PART IV: Impacts of Improved Cultivars and Future Directions

Productivity Impacts of Improved Sorghum Cultivars

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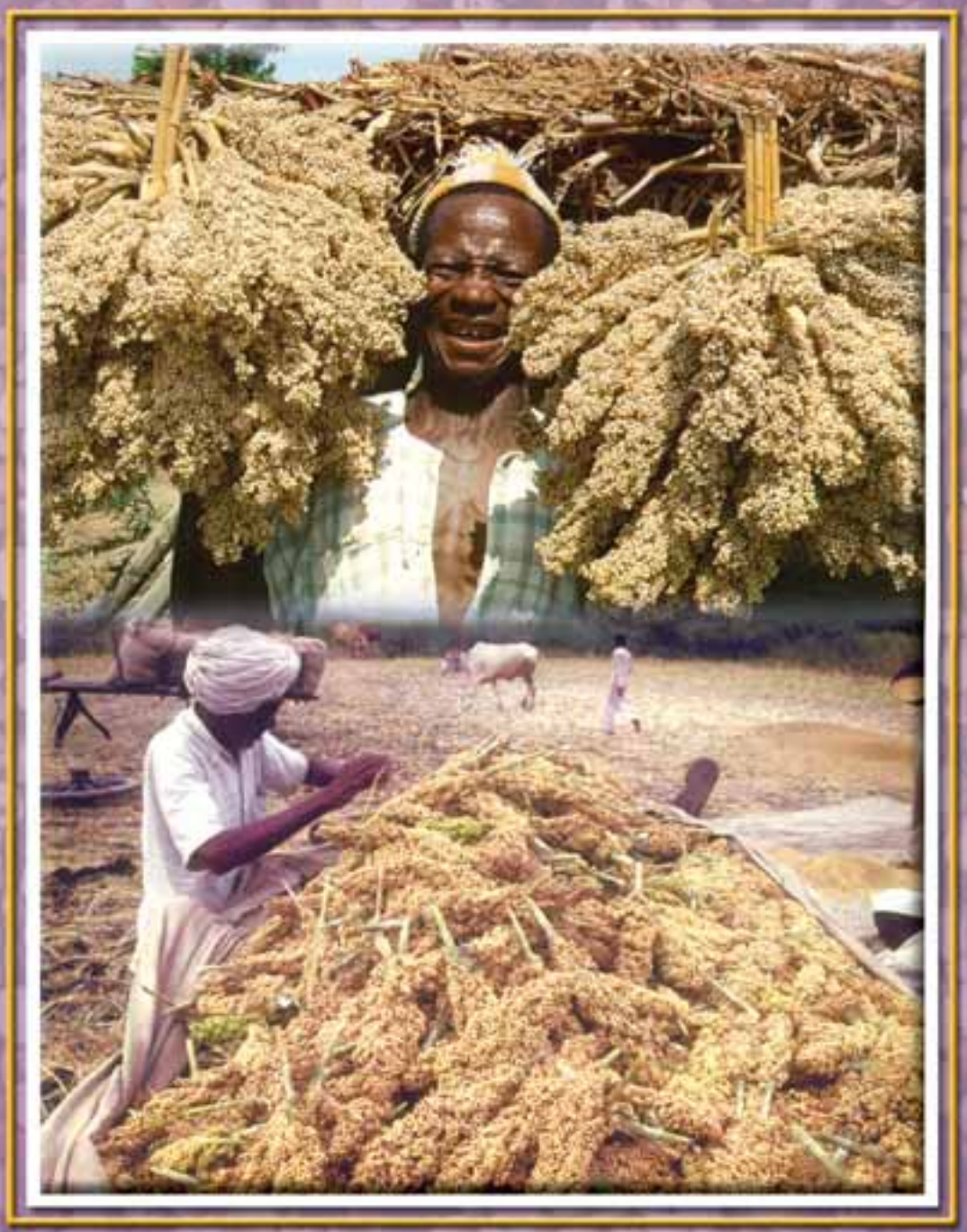
UK Deb, MCS Bantilan, RE Evenson and AD Roy



Productivity Impacts of Improved Sorghum Cultivars

UK Deb[1], MCS Bantilan[2], RE Evenson[3] and AD Roy[4]

9.1. Introduction

The ultimate goal of sorghum breeding is to create impacts in farmers' fields. Impacts from improved sorghum cultivars may be obtained through increase in yield, reduction in per unit cost of production or increase in stability of yield. This chapter analyzes all these aspects based on data collected from different sources.

9.2. Methodology

The indicators used in measuring productivity impacts are reduction in per unit cost of production, yield gains and yield variability. Variability in yield of sorghum has been measured in relative terms using the Cuddy-Della Valle Index, used in recent years as a measure of variability in time series data (Weber and Sievers 1985; Singh and Byerlee 1990). The simple coefficient of variation (CV) overestimates the level of instability in time series data characterized by long-term trends, whereas the Cuddy-Della Valle Index corrects the coefficient of variation by:

$$CV = (CV^*)\,(1-R^2)^{0.5} \qquad ...(9.1)$$

where

CV is the Cuddy-Della Valle Index, ie, the corrected CV. Henceforth, any mention of CV would refer to the Cuddy-Della Valle Index.

CV^* is the simple estimate of the CV (%)

R^2 is the coefficient of determination from time trend regression adjusted by the number of degrees of freedom.

Some authors have estimated CV around trend as the standard error of regression divided by the mean. After estimating CV both ways from the same set of data, Singh and Byerlee (1990) found identical results whichever method was used. In their case, the correlation between the instability indices of two methods was 0.9998. Since both methods provide similar results, here we have estimated instability index using the Cuddy-Della Valle Index.

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Deb UK, Bantilan MCS, Evenson RE and Roy AD. 2004. Productivity impacts of improved sorghum cultivars. Pages 203-222 *in* Sorghum genetic enhancement: research process, dissemination and impacts (Bantilan MCS, Deb UK, Gowda CLL, Reddy BVS, Obilana AB and Evenson RE, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

9.3. Impact on Sorghum Yield

9.3.1. Global Yield Scenario

Figure 9.1 depicts sorghum yields and yield gains in different countries of the world in 1999-2001 compared to 1971-73. In the early 1970s, yield levels were very low in a majority of the developing countries. However, in the mid-1990s yields rose in Asia (China, India, Pakistan and Korean Republic). Per hectare yield increased by more than 3 t (3213 kg) in China and by 320 kg (65%) in India. By 1998, hybrid adoption in China had exceeded 98% and the adoption of improved cultivars in India was about 73%. Yields increased in Pakistan by 21% and doubled in North Korea. In Thailand, sorghum yield decreased. In the 1960s, Thailand used to grow sorghum for grain purposes but since the 1980s, a large area under the crop is being used for fodder, and the dried fodder is exported to Japan. FAO data do not record this fact since only area harvested and grain production are reported.

In Africa, yield has increased in South Africa, Egypt, Uganda, Ethiopia, Ghana, Burkina Faso, Lesotho, Nigeria and Namibia to a significant extent. Sorghum yield in South Africa tripled and the adoption rate of improved cultivars in South Africa is 77%. Yield has declined in Niger, Sudan, Mozambique, Rwanda, Kenya and Eritrea to a notable extent. There has been no significant change in other African countries. In many southern African countries, yields declined in the 1990s compared to the early 1960s. This decline could have been due to low fertilizer use and a shift in sorghum cultivation to poorer land. Moreover, breeders have laid emphasis on developing improved cultivars with early maturity and yield stability rather than high yield. A thorough analysis is required to identify the reasons for the decline in yield in many African countries.

Sorghum yield in European countries has increased substantially. It has doubled in Italy and France, tripled in Greece and increased fivefold in Spain. There was a notable increase in yield in the Americas (Colombia, Mexico and USA). Yield doubled in Argentina, Nicaragua, Albania, Guatemala and Peru.

A comparison of trends in average yield in Africa and India for the last four decades indicates that sorghum yield in India has consistently gone up and has already crossed the average yield of Africa, though the yield of sorghum in Africa in the 1960s was much higher than that of India (Figure 9.2). As is known, this happened due to the development of improved sorghum cultivars by scientists and the uptake of these cultivars by farmers in India, given the more favorable infrastructure and policy environment supporting technology uptake. Regression analyses of the same sorghum data confirm the significance of several factors influencing yield. Important among these are high yielding varieties (HYVs), agroecological factors and infrastructure variables (market density, road infrastructure and irrigation) (Bantilan 2003).

9.3.2. District-level Yield in India

Figures 9.3 and 9.4 portray the yields in different sorghum-growing districts of India for rainy-season sorghum and postrainy-season sorghum. Figure 9.3 shows that the yield gains from rainy-season sorghum in Maharashtra and Andhra Pradesh were high where adoption rates too were high. Yield per hectare increased by at least 750 kg in the districts in these states and by more than one ton in many districts. It may be noted here that India's research focus has been mainly on rainy-season sorghum. There was less research on postrainy-season sorghum; so fewer improved cultivars were developed and yield increases were lower (Figure 9.4).

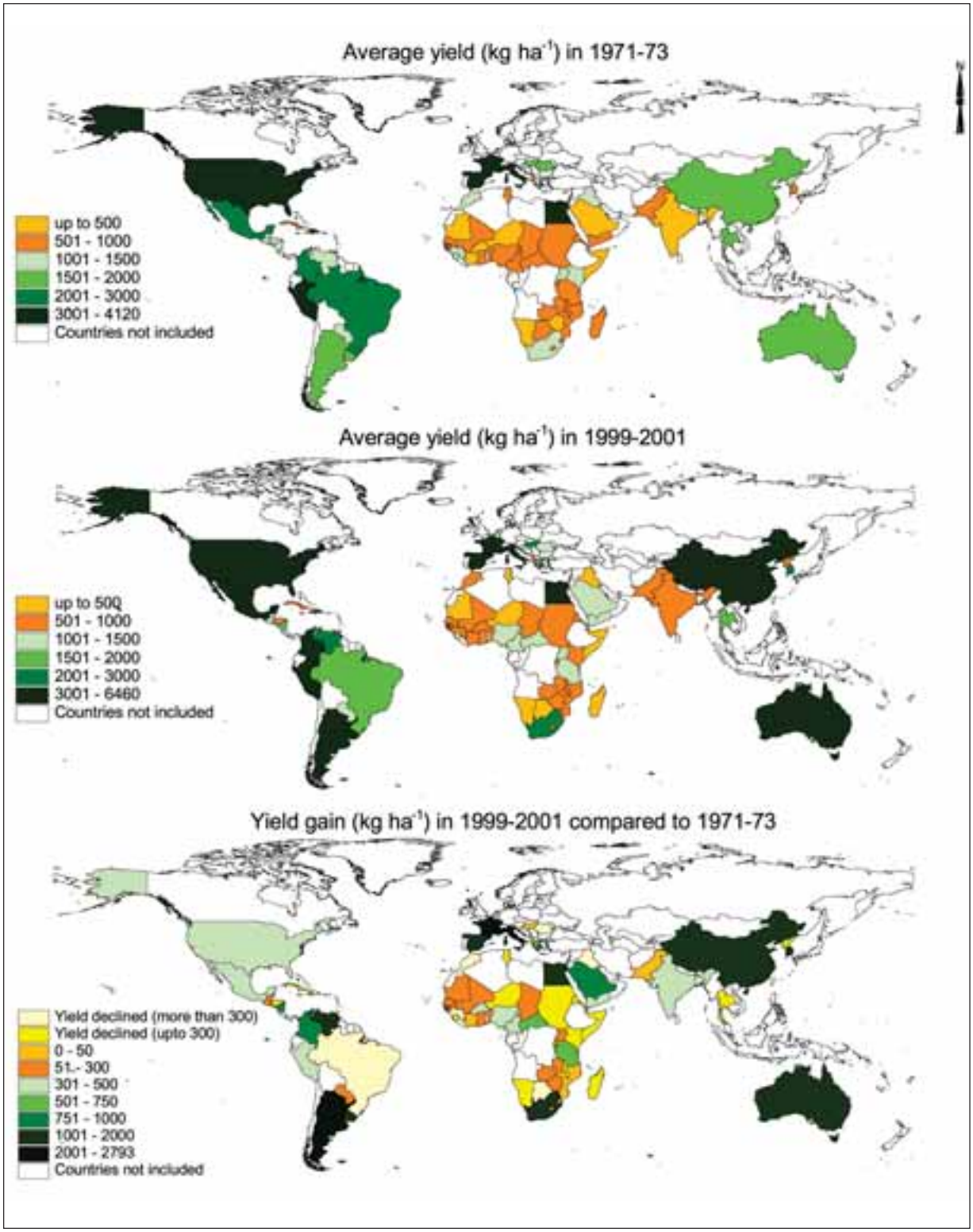

Figure. 9.1. Average yield and yield gain in sorghum in different countries.

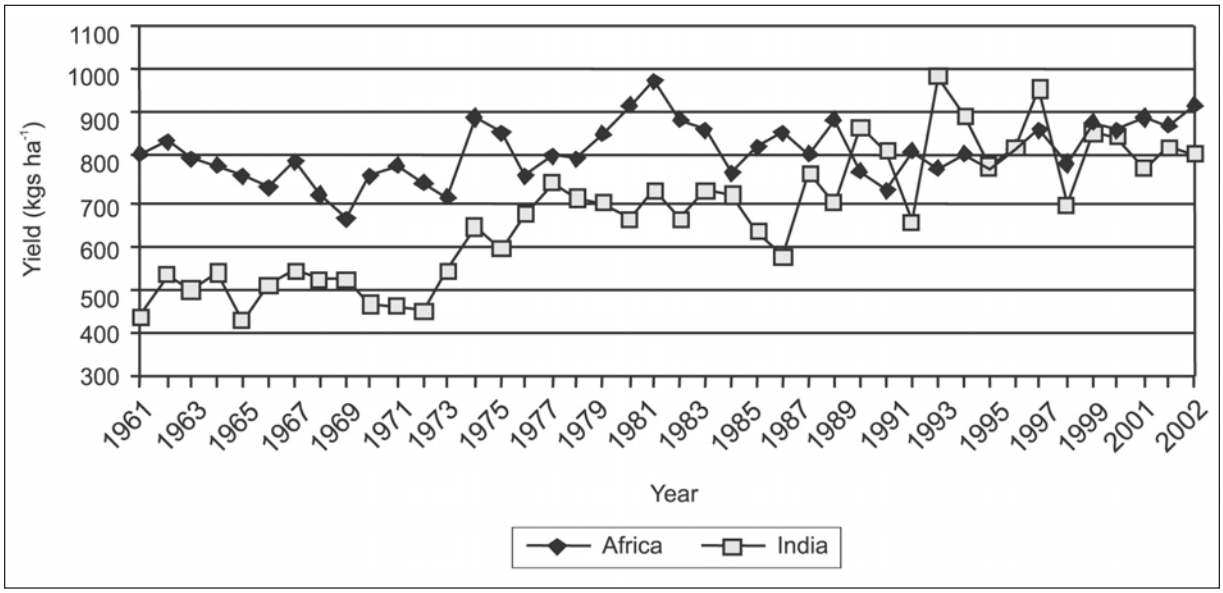

Figure. 9.2. Trends in sorghum yields in Africa and India, 1961-2002.

9.3.3. Yield Gain at the Farm Level

Table 9.1 summarizes farm-level yield gains from different studies conducted in Africa. Yields of improved cultivars were 7-63% higher than the best local cultivars in Nigeria. Improved sorghum variety S 35 had a 51% yield advantage in Chad and 14% in Cameroon. Ndjomaha et al. (1998) reported that during 1986-95, the per hectare difference in productivity between S 35 and the local variety was 432 kg in Mayo Sava, 89 kg in Diamaré and 52 kg in Mayo Danay regions of Cameroon. These differences indicate a better genetic potential for S 35 in Mayo Sava than in the other two areas, probably because rainfall is more congruent with the 300-800 mm research recommendation. In Mali, sorghum yields increased from 620 kg ha^{-1} with the best local variety to 940 kg ha^{-1} for improved varieties and profits increased by 51% (Yapi et al. 1998). These yields are consistent with those found in previous studies. Shetty et al. (1991) noted that sorghum yields in Mali were about 600 kg ha^{-1} compared to 2,000-3,000 kg ha^{-1} on research stations.

9.4. Impact on Cost of Production

An analysis of the cost of cultivation data based on farm-household surveys conducted by the Government of India shows that real cost of production per ton of sorghum in India decreased in the 1980s and the 1990s compared to the early 1970s. In Maharashtra, it fell by 40% in the 1990s compared to the 1970s. In Rajasthan this figure was 37% (Table 9.2).

The farm-level impact of improved sorghum cultivars on per unit cost of production is presented in Table 9.3. S 35 had a cost advantage of 12% in Cameroon and 25% in Chad (Yapi et al. 1999). Using improved sorghum varieties in Mali reduced production cost by as much as 25% (US$34 t^{-1}), compared to local varieties. The absolute production cost per hectare was higher for improved varieties because of additional inputs, but the higher productivity still provided these economies. With this higher productivity, farmers have the opportunity to reduce the area sown to sorghum and diversify their farming to grow other crops for either the market or their own consumption.

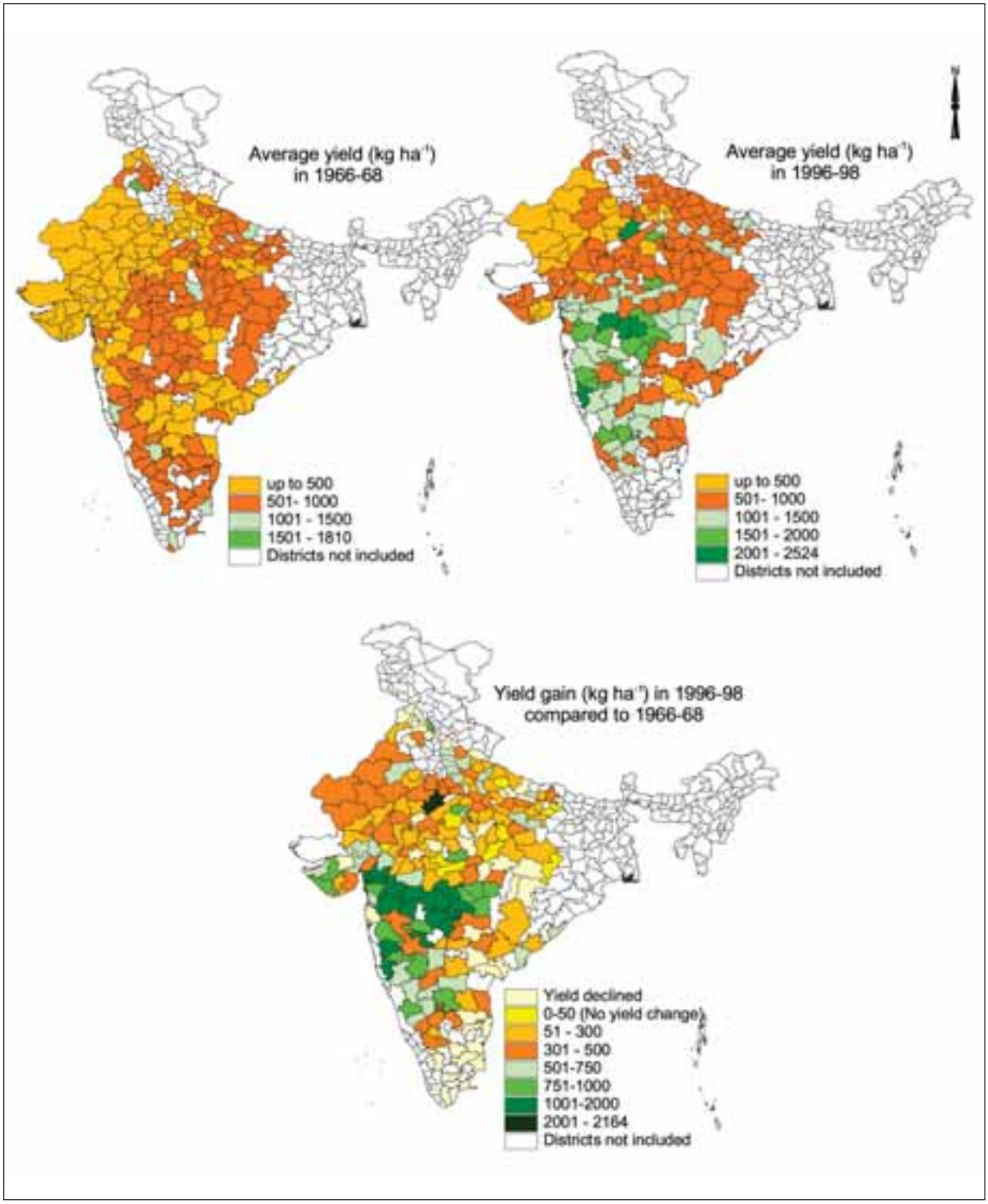

Figure. 9.3. Average yield and yield gain in rainy-season sorghum in India.

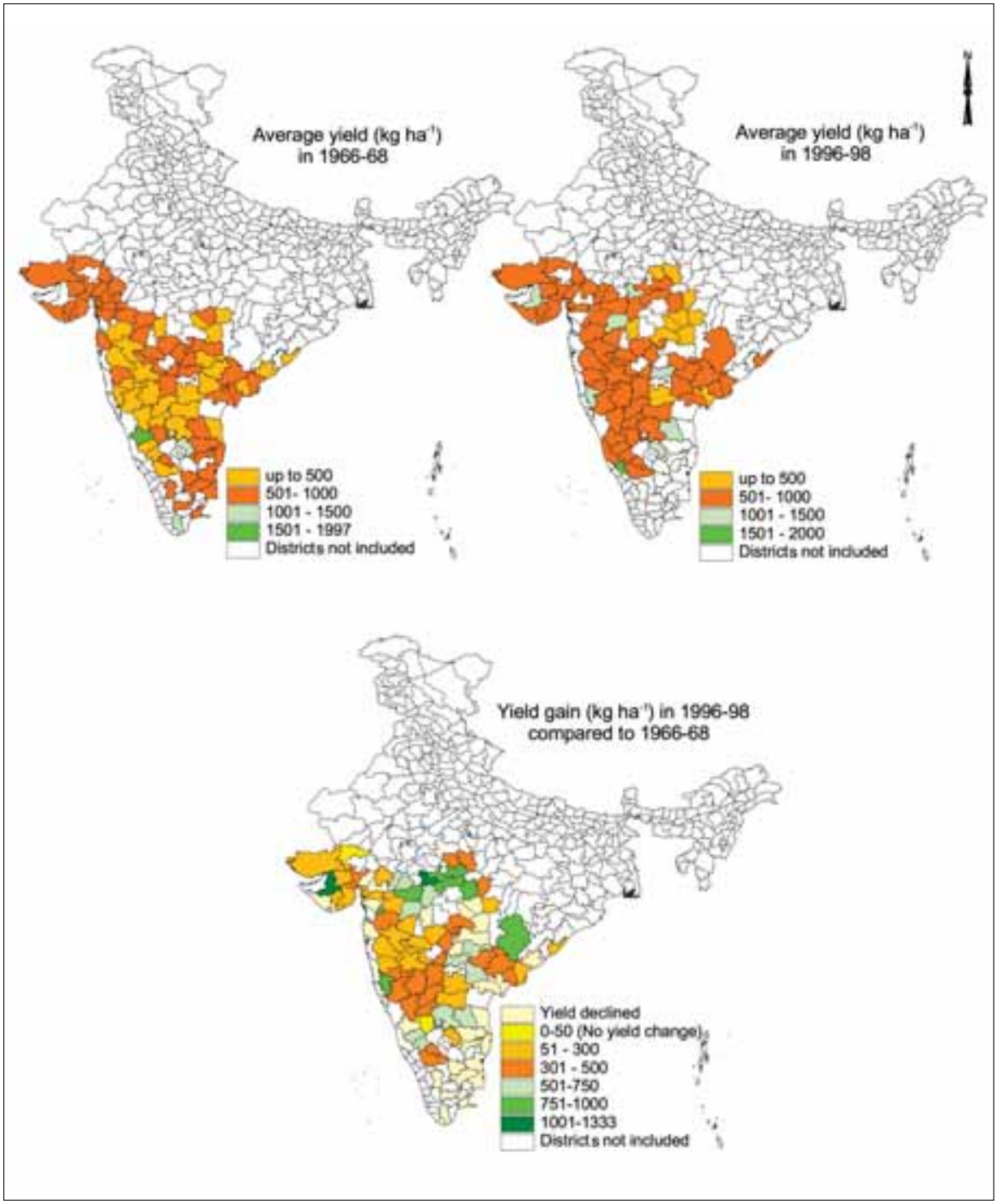

Figure. 9.4. Average yield and yield gain in postrainy-season sorghum in India.

Table 9.1. Impacts of improved sorghum cultivars on yield.

Country	Region	Year	Improved cultivar	Yield (kg ha^{-1}) of		Yield gain (%)
				Local	Improved	
Cameroon	Mayo-Sava	1995	S 35	1220	1650	36
Cameroon	Diamaré	1995	S 35	1450	1540	6
Cameroon	Mayo Danay	1995	S 35	1420	1470	4
Cameroon		1995	S 35	1360	1550	14
Chad	Guéra	1995	S 35	710	1090	54
Chad	Mayo-Kebbi	1995	S 35	780	1190	53
Chad	Chari-Baguirmi	1995	S 35	810	1180	46
Chad		1995	S 35	760	1150	51
Nigeria	Kano	1996	ICSV 400	875	1165	33
Nigeria	Katsina	1996	ICSV 400	1003	1073	7
Nigeria	Jigawa	1996	ICSV 400	865	1398	62
Nigeria		1996	ICSV 400	914	1212	33
Nigeria	Kano	1996	ICSV 111	875	1221	40
Nigeria	Katsina	1996	ICSV 111	1003	1274	27
Nigeria	Jigawa	1996	ICSV 111	865	1406	63
Nigeria		1996	ICSV 111	914	1300	42

Source: For Cameroon and Chad, Yapi et al. 1999; and for Nigeria, Ogungbile et al. 1998.

Table 9.2. Impact of improved sorghum cultivars on per ton production cost[1] in India, 1971-95.

States	Average cost (Rs t^{-1})			Cost reduction (%) compared to the early 1970s	
	Early 1970s [2]	Early 1980s [3]	Early 1990s [4]	Early 1980s	Early 1990s
Andhra Pradesh	270	NA [5]	286	NA	- 6
Karnataka	224	192	231	14	- 4
Madhya Pradesh	223	169	208	24	7
Maharashtra	253	188	153	25	40
Rajasthan	309	264	195	14	37

1. All costs are real costs of production. For Rajasthan, the real cost is computed on the basis of 1992 prices and for all the other states it is based on 1989 prices.
2. Early 1970s indicate for Andhra Pradesh (average of 1973-74), Karnataka (average of 1972-74), Madhya Pradesh (1976), Maharashtra (average of 1972-74) and Rajasthan (average of 1972-74).
3. Early 1980s indicate for Karnataka (average of 1981-83), Madhya Pradesh (average of 1981-83), Maharashtra (average of 1982-83) and Rajasthan (average of 1981-83).
4. Early 1990s indicate for Andhra Pradesh (average of 1994-95), Karnataka (1991), Madhya Pradesh (average of 1994-95), Maharashtra (1995) and Rajasthan (1992).
5. NA = Not available.

Source: Calculated from various reports of the Commission for Agricultural Costs and Prices, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

9.5. Impact on Yield Stability

9.5.1. Asia

Relative variability in yield is an important indicator of stability in the productivity of a given crop in a given region. Table 9.4 shows the relative variability in sorghum yield in different countries and the changes (%) in the index in the 1980s (1981-90) and the 1990s (1991-99) compared to the 1970s (1971-80). This relative variability is the Cuddy-Della Valle Index explained earlier. An increase in variability in area, production and yield is not desirable since it indicates instability in the system.

Table 9.3. Impacts of improved sorghum cultivar S 35 on per unit cost of production in Cameroon and Chad, 1995.

Country	Region	Unit variable costs (CFA Francs t^{-1})		Unit cost reduction (%)
		Local	Improved	
Cameroon	Mayo-Sava	77500	57700	26
Cameroon	Diamaré	63500	58900	7
Cameroon	Mayo Danay	50000	49300	1
Cameroon		63161	55607	12
Chad	Guera	89296	65825	26
Chad	Mayo-Kebbi	45994	37903	18
Chad	Chari-Baguirmi	67765	49947	26
Chad		80805	60817	25

Source: Yapi et al. 1999.

There was an increase in variability in sorghum yield in five out of the nine study countries of Asia during the 1990s. In both India and China, relative variability in yield increased during this period. In the 1990s, both countries had a relative variability in yield of around 12.3%, though China had a much lower yield variability in the 1970s (4.23%) compared to India (8.72%). On the other hand, Pakistan was the only major sorghum-producing country which showed a decline in relative variability in yield in all the time periods, except for the 1980s compared to the 1970s.

Tables 9.5, 9.6 and 9.7 show the association between yield and instability in sorghum yield during the 1990s compared to earlier decades (ie, the 1970s and 1980s); and the 1980s compared to the 1970s, respectively. The types of association were split into four categories: AA - increase in yield with decrease in variability; AB - increase in yield with increase in variability; BA - decrease in yield with decrease in variability; and BB - decrease in yield with increase in variability. AA is the most ideal type of association while BB is the undesired type of association (Fig. 9.5).

Pakistan, Saudi Arabia and Thailand were the three countries under AA association during the 1990s compared to the 1970s (Table 9.5). China, India, the Korean Republic and Yemen fell under AB type. None of the countries fell under type BA in the 1990s compared to the 1970s, while only Korea DPR was in type BB association.

In the 1990s compared to the 1980s (Table 9.6), as many as 4 countries – Saudi Arabia, Yemen, Thailand and Pakistan – out of the 8 studied were under AA type of association. Among these, except for Pakistan and Yemen, the other two countries were minor producers of sorghum. China and India were in AB type; the Korean Republic in BA type and Korea DPR slid to the most undesirable BB type. Pakistan was the only major sorghum-producing country in the region that experienced type AA association in the 1990s compared to the 1980s and the 1970s. India and China on the other hand exhibited an increase in yield as well as an increase in variability in yield.

Comparing the 1970s and the 1980s (Table 9.7), there was an AA type of association in only one country (Korea DPR) out of the eight studied. India, China, the Korean Republic and Saudi Arabia showed AB type of association, and Pakistan and Thailand the BA type.

9.5.2. Africa

It is noted that 17 of the 24 countries in WCA saw a decline in variability in yield (Table 9.8). The countries that showed the greatest decline in yield variability were Guinea-Bissau (-88.1%), Nigeria

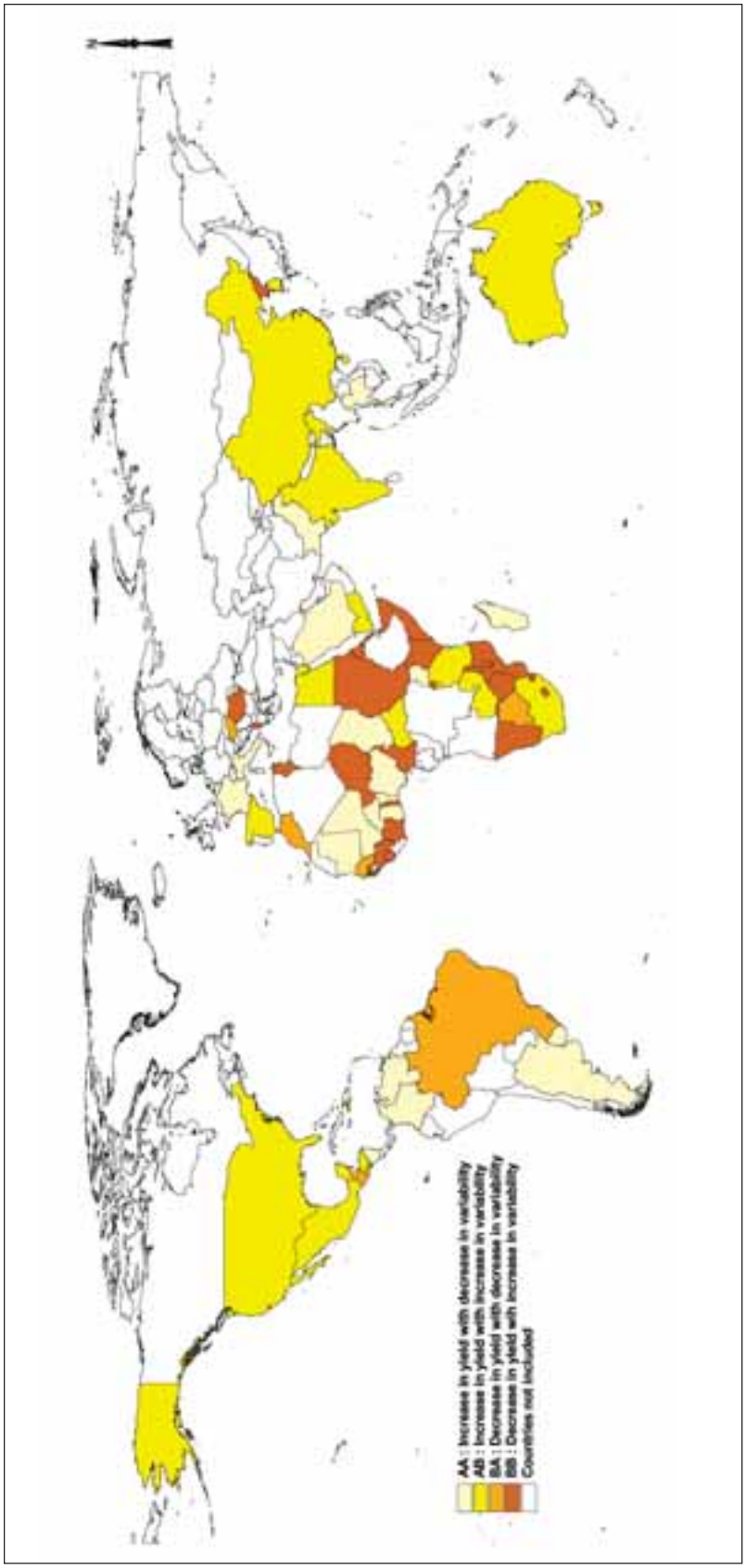

Figure. 9.5. Association between yield and instability in yield of sorghum.

Table 9.4. Relative variability in sorghum yield in different countries.

	Relative variability (CV)			Change compared to 1971-80 (%)	
Country	1971-80	1981-90	1991-99	1981-90	1991-99
Albania	6.15	2.81	9.62	-54.38	56.40
Argentina	13.81	9.06	8.49	-34.38	-38.49
Australia	15.19	16.45	19.71	8.25	29.74
Benin	11.79	8.87	3.03	-24.79	-74.33
Botswana	60.35	33.36	31.00	-44.71	-48.63
Brazil	16.94	10.40	8.78	-38.63	-48.16
Burkina Faso	8.12	11.13	5.31	37.04	-34.59
Burundi	3.09	9.03	5.69	192.12	83.96
Cameroon	5.67	16.52	5.81	191.43	2.42
Central African Rep	9.62	16.97	16.15	76.36	67.80
Chad	11.47	13.00	8.61	13.34	-24.93
China	4.23	8.70	12.34	105.70	191.68
Colombia	7.02	5.76	3.57	-17.92	-49.21
Egypt	1.97	3.87	9.33	96.62	373.74
El Salvador	7.60	28.97	8.13	281.26	6.97
Eritrea	4.99	7.62	35.20	52.84	605.62
France	13.59	13.74	6.32	1.12	-53.50
Gambia	20.99	13.59	10.38	-35.26	-50.54
Ghana	10.46	23.19	7.82	121.79	-25.18
Guatemala	16.31	18.68	1.12	14.51	-93.15
Guinea	3.68	11.41	16.41	210.48	346.40
Guinea-Bissau	7.97	27.90	3.32	249.84	-58.41
Haiti	12.10	4.38	2.69	-63.79	-77.72
Honduras	17.91	12.37	19.12	-30.93	6.74
Hungary	26.67	42.87	25.12	60.73	-5.83
India	8.72	10.68	12.39	22.45	42.09
Italy	8.96	17.49	4.03	95.22	-55.07
Ivory Coast	9.87	6.04	11.10	-38.81	12.50
Kenya	4.27	27.27	10.65	538.02	149.09
Korea DPR	3.45	2.83	10.25	-18.03	197.19
Korea Rep.	4.65	24.67	8.43	430.42	81.23
Lesotho	29.06	20.01	30.46	-31.16	4.82
Madagascar	47.23	21.02	6.27	-55.50	-86.72
Malawi	10.05	21.16	31.44	110.52	212.78
Mali	18.63	15.06	13.40	-19.18	-28.05
Mauritania	33.67	23.40	7.41	-30.49	-78.01
Mexico	6.20	7.21	9.02	16.38	45.54
Morocco	46.20	19.17	36.22	-58.51	-21.59
Mozambique	14.10	13.62	19.96	-3.44	41.53
Namibia	10.12	4.20	57.88	-58.45	471.90
Nicaragua	15.81	13.70	15.37	-13.40	-2.82
Niger	14.70	22.06	17.00	50.05	15.66
Nigeria	21.33	12.07	2.67	-43.43	-87.50

...continued

Table 9.4. ***Continued***

Country	Relative variability (CV)			Change compared to 1971-80 (%)	
	1971-80	1981-90	1991-99	1981-90	1991-99
Pakistan	3.97	1.72	1.22	-56.61	-69.16
Peru	7.95	9.93	15.05	24.98	89.45
Romania	26.55	16.48	39.41	-37.92	48.47
Rwanda	6.48	10.40	23.15	60.56	257.30
Saudi Arabia	27.85	31.97	5.10	14.80	-81.70
Senegal	21.28	9.73	10.67	-54.29	-49.85
Sierra Leone	5.66	25.12	9.02	344.05	59.40
Somalia	5.12	5.52	14.27	7.77	178.71
South Africa	20.76	22.40	26.42	7.92	27.28
Spain	5.79	5.18	12.75	-10.44	120.31
Sudan	7.06	30.67	13.56	334.33	92.06
Swaziland	25.72	57.18	39.56	122.28	53.80
Tanzania, United Rep.	17.93	32.02	20.63	78.56	15.06
Thailand	16.93	8.91	5.04	-47.34	-70.24
Togo	5.18	17.55	13.11	238.54	152.91
Tunisia	8.37	12.26	17.96	46.43	114.49
Uganda	15.91	14.82	13.28	-6.79	-16.49
Uruguay	20.07	13.94	5.57	-30.57	-72.25
USA	11.26	10.20	12.76	-9.46	13.33
Venezuela	11.11	4.43	5.20	-60.08	-53.19
Yemen	7.81	32.17	14.86	311.93	90.26
Zambia	14.00	15.60	17.74	11.36	26.64
Zimbabwe	13.67	37.73	26.41	176.08	93.24

Source: Authors' calculation is based on FAO (2002).

(-77.9%) and Mauritania (-68.4%). In all these countries except Nigeria, absolute sorghum yield was quite low, lower than even the regional average yield in both the 1980s and the 1990s. On the other hand, there has been an increase in variability in yield in Egypt, a country with the highest yield among those studied in the WCA and SEA regions. Therefore, though there has been a decline in variability in yield in a majority of the countries in WCA, this has been truer in the case of countries with low absolute yield than those with high absolute yield.

The SEA region presented a different picture. There was an increase in relative variability in both area and production of sorghum during the 1980s and the 1990s. There has been a decline in variability in area in only 5 (Madagascar, Tanzania, Zambia, Somalia and Mozambique) of the 14 countries studied. The rest of the countries saw an increase in variability in area. A similar trend was noticed in SEA, where only 6 (Madagascar, Swaziland, Kenya, Zambia, Botswana and Zimbabwe) of the 14 countries studied witnessed a decline in variability in production. Among all these countries, except for Kenya, the rest contributed a minor share in the region's production of sorghum. Tanzania and South Africa, the major sorghum producers in the region, on the other hand witnessed an increase in variability in production in the 1990s compared to the 1980s. In terms of variability in yield in SEA, there has been a decline in variability in only 6 countries – Madagascar, Kenya, Tanzania, Swaziland, Zimbabwe and Botswana (listed in the order of decline). Among these countries, except for Tanzania and Kenya, which showed high absolute yields, the rest fared poorly.

Table 9.5. Association between yield and instability in yield of sorghum in different countries in the 1990s (1991-99) compared to the 1970s (1971-80).

Region	Types of association			
	AA: Increase in yield with decrease in variability	AB: Increase in yield with increase in variability	BA: Decrease in yield with decrease in variability	BB: Decrease in yield with increase in variability
Asia	Saudi Arabia, Pakistan, Thailand	India, Korea Rep, Yemen, China	-	Korea DPR
Others	Italy, France	USA, Australia, Spain	Hungary	Albania, Romania
Latin America	Uruguay, Venezuela, Colombia, Argentina, Nicaragua	Honduras, El Salvador, Mexico, Peru	Haiti, Guatemala, Brazil	
Southern and Eastern Africa	Madagascar	Tanzania, Zambia, South Africa	Botswana	Lesotho, Mozambique, Swaziland, Zimbabwe, Kenya, Somalia, Malawi, Namibia, Eritrea
Western, Central and Northern Africa	Nigeria, Mauritania, Benin, Guinea-Bissau, Gambia, Burkina Faso, Mali, Ghana, Chad, Uganda	Central African Rep, Burundi, Egypt	Senegal, Morocco	Cameroon, Ivory Coast, Niger, Sierra Leone, Sudan, Tunisia, Togo, Rwanda, Guinea

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

Table 9.6. Association between yield and instability in yield of sorghum in different countries in the 1990s (1991-99) compared to the 1980s (1981-90).

Region	Types of association			
	AA: Increase in yield with decrease in variability	AB: Increase in yield with increase in variability	BA: Decrease in yield with decrease in variability	BB: Decrease in yield with increase in variability
Asia	Saudi Arabia, Yemen, Thailand, Pakistan	China, India	Korea Rep	Korea DPR
Others	Italy, France	Australia, Romania, Spain	Hungary	USA, Albania
Latin America	El Salvador, Uruguay, Colombia, Argentina	Venezuela, Peru, Honduras	Guatemala, Haiti, Brazil	Nicaragua, Mexico
Southern and Eastern Africa	Madagascar, Kenya, Zimbabwe, Botswana	South Africa, Lesotho	Tanzania, Swaziland	Zambia, Mozambique, Malawi, Somalia, Eritrea, Namibia
Western, Central and Northern Africa	Guinea-Bissau, Mauritania, Ghana, Benin, Cameroon, Sudan, Burkina Faso, Burundi, Chad, Gambia	Egypt	Nigeria, Sierra Leone, Togo, Niger, Mali, Uganda, Central African Rep	Senegal, Guinea, Tunisia, Ivory Coast, Morocco, Rwanda

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

Table 9.7. Association between yield and instability in yield of sorghum in different countries in the 1980s (1981-90) compared to the 1970s (1971-80).

	Types of association			
Region	AA: Increase in yield with decrease in variability	AB: Increase in yield with increase in variability	BA: Decrease in yield with decrease in variability	BB: Decrease in yield with increase in variability
Asia	Korea DPR	Saudi Arabia, India, China, Korea Rep	Pakistan, Thailand	Yemen
Others	Albania, Spain, USA	Australia, France, Hungary, Italy	Romania	
Latin America	Venezuela, Argentina, Honduras, Uruguay, Colombia, Nicaragua	Guatemala, Mexico, Peru	Brazil, Haiti	El Salvador
Southern and Eastern Africa	Namibia, Madagascar	Somalia, Zambia, Eritrea, Tanzania United Rep, Swaziland	Botswana, Lesotho, Mozambique	South Africa, Malawi, Zimbabwe, Kenya
Western, Central and Northern Africa	Senegal, Nigeria, Ivory Coast, Gambia, Mauritania, Benin, Mali, Uganda	Chad, Burkina Faso, Rwanda, Central African Rep, Egypt, Burundi, Guinea, Togo, Guinea-Bissau	Morocco	Tunisia, Niger, Ghana, Cameroon, Sudan, Sierra Leone

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

Table 9.9 shows the association between sorghum yield and instability in yield in different African countries. As many as 10 of the 24 countries in WCA fell under type AA association (increase in yield with a decline in variability). This is a positive sign as far as sorghum production is concerned. In SEA on the other hand, many of the countries fell under type BB (decrease in yield with increase in variability). This speaks unfavorably for the region as a whole. As many as 6 countries out of 14 in SEA were in BB type, while in WCA only 6 countries out of the 24 came under this type. On the whole, it can be said that sorghum production in terms of yield and stability in yield has been better in WCA than in SEA.

Table 9.10 classifies the sorghum area of countries by changes in the CV in sorghum yield between the 1970s and the 1990s. Majority of the countries in WCA (16 out of 24) experienced a decline in variability in yield of 10% or more. These countries account for 97% of the total area under sorghum. On the other hand, 8 countries of the 14 in SEA recorded increases in yield variability of 10% or more. These countries account for 57% of the total area under sorghum. This therefore reaffirms our earlier observation that WCA on the whole has performed better than SEA in terms of sorghum production stability in Africa.

9.6. Relationship between Adoption of Improved Cultivars,Yield and Variability in Yield

Table 9.11 shows the association between percentage change in yield and adoption of improved sorghum cultivars in Africa in the 1980s and the 1990s. In WCA, 5 of the 6 countries for which we have adoption data saw an increase in yield between the early eighties (1981-83) and the late nineties

(1997-99) (46% in Egypt to 9% in Sudan). Nigeria was the only exception among the countries in WCA, where in spite of low to moderate levels of adoption (3-29%), there was a sharp decline in yield (32%). Nigeria seems not to have benefited from the adoption of improved cultivars in terms of increments in average yield. In WCA, 5 of the 6 countries for which adoption data was available witnessed a decline in relative variability in yield (77.9% in Nigeria to 10.9% in Mali). The only exception was Egypt, though this country is one of the highest adopters of improved cultivars in the region. In fact, Egypt has the highest yield level among all the countries studied in Africa.

Table 9.8. Relative variability in sorghum yield in African countries.

		Relative variability (CV) in yield		Change in yield CV (%)
Country	Region	1981-90	1991-99	1981-90 to 1991-99
Benin	WCA	8.87	3.03	-65.86
Burkina Faso	WCA	11.13	5.31	-52.27
Burundi	WCA	9.03	5.69	-37.03
Cameroon	WCA	16.52	5.81	-64.86
Central African Rep.	WCA	16.97	16.15	-4.85
Chad	WCA	13.00	8.61	-33.77
Ivory Coast	WCA	6.04	11.10	83.86
Egypt	WCA	3.87	9.33	140.94
Gambia	WCA	13.59	10.38	-23.60
Ghana	WCA	23.19	7.82	-66.27
Guinea	WCA	11.41	16.41	43.78
Guinea-Bissau	WCA	27.90	3.32	-88.11
Mali	WCA	15.06	13.40	-10.98
Mauritania	WCA	23.40	7.41	-68.36
Morocco	WCA	19.17	36.22	89.00
Niger	WCA	22.06	17.00	-22.92
Nigeria	WCA	12.07	2.67	-77.90
Rwanda	WCA	10.40	23.15	122.53
Senegal	WCA	9.73	10.67	9.70
Sierra Leone	WCA	25.12	9.02	-64.10
Sudan	WCA	30.67	13.56	-55.78
Togo	WCA	17.55	13.11	-25.30
Tunisia	WCA	12.26	17.96	46.48
Uganda	WCA	14.82	13.28	-10.40
Botswana	SEA	33.36	31.00	-7.08
Eritrea	SEA	7.62	35.20	361.68
Kenya	SEA	27.27	10.65	-60.96
Lesotho	SEA	20.01	30.46	52.26
Madagascar	SEA	21.02	6.27	-70.16
Malawi	SEA	21.16	31.44	48.58
Mozambique	SEA	13.62	19.96	46.58
Namibia	SEA	4.20	57.88	1276.55
Somalia	SEA	5.52	14.27	158.61
South Africa	SEA	22.40	26.42	17.94
Swaziland	SEA	57.18	39.56	-30.81
Tanzania, United Rep	SEA	32.02	20.63	-35.56
Zambia	SEA	15.60	17.74	13.72
Zimbabwe	SEA	37.73	26.41	-30.01

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

Table 9.9. Association between yield and instability in yield of sorghum in different African countries in the 1990s (1991-99) compared to the 1980s (1981-90).

	Types of association			
Region	AA: Increase in yield with decrease in variability	AB: Increase in yield with increase in variability	BA: Decrease in yield with decrease in variability	BB: Decrease in yield with increase in variability
Southern and Eastern Africa	Madagascar, Kenya, Zimbabwe, Botswana	South Africa, Lesotho	Tanzania United Rep, Swaziland	Zambia, Mozambique, Malawi, Somalia, Eritrea, Namibia
Western, Central and North Africa	Guinea-Bissau, Mauritania, Ghana, Benin, Cameroon, Sudan, Burkina Faso, Burundi, Chad	Egypt	Nigeria, Sierra Leone, Togo, Gambia, Niger, Mali, Uganda, Central African Rep	Senegal, Guinea, Tunisia, Ivory Coast, Morocco, Rwanda

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

In SEA, 8 of the 9 countries for which we have adoption data saw an increase in yield between the early eighties (1981-83) and the late nineties (1997-99), the exception being Tanzania which saw a 16% reduction in yield. However the adoption level in Tanzania was very low, only 2%. The highest yield gain was recorded in Swaziland (91%), which has an adoption level of 50%. The other notable countries in terms of yield gains were Zimbabwe with a 46% yield gain and 36% adoption and South Africa with a yield gain of 38% and 77% adoption. However, a dismal picture emerges when we compare relative variability in yield with adoption of improved cultivars in SEA. There was an increase in relative variability in yield in 5 of the 9 countries for which we have yield data. The rest of the countries saw a decline between the 1980s and the 1990s. These countries (in the order of magnitude of decline) were Tanzania, Swaziland, Zimbabwe and Botswana. However as noted earlier, since Tanzania has a very low rate of adoption, the decline cannot be solely attributed to rates of adoption. On the other hand, South Africa which has a very high adoption rate of 77%, witnessed an increase in the variability of yield. Therefore, no consistent relationship emerges between adoption of improved cultivars and its effect on decline in yield variability for Africa as a whole and for countries in SEA in particular.

9.6.1. South America

Yield variability is one of the most important indicators of stability in the farming system of a region. In terms of variability in yield of sorghum, there has been a decline in eight countries in South America, which includes Argentina (the second largest producer of sorghum in the region). The other countries where yield variability declined were Brazil, Colombia, Guatemala, Haiti, Nicaragua, Uruguay and Venezuela. Yield variability increased in Mexico, Peru, El Salvador and Honduras. All these countries except Mexico and Peru had absolute yield levels below the regional average. In spite of their high absolute yields, Peru and Mexico experienced increases in yield variability. Argentina and Uruguay, which had high absolute yields, recorded a decline in yield variability. This is a positive sign as far as the production of sorghum in the region is concerned.

In the 1980s compared to the 1970s, 6 (Venezuela, Argentina, Honduras, Uruguay, Colombia and Nicaragua) of the 12 countries studied fell under type AA association (increase in yield and decline in variability). Of these, the absolute yield levels in Argentina, Uruguay and Colombia were higher than the regional average. Mexico, Peru and Guatemala (type AB association with increase

Table 9.10. Classification of countries and sorghum area by changes in coefficients of variation of sorghum yields.

Periods	Change in CV		
	Decrease of 10% or more	Less than + 10% change	Increase of 10% or more
In the 1980s, compared to the 1970s	Haiti, Venezuela, Morocco, Namibia, Pakistan, Madagascar, Albania, Senegal, Thailand, Botswana, Nigeria, Ivory Coast, Brazil, Romania, Gambia, Argentina, Lesotho, Honduras, Uruguay, Mauritania, Benin, Mali, Korea DPR, Colombia, Nicaragua, Spain (26)	USA, Uganda, Mozambique, France, Somalia, South Africa, Australia (7)	Zambia, Chad, Guatemala, Saudi Arabia, Mexico, India, Peru, Burkina Faso, Tunisia, Niger, Eritrea, Rwanda, Hungary, Central African Rep, Tanzania United Rep, Italy, Egypt, China, Malawi, Ghana, Swaziland, Zimbabwe, Cameroon, Burundi, Guinea, Togo, Guinea-Bissau, El Salvador, Yemen, Sudan, Sierra Leone, Korea Rep, Kenya (33)
Percentage of countries	39.4	10.6	50.0
Percentage of sorghum area	17.4	15.9	66.7
In the 1990s compared to the 1970s	Guatemala, Nigeria, Madagascar, Saudi Arabia, Mauritania, Haiti, Benin, Uruguay, Thailand, Pakistan, Guinea-Bissau, Italy, France, Venezuela, Gambia, Colombia, Botswana, Brazil, Argentina, Burkina Faso, Mali, Ghana, Chad, Morocco, Uganda (26)	Hungary, Nicaragua, Cameroon, Lesotho, Honduras, El Salvador (6)	Ivory Coast, USA, Tanzania United Rep, Niger, Zambia, South Africa, Australia, Mozambique, India, Mexico, Romania, Swaziland, Albania, Sierra Leone, Central African Rep, Korea Rep, Burundi, Peru, Yemen, Sudan, Zimbabwe, Tunisia, Spain, Kenya, Togo, Somalia, China, Korea DPR, Malawi, Rwanda, Guinea, Egypt, Namibia, Eritrea (34)
Percentage of countries	39.4	9.1	51.5
Percentage of area under sorghum	28.4	1.9	69.7
In the 1990s compared to the 1980s	Guatemala, Guinea-Bissau, Saudi Arabia, Nigeria, Italy, El Salvador, Madagascar, Mauritania, Ghana, Benin, Korea Rep., Cameroon, Sierra Leone, Kenya, Uruguay, Sudan, France, Yemen, Burkina Faso, Thailand, Hungary, Haiti, Colombia, Burundi, Tanzania United Rep, Chad, Swaziland, Zimbabwe, Pakistan, Togo, Gambia, Niger, Brazil, Mali, Uganda (35)	Botswana, Argentina, Central African Rep, Senegal (4)	Nicaragua, Zambia, India, Venezuela, South Africa, Australia, Mexico, USA, China, Guinea, Tunisia, Mozambique, Malawi, Peru, Lesotho, Honduras, Ivory Coast, Morocco, Rwanda, Romania, Egypt, Spain, Somalia, Albania, Korea DPR, Eritrea, Namibia (27)
Percentage of countries	53.0	6.1	40.9
Percentage of area under sorghum	49.0	2.2	48.7

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org).

Table 9.11. Association between relative variability in yield and adoption of improved cultivars of sorghum in Africa.

	Relative variability (CV) in yield		Change in yield CV (%)	
Country	1981-90	1991-99	1981-90 to 1991-99	Adoption of IC (%)
Western and Central Africa				
Benin	8.87	3.03	-65.86	
Burkina Faso	11.13	5.31	-52.27	
Burundi	9.03	5.69	-37.03	
Cameroon	16.52	5.81	-64.86	12 to 49
Central African Rep.	16.97	16.15	-4.85	
Chad	13.00	8.61	-33.77	24 to 38
Egypt	3.87	9.33	140.94	35
Gambia	13.59	10.38	-23.60	
Ghana	23.19	7.82	-66.27	
Guinea	11.41	16.41	43.78	
Guinea-Bissau	27.90	3.32	-88.11	
Ivory Coast	6.04	11.10	83.86	
Mali	15.06	13.40	-10.98	29
Mauritania	23.40	7.41	-68.36	
Morocco	19.17	36.22	89.00	
Niger	22.06	17.00	-22.92	
Nigeria	12.07	2.67	-77.90	3 to 29
Rwanda	10.40	23.15	122.53	
Senegal	9.73	10.67	9.70	
Sierra Leone	25.12	9.02	-64.10	
Sudan	30.67	13.56	-55.78	22
Togo	17.55	13.11	-25.30	
Tunisia	12.26	17.96	46.48	
Uganda	14.82	13.28	-10.40	
Southern and Eastern Africa				
Botswana	33.36	31.00	-7.08	33
Eritrea	7.62	35.20	361.68	
Kenya	27.27	10.65	-60.96	
Lesotho	20.01	30.46	52.26	4
Madagascar	21.02	6.27	-70.16	
Malawi	21.16	31.44	48.58	10
Mozambique	13.62	19.96	46.58	5
Namibia	4.20	57.88	1276.55	
Somalia	5.52	14.27	158.61	
South Africa	22.40	26.42	17.94	77
Swaziland	57.18	39.56	-30.81	50
Tanzania, United Rep.	32.02	20.63	-35.56	2
Zambia	15.60	17.74	13.72	35
Zimbabwe	37.73	26.41	-30.01	36

Source: Authors' calculation based on FAO Agricultural Statistics (http://www.fao.org). Adoption data is from Chapter 8 of this book.

in yield and increase in variability) saw increases in absolute yield levels; but this was not accompanied by a corresponding decline in yield variability. Both Mexico and Peru have very high absolute yield levels, the highest among South American countries. Guatemala showed a low level of absolute yield. Brazil and Haiti (type BA with decrease in yield and decrease in variability), had very low levels of absolute yield. The average yield in Haiti was only 768 kg ha^{-1} in the 1990s. El Salvador was the only country during this period to fall under type BB association with decrease in yield and increase in variability.

In the 1990s compared to the 1970s, Uruguay, Venezuela, Colombia, Argentina and Nicaragua were in type AA association. All these countries except Venezuela and Nicaragua had high levels of absolute yield, higher than the average for the continent as a whole. El Salvador, Mexico, Peru and Honduras fell under AB type association. Haiti, Guatemala and Brazil were in type BA during this period. During this period, it is noted that all the countries with high levels of absolute yield also witnessed a decline in relative variability in yield. The only exceptions were Mexico and Peru.

The association between yield and relative variability of yield in the 1990s compared to the 1980s shows a slightly different trend. Mexico, the largest producer of sorghum in the region, fell under type BB association. However, Argentina, the second largest producer, recorded an increase in yield and a decline in yield variability during this period.

9.7. Conclusions

This chapter discussed three dimensions of productivity impact derived from the adoption of improved sorghum cultivars.

The yield trends demonstrated varying scenarios of yield gains across countries, regions and continents. In addition, the synthesis of available farm-level survey studies confirmed the measurable decline in unit cost of producing sorghum in Asia and Africa. Countries with higher level of adoption of improved cultivars were shown to have achieved higher yield gains as in the case of China, India and South Africa. In particular, the yield trends revealed different scenarios of yield impact in India and Africa. The data covering four decades from 1961 to 2002 clearly show that India has progressed tremendously in terms of sorghum yield, while most countries in Africa are lagging behind. As elucidated in Section 9.3, improved cultivars along with infrastructure variables and policy, played a key role in this differential growth in sorghum yield.

The global and country-level analysis attempted to establish a link between adoption, yield gain and reduction in yield variability. The types of association relating sorghum yield and instability in yield facilitated the identification of country scenarios where the ideal outcome of increase in yield and reduced variability (eg, type AA) are shown, as in the case of Pakistan during the period from the 1970s to the 1990s. In both India and China, relative variability in yield increased in the 1990s compared to the 1970s. Both countries experienced increased yield with adoption of improved cultivars, along with increased yield variability. This analysis based on aggregate data for India does not corroborate the results found earlier using district-level data (Deb et al. 1999). The earlier results indicate that the expansion of area under improved cultivars helped to increase sorghum yield as well as reduce its relative variability in India. In Africa, no consistent relationship emerged between adoption of improved cultivars and decline in yield variability.

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