Estimating Mandal-Level Gross Agricultural Product in Mahabubnagar, Andhra Pradesh

Report Submitted

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Abstract

Using data on mandal-level rainfall in the district of Mahabubnagar[1], we estimate yield for seven different crops using a multivariate regression model with rainfall and temperature as the dependent variables. Using estimated yield and area and crop prices from the Mahabubnagar census we estimate changes in mandal-level VOP and response to rainfall. This research emphasizes the importance of developing drought-tolerant technologies to mitigate the effect of drought on agricultural output.

[1] A district is composed of many mandals. The district of Mahabubnagar has 64 mandals.

District-Level VOP in Mahabubnagar

The value of production (VOP) method is an estimate of the agricultural output of a district or mandal. (Indicus, 2007). Crop-wise, district-level output, a measure of gross agricultural product at a sub-macro level, is the product of annual price and average production,

$$VOP_{i,t} = \sum_{i=1}^{N=19} p_{i,t} * q_{i,t}(yield_{i,t}, ha_{i,t})$$

where p is the annual price, q is production, the subscript i represents a specific crop and t the year. The benefits of the VOP method are twofold: First, it requires a minimum amount of data and second, the VOP provides an estimate of the gross income of a district. We assume that non-farm sectors are insulated from the economic impacts of drought. We also assumed that the market for agricultural goods is perfectly competitive and that market prices are taken as given.

In 2003, total agricultural district income for fourteen crops (paddy, jowar, bajra, red gram, bengal gram, castor, groundnut, cotton, ragi, maize, horsegram, green gram, sunflower and chilies) crops in Mahabubnagar were 81,767 lakhs (10^5 Rs). VOP declined by 25% in 2003-04, increased 64% between 2004-2005, and declined 8.3% in 2005-2006 for a total VOP of 91,723 lakhs in 2006. Over four years, the largest economic gains occurred in paddy (5000 lakhs), groundnut (4000 lakhs) and maize (2000 lakhs).

Table 1: VOP in Mahabubnagar (Lakhs)

Crop	2003	2004	2005	2006
Paddy	12949	10021	18527	17955
Jowar	3919	2467	5004	3977
Bajra	321	200	353	133
Red Gram	3833	3454	7415	2784
Bengal Gram	2352	1588	3612	4252
Castor	9086	8078	9863	8416
Groundnut	11681	10874	15169	15542
Cotton	13851	10514	8413	11304
Ragi	414	372	576	302
Maize	9948	7509	18949	11913
Horsegram	186	469	231	125
Green Gram	735	165	2797	1200
Sunflower	3142	2523	2011	2381
Chilies	9350	2497	7068	11439
Total	**81767**	**60732**	**99987**	**91723**
% Change		**-25.7**	**64.6**	**-8.3**

Source: Directorate of Economics and Statistics

Mandal-Level VOP

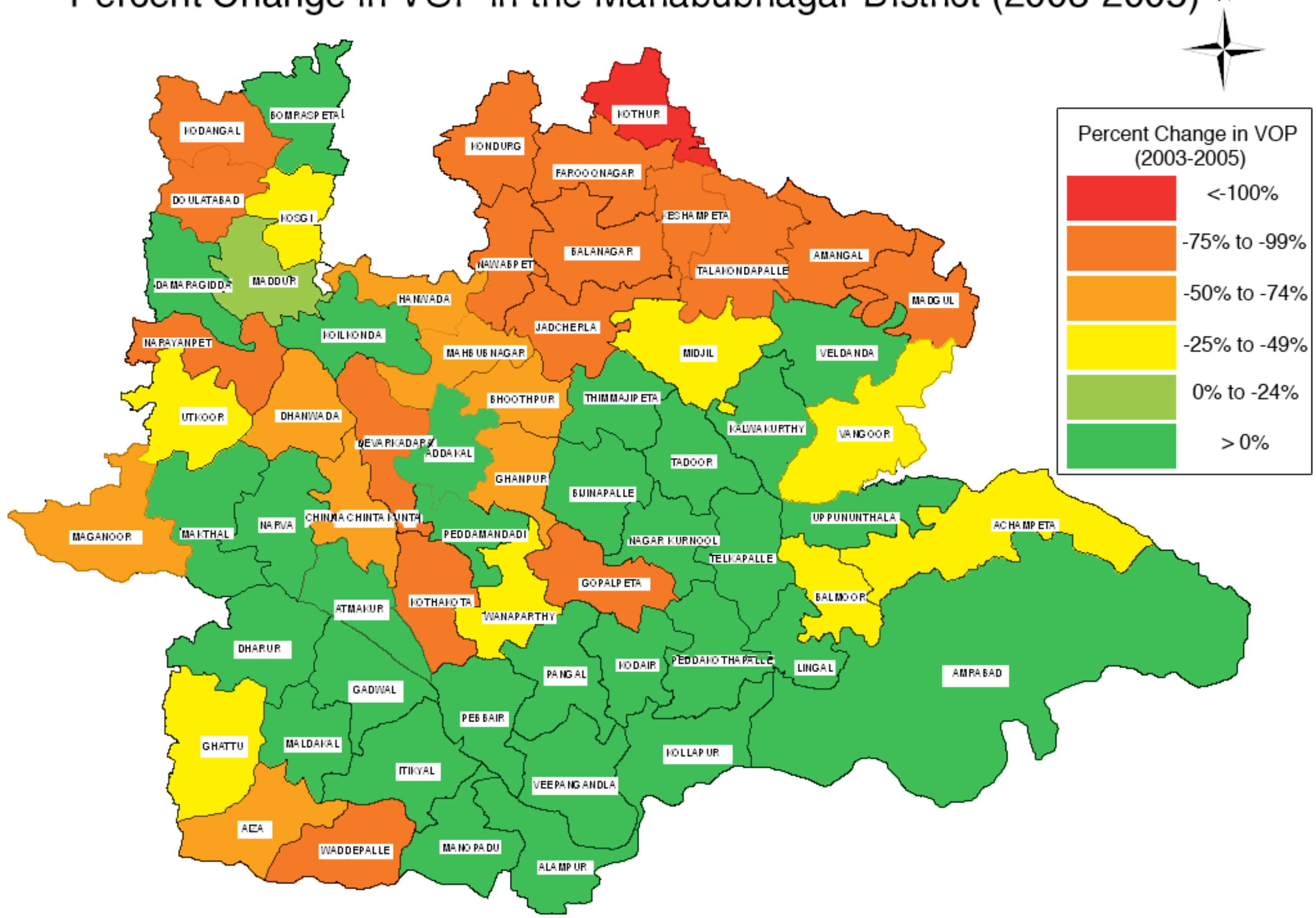
The 2003-2006 Census of Mahabubnagar provided crop production data at the mandal level for seven of the fourteen crops: paddy, jowar, bajra, red gram, bengal gram, castor and groundnut. Mandal-level area was not available for other crops, but we still believe that VOP is an imperfect indicator for gross agricultural income.

Results suggest that while VOP declined in northwest mandals and increased in southwest mandals from 2003-2005, VOP increased in almost all mandals from 2005-2006. In the next section, we test the hypothesis of the effect rainfall of rainfall on yield, a crucial component of VOP.

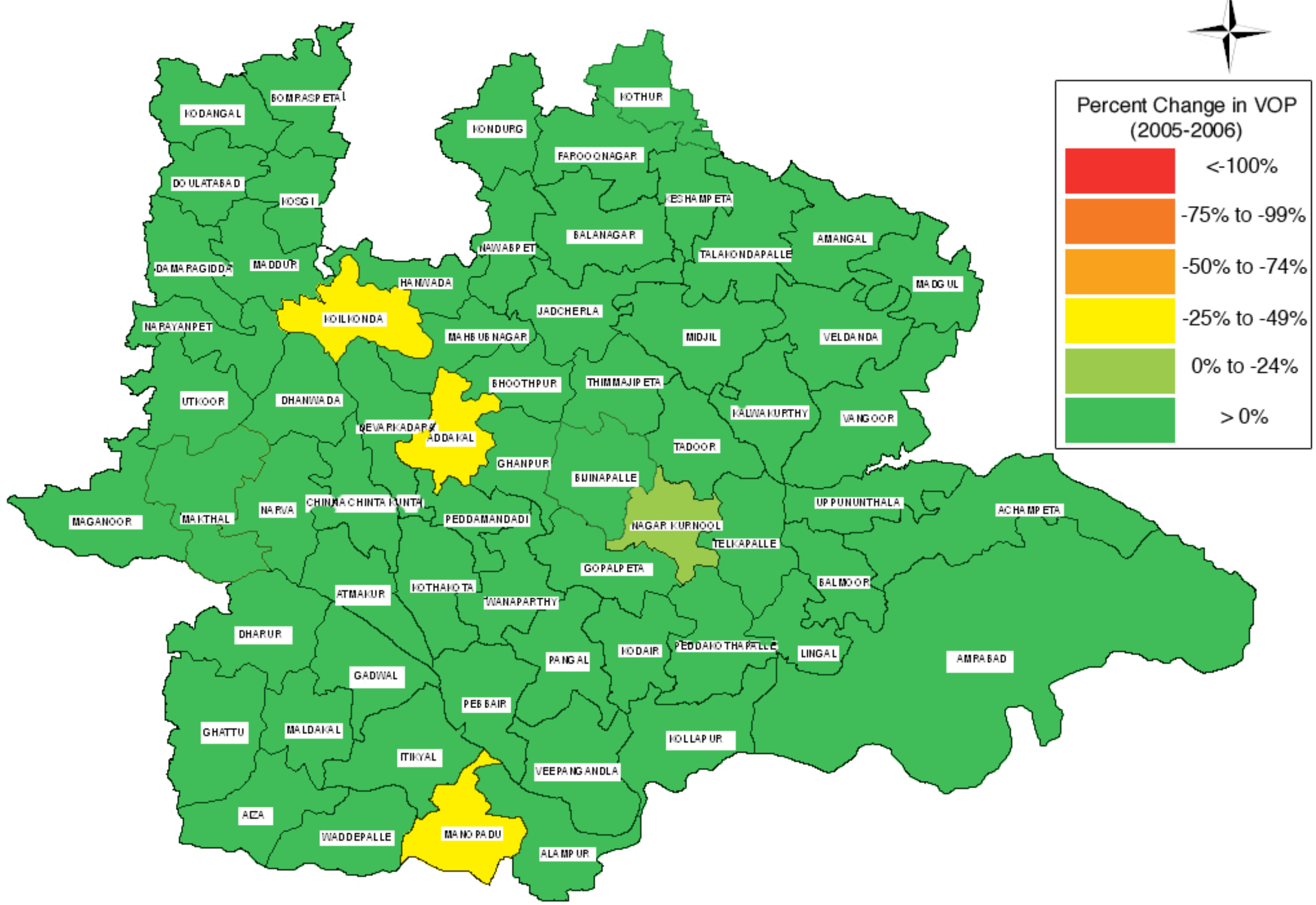
Table 2: Mandal-Level VOP (Lakhs)

Mandal	2003	2005	2006	Mandal	2003	2005	2006
Achampet	2531	1385	8995	Kosgi	1548	1270	2386
Addakal	523	1336	975	Kothakota	4023	849	1342
Alampur	1236	3048	4092	Kothur	2998	13	14
Amangal	2318	877	2160	Lingal	730	1166	2985
Amrabad	577	834	7558	Maddur	702	777	1889
Atmakoor	1348	1405	5178	Madgul	6112	264	869
Balanagar	5178	404	901	Maganoor	6520	2062	7834
Balmoor	2241	1338	4793	Mahabubnagar	979	402	952
Bijinapally	226	318	1256	Makthal	1649	2397	5009
Bomraspet	207	1148	1591	Maldakal	805	2421	6900
Boothpur	900	438	732	Manopad	2316	2520	1600
C.C.kunta	1455	656	1147	Midjil	2717	1879	3981
Damargidda	317	1079	1367	Nagarkurnool	270	779	614
Devarkadra	2507	635	2653	Narayanpet	4403	664	2434
Dhanwada	2664	779	1819	Narva	840	1265	1687
Dharoor	347	3138	5921	Nawabpet	1723	206	486
Doultabad	1372	429	1898	Pangal	1387	4308	14618
Gadwal	559	1922	3640	Pebbair	1572	2401	8028
Ghanapur	554	238	742	Peddakothapally	954	1801	6850
Ghattu	3793	2780	13321	Peddamandadi	1202	1367	2070
Gopalpet	4819	693	1157	Shadnagar	1368	87	207
Hunwada	2774	963	2836	Tadoor	414	2180	4070
Ieez	6057	2572	15040	Talakondapally	2315	542	4013
Itkyal	4413	5451	11434	Telkapally	22	964	4117
Jadcherla	3882	483	953	Thimmajipet	43	181	813
Kalwakurthy	1326	1668	20820	Uppununthala	956	3627	13459
Keshampet	2918	167	203	Utkoor	1639	1262	4125
Kodair	2432	3316	9260	Vangoor	9365	5022	24259
Kodangal	2238	201	788	Veldanda	2540	2597	28791
Koilkonda	430	2673	1909	Waddepally	5176	1259	3253
Kollapur	647	3449	21246	Wanaparthy	2595	1400	5545
Kondurug	2186	313	468	Weepangandla	19322	12094	94921

Percent Change in VOP in the Mahabubnagar District (2003-2005)



Percent Change in VOP in the Mahabubnagar Distrcit (2005 to 2006)



Crop Production

Production is the product of two different functions, yield and area, for every crop *i.*

$$q_i(kg) = yield_i(kg/ha) * area_i(ha)$$

Although production is dependent on a variety of random biological and anthropogenic variables, rainfall is a reasonable proxy for predicting increases or decreases in production. Production is positively correlated with rainfall in about 75% of the cases for all nineteen crops, especially during years with more severe rainfall. For example, when rainfall decreased from the normal amount of 600 to a low of 432 in 2004, 16 of the 19 crops responded accordingly with a decrease in production. The following year, moving from 432 mm to an eight-year high of 889 mm, production for 15 of the 19 crops increased.

Table 3: District-Level, Monthly Rainfall in Mahabubnagar (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1999	0	1	0	14	99	64	135	102	75	33	0	0	522
2000	0	7	0	2	42	198	84	216	76	62	2	0	690
2001	2	0	0	12	5	67	34	108	242	184	3	0	656
2002	3	0	1	7	40	77	71	153	63	128	5	0	545
2003	0	0	34	10	0	74	137	184	96	66	0	0	600
2004	4	19	18	18	16	23	110	32	107	85	1	0	432
2005	1	2	9	25	20	44	214	136	215	214	8	0	889
2006	0	0	28	50	64	112	55	47	153	18	30	0	557
Mean	**1**	**4**	**11**	**17**	**36**	**82**	**105**	**122**	**128**	**99**	**6**	**0**	**557**

Source: Indian Meteorological Department

Estimating production as a function of rainfall would introduce some spurious correlations between area and yield. While yield may be responsive to rainfall it can hardly be considered responsive to the market price. On the other hand, the farmer is responsive to prices and availability but accepts rainfall as given. In order to estimate future changes in yield and area, one has to break down production into these two parameters and forecast separately.

Distribution of Mandal-Level Rainfall

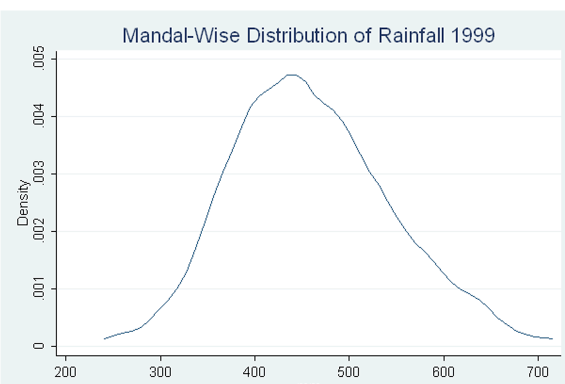
Farmers sow according to India's two monsoons, kharif and rabi. Kharif, the monsoon that supplies the majority of rainfall, starts in April and moves to the northeast by September with harvest in October. Rabi follows the harvest, moving southwest in November with harvest in June.

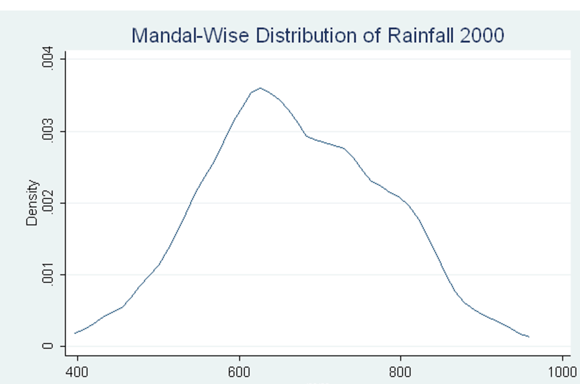
Mandal-level annual rainfall averages are similar to district-level rainfall averages.

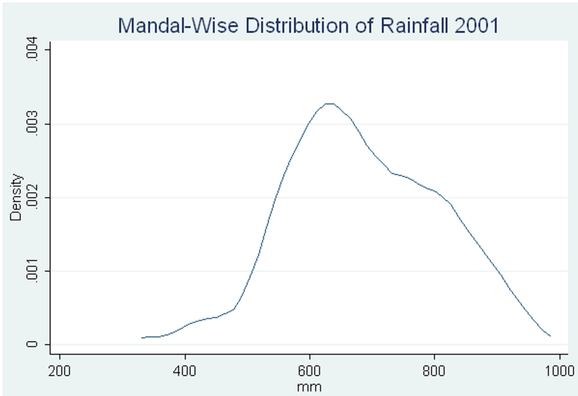
Table 4: Mandal-Level Distribution of Rainfall							
Year	**Mean**	**Std. Dev**	**Min**	**Max**	**n**	**Skewness**	**Kurtosis**
1999	460	82	272	684	64	0.38	2.97
2000	669	106	438	918	64	0.108	2.5
2001	686	118	377	940	64	0.017	2.62
2002	538	108	338	850	64	0.433	2.93
2003	624	139	320	1132	64	0.594	4.77
2004	445	78	247	671	64	0.127	3.2
2005	973	220	471	1744	64	0.67	4.67
2006	482	135	226	809	64	0.472	2.6
2007	840	203	535	1680	64	1.4	6.32

Source: India Meterological Department

However, the variance, skewness and kurtosis reveal trends that district-level data obscures. In 1999, the standard deviation among mandals was 81 mm with a skew of .38. Symmetry is the exception, rather than the rule, however. In all other years, rainfall is positively skewed reaching a maximum of 1.4 in 2007. Kurtosis similarly increases from 2.97 in 1999 and 6.7 in 2007. If we see this "water inequality" trend continuing in the future, institutions in charge of water infrastructure may benefit their users in drier mandals by increasing investments in conveyance.






Mandal-Wise Distribution of Rainfall 2001
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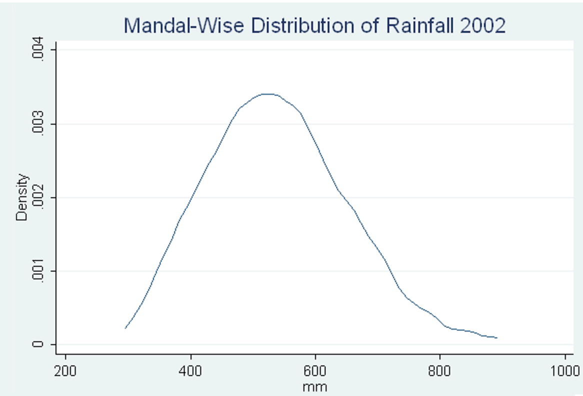
Mandal-Wise Distribution of Rainfall 2002
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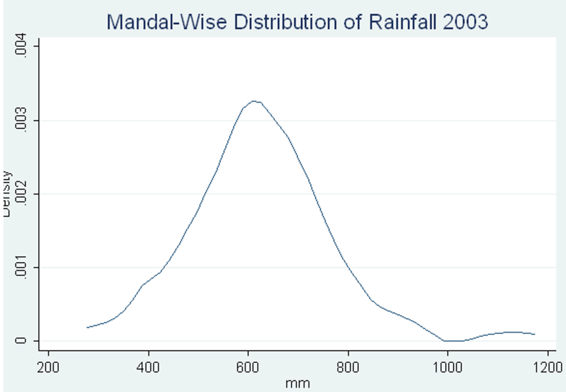
Mandal-Wise Distribution of Rainfall 2003
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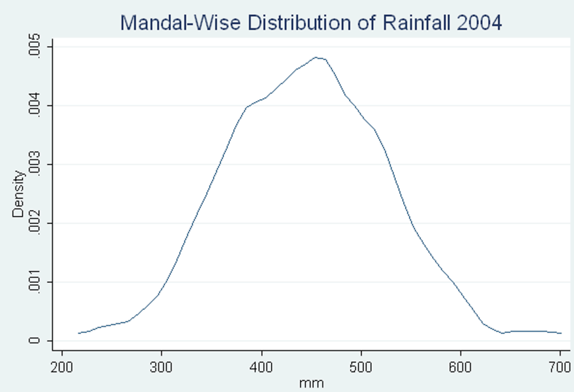
Mandal-Wise Distribution of Rainfall 2004
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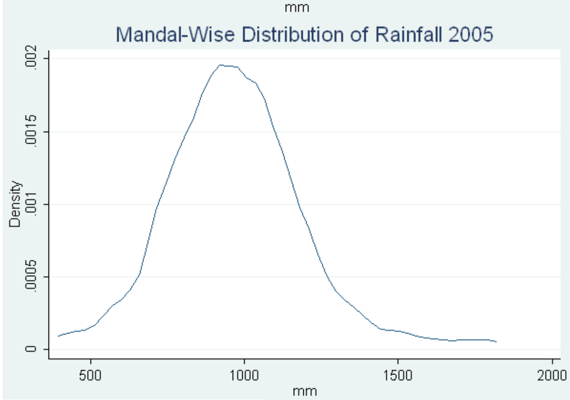
Mandal-Wise Distribution of Rainfall 2005
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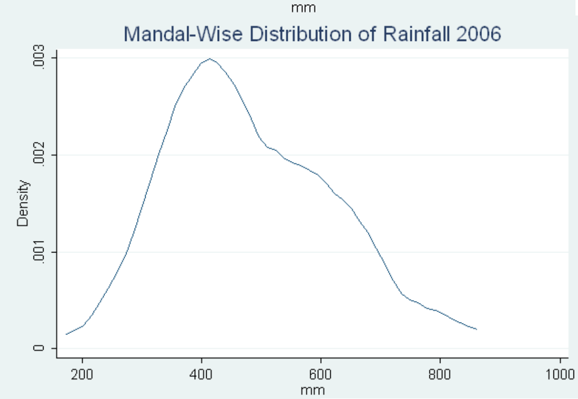
Mandal-Wise Distribution of Rainfall 2006
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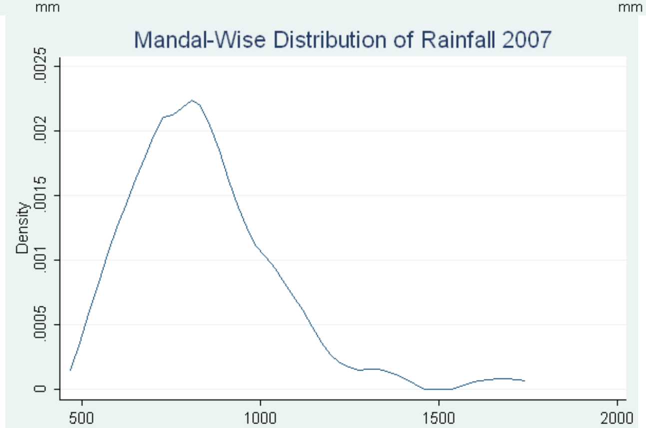
Mandal-Wise Distribution of Rainfall 2007
Density
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.001
.0015
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.0025
500
1000
1500
2000

Forecasting Yield

A single estimate of crop-wise yield for all of Mahabubnagar does not account for climate and spatial variability. To estimate the effect of these parameters on yield, a multivariate OLS regression technique was used to forecast yield for each of the nineteen crops *i*. Yield, the dependent variable, is a function of district-level monthly rainfall (mm) and monthly maximum and minimum temperature (°C). To control for confounding over time, a variable for each of the eight years (1999-2007) was included.

Eight years of daily meteorological data for the Mahabubnagar district came from the Indian Meteorological Department. Only the eight months of Kharif were included, as the quantity of rainfall during rabi never exceeded 8% of the annual total over the past eight years.

Although daily (or weekly) data more accurately accounts for the effect of rain dispersion on yield, monthly data was used because monthly data allows us to include eight additional districts over eight years, raising the crop-wise number of observations from eight to a more robust sixty-four. The neighboring districts included are Gulbarga, Raichur and Bidar in Karnataka; Medak, Nalgonda, Guntur, Prakasam and Kurnool in Andhra Pradesh. Monthly rainfall data for adjacent districts came from the Indian Water Portal (1998-2003) and the India Meteorological Department (2004-2006). To further control for the differences among districts such as soil quality, geographic coordinates were included in the regression.

$$yield_i = \beta_0 + \beta_1 rain_{t,d} + \beta_2 \max temp_{t,d} + \beta_3 \min temp_{t,d} + \beta_4 year + \beta_5 latitude + \beta_6 longitude + \varepsilon$$

Even if one particular month's rainfall is insignificant, this does not imply that rainfall as a whole is also insignificant. Because we are testing multiple hypothesis (rain for the eight months of kharif), a joint F-test is used to determine the sign, size, and significance of the effect of rainfall on yield. The null hypothesis in this case is that rainfall has no effect on yield.

$$H_0 : \beta_{rain_{t,i}} = 0$$
$$H_1 : \beta_{rain_{t,i}} \neq 0$$

Results show that the F-statistic is greater than the corresponding critical value at a minimum 5% level. Thus, we can reject the hypothesis that rainfall and temperature have no effect on yield. This is true in all cases except for cotton. The year, directional coordinates and y-intercept are at least marginally significant for all eight crops.

Table 5: Effect of Rainfall and Temperature on Yield

Independent Variable	Paddy	Jowar	Bajra	Red Gram	Bengal Gram	Castor	Groundnut
Model	Linear	Log-Level	Linear	Level-Log	Log-Level	Log-Log	Log-Level
Year	0.1327 (.136)	-2.557 (.142)	-.184** (.072)	-.0096 (.0273)	.0407 (.265)	.0739 (.074)	-.1087 (.101)
March	0.003 (.009)	-.0086 (.0088)	-.0013 (.0045)	0.0175 (.033)	-.0053 (.003)	-.1508 (.096)	.0018 (.006)
April	-0.0006 (.005)	.00795 (.005)	.0023 (.003)	-.0109 (.03)	.0061** (.003)	.1923** (.083)	.0066 (.004)
May	-0.0025 (.004)	.0048 (.004)	.0026 (.002)	0.0655 (.045)	-.0041** (.001)	.0954 (.135)	-.0003 (.003)
June	-0.0009 (.003)	.009** (.003)	.0028 (.002)	0.0868 (.077)	0.0015 (.001)	.5103** (.203)	.003 (.002)
July	0.0006 (.002)	.0019 (.002)	.0014 (.001)	0.1232** (.05)	.0004 (.0008)	.2764** (.131)	.0005 (.001)
August	-0.0001 (.002)	.0009 (.002)	.0006 (.001)	-.0292 (.064)	.0008 (.001)	.0899 (.180)	.0007 (.001)
September	0.0018 (.002)	.0049** (.002)	.0003 (.001)	0.124 (.044)	.0011 (.001)	.0363 (.207)	.0039** (.002)
October	-0.0001 (.001)	.0009 (.001)	.0024** (.001)	0.1519 (.059)	.0009 (.001)	.1443 (.167)	.0024** (.001)
latitude	0.5183** (.112)	-.334** (.117)	.2043** (.06)	.1232 (.044)	.2004** (.048)	-.028 (.15)	-.1494 (.083)
longitude	0.1362 (.083)	.13 (.087)	.0046 (.045)	-.006 (.03)	.2347** (.035)	-.0886 (.086)	.164** (.062)
y-intercept	32.5** (12.7)	-37** (13.2)	-5.02 (7.248)	-1.57 (2.068)	-15.5** (2.79)	.8694 (5.558)	-15.598 (9.434)
adj. R^2	0.6756	0.34	0.57	0.3498	0.63	0.3078	50.48
n	66	66	64	39	68	34	66
F-test	**2.11**	**2.78**	**2.46**	**3.11**	**3.17**	**2.29**	**2.4**

**Significant at the 1% level

Interpretation of Regression Output

Paddy crops are more responsive to temperature than rainfall. Taken together, rainfall and weather are significant at the 5% level with an adjusted R^2 of 67%. I suspect that irrigation plays a role in mitigating the impact of rainfall on yield. After all, from 1998-2005, between 2/3 to 75% of all irrigation went to paddy crops. By being able to store water and apply it optimally, water application could be optimized.

Table 6: Irrigated Area Relative to Total Area for Paddy (Ha)			
Year	Irrigated Area	Total Area	%
1998	353417	519021	68.1
1999	317053	459127	69.1
2000	393527	545378	72.2
2001	323342	478840	67.5
2002	257859	398773	64.7
2003	95500	148448	64.3
2004	80855	134100	60.3
2005	123930	191100	64.9

I suspect that the complementary relationship between rainfall and irrigation also explains the curious case of cotton. It turns out that cotton is not correlated with rainfall at all. However, cotton is positively correlated with irrigation with a correlation coefficient of 99% controlling for time and spatial variability.

While paddy and cotton are tested using a linear model, a log-level model more accurately explains the effect of rainfall on jowar yield with an adjusted R^2 of 35% with significance bordering on 1%. Jowar, a crop grown during both Kharif and Rabi, is most effected by rainfall by the largest magnitude during April and June, when an additional mm of rainfall increases yields by .7% or .8%, respectively. While this sounds minor, it translates to an increase in yields between 3 and 16 kg/ha. (The wide confidence interval is due to the variability of yields caused by other variables besides rainfall and temperature in other districts. In Mahabubnagar, the increase in yields in April and June is between 3.5 and 7.5 kg/ha.)

The effect of rainfall on bajra yield were best fit by a linear model with an adjusted R^2 of 57% with a 1% significance level when rainfall and weather are tested together. Bajra, which is sown only during kharif, is more responsive to rainfall during April, May and June, with the effect diminishing for the remainder of the monsoon. An additional mm of rainfall in any of those months suggests an increase in yields between 2.3 and 2.7 kg/ha.

Although the adjusted R^2 for red gram is only 35%, the significance of rainfall is just under the 1% level. The explanatory variables of rainfall were expressed in logarithmic form with only a few observations removed for having a value of 0. Red gram is only sown during kharif.

Bengal gram is only sown during rabi. A multivariate regression including 12 months worth of rainfall was included to account for the 8% of rainfall that occurs between November and February. However, the model that excluded these months had a higher adjusted R^2 (65.15%) and level of significance (1.3%). A semi-log function was the most robust in predicting the effect of rainfall on yield. The magnitude of the impact of rainfall on yields (expressed as a percentage) is highest in March, April and May. They are also the most significant. The magnitude within this domain is between -0.4% to .5%. I do not know why the effect of rainfall would oscillate between negative and positive values.

Castor is sown during kharif and is most responsive to rainfall in June and July, when a 10% increase in rainfall leads to a 5% and 2.5% increase in yield, respectively. Both of these variables on their own are highly significant on their own. Taken with other variables the model is statistically significant at the 5% level with an adjusted R^2 of 31%.

Groundnut yields are most responsive in June, September and October (Groundnut is double-cropped during kharif and rabi). Rainfall is significant beyond the 5% level and the adjusted R^2 value is about 51%, including temperature variables.

Plugging mandal-level rainfall data into the yield equations derived in the previous two sections, we can calculate total production per mandal.

Area

Mahabubnagar has a total size of 1.8 million ha. Between 2000 to 2006, while other forms of land use (forest, barren, urban, pasture, etc.) remained similar, the net area sown decreased by 21% from 923,000 ha in 2000 to 723,000 ha in 2006. This is a decrease of 200,000 ha, about 10 Addakals or an area one-third the size of Hyderabad. In addition, the area sown more than once (ie. during rabi) has declined from 77,000 in 2000 to 52,000 in 2006, a 25,000 ha or 32% decline.

Nearly all agricultural land that has been sown has become fallow. As the table below indicates, fallows have increased 51% from 339,000 hectares in 2000 to 515,000 in 2006, a 176,000 ha or 51% increase.

Table 7: Land Utilization ('000 Ha)

Use	2000	2001	2002	2003	2004	2005	2006
Forests	267	267	267	267	267	267	256
Barren and Uncultivatable Land	96	96	96	96	96	96	96
Land put to non-agricultural uses	80	80	80	80	80	80	81
Permanent pastures and other grazing lands	25	25	25	25	25	25	23
Land under miscellaneous tree crops	6	6	8	8	7	7	8
Cultivable waste	11	11	14	15	15	15	23
Other fallow lands	103	99	147	145	147	147	118
Current fallows	**339**	**439**	**457**	**476**	**529**	**529**	**515**
Net area sown	**920**	**824**	**753**	**735**	**681**	**681**	**723**
Total Geographical area	1847	1847	1847	1847	1847	1847	1843
Total cropped area	997	906	813	797	737	737	775
Area sown more than once	77	82	60	62	56	56	52

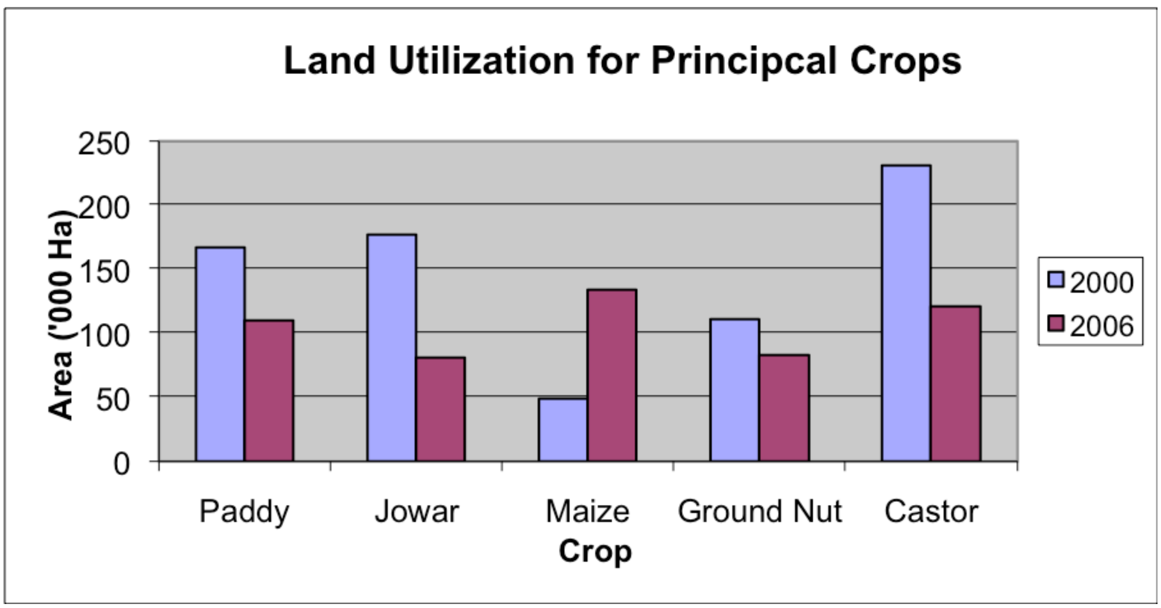
Source: Directorate of Economics and Statistics

The highest magnitude changes in crop choice can be attributed to paddy (-34%), jowar (-54%), maize (+173%), groundnut (-25%), and castor (-48%). Despite the huge increase in land devoted to maize between 2000 and 2006, the increase is offset by declines in paddy, jowar, groundnut and castor. The decrease in crop-wise land use for all other crops is 20,000 ha, or just 10% of the decline attributed to paddy, jowar, maize, groundnut and castor.

Unlike yield, land use changes are unpredictable as far as quantitative analysis is concerned. While quantitative analysis reveals trends, farmer interviews may be the best indicator of explanations of grower behavior.

Table 8: Crop-Wise Area ('000 Ha)

Crop	2000	2006	% Change
Paddy	167	110	-34
Jowar	177	81	-54
Maize	49	134	173
Ground Nut	111	83	-25
Castor	231	121	-48
Total	**2735**	**2535**	



Socio-economic Drought

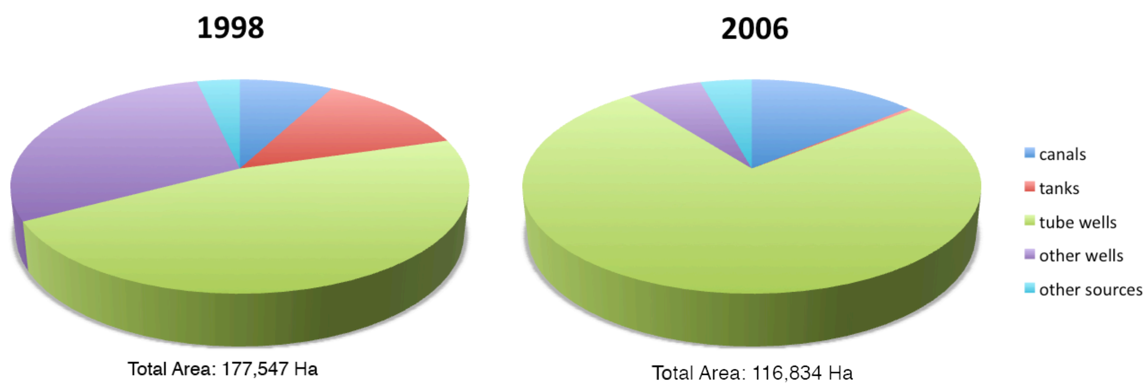
For this time period, the net area irrigated has been positively correlated with yearly rainfall.

Table 2: Annual Change in Annual Rainfall and Source-Wise Irrigated Area									
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Rainfall (mm)	792	460	669	656	539	624	412	973	482
% change		-0.72	0.31	-0.02	-0.22	0.14	-0.51	0.58	-1.02
Area Irrigated (ha)	177547	157186	187906	163606	140901	171010	159492	211454	116834
% change		-0.13	0.16	-0.15	-0.16	0.18	-0.07	0.25	-0.81

Sources: Indian Meteorological Department & Chief Planning Officer

However, the net area irrigated has actually decreased by 34% from 177,500 ha in 1998 to 116,800 ha in 2006 (the most recent year with available data) despite an increase in registered irrigation projects. 36% of the decrease in source-wise irrigation can be attributed to the decline of water tanks from 22,610 ha to 595 ha in 2006. The decrease in the net area irrigated is partially offset by the adoption of tube wells for water storage, which have increased by over 30,000 ha since 1998.

Figure 1: Total Area Irrigated and Method



Conclusion

Using a multivariate regression, we are able to forecast future changes in yield as effected by disperse rainfall and temperature. The most current rainfall data from the IMD, which runs through June 2009, is below the monthly average. Village-level data from the VASAT wiki[2] confirms below-average rainfall for the Addakal mandal, with rainfall between 140 mm to 302 mm from June 1st 2009 through September 10th 2009. We expect that this will have a detrimental effect on yield.

While changes in land use, especially with respect to maize, can not be forecasted with the available data, farmer surveys and interviews could be indicative of farmer behavior.

The positive correlation between rainfall and mandal-level VOP is clear as indicated by the maps on pages 5 and 6. In 2004 (a drought year), VOP was much lower then previous years. In 2005 (a higher than normal year), VOP much improved.

[2] http://vasatwiki.icrisat.org/index.php/Main_Page

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