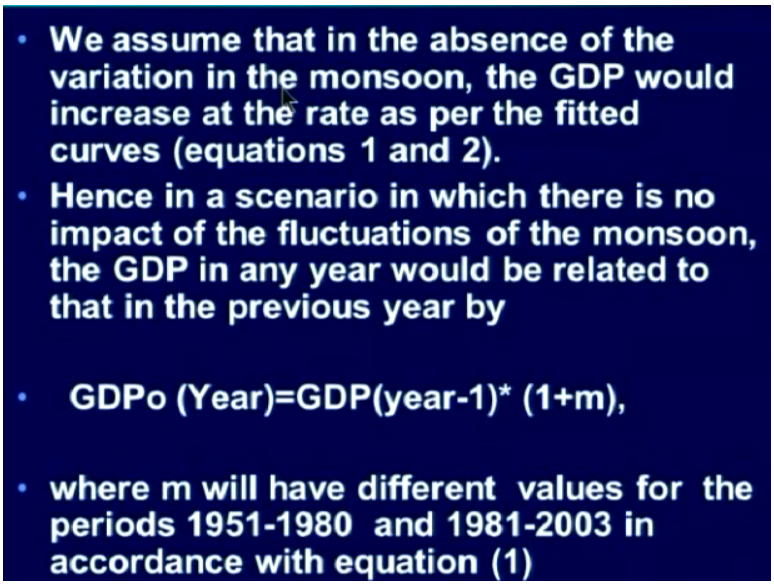

We actually assume that in the absence of variation of the monsoon, GDP would increase at the rate as per the fitted curves. Hence in a scenario, in which there is no impact of the fluctuations of the monsoon, the GDP in any year would be related to the GDP in the previous year simply by the equation that GDP of that year = GDP year –1*1+m, where m will have different values for this period 51-80 and 81-2003.

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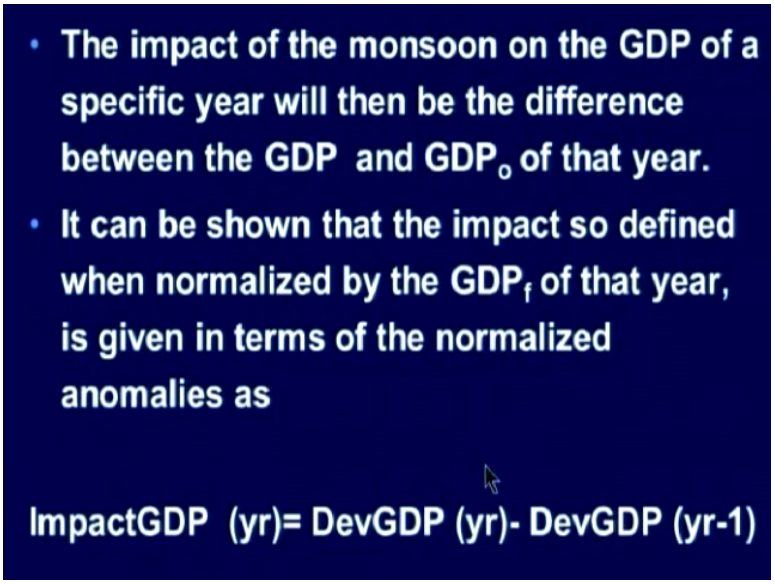

We are saying it is growing with the given rate. Now impact of the monsoon and the GDP of the specific year will then be the difference between the GDP and GDP0. Left to itself, GDP would grow at the rate m. Now if it did not grow at the rate m, it would be something different from

GDP0 and the difference between GDP and GDP0 will be the impact of monsoon or any other event of that year.

Now it can be shown that the impact so defined when normalized by the GDPf of that year, which is what we had done is given in terms of the normalized anomalies as impact of GDP will be deviation of GDP year – deviation of GDP year -1. This can be shown. It is a matter of doing the algebra.

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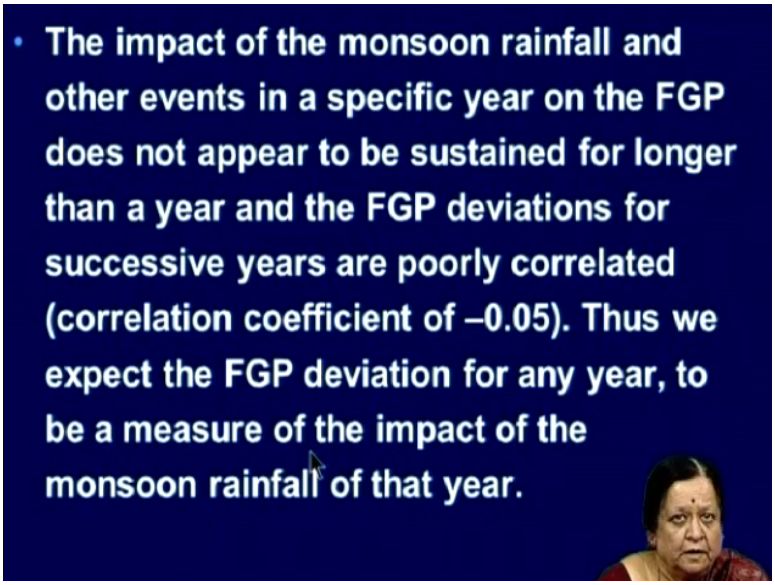

Now impact of the monsoon rainfall and other events in a specific year on the FGP does not appear to be sustained for longer than a year. So unlike GDP, we do not have to worry too much about FGP and the FGP deviations for successive years are poorly correlated. Correlation between them is only-0.05. Thus we expect the FGP deviation for any year to be a measure of the impact of the monsoon rainfall of that year.

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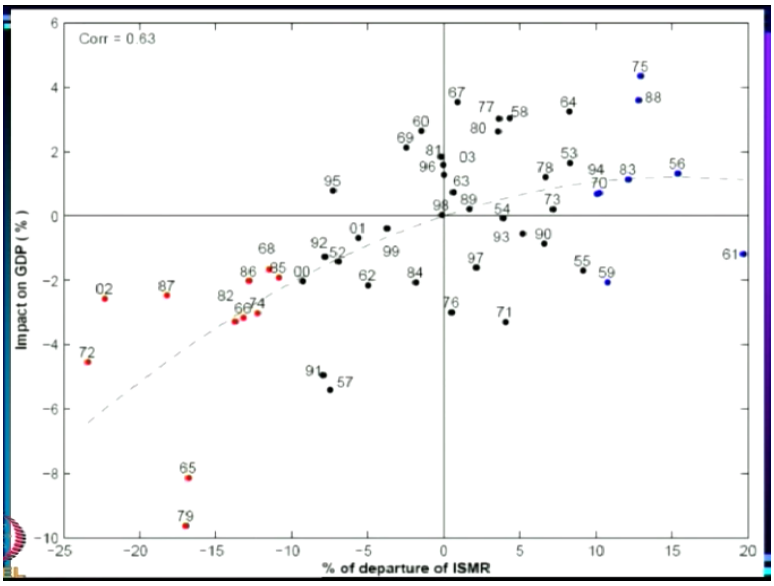

Now here is the final plot that came out from this and what you see here is the impact on GDP on the y-axis and the percentage departure of ISMR, this is the monsoon rainfall on the x-axis. Now what you see is, this is the 0 line on the x-axis. So all these years there has been deficit monsoon and beyond -10, there are all droughts and they are marked with red dots here. Now this is all positive, this means monsoon rainfall has been above normal for the country as a whole.

When it is more than 10, the ISMR anomaly more than 10%, then you have all these excess monsoon seasons hear. Now what is the impact like. First thing that strikes you is if you wanted to fit a curve of the impact versus monsoon, it is a highly non-linear curve. You see as the deficit increases; it dips very fast. In other words, when we have severe droughts, we get a very, very large impact and you know, it does not matter when it is.

Even 2002, which is after so much progress and as I will show later, the contribution of agriculture to GDP has decreased from around 50% towards the beginning of this period in 1950 to < 20% now and so one would have thought that the economy would become drought proof, but this shows the point to the contrary that even in 2002, when agriculture did not contribute so much to the economy, still a drought had an impact of more than 2%, which is a huge impact. So all the droughts have impact roughly between 2-5%.

In this part, the more the deficit, the more the impact. The impact increases rapidly with the magnitude of the deficit in monsoon rainfall, but on this side, it hardly increases. So we have a very large impact due to negative anomalies of ISMR. We have bad impact in other words, dipping of GDP or negative GDP impact associated with negative ISMR anomalies, but the positive GDP impact associated with positive anomalies is not at all commensurate with the negative impact.

So this is a highly non-linear thing and this was most unexpected. So what we see is that in fact, the negative impact of deficit monsoon is much larger than the positive impact of above normal monsoon with the same magnitude of the ISMR anomaly and for FGP, the story is exactly the same, again highly non-linear, we get a huge suppression, depression in FGP when we have droughts, but we do not have anything like the increase when we have good rainfall.

So the same story again.

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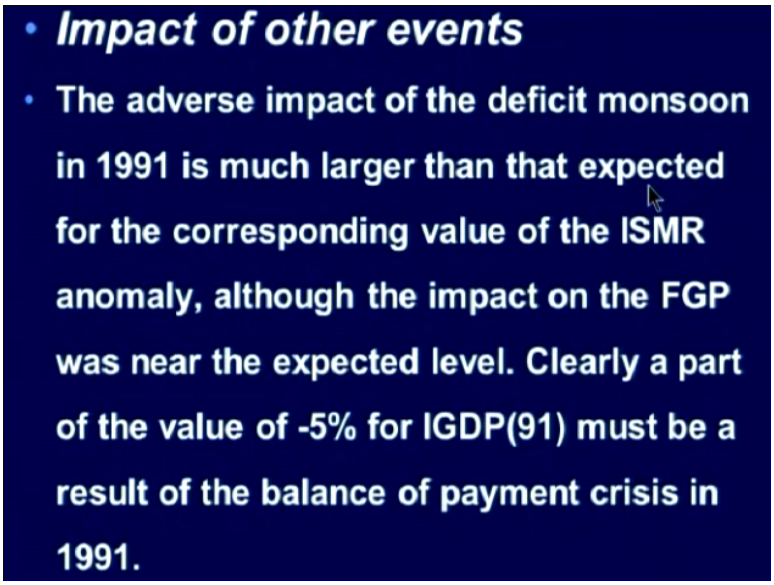

Now before I go to the impact of the monsoon, which I am going to dwell on of course, we have to remember that there are other events, which also have an impact. We talked of the event of 1991 and what has happened is, we can see here now. Let us see impact of 1991 and you see it here. This is 91. It was not a very large deficit monsoon, as you can see. Most of the points for

this kind of monsoon are around here, but we got a very, very large dip in GDP because of other reasons, other than the monsoon.

So the adverse impact of the deficit monsoon in 1991 is much larger than that expected from the corresponding ISMR anomaly, although the impact on the FGP was near the expected level. So in fact, impact from FGP is exactly near the expected level. So what happened is because the monsoon was not that much in deficit, the impact on food grain production was not very high in magnitude. It was commensurate with what we expect.

But the impact on GDP was very large, I mean it was larger than many, many droughts that we have seen. So clearly a part of the value of -5% for the impact on GDP at 91 must be a result of the balance of payment crisis.

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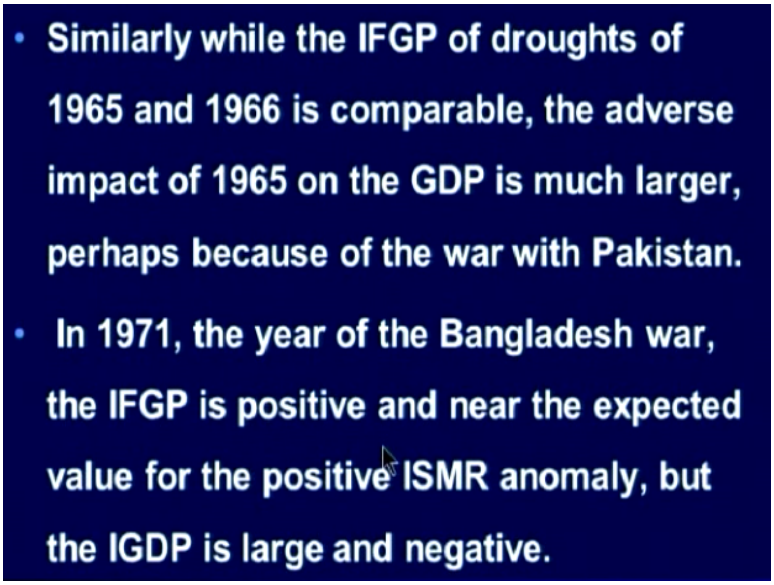

Similarly, while IFGP that is to say impact on FGP of droughts of 65 and 66 is comparable, adverse impact of 65 on GDP is much larger, probably because of the war with Pakistan. So let us just see here, 65 and 66, this is impact on food grain production and the anomalies close to -15% and impact of food grain production is very, very similar for 65 and 66, but it you see here on GDP, 65 is a point which comes way below the expected here.

And that is probably this extra is because of the war with Pakistan that we had. In 71, the year of the Bangladesh war, IFGP is positive and near the expected value for the positive ISMR anomaly, but the IGDP is large and negative. So let us see if we can find this 71 here and here it is. 71 has an ISMR anomaly of 5% positive and for that year we have impact on FGP exactly on the curve, but if you look at 71, impact on GDP is almost 4%.

So big impact again and this has to do with the Bangladesh war, but by unless there are only few years, where you see that the impact is not of the monsoon, but some other events, probably some other event. So values of IGDP, which are very different from those expected from value of ISMR anomaly associated with the incidents such as wars or economic crisis, not related with the monsoon.

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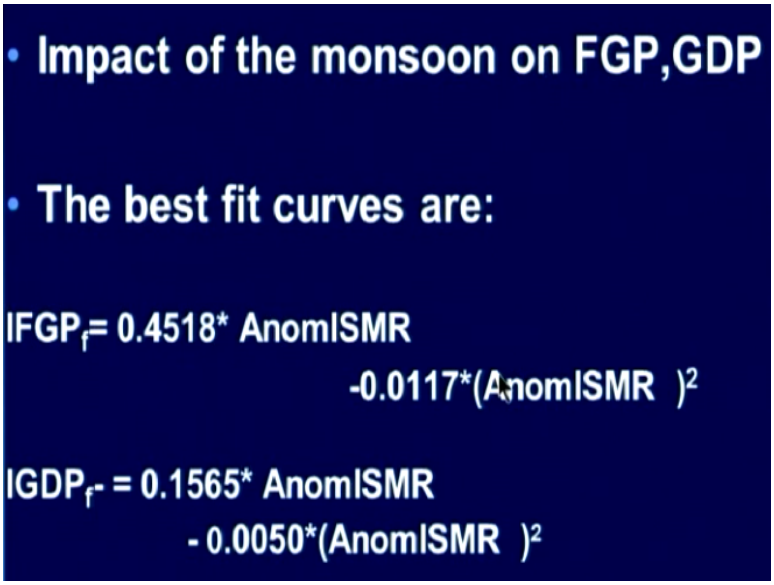

But now we do not worry about that. Now we look at most of the years for which actually we can understand the deviations in FGP and GDP in terms of impact of the monsoon itself. Now what are the best fit curves for these that you saw. Now we are talking about the best fit curves like this. This is the dash line, which is the best fit curve, this one. The equations for those best fit curves are that you have 0.4518 anomaly ISMR – this square.

You can see how non-linear it is. It is a quadratic form you are getting here and similarly you have a best fit curve for the impact of GDP as well.

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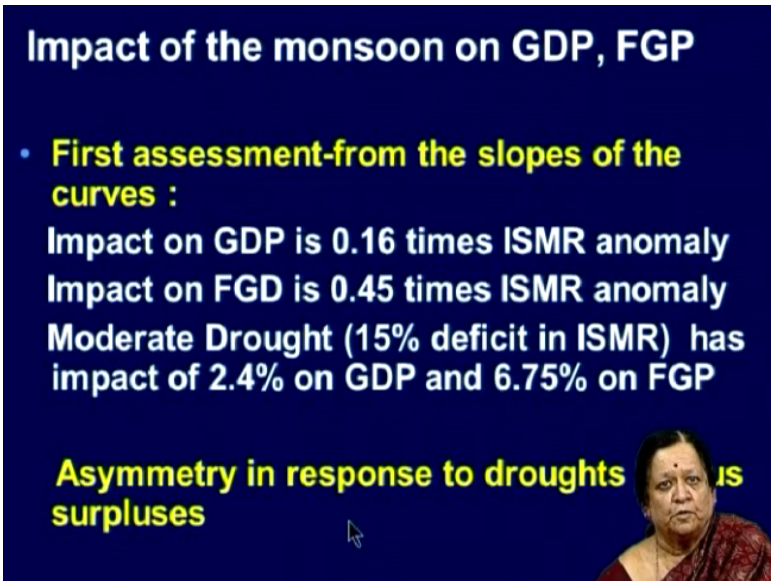

So from these best fit curves, we can get a first assessment of how much is the impact of the monsoon on GDP or FGP and the impact on GDP is 0.16 * the ISMR anomaly. Impact on FGP is 0.45 * the ISMR anomaly, that is to say a moderate drought 15% deficit has an impact of 2.4% of GDP and 6.75% on FGP. That is to say if the impact were according to those fitted lines, which I just show you.

And already you can see that for ISMR anomaly of the same magnitude, a negative anomaly will have much larger impact than a positive anomaly.

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And we will see that. So the impact of the monsoon and FGP and GDP is highly non-linear with the magnitude of the impact of a negative ISMR anomaly being larger than that of a positive ISMR anomaly of the same magnitude. So even if the all India monsoon rainfall does not vary over long period, the impact of deficit rainfall years will never be made up by impact of normal or good monsoon years.

Now this is a very worrisome thing because this means that the integral effect of the impact of the monsoon will be to decrease the food grain production over the years, simply because impact of negative anomalies are never made up by impact of positive anomaly.

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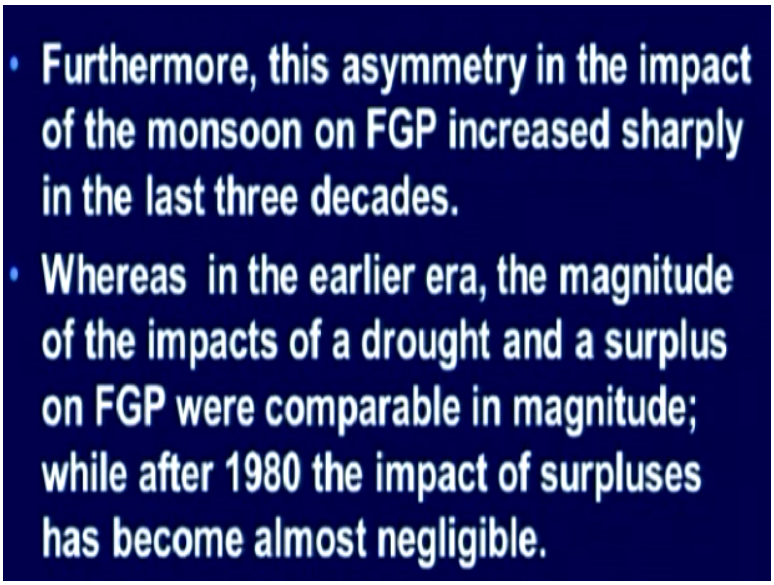

Furthermore, this asymmetry in the impact of the monsoon on FGP increase sharply in the last 3 decades whereas in the earlier era, the magnitude of the impacts of a drought and a surplus of FGP were comparable in magnitude after 1980, the impact of surplus has become almost negligible.

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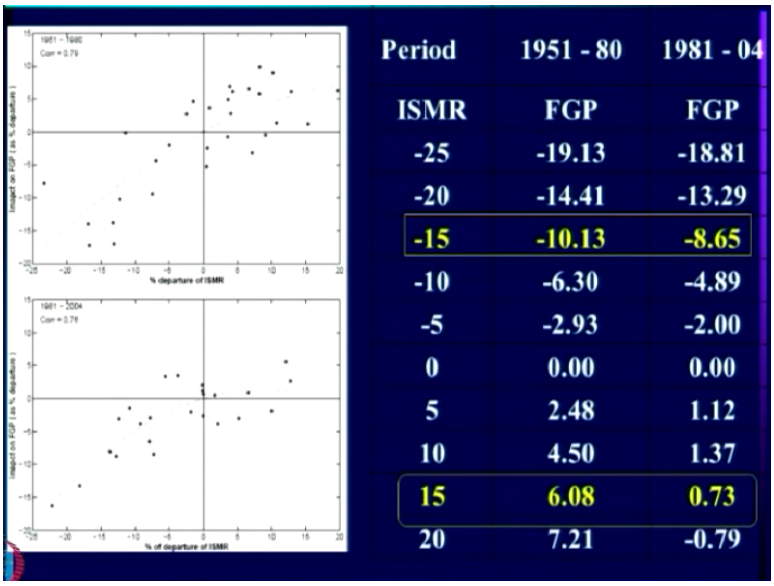

Period	1951 - 80	1981 - 04
ISMR	FGP	FGP
-25	-19.13	-18.81
-20	-14.41	-13.29
-15	-10.13	-8.65
-10	-6.30	-4.89
-5	-2.93	-2.00
0	0.00	0.00
5	2.48	1.12
10	4.50	1.37
15	6.08	0.73
20	7.21	-0.79

Now this is the same graph, this is in the era before 1980 where you have some surplus, but after 1980, there is hardly any surplus at all, although you have more monsoon. So if you look at this is the period from 51-80 for selected and 81-2004 then impact of a 15% deficit is -10% in the earlier era and -8.65 now, so roughly comparable, but positive anomaly of the same magnitude impact earlier uses by 6%, which is comparable to 10%.

But now it is almost just down to < 1%. So now you are getting hardly any positive impact of positive anomaly. So in fact the curve of impact of FGP or GDP versus monsoon, ISMR is non-linear, but now it is becoming more non-linear in the later era after 1980s. This is an observation.

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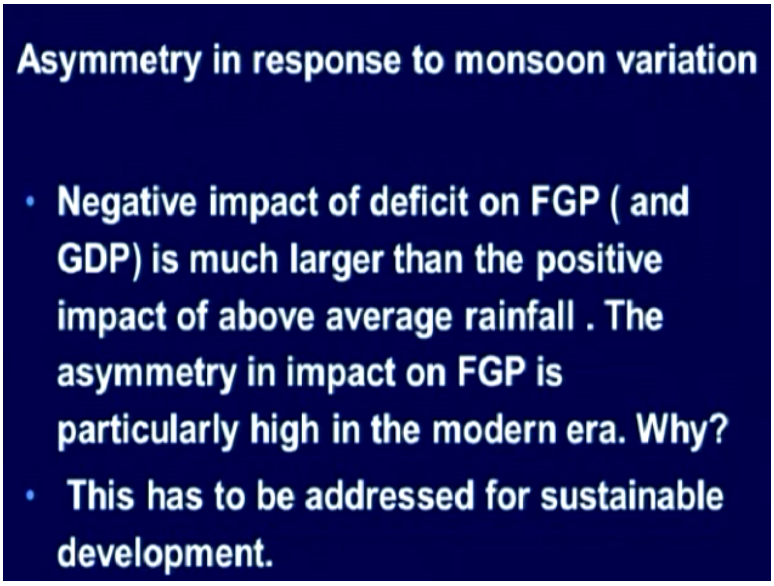

So negative impact of deficit on FGP is much larger than the positive impact of above average rainfall. The asymmetry in impact on the FGP is particularly high in the modern era, why this problem we have to address if you want sustainable development.

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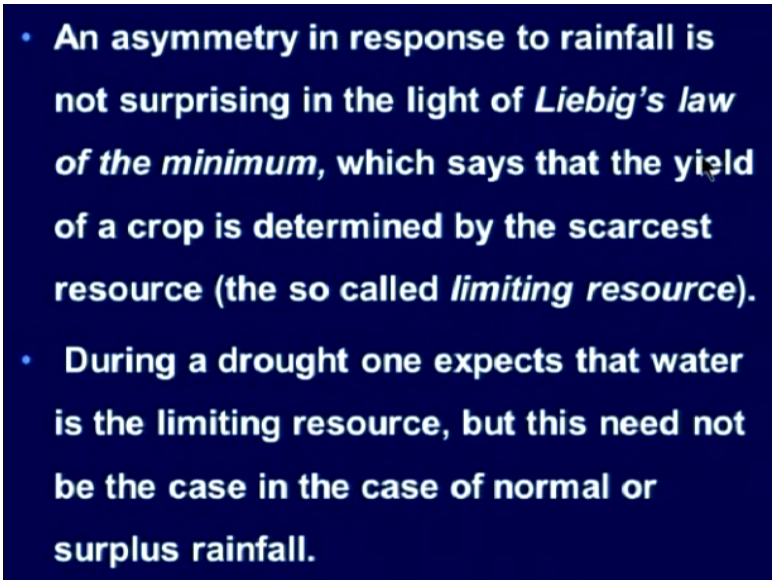

Now an asymmetry in response to rainfall is not surprising in the light of Liebig's law of the minimum which says that the yield of a crop is determined by the scarcest resource, the so called limiting resource. Now during a drought 1 expects that water is the limiting resource, but this need not be the case in the case of normal or surplus rainfall.

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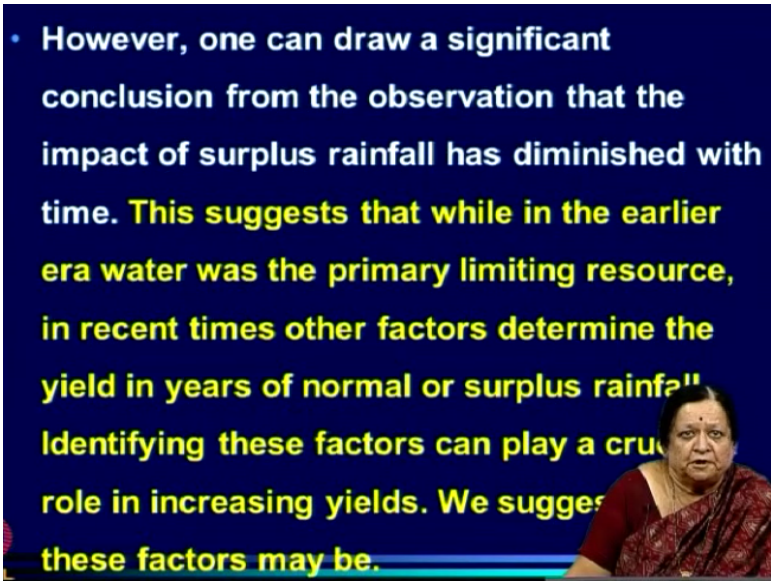

However, 1 can draw a significant conclusion from the observation that the impact of surplus rainfall has diminished with time. It is much less after the 80s, than it was before. This suggests that while in the earlier era water was the primary limiting resource, in recent times other factors determine the yield in years of normal or surplus rainfall, identifying these factors can play a crucial role in increasing these yield. So we now try and see what these factors could be.

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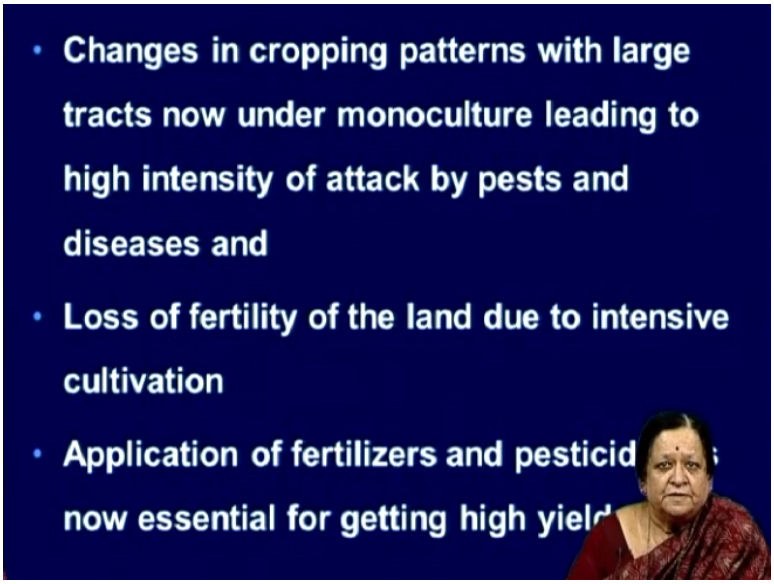

So look at what has changed over a period, changes in cropping patterns with large tracts now under monoculture leading to a high intensity of attack by pests and diseases, loss of fertility of land due to intensive cultivation, because of these 2 things application of pesticides and fertilizers is now essential for getting high yields.

Even if you have good rainfall, you will not high yields unless you apply fertilizers to make up for the loss of fertility of the soil, and unless you apply pesticides to keep the pests under control, because now pests have become endemic in many regions.

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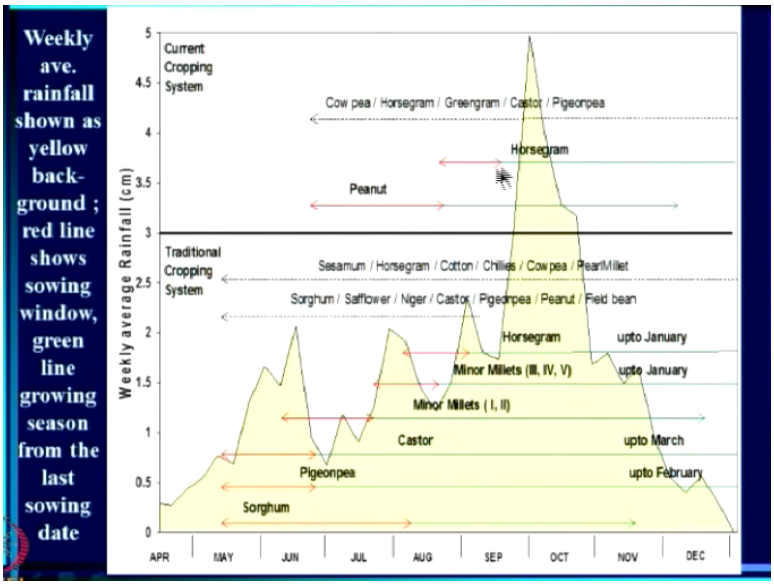

So earlier you know, for example in semi-arid region where we worked near Pavagada there used to be a whole variety of crops grown, a large number of millets and so many other sorghum and pigeon pea and so on, this is the weekly rainfall in that region, and the entire rainfall profile needs to be utilized. Now what they do is use primarily groundnut and horse gram, only 2 crops are now grown. So there is much less variety in cropping pattern now.

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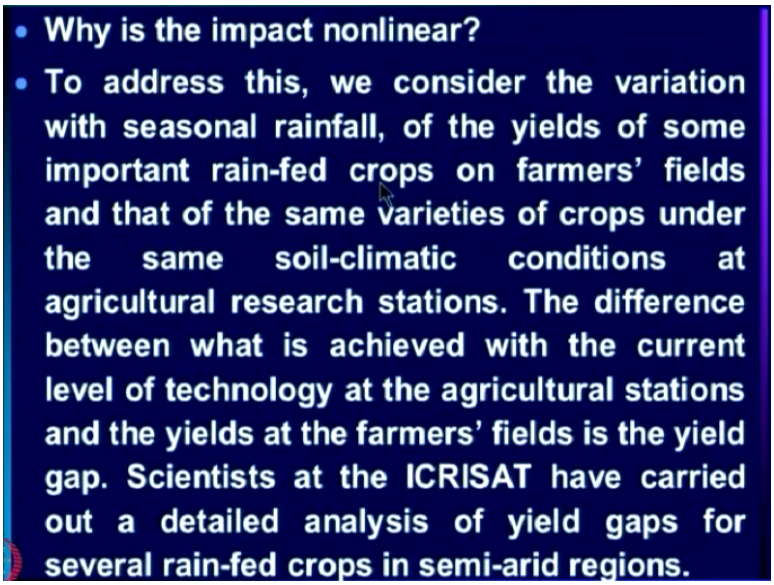

So now to understand why is the impact non-linear, we consider the variation with seasonal rainfall of the yields of some important rain-fed crops on farmer's fields and that of the same varieties under the same soil-climatic conditions at agricultural research stations. So we are

comparing the yields in the same agro climatic region for the same variety of the crop, but grown by the farmer on the 1 hand and at the agricultural resource station on the other.

The difference is what is called the yield gap, and this difference between what is achieved with the current level of technology at the agricultural station and the yields at the farmer's fields is the yield gap. And actually scientists at ICRISAT at Hyderabad have carried out a detail analysis and this is 1 of the figure from theirs.

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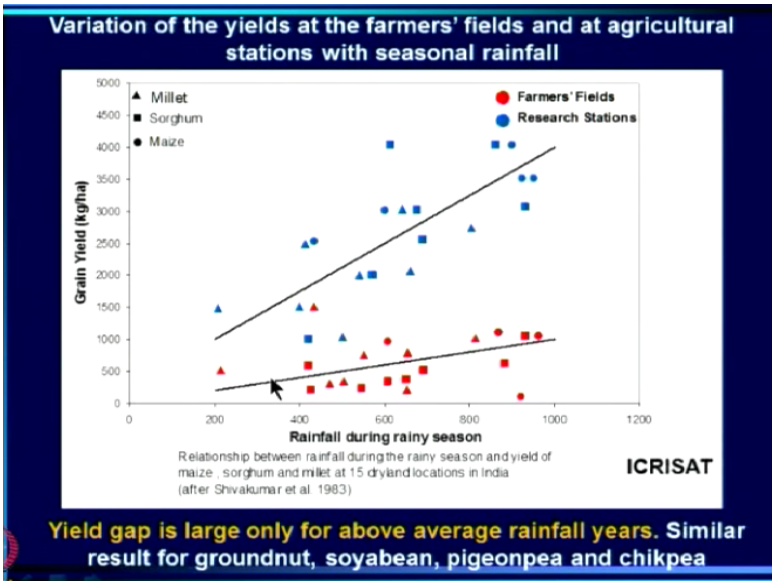

What you see is, this is the grain yield and this is of several crops here millet, sorghum and maize, and this is the seasonal rainfall. So seasonal rainfall increases as you go, this way red dots corresponds to farmer's field, blue dots correspond to the yield in the research station. What you see is that when the rainfall is low, there is not too much difference between the 2, but as rainfall increases then the yield gap widens.

And what is achieved at the agricultural stations in terms of yield is much, much higher than what the farmer gets. So yield gap is very large only for above rainfall years and a similar result ICRISAT people have got for groundnut, soya bean, pigeon pea, chick peas so many other crops.

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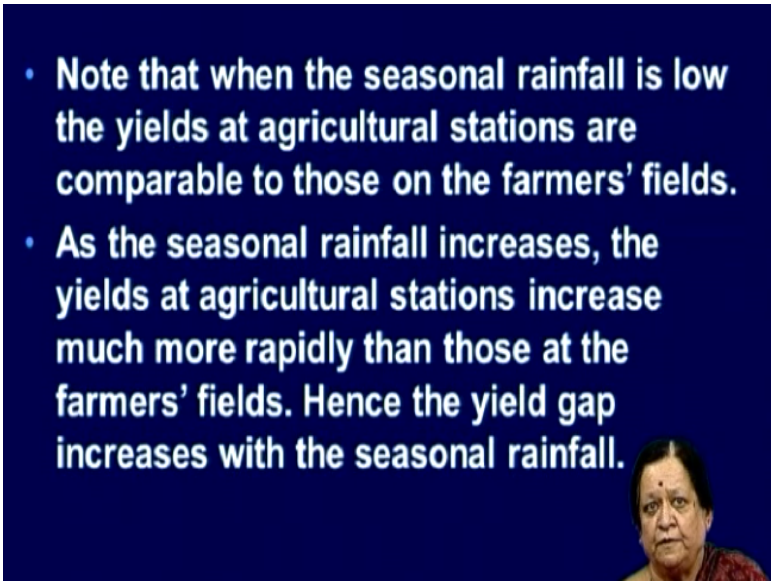

So when the seasonal rainfall is low the yields at the agricultural stations are comparable to those on the farmer's fields. As the seasonal rainfall increases the yields at the agricultural stations increase much more rapidly than those at farmer's fields and so the yield gap increases with rainfall.

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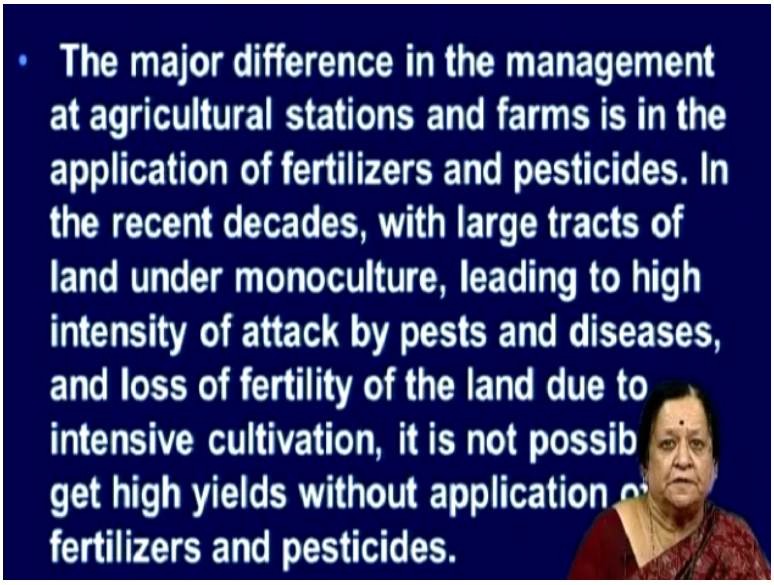

Now why does this happen, so what is the difference in the agricultural practices in the 2 situations. The major difference in the management at the agricultural stations and farms is in the application of fertilizers and pesticides. In the recent decades with large tracts of land under monoculture, leading to high intensity of attack by pests and diseases, and loss of fertility of the

land due to intensive cultivation, it is not possible to get high yields without application of fertilizers and pesticides.

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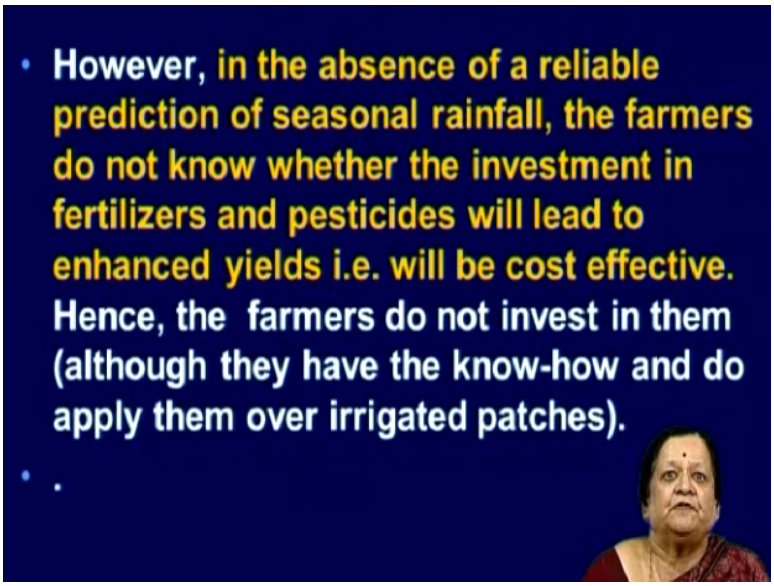

However, in the absence of a reliable prediction of seasonal rainfall the farmers do not know whether the investment in fertilizers and pesticides will lead to enhanced yields that is to say it will be cost effective or not. The point is only if the rainfall is normal or above normal it pays to investing fertilizers or pesticides. As you have seen, when the rainfall is low, even with fertilizers and pesticides agricultural research stations were not able to get much higher yields, and farmers have to pay for the fertilizers and pesticides.

So they have to calculate what is the enhancement in yield that they would get by the additional expenditure on the fertilizer and pesticide, and they do not believe it is cost effective, that is to say benefit is larger than cost, if the rainfall is not high, if it is low. So since they do not know whether the rainfall will be low or not, the farmers do not invest in them, although they have known, they will apply them at the irrigated patches.

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On the other hand, at agricultural stations farm economics is irrelevant, because they get all their money from the government. So liberal does of fertilizers and pesticides can be applied. Even then the yields are not very much better than the farmer's yields in poor rainfall year. In normal or good monsoon years, the yield enhancement due to this application is very large, hence the yield gap increases with rain.

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So now what are the farmers doing, farmers in this rain-fed track are basically not investing in fertilizers and pesticides. Now so they are adopting a strategy which is the same strategy year after year, which is not using any information that we have on rainfall variability. Even if we did not have prediction for a specific year, say 2013, as to how the rain is going to be over a region,

we have a lot of data 100 years of data and with that we should be able to see what is possibility, what is the probability of occurrence of low rainfall, low as defined on the yield curve.

So the farmers are really concerned with the case of rainfall lower than around year, because after this then application of fertilizers and pesticides does give substantive enhancement in yields year. So we want to know what is the probability of rainfall lower than this and that can be easily calculated, surely that is never 100%, even in small regions it will never exceed 30% or so. So the farmers are adopting a strategy which is insensitive to climate variation and is not appropriate for a majority of the years,

For example, ISMR deficit is large, meaning that you have actually droughts, if you consider the period of 58-2010, it is large only for 25% of the years, so on the 75% of the year's farmers could have actually gained. So if you think of a long term average by applying pesticides and fertilizers they can gain and they can close the yield gap successfully. But what they are doing is adopting the strategy, which is appropriate for a say, 25-30% of the years, every year.

And that is really what is causing this huge yield gap and also that is what is leading to their not getting benefits of good monsoon years, because they are not giving another very important input to the fertilizers and they are not controlling pests which can have a very large impact on the thing. So our problem that the negative impact of a deficit monsoon is much higher than the positive impact, which will lead in the long run to a successive decrease in the food grain production.

If you want to actually stop that, if you want to mitigate over that, then it is essential that the farmers adopt a strategy which is appropriate to the rainfall variability of the region. Now if in particular or reliable prediction of a non occurrence of droughts is possible, then it will have a very huge impact on agricultural production, that is very clear.

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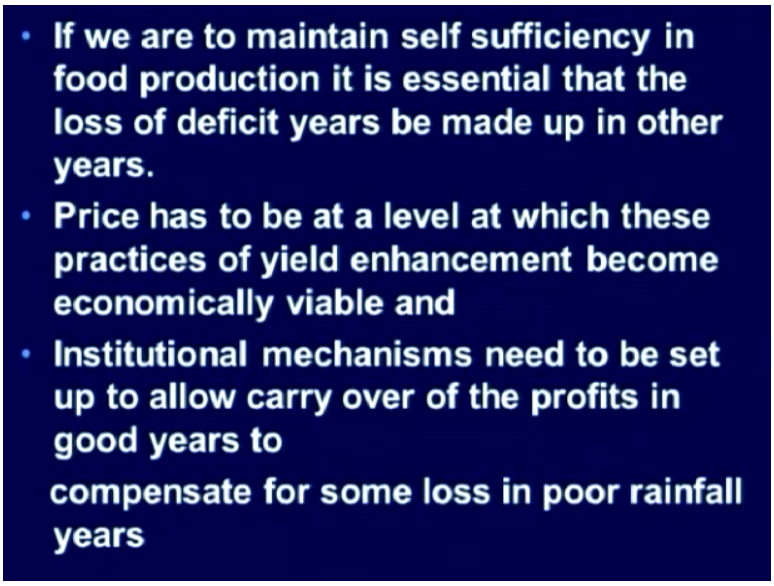

If we are to maintain self sufficiency in food production, it is essential that the loss of deficit years be made up in other years. Now how do we do that, price has to be at a level at which these practices of yield enhancement become economically viable, because why are farmers not investing in it, not because they do not know, they invest in it on irrigated patches where the yield is assured.

They are not investing in it on rain-fed patches because their estimate of enhanced benefit due to enhanced yield is not larger than the cost they incur, in some of the years. Now if the price was high to a level, to a higher level than the present, then obviously the enhanced benefit due to enhanced yield will be larger and that may make it economically viable for them to actually invest in fertilizers and pesticides.

So this is something that we have to think about and institutional mechanisms need to be set up to carry over the profits of the good years to compensate for some loss in poor rainfall years, now this is where it is very difficult for marginal farmers and farmers without any capital to do. But this is where farmers in places like Australia are able to actually tailor their strategies to climate variability and in their case wheat is not irrigated like in ours.

And in Australia 3 years' large profits can take care of 7 years of relatively low profits or even losses. And this is because the farmers are able to carry over this, so we may need to make up mechanisms to address this.

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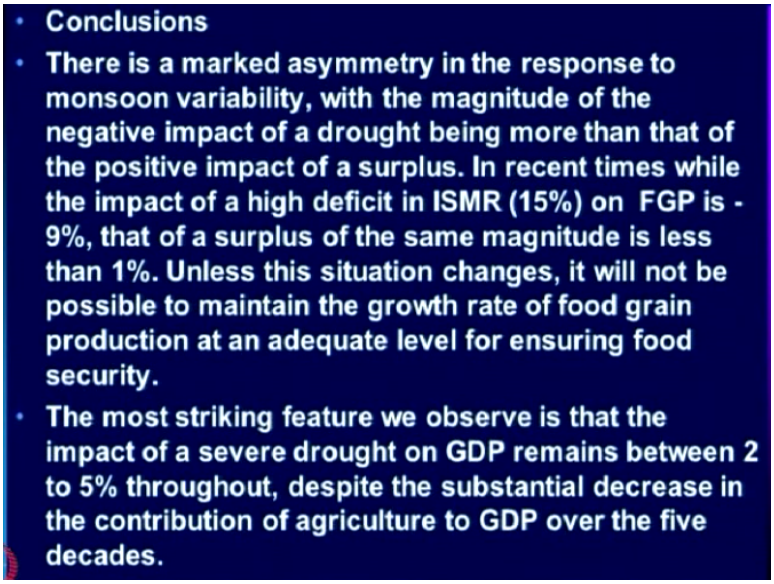

So a surprising result of this study which was a straight forward study of impact of monsoon on FGP and GDP, made by fitting long period trends and saying that the deviation from these trends, long period trends must be caused by events of the year which include wars, which include balance of payment crisis, but most often which include vagaries of the monsoon. So by saying that the 2 should be related we assess the impact of the monsoon on both food grain production and on GDP.

And the most surprising result from here which was not expected from the work literature on the subject was the enormous non-linearity, very strong non-linearity or the marked asymmetry in the response to negative versus positive ISMR anomalies. So there is a marked asymmetry in the response to monsoon variability with the magnitude of the negative impact of a drought being more than that of the positive impact of a surplus.

And in recent times of a high deficit in ISMR, which is 15% is 9% that of a surplus of the same magnitude is < 1%. So unless this situation changes it will not be possible to maintain the growth rate of food grain production at an adequate level for ensuring food security. The most striking

feature we observe is the impact of a severe drought on GDP remains 2 to 5% throughout, despite the substantial decrease in the contribution of agriculture to GDP over the past 5 decades.

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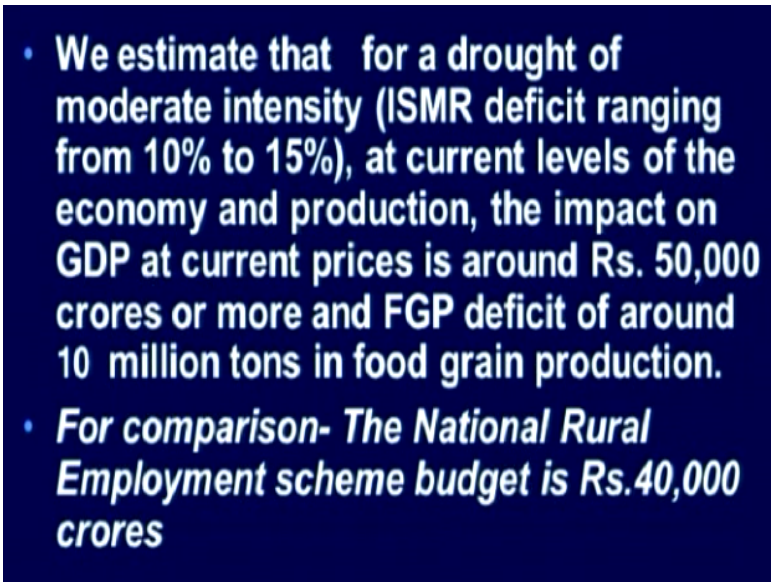

Now this is important and we need to understand why that happens, that happens because although agriculture is contributing less and less to GDP, since 16% of the population depends on agriculture for its living in 1 way or another, their purchasing power depends on the agricultural production. So it has a very large impact, a deficit monsoon which has a large negative impact on agricultural production has a large impact on the purchasing power and hence on the GDP.

In fact we estimate that for a drought of moderate intensity at current levels of economy and production and this is an estimate made in 2006 when the paper was published. The impact on GDP at current prices is around 50000 crores, this is10 times one of our usual scams, so it is an order of magnitude larger than that and so the impact on GDP is 50000 crores or more and on FGP deficit of around 10 million tons in food grain production.

Just let us see for comparison that the Mahatma Gandhi National Rural Employment scheme budget at that time was 40000 crores. So this will give you an idea of how large the impact of the monsoon can be and we ought to do more than we do to be prepared for that.

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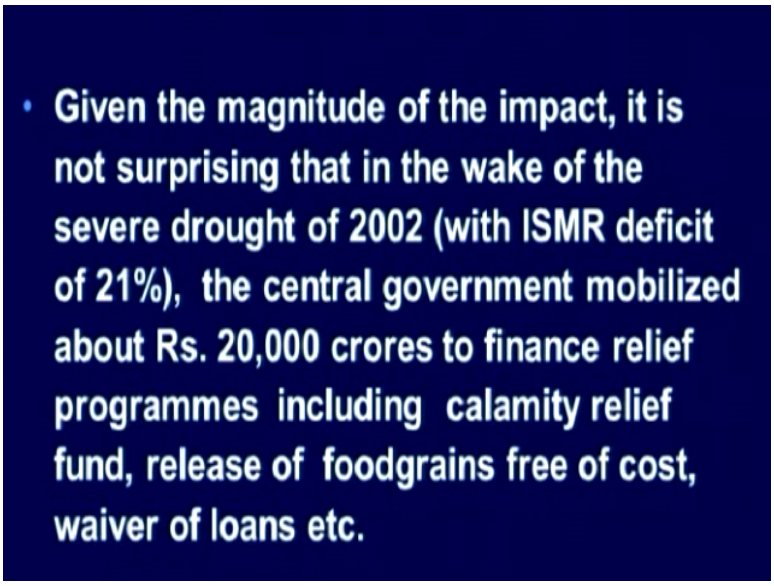

Given the magnitude of the impact it is not surprising that in the wake of the severe drought of 2002, with ISMR deficit of 21%, the central government mobilized 20000 crores to finance relief programs including calamity relief, release of food grains free of cost, waiver of loans, etc.

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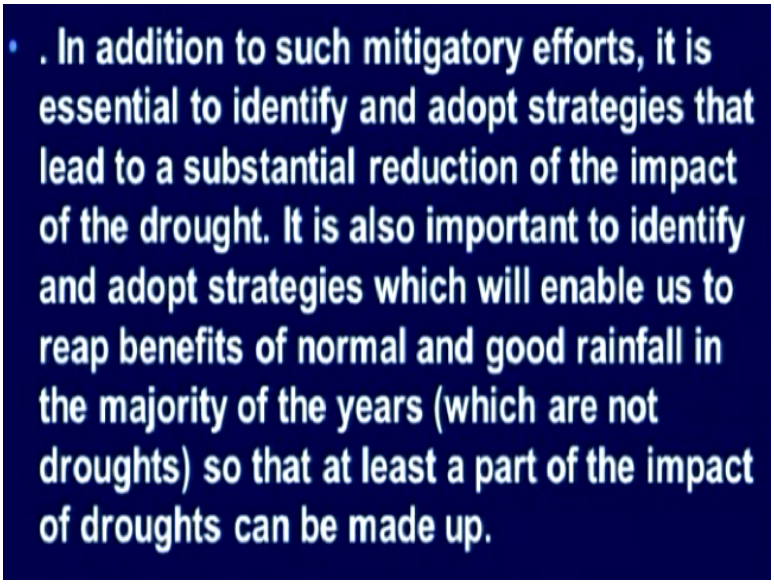

In addition to such mitigatory efforts it is essential to identify and adopt strategies that lead to a substantial reduction of the impact of the drought. It is also important to identify and adopt strategies which will enable us to reap benefits of normal and good rainfall in the majority of the years, which are not drought, so that at least a part of the impact of the droughts can be made up. Thank you, I think this is where I am going to stop.