The Indian Monsoon, GDP and Agriculture

This paper attempts to assess the impact of the inter-annual variation of the all-India summer monsoon rainfall on the gross domestic product and foodgrain production by analysing the observed variation during 1951-2003. A substantial decrease in the annual rate of growth of grain production in the last decade (to a value of less than 1 per cent from the 2.7 per cent prevailing until the 1990s) suggests that self-sufficiency in foodgrains may not be sustained without changes in strategies. A significant finding is the observed asymmetry in the response to monsoon variation, with the magnitude of the impact of deficit rainfall on GDP and grain production being larger than the impact of surplus rainfall. We find that despite a substantial decrease in the contribution of agriculture to GDP over the five decades, the impact of severe droughts has remained between 2 and 5 per cent of GDP throughout. We have suggested that a possible reason for the relatively low response of grain production to average or above average monsoon rainfall post-1980 is that the strategies which would allow farmers to reap benefits of the rainfall in good monsoon years are not economically viable in the current milieu. The experience of the monsoon season of 2006 suggests that losses due to floods, caused in part by the sudden release of the water stored in the reservoirs of dams may be another important factor.

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It is well known that monsoon variability has a large impact on agricultural production and hence the economy in India. Naturally, considerable funds are allotted to research and development efforts towards identifying and adopting strategies that will allow us to cope better with the vagaries of the monsoon. These involve improvement in the skill of monsoon prediction, identification of the appropriate strategies for management of soil and water resources, appropriate choice of crops/ trees/fodder and farming strategies, etc. For estimation of the economic value of forecasts or the benefit of alternative strategies and several other purposes, a quantitative assessment of the impact of the monsoon is required. However, the system is complex with several factors besides the monsoon contributing to the variation in agricultural production and the gross domestic product (GDP). It is, therefore, not easy to assess the impact of a specific drought or excess monsoon year. Here we present an analysis of the variation of the foodgrain production (FGP) in the country and the Indian GDP along with that of the all-India monsoon rainfall over the last five decades, to assess the impact of the variability of the monsoon rainfall.

I
Observed Variation of the Monsoon, Foodgrain Production and GDP

We have analysed data for all-India foodgrain production from *Agricultural Statistics* published by the ministry of agriculture and updates from data at the Centre for Monitoring Indian Economy, for GDP (at factor cost based on 1993-94 prices) from the Central Statistical Organisation. The data on monthly all-India rainfall from 1871 onwards are obtained from the website (www.tropmet.res.in) of the Indian Institute of Tropical Meteorology, Pune.

The rainfall, averaged over the entire country, is largely restricted to the summer monsoon months of June-September (Figure 1). The dominant component of the observed variation of the all-India summer monsoon rainfall (henceforth ISMR) is the variation from year to year around the long-term average of 85.24 cm (Figure 2). The standard deviation of ISMR is about 10 per cent of this average value. A monsoon season is characterised as one with excess rainfall when ISMR is more than 110 per cent and droughts are said to occur when ISMR is less than 90 per cent of the average. It is seen from Figure 2, that there are no long-term trends in ISMR in the period 1871-2004.

On the other hand, the variation of the GDP during 1951-2003 (Figure 3) is dominated by a sustained increase. Over the five decades, there has also been more than a threefold increase in the FGP (Figure 4). Over and above the long-term increasing trend, there are fluctuations in the FGP from year to year. The anomaly of ISMR for each year, which is defined as the difference between the ISMR for that year and the long-term average (expressed as a percentage of the long-term average), is also shown in Figure 4. It is clearly seen that the major dips in the foodgrain production (such as of 1965, 1979, 1987, 2002) correspond to large deficits in monsoon rainfall. This is a manifestation of the well known impact of the monsoon on Indian foodgrain production [Hanumantha Rao et al 1988; Parthasarathy et al 1992; Krishnakumar et al 2004].

Our analysis of the impact of the monsoon is based on the premise that while the monsoon (and hence factors depending

Figure 1: All-India Average Monthly Rainfall

(In cm)

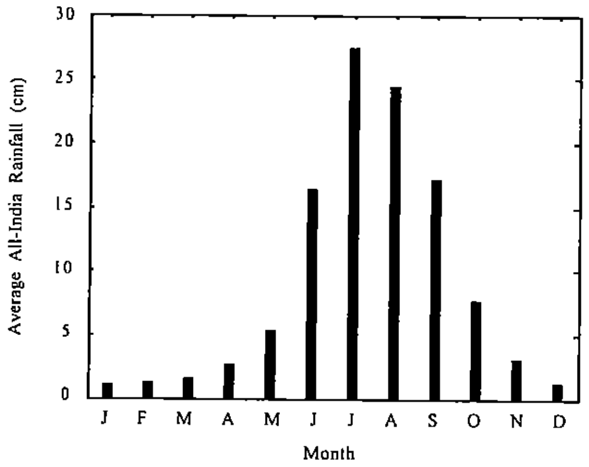


Figure 3: Variation during 1951-2003 of GDP

(at 1993-94 prices)

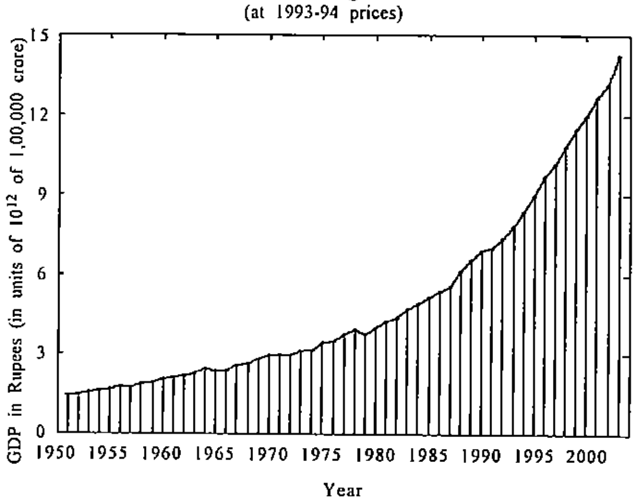
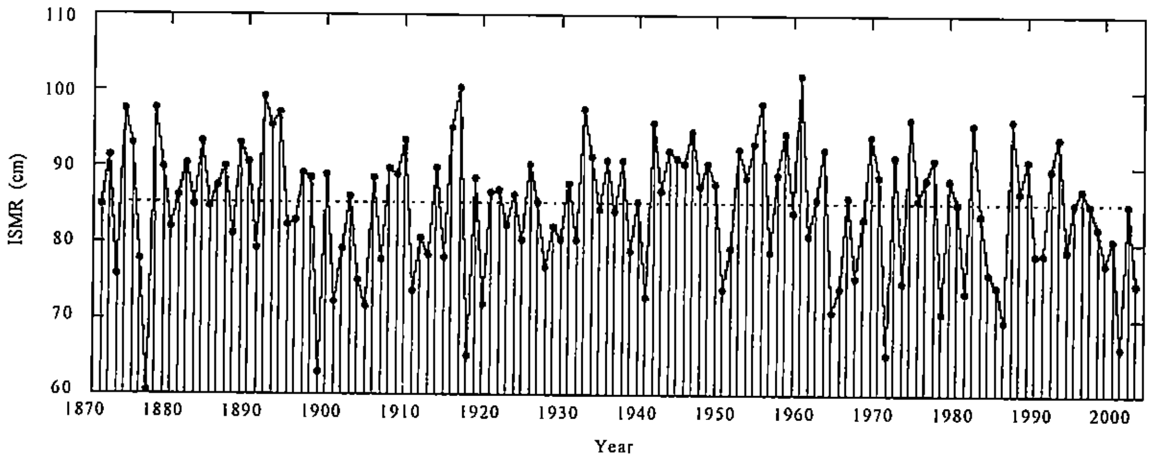


Figure 2: Variation of All-India Average Summer Monsoon Rainfall (ISMR) during 1871-2004



on the monsoon) fluctuates from year to year, most of the other factors leading to the growth of agricultural production and economy are characterised by a time-scale of several years. We expect the deviations of the FGP/GDP in any year from the long-term trends, to be related to the impact of the monsoon of that year. However, it must be noted that other special events which have timescales of the order of an year or so, such as wars, can also contribute to such deviations and impacts of such events are also seen in our analysis.

It should be noted that when the ISMR anomaly is large, most of the country experiences a similar anomaly (drought or excess rainfall as the case may be) whereas, for years for which the ISMR is near its average value (i e, the anomalies are between 5 per cent and -5 per cent), there is a large spatial variation in the rainfall anomalies over the country, with deficit rainfall over some parts of the country and normal or excess over other parts. The variation of the total all-India production depends on the variation of the production in different agroclimatic zones of the country. The production of each zone in any year depends on the rainfall over that zone. Hence, we expect the ISMR anomaly to have a large impact on the all-India production primarily when the magnitude of the ISMR anomaly is large (such as for the droughts in Figure 4).

We find that corresponding to large deficits in ISMR, there are small dips in the GDP as well. Virmani (2004) has shown that there is no change in the effect of rainfall on the GDP from agriculture during 1950 to 2003. However, since the contribution of the agricultural sector to overall GDP has decreased from over 50 per cent soon after independence to about 22 per cent in 2000, we expect a substantial reduction of the impact of the monsoon on the economy over the five decades. We will assess if such a reduction in the impact of the monsoon over time has, in fact, occurred.

In order to assess the impact of the monsoon on the GDP for a specific year, we need to estimate what the GDP would have been in the absence of the fluctuations of the monsoon, i e, the long term trends. We expect the rate of growth in GDP at any point of time to be proportional to the value of the GDP at that point of time. In other words, we expect the growth to be exponential. Parthasarathy et al (1988) have shown that an exponential function is also a good fit for the trend of the growth of FGP. Hence we have fitted exponential growth curves to the foodgrain production and the GDP. We have chosen the simplest possible curves (combination of straight-lines for the logarithm of FGP, GDP) required for ensuring that the magnitude of the error (i e, the difference

Figure 4: Variation during 1951-2004 of the ISMR Anomaly and All-India Foodgrain Production

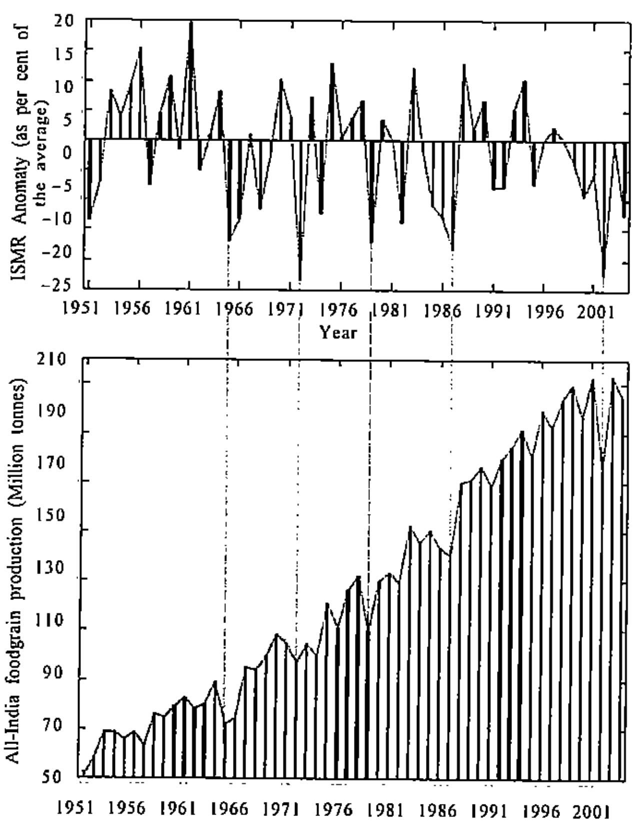


Figure 5a: Variation in GDP
(log values)

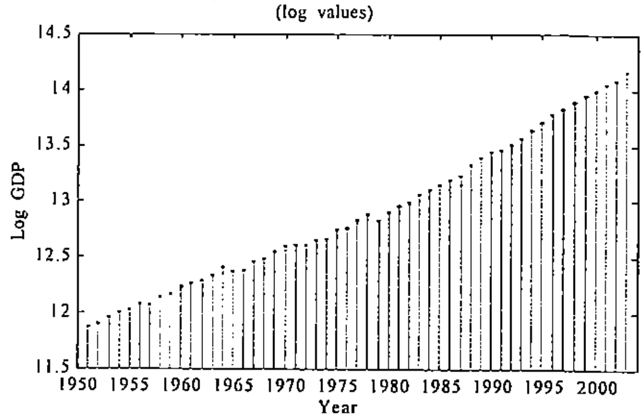
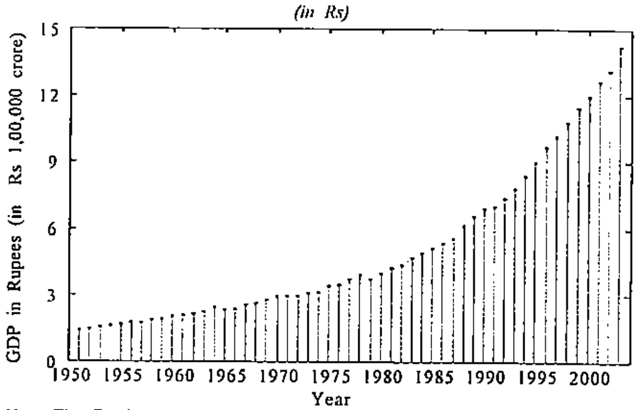


Figure 5b: Variation in GDP
(*in Rs*)



Note: The fitted curves (equations 1, 2) are also shown; the dashed curve is an extension of the fitted curve for 1951-80.

between the actual values and the fitted curves), is within a reasonable limit.

I
Trends

The variation with time of the natural logarithm of the GDP and FGP is shown in Figures 5a and 6a respectively, and that of GDP (value) and FGP (tonnage) is shown in Figures 5b and 6b, respectively. The equations for the best-fit curves, also shown in Figures 5 and 6 are:

$$\text{Log GDP}_f = 11.8622 + 0.0348 * (\text{year-1950}); \text{year} = 1951 \text{ to } 81.$$
$$= 12.9410+0.0553*(\text{year-1981}); \text{year}=1981 \text{ to } 2003; \quad \ldots(1)$$
$$\text{GDP}_f = \exp(\text{Log GDP}_f)$$
$$\text{Log FGP}_f = 4.0447+0.0273*(\text{year-1950}); \text{year}=1951 \text{ to } 1994,$$
$$= 5.2459+0.0078*(\text{year-1994}); \text{year}=1994 \text{ to } 2004. \quad \ldots(2)$$
$$\text{FGP}_f = \exp(\text{Log FGP}_f)$$

The root mean square error, which is a measure of the typical deviation from the fitted curve for GDP is Rs 1,500 crore, and for FGP is about 1 million tonnes.

We first consider whether these empirically determined trends are consistent with what is known about the variation. While the annual rate of growth of GDP had been about 3.5 per cent during 1951-80, since the 1980s it has increased more rapidly (at the rate of 5.5 per cent).Thus the structural break in the GDP growth rate around 1980 marking the transition from the so-called Hindu rate of growth of the GDP [Wallack 2003; Panagariya 2004 and references therein] has been captured by the empirically fitted curve. While the increase in the growth rate around 1980 has generally been attributed to the start of market liberalisation in 1980s, a recent study [Nayar 2006] has suggested that the first phase of liberalisation starting in 1975 with economic reform including adopting an economic stabilisation package, covert devaluation, etc, led to the increased growth rate.

It is interesting that the growth rate of FGP has increased steadily from 1951, well before the green revolution in the mid-1960s. This is consistent with the analysis of Kurosaki (1999), who showed that the trend in the total foodgrain production had reversed in 1947, and that a sustained growth in production was observed since independence. Hanumantha Rao et al (1988) have shown that there was no significant change in growth rate with the green revolution because although the growth rate of wheat was enhanced by the new technology, that of the several other food crops decreased. Parthasarathy et al (1988) have shown that the growth rate of FGP increased at 2.8 per cent during 1961 to 1986. Our analysis also shows a steady increase in the growth rate at about 2.7 per cent from 1951 until the early 1990s with no enhancement associated with the green revolution. In the last decade, the growth rate has decreased to less than 1 per cent (Figures 6a and 6b). This "fatigue of the green revolution" (which is also seen in world food production)

Figure 6a: Variation in Foodgrain Production
(log values)

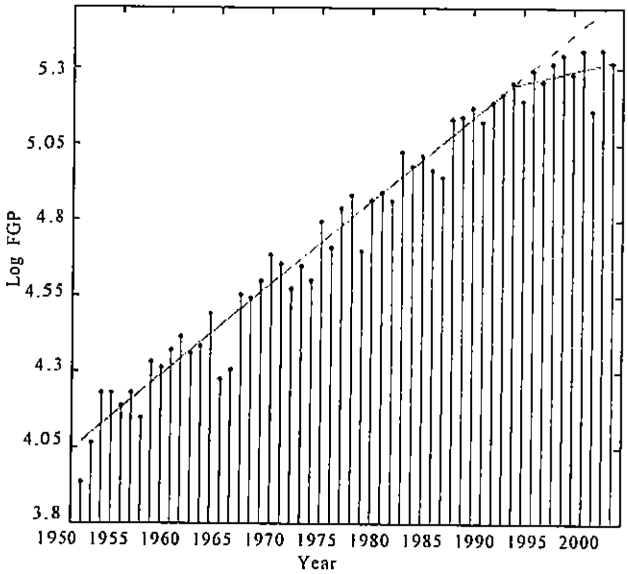
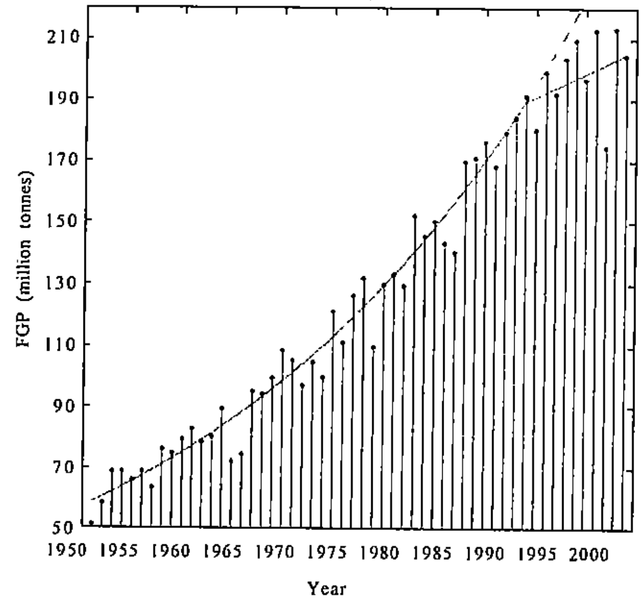


Figure 6b: Variation in Foodgrain Production
(in tonnes)



Note: The fitted curves (equations 3, 4) are also shown; the dashed curve is an extension of the fitted curve for 1951-94.

Figure 7: Variation of the Growth Rates of GDP and FGP
(Derived Using Equation (5))

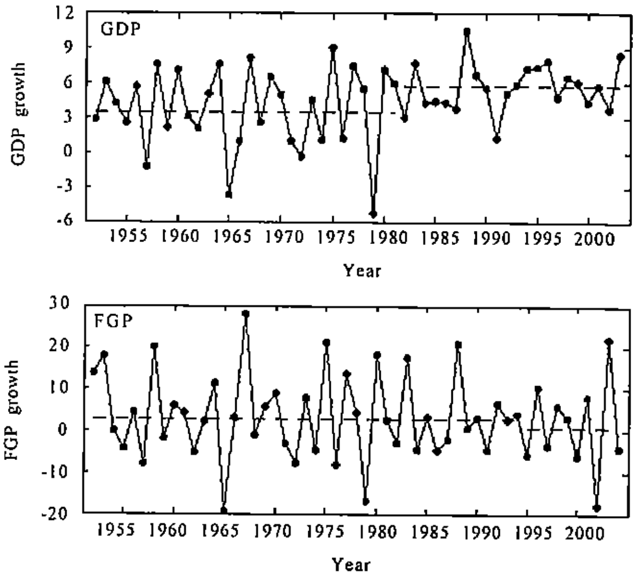
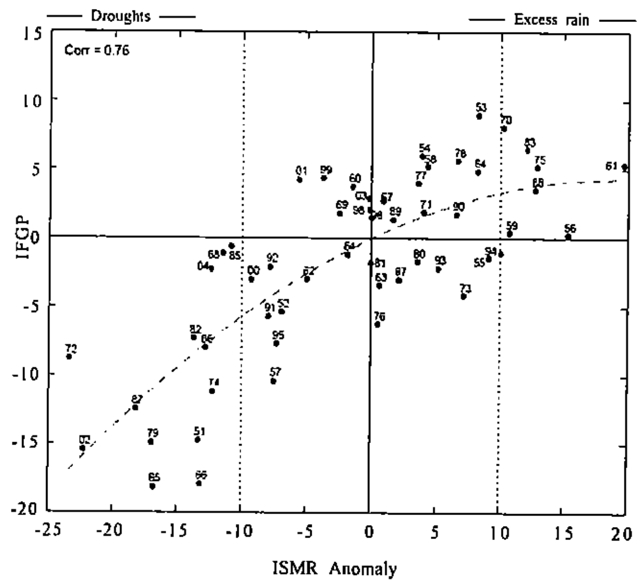


Figure 8: Variation of IFGP with Monsoon Rainfall Anomaly



Note: Numbers represent years, e g, 57 is 1957.

has been attributed to decrease in the growth rates of (i) irrigated land (due to salinity, water-logging, etc), and (ii) the yield because of the steady decrease of fertility (nutrient availability) of the lands due to intensive agriculture in the previous three decades [Abrol I P 1996]. Change in cropping patterns has also contributed to the decrease in the area under cultivation of foodgrains.

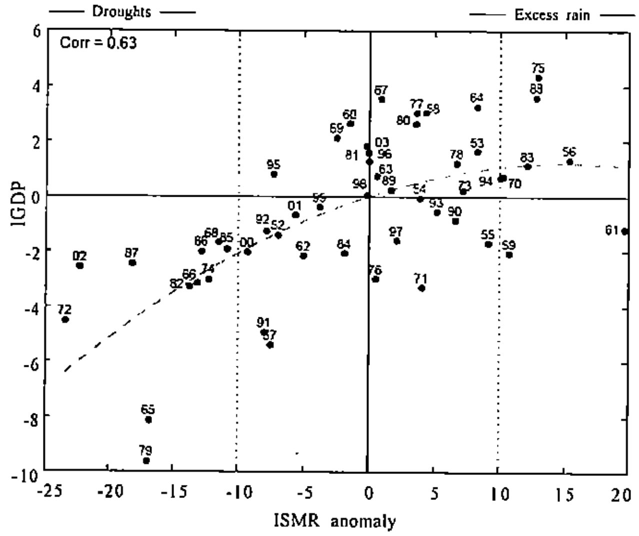
It should be noted that generally the growth rate of FGP/GDP for each year (expressed as a percentage) is the local growth rate determined as

GDP_{gr} (year) = 100*(GDP (year) – GDP (year-1))/GDP (year-1)

FGP_{gr} (year) = 100(FGP (year) – FGP (year-1))/FGP (year-1)

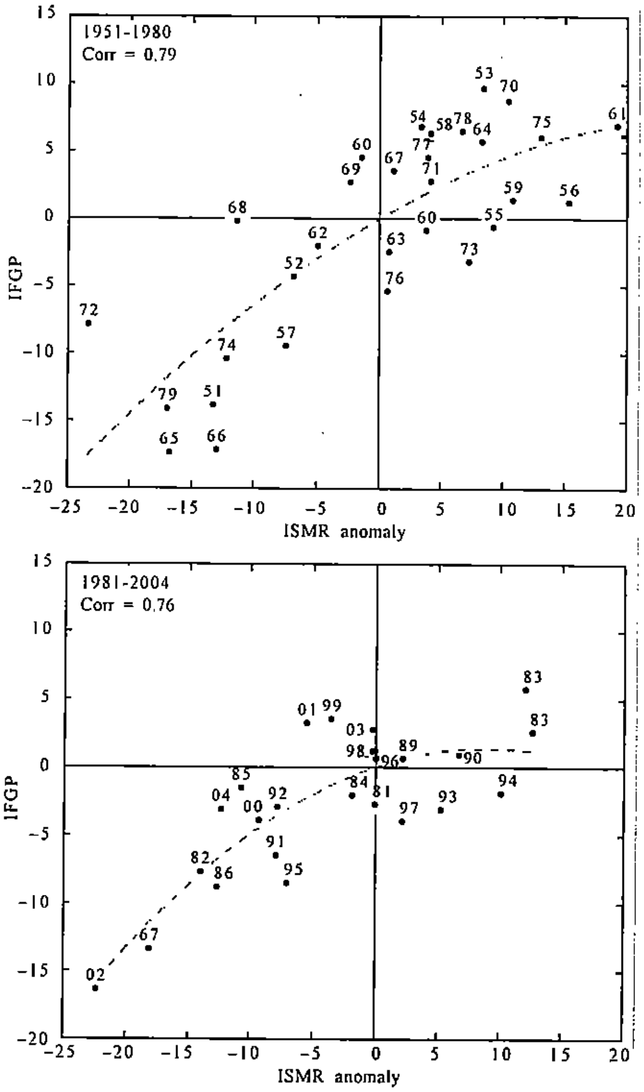
[e g, Virmani 2004 for GDP, Krishnakumar et al 2004 for FGP]. The growth rates so defined are naturally very sensitive to the value in the previous year, i e, the base effect and there are large fluctuations of the GDP_{gr}, FGP_{gr} from year to year (Figure 7). While the adverse impact on GDP of the poor monsoon of 1987 (GDP_{gr} =3.8) thus derived was found to be subdued because of the low base level associated with the drought in 1986, the impact of the drought of 1979 was exaggerated (GDP_{gr} = -5. 2) because of the high base level in 1978 [CRISIL 2003]. Trends are derived from the local growth rates by filtering the high frequency fluctuations [e g, Virmani 2004]. On the other hand, in this study, the growth rate trends are determined from the curves, which

Figure 9: Variation of IGDP with Monsoon Rainfall Anomaly



Note: Numbers represent years.

Figure 10: Variation of IFGP with Monsoon Rainfall Anomaly



Note: Years are indicated by numbers.

represent variation on time-scales of several years, directly fitted to the data.

III
Relationship between the Impacts and the Monsoon Rainfall Anomaly

We expect the observed deviations of GDP and FGP from the long-term trends (i e, fitted curves equations (1,2)), for a specific year to be related to the important events in that year and particularly to the monsoon rainfall of that year. The methodology of the assessment of the impact on FGP (denoted by IFGP) and GDP (denoted by IGDP) from these deviations is described in the Appendix. The variation of IFGP with the ISMR anomaly is shown in Figure 8. It is seen that the IFGP is negative for all droughts (with values up to –20 per cent) and positive for ISMR anomaly larger than 10 per cent (with values up to +10 per cent). IFGP is highly correlated with the ISMR anomaly, with the correlation coefficient of 0.76 significant at 1 per cent level. The best fit curve is governed by:

$$IFGP_{f\text{-}i} = 0.4518^* \text{ AnomISMR } -0.0117^* (\text{AnomISMR})^2 \quad \ldots(3)$$

The variation of IGDP with the ISMR anomaly is shown in Figure 9. The IGDP is seen to be well correlated with the ISMR anomaly, with the correlation coefficient of 0.63. The best fit curve shown in Figure 9 is governed by

$$IGDP_{f\text{-}} = 0.1565^* \text{ AnomISMR } -0.0050^* (\text{AnomISMR})^2 \quad \ldots(4)$$

The most striking feature of the variation of the FGP/GDP anomaly with the anomaly of ISMR (Figures 8, 9) is the asymmetry in response to deficits versus excess of ISMR. It is seen that the magnitudes of the impacts on FGP/GDP increase rapidly with increasing deficits of ISMR. However, for positive anomalies of ISMR, the rate of increase of impacts on FGP/GDP with ISMR is very small.

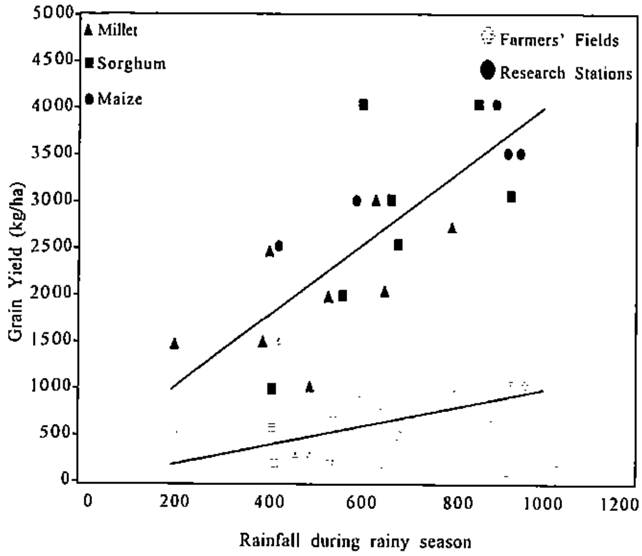
The major conclusions we can draw about the impact of the monsoon on the GDP and FGP are:

Estimation of magnitude of the impact: Firstly, we estimate the average magnitude of the impact of the variability of ISMR on GDP and FGP. This is the linear coefficient in the equations (3,4) for our fitted curves, which implies an impact on GDP and FGP of about 0.16 and 0.45 times the ISMR anomaly respectively. Thus the first estimates of the average impact of a moderate drought or excess, i e, with an ISMR anomaly of 15 per cent, are about 2.4 per cent on the GDP and 6.8 per cent on the FGP. This is a significant impact on the foodgrain

Table 1: Expected Impact of the Variation of the Monsoon Rainfall for 1951-2003

ISMR	GDP	FGP
-25	-7.04	-18.61
-20	-5.13	-13.72
-15	-3.47	-9.41
-10	-2.06	-5.69
-5	-0.91	-2.55
0	0.00	0.00
5	0.66	1.97
10	1.06	3.35
15	1.22	4.14
20	1.13	4.36

Figure 11: Relationship between Rainfall during the Rainy Season and Yield of Maize, Sorghum and Millet at 15 Dryland Locations in India



Note: Based on Sivakumar et al (1983).

production and economy. In fact, the impact of the last severe drought (2002) is seen to be a little over 2 per cent of GDP and more than 15 per cent of FGP.

Asymmetry in response to rainfall variation: Droughts versus Surpluses: A striking feature we observe is the difference between the impact of droughts and the impact of surplus rainfall. This is captured in the quadratic term of our fitted curve. Concretely, while a 15 per cent surplus has an impact on the FGP of about 4.1 per cent and on the GDP of about 1.2 per cent, the impact of a deficit of 15 per cent on the FGP is about -9.4 per cent while that on the GDP is about -3.5 per cent (Table 1).

Change in impact over time: As agriculture has come to play a smaller role in the economy, we expect the impact of the monsoon on the GDP to decrease with time. However, it is seen that the typical impact of severe droughts on GDP has remained between 2 to 5 per cent throughout the period. To assess whether there has been a change in the impact of the monsoon on FGP after 1980, when the GDP started growing more rapidly, we consider separately the periods before and after 1980 (Figure 10, Table 2). The results are not sensitive to the specific choice of the year of 1980 as the culmination of the earlier era. An interesting feature we see is the change in the relative impacts of droughts and surpluses on FGP. In the era up to 1980, we expect a deficit in rainfall of 15 per cent to reduce the FGP by about 10 per cent and a surplus to increase FGP by about 6 per cent. In contrast, in the era beginning in 1980, the expected effect of a deficit of 15 per cent on the FGP is about 9 per cent while the estimated impact of a surplus of 15 per cent on the FGP is only 0.7 per cent! Thus, in the earlier era, the magnitude of the impacts of a drought and a surplus on FGP were comparable in magnitude; while after 1980 the impact of surpluses has become almost negligible.

Impact of other events: A comparison of Figures 8 and 9 shows that the adverse impact of the deficit monsoon in 1991 is much larger than that expected for the corresponding value of the ISMR anomaly, although the impact on the FGP was near the expected level. Clearly a part of the value of –5 per cent for IGDP(91) must be a result of the balance of payment crisis in 1991. Similarly while the IFGP of droughts of 1965 and 1966 is comparable, the adverse impact of 1965 on the GDP is much larger, perhaps because of the war with Pakistan. In 1971, the year of the Bangladesh war, the IFGP is positive and near the expected value for the positive ISMR anomaly, but the IGDP is large and negative. Thus, values of IGDP which are very different from those expected from the value of the ISMR anomaly (i e, far away from the fitted curve (equation 4)) are generally associated with incidents such as wars or economic crises, not related with the monsoon.

IV
Discussion of Results

We find that there is an asymmetry in the response to monsoon variability with the impact of deficit on GDP and FGP being larger than the impact of excess rainfall. The impact of severe droughts on GDP is large in the earlier era as well as the modern era, despite the substantial reduction in the contribution of agriculture to GDP over the last five decades. This suggests that the indirect impacts of droughts, such as on the purchasing power of the majority of the population remain very significant in the modern era as well.

We have seen that the impact of large deficits in ISMR on the FGP is significantly more than that of surplus rainfall, particularly since 1980. In fact, in the earlier era, the magnitude of the surpluses of FGP in good rainfall years was comparable to that of the deficits in poor monsoon years. For sustainable development, this asymmetry in response to rainfall variability in the modern era has to be addressed.

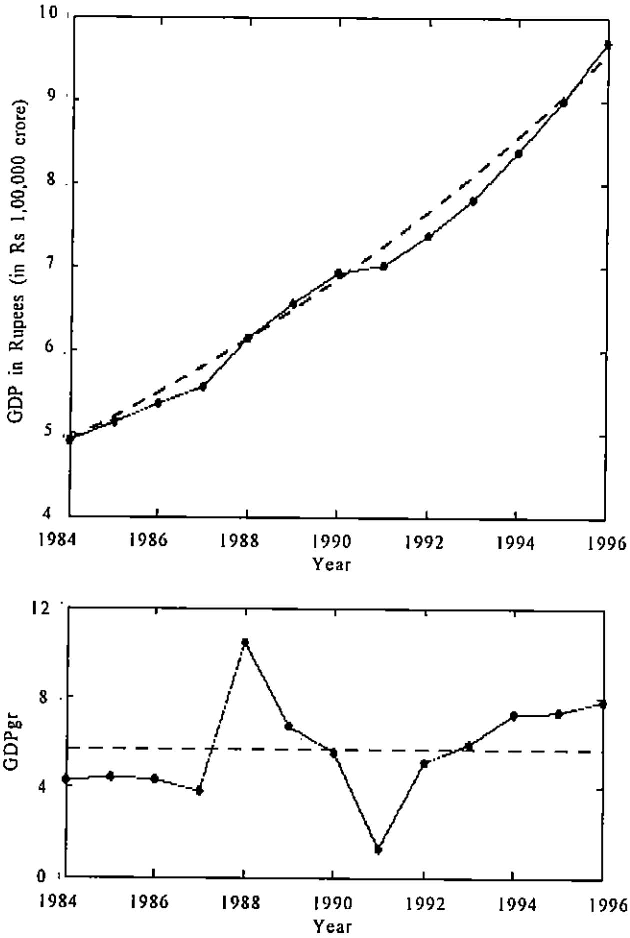
An asymmetry in response to rainfall is not surprising in the light of *Liebig's law of the minimum,* which says that the yield of a crop is determined by the scarcest resource (the so-called *limiting resource*). During a drought one expects that water is the limiting resource, but this need not be the case in the case of normal or surplus rainfall. However, one can draw a significant conclusion from the observation that the impact of surplus rainfall has diminished with time. 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 yields. We suggest below what these factors may be.

It is important to note that over the last three decades, there have been major changes in the cropping patterns due to various

Table 2: Impact of Variation of Monsoon Rainfall on FGP for 1951-80 and 1981-2004

Period ISMR	1951-80 FGP	1981-04 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

Figure A1: Variation during 1984-96 of (i) the GDP, and the Fitted Curve from Equations (1) and (2) (above) and (ii) GDPgr (equation 5); the Growth Rate of the Fitted GDP Shown as Dashed Line (below)



factors including a larger impact of the market economy, availability of high yielding varieties, etc, and the traditional complex cropping system is now replaced by mono-cropping over large tracts of land. This has led to a large number of pests and diseases becoming endemic. Furthermore, intensive farming has resulted in loss of fertility of the soil. In this situation, application of fertilisers and pesticides has become necessary for getting high yields. A comparison of the observed yield for rainfed crops at farmers' fields and with that on agricultural stations in the same regions [Figure 11, after Sivakumar et al 1983], suggests the reason for the asymmetry in response to rainfall variability. When the rainfall is low, both yields are low but when the rainfall is high, the yield at the agricultural stations is much higher than that of the farmers' fields. The major management differences between the farmers' fields and the agricultural stations are fertiliser and pesticide applications. In rainfed agriculture such applications enhance yield substantially (and hence are cost-effective) only when there is sufficient rainfall. Although, generally the farmers have the know-how (and, in fact, do invest in fertilisers and pesticides in irrigated patches), they do not do so over the rainfed areas because it is not economically viable in years of poor rainfall [Gadgil et al 2002]. Hence the farmers do not get enhancement of yields commensurate with rainfall in good rainfall years. It is clear that a reliable forecast for average or above average rainfall (i e, for no drought) can help in increasing the overall surpluses in FGP.

If we are to maintain self- sufficiency in foodgrain production it is essential that the deficit in drought years is made up to some extent at least in the years with normal and good rainfall. This could be achieved with existing technology, if (i) the market prices rise to a level at which the application of fertilisers, pesticides becomes economically viable in the rainfed regions for most of the years and (ii) institutional support is created for using the profits in such years to overcome the loss in the few drought years. Mechanisms such as weather-indexed insurance for risk mitigation in the case of droughts can also contribute to increasing yields in years of surplus rainfall.

The experience of the monsoon of 2006 suggests another factor that could contribute to the response in production not being commensurate with the rainfall in seasons with above average rainfall. During this monsoon season, enormous losses in agricultural production occurred due to flooding which was caused partly by the sudden release of water from the reservoirs of a large number of dams (e g, the Surat floods in August) and partly by intense rainfall events. It is important to make a quantitative assessment of the contribution of anthropogenic factors to the damage and loss caused by flooding and derive management strategies which can minimise such losses.

V
Conclusions

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. In recent times while the impact of a high deficit in ISMR (15 per cent) on FGP is -9 per cent, that of a surplus of the same magnitude is less than 1 per cent. Unless this situation changes, it will not be possible to maintain the growth rate of foodgrain production at an adequate level for ensuring food security. The most striking feature we observe is that the impact of a severe drought on GDP remains between 2 to 5 per cent throughout, despite the substantial decrease in the contribution of agriculture to GDP over the five decades.

We estimate that for a drought of moderate intensity (ISMR deficit ranging from 10 per cent to 15 per cent), at current levels of the economy and production, the impact on GDP at current prices is around Rs 50,000 crore or more and FGP deficit of around 10 million tonnes in foodgrain production. 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 per cent), the central government mobilised about Rs 20,000 crore to finance relief programmes including calamity relief fund, release of foodgrains free of cost, waiver of loans, etc. 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. This critical issue has been addressed by scientists of different hues as well as planners, particularly since the severe drought of 1987, but it appears that there has not been adequate progress. 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 droughts) so that at least a part of the impact of droughts can be made up.

Appendix: Methodology

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.

GDP_{devi} (year) = GDP(year) – GDP_f (year) ...(A1)

The FGP $_{devi}$ is defined in a similar manner, viz.

FGP_{devi} (year) = FGP(year) – FGP_f (year) ...(A2)

Since the fitted GDP varies considerably over the 50-year period, the expected GDP (from the fitted curve) i e, GDP_f(year) is used to normalise the deviation of each year and express it as a percentage of the GDP_f(year). Thus, for any year, the normalised GDP deviation (expressed as percentage) is defined as:

DevGDP (year) =100GDP_{devi} (year)/GDP_f (year) ...(A3)

Similarly,

DevFGP (year) =100 FGP_{devi} (year)/FGP_f (year) ...(A4)

Since there are no trends in ISMR, the normalised anomaly of ISMR, AnomISMR, is defined in terms of the long-term average of ISMR, viz, Aver ISMR as

AnomISMR(year)=100*(ISMR(year)–Aver ISMR)/ Aver ISMR ...(A5)

We expect the observed deviations of GDP and FGP for a specific year (i e, DevGDP (year) and DevFGP (year) given by equations A4 and A5), to be related to the important events in that year and particularly to the ISMR anomaly of that year. However, the deviation of the GDP from the fitted curve depends not only on the events (such as a deficit monsoon) of that year, but also on the deviation of the previous year. For example, consider the deviations of GDP as well as the local growth rate GDP_{gr} (Section II) in the period 1984-1996 (Figure A1). Subsequent to the major dip in 1991 (probably in association with the balance of payment crisis), although the growth rate GDP_{gr} increased to almost equal the long-term growth rate of 5.5 per cent in 1992 , increased further in 1993 and was substantially higher in 1994, the deviation remains negative for 1992, 1993 and 1994. Thus even in 1994, which was a season with excess monsoon rainfall and which is considered to be a highpoint of growth per annum in the period after 1980 [Virmani 2004], the GDP-deviation is negative. Clearly, DevGDP (1994) reflects sustained impact of the large dip in 1991 and cannot be considered to be the effect of only the monsoon of that year. It should be noted that the monsoon rainfall anomaly in any year does not depend on the anomaly of the previous year (correlation coefficient of –0.08 between ISMR anomalies of successive years). However, there is a significant correlation (correlation coefficient 0.25) between the GDP deviations of successive years. To assess the impact of the monsoon of a specific year from the deviations corresponding to that year, the impact of the events of earlier years has to be removed. This is done as follows. We assume that in the absence of the variation in the monsoon, the GDP would increase at the rate as per the fitted curves (Equations 1 and 2). 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 that in the previous year by

GDPo (Year)=GDP(year-1)* (1+m),

where m will have different values for the periods 1951-1980 and 1981-2003 in accordance with Equation (1). The impact of the monsoon on the GDP of a specific year will then be the difference between the GDP and GDPo of that year. It can be shown that the impact so defined when normalised by the GDP_f of that year, is given in terms of the normalised anomalies as

ImpactGDP (year)= DevGDP (year) – DevGDP (year-1) ...(A6)

The 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 and the FGP deviations for successive years are poorly correlated (correlation coefficient of –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 (as suggested by Figure 4).

The impact on the GDP of the ISMR anomaly, IGDP, is taken as the difference between the ImpactGDP (year) given by the equation (A6) and the impact of an average monsoon. Similarly, the impact on FGP of the ISMR anomaly, IFGP, is calculated as the difference between DevFGP (equation A4) and the deviation corresponding to the average monsoon. EPW

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