Projected Effect of Droughts on Supply, Demand, and Prices of Crops in India

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This paper assesses the effect of monsoon droughts on the production, demand, and prices of seven major agricultural commodities – rice, sorghum, pearl millet, maize, pigeon pea, groundnut and cotton. A partial generalised equilibrium model is developed to simulate the effects of deficit rainfall on acreage, yield, production, demand, and prices of different agricultural commodities in India. It is used to project the effect of rain deficits on supply, demand, and prices of monsoon session crops.

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1 Introduction

Global climate change is causing different types of risks, which are adversely affecting agricultural production and farm incomes (Kumar and Parikh 2001). These risks are emanating from the increasing intensity and extent of droughts, floods, temperature rise and fall, and other calamities. India is vulnerable to climate shocks and associated risks, especially unpredicted and deficit rainfall despite impressive irrigation development. Historical analysis reveals that the frequency of extreme rainfall has increased over time during the south-west monsoon season, which is accompanied by a decreasing trend in smaller rainfall events. All agricultural commodities are sensitive to droughts, floods, tropical cyclones, and low and high temperatures, and this can have an adverse effect on agricultural production and farmers' livelihoods (Selvaraju 2003; Kumar et al 2004; Lahiri and Roy 1985). For example, foodgrain production in 2012 was estimated to be 10 million tonnes short because of deficit and delayed rainfall. There were significant shortfalls in agricultural production due to deficit rainfall in 1998, 2002 and 2009 as well. Indian agriculture is vulnerable to climate shocks such as drought, floods and extreme hot and cold temperatures. It is also likely that hot, extreme, and heavy precipitation events will become more frequent. The projected increase in droughts and floods could result in greater instability in food production and threats to the livelihood security of farmers, especially smallholders.

Rain-fed agriculture in India is more prone to climate risks; it is spread out over more than 100 million hectares. These areas did not figure in the green revolution of the 1970s and 1980s. They are still characterised as low yielding and high risk prone due to a fluctuating and uncertain rainfall pattern. However, these areas are projected as the potential sources for increasing agricultural production in future. At the same time, climate change is a major constraint on increasing agricultural production. To meet the future demand for agricultural commodities, it is important to know about past and future climatic trends and assess their implications on agricultural production. Earlier studies have assessed the effect of rainfall on crop yields and noted that the elasticity of yield with respect to rainfall was positive for most crops (Rao et al 1988; Kumar et al 2011). These studies have not incorporated the area response of different crops to climate change. These studies have also not assessed the effect of climate change on production, demand, and prices of agricultural commodities.

This study is an attempt to estimate the effect of rainfall on the supply and demand sides of agricultural commodities, and their implications for prices. The main purpose is to assess the effect of deficit rainfall (lower and erratic rainfall and its distribution) on crop acreage and yield by incorporating the rainfall intensity (measured by deficit monsoon) and rainy days intensity (measured by distribution of rainfall) on acreage and the yield response model. A partial generalised equilibrium model was developed to simulate the effects of deficit rainfall on acreage, yield, production, demand, and prices with the following specific objectives.

(1) To analyse area and yield responses to rainfall for principal rainy season crops in India.

(2) To build supply, demand, and price models and analyse the potential effect of rainfall intensity and distribution on supply, demand, and prices of selected agricultural commodities in the past and future.

(3) To project supply of and demand for selected agricultural commodities in India until 2030 under different rainfall scenarios.

2 Analytical Approach

Monson Session Crops

The study purposively selected seven important crops grown during the rainy season. These were rice, sorghum, pearl millet, maize, pigeon pea, groundnut and cotton. These crops account for nearly 77% of total cropped area during the monsoon period in the country. These crops are sensitive to rainfall intensity and distribution for area allocation and yield.

Data

Data on area, production, and yield of all the selected agricultural commodities from 1980 to 2005 was obtained from the Ministry of Agriculture. Input and output data for selected commodities were from the "Comprehensive Scheme for the Study on Cost of Cultivation of Principal Crops" compiled by the Directorate of Economics and Statistics (DES), Government of India. State-wise weather data for the same period was estimated from the gridded data available from the Indian Institute of Tropical Meteorology.

The Crop Model

It is important how we define the climate variables to estimate the responses of various parameters. Earlier studies have included the intensity of climate variables on a monthly or yearly basis. Chen et al (2004) included the monthly average temperature and precipitation and also the seasonal mean of both temperature and precipitation. Kumar et al (2011) included the annual precipitation and the number of wet days, with both monthly and seasonal measures. Following these studies, we included both monthly and seasonal measures of climatic parameters in the analysis. Monthly average precipitation and temperature in the area and yield response model could not turn out to be of the expected signs with excepted levels of significance. Therefore, we included monthly precipitation and number of wet days in a quadratic functional form and defined monthly rainfall and wet days as percentage deviation from normal rainfall and percentage deviation from normal number of rainy days, respectively. Using these variables, the responses turned out to be significant and had expected signs for measuring the response for most of the crops. Based on the sowing and growing seasons, important months were identified and included as the climatic variables (precipitation and number of wet days) for these months in the area and yield response functions as shown in Appendix Table 1 (p 61). Initial results did not indicate any significant effect of temperature on monsoon crops and hence was ignored. In this study, we defined drought elasticity as the sum of elasticities of negative deviation in rainfall and the number of rainy days from the normal rainfall and normal rainy days.

Supply Model

Supply of any crop is determined by area, yield, total factor productivity, and climate response on area and yield. Therefore, the supply model can be expressed as:

S = S (A, y, TFP, CL)

where, *A* is crop area, *y* is crop yield, *TFP* denotes total factor productivity, and *CL* is climate factors, defined by rainfall intensity and distribution.

Area Model

At the first stage, we estimated the area response model of selected crops as specified below:

$\log A_t = (\log A_{t-1}$, Month-P, Month-P-sq, State dummy)

Yield Model

At the next stage, we estimated the yield response model as specified below:

$\log y_t = y(\log y_{t-1}$, Month-P, Month-P-sq, Month-d, Month-d-sq, State dummy)

where, *A* is the area under crop; *y* is yield of crop per unit of area; *TFP* is total factor productivity of the crop; *Month-P* is per cent deviation from normal rainfall in respective months; *Month-P-sq* is square of per cent deviation from normal rainfall in respective months; *Month-d* is per cent deviation from normal number of rainy days during respective months; and *Month-d-sq* is square of per cent deviation from normal number of rainy days during the respective months.

The sowing months and crop growth months were included in the area and yield response functions. A state dummy was also included in the analysis to control fixed effects of states.

Area response elasticity on deviation from normal rainfall was computed as:

$E_A^{Month\text{-}P}$ = (Regression coefficient of Month-P)/(1-Coefficient of $\log A_{t-1}$)

$E_y^{Month\text{-}P}$ = (Regression coefficient of Month-P)/(1-Coefficient of $\log y_{t-1}$)

$E_y^{Month\text{-}d}$ = (Regression coefficient of Month-d)/(1-Coefficient of $\log y_{t-1}$)

E_A^{D} = (Sum across months, the area response elasticity with respect to deviation from normal rain) x (-1)

$E_y^D = -(E_y^P + E_y^d)$

E_y^P = Sum across months, yield response elasticity with respect to deviation from normal rainfall

E_y^d = Sum across months, yield response elasticity with respect to deviation from normal number of rainy days

D = Drought intensity in percent as computed by taking the combined effect of rainfall deviation and number of rainy days

P = Deviation from normal rainfall

d = Deviation from normal number of rainy days

The area and yield response functions for rice, sorghum, pearl millet, maize, pigeon pea, groundnut, and cotton were estimated and are given in Appendix Table 2 (p 61) for acreage response and Appendix Table 3 (p 62) for yield response. Standardised coefficients were used to estimate the area and yield response elasticities with respect to climatic variations.

Supply Growth Model

Supply elasticity, input-output price environment, total factor productivity (TFP), crop area (A), and rainfall variability (intensity and days) are the major factors influencing the production of agricultural commodities. Thus, the supply growth model for selected agricultural crops can be expressed as:

$\dot{S}=E_y^P\dot{P}+\sum E_y^{p_i}\dot{p}_i+\dot{A}+T\dot{F}P+E_A^D\dot{D}+E_y^D\dot{D}$

where,

$\dot{S}$: Supply growth for selected crop

E_y^P: Yield response elasticity with respect to crop output price

E_y^{p}: Yield response elasticity with respect to i[th] input price

$\dot{A}$: Acreage growth of the commodity

$T\dot{F}P$: TFP growth of the commodity

E_A^D: Area elasticity with respect to deficit rainfall and rainy days

E_y^D: Yield elasticity with respect to deficit rainfall and rainy days

Demand Model

Direct and indirect demand for different commodities was estimated by following the per capita consumer demand approach.

Following the consumer demand theory, the per capita growth in consumer demand can be expressed as:

$\dot{d} = E_d^P\dot{P} + E_d^I\dot{I}$

$P = [P_o, P_S, P_C]$

$\dot{d} = E_d^P\dot{P} + E_d^{Ps}\dot{P}_S + E_d^{Pc}\dot{P}_C + E_d^I\dot{I}$

where,

P: Vector of commodity prices

P_o: Price of own commodity

P_S: Price of substitute commodity

P_c: Price of complementary commodity

E_d^Z: Elasticity of demand with respect to Z

$Z = [P, P_s, P_c, I]$

Indirect Demand

ID = (SEED* CRAREA + OU)/POP

OU = (FEED +WAST +INDUSE)/POP

ID = s_1 SEED +s_1CRAREA +s_2 OU

Total Demand Growth

$\dot{D}= S^*ID + (\dot{1}\text{-}S)\dot{d} + P\dot{O}P$

where,

P = Price of the i[th] commodity

I = Per capita consumer income

SEED = Seed rate of selected commodity or crop

CRAREA = Area under selected commodity or crop

OU= other uses

FEED = Feed demand of selected commodity or crop

WAST = Wastages of selected commodity or crop

POP = Population

ID = Indirect demand per capita for seed, feed, industrial use, and wastages

S = Share of indirect demand in total demand

s_1 = Share of seed demand in total indirect demand

s_2 = Share of other uses in total indirect demand

Price Model

Supply and demand relationship for each crop has endogenous and exogenous components (shifters). In the market, product prices and product quantities are endogenous (prices are actually exogenous to the farm producer, but are endogenous and determined within agricultural markets). The exogenous shifters – technology movers, population growth, income growth, indirect demand within domestic and international markets – are assumed to be given and are not determined within the markets per se. However, the equilibrium product prices are determined by equating output supply to its demand for each crop (S = D). The models solved for prices and endogenous variables were expressed as:

P = P (Input price, TFP, A, Drought effects, Demand shifter)

where,

Input price = [p/P] = [w/P, b/P, m/P, r/P, o/P]

TFP = Total factor productivity

A = Area under crop

Drought effect = Monthly rainfall deficit and rainy days: [Month-P, Month-d]

Month-P = [Apr-P, Jun-P, July-P, Aug-P]

Month-P-d = [July-P-d, Aug-P-d, Sep-P-d, Oct-P-d]

Demand shifter = [Income, SFIW, Population]

p = Vector of input price

P = Output price

w = Wage

b = Cost per unit of animal labour (animal wage)

m = Cost per unit of machine labour (machine labour price)

r = Cost per unit of fertiliser (fertiliser price)

o = other input per unit cost (Other input price)

Price Growth Model

The price growth model can be expressed as

$\dot{P} = E_P^p P + E_P^{TFP} T\dot{F}P + E_P^A\dot{A} + E_P^D\dot{D} + E_P^I\dot{I} + E_P^{SFIW} SF\dot{I}W + E_P^{POP} P\dot{O}P$

(.) Indicate the growth

POP = Population

SFIW = Seed, feed, industrial use and wastages (Indirect demand)

3 Results and Discussion

Climate Response on Area and Yield

Regression parameters were used to estimate the area and yield elasticities with respect to climatic factors, more specifically deficit rainfall and number of rainy days. Area and yield response functions to climate variables for selected crops are given in Appendix Tables 2 and 3, respectively. The rainfall during the sowing period influenced the acreage and yield of crops. Rainfall is positively associated with crop acreage and yield. Using the standardised coefficients of the climate response model, the area and yield response elasticities with respect to climatic factors were computed. They are presented in Table 1.

Table 1: Area and Yield Model for Food and Non-food Commodities, India

	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Area growth model							
Acreage shifter							
Area under crop	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Climate response on acreage							
Rainfall elasticity							
Apr-P	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1517
Jun-P	0.0481	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
July-P	0.2732	0.0485	0.1553	0.0000	0.0000	0.0000	0.2789
Aug-P	0.1161	0.0376	0.1201	0.1129	0.0000	0.0554	0.0000
Drought elasticity	-0.4375	-0.0862	-0.2754	-0.1129	0.0000	-0.0554	-0.4306
Yield growth model							
Price factors							
P	0.2249	0.4206	0.6424	0.1189	0.0949	0.3700	0.2623
w/P	-0.0786	-0.1534	-0.2792	-0.0164	-0.0326	-0.1691	-0.1046
b/P	-0.0369	-0.0921	-0.1490	-0.0527	-0.0251	-0.0534	-0.0197
m/P	-0.0335	-0.0798	-0.0704	-0.0350	-0.0332	-0.0414	-0.0252
r/P	-0.0155	-0.0505	-0.0861	0.0347	-0.0056	-0.0498	-0.0480
o/P	-0.0603	-0.0448	-0.0577	-0.0493	0.0017	-0.0563	-0.0647
o/P	-0.0603	-0.0448	-0.0577	-0.0493	0.0017	-0.0563	-0.0647
Technology shifter							
TFP	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Climate response on yield							
Carbon (Co_2)	0.2310	0.1374	0.3494	0.2843	0.2702	0.1900	0.3143
Rainfall elasticity							
Jul-P	0.1549	0.1424	0.3450	0.0000	0.0000	0.0000	0.0000
Jul-P-d	0.0838	0.0783	0.0000	0.0752	0.0000	0.0000	0.0000
Aug-P-d	0.0503	0.1257	0.2194	0.0795	0.0768	0.0000	0.1347
Sep-P-d	0.1760	0.1791	0.1710	0.1226	0.1980	0.0877	0.2708
Oct-P-d	0.1688	0.1520	0.0295	0.0000	0.1785	0.2748	0.0000
Drought elasticity	-0.6339	-0.6776	-0.7649	-0.2773	-0.4533	-0.3625	-0.4055

Area Response to Climate Variables

It is evident from the area growth model (Table 1) that July and August rainfall played an important role in determining the area for rice, pearl millet and sorghum. The cotton area is influenced by July rainfall, while the maize and groundnut areas are influenced by August rainfall. The estimated elasticity of acreage with respect to drought intensity was highest for rice (–0.44), followed by pearl millet (–0.28), maize (–0.11), sorghum (–0.09) and groundnut (–0.05). This means that a drought intensity of 10% will reduce the area under rice by 4.4%, of pearl millet by 2.8%, maize by 1.1%, sorghum by 0.9% and groundnut by 0.5%. There was no significant impact of drought on area under pigeon pea as the crop is of long duration and sowing may be adjusted depending on the rainfall.

Yield Response to Climate Variables

Rainfall intensity and distribution significantly influence crop yields during the monsoon season. To capture the effect of rainfall and its distribution, we measured it as deviation from the extent and normal number of rainy days. The yield growth model in Table 1 revealed that July rainfall is crucial for increases in yield of rice, sorghum and pearl millet. The distribution of rainy days is crucial during the months of August, September and October. The elasticity of yield with respect to drought was estimated highest for pearl millet (–0.76), followed by sorghum (–0.68), rice (–0.63), pigeon pea (–0.45), cotton (–0.41), and groundnut (–0.36). It was the lowest for maize (–0.28). These elasticities reveal that the highest negative effect of drought will be on yields of pearl millet and sorghum. The results suggest that a drought of 10% intensity will be responsible for a decline in the yield of pearl millet by 7.6% and of sorghum by 6.8%. These crops are largely grown in low rainfall arid and semi-arid areas; and any deficit rainfall significantly reduces water for these crops and adversely affects their yields. For other crops, the yield loss as a result of a 10% deficit rainfall is 6.3% for rice, 4.5% for pigeon pea, 4.1% for cotton, 3.6% for groundnut, and 2.8% for maize.

Yield Response to Prices

Yield response elasticities for all the selected crops were estimated from Appendix Table 3 and the results are in Table 1. Among crops, the highest yield elasticity with respect to its price was for pearl millet (0.64), followed by sorghum (0.42), groundnut (0.37), cotton (0.26), rice (0.22), maize (0.12) and pigeon pea (0.09). The differential responses are mainly due to crop responses to incremental input costs. The higher the yield response to incremental costs, the more will be the response to increased prices. Pearl millet and sorghum are low-input crops, therefore incremental input uses will have more response to yield. In the event of rising prices, farmers will go for higher inputs to gain from output prices. The input price yield response elasticities were highly inelastic, nearly zero for fertiliser and machinery. The results reveal that higher output prices of selected crops will enhance the yield of most of the commodities because farmers will allocate more inputs.

Supply Growth Model

The sum of area and yield growth provides the supply growth (Table 2, p 58). The supply of different crops was influenced by prices (inputs and output), technology shifter (TFP), acreage shifter (area under crop), and climate response factors (carbon, rainfall).

The TFP and acreage had a unitary scale influence on supply. The output price had a significant effect on supply; it ranged from 0.095 for pigeon pea to 0.64 for pearl millet. Input prices had a marginally negative impact on supply of most of the crops. The supply elasticities ranged from 0.14 for sorghum to 0.35 for pearl millet. Supply elasticities with respect to rainfall intensity varied across crops in different sowing and crop growth months. The sum of supply elasticities with respect to rainfall across months provided the aggregate effect of rainfall on supply.

Table 2: Supply Model for Food and Non-food Commodities, India

	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Supply growth model							
Price factors							
P	0.2249	0.4206	0.6424	0.1189	0.0949	0.3700	0.2623
w/P	-0.0786	-0.1534	-0.2792	-0.0164	-0.0326	-0.1691	-0.1046
b/P	-0.0369	-0.0921	-0.1490	-0.0527	-0.0251	-0.0534	-0.0197
m/P	-0.0335	-0.0798	-0.0704	-0.0350	-0.0332	-0.0414	-0.0252
r/P	-0.0155	-0.0505	-0.0861	0.0347	-0.0056	-0.0498	-0.0480
o/P	-0.0603	-0.0448	-0.0577	-0.0493	0.0017	-0.0563	-0.0647
Technology shifter							
TFP	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Acreage shifter							
Crop area	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Climate response on production (supply)							
Carbon (Co_2)	0.231	0.137	0.349	0.284	0.270	0.190	0.314
Rainfall elasticity							
Apr-P	0.000	0.000	0.000	0.000	0.000	0.000	0.152
Jun-P	0.048	0.000	0.000	0.000	0.000	0.000	0.000
July-P	0.428	0.191	0.500	0.000	0.000	0.000	0.279
Aug-P	0.116	0.038	0.120	0.113	0.000	0.055	0.000
Jul-P-d	0.084	0.078	0.000	0.075	0.000	0.000	0.000
Aug-P-d	0.050	0.126	0.219	0.079	0.077	0.088	0.135
Sep-P-d	0.176	0.179	0.171	0.123	0.198	0.275	0.271
Oct-P-d	0.169	0.152	0.029	0.000	0.179	0.000	0.000
Drought elasticity	-1.071	-0.764	-1.040	-0.390	-0.453	-0.418	-0.836

Deficit rain had the highest negative effect on production of rice and pearl millet as their acreage and yields are more sensitive to rainfall intensity and distribution compared to other crops. The elasticity of production with respect to drought intensity was estimated to be highest for rice (–1.07), followed by pearl millet (–1.04), cotton (–0.84), sorghum (–0.76), pigeon pea (–0.45), groundnut (–0.41) and maize (–0.39). These elasticities suggest that the drought intensity of 10% will reduce the production by 10.7% of rice, 10.4% of pearl millet, 8.4% of cotton, 7.6% of sorghum, and about 4% each of maize, pigeon pea and groundnut.

Sources of Supply

Using supply response elasticity (Appendix Table 4, p 62), TFP growth (Appendix Table 5, p 63), area, yield and production growth (Appendix Table 6, p 63), and input-output prices growth (Appendix Table 7, p 63), the sources of supply were computed. They are given in Table 3. Supply growth is predicted at 1.52% for rice, 0.58% for sorghum, 3.05% for pearl millet, 0.79% for pigeon pea, 1.01% for groundnut, and 4.77% for cotton. The output price and TFP are the major sources of supply growth.

Table 3: Sources of Supply for Commodities, India (% annual growth)

Sources	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Output price	1.52	3.27	4.13	0.72	0.77	2.58	1.97
Input price	-0.42	-0.53	-1.93	-0.41	-0.11	-0.76	-0.19
Acreage	-0.36	-2.86	-0.34	2.63	0.70	-1.67	1.44
TFP	0.67	0.63	1.04	1.39	-0.69	0.77	1.41
CO_2	0.10	0.06	0.16	0.13	0.12	0.09	0.14
Total annual growth (%)	1.52	0.58	3.05	4.46	0.79	1.01	4.77

Demand for Agricultural Commodities

A number of demand models are available for estimating price and income elasticities of demand for food commodities. In a recent study on food demand, Kumar et al (2011) have computed price and income elasticities based on Food Characteristic Demand Systems (FCDS), and this has been used in the present study (Appendix Table 8, p 63). The income elasticity for rice was highly inelastic and negative for coarse cereals (sorghum, pearl millet and maize). The income elasticity for demand of pulses and edible oils was estimated in the range of 0.22 to 0.30. For all commodities, own price elasticities were found to be negative, as expected, and were estimated to be highest for edible oils (–0.50), followed by pulses (–0.45), and rice (–0.25). It was lowest for coarse cereals (–0.19). The magnitude of these elasticities indicates that consumers respond more to the prices of edible oil and pulses than rice and coarse cereals. It is obvious that rice and coarse cereals are the main food commodities. The sum of price and income elasticities was also negative for all the commodities under study.

The aggregate demand for commodities is influenced not only by price and income factors, but also by non-price factors (shifters) – population and indirect demand sources (seed, feed, industrial uses and wastages). The aggregate demand model for selected agricultural commodities for India is presented in Table 4. Here, the aggregate demand elasticity with respect to population is assumed to be one.

Table 4: Demand Model for Food and Non-food Commodities, India

Growth in Demand Factors	Growth in Quantity Demand for Commodities (% per annum)						
	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Ground-nut	Cotton
Consumer demand elasticity							
Price	-0.247	-0.194	-0.194	-0.194	-0.453	-0.504	-1.237
Income	0.024	-0.125	-0.125	-0.125	0.219	0.297	1.903
Indirect demand elasticity							
SFIW	0.051	0.324	0.324	0.324	0.188	0.172	0.000
Total demand elasticities							
Price	-0.234	-0.131	-0.131	-0.131	-0.368	-0.417	-1.237
Income	0.023	-0.084	-0.084	-0.084	0.178	0.246	1.903
Indirect demand	0.051	0.324	0.324	0.324	0.188	0.172	0.000
Population	1.000	1.000	1.000	1.000	1.000	1.000	1.000

SFIW: Seed, feed, industrial use and wastages (indirect demand).

Price Model for Commodities

The estimated supply and demand models for food and non-food commodities are given in Tables 2 and 4, respectively. At equilibrium level, the demand growth is equal to the supply growth for commodities. By solving these supply and demand models simultaneously, the equilibrium price models were derived. They are presented in Table 5 (p 59) for the commodities under study. The input price effects are positive on commodity prices. With a 10% increase in input price, the output price will increase by 6.2% for rice, 6.7% for maize, 8.4% for sorghum, and 9.0% for pearl millet. The magnitude of change in output prices due to a 10% increase in input prices was low for pigeon pea (2.0%), cotton (2.1%), and groundnut (5.4%).

This was mainly due to higher quantity of input use for rice and coarse cereals compared to other crops. The TFP growth has a negative effect on commodity prices. Technology and acreage shifters will induce supply and reduce the prices of different commodities. The results reveal that a 1% increase in the TFP index and acreage response would lead to a fall in prices of different commodities ranging from 0.67% for cotton to 4.0% for maize. Drought has a negative impact on supply and commodity prices will increase in the range of 6.0% for cotton to 23% for rice with a drought intensity of 10%. Population growth will further increase the demand for selected commodities and will lead to a price rise. Income and indirect demand will have only a mild effect on commodity prices.

Table 5: Price Model for Food and Non-food Crops, India

	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Input price							
w/P	0.171	0.278	0.361	0.066	0.071	0.215	0.070
b/P	0.080	0.167	0.193	0.211	0.054	0.068	0.013
m/P	0.073	0.145	0.091	0.140	0.072	0.053	0.017
r/P	0.034	0.092	0.111	-0.139	0.012	0.063	0.032
o/P	0.131	0.081	0.075	0.197	-0.004	0.072	0.043
Total input price effect	0.621	0.844	0.905	0.673	0.201	0.541	0.218
Technology shifter							
TFP	-2.177	-1.813	-1.293	-4.001	-2.162	-1.270	-0.667
Acreage shifter							
Area	-2.177	-1.813	-1.293	-4.001	-2.162	-1.270	-0.667
Climate response on price							
Carbon CO_2	-0.503	-0.249	-0.452	-1.137	-0.584	-0.241	-0.210
Rainfall effect							
April-P	0.000	0.000	0.000	0.000	0.000	0.000	-0.101
June-P	-0.105	0.000	0.000	0.000	0.000	0.000	0.000
July-P	-0.932	-0.346	-0.647	0.000	0.000	0.000	-0.186
August-P	-0.253	-0.068	-0.155	-0.452	0.000	-0.070	0.000
July-P-d	-0.183	-0.142	0.000	-0.301	0.000	0.000	0.000
August-P-d	-0.110	-0.228	-0.284	-0.318	-0.166	-0.111	-0.090
September-P-d	-0.383	-0.325	-0.221	-0.491	-0.428	-0.349	-0.181
October-P-d	-0.368	-0.275	-0.038	0.000	-0.386	0.000	0.000
Drought effect	2.332	1.384	1.345	1.561	0.980	0.531	0.558
Demand shifter							
Income	0.050	-0.153	-0.109	-0.338	0.384	0.312	1.269
SFIW	0.110	0.588	0.419	1.297	0.407	0.219	0.000
Population	2.177	1.813	1.293	4.001	2.162	1.270	0.667

Effect of Drought on Crop Economy

The effect of drought on crop acreage, yield, production, price, gross returns, and consumer demand is summarised in Table 6. A drought will have a negative effect on crop area, yield, and production, leading to a rise in prices and reduction in consumer demand. It was found that the price

Table 6: Elasticity of Acreage, Production, Price, Income and Food Demand with Respect to Drought, India

	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Crop area	-0.437	-0.086	-0.275	-0.113	0.000	-0.055	-0.431
Yield	-0.634	-0.678	-0.765	-0.277	-0.453	-0.363	-0.405
Production	-1.071	-0.764	-1.040	-0.390	-0.453	-0.418	-0.836
Price	2.332	1.384	1.345	1.561	0.980	0.531	0.558
Gross revenue	1.261	0.621	0.305	1.171	0.527	0.113	-0.278
Demand	-0.547	-0.181	-0.176	-0.205	-0.360	-0.222	-0.690

effect would dominate the negative supply effect, resulting in a higher value of output (VOP) at current prices under free trade.

Table 7 provides the effect of drought intensity on supply, prices, VOP, and demand for selected commodities. Rice and pearl millet are the most important crops that would be seriously affected by drought. It was estimated that a 10% drought intensity would be responsible for a fall in production of rice and pearl millet by more than 10%. For cotton and sorghum, the corresponding fall in production will be 8.4% and 7.6% respectively. Production of maize, groundnut, and pigeon pea will fall by about 4% with a 10% deficit rainfall. The prices of food commodities will show a significant inflationary trend in a free market of demand and supply. Rice being a staple commodity will witness an increase in its prices as high as 23%, followed by maize (16%), sorghum, and pearl millet (13% each), pigeon pea (10%), and groundnut and cotton (about 5% each) due to a 10% drought. Higher deficit rainfall will have much higher effect on inflation of agricultural commodities and adversely affect their demand. Rice demand will fall by about 5.5% due to an increase in prices in a situation of 10% drought. For other food commodities, the demand will fall by about 2% to 4%.

Table 7: Effect of Drought on Crop Economy, India

Drought Intensity (%)	Rice	Sorghum	Pearl Millet	Maize	Pigeon Pea	Groundnut	Cotton
Supply of commodities (%)							
5.00	-5.36	-3.82	-5.20	-1.95	-2.27	-2.09	-4.18
10.00	-10.71	-7.64	-10.40	-3.90	-4.53	-4.18	-8.36
15.00	-16.07	-11.46	-15.61	-5.85	-6.80	-6.27	-12.54
20.00	-21.43	-15.27	-20.81	-7.80	-9.07	-8.36	-16.72
25.00	-26.79	-19.09	-26.01	-9.75	-11.33	-10.45	-20.90
30.00	-32.14	-22.91	-31.21	-11.71	-13.60	-12.54	-25.08
Price of commodities (%)							
5.00	11.66	6.92	6.72	7.81	4.90	2.65	2.79
10.00	23.32	13.84	13.45	15.61	9.80	5.31	5.58
15.00	34.99	20.76	20.17	23.42	14.70	7.96	8.36
20.00	46.65	27.69	26.90	31.22	19.60	10.62	11.15
25.00	58.31	34.61	33.62	39.03	24.50	13.27	13.94
30.00	69.97	41.53	40.35	46.83	29.39	15.93	16.73
Value of output (%)							
5.00	6.30	3.10	1.52	5.85	2.63	0.56	-1.39
10.00	12.61	6.21	3.05	11.71	5.27	1.13	-2.78
15.00	18.91	9.31	4.57	17.56	7.90	1.69	-4.18
20.00	25.22	12.41	6.09	23.42	10.53	2.26	-5.57
25.00	31.52	15.51	7.62	29.27	13.16	2.82	-6.96
30.00	37.83	18.62	9.14	35.13	15.80	3.39	-8.35
Demand for commodities (%)							
5.00	-2.73	-0.91	-0.88	-1.02	-1.80	-1.11	-3.45
10.00	-5.47	-1.81	-1.76	-2.05	-3.60	-2.22	-6.90
15.00	-8.20	-2.72	-2.64	-3.07	-5.40	-3.32	-10.35
20.00	-10.94	-3.63	-3.53	-4.09	-7.21	-4.43	-13.80
25.00	-13.67	-4.54	-4.41	-5.12	-9.01	-5.54	-17.25
30.00	-16.41	-5.44	-5.29	-6.14	-10.81	-6.65	-20.69

Projected Impact of Drought on Supply and Demand

We have projected the supply of the selected commodities by 2020 and 2030 under different drought situations. The results are presented in Table 8 (p 60). They clearly show that the production of all the crops, barring sorghum, will increase in the next 20 years under normal rainfall but will be adversely affected if drought conditions prevail. For example, rice production in 2020 will be below that in 2010 under 20% and 30% droughts. The fall in production will be substantial (15.61 million tonnes) in a situation of 30% drought in 2020. For pigeon pea also, the production in 2020 will be lower than in 2010 if rainfall is 20% or 30% lower than normal. For other commodities, production will increase in 2020 and 2030, but deficit rainfall will lead to a fall, though it will remain higher than the base year of 2010.

Table 8: Projected Production of Selected Crops under Different Drought Situations by 2020 and 2030, India (million tonnes)

Crop	2010	2020			2030		
	Normal Rainfall	Normal Rainfall	20% Deficit	30% Deficit	Normal Rainfall	20% Deficit	30% Deficit
Rice	95.97	118.43	93.05	80.36	137.70	108.19	93.44
Sorghum	6.94	6.32	5.35	4.87	6.70	5.67	5.16
Pearl millet	8.75	13.37	10.59	9.20	18.06	14.30	12.42
Maize	20.10	31.54	29.08	27.85	48.78	44.98	43.07
Pigeon pea	2.56	2.77	2.52	2.39	3.00	2.73	2.59
Groundnut	6.78	7.50	6.87	6.56	8.29	7.59	7.25
Cotton	4.77	7.60	6.33	5.69	12.11	10.08	9.07

We have updated and revised the projections of a study (Joshi and Kumar 2011) on food demand for major commodities in India up to 2030. The study has not incorporated the drought effect on prices and their implications on demand for the selected commodities. We compared the projected demand for and supply of different commodities by 2020 and 2030 to examine if the country will face a shortfall in the event of deficit rainfall (Tables 9 and 10). The total demand for a food commodity was estimated by taking it as the sum of direct and indirect demands. The direct demand comprises food consumption at home and outside home. The indirect demand includes its use as seed and feed, in industry and wastages/spoilage. As stated earlier, the demand for the selected commodities will decline with deficit rainfall compared to normal rainfall because of a rise in their prices.

Table 9: Projected Demand for Selected Crops under Different Drought Situations by 2020 and 2030 (million tonnes)

Crop	2010	2020			2030		
	Normal Rainfall	Normal Rainfall	20% Deficit	30% Deficit	Normal Rainfall	20% Deficit	30% Deficit
Rice	95.7	108.10	96.28	90.36	122.1	108.74	102.07
Sorghum	6.46	6.66	6.41	6.29	6.61	6.37	6.25
Pearl millet	8.03	9.86	9.51	9.33	11.46	11.06	10.86
Maize	18.45	25.44	24.40	23.88	33.44	32.07	31.38
Pulses	11.33	13.77	12.78	12.26	16.64	15.44	14.84
Edible oil	13.63	16.97	16.22	15.84	21.26	20.32	19.85
Cotton	4.77	7.60	6.55	6.03	12.11	10.44	9.60

Table 10: Projected Supply-Demand Gap for Selected Crops under Different Drought Situations by 2020 and 2030 (million tonnes)

Crop	2010	2020			2030		
	Normal Rainfall	Normal Rainfall	20% Deficit	30% Deficit	Normal Rainfall	20% Deficit	30% Deficit
Rice	0.27	10.33	–15.05	–27.74	15.6	–13.91	–28.66
Sorghum	0.48	–0.38	–1.31	–1.79	0.09	–0.94	–1.45
Pearl millet	0.72	3.51	0.73	–0.66	6.60	2.84	0.96
Maize	1.65	6.1	3.64	2.41	15.34	11.54	9.63
Cotton	0.00	0.00	–1.27	–1.91	0.00	–2.03	–3.04

The supply-demand gap reveals that there will be a deficit of about 15 million tonnes of rice in 2020 in the case of a 20% drought if the government intends to maintain prices under deficit rainfall. The gap will be about 28 million tonnes in a 30% rainfall deficit scenario. These projections suggest that in a situation of 20% drought, there will be a 14% shortfall of rice in 2020, and a 26% shortfall under 30% drought, both if the government intends to maintain prices at a normal rainfall situation level. For sorghum and cotton, there will be a deficit in supply-demand in 2020 and 2030 if there is a drought of 20% or 30% intensity. In the case of rice, the huge projected deficit will have two serious implications. One, global food prices will significantly shoot up as India would import to meet its demand. Two, the food security of the poor in India will be adversely affected, and rising prices will drag many into debt traps. It is therefore important to evolve appropriate strategies to combat the effect of climate change, especially of drought, and ensure that the poor have food security.

4 Conclusions

The study has showed that drought during the monsoon period adversely affects the agricultural sector in India. Production is seriously affected, which, in turn, increases the prices of agricultural commodities and affects their demand. In a free market situation, farmers will benefit from higher prices, but consumers will be badly hit, and their demand will come down. Unfortunately, the benefits of higher prices are not passed on to the majority of farmers, especially smallholders, but seized by middlemen/traders. In such circumstances, both smallholder farmers and poor consumers will be seriously affected by a drought. A large number of smallholders and poor consumers will be pushed into poverty. Their purchasing power will shrink and consumption of food commodities will decline, thus adversely affect their food and nutritional security.

Government intervention would be necessary to ensure the food and nutritional security of poor consumers and smallholders. The study shows that there will be a huge deficit (about 15 million tonnes) of rice in 2020 in a situation of 20% rainfall deficit. The volume will be more if rainfall deficiency is higher. To meet demand, a high level of import will be necessary, which will lead to a spike in the prices of rice and other complementary commodities in the global market, further fuelling the price rise. It is therefore necessary to have a strategy to minimise the impact of a drought on the food and nutritional security of the poor. This will require having a strong social safety net programme for the targeted population, especially for poor consumers and smallholders. In the long run, technological interventions will be necessary to offset the effects of drought. Therefore more research effort on alternative coping mechanisms and investment in them will be necessary to protect the poor from the effects of drought.

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Appendix Table 1: Important Months Included in Area and Yield Response Models

Crop	Area Response Function	Yield Response Function	
	Rainfall (Month-P)	Rainfall (Month-P)	Number of Rainy Days (Month-P-d)
Rice	June, July, August	July	July, August, September, October
Sorghum	June, July, August	July	July, August, September, October
Pearl millet	June, July, August	July	July, August, September, October
Maize	June, July, August	July	July, August, September, October
Pigeon pea	May, June, July		August, September, October
Groundnut	June, July, August		August, September
Cotton	April, May, June, July		August, September

Appendix Table 2: Climate Area Response for Selected Crops in India

Variable	Unstandardised Coefficients	Standard Error	Standardised Coefficients	t-value	p-value
Dependent variable: ln(rice area in 't' th year)					
(Constant)	0.5906	0.1048		5.63	0
ln(Area in t-1 year)	0.8873	0.0199	0.8845	44.53	0
Per cent deviation from normal rain					
Jun-P	0.0002	0.0001	0.0056	1.51	0.13
July-P	0.0008	0.0001	0.0315	8.22	0
Aug-P	0.0004	0.0001	0.0134	3.95	0
Jun-P-sq	0	0	–0.0035	–0.92	0.36
July-P-sq	0	0	–0.0177	–2.62	0.01
Aug-P-sq	0	0	–0.005	–0.74	0.46
Adjusted R-square	0.995				
Dependent variable: ln(sorghum area in 't' th year)					
(Constant)	1.2678	0.2273		5.58	0
ln(Area in t-1 year)	0.8092	0.0335	0.8094	24.18	0
Per cent deviation from normal rain					
Jun-P	–0.0002	0.0004	–0.0037	–0.57	0.57
July-P	0.0005	0.0004	0.0093	1.19	0.24
Aug-P	0.0005	0.0004	0.0072	1.13	0.26
Jun-P-sq	0	0	–0.0038	–0.56	0.58
July-P-sq	0	0	–0.0008	–0.05	0.96
Aug-P-sq	0	0	–0.0142	–0.87	0.39
Adjusted R-square	0.987				
Dependent variable: ln(pearl millet area in 't' th year)					
(Constant)	1.1387	0.2675		4.26	0
ln(Area in t-1 year)	0.8682	0.031	0.8617	28.01	0
Per cent deviation from normal rain					
Jun-P	–0.0002	0.0004	–0.0033	–0.46	0.64
Jul-P	0.001	0.0004	0.0215	2.7	0.01
Aug-P	0.001	0.0004	0.0166	2.44	0.02
Jun-P-sq	0	0	–0.0014	–0.19	0.85
Jul-P-sq	0	0	–0.0029	–0.21	0.84
Aug-P-sq	0	0	–0.0263	–1.9	0.06
Adjusted R-square	0.9868				
Dependent variable: ln(maize area in 't'th year)					
(Constant)	0.4147	0.1268		3.27	0
ln(Area in t-1 year)	0.9408	0.0181	0.9352	52.01	0
Per cent deviation from normal rain					
Jun-P	-0.0001	0.0002	-0.0049	-0.77	0.44
Jul-P	0.0002	0.0002	0.006	0.89	0.37
Aug-P	0.0002	0.0002	0.0073	1.23	0.22
Jun-P-sq	0	0	-0.0009	-0.14	0.89
Jul-P-sq	0	0	0.0005	0.04	0.97
Aug-P-sq	0	0	-0.0044	-0.38	0.71
Adjusted R-square 0.9863					
Dependent variable: ln(pigeon pea area in 't'th year)					
(Constant)	0.3937	0.0949		4.15	0
ln(Area in t-1 year)	0.9046	0.0221	0.8997	40.88	0
Per cent deviation from normal rain					
May-P	0	0.0002	0.0001	0.01	0.99
Jun-P	0.0001	0.0003	0.0017	0.24	0.81
Jul-P	–0.0002	0.0003	–0.0041	–0.52	0.6
May-P-sq	0	0	–0.0004	–0.05	0.96
Jun-P-sq	0	0	–0.0048	–0.66	0.51
Jul-P-sq	0	0	–0.0001	–0.02	0.99
Adjusted R-square	0.9845				
Dependent variable: ln(groundnut area in 't'th year)					
(Constant)	0.9648	0.1547		6.24	0
ln(Area in t-1 year)	0.8271	0.0253	0.8282	32.67	0
Per cent deviation from normal rain					
Jun-P	–0.0006	0.0005	–0.0097	–1.25	0.21
July-P	0.0002	0.0005	0.0038	0.44	0.66
Aug-P	0.0007	0.0005	0.0095	1.3	0.19
Jun-P-sq	0	0	–0.0041	–0.51	0.61
July-P-sq	0	0	0.0058	0.33	0.74
Aug-P-sq	0	0	–0.012	–0.7	0.49
Adjusted R-square	0.8963				
Dependent variable: ln(cotton area in 't'th year)					
(Constant)	0.4637	0.1477		3.14	0
ln(Area in t-1 year)	0.9247	0.0234	0.9206	39.57	0
Per cent deviation from normal rain					
Apr-P	0.0002	0.0001	0.012	1.3	0.19
May-P	0.0001	0.0001	0.0072	0.86	0.39
Jun-P	–0.0001	0.0003	–0.0016	–0.25	0.8
Jul-P	0.0008	0.0003	0.0221	2.82	0.01
Apr-P-sq	0	0	–0.0117	–1.26	0.21
May-P-sq	0	0	–0.0046	–0.55	0.58
Jun-P-sq	0	0	–0.0011	–0.17	0.86
Jul-P-sq	0	0	–0.0151	–1.92	0.06
Adjusted R-square 0.9904					

Appendix Table 3: Climate Yield Response for Selected Crops in India

Variable	Unstandardised Coefficients	Standard Error	Standardised Coefficients	t-value	p-value
Dependent variable: ln(rice yield in 't' th year)					
(Constant)	−5.0272	1.1789		−4.26	0
ln(Yield in 't-1' year)	0.3686	0.0336	0.3815	10.98	0
Per cent deviation from normal rain					
Jul-P	0.0009	0.0002	0.0958	4.63	0
Jul-P-sq	0	0	−0.0276	−0.75	0.45
Per cent deviation from normal number of rainy days					
Jul-P-d	0.0008	0.0003	0.0519	2.93	0
Aug-P-d	0.0006	0.0003	0.0311	1.84	0.07
Sep-P-d	0.0012	0.0002	0.1088	5.84	0
Oct-P-d	0.0006	0.0001	0.1044	4.81	0
Jul-P-d-sq	0	0	−0.0021	−0.11	0.91
Aug-P-d-sq	0	0	−0.0786	−2.2	0.03
Sep-P-d-sq	0	0	−0.0851	−4.32	0
Oct-P-d-sq	0	0	−0.1009	−4.43	0
Carbon					
ln(CO_2)	1.6496	0.2196	0.1429	7.51	0
Adjusted R-square	0.871				
Dependent variable: ln(sorghum yield in 't' th year)					
(Constant)	−2.5936	2.0152		−1.29	0.2
ln(Yield in 't-1' year)	0.2811	0.0466	0.2871	6.03	0
Per cent deviation from normal rain					
Jul-P	0.0009	0.0003	0.1015	2.51	0.01
Jul-P-sq	0	0	−0.1128	−1.3	0.2
Per cent deviation from normal number of rainy days					
Jul-P-d	0.0008	0.0005	0.0558	1.78	0.08
Aug-P-d	0.0017	0.0006	0.0896	2.88	0
Sep-P-d	0.0014	0.0004	0.1277	3.7	0
Oct-P-d	0.0006	0.0002	0.1083	2.74	0.01
Jul-P-d-sq	0	0	0.0217	0.64	0.52
Aug-P-d-sq	0	0	−0.0518	−0.64	0.52
Sep-P-d-sq	0	0	−0.0781	−2.15	0.03
Oct-P-d-sq	0	0	−0.0997	−2.39	0.02
Carbon					
ln(CO_2)	1.175	0.3521	0.098	3.34	0
Adjusted R-square	0.739				
Dependent variable: ln(pear millet yield in 't' th year)					
(Constant)	−11.2385	2.9215		−3.85	0
ln(Yield in 't-1' year)	0.5156	0.0448	0.5139	11.52	0
Per cent deviation from normal rain					
Jul-P	0.0017	0.0004	0.1677	3.81	0
Jul-P-sq	0	0	−0.0807	−1.08	0.28
Per cent deviation from normal number of rainy days					
Jul-P-d	0.0007	0.0006	0.0407	1.15	0.25
Aug-P-d	0.0022	0.0007	0.1067	3.14	0
Sep-P-d	0.001	0.0005	0.0832	2.14	0.03
Oct-P-d	0.0001	0.0003	0.0143	0.32	0.75
Jul-P-d-sq	0	0	0.0605	1.61	0.11
Aug-P-d-sq	0	0	−0.1433	−−2.01	0.05
Sep-P-d-sq	0	0	−0.0391	−0.97	0.33
Oct-P-d-sq	0	0	−0.0257	−0.54	0.59
Carbon					
ln(CO_2)	2.4115	0.5156	0.1699	4.68	0
Adjusted R-square	0.6477				
Dependent variable: ln(maize yield in 't' th year)					
(Constant)	−8.6734	1.6421		−5.28	0
ln(Yield in 't-1' year)	0.275	0.0414	0.276	6.65	0
Per cent deviation from normal rain					
Jul-P	0.0002	0.0003	0.0257	0.85	0.4
Jul-P-sq	0	0	−0.1053	−1.98	0.05
Per cent deviation from normal number of rainy days					
Jul-P-d	0.0008	0.0004	0.0544	2.13	0.03
Aug-P-d	0.0011	0.0004	0.0576	2.35	0.02
Sep-P-d	0.001	0.0003	0.0888	3.26	0
Oct-P-d	0	0.0002	−0.0092	−0.29	0.77
Jul-P-d-sq	0	0	0.0194	0.7	0.48
Aug-P-d-sq	0	0	−0.0032	−0.06	0.95
Sep-P-d-sq	0	0	−0.1014	−3.51	0
Oct-P-d-sq	0	0	0.0148	0.45	0.66
Carbon					
ln(CO_2)	2.3371	0.2983	0.2058	7.83	0
Adjusted R-square	0.7463				
Dependent variable: ln(pigeon pea yield in 't' th year)					
(Constant)	4.804	2.0808		2.31	0.02
ln(Yield in 't-1' year)	0.3355	0.0422	0.3424	7.94	0
Per cent deviation from normal number of rainy days					
Aug-P-d	0.001	0.0006	0.0505	1.64	0.1
Sep-P-d	0.0015	0.0004	0.1302	3.95	0
Oct-P-d	0.0007	0.0002	0.1174	2.88	0
Aug-P-d-sq	0	0	−0.05	−1.57	0.12
Sep-P-d-sq	0	0	−0.1034	−2.98	0
Oct-P-d-sq	0	0	−0.0821	−1.95	0.05
Carbon					
ln(CO_2)	1.8861	0.3464	0.1777	5.44	0
Adjusted R-square	0.6341				
Dependent variable: ln(groundnut yield in 't' th year)					
(Constant)	−2.9775	2.2536		−1.32	0.19
ln(Yield in 't-1' year)	0.2078	0.0446	0.2126	4.66	0
Per cent deviation from normal number of rainy days					
Aug-P-d	0.001	0.0006	0.069	1.61	0.11
Sep-P-d	0.0019	0.0004	0.2164	4.75	0
Aug-P-d-sq	0	0	−0.0598	−1.36	0.18
Sep-P-d-sq	0	0	−0.1358	−2.79	0.01
Carbon					
ln(Co_2)	1.435	0.3945	0.1496	3.64	0
Adjusted R-square	0.3478				
Dependent variable: ln(cotton yield in 't' th year)					
(Constant)	−10.6663	2.5733		−4.15	0
ln(Yield in 't-1' year)	0.4723	0.049	0.466	9.64	0
Per cent deviation from normal number of rainy days					
Aug-P-d	0.0014	0.0006	0.0719	2.21	0.03
Sep-P-d	0.0017	0.0004	0.1446	4.1	0
Aug-P-d-sq	0	0	−0.0607	−1.82	0.07
Sep-P-d-sq	0	0	−0.0985	−2.66	0.01
Carbon					
ln(Co_2)	2.3168	0.4535	0.1678	5.11	0
Adjusted R-square	0.7173				

Appendix Table 4: Supply Response Elasticity for Selected Crops in India

Crop	Output P	Human Labour w/P	Animal Labour b/P	Machinery m/P	Fertiliser r/P	Other Inputs o/P
Rice	0.2249	−0.0786	−0.0369	−0.0335	−0.0155	−0.0603
Sorghum	0.4206	−0.1534	−0.0921	−0.0798	−0.0505	−0.0448
Pearl millet	0.6424	−0.2792	−0.1490	−0.0704	−0.0861	−0.0577
Maize	0.1189	−0.0164	−0.0527	−0.0350	0.0347	−0.0493
Pigeon pea	0.0949	−0.0326	−0.0251	−0.0332	−0.0056	0.0017
Groundnut	0.3700	−0.1691	−0.0534	−0.0414	−0.0498	−0.0563
Cotton	0.2623	−0.1046	−0.0197	−0.0252	−0.0480	−0.0647

Source: Computed by authors.

Appendix Table 5: Annual Growth Rate in TFP for Selected Crops, India

Crop	1975-85	1986-95	1996-2005	1975-2005
Paddy	0.90	0.74	0.40	0.67
Sorghum	1.15	0.74	–0.42	0.63
Pearl millet	1.22	0.39	1.50	1.04
Maize	2.00	0.67	1.64	1.39
Pigeon pea		0.21	–0.54	–0.69
Groundnut	0.49	0.55	1.30	0.77
Cotton	2.84	0.92	0.80	1.41

Source: Computed by the authors.

Appendix Table 6: Base Year Area, Yield and Production of Selected Crops: TE 2010

Crops	Yield (kg/ha)	Area (million ha)	Production (million tonnes)
Rice	2181.3	43.34	94.53
Sorghum	924.6	7.46	6.90
Pearl millet	940.6	9.03	8.49
Maize	2316.2	8.31	19.24
Pigeon pea	676.9	3.75	2.54
Groundnut	1144.8	5.86	6.71
Cotton	446.2	10.20	4.55

Source: *Agricultural Statistics at a Glance 2011*, Directorate of Economics and Statistics, Ministry of Agriculture and Cooperation, New Delhi.

Appendix Table 7: Annual Growth of Input-Output Prices, and Area Growth for Selected Crops in India (1981-2008)

Input Price	Crop Price (P)	w/P	b/P	m/P	r/P	i/P	Area Growth
Rice	6.78	4.18	5.19	–0.64	–1.60	–0.91	–0.36
Sorghum	7.78	3.18	4.19	–1.64	–2.60	–1.92	–2.86
Pearl millet	6.43	4.53	5.55	–0.29	–1.25	–0.56	–0.34
Maize	6.09	4.87	5.88	0.05	–0.91	–0.22	2.63
Pigeon pea	8.11	2.85	3.86	–1.97	–2.93	–2.25	0.70
Groundnut	6.97	3.99	5.00	–0.83	–1.79	–1.11	–1.67
Cotton	7.52	3.44	4.45	–1.38	–2.34	–1.66	1.44

Source: Computed from cost of cultivation data, Directorate of Economics and Statistics, Ministry of Agriculture and Cooperation, New Delhi.

Appendix Table 8: Food and Non-food Demand Elasticities, India

Item	Price Elasticity	Income Elasticity
Rice	–0.247	0.024
Wheat	–0.340	0.075
Coarse cereals (maize, sorghum, pear millet)	–0.194	–0.125
Pulses (pigeon pea)	–0.453	0.219
Edible oils (groundnut)	–0.504	0.297
Non-food (cotton)	–1.237	1.903

Source: Kumar et al (2011).