Project Completion Report
2013-18

Strengthening Bhoochetana:

A Sustainable Agriculture Mission for Improved Livelihoods in Karnataka

Submitted to
Government of Karnataka

ICRISAT DEVELOPMENT CENTER

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Contents

Executive summary

Based on the success of Bhoochetana Project phase I, the Government of Karnataka extended the science-led productivity enhancing initiative to cover not only rainfed areas in 30 districts of Karnataka but also to extend the initiative to irrigated crops in the state. The vision of Bhoochetana Mission Program Phase II was to "sustainably improve livelihoods of small and marginal farmers in the state by developing a farmer-centric science-led inclusive market-oriented integrated farming systems participatory development approach".

Phase II of the program was implemented in 2013-14, covering over 6.5 million ha of both rainfed and irrigated crops. During the project period, a number of innovative proven technologies were scaled-out with a focus on increasing yields and incomes. The program aimed at harnessing low-hanging fruits during its initial phase and subsequently tested and scaled-up innovative technologies aimed at achieving resource use efficiency, tackling labor scarcity and climate change, building resilience and improving rural livelihoods. The Mission Program helped achieve increased crop production and realise additional net income due to improved agricultural practices. Innovative practices such as the use of micro- and secondary-nutrients based on soil analysis were promoted through the distribution of incentivized fertilizers. Other innovative practices included landform management, use of biofertilizers and vermicompost, biomass generation for soil health, using Azolla fern as soil fertilizer, paired row planting in pigeonpea, pheromone traps for pest monitoring and management, biotic- and abiotic-stress tolerant cultivars, good agronomic practices, direct-seeded/drum-seeded/machine-transplanted rice, bud chip method of sugarcane planting, gully method of finger millet cultivation and high density planting in sugarcane.

The Bhoochetana Mission Program demonstrated the effectiveness of a consortium model of knowledge generating institutions and knowledge disseminating line departments for scaling-up good agricultural practices in Karnataka. Soil health assessment after four years of incorporating improved nutrient management practices in farmers' fields showed a decline in deficiency in boron from 35-14%, in sulphur from 80-35%, in phosphorus from 55-25%. However, in Dharwad district, the deficiency in nitrogen and zinc in farmers' fields increased mainly due to increased mining. Mean nutrient content in soil in 2014 was marginally higher than in 2008, indicating improvement due to soil test-based nutrient application over the years from 2009. In irrigated areas, soil test-based nutrient management practices together with dry-seeded rice and drip irrigation in paddy and single eyebud planting with wider row spacing in sugarcane led to significant yield increase. Farmer participatory evaluation of climate smart crop varieties have shown the existence of a large yield gap.

During the project period (2013-14 to 2017-18), average seasonal rainfall was below normal (-18 to -31%) during kharif and rabi seasons. Field trials with improved cultivars of groundnut like ICGV 91114 have shown maximum yield to 2.6 t/ha in Raichur district, with average productivity ranging from 1 to 2 t/ha in different districts. Similarly, other improved varieties of groundnut like ICGV 00351, ICGV 00308 and ICGV 02266 were also preferred by farmers in different districts. Improved varieties of finger millet, soybean, sorghum, pearl millet, castor and sunflower were preferred by the farmers due to their significantly higher yields that ranged from 29-67% compared to their average yields in the state. During 2013-14, additional yield ranged between 100 kg/ha in green gram and 1200 kg/ha in maize, which resulted in

additional income of ₹ 3954/ha and ₹ 15,667/ha, respectively. In 2014-15, additional yield ranged between 60 kg/ha in green gram and 940 kg/ha in maize, which resulted in additional income of ₹ 2760/ha and ₹ 12,337/ha respectively. An initial impact assessment spanning four years revealed an net increased income of ₹ 1780 crore (US$ 293 million).

Two GCM models namely CESM1-CAM5 and NCAR-CCSM4 under climate change scenario of RCP8.5 for the period 2030 and 2050 and APSIM pigeonpea crop-growth simulation model are used for assessing the impacts of projected climate change on pigeonpea yields in the five selected districts. In general, the two projection models show increased rainfall by 2030 and 2050 periods in the range of 15 to 120 mm annually. Pigeonpea crop duration would reduce as indicated by both the models and periods. Crop water uptake would be impacted differently under the two models. Pigeonpea yields under CESM1-CAM5 model show a slight increase by the year 2030 while a slight reduction by the year 2050. Under NCAR-CCSM4 model, pigeonpea yields show a general reduction in both the years 2030 and 2050. Year-to-year variability in yield showed increasing trends in both the models / periods. Projected climate impacts indicated increased risk of sustainable yield under future climate change scenarios.

The mission project streamlined good practices for knowledge dissemination, data recording, and crop cutting. Using a scientific approach and technical support enabled rainfed farmers to enhance crop productivity significantly during rainy and postrainy seasons for different crops. It was evident that small and marginal farmers need to be enabled through capacity building trainings, exposure visits, and demonstrations by ensuring the availability of inputs and handholding support. However, a weak extension system was the bottleneck for scaling up although an effective institutional mechanism was put in place by the Department of Agriculture (DoA) during the project's first phase.

During the project period, 165 training courses were conducted at the district level with 15,820 participants; 540 trainings at taluk level to train 42,273 trainees; and 17,382 cluster village level trainings to train 980,827 farmers, including women.

1. Background

Based on the success of phase I of Bhoochetana project, Bhoochetana Mission Program (BCMP) was initiated for science-led productivity enhancement in rainfed areas in 30 districts and extended to irrigated crops in the state. The program continued to adopt the consortium approach through convergence, collective action and capacity building along with inclusivity, innovation, integration and intensification to achieve economic benefits, protect the environment, and enhance efficiency by empowering stakeholders. The program's vision was to sustainably improve livelihoods of small and marginal farmers in the state by developing a farmer-centric science-led inclusive market-oriented integrated farming systems participatory development approach.

The program's goal was to operationalize an integrated and participatory knowledge-led farming systems development approach to increase agricultural productivity by 20% in five years through convergence and better coordination among different agriculture research-extension and development sectors in the state to sustainably improve the livelihoods of farmers. This would be done using a market-oriented farmer-centric partnership approach.

2. Objectives

The specific objectives of the second phase of Bhoochetana Mission Program are:

1. To strengthen the Bhoochetana consortium to increase yields of irrigated and rainfed crops by 20% over the first phase of the project, in five years in 30 districts (Figure 1) of Karnataka, through science-led development and new innovation systems.

2. To strengthen institutional mechanisms such as seed villages, village seed banks, participatory research for development (PR4D), input supply, agricultural machinery hiring centres, farm extension through farm facilitators and communication systems for small and marginal farmers in the state for the DoA through capacity development, convergence, collective action, and partnerships.

3. To assess the impact of climate change in different agro-ecoregions of the state in terms of anticipated shifts in crop growing periods, water availability and crop yields, and evaluate adaptation strategies for climate resilient farming systems.

4. To document the process of consortium functioning, learning, and impact of BCMP in terms of increased crop yields, institutional development and capacity building of stakeholders in the state.

3. Consortium Partners

The consortium comprised of Karnataka's State Department of Agriculture, with its Commissioner and Director as nodal officers to implement the project. The other partners include:

- Watershed Development Department; its Commissioner is the focal person to co-ordinate activities.
- Four State Agricultural Universities of Agricultural Sciences (SAUs) (Bengaluru, Raichur, Dharwad and Shivamogga) in the state; their Vice-Chancellors are SCC members supporting technical help from university scientists.
- Karnataka State Natural Disaster Management Cell (KSDMC)
- Karnataka State Seed Corporation (KSSC)
- Department of Economics & Statistics
- Krishi Vigyan Kendras in the state
- Community-based Organizations (CBOs)
- Watershed Committees, user groups and watershed associations
- International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT) to facilitate improved technologies to all stakeholders and participating farmers.
- Private companies

4. Project Strategy

Phase II of the program saw the strengthening and expansion of the consortium formed during phase I and the translation of the phase I mission mode project into a Bhoochetana Mission Program (BCMP). The tried and tested principle of convergence was institutionalized in phase II. The salient strategies for the mission mode program were as follows:

The conversion of the mission project into a mission program involved the institutionalization of the principle of *convergence* of different line departments' agriculture related development programs through Bhoochetana, which called for changing the mindset of different actors, for which we sought external drivers.

The mission program adopted the principle of 4 ICEs as indicated - **Is**: Innovative, Inclusive, Integrated, Intensification; **Cs**: Collective, Cooperation, Capacity building, Consortium; and **Es**: Efficiency, Equity, Environment protection, Economic gain. The consortium comprised of knowledge transforming development agencies such as line departments of the state government, i.e., Department of Agriculture, Karnataka State Seeds Corporation (KSSC), Watershed Development Department (WDD), Department of Horticulture (DoH), Department of Economics and Statistics (DES) along with knowledge generating academic and research institutions like State Agricultural Universities (SAUs), University of Horticultural Sciences (UoH) in the state, Karnataka State Disaster Management Center (KSDMC) and ICRISAT.

ICRISAT led the consortium and selected suitable experts from SAUs to address issues of climate change for inclusion in the consortium. During phase II, the SAUs and University of Horticulture Sciences played an active role in supporting and institutionalizing the concept of convergence and consortium for capacity development.

The emphasis was on capacity strengthening by building human resource capacity through training as well as building the capacity of the institutions, networking and building partnerships.

The mission's approach was to strengthen backward linkages to meet the 4 Es (Efficiency, Equity, Environment protection, Economic gain) through 4 Cs (Collective, Cooperation, Capacity building, Consortium) by establishing seed villages, village seed banks, custom hiring centers for agricultural equipment, ensuring timely supply, availability and access to inputs such as knowledge-based soil nutrient management options, acquiring micronutrients, availability of good quality seed and necessary financial incentive to undertake best-bet options for increasing agricultural productivity through sustainable intensification. The institutionalization of CBOs and service providers was envisaged to enhance the impact of the program.

The extension system piloted during phase I using Farm Facilitators (FFs) and Lead Farmers (LFs) to share knowledge with farmers was strengthened through capacity development and building partnerships for large scale scaling-up of improved best-bet management practices.

ICT tablet-based knowledge sharing systems were piloted in selected Rytha Samparka Kendras (RSKs) in the four districts.

The scientific approach of mapping soil nutrient deficiencies continued in phase II by monitoring changes in soil fertility status after the adoption of best-bet management practices for five years. This approach increased the productivity of the land, water and applied fertilizers and also reduced the cost of cultivation by advising the farmers not to apply fertilizers not required by their soils.

Other best-bet practices such as rainwater management, pest management and organic matter building have supported the project's long-term sustainability and enhanced productivity. The convergence of activities of the WDD and DOH will ensure increased water availability which is an important driver for sustainable intensification in the state.

The most important constraint in dryland areas is the establishment of good crop stand and the availability of good quality and high yielding seeds of improved cultivars. The mission will emphasize integration of KSSC's seed production program to ensure production of improved quality of seeds with best-bet management practices as well as ensure their timely supply to the farmers through the establishment of seed villages and village seed banks for self-pollinated crops such as groundnut and chickpea and cross pollinated crops such as sorghum and pigeonpea. Farmers will be trained and producers will be provided opportunities for value addition.

The Program has planning and monitoring mechanisms at the cluster, taluk, district and state levels. The Additional Chief Secretary/Agriculture Production Commissioner (ACS/APC) is the chair of the State Coordinators Committee (SCC) which includes decision makers representing consortium partners including line departments to pass on government orders to mission staff concerned. The SCC meets regularly to ensure smooth convergence.

5. Project Activities

Rainfall and Climate Analysis for Karnataka (2013-2017)

Karnataka is divided into four regions, South Interior Karnataka (SIK), North Interior Karnataka (NIK), Malnad and Coastal. The state's normal annual rainfall is about 1165 mm, of which about 138 mm (12%) occurs between January and May. The Southwest (SW) monsoon normally sets in by the first week of June; about 839 mm of rainfall (72% of the annual rainfall) is from the Southwest monsoon (Jun-Sep). In the post-monsoon (Oct-Dec) season, the state receives about 188 mm of rain (16% of the annual rainfall). Thus both these seasons are important. Figure 1 shows the rainfall departure from normal for both the Southwest and post-monsoon periods for five years (2013-2017).

Rainfall departures figures indicate that except for the year 2013 when the SW monsoon rainfall was above normal, all years and both monsoon periods received less rainfall compared to normal. If the departure of actual rainfall from normal is more than 20%, it is classified as "Excess"; if between -19 and +19%, it is classified as "Normal"; if between -20 and -59%, it is classified as "Deficit"; and if between -60 and -99%, then it is classified as "Scanty". The SW monsoon in 2015 and post-monsoon rainfall in 2013 were in the deficit category. The year 2016's SW monsoon rainfall saw a -18% departure from the normal, which though categorized as normal, was very close to a deficit.

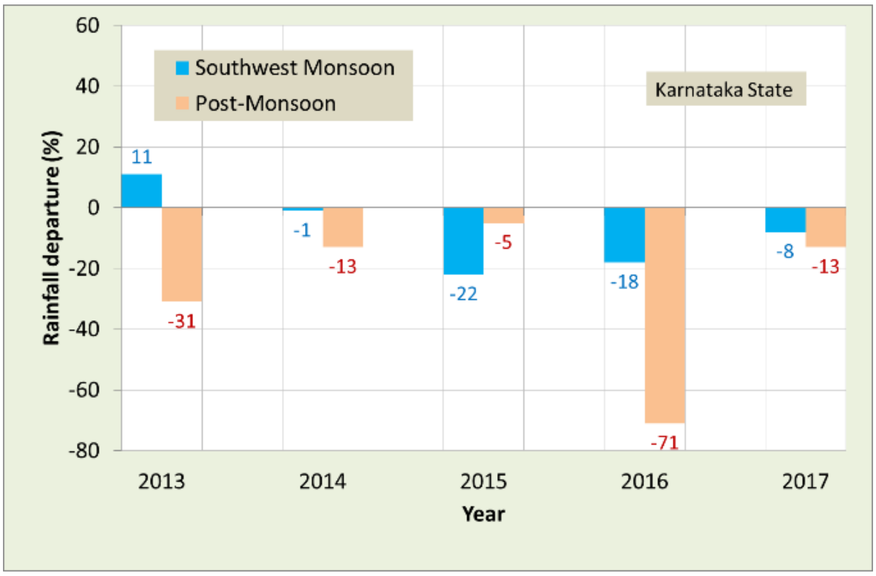


Figure 1: Seasonal rainfall departure from the normal in Karnataka during 2013-2017.

Rainfall Situation in 2013

The SW monsoon set in over parts of SIK and coastal regions on 1 Jun 2013 and covered the entire State by 7 June (Table 1). During June 2013, monsoon was active and the state received 216 mm of rainfall as against the normal 195 mm. In July, monsoon was active over Karnataka, except in some parts of SIK and NIK; and the state as a whole received about 350 mm as against the normal 278 mm. In August 2013, the monsoon was relatively weak over Karnataka and the state as a whole received only 163 mm as against a normal of 205 mm. During September 2013, the monsoon was active and the state as a whole received about 205 mm of rainfall compared to the normal 158 mm. In summary, the year 2013 was a good rainfall year as Karnataka received about 934 mm of rainfall in the SW monsoon period against the normal 839 mm; and the percentage departure was +11%, namely normal. Rainfall received was normal in June, excess in July and September and deficit in August. During the post-monsoon period (Oct-Dec), the state as a whole recorded 129 mm of rainfall as against the normal 188 mm; and the percentage departure was -31% , classified as deficit (Table 2). Thus, Karnataka received normal rainfall during the SW monsoon period and deficit rainfall during the post-monsoon period.

Table 1. Region-wise rainfall in Karnataka during 2013.

Region	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
SI Karnataka	359	412	15	210	125	-40
NI Karnataka	494	533	8	145	100	-31
Malnad	1504	1816	21	228	135	-41
Coastal	3019	3206	6	261	266	2

Table 2. District-wise rainfall in Karnataka during 2013.						
District	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
Bagalkote	350	353	1	144	114	-21
Ballari	352	343	-3	150	98	-35
Belagavi	612	656	7	153	88	-42
Bengaluru Rural	441	513	16	234	143	-39
Bengaluru Urban	460	515	12	229	158	-31
Bidar	684	798	17	116	135	16
Chamarajanagar	305	358	17	257	175	-32
Chikkaballapur	399	394	-1	222	148	-33
Chikkamagalur	1349	1692	25	228	104	-54
Chitradurga	276	357	29	160	67	-58
Dakshina Kannada	3441	3683	7	367	434	18
Davanagere	373	440	18	173	56	-68
Dharwad	498	483	-3	159	86	-46
Gadag	382	392	3	162	101	-38
Hassan	673	924	37	225	132	-41
Haveri	485	549	13	168	64	-62
Kalaburagi	614	659	7	127	85	-33
Kodagu	2345	2656	13	288	213	-26
Kolar	387	358	-7	236	162	-31
Koppal	376	392	4	142	135	-5
Mandya	304	344	13	233	142	-39
Mysuru	395	447	13	211	150	-29
Raichur	450	572	27	143	113	-21
Ramanagara	430	456	6	238	147	-38
Shivamoga	1889	2228	18	202	126	-38
Tumakuru	361	448	24	204	115	-44
Udupi	4071	3939	-3	299	356	19
Uttara Kannada	2457	2725	11	198	156	-21
Vijayapura	428	461	8	141	90	-36
Yadgir	592	594	0	150	118	-21
State	839	934	11	188	129	-31

Data source: KSNDMC, Govt. of Karnataka

Rainfall Situation in 2014

The SW monsoon set over coastal Karnataka on 9 Jun 2014, late by one week. The monsoon was stagnant for about five days, slowly progressed covered all Karnataka by about 20 Jun. Koppal, Hassan, Mandya, Chitradurga and Davanagere received excess rainfall, Chikkaballapur, Bidar, Kolar and Kalaburagi received deficit rainfall, while the remaining 21 districts received normal rainfall. The year 2014 was good as the state received about 833 mm of rainfall in the SW monsoon period against the normal 839 mm; and the percentage departure was only -1% (Table 3).

During the post-monsoon period (Oct-Dec), Karnataka as a whole received only 163 mm compared to a normal of about 188 mm; the percentage departure was -13% and categorized as normal (Table 4). Thus, Karnataka received normal rainfall both during the SW monsoon and post-monsoon periods in 2014. In the post-monsoon period, 15 districts received normal rainfall, 2 districts excess rainfall and 13 districts deficit rainfall. Bidar, Chikkaballapur, Kalaburagi and Kolar districts received deficit rainfall in both the monsoon periods.

Table 3. Region-wise rainfall in Karnataka during 2014.

Region	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
SI Karnataka	359	379	6	210	205	-2
NI Karnataka	494	475	-4	145	112	-23
Malnad	1504	1592	6	228	171	-25
Coastal Karnataka	3019	2867	-5	261	260	0
State	839	833	-1	188	163	-13

The weekly rainfall departures from normal during Jun to Dec 2014 show that rainfall was less than 50% of the normal in two consecutive weeks (25 Jun to 8 Jul) in the SW monsoon season (Figure 2). On the other hand, during the post-monsoon period, rainfall departures were always negative, except during three weeks ending on 28 Oct, 18 Nov and 16 Dec. The 3-week period from 19 Nov to 9 Dec experienced deficit rainfall conditions and restricted water availability to crops.

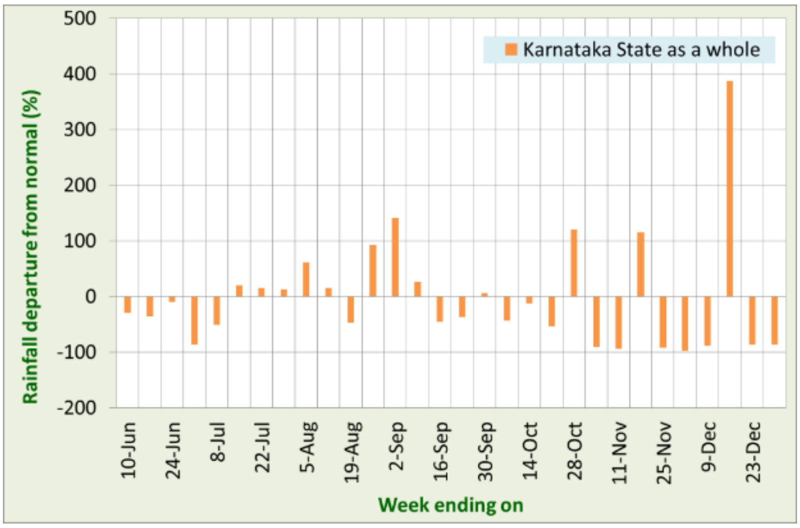


Figure 2: Weekly rainfall departure from the normal in Karnataka during 2014.

Table 4. District-wise rainfall in Karnataka during 2014.						
District	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
Bagalkote	350	373	6	144	86	-40
Ballari	352	393	12	150	143	-5
Belagavi	612	649	6	153	166	9
Bengaluru Rural	441	428	-3	234	257	12
Bengaluru Urban	460	376	-18	229	269	15
Bidar	684	443	-35	116	50	-57
Chamarajanagar	305	336	10	257	177	-31
Chikkaballapur	399	221	-45	222	143	-36
Chikkamagalur	1349	1525	13	228	179	-22
Chitradurga	276	363	32	160	212	33
Dakshina Kannada	3441	3195	-7	367	336	-8
Davanagere	373	507	36	173	212	23
Dharwad	498	477	-4	159	177	11
Gadag	382	438	15	162	132	-18
Hassan	673	818	22	225	167	-26
Haveri	485	576	19	168	188	12
Kalaburagi	614	491	-20	127	80	-37
Kodagu	2345	2116	-10	288	193	-33
Kolar	387	263	-32	236	182	-23
Koppal	376	452	20	142	125	-12
Mandya	304	387	27	233	217	-7
Mysuru	395	463	17	211	181	-14
Raichur	450	464	3	143	67	-53
Ramanagara	430	396	-8	238	209	-12
Shivamoga	1889	2012	6	202	156	-23
Tumakuru	361	379	5	204	221	8
Udupi	4071	3438	-16	299	310	4
Uttara Kannada	2457	2513	2	198	207	5
Vijayapura	428	373	-13	141	71	-50
Yadgir	592	484	-18	150	88	-41
State	839	833	-1	188	162	-13

Data source: KSNDMC, Govt. of Karnataka

Rainfall Situation in 2015

During the year 2015, the SW monsoon advanced over the Andaman Sea on 16 May, which was 4 days earlier than normal. However, it set in over Kerala on 5 June, which was 4 days later than its normal date of onset. Monsoon covered the entire Karnataka by 13 June. Between 1 June and 30 September, the State as a whole recorded 653 mm rainfall as against the normal 839 mm; the percentage departure from normal was -22% (Figure 3) and was classified as deficit.

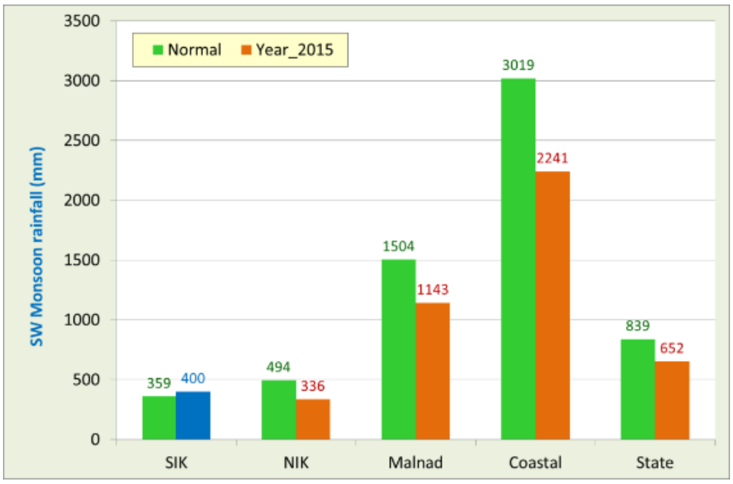


Figure 3: Region-wise rainfall in Karnataka during Southwest Monsoon 2015.

Out of the 30 districts, only Tumakuru and Chitradurga districts received excess rainfall. Fifteen districts (Bagalkote, Udupi, Uttara Kannada, Raichur, Dakshina Kannada, Kodagu, Gadag, Haveri, Shivamoga, Vijayapura, Dharwad, Yadgir, Kalaburagi, Bidar and Belagavi) received deficit rainfall; the remaining 13 districts received normal rainfall.

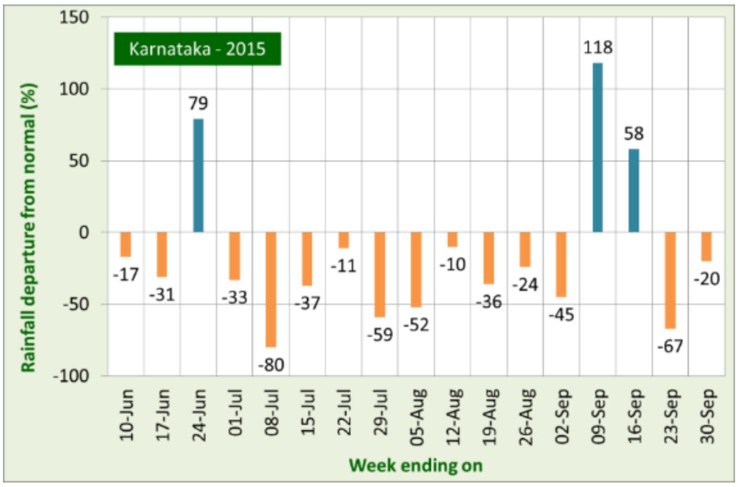


Figure 4: Weekly rainfall departure from the normal in Karnataka during 2015.

Weekly distribution of monsoon rainfall (Figure 4) shows that the State experienced very dry conditions during July and August. In September 2015, the rainfall situation improved in NI Karnataka and Malnad. Among the 176 taluks in the State, 21 received excess rainfall, 72 normal rainfall, 81 deficit rainfall, and two taluks received scanty rainfall (Table 5).

About 43% of the total geographical area (covering parts of the districts of Kolar, Chikkaballapur, Tumakuru, Chitradurga, Davanagere, Mysuru, Mandya, Ballari, Koppal, Raichur, Kalaburagi, Bidar, Belagavi, Bagalkote, Vijayapura, Gadag, Haveri, Dharwad and Yadgir) experienced moderate to severe moisture stress for agricultural crops (KSNDMC, 2015).

Table 5. District-wise rainfall in Karnataka during 2015.						
District	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
Bagalkote	350	278	-21	144	61	-58
Ballari	352	387	10	150	107	-29
Belagavi	612	363	-41	153	76	-50
Bengaluru Rural	441	482	9	234	333	42
Bengaluru Urban	460	492	7	229	328	43
Bidar	684	402	-41	116	34	-71
Chamarajanagar	305	298	-2	257	360	40
Chikkaballapur	399	413	4	222	431	94
Chikkamagalur	1349	1097	-19	228	286	25
Chitradurga	276	344	25	160	200	25
Dakshina Kannada	3441	2498	-27	367	436	19
Davanagere	373	378	1	173	152	-12
Dharwad	498	303	-39	159	110	-31
Gadag	382	272	-29	162	74	-54
Hassan	673	647	-4	225	229	2
Haveri	485	340	-30	168	123	-27
Kalaburagi	614	367	-40	127	43	-66
Kodagu	2345	1700	-28	288	275	-5
Kolar	387	374	-3	236	441	87
Koppal	376	343	-9	142	46	-68
Mandya	304	332	9	233	309	33
Mysuru	395	410	4	211	224	6
Raichur	450	327	-27	143	48	-66
Ramanagara	430	466	8	238	312	31
Shivamoga	1889	1308	-31	202	165	-18
Tumakuru	361	481	33	204	329	61
Udupi	4071	3073	-25	299	402	34
Uttara Kannada	2457	1832	-25	198	135	-32
Vijayapura	428	262	-39	141	54	-62
Yadgir	592	363	-39	150	39	-74
State	839	652	-22	188	178	-5

Data source: KSNDMC, Govt. of Karnataka

Rainfall during the Southwest Monsoon 2016

The SW monsoon advanced into south Andaman Sea and Nicobar Islands on 18 May 2016 (2 days ahead of its normal date). However, further advance was sluggish. It set in over Kerala on 8 June (7 days behind schedule) and covered the entire country by 13 July (against the normal date of 15 July). It entered Karnataka on 9 June 2016. After witnessing good rains over the first two days, the SW monsoon got subdued and no further advancement was observed until 19 June when it covered the whole state.

Between 1 June and 30 September, the whole state recorded 690 mm of rainfall as against the normal 839 mm; the percentage departure from normal was -18% and was classified normal (Table 6). Rainfall received in different regions indicates that all regions received lesser rainfall compared to their normal, with coastal Karnataka showing the largest deviation (Figure 5 & 6).

Table 6: District-wise rainfall in Karnataka during 2016.

District	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
Bagalkote	350	303	-13	144	10	-93
Ballari	352	310	-12	150	15	-90
Belagavi	612	519	-15	153	26	-83
Bengaluru Rural	441	471	7	234	101	-57
Bengaluru Urban	460	454	-1	229	106	-54
Bidar	684	901	32	116	100	-14
Chamarajanagar	305	206	-32	257	76	-70
Chikkaballapur	399	346	-13	222	76	-66
Chikkamagalur	1349	996	-26	228	70	-69
Chitradurga	276	213	-23	160	34	-79
Dakshina Kannada	3441	2627	-24	367	120	-67
Davanagere	373	367	-2	173	23	-87
Dharwad	498	369	-26	159	26	-84
Gadag	382	273	-29	162	10	-94
Hassan	673	580	-14	225	70	-69
Haveri	485	360	-26	168	24	-86
Kalaburagi	614	717	17	127	40	-69
Kodagu	2345	1557	-34	288	99	-66
Kolar	387	345	-11	236	107	-55
Koppal	376	317	-16	142	18	-87
Mandya	304	296	-3	233	93	-60
Mysuru	395	274	-31	211	56	-73
Raichur	450	404	-10	143	16	-89
Ramanagara	430	356	-17	238	92	-61
Shivamoga	1889	1264	-33	202	66	-67
Tumakuru	361	345	-4	204	63	-69
Udupi	4071	3161	-22	299	106	-65
Uttara Kannada	2457	2022	-18	198	110	-44
Vijayapura	428	383	-11	141	21	-85
Yadgir	592	530	-11	150	27	-82
State	839	690	-18	188	54	-71

Data source: KSNDMC, Govt. of Karnataka

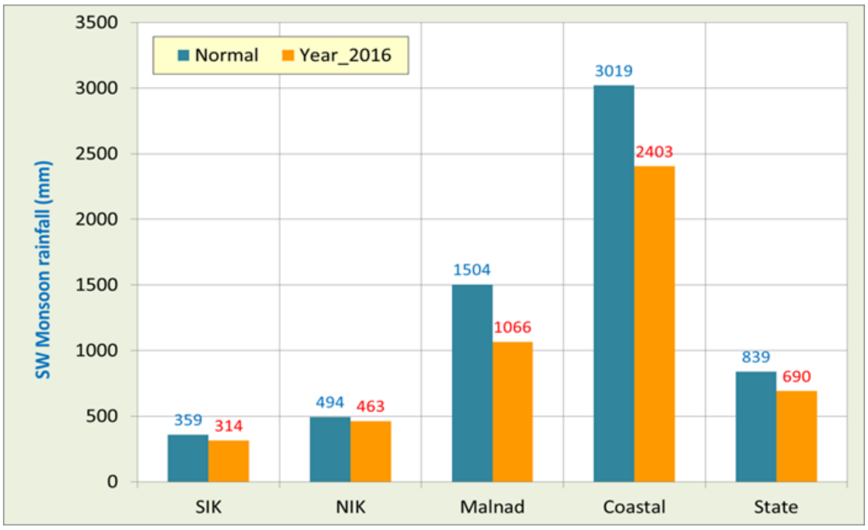


Figure 5: Region-wise rainfall in Karnataka during the Southwest monsoon, 2016.

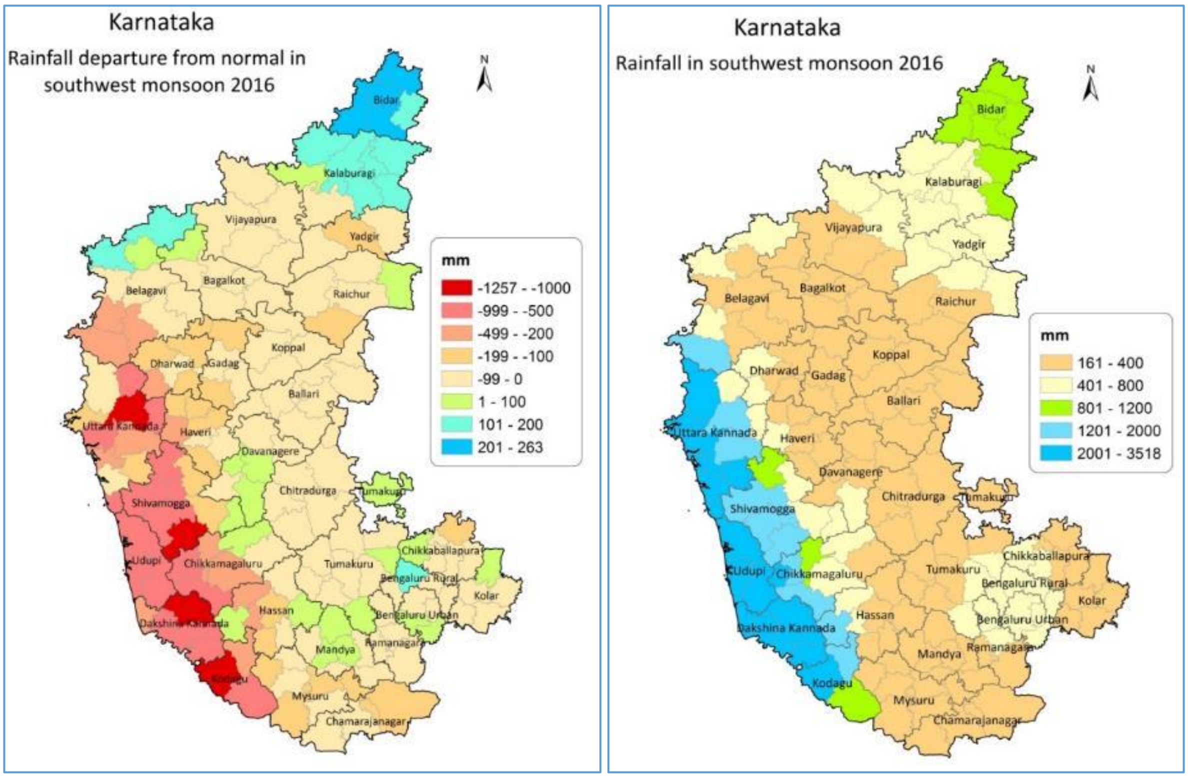


Figure 6: (L) Rainfall during the Southwest monsoon in 2016 and (R) rainfall departure from the normal.

Out of the 30 districts, only Bidar received excess rainfall. Eleven districts (Chamarajanagar, Chikkamagalur, Chitradurga, Dakshina Kannada, Dharwad, Gadag, Haveri, Kodagu, Mysuru, Shivamoga and Udupi) received deficit rainfall. The remaining 18 districts received normal rainfall. Out of the 176 taluks, 11 taluks received excess rainfall, 72 taluks deficit rainfall and the remaining 93 taluks received normal rainfall during the SW monsoon in 2016.

However, weekly rainfall distribution (Figure 7) shows that from the week ending 8 July onwards, the state as a whole experienced deficit rainfall, except for one week ending on 16 September. Different districts experienced different moisture conditions in different weeks. Chikkamagalur, Dakshina Kannada, Kodagu and Shivamogga districts experienced deficit rainfall from mid-July till end of September.

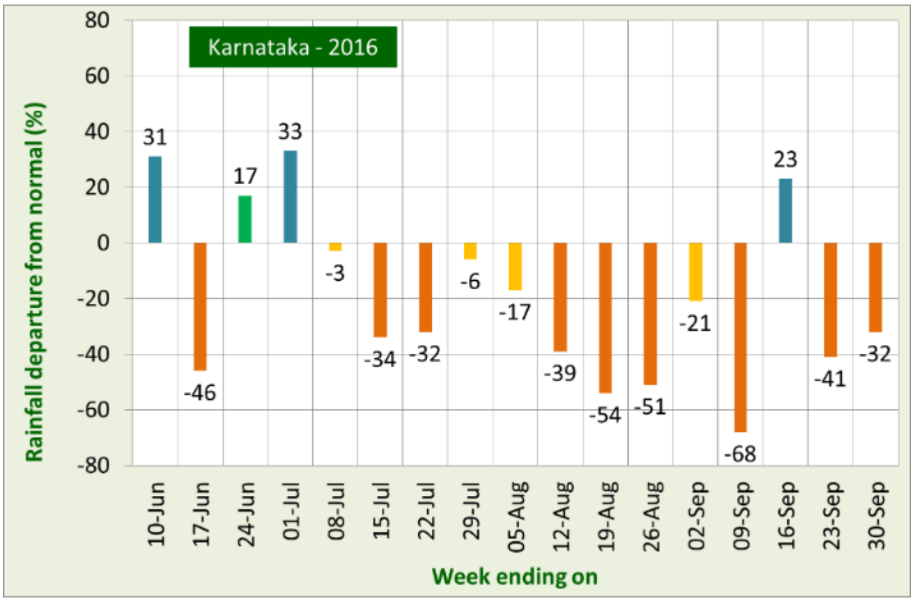


Figure 7: Weekly rainfall departure from the normal in Karnataka during 2016.

Rainfall Southwest Monsoon 2017

The SW monsoon advanced over Kerala on 30 May 2017. It further advanced into some more parts of northeast Bay of Bengal, remaining parts of Arunachal Pradesh, Nagaland, Manipur, Mizoram and most parts of Tripura and Assam and Meghalaya on 2 June. Subsequently there was a hiatus in the advancement due to the weakening of the monsoon flow over the Arabian Sea up to 5 June. Later on, the formation of a cyclonic circulation over Central Maharashtra and nearby and the formation of a low pressure area over west central Arabian Sea on 6 June revitalized the monsoon current. The SW monsoon commenced over Karnataka on 7 June 2017.

Between 1 June and 30 September 2017, Karnataka State as a whole received about 774 mm of rainfall (Figure 8) as against the normal rainfall of 839 mm; the percentage departure from normal was -8% and was classified under a normal category. Rainfall received in different regions indicates that all regions received normal rainfall, with south interior Karnataka showing excess rainfall.

Out of the 30 districts, 10 received excess rainfall and 14 normal rainfall. Six districts (Dakshina Kannada, Yadgir, Haveri, Shivamogga, Dharwad and Kodagu) received deficit rainfall. Out of the 176 taluks, 51 taluks received excess rainfall, 100 taluks normal rainfall and the remaining 25 taluks received deficit rainfall.

Table 7: District-wise rainfall in Karnataka during 2017.

District	Southwest Monsoon (Jun-Sep)			Post-monsoon (Oct-Dec)		
	Normal (mm)	Actual (mm)	Percentage departure	Normal (mm)	Actual (mm)	Percentage departure
Bagalkote	350	324	-7	144	121	-16
Ballari	352	439	24	150	129	-14
Belagavi	612	494	-19	153	120	-22
Bengaluru Rural	441	503	14	234	321	37
Bengaluru Urban	460	666	45	229	260	14
Bidar	684	591	-14	116	119	3
Chamarajanagar	305	448	47	257	209	-19
Chikkaballapur	399	402	1	222	275	24
Chikkamagalur	1349	1127	-16	228	144	-37
Chitradurga	276	344	25	160	209	31
Dakshina Kannada	3441	2763	-20	367	252	-31
Davanagere	373	448	20	173	199	15
Dharwad	498	381	-23	159	123	-23
Gadag	382	342	-10	162	105	-35
Hassan	673	691	3	225	129	-43
Haveri	485	385	-21	168	117	-30
Kalaburagi	614	568	-7	127	122	-4
Kodagu	2345	1815	-23	288	126	-56
Kolar	387	479	24	236	374	58
Koppal	376	489	30	142	134	-6
Mandya	304	507	66	233	177	-24
Mysuru	395	473	20	211	135	-36
Raichur	450	519	16	143	149	4
Ramanagara	430	642	49	238	258	8
Shivamoga	1889	1483	-21	202	108	-47
Tumakuru	361	421	16	204	234	15
Udupi	4071	3436	-16	299	284	-5
Uttara Kannada	2457	2195	-11	198	140	-29
Vijayapura	428	412	-4	141	116	-18
Yadgir	592	471	-21	150	135	-10
State 839	774	-8	188	163	-13	

Data source: KSNDMC, Govt. of Karnataka

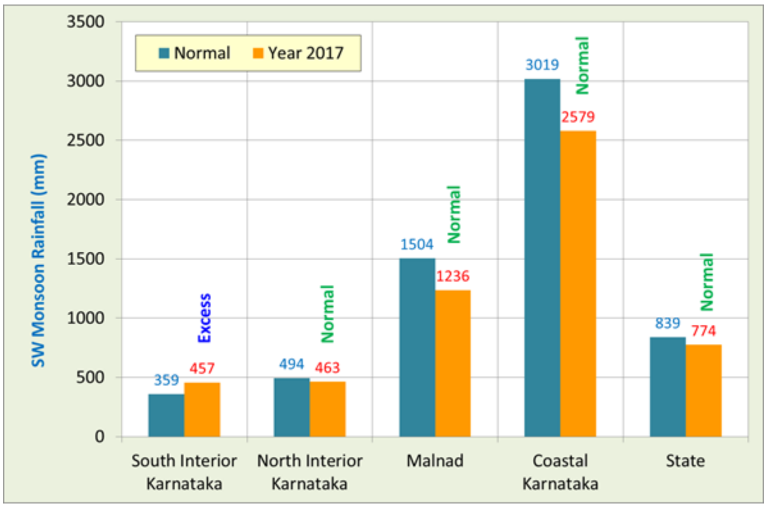


Figure 8: Region-wise rainfall in Karnataka during Southwest monsoon, 2017.

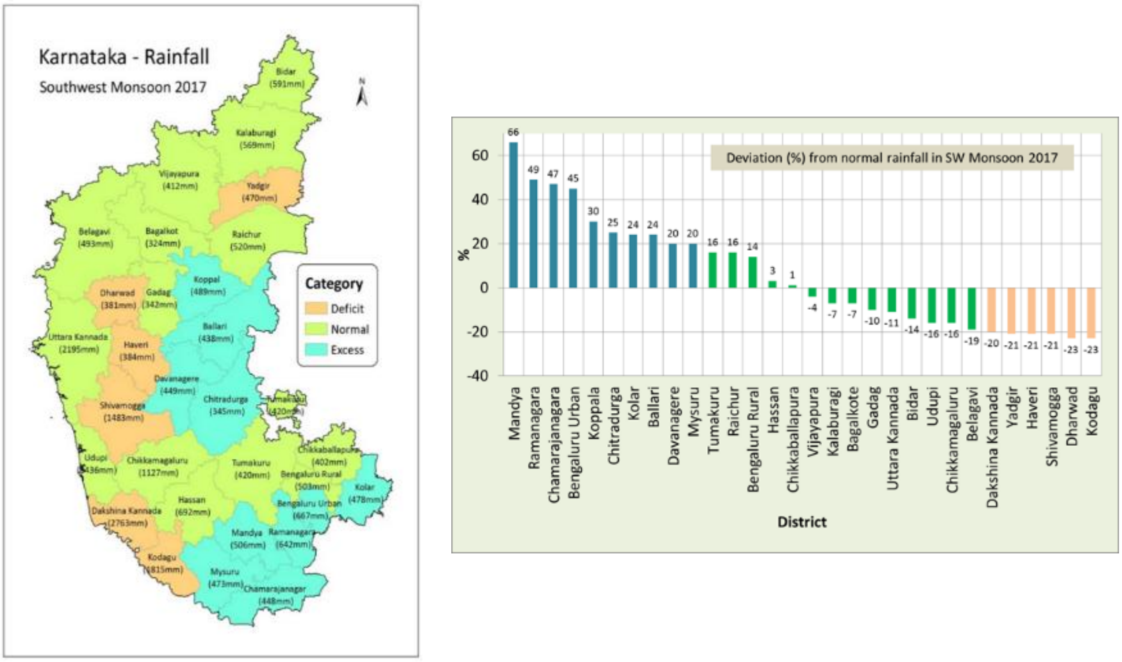


Figure 9: (L) Rainfall during the Southwest monsoon 2017 and (R) rainfall deviation (%) from the normal.

Weekly distribution of rainfall during June to December 2017 (Figure 10) shows deficit conditions from July to mid-August. Excess rainfall conditions were observed from the third week of August to mid-October; from week ending 28 October onwards, the State as a whole experienced deficit and scanty rainfall conditions.

Table 8: Region-wise seasonal rainfall in Karnataka during 2013-17.							
Region	Season	Item	Year				
			2013	2014	2015	2016	2017
South Interior Karnataka	Southwest Monsoon	Actual	412	379	400	314	457
		Normal	359	359	359	359	359
		% Departure	15	6	11	-13	27
	Post-Monsoon	Actual	125	205	297	67	227
		Normal	210	210	210	210	210
		% Departure	-40	-2	41	-68	8
North Interior Karnataka	Southwest Monsoon	Actual	533	475	336	463	463
		Normal	494	494	494	494	494
		% Departure	8	-4	-32	-6	-6
	Post-Monsoon	Actual	100	112	66	27	124
		Normal	145	145	145	145	145
		% Departure	-31	-23	-54	-81	-14
Malnad	Southwest Monsoon	Actual	1816	1592	1143	1066	1236
		Normal	1504	1504	1504	1504	1504
		% Departure	21	6	-24	-29	-18
	Post-Monsoon	Actual	135	171	231	73	126
		Normal	228	228	228	228	228
		% Departure	-41	-25	1	-68	-45
Coastal Karnataka	Southwest Monsoon	Actual	3206	2867	2241	2403	2579
		Normal	3019	3019	3019	3019	3019
		% Departure	6	-5	-26	-20	-15
	Post-Monsoon	Actual	266	260	264	112	196
		Normal	261	261	261	261	261
		% Departure	2	0	1	-57	-25
Karnataka State	Southwest Monsoon	Actual	934	833	653	690	774
		Normal	839	839	839	839	839
		% Departure	11	-1	-22	-18	-8
	Post-Monsoon	Actual	129	163	178	54	163
		Normal	188	188	188	188	188
		% Departure	-31	-13	-5	-71	-13

Data source: KSNDMC, Govt. of Karnataka

In the post-monsoon period (1 October to 31 December 2017), Karnataka received a rainfall of 163 mm against the normal of 188 mm, the percentage departure from the normal was -13% and thus classified as normal.

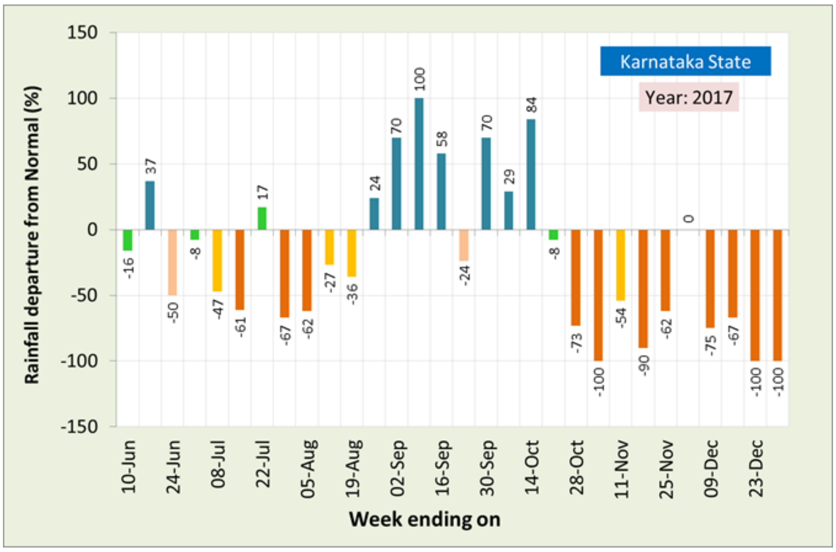


Figure 10: Weekly rainfall departure from the normal in Karnataka during 2017.

Chikkaballapur, Chitradurga, Bengaluru Rural and Kolar received excess rainfall; Belagavi, Dharwad, Mandya, Uttara Kannada, Haveri, Dakshina Kannada, Gadag, Mysuru, Chikkamagalur, Hassan, Shivamoga and Kodagu districts received deficit rainfall. The remaining 14 districts received normal rainfall.

An assessment of both SW monsoon and post-monsoon periods in the four regions (SI Karnataka, NI Karnataka, Malnad and Coastal Karnataka) and Karnataka state during 2013-17 will reveal that rainfall was in excess thrice, in deficit sixteen times and scanty four times (all in the year 2016). Thus, in the five-year period, Karnataka experienced dry conditions many times.

Long-term changes in rainfall in Karnataka districts

Monthly rainfall data of the 30 districts in Karnataka was collected for the period 1971 to 2016 (46 years) from the publications of the India Meteorological Department. The 30-year period (1971-2000) was considered as the "Normal" and the average rainfall for the 16-year (2001-2016) period was computed. The difference between the latest average rainfall with the long-term normal rainfall was compared for different seasons; Figure 10 shows the changes in annual rainfall.

Figure 10 shows that great changes in annual rainfall have occurred in the recent period. Dakshina Kannada and Shivamoga districts had the greatest reduction in rainfall (>300 mm) while Chitradurga, Davanagere and Kolar districts had increased rainfall. When different seasons are considered, summer season (March-May) had more rainfall; while both the SW monsoon and post-monsoon seasons experienced lower rainfall compared to the normal. In general, the whole Karnataka state appears to be having lesser rainfall in the present compared to the recent past.

Table 9: Rainfall changes in Karnataka in two selected periods (2001-2017 and 1971-2000).				
District	Rainfall change (mm)			
	Summer (Mar-May)	SW Monsoon (Jun-Sep)	Post-monsoon (Oct-Dec)	Annual
Chitradurga	50	39	7	96
Davanagere	40	27	-7	63
Kolar	43	2	15	60
Hassan	43	-10	0	36
Chikkamagalur	32	31	-31	35
Tumakuru	27	-10	-2	24
Koppal	30	-6	-13	23
Chikkaballapur	39	-12	-9	15
Bengaluru Urban	54	-38	-2	12
Mandya	31	-30	5	6
Bidar	18	19	-35	-1
Haveri	32	-11	-29	-4
Ballari	28	-18	-16	-5
Mysuru	12	-19	-12	-21
Kalaburagi	28	5	-56	-24
Udupi	51	-133	41	-38
Gadag	23	-41	-28	-46
Bagalkote	12	-33	-28	-50
Bengaluru Rural	36	-57	-25	-50
Chamarajanagar	-3	-52	-6	-65
Uttara Kannada	38	-99	-11	-69
Vijayapura	10	-29	-50	-70
Kodagu	48	-114	-20	-80
Dharwad	10	-65	-34	-89
Raichur	11	-52	-51	-92
Belagavi	6	-103	-16	-112
Ramanagara	-7	-95	-25	-132
Yadgir	5	-200	-74	-274
Dakshina Kannada	53	-438	3	-378
Shivamoga	40	-475	-43	-474
State	29	-68	-19	-57

Data source: India Meteorological Department

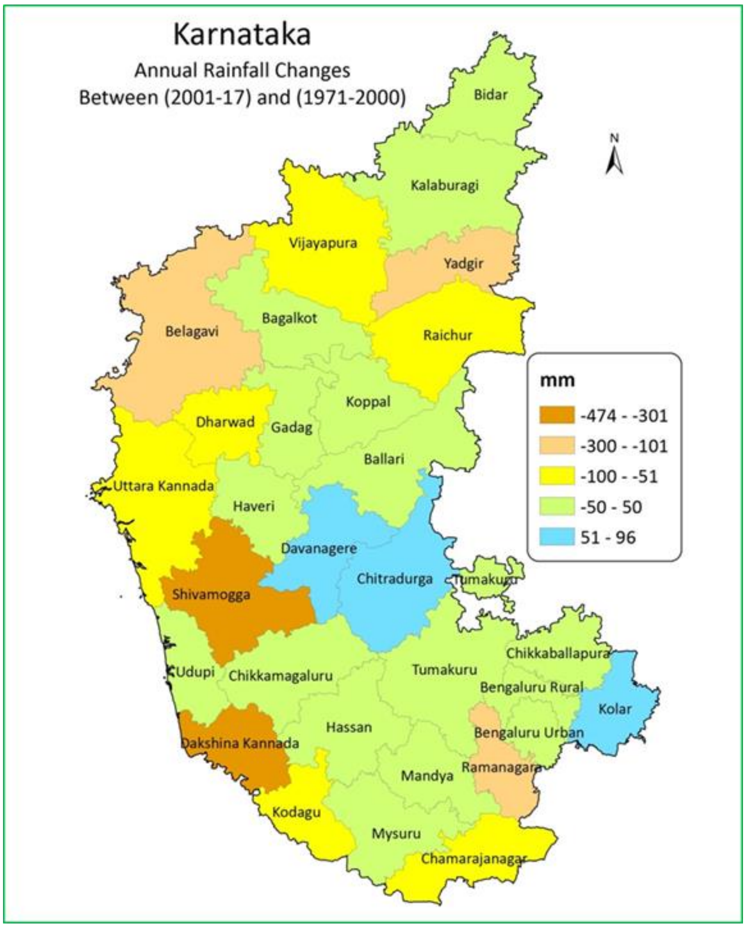


Figure 11: Changes in Southwest monsoon rainfall in Karnataka.

Meteorological droughts in Karnataka

As per the India Meteorological Department (IMD), the State is divided into three meteorological sub-divisions -- North Interior Karnataka, South Interior Karnataka and Coastal Karnataka. In August 2017, the Indian Institute of Tropical Meteorology (IITM), Pune released monthly rainfall data series for 1871-2016 for the 30 sub-divisions in India. Data for the three sub-divisions in Karnataka was collected from the IITM and used for understanding the occurrence of meteorological droughts.

According to India Meteorological Department, meteorological drought over an area is defined as a situation when the seasonal rainfall received over the area is less than 75% of its long term average value. It is further classified as "Moderate drought" if the rainfall deficit is between 26-50% and as "Severe drought" when the deficit exceeds 50% of the normal. This criterion was used to classify seasonal droughts.

To classify a drought, a 30-year normal is needed. Hence data for 1931-60 was taken for computing the monthly and seasonal normal for the three meteorological sub-divisions in Karnataka. Actual rainfall each year for the period 1961-2016 was compared with the normal and each year drought, if any, was classified and decadal totals were obtained.

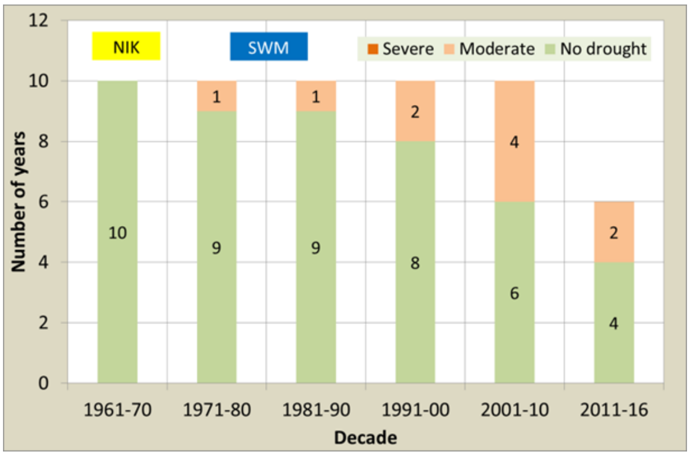


Figure 12: Decadal frequency of Southwest monsoon droughts in North Interior Karnataka.

Decadal frequencies of meteorological droughts in the SW monsoon (Jun-Sep) period for 1961-2016 in the three IMD meteorological sub-divisions in Karnataka are presented in Figures 12, 13 and 14. In all the three sub-divisions, increasing trends in the occurrence of droughts are seen, highlighting the need for proper water management at watershed level in future.

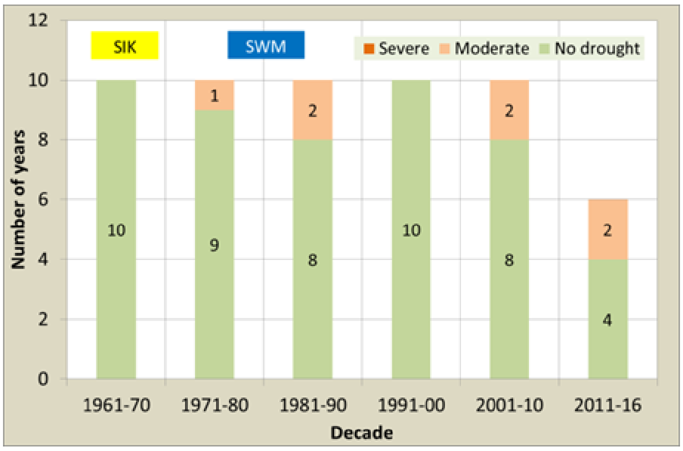


Figure 13: Decadal frequency of Southwest monsoon droughts in South Interior Karnataka.

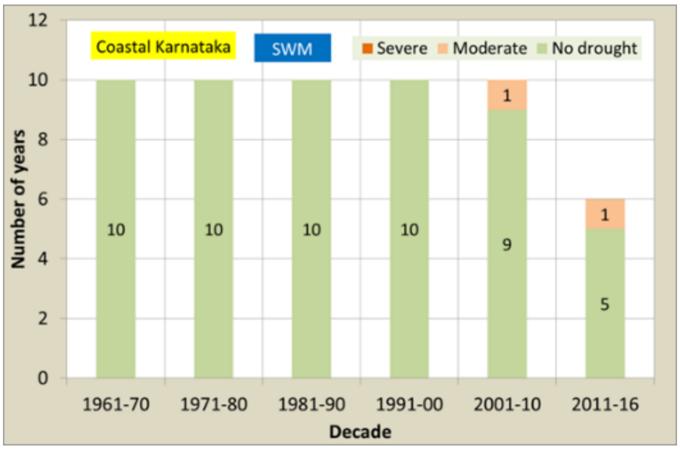


Figure 14: Decadal frequency of Southwest monsoon droughts in Coastal Karnataka.

6. Repeat Soil Analysis in Districts

An effort has been made to assess the quality of soil in the first year in the district, to ascertain whether the adoption of micro and secondary nutrient had resulted in improving soil health in these districts. Soil samples analyzed from four districts during 2013-14 indicated a positive trend in terms of improved soil health.

Employing a soil test-based nutrient management strategy in farmers' fields in Karnataka improved the soil fertility status of farmers' fields as was evident from decreased deficiency (%) in potassium, phosphorus, sulphur, and boron (Figure 15). However, organic carbon and zinc deficiency increased.

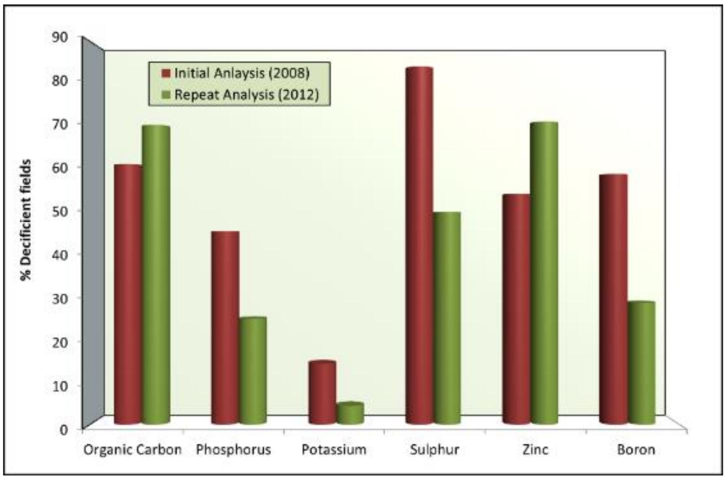


Figure 15: Percentage of fields deficient in micro and secondary nutrients in Karnataka.

In Chitradurga, the soil fertility status improved in terms of potassium, phosphorus, sulphur, zinc and boron (Figure 16). However, organic carbon deficiency increased.

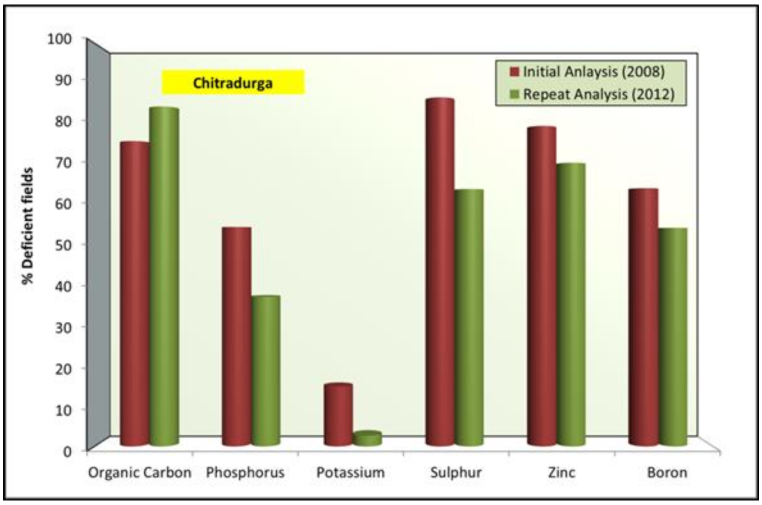


Figure 16: Percentage of fields deficient in micro and secondary nutrients in Chitradurga.

In Haveri, the soil fertility status of farmers' fields is improving as is evident from decreased deficiency in potassium, phosphorus, sulphur, and boron (Figure 17). However, organic carbon and zinc deficiency increased. In Kolar, zinc deficiency increased (Figure 18).

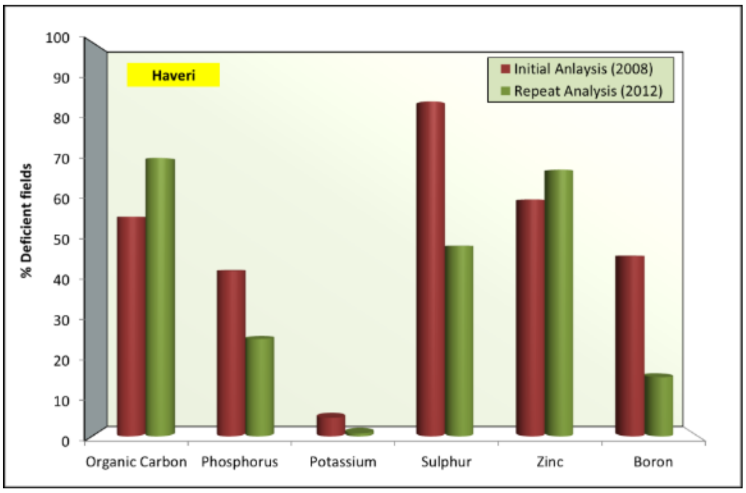


Figure 17: Percentage of fields deficient in micro and secondary nutrients in Haveri

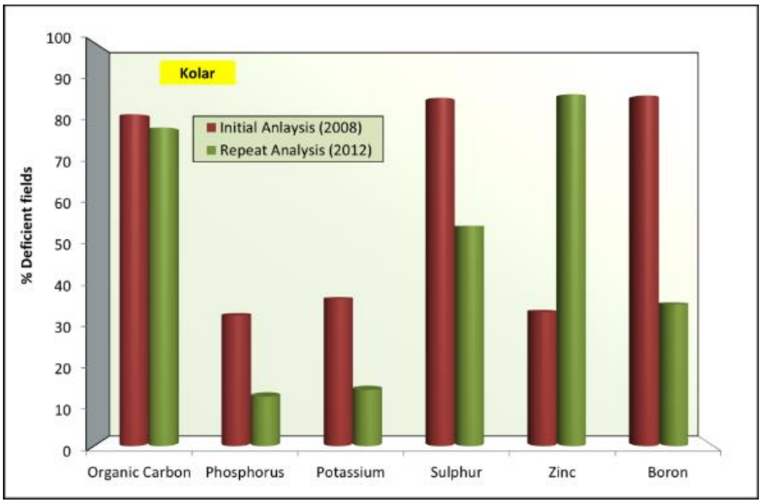


Figure 18: Percentage of fields deficient in micro and secondary nutrients in Kolar.

In Dharwad, soil fertility status improved in terms of potassium, phosphorus, sulphur, and boron (Figure 19). However, organic carbon and zinc deficiency increased.

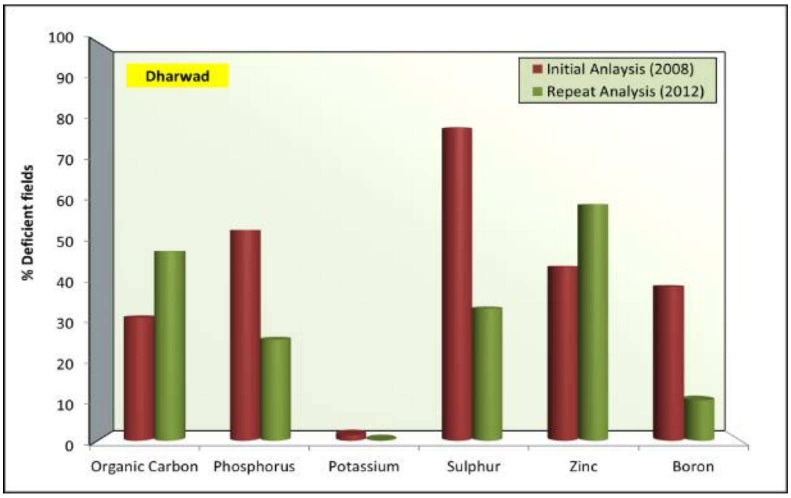


Figure 19: Percentage of fields deficient in micro and secondary nutrients in Dharwad.

In terms of mean availability of soil nutrients, there was a positive improvement in potassium, phosphorus, sulphur, zinc, organic carbon and boron (Figure 20), other nutrients need attention.

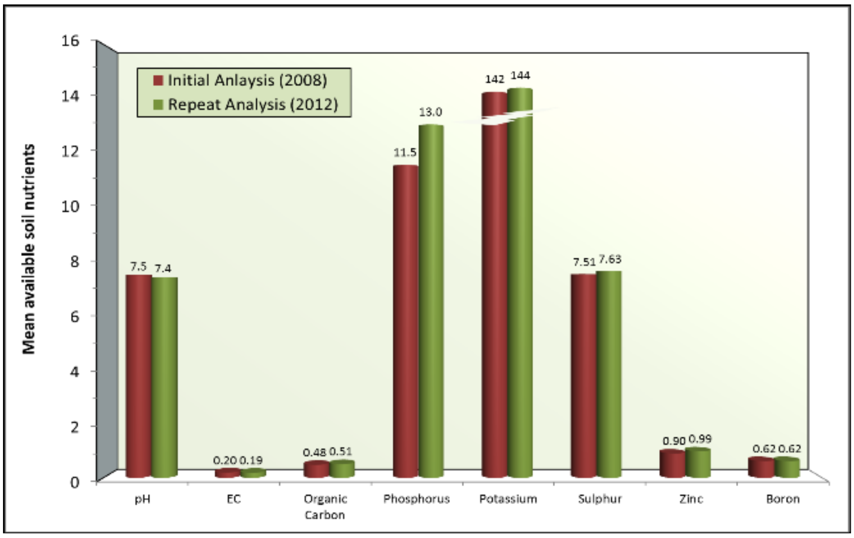


Figure 20: Mean available soil nutrients in farmers' fields in Karnataka.

7. Rainfed Agricultural Technologies Promoted

The technologies below have been popularized and recommended in different districts to enhance their benefits.

In-situ Soil and Water Conservation Techniques

i. Conservation furrow system

Contour furrows are simple and efficient for conserving moisture. These are laid with the help of country ploughs on a gradient of 0.2 to 0.4% at the time of sowing or during intercultural operations.

ii. Cultivation across slope

Cultivation across the slope, or contour cultivation, is the most common practice for conserving soil moisture. In this method, all field activities including ploughing, planting, and intercultivation are done across the slope.

iii. Broad-bed and furrow (BBF)

For *in-situ* soil and water conservation, the broad-bed (1 m) and furrow (0.5 m) system (BBF) has been found to be satisfactory on deep black soils. The BBF system is laid out on a slope of 0.4–0.8% with an optimum slope of 0.6%. The BBF system facilitates draining of excess rainwater as runoff and furrows act as traffic zones for plough bullocks. On Alfisols, raised beds are well-suited for groundnut cultivation as beds facilitate good aeration and store more moisture for the roots, resulting in good crop growth. Deep tillage, shallow cultivation and application of organic residues are some of the other promising *in-situ* moisture conservation practices.

7.1 Integrated Nutrient Management techniques

i. Balanced nutrient application

Balanced use of plant nutrients involves correcting nutrient deficiency and restoring soil fertility of degraded lands (due to overexploitation). It increases nutrient and water use efficiency, enhances crop yields and farmers' income, and improves crop and environmental quality. Hence we used soil analysis results and seasonal rainfall as the basis to recommend fertilizer doses. Availability of organic manure, crop residues, and biofertilizers was also considered in order to provide taluk-wise recommendations for different crops in all districts.

ii. Biofertilizers

Biofertilizers are very important, low-cost, eco-friendly organic agro-inputs, supplementary to chemical fertilizers. *Rhizobium, Azospirillum* and *Azotobacter* add nitrogen to the soil, and phosphate-solubilizing bacteria make citrate soluble phosphorous available to crops and also secrete certain growth promoting substances. Biofertilizers improve soil structure (porosity) and its water-holding capacity. They also increase soil fertility, fertilizer use efficiency (FUE) and ultimately help by increasing yields by 15-20%. Due to a higher concentration of calcium in alkaline soils, large quantities of applied phosphatic fertilizers get fixed as citrate soluble tri-calcium phosphate and become unavailable to the crops.

Phosphate solubilizing bacteria (PSB) are useful for all crops i.e. cereals, cash crops, leguminous crops and vegetables, as they secrete organic acids to make citrate soluble tri-calcium phosphate available to crops in alkaline soils. Effective strains of PSB increase the level of available P_2O_5 in the soil. About 10-15% increase in crop yield can be achieved with the use of this culture. Seed treatment with 250 g/10 kg of seed is advised. As suggested, PSB and *Trichoderma viride* were applied to soil as seed treatment along with *Rhizobium* and fungicides for groundnut and soybean.

iii. Vermicomposting

Vermicomposting converts farm residues and organic waste in villages with the help of earthworms into valuable manure. This was introduced to farmers and rural women as a technology through the Sujala-ICRISAT project. Several compost units were constructed in the watershed villages during the project period. Technology components mainly include selection and use of non-burrowing type of earthworms (*Eisenia sp*., *Eudrilus sp*.), and the use of biodegradable materials like weeds, crop and sericulture residues, animal and poultry manure, and rock phosphate.

During training sessions, farmers and Farm Facilitators were briefed about vermicomposting's advantages of enriching soil organic carbon, raising productivity and achieving good storage quality of the produce without toxic residues, thereby fetching a higher price for organic produce in the markets. Training on scientific methods of vermicompost preparation was provided to rural women SHG members and field facilitators as a rural livelihood option.

iv. *Gliricidia* on field bunds

Farmers were encouraged to plant 3-4 month-old *Gliricidia* saplings acquired from a nursery or cuttings of tender branches at a spacing of 50 cm on field bunds. *Gliricidia* abundantly produces green leaves and succulent green branches which are rich in nitrogen. Green leaf and loppings can be harvested, leaving one-year-old 1 m tall plants in place. This is applied to the topsoil for enriching organic carbon and nutrients in the soil. *Gliricidia* on bunds can be harvested thrice a year and applied before sowing of rainy season, rabi and summer season crops.

v. *Azolla* Fern

Farmers grow *Azolla* fern in small ponds to use as soil fertilizer as well as to enrich the feed for their livestock. Given the drought in the state that affected livestock and deprived farmers of extra income for the family, farmers were enthusiastic to adopt this method as it has improved milk yield as well as its fat content.

7.2 Improved crop production practices

i. Transplanting in pigeonpea

The main challenge in pigeonpea is the time of sowing. Farmers sow during late June or early July. Delay in sowing drastically affects yields. Sowing is completely dependent on the monsoon. To overcome this natural problem, several hundred farmers grow this crop in polybags first and then transplant them in the main field for better yields. Transplantation of pigeonpea was adopted by farmers in Bidar, Gulbarga, Yadgir and Kolar districts of Karnataka (Figure 20). The process involves raising seedlings in polythene bags in the nursery for a month and transplanting them in the field during the onset of the monsoon.

The major advantages for farmers are: sowing can be done in the second week of May every year even if it does not rain at the right time; due to early sowing, pod borer insect damage can be avoided; drought tolerance develops due to deep rooting; it is easy to spray insecticides as plants are at definite intervals; wider spacing allows enough sunlight to reach the leaves of each pigeonpea plant thus reducing competition for water, space and nutrients. Seed saving is also considerable as only 2 kg of seeds are required per hectare against 10-12 kg per hectare with the normal practice.

Figure 21: Transplanting in pigeonpea.

ii. Guli method of finger millet cultivation

Despite resorting to high yielding varieties and applying fertilizers and chemicals, farmers get at most 3,750 kg of finger millet per ha. Farmers in Karnataka practice a unique method of cultivating finger millet called *Guli Vidhana* – square planting, which is easy to adopt. Guli Vidhana is simple and similar to SRI, popularly known as the Madagascar method of cultivation. Sowing 2.5 kg of a local variety of seed leads to yields between 4500 to 5,000 kg per ha. A row spacing of 1.5 feet must be maintained to reduce disease.

iii. Paired row planting of pigeonpea

Pigeonpea is often intercropped with legumes or cereals in rainfed areas. Recent interest in integrated weed management has brought attention to the possibility of suppressing weeds with intercrops. Short-duration legumes which have fast early growth and close canopies are good competitors with weeds. A short-duration legume intercrop means that it only competes with pigeonpea for a short period of time; this minimizes pigeonpea yield loss due to intercropping. In addition, the intercrop itself can contribute to total productivity of the plot. Intercropping using legumes (green gram, black gram, cowpea, groundnut, and soybean) and cereals (sorghum, finger millet and maize) with paired row planting of pigeonpea could greatly reduce the need for other financially and environmentally costly weed control measures and increase the productivity of the system (Figure 21).

Figure 22: Paired row planting of pigeonpea in maize, Davanagere district

iv. Pest monitoring using pheromone traps

Sex pheromones are used to monitor populations of a number of pest species including *Helicoverpa* spp. and *Spodoptera* spp. Pheromones are specific to individual insects and monitoring them helps to take precautions and minimizes unnecessary insecticide sprays. Pheromone traps cannot control crop pests but the data obtained from these traps helps predict infestations and assists in the timely use of control measures. Farmers in the project are using pheromone traps to monitor pest incidence as well as to take suitable control measures at the appropriate time.

v. Pest-tolerant cultivars

ICRISAT has developed cultivars resistant to pests, diseases and drought in sorghum, pearl millet, groundnut, pigeonpea and chickpea. By adopting cultivars resistant to insect pests and diseases, farmers can avoid crop losses with minimum use of pesticides. High yielding, pest, disease and drought tolerant cultivars of different crops were supplied by ICRISAT for farmer participatory varietal evaluation and selection in all the districts of Karnataka.

vi. Cultural control

Another major component of an IPM program is cultural control. Farming systems can be manipulated and adjusted in various ways. These options include early or delayed sowing, selection of intercrops, altering plant density or arrangement and sowing genetic mixtures to reduce the impact or severity of insect pests. These options are location-specific and must be designed to suit local practices and customs. Farmers in Karnataka are adopting the following cultural control methods.

- Intercropping coriander with chickpea may provide a nectar source for adult parasitoids and improve natural control of *Helicoverpa* in chickpea.
- Castor or sunflower attracts *Spodoptera* when intercropped with groundnut and thus reduces pest infestation of groundnut.
- Manually shaking pigeonpea plants helps dislodge *Helicoverpa* larvae when there is heavy infestation.
- Aphid or jassid infestation can be minimized by growing mung bean or cowpea as an intercrop or border crop with cotton.

vii. Increasing the natural control process

All pests on crops are not harmful. There are several “farmer-friendly” pests too which are categorized into three groups: parasites, predators and pathogens. Predators hunt and consume all or part of their prey; e.g. spiders, ladybird beetles, dragonflies and insectivorous birds. Parasitoids live on or in the body of their host. Many parasitoids have been reported to feed on *Helicoverpa* and *Spodoptera*. Parasitoids can be mass-reared and released into an infested field. In addition, departmental biological control labs and a number of commercial companies are making parasitoids, the most common being the egg parasitoid, *Trichogramma* spp. which attack eggs of *Helicoverpa* and other lepidopterans. Among insect pathogens that cause severe mortality, viruses are important. Of viruses that kill pests, the nuclear polyhedrosis virus (NPV) is the most important. Farmers in Karnataka are adopting the following control measures to increase natural enemies in crop fields.

- Installing bird perches in the field to attract predatory birds (egrets) which prey on insect pests.
- Irrigating groundnut fields during the day; *Spodoptera* larvae are forced to come out of the soil and are eaten by birds.
- Using eco-friendly bio-rational and synthetic pesticides to save natural enemy populations.

viii. Bio-rational pesticides

Bio-rational pesticides contain biologically active products such as plant derived products, hormones, microbial agents (*Bacillus thuringiensis*, NPV), pathogenic fungi, etc. These products are usually safe for human beings and for the environment. Among various bio-rational products, neem and NPV are used by farmers in Karnataka for plant protection.

ix. Bio-fungicide

Trichoderma viride is a fungus used for seed treatment and soil application. It is mixed with FYM for the suppression of various diseases caused by fungal pathogens through seeds and the soil. The procedure to treat seeds is to mix *Trichoderma viride* with cooled rice gruel or jaggery solution and thoroughly mix this solution with enough seeds for one acre so as to have a uniform coating over the seeds. These seeds are dried for 30 minutes in the shade and the treated seeds are sown within 24 hours. For soil application, the culture can be mixed with 50 kg or 100 kg FYM and incorporated in the field.

8. Technologies adopted in Irrigated Paddy and Sugarcane

Since the project's focus is to extend it to irrigated crops, different technologies have been promoted to spread its benefits to farmers; among those used in irrigated paddy during kharif season 2014 were machine transplantation (4,278 ha) and Dry Seeded Rice method (15,435 ha), in 14 major rice growing districts in Karnataka. Similarly, the new technologies being used in sugarcane are single eyebud demo (746 ha), wider row spacing (28,925 ha), and drip irrigation (16,075 ha) in 12 major districts. Technologies related to integrated nutrient management and integrated pest management were also adopted with great benefits.

i. Direct-seeded rice (DSR)

Water and labor scarcity and climatic changes are making the growing of conventional puddled transplanted rice difficult. Under direct seeding, the rice seeds are directly sown in a well prepared main field (either in dry or wet condition). In dry rice cultivation, seeds are treated with 1% KCl and sown at 15-20 cm distance using seed drills at 5 cm depth. In wet rice cultivation, the seeds are soaked in water and kept in the dark to sprout before they are sown. The sprouted seeds are sown in well puddled and levelled fields using drum seeders. Both the methods have their own merits and demerits.

Direct-seeded rice (DSR) is a feasible alternative with good potential to save water, reduce labor requirement, mitigate greenhouse gas (GHG) emission and adapt to climatic risks. The yields are comparable with transplanted rice if the crop is properly managed. In recent years, efforts have been made by various organizations to promote this technology, for which scientists are concentrating on developing suitable varieties and agronomic packages. However, DSR suffers from some constraints particularly, high weed infestation. The system has proven to be cost-effective and farmer friendly but requires further improvements to realize greater benefits.

ii. Drum seeded rice plantation

In the direct seeding method of rice cultivation, the need for a nursery, pulling, transporting and transplanting seedlings are avoided as pre-germinated seeds are directly sown using a well puddled and levelled wet field. The seed is dropped in rows at 20 cm row-to-row spacing and the seed rate is about 25-37.5 kg/ha. The drum seeder is made of fiber material and hence requires a low pulling force to operate. It allows one person to sow one hectare in 5-6 hours compared to three to four days of transplanting by 30-40 people with the traditional cultivation method.

iii. Machine transplanting

Machine transplanting using rice transplanters requires considerably less time and labor than manual transplanting. It increases the approximate area that a person can plant from 700 to 10,000 square metres per day. A rice transplanter is a specialized transplanter designed to transplant rice seedlings onto a paddy field. A common rice transplanter comprises:

- A seedling tray like a shed roof on which a mat type rice nursery is set;
- A seedling tray shifter that shifts the seedling tray like a carriage of typewriters; and
- Plural pickup forks that pick up a seedling from the mat type nursery on the seedling tray and put the seedling into the earth, as if the seedling were taken between human fingers (Figure 22).

Figure 23: (L) A paddy nursery ready for machine transplanting and (R) machine transplanting of paddy in Davanagere district.

iv. Bud chip method of sugarcane planting

Sugarcane is a vegetatively propagated crop. Cane cuttings with one, two or three buds known as sets are used as seed. In India, the conventional system of sugarcane cultivation uses about 6-8 metric tons of seed cane/ha as planting material, which comprises about 32,000 stalk pieces, each with 2-3 buds. This large mass of planting material poses a great problem in transportation, handling and storage of seed cane and undergoes rapid deterioration thus reducing the viability of the buds and subsequently their sprouting. One alternative to reduce the mass and improve the quality of seed cane would be to plant excised axillary buds of cane stalk, popularly known as bud chips. These bud chips are less bulky, easily transportable and more economical seed material. The bud chip technology holds great promise in rapid multiplication of new cane varieties. The leftover cane can be utilized to prepare juice or sugar or jaggery.

v. High Density Planting (HDP) of sugarcane:

Increased planting density using High Density Planting (HDP) can significantly improve the yield per unit area from a sugarcane crop (Figure 23). HDP generates a more rapid ground cover than the traditional crop grown with 1.5 meter (5.0 foot) row spacing, thereby increasing solar radiation interception and absorption of water and nutrients. In various studies, increased plant density has translated into increased numbers of sugarcane stalks per unit area, and increased stalk number is directly correlated to increased yield.

Figure 24: (L) Paired row planting of sugarcane in Gowribidanur taluk, Chikkaballapur district and (R) sugarcane crop under drip irrigation with green manure crop for incorporation, Maddur taluk of Mandya district.

9. Area and beneficiary coverage during Bhoochetana phase 2

Under Bhoochetana phase 2, farmers were motivated to cover a large area under different crops with different activities for possible benefits. However, due to variation in rainfall, the area coverage did not reach the expected level. During 2013 kharif season, Bhoochetana activities were targeted to cover an area of 56.09 lakh ha with improved management to enhance rainfed as well as irrigated crop productivity in all 30 districts. The project implemented crop productivity enhancement technologies with major cereals, legumes and oilseeds on 50.41 lakh ha which corresponded to 89.9% of the target area. During rabi season, the area coverage was 90.6% of the target area (Table 10). Similarly, 2014-15 kharif and rabi season, the area coverage was nearly 88% and 77% respectively. The same pattern was continued during 2015-16 season also. During 2016-17, the area coverage was more than 95% of the target area in kharif season but less than 70% in rabi season. Due to change in guidelines, the cluster level demonstrations were targeted during 2017-18 season (Annexure 1).

Table 10. Area coverage under Bhoochetana phase 2 in Karnataka – 2013-14 to 2017-18

	Kharif			Rabi		
Year	Target (ha)	Achieved (ha)	% achieved	Target (ha)	Achieved (ha)	% achieved
2013-14	56,09,830	50,41,300	89.9	25,00,000	22,63,832	90.6
2014-15	55,97,894	49,15,597	87.8	5,37,350	4,10,992	76.5
2015-16	52,70,280	44,26,033	84.0	26,42,500	22,59,809	85.5
2016-17	55,26,516	53,40,926	96.6	25,00,000	16,82,580	67.3
2017-18*	86,992	62,683	72.1	64,832	32,875	50.7

Note: During 2017-18, Bhoochetana guidelines were changed to target cluster level demonstrations of 100 ha in each district. However, few districts reported demonstrations undertaken in other programs as well.

During five year period of Bhoochetana 2 Phase, nearly 4 million farmers were covered in the state. The major crops covered include pigeonpea, sorghum, pearlmillet, finger millet, groundnut, sunflower, soybean, safflower, greengram, blackgram, maize, foxtail millet, cotton, chickpea, etc.

10. Yield Analysis of Major Crops

Farmers were selected for participatory trials to evaluate the impact of improved management practices on crop yields. Of the selected farmers, those who implemented improved management practices in their fields were monitored and crop cutting experiments were done. The improved management practice also involved soil test-based balanced nutrient management which involved the application of deficient S, B, Zn, N, P and K. There were two treatments: (1) farmer's practice (FP) of applying N, P and K, and traditional crop cultivation; and (2) Improved management comprising soil test-based nutrient management (application of N, P and K plus deficient S, B and Zn) plus other improved crop practices. Soil test-based balanced nutrient management protocols were developed based on the soil test results at the taluk level. Where more than 50% of farmers' fields were deficient in a particular nutrient, the full complement of that nutrient was recommended and where less than 50% of farmers' fields were deficient, half the rate of the nutrient was recommended. Crop cutting experiments were conducted with all prominent crops such as chickpea, sorghum, sunflower and safflower, pigeonpea, maize, groundnut, finger millet, pearl millet.

Crop season 2013-14

In Karnataka as a whole, cereals' yield increase was significant during rainy season 2013 (Figure 25). Yield increase ranged between 20 and 53% across different cereals. While maize recorded the highest yield, pearl millet recorded highest incremental yield (the difference between farmers' practice and improved practice). Similarly, legumes performed significantly better over farmers' practice, the yield increase ranging between 28 and 37%.

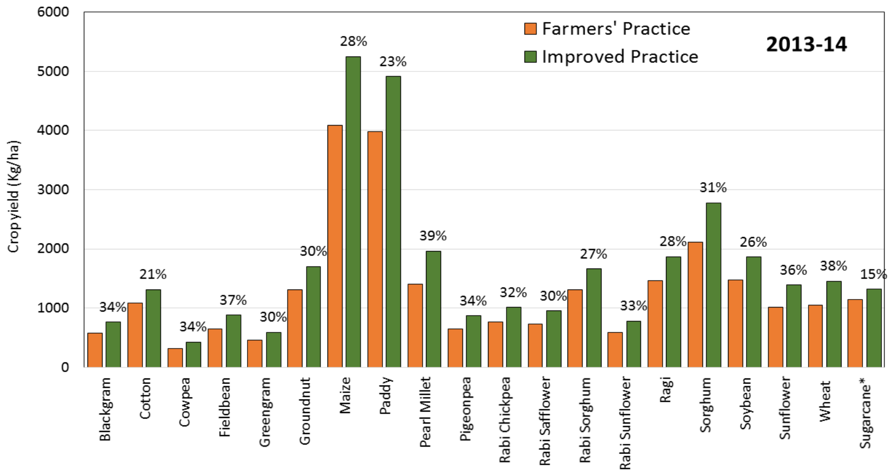


Figure 25: Increase in mean crop yields during 2013-14.

Crop season 2014-15

In all the 30 districts, crop cutting experiments were undertaken following uniform CCE guidelines. Harvest data was collected with the help of staff of DoA, DE&S, FFs, farmers and ICRISAT's research technicians.

Data from crop cutting experiments clearly revealed that crop yields increased from 17 to 34% depending on crop type. The highest yield was recorded in black gram (35%) while the lowest was in cotton (19%) compared to farmers' practice (Figure 26). Pulses and cereal crops recorded increased yields compared to oilseeds.

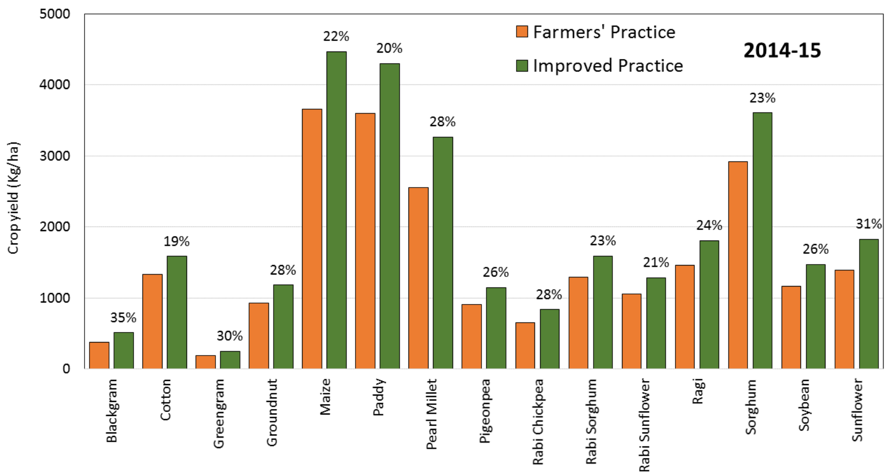


Figure 26: Increase in mean crop yields during 2014-15.

Crop season 2015-16

Altogether, 4532 CCEs were conducted across 30 districts. Results showed that with soil test-based application of micro and secondary nutrients and other improved practices during Kharif 2015, increase in grain yields of major crops varied between 17 and 33%. The difference in crop yields among treated and control fields for different crops was as follows: finger millet (24%), pearl millet (24%), sorghum (22%), maize (23%), soybean (18%), pigeonpea (25%), groundnut (22%) and paddy (21%) (Figure 27). Similarly, during Rabi 2015-16, the difference in crop yield among treated and control fields for sorghum, chickpea and wheat was 23% and 33% respectively.

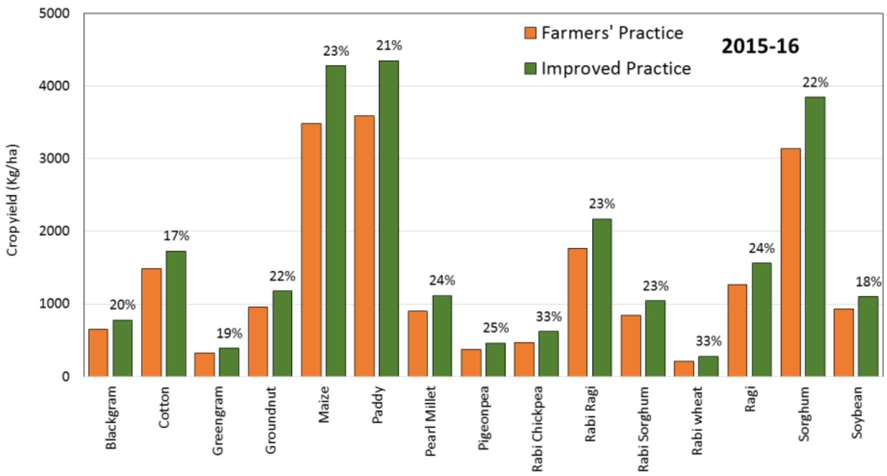


Figure 27: Increase in mean crop yields during 2015-16.

Crop season 2016-17

Crop yield increases ranged between 17 and 32% depending on the crop. The highest yield was recorded for green gram (32%) and the lowest for cotton (17%) compared to farmers' practices. Pulses and cereal crops also recorded yield increases compared to oilseeds crops. About 53 lakh ha in kharif and 16 lakh ha in rabi were subject to improved management practices. During kharif, increased crop yields were registered in paddy (21%), maize (20%), green gram (32%), black gram (27%), pigeonpea (22%), pearl millet (23%), groundnut (22%), soybean (19%), sorghum (22%) and finger millet (24%) compared to farmers' practices. Similarly, during rabi, crop yields increased by 21% in chickpea and 19% in sorghum and finger millet (Figure 28). It is important to mention that finger millet is cultivated under irrigated conditions during rabi season in districts like Davanagere.

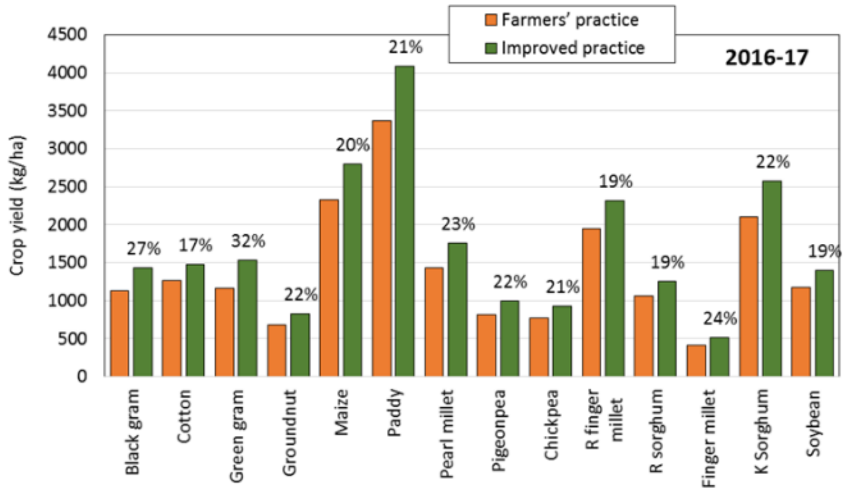


Figure 28: Increase in mean crop yields during 2016-17.

Crop season 2017-18

Crop cutting studies revealed grain yield increases ranging between 17 and 34% depending on the crop. The highest yield was recorded for black gram (34%), green gram (32%) and DSR paddy (29%); the modest yield was recorded for cotton (17%) compared to farmers' practices. Similarly, fodder yield was ranging between 17 and 33% higher as compared to farmers' practice (Figure 29).

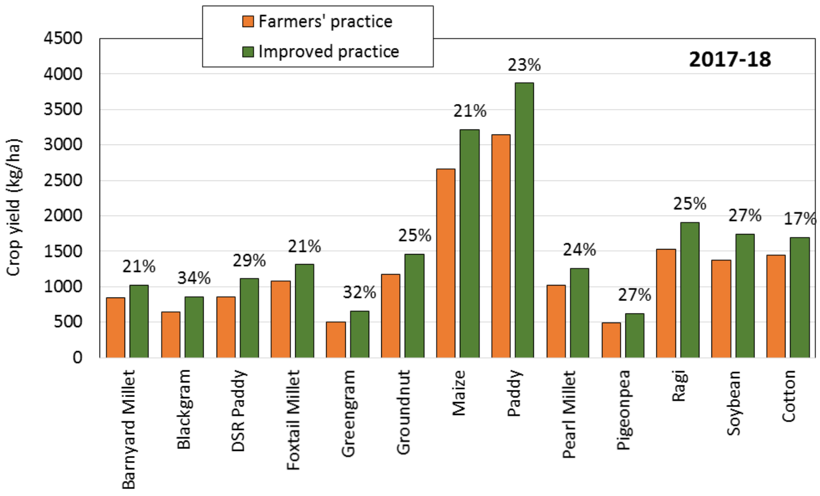


Figure 29: Increase in mean crop yields during 2017-18.

11.Performance of improved varieties

ICRISAT along with DoA evaluated the performance of new improved crop cultivars in Karnataka. The major crops evaluated were groundnut (ICGV 9114), finger millet (MR 1), soybean (JS 9560), sorghum (CSV 15 and CSV 23), pearl millet (ICTP 8203 and HHB 67), castor (DCH 177 and Jyothi) and sunflower (DRSH 1). These demonstrations were conducted with farmers' participation with close monitoring by ICRISAT staff in each district supported by Scientific Officers and scientists.

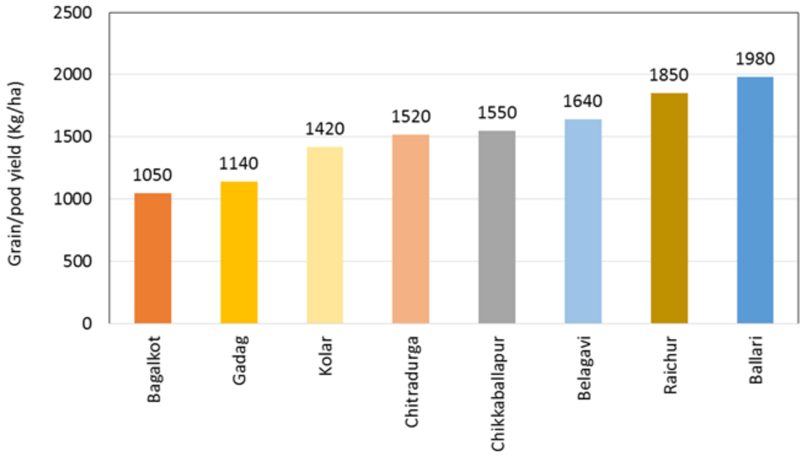


Figure 30: District-wise average grain yields of groundnut variety ICGV 91114 during rainy season 2013.

Groundnut (ICGV 91114)

During 2013-14 crop season, field trials with ICGV 91114 were undertaken in twelve districts of Karnataka. A total of 26 trials were conducted on 9.2 ha. Maximum yield (1980 kg/ha) was observed in Ballari district (Figure 30). Low grain yields in Gadag (1140 kg/ha) and Bagalkot (1050 kg/ha) were because of poor rainfall. Poor rainfall affected crop establishment in Dharwad, Davanagere and Hassan districts. Excluding nine trials in these five districts, the average yield of trials in other districts was 1518 kg/ha.

In Raichur district, ICGV 91114 performed better as the average yield was 1850 kg/ha followed by ICGV 02266 (1660 kg/ha), ICGV 00351 (1650 kg/ha), and ICGV 00308 (1560 kg/ha) respectively (Figure 31-33).

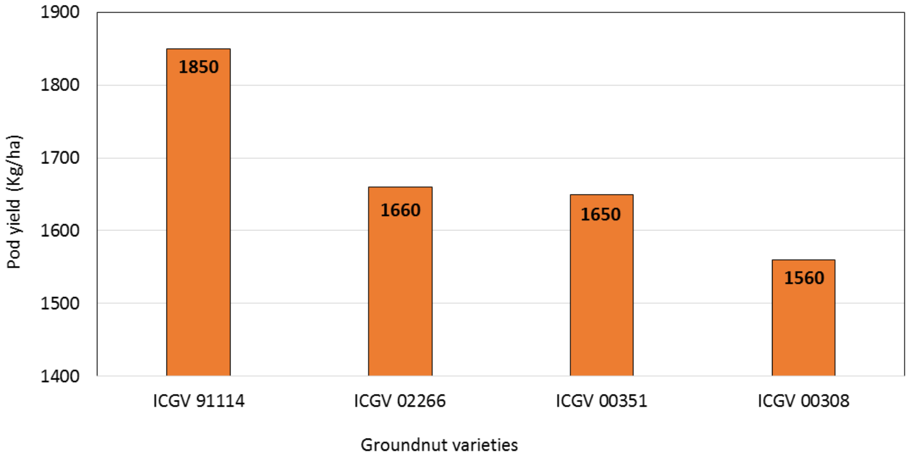


Figure 31: Performance of groundnut varieties in Raichur district.

Figure 32: Groundnut variety ICGV 00351 grown in a demo plot by Gopal Basanna, Neeramanvi village, Raichur district, rainy season 2013.

Figure 33: (L) Groundnut variety ICGV 00308 grown on Gopal Basappa Kallur's field, Neermanvi village, and (R) variety ICGV 02266 grown by Muniyappa Naik's field, Idapnur village, Raichur district, rainy season 2013.

Finger Millet (MR 1)

Trials for finger millet cultivar MR 1 were conducted in six districts. A total of 56 trials were conducted on 28 ha. Finger millet is a hardy crop requiring less water, but higher yields can be achieved with supplemental irrigation (Figure 34) The average yield of all 56 trials was 2530 kg/ha (Figure 35). Yield data from Chamarajnagar district indicated that the observed grain yield of MR 1 (2210 kg/ha) was 20% more than that from cultivar GPU 28 (1850 kg/ha).

Figure 34: Finger millet (MR 1) under supplemental irrigation in Kolar district.

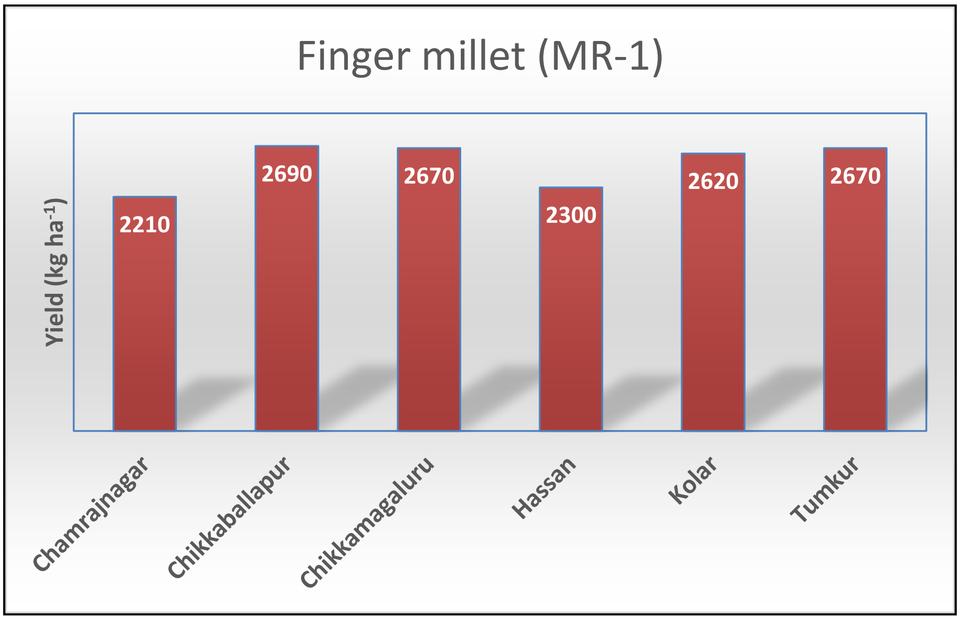


Figure 35: District-wise average grain yields of finger millet.

Soybean (JS 9560)

Eight trials were conducted for soybean (JS 9560) on 3.6 ha area. Average grain yield for these trials was 2320 kg/ha (Figure 36). Highest yield was observed in trials from Dharwad district (2910 kg/ha). Soybean trials were conducted in three districts (Figure 37).

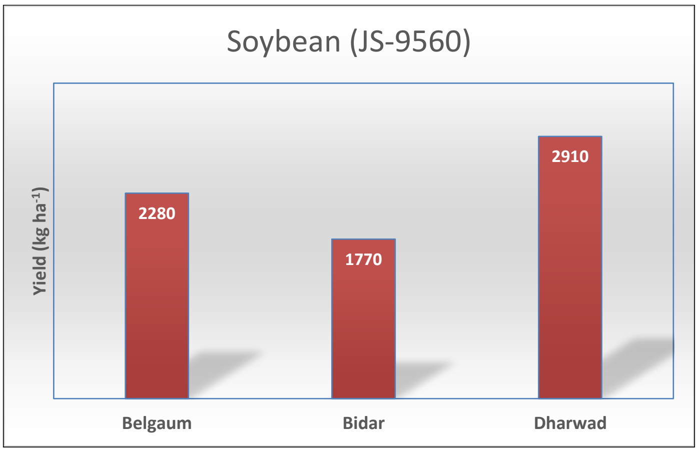


Figure 36: District-wise average grain yields of soybean.

Figure 37: Soybean (JS 9560) grown by Tippanna A Parmoji, Garag village, Dharwad district, rainy season 2013.

Sorghum (CSV 15 and CSV 23)

Trials for two sorghum cultivars (CSV 15 and CSV 23) were demonstrated in eight districts. Maximum yield observed for CSV 15 was 2640 kg/ha in Koppal and for CSV 23 is 2910 kg/ha in Davanagere (Figure 38). Heavy rainfall during the crop season damaged trials of both the cultivars in Bidar and Kalburgi districts and CSV 23 in Koppal and Haveri districts. Overall average yield for CSV 15 was 2240 kg/ha and for CSV 23 2580 kg/ha. Observed data from Belgaum and Davanagere indicated that CSV 23 showed 18-22% more grain yield than CSV 15.

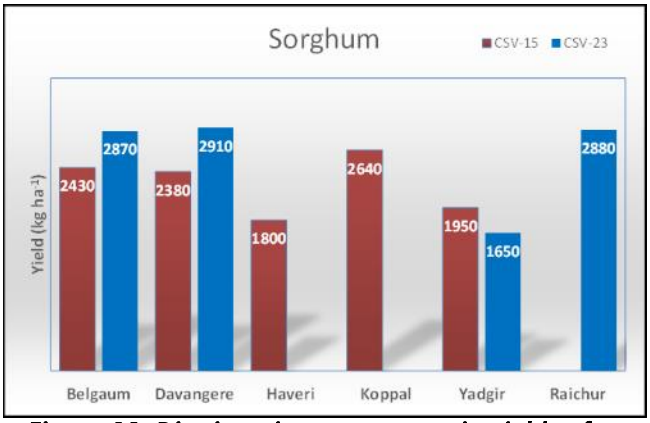


Figure 38: District-wise average grain yields of sorghum.

Pearl Millet (ICTP 8203 and HHB 67)

A total of 36 trials were conducted with two cultivars (ICTP 8203 and HHB 67) on 19.2 ha, for which 120 kg seed was supplied by ICRISAT. For HHB 67, maximum yield of 2320 kg/ha was observed in Yadgir district (Figure 39) whereas lowest grain yield was recorded in Bagalkote. For ICTP8203, highest yield was 1670 kg/ha in Koppal district and the lowest yield was observed in 790 kg/ha in Bagalkote. Average yield from cultivar ICTP 8203 was 1370 kg/ha and from HHB 67 it was 1420 kg/ha. The trials were conducted in seven districts (Figure 39 & 40).

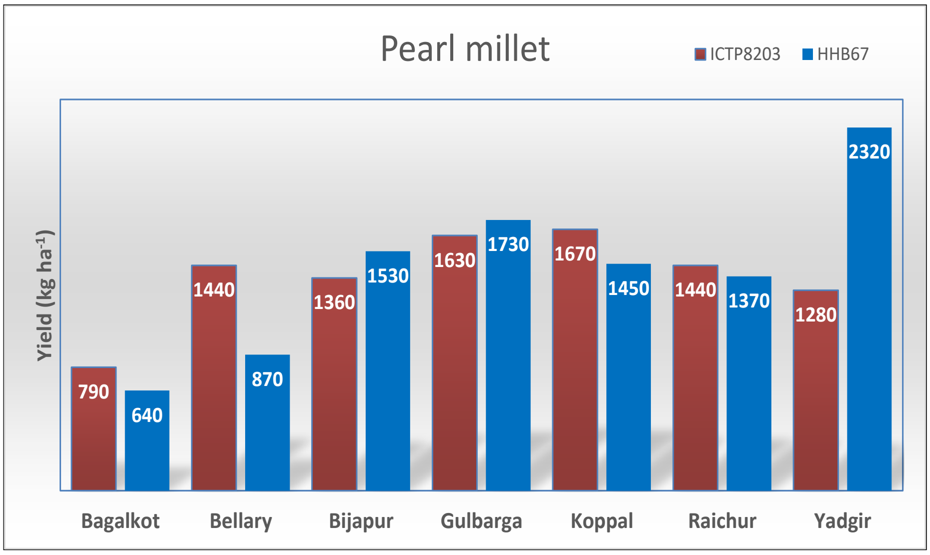


Figure 39: District-wise average grain yields of pearl millet.

Figure 40: (L) Pearl millet hybrid HHB 67 grown in Aiyappa Batangi's field, Doddi village, and (R) variety ICTP 8203 in Basappa Pujar's field, Neermanvi village, Raichur district, rainy season 2013.

Castor (DCH 177 and Jyothi)

Trials for castor cultivars DCH 177 and Jyothi were conducted in eight districts, out of which trials were successful in six districts. A total of 58 trials of cultivar DCH 177 were done on 20.8 ha, for which 140 kg seed was supplied by ICRISAT. Similarly, 10 trials of cultivar Jyothi were done on 5 ha. Grain yields from these trials are shown in Figures 41 and 42. Maximum yield was observed in Raichur for both DCH 177 and Jyothi. Yield from DCH 177 was 5-19% more than that from Jyothi.

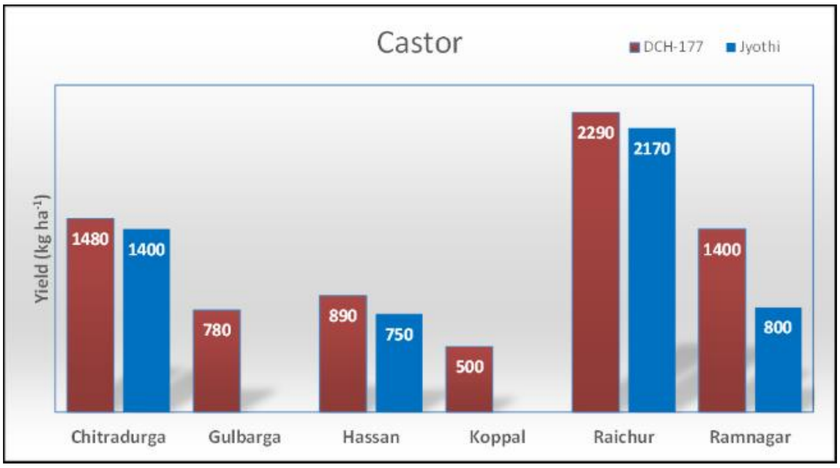


Figure 41: District-wise average grain yields of castor.

Figure 42: Castor variety Jyothi grown in Bheemaih's field in Idapnur village, Raichur district.

Sunflower (DRSH 1)

Trials for sunflower cultivar DRSH 1 were conducted in four districts, out of which trials were successful in two. A total of eight trials were conducted on 3.4 ha, for which 24 kg seed was supplied by ICRISAT. Maximum yield of 1570 kg/ha was observed in Raichur district (Figures 43 and 44).

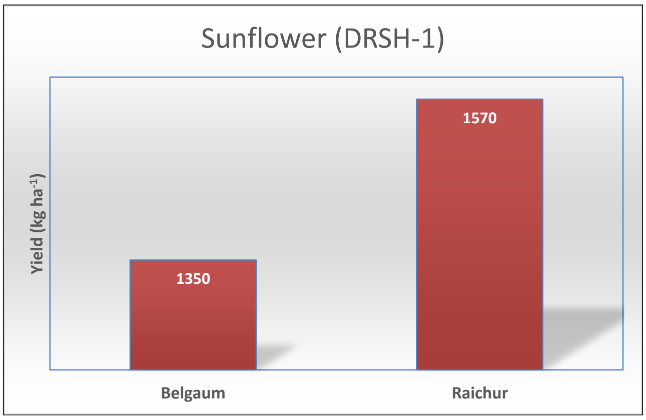


Figure 43: District-wise average grain yields of sunflower.

Figure 44: Sunflower Hybrid DRSH 1 grown in Aiyappa Batangi's field in Doddi village, Raichur district, rainy season 2013.

During 2014-15, field demonstrations for groundnut cultivar ICGV 91114 were conducted in Raichur district. The variety is high yielding, matures in 90-95 days, is tolerant of mid-season and end-of-season drought, has an average shelling percentage of 75%, oil content of 48%, and has better digestibility and palatability of haulms for animals. Due to its early and uniform maturity, attractive pod and seed shape and high shelling percentage, it is becoming popular among farmers of Karnataka. Ten trials were conducted on 5 ha; average pod yield was very high - more than 2,540 kg/ha with the improved practice compared to 1,450 kg/ha with the farmers' traditional practice (Figure 45). There was a 75% increase in pod yield with improved management compared to local variety TMV 2.

Similarly, pigeonpea cultivar evaluation of two hybrids, ICPH 2671 and ICPH 2740, were evaluated with popular ICRISAT varieties Asha and Maruti. These hybrids are most promising with respect to yield, stability and disease resistance, are resistant to shattering and have more root biomass compared to existing varieties. The special characteristic of the hybrids is the good dal quality. Most (80%) respondents rated them as "better than the market sample" in flavor, taste, and cooking time.

As regards hybrid ICPH 2671 (Pushkal), four varietal evaluation trials were carried out and the hybrid performed quite well under good management conditions and recorded a maximum yield in Raichur (1,545 kg/ha) (Figure 45) whereas average yield across the district was 971 kg/ha which is 66% higher than that obtained with the traditional farmers' practice (525 kg/ha). The evaluation of Hybrid ICPH 2740 was carried out on two farmer's fields and responded well to good management practices.

The varietal trials on castor were conducted with hybrid DCH 177. This hybrid is high yielding (1,550 to 2,130 kg/ha) and early maturing (90 to 100 days), has an oil content of about 49% and is recommended for growing in Karnataka, Tamil Nadu, Maharashtra and Orissa. More importantly, this hybrid has tolerance for Fusarium wilt and Whitefly insect. Overall, the average increase in yield across all the districts over the traditional variety was 28%. As regards castor cultivar Jyothi, trials were conducted for which seed was supplied from ICRISAT. The maximum yield of Jyothi in Raichur district was 2,170 kg/ha and overall it recorded a 25 to 37% increase in seed yield compared to that obtained with the farmers' practice using the traditional variety (Figure 46).

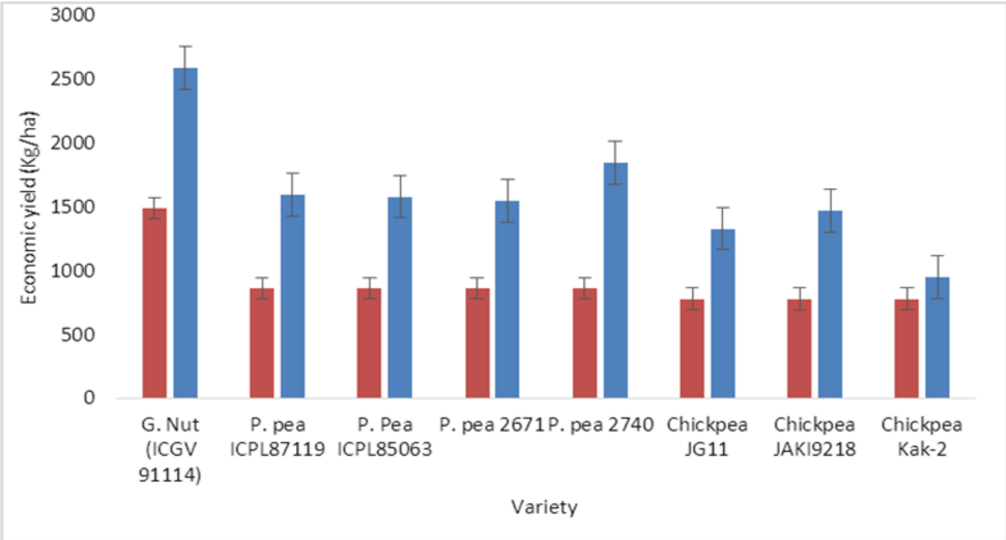


Figure 45: Farmer participatory varietal evaluation of pulses in Raichur district.

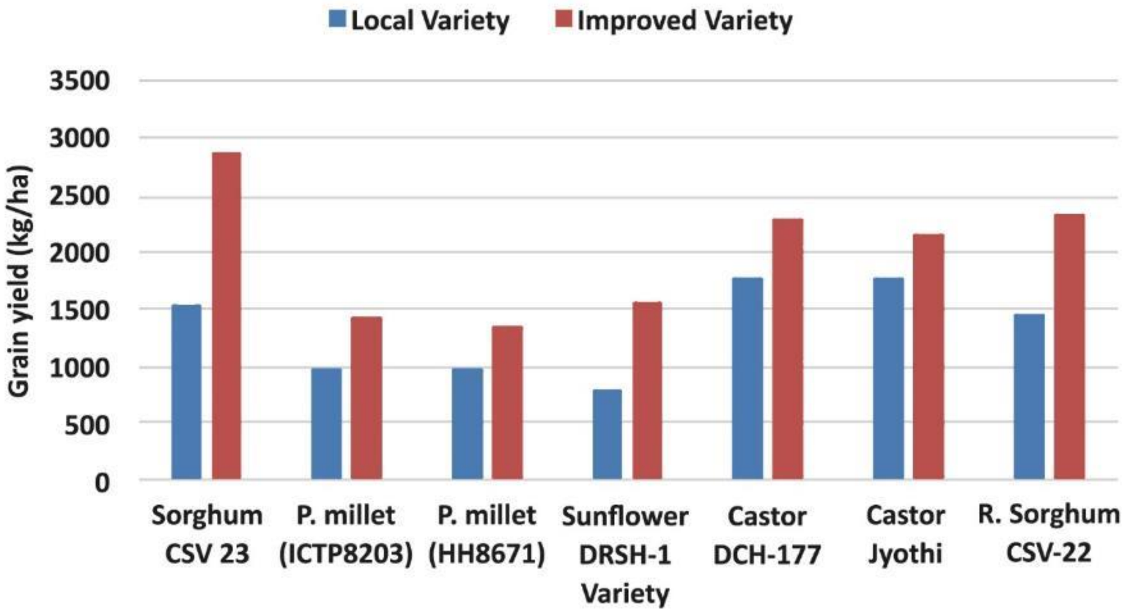


Figure 46: Farmer participatory varietal evaluation of cereals and oilseeds in Raichur district.

Evaluation of two pearl millet hybrid cultivars ICTP 8203 and HHB 67 (Improved) were conducted in Vijayapura. ICTP 8203 is a medium duration variety (75 to 80 days) with medium height (1.5-1.6 m) and has good resistance to downy mildew and tolerance to drought. HHB 67 performed quite well and recorded a 29% higher yield compared to the traditional variety (Figure 47).

The next improved introduction was hybrid HHB 67-2 (Improved) which is the first product of marker-assisted breeding to reach cereal farmers in India. It is a downy mildew tolerant improved version of HHB 67, a single-cross grain hybrid developed at Chaudhary Charan Singh Haryana Agricultural University, Hisar in collaboration with ICRISAT. HHB 67-2, like HHB 67, is early maturing, has high tillering, extra-early maturity (64-65 days) and is of medium-height (170-200 cm). The hybrid performed well and recorded a 46% higher yield than the traditional variety.

As regards pigeonpea, variety Asha performed well compared to the sterility mosaic susceptible local variety, and recorded a 12 % higher yield over the local variety.

Farmer participatory varietal evaluation of chickpea cultivars JG 11 and JAKI 9218 were conducted in Raichur. JG 11 (ICCV 93954) is a desi chickpea variety developed by ICRISAT in partnership with Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India. It was released by the Central Variety Release Committee of India for southern India. JG 11 has spread rapidly in southern India during the past five years. It is gradually replacing the variety 'Annigeri' that has been holding sway here for over four decades. Farmers prefer JG 11 because of its early maturity (95-100 days), high yield (up to 2.5 metric tons/ha in rainfed condition and up to 3.5 metric tons/ha under irrigated conditions), attractive large seeds (22 g/100 seed) and most significantly high tolerance to Fusarium wilt (<10% mortality). The average recorded yield in the district was 55% higher than that with the traditional variety preferred by farmers.

As regards the variety JAKI 9218, it is semi-spreading, profusely branching and bold seeded with excellent seedling vigor and a golden yellow grain color. The variety recorded a 45% higher grain yield than that obtained with the farmers' practice of using the local variety (Figure 47).

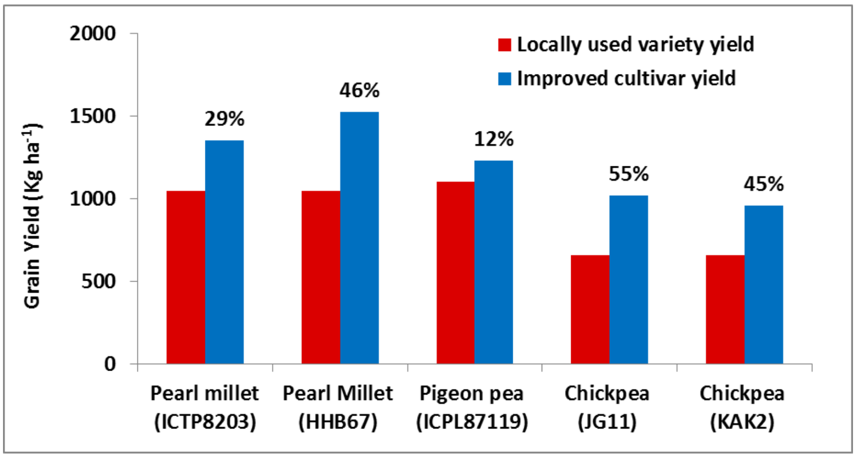


Figure 47: Farmer participatory varietal evaluation in Vijayapura district.

12. Climate change impacts on pigeonpea in selected districts of Karnataka

Evidence over the past few decades shows significant changes in climate are taking place all over the world due to enhanced human activities such as deforestation, emission of various greenhouse gases and indiscriminate use of fossil fuels. Results of climate change research indicate that climate variability and change may lead to more frequent weather related disasters in the form of floods, droughts, landslides and sea level rise. Global atmospheric concentration of CO_2 has increased from preindustrial level of 280 parts per million (ppm) to 408 ppm in Feb 2018. Global projections indicate higher temperature of 1.5 to 4.5°C by the year 2050, as a result of enhanced emission of greenhouse gases.

Various studies show that climate change in India is real and it is one of the major challenges faced by Indian agriculture. India Meteorological Department (IMD, 2017) reported that the annual mean temperature for the country in the year 2016 was +0.87 °C above the 1971-2000 average, thus the year 2016 was the warmest year on record since 1901. At the country scale, no long-term trend was observed in the onset date of southwest monsoon over Kerala and total monsoon rainfall over whole country was observed. Significant increasing trends were reported in mean maximum temperature over many states in India.

A study carried out by ICRISAT under the National Initiative on Climate Resilient Agriculture (NICRA) project based on the gridded rainfall and temperature data of India Meteorological Department quantified the changes in areas under different climates in India. The study indicated a net reduction in the dry sub-humid area (10.7 m ha) in the country, of which about 5.1 million ha (47%) shifted towards the drier side and about 5.6 million ha (53%) became wetter, between the periods 1971-1990 and 1991-2004 (Kesava Rao et al., 2013a). Madhya Pradesh has shown the largest increase in semi-arid area (about 3.82 million ha) followed by Bihar (2.66 million ha) and Uttar Pradesh (1.57 million ha). Relatively little changes occurred in AP; semi-arid areas decreased by 0.24 million ha, which shifted towards drier side (0.13 million ha under arid type) as well as wetter side (0.11 million ha under dry sub-humid type). Results indicated that dryness and wetness were increasing in different parts of the country in place of moderate climates existing earlier in these regions.

The Fifth Assessment Report (AR5) of the International Panel on Climate Change (IPCC) mentions that climate change is impacting food security now and that it is no longer a hypothetical future scenario (IPCC, 2011). Variability in rainfall is increasing and extreme rainfall events are occurring more often. Annual mean area-averaged surface warming over the Indian subcontinent is projected to range between 3.5 and 5.5°C, over the region during 2080s. During winter, India may experience between 5 and 25% decline in rainfall, which is likely to be significant and may lead to droughts during the dry summer months (Lal et al., 2001).

Karnataka state in Southern India has large rainfed area (7.5 million ha) in the country, after Rajasthan, with diverse agro-ecological characteristics. Quantitative distribution of rainfall determines the growth of the agriculture sector in Karnataka as 70% of the total agricultural area comes under rainfed lands. The state's average rainfall is 1139 mm, which varies from 3085 mm in the coastal region to 593 mm in the northern dry region. Nearly half the total rainfall is received during the monsoon season (GoK, 2011). Large variability is also found in its distribution between years.

Rice, finger millet, pearl millet, sorghum and maize are the major staple crops occupying more than 50% of the land area and accounting for more than 60% of the population's calorie intake (GoK, 2011). Crops such as pigeonpea, greengram, blackgram, chickpea, groundnut, soybean, and sunflower also play an important role in fulfilling the food requirement of the state. Karnataka is also known for commercial plantation crops such as arecanut, coconut, coffee and tea plantations concentrated in Malnad and hilly regions.

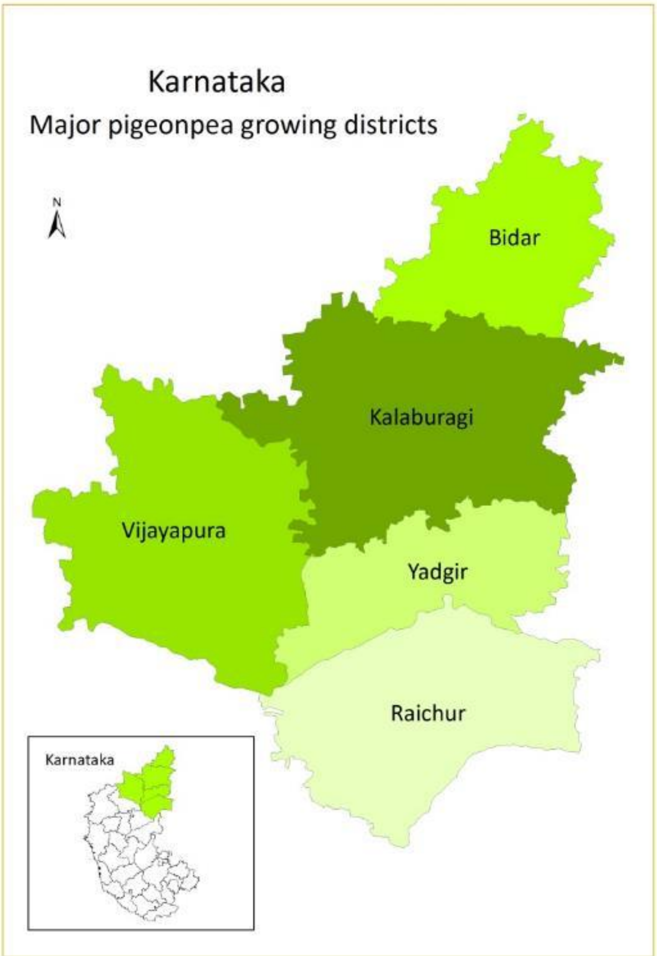


Figure 48: Major pigeonpea cultivating districts in Karnataka

Pigeonpea

Pigeonpea [*Cajanus Cajan (*L.) Millsp.] is a major legume crop and rich source of protein. It is largely cultivated in different semi-arid regions of the country, and is the second most important pulse crop after chickpea. In Karnataka, pigeonpea is largely grown in the northern parts of the state especially in Kalaburagi district, which is known as "Pulse Bowl of Karnataka". Pigeonpea occupies an area of about 0.339 million ha in Kalaburagi (average of five years from 2010-11 to 2015-16) with a production of about 0.222 million tonnes and thus the district average productivity is 0.64 t ha^{-1}. Bidar, Vijayapura, Kalaburagi, Yadgir and Raichur districts are the major pigeonpea growing districts (Figure 48) having together an area of about 0.667 million ha with a production of about 0.419 million tonnes.

Objectives

Objectives of this study are to understand climate variability and projected climate change in the selected districts and to assess the impacts of projected climate change on yield, phenology and water balance of pigeonpea using IMD district level climate data, IMD gridded climate data and APSIM pigeonpea crop-growth simulation model.

Climate data and analyses

Monthly rainfall data of fifty seven years (1961-2017) were collected for the five selected districts from the India Meteorological Department (IMD) and seasonal totals were computed for all the years. The thirty-year period from 1961 to 1990 was considered as normal and seasonal rainfall of this normal period was compared with the average rainfall of 27-years (1991-2017) for the selected districts, to understand the rainfall variability and change.

A high resolution daily gridded temperature data set for the Indian region was developed using temperature data of 395 quality controlled stations for the period 1969–2005. A modified version of the Shepard's angular distance weighting algorithm was used for interpolating the station temperature data into 1◦ latitude × 1◦ longitude grids (Srivastava et al., 2009). Using cross validation, errors were estimated and found less than 0.5 ◦C. The data set was also compared with another high resolution data set and found comparable. The gridded temperature data were updated by IMD for the period 1951-2016; this updated data were procured from the IMD and daily gridded maximum and minimum temperature data of representative pixels for the five selected districts in Karnataka were retrieved. A new daily gridded rainfall data (IMD4) set at a high spatial resolution (0.25° × 0.25°, latitude × longitude) covering a long period of 110 years (1901–2010) over the Indian mainland was developed based on Inverse Distance Weighted Interpolation (Pai et al., 2014). The gridded data set was developed after making quality control of basic raingauge stations. The comparison of IMD4 with other data sets suggested that the climatological and variability features of rainfall over India derived from IMD4 were comparable with the existing gridded daily rainfall data sets. In addition, the spatial rainfall distribution like heavy rainfall areas in the orographic regions of the west coast and over northeast, low rainfall in the leeward side of the Western Ghats, etc. were more realistic and better presented in IMD4 due to its higher spatial resolution and to the higher density of rainfall stations used for its development. The IMD4 data were updated by IMD to include data up to the year 2016; this updated data were procured from the IMD and daily gridded rainfall data of representative pixels for the five selected districts in Karnataka for 30 years (1987–2016) were retrieved. These gridded data was used as input in to the pigeonpea crop-growth simulation model.

Crop growth simulation models

Crop simulation models are software tools which can mimic crop growth processes in real time. These models are valuable tools in assessing impact of climate change on crops, sustainability of cropping systems, estimating potential yields and optimizing crop management. Some of the methodological challenges in assessing sustainability in both temporarily and spatially can be addressed using crop simulation models. Decision Support System for Agro-Technology Transfer (DSSAT v4.7) and Agricultural Production Systems sIMulator (APSIM) are two crop simulation models widely used globally.

DSSAT is a suite of 27 crop models including major cereals, legumes, oilseeds and vegetables (Hoogenboom et al., 2017). The major components of the model are vegetative and reproductive development, carbon balance, water balance and nitrogen balance. It simulates growth and development of crops using a daily time step from sowing to maturity and ultimately predicts yield. Genotypic differences in growth, development and yield of crop cultivars are affected through genetic coefficients (cultivar-specific parameters) that are inputs to the model. The physiological processes that are simulated describe the crop response to major weather factors, including temperature, precipitation and solar radiation and include the effect of soil characteristics on water availability for crop growth.

APSIM software is a modular modelling framework that has been developed by the APSIM Initiative and its predecessor the Agricultural Production Systems Research Unit (APSRU) in

Australia (Holzworth et al., 2014). These models consists many new modules like intercropping, climate change options and incorporation of GCM model outputs. Crop models are better suited to evaluate different crop management options viz. optimizing sowing dates, fertilizers, irrigations, cultivars and many more. These models are the important tools for assessing climate change impacts on various crops. In this study, APSIM pigeonpea model is used to assess the impacts of projected climate change on pigeonpea.

General Circulation Models (GCMs)

Coupled atmosphere-ocean general circulation models (GCMs) simulate different realizations of possible future climates at global scale under contrasting scenarios of land-use and greenhouse gas emissions. Outputs from many GCMs are available in the public domain, notably in the World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model dataset. This dataset contains model outputs from 22 of the GCMs used for the Fifth Assessment and for a range of scenarios including the four scenarios reported in the IPCC's working group1 of fifth assessment report (IPCC, 2013). A set of four pathways were produced that lead to radiative forcing levels of 8.5, 6.0, 4.5 and 2.6 W/m2, by the end of the century. Each of the RCPs covers the 1850–2100 period, and extensions have been formulated for the period thereafter (up to 2300). The four RCPs formulated are: RCP8.5, throughout the twenty-first century before reaching a level of about 8.5 W m^{-2} at the end of the century. In addition to this "high" scenario, there are two intermediate scenarios, RCP4.5 and RCP6.0, and a low so-called peak-and-decay scenario, RCP2.6, in which radiative forcing reaches a maximum near the middle of the twenty-first century before decreasing to an eventual nominal level of 2.6 W m^{-2}. Many of the GCMs also project that the floods and droughts are going to be more frequent in the future.

The output data from GCM requires several additional processing steps before it can be used to drive impact models. Spatial downscaling, typically by regional climate models (RCM), and bias-correction are two such steps that have already been addressed. Yet, the errors in resulting daily meteorological variables may be too large for specific model applications. Crop simulation models are particularly sensitive to these inconsistencies and thus require further processing of GCM-RCM outputs. GCM models simulates typically a single time series for a given emission scenario. To help in agricultural policy making, data on near and medium-term decadal time scale is mostly used, e.g., 2030 or 2050.

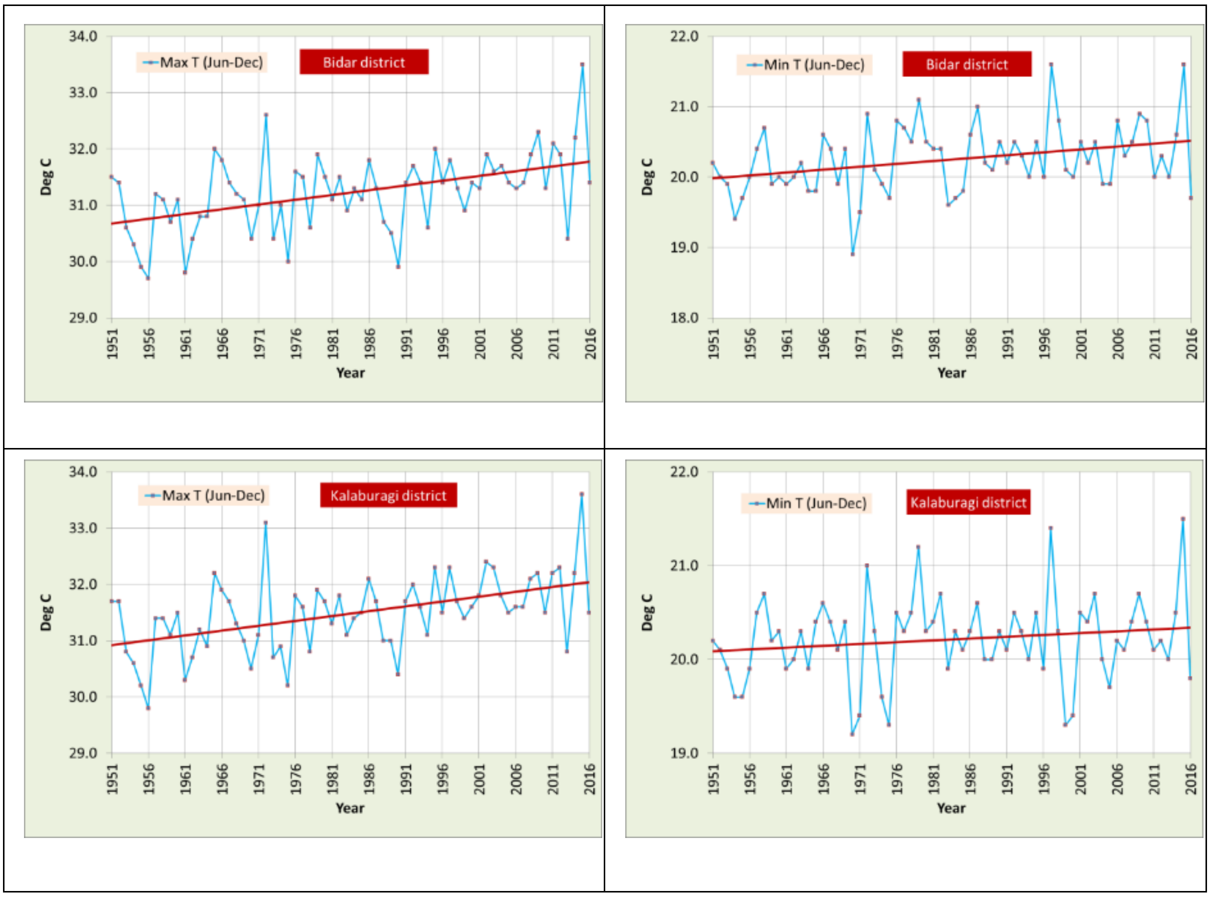
Several studies have been conducted on the possible increments in Indian summer monsoon precipitation in the future. Unfortunately, none of them has endeavoured to discover the models whose yields give the best fit to the observed data. Some statistical tests performed (Pravat et al., 2015) to quantify the models of Coupled Model Inter-comparison Project 5 (CMIP5) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method was used to select optimum models. Their study showed that four models, NCAR-CCSM4, CESM1-CAM5, GFDL-CM3, and GFDL-ESM2G, best capture the pattern in Indian summer monsoon rainfall over the historical period (1871–2005).

The Earth System Model CESM1 (version 1.2.1) is a fully coupled global climate model. Many physics-based models serve for the different Earth system components. The atmosphere component, CAM5, provides a set of physics parametrizations, and several dynamical cores, which also include advection (Baumgaertner et al., 2016). The Community Climate System Model (CCSM4) developed by National Center for Atmospheric Research (NCAR) in Boulder, Colorado, USA is a coupled climate model for simulating Earth's climate system. The CCSM4 model is composed of five separate models simultaneously simulating the Earth's atmosphere, ocean, land, land-ice, and sea-ice, plus one central coupler component (Peter et al., 2011). In the present study, these two GCM models namely CESM1-CAM5 and NCAR-CCSM4 under climate change scenario of RCP8.5 for the period 2030 and 2050 are used.

Daily gridded temperature and rainfall data of thirty years (1987-2016) were used as base and projected climate changes were applied on the base data. Monthly differences in temperatures and percent deviations in rainfall were incorporated in respective months over the base data uniformly to obtain projected daily climate data for assessing the impacts on pigeonpea yields using APSIM pigeonpea crop-growth simulation model.

Climate variability and change

Global warming due to increase in the carbon dioxide in the atmosphere is witnessed in India including Karnataka. Sixty six years' (1951-2016) data were used to assess the changes in temperature in selected pigeonpea cultivation districts of Karnataka (Figure 49). Analysis of temporal variation of temperature during the seven month period (June to December) shows that there appears to be a clear increase in maximum temperature of about one degree centigrade in all the three districts; while the minimum temperature shows very little increase in Bidar and Kalaburagi districts and a slight reduction in Raichur district. This indicates that in future, the major pigeonpea growing districts are likely to have higher temperatures during the crop-growing period, impacting the crop duration and productivity.



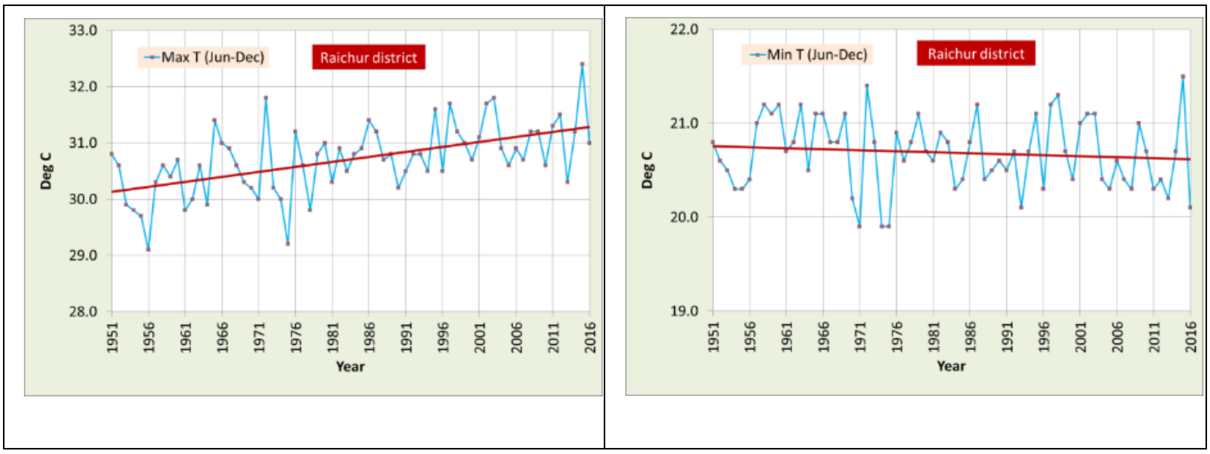


Figure 49: Temperature trend in selected pigeonpea cultivating districts of Karnataka

Changes in seasonal rainfall

To understand the rainfall variability, fifty seven years' (1961-2017) monthly rainfall data of four districts were collected and seasonal totals computed for all the years. Yadgir district was not included because long-period rainfall data at district-level was not available, as Yadgir is a newly formed district (30 December 2009). The thirty-year period from 1961 to 1990 was considered as normal and seasonal rainfall for this period was compared with the average rainfall of 27-years (1991-2017) for the selected districts (Table 11). It is seen that all the districts show reduction of rainfall in both Kharif and Rabi seasons. Vijayapura district witnessed greatest reduction of 86 mm in annual rainfall; while Bidar district showed lowest reduction in annual rainfall of about 66 mm. Kharif season rainfall is critical for pigeonpea crop and all the four districts show considerable reduction in rainfall which is alarming. Results indicate that summer rainfall is increasing slightly in Kalaburagi and Bidar districts.

Table 11: Rainfall changes between (1991-2017) and (1961-1990)

Sl. No.	District	Changes in Rainfall (mm)			
		Summer (Mar-May)	Kharif (Jun-Oct)	Rabi (Nov-Feb)	Annual
1	Bidar	8	-62	-12	-66
2	Raichur	2	-72	-8	-78
3	Kalaburagi	11	-80	-10	-79
4	Vijayapura	-1	-66	-19	-86

Devappa and Khageshan (2011) reported a decreasing trend in the annual rainfall @ 3.44 mm per year for Kalaburagi district, based on data for 1961-2008. Climate trends indicate the need for critically assessing water requirement of pigeonpea under the increased temperature conditions and addressing the water availability issues due to reduction in Kharif rainfall. Variations in rainfall amount and distribution, increased temperatures, depleting soil productivity and disturbed water balance are going to affect pigeonpea productivity in northern Karnataka.

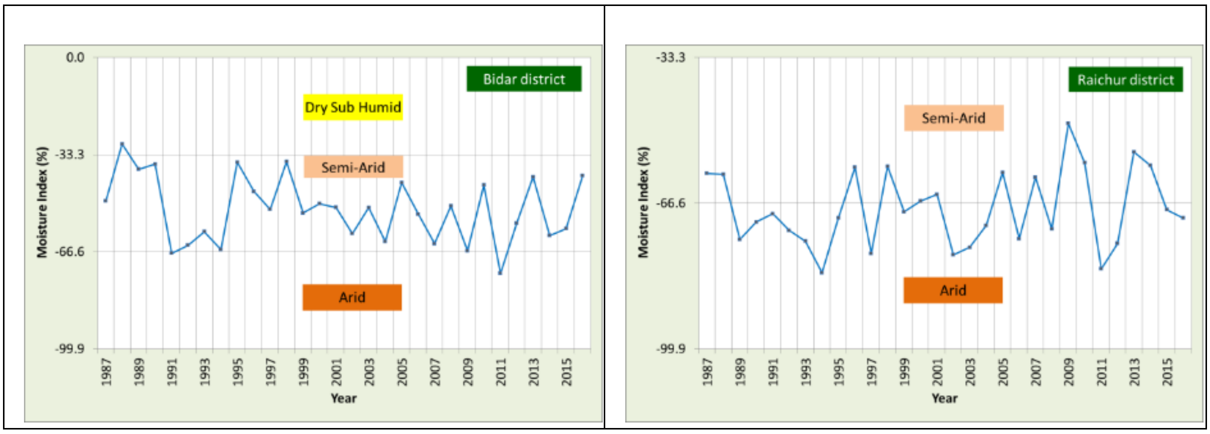


Figure 50: Climate variability in selected pigeonpea cultivating districts of Karnataka

Changes in temperature and rainfall will ultimately change the type of climate a region enjoys. Using the climatic water balance approach and classification of climates (Thornthwaite and Mather, 1955), climates of two districts (Bidar and Raichur) were classified for 30 years (1987-2016) and shown in the Figure 50. Normal climate of Bidar is Semi-Arid and it is seen that the climate was mostly under this type; once the climate shifted to Dry Sub Humid (Year 1988) and once to Arid (Year 2011) type of climate. Bidar shows a slight tendency towards drier climate. Parts of Raichur district fall under Semi-Arid and Arid types of climates. It is seen that out of the 30 years, Raichur was under Semi-Arid type of climate for 12 years and was under Arid type for 18 years. Raichur district does not show any trend in climate shifts and there is a great year-to-year variability, which indicates the need for seasonal climate forecasts to choose the crops and varieties for that particular year and the need for developing climate smart pigeonpea varieties suitable for the districts.

Pigeonpea Area, Production and Yield

Historical pigeonpea crop area, production and yield data in Karnataka state were procured from Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India (DACNET, 2018). In Karnataka, Bidar, Kalaburagi, Vijayapura, Yadgir and Raichur districts contribute about 90 percent of pigeonpea in terms of area and production. Kalaburagi alone consists an area of about 3.39 lakh ha under pigeonpea and contributes about 45 percent of area and 50 percent of production of the state.

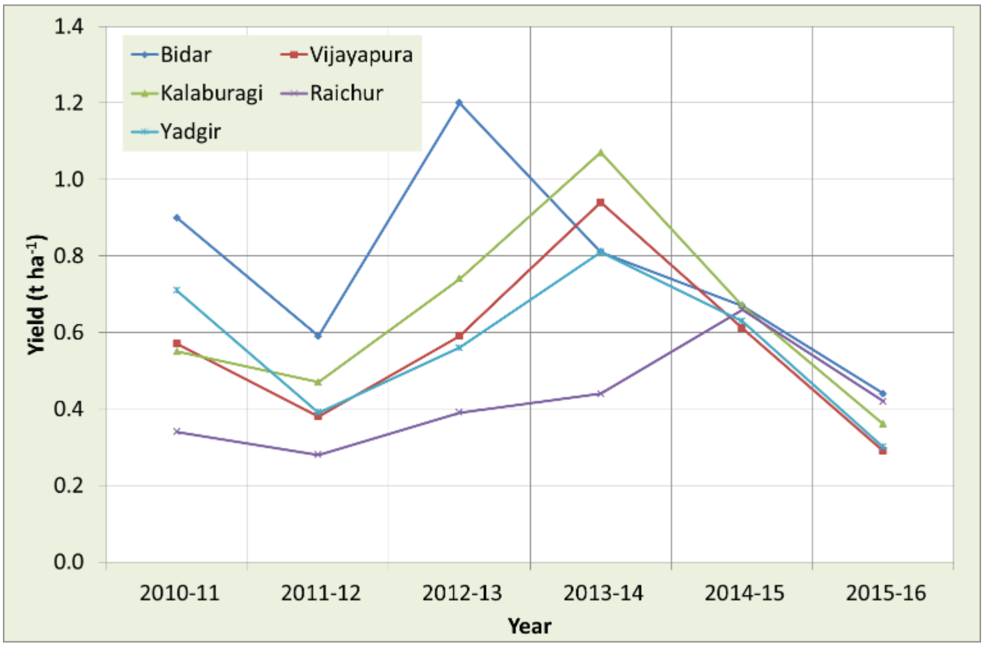


Figure 51: Variability of pigeonpea yields in Karnataka from 2010-11 to 2015-16

There are significant variations in the yields of pigeonpea between districts and from year to year (Figure 51). It is seen that during 2012-13 season, Bidar district produced about 1.2 t of pigeonpea per ha, where as in Raichur it was only 0.4 t ha^{-1}. During 2014-15 season, all the districts produced pigeonpea yield between 0.61 to 0.63 t ha^{-1}. The pigeonpea yields mostly depend on rainfall amount, distribution and water holding capacities of the soils. Two to three rains during October and November would be most useful for pigeonpea crop. It is observed that the district yields are far below to their potential.

Climate change impacts on pigeonpea

Crop simulation models provide a more scientific approach to study the potential impacts of climate change and climate variability on agriculture production (Onwonga et al., 2010). In the present study, pigeonpea simulation model in APSIM 7.10 (McCown et al., 1996) version was used to assess the impacts of projected climate change. APSIM pigeonpea crop simulation model was extensively evaluated by Robertson et al (2001) using 38 datasets which include wide range of sowing densities, growing seasons and cultivars on both Alfisols and Vertisols under rainfed and irrigated conditions. APSIM was developed primarily as a research tool to investigate on-farm management practices especially where outcomes are affected by variable climatic conditions (Holzworth et al., 2006, 2014 and 2018). APSIM was used earlier to estimate potential yields and yield gaps of pigeonpea in India (Bhatia et al., 2006).

TS-3R is a medium duration (150-160 days) pigeonpea variety and is resistant to wilt and tolerant to fog (Balatkar et al., 2012). It is a very popular pigeonpea variety in Kalaburagi region and was developed by the University of Agricultural Sciences, Raichur. Genetic coefficients for this pigeonpea variety TS-3R were estimated based on field experiments conducted at ICRISAT, Patancheru.

Using a calibrated APSIM model, a study was conducted at ICRISAT to assess the projected climate change impacts on pigeonpea variety TS-3R at Kalaburagi. In this study, ten climate change scenarios and the present climate conditions were considered (Kesava Rao et al., 2013b). The scenarios included 1° C, 2° C increase in both maximum and minimum temperatures with 10% and 20% decrease and increase in rainfall. Results showed that in Kalaburagi, increase in temperature by 2°C could reduce pigeonpea yields by about 16%. Rainfall decrease of 10% from present coupled with 2°C increase in temperature could reduce yields further by 4%, making the total reduction to be at 20%. Increased temperature could shorten the crop duration. Days to flowering shortened by 2 and 4 and the total crop duration by 5 and 9 days with increase in temperature by 1 and 2 °C, respectively. Increase in temperature causes more transpiration per day which results in water stress during the dry periods. Water balance outputs have shown that decrease in rainfall by 10 and 20% could result in less plant water use by 18 and 45 mm, respectively with increase in temperature by 2 °C. Increments in rainfall by 10 and 20% are likely to result in more rainfall only for those days with rainfall and will not affect non-rainy days. Thus, additional rainfall will contribute more towards runoff and drainage than to evapotranspiration.

Impacts of Projected Climates

In general, the two projection models show increased rainfall by 2030 and 2050 periods in the range of 15 to 120 mm annually. As per IPCC report (AR5), floods and droughts are likely to increase in the future; though rainfall increases it leads to more of floods due to high intense rainfall events. District-wise impacts of projected climate change on pigeonpea are as follows:

Bidar District

In Bidar district, rainfall changes are +32 and -21 mm during 2030 and 84 and 53 mm during 2050 under CESM1-CAM5 and NCAR-CCSM4 projection models respectively (Table 17). Grain yield of pigeonpea would increase by 3.5 percent in 2030 and decrease by -1.8 percent in 2050 as per CESM1-CAM5 model (Table 12). Under NCAR-CCSM4 model, the grain yield would decrease by twelve percent in 2030 and 6 percent in 2050 (Table 13). Pigeonpea crop duration would reduce by nine days in 2030 and by fourteen days in 2050 as per CESM1-CAM5 model (Table 14). Under NCAR-CCSM4 model, the crop duration would reduce by nine days and twelve days in 2030 and 2050 respectively. Surface runoff would increase in both periods as per CESM1-CAM5 model (Table 15). Crop water uptake would increase as per CESM1-CAM5 and decrease under NCAR-CCSM4 model (Table 16).

Table 12: Impact of projected climate change on pigeonpea yields under CESM1-CAM5 model

District	District Yield (kg/ha)	Rainfed Potential Yield (kg/ha)	Year 2030		Year 2050	
			Yield (kg/ha)	Change (%)	Yield (kg/ha)	Change (%)
Bidar	768	1861	1927	3.5	1828	-1.8
Kalaburagi	643	1532	1647	7.5	1501	-2.0
Raichur	422	1522	1632	7.2	1544	1.5
Vijayapura	563	1226	1384	12.8	1156	-5.8
Yadgir	567	1504	1671	11.1	1424	-5.3

Table 13: Impact of projected climate change on pigeonpea yields under NCAR-CCSM4 model

District	District Yield (kg/ha)	Rainfed Potential Yield (kg/ha)	Year 2030		Year 2050	
			Yield (kg/ha)	Change (%)	Yield (kg/ha)	Change (%)
Bidar	768	1861	1630	-12.4	1751	-5.9
Kalaburagi	643	1532	1394	-9.0	1525	-0.5
Raichur	422	1522	1485	-2.4	1447	-4.9
Vijayapura	563	1226	1214	-1.0	1269	3.5
Yadgir	567	1504	1433	-4.7	1431	-4.9

Table 14: Impact of projected climate change on pigeonpea crop duration

District	Climate Projection Model / Period				
	Present	CESM1-CAM5		NCAR-CCSM4	
		2030	2050	2030	2050
Bidar	159	150	145	150	147
Kalaburagi	154	147	140	146	145
Raichur	156	146	143	146	142
Vijayapura	155	146	138	146	144
Yadgir	151	145	139	144	141

Table 15: Impact of projected climate change on runoff (mm) of pigeonpea

District	Climate Projection Model / Period				
	Present	CESM1-CAM5		NCAR-CCSM4	
		2030	2050	2030	2050
Bidar	100	102	131	90	117
Kalaburagi	31	31	36	35	46
Raichur	41	56	54	46	65
Vijayapura	36	65	53	32	49
Yadgir	25	37	35	26	35

Table 16: Impact of projected climate change on crop water usage (mm) of pigeonpea

District	Climate Projection Model / Period				
	Present	CESM1-CAM5		NCAR-CCSM4	
		2030	2050	2030	2050
Bidar	481	487	490	447	479
Kalaburagi	436	451	438	427	457
Raichur	398	411	409	401	404

District	Climate Projection Model / Period				
	Present	CESM1-CAM5		NCAR-CCSM4	
		2030	2050	2030	2050
Vijayapura	336	347	327	338	353
Yadgir	417	441	419	415	428

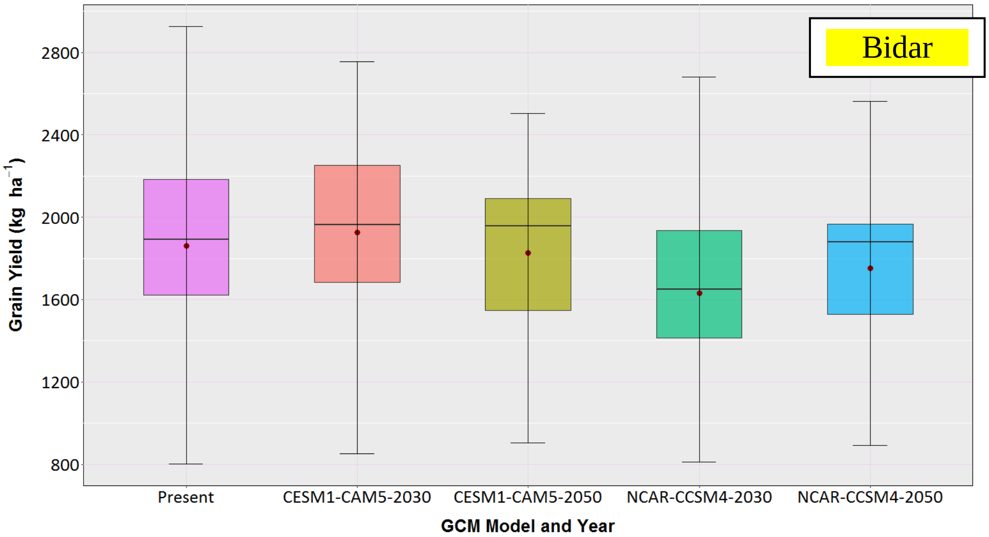


Figure 52: Variability of grain yield under different climate change scenarios in Bidar district

Year-to-year variability in yield would increase in both the models / periods. Under two models and two periods, first quartile, median and third quartile values are less compared to base yield which show increased risk of sustainable yield under future climate change scenarios (Figure 52).

Kalaburagi District

In Kalaburagi district, annual rainfall would increase by 38 mm in 2030 and 27 mm in 2050 as per CESM1-CAM5 model (Table 17). Under NCAR-CCSM4 model, annual rainfall would increase by 17 mm and 80 mm in 2030 and in 2050 respectively. Grain yield of pigeonpea would increase by 7.5 percent in 2030 and decrease by two percent in 2050 as per CESM1-CAM5 model (Table 12). Under NCAR-CCSM4 model, the grain yield would decrease by nine percent in 2030 and 0.5 percent in 2050 (Table 13). Pigeonpea crop duration would reduce by seven days in 2030 and by fourteen days in 2050 as per the CESM1-CAM5 model (Table 14). Under NCAR-CCSM4 model, the crop duration would reduce by eight days and ten days in 2030 and 2050 respectively. In general, the crop water uptake would increase in Kalaburagi (Table 16). Surface runoff would increase as per both the models and periods (Table 15). Year-to-year variability in yield would increase in both the models / periods. First quartile yields as per projections would be less compared to base across periods. Median and third quartile yields as per CESM1-CAM5 model would be more and as per the model NCAR-CCSM4 would be less compared to base yields which show increased risk of sustainable yield under future climate change scenarios (Figure 53).

Table 17: Climate change projections

GCM Model	Year	Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	POM	Annual
Bidar district																	
CESM1-CAM5	2030	Rainfall (mm)	7	2	3	-1	13	3	-17	-16	6	14	0	18	-24	32	32
		MaxT (°C)	0.3	0.2	0.6	1.2	1.3	1.3	1.1	1	0.9	1	1.6	1.1	1.1	1.2	1.0
		MinT (°C)	2.5	1.4	0.8	0.3	1.2	1.3	1	1	1.1	1.9	2.7	3.3	1.1	2.6	1.5
NCAR-CCSM4	2030	Rainfall (mm)	-1	2	-4	4	3	2	8	-9	0	-42	18	-2	1	-26	-21
		MaxT (°C)	1.8	1.9	2.1	1.5	1.8	1.2	1	0.9	1.1	1.3	1.4	1.5	1.1	1.4	1.5
		MinT (°C)	0.9	1.5	1.9	1.7	2	1.4	1.2	1.1	1.2	1.2	2.3	1.1	1.2	1.5	1.5
CESM1-CAM5	2050	Rainfall (mm)	2	1	2	-1	3	-18	-4	10	43	31	4	11	31	46	84
		MaxT (°C)	1.7	2	2	2.6	2.9	3.5	2.1	1.7	1.7	1.9	2.4	1.9	2.3	2.1	2.2
		MinT (°C)	3.3	2.7	2.2	2.1	2.6	2.7	2	1.7	1.9	3	3.5	4	2.1	3.5	2.6
NCAR-CCSM4	2050	Rainfall (mm)	1	0	-3	-1	-8	7	28	30	13	-12	-2	0	78	-14	53
		MaxT (°C)	2.7	3	3.1	2.6	3.6	3	1.8	1.4	1.8	2	2.5	2.8	2.0	2.4	2.5
		MinT (°C)	1.7	2.6	2.6	2.8	3.2	2.3	2	1.7	1.9	2.1	2.5	1.5	2.0	2.0	2.2
Kalaburagi district																	
CESM1-CAM5	2030	Rainfall (mm)	6	2	2	-1	12	11	-25	-16	7	19	3	18	-23	40	38
		MaxT (°C)	-0.1	-0.2	0.6	1.4	1	1	1.1	1	0.8	0.9	1.4	0.6	1.0	1.0	0.8
		MinT (°C)	2.2	1.1	0.3	1	1.2	1.1	0.9	1	1.1	1.7	2.6	3	1.0	2.4	1.4
NCAR-CCSM4	2030	Rainfall (mm)	0	2	-4	2	3	-4	37	2	-1	-34	14	0	34	-20	17
		MaxT (°C)	1.8	1.9	2.1	1.5	1.5	1.1	0.9	0.8	1.1	1.2	1.3	1.3	1.0	1.3	1.4
		MinT (°C)	0.7	1.4	1.5	2	2.4	1.5	1.1	1.1	1.2	1.1	2.2	1	1.2	1.4	1.4
CESM1-CAM5	2050	Rainfall (mm)	2	1	-1	-2	3	-13	-11	-6	13	27	4	10	-17	41	27
		MaxT (°C)	1.3	1.7	2.2	2.8	2.4	3	2	1.6	1.6	1.7	2.2	1.3	2.1	1.7	2.0
		MinT (°C)	3	2.4	1.9	3	2.7	2.3	1.9	1.7	1.8	2.7	3.5	3.7	1.9	3.3	2.6
NCAR-CCSM4	2050	Rainfall (mm)	1	0	-2	-5	-9	9	39	36	17	-3	-5	2	101	-6	80
		MaxT (°C)	2.5	2.7	2.8	2.6	3.3	2.7	1.6	1.4	1.8	1.8	2.2	2.4	1.9	2.1	2.3
		MinT (°C)	1.5	2.5	2.3	3	3.1	2.1	1.8	1.6	1.9	2	2.5	1.3	1.9	1.9	2.1
Raichur district																	
CESM1-CAM5	2030	Rainfall (mm)	0	2	0	-3	9	8	-25	-7	6	29	12	24	-18	65	55
		MaxT (°C)	-0.2	-0.4	0.7	1.9	0.9	1.1	1.3	1.2	0.9	1.1	1.5	0.9	1.1	1.2	0.9
		MinT (°C)	1.9	0.7	0	1.6	1.4	1.3	1.2	1.3	1.1	1.5	2.2	3	1.2	2.2	1.4

GCM Model	Year	Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SWM	POM	Annual
NCAR-CCSM4	2030	Rainfall (mm)	0	0	-3	-2	2	12	41	8	-1	-31	8	9	60	-14	43
		MaxT (°C)	1.7	2	2.1	1.7	1.8	1.5	1.3	1.2	1.3	1.4	1.4	1.5	1.3	1.4	1.6
		MinT (°C)	0.7	1.9	2	2	2.1	1.8	1.3	1.4	1.4	1.4	2	1.4	1.5	1.6	1.6
CESM1-CAM5	2050	Rainfall (mm)	0	1	-2	-6	0	-11	-7	-11	2	35	7	11	-27	53	19
		MaxT (°C)	1.1	1.6	2.4	3.2	2.6	3.1	2.1	1.9	1.7	1.9	2.2	1.6	2.2	1.9	2.1
		MinT (°C)	2.8	2.1	1.8	3.3	2.7	2.5	2.1	1.9	1.8	2.4	3.2	3.8	2.1	3.1	2.5
NCAR-CCSM4	2050	Rainfall (mm)	0	0	-3	-9	-8	23	52	36	7	-3	-8	0	118	-11	87
		MaxT (°C)	2.4	2.7	2.9	2.8	3.6	2.9	2	1.8	1.9	2	2.3	2.5	2.2	2.3	2.5
		MinT (°C)	1.6	3	3	3	3.1	2.6	2.1	2	2.1	2.3	2.4	1.8	2.2	2.2	2.4
Vijayapura district																	
CESM1-CAM5	2030	Rainfall (mm)	4	2	0	-5	8	10	-31	-5	12	29	6	17	-14	52	47
		MaxT (°C)	0.1	0	0.8	1.7	1.6	1.3	1.5	1.3	1	1	1.8	1	1.3	1.3	1.1
		MinT (°C)	2.6	1.7	0.9	0.9	1.7	1.3	1.3	1.4	1.3	1.9	2.7	3.4	1.3	2.7	1.8
NCAR-CCSM4	2030	Rainfall (mm)	0	2	-2	-1	4	-2	65	16	-7	-31	5	1	72	-25	50
		MaxT (°C)	1.9	2.2	2.2	1.8	1.7	1.1	1.1	1.1	1.4	1.4	1.6	1.7	1.2	1.6	1.6
		MinT (°C)	0.7	1.5	1.5	2.1	2.4	1.7	1.4	1.5	1.3	1.4	2.2	1.3	1.5	1.6	1.6
CESM1-CAM5	2050	Rainfall (mm)	1	1	-3	-5	2	-18	-9	1	4	38	5	8	-22	51	25
		MaxT (°C)	1.5	2	2.4	3	2.8	3.1	2.1	1.8	1.8	1.8	2.5	1.7	2.2	2.0	2.2
		MinT (°C)	3.4	2.8	2.3	2.8	2.8	2.4	2.2	2.1	1.9	2.8	3.6	4.1	2.2	3.5	2.8
NCAR-CCSM4	2050	Rainfall (mm)	2	1	-2	-7	-7	13	67	46	17	-1	-12	-1	143	-14	116
		MaxT (°C)	2.6	3.1	3	2.9	3.5	2.4	1.8	1.6	2	1.9	2.5	2.8	2.0	2.4	2.5
		MinT (°C)	1.6	2.6	2.4	3.1	3.1	2.2	2.1	2	1.9	2.2	2.5	1.5	2.1	2.1	2.3

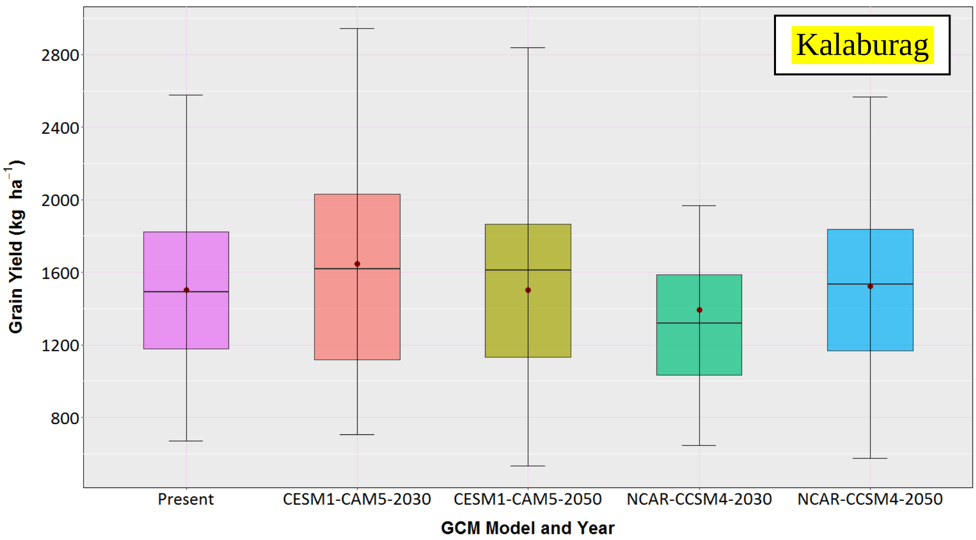


Figure 53: Variability of grain yield under different climate change scenarios in Kalaburagi district

Raichur District

Raichur district is having lesser rainfall compared to other four districts. Increased rainfall in future climate change scenarios is beneficial for pigeonpea in the district. In Raichur district, annual rainfall would increase by 55 mm in 2030 and by 19 mm in 2050 as per the CESM1-CAM5 model (Table 17). Under NCAR-CCSM4 model, annual rainfall would increase by 43 mm and 87 mm in 2030 and in 2050 respectively. The grain yield of pigeonpea would increase by 7.2 percent in 2030 and by 1.5 percent in 2050 as per the CESM1-CAM5 model (Table 12). Similarly, under NCAR-CESM1 model, grain yield would decrease by 2.4 percent in 2030 and by 4.9 percent in 2050 (Table 13). Crop duration of pigeonpea would be reduced by 10 days in 2030 and 13 days in 2050 as per the CESM1-CAM5 model (Table 14). Under NCAR-CCSM4 model, the crop duration would be reduced by 10 days and 14 days in 2030 and in 2050 respectively. In general, the crop water uptake would be increased in Raichur district (Table 16). Surface runoff would increase in both periods and models (Table 15). Year-to-year variability in yield would increase in both the models / periods. First quartile yields and median yields would be more compared to base under CESM1-CAM5 model. As per the NCAR-CCSM4 model, all the quartile yields would be less compared to base which shows increased risk of sustainable yield under future climate change scenarios (Figure 54).

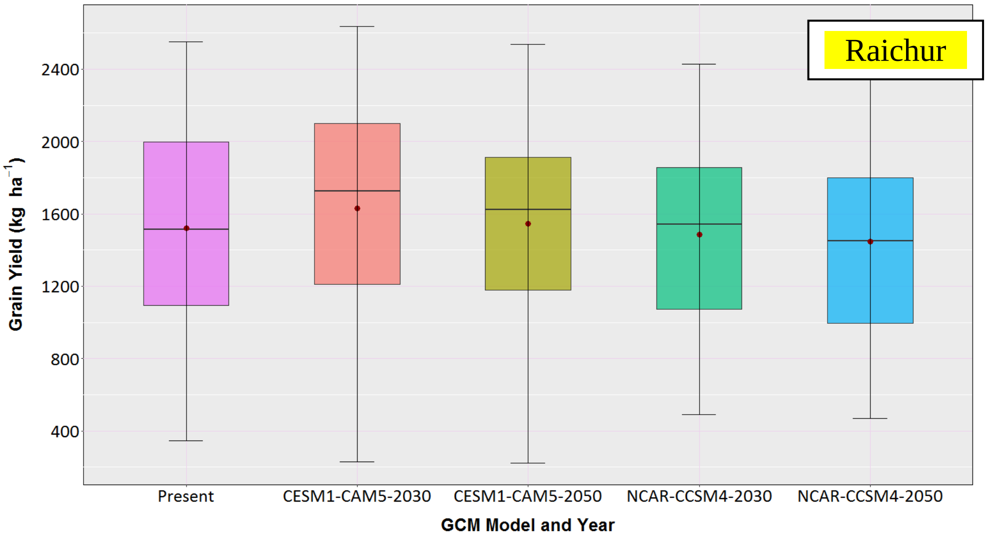


Figure 54: Variability of grain yield under different climate change scenarios in Raichur district

Vijayapura District

In Vijayapura district, annual rainfall would increase by 47 mm in 2030 and 25 mm in 2050 under CESM1-CAM5 model (Table 17). As per the NCAR-CCSM4 model, annual rainfall would increase by 50 mm and 116 mm in 2030 and in 2050 respectively. Pigeonpea yields would increase by 12.8 percent in 2030 and decrease by 5.8 percent in 2050 under CESM1-CAM5 model (Table 12). Similarly as per NCAR-CCSM4 model, the grain yield would decrease by one percent in 2030 and increase by 3.5 percent in 2050 (Table 13). Crop duration of pigeonpea would reduce by nine days in 2030 and 17 days in 2050 under the CESM1-CAM5 model (Table 14). As per NCAR-CCSM4 model, the crop duration would be reduced by 9 days and 12 days in 2030 and in 2050 respectively. In general, the crop water uptake would be increased in Vijayapura district (Table 16). Surface runoff would increase in both periods and models (Table 15). First quartile yields would be more compared to base under all scenarios (Figure 55).

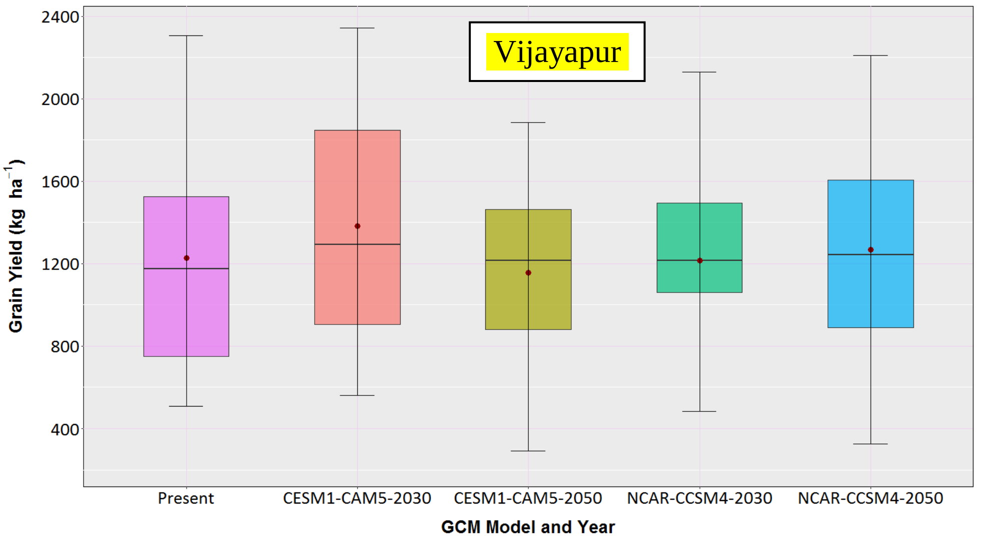


Figure 55: Variability of grain yield under different climate change scenarios in Vijayapura district

Yadgir District

In Yadgir district, annual rainfall would increase by 50 mm in 2030 and by 28 mm in 2050 under CESM1-CAM5 model (Table 17). As per the NCAR-CCSM4 model, annual rainfall would increase by 20 mm and 70 mm in 2030 and 2050 respectively. Grain yield of pigeonpea would increase by 11.1 percent in 2030 and decrease by 5.3 percent in 2050 under CESM1-CAM5 model (Table 12). As per the NCAR-CCSM4 model, the grain yield would decrease by 4.7 percent in 2030 and 4.9 percent in 2050 (Table 13). The crop duration of pigeonpea would be reduced by six days in 2030 and twelve days in 2050 under CESM1-CAM5 model (Table 14). As per NCAR-CCSM4 model, the crop duration would be reduced by seven days and ten days in 2030 and 2050 respectively. Crop water uptake would increase in Yadgir district (Table 16) as per both the models. Surface runoff would increase in both periods and models (Table 15). Year-to-year variability in yields would be increasing in both the models / periods. First quartile, median and third quartile yields would be less in both the models and years except CESM1-CAM5 in 2030 which indicates increased risk of sustainable yield under future climate change scenarios (Figure 56).

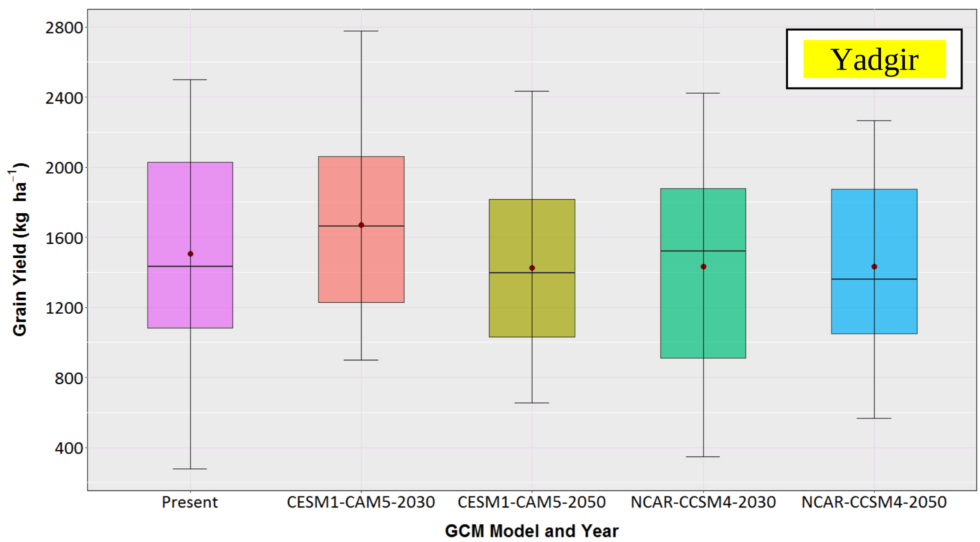


Figure 56: Variability of grain yield under different climate change scenarios in Yadgir district

Summary

Various studies show that climate change in India is real and it is one of the major challenges faced by Indian Agriculture. Significant increasing trends in mean maximum temperature over many states in India were reported. At the country scale, no long-term trend in the onset date of southwest monsoon over Kerala and total monsoon rainfall over whole country was observed. Changes in climate affect agriculture and water demand of an area. Changes in temperatures impacts crop yields, enhance crop water requirements and change the length of the growing period; all these necessitates region-wise changes in crops / varieties and management practices for sustainable crop production. In Karnataka, pigeonpea is largely grown in the northern parts of the state. Bidar, Vijayapura, Kalaburagi, Yadgir and Raichur districts are the major pigeonpea growing districts together have an area of about 6.67 lakh ha with a production of about 4.19 lakh tonnes. Kalaburagi district is known as “Pulse Bowl of Karnataka”.

District-wise monthly rainfall data and IMD gridded daily temperature and rainfall data was used to assess the temperature and rainfall trends and climate trends in the five selected districts having major area under pigeonpea cultivation. Analysis of temporal variation of temperature during the seven month period (June to December) showed that there appears to be a clear increase in maximum temperature of about one degree centigrade, indicating that in future, major pigeonpea growing districts in Karnataka are likely to have higher temperatures during the crop-growing period, impacting the crop duration and productivity. All the districts show reduction in rainfall in both Kharif and Rabi seasons. Vijayapura district witnessed greatest reduction of 86 mm in annual rainfall; while Bidar district experienced lowest reduction of annual rainfall of about 66 mm. Kharif season rainfall is critical for pigeonpea crop and all districts show considerable reduction in rainfall which is alarming.

Two GCM models namely CESM1-CAM5 and NCAR-CCSM4 under climate change scenario of RCP8.5 for the period 2030 and 2050 and APSIM pigeonpea crop-growth simulation model are used for assessing the impacts of projected climate change on pigeonpea yields in the five selected districts. In general, the two projection models show increased rainfall by 2030 and 2050 periods in the range of 15 to 120 mm annually. Pigeonpea crop duration would reduce as indicated by both the models and periods. Crop water uptake would be impacted differently under the two models. Pigeonpea yields under CESM1-CAM5 model show a slight increase by the year 2030 while a slight reduction by the year 2050. Under NCAR-CCSM4 model, pigeonpea yields show a general reduction in both the years 2030 and 2050. Year-to-year variability in yield showed increasing trends in both the models / periods. Projected climate impacts indicated increased risk of sustainable yield under future climate change scenarios. Important point to note is that even under the present climate conditions, district level pigeonpea yields are very low compared to the rainfed potential yields. The present pigeonpea yield gap varies from 54 percent at Vijayapura to 72 percent at Raichur, which highlights the need for helping the rainfed farmers of this region through strengthened extension services for better crop management.

13. Climate Change Impacts on Pigeonpea at Kalaburagi: NICRA Experiences

Pigeonpea is largely grown in the northern parts of the state, especially in Kalaburagi, which is known as "Pulse Bowl of Karnataka". Pigeonpea occupies about 3.7 lakh ha in Kalaburagi with a production of about 0.23 M t; the district average productivity (2004-2013) is 0.7 t/ha. District-wise data of Kalaburagi shows that pigeonpea area has increased three-folds from about 1.4 lakh ha in 1970 to 3.7 lakh ha in 2013. There has been a sharp and steady increase in area under pigeonpea since 1995.

In 1992, due to severe infestation of pod borer, the lowest productivity of 0.023 t/ha was recorded. TS 3R is a medium duration (150-160 days) variety released by the University of Agricultural Sciences, Raichur, and has higher yield potential (1.0 - 1.25 t/ha) in Karnataka. Estimating cultivar coefficients for pigeonpea help in using crop-growth simulation models to identify areas with potential for higher yields in a changing climate, and also helps in suggesting adaptation strategies at specific locations.

Pigeonpea's productivity and water use were assessed under 11 climate scenarios using the pigeonpea model in Agricultural Production Systems Simulator (APSIM). Simulations were carried out with automatic sowing based on rainfall and soil moisture availability during the sowing window (15 Jun to 20 Aug) and following recommended crop management practices.

Simulated pigeonpea grain yield and total biomass were 2057 and 8708 kg/ha, respectively under baseline (present) climate. Increase in temperature by 1 and 2°C could decrease grain yields by 9 and 16%, respectively (Table 18). Similarly, total biomass decreased by 5 and 9% with increase in temperature by 1 and 2°C. Decrease in rainfall by 10% coupled with increase in temperatures by 1 and 2°C could further reduce grain yields by 5 and 4% making the total reduction 14% and 20%. The situation could further worsen with reduction in rainfall by 20%, increasing loss of grain yields by 21 and 28% with increase in temperature by 1 and 2°C, respectively. Increased rainfall scenarios could benefit the crop to some extent, particularly in the low rainfall years, but the net effect still remained negative.

Table 18. Recommended crop management practices based on crop simulation results.

Climate scenario	Days to flowering	Days to maturity	Total biomass (kg/ha)	Grain yield (kg/ha)	Change in yield (%)
Present (P)	103	157	8708	2057	0
P+1°C	101	151	8286	1875	-9
P+1°C-10% rainfall	99	150	7798	1771	-14
P+1°C-20% rainfall	99	150	7090	1615	-21
P+1°C+10% rainfall	101	151	8659	1961	-5
P+1°C+20% rainfall	101	152	8866	2005	-3
P+2°C	99	148	7943	1734	-16
P+2°C-10% rainfall	98	147	7465	1636	-20
P+2°C-20% rainfall	98	147	6763	1486	-28
P+2°C+10% rainfall	100	149	8302	1809	-12
P+2°C+20% rainfall	99	148	8525	1854	-10

Increased temperature can shorten crop duration. Days to flowering were shortened by 2 and 4 and the total crop duration by 5 and 9 days with increase in temperature by 1 and 2°C, respectively. Increase in temperature causes more transpiration per day which results in water stress during dry periods. Water balance outputs have shown that decrease in rainfall by 10 and 20% resulted in less plant water use by 18 mm and 45 mm, respectively with increase in temperature by 2°C. Increments in rainfall by 10 and 20% will result in more rainfall only for the days having rainfall and will not affect non-rainy days. Thus, additional rainfall has contributed more towards runoff and drainage than evapotranspiration. Simulated water use efficiency of pigeonpea reduced from 7.2 kg/ha/ mm in the baseline by 6.6 and 6.0 kg/ha/mm with temperature increase of 1 and 2°C, respectively.

Results indicated that better water and nutrient management is key, and Integrated Watershed Management plays a major role in sustaining pigeonpea productivity under future climate scenarios. Adoption of varieties tolerant to high temperature could also play a major role in sustainable pigeonpea yields in Kalaburagi district. Water stress during the end of season could be avoided by sowing short- and extra-short-duration varieties. Breeding of varieties which can put extra root mass is required for sustainable pigeonpea production in the future.

Assessing projected climate change impacts on pigeonpea at Gulbarga using crop-growth simulation models

More than 50% of the population in the state depends on agriculture. Almost 80% of agricultural land is under rainfed conditions and is sensitive to droughts and floods, and thus to climate variability. An attempt was made to assess the impacts of climate change on pigeonpea at Gulbarga.

Details of field experiments

Pigeonpea varieties and a hybrid were selected for field experiments at Farhatabad, Gulbarga and at ICRISAT, Patancheru during 2011-12, 2012-13 and 2013-14. Pigeonpea variety ICP 8863 (Maruti) is a medium duration (170-180 days) variety with a yield potential of 1.5 t/ha and is popular in AP, Karnataka and Maharashtra. ICP 87119 (Asha) is a medium duration (160-200 days) variety with a yield potential of 1.5 - 2.0 t/ha and is suitable for Karnataka, Maharashtra and Gujarat. ICPH 2671 (hybrid) is a medium duration (170-180 days) hybrid having a high yield potential of 2.7 t/ha and is suitable for Maharashtra and Karnataka. Variety TS-3R was developed by the University of Agricultural Sciences, Raichur and is very popular in Gulbarga region. It is of medium duration (150-160 days) with high yield potential (1.0 -1.25 t/ha) and is resistant to wilt and tolerant to fog.

Layer-wise soil sampling was done at Farhatabad. Soil samples were analyzed in the lab to estimate pH, EC, organic carbon and nutrients P, K, S, Zn and B. The results were used to apply balanced nutrition as per the recommended package of practices. BBF system and recommended crop spacing were followed. At Farhatabad, soils have a pH of 8.3, EC of 0.35 dS/m, OC of 0.68%, available P of 6.8 mg/kg, K of 279 mg/kg, Zn of 1.46 mg/kg, Fe of 8.7 mg/kg and B of 2.10 mg/kg soil.

Figure 57: Farmer-participatory soil sampling at Farhatabad.

To assess the status of moisture availability to crops, soil moisture observations were taken at fortnightly intervals by gravimetric method (0-30 cm depth). Crop observations were taken at different growth stages for evaluating experimental data with simulation model outputs. APSIM version 7.4 was used for pigeonpea crop growth simulation. Most of the soil and crop data required for generating genetic coefficients was generated at ICRISAT watershed and observations were made following procedures specifically prescribed for simulation models.

Figure 58: Recording pigeonpea growth at Farhatabad.

Fourteen morphological parameters were taken from a sample area of 1.0 x 0.5 m at an interval of 15 days during crop growth stage. Six phenological observations for pigeonpea were taken during crop growth. Five yield parameters were taken at harvest stage from a sample area of 4x3 m.

Assessing impacts of climate on pigeonpea

In Karnataka, pigeonpea is largely grown in the northern parts of the state especially in Gulbarga, which is known as "Pulse Bowl of Karnataka". Pigeonpea occupies an area of about 0.38 M ha in Gulbarga with a production of about 0.22 M t and thus the district average productivity is 0.57 t/ha. Major soils of the district are Vertisols and associated intergrades (deep black, medium black, shallow black) and lateritic, with water holding capacity of 200-230 mm, and are suitable for pigeonpea cultivation. Gulbarga district experiences a typical semi-arid climate. Normal annual rainfall for Gulbarga station is 834 mm received in 48 rainy days (IMD, 2010). Kharif (Jun-Oct) rainfall is about 720 mm, which is 86 % of the annual rainfall. May is the hottest month with an average maximum temperature of 40°C and December is the coldest month with an average minimum temperature of 15.9°C.

A decreasing trend in the annual rainfall at 3.44 mm per year for Gulbarga district was reported by earlier researchers based on data for 1961-2008. Variations in rainfall amount and distribution, increased temperatures, depleting soil productivity and disturbing water balance are affecting pigeonpea productivity in Gulbarga.

Daily weather data on maximum temperature, minimum temperature and rainfall were procured from the India Meteorological Department for the period 1969-2009 (41 years). Pigeonpea data of Gulbarga were collected from 1970 to 2009 for assessing the changes in area, production and productivity of the crop.

In the present study, pigeonpea simulation model in APSIM 7.4 version was used to assess the impacts of projected climate change. Pigeonpea variety TS-3R was developed by the University of Agricultural Sciences, Raichur and is very popular in Gulbarga region. It is a medium duration (150-160 days) variety and is resistant to wilt and tolerant to fog.

Ten climate change scenarios and the present were considered (Table 19) for assessing impacts of projected climate on pigeonpea using the calibrated APSIM model. The scenarios included 1 °C, 2 °C increase in both maximum and minimum temperatures and with 10% and 20% decrease and increase in rainfall.

These climate change scenarios are incorporated in the model by increasing daily maximum and minimum temperatures and multiplying the rainfall by specified change.

Table 19. Projected climate scenarios

Sl. No.	Climate scenario description
1	Present
2	Present + 1 °C Temp.
3	Present + 1 °C Temp.-10% Rainfall
4	Present + 1 °C Temp.-20% Rainfall
5	Present + 1 °C Temp.+10% Rainfall
6	Present + 1 °C Temp.+20% Rainfall
7	Present + 2 °C Temp.
8	Present + 2 °C Temp.-10% Rainfall
9	Present + 2 °C Temp.-20% Rainfall
10	Present + 2 °C Temp.+10% Rainfall
11	Present + 2 °C Temp.+20% Rainfall

Results and Discussion

District-wise data shows that pigeonpea area increased three-folds from about 0.14 M ha in 1970 to 0.43 M ha in 2007 (Figure 59). There has been a sharp and steady increase in area since 1995. Average pigeonpea productivity was 0.42 t/ha. In 1992, due to severe pod borer infestation, the lowest productivity of 0.023 t/ha was recorded.

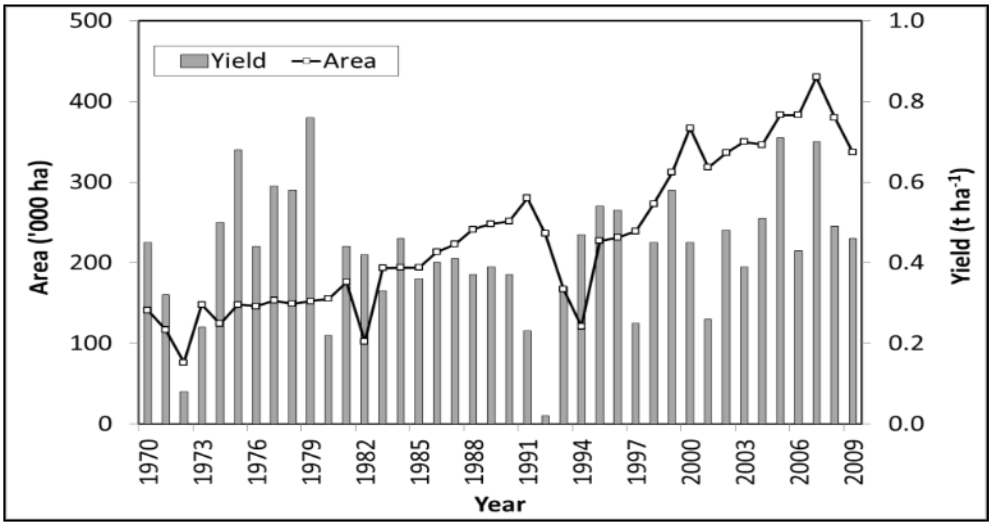


Figure 59: Area and productivity of pigeonpea in Gulbarga, 1970-2009.

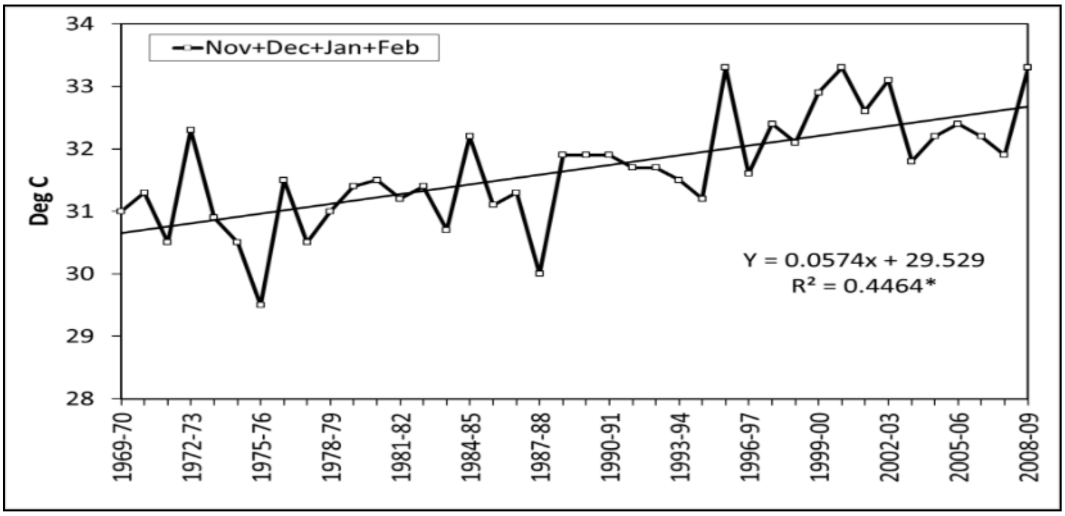


Figure 60: Climatic shifts in Gulbarga.

Gulbarga's climate was more or less stable except for a few years when it changed to dry sub-humid and arid types of climate (Figure 60). Analysis of seasonal rainfall indicates that no significant trend exists in southwest monsoon rainfall during the period 1969-2009.

Due to climate change, temperatures have shown an increasing trend, particularly in winter. Maximum temperature during Rabi season (Nov-Feb) at Gulbarga showed a statistically significant increasing trend (Figure 61).

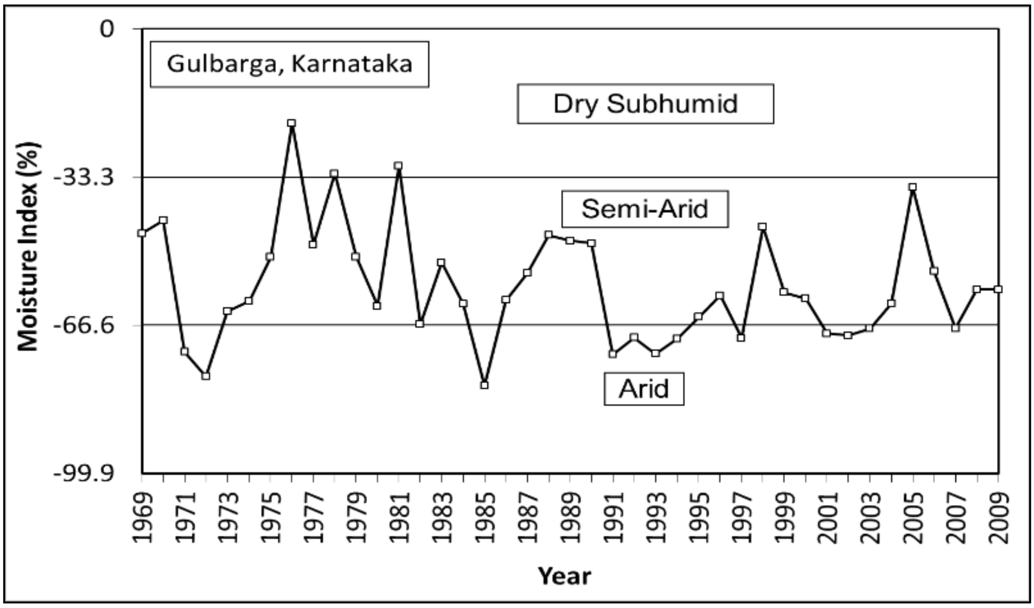


Figure 61: Maximum temperature during Nov-Feb at Gulbarga.

Estimation of pigeonpea genetic coefficients

Genetic coefficients for variety TS-3R were estimated based on observed phenology and crop growth data from field experiments at ICRISAT, Patancheru during 2011. APSIM simulated growth parameters fairly matched observed data. Observed and simulated total biomass (Figure 62) indicate that the APSIM pigeonpea model can be used to assess the impacts of climate change on pigeonpea at Gulbarga. Other crop growth parameters like grain yield, pod yield and leaf area index simulated by the model were within acceptable range compared with observed values. Observed and simulated grain yields were 1780 and 1570 kg/ha, respectively. Simulated flowering and maturity days were 89 and 162 days and compared well with the observed values of 88 and 164 days, respectively.

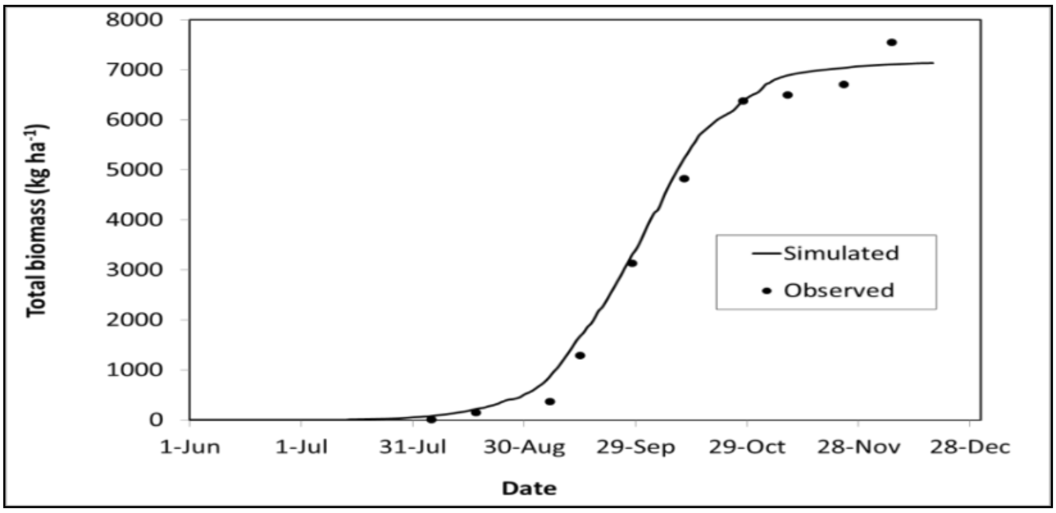


Figure 62: Observed and simulated total biomass of pigeonpea variety TS-3R.

Climate change impacts on pigeonpea

Climate change is likely to alter the growing conditions of crops due to increase in temperature and changes in the rainfall pattern. In semi-arid tropics, the duration of growing period generally decreases and the abiotic and biotic stresses are likely to increase. Such adverse conditions in future climate will impact the crop yields negatively.

Simulated pigeonpea grain yield and total biomass at Gulbarga were 2057 and 8708 kg/ha, respectively under baseline (present) climate. Increase in temperature by 1 and 2 °C could decrease grain yield by 9 and 16%, respectively (Table 13). Similarly, total biomass decreased by 5 and 9% with increase in the temperature by 1 and 2 °C. Decrease in rainfall by 10% coupled with increase in temperatures by 1 and 2 °C could further reduce grain yields by 5 and 4% making the total reduction at 14 and 20%. The situation could further worsen with reduction in rainfall by 20%, making the loss of grain yields by 21 and 28% with increase in temperature by 1 and 2 °C, respectively. Increased rainfall scenarios could benefit the crop to some extent, particularly in the low rainfall years, but net effect still remained negative.

Increased temperature could shorten the crop duration. Days to flowering shortened by 2 and 4 and the total crop duration by 5 and 9 days with increase in temperature by 1 and 2 °C, respectively (Table 20). The increase in temperature causes more transpiration per day which results in water stress during the dry periods. Water balance outputs have shown that decrease in rainfall by 10 and 20% resulted in less plant water use by 18 and 45 mm, respectively with increase in temperature by 2 °C (Table 21). Slight reduction in runoff and drainage with increased temperatures is due to shortened crop duration. Increments in rainfall by 10 and 20% will result in more rainfall only for the days having rainfall and will not affect non-rainy days. Thus, additional rainfall has contributed more towards runoff and drainage than evapotranspiration. Simulated water use efficiency of pigeonpea reduced from

7.2 kg/ha/mm in the baseline by 6.6 and 6.0 kg/ha/ mm with temperature increase of 1 and 2 °C, respectively.

Table 20. Effect of projected climate on phenology and productivity of pigeonpea variety TS-3R.

Climate scenario	Days to flowering	Days to maturity	Total biomass (kg/ha)	Grain yield (kg/ha)	Change in yield (%)
Present (P)	103	157	8708	2057	0
P+1°C	101	151	8286	1875	-9
P+1°C-10% rainfall	99	150	7798	1771	-14
P+1°C-20% rainfall	99	150	7090	1615	-21
P+1°C+10% rainfall	101	151	8659	1961	-5
P+1°C+20% rainfall	101	152	8866	2005	-3
P+2°C	99	148	7943	1734	-16
P+2°C-10% rainfall	98	147	7465	1636	-20
P+2°C-20% rainfall	98	147	6763	1486	-28
P+2°C+10% rainfall	100	149	8302	1809	-12
P+2°C+20% rainfall	99	148	8525	1854	-10

The simulation results have shown that the selected temperature and rainfall change scenarios could reduce pigeonpea grain yields by 3 to 28%. Days to flowering and maturity reduced by 5-10 days under different climate change scenarios. Increased temperature by 2 °C coupled with 20% reduction in rainfall could reduce water use by 45 mm. Increased rainfall could help to recoup the yield losses in the low rainfall years. Results of study indicated that, better water and nutrient management approach is the key and Integrated Watershed Management plays a major role in sustaining pigeonpea productivity under future climate scenarios. Adoption of varieties tolerant to high temperature could also play a major role in sustainable pigeonpea yields. Water stress during the end of season could be avoided by sowing the short and extra-short duration varieties. Breeding of varieties which can put extra root mass is required for sustainable pigeonpea production in the future.

Table 21. Effect of projected climate on water balance of pigeonpea.

Climate Scenario	Rainfall (mm)	Runoff (mm)	Drainage (mm)	Evapo-transpiration (mm)	Soil evaporation (mm)	Plant use (mm)
Present (P)	594	66	103	475	187	287
P+1°C	589	65	102	472	186	286
P+1°C -10% rainfall	522	48	70	449	181	268
P+1°C -20% rainfall	457	33	45	420	178	242
P+1°C +10% rainfall	650	84	135	487	188	299
P+1°C +20% rainfall	710	104	171	498	191	307
P+2°C	587	64	99	474	187	287
P+2°C -10% rainfall	520	47	68	450	182	269
P+2°C -20% rainfall	455	33	43	420	179	242
P+2°C +10% rainfall	648	82	132	490	190	300
P+2°C +20% rainfall	709	102	167	501	192	309

14.Awareness Programs on Climate Change

Climate variability and change threaten agriculture, water availability, forest biodiversity and livelihoods in Karnataka. Agriculture contributes significantly to the economy of Karnataka and it is necessary to enhance productivity in good weather years and to ensure resilience during years with unfavourable /aberrant weather. Adaptation strategies to cope with current climate variability and mitigation strategies to help build resilience for the future climate are needed for continued economic growth. Building awareness about climate change among the farming community and among policy makers is crucial. Understanding the urgent need for enhancing climate awareness among various stakeholders, 37 climate awareness programmes were conducted across the districts of Karnataka under the project (Annexure 2). Many of these were part of district-level workshops on climate change (Figure 63).

Figure 63: Climate awareness programs at (L) DATC, Kotnoor-Kalaburagi on 21 April 2014 and (R) KVK, Mysore on 12 June 2014.

15. Capacity Building

District level trainings covering a wide range of topics were organized to sensitize Department staff, Farm Facilitators and ICRISAT staff located in different districts, attended by DoA officials (JDA, ADAs, AOs, AAOs), scientists from universities, KVKs, and scientists, scientific officers and research technicians of ICRISAT. During 2015-16, 52 trainings were organized with 4374 participants; about 75 trainings with 7165 participants during 2014-15 and 38 trainings with 4283 participants during 2013-14. (Table 22).

Taluk-level trainings were organized for agricultural assistants, newly appointed field facilitators and lead farmers in each taluk at different intervals in all the districts. These trainings provided hands-on training and demonstration of technologies, such as seed treatment, soil sampling, use of tropicultor, crop harvest sampling, and village level record keeping by field facilitators. In all the 30 districts, 169 trainings were conducted during 2015-16 with 13,056 participants; 187 trainings during 2014-15 with 15,769 participants and 13,448 were trained during 2013-14 (Table 23).

Cluster/village-level trainings were organized by AOs of DoA and research technicians of ICRISAT who were sometimes assisted by resource persons, either scientists or scientific officers from ICRISAT. These were even informal gatherings of farmers in a village to discuss input distribution or specific soil/crop related issues. During 2013-14, these trainings covered more than 4.9 lakhs farm men and women before the start of the season in all the 30 districts.

Similarly, 3.7 lakh and 1.2 lakh farmers were trained during 2014-15 and 2015-16 respectively under the project (Table 24).

Table 22. District-level trainings conducted under the project from 2013-14 to 2015-16.

Sl. No	District	2015-16		2014-15		2013-14	
		No. of trainings	Participants	No. of trainings	Participants	No. of trainings	Participants
1	Bagalkote	3	239	2	130	1	60
2	Ballari	3	210	3	300	1	77
3	Bengaluru R	1	65	3	150	1	71
4	Bengaluru U	0	0	1	55	1	45
5	Belagavi	2	223	3	300	1	100
6	Bidar	4	250	3	485	1	380
7	Vijayapura	2	88	3	153	1	60
8	Chamarajanagar	1	60	3	381	1	52
9	Chikkaballapur	3	450	2	66	1	84
10	Chikkamagalur	2	138	1	65	1	56
11	Chitradurga	2	285	2	241	2	214
12	Davangere	0	0	2	652	2	370
13	Dharwad	3	656	3	608	1	299
14	Dakshina Kannada	3	150	2	187	2	150
15	Gadag	1	21	4	260	1	205
16	Kalaburagi	2	246	3	559	1	350
17	Hassan	3	274	3	360	1	138
18	Haveri	1	156	1	75	2	190
19	Kolar	3	213	1	102	1	69
20	Kodugu	2	133	4	156	2	69
21	Koppal	2	77	3	180	1	48
22	Mandya	2	78	3	214	1	75
23	Mysuru	1	85	3	282	2	200
24	Raichur	0	0	6	220	1	157
25	Ramanagara	0	0	3	180	1	95
26	Shivamoga	2	100	1	65	1	180
27	Tumakuru	1	50	3	213	2	80
28	Udupi	2	60	3	197	2	120
29	Uttara Kannada	0	0	3	148	1	58
30	Yadgiri	1	67	2	246	1	300
	Total	52	4374	75	7165	38	4283

Table 23. Taluk-level trainings conducted under the project from 2013-14 to 2015-16.

District	2015-16		2014-15		2013-14	
	No. of Trainings	Participants	No. of Trainings	Participants	No. of Trainings	Participants
Bagalkote	12	817	12	592	6	296
Ballari	14	695	7	393	7	566
Bengaluru R	2	296	4	374	3	194
Bengaluru U	0	0	4	379	4	302

Table 23. Taluk-level trainings conducted under the project from 2013-14 to 2015-16.						
District	2015-16		2014-15		2013-14	
	No. of Trainings	Participants	No. of Trainings	Participants	No. of Trainings	Participants
Belagavi	15	2369	10	1013	10	775
Bidar	10	739	5	975	5	935
Vijayapura	2	258	5	350	5	635
Chamarajanagar	2	80	8	124	4	200
Chikkaballapur	6	368	6	469	6	648
Chikkamagalur	10	616	7	450	7	322
Chitradurga	7	341	6	382	6	546
Davanagere	0	0	6	736	12	596
Dharwad	9	465	5	450	5	597
Dakshina Kannada	6	448	5	452	5	289
Gadag	2	150	12	850	5	349
Kalaburagi	10	833	7	805	7	840
Hassan	8	914	8	1849	7	834
Haveri	1	86	7	668	7	490
Kolar	6	537	5	517	5	551
Kodagu	5	157	3	115	6	242
Koppal	0	0	4	200	4	465
Mandya	2	87	7	382	7	236
Mysuru	1	46	7	612	7	612
Raichur	7	840	11	750	5	203
Ramanagara	0	0	4	426	4	250
Shivamoga	5	138	7	450	8	715
Tumakuru	2	125	10	1019	10	900
Udupi	5	350	3	232	3	259
Uttara Kannada	2	179	11	448	11	250
Yadgiri	1	80	3	274	3	550
Total	169	13056	187	15769	184	13448

Table 24. Village-level trainings conducted under the project from 2013-14 to 2015-16.						
District	2015-16		2014-15		2013-14	
	No. of Trainings	Participants	No. of Trainings	Participants	No. of Trainings	Participants
Bagalkote	81	2388	192	39809	193	15625
Ballari	278	10000	412	15230	528	24572
Bengaluru R	84	2772	81	2947	121	4362
Bengaluru U	0	0	59	1956	55	2303
Belagavi	144	6547	347	16357	469	14475
Bidar	280	5562	405	20453	451	22045
Vijayapura	91	4610	559	16770	638	562
Chamarajanagar	89	2740	112	4480	105	8600

Table 24. Village-level trainings conducted under the project from 2013-14 to 2015-16.						
District	2015-16		2014-15		2013-14	
	No. of Trainings	Participants	No. of Trainings	Participants	No. of Trainings	Participants
Chikkaballapur	350	8750	208	10060	275	8525
Chikkamagalur	134	3908	202	8986	204	8160
Chitradurga	387	15529	412	12964	535	21400
Davanagere	0	0	471	91344	580	260870
Dharwad	208	7996	123	5315	314	22306
Dakshina Kannada	48	1986	62	1569	74	754
Gadag	15	420	286	10527	104	4000
Kalaburagi	50	1650	184	5336	184	750
Hassan	251	6421	304	13059	30	2186
Haveri	256	5897	275	7150	135	12150
Kolar	47	2093	201	6892	201	6432
Kodagu	45	677	95	4183	64	3852
Koppal	20	832	160	7027	20	1347
Mandya	59	2454	201	9967	212	7940
Mysuru	30	730	292	11997	371	12985
Raichur	246	9840	184	7852	0	0
Ramanagara	0	0	187	5546	206	5690
Shivamogga	99	2425	202	8986	138	12500
Tumakuru	49	1410	365	14927	510	18726
Udupi	40	880	104	5893	88	3427
Uttara Kannada	90	1429	198	4356	11	2522
Yadgiri	18	592	68	4654	150	1600
Total	3667	117512	6749	367606	6966	495709

16. Economic Benefits

Additional yield benefits ranging between 60 kg/ha in green gram and 1200 kg/ha in maize resulted in additional income of ₹ 3954/ha and 15667/ha respectively during 2013-14. It is to be noted that sugarcane recorded the highest additional yield (16720 kg/ha) and income (₹ 36784/ha) as a cash crop during 2013-14. During 2014-15, additional yield ranged between 60 kg/ha in green gram and 940 kg/ha in maize which resulted in additional income of ₹ 2760/ha and 12337/ha respectively. Similar levels of additional yield and income were observed during 2015-16, 2016-17 and 2017-18 crop seasons (Table 25 & Annexure 3).

Table 25: Additional yields and incomes accrued through improved management practices under the project between 2013-14 and 2017-18.										
Major crops	Additional yield (kg/ha) and income (₹/ha) during									
	2013-14		2014-15		2015-16		2016-17		2017-18	
	Yield (Kg/ha)	Income (₹/ha)	Yield (Kg/ha)	Income (₹/ha)	Yield (Kg/ha)	Income (₹/ha)	Yield (Kg/ha)	Income (₹/ha)	Yield (Kg/ha)	Income (₹ha)
Black gram	165	7083	130	5655	130	5655	310	15500	220	11880
Cotton	228	9125	218	8156	228	8563	208	8010	240	9648
Chickpea	245	7597	160	5063	145	4503	143	5733	152	6673
Cowpea	100	3954								
Field bean	211	8443								
Foxtail Millet									270	8100
Green gram	140	6295	60	2760	60	2760	370	19333	160	8920
Groundnut	438	17504	276	11040	236	9440	167	7033	261	11634
Maize	1196	15667	942	12337	766	10035	538	7342	637	9073
Paddy	951	12463	732	9959	787	10708	748	10994	717	11108
Paddy DSR									650	10075
Pearl Millet	633	7913	672	8396	300	3750	323	4289	248	3534
Pigeonpea	188	7241	258	11201	95	4133	160	8080	139	7562
Finger millet	397	5960	382	5924	308	4772	90	1553	360	6840
Rabi Finger millet							370	6383		
Sorghum	575	8734	409	6260	299	4576	453	7480		
Rabi Sorghum	359	5458					235	3878	254	3620
Soybean	398	10198	376	9400	150	3750	215	5966	370	11285
Safflower	222	6660								
Sunflower	316	11686	335	12563						
Rabi Sunflower	234	8654								
Sugarcane	16720	36784					7250	18488		
Wheat	402	5628			70	1068				
Little Millet									180	5400

Source: Based on crop cutting experiments data collected from 30 districts between 2013-14 and 2017-18

Overall, BCMP contributed nearly ₹ 1800 crores net income to Karnataka's economy between 2012-13 and 2015-16 (Table 26). Table 18 clearly reveals that rainfall variation had a clear impact on crop yield and income. However, additional revenue was generated through increased crop yield by adopting improved management practices.

Table 26. Economic benefits accrued from the project from 2012-13 to 2015-16.					
Year	2012-13	2013-14	2014-15	2015-16	Total
Net income (₹ in crores)	451.8	695.15	487	146.48	1780.83
Net income (Million US$)	82.44	110.35	77.3	22.53	292.62
Rainfall during crop growing season (mm)	618	934	833	652	

Source: Bhoochetana CCE data.

17. Learnings

- Bhoochetana Mission Program demonstrated the effectiveness of a consortium model of knowledge generating institutions and knowledge disseminating line departments in scaling up of good agricultural practices in Karnataka.
- Increased crop production and additional net income were realized due to improved agricultural practices.
- During the second phase, soil nutrients' contents were marginally higher compared to results from the 2008 soil analysis. Taking Dharwad district as a test case, significant reduction in boron, sulphur and phosphorus deficiency in farmers' fields was observed compared to 2008. However, higher mining of carbon and zinc was recorded in 2014 compared to 2008.
- The mission project has streamlined good practices for knowledge dissemination, data recording, and crop cutting. However, there is still scope to fully harness the agricultural potential in the state.
- A scientific approach and technical support enabled rainfed farmers to enhance crop productivity significantly (15 to 33%) during rainy and postrainy seasons for different crops.
- Intense and regular monitoring by the high-power State Coordination Committee helped with mid-course corrections and ensured timely project deliverables.
- Knowledge-based improved agricultural practices have proven to be effective techniques to enhance crop productivity as was evident from participatory evaluation of technologies.
- It is evident that small and marginal farm holders need to be enabled through capacity building trainings, exposure visits, demonstrations, access to inputs and handholding to achieve desired impacts in terms of increasing agricultural productivity of dryland systems.
- Supply chain for quality inputs need to be strengthened and put in place ahead of the beginning of the season.
- A weak extension system is a bottleneck for scaling up of the program although an effective institutional mechanism was put in place by the DoA during the first phase. Thus, capacity of available extension personnel need to be strengthened through regular capacity building programs.
- Farmer participatory evaluation of climate smart crop varieties has revealed the large yield gap that can be filled.
- Climate smart improved cultivars of groundnut, pigeonpea, finger millet, chickpea, green gram, and black gram are needed to increase production and to double farmer's income in view of increasing climate risks.

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Annexures

Annexure 1: Area coverage under Bhoochetana 2 phase in Karnataka

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
1	Bagalkot	Sorghum	1500	1500	100.0
	Bagalkot	Pearl millet	22000	18535	84.0
	Bagalkot	Maize	34000	25011	74.0
	Bagalkot	Pigeonpea	5000	5000	100.0
	Bagalkot	Green gram	26500	26500	100.0
	Bagalkot	Sunflower	5000	4230	85.0
	Bagalkot	Soybean	3000	3000	100.0
2	Bengaluru Rural	Ragi	44000	39314	89.0
	Bengaluru Rural	Maize	10000	12500	125.0
3	Bengaluru Urban	Ragi	20000	20000	100.0
4	Belgaum	Rice	64000	62579	97.8
	Belgaum	Jowar	23000	21934	95.4
	Belgaum	Maize	40000	52655	131.6
	Belgaum	Pearl millet	15000	8680	57.9
	Belgaum	Pigeonpea	5000	254	5.1
	Belgaum	Black gram	3000	3000	100.0
	Belgaum	Green gram	24000	15077	62.8
	Belgaum	Cowpea and others	2000	1383	69.2
	Belgaum	Groundnut	35000	32827	93.8
	Belgaum	Sunflower	5000	1744	34.9
	Belgaum	Soybean	80000	79037	98.8
	Belgaum	Cotton	30000	23144	77.1
5	Bellary	Paddy	70000	65643	94.0
	Bellary	Jowar	25000	19598	78.0
	Bellary	Maize	59000	70853	120.0
	Bellary	Pearl millet	12000	16700	139.0
	Bellary	Pigeonpea	9000	9321	104.0
	Bellary	Groundnut	56000	48021	86.0
	Bellary	Sunflower	28000	11933	43.0
	Bellary	Cotton	15000	30992	207.0
6	Bidar	Sorghum	58075	38860	66.9
	Bidar	Maize	2900	2022	69.7
	Bidar	Pearl Millet	6420	4540	70.7
	Bidar	Black gram	35282	23352	66.2
	Bidar	Green gram	33334	23186	69.5
	Bidar	Pigeonpea	65765	72013	109.5
	Bidar	Soybean	85864	112699	131.2
7	Bijapur	Maize	35000	65225	186.0

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
	Bijapur	Pearl millet	28500	35600	125.0
	Bijapur	Pigeonpea	175000	152575	87.0
	Bijapur	Sunflower	20500	13515	66.0
	Bijapur	Green gram	12000	6839	57.0
	Bijapur	Groundnut	27000	16000	59.0
8	Chamarajanagara	Ragi	14550	13775	94.7
	Chamarajanagara	Maize	26450	32792	124.0
	Chamarajanagara	Sorghum	18000	13577	75.4
	Chamarajanagara	Ground	18000	16457	91.4
	Chamarajanagara	Sunflower	16050	8092	50.4
	Chamarajanagara	Green Gram	2600	2716	104.5
	Chamarajanagara	Black Gram	5000	4650	93.0
	Chamarajanagara	Fieldbean	3250	1910	58.8
	Chamarajanagara	Cowpea	3000	2608	86.9
	Chamarajanagara	Cotton	5100	10740	210.6
9	Chikkaballapur	Ragi	41000	45117	110.0
	Chikkaballapur	Maize	39000	44827	114.0
	Chikkaballapur	Pigeonpea	8000	4950	61.0
	Chikkaballapur	Fieldbean	5000	4173	83.0
	Chikkaballapur	Groundnut	32500	19263	59.0
10	Chikkamagaluru	Paddy	31100	32210	103.6
	Chikkamagaluru	Ragi	46500	41335	88.9
	Chikkamagaluru	Maize	24700	33950	137.4
	Chikkamagaluru	Groundnut	3300	5950	180.3
	Chikkamagaluru	Sunflower	4940	4493	91.0
11	Chitradurga	Groundnut	146000	106860	73.0
	Chitradurga	Maize	81000	80913	100.0
	Chitradurga	Ragi	35000	30990	89.0
	Chitradurga	Pigeonpea	11000	8331	76.0
	Chitradurga	Green gram	3000	2975	99.0
	Chitradurga	Cotton	9000	8350	93.0
12	D. Kannada	Paddy	25000	25000	100.0
13	Davanagere	Sorghum	11000	13211	120.0
	Davanagere	Ragi	11000	4725	43.0
	Davanagere	Maize	154000	176833	115.0
	Davanagere	Pigeonpea	4000	9081	227.0
	Davanagere	Fieldbean	1000	1151	115.0
	Davanagere	Groundnut	12000	6872	57.0
	Davanagere	Sunflower	4000	1114	28.0
	Davanagere	Cotton	30000	20485	68.0
	Davanagere	Paddy	55000	55312	101.0

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
	Davanagere	Sugarcane	3000	4519	151.0
14	Dharwad	Soybean	34000	32602	96.0
	Dharwad	Groundnut	29000	26750	92.0
	Dharwad	Greengram	27000	20930	78.0
	Dharwad	Maize	20000	23900	120.0
	Dharwad	Paddy	20000	19000	95.0
	Dharwad	Hy. cotton	24500	31318	128.0
15	Gadag	Maize	17000	10768	63.0
	Gadag	Pearl millet	2000	1385	69.0
	Gadag	Jowar	7000	4885	70.0
	Gadag	Green gram	70000	67186	96.0
	Gadag	Pigeonpea	3000	1971	66.0
	Gadag	Groundnut	55000	36545	66.0
	Gadag	Sunflower	14000	5381	38.0
	Gadag	Cotton	12500	7275	58.0
16	Gulbarga	Blackgram	54000	34369	64.0
	Gulbarga	Greengram	41000	17741	43.0
	Gulbarga	Pigeonpea	320000	344625	108.0
	Gulbarga	Sunflower	46000	23517	51.0
	Gulbarga	Pearl millet	18000	15759	88.0
17	Hassan	Ragi	69765	68530	98.0
	Hassan	Paddy	52350	46380	89.0
	Hassan	Maize	66325	65890	99.0
	Hassan	Jowar	2350	1805	77.0
	Hassan	Black gram	2200	1375	63.0
	Hassan	Green gram	12100	4295	35.0
	Hassan	Cowpea	12700	13460	106.0
	Hassan	Fieldbean	4625	3513	76.0
	Hassan	Pigeonpea	2175	1415	65.0
	Hassan	Groundnut	1260	407	32.0
	Hassan	Sunflower	650	280	43.0
	Hassan	Castor	1450	927	64.0
	Hassan	Cotton	50	5	10.0
	Hassan	Sugarcane	2000	1610	81.0
	Hassan	Cotton	50	5	10.0
18	Haveri	Cotton	79000	79000	100.0
	Haveri	Groundnut	15000	14750	98.0
	Haveri	Maize	133150	108500	82.0
	Haveri	Soybean	53000	19618	37.0
	Haveri	Sorghum	8000	6256	78.0
	Haveri	Paddy	9850	9040	92.0

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
	Haveri	Pulses	8500	4998	59.0
19	Kodagu	Paddy	29500	29051	98.0
	Kodagu	Maize	3000	3000	100.0
20	Kolar	Ragi	60000	44987	75.0
	Kolar	Groundnut	12000	6599	55.0
	Kolar	Pigeonpea	4000	2133	53.0
	Kolar	Cowpea	2000	1172	59.0
	Kolar	Fieldbean	9000	4054	45.0
21	Koppal	Maize	19000	38720	204.0
	Koppal	Jower	10000	2419	24.0
	Koppal	Pearl millet	54000	54814	102.0
	Koppal	Pigeonpea	13000	9983	77.0
	Koppal	Horse gram	6000	2169	36.0
	Koppal	Green gram	12500	20853	167.0
	Koppal	Groundnut	25000	9143	37.0
	Koppal	Sunflower	20500	15926	78.0
	Koppal	Paddy	35000	32775	94.0
22	Mandya	Ragi	62500	32046	51.0
	Mandya	Maize	4000	2680	67.0
	Mandya	Cowpea	4500	3580	80.0
	Mandya	Groundnut	1000	770	77.0
	Mandya	Paddy	55000	55312	101.0
	Mandya	Sugarcane	20000	11734	59.0
23	Mysore	Ragi	44000	28869	66.0
	Mysore	Cotton	44000	46274	105.0
	Mysore	Maize	32000	31656	99.0
	Mysore	Cowpea	26000	28061	108.0
	Mysore	Fieldbean	18000	7774	43.0
	Mysore	Black gram	10000	8066	81.0
	Mysore	Groundnut	6000	3553	59.0
	Mysore	Sorghum	5000	4821	96.0
	Mysore	Pigeonpea	3000	2717	91.0
	Mysore	Green gram	6000	5063	84.0
	Mysore	Sunflower	1000	785	79.0
	Mysore	Paddy	90000	99244	110.0
	Mysore	Sugarcane	7000	7049	101.0
24	Raichur	Pearl millet	50,000	44,100	88.0
	Raichur	Pigeonpea	40,000	40,762	102.0
	Raichur	Sunflower	30,000	36,410	121.0
	Raichur	Groundnut	5,000	2,026	41.0
	Raichur	Cotton	30,000	24,744	82.0

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
	Raichur	Paddy	96,000	90,009	94.0
25	Ramanagara	Pigeonpea	4000	3944	99.0
	Ramanagara	Ragi	75000	73550	98.0
	Ramanagara	Cowpea	2500	2450	98.0
	Ramanagara	Fieldbean	4000	3925	98.0
	Ramanagara	Maize	1500	1400	93.0
	Ramanagara	Groundnut	7000	5130	73.0
26	Shimoga	Maize	55000	55000	100.0
	Shimoga	Paddy (rainfed)	20000	20000	100.0
	Shimoga	Paddy (irrigated)	60000	59800	99.6
	Shimoga	Sugarcane	2000	1975	96.3
27	Tumkur	Green gram	12000	9,117	76.0
	Tumkur	H. Maize	20000	12,841	64.2
	Tumkur	Ragi	184000	137,688	74.8
	Tumkur	Groundnut	151000	76,540	50.7
	Tumkur	Pigeonpea	23000	11,478	49.9
	Tumkur	Fieldbean	13500	6,690	49.6
	Tumkur	Cowpea	3500	2,482	70.9
28	Udupi	Paddy	45000	44367	99.0
29	Uttara Kannada	Paddy	68500	66157	96.6
	Uttara Kannada	Maize	4000	4000	100.0
	Uttara Kanada	Cotton	2000	1400	70.0
	Uttara Kanada	Sugarcane	4000	4000	100.0
30	Yadgir	Pigeonpea	50250	55288	110.0
	Yadgir	Cotton	17350	25476	146.8
	Yadgir	Paddy	13000	34700	99.1
	Yadgir	Greengram	36600	24850	67.9
	Yadgir	Pearl millet	14200	25485	179.5
Total	**30 Districts**	**All crops**	**5609830**	**5041300**	**89.9**

District-wise target cropping area (hectares) sown with major crops during *Rabi* 2013-14.					
	Districts	Crops	Target	Area sown	% achieved
1	Baglkote	Rabi jowar, Cowpea. Sunflower. Sugarcane	145000	137679	95
2	Belgaum	Rabi jowar, Cowpea. Wheat	200000	183353	92
3	Bellary	Rabi jowar, Cowpea. Sunflower. Sunflower	145000	96026	66
4	Bidar	Rabi jowar, Cowpea. Sunflower, Sunflower, Wheat	100000	90292	90
5	Bijapur	Rabi jowar, Cowpea	325000	301014	93
6	Chikkmanglore	Rabi jowar, Cowpea	20000	26607	133
7	Chithrdurga	Rabi jowar, Cowpea	20000	17631	88

District-wise target cropping area (hectares) sown to major crops during crop season 2013-14					
S.No	**District**	**Major rainfed crop**	**Target area**	**Area sown**	**% Achieved**
8	Davngere	Rabi jowar, Cowpea. Wheat, Maize	10500	14949	142
9	Dharwad	Rabi jowar, Cowpea. Wheat. Sunflower	137000	135357	99
10	Gadag	Rabi jowar, Sunflower, safflower, Wheat, Cotton	220000	198237	90
11	Gulbarga	Rabi jowar, Sunflower, safflower, Wheat.	450000	409747	91
12	Haveri	Rabi jowar, Sunflower, Cowpea	44000	32913	75
13	Koppal	Rabi jowar, Sunflower, safflower, Wheat. Cotton. Mize	132000	127717	97
14	Raichur	Rabi jowar, Sunflower, Safflower, Wheat, Cotton, Paddy, Groundnut	411500	378580	92
15	Yadgir	Rabi jowar, Sunflower, Safflower, Wheat, Groundnut	140000	113730	81
	Total	**All crops**	**2500000**	**2263832**	**91**

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
Ballari	Kharif Cotton	15000	34839	232
	Kharif Groundnut	56000	46876	84
	Kharif Sorghum	25000	14112	56
	Kharif Sunflower	28000	8862	32
	Kharif Maize	59000	77018	131
	Kharif Paddy	70000	70414	101
	Kharif Pearl Millet	12000	15986	133
	Kharif Pigeonpea	9000	6486	72
Bidar	Kharif Sorghum	33000	26498	80
	Kharif Paddy	1000	1095	110
	Kharif Pigeonpea	64000	56396	88
	Kharif Blackgram	24000	13500	56
	Kharif Greengram	33000	13474	41
	Kharif Soybean	115000	142270	124
	Kharif Sugarcane	20000	3850	19
Haveri	Kharif Cotton	82000	82000	100
	Kharif Groundnut	17000	15235	90
	Kharif Maize	106800	106560	100
	Kharif Paddy	15500	15500	100
	Kharif Pulses	6000	2768	46
	Kharif Sorghum	27700	26950	97
	Kharif Soybean	6000	5335	89

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
Koppal	Kharif Greengram	16000	15274	95
	Kharif Groundnut	20000	12665	63
	Kharif Horsegram	3500	3595	103
	Kharif Maize	30000	43930	146
	Kharif Paddy	35000	35000	100
	Kharif Pearl Millet	55000	51010	93
	Kharif Pigeonpea	8500	12170	143
	Kharif Sorghum	6500	1180	18
	Kharif Sunflower	20500	12894	63
Udupi	Kharif Paddy	10000	10000	100
Chitradurga	Kharif Cotton	9000	8196	91
	Kharif Greengram	3000	2998	100
	Kharif Groundnut	146000	115082	79
	Kharif Maize	81000	76378	94
	Kharif Pigeonpea	11000	7231	66
	Kharif Ragi	35000	33061	94
Davanagere	Kharif Cotton	29450	25735	87
	Kharif Fieldbean	990	524	53
	Kharif Groundnut	12025	5287	44
	Kharif Maize	154415	171816	111
	Kharif Maize	850	328	39
	Kharif Paddy	55000	55788	101
	Kharif Pigeonpea	4000	5407	135
	Kharif Ragi	10980	9193	84
	Kharif Sorghum	11100	7419	67
	Kharif Sugarcane	3060	5246	171
	Kharif Sunflower	3980	1031	26
Mandya	Kharif Cowpea	4500	3038	68
	Kharif Groundnut	1000	212	21
	Kharif Maize	5000	1705	34
	Kharif Paddy	54000	27730	51
	Kharif Ragi	62000	41260	67
	Kharif Sugarcane	19000	16207	85
Mysuru	Kharif Blackgram	10000	9341	93
	Kharif Cotton	50500	82883	164
	Kharif Cowpea	26000	23992	92
	Kharif Fieldbean	18000	8347	46
	Kharif Greengram	5900	7195	122
	Kharif Groundnut	3700	4005	108
	Kharif Maize	26800	27563	103
	Kharif Paddy	96500	84506	88
	Kharif Pigeonpea	3000	2154	72
	Kharif Ragi	38000	34992	92
	Kharif Sorghum	5000	4674	93

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
	Kharif Sugarcane	7600	7698	101
	Kharif Sunflower	1000	824	82
Ramanagara	Kharif Cowpea	2500	2157	86
	Kharif Fieldbean	4000	3705	93
	Kharif Groundnut	7000	4175	60
	Kharif Maize	1500	1305	87
	Kharif Pigeonpea	4000	3393	85
	Kharif Ragi	75000	67956	91
Bagalkot	Kharif Greengram	26500	22000	83
	Kharif Groundnut	800	665	83
	Kharif Maize	34000	32700	96
	Kharif Pearl Millet	24700	18000	73
	Kharif Pigeonpea	5000	3500	70
	Kharif Sorghum	2500	2100	84
	Kharif Soybean	6000	5500	92
	Kharif Sugarcane	28500	26100	92
	Kharif Sunflower	8000	7000	88
Belgavi	Kharif Blackgram	3000	3000	100
	Kharif Cotton	31000	31000	100
	Kharif Greengram	17000	17000	100
	Kharif Groundnut	23500	23500	100
	Kharif Maize	96500	96500	100
	Kharif Paddy	63000	63000	100
	Kharif Pearl Millet	21000	19498	93
	Kharif Sorghum	24000	24000	100
	Kharif Soybean	60000	56800	95
	Kharif Sugarcane	40000	40000	100
Dharwad	Kharif Cotton	24500	38656	158
	Kharif Greengram	22000	18175	83
	Kharif Groundnut	30000	22040	73
	Kharif Maize	33000	24481	74
	Kharif Paddy	18000	20400	113
	Kharif Soybean	33500	30923	92
Gadag	Kharif Cotton	20500	36055	176
	Kharif Greengram	70000	57506	82
	Kharif Groundnut	56000	33356	60
	Kharif Maize	49500	24727	50
	Kharif Paddy	1000	377	38
	Kharif Pearl Millet	2000	1600	80
	Kharif Pigeonpea	3000	1342	45
	Kharif Sorghum	9000	2889	32
	Kharif Sunflower	20000	3761	19
Vijayapura	Kharif Greengram	7500	5204	69
	Kharif Groundnut	14600	11488	79

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
	Kharif Maize	59300	49426	83
	Kharif Pearl Millet	34700	29635	85
	Kharif Pigeonpea	162600	147876	91
	Kharif Sugarcane	4500	4663	104
	Kharif Sunflower	21300	17005	80
Bengaluru Rural	Kharif Ragi	44000	35537	81
	Kharif Maize	10000	11074	111
Bengaluru Urban	Kharif Ragi	30000	19670	66
Raichur	Kharif Cotton	50200	86078	171
	Kharif Groundnut	5620	4468	80
	Kharif Paddy	105500	96022	91
	Kharif Pearl Millet	27342	27315	100
	Kharif Pigeonpea	23842	24915	105
	Kharif Sunflower	33300	11037	33
Uttara Kannada	Kharif Cotton	2000	1413	71
	Kharif Maize	6000	5140	86
	Kharif Paddy	66000	65046	99
	Kharif Sugarcane	4000	4000	100
Chikkamagaluru	Kharif Paddy	23000	21495	93
Shivamogga	Kharif Maize	55000	50070	91
	Kharif Paddy	72200	67500	93
	Kharif Sugarcane	2000	1080	54
Chamarajanagar	Kharif Fieldbean	2750	2434	89
	Kharif Blackgram	5000	3011	60
	Kharif Cotton	12200	12325	101
	Kharif Cowpea	3300	2957	90
	Kharif Greengram	3100	2857	92
	Kharif Groundnut	14900	11150	75
	Kharif Sorghum	10000	9600	96
	Kharif Sunflower	8450	8400	99
	Kharif Maize	41100	24890	61
	Kharif Paddy	16000	11277	70
	Kharif Ragi	15940	10155	64
	Kharif Sugarcane	4000	3765	94
Kodagu	Kharif Maize	3000	3000	100
	Kharif Paddy	29500	28380	96
Kalaburagi	Kharif Blackgram	54000	17923	33
	Kharif Greengram	41000	17010	41
	Kharif Groundnut	5000	429	9
	Kharif Pearl Millet	18000	15165	84
	Kharif Pigeonpea	320000	299958	94
	Kharif Soybean	14500	22127	153
	Kharif Sunflower	46000	16954	37
Dakshina Kannada	Kharif Paddy	25000	25000	100

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
Hassan	Kharif Blackgram	1600	1230	77
	Kharif Castor	800	310	39
	Kharif Cowpea	13000	11480	88
	Kharif Fieldbean	2100	1685	80
	Kharif Greengram	4400	3975	90
	Kharif Groundnut	1100	343	31
	Kharif Maize	72500	70070	97
	Kharif Paddy	42000	37441	89
	Kharif Pigeonpea	800	885	111
	Kharif Ragi	67000	60530	90
	Kharif Sorghum	1800	1175	65
	Kharif Sunflower	700	608	87
	Kharif Sugarcane	2000	1655	83
Tumakuru	Kharif Cotton	150	150	100
	Kharif Cowpea	3500	3210	92
	Kharif Fieldbean	13850	8455	61
	Kharif Greengram	12000	8902	74
	Kharif Groundnut	141500	83504	59
	Kharif Maize	20000	24912	125
	Kharif Paddy	16000	3846	24
	Kharif Pigeonpea	22400	13811	62
	Kharif Ragi	186600	167853	90
Chikballapur	Kharif Groundnut	35000	16562	47
	Kharif Maize	39200	49506	126
	Kharif Pigeonpea	2000	2479	124
	Kharif Ragi	41300	44951	109
Yadgir	Kharif pearl Millet	20700	6706	32.4
	Pigeonpea	42000	25763	61.34
	Kharif Green Gram	28150	7534	26.76
	Kharif Cotton	29650	43227	145.79
	Kharif Sunflower	13900	3464	24.92
	Kharif Paddy	35000	19863	56.75
	Kharif Groundnut	1600	827	51.69
Kolar	Ragi	60000	38162	64
	Pigeonpea	4000	4751	119
	Fieldbean	9000	1816	20
	cowpea	2000	1300	65
	Groundnut	12000	3102	26
	Total	**5597894**	**4915597**	**87.8**
District-wise target cropping area (hectares) sown with major crops during *Rabi* 2014-15.				
Bidar	Rabi Chickpea	59000	29631	50
	Rabi Safflower	10000	7018	70
	Rabi Sorghum	26000	9557	37
	Rabi Wheat	8300	2439	29

District-wise target cropping area (hectares) sown to major crops during Kharif 2014				
District	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
Chitradurga	Rabi Chickpea	15000	14465	96
	Rabi Sorghum	5000	4340	87
Davanagere	Rabi Chickpea	5065	968	19
	Rabi Ragi	585	164	28
	Rabi Sorghum	6000	1532	26
Raichur	Rabi Chickpea	115000	101000	88
	Rabi Groundnut	36400	27328	75
	Rabi Paddy	70900	69000	97
	Rabi Sorghum	118000	96500	82
	Rabi Sunflower	33100	21450	65
Chikkamagaluru	Rabi Chickpea	11700	9145	78
	Rabi Horsegram	7300	8170	112
	Rabi Sorghum	10000	8285	83
	Total	**537350**	**410992**	**76.5**

District-wise target cropping area (hectares) sown with major crops during *Kharif* 2015.					
Sl. No	**District**	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
1	Bagalkote	Green gram, maize, pearlmillet	98000	83952	85.7
2	Ballari	Sorghum, maize,pearlmillet, pigeonpea, groundnut, sunflower, cotton	235000	220130	94
3	Bengaluru Rural	Ragi, maize	52955	48037	91
4	Bengaluru Urban	Ragi	28045	22822	81
5	Belagavi	Soyabean, cotton, maize, groundnut, paddy	360000	293590	82
6	Bidar	Sorghum, rice, pigeonpea, black gram, green gram, soybean, sugarcane	298000	287253	96
7	Chamarajanagara	Ragi, jowar, maize, red gram, green gram, black gram, cowpea, hyacinth bean, groundnut, sunflower, cotton	77280	65667	73
8	Chikkaballapur	Maize, groundnut, ragi, pigeonpea	117500	102363	87
9	Chikkamagalur	Paddy, maize, ragi, groundnut, sunflower	139500	121360	79
10	Chitradurga	Groundnut, maize, ragi, pigeonpea, cotton, green gram	153000	111952	73
11	Davanagere	Sorghum, ragi, maize, pigeonpea, hyacinth bean, sunflower, groundnut, cotton, paddy, sugarcane	268000	266495	99.4
12	Dharwad	Soyabean, groundnut, greengram, maize, paddy, cotton	155000	154804	99.7
13	Dakshina Kannada	Paddy	15000	14489	97

District-wise target cropping area (hectares) sown with major crops during *Kharif* 2015.					
Sl. No	**District**	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
14	Gadag	Pigeonpea	177500	177500	100
15	Kalaburagi	Pearl millet, pigeonpea, black gram, green gram, soybean, cotton, sugarcane	512500	427176	83
16	Hassan	Ragi, maize, paddy	197000	151108	77
17	Haveri	Soyabean, groundnut, maize, paddy, cotton	275000	265034	96
18	Kolar	Ragi, red gram, hyacinth bean, cowpea, groundnut	87000	70245	78
19	Kodagu	Paddy	22000	22000	100
20	Koppal	Maize, hybrid sorghum, pearl millet, green gram, horse gram, groundnut, sunflower, pigeonpea, paddy	183000	156708	85
21	Mandya	Ragi, maize, paddy, groundnut, sugarcane, cowpea	115000	74362	65
22	Mysuru	Ragi, cotton, maize, hyacinth bean, red gram, sunflower, groundnut	280000	237000	85
23	Raichur	Pearlmillet, pigeonpea, cotton, paddy	254000	214670	84
24	Ramnagara	Ragi, maize, pigeonpea, cowpea, hyacinth bean, groundnut	94000	86480	92
25	Shivamogga	Paddy, maize, sugarcane	101000	71250	71
26	Tumakuru	Green gram, hybrid maize, ground nut, ragi, hyacinth bean, red gram, cowpea, cotton, paddy	401000	287935	72
27	Udipi	Paddy	22000	22000	100
28	Uttara Kannada	Paddy, maize, cotton, sugarcane	78000	75986	97.4
29	Vijayapura	Pigeonpea	292000	153665	53
30	Yadgir	Green gram, black gram, cotton, bajra, paddy, sunflower, sugarcane	182000	140000	77
	Total		**5270280**	**4426033**	**84.0**

District-wise target cropping area (hectares) sown with major crops during *Rabi* 2015-16.					
Sl. No	**District**	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
1.	Chitradurga	*Rabi* sorghum, cowpea	40000	28857	72
2.	Haveri	*Rabi* sorghum, chickpea, sunflower	35000	32045	92
3.	Dharwad	*Rabi* sorghum, cowpea, wheat, sunflower	122000	116693	96

District-wise target cropping area (hectares) sown with major crops during *Rabi* 2015-16.					
Sl. No	**District**	**Major rainfed crop**	**Target area**	**Sown area**	**% achieved**
4.	Davangere	*Rabi* sorghum, cowpea, wheat, maize	12500	12275	98
5.	Gadag	*Rabi* sorghum, sunflower, safflower, wheat, cotton	175000	175000	100
6.	Bijapur	*Rabi* sorghum, cowpea	472000	431810	91
7.	Raichur	*Rabi* sorghum, sunflower, safflower, wheat, cotton, paddy, groundnut	300000	291620	97
8.	Gulbarga	Wheat, chickpea, sorghum, sunflower and sesamum	508000	381461	75
9.	Yadgiri	*Rabi* jowar, sunflower, safflower, wheat, groundnut	120000	91312	76
10.	Bidar	Pigeonpea, wheat, sunflower, sorghum	108000	110196	102
11.	Bagalkot	*Rabi* sorghum, chickpea, sunflower, sugarcane	150000	120000	80
12.	Belgaum	*Rabi* sorghum, maize, wheat, chickpea	225000	194000	86
13.	Ballari	*Rabi* sorghum, cowpea, sunflower	170000	123943	73
14.	Chikkamagalur	*Rabi* sorghum, cowpea	30000	22255	74
15.	Koppal	*Rabi* sorghum, maize, wheat, chickpea, sunflower, cotton	175000	128342	73
	Total		**2642500**	**2259809**	**85.5**

District-wise target cropping area (ha) sown with major crops during *kharif* 2016.					
Sl. No	District	Major crops	Target area (ha)	Sown area (ha)	% achieved
1	Kolar	Finger millet, groundnut, pigeonpea, field bean, cowpea	70066	70000	100
2	Chikkaballapura	Finger millet, Hy-Maize, pigeonpea, field bean, groundnut	114516	113000	99
3	Tumakuru	Greengram, Hy-Maize, groundnut, finger millet, *Avare*, cowpea, red gram	327736	317736	97
4	Chitradurga	Red gram, green gram, finger millet, groundnut	263311	229000	87
5	Haveri	Maize, groundnut, soybean, cotton	253844	247124	97
6	Dharwad	Soybean, cotton, maize, groundnut	168461	168461	100
7	Bengaluru (R&U)	Finger millet, maize	77016	77000	100

District-wise target cropping area (ha) sown with major crops during *kharif* 2016.					
Sl. No	District	Major crops	Target area (ha)	Sown area (ha)	% achieved
8	Chamarajanagara	Greengram, maize, groundnut, finger millet, *Avare*, cowpea, red gram	113311	113000	100
9	Hassan	Green gram, maize, groundnut, finger millet, *Avare*, cowpea, red gram	191441	191400	100
10	Davangere	Cotton, sorghum, finger millet, maize, pigeonpea, cowpea, groundnut, sunflower	256154	256486	100
11	Gadag	Sorghum, pearl millet, maize, pigeonpea, green gram, sunflower, groundnut, cotton	180438	160700	89
12	Bijapur	Maize, pearl millet, pigeonpea, sunflower, groundnut, green gram	323960	326815	101
13	Raichur	Pearl millet, pigeonpea, groundnut, sunflower, cotton, paddy	226169	226169	100
14	Gulbarga	Sorghum, pearl millet, maize, pigeonpea, green gram, sunflower, groundnut, cotton	429273	420000	98
15	Yadgir	Pearl millet, pigeonpea, green gram, sunflower	199794	199794	100
16	Bidar	Pigeonpea, black gram, green gram, soybean, Hy-sorghum, pearl millet, sunflower, maize	255853	255853	100
17	Bagalkot	Sorghum, pearl millet, maize, pigeonpea, green gram, groundnut, sunflower, sugarcane	180815	178096	98
18	Belgaum	Soybean, cotton, maize, groundnut	482172	482172	100
19	Bellary	Sorghum, maize, pearl millet, pigeonpea, groundnut, sunflower, cotton	274989	269611	98
20	Chikkamagaluru	Finger millet, sorghum, maize, sunflower, groundnut	112919	100000	89
21	Koppal	*Hy-Jawar*, maize, sunflower, pearl millet, groundnut, green gram, pigeonpea	190232	194618	102
22	Mandya	Finger millet, cowpea, maize, groundnut	150830	140830	93

District-wise target cropping area (ha) sown with major crops during *kharif* 2016.					
Sl. No	District	Major crops	Target area (ha)	Sown area (ha)	% achieved
23	Mysore	Finger millet, maize, cowpea, field *beans*, pigeonpea, sunflower, groundnut	292483	220000	75
24	Ramanagara	Finger millet, maize, *sorghum*, cowpea, field *bean,* pigeonpea, sunflower, groundnut, greengram, cotton	90603	88692	98
25	Shivamogga	Maize, paddy, sugarcane	130657	125896	96
26	Bangaluru Urban	Finger millet	26516	26516	100
27	Dakshina Kannada	Rainfed paddy	21622	21622	100
28	Kodagu	Rainfed paddy, maize	25992	25992	100
29	Uttara Kannada	Maize, cotton	61439	61439	100
30	Udupi	Rainfed paddy	33904	32904	97
Total		**All crops**	**55,26,516**	**53,40,926**	**97**

District-wise target cropping area (ha) sown with major crops during r*abi* 2016-17.					
Sl. No.	Districts	Crops	Target area (ha)	Sown area (ha)	%
1	Chitradurga	*Rabi* sorghum, cowpea	20000	5288	26
2	Haveri	*Rabi* sorghum*,* chickpea, sunflower	35000	12532	36
3	Dharwad	*Rabi* sorghum, cowpea, wheat, sunflower	180000	122023	68
4	Davanagere	*Rabi* sorghum, cowpea, wheat, maize	20000	4801	24
5	Gadag	*Rabi* sorghum*,* sunflower, safflower, wheat, cotton	225000	69000	31
6	Bijapur	*Rabi* sorghum, cowpea	280000	230000	82
7	Raichur	*Rabi* sorghum, sunflower, safflower, wheat, cotton, paddy, groundnut	300000	254872	85
8	Gulbarga	Wheat, chickpea, sorghum, sunflower, sesamum	320000	240000	75
9	Yadgir	*Rabi* sorghum, sunflower, safflower, wheat, groundnut	140000	117000	84
10	Bidar	Chickpea, wheat, sunflower, sorghum	130000	100506	77
11	Bagalkot	*Rabi* sorghum, chickpea, sunflower	290000	145000	50
12	Belgaum	*Rabi* sorghum, maize, wheat, chickpea	240000	185280	77
13	Bellary	*Rabi* sorghum, cowpea, sunflower	150000	97826	65

District-wise target cropping area (ha) sown with major crops during *kharif* 2016.					
Sl. No	District	Major crops	Target area (ha)	Sown area (ha)	% achieved
14	Chikkamagaluru	*Rabi* sorghum, cowpea	20000	8333	42
15	Koppal	*Rab*i sorghum, maize, wheat, chickpea, sunflower, cotton	150000	90119	60
	Total		**25,00,000**	**16,82,580**	**67**

Area covered under Bhoochetana during 2017 *Kharif*				
Sl. No	**District**	**Crops/components covered**	**Total Demonstrations Targets (ha)**	**Total Demonstrations completed (ha)**
1	Bagalkot	Pigeonpea, Minor millets	8000	4756
2	Belagavi	Paddy, minor millets, groundnut	15000	10930
3	Ballari	Paddy, Groundnut intercropping Pigeonpea, Miner millets; DSR; Mach Paddy Trans; Pearl millet	13500	12292
4	Bidar	Pigeonpea, pearl millet	8200	3850
5	Vijayapur	Perl millet, Pigeonpea	100	88
6	Chamarajanagar	Ragi, Maize, Groundnut, Paddy	100	48
7	Chikkamagaluru	Paddy, Ragi, Groundnut, maize.	100	100
8	Chitradurga	Groundnut, Ragi, Pigeonpea, millets	100	80
9	Davanagere	Paddy, Ragi, Minor millets, Pigeonpea, Groundnut	100	100
10	Dharwad	DSR Paddy	100	100
11	Gadag	IPM and IDM	100	46
12	Hassan	Ragi, Paddy: DSR, drilled/transplanting, mechanical rice transplanting	10667	9267
13	Haveri	Minor millets, Groundnut, DSR paddy	60	51
14	Kalaburagi	Pigeonpea, pearl millet	12000	7700
15	Koppal	Pigeonpea, maize, pearl millet	100	24
16	Raichur	Pigeonpea dibbling, transplanting, varietal evaluation, Nipping, conservation furrows, DSR, BBF, IPM & IDM	100	146
17	Yadgir	Pigeonpea, paddy, Groundnut, pearl millet	5100	1813
18	Bangalore (R)	Ragi	4400	4296
19	Bangalore (U)	Ragi	2100	2045
20	Chikkaballapur	Pigeonpea, Groundnut, ragi	100	100
21	Dakshina Kannada	Paddy Machine transplantation	100	48
22	Kodagu	Paddy ,Machine transplanting	32	30
23	Kolar	Minor millets	100	100

Area covered under Bhoochetana during 2017 *Kharif*				
Sl. No	**District**	**Crops/components covered**	**Total Demonstrations Targets (ha)**	**Total Demonstrations completed (ha)**
24	Mandya	Ragi, Paddy, Maize	100	25
25	Mysore	Ragi, Maize, Paddy	100	46
26	Ramanagar	Ragi, Groundnut	100	85
27	Shivamogga	Paddy	33	33
28	Tumakuru	Groundnut, Pigeonpea, Millets	100	78
29	Udupi	Paddy	2000	1447
30	Uttara Kannada	Paddy	4300	2959
	Total		**86992**	**62683**

Area covered under Bhoochetana during 2017-18 *Rabi*				
Sl.No	**District**	**Crops/components covered**	**Total Demonstrations Targets (ha)**	**Total Demonstrations completed (ha)**
1	Bagalkot	Chickpea, Sorghum	20000	11500
2	Belagavi	Chickpea, Sorghum	23820	15630
3	Ballari	Chickpea, Sorghum, Paddy-Chickpea-greengram	19620	4600
4	Bidar	Chickpea, sorghum	100	100
5	Vijayapur	Chickpea	100	60
6	Chikkmagluru	Chickpea	500	500
7	Davanagere	Chickpea	100	100
8	Dharwad	Chickpea; paddy-pulses;Sugarcane trash cutter; relay planting	100	136
9	Gadag	INM, IDM & IPM	80	60
10	Haveri	*Rabi* Sorghum; Hand Dibbling in Chickpea; Paddy - Chickpea; Cowpea, Greengram, Blackgram	112	64
11	Kalaburagi	Chickpea, sorghum	100	60
12	Koppal	Chickpea	100	32
13	Raichur	Chickpea varietal trails, Nipping, sowing across the slope, IPM and IDM	100	33
	Total		**64832**	**32875**

Annexure 2. List of climate change awareness training programs conducted.

Sl.	Topic	Place
1	Climate change and agriculture	Kalaburagi, 16 Apr 2013
2	Climate Change and Resilient Agriculture Reference to Udupi district	Udupi, 6 Jun 2013
3	Climate Change and Resilient Agriculture Reference to Hassan district	Hassan, 8 Jun 2013
4	Climate Change and Resilient Agriculture Reference to Kodagu district	Kushal Nagar, Kodagu, 21 Jun 2013
5	Climate Change and Resilient Agriculture Reference to Chamarajanagar district	KVK Haradanahalli, Chamarajanagar, 22 Jun 2013

Sl.	Topic	Place
6	Climate Change and Resilient Agriculture Reference to Karnataka state	Bengaluru;31 Jul 2013
7	Resilient Agriculture Investigator Network (RAIN)	KSNDMC, Bengaluru,19 Aug 2013
8	Climate change impacts on Pigeonpea at Kalaburagi	DATC, Kotnoor, Kalaburagi, 21 Apr 2014
9	Climate Change and Resilient Agriculture with reference to Hassan district	Hassan, 25 Apr 2014
10	Climate Change and Resilient Agriculture with reference to Yadgir district	Yadgir, 28 Apr 2014
11	Climate Change and Resilient Agriculture with reference to Dakshina Kannada district	Dakshina Kannada, 7 May 2014
12	Climate Change and Resilient Agriculture with reference to Udupi district	Udupi, 7 May 2014
13	Climate Change and Resilient Agriculture in Karnataka – with reference to Kolar district	Kolar, 21 May 2014
14	Climate Change and Resilient Agriculture in Karnataka – with reference to Gadag district	Gadag, 28 May 2014
15	Climate Change and Resilient Agriculture with reference to Ballari district	DATC, Kampli, Ballari, 31 May 2014
16	Climate Change and Resilient Agriculture with reference to Belagavi district	Belagavi, 31 May 2014
17	Climate Change and Resilient Agriculture with reference to Bidar district	Bidar, 10 Jun 2014
18	Climate Change and Resilient Agriculture in Karnataka – with reference to Mysore district	Naganahalli Organic Farm, KVK, Mysore
19	Climate Change and Resilient Agriculture in Karnataka – with reference to Davanagere district	Tungabhadra Sabhangana, New DC Office, Davanagere, 14 June 2014
20	Climate Change and Resilient Agriculture Reference to Vijayapura district	Vijayapura, 17 Jun 2014
21	Climate Change and Resilient Agriculture in Karnataka – with reference to Chikkaballapur district	Chikkaballapur, 19 Jun 2014
22	Climate Change and Resilient Agriculture in Karnataka – with reference to Kodagu district	Kodagu, 20 Jun 2014
23	Climate Change and Resilient Agriculture in Karnataka – with reference to Mandya district	DATC, Mandya, 21 Jun 2014
24	Climate Change and Resilient Agriculture in Karnataka – with reference to Uttara Kannada district	Uttara Kannada, 23 Jun 2014
25	Climate Change and Resilient Agriculture in Karnataka – with reference to Davanagere district	Davanagere, 26 Jun 2014
26	Climate Change and Resilient Agriculture in Karnataka – with reference to Tumakuru district	Tumakuru, 14 Jul 2014
27	Climate Change and Resilient Agriculture in Karnataka – with reference to Ramanagara district	Ramanagara, 19 Jul 2014
28	Climate Change and Resilient Agriculture in Karnataka – with reference to Bengaluru Rural district	Bengaluru (R), 24 Jul 2014
29	Climate Change and Resilient Agriculture in Karnataka – with reference to Bagalkote district	Bagalkot, 24 Jul 2014
30	Climate Change and Resilient Agriculture in Karnataka – with reference to Koppal district	Koppal, 21 Aug 2014
31	Climate Change and Resilient Agriculture in Karnataka – with reference to Dharwad district	Dharwad, 26 Aug 2014
32	Climate Change and Resilient Agriculture in Karnataka – with reference to Chikkamagalur district	Lingadahalli, Chikkamagalur, 21 Oct 2014
33	Climate variability and change in Kalaburagi	DATC, Kotnoor, Kalaburagi, 8 Apr 2015
34	Climate variability and change in Yadgir	Bhima Rayanna Gudi Agriculture College, Yadgir, 17 Apr 2015

Sl.	Topic	Place
35	Climate variability and change in Dakshina Kannada	KVK Kankanady, Mangaluru, 28 Apr 2015
36	Climate variability and change in Haveri district	Horticultural Research Station Devihosur, Haveri ,18 Jun 2015
37	Climate variability, change and agriculture reference to Udupi District	KVK Brahmavar, Udupi, 29 Aug 2015

Annexure 3:

A. **Additional benefits of improved management practices under Bhoochetana during 2013-14.**

District	Crop	Additional yield benefit (kg/ha)	Additional income (₹ /ha)
Bagalkot	Maize	1500	19643
Bagalkot	Pearl Millet	662	8275
Bagalkot	Pigeonpea	60	2310
Bagalkot	Rabi Chickpea	534	16543
Bagalkot	Rabi Sorghum	168	2553
Bagalkot	Rabi Sunflower	187	6902
Bagalkot	Sorghum	424	6452
Bagalkot	Soybean	362	9267
Bagalkot	Sunflower	329	12185
Ballari	Cotton	323	12920
Ballari	Groundnut	639	25552
Ballari	Maize	1362	17843
Ballari	Paddy	1011	13241
Ballari	Pearl Millet	378	4725
Ballari	Pigeonpea	87	3337
Ballari	Rabi Chickpea	169	5249
Ballari	Rabi Sorghum	149	2257
Ballari	Rabi Sunflower	134	4967
Ballari	Sorghum	1148	17442
Ballari	Sunflower	164	6059
Belagavi	Groundnut	692	27680
Belagavi	Maize	1412	18499
Belagavi	Rabi Chickpea	155	4817
Belagavi	Rabi Sorghum	679	10320
Belagavi	Sorghum	442	6718
Belagavi	Soybean	274	7026
Bengaluru Rural	Maize	1187	15550
Bengaluru Rural	Finger millet	566	8494
Bengaluru Urban	Finger millet	544	8153
Bidar	Black gram	257	11043
Bidar	Green gram	181	8160
Bidar	Pigeonpea	241	9288
Bidar	Rabi Chickpea	363	11253
Bidar	Rabi Safflower	222	6660
Bidar	Rabi Sorghum	454	6901
Bidar	Sorghum	669	10167
Bidar	Soybean	542	13875
Chamarajanagar	Maize	1245	16310
Chamarajanagar	Sunflower	367	13579
Chikkaballapur	Groundnut	275	11013
Chikkaballapur	Maize	922	12084
Chikkaballapur	Finger millet	389	5829

District	Crop	Additional yield benefit (kg/ha)	Additional income (₹ /ha)
Chikkamagalur	Groundnut	540	21580
Chikkamagalur	Paddy	643	8423
Chitradurga	Cotton	185	7380
Chitradurga	Green gram	111	4995
Chitradurga	Groundnut	227	9060
Chitradurga	Maize	762	9976
Chitradurga	Pigeonpea	65	2510
Chitradurga	Rabi Chickpea	155	4797
Chitradurga	Rabi Sorghum	237	3607
Chitradurga	Finger millet	199	2992
Dakshina Kannada	Paddy	1170	15331
Davanagere	Cotton	241	9629
Davanagere	Groundnut	392	15690
Davanagere	Maize	1215	15914
Davanagere	Paddy	938	12291
Davanagere	Pigeonpea	116	4478
Davanagere	Rabi Chickpea	159	4927
Davanagere	Rabi Sorghum	447	6795
Davanagere	Finger millet	310	4650
Davanagere	Sorghum	454	6907
Davanagere	Sunflower	213	7887
Dharwad	Groundnut	468	18720
Dharwad	Rabi Chickpea	286	8866
Dharwad	Rabi Sorghum	418	6354
Dharwad	Soybean	343	8772
Dharwad	Wheat	402	5628
Gadag	Field bean	126	5029
Gadag	Groundnut	350	13983
Gadag	Groundnut	475	18993
Gadag	Maize	599	7844
Gadag	Paddy	794	10403
Gadag	Pigeonpea	85	3273
Gadag	Finger millet	331	4968
Gadag	Sorghum	165	2508
Haveri	Cotton	282	11280
Haveri	Groundnut	549	21973
Haveri	Maize	1255	16446
Haveri	Paddy	881	11541
Haveri	Rabi Chickpea	121	3751
Haveri	Rabi Sorghum	294	4463
Haveri	Rabi Sunflower	381	14094
Haveri	Soybean	471	12050
Kalaburagi	Black gram	206	8874
Kalaburagi	Green gram	184	8280
Kalaburagi	Pearl Millet	1053	13167

District	Crop	Additional yield benefit (kg/ha)	Additional income (₹ /ha)
Kalaburagi	Pigeonpea	561	21601
Kodagu	Maize	1573	20606
Kodagu	Paddy	859	11253
Kolar	Groundnut	496	19848
Kolar	Finger millet	533	7995
Koppal	Groundnut	537	21480
Koppal	Maize	1636	21432
Koppal	Paddy	970	12707
Koppal	Pearl Millet	591	7383
Koppal	Rabi Chickpea	319	9881
Koppal	Rabi Sorghum	430	6528
Koppal	Sorghum	720	10944
Koppal	Sunflower	230	8510
Mandya	Cowpea	124	4960
Mandya	Maize	1345	17620
Mandya	Paddy	1264	16554
Mandya	Finger millet	372	5580
Mysuru	Black gram	31	1333
Mysuru	Cotton	54	2140
Mysuru	Cowpea	39	1556
Mysuru	Maize	877	11489
Mysuru	Paddy	1011	13244
Mysuru	Pigeonpea	52	1986
Mysuru	Finger millet	199	2985
Mysuru	Sugarcane	16720	36784
Raichur	Cotton	285	11400
Raichur	Groundnut	438	17520
Raichur	Paddy	1260	16506
Raichur	Pearl Millet	684	8550
Raichur	Pigeonpea	136	5222
Raichur	Sunflower	220	8140
Ramanagara	Cowpea	134	5347
Ramanagara	Field bean	296	11857
Ramanagara	Groundnut	377	15080
Ramanagara	Maize	1378	18052
Ramanagara	Pigeonpea	296	11413
Ramanagara	Finger millet	628	9420
Shivamoga	Paddy	853	11177
Tumakuru	Groundnut	110	4387
Tumakuru	Maize	604	7906
Tumakuru	Finger millet	300	4500
Udupi	Paddy	801	10497
Uttara Kannada	Paddy	863	11311
Vijayapura	Green gram	82	3690
Vijayapura	Maize	1460	19126

District	Crop	Additional yield benefit (kg/ha)	Additional income (₹ /ha)
Vijayapura	Pearl Millet	430	5375
Vijayapura	Pigeonpea	370	14232
Vijayapura	Rabi Chickpea	190	5890
Vijayapura	Rabi Sorghum	316	4798
Vijayapura	Sunflower	688	25444
Yadgir	Green gram	141	6350

B. **Additional benefits of improved management practices under Bhoochetana during 2014-15.**

District	Crop	Additional yield (kg/ha)	Additional income (₹ /ha)
Bagalkot	Maize	730	9563
Bagalkot	Pearl Millet	460	5750
Bagalkot	Sorghum	520	7956
Bagalkot	Sunflower	280	10500
Ballari	Cotton	280	10500
Ballari	Groundnut	290	11600
Ballari	Maize	1420	18602
Ballari	Paddy	1070	14552
Ballari	Pearl Millet	620	7750
Ballari	Sorghum	980	14994
Belgavi	Groundnut	220	8800
Belgavi	Maize	890	11659
Belgavi	Sorghum	530	8109
Belgavi	Soybean	250	6250
Bengaluru Rural	Maize	1360	17816
Bengaluru Rural	Finger millet	530	8215
Bengaluru Urban	Finger millet	370	5735
Bidar	Black gram	130	5655
Bidar	Soybean	210	5250
Chamarajanagar	Paddy	680	9248
Chamarajanagar	Finger millet	410	6355
Chikballapur	Groundnut	190	7600
Chikballapur	Maize	580	7598
Chikballapur	Finger millet	280	4340
Chikkamagalur	Maize	1270	16637
Chikkamagalur	Paddy	790	10744
Chikkamagalur	Finger millet	430	6665
Chitradurga	Cotton	200	7500
Chitradurga	Green gram	60	2760
Chitradurga	Groundnut	140	5600
Chitradurga	Maize	1000	13100
Chitradurga	Pigeonpea	110	4785
Chitradurga	Finger millet	340	5270

District	Crop	Additional yield (kg/ha)	Additional income (₹ /ha)
Dakshina Kannada	Paddy	670	9112
Davanagere	Cotton	250	9375
Davanagere	Groundnut	460	18400
Davanagere	Maize	1240	16244
Davanagere	Paddy	1140	15504
Davanagere	Finger millet	260	4030
Davanagere	Sorghum	600	9180
Dharwad	Paddy	360	4896
Dharwad	Soybean	400	10000
Gadag	Groundnut	360	14400
Gadag	Maize	590	7729
Haveri	Cotton	140	5250
Haveri	Groundnut	400	16000
Haveri	Maize	920	12052
Haveri	Paddy	770	10472
Haveri	Soybean	580	14500
Kalaburagi	Pearl Millet	1030	12875
Kalaburagi	Pigeonpea	480	20880
Kalaburagi	Soybean	440	11000
Kalaburagi	Sunflower	590	22125
Kodagu	Maize	1240	16244
Kodagu	Paddy	640	8704
Koppal	Groundnut	190	7600
Koppal	Maize	900	11790
Koppal	Paddy	770	10472
Koppal	Pearl Millet	650	8125
Raichur	Paddy	770	10472
Raichur	Pearl Millet	560	7000
Raichur	Pigeonpea	120	5220
Ramanagara	Groundnut	340	13600
Ramanagara	Maize	620	8122
Ramanagara	Finger millet	390	6045
Shivamoga	Maize	730	9563
Shivamoga	Paddy	570	7752
Tumakuru	Groundnut	170	6800
Tumakuru	Maize	580	7598
Tumakuru	Finger millet	430	6665
Udupi	Paddy	500	6800
Uttara Kannada	Maize	1290	16899
Uttara Kannada	Paddy	790	10744
Vijayapura	Maize	650	8515
Vijayapura	Pigeonpea	320	13920
Yadgir	Pearl Millet	710	8875
Bagalkot	Chickpea	50	1550
Bagalkot	Sorghum	120	1836
Ballari	Chickpea	340	10540
Ballari	Sorghum	540	8262
Ballari	Sunflower	170	6375

District	Crop	Additional yield (kg/ha)	Additional income (₹ /ha)
Chitradurga	Chickpea	140	4340
Chitradurga	Sorghum	210	3213
Davanagere	Chickpea	280	8680
Davanagere	Sorghum	410	6273
Gadag	Chickpea	90	2790
Haveri	Chickpea	160	4960
Haveri	Sorghum	280	4284
Haveri	Sunflower	300	11250
Koppal	Chickpea	180	5580
Koppal	Sorghum	340	5202
Raichur	Chickpea	150	4650
Raichur	Sorghum	230	3519
Vijayapura	Chickpea	80	2480
Vijayapura	Sorghum	150	2295

C. Additional benefits of improved management practices under Bhoochetana during 2015-16.

District	Crop	Additonal yield (Kg/ha)	Additional income (₹ /ha)
Ballari	Cotton	250	9375
Ballari	Groundnut	230	9200
Ballari	Maize	1030	13493
Ballari	Paddy	850	11560
Ballari	Pearl Millet	440	5500
Ballari	Sorghum	510	7803
Bengaluru Rural	Maize	670	8777
Bengaluru Rural	Finger millet	460	7130
Bengaluru Urban	Finger millet	360	5580
Bidar	Black gram	130	5655
Bidar	Pigeonpea	110	4785
Chamarajanagar	Groundnut	280	11200
Chamarajanagar	Maize	870	11397
Chamarajanagar	Finger millet	390	6045
Chikkaballapur	Groundnut	170	6800
Chikkaballapur	Maize	200	2620
Chikkaballapur	Finger millet	160	2480
Chikkamagalur	Paddy	1040	14144
Chikkamagalur	Finger millet	280	4340
Chitradurga	Cotton	150	5625
Chitradurga	Green gram	60	2760
Chitradurga	Groundnut	110	4400
Chitradurga	Maize	880	11528
Chitradurga	Pigeonpea	140	6090
Chitradurga	Finger millet	220	3410
Dakshina Kannada	Paddy	780	10608
Davanagere	Cotton	100	3750
Davanagere	Groundnut	440	17600
Davanagere	Maize	770	10087

District	Crop	Additonal yield (Kg/ha)	Additional income (₹ /ha)
Davanagere	Paddy	1040	14144
Davanagere	Pigeonpea	60	2610
Davanagere	Finger millet	360	5580
Davanagere	Sorghum	840	12852
Dharwad	Soybean	90	2250
Gadag	Groundnut	200	8000
Hassan	Maize	840	11004
Hassan	Paddy	1010	13736
Hassan	Finger millet	480	7440
Haveri	Cotton	100	3750
Haveri	Groundnut	450	18000
Haveri	Maize	780	10218
Haveri	Paddy	1030	14008
Haveri	Soybean	210	5250
Kalaburagi	Pigeonpea	110	4785
Kodagu	Maize	1080	14148
Kodagu	Paddy	800	10880
Kolar	Finger millet	140	2170
Koppal	Groundnut	130	5200
Koppal	Maize	530	6943
Koppal	Paddy	1070	14552
Koppal	Pearl Millet	160	2000
Mandya	Paddy	490	6664
Mandya	Finger millet	160	2480
Mysuru	Cotton	670	25125
Mysuru	Maize	240	3144
Mysuru	Paddy	500	6800
Mysuru	Finger millet	160	2480
Raichur	Cotton	100	3750
Raichur	Paddy	570	7752
Raichur	Pigeonpea	110	4785
Ramanagara	Groundnut	210	8400
Ramanagara	Maize	1090	14279
Ramanagara	Pigeonpea	80	3480
Ramanagara	Finger millet	410	6355
Shivamoga	Maize	770	10087
Shivamoga	Paddy	840	11424
Tumakuru	Groundnut	140	5600
Tumakuru	Maize	550	7205
Tumakuru	Paddy	430	5848
Tumakuru	Finger millet	330	5115
Udupi	Paddy	620	8432
Uttara Kannada	Maize	1190	15589
Uttara Kannada	Paddy	740	10064
Vijayapura	Pigeonpea	70	3045
Yadgir	Pigeonpea	80	3480

District	Crop	Additonal yield (Kg/ha)	Additional income (₹ /ha)
Bagalkot	Chickpea	140	4340
Bagalkot	Sorghum	220	3366
Ballari	Chickpea	190	5890
Ballari	Sorghum	240	3672
Belgavi	Sorghum	70	1071
Chitradurga	Chickpea	110	3410
Chitradurga	Sorghum	150	2295
Davanagere	Chickpea	230	7130
Davanagere	Finger millet	400	6200
Davanagere	Sorghum	280	4284
Dharwad	Sorghum	400	6120
Dharwad	Wheat	70	1068
Haveri	Chickpea	150	4650
Haveri	Sorghum	260	3978
Koppal	Chickpea	50	1600
Koppal	Sorghum	140	2142
Vijayapura	Sorghum	180	2754

D. Additional benefits of improved management practices under Bhoochetana during 2016-17.

District	Crop	Additional yield (Kg/ha)	Additional income (₹ /ha)
Bagalkot	Maize	800	10920
Bagalkot	Pearl Millet	380	5054
Bagalkot	Pigeonpea	210	10605
Bagalkot	Soybean	200	5550
Ballari	Cotton	450	17370
Ballari	Groundnut	270	11394
Ballari	Maize	720	9828
Ballari	Paddy	1570	23079
Ballari	Pearl Millet	220	2926
Ballari	Sorghum	470	7755
Belagavi	Groundnut	160	6752
Belagavi	Maize	370	5051
Belagavi	Paddy	410	6027
Belagavi	Sorghum	400	6600
Belagavi	Soybean	200	5550
Bengaluru Rural	Maize	270	3686
Bengaluru Rural	Finger millet	90	1553
Bengaluru Urban	Finger millet	90	1553
Bidar	Black gram	310	15500
Bidar	Green gram	370	19333
Bidar	Pigeonpea	270	13635
Bidar	Rabi Chickpea	320	12800
Chikkamagalur	Maize	710	9692
Chikkamagalur	Paddy	770	11319
Chikkamagalur	Finger millet	70	1208
Chitradurga	Groundnut	20	844

District	Crop	Additional yield (Kg/ha)	Additional income (₹ /ha)
Chitradurga	Maize	390	5324
Chitradurga	Finger millet	40	690
Dakshina Kannada	Paddy	610	8967
Davanagere	Cotton	60	2316
Davanagere	Groundnut	240	10128
Davanagere	Maize	450	6143
Davanagere	Paddy	780	11466
Davanagere	Pigeonpea	60	3030
Davanagere	Rabi Finger millet	370	6383
Davanagere	Rabi Sorghum	340	5610
Davanagere	Finger millet	120	2070
Davanagere	Sorghum	490	8085
Davanagere	Sugarcane	7250	18488
Dharwad	Soybean	230	6383
Gadag	Maize	410	5597
Hassan	Maize	350	4778
Hassan	Paddy	1080	15876
Hassan	Finger millet	160	2760
Haveri	Cotton	100	3860
Haveri	Groundnut	270	11394
Haveri	Maize	580	7917
Haveri	Paddy	440	6468
Haveri	Soybean	230	6383
Kalaburagi	Pigeonpea	180	9090
Kodagu	Maize	940	12831
Kodagu	Paddy	760	11172
Koppal	Maize	170	2321
Koppal	Paddy	760	11172
Koppal	Pearl Millet	260	3458
Raichur	Cotton	220	8492
Raichur	Paddy	850	12495
Raichur	Pearl Millet	430	5719
Raichur	Pigeonpea	90	4545
Raichur	Rabi Chickpea	30	1200
Raichur	Rabi Sorghum	130	2145
Shivamoga	Maize	320	4368
Shivamoga	Paddy	400	5880
Tumakuru	Groundnut	40	1688
Tumakuru	Paddy	690	10143
Tumakuru	Finger millet	60	1035
Udupi	Paddy	870	12789
Uttara Kannada	Maize	1050	14333
Uttara Kannada	Paddy	480	7056
Vijayapura	Pigeonpea	150	7575

District	Crop	Additional yield (Kg/ha)	Additional income (₹ /ha)
Vijayapura	Rabi Chickpea	80	3200

E. Additional benefits of improved management practices under Bhoochetana during 2017-18.

District	Crop	Additional yield (kg/ha)	Additional income (₹ /ha)
Bidar	Black gram	220	11880
Raichur	Cotton	240	9648
Ballari	Foxtail Millet	140	4200
Chitradurga	Foxtail Millet	210	6300
Davanagere	Foxtail Millet	300	9000
Haveri	Foxtail Millet	430	12900
Bidar	Green gram	160	8920
Ballari	Groundnut	430	19135
Chikballapur	Groundnut	350	15575
Chitradurga	Groundnut	150	6675
Davanagere	Groundnut	220	9790
Haveri	Groundnut	370	16465
Ramanagara	Groundnut	170	7565
Tumakuru	Groundnut	140	6230
Chamarajanagar	Maize	770	10973
Davanagere	Maize	850	12113
Mysuru	Maize	290	4133
Ballari	Paddy	390	6045
Chikmagalur	Paddy	790	12245
Dakshina Kannada	Paddy	800	12400
Davanagere	Paddy	570	8835
Dharwad	Paddy	310	4805
Hassan	Paddy	870	13485
Kodagu	Paddy	1130	17515
Mandya	Paddy	500	7750
Mysuru	Paddy	400	6200
Raichur	Paddy	680	10540
Udupi	Paddy	970	15035
Yadgir	Paddy	1190	18445
Ballari	Pearl Millet	170	2423
Chitradurga	Pearl Millet	230	3278
Dharwad	Pearl Millet	130	1853
Raichur	Pearl Millet	410	5843
Vijayapura	Pearl Millet	300	4275
Bidar	Pigeonpea	270	14715
Chitradurga	Pigeonpea	150	8175
Davanagere	Pigeonpea	20	1090
Kalaburgi	Pigeonpea	70	3815

District	Crop	Additional yield (kg/ha)	Additional income (₹ /ha)
Raichur	Pigeonpea	110	5995
Vijayapura	Pigeonpea	210	11445
Yadgir	Pigeonpea	40	2180
Bagalkot	Pigeonpea	240	13080
Ballari	Finger millet	130	2470
Bangalore	Finger millet	1090	20710
Chamarajanagar	Finger millet	190	3610
Chikballapur	Finger millet	430	8170
Chikmagalur	Finger millet	420	7980
Chitradurga	Finger millet	220	4180
Davanagere	Finger millet	360	6840
Hassan	Finger millet	340	6460
Kolar	Finger millet	530	10070
Mandya	Finger millet	180	3420
Mysuru	Finger millet	220	4180
Ramanagara	Finger millet	250	4750
Tumakuru	Finger millet	320	6080
Bidar	Soybean	370	11285
Haveri	Little Millet	180	5400
Haveri	Paddy DSR	250	3875
Shivamoga	Paddy DSR	1050	16275
Ballari	Chickpea	240	10560
Raichur	Chickpea	140	6160
Koppal	Chickpea	120	5280
Gadag	Chickpea	30	1320
Bagalkot	Chickpea	100	4400
Belagavi	Chickpea	280	12320
Ballari	Sorghum	330	4703
Haveri	Sorghum	250	3563
Koppal	Sorghum	410	5843
Gadag	Sorghum	80	1140
Belagavi	Sorghum	200	2850