The Link between Climate Variability, Cropping Pattern and Revenue: Insights from Kanzara Village, India

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List of Abbreviations

BT	Bacillus thuringiensis
CCL	Climate Change Levy
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPCC	Intergovernmental Panel on Climate Change
MW	Megawatts
NREGS	National Rural Employment Guarantee Scheme
SAT	Semi-Arid Tropics
VLS	Village Level Studies

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Abstract

Climate change is one of the most pressing issues facing mankind now. On the agricultural side, climate change may reduce crop yield. Change in cropping pattern is one of the adaptation strategies to climate change. However, revenue and expenses considerations, not climate change, are the main drivers of change in cropping pattern. Additionally, farmers' risk-averseness means that past experience by early adopters plays an important role in effecting change in cropping pattern. The decision-making process results in 2 implications: 1) Delay in reaping the benefits of change in cropping pattern and 2) No significant changes in cropping pattern unless significant gain in revenue can be observed from the early adopters even though climate necessitates change. As small households tend to be more risk-averse, this study confirms the widely accepted fact that the poor loses more than the rich. Linking climate to revenue may result in farmers giving more weightage to climate, which is easily accessible, as a factor to change cropping pattern and hence altering the decision-making dynamics altogether.

Key Words: Climate Change, Cropping Pattern, Revenue

1. Introduction

1.1. Background

Climate change is one of the most pressing issues facing mankind now. Scientific studies using different approaches and models have shown that earth is warming up exponentially[1] and unless firm and concrete actions are taken now, negative consequences await us[2]. The rise of sea levels could threaten more than 60 million people and $200 billion in assets in developing countries alone[3]. On the agricultural side, a one-degree rise in temperature may reduce yields of wheat and groundnut by 3-7%[4].

With dire messages being publicized in the media, many international organizations, national governments, companies and volunteers have done activities ranging from funding provision and research to education and implementation. Among the numerous strategies pursued by The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) based in Patancheru, India to tackle climate change, one involves the usage of Village Level Studies (VLS) data collected over periods of time to analyze the impacts of climate change on the rural households' livelihoods and identify key measures to alleviate them.

The various measures that are proposed and/or have been implemented can be broadly divided into 2 different groups, namely mitigation and adaptation. Mitigation measures are those that can slow down the rate of climate change. Examples include improving energy efficiency[5], utilization of cleaner energy[6] and tax reforms[7].

Wind power has been growing at an annual rate of 31%. By end of 2009, this widely used power source already has a worldwide installed capacity of 157,900 megawatts (MW)[8]. A tax on energy delivered to non-domestic users called Climate Change Levy (CCL) has been introduced in the United Kingdom and reduced annual emissions by 3.7 million tonnes by end of 2002[9].

On the other hand, adaptation measures are those taken to alleviate the severities of climate change that are already affecting the daily lives. Ricardian studies in the United States showed that adaptation by households could soften the blow of climate change[10]. Adaptation measures, therefore present complementary approach to mitigation measures[11]. Examples of adaptation measures include improving the public healthcare system, increasing investments in infrastructure and changing of cropping patterns.

Report published in The Lancet outlined how climate change can affect health both directly as well as indirectly and how improvement in public health system will be able to tackle its adverse effects[12]. Studies have also shown that justifiable investments in rural infrastructure such as irrigation systems and roads can help farmers to adapt to the changing climate[1].

Change in cropping pattern is an interesting adaptation measures because although it is expected to reduce the economic impact of climate change, rural households involved in agriculture rarely change their cropping pattern using climate change as their sole reason. Factors such as market forces and technology improvements inherent in the new seedlings appear to be driving the change in cropping pattern as well[13]. Despite requiring more water than other crops growing in the same region, households continue to grow BT cotton because of its high market price.

However, regardless of the reasons given by rural households for changing their cropping patterns, studies have validated that it indeed is one of the adaptation measures to alleviate the impact of climate change. White showed the effect of changing cropping patterns on yield of sorghum, wheat and cotton in Arizona, United States[14]. Additionally, farmers in Gambia prefer non-cereal to cereal crops due to the low yield of cereal crops under the existing climatic conditions[15].

The Semi-Arid Tropics (SAT) is a climatic region not spared from the impact of climate change. Surveys on households' perception from six villages in SAT done in 2002 shows that 80.4% of farmers believe that climate change is a phenomenon affecting their lives[13]. It is also not encouraging to discover that the temperature of the Indian sub-continent is projected to increase annually by 3.5-5.5°C and its rainfall projected to decrease annually by 5-25% in 2080s[16].

The Intergovernmental Panel on Climate Change (IPCC) noted in 2007 that climate change is likely to impact first and foremost the poor and vulnerable[2]. Unpublished study in the village of Kanzara, Maharashtra shows that landless households and small households (<2.2 acres land holding) are more affected by droughts than the medium and large households (>2.2 acres land holding). Studies on the impact of climate change on the SAT are meaningful and likely to bring huge benefits considering that 1.4 billion people call the region their home[17]. Of these, 560 millions are living below the poverty line, about 70% lives in rural areas and likely to have agriculture, a vulnerable area, as their means of living[18].

Although many studies on the feasibility of change in cropping pattern as an adaptation measures have been carried out all over the world, none has studied in terms of monetary value, the gains to households that adopt change in cropping pattern in the SAT, as compared to households that do not change their cropping patterns. Kumar and Parikh (2001) as well as Sanghi and Mendelsohn (2008) estimated that farm-level net revenues in India could decline by 7-17% due to climate change but both used Ricardian approach whereby adaptation strategies of farmers are automatically included in the analysis[19,20]. When comparing the performance of households, the output has already included all the adaptation strategies each household has made to get the best possible output from the land. Households are not divided according to adaptation strategies adopted. This made it impossible to analyze solely the effect of change in cropping pattern as an adaptation strategy.

1.2. Objectives

The objective of this preliminary study is to observe changes in the cropping pattern for an SAT district in India. A village that is representative of the district and whose data available in the VLS database will be selected and its cropping pattern analyzed. Reasons for changes in cropping pattern will also be determined through village visit. This will serve to validate/ invalidate the assumptions that changes in cropping pattern is often driven by reasons other than climate. The implications of these drivers of change in cropping pattern on each household will be identified and a hypothesis that may alleviate the implications be proposed. Focus will be given to the 2001-2007

VLS data so as to give relevance to study. It is envisioned that the findings of this study will result in a better economic wellbeing for the relevant stakeholders, in particular the rural households involved in agricultural activities. It is hoped that it can also serve as a reference for future studies in the area of rural development.

1.3. Limitations

Only qualitative analysis can be made for changes in cropping pattern at district-level and those obtained from 1st generation VLS due to time constraints. Analysis is done on a single village again due to time constraints. Data from the single village may not be fully representative of the district, let alone the state. If time permits, it would have been better to include more villages. This will allow for inter-villages comparison to be made as well.

For quantitative analysis of soybean adoption, only data from two years (2006-07) were used because this observation is a very recent event. Prior to these years, there were no/little significant changes in both the number of households adopting soybean and the proportion of soybean in the cropped area. Additionally, data after these years are still in the process of being validated and hence not publicly available yet.

Consequent to the small number of available data-points is the number of independent variables that can be included in the regression model because the higher the number of variables, the smaller the degrees of freedom will be, raising the possibility of insignificant coefficients.

2. Methodology, Results and Discussions

2.1. Climatic Analysis

2.1.1. Using 39-year mean rainfall as base

2.1.1.1. Annual rainfall

Monthly rainfall data of Akola District in the State of Maharasthra, India was used to determine the district annual rainfall for year 1971-2009. This was then utilized to obtain the 39-year mean annual rainfall. Following that, deviation of annual rainfall from the mean was calculated. The number of negative deviations as well as the magnitude of deviations for each decade were then summarized in the table and plot below:

Year	% of negative deviation	Distribution of negative deviation					
		<10%	10-20%	20-30%	30-40%	40-50%	50-60%
1st 10-year (1971-1980)	40.0% (4 of 10)	0	3	1	0	0	0
2nd 10-year (1981-1990)	50.0% (5 of 10)	2	1	1	1	0	0
3rd 10-year (1991-2000)	40.0% (4 of 10)	1	2	0	0	1	0
4th 10-year (2001-2010)	77.8% (7 of 9)	3	1	1	1	0	1

Table 1. Distribution of negative deviation of annual rainfall using 39-year mean as base

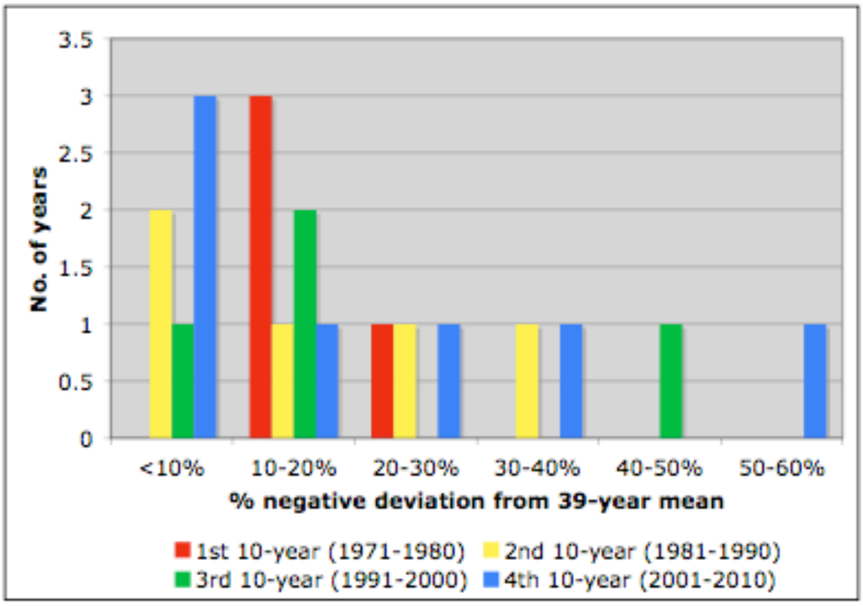


Figure 1. Bar-graphs showing distribution of negative deviation of annual rainfall using 39-year mean as base

From table 1 and figure 1, it can be observed that the number of negative deviations (in percentage) has increased from 40.0% in the 1st 10-year (1971-1980) to 77.8% in the last 10-year (2001-2010). Additionally, the magnitude of negative deviations has also increased from a maximum of 24.3% in the 1st 10-year (1971-1980) to a maximum of 54.5% in the last 10-year (2001-2010). To verify the consistency of the findings, farmers were asked to identify years with climatic shocks. With the exception of 1973 and 1986, the years (1972, 1981, 1982, 1988, 1991, 2003, 2004) as observed by farmers coincide with the sign of deviation observed in the analysis.

These findings show that Akola District is not spared from the effect of climate change.

2.1.1.2. Kharif (June-September) rainfall

The same methodology was also used to determine if there have been significant changes in the number of negative deviations and the magnitude of deviations for Kharif rainfall. Two main reasons define the importance of Kharif as a season. Firstly, most rainfed crops are grown in Kharif. Secondly, Kharif season is considered the beginning of cropping year and farmers classify years into good and bad depending on the amount of Kharif rainfall. Note that there are different definitions for Kharif. In this study, Kharif refers to the period from the beginning of June to the end of September, which is in agreement with the rainy season locally referred to as Pavsala. The results of the analysis are summarized in the table and plot below:

Year	% of negative deviation	Distribution of negative deviation					
		<10%	10-20%	20-30%	30-40%	40-50%	50-60%
1st 10-year (1971-1980)	40.0% (4 of 10)	2	0	2	0	0	0
2nd 10-year (1981-1990)	50.0% (5 of 10)	3	0	1	0	1	0
3rd 10-year (1991-2000)	40.0% (4 of 10)	1	3	1	1	0	0
4th 10-year (2001-2010)	77.8% (7 of 9)	2	2	1	0	2	0

Table 2. Distribution of negative deviation of Kharif rainfall using 39-year mean as base

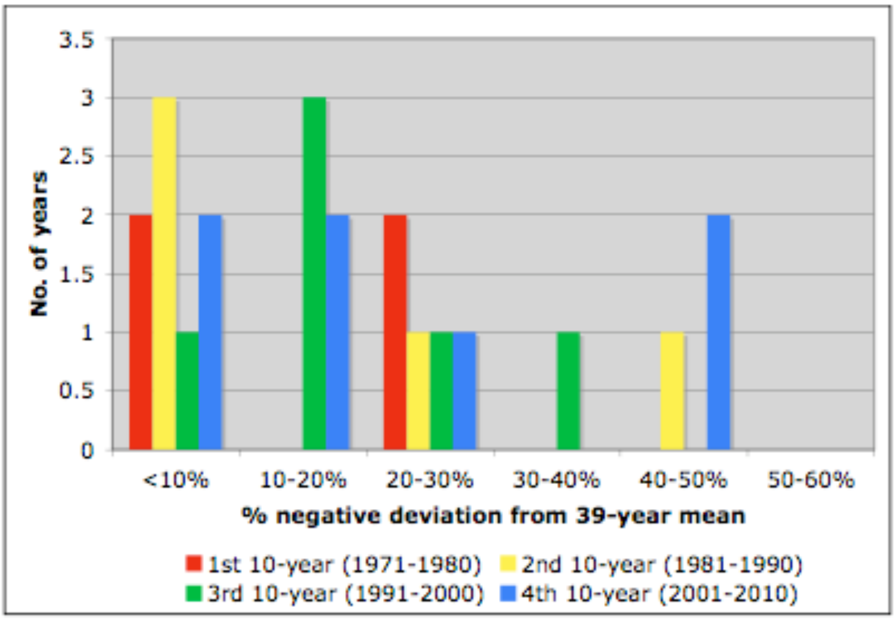


Figure 2. Bar-graphs showing distribution of negative deviation of Kharif rainfall using 39-year mean as base

From table 2 and figure 2, it can be observed that the number of negative deviations (in percentage) has increased from 40.0% in the 1st 10-year (1971-1980) to 77.8% in the last 10-year (2001-2010). In addition, the magnitude of negative deviations has also increased from a maximum of 26.7% in the 1st 10-year (1971-1980) to a maximum of 47.0% in the last 10-year (2001-2010). Similarly, these findings show that Akola District is not spared from the effect of climate change.

2.1.2. Using 1st 10-year (1971-1980) mean rainfall as base

The rationale behind the usage of 1st 10-year mean rainfall is to prevent the calculated mean to be tainted by contributions from more recent years, which are believed to have been affected by climate change to a larger extent than the earlier years.

2.1.2.1. Annual rainfall

Monthly rainfall data of Akola District in the State of Maharasthra, India was used to determine the district annual rainfall for year 1971-2009. Years were divided into a group of ten for decadal analysis. The mean for the 1st 10-year (1971-1980) was calculated. The deviation of annual rainfall from this mean was obtained. The number of negative deviations as well as the magnitude of deviations for each decade were then summarized in the table and plot below:

Year	% of negative deviation	Distribution of negative deviation					
		<10%	10-20%	20-30%	30-40%	40-50%	50-60%
1st 10-year (1971-1980)	40.0% (4 of 10)	0	1	3	0	0	0
2nd 10-year (1981-1990)	60.0% (6 of 10)	2	2	1	1	0	0
3rd 10-year (1991-2000)	50.0% (5 of 10)	1	3	0	0	1	0
4th 10-year (2001-2010)	88.9% (8 of 9)	3	1	2	0	1	1

Table 3. Distribution of negative deviation of annual rainfall using 1st 10-year mean as base

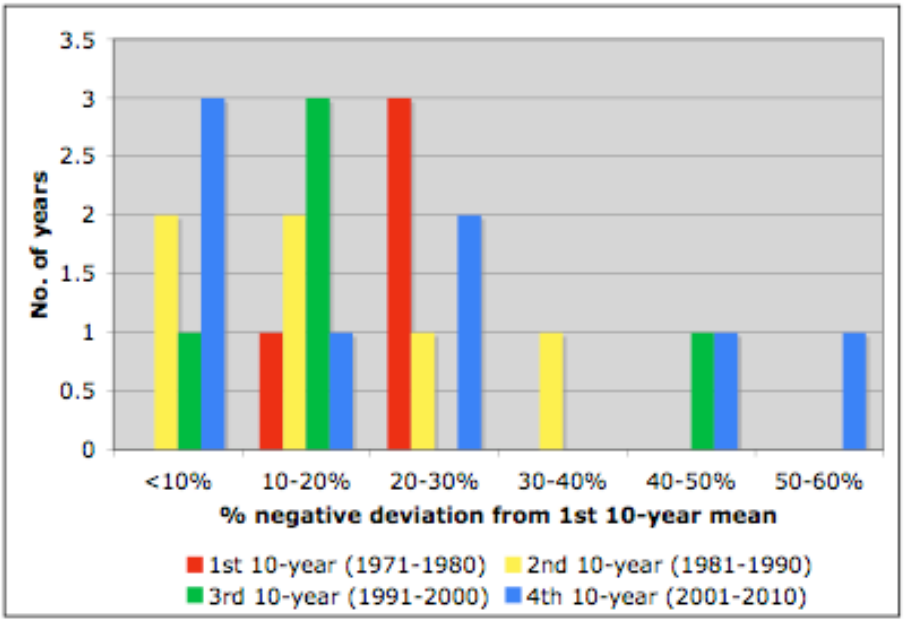


Figure 3. Bar-graphs showing distribution of negative deviation of annual rainfall using 1st 10-year mean as base

From table 3 and figure 3, it can be observed that the number of negative deviations (in percentage) has increased from 40.0% in the 1st 10-year (1971-1980) to 88.9% in the last 10-year (2001-2010). Additionally, the magnitude of negative deviations has also increased from a maximum of 26.6% in the 1st 10-year (1971-1980) to a maximum of 55.9% in the last 10-year (2001-2010). To verify the consistency of the findings, farmers were asked to identify years with climatic shocks. With the exception of 1973 and 1986, the years (1972, 1981, 1982, 1988, 1991, 2003, 2004) as observed by farmers coincide with the sign of deviation observed in the analysis. Similarly, these findings show that Akola District is affected by climate change.

2.1.2.2. Kharif (June-September) rainfall

The same methodology was also used to determine if there have been significant changes in the number of negative deviations and the magnitude of deviations for Kharif rainfall. The reasons for performing this analysis are similar to that given in 2.1.1.2. The results of the analysis are summarized in the table and plot below:

Year	% of negative deviation	Distribution of negative deviation					
		<10%	10-20%	20-30%	30-40%	40-50%	50-60%
1st 10-year (1971-1980)	50.0% (5 of 10)	2	1	1	1	0	0
2nd 10-year (1981-1990)	50.0% (5 of 10)	0	3	1	0	1	0
3rd 10-year (1991-2000)	60.0% (6 of 10)	1	1	3	0	1	0
4th 10-year (2001-2010)	77.8% (7 of 9)	0	3	1	1	2	0

Table 4. Distribution of negative deviation of Kharif rainfall using 1st 10-year mean as base

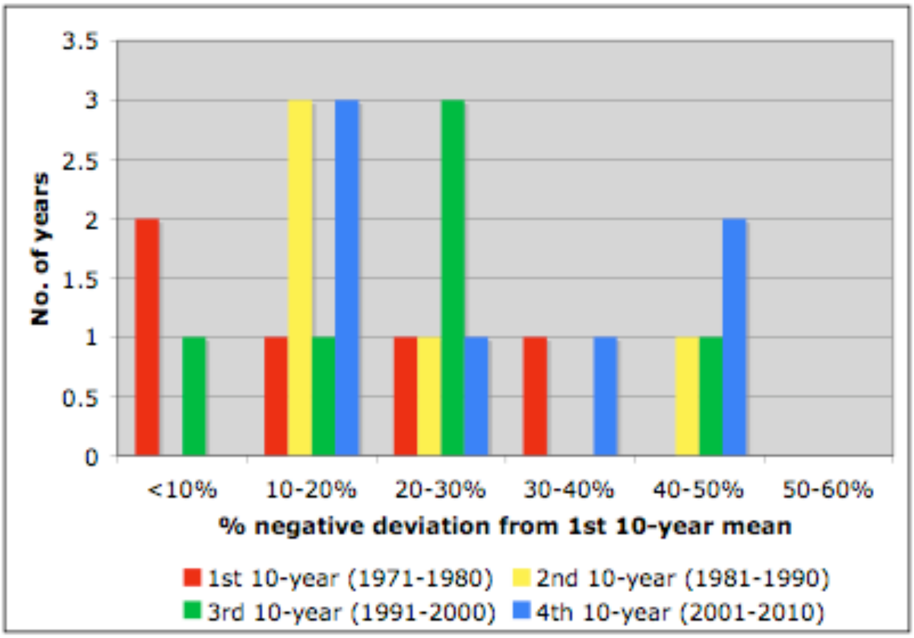


Figure 4. Distribution of negative deviation of Kharif rainfall using 1st 10-year mean as base

From table 4 and figure 4, it can be observed that the number of negative deviations (in percentage) has increased from 50.0% in the 1st 10-year (1971-1980) to 77.8% in the last 10-year (2001-2010). In addition, the magnitude of negative deviations has also increased from a maximum of 30.1% in the 1st 10-year (1971-1980) to a maximum of 49.7% in the last 10-year (2001-2010). Similarly, these findings show that Akola District is affected by climate change. It is also important to note that since the mean used is untainted by more recent rainfall, both the number of negative deviations as well as the magnitude of the deviations are more pronounced than that using 39-year mean.

2.2. Cropping Pattern Analysis

Having verified that Akola District is affected by climate change, the next step would be to analyze its cropping pattern changes. If there are no changes in cropping pattern, the fact that climate is changing can be used as a valid reason to induce farmers to change their cropping pattern. On the other hand, if there are changes in cropping pattern, main reasons for the changes can be identified. In the context of this report, cropping pattern refers to Kharif cropping pattern since Kharif is the season where large varieties of crops are grown. This is in clear contrast to Rabi where approximately 90% of the crops grown are wheat.

2.2.1. District Level

The area occupied by each Kharif crop from 1971-2007 was obtained from district-level data maintained by ICRISAT IMPI. Total cropped area was calculated for each year by summing up the area occupied by each of these crops. The percentage of cropped area occupied by each crop was then determined by simple arithmetic. Crops that consistently occupied less than 2% of total cropped area for all years were grouped together under the category 'Others'. In our analysis, these crops are rice, pearl millet, maize, sesamum, rape & mustard seed, castor, linseed, sunflower, sugarcane, fruits and vegetables. Mung is grouped under 'Minor Pulses' in the data. Plot of the cropping pattern is given below:

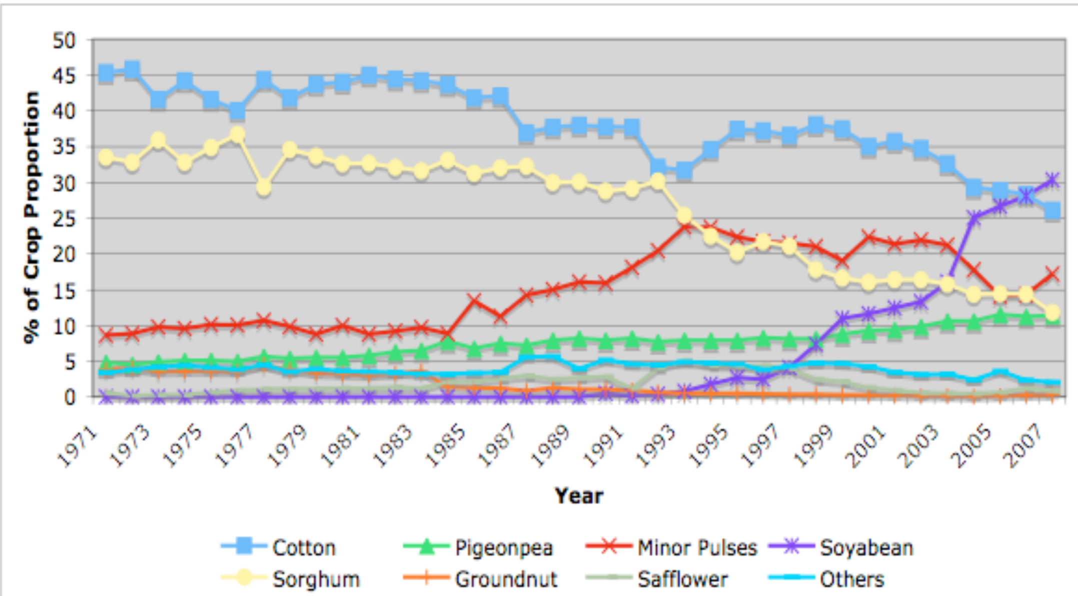


Figure 5. 1971-2007 Akola District cropping pattern

Similar to climatic analysis, years were divided into group of ten for consistency and to facilitate analysis. Key observations and the reasons behind the observations are given in the table on the next page.

Years	Key Observations	Reasons for Observations
1971-1980	• Cotton was the major crop, followed by sorghum. • The crop proportion appears to be stable.	• Historically well known as cotton tracts and have good supporting infrastructure. • Sorghum was used as food, fodder and most importantly, as wages in kind.
1981-1990	• Cotton was the major crop, followed by sorghum. • Cotton and sorghum proportion started to decline and this was compensated by an increase in minor pulses (presumably mung). • A steady increase in pigeonpea can be observed as well.	• Decrease in sorghum price. • Increase in mung and pigeonpea price.
1991-2000	• Cotton was the major crop. • In the early1990s, sorghum was the next major crop but was replaced by minor pulses (presumably mung) in 1994. • Cotton proportion was stable • Sorghum proportion continued to decline but while they were compensated by an increase in mung up to 1993/1994, they started to be compensated by an increase in soybean from 1994 onwards. • From 1994 onwards, mung proportion was stable. • Similarly, a steady increase in pigeonpea continued to be observed.	• Decrease in sorghum price. • Grainmold problem on sorghum. • Pest attacks on mung. • Government initiative to promote oilseeds in certain part of the district. • Introduction of suitable variety of pigeonpea that was wilt resistant.
2001-2007	• Observations are fairly similar to the late 1990s. • Sorghum proportion continued to decline and was replaced by an increase in soybean proportion. • Cotton proportion started to decline again after period of stability in the 1990s • In 2007, soybean replaced cotton as the major crop for the district. • While mung was stable in the early 2000s, it started to decline in 2003 and was replaced by an increase in soybean proportion. • A steady increase in pigeonpea proportion continued to be observed.	• Failure of cotton procurement scheme. • Continued decrease in sorghum price. • Continued grainmold problem on sorghum. • Wild boar attacks on sorghum. • Continued pest attacks on mung. • Increase in pigeonpea price. • Spread of soybean to other part of the district.

Source: V.K. Chopde (Forthcoming)

2.2.2. Village Level

To allow for household level analysis at a later stage of the study, village that is representative of the district was selected. Due to time constraint, it was advised that VLS village be chosen because of its data-richness and the fact that it is collected at regular intervals.

2.2.2.1. Selection of Kanzara

Kanzara was the collection centre of revenue for 75 villages during the British rule. Till the 1900s, the village was dominated by the Maratha and the Deshmukhs. It is located 9km south of Murtizapur, which is the closest town from the village. It has a typical SAT climate, i.e it is characterized by hot summers where temperatures can range from 45-48°C in the months of May. The onset of the monsoons is usually in the second week of June continuing on to end of September.

Kanzara was selected as representative village because of five main reasons. Firstly, it is one of the only 2 villages in Akola District that were selected for Village Level Studies (VLS) in 1975. Secondly, households in Kanzara have agriculture as their main means of living. Thirdly, there is a low level of migration in Kanzara.

	Aurepalle	Dokur	Kalman	Kanzara	Kinkheda	Shirapur
Agriculture (%)	46	24.6	66.0	67.3	67.7	65.2
Non-agriculture (%)	54	75.4	34.0	32.7	32.3	34.8

Table 6. % of agriculture and non-agriculture activities in 6 VLS villages

	Aurepalle	Dokur	Kalman	Kanzara	Kinkheda	Shirapur
No. of migrants per household	0.4	0.9	0.1	0.2	0.1	0.2

Table 7. No. of migrants per household in 6 VLS villages

This led to the inference that in order for the households in Kanzara to sustain their means of living, they have to respond accordingly to climate, price level, etc and one major way of doing so is through change of cropping pattern. This is unlike other villages that have a tendency to switch occupations or migrate to the cities when agriculture is viewed as non-viable.

Fourthly, qualitative study titled "Vulnerability to Climate Change: A Comparative Study of Perceptions and Adaptive Capacities of Kanzara and Dokur Villages" is available for reference. Lastly, respondents from the village are popular among the investigators and researchers for their cooperativeness.

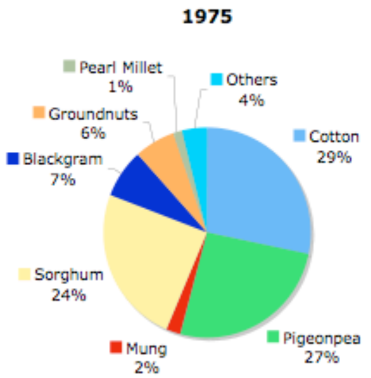
2.2.2.2. First Generation VLS (1975-1984)

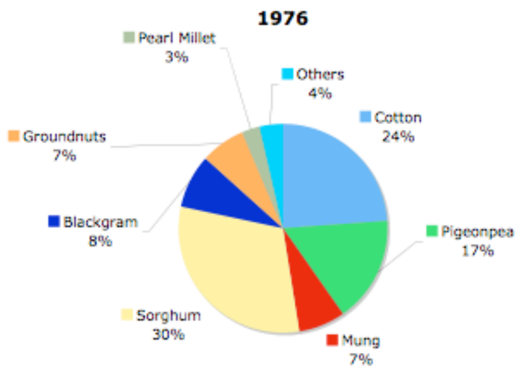
Cropping pattern for 1975-1984 were calculated using first generation VLS data. Unfortunately, if crops are grown in the form of intercropping, no proportion for each crop is given for that specific plot/subplots. This makes it challenging to determine accurately the crop proportion for each crop at village as well as household level. Three methods were explored.

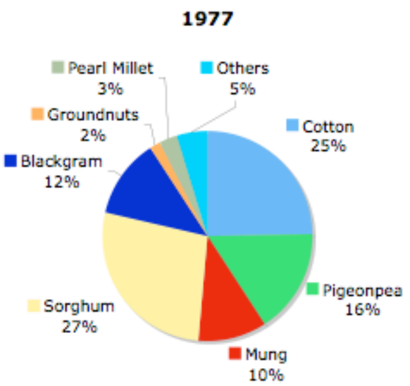
Firstly, the entire area was assigned to the first crop (major crop) in the plot. The problem with the method is that it ignores totally the second crop that may occupy a large proportion of the cropped area. Particularly for Kanzara, this method resulted in low proportion for pigeonpea since it is commonly the second crop in the plot.

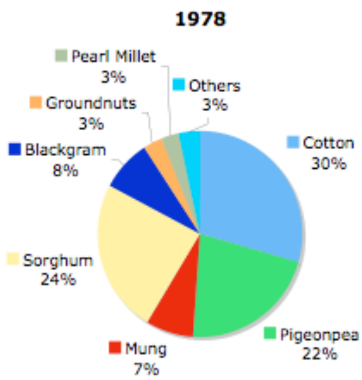
Secondly, based on the district level data, the yield per acre for each of the major crop was calculated and used to determine the acreage for each crop since the output can be found in the Y-files. The problem with the method is that the district level yield per acre may not accurately reflect the village level yield per acre, resulting in spurious calculations. This was confirmed when the calculated acreage for some crops, particularly cotton is higher than the total cropped area for the village.

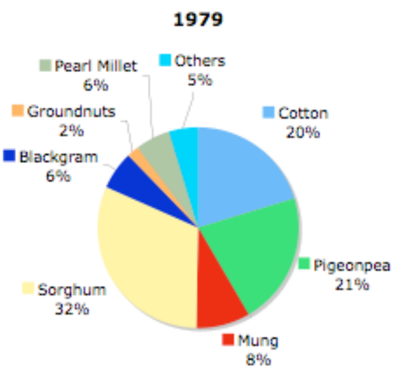
Lastly, plot/subplot was divided equally among the crops occupying it. This means that if two crops occupy a plot, 50% is assigned to first crop and 50% is assigned to second crop. If 5 crops occupy a plot, 20% is assigned to each crop. The result is as follows:

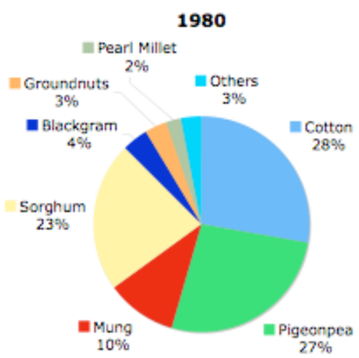












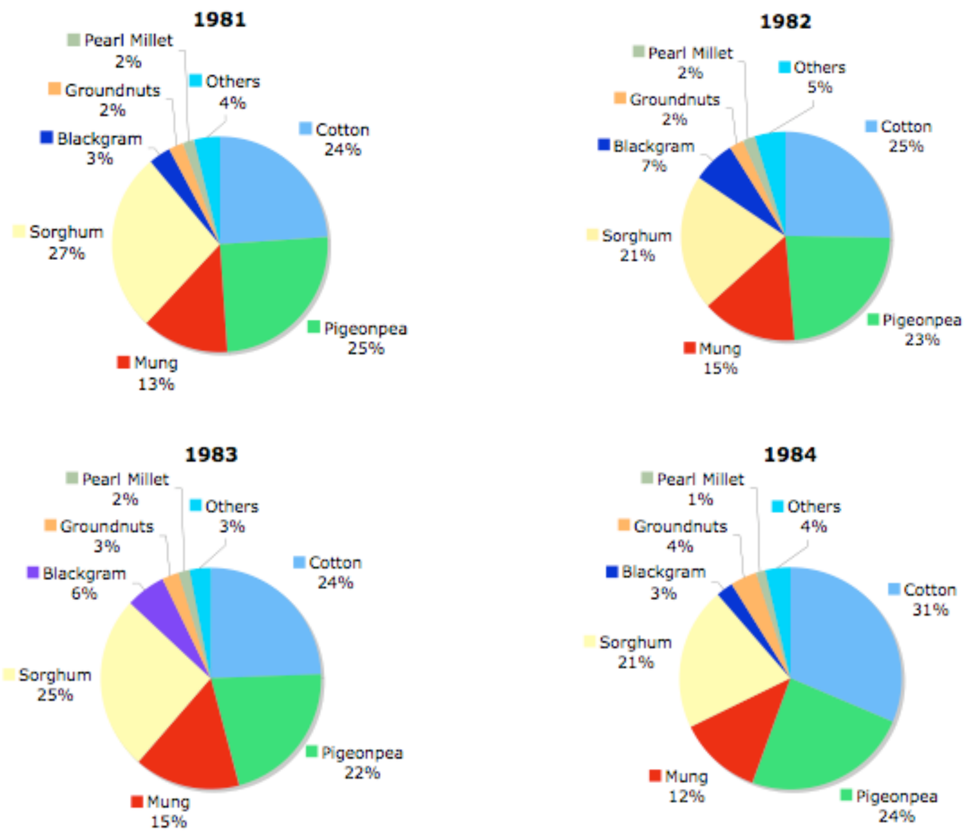


Figure 6. Pie charts of 1975-84 Kanzara cropping pattern

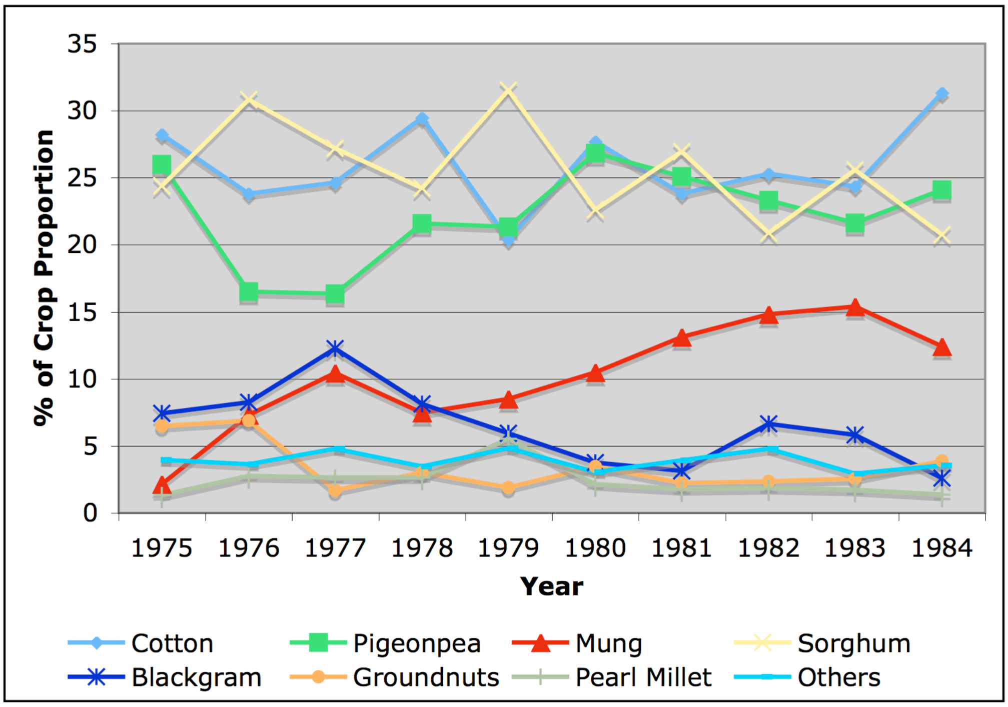


Figure 7. Line graphs of 1975-84 Kanzara cropping pattern

Since there are big fluctuations in the cropping pattern, clear observations of the trend in crop proportion cannot be made. Hodrick-Prescott filter was used to detrend the data and the results plotted:

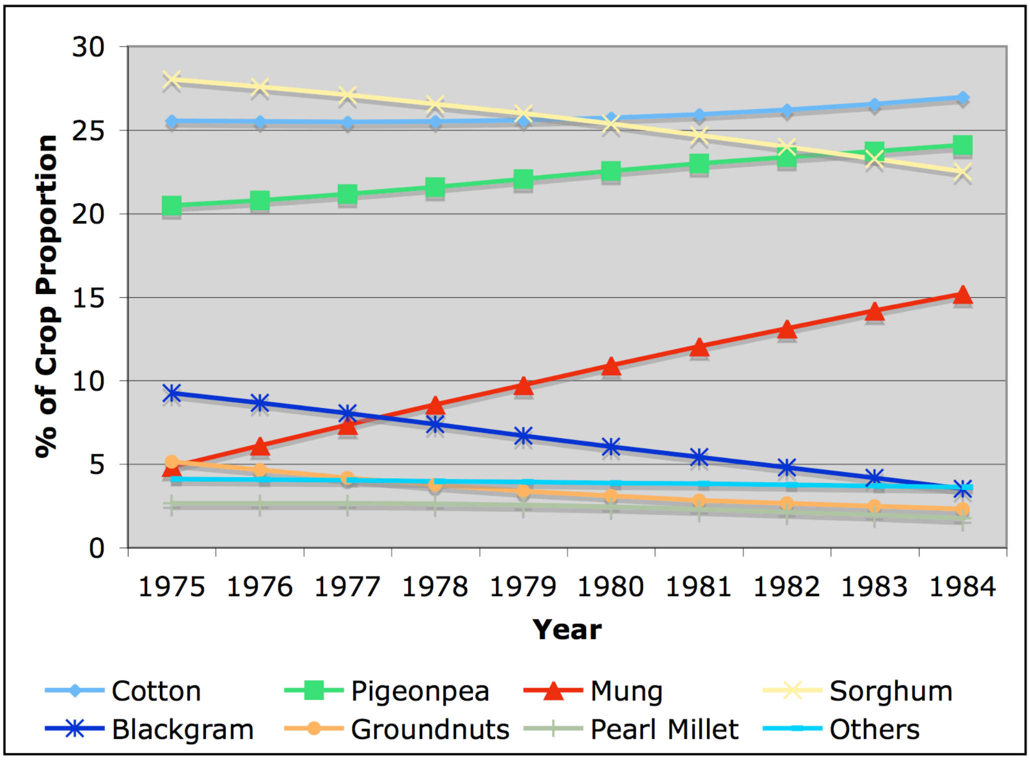


Figure 8. Line graphs of 1975-84 Kanzara cropping pattern (detrended)

Figure 8 shows that from 1975-1980, sorghum was the major crop, followed by cotton. From 1980 onwards, cotton replaced sorghum as the major crop. From 1980-1982, sorghum was the second major crop but was replaced by pigeonpea in 1983. Throughout the study years, sorghum and blackgram proportion decreased while mung and pigeonpea proportion increased. Slight increase in cotton proportion was observed as well. Some of the reasons for the observations included the decrease in the price of sorghum as well as the increase in the price of mung and pigeonpea.

2.2.2.3. Second Generation VLS (2001-2007)

VLS studies were suspended during 1985 and were not resumed until 2001. In the gap of 15 years, many changes, including cropping pattern would have occurred in the village. As mentioned earlier, analysis of recent cropping pattern of the village would be the focus as it adds relevance to the study.

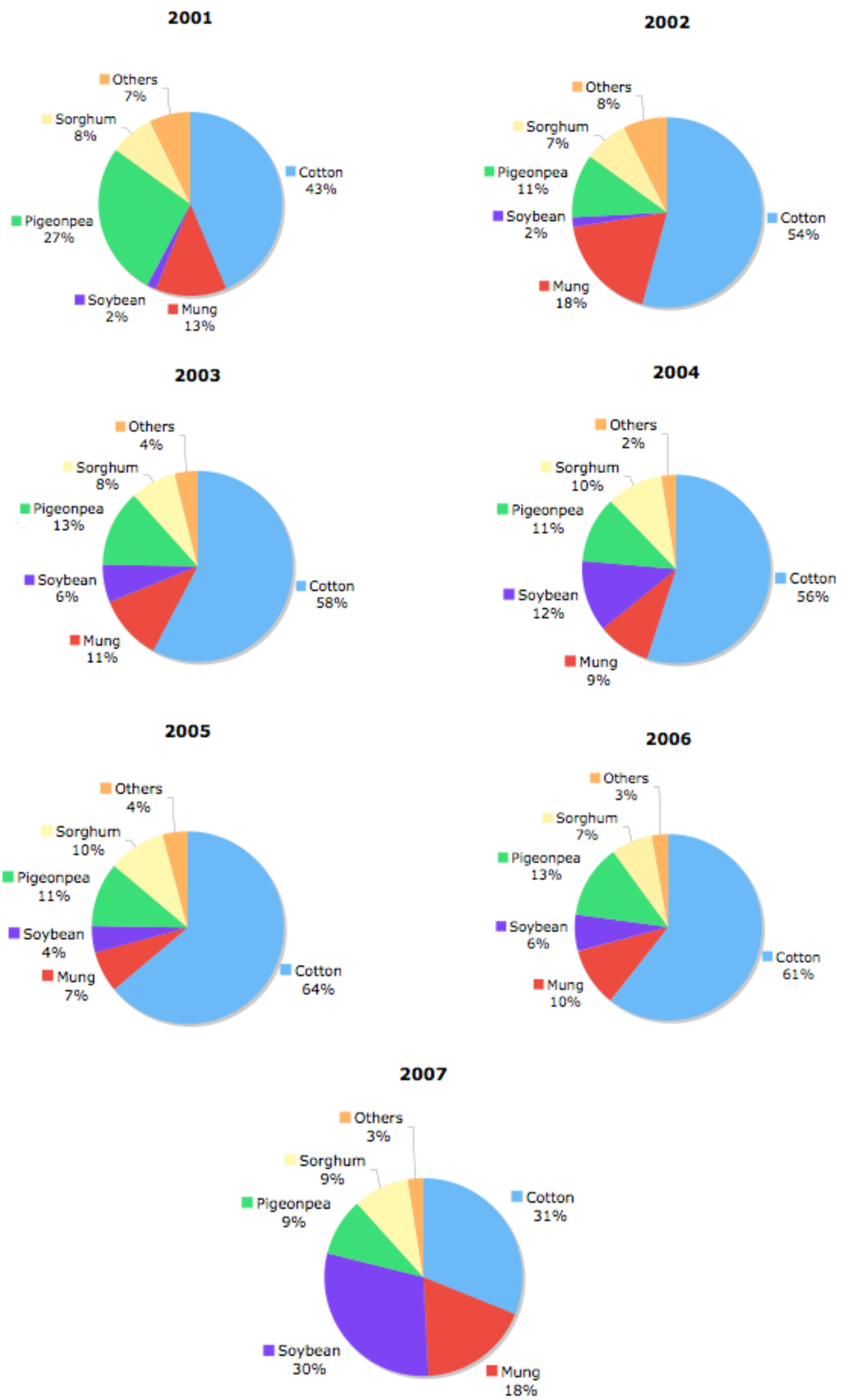


Figure 9. Pie charts of 2001-07 Kanzara cropping pattern

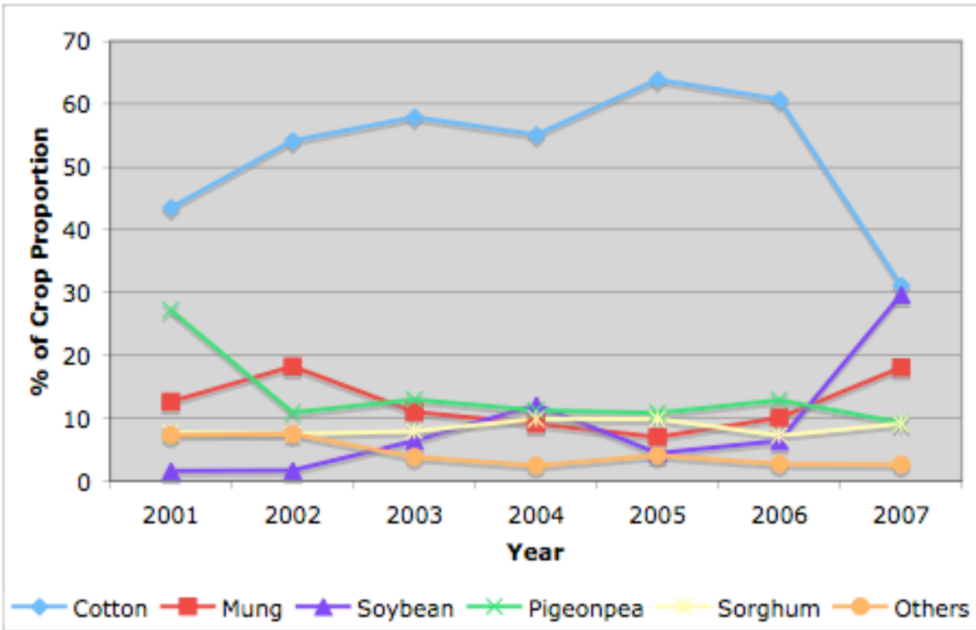


Figure 10. Line graphs of 2001-07 Kanzara cropping pattern

The main crops grown are cotton, mung, pigeonpea, soybean and sorghum. Figure 10 shows that cotton has the highest proportion from 2001 to 2007 but in 2007, it has approximately the same proportion as soybean. With the exception of 2003, it can be seen that when the proportion of cotton increases, the proportion of soybean decreases. The proportion of pigeonpea decreases from 2001 to 2002 and has remained consistent at approximately 11%. The proportion of mung is lowest at 7% in 2005 and highest at 18% in 2002. The proportion of sorghum is consistent at approximately 8.5%.

Special attention was paid to soybean because while only a few households adopted soybean in the earlier years, the proportion of households with soybean as one of its crops increased to 71.1% in 2007.

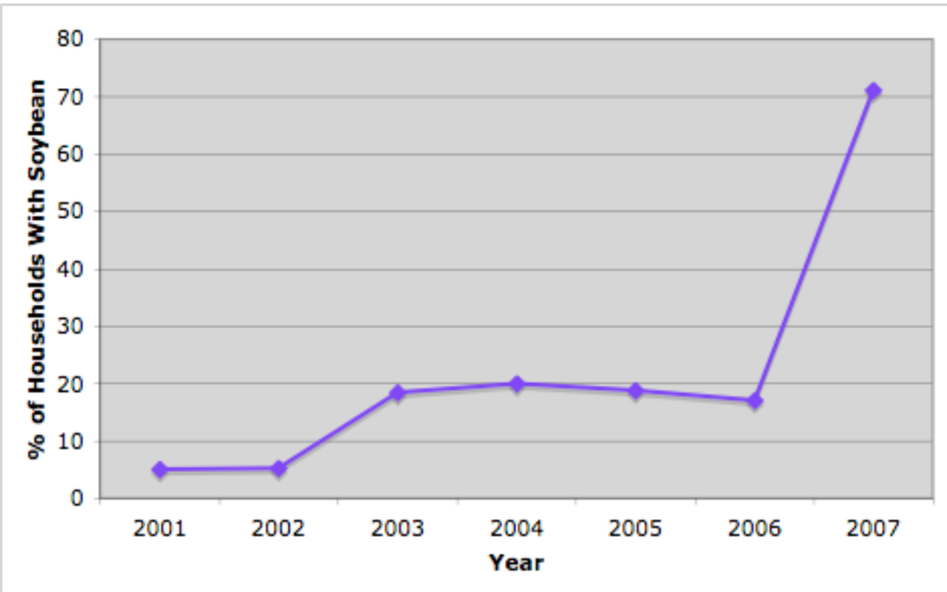


Figure 11. % of households with soybean as a crop (2001-07)

Additionally, while soybean only occupied very low proportion in the earlier years, its proportion was similar to that of cotton in 2007. Specifically for medium households (households having between 4.45 and 13.10 acres of land), soybean proportion was higher than that of cotton.

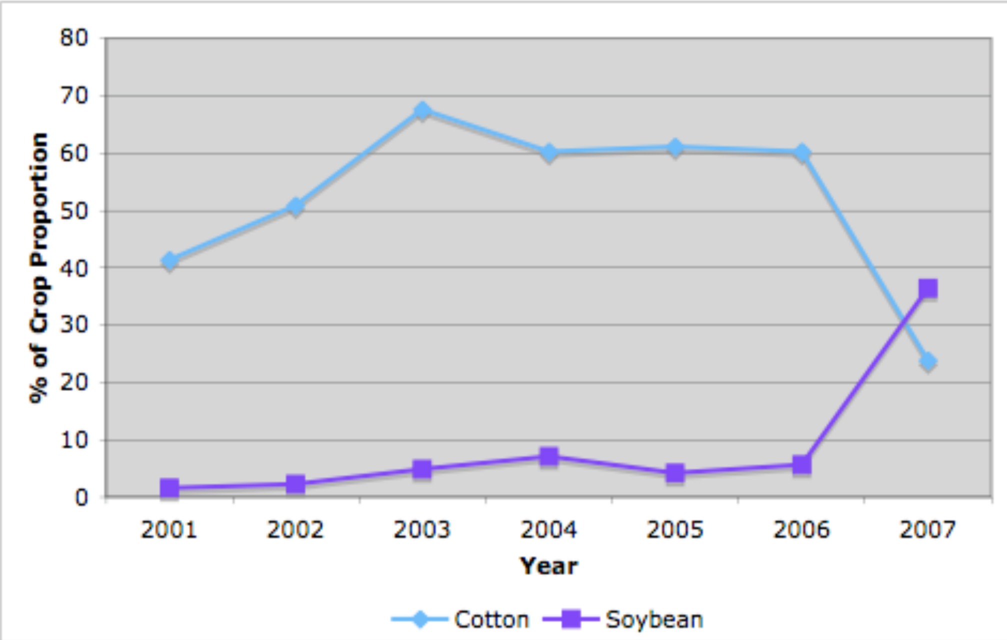


Figure 12. % of cotton and soybean proportion of medium households (2001-07)

It is also interesting to note that when households are divided into three groups according to landholding size and their soybean proportion plotted, there appears to be a lag of one year by small households (households having less than 4.45 acres of land) relative to medium and large households (households having more than 13.10 acres of land).

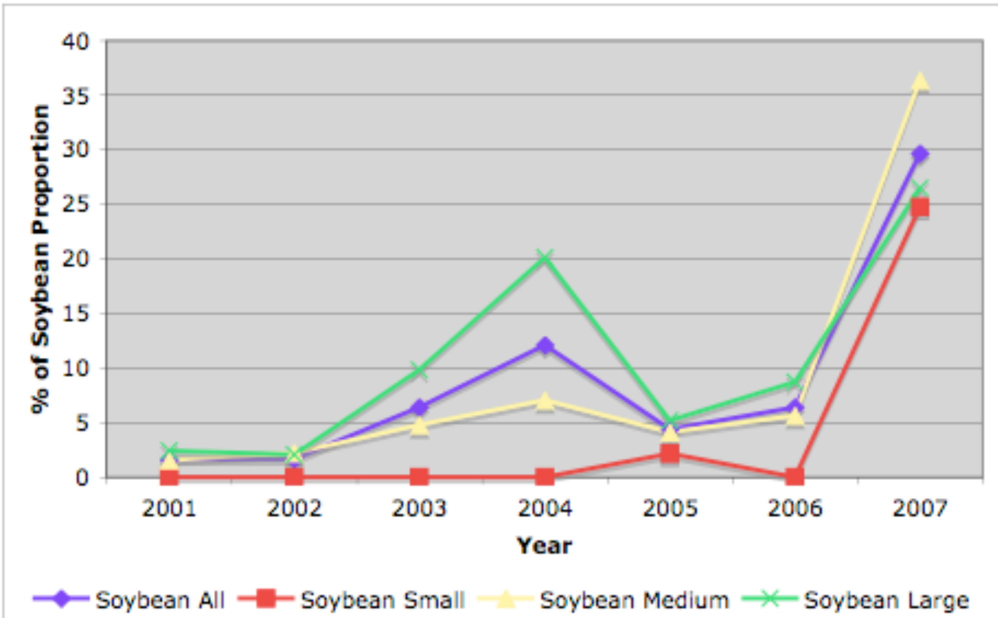


Figure 13. % of soybean proportion by household size (2001-07)

From figure 13, it can be observed that while medium and large households increased their soybean proportion between 2003 and 2004, small households increased their soybean proportion between 2004 and 2005 (i.e one year later). Similarly, while medium and large households decreased their soybean proportion between 2004 and 2005, small households decreased their soybean proportion between 2005 and 2006.

The natural step to take, upon making these observations, was to discover the reasons behind them, in particular, the transformation of soybean from being a minor substitute crop to a major crop capable of ending the dominance of cotton. Reasons obtained from qualitative study of the district level data and first generation VLS data were considered as potential reasons.

2.2.2.4. The Folly of Data mining

Disregarding the fact that change in cropping pattern is driven by many factors and eager to show that climate change/variability is the main reason for the change, cotton and soybean proportion were superimposed on different varieties of rainfall index to try to establish certain level of linkages between them when in reality, there are no linkages. This results in data mining, which can be defined as the process of extracting patterns from data.

Data mining is a prevalent problem in analytical work and should be avoided at all costs. One way to avoid data mining is to try to reach the same conclusion using different types of analysis. If data mining is present, it is highly likely that while certain relationships can be 'observed' in one type of analysis, it disappears under another type of analysis.

Specifically in this study, one clear example of data mining is linking cotton and soybean proportion to the average rainfall index (the average of current-year and previous-year rainfall index) when in reality, as will be shown in the next section, there is no linkage between them.

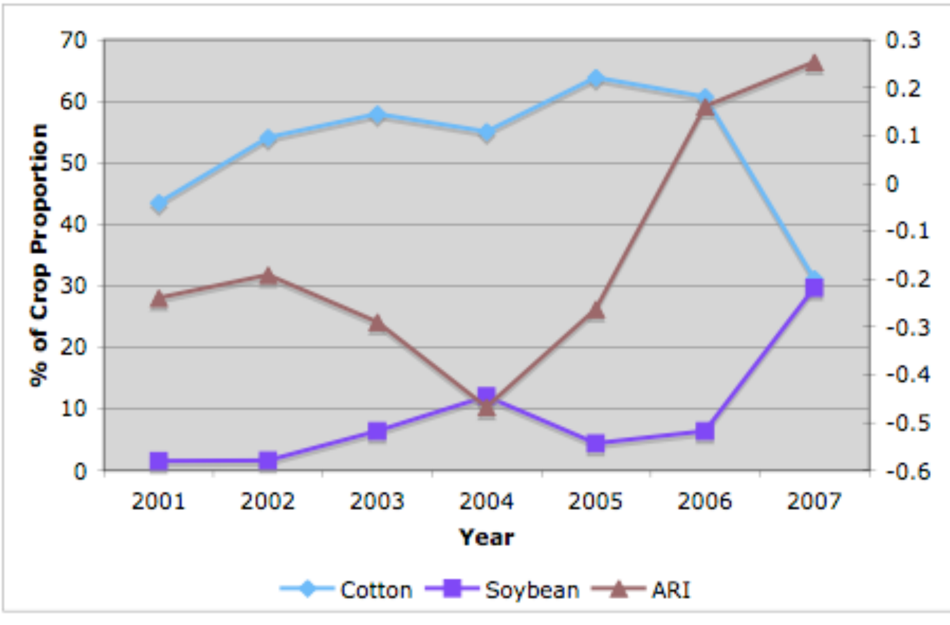


Figure 14. Relationship between cotton proportion, soybean proportion and average rainfall index (2001-07)

```
. reg cotton dy ari ard

      Source |       SS       df       MS              Number of obs =       7
-------------+------------------------------           F(  3,     3) =    2.56
       Model |  .055491507     3  .018497169           Prob > F      =  0.2298
    Residual |  .021636778     3  .007212259           R-squared     =  0.7195
-------------+------------------------------           Adj R-squared =  0.4389
       Total |  .077128285     6  .012854714           Root MSE      =  .08493

------------------------------------------------------------------------------
      cotton |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          dy |   .5950485    .299944     1.98   0.142    -.3595072    1.549604
         ari |  -.0992957   .4038056    -0.25   0.822    -1.384385    1.185794
         ard |  -3.071985   1.351906    -2.27   0.108    -7.374354    1.230385
       _cons |   .5200104   .1231035     4.22   0.024     .1282401    .9117808
------------------------------------------------------------------------------
```
Figure 15. Regression of cotton proportion on average rainfall index

2.3. Kanzara Village Visit

In order to find out the reasons for the adoption of soybean by a large proportion of the households in the village, a village visit was proposed. It was justifiable by the fact that the adoption of soybean was a relatively recent event and the reasons still fresh in the mind of potential respondents.

A semi-structured questionnaire was prepared prior to the visit. The questionnaire can be broadly divided into 4 main sections:

Type of questions	Purpose
Pre-soybean	• To confirm the cropping pattern prior to soybean adoption.
Post-soybean	• To confirm the cropping pattern after soybean adoption. • To find out the reasons for the adoption of soybean.
Well-being	• To estimate the gain/loss of revenue since soybean adoption. • To identify households that can be used for case studies.
Response time	• To see if there is any difference in the response time between households of different sizes.

Table 8. Classification and purpose of questions in questionnaire

2.3.1. Interview Summary

10 respondents (3 small households, 5 medium households and 2 large households) were interviewed using the questionnaires developed above. For respondents that adopt soybean, the adoption happened between 2005 and 2007. Prior to the adoption, the main crop of the respondents was cotton. The reasons given by the respondents for the adoption are as follows:

	1^{st} Reason	2^{nd} Reason	3^{rd} Reason	Total
Labor and Input Requirement	IIIIIIIII (27)			27
Wholesale Price		IIIIII (12)		12
Shorter Maturity		IIII (4)	IIIIIII (7)	11
Others	I (3)	II (4)		7

Table 9. Reasons for adoption of soybean in 2007

In order to rank the reasons, a score of 3 is given to a particular reason if it is given as the 1^{st} reason, a score of 2 if it is given as the 2^{nd} reason and a score of 1 if it is given as the 3^{rd} reason. Labor and input requirement comes out as the top reason with a total score of 27. Next is wholesale price with at total score of 12. This is then followed by shorter maturity with a total score of 11. Other reasons are categorized as “Others” since only a single farmer mentioned them.

Most respondents agreed that soybean is less vulnerable to rainfall variability. However, it is worthwhile to note that this realization of the climate suitability of soybean occurred after growing soybean for 2-3 years and not at the time of adoption.

For respondents that adopted soybean, there was a mixed response on whether revenue has increased/ decreased. However, there was a consensus that even though revenue had decreased for some respondents, the decrease would have been more severe had they not adopted soybean. In other words, soybean increases their revenue or minimizes their losses.

There is no information lag between the small, medium and large households. All households, irrespective of size, receive information at approximately the same time. The reason for the slower response of the small households is due to risk-averseness.

2.3.2. Deeper Analysis of the Reasons for Adoption

It is imperative that the reasons given by respondents be validated whenever possible. A good source for validation is the second generation VLS data. Besides preventing the accusations that the reasons given are baseless, it also allows for the identification of potential variables to be used in regression analysis.

2.3.2.1. Labor and Input Requirement

Input cost is a good measure of the labor and input requirement of cotton and soybean. However, two problems were encountered when trying to obtain the input cost. Firstly, if there is intercropping in a plot, there is no clear division of costs between the various crops in the plot. Secondly, there is evidence of over-reporting of costs by the farmers in order to obtain more compensation from the government.

The number of times of key activities such as weeding, spraying, hoeing and picking/harvesting are used as proxy since they are proportional to input cost. This means that the greater the number of times of key activities, the higher is the input cost and vice versa. The average number of key activities as obtained from the second generation VLS data are as follows:

	Cotton	Soybean
No. of weeding	2-3	1-2
No. of spraying	1-2	0-1
No. of hoeing	4-5	3
No. of picking/ harvesting	4-5	1

Table 10. Comparison of number of key operations when growing cotton and soybean

From the table, it can be seen that cotton requires more number of weeding, spraying, hoeing and picking/harvesting than that of soybean. This consequently means that the input cost for cotton is higher than that for soybean.

Additionally, the availability of education, the improvement of transport infrastructure and the introduction of NREGS (National Rural Employment Guarantee Scheme) have reduced rural labor supply further, causing labor quantity to decrease and labor cost to increase.

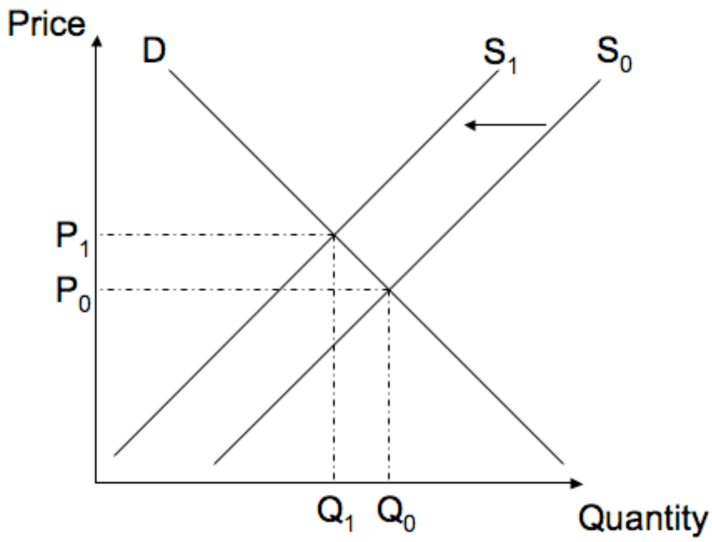


Figure 16. Supply-demand analysis of the effect of education, transport infrastructure and NREGS on rural labor

2.3.2.2. Wholesale Price

The average wholesale price per kg for year 2001-2007 was determined from second generation VLS data. These were then standardized using WPI (weighted price index) to control for inflation. The current base year is 1993-94.

It can be noted from figure 17 and 18 that at the point of adoption, the wholesale price per kg of cotton fell while the wholesale per kg of soybean rose. Quantitatively, the wholesale price per kg of cotton fell by approximately 7.4% while the wholesale price per kg of soybean rose by 0.4%.

Figure 17. Cotton wholesale price with 1983-84 as base (2001-07)

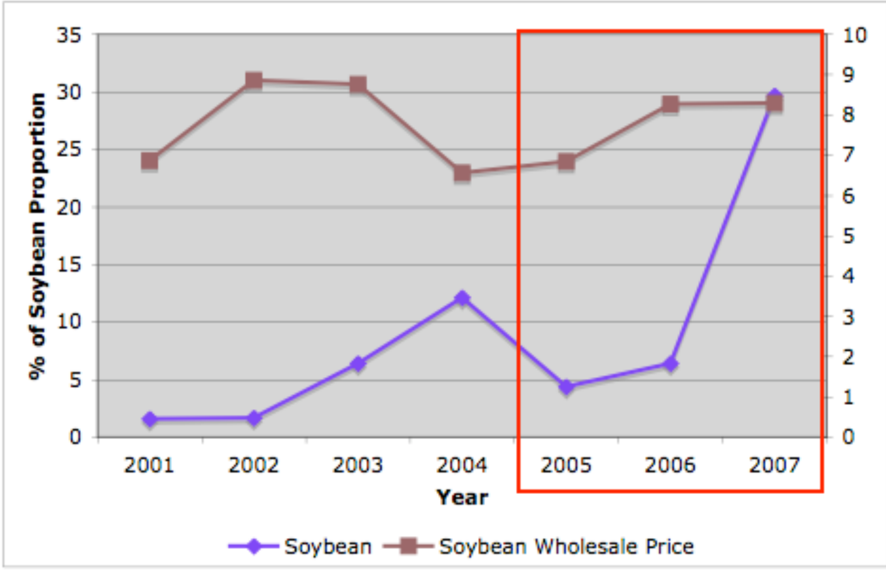


Figure 18. Soybean wholesale price with 1983-84 as base (2001-07)

2.3.2.3. Shorter Maturity

According to the respondents, shorter maturity of soybean is one of the reasons for its adoption. While cotton takes approximately 9 months from sowing to picking, soybean only takes approximately 4 months from sowing to harvesting.

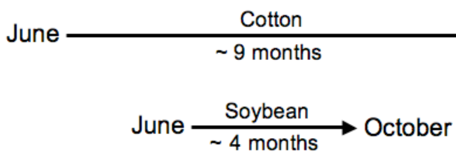


Figure 19. Maturity time of cotton and soybean

The shorter maturity presented the correspondents with several underlying benefits, including less stress, reduction in climate risk and possibility of double cropping. The first two benefits are interlinked in the sense that with shorter maturity, crops are in the plots for a shorter period of time. Therefore, the probability of the crop being exposed to the brunt of large climate variation is greatly reduced. This consequently means that the probability of crop failure is lower and hence, less stress to the farmers.

As for the possibility of double cropping, the shorter maturity of soybean simply means that the same plot can be used to grow other crops once soybean is harvested. Specifically for Kanzara, the same plot is usually used to grow wheat in Rabi season.

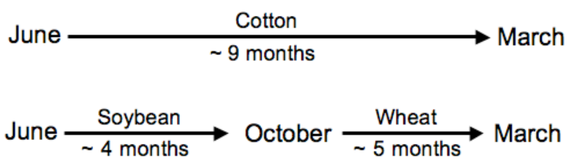


Figure 20. Common double cropping scenario

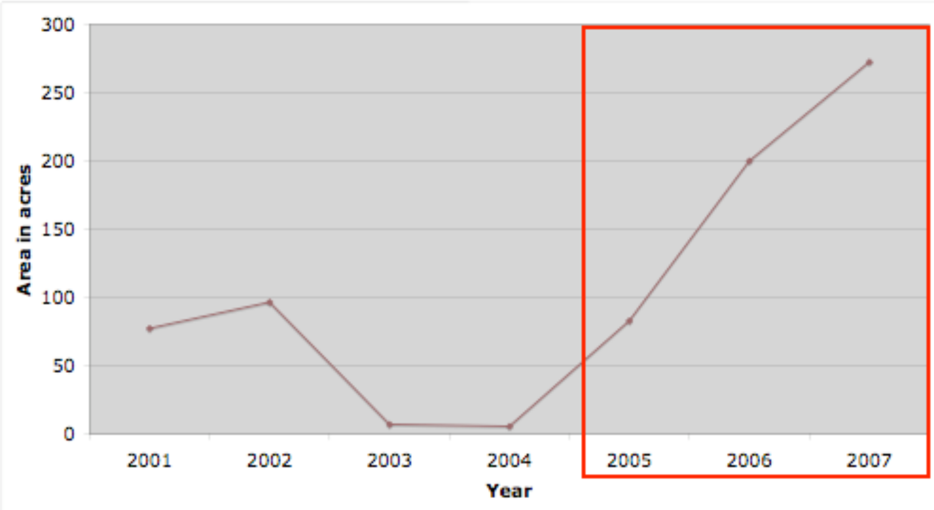


Figure 21. Wheat area in Rabi (2001-07)

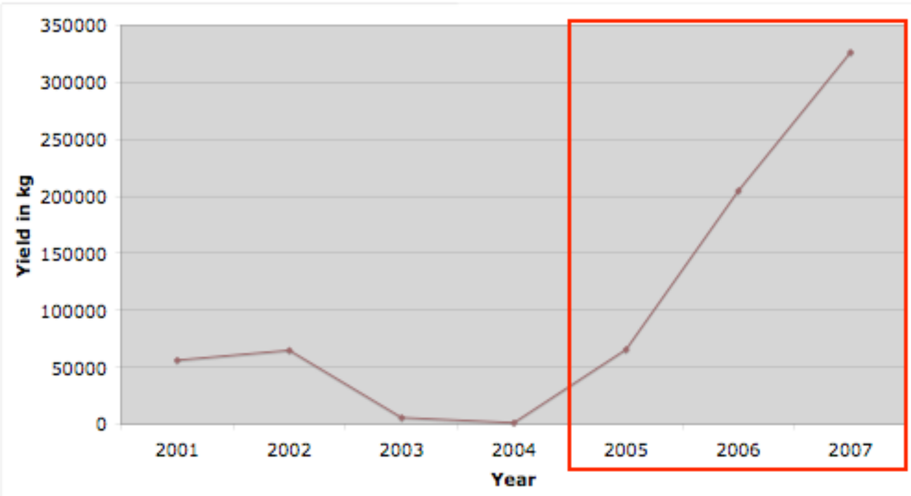


Figure 22. Wheat yield in Rabi (2001-07)

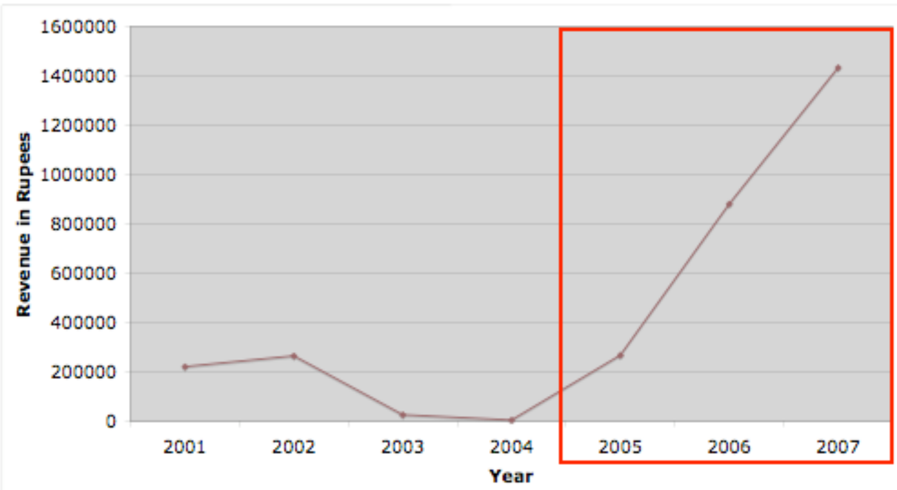


Figure 23. Wheat revenue in Rabi (2001-07)

From the figures above, it can be observed that wheat area has more than doubled since the adoption of soybean. Consequently, yield has increased by more than 6 times and revenue has increased by more than 7 times.

2.3.2.4. Others

Other reasons given for the adoption of soybean include as a source of early money, as a means of crop rotation and soybean being less prone to pest attack. Note that these are mentioned by only a single farmer.

2.3.3. The Importance of Experience

It is crucial to find out whether the adoption of soybean by a large number of households is an ad-hoc decision based solely on the reasons given during the interviews (i.e labor and input requirement, wholesale price, etc) or does experience of early adopters play a significant role in driving it.

Further analysis of the interview information revealed that experience of early adopters indeed act as strong driver. All respondents said that prior to the mass adoption in 2007, several farmers, specifically progressive farmers, through information obtained from relatives, friends and the regional agricultural university had grown soybean in their fields. In 2006, a combination of price, expenses as well as climate (heavy rainfall) resulted in high soybean revenue and low cotton revenue. This then triggered many farmers to adopt soybean in 2007.

2.3.4. Interview Inferences

Several inferences were made from the interview summary. Firstly, change in cropping pattern is driven mainly by revenue and expenses considerations. 90% of respondents quote labor and input requirement as the 1st reason for adoption of soybean. Additionally, 60% of respondents quote wholesale price as the 2nd reason for adoption of soybean.

Secondly, climate change is not the main driver for change in cropping pattern. 70% of respondents quote shorter maturity as the 3rd reason for adopting soybean. Of these, only 20% of respondents are able to see the link between shorter maturity and reduction in climate risk at the point of adoption. This is so even though adopting soybean is a valid adaptation strategy to climate change. 70% of respondents acknowledge the suitability of soybean for erratic rainfall condition but this realization comes only 2-3 years after adoption.

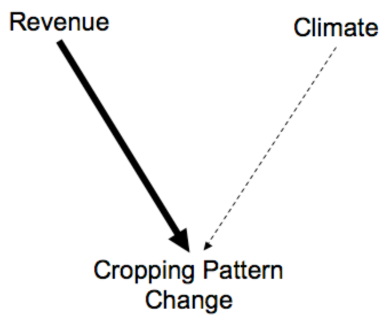


Figure 24. Linkage between revenue, climate and cropping pattern change

In order to show quantitatively the role played by revenue and expenses in triggering the adoption of soybean, logit and probit regression were performed to give a measure of the increase in the probability of adoption of soybean for every unit change in the independent variables. Two independent variables are used: 1) The difference in revenue per acre between cotton and soybean and 2) The difference in the number of operations needed to grow cotton and soybean. Difference in revenue per acre is used to take into account price and yield difference between the crops while difference in number of operations is used as a proxy for the difference in expenses between cotton and soybean since it is difficult to assign specifically the sole expenses for cotton and soybean. The results of the regression are shown below:

```
. logit adopt rev_diff differences_operation

Iteration 0:   log likelihood = -24.151673
Iteration 1:   log likelihood = -8.7872403
Iteration 2:   log likelihood = -6.2261071
Iteration 3:   log likelihood = -5.4286116
Iteration 4:   log likelihood = -5.2605226
Iteration 5:   log likelihood = -5.2474524
Iteration 6:   log likelihood = -5.2473288

Logistic regression                               Number of obs   =         42
                                                  LR chi2(2)      =      37.81
                                                  Prob > chi2     =     0.0000
Log likelihood = -5.2473288                       Pseudo R2       =     0.7827

------------------------------------------------------------------------------
       adopt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    rev_diff |   .0005449   .0002701     2.02   0.044     .0000154    .0010744
difference~n |   .5840695    .277316     2.11   0.035     .0405401    1.127599
       _cons |  -2.529197   1.155365    -2.19   0.029    -4.793671   -.2647233
------------------------------------------------------------------------------
```

Figure 25. Logit regression for soybean adoption in 2007

```
. probit adopt rev_diff differences_operation

Iteration 0:   log likelihood = -24.151673
Iteration 1:   log likelihood = -8.5063004
Iteration 2:   log likelihood = -5.9594984
Iteration 3:   log likelihood =  -5.348435
Iteration 4:   log likelihood = -5.2471918
Iteration 5:   log likelihood =  -5.242478
Iteration 6:   log likelihood = -5.2424634

Probit regression                                 Number of obs   =         42
                                                  LR chi2(2)      =      37.82
                                                  Prob > chi2     =     0.0000
Log likelihood = -5.2424634                       Pseudo R2       =     0.7829

------------------------------------------------------------------------------
       adopt |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    rev_diff |   .0003139   .0001549     2.03   0.043     .0000103    .0006175
difference~n |   .3039029   .1368257     2.22   0.026     .0357296    .5720763
       _cons |  -1.313087   .5242534    -2.50   0.012    -2.340605    -.285569
------------------------------------------------------------------------------
```

Figure 26. Probit regression for soybean adoption in 2007

	Logit	Probit
z	3.339	1.884
f(z)	0.0331	0.0676
Increase in Probability for Unit Difference in Revenue per Acre	1.80×10^{-5}	2.12×10^{-5}
Increase in Probability for Unit Difference in No. of operations	0.0193	0.0205

Table 11. Interpretation of logit and probit analysis for adoption of soybean in 2007

Both regressions show significantly at 5% level that for every unit of positive difference in revenue per acre, there is an increase in the probability of adoption of soybean by households. The same can be said for every unit of difference in number of operations between cotton and soybean.

Lastly, households are in general risk-averse. As can be seen in the earlier section, the adoption of soybean in 2007 is not an ad-hoc move but based on the experience of some households in 2006. To further show that experience plays an important role, it is worthwhile to note that households face similar situations with regards to labor and input requirement, wholesale price as well as climate in both years. The only difference is the absence of experience in 2006 and its presence in 2007. However, from the table below, it can be observed that the percentage of households that adopted soybean pre-experience, irrespective of landholding size, are smaller than that post-experience.

Type of Households	Pre-Experience % with Soybean	Post-Experience % with Soybean
Small (S)	0%	58.8%
Medium (M)	6.7%	80%
Large (L)	70%	100%

Table 12. % of households that adopted soybean pre- and post-experience

2.3.5. Case Studies

Case studies from three respondents are singled out to give a perspective of the way soybean changes the life of these people.

2.3.5.1. Shankar L. Kalekar

Mr. Kalekar is a small farmer who adopted soybean in 2007. Prior to adoption, cotton used to be his main crop. Soybean occupies 80% of his field now. His revenue per acre has increased by 30-40%. Mr. Kalekar shared that before adopting soybean, he was not able to save but with soybean, it is possible for him to save and have long-term plans. He has been using his savings to improve his farm infrastructure. Currently, he is digging a well in his farm.

2.3.5.2. Laxman G. Agarkar

Mr. Agarkar is a medium farmer. Cotton used to be his main crop but soybean took over in 2007. Soybean occupies 50% of his field now. His revenue per acre has increased by 50-60%. Mr. Agarkar said that soybean has definitely improved his standard of living. With revenue from soybean, he has managed to increase his landholding from 7 to 11 acres. In addition, he has managed to lease 4 acres of land, bringing the total of land under his care to 15 acres, double the size he used to oversee.

2.3.5.3. Ramesh P. Nagolkar

Mr. Nagolkar used to be a small farmer. Cotton was always his main crop. When most of the households adopted soybean in 2007, he continued growing cotton due to risk-averseness. Due to the climatic conditions, he lost most of his cotton. He is now landless, has no savings and has left farming for 3 years. His main source of income now is from a small shop in the village. Given opportunities, he said that he would want to return to farming.

2.4. Implications

From the information obtained, decision-making process with respect to cropping pattern in the village appears to be from the early adopters to 1st group of followers and subsequently, the 2nd group of followers. This means that early adopters will grow the new crop first. Depending on the results obtained by the early adopters, the 1st group of followers decides whether to follow the early adopters or not. Similarly, depending on the results obtained by the 1st group of followers, the 2nd group of followers decides whether to follow the 1st group or not.

Early Adopters → 1st Followers → 2nd Followers

Figure 27. Current decision-making process for adoption of new crop

One implication of this process is the delay in reaping of benefits by the 1st and the 2nd group of followers. While the cost of delay is not high in general, in the sense that followers will get the benefits as a matter of time, there are cases whereby it is not possible to reap the benefits anymore because by the time followers realize the advantages of adoption, they may no longer have the necessary resources to do so.

A second implication is that as long as no significant gain in revenue can be observed from the early adopters, the 1st group of followers and consequently, the 2nd group of followers will not even consider adoption, even though climate necessitates adoption. This translates to persistent revenue losses, landholding losses and the eventual transformation to landless households.

To paint a bleaker picture, these two implications are likely to apply more to small households than to medium and large households due to their risk-averseness. In other words, these two implications are likely to impact the poor more than the rich, which is in agreement to the statement by IPCC.

Question on how the situation could be alleviated arose. Specifically, could we have convinced those that decided not to adopt soybean in 2007 like Mr. Nagolkar to change their mind (i.e at least adopt it in 2007 if not earlier)? Could we have encouraged those that decided to adopt soybean only in 2007 like Mr. Kalekar and Mr. Agarkar to have done it earlier?

Type of Households	No. of samples	% with Soybean in 2007	% without soybean in 2007
Small (S)	17	58.8%	41.2%
Medium (M)	15	80%	20%
Large (L)	10	100%	0%

Table 13. % of households that adopted and did not adopt soybean in 2007

2.5.Potential Method of Alleviation

One method of alleviation is to convince farmers to give more considerations to climate when changing cropping pattern because of its easy accessibility. Raising their awareness of the surroundings is a good start.

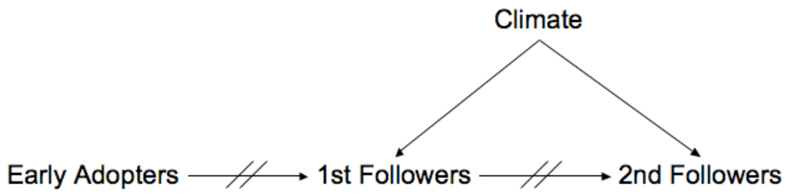


Figure 28. Proposed decision-making process for adoption of new crop

However, from the interview summary, it has been found that climate as a factor, is not significant when changing cropping pattern. Hypothesizing that farmers will increase the weightage of climate as a factor to change cropping pattern if climate is linked to revenue, this question was put forward to the respondents during the interview. All respondents said that they would give climate more considerations if linkage between climate and revenue could be shown.

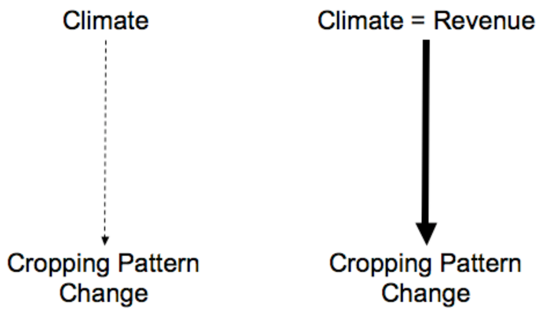


Figure 29. Method to increase the weightage of climate as a factor to change cropping patttern

To show this linkage, at least two years with approximately similar climatic conditions but different cropping pattern are needed. If one cropping pattern is indeed better than the other in generating revenue for farmers at that climatic condition, regression analysis would show it quantitatively. Given that soybean adoption is a recent development and second generation VLS data is only available until 2007, it was a challenge to find such years. Fortunately, the last two years in VLS (i.e 2006 and 2007) are such years. Both years are linked to heavy rainfall, which is detrimental to cotton. On the cropping pattern side, most farmers had cotton as the major crop in 2006 but switched to growing soybean in 2007 for reasons already mentioned in section 2.3.2 and 2.3.3.

5.1. Without Price Control

To start off, the cropping pattern and the revenue per acre for the households in these two years were determined quantitatively. The difference in the crop proportion of the main crops (cotton, soybean, pigeonpea, mung and sorghum) and the corresponding difference in the revenue per acre for each household were then calculated.

Households were split into three main groups, namely small, medium and large so as to see if there are any significant differences, in terms of revenue per acre, between households of different sizes. The result of the regression is as follows:

Source	SS	df	MS
Model	944975350	17	55586785.3
Residual	375056282	24	15627345.1
Total	1.3200e+09	41	32195893.5

Number of obs =	42
F(17, 24) =	3.56
Prob > F =	0.0023
R-squared =	0.7159
Adj R-squared =	0.5146
Root MSE =	3953.1

rev_diff_ori	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medium	7000.724	3439.776	2.04	0.053	-98.6251	14100.07
large	8566.154	5722.661	1.50	0.147	-3244.838	20377.15
cotton_cha~e	38061.05	9964.584	3.82	0.001	17495.16	58626.94
soybean_ch~e	54952.66	10941.34	5.02	0.000	32370.85	77534.46
pigeonpea_~e	50426.98	17188.54	2.93	0.007	14951.58	85902.39
mung_change	36613.13	12422.32	2.95	0.007	10974.71	62251.55
sorghum_ch~e	44368.97	12150.5	3.65	0.001	19291.57	69446.37
cotton_cha~m	-36196.57	26387.48	-1.37	0.183	-90657.67	18264.52
soybean_ch~m	-52846.17	27263.24	-1.94	0.064	-109114.7	3422.386
pigeonpea_~m	-42384.96	30422.23	-1.39	0.176	-105173.4	20403.45
mung_chang~m	-37068.35	27539.75	-1.35	0.191	-93907.6	19770.9
sorghum_ch~m	-45402.13	33293.69	-1.36	0.185	-114116.9	23312.67
cotton_cha~l	-14674.77	35005.94	-0.42	0.679	-86923.48	57573.94
soybean_ch~l	-25372.88	41943.11	-0.60	0.551	-111939.2	61193.44
pigeonpea_~l	-8756.907	40423.1	-0.22	0.830	-92186.08	74672.27
mung_chang~l	-32694.32	55902.84	-0.58	0.564	-148072.1	82683.46
sorghum_ch~l	-10565.59	42103.04	-0.25	0.804	-97461.99	76330.8
_cons	-4536.794	2128.688	-2.13	0.044	-8930.19	-143.3973

Figure 30. Regression of ΔRevenue per acre on ΔCrop proportion (Without price control)

Three main points can be obtained from the analysis of this regression. Firstly, households, regardless of size, stand to gain by switching from cotton to soybean. This is obtained by looking at the cotton and soybean coefficients. Note that both coefficients are significant at 0.1% level.

Secondly, by not changing their cropping pattern, small households tend to lose more than medium and large households. The constant value of -4536 can be interpreted as a loss of 4536 Rupees per acre for small households if they do not change their cropping pattern (significant at 5% level). On the other hand, by not changing their cropping pattern, medium and large households do not lose anything. In fact, in absolute value, medium households gain 2464 rupees per acre (significant at 5% level) and large farmers gain 4029 rupees per acre (not significant due to small sample size). A valid explanation for this observation is that there is a difference in resources, access to technology, irrigation facilities, etc between households of different sizes. This is in line with the widely accepted statement that the poor loses more than the rich.

Thirdly, combining the first and second points, small households can minimize their losses by adopting and/or increasing their soybean proportion and once they cross a certain threshold of soybean proportion, will start to see a positive increase in their revenue per acre. As for medium and large households, although they do not lose anything by not changing their cropping pattern, they stand to gain even more revenue per acre if they decide to adopt and/or increase their soybean proportion.

There is actually an additional observation of small households standing to gain more revenue per acre than the medium and large households for each unit of change from cotton to soybean. Unfortunately, although the magnitudes of the relevant coefficients validate this observation, they are not statistically significant. Again, this observation, has it been significant, could have been explained by the difference in resources, technology, etc between households of different sizes.

5.2. With Price Control

To ensure that the difference in revenue per acre between cotton and soybean is not solely driven by a decrease in the wholesale price of cotton and an increase in the wholesale price of soybean, prices were controlled. This means that to calculate the revenue per acre in 2007, wholesale prices in 2006 were used. The result of the regression is as follows:

Source	SS	df	MS		
Model	802674402	17	47216141.3	Number of obs =	42
Residual	333098298	24	13879095.7	F(17, 24) =	3.40
				Prob > F =	0.0031
Total	1.1358e+09	41	27701773.2	R-squared =	0.7067
				Adj R-squared =	0.4990
				Root MSE =	3725.5

rev_diff_~06	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medium	7374.218	3241.665	2.27	0.032	683.7501	14064.69
large	9474.519	5393.07	1.76	0.092	-1656.229	20605.27
cotton_cha~e	36122.89	9390.683	3.85	0.001	16741.47	55504.3
soybean_ch~e	52013.28	10311.18	5.04	0.000	30732.05	73294.51
pigeonpea_~e	53377.49	16198.58	3.30	0.003	19945.26	86809.72
mung_change	35359.75	11706.87	3.02	0.006	11197.95	59521.54
sorghum_ch~e	42908.9	11450.7	3.75	0.001	19275.81	66541.99
cotton_cha~m	-34980.26	24867.72	-1.41	0.172	-86304.72	16344.19
soybean_ch~m	-51638.94	25693.04	-2.01	0.056	-104666.8	1388.886
pigeonpea_~m	-46827.43	28670.09	-1.63	0.115	-105999.6	12344.73
mung_chang~m	-36363.59	25953.62	-1.40	0.174	-89929.23	17202.05
sorghum_ch~m	-44644	31376.17	-1.42	0.168	-109401.2	20113.23
cotton_cha~l	-15692.14	32989.8	-0.48	0.639	-83779.75	52395.46
soybean_ch~l	-28988.49	39527.43	-0.73	0.470	-110569.1	52592.12
pigeonpea_~l	-14617.85	38094.96	-0.38	0.705	-93242	64006.29
mung_chang~l	-38560.94	52683.16	-0.73	0.471	-147293.6	70171.77
sorghum_ch~l	-14167.82	39678.15	-0.36	0.724	-96059.5	67723.85
_cons	-4191.556	2006.088	-2.09	0.047	-8331.919	-51.19332

Figure 31. Regression of ΔRevenue per acre on ΔCrop proportion (With price control)

Similar observations are obtained. This shows that even without price changes, it is advisable to adopt soybean as opposed to continuing with cotton.

5.3. Additional Stress Tests

Stress tests go beyond just controlling the price (i.e. assuming that there was no price change between the two years). Specifically for our case, the price of soybean was decreased by a certain percentage while the price of cotton was increased by a certain percentage. Crop yields were kept constant.

The first test involves decreasing the price of soybean by 10% while increasing the price of cotton by 10%. The second test is similar to the first but this time the price of soybean is decreased by 25% while the price of cotton is increased by 25%. The third test is also similar but 50% is used instead.

The objective of additional stress tests is to inform farmers that decision-making driven purely by market and not taking into consideration factors such as climate may not necessarily results in a good outcome for them. The results of the regression are as follows:

Source	SS	df	MS		
				Number of obs =	42
				F(17, 24) =	3.26
Model	769240093	17	45249417.2	Prob > F =	0.0041
Residual	333139765	24	13880823.5	R-squared =	0.6978
				Adj R-squared =	0.4837
Total	1.1024e+09	41	26887313.6	Root MSE =	3725.7

rev_diff_~10	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medium	7265.864	3241.867	2.24	0.035	574.9793	13956.75
large	9796.697	5393.405	1.82	0.082	-1334.744	20928.14
cotton_cha~e	36257.3	9391.267	3.86	0.001	16874.68	55639.92
soybean_ch~e	51643.54	10311.82	5.01	0.000	30360.99	72926.1
pigeonpea_~e	52918.56	16199.59	3.27	0.003	19484.25	86352.87
mung_change	35597.34	11707.6	3.04	0.006	11434.04	59760.64
sorghum_ch~e	42925.34	11451.42	3.75	0.001	19290.77	66559.9
cotton_cha~m	-35985.74	24869.27	-1.45	0.161	-87313.39	15341.9
soybean_ch~m	-52500.83	25694.64	-2.04	0.052	-105532	530.2931
pigeonpea_~m	-46812.24	28671.88	-1.63	0.116	-105988.1	12363.6
mung_chang~m	-36819.5	25955.24	-1.42	0.169	-90388.47	16749.48
sorghum_ch~m	-46063.38	31378.12	-1.47	0.155	-110824.6	18697.88
cotton_cha~l	-15643.7	32991.86	-0.47	0.640	-83735.55	52448.14
soybean_ch~l	-29657.77	39529.89	-0.75	0.460	-111243.5	51927.92
pigeonpea_~l	-13617.56	38097.34	-0.36	0.724	-92246.6	65011.47
mung_chang~l	-39198.57	52686.44	-0.74	0.464	-147938	69540.9
sorghum_ch~l	-15155.06	39680.62	-0.38	0.706	-97051.83	66741.72
_cons	-4141.998	2006.213	-2.06	0.050	-8282.619	-1.377991

Figure 32. Regression of ΔRevenue per acre on ΔCrop proportion
(With cotton price +10% and soybean price -10%)

Source	SS	df	MS
Model	723975105	17	42586770.9
Residual	334294531	24	13928938.8
Total	1.0583e+09	41	25811454.5

Number of obs	= 42
F(17, 24)	= 3.06
Prob > F	= 0.0061
R-squared	= 0.6841
Adj R-squared	= 0.4604
Root MSE	= 3732.1

rev_diff_~25	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medium	7103.332	3247.481	2.19	0.039	400.8614	13805.8
large	10279.96	5402.745	1.90	0.069	-870.753	21430.68
cotton_cha~e	36458.92	9407.529	3.88	0.001	17042.73	55875.11
soybean_ch~e	51088.94	10329.68	4.95	0.000	29769.53	72408.34
pigeonpea_~e	52230.16	16227.64	3.22	0.004	18737.95	85722.37
mung_change	35953.73	11727.87	3.07	0.005	11748.59	60158.87
sorghum_ch~e	42949.99	11471.25	3.74	0.001	19274.5	66625.48
cotton_cha~m	-37493.96	24912.33	-1.51	0.145	-88910.49	13922.57
soybean_ch~m	-53793.67	25739.13	-2.09	0.047	-106916.6	-670.7151
pigeonpea_~m	-46789.46	28721.53	-1.63	0.116	-106067.8	12488.86
mung_chang~m	-37503.37	26000.18	-1.44	0.162	-91165.11	16158.37
sorghum_ch~m	-48192.45	31432.46	-1.53	0.138	-113065.9	16680.96
cotton_cha~l	-15571.04	33048.99	-0.47	0.642	-83780.8	52638.71
soybean_ch~l	-30661.69	39598.34	-0.77	0.446	-112388.7	51065.27
pigeonpea_~l	-12117.13	38163.31	-0.32	0.754	-90882.32	66648.07
mung_chang~l	-40155.02	52777.68	-0.76	0.454	-149082.8	68772.75
sorghum_ch~l	-16635.91	39749.33	-0.42	0.679	-98674.5	65402.68
_cons	-4067.662	2009.687	-2.02	0.054	-8215.453	80.12864

Figure 33. Regression of ΔRevenue per acre on ΔCrop proportion
(With cotton price +25% and soybean price -25%)

Source	SS	df	MS
Model	661564096	17	38915535
Residual	339132641	24	14130526.7
Total	1.0007e+09	41	24407237.5

Number of obs	= 42
F(17, 24)	= 2.75
Prob > F	= 0.0114
R-squared	= 0.6611
Adj R-squared	= 0.4211
Root MSE	= 3759.1

rev_diff_~50	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
medium	6832.446	3270.896	2.09	0.048	81.64838	13583.24
large	11085.41	5441.7	2.04	0.053	-145.7081	22316.53
cotton_cha~e	36794.96	9475.361	3.88	0.001	17238.77	56351.14
soybean_ch~e	50164.6	10404.16	4.82	0.000	28691.47	71637.72
pigeonpea_~e	51082.83	16344.65	3.13	0.005	17349.13	84816.52
mung_change	36547.71	11812.44	3.09	0.005	12168.04	60927.38
sorghum_ch~e	42991.08	11553.96	3.72	0.001	19144.88	66837.27
cotton_cha~m	-40007.66	25091.96	-1.59	0.124	-91794.92	11779.6
soybean_ch~m	-55948.4	25924.72	-2.16	0.041	-109454.4	-2442.416
pigeonpea_~m	-46751.49	28928.62	-1.62	0.119	-106457.2	12954.25
mung_chang~m	-38643.15	26187.65	-1.48	0.153	-92691.81	15405.51
sorghum_ch~m	-51740.89	31659.1	-1.63	0.115	-117082.1	13600.27
cotton_cha~l	-15449.95	33287.28	-0.46	0.647	-84151.52	53251.62
soybean_ch~l	-32334.89	39883.86	-0.81	0.425	-114651.1	49981.34
pigeonpea_~l	-9616.401	38438.48	-0.25	0.805	-88949.52	69716.71
mung_chang~l	-41749.1	53158.22	-0.79	0.440	-151462.3	67964.07
sorghum_ch~l	-19103.99	40035.94	-0.48	0.638	-101734.1	63526.12
_cons	-3943.768	2024.178	-1.95	0.063	-8121.465	233.9296

Figure 34. Regression of ΔRevenue per acre on ΔCrop proportion
(With cotton price +50% and soybean price -50%)

Although the spread becomes narrower, it can be seen that adoption of soybean still results in better revenue per acre than that of cotton. Farmers should seriously start to give more weight age to climate when making their cropping pattern decision instead of relying heavily on market.

3. Conclusion

This study has validated the assumptions that change in cropping pattern is driven by reasons other than climate. Specifically for Kanzara, the adoption of soybean is driven by revenue and expenses considerations, not climate change. Given the risk-averseness of households, the role of experience adds another dimension to the decision-making process of cropping pattern change. Two implications of the current decision-making process are identified: 1) Delay in reaping the benefits of change in cropping pattern and 2) No significant changes in cropping pattern unless significant gain in revenue can be observed from the early adopters even though climate necessitates change.

However, by linking climate to revenue, households show willingness in giving more weightage to climate as a factor to change cropping pattern. Three main points can be obtained from this part of the study: 1) Households, regardless of size, stand to gain by switching from cotton to soybean. 2) By not changing their cropping pattern, small households tend to lose more than medium and large households. A valid explanation for this observation is that there is a difference in resources, access to technology, irrigation facilities, etc between households of different sizes. This is in line with the widely accepted statement that the poor loses more than the rich. 3) Combining the first and second points, small households can minimize their losses by switching and/or increasing their soybean proportion and once they cross a certain threshold of soybean proportion, will start to see a positive increase in their revenue per acre. As for medium and large households, although they do not lose anything by not changing their cropping pattern, they stand to gain even more revenue per acre if they decide to switch and/or increase their soybean proportion. This could be a seed to alter the decision-making dynamics.

References

1. Nelson et al. 2009. Climate Change: Impact on Agriculture and Costs of Adaptation. International Food Policy Research Institute.

2. IPCC et al. 2007. Climate Change 2007: Impacts, adaptation and vulnerability.

3. Dasgupta, SB et al. 2009. The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis. Climactic Change Vol. 93 (3-4):379-88.

4. Aggarwal, P.K. 2009. Vulnerability of Indian Agriculture to Climate Change: Current State of Knowledge. Indian Ministry of Environment and Forests.

5. Worrell E et al. 2009. Industrial energy efficiency and climate change mitigation. Energy Efficiency 2:109–123.

6. Lidula NWA et al. 2007. ASEAN towards clean and sustainable energy: Potentials, utilization and barriers. Renewable Energy Vol. 32, 9:1441-1452.

7. Jean-Philippe Barde. 2004. Green Tax Reforms in OECD Countries: An Overview. OECD Environment Directorate.

8. Lars Kroldrup. 2010. Gains in Global Wind Capacity Reported by Green Inc.

9. David Pearce. 2005. The United Kingdom Climate Change Levy: A Study in Political Economy. OECD Environment Directorate.

10. Adams R et al. 1999.The economic effect of climate change on US agriculture. In: Mendelsohn R, Neumann J. (Eds.), The Economic Impact of Climate Change on the Economy of the United States. Cambridge University Press, Cambridge.

11. Easterling III W.E. 2004. Coping with Global climate change: The Role of Adaptation in the United States.

12. Haines A et al. 2009. Aligning climate change and public health policies. The Lancet Vol 374, 9707:2035-2038.

13. Rao KPC and Kumara Charyulu D. 2007. Changes in Agriculture and Village Economies. Research Bulletin no. 21. Patancheru 502324, Andhra Pradesh, India: International Crop Research Institute for the Semi-Arid Tropics.

14. White JW. Adapting Cropping Patterns to Climate Change. US Arid Land Agricultural Research Center, USDA-ARS Maricopa, Arizona.

15. Leary N. 2008. Climate Change and Adaptation. Cambridge University Press, Cambridge

16. Lal M et al. 2001. Future Climate Change: Implications from Indian Summer Monsoon and its Variability. Current Science, Vol.81, 9.

17. Thurston HD. 1997. Slash/Mulch Systems: Sustainable Methods for Tropical Agriculture. Westview Press, Boulder, Colorado, USA.

18. Ryan JG, Spencer DC. 2001. Some challenges, trends and opportunities shaping the future of the semi-arid tropics. In: Bantilan, M.C.S, Parthasarathy Rao, P., Padmaja, R. (eds.), Future of Agriculture in Semi-arid Tropics. Proceedings of International Symposium on the Future of Agriculture in the Semiarid Tropics. International Crop Research Institute for the Semi-Arid Tropics.

19. Kumar KSK, Parikh J. 2001. Indian agriculture and climate sensitivity. Global Environmental Change 11:147–154.

20. Sanghi A, Mendelsohn R. 2008. The impacts of global warming on farmers in Brazil and India. Global Environmental Change 18:655–665.