

Global Sorghum Production Scenario

UK Deb, MCS Bantilan, AD Roy and P Parthasarathy Rao



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2.1. Introduction

Sorghum is an important cereal crop which is grown globally for food and feed purposes. It is most widely grown in the semi-arid tropics where water availability is limited and frequently subjected to drought. About 100 countries grow sorghum, of which 66 cultivate it over more than 1000 ha or produce more than 1000 t. India has the largest sorghum area with 10.06 million ha (Table 2.1). The second largest sorghum cultivating country is Nigeria, followed by Sudan, USA and Niger. More than 90% of the world's sorghum area lies in the developing countries, mainly in Africa and Asia. In terms of annual production, USA tops the list with 13.38 million t during 1999-2001, followed by India (8.23 million t), Nigeria (7.65 million t), Mexico (6.09 million t) and Argentina (3.16 million t). However, none of these countries recorded the highest global yields. The highest sorghum yields during 1999-2001 were recorded by Israel (12 664 kg ha⁻¹), followed by Jordan (11 711 kg ha⁻¹), Italy (6458 kg ha⁻¹), Algeria (6400 kg ha⁻¹) and France (6094 kg ha⁻¹). Thus while Asian and African countries like India and Nigeria had the largest area devoted to sorghum cultivation, those in West Asia (like Israel and Jordan) and Europe (Italy and France) reaped the highest yields. It may be noted that Israel and Jordan are not major sorghum-growing countries. The average area under the crop during 1999-2001 was 1006 ha and production 13 400 t in Israel, and 30 ha and 300 t in Jordan. This chapter presents the global sorghum production situation and trends. It updates the trends and outlook given in FAO and ICRISAT (1996). It also analyzes changes in sorghum production and sources of changes during the last three decades.

2.2. Spatial Distribution of Sorghum

Sorghum cultivation is distributed throughout the world (Figures 2.1 and 2.2). In Asia, it is grown in China, India, Korea, Pakistan, Thailand and Yemen. Australia and USA grow the crop too. In Southern and Eastern Africa, the sorghum-growing countries are Botswana, Eritrea, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Somalia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. In West and Central Africa, the crop is grown in Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Egypt, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Mali, Mauritania, Morocco, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Togo, Tunisia and Uganda. In Latin America, the sorghum-growing countries are Argentina, Brazil, Colombia, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Peru, Uruguay and Venezuela. In Europe, it is grown in France, Italy, Spain, Albania and Romania.

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Table 2.1. Area, production and yield of sorghum in different sorghum-producing countries, 1999-2001.

Country	Area ('000 ha)	Production ('000 t)	Yield (kg ha ⁻¹)	Global rank based on		
				Area	Production	Yield
India	10 055.7	8231.7	818.6	1	2	72
Nigeria	6816.0	7647.3	1122.0	2	3	54
Sudan	4306.5	2441.0	566.8	3	7	89
USA	3352.7	13 379.8	3990.7	4	1	12
Niger	2286.2	500.9	219.1	5	16	98
Mexico	1992.4	6092.0	3057.6	6	4	19
Burkina Faso	1301.9	1130.6	868.4	7	10	68
Ethiopia	1189.8	1377.6	1157.9	8	9	53
China	941.5	2947.7	3130.9	9	6	16
Chad	879.4	529.6	602.2	10	15	85
Mali	718.5	649.5	903.8	11	14	67
Argentina	690.5	3159.1	4575.3	12	5	8
Tanzania	638.9	653.6	1023.0	13	13	57
Australia	601.8	1810.0	3007.8	14	8	20
Brazil	452.8	742.9	1640.4	15	12	38
Yemen	362.3	383.1	1057.5	16	19	56
Mozambique	360.8	297.5	824.6	17	22	71
Pakistan	353.7	224.6	635.2	18	25	83
Cameroon	317.4	380.7	1199.5	19	20	52
Ghana	296.4	287.2	969.1	20	24	61
Uganda	279.0	399.0	1430.1	21	18	42
Somalia	270.0	87.3	323.5	22	42	96
Senegal	186.9	145.0	775.3	23	33	75
Mauritania	183.3	90.1	491.2	24	41	91
Venezuela	181.5	457.7	2522.0	25	17	24
Togo	180.1	150.5	835.2	26	30	70
Eritrea	179.0	117.0	653.9	27	36	80
Benin	170.7	138.2	809.7	28	34	73
Zimbabwe	166.8	97.4	584.0	29	38	88
Egypt	162.7	945.1	5810.3	30	11	6
Rwanda	155.8	145.9	936.3	31	31	63
Saudi Arabia	155.4	204.0	1312.7	32	28	46
Kenya	136.7	125.3	917.1	33	35	66
Haiti	132.7	92.7	698.5	34	40	78
South Africa	110.5	293.6	2657.8	35	23	23
El Salvador	99.3	145.8	1468.6	36	32	40
Botswana	90.3	11.9	131.5	37	63	99
Thailand	87.7	163.3	1862.4	38	29	35
Congo	77.0	50.0	649.4	39	48	81
Honduras	72.3	70.2	971.6	40	45	60
Colombia	66.2	212.2	3203.0	41	27	15
France	59.8	364.2	6094.3	42	21	5
Malawi	56.4	38.7	686.2	43	52	79
Ivory Coast	53.3	28.2	529.4	44	54	90
Bolivia	51.8	115.7	2233.8	45	37	29
Burundi	51.7	63.3	1226.1	46	46	49
USSR (former)	47.3	86.8	1834.4	47	44	36
Nicaragua	45.5	87.3	1918.8	48	43	33
Lesotho	45.1	41.6	920.8	49	51	65
Guatemala	42.3	51.0	1205.4	50	47	51

...continued

Table 2.1. Continued

Country	Area ('000 ha)	Production ('000 t)	Yield (kg ha ⁻¹)	Global rank based on		
				Area	Production	Yield
Zambia	37.0	26.4	713.1	51	55	77
Central African Republic	35.0	47.6	1361.0	52	49	44
Italy	33.5	216.6	6457.8	53	26	3
Uruguay	26.8	95.0	3539.1	54	39	13
Paraguay	22.9	30.5	1331.5	55	53	45
Morocco	21.3	12.8	602.0	56	61	86
Namibia	20.7	7.0	338.7	57	70	94
Gambia	19.6	24.0	1221.9	58	56	50
Guinea-Bissau	16.1	13.7	850.4	59	59	69
Albania	15.7	14.6	930.1	60	58	64
Ukraine	11.7	12.7	1085.7	61	62	55
Sierra Leone	11.6	11.1	958.1	62	64	62
Korea DPR	10.0	10.0	1000.0	63	65	58
Spain	8.5	44.1	5164.1	64	50	7
Guinea	7.0	5.1	730.4	65	72	76
Uzbekistan	6.0	18.5	3083.3	66	57	18
Ecuador	5.5	8.2	1479.0	67	69	39
Hungary	4.5	9.1	2010.6	68	66	30
Dominican Republic	4.2	8.4	1995.8	69	68	32
Syria	3.7	2.3	630.5	70	77	84
Tunisia	3.0	1.0	333.3	71	80	95
Iraq	2.6	0.7	265.8	72	84	97
Panama	2.6	6.5	2493.5	73	71	26
Romania	2.2	3.2	1441.3	74	74	41
Yugoslavia, Fed. Republic of	2.2	9.1	4102.7	75	67	11
Madagascar	2.0	0.9	466.7	76	83	92
Korea, Republic of	1.5	2.9	1888.4	77	76	34
Papua New Guinea	1.1	3.4	3121.2	78	73	17
Israel	1.1	13.4	12 663.5	79	60	1
Lebanon	1.0	1.7	1666.7	80	79	37
Cuba	1.0	1.0	1000.0	81	81	59
Greece	1.0	2.0	2000.0	82	78	31
Swaziland	1.0	0.6	600.0	83	85	87
Oman	0.9	2.9	2983.1	84	75	22
Tajikistan	0.6	0.4	635.3	85	88	82
Bangladesh	0.4	1.0	2489.6	86	82	27
Moldova	0.2	0.2	1267.3	87	92	48
Sri Lanka	0.2	0.1	800.0	88	93	74
Croatia	0.1	0.5	4115.4	89	86	10
Peru	0.1	0.3	3268.9	90	90	14
New Caledonia	0.1	0.1	1366.7	91	95	43
Algeria	0.1	0.4	6400.0	92	87	4
Kazakhstan	0.1	0.2	4392.6	93	91	9
Macedonia	0.1	0.1	1300.0	94	96	47
Azerbaijan	0.1	0.0	104.2	95	100	100
Slovakia	negligible	0.1	2310.1	96	94	28
Kyrgyzstan	negligible	0.0	433.6	97	98	93
Jordan	negligible	0.3	11 710.5	98	89	2
Fiji	negligible	0.0	3000.0	99	97	21
Micronesia, Fed. States of	negligible	0.0	2500.0	100	99	25
World	41 859.3	58 556.5	1398.9			

Source: FAO website (www.fao.org).

2.3. Trends in Area, Production and Yield

The area under sorghum in countries across the world has recorded a mixed trend over the last three decades (Table 2.2). Trends in sorghum area in Africa are presented in Figure 2.3, where sorghum area is consistently increasing in Eastern and Western Africa and remains the most important cereal in these regions (Bantilan 2003). Area declined in many major sorghum-growing countries like Argentina, Australia, Burkina Faso, China, India, Mali, Mexico, Pakistan, Somalia, South Africa, USA, Yemen and Zimbabwe. However, some important sorghum-growing countries like Brazil, Burundi, Chad, Mauritania, Mozambique, Senegal, Sudan and Tanzania experienced notable increases in area at the end of the 20th century compared to the early 1970s, and this increase has been consistent over the last three decades. Though Nigeria experienced a decline in area under sorghum in the early 1980s, it increased in the early 1990s and, at the end of the 20th century, was 42% higher than in the early 1970s.

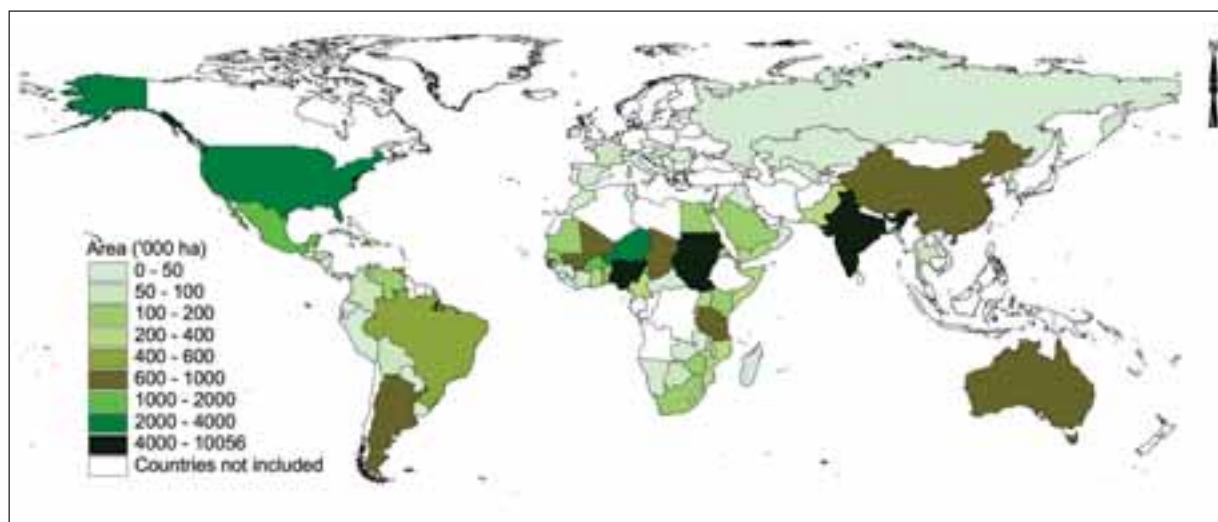


Figure 2.1. Distribution of sorghum area, 1999-2001.

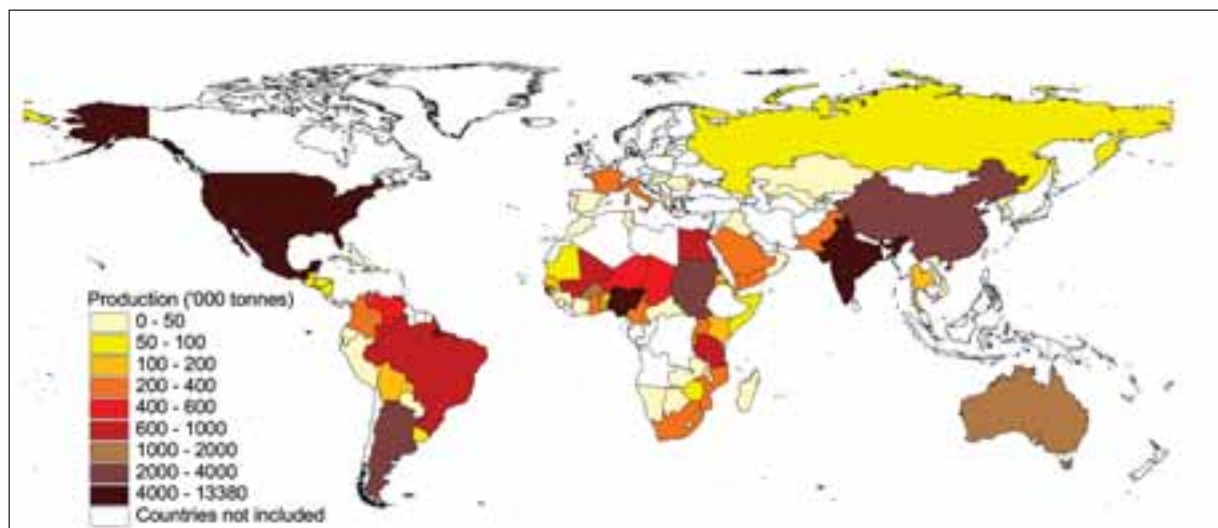


Figure 2.2. Distribution of sorghum production, 1999-2001.

Table 2.2. Area, production and yield of sorghum in different countries, 1971-2001.

Country	Average area ('000 ha)				Average production ('000 t)				Yield (kg ha ⁻¹)			
	1971-73	1981-83	1991-93	1999-2001	1971-73	1981-83	1991-93	1999-2001	1971-73	1981-83	1991-93	1999-2001
Albania	20	26	11	16	20	32	11	15	994	1232	992	930
Argentina	2074	2411	721	690	4140	7935	2626	3159	1953	3306	3635	4585
Australia	629	671	460	602	1181	1160	915	1810	1912	1738	1931	3003
Benin	90	98	143	171	59	58	110	138	653	594	773	810
Botswana	97	65	80	90	50	12	29	12	557	160	341	137
Brazil	50	117	159	453	85	224	274	743	2231	1953	1739	1639
Burkina Faso	1038	1073	1417	1302	489	626	1280	1131	471	583	903	867
Burundi	21	53	58	52	20	53	66	63	951	1000	1138	1225
Cameroon	343	404	510	317	243	266	390	381	710	659	765	1191
Central African Republic	47	54	27	35	38	43	24	48	809	820	903	1361
Chad	486	273	516	879	259	166	326	530	531	624	632	611
China	5072	2704	1368	941	8680	7343	5151	2948	1711	2716	3765	3124
Colombia	104	265	235	66	243	565	708	212	2394	2147	3025	3207
Ivory Coast	31	34	48	53	15	18	29	28	495	539	597	528
Cuba	2	1	1	1	2	1	1	1	1000	1000	1000	1000
Dominican Republic	4	9	7	4	16	26	16	8	3717	2913	2367	2107
Egypt	205	166	144	163	846	623	740	945	4120	3747	5149	5811
El Salvador	125	115	135	99	153	128	194	146	1224	1111	1430	1475
Eritrea	85	88	87	179	75	79	77	117	882	898	855	610
France	68	59	85	60	258	276	489	364	3857	4642	5725	6109
Gambia	7	7	11	20	7	7	11	24	1000	1056	990	1213
Ghana	218	211	293	296	164	91	276	287	753	438	939	969
Greece	5	1	1	1	7	2	2	2	1433	1333	2333	2000
Guatemala	41	40	67	42	41	82	80	51	1033	2097	1188	1205
Guinea	20	20	13	7	25	24	12	5	1250	1180	843	730
Guinea-Bissau	6	35	13	16	4	23	13	14	638	658	950	851
Haiti	198	157	120	133	187	114	97	93	936	730	807	698
Honduras	43	56	73	72	46	54	77	70	1098	963	1063	980
Hungary	1	6	14	5	3	20	33	9	2000	3272	2299	2006
India	16 335	16 469	12 574	10 056	7929	11 578	10 588	8232	485	703	839	819
Iraq	6	5	2	3	7	6	1	1	1063	1083	667	265
Italy	3	21	32	34	10	105	185	217	3667	5017	5772	6460
Kenya	204	97	146	137	227	62	114	125	1111	685	822	915
Korea, DPR	23	12	10	10	27	18	11	10	1157	1432	1133	1000

...continued

Table 2.2. Continued

Country	Average area ('000 ha)				Average production ('000 t)				Yield (kg ha ⁻¹)			
	1971-73	1981-83	1991-93	1999-2001	1971-73	1981-83	1991-93	1999-2001	1971-73	1981-83	1991-93	1999-2001
Korea, Republic of	8	3	1	2	6	4	1	3	738	1194	1000	2100
Lesotho	77	52	32	45	56	35	26	42	726	667	773	949
Madagascar	4	3	2	2	2	1	1	1	533	444	500	467
Malawi	120	28	34	56	96	16	15	39	797	546	419	686
Mali	373	534	875	719	284	452	716	649	765	848	833	902
Mauritania	171	111	128	183	35	31	67	90	203	272	513	489
Mexico	1077	1520	1305	1992	2799	5286	4582	6092	2601	3485	3513	3056
Morocco	68	35	31	21	77	22	18	13	1105	606	589	597
Mozambique	250	333	402	361	209	197	121	298	836	594	305	875
Namibia	10	15	14	21	5	7	6	7	467	444	398	333
Nicaragua	45	47	51	45	45	92	88	87	1010	1971	1724	1911
Niger	531	1075	2315	2286	200	345	424	501	370	322	185	217
Nigeria	4792	2216	4535	6816	3072	3589	4832	7647	637	1620	1064	1122
Pakistan	532	391	384	354	331	223	225	225	620	570	586	635
Paraguay	5	8	14	23	6	10	19	30	1200	1241	1349	1342
Romania	2	16	6	2	3	20	6	3	2000	1276	1042	1449
Rwanda	130	179	143	156	142	199	156	146	1092	1113	1085	930
Saudi Arabia	160	109	137	155	68	66	152	204	439	653	1097	1313
Senegal	122	113	119	187	88	123	98	145	716	1040	820	793
Sierra Leone	5	9	37	12	6	13	22	11	1200	1468	586	1123
Somalia	380	464	310	270	133	192	106	87	349	407	336	321
South Africa	305	183	196	110	428	337	292	294	1357	1827	1371	2544
Spain	43	27	11	9	172	112	58	44	3993	4138	5106	5173
Sudan	1974	3682	5345	4307	1527	2300	3323	2441	775	619	616	568
Tanzania	338	500	642	639	172	493	619	654	509	1134	965	1027
Thailand	70	251	171	88	129	279	236	163	1872	1111	1388	1857
Tunisia	14	14	5	3	8	5	2	1	607	325	311	333
USA	6077	5101	4160	3353	21 951	18 614	16 839	13 380	3625	3596	4001	3986
Uganda	304	192	250	279	385	332	374	399	1269	1733	1495	1430
Uruguay	70	62	45	27	118	143	134	95	1561	2253	3020	3105
Venezuela	4	215	220	182	6	363	498	458	1300	1692	2276	2522
Yemen	866	575	424	362	626	460	393	383	722	808	915	1057
Zambia	74	20	40	37	47	14	23	26	629	689	575	713
Zimbabwe	220	235	112	167	112	81	62	97	487	367	531	583

Source: Three-year average of data based on FAO website (www.fao.org).

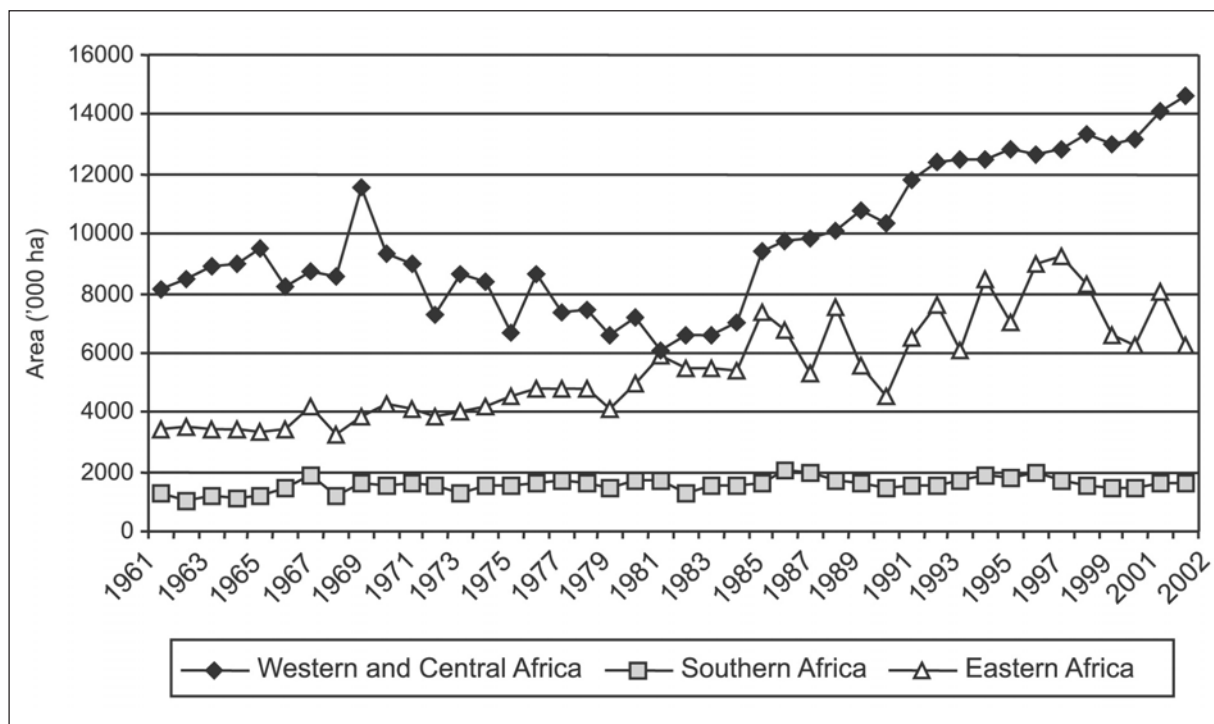


Figure 2.3. Trends in sorghum area in Africa, 1961-2002.

The data on area, production and yield contained in Table 2.2 facilitate the identification of countries with increasing, decreasing or fluctuating trends. For example, average annual production increased in Thailand in 1999-2001, mainly because the country exports sorghum to Japan, for which producers cut the plants at the 'dough stage'. Since FAO data do not record this type of information nor changes in commodity use, a decline in the grain area of sorghum was recorded in Thailand.

Although yields have increased in most of the sorghum-growing countries in Asia, Africa and Latin America, some countries like Brazil, Honduras, Iraq, Morocco, Romania and Rwanda experienced a decline, and Gambia, Guatemala, Guinea, Sierra Leone and Thailand experienced a fluctuating trend. Such declines and fluctuations deserve investigation. The decline in yield may be due to changes in sorghum use, eg, as livestock feed, harvesting for silage, or shifting of sorghum production to more marginal lands.

The trends in the area, production and yield of sorghum in major sorghum-growing states in India are presented in Table 2.3. The area under sorghum in the late 1990s (1998-2002) declined by 1 to 60% in major sorghum-growing states (Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan and Tamil Nadu) compared to the early 1970s, early 1980s and early 1990s. In fact, the niche of sorghum production primarily remains in the two states of Maharashtra and Karnataka, where area under sorghum production stands at a total of 7 million ha (Figure 2.4). Average annual area under sorghum in India declined from 16 million ha in the early 1970s to 10 million ha in the late 1990s. Sorghum production was increasing until the early 1980s but declined after that. Yield of sorghum has increased over time. Average sorghum yield in the late 1990s was 826 kg ha⁻¹ against 543 kg ha⁻¹ in the early 1970s. Decrease in sorghum production was primarily due to the decrease in area under sorghum.

Table 2.3. Area, production and yield of sorghum in different states of India.

State	Area ('000 ha)			
	1972-75	1981-84	1991-94	1998-2002
Andhra Pradesh	2709.9	2102.2	1057.2	721.6
Gujarat	970.6	956.6	444.6	206.1
Karnataka	2037.3	2205.7	2159.2	1885.0
Madhya Pradesh	2122.7	2138.0	1363.9	690.6
Maharashtra	5718	6588.7	5857.0	5019.8
Rajasthan	971.7	968.3	714.6	588.4
Tamil Nadu	665.3	688.7	500.8	402.6
India	16139.3	16469.0	12703.5	10012.3
State	Production ('000 t)			
	1972-75	1981-84	1991-94	1998-2002
Andhra Pradesh	1363.9	1326.4	815.6	559.2
Gujarat	321.4	544.7	267.6	190
Karnataka	1578	1726.3	1842.7	1707.7
Madhya Pradesh	1598	1747.7	1277.3	575.9
Maharashtra	2577.7	4740.7	5351.3	4388
Rajasthan	337.3	451.7	243.1	153.8
Tamil Nadu	504	492	508.3	403.9
India	8826.3	11578.0	10773.3	8272.0
State	Yield (kg ha ⁻¹)			
	1972-75	1981-84	1991-94	1998-2002
Andhra Pradesh	506.7	630.0	770.0	779.3
Gujarat	333.3	570.0	616.7	896.7
Karnataka	763.3	783.3	856.7	906.0
Madhya Pradesh	750.0	816.7	936.7	828.7
Maharashtra	436.7	720.0	906.7	875.3
Rajasthan	350.0	463.3	330.0	363.6
Tamil Nadu	760.0	710.0	1013.3	1001.7
India	543.3	706.7	846.7	826.0

Source: Authors' calculations are based on data obtained from CMIE (2002).

2.4. Growth Rates of Area, Production and Yield

The annual compound rates of growth of area, production and yield of sorghum were estimated for the periods 1971-80 (the 1970s), 1981-90 (the 1980s) and 1991-2001 (the 1990s). The following equation was used for estimating growth rates in area, production and yield:

$$\ln Y = a + bt$$

where

a is the intercept term;

$\ln Y$ is the area (ha)/production (metric t)/yield (kg ha⁻¹) expressed in natural log form;

t is the time trend denoting years; and

b is the annual compound rate of growth of area/production/yield.

The annual compound rates of growth of sorghum production, area and yield for different countries are estimated. We see a four-level hierarchy: (1) high growth (5% or more); (2) moderate growth (> 1% to < 5%); (3) slow growth (up to 1.0%) and (4) negative growth. The temporal changes in sorghum production under these four growth levels are given in Table 2.4.

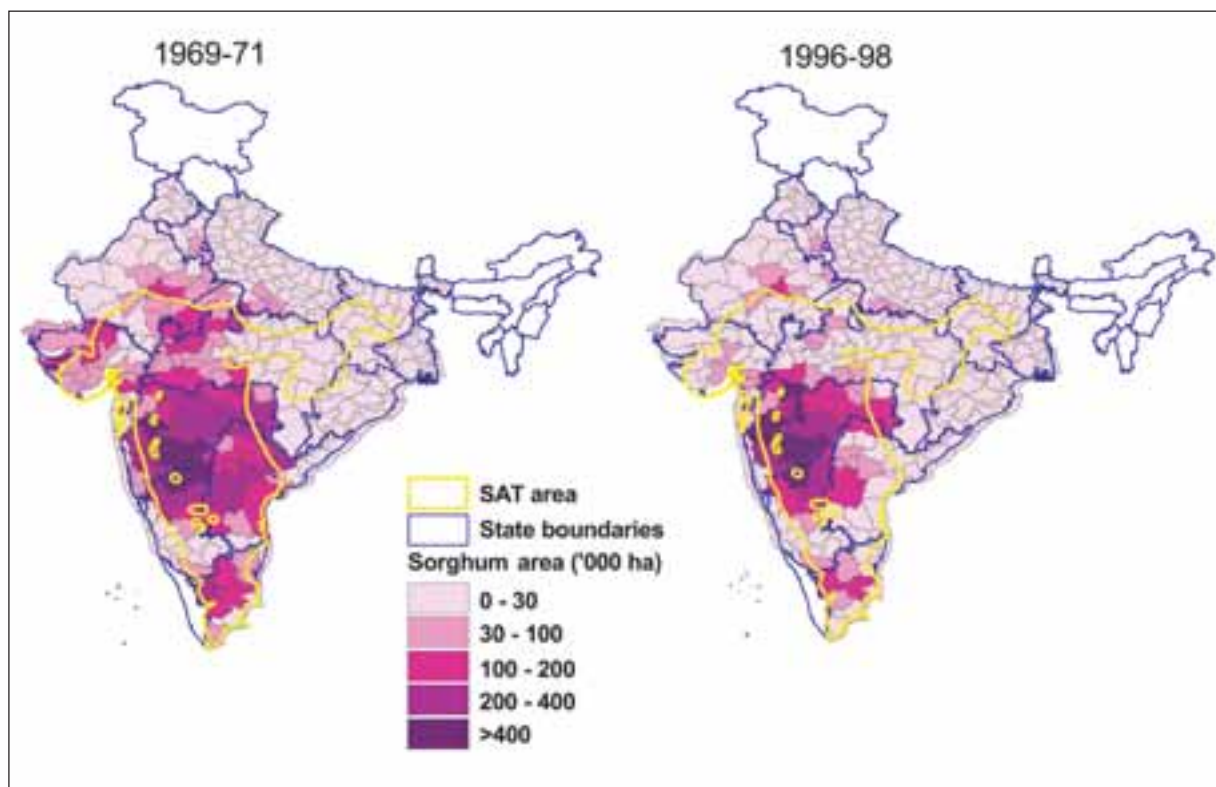


Figure 2.4. Change in sorghum area in India by district, 1970s-1990s.

The rates of growth of sorghum area, production and yield in India are given in Table 2.5. The area under sorghum has declined over time. During the last three decades (1972/73-2000/01), all the major sorghum-growing states except two (Maharashtra and Karnataka) experienced a measurable decline in area under sorghum. The rate of decline in sorghum area in India in the 1990s (3.08% per year) was much faster than in the 1980s (1.57% per year). Decline in sorghum production in India during 1972/73-2000/01 was 0.42% per year. The yield of sorghum in all these states has increased during the same period. During 1972/73-2000/01, annual growth in sorghum yield in India was 1.44% while the highest growth in yield was observed in Gujarat (2.44%) and Maharashtra (2.24%). During the 1990s, the highest growth in yield was observed in Gujarat (5.87% per year), followed by Rajasthan (3.43% per year). For the two sorghum niche states of Maharashtra and Karnataka, production increased from 4 to 6 million t during the period.

2.5. Sources of Changes in Average Sorghum Production

Results presented in the previous sections clearly depict three distinct situations where countries have experienced: (1) consistent increase in production; (2) persistent decrease in production and (3) fluctuations in production. Therefore, it is useful to analyze the average production in the 1990s compared to the 1970s and 1980s (Table 2.6). An analysis of the sources of these trends is important. A model developed by Hazell (1982) was used to analyze the changes in average

Table 2.4. Temporal changes in sorghum production in the 1970s, 1980s and 1990s.

Region	High growth			Moderate growth		
	1970s	1980s	1990s	1970s	1980s	1990s
Asia	Thailand	Saudi Arabia	Korea, Saudi Arabia	India, Saudi Arabia	Yemen	
Southern and Eastern Africa	Lesotho, Somalia, Tanzania	Botswana, Kenya, Zambia	Eritrea, Lesotho, Malawi, Mozambique, Zimbabwe	Namibia, South Africa	Lesotho, Malawi, Namibia, Somalia, South Africa, Zimbabwe	Kenya, Namibia, South Africa, Tanzania, Zambia
West and Central Africa	Burundi, Guinea-Bissau, Ivory Coast, Niger, Senegal, Togo	Benin, Burkina Faso, Chad, Ghana, Guinea, Mali, Mauritania, Togo	Central African Republic, Chad, Gambia, Nigeria, Senegal	Benin, Burkina Faso, Cameroon, Mali, Rwanda, Sierra Leone, Sudan	Burundi, Cameroon, Gambia, Ivory Coast, Niger, Nigeria, Senegal, Uganda	Benin, Egypt, Ghana, Guinea-Bissau, Mauritania, Niger, Togo
South America	Brazil, Colombia, Guatemala, Mexico, Nicaragua, Peru, Venezuela	Mexico, Venezuela	Brazil, Mexico	Argentina	Brazil, Colombia, Guatemala, Honduras	Argentina, Honduras
Others	Albania, Hungary, Italy, Romania	Hungary	Albania, Australia, Romania	France, Spain		
	Slow growth			Negative growth		
	1970s	1980s	1990s	1970s	1980s	1990s
Asia		India, Pakistan		China, Korea DPR, Korean Republic, Pakistan, Yemen	China, Korea DPR, Korean Republic, Thailand	China, India, Korea DPR, Pakistan, Thailand
Southern and Eastern Africa	Eritrea			Botswana, Kenya, Madagascar, Malawi, Mozambique, Swaziland, Zambia, Zimbabwe	Eritrea, Madagascar, Mozambique, Swaziland	Botswana, Madagascar, Somalia, Swaziland, Tanzania
West and Central Africa			Burundi, Cameroon, Uganda	Central African Republic, Chad, Egypt, Ghana, Gambia, Guinea, Mauritania, Morocco, Nigeria, Tunisia, Uganda	Central African Republic, Egypt, Guinea-Bissau, Morocco, Rwanda, Sierra Leone, Sudan, Tunisia	Burkina Faso, Guinea, Ivory Coast, Mali, Morocco, Rwanda, Sierra Leone, Sudan, Tunisia
South America	El Salvador		El Salvador, Haiti	Haiti, Honduras, Uruguay	Argentina, El Salvador, Haiti, Nicaragua, Peru, Uruguay	Colombia, Guatemala, Nicaragua, Peru, Uruguay, Venezuela
Others		Italy		Australia, USA	Albania, Australia, France, Romania, Spain, USA	France, Hungary, Italy, Spain, USA

Source: Authors' calculations are based on data from FAO.

Table 2.5. Annual compound rates of growth (%) in sorghum area, production and yield in India.

State	Area			
	1972/73-1980/81	1981/82-1990/91	1990/91-2000/01	1972/73-2000/01
Andhra Pradesh	-3.17	-6.84	-5.37	-5.24
Gujarat	-0.68	-2.55	-11.00	-5.99
Karnataka	-1.37	0.23	-2.01	0.04
Madhya Pradesh	0.20	-2.68	-9.94	-4.04
Maharashtra	2.63	-0.52	-1.67	-0.63
Rajasthan	-1.19	-0.34	-2.63	-1.65
Tamil Nadu	-1.02	-2.12	-2.79	-2.55
India	0.13	-1.57	-3.08	-1.86
			Production	
Andhra Pradesh	0.62	-6.71	-4.61	-3.64
Gujarat	9.96	-6.37	-5.15	-3.54
Karnataka	1.16	-1.89	-1.28	0.29
Madhya Pradesh	-1.17	-0.63	-10.40	-3.19
Maharashtra	13.40	2.55	-1.60	1.60
Rajasthan	-3.24	-0.80	-4.25	-1.99
Tamil Nadu	0.64	2.35	-3.28	-1.58
India	4.64	0.18	-3.06	-0.42
			Yield	
Andhra Pradesh	3.81	0.21	0.81	1.60
Gujarat	10.60	-3.85	5.87	2.44
Karnataka	2.58	-2.06	0.69	0.27
Madhya Pradesh	-1.32	1.96	-1.01	0.84
Maharashtra	10.80	3.06	0.05	2.24
Rajasthan	-2.01	-0.36	3.43	0.25
Tamil Nadu	1.59	4.49	-0.47	0.97
India	4.57	1.66	-0.01	1.44

Source: Authors' calculations are based on data obtained from CMIE (2002).

production in the 1990s compared to the 1970s and 1980s in all major sorghum-growing countries in the world and states in India. Details of the analytical procedure are given in Appendix 2.1.

The temporal changes in average sorghum production in India are reported in Table 2.7. In the 1990s (1991/92-2000/01) compared to the 1970s (1972/73-1980/81), production increased in Karnataka by 7.3% and in Maharashtra by 23.1%. Average sorghum production in all other major sorghum-growing states (Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan and Tamil Nadu) declined. Sorghum production declined in India in the 1990s by 8.2%. Sorghum production decreased by about 50% in Andhra Pradesh and Gujarat, 41% in Madhya Pradesh and by less than 30% in Rajasthan and Tamil Nadu.

An analysis of the sources of the trends in average production in the 1990s compared to the 1970s and the 1980s showed that there were four sources of change in average production. Two of these originated from the changes in mean yield and mean area, which are pure effects that would arise even if there were no other sources of change. The third source was an interaction effect, arising from simultaneous changes in the mean yield and mean area. This term will obviously be

Table 2.6. Trends in changes in average production of sorghum, 1971-2001.

Country	Average annual production ('000 t)			Change compared to 1971-80 (%)	
	1971-80	1981-90	1991-2001	1981-90	1991-2001
Albania	26	33	14	26.72	-45.56
Argentina	5200	5082	2686	-2.28	-48.35
Australia	1035	1339	1315	29.42	27.07
Benin	64	82	121	29.09	90.85
Bolivia	5	43	92	754.00	1747.87
Botswana	40	28	27	-28.61	-30.60
Brazil	194	283	456	46.01	135.02
Burkina Faso	584	788	1207	34.88	106.64
Burundi	27	59	64	117.04	135.88
Cameroon	272	321	406	17.78	49.00
Central African Rep	35	42	31	18.13	-12.10
Chad	277	232	454	-16.23	63.77
China	8201	6255	4452	-23.73	-45.71
Colombia	369	627	448	70.07	21.53
Ivory Coast	24	22	26	-9.09	6.84
Dominican Rep	17	36	15	120.61	-7.54
Egypt	751	594	793	-20.90	5.69
El Salvador	153	129	181	-15.66	18.25
Eritrea	78	80	105	2.32	35.24
France	305	250	386	-18.00	26.51
Gambia	5	8	15	55.56	173.33
Ghana	154	144	313	-6.45	104.15
Greece	5	2	2	-70.59	-59.00
Guatemala	57	91	60	60.67	6.11
Guinea-Bissau	9	18	16	110.47	80.92
Haiti	142	120	94	-15.48	-34.02
Honduras	47	51	75	7.61	59.07
Hungary	13	29	17	132.00	33.01
India	9981	11 246	9437	12.68	-5.44
Italy	28	98	200	253.79	620.90
Kenya	217	103	120	-52.54	-44.86
Korea DPR	23	16	9	-32.19	-62.93
Korea Rep	5	3	2	-46.00	-60.71
Lesotho	59	38	33	-35.93	-44.75
Malawi	77	17	33	-77.59	-57.77
Mali	326	511	673	56.60	106.15
Mauritania	32	63	95	95.03	196.25
Mexico	3693	5650	5354	52.99	44.97
Mozambique	205	201	227	-1.71	10.77
Namibia	5	7	7	37.74	23.43
Nicaragua	56	108	86	92.02	51.79
Niger	279	359	422	28.54	50.98
Nigeria	3203	4537	6482	41.62	102.36
Pakistan	282	228	231	-18.86	-17.81
Panama	4	21	17	475.68	347.25
Paraguay	8	19	24	141.56	212.83
Rwanda	154	186	128	21.11	-16.32
Saudi Arabia	117	86	191	-26.05	63.59

...continued

Table 2.6. Continued

Country	Average annual production ('000 t)			Change compared to 1971-80 (%)	
	1971-80	1981-90	1991-2001	1981-90	1991-2001
Senegal	105	128	123	21.37	16.56
Sierra Leone	9	18	18	108.14	111.31
Somalia	134	232	120	73.78	-10.45
South Africa	479	452	354	-5.74	-26.08
Spain	185	101	53	-45.30	-71.57
Sudan	1801	2330	3228	29.35	79.20
Tanzania	327	518	645	58.45	97.44
Thailand	180	270	198	50.47	10.07
Togo	25	107	139	324.51	450.43
USA	19 252	19 356	15 300	0.54	-20.53
Uganda	367	320	374	-12.76	2.09
Uruguay	123	115	109	-5.87	-10.74
Venezuela	162	537	466	232.20	188.34
Yemen	663	433	403	-34.68	-39.15
Zambia	36	24	27	-34.17	-23.85
Zimbabwe	100	97	83	-3.39	-16.98

Source: Authors' calculations are based on data from FAO.

Table 2.7. Trends in average annual sorghum production in some states in India.

State	Average production ('000 t)			Change compared to 1972-81 (%)	
	1972/73-1980/81	1981/82-1990/91	1991/92-2000/01	1981/82-1990/91	1991/92-2000/01
Andhra Pradesh	1307	1086	656	-16.91	-49.84
Bihar	5	4	2	-7.19	-51.97
Gujarat	486	410	234	-15.64	-51.87
Haryana	38	34	29	-11.31	-23.34
Karnataka	1598	1659	1716	3.82	7.34
Madhya Pradesh	1454	1663	859	14.35	-40.94
Maharashtra	3976	4885	4897	22.88	23.17
Orissa	18	26	12	40.84	-36.60
Rajasthan	296	398	216	34.49	-26.98
Tamil Nadu	606	578	430	-4.56	-29.11
Uttar Pradesh	440	494	364	12.25	-17.20
India	10 232	11 246	9389	9.92	-8.24

Source: Authors' calculations are based on data obtained from CMIE (2002).

zero if either the mean yield or the mean area remain unchanged. The last source arose from changes in variability in area and yields.

As shown in Table 2.6, average annual sorghum production has increased in many countries but decreased in some. The sources of change in production are shown in Table 2.8. Yield improvement made a positive contribution to increase in sorghum production. It explained 98% of the increase in sorghum production in Uganda; about 90% in Egypt, Guatemala, Ivory Coast and Thailand; more than 80% in Colombia, El Salvador and Senegal; 70% or more in Australia, France, Hungary, Mozambique and Namibia; about 60% or more in Cameroon, Chad, Guinea-Bissau, Honduras and Nicaragua and more than 50% in Benin, Burkina Faso, Ghana, Mali, Nigeria, Sudan

Table 2.8. Contribution of different sources of change to the increase in average sorghum production in the 1990s (1991 to 2001) compared to the 1970s (1971 to 1980).

Country	Contribution of different sources of change (%)				Total
	Change in yield	Change in area	Interaction between changes in area and yield	Change in area yield covariance	
Australia	79	5	14	2	100
Benin	55	38	6	1	100
Bolivia	4	104	3	-11	100
Brazil	37	72	-8	0	100
Burkina Faso	53	17	30	0	100
Burundi	46	44	10	0	100
Cameroon	69	26	9	-4	100
Chad	64	23	13	0	100
Colombia	80	-8	28	0	100
Egypt	89	-19	30	0	100
El Salvador	83	-6	23	0	100
Eritrea	69	41	-12	3	100
France	74	-13	39	1	100
Gambia	41	45	13	2	100
Ghana	54	24	22	1	100
Guatemala	90	25	-16	2	100
Guinea-Bissau	59	16	24	0	100
Honduras	66	22	9	3	100
Hungary	74	23	-6	8	100
Italy	17	76	7	-1	100
Ivory Coast	90	27	-13	-3	100
Mali	52	42	7	-1	100
Mauritania	42	23	28	7	100
Mexico	70	24	7	-1	100
Mozambique	79	46	-22	-3	100
Namibia	71	52	-17	-7	100
Nicaragua	64	-5	42	-1	100
Niger	36	84	-20	0	100
Nigeria	54	27	16	2	100
Panama	22	53	125	-100	100
Paraguay	34	63	4	-1	100
Saudi Arabia	45	-17	71	1	100
Senegal	84	23	-5	-2	100
Sierra Leone	29	92	-12	-9	100
Sudan	50	57	-9	1	100
Tanzania	54	12	36	-2	100
Thailand	91	-7	12	4	100
Togo	18	81	45	-44	100
Uganda	98	-6	5	3	100
Venezuela	40	44	21	-5	100

Source: Authors' calculations are based on data from FAO.

and Tanzania. In other countries such as Brazil, Burundi, Gambia, Italy, Mauritania, Niger, Panama, Paraguay, Saudi Arabia, Sierra Leone, Togo and Venezuela, yield increase contributed less than 50% of the total increase in production. Change in area made a positive contribution to increase in production except in Colombia, Egypt, El Salvador, France, Saudi Arabia, Thailand and Uganda, implying that had there been no decline in sorghum area, production would have increased further in these countries. The contribution of the area-yield interaction was positive in these countries, indicating that areas less suitable for sorghum were shifted to other crops in Colombia, Egypt, El Salvador, France, Saudi Arabia and Thailand. In Panama, increase in yield contributed 22% of the total production increase while increase in area accounted for 53%. The area-yield interaction accounted for 125% of the change, indicating the expansion in sorghum cultivation. However, both the area and yield were fluctuating in Panama; therefore, changes in variability in area and yield contributed negatively to sorghum production. The research and policy implication of this finding for Panama is that the country should encourage a stable average area under sorghum for a further increase in production, and sorghum researchers should give priority to reducing variability in sorghum yield.

The factors that led to a decrease in sorghum production are reported in Table 2.9. Yield decline was an important factor in all the countries that suffered a decrease in production. Expansion of area contributed negatively to the decrease. In other words, had the area under sorghum not increased, production would have been much lower. The interaction between area and yield contributed positively to the decrease in sorghum production in Argentina, Central African Republic, China, Greece, India, Korean Republic, South Africa, Spain, Uruguay, USA, Yemen and Zambia. This indicates that sorghum production in these countries has shifted to the more marginal environments. In other words, a shift to less suitable land reduced the yield of sorghum and thereby production. The interaction between area and yield had a negative contribution to the decrease in sorghum production in Albania, Botswana, Dominican Republic, Haiti, Kenya, Korea DPR and Lesotho. This means that cultivation of sorghum in these countries has shifted towards relatively suitable areas. Variability in area and yield made no noteworthy contribution to the decrease in sorghum production in these countries.

The sources of change in sorghum production in different Indian states are reported in Table 2.10. Average sorghum production in India decreased in the 1990s (1991/92-2000/01) compared to the 1970s (1972/73-1980/81). Karnataka and Maharashtra experienced increases in average sorghum production in the 1990s while all other major sorghum-growing states experienced decreases in production in the 1990s. Increases in sorghum production in Karnataka and Maharashtra were mainly due to increase in yield. There was no substantial effect of “changes in area-yield covariance” and “interaction between change in area and yield”. Sorghum production in Gujarat declined due to the decrease in area while yield made a negative contribution to the decrease in production, indicating that if yield had not increased in Gujarat, the decrease in production would have been greater. Production decreased in Andhra Pradesh, Madhya Pradesh, Rajasthan and Tamil Nadu due to significant decline in area.

2.6. Conclusions

Though the global sorghum area at the end of the 20th century was 42% higher than in the early 1970s, the area under the crop declined in many major sorghum-growing countries including China, India and USA. High growth in sorghum area in the 1990s was attained by Eritrea,

Table 2.9. Contribution of different sources of change to the decrease in average sorghum production in the 1990s (1991 to 2001) compared to the 1970s (1971 to 1980).

Country	Contribution of different sources of change (%)					Total
	Change in yield	Change in area	Interaction between changes in area and yield	Change in area yield covariance		
Albania	201	-76	-24	-1	100	
Argentina	107	-73	67	-1	100	
Botswana	130	22	-57	5	100	
Central African Rep	97	-37	38	1	100	
China	87	-62	72	3	100	
Dominican Rep	99	29	-29	1	100	
Greece	155	-108	48	5	100	
Haiti	159	-38	-20	-1	100	
India	95	-29	33	0	100	
Kenya	198	-70	-27	-2	100	
Korea DPR	337	-195	-46	4	100	
Korea Rep	103	-79	76	0	100	
Lesotho	192	-81	-19	8	100	
Malawi	360	-141	-109	-10	100	
Pakistan	121	-24	3	0	100	
Rwanda	120	-15	-3	-2	100	
Somalia	112	-15	0	3	100	
South Africa	122	-47	26	-1	100	
Spain	278	-206	30	-2	100	
USA	115	-40	24	1	100	
Uruguay	77	-39	63	-1	100	
Yemen	140	-70	29	2	100	
Zambia	120	-43	26	-3	100	
Zimbabwe	121	-21	-3	2	100	

Table 2.10. Sources of change in average sorghum production in India.

States	Nature of production change	Contribution of different sources of change (%)					Total
		Change in yield	Change in area	Interaction between changes in area and yield	Change in area yield covariance		
Maharashtra	Increase	123.71	-15.22	-6.57	-1.92	100.00	
Karnataka	Increase	96.68	3.92	0.17	-0.77	100.00	
Andhra Pradesh	Decrease	722.86	-458.42	-167.67	3.23	100.00	
Gujarat	Decrease	-1743.57	1173.99	630.86	38.71	100.00	
Madhya Pradesh	Decrease	263.13	-136.15	-28.52	1.54	100.00	
Rajasthan	Decrease	139.59	-37.96	-2.87	1.24	100.00	
Tamil Nadu	Decrease	185.85	-72.74	-12.28	-0.84	100.00	
India	Decrease	163.47	-48.77	-14.95	0.26	100.00	

Malawi, Namibia and Zimbabwe in Southern and Eastern Africa; by Chad, Guinea-Bissau, Nigeria and Sierra Leone in Western and Central Africa and by Brazil and Mexico in South America. Among the developed countries, high growth was experienced by Albania and Australia in the 1990s. None of the Asian countries experienced high growth in sorghum area in the 1990s. In the 1990s, high growth in sorghum production was experienced by Saudi Arabia in Asia; Eritrea, Lesotho, Malawi, Mozambique and Zimbabwe in Southern and Eastern Africa; Chad, Central African Republic, Gambia, Nigeria and Senegal in Western and Central Africa and Brazil and Mexico in South America. Among the developed countries, Australia experienced high growth in sorghum production in the 1990s. Significant growth in sorghum yield in the 1990s was attained by the Korean Republic in Asia; by Malawi, Mozambique, South Africa and Swaziland in Southern and Eastern Africa and by the Central African Republic and Mauritania in Western and Central Africa. None of the South American countries experienced high growth in sorghum yield in the 1990s.

There has been a sixfold increase in sorghum production in the 1990s (compared to the 1970s) in Bolivia and Italy and between two to five times in Panama, Paraguay and Togo. On the other hand, many countries like Albania, Argentina, Botswana, Central African Republic, China, Greece, Haiti, Kenya, Korea DPR, Korean Republic, Lesotho, Malawi, Pakistan, Rwanda, Somalia, South Africa, Spain, Uruguay, USA, Yemen, Zambia and Zimbabwe experienced decreases in average sorghum production in the 1990s (compared to the 1970s). Yield made a positive contribution to increase in sorghum production in most of the countries. The main reason for the fall in production in most of the countries was the decrease in area under sorghum. However, some countries also experienced decrease in production due to decrease in average yield. The reasons behind the decrease in average production need to be studied for appropriate policy actions.

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Appendix 2.1.

Analytical Procedure to Measure Changes in Average Production and Sources of Change

Changes in average annual sorghum production in different countries of the world and in different states of India were computed for the 1970s, 1980s and 1990s. The model used in this study was developed by Hazell (1982) and adapted for the purpose of this study in the following manner:

$$Q = \sum A_j Y_j \quad \dots (2.1)$$

where, A = area, Y = yield, and j = the country.

The average production of a selected crop in the first period is:

$$E(Q_I) = \sum [\bar{A}_{Ij} * \bar{Y}_{Ij} + COV(A_{Ij}, Y_{Ij})] \quad \dots (2.2)$$

The average production in the second period is:

$$E(Q_{II}) = \sum [\bar{A}_{IIj} * \bar{Y}_{IIj} + COV(A_{IIj}, Y_{IIj})] \quad \dots (2.3)$$

Each variable in the second period can be expressed as its counterpart in the first period plus the change in the variable between the two time periods. Thus the change in average production, $\Delta E(Q)$, can be decomposed in the following way:

$$\Delta E(Q) = \sum [\bar{A}_{Ij} \Delta \bar{Y}_{Ij} + \bar{Y}_{Ij} \Delta \bar{A}_{Ij} + \Delta \bar{A}_{Ij} \Delta \bar{Y}_{Ij} + \Delta COV(A_{Ij}, Y_{Ij})] \quad \dots (2.4)$$

Different sources of change are shown in the following Table. There are two methods of decomposition: method I uses the first period as the base and method II uses the second period as the base. Both the methods are mathematically correct, but since method II combines pure and interaction effects, it is less useful for this type of analysis. Thus method I has been used in this study.

There are four sources of change in average production $\Delta E(Q)$. Two parts, $A_j \Delta Y$ and $Y_j \Delta A$, arise from changes in the mean yield and the mean area. These are "pure effects"; they arise even if there are no other sources of change. The term $\Delta \bar{A} \Delta \bar{Y}$ is an interaction effect, which arises from the simultaneous occurrence of changes in mean yield and mean area. Obviously, this term will be zero if either the mean yield or the mean area remains unchanged. The last term $\Delta COV(A, Y)$ arises from the changes in the variability of area and yields. Since $COV(A, Y) = r[V(A), V(Y)]^{1/2}$, where r is the correlation coefficient, it can be seen that $\Delta COV(A, Y)$ arises from the changes in the variances of areas and yields and from changes in the correlation between areas and yields.

Components of change in average sorghum production.

Sources of change	Symbols	Components of change	
		Method I	Method II
Change in mean yield	$\Delta \bar{Y}$	$\bar{A}_I \Delta \bar{Y}$	$\bar{A}_{II} \Delta \bar{Y}$
Change in mean area	$\Delta \bar{A}$	$\bar{Y}_I \Delta \bar{A}$	$\bar{Y}_{II} \Delta \bar{A}$
Interaction between changes in mean area and mean yield	$\Delta \bar{A}, \Delta \bar{Y}$	$\Delta \bar{A} \Delta \bar{Y}$	$-\Delta \bar{A} \Delta \bar{Y}$
Change in area-yield covariance	$\Delta COV(A, Y)$	$\Delta COV(A, Y)$	$\Delta COV(A, Y)$

Note: Method I uses the first period as base while method II uses the second period as base.