Sorghum and Millet
Economies in Asia
Facts, Trends and Outlook

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Sorghum and Millet Economies in Asia

Facts, Trends and Outlook

**S Bhagavatula, P Parthasarathy Rao,
G Basavaraj and N Nagaraj**

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International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

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Executive Summary

Sorghum and millets are important cereals that play a significant role in the food and nutrition security of developing countries. Together, they account for 10% of Asia's coarse grain production. India is the largest producer of sorghum and millets, accounting for over 80% of Asia's production. However, the yield levels in India are relatively low despite the adoption of improved cultivars and hybrids.

The low yield of sorghum and millets in India compared to yields in developed countries and China can be attributed to a shift in crop area from favorable to marginal environments, the slow uptake of improved varieties and other production technologies post the 1980s and their cultivation on poor soils under erratic rainfall conditions. Additionally, a number of biotic and abiotic factors limit realization of yield potential of these crops. Despite the lower average yield at the all-India level, at a more disaggregated district level there has been some shift in the area from lower to higher yield range, particularly for rainy season sorghum.

The pattern of utilization for both sorghum and millets varies across countries/regions. In developing countries of Africa and Asia, these crops are used primarily as food grain and form the staple particularly for the poor. However, in the developed countries sorghum is used largely as a feed grain and millets are used as bird feed. In recent years in both Asia and Africa, the use of sorghum and millet grain in the alcohol industry – beer in Africa and potable alcohol in India – is gaining popularity, with nearly 20% of grain stocks being utilized for this purpose. For urban consumers processed food products made from sorghum and millets is gaining importance but the low shelf-life of their flour and poor consumer acceptance are some of the constraints that need to be overcome for more widespread utilization.

Trade in sorghum is relatively robust and has been growing over time. Both sorghum and millets are primarily traded for use as feed in the importing countries. Trade in millets is relatively thin, accounting for less than 1% of total production. Close to 11% of the total sorghum produced in 2007-09 entered the international market. Asia is a net importer of the grain, with a majority of the imports heading for Japan. Africa is also a net importer of sorghum although the traded volumes are relatively low. Asia is the single largest millet exporter, with most of the exports originating from India.

As both sorghum and millets are traded for feed by the developed countries, the international prices for these grains have been relatively low. However, the recent (2006-2008) rise in global prices of all agricultural commodities has also led to a rise in prices for both sorghum and millets. The outlook in the short to medium term indicates that the demand for and prices of these grains will register an increase, largely owing to spillover effects from the changes in the world maize markets and the general increase in feed demand owing to increased incomes, particularly in the emerging developing economies.

Despite the continued increase in demand for food and feed, it should be noted that agriculture is becoming increasingly vulnerable and sensitive to limiting factors such as land availability, climate change effects and the increasing frequency of extreme events. Therefore the main challenges for research and development are to (i) bridge the gap between actual and attainable yield by enhancing farmers' access to quality inputs, improved technologies and information; (ii) improve the competitiveness of sorghum and millets through domestic incentives related to production, marketing, processing, prices etc. in line with those for fine cereals and other competing crops; (iii) achieve a technological breakthrough that not only overcomes yield barriers but also provides effective protection against insect pests and diseases and resistance to moisture stress; and (iv) create greater awareness among consumers on the nutritional qualities of both sorghum and millets.

1. Background

1. Background

With the sustained rise in per capita income and urbanization, food consumption patterns have undergone a sea change in many developing countries in Asia, Latin America and Africa. The shift has taken place away from coarse cereals, specifically sorghum and millets (an aggregate term for a variety of crops such as pearl millet, finger millet, and proso millet), toward rice and wheat and animal products. At the same time, declining food use of coarse cereals is matched by their increasing use in the feed and alcohol industries. However, sorghum and millets continue to remain important staple food for the poor in many developing countries in Africa and Asia, particularly in rural areas.

Globally, coarse cereal production increased from 743 million tons (t) in 1980-82 to over 1 billion t in 2006-08. The pattern of relative contribution of the developed and developing countries has undergone a change over the period with both blocks of countries accounting for roughly the same production quantity to the global total in 2006-08. In the early 1980s, the developed countries accounted for two thirds of the global total. The share of maize among coarse cereals is the largest, accounting for 73% of global production (Fig. 1). Barley and sorghum, the next most important coarse cereals, together account for 19%, while millets account for 3% of global production. This pattern is replicated in

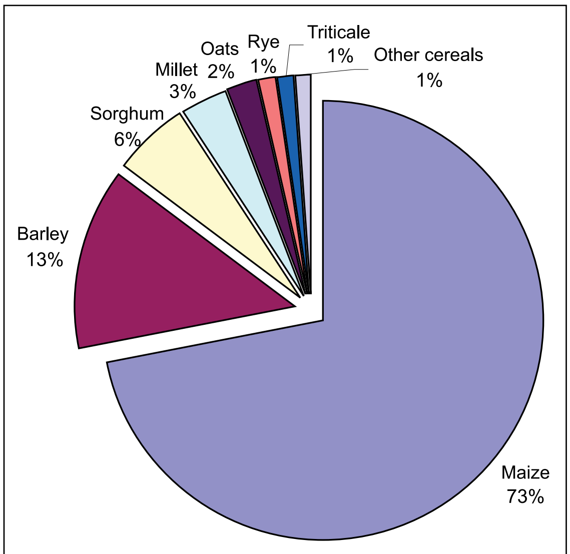


Figure 1. Share of crops in global coarse cereal production, 2006-08.

Asia, which accounted for 25% of global coarse cereal production in 2006-08 (Appendix Table 1). In Asia, too, maize dominates coarse cereal production, accounting for 82%, while barley and sorghum account for 12% and millets for 5% (Fig. 2). China is the largest producer of coarse cereals in the region, accounting for 62% of Asia's coarse cereal production, the bulk of which is maize. China is also an important player on the world stage, accounting for 15% of global coarse cereal production. India, accounting for only 4%, is far less important globally. However, India accounts for 20% of global sorghum and millet production.

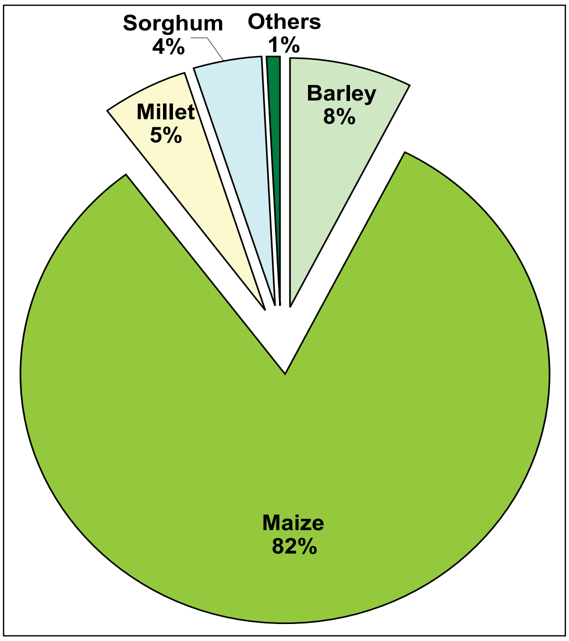


Figure 2. Share of different crops in Asia's coarse cereal production, 2006-08.

In the years between 1980 and 2008, global coarse cereal production grew at 1.1% per annum. While the rate of increase was relatively low at 0.6% in the developed countries, it was much higher at 2.3% in the developing countries. The increase in production in the developing countries was due to a combination of rapid adoption of high-yielding varieties in intensively cropped systems in some countries and area expansion in other countries. In the major growing countries in Asia and Latin America, production increased mainly due to adoption of high-yielding varieties while the area sown did not increase significantly. In contrast, in countries in Africa, the near doubling of production owes more to a doubling of area under coarse cereals than adoption of high-yielding varieties. Yields in Africa have remained roughly the same since the early 1980s, ranging between 1.1 and 1.2 t ha^{-1}.

Close to 13% of global coarse cereal production is traded on the international market. Most of this is for use as feed, with a very small percentage being traded for use as food. Despite a doubling of production, Asia remains a net importer of coarse cereals, with the region importing 60 million t in 2006-08. The bulk of the imports comprise maize, with barley and sorghum coming a distant second and third respectively. Japan accounts for the largest share of coarse grain imports while India and China are among the major exporters within the region.

This report highlights the production, trade, consumption and utilization trends of sorghum and millets in Asia (pearl millet for India), where the two crops account for 9% of the total coarse cereal production. The paper then highlights constraints related to their production, and markets, institutions and policies affecting their supply and demand. In the outlook section, the future prospects of these crops under varying scenarios of yield and income growth in specific countries of Asia are addressed.

The data analyzed in this report is downloaded from FAOSTAT (http://www.faostat.fao.org) for all major producing countries and regions. Disaggregated data at the state, district or province levels for India are from published sources from the Government of India (GOI), (various years), Directorate of Economics and Statistics (DES) Ministry of Agriculture, Government of India. Graphical and spatial analyses were carried out in order to capture the crop distribution, changing dynamics of production, utilization, prices and trade. For spatial analysis, GIS digitized maps (arc view) with relevant boundaries (state, district, etc.) were used. Future trends and outlook for the crops have been generated for 2020 using the partial equilibrium IMPACT-WATER model.

The facts and trends relating to sorghum and millets in Asia highlighted in this report will provide valuable direction to researchers working on these crops, research managers, stakeholders along the value chain, and policy makers in improving the overall efficiency of these crops to meet the requirements of their producers and end users.

2. Sorghum: Facts and Trends

2. Sorghum

Introduction

Sorghum (*Sorghum bicolor (L.) Moench)* is the fifth largest produced cereal crop in the world and one of the staples of the world's poorest, particularly in the developing countries of Africa and South Asia. Sorghum accounts for 6% of the global coarse cereal production and is particularly well suited to hot and dry agroecologies. Sorghum grain and stover are of economic value – the grain is used as food, cattle and poultry feed and in alcohol manufacture while its stover is an important dry fodder resource for large ruminants. In India, for example, the stover value accounts for nearly 30-40% of the total value of the crop (Parthasarathy Rao et al. 2003).

Sorghum is grown primarily in the developing countries, which account for 92% of global area under the crop. Africa, in particular, accounts for 61% of the global sorghum area and 41% of global production (Fig. 3). The bulk of the crop in Africa is grown on marginal lands under low input conditions and, consequently, yield levels are relatively low. Asian countries are the second most important block of sorghum producers, accounting for 22% of the global sorghum area and 18% of the global production. Yields are closer to the global average in Asia as improved seeds and fertilizers are used, though production has been falling as farmers shift to other, more remunerative crops (Table 1). Furthermore, there is a large disparity in yield levels within Asia in the major sorghum-growing countries with yields in China nearly four times those in India and Pakistan (Fig. 4). Developed countries account for only 8% of global sorghum area but 22% of global production since the yield levels in these countries is about three times higher than the global average. Intensive cultivation of sorghum with high input usage distinguishes sorghum production in North America, Oceania and Europe.

The utilization of sorghum varies by region. In Africa and Asia, it is grown mainly for food use, although industrial use of sorghum grain has been increasing in Asia, particularly in Southeast Asia and in India in the last two decades. In North America (which is the third largest sorghum-growing region), Europe, Australia and Latin America, the grain is used primarily as feed.

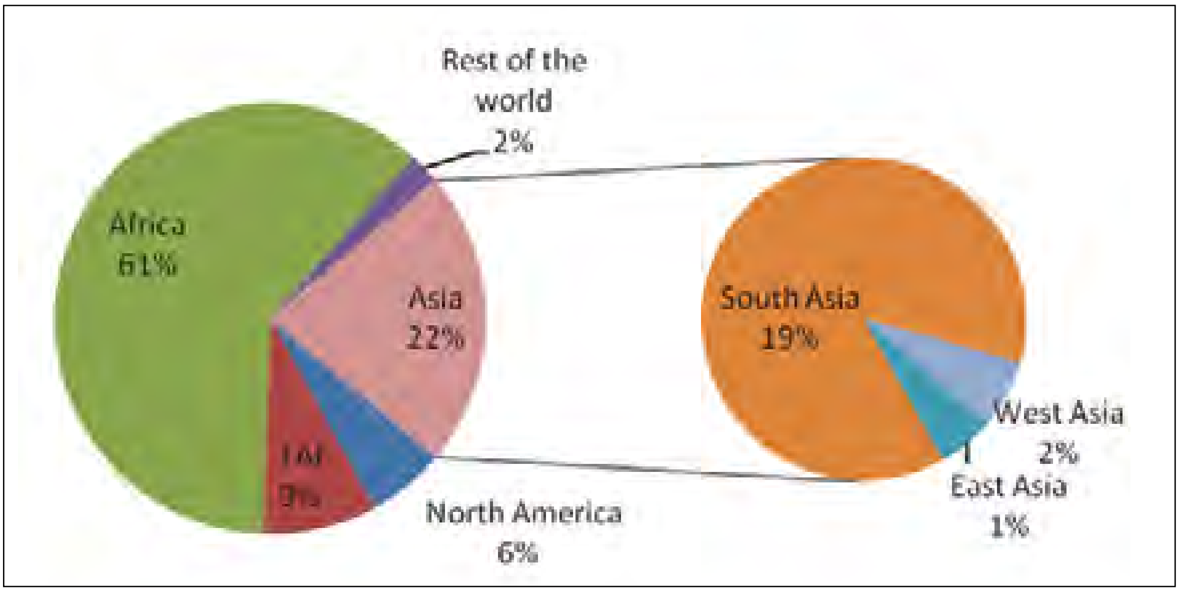


Figure 3. Global distribution of sorghum area, 2006-08.

Table 1. Trends in sorghum area, yield and production.

	Area ('000 ha)			Yield (kg ha^{-1})			Production ('000)		
Country/Region	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**
World	45,170	42,905	44,086	1,469	1,334	1,411	66,376	57,225	62,219
Developed countries	6,329	4,201	3,550	3,364	3,692	3,835	21,291	15,510	13,614
Europe	278	149	211	2,691	4,469	3,410	749	666	721
North America	5,440	3,514	2,563	3,565	3,948	4,118	19,392	13,874	10,555
Oceania	610	538	775	1,885	1,802	3,017	1,151	970	2,339
Developing countries	38,841	38,704	40,537	1,161	1,078	1,199	45,085	41,716	48,605
Africa	13,840	21,451	26,903	927	801	947	12,825	17,185	25,471
LAC	4,567	2,871	3,788	2,881	2,734	3,170	13,159	7,847	12,009
Asia	20,434	14,383	9,845	935	1,160	1,130	19,100	16,685	11,125
East Asia	2,715	1,342	560	2,518	4,208	4,536	6,837	5,648	2,542
China	2,698	1,333	539	2,525	4,230	4,656	6,815	5,638	2,508
South Korea	13	8	20	1,395	1,040	1,533	18	9	31
South Asia	16,655	12,258	8,580	679	828	902	11,309	10,146	7,741
India	16,262	11,850	8,301	681	836	912	11,082	9,902	7,569
Pakistan	392	407	279	575	598	616	225	244	172
South East Asia	253	148	33	1,041	1,424	1,694	264	210	55
Thailand	245	147	32	1,014	1,424	1,692	249	210	55
West Asia	810	626	669	853	1,063	1,156	691	665	773
Yemen	592	451	554	987	1,021	879	584	461	487
Saudi Arabia	206	163	101	422	1,164	2,414	87	189	245

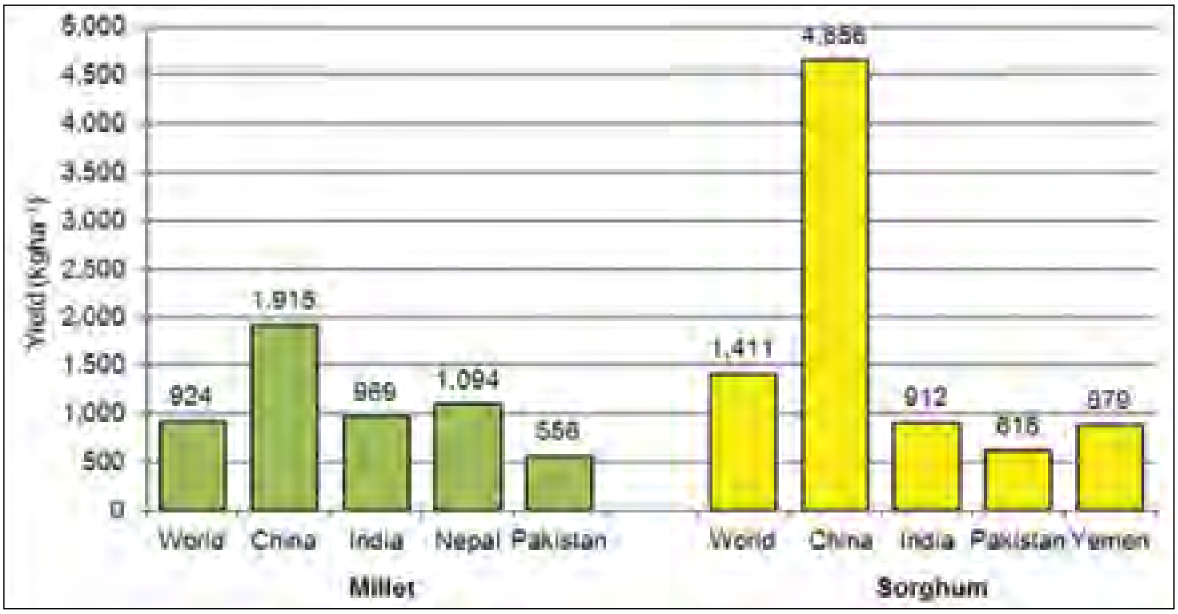


Figure 4. Sorghum and millet yields in top producing countries in Asia, 2006-08.

Crop Distribution

Sorghum originated in northern Africa and is now cultivated widely in tropical and subtropical regions, generally in areas which are considered too dry for maize. Grain sorghum is similar to maize in vegetative appearance, but has more tillers and more finely branched roots. It is typically an annual crop, although some cultivars are perennial. It grows in clumps that may reach over 4 m high. The grain is small, ranging from 3 to 4 mm in diameter. The species can grow in arid soils and requires an annual rainfall of 400-750 mm. Sorghum has the ability to withstand prolonged drought by becoming dormant under adverse conditions. It also has a very large root-to-leaf surface area and its leaves are protected by a waxy cuticle that reduces water loss. It is adapted to a wide range of soils, from deep sands to heavy black cracking clays - good drainage, however, is necessary. Its deep rooting system can extract water from deep sources, though not as deep as pearl millet. Its optimal soil pH range lies between 5 and 8.5. Sorghum is normally self-fertilized, but can cross pollinate. Sweet sorghum is a sorghum cultivar that is primarily grown for foliage and is typically taller than grain sorghum cultivars, with sugar-rich stalks.

In 2006-08 sorghum was grown on 44 million ha in all regions of the world (Table 1). Africa accounts for 61% of global sorghum area and its cultivation is distributed all over the continent, where it is a key staple. In Asia, which accounts for 22% of global area, sorghum cultivation is more concentrated within India and China, which account for 90% of the regional area under the crop. Latin America accounts for nearly 9% of the global sorghum acreage, with Argentina and Mexico dominating the regional area share.

Developed countries contribute 22% of the global sorghum output, despite accounting for only 8% of the global sorghum area. The United States (USA) is the most significant producer, accounting for 17% of the global output while accounting for only 6% of global area. Sorghum is grown in the central and southern plains of USA, where rainfall is low and variable. Australia has been increasing sorghum production since the mid-1990s, but it continues to account for only 2% of global area, and accounts for 4% of global sorghum production.

In India, during 2006-08, sorghum was grown on 8 million ha. It is grown both in the rainy and postrainy season. In the former, the crop is grown on rainfed conditions, while in the postrainy season it is grown on residual soil-moisture. Only 9% of the sorghum crop is irrigated. Forage sorghum is important in the semi-arid temperate regions, where it is grown under irrigation in the states of Punjab, Haryana, and western UP.

The main rainy season sorghum-growing state is Maharashtra, which accounts for 38% of area under the crop followed by Rajasthan and Madhya Pradesh which together account for 35% of area (Map 1). Rainy season sorghum is predominantly grown in the semi-arid tropics (SAT) (82% of rainy season sorghum area), with 13% of the area falling in the semi-arid temperate zones. The area under rainy season sorghum in the semi-arid temperate region has been declining since the 1970s owing to the declining competitiveness of sorghum with the emergence of irrigation and shift to irrigated crops like rice, wheat, sugarcane and cotton.

Postrainy season sorghum is primarily grown in Maharashtra, which accounts for 68% of the area, followed by Karnataka with 25% (Map 2). Cultivation of postrainy season sorghum is concentrated almost exclusively in the SAT, accounting for 98% of total postrainy season area.

Trends in Area, Yield, and Production

Area

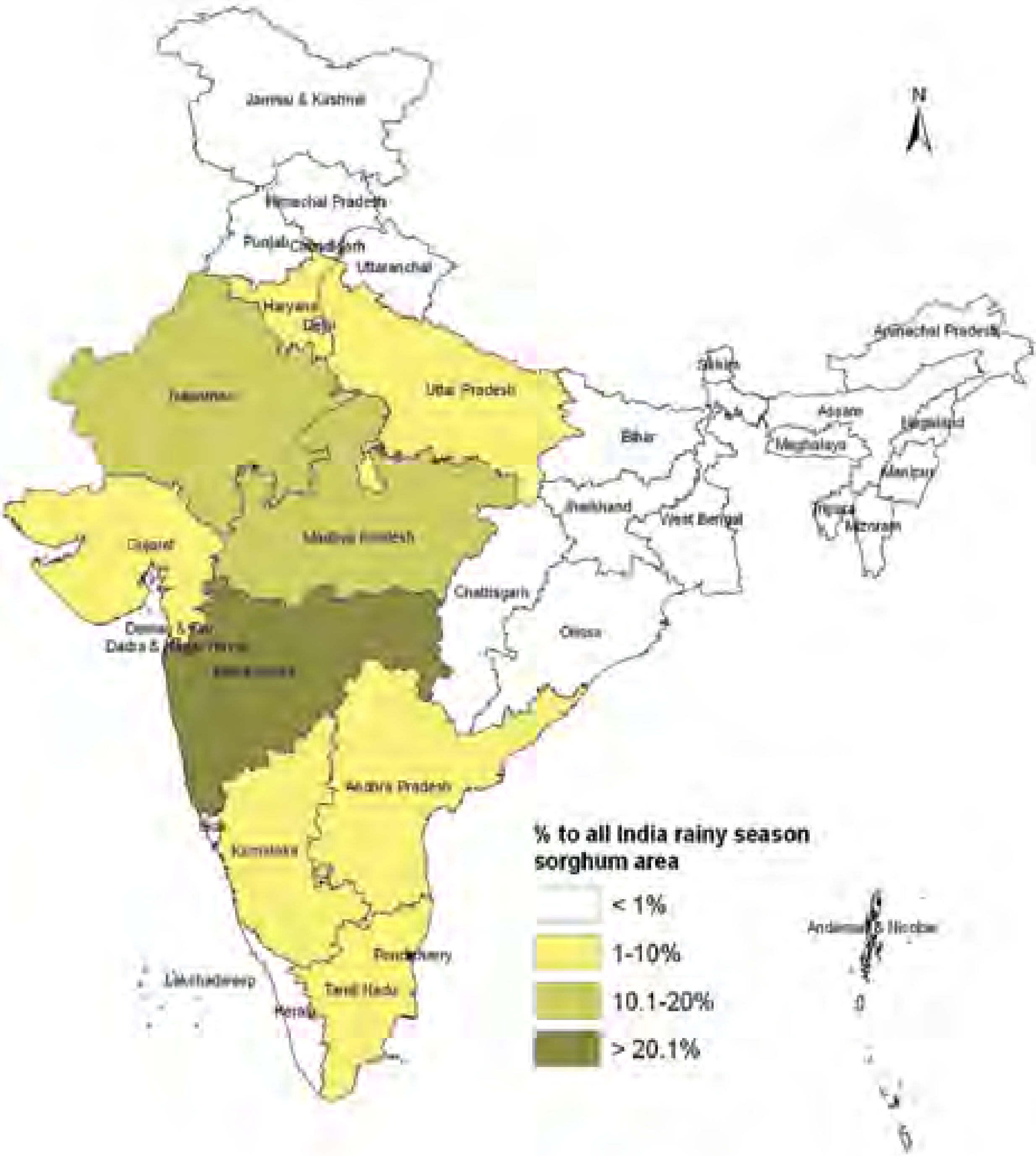
Global sorghum area remained stagnant with a marginal decline of 0.4% between 1980 and 2009 (Table 2). The decline was more marked in the developed countries (-2.6% per year) than in the developing countries, where it remained relatively stagnant at -0.1% per year. Area declined in North America over the entire period, accelerating in the latter half to -4.4% per year. In Europe, however, after declining in the 1980s and early 1990s, area under sorghum increased at the rate of 2.4% between 1995 and 2009. Australia (Oceania) also displayed a similar trend with area increasing at 2% per annum in 1995-2009, after declining at 3% between 1980 and 1994. In North America, the decline in area under sorghum starting in the late 1980s was due to a reduction in agricultural support policies for sorghum and the development of drought tolerant maize varieties which were more profitable (Lin and Hoffman 1989).

The trends in the developing countries also varied considerably. Africa witnessed an increase in area, although the rate appears to have slowed down since 1995, with area growing at 1.5% between 1995 and 2009 compared to 3.4% between 1980 and 1994. The area expansion in the years between 1980 and 1995 was due to expansion into drier lands as a result of population expansion[1]. Yields, however, fell during this period due to the same reason. In the later period while area expansion slowed down production continued to grow due to yield growth.

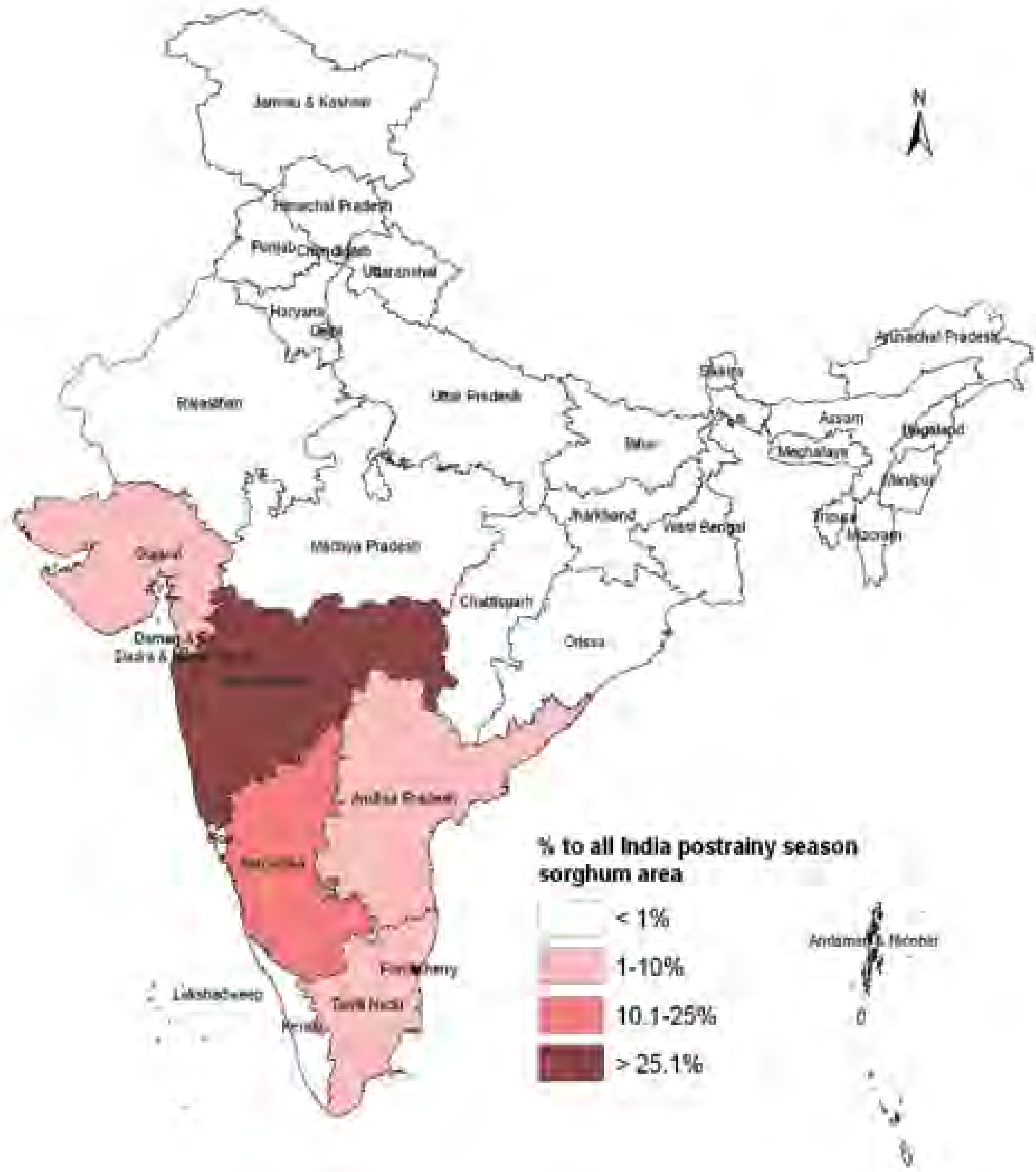
Sorghum area in Latin America declined between 1980 and 1994 and then increased, albeit at a slower rate of 0.8% between 1995 and 2009. Area in Latin America, particularly in Argentina, fell dramatically owing to reduced import demand from the former USSR in the late 1980s following a lifting of the trade embargo on maize exports from the USA.

In Asia, sorghum area declined steadily at 3% per annum between 1980 and 2009. Thus, Asia accounted for only 22% of global sorghum area in 2006-08 compared to 45% in 1980-82. The decrease in area was most dramatic in China, where it fell from 2.7 million ha in 1980-82 to 0.6 million ha in 2006-08 (Table 1 and Figure 5). This can be attributed to decline in food demand for sorghum (Kumar et al. 2007) and higher profitability of maize. Area in West Asia also registered a decline but not as steep as that in the rest of Asia, declining by 0.7% between 1980 and 2009. In absolute terms, the greatest impact in area declines have occurred in India, with nearly 8 million ha being diverted from sorghum cultivation since the 1980s (Table 1). Sorghum area in India declined at a rate of 3% per annum between 1980 and 2009, with oilseeds such as sunflower and soybeans and cash crops such as cotton being planted instead that were more profitable driven by yield increase and higher prices due to growing consumer demand.

1. Population in Africa grew at 2.46% per annum between 1980 and 2009



Map 1. Distribution of rainy season sorghum area by state in India, 2005-07.



Map 2. Distribution of postrainy season sorghum area by state in India, 2005-07.

Table 2. Annual compound growth rates (%) of sorghum area, yield and production[2].

Country/Region	Area			Yield			Production		
	1980-2009	1980-94	1995-2009	1980-2009	1980-94	1995-2009	1980-2009	1980-94	1995-2009
World	-0.36	-0.67	-0.08	-0.29	-0.74	-0.32	-0.66	-1.40	-0.40
Developed countries	-2.62	-3.42	-3.01	0.24	1.11	-0.62	-2.38	-2.35	-3.60
Europe	-2.74	-3.72	2.37	2.49	4.80	-2.15	-0.31	-2.46	-4.74
North America	-3.17	-3.43	-4.37	0.22	-0.73	1.56	-2.97	0.91	0.17
Oceania	0.39	-3.29	2.05	1.66	0.71	1.63	2.05	-2.60	3.72
Developing countries	-0.09	-0.28	0.21	0.09	-0.69	0.48	0.00	-0.96	0.69
Africa	2.33	3.42	1.53	0.36	-1.01	1.12	2.70	2.37	2.68
Latin America	-0.96	-4.56	0.78	0.43	-0.26	0.98	-0.53	-4.81	1.76
Asia	-3.03	-2.87	-2.66	0.36	1.76	-0.75	-2.68	-1.16	-3.39
East Asia	-6.00	-5.99	-7.32	1.77	3.47	0.54	-4.33	-2.73	-6.17
China	-6.09	-6.11	-7.62	1.85	3.43	0.52	-4.37	-2.89	-6.28
South Korea	0.89	-1.84	14.07	0.30	-2.91	2.91	1.20	-4.67	17.30
South Asia	-2.80	-2.49	-2.38	0.71	2.14	-0.06	-2.11	-0.40	-2.44
India	-2.85	-2.81	-2.36	0.74	2.35	-0.05	-2.14	-0.48	-2.43
Pakistan	-1.08	0.44	-3.15	0.28	0.27	0.16	-0.80	0.72	-3.00
Southeast Asia	-7.50	-4.46	-11.41	2.11	1.67	1.94	-5.54	-2.86	-9.70
Thailand	-7.45	-4.60	-11.43	2.23	1.48	2.03	-5.46	-3.28	-9.72
West Asia	-0.72	-1.62	0.22	2.13	4.03	0.62	1.40	2.34	0.84
Yemen	-1.44	-3.15	1.72	0.80	5.28	-2.39	-0.64	2.08	-0.68
Saudi Arabia	2.59	9.78	-4.94	3.79	3.09	7.27	6.70	13.67	1.94

[2] All the growth rates in the text are calculated based on three-year moving averages. The year 1995 was chosen as a convenient mid-point in the study period of 1980-2008 in order to examine any changes that may have occurred over the 28-year study period.

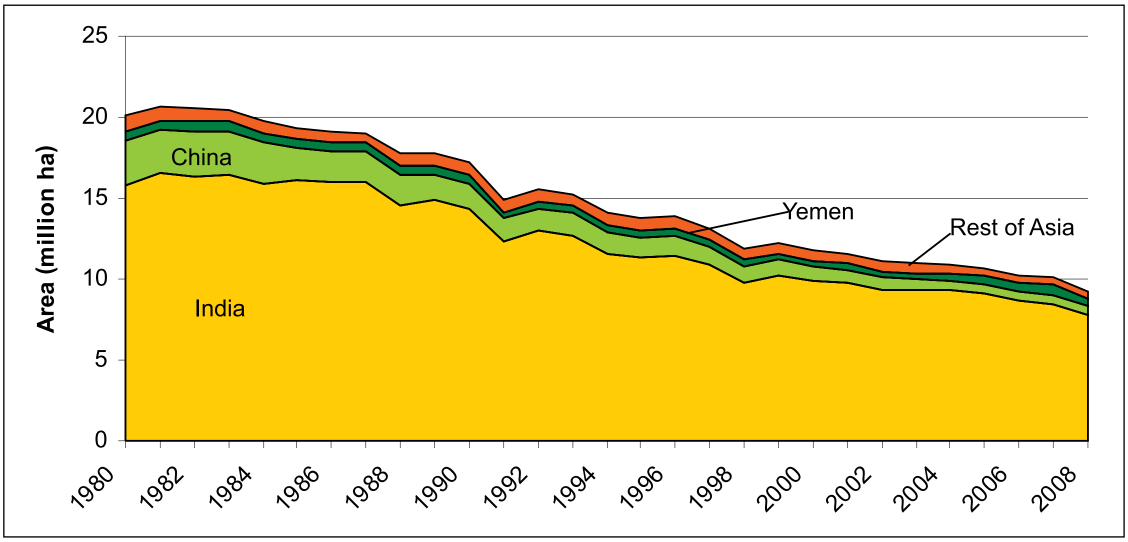


Figure 5. Sorghum area trends in Asia, 1980-2008.

Rainy and postrainy season sorghum area in India

FAO data does not separate sorghum data for India by season and hence in this section we use GOI data to look at the trends for rainy and postrainy season sorghum separately. Rainy season sorghum is typically sown in June and harvested in September, while postrainy season sorghum is sown in October and harvested in February of the following year.

Rainy season sorghum

While overall sorghum area in India has declined, areas under rainy season and postrainy season sorghum have trended differently. Rainy season sorghum area declined 4.5% per annum between 1980 and 2007 while postrainy season sorghum area declined at only 1% per annum (Table 3). Consequently, the division of total sorghum area between rainy season and postrainy-season sorghum also underwent a change with the postrainy season accounting

Table 3. Area growth rates and area share of rainy season and postrainy season sorghum in India, by climatic zone.

	Area growth rate (%)			Area share (%)
	1980-94	1995-2007	1980-2007	2005-07
Zone	Rainy season			
India	-3.58	-3.69	-4.52	3595.9*
Humid	-3.34	-7.5	-7.26	1.3
Semi-arid temperate	-3.51	-3.4	-3.75	12.5
Semi-arid tropic	-3.55	-3.94	-4.61	82.1
Arid	-4.04	0.4	-3.45	4.2
	Postrainy season			
India	-1.02	-0.1	-1.22	4604.6*
Humid	-5.86	-11.65	-7.85	1
Semi-arid temperate	NA	NA	NA	NA
Semi-arid tropic	-0.83	0.19	-0.97	98.3
Arid	1.87	-3.74	-3.74	0.8

* Average area in '000 ha

for 56% of total sorghum area in 2005-07 compared to 37% in 1980-82 (Table 3). One of the main reasons for the relative stability in postrainy season sorghum area is because it is grown under residual soil moisture where other crops are less competitive. On the demand side its grain continues to be an important food staple in the states where it is grown, mainly Maharashtra and Karnataka, and its stover is valued as a nutritive animal feed.

While 82% of the rainy season sorghum is grown in the SAT, the semi-arid temperate zone is also a significant growing area, accounting for 13% of its area while the arid zone accounts for only 4% (Table 3). Negligible area under rainy season sorghum is found in the humid regions, and what little was there dwindled to near zero (Fig. 6). The decline in area is evident in all agroecological zones with the decline being the greatest in the SAT, where the area under the crop decreased at the rate of 4.6% between 1980 and 2007.

The trend of declining area under rainy season sorghum is further corroborated at a more disaggregated district level. In Figure 7 we find that the majority of the sorghum-growing districts fall below the 45 degree line[3], indicating that the area under sorghum in 2005-07 in those districts is lower than in 1980-82. This is also evident in the reduction in the number of districts with large area (greater than 100,000 ha) under the crop since the 1980s (Fig. 8). In 1980-82, 31 districts had more than 100,000 ha under rainy season sorghum cultivation, which dwindled to 9 by 2005-07. Furthermore, the number of districts in the medium category (50,000-100,000 ha) also registered a decrease with only 11 districts in the country falling in this category in 2005-07 compared to 38 in 1980-82. Thus, the area under the crop is getting fragmented with 165 districts having areas of less than 10, 000 ha under the crop in 2005-07 compared to 103 in 1980-82.

The spatial distribution of rainy season sorghum area under the four area categories (very low, low, medium and high) is shown in Map 3. Between 1982 and 2007, by and large the districts that were growing rainy season sorghum continued to grow it albeit with reduction in area. The decline in area in Andhra Pradesh and Madhya Pradesh was most prominent. In addition, even as the area under rainy season sorghum is getting fragmented, its overall area is now increasingly concentrated in fewer districts. For instance, in 1980-82, 133 districts accounted for 97% of rainy season sorghum area in India, while in 2005-07, only 71 districts accounted for 91% of the area.

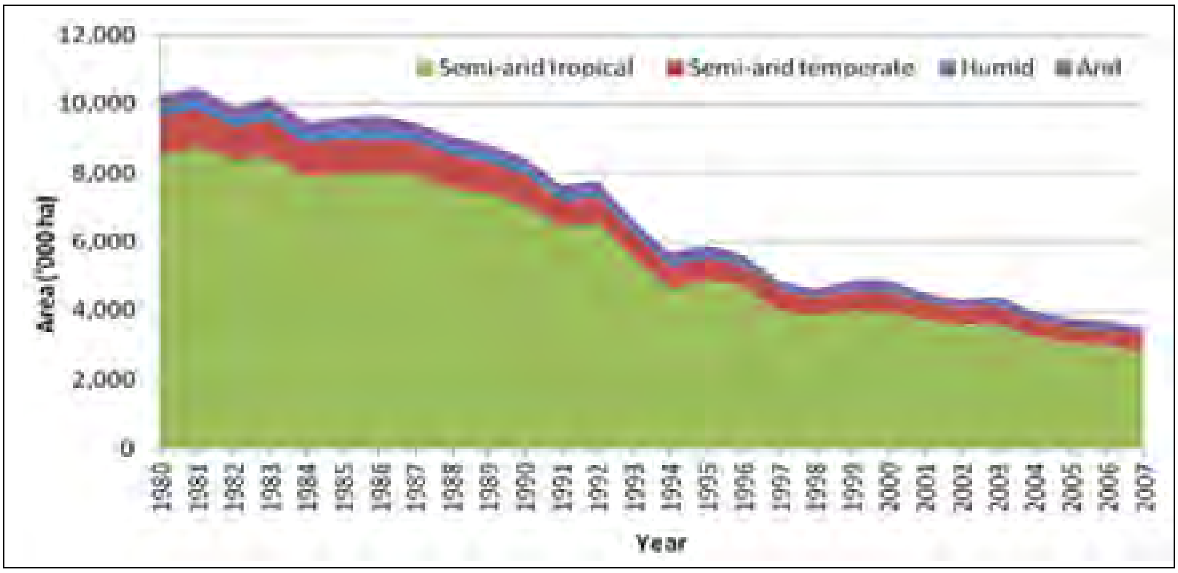
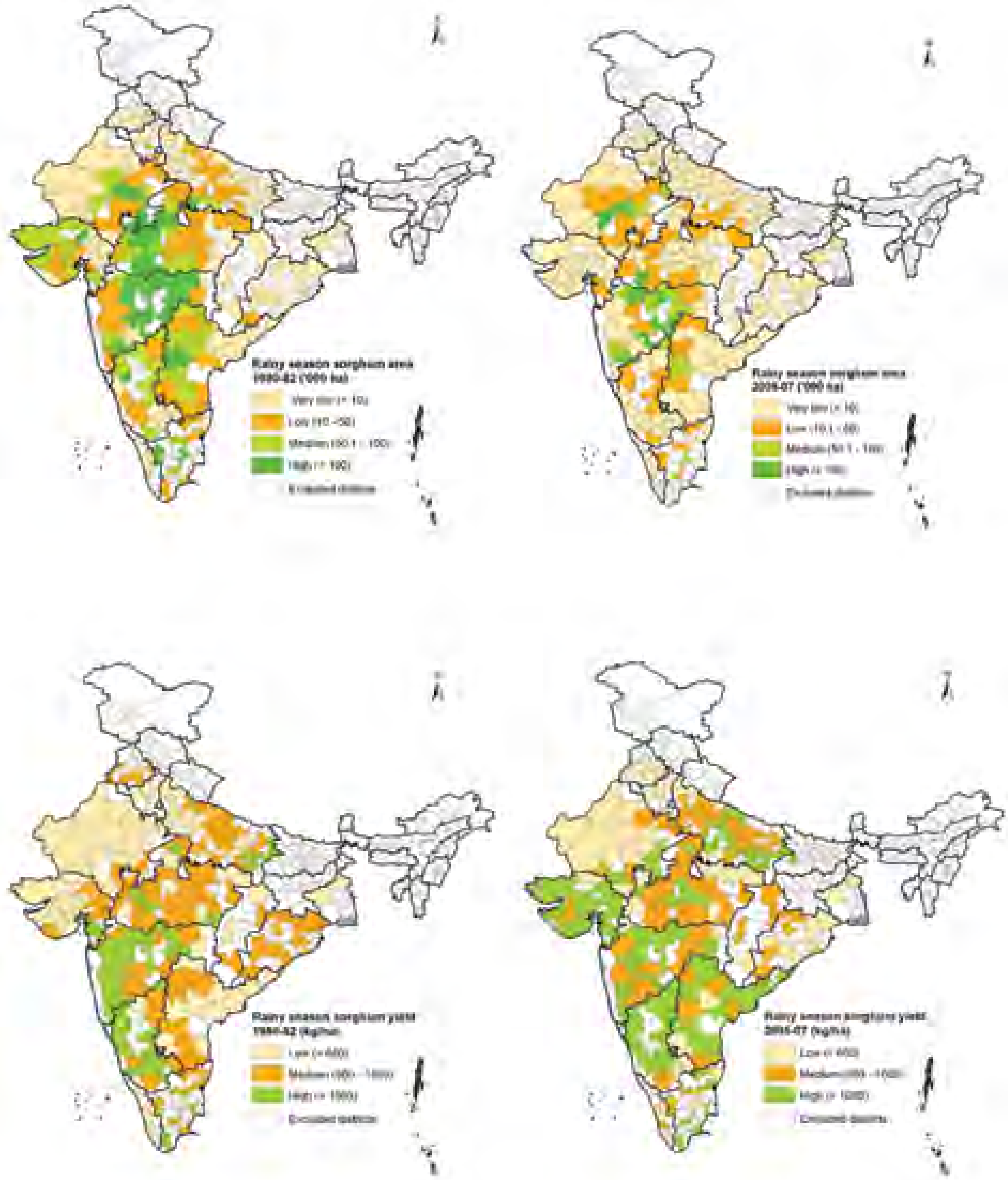


Figure 6. Rainy season sorghum area trends by zone, 1980 to 2007.

[3] The 45 degree line represents those districts where the ratio of area under this crop has remained unchanged between 1980-82 and 2005-07.



Map 3. Variations in rainy season sorghum area and yield by district in India

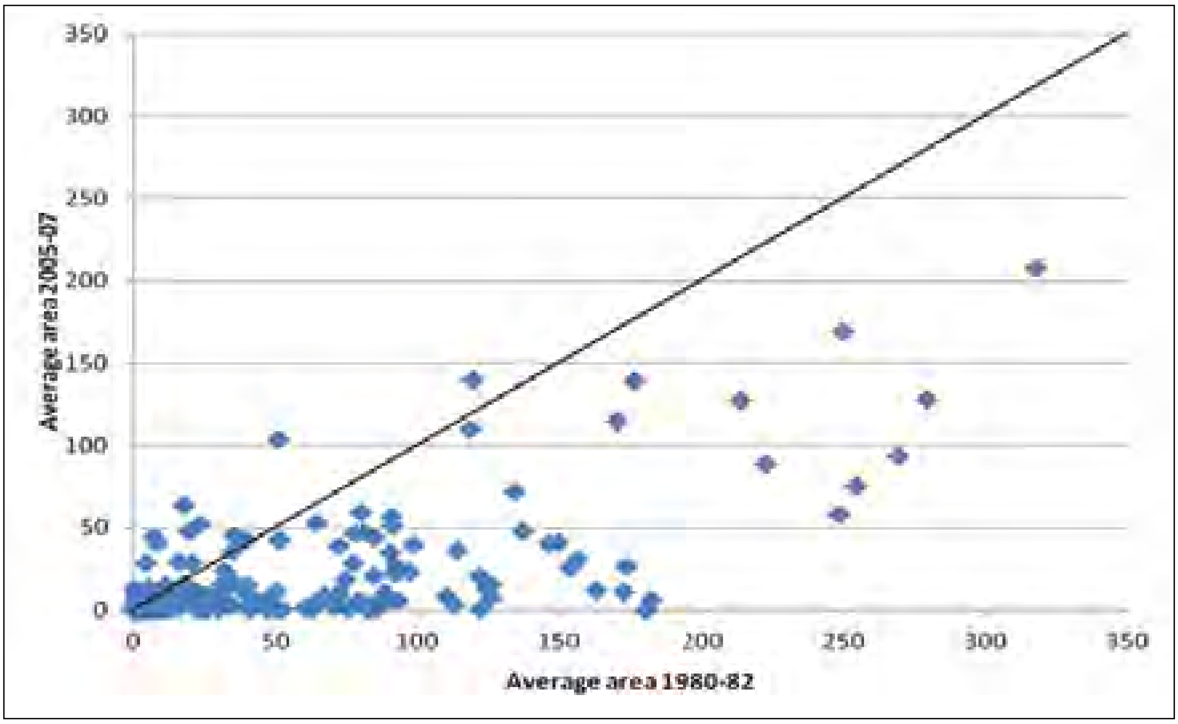


Figure 7. District-level change in rainy season sorghum area ('000 ha) in India, 1980-2007.

Postrainy season sorghum

The SAT accounts for 98% of the area under postrainy season sorghum (Fig. 9 and Table 3). The decline in area under the crop has been much slower compared to rainy-season sorghum, declining at 1.2% per annum between 1980 and 2007. Much of the decline is due to the decline in area in Karnataka and Andhra Pradesh. However, between 1995 and 2007, the area decline was arrested and since then area growth has been virtually stagnant.

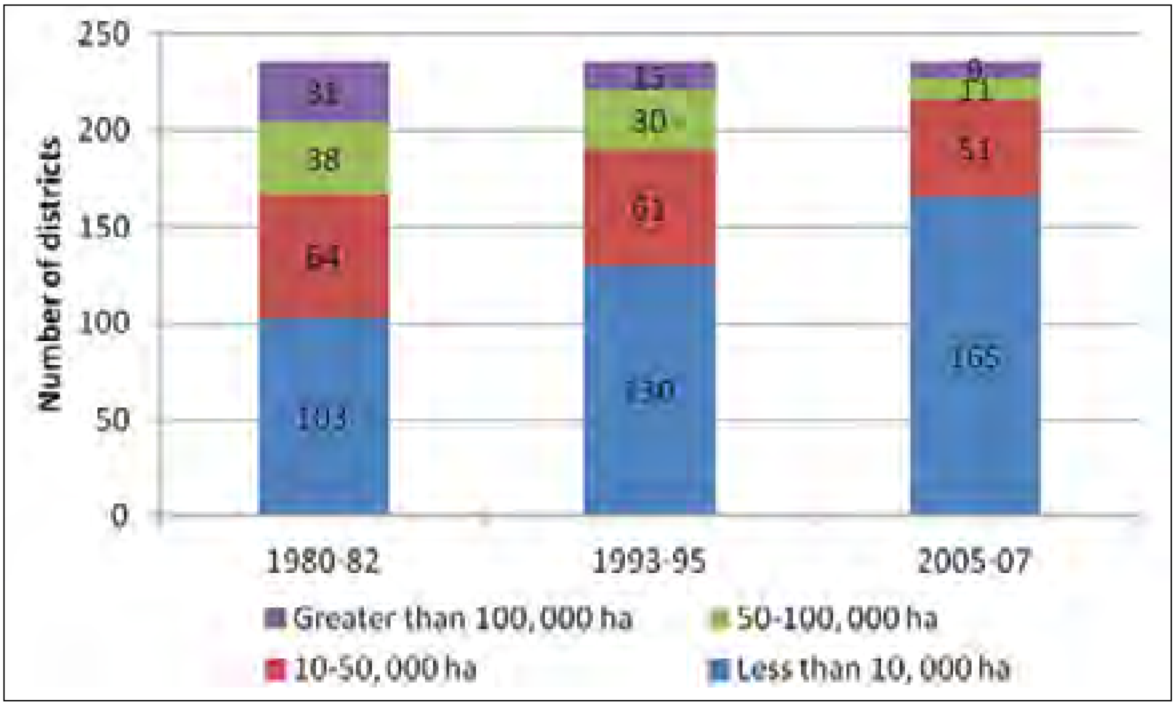


Figure 8. Distribution of rainy season sorghum districts by area, 1980-2007.

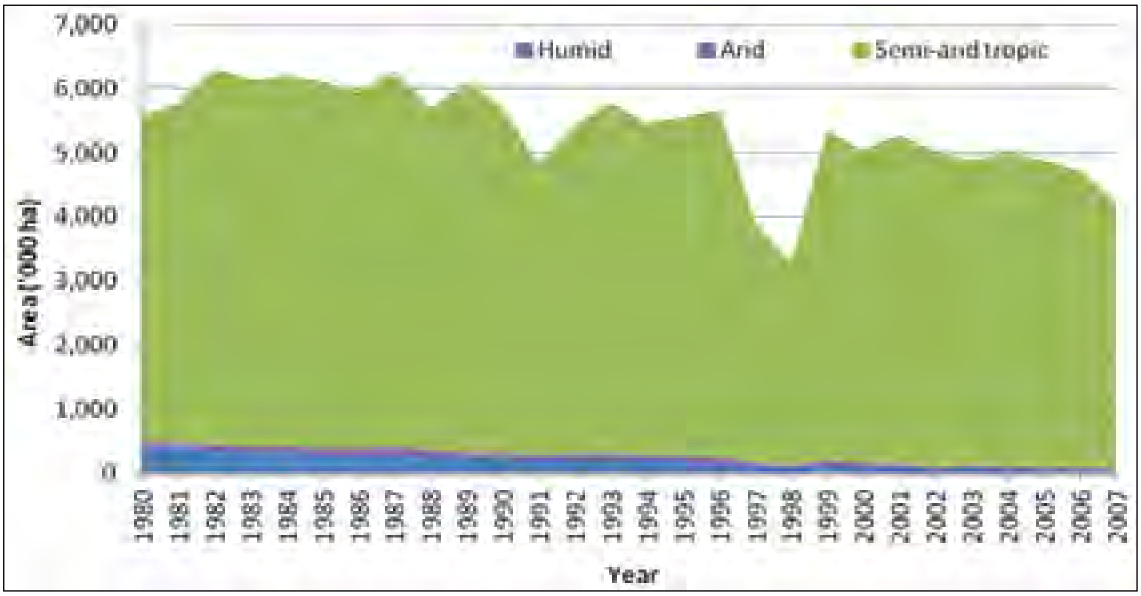


Figure 9. Postrainy season sorghum area trends by zone, 1980-2007.

Postrainy season sorghum area is also becoming fragmented but less so compared to rainy-season sorghum. Hence, the distribution of postrainy season sorghum-growing districts remained relatively similar in 2005-07 when compared to that in 1980-82. Only the medium category (50,000-100,000 ha) registered some change, falling from 11 districts in 1980-82 to 1 in 2005-07. Most of these districts now fall in the (less than 10,000 ha) growing districts (Fig. 10).

Spatial distribution of postrainy season sorghum area under the four area categories is shown in Map 4. While the area under postrainy season sorghum remained more or less similar between the two periods in Karnataka and western Maharashtra, the area under the crop declined mainly in Andhra Pradesh and central Maharashtra. The bulk of postrainy season sorghum area is now concentrated only in western Maharashtra and northern Karnataka, indicating greater concentration or specialization.

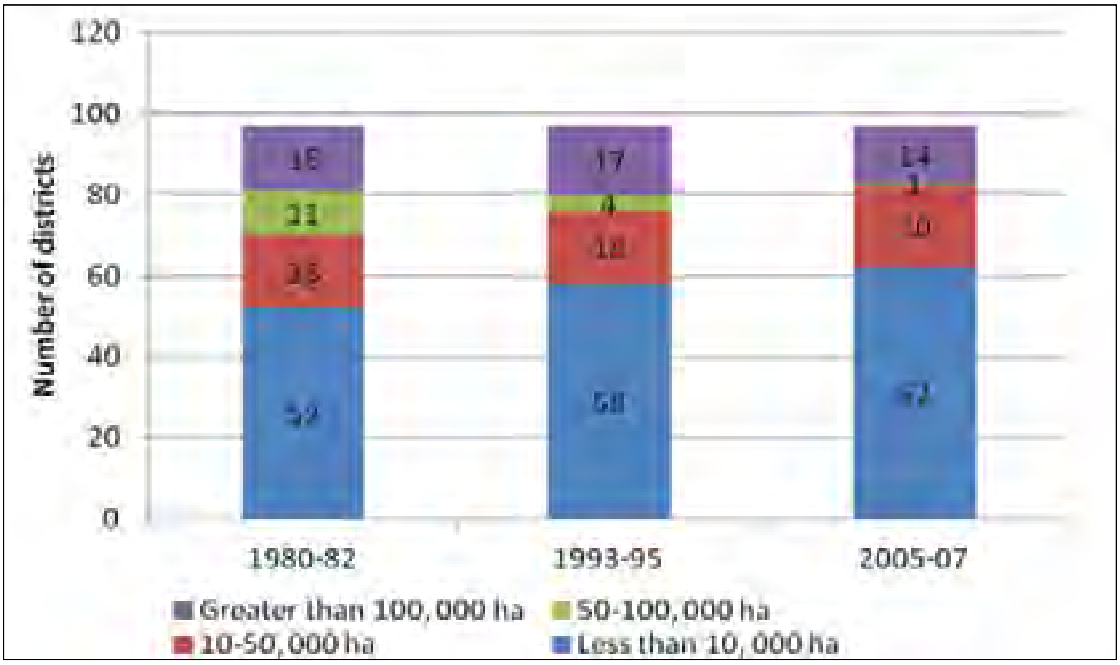
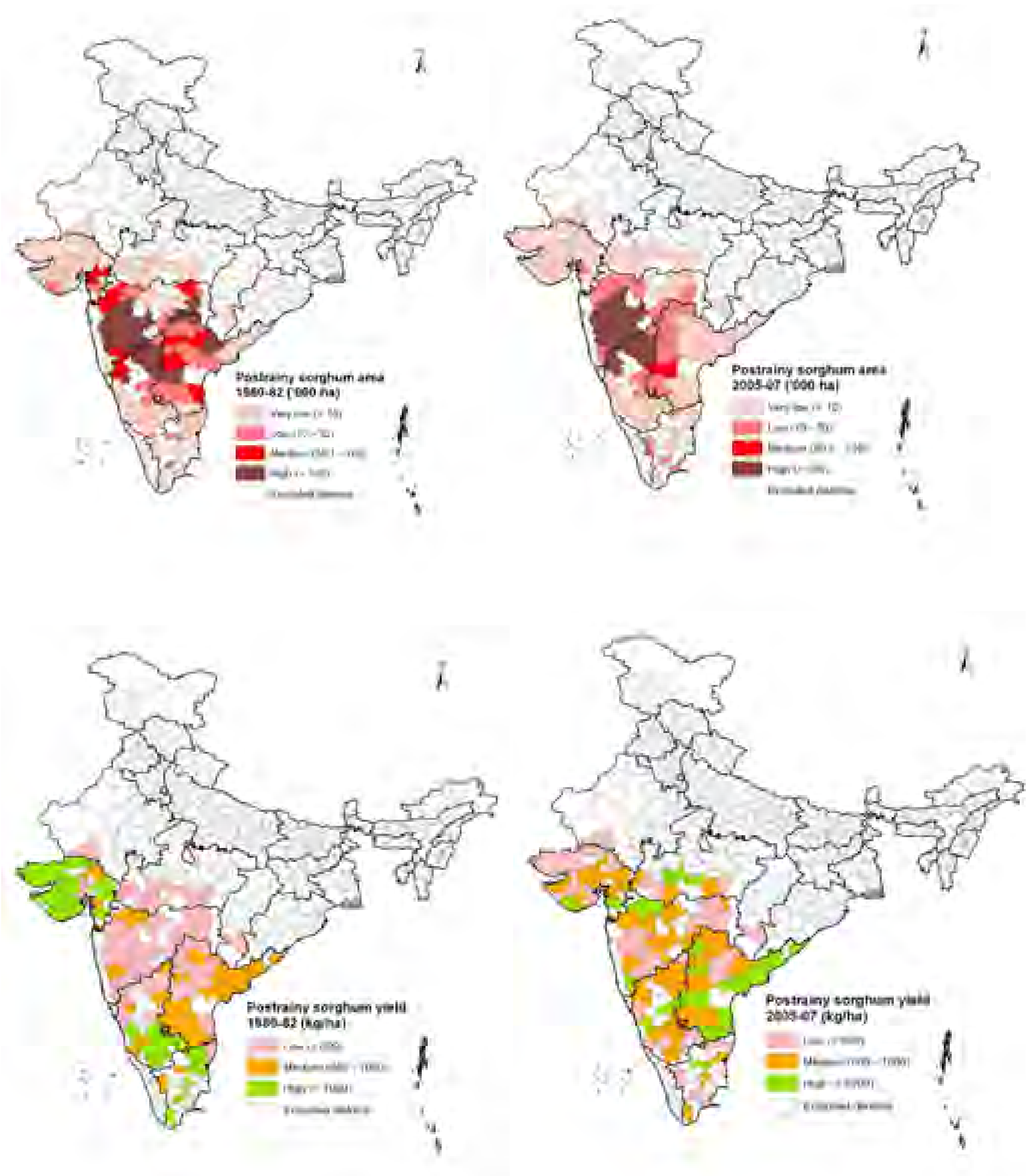


Figure 10. Distribution of postrainy season sorghum districts by area, 1980-2007.



Map 4. Variations in postrainy season sorghum area and yield by district.

Yield

Global yields of sorghum have remained relatively stagnant. Between 1980 and 2009, global yields declined marginally at 0.4% (Table 2) per annum from 1.5 t ha^{-1} to 1.4 t ha^{-1} (Table 1). The decline was slightly more marked in the early period (1980-1994), when yields decreased at 0.7%. While most of the regions and important growing countries such as India and China significantly influenced this trend, other regions like Oceania, Africa and Latin America went against it, registering a positive growth in the second period (Table 2). In Africa, while overall growth in yields remained relatively stationary at 0.4% over the period 1980-2009, the later part (1995-2009) witnessed a positive growth rate of 1.1% compared to the negative growth rate of -1.0% in 1980-1994. Area expansion, however, continues to be the dominating influence on overall positive growth in sorghum production in the region. In Latin America, despite the overall decrease in area, sorghum production in the latter period experienced an increase owing to increased yields.

In Asia, yield levels are generally close to the the world average and the yield growth rate in the region was relatively stagnant at 0.4% between 1980 and 2008. Growth was highest in Southeast and West Asia albeit from low bases, increasing at 2% per annum during 1980-2009.

Despite the general reduction in sorghum area and production in East Asia, yields increased overall at 1.8% between 1980 and 2009 (Table 2). The region is dominated by the trends prevailing in China. The average yield levels in China were the highest in the world at 4 t ha^{-1} in 2006-08, and thus China accounted for nearly 4% of global sorghum production despite accounting only for 1% of global area. Yield levels in South Asia are dominated by the trends in India. Yield levels in India were on average relatively low at about 0.9 t ha^{-1} in 2006-08 (Table 1). While sorghum is grown in Pakistan, it is not a very large producer, accounting only for 3% of Asia's sorghum area.

Rainy and postrainy season sorghum yields in India

Rainy season sorghum

Yield levels of sorghum, vary across the growing seasons in India. Yields of rainy season sorghum were higher at 1 t ha^{-1} in 2005-07 than those of postrainy season sorghum which are at 0.7 t ha^{-1}. Yield growth rates for rainy season sorghum were also higher at 1.2% per annum for the period 1980 to 2007 compared to 0.8% for postrainy season sorghum during the same period (Table 4). The lower yield for postrainy sorghum is due to the fact that it is cultivated on residual soil moisture with low input use

Table 4. Growth rates and yields for rainy season and postrainy season sorghum by zone.

	Growth rate (%)			Yield (kg ha^{-1})
	1980-94	1995-2007	1980-2007	2005-07
Zone	**Rainy season sorghum**			
India	2.2	-0.23	1.2	**1,016**
Humid	1.01	-1.23	-0.63	987
Semi-arid temperate	2.06	-0.25	0.58	761
Semi-arid tropic	2.26	-0.02	1.39	1,085
Arid	2.51	0.52	0.9	590
	Postrainy season sorghum			
India	1.7	-0.38	0.81	**739**
Humid	-1.13	4.29	0.25	834
Semi-arid temperate	NA	NA	NA	NA
Semi-arid tropic	1.87	-0.49	0.87	736
Arid	0.36	0.81	1.11	812

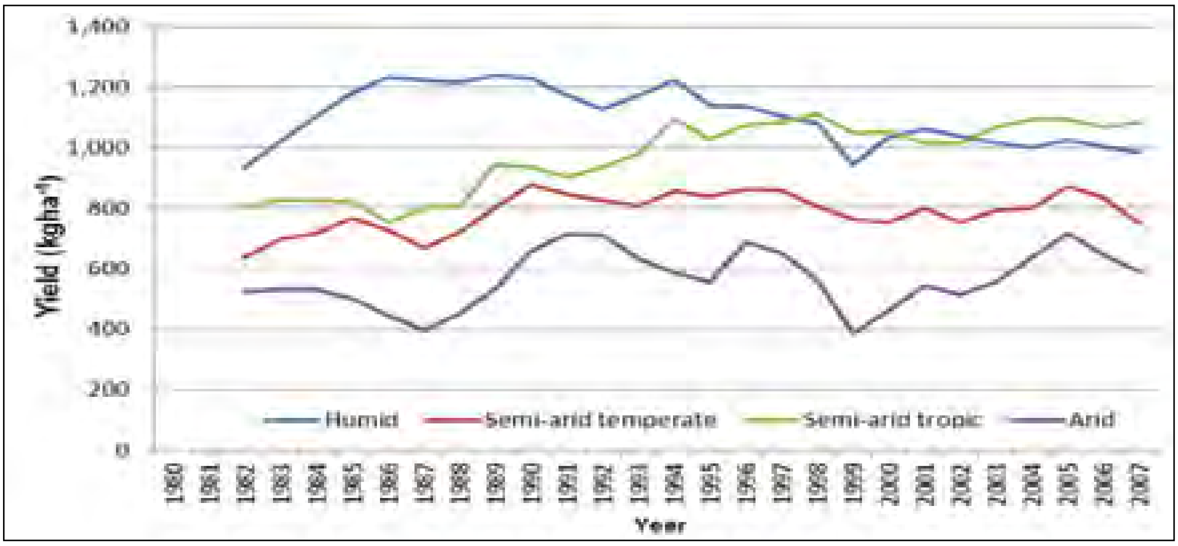


Figure 11. Rainy season sorghum yield trends by zone, 1980-2007 (smoothed 3 year averages).

in areas where there are few alternatives. The most dominant cultivar that is grown is the improved landrace cultivar *maldandi* which is a high-yielding variety, and accounts for nearly 86% of the area under postrainy season sorghum.

There are considerable differences in the yields of rainy season sorghum by zone, owing to differences in soil type and rainfall. Sorghum cultivation is concentrated in the SAT, particularly in Maharashtra, and consequently the yields in this state contribute greatly to the overall yield in the country. The yields are highest in the SAT at 1.1 t ha^{-1} compared to 0.8 t ha^{-1} in the semi-arid temperate zone. Until the 1990s, yields were highest in the semi-arid temperate zone (Fig. 11). Yields were lowest in the arid zone at 0.6 t ha^{-1} (Table 4).

The faster yield growth for rainy season sorghum is also reflected at a more disaggregated district level. The distribution of area growing rainy season sorghum has been tilting towards yields greater than 1 t ha^{-1} since the 1980s. The area under rainy season sorghum with higher yields increased to 43% of rainy season sorghum area in 2005-07 compared to 26% in 1980-82 (Fig. 12). Consequently the area under medium and low yields fell from 74% in 1980-82 to 57% in 2005-07.

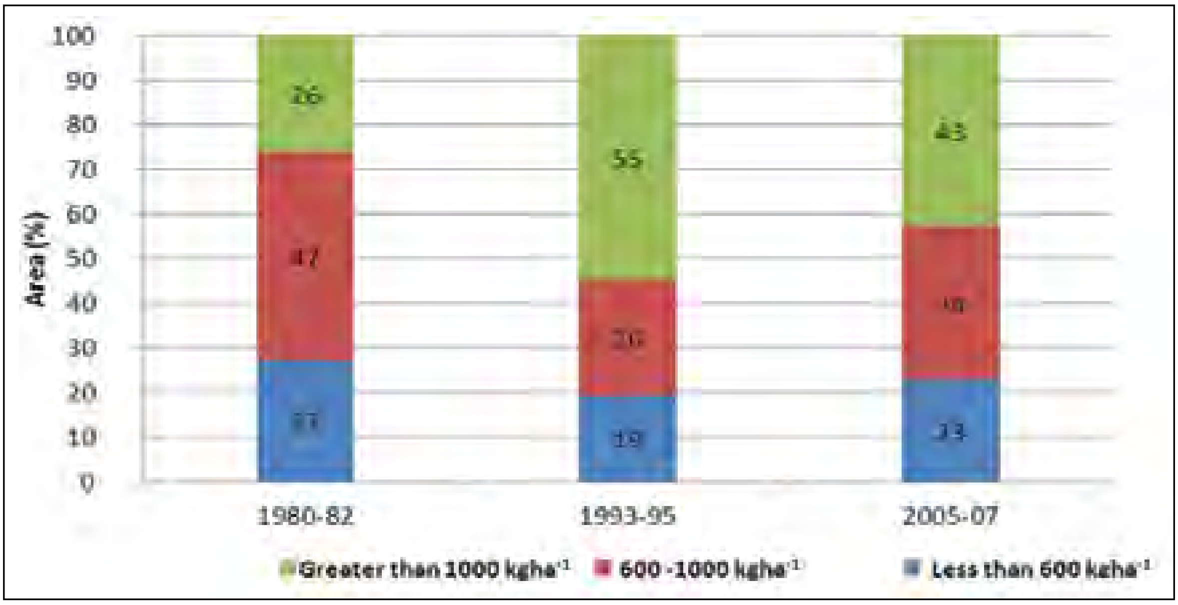


Figure 12. Distribution of rainy season sorghum area by yield, 1980-2007.

The spatial changes in yields of rainy season sorghum across districts between 1980 and 2007 are shown in Map 3. As can be seen there is an overall increase in yields across the districts. While the districts in Rajasthan (western India) continue to be dominated by low yield levels, districts in Gujarat and Uttar Pradesh, as also Maharashtra and Karnataka, now fall into the high yield category.

There are considerable yearly fluctuations in yields of rainy season sorghum in the different agroecological zones where it is grown. With the exception of the SAT, where after the mid-1990s the fluctuations reduced (Fig. 14), fluctuations increased both in magnitude and frequency in the other agroecological zones. In the semi-arid temperate region, in 8 out of the 26 years considered, yields declined by more than 10% from the long-term average yield while they were greater than 10% of the long-term average yield also in 8 out of 26 years (Fig. 13). The yield variation in the arid regions is far more prominent with the widest fluctuations being recorded in 1996, when yield increased by 90% over the long-term average yield, only to fall by 60% in 1998 (Fig. 15).

Figure 13. Variations in rainy season sorghum yields in semi-arid temperate regions, India.

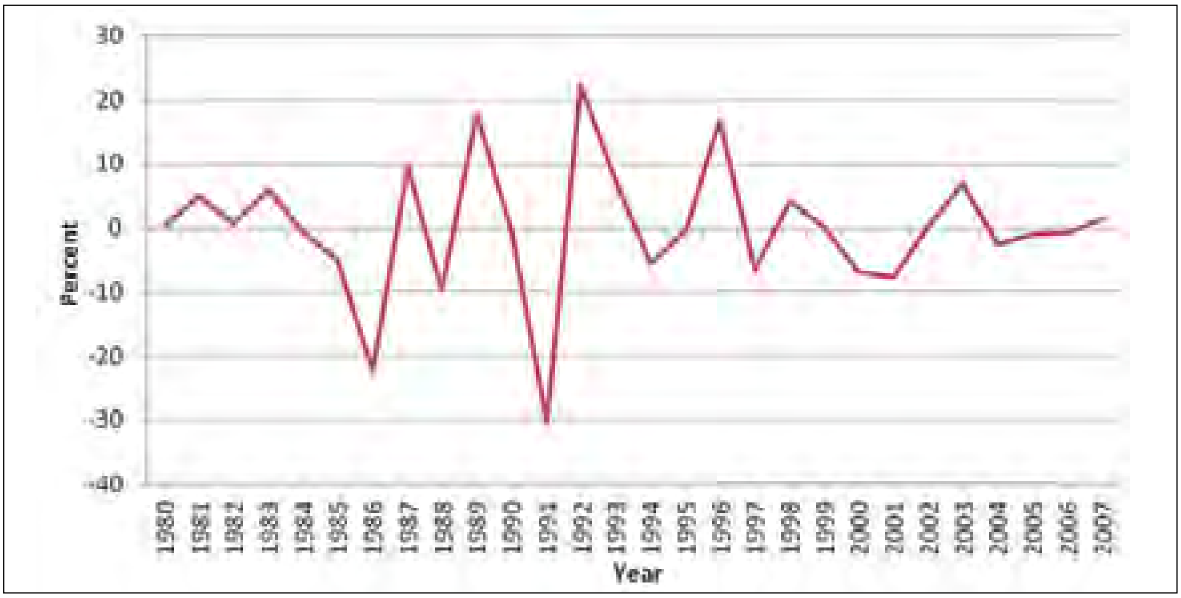


Figure 14. Variations in rainy season sorghum yields in semi-arid tropic regions, India.

Figure 15. Variations in rainy season sorghum yields in arid regions, India.

Postrainy season sorghum

The yield levels across agroecological zones for postrainy season sorghum appear to be converging since the early 2000s (Fig. 16). The yields in the SAT were lowest among the agroecological zones at 0.7 t ha^{-1} in 2005-07. Despite the yield levels being marginally higher in both the arid and the humid regions, these regions do not exert much influence at the aggregate level. The yields of postrainy season sorghum in the SAT grew at 0.9% per annum over the period 1980 to 2007 (Table 4).

Unlike for rainy season sorghum, districts with yields above 1 t ha^{-1} of postrainy season sorghum accounted for only 5% of the total area in 2005-07 (Fig. 17). Fifty-three percent of the area was accounted for by districts where yields averaged between 600-1000 kg ha^{-1}, mostly concentrated in Maharashtra. The only visible change in the past 25 years is that districts with low yield levels that accounted for 42% of postrainy season sorghum area in 2005-07 compared to 75% in the 1980s. There has thus been a transition of area/districts from low to medium yield categories.

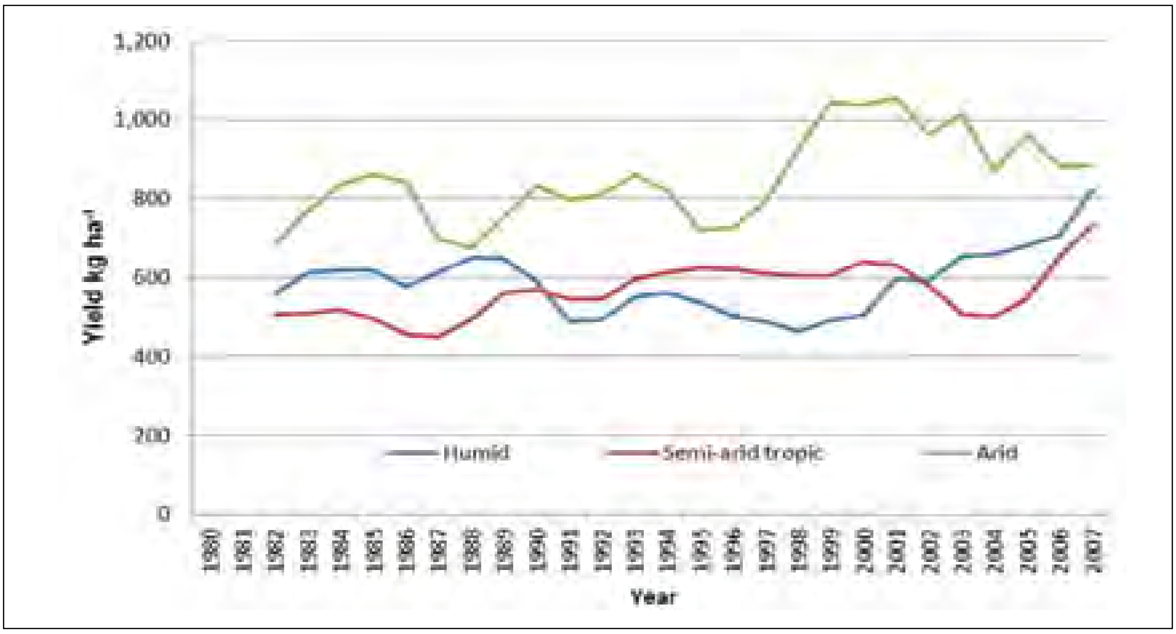


Figure 16. Postrainy season sorghum yield trends by zone (smoothed, 3 year averages).

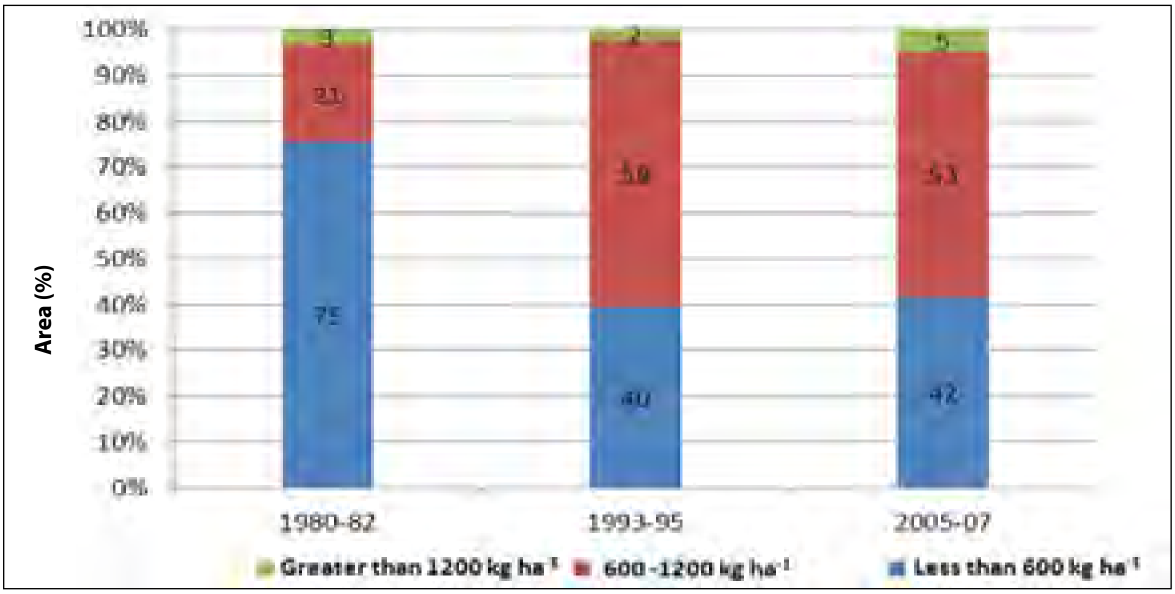


Figure 17. Distribution of postrainy season sorghum area by yield, 1980-2007.

The spatial changes in postrainy season sorghum yields across districts between 1980 and 2007 are shown in Map 4. It is evident that despite the drop in area in Andhra Pradesh and Karnataka, the little area under postrainy season sorghum in these states is under the medium- to high-yield categories. Much of the growing area in Maharashtra is in the low- to medium-yield category as old improved landrace cultivars such as *maldandi* are still popular with the farmers.

Yearly fluctuations of postrainy season sorghum yields are wide and common in all agroecological zones, with yields falling below 10% of average in 7 out of 26 years in the SAT (Fig. 18). 2003 was the worst affected, with yields declining by more than 40% from the long-term average yield levels.

Production

Global sorghum production declined at the rate of 0.7% per annum between 1980 and 2009 (Table 2). The decline was more marked in the first period between 1980 and 1994 (-1.4%) compared to -0.4% in the period 1995 to 2009. Overall, owing to the availability of more drought-tolerant maize varieties and

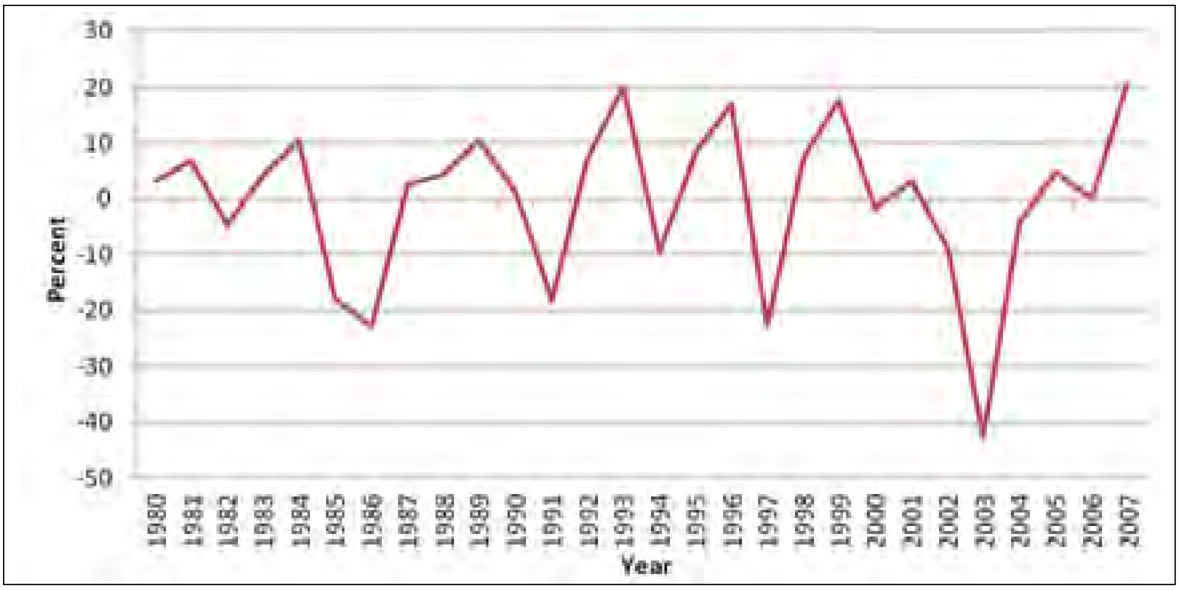


Figure 18. Variations in postrainy season sorghum yields in semi-arid tropic regions, India.

policy – induced changes (lowered support prices for sorghum in the US in 1985 (Lin and Hoffman 1989), the production in developed countries, (particularly in USA), declined from 21 million t in 1980-82 to 14 million t in 2007-09 (Table 1). Developed countries accounted for only 22% of the global production in 2006-08 compared to 32% in the early 1980s. The share of Australia in the global sorghum market has shown an increase from a low base in the 1980s. Production increased from 1 million t in 1980-82 to 2.3 million t in 2006-08, largely due to a combination of increase in area and yield.

Global share of developing countries in sorghum production increased to 78% by 2009. However, individual countries exhibited varying trends during the same period which are somewhat masked at an aggregate level. Production in Africa doubled from 12 million t in 1980-82 to 25 million t in 2007-09, more due to area expansion than productivity increases. Production in Latin America has remained relatively steady, declining slightly from 13 million t in 1980-82 to 12 million t in 2006-08, despite contraction in area.

Sorghum production decreased in Asia, declining by nearly 4 million t each in both South Asia and East Asia between 1980-82 and 2007-09. Production increased marginally in West Asia from 0.6 million t in 1980-82 to 0.7 million t in 2007-09, largely due to productivity gains, as area under sorghum declined in the same period. Saudi Arabia in particular drove this increase, with production increasing from 87,000 t in 1980-82 to 245,000 t in 2006-08.

In India, production declined at 2.1% per annum between 1980 and 2008 (Table 2). The decline was more rapid during the latter period of 1995 to 2009 (2.4%). In keeping with the area trends, rainy season sorghum production decreased at a faster rate than postrainy season sorghum. Consequently, the share of rainy season sorghum production in total sorghum production declined to 44% from 63% in the early 1980s. Sorghum in India is largely grown under rainfed conditions, which accounts for the wide fluctuations in the production trends for both postrainy season and rainy season orphan.

Production Constraints

The cultivation of sorghum is beset by many biotic and abiotic constraints in the major growing areas that contribute to keep the yield levels low. Grain mold causes significant losses in both grain yield and quality, particularly in areas where improved cultivars have been adopted as they are of short- to medium-term duration. In these cultivars, flowering and grain development coincides with high rainfall that increases their susceptibility to mold. Other important diseases include anthracnose, charcoal rot, downy mildew, ergot and leaf blight. Insect pests constrain production in many areas. Stem borers occur in all areas, head bugs and midge are most important in western Africa, and shoot fly causes substantial losses in late and off-season sowings in both Asia and Africa.

Sorghum cultivation is dominated by smallholder production systems under rainfed conditions and low input use. Consequently, variable rainfall leads to large fluctuations in production. This increases the price risk that sorghum producers face, as a result of which they tend not to invest in fertilizers or seed of improved varieties.

Inadequate government policy support also limits the expansion of sorghum output in many countries. In a number of developing countries that had long-standing price support policies for sorghum, this support has been drastically reduced or eliminated, mainly as a result of market deregulation. In Africa, maize supplanted sorghum, as government support measures for sorghum are relatively small compared to maize. In Asia, particularly in India, irrigation and fertilizer subsidies have increasingly favored rice, wheat and cash crops at the expense of coarse grains, while favorable procurement policies for rice and wheat have helped to increase to a large extent the area under these crops (Nagaraj et al. 2012).

On the demand side, changing food preferences owing to rising income and increased urbanization is leading to a substitution of coarse grains like sorghum with fine cereals and livestock products.

Utilization

Sorghum has been used as a food and feed crop for centuries all over the world. As a food crop it is consumed as whole grain or is processed into flour. Two common types of sorghum are grown — red and white grain. In Africa, typically, white-grain sorghum is eaten as meal, while red-grain sorghum is used for brewing beer. Sorghum is a rich source of protein, vitamin B1, B2, niacin, iron and zinc. It is one of the cheapest sources of iron and zinc, second only to pearl millet (Parthasarathy Rao et al. 2006). As animal feed, sorghum grain is considered to be a close substitute for maize, and sorghum feed grain prices generally track those of maize very closely. Furthermore, sorghum fodder is an important livestock feed source in the developing countries, particularly in the dry months when other sources of feed are scarce. Globally, total availability of sorghum decreased from 64 million t in 1980-82 to 59 million t in 2005-07 (Table 5). The steepest declines occurred in Asia, North America and Europe owing to a number of policy induced measures that led to a decline in area and production and changing consumer preferences. Consumption in Africa has nearly doubled during the same period owing to increased production and area expansion in the region. Similarly, availability in Australia increased from 0.3 million t in 1980-82 to 1.8 million t in 2005-07, as also in Latin America where it increased marginally from 12 million t to 13 million t over the same period. Availability in East and South Asia decreased from 11 million t each in 1980-82 to 4 million t in East Asia and 7 million t in South Asia in 2005-07.

Sorghum availability in India declined from 11 million t in 1980-82 to 7 million t in 2005-07. There are, however, differences in the utilization of rainy and postrainy season sorghum in India. The decline in per capita food consumption of sorghum at the all-India level is mainly due to decline in consumption of rainy season sorghum while the decline was less sharp for postrainy season sorghum. Most of the postrainy season sorghum grain is used for food since it is of superior quality with a bold grain, lustrous white color and sweeter taste. Postrainy season sorghum grain prices are higher by 20-40% compared to rainy season sorghum, thus making it uneconomical for alternative uses like poultry feed and alcohol manufacture

Table 5. Trends in sorghum utilization ('000 t).

	1980-82				2005-07			
Region/ Country	**Total availability**	**Feed**	**Food**	**Other uses**	**Total availability**	**Feed**	**Food**	**Other uses**
World	63,908	35,318	23,584	5,007	58,567	26,278	25,606	6,683
Europe	4,573	4,273	0	299	1,802	1,785	0	17
North America	10,729	10,452	110	166	4,831	3,533	308	989
Oceania	379	258	0	121	1,849	1,805	24	45
Africa	11,845	1,336	8,248	2,262	24,201	3,219	16,760	4,222
Latin America	12,410	11,654	248	507	13,494	12,886	185	424
Asia	23,973	7,345	14,977	1,652	12,389	3,051	8,353	985
Eastern Asia	11,403	6,521	4,438	445	3,968	2,775	1,041	151
China	7,562	2,699	4,423	440	2,496	1,331	1,016	149
Japan	3,656	3,656	0	0	1,430	1,430	0	0
Korea, Republic of	168	165	0	3	10	10	0	0
South Asia	11,384	214	10,033	1,137	7,484	97	6,619	769
India	11,090	133	9,843	1,114	7,316	88	6,473	755
Pakistan	216	11	185	19	168	8	145	14
Southeast Asia	60	49	0	11	78	75	0	3
Thailand	37	26	0	11	66	64	0	3
Western Asia	1,126	560	506	59	848	93	693	62
Israel	441	422	0	16	90	73	0	17

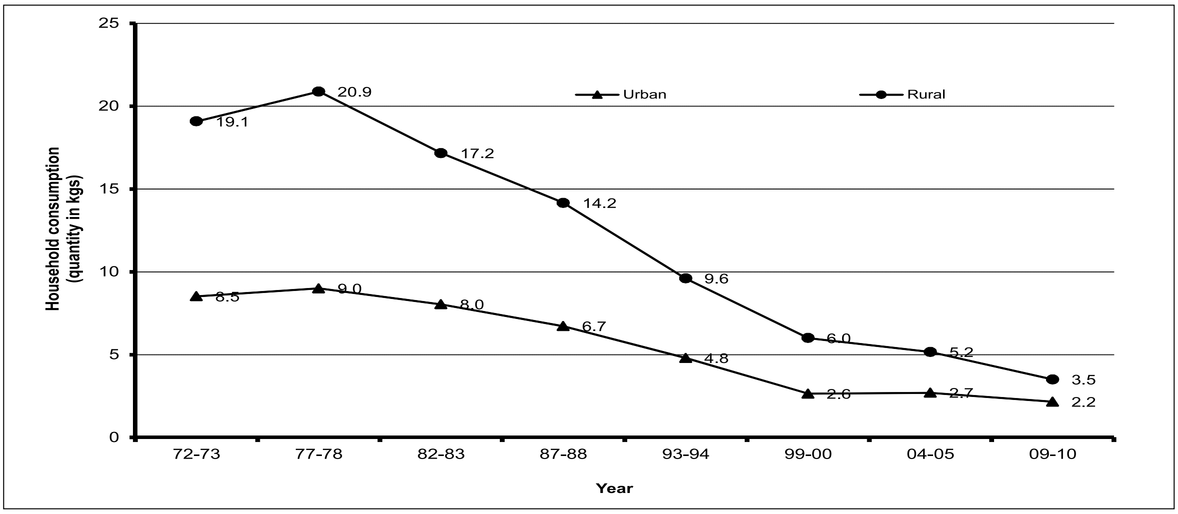
compared to other close substitutes. Besides its use as a staple at household level, small quantities of postrainy season sorghum are used in the processed food industry. On an average, 3–5% of postrainy season sorghum is used in the processed food industry while another 5% is used to prepare *rotis* sold at restaurants (Basavaraj and Parthasarathy Rao 2012).

Food use

Sorghum continues to be an important staple in Africa and in parts of India where it is traditionally consumed. Food consumption of sorghum in Africa doubled between 1980-82 and 2005-07 from 8 million t to 17 million t (Table 5). Per capita food consumption of sorghum is the highest in Africa, where despite an increase in the population between 1980 and 2007, per capita consumption increased from 17 kg capita^{-1}yr^{-1} in 1980-82 to 18 kg capita^{-1}yr^{-1} (Table 6). The importance of sorghum in the region is further demonstrated when country-wise consumption trends are examined. For example, sorghum contributes over one third of the total caloric intake in Sudan and Burkina Faso (FAO / ICRISAT 1996).

In Asia, increases in income and changing consumer preferences have led to the decline in consumption. Consumption of sorghum as food in China declined steadily from 4.4 kg capita^{-1} in 1980-82 to 0.8 kg capita^{-1} in 2005-07 (Table 6). However, it continues to be consumed in the rural semi-arid and arid regions as porridge, substituting for rice. In India sorghum is a traditional cereal staple but has been declining in popularity and importance over time, particularly in urban areas.

An in-depth analysis of the consumer survey data for India conducted by the National Sample Survey Organization reveals that between 1980 and 2010[4] both for rural and urban consumers, the annual per capita consumption of sorghum declined sharply (Fig.19). This decline is largely attributable to the fact that as incomes increase, fine cereals are substituted for sorghum. Government policies providing subsidized fine cereals like rice and wheat have further exacerbated this situation. However, since the mid-1990s, per capita sorghum consumption while continuing to decline has slowed down compared to the sharp declines in the 1970s and 1980s.



Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62stnd Round, 2009-10.

Figure 19. Annual per capita consumption of sorghum in urban and rural India (kg).

[4] National Sample Survey Organization (NSSO) conducts regular consumer expenditure surveys as part of its "rounds", with each round normally of a year's duration. The surveys are conducted through household interviews, using a random sample of households covering practically the entire geographical area of the country. NSSO adopts a multi-stage stratified sampling design in their surveys. The first-stage units are villages for the rural sector and Urban Frame Survey (UFS) blocks for the urban sector. The second-stage units are households and an intermediary stage for the larger sample villages or blocks. The survey period is divided into four sub-rounds of three months' duration for each of the round. For the 61st round (July 2004-2005) a sample of 79,298 and 45,346 households from rural and urban areas respectively were surveyed. The estimates presented here are based on these surveys.

Table 6. Per capita consumption trends of sorghum (kg $capita^{-1}$ yr^{-1}).

Region/ Country	1980-82	1993-95	2005-07
World	5.3	4.5	3.9
Europe	0.0	0.0	0.0
North America	0.4	1.2	0.9
Oceania	NA	NA	NA
Africa	16.8	18.0	18.0
Central America	1.6	1.3	1.0
Asia	5.8	3.6	2.1
Eastern Asia	3.8	1.7	0.7
China	4.4	2.0	0.8
Japan	0.0	0.0	0.0
South Asia	10.5	6.9	4.2
India	13.9	9.3	5.6
Pakistan	2.2	1.7	0.9
Southeast Asia	0.0	0.0	0.0
Western Asia	5.7	4.3	3.8
Saudi Arabia	9.0	9.8	9.2

The largest decline in consumption has been in the states of Andhra Pradesh and Madhya Pradesh where the availability of subsidized staples such as rice in Andhra Pradesh and wheat in Madhya Pradesh has contributed to the increased substitution of sorghum. In the major growing regions of the states of Maharashtra and Karnataka, where sorghum had a major share in the consumption basket in the 1970s, it is still able to compete in the cereal consumption basket because of existence of strong preference for sorghum in the daily food requirement (Basavaraj and Parthasarathy Rao 2012).

Furthermore, disaggregation of NSSO data by expenditure classes reveals that sorghum is an important crop for the nutritional security of the poor in India[5]. The low income consumers (about 50% of the population in rural and urban areas each) account for 52% and 67% of sorghum consumption in rural and urban areas of India respectively (Table 7). Their per capita consumption is also the highest among the three income groups.

Feed use

In the early 1980s 55% of sorghum grain was used as feed globally (Table 5). Sorghum provides nearly the same metabolizable energy as maize, is rich in niacin, and has higher crude protein content than maize (FAO-ICRISAT 1996). The demand for sorghum grain as feed is concentrated in the developed countries and the middle income countries of Latin America and Asia where the demand for livestock products is relatively high. However, the demand for sorghum from this sector is very sensitive to change in the maize market, as maize is a close substitute. The yield improvements in maize and the policy changes in USA (the main driver in sorghum feed markets) favoring maize over sorghum has lowered the competitiveness of sorghum vis-à-vis maize. Furthermore, consumer preferences for meat color have contributed to sorghum being discounted for feed use (poultry meat from maize-fed birds tend to have a golden yellow shank color compared to the white color of sorghum-fed birds). It is expected, however, that sorghum

[5] The NSSO survey reports classify the data in 12 expenditure categories. The 3 categories used in the text (high, medium, and low) were obtained by equally aggregating the 12 categories (bottom, middle and top one third each).

Table 7. Consumption of sorghum by expenditure class, 2009-10.

Expenditure category	Consumption ('000 t)	Consumption (%)	Per capita consumption (Kg yr^{-1})	Population (%)
Rural average consumption by expenditure category				
Low (Less than Rs. 765 ($14.98) per month)	1,447.6	52.2	4.75	50
Medium (Rs. 765- 1477 ($14.98- 28.93 per month)	1,106.9	39.9	3.64	40
High (Greater than Rs. 1477 ($28.93) per month)	221.1	8.0	1.45	10
Urban average consumption by expenditure category				
Low (Less than Rs. 1307 ($25.60) per month)	414.5	67.3	3.67	50
Medium (Rs. 1307-3166 ($25.60- 62.02) per month)	172.0	27.9	1.52	40
High (Greater than Rs. 3166 ($62.02) per month)	29.1	4.7	0.52	10

Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62[stnd] Round, 2009-10.

feed use will increase in the future, largely owing to renewable energy legislation in most countries that mandates the mixing of biofuels to meet emission reduction cutoffs, and which has resulted in a diversion of maize to ethnol production lowering its availability for feed use.

Overall, the utilization of sorghum as feed has declined in the world, largely due to decreases in North America and Europe where maize has taken over as the primary feed source. In Australia, sorghum is almost entirely used for feed and plays a key role in providing feed grains to the beef, dairy, pig and poultry industries in the country. Sorghum feed usage in Latin America is the highest in the world, accounting for 46% of the total in 2005-07, with Mexico, Argentina and Brazil being the largest consumers. These trends are expected to continue owing to increased livestock demand in the region and the domestic policies in various Latin American countries that restrict maize imports.

In Asia, Japan and China are the main consumers of sorghum grain feed. In 2005-07 together they accounted for 90% of Asia's sorghum feed consumption. In Japan, where there is a preference for white meat, sorghum is an important ingredient in compound feed rations for poultry, pork and some beef cattle. However, historical trends in both countries indicate that the popularity of sorghum feed is declining (Table 5).

Grain sorghum is a valuable feed for livestock because it has a higher protein and fat content than maize. It is also high in vitamin A. It is however, more difficult to digest because of the tough seed coating and often needs to be cracked or heated using mechanical methods to break the seed coating. In India, sorghum grain is used as poultry feed. Its popularity in this use pattern has been increasing, with the poultry farms substituting sorghum for maize depending on the relative price of the two crops. Sorghum is generally substituted to the extent of 25-50% of maize if its price is 10-15% lower than maize price. The poultry industry in India is growing at 5% per annum and the associated demand for sorghum feed is expected to increase in the near future.

Fodder

The use of sorghum as a dual-purpose crop is restricted largely to the developing countries of Africa and Asia, where besides grain, the straw/stalk is an important component of livestock feed. Sorghum stover is also considered to be more nutritious with a higher digestibility co-efficient compared to rice and wheat stover. In India, sorghum stover is stored and constitutes an important feed for livestock in the dry months of the year when other feed sources are scarce.

In India, the increased demand for livestock products due to increasing incomes and urbanization is driving the derived demand for fodder and feed from different sources. For sorghum, this is reflected in the faster increase in sorghum straw prices compared to grain. The grain to fodder price ratio fell from 6:1 in 1980 to 3:1 by 2005. Consequently, the value of fodder in total value of sorghum crop production also increased from 20% to 40% by mid-2000 (Kelley et al. 1993, Parthasarathy and Hall 2004). In Rajasthan, the value from sorghum fodder was nearly equal to the value from sorghum grain in 2009-10 (GOI). This trend is expected to continue in the near future with feed demand estimated to increase to 855 million t in India by 2020 driven by the livestock revolution (Dikshit and Birthal 2010).

Other uses

An increasing proportion of sorghum grain is being used in industrial alcohol and beer production. This is especially true of Africa where sorghum beer is an important cottage industry. Variously known as *bil-bil* in Cameroon, *burukuto* in Nigeria, *pombe* in East Africa and *bjala* in North Sotho region, sorghum beer is popular as it provides a cheaper alternative to barley-based beverages in these countries. In USA there has been a recent increase in the utilization of sorghum in gluten-free beer. In Asia, the use of sorghum in alcohol production is most popular in China to make beverages such as *kaoliang* and *maotai.* In India, the use of sorghum grain in making commercial grade alcohol is increasing in popularity. With the lifting of the ban on the use of food grains for the manufacture of alcohol, the demand for sorghum from this sector is expected to increase. Small quantities of sorghum are also being used by the food manufacturing industry for making biscuits, breads, noodles and cakes. With increasing awareness about the nutritional properties of sorghum, the demand for such products is increasing from a low base.

Trade

Global trade in sorghum grain is mainly to meet demand for livestock feed, primarily in the developed countries where it is an important ingredient of cattle feed. Consequently, traded volumes are very sensitive to sorghum-maize price differentials in the developed world.

The world market for sorghum currently represents only about three percent of global cereal trade as most sorghum continues to be consumed in the countries where it is produced. On an average about 15% of sorghum is traded relative to its production and this figure has been decreasing over time. Export volumes fell from 13 million t in the early 1980s to 6.8 million t by 2007-09 (Table 8). Global trade peaked in the early 1980s when the former USSR, as a result of the USA's export embargo, started to purchase large quantities of sorghum on the international market, mainly from Latin America. Only 6% of world sorghum trade is for use as food, mainly imported by countries in Africa.

North America, in particular USA, is the largest exporter of sorghum and has been dominating the international trade market since the early 1980s. However, exported volumes fell from 7 million t in 1980-82 to 5 million t in 1993-95 and have continued to maintain this level (Table 8). The reduction in export volumes was a result of the sharp cutback in sorghum production in USA in the late 1980s to early 1990s owing to agricultural policies that favored maize production over sorghum. Over 25% of sorghum exports from USA are sent to Mexico with France being the next largest importer.

Latin America is the second largest exporter of sorghum, but the exported volumes have reduced drastically. The main exporting country was Argentina in the early 1980s which exported 3 million t in 1980-82. However, the lifting of import restrictions on maize in various Latin American countries such as Mexico, Colombia and Venezuela and in the former USSR resulted in export volumes declining to 1.1 million t in 2007-09. The region is a net importer of sorghum, importing 2.5 million t with the greatest volume of imports going to Mexico.

Table 8. Trends in sorghum trade ('000 t).

	Exports			Imports		
Regions	**1980-82**	**1993-95**	**2007-09**	**1980-82**	**1993-95**	**2007-09**
World	13,129	7,620	6,881	12,803	7,485	7,650
Developed countries	8,404	6,293	5,357	4,266	815	2,608
North America	255	250	4,921	4,255	698	7
Europe	7,378	5,879	387	1	3	2,497
Oceania	771	165	50	10	114	104
Developing countries	4,725	1,327	1,525	8,537	6,670	5,041
Africa	456	455	118	183	377	939
Latin America	3,997	580	1,197	3,244	3,236	2,546
Asia	273	292	210	5,110	3,058	1,557
Eastern Asia	1	220	133	4,494	2,863	1,391
Japan	0	0	0	3,649	2,704	1,317
China	1	216	133	674	107	67
Republic of Korea	0	0	0	164	41	7
South Asia	2	69	71	85	14	14
India	0	69	71	8	0	0
Southeast Asia	269	4	5	46	12	22
Philippines	0	0	0	0	0	16
Thailand	230	3	5	0	1	1
Western Asia	0	0	0	486	169	130
Israel	0	0	0	357	168	74

Asia has been, and continues to be, a net importer. The bulk of imports flow into East Asia, particularly Japan, where sorghum is a preferred ingredient in feed concentrates in the poultry and pork industry. However, the volumes have been declining – from 3.6 million t in 1980-82 to 1.5 million t in 2007-09. Sorghum trade in the rest of Asia is very thin and does not account for very much of Asian sorghum trade.

Within India sorghum is traded across district and state boundaries. Typically rainy season sorghum is traded to meet the food demand for lower income consumers in the postrainy season sorghum districts. Similarly, postrainy season sorghum grain is traded to meet the demand of the high income groups in the rainy season growing states/districts. The trade for sorghum grown in both seasons also meets the demand of urban consumers in the major growing states. Besides food use, rainy season sorghum is traded long distance across the country to meet the demand of poultry feed industry and alcohol manufacturers (Market surveys under HOPE project, 2011).

Prices

Sorghum export prices

The international prices for sorghum are largely determined by the demand for sorghum feed and consequently USA as the largest exporter has a considerable dominance in the global price trends. During the past 25 years, the real prices of sorghum have exhibited a decreasing trend in line with other agricultural commodities. This decline was more marked in the 1980s, followed by a more gradual decline till 2000 after which there was a gradual recovery (Fig. 20).

The decline in real export prices for sorghum in the 1980s was largely in response to the development of new hybrids and drought resistant varieties that led to an increase in yields and production of sorghum. The price of sorghum continued to decline in the mid to late 1980s after a brief period of increase in 1984, owing to the trade embargoes on maize imports on the former USSR which led to an increase in the demand for sorghum. The period between 1985 and 2000, however, saw a steady decline in real export prices. This can be attributed to a decrease in demand from USA owing to government policies favoring maize over sorghum; the presence of large wheat surpluses globally that exerted a downward pressure on the price of sorghum; the increase in production in India owing to the use of new varieties of sorghum and better agricultural practices; and finally, to the decrease in demand from the former USSR and other Asian countries owing to the lower price of maize due to good maize harvests with maize exports growing by nearly two percent per annum for the period 1985-2001.

The period between 2001 and 2007 was marked by a gradual recovery in the price of sorghum where the prices grew at a rate of 2.5%, following an all-time low real export price of US$ 55 in 2000. The increase can be attributed to an

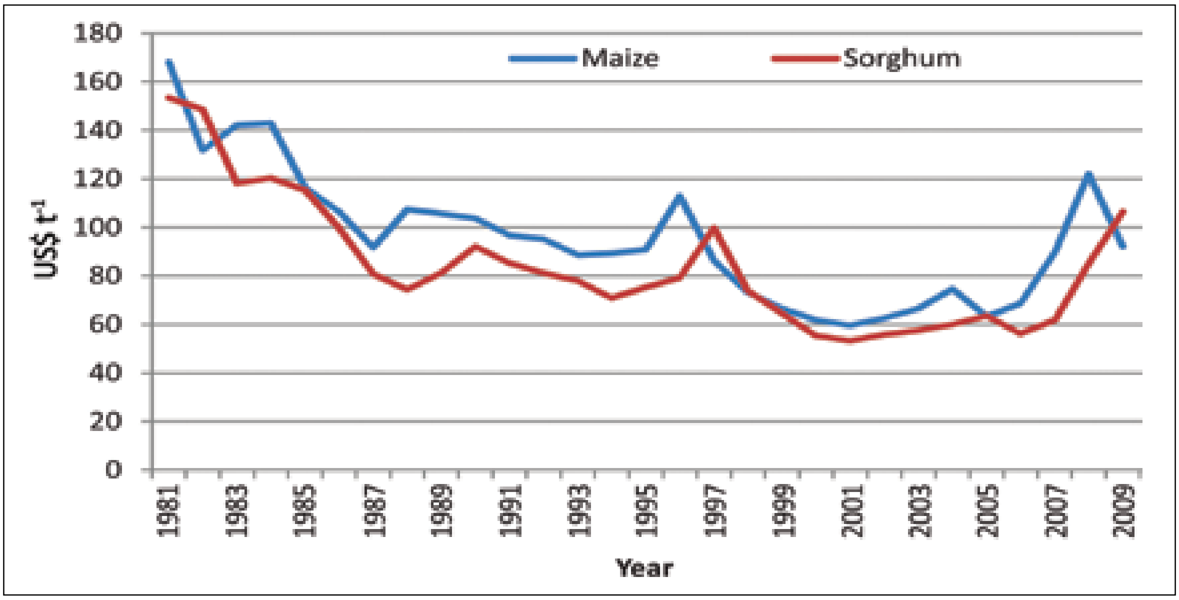


Figure 20. Trends in real export prices for sorghum and maize (1983-84 prices).

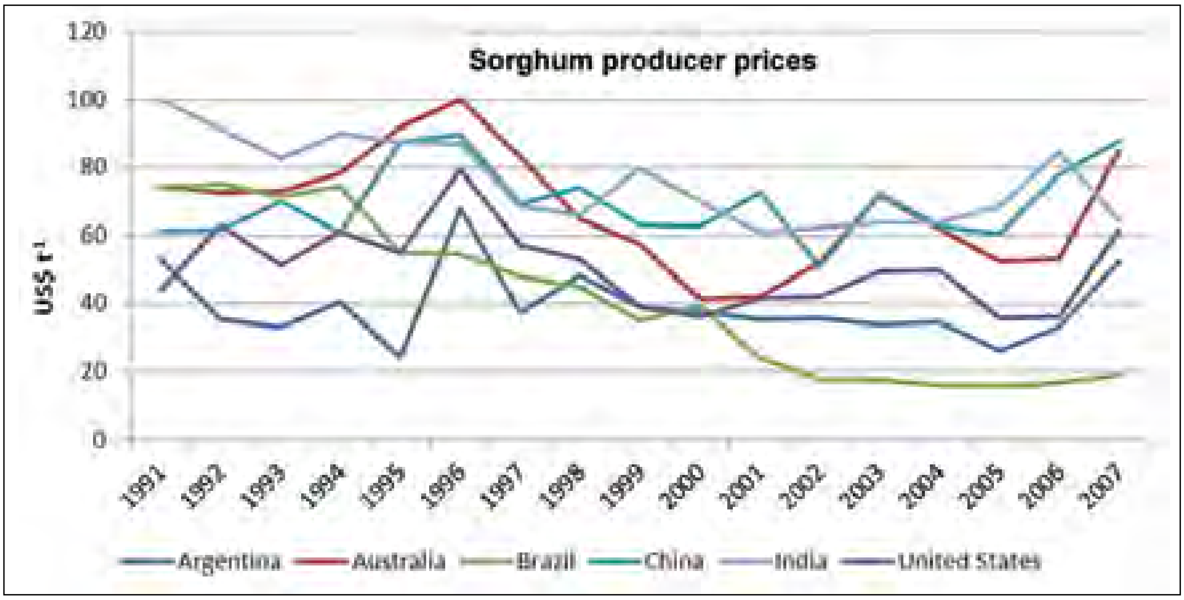


Figure 21. Trends in sorghum producer prices, 1991-2008 (1983-84 prices).

increase in the demand for both sorghum and maize in the bio-ethanol industry that exerted an upward pressure on prices. The US is a main driver here, diverting close to 40% of its maize to the biofuel industry for the production of ethanol (Walsh 2011). In addition to this, there was an increased substitution of sorghum for feed grain in Europe owing to a shortage of feed grains. The strong global consumption of sorghum, led by robust growth in demand from China, Mexico, South Korea, Brazil and USA, continued to outstrip the expanding world production of sorghum thus pushing up prices (USDA 2004). The dip in prices in 2005 was due to the decline in feed grain demand owing to the avian influenza outbreak in Asia and a bumper harvest in USA due to increased plantings, but the subsequent price recovery was largely led by the resurgence of the feed grain industry and the increased demand for maize grain for ethanol (USDA 2005). Since sorghum and maize are close substitutes in the feed industry and in other industrial uses, the price of sorghum tracks the price of maize and is, on an average, lower than that of maize by 5-10%. The sorghum to maize price ratio is on an average 0.87. The recent increase in demand for maize in the bio-ethanol industry has led to an increase in the demand for sorghum and consequently its price. Thus, the price difference between sorghum and maize has been narrowing since 2000.

Sorghum producer prices

Figure 21 shows the trends in the main sorghum-growing countries of the world. Producer price trends can help elucidate the relative competitiveness of sorghum in these countries. In the early 1990s, the prices in Argentina were the lowest in the world. However, this changed in 2001, when Brazil became the country with the lowest producer prices. Producer prices in India are among the highest in the world, making its sorghum uncompetitive in global markets. This is mainly because the postrainy season sorghum prices are high owing to its higher quality grain.

Sorghum prices in India

Rainy season and postrainy season sorghum prices have followed roughly similar trends although the variations in the prices of postrainy season sorghum are sharper (Fig. 22). Typically, postrainy season sorghum prices are higher compared to rainy season sorghum prices as

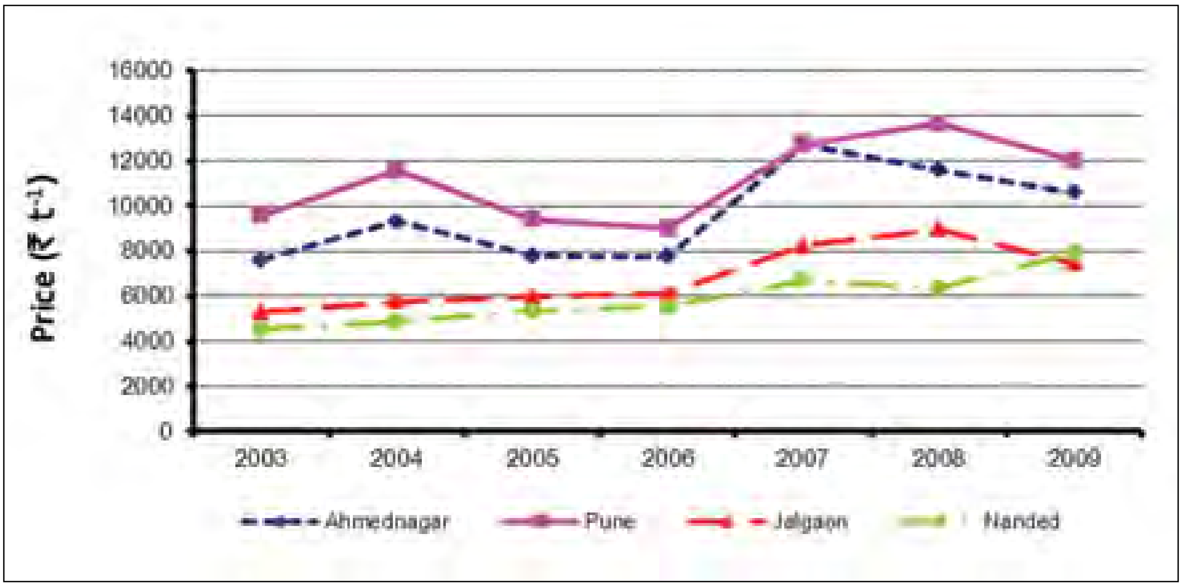


Figure 22. Trends in annual wholesale prices of sorghum in Maharashtra and Karnataka (nominal prices).

consumers are willing to pay a premium for a perceived higher grain quality. The general price rise in 2006 globally contributed to the surge in sorghum prices in India for both the rainy and postrainy season, although the spike was larger for postrainy season sorghum. However, following bumper harvests in 2009, prices decreased once again. Since then, owing to a recent urban-led increased demand for food and the processed food sector, sorghum prices registered an increase in 2011. The decline in sorghum production in 2010-11 due to adverse climatic conditions further fueled the price rise.

3. Millets: Facts and Trends

3. Millets

Introduction

Millets are a group of small-seeded annual grasses grown mainly in Asia and Africa. They are grown on soils which typically are too poor to support any other crop. They have a higher tolerance for drought, low nutrient application, and fluctuations in temperature than other cereal crops. Millets account for less than 1% of global cereal production and 3% of coarse cereal production. They are thinly traded with less than 1% of total millet production being exported. However, they are significant contributors to the food security of the people living in Africa and Asia. The most important millets by area cultivated and production quantities are pearl millet, finger millet, proso millet and foxtail millet (Box 1).

Millets are grown primarily in the developing countries of Africa and Asia. African countries account for 59% of the global area under millets and 55% of global production (Fig. 23). Much of the crop is grown on marginal lands with low inputs and consequently yields in this region are relatively low. Asian countries are the second most important block of millet producers, accounting for 38% of the global area and 42% of the global production. Yields are somewhat higher here compared to Africa, as improved/hybrid seeds are widely used, though the total production in these countries has been falling as farmers shift to other, more remunerative crops.

Crop distribution

Millets are grown mainly in the developing countries of Asia and Africa (Table 9). In Africa, their cultivation is spread across most of the region with Nigeria being the largest single contributor to regional area. Pearl millet is grown in the Sahel and eastern and southern Africa. Finger millet is cultivated in Uganda and Tanzania, with the rest of the eastern and southern African countries also growing small amounts of the crop. Foxtail and proso millets are not widely grown and their cultivation is restricted to Kenya and other upland areas in the region. Teff cultivation is limited to Ethiopia, where it is an important subsistence crop.

Box 1. Types of millet and their distribution:

Pearl millet accounts for over half of global millet production. It is grown across most of Africa, mainly in the Sahel; and in Asia, mainly in South and East Asia. It can be grown on poor soils in dry areas that are unsuitable for the cultivation of other coarse cereals.

Finger millet is an important staple food in India, Nepal and eastern Africa. It has a slightly higher water requirement than pearl millet and is typically grown on higher latitudes.

Proso or common millet cultivation is concentrated in the temperate parts of Russia, Ukraine, Kazakhstan, USA, Argentina and Australia.

Foxtail millet is grown mainly in China where it is used both as food and feed. It is also grown in India, Indonesia, Korea and some parts of southern Europe.

Teff is grown in Ethiopia where it is used primarily for food.

White fonio, black fonio, and Guinea millet are all minor millets that are important regionally in Africa.

Barnyard millet, little millet, Job's tears, and Kodo millet are minor millets that are important regionally in southern and south eastern Asia. Kodo millet is also grown in western Africa.

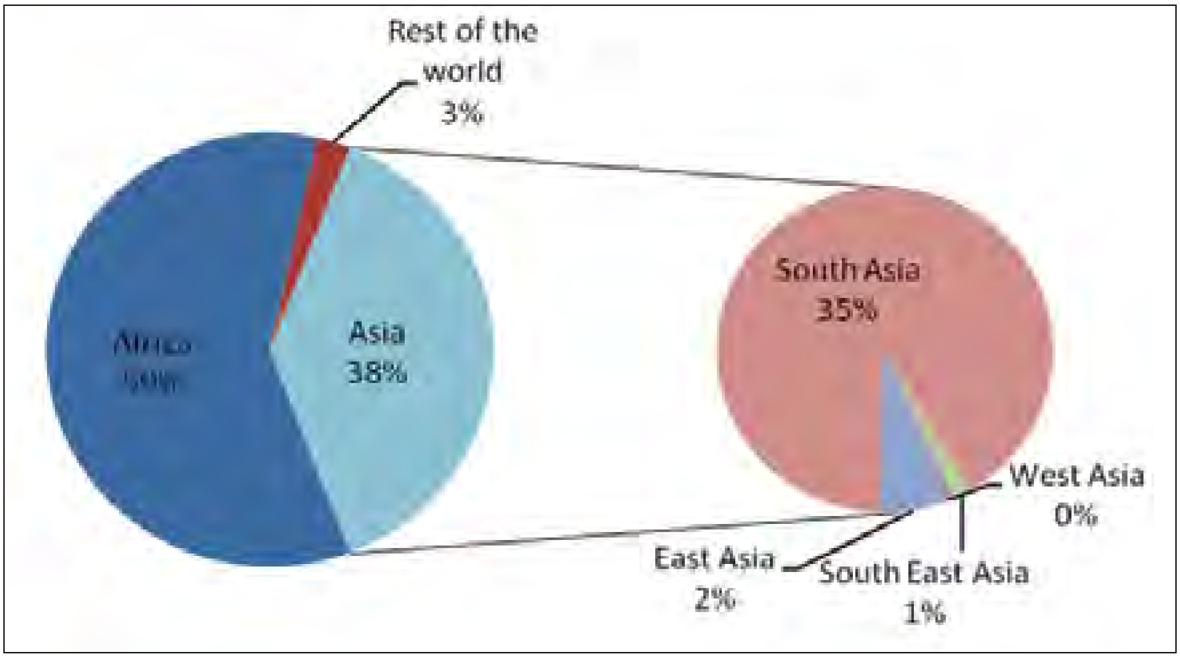


Figure 23. Global millets area distribution, 2006-08.

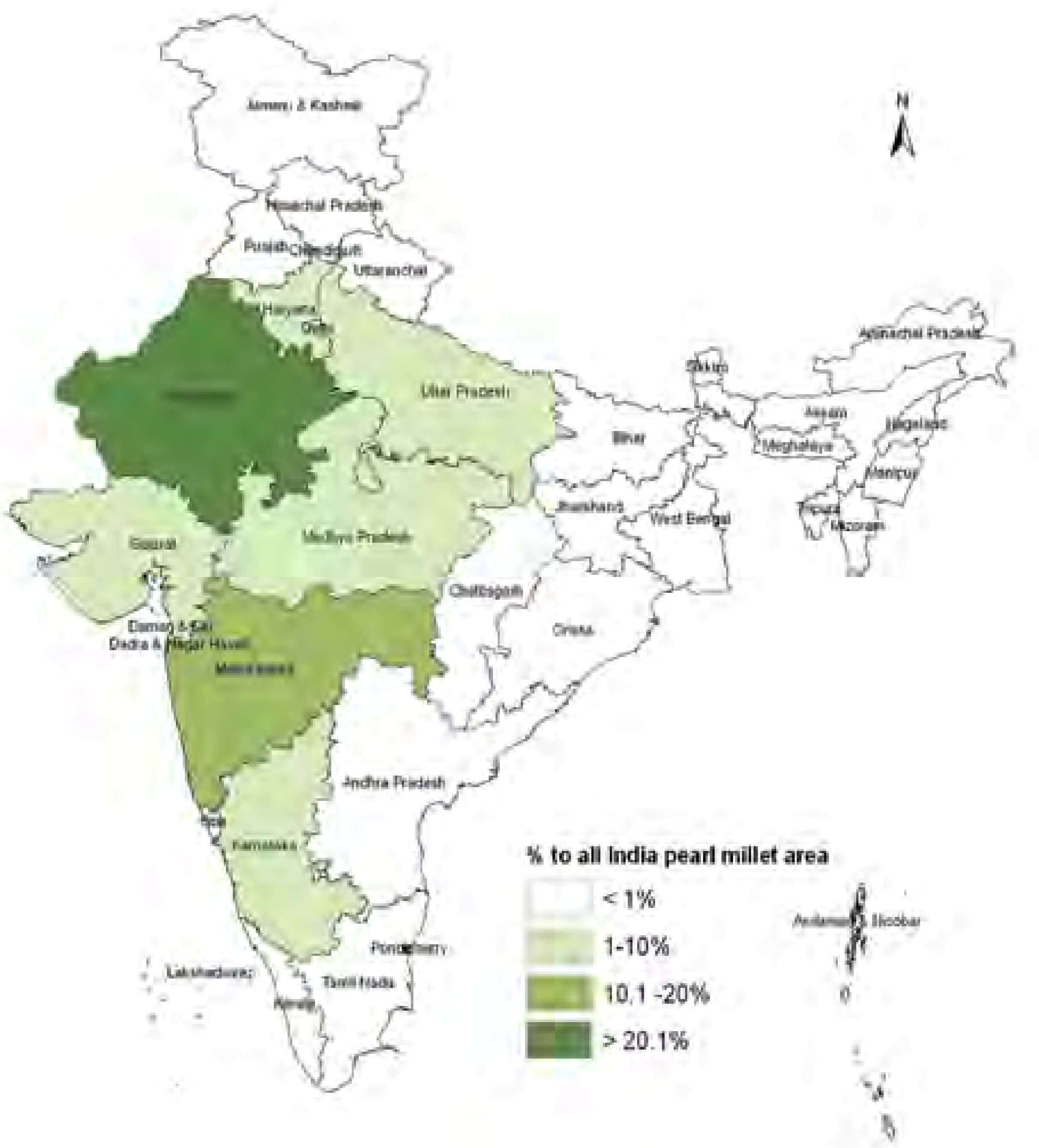
In Asia, millets are grown almost exclusively in South and East Asia. China is the second largest producer of millets in Asia, accounting for nearly 2% of global millets area in 2007-09. Foxtail millet is the main millet grown in the country, mainly in the provinces of Hebei, Shanxi, and Shandong. Myanmar in Southeast Asia and Yemen in West Asia also grow small quantities of millet. Pearl millet is the most important millet grown in these countries as well.

India is the single largest millet producing country in the world, contributing 32% of global millet area in 2006-08. Pakistan and Nepal also produce small quantities of millets, with finger millet being grown in Nepal and pearl millet being grown in Pakistan.

In the rest of the world, millet cultivation, mainly proso millet, is limited to Russia, Kazakhstan and Ukraine. Millets are not commonly cultivated in North America, Latin America, Australia and Europe. In Europe and North America in particular, millets are grown for bird feed, but their cultivation is limited to about 0.8 million ha.

Pearl millet: India

Since FAO does not separate millet data by type, we have used national statistics on pearl millet published by the Government of India to analyze pearl millet trends in India. Pearl millet is the main millet that is grown in India, accounting for nearly 75% of total area under millets. The cultivation of pearl millet is largely concentrated in Rajasthan, north and central Maharashtra and northern Karnataka (Map 5), which together account for 72% of pearl millet area in India.



Map 5. Distribution in pearl millet area by state in India, 2006-08.

Trends in Area, Yield, and Production

Area

Global area under millet cultivation decreased marginally from 37 million ha in 1980-82 to 36 million ha in 2006-08 (Table 9). Consequently the overall growth rate for the period remained stagnant at -0.2% (Table 10). Millet cultivation continues to be concentrated in the developing countries, which account for 98% of the global millet area. Developed countries lost nearly 2.1 million ha between 1980 and 2008, particularly Europe, where over 2 million ha of area under millets were diverted to other crops. Millet cultivation doubled in North America since the 1980s, but it started from a very low base of 83,000 ha in 1980-82 and therefore continues to have a negligible share in the global area.

Millet area in the developing countries was almost stagnant between 1980-82 and 2006-08. However, there are very divergent trends when one examines the regional crop area dynamics more closely. Millet area in Africa expanded from 11 million ha in 1980-82 to 21 million ha in 2006-08. The area expansion under millet can be attributed to increases in the Sahel primarily, where millet cultivation is able to withstand the harsh growing conditions characterized by frequent droughts and high temperatures.

Table 9. Global and regional trends in millets area, yield and production.

	Area ('000 ha)			Yield (kg ha-1)			Production ('000)		
Country/Region	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**
World	37,116	36,681	36,265	700	728	924	25,984	26,703	33,514
Developed countries	2,914	1,277	872	716	922	1,315	2,085	1,177	1,146
Europe	2,804	1,121	639	694	859	1,244	1,945	962	795
North America	83	122	196	1,362	1,500	1,603	113	183	315
Oceania	27	34	36	995	922	1,000	27	32	36
Developing countries	34,203	35,404	35,394	699	721	915	23,899	25,525	32,368
Africa	11,274	18,974	21,471	680	623	851	7,663	11,824	18,280
LAC	167	40	10	1,157	1,483	1,601	193	59	16
Asia	22,762	16,390	13,912	705	832	1,011	16,042	13,642	14,071
East Asia	3,999	1,707	863	1,501	2,111	1,959	6,002	3,603	1,691
China	3,936	1,676	849	1,507	2,132	1,915	5,933	3,572	1,627
South Korea	58	29	12	1,080	977	5,167	63	28	62
South Asia	18,455	14,076	12,642	532	688	955	9,814	9,689	12,074
India	17,731	13,284	11,815	527	689	969	9,352	9,150	11,453
Nepal	124	255	264	977	1,039	1,094	121	265	289
Pakistan	468	406	502	503	433	558	235	176	280
South East Asia	155	211	239	542	658	697	84	139	167
Myanmar	155	211	237	542	658	695	84	139	165
West Asia	153	109	130	935	694	791	143	76	103
Yemen	108	94	115	946	592	709	102	56	81

In Asia, millet area decreased by nearly 40% between 1980-82 and 2006-08 to 14 million ha at the rate -2% per year (Table 10). The decline was faster between 1980 and 1994 when area declined at the rate -2.5% compared to -1.2% between 1995 and 2009. The primary driver for Asian area trends was the decline in acreage in China (Fig. 24). The decline was spurred by policy changes in the country when agriculture became more liberalized in 1987 triggering a shift in area under millets to other more remunerative crops. China now accounts for only 0.8 million ha compared to 3.9 million ha in the early 1980s. Southeast Asia has increased acreage of millet gradually, but it continues to be a marginal crop also West Asia regions. In India, acreage under millet declined from 17 million ha in 1980-82 to 12 million ha in 2006-08 (Table 9) declining at the rate of -1.7% per year (Table 10). The decrease in area was more marked between 1980 and 1994 at -2.1% compared to the latter period of 1995-2008 where the decline was much slower at -0.9%.

Pearl millet: India

Area under pearl millet in India also declined between 1980 and 2007, albeit at a much slower rate, from 11 million ha in 1980-82 to 9 million ha in 2005-07 at the rate of -0.9% per year (Table 11). The decline was greater during the period between 1980-1994 due largely

Table 10. Annual compound growth rates (%) of millet area, yield and production.

Country/Region	Area			Yield			Production		
	1980-2009	1980-94	1995-2009	1980-2009	1980-94	1995-2009	1980-2009	1980-94	1995-2009
World	-0.19	0.13	-0.23	0.68	-0.20	1.80	0.49	-0.07	1.59
Developed countries	-5.12	-4.49	-2.83	1.42	0.82	3.34	-3.75	-3.86	0.64
Europe	-6.11	-4.93	-4.38	1.26	0.48	3.94	-4.89	-4.59	-0.30
North America	3.55	2.15	4.87	-0.12	0.96	-0.92	3.58	3.13	3.93
Oceania	0.16	-0.72	0.68	0.87	-0.85	-0.92	0.96	-1.19	-0.03
Developing countries	0.08	0.42	-0.14	0.72	-0.22	1.76	0.80	0.20	1.63
Africa	2.56	4.72	0.67	0.48	-1.03	2.47	3.06	3.62	3.17
LAC	-10.35	-10.01	-14.87	1.61	2.77	3.79	-8.94	-7.47	-11.57
Asia	-2.07	-2.57	-1.21	1.23	0.86	1.27	-0.85	-1.73	0.06
East Asia	-6.20	-7.34	-5.50	0.82	1.40	0.09	-5.43	-6.06	-5.44
China	-6.18	-7.41	-5.55	0.70	1.45	-0.21	-5.53	-6.09	-5.77
South Korea	-7.82	-3.30	-1.62	7.12	-1.02	20.74	-1.25	-4.14	18.60
South Asia	-1.60	-2.04	-0.81	2.29	2.39	2.04	0.67	0.30	1.24
India	-1.68	-2.10	-0.87	2.37	2.47	2.13	0.67	0.31	1.27
Nepal	3.19	6.06	0.06	0.63	1.99	0.39	3.83	8.15	0.45
Pakistan	-0.69	-2.69	1.72	0.66	-1.04	1.68	-0.03	-3.74	3.44
Southeast Asia	1.55	0.36	0.16	-0.58	-3.49	1.88	0.88	-3.54	2.03
Myanmar	1.51	0.36	0.10	-0.59	-3.49	1.86	0.83	-3.54	1.95
West Asia	-1.10	-3.33	1.04	0.46	-2.01	0.90	-0.65	-5.34	1.97
Yemen	-0.72	-2.29	1.14	0.45	-2.56	1.38	-0.25	-4.88	2.55

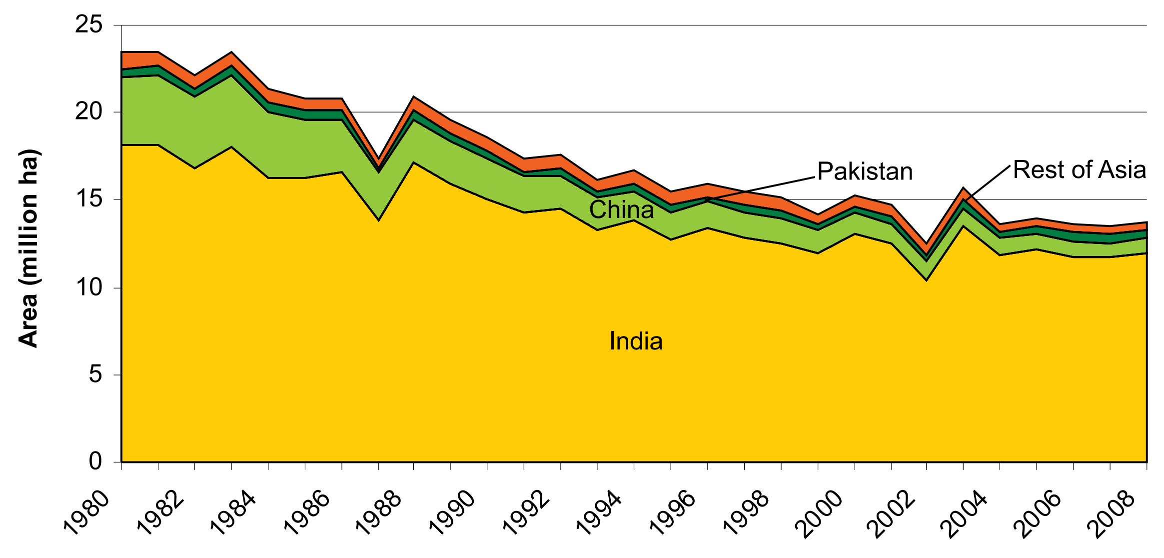


Figure 24. Millets area trends in Asia, 1980-2008.

to the dissemination and wide adoption of high-yielding hybrid pearl millet cultivars that enabled the release of land for cultivation of other crops.

Unlike sorghum, pearl millet area is more evenly spread in India across agroecological zones. Arid regions have the largest concentration of pearl millet area, accounting for nearly 40% in 2005-07 (Table 11). The SAT accounts for the next highest area under pearl millet at 33% and semi-arid temperate zone accounts for 27%. Pearl millet is not widely cultivated in the humid regions of the country. Finger millet is also grown in the country, mainly in the southern states of Karnataka and Tamil Nadu.

While pearl millet area has declined on the whole, the relative shares of pearl millet area under the different agroecological zones has remained more or less the same since the 1980s (Fig. 25). The area declined faster in the SAT, declining at 1.5% per annum between 1980 and 2007. Much of this decline occurred during 1995 to 2007. In contrast, the semi-arid temperate zone registered a small increase in pearl millet area since the late 1990s, growing at 2.1% per annum between 1995 and 2007 (Table 11).

At a more disaggregated level, historically there are very few districts with large area under pearl millet and this trend has continued (Fig. 26). In 1980-82, only 56 out of 211 districts had more than 50,000 ha under pearl millet and this figure fell only marginally to 50 districts in 2005-07. With the introduction of high-yielding varieties, farmers have tended to allocate lower proportions of their land to pearl millet cultivation, releasing land for other crops. This explains the decrease in the number of districts in the 10-50,000 ha category. The number of districts with less than 10,000 ha increased between 1980 and 2007 from 103 to 129.

Table 11. Growth rates and area share for pearl millet by zone in India.

	Growth rate (%)			
Zone	**1980-1994**	**1995-2007**	**1980-2007**	**Area share (%)**
India	**-0.91**	**-0.18**	**-0.9**	**9,194.4***
Humid	-2.64	-9.77	-6.1	0.3
Semi-arid temperate	-1.09	2.05	0.02	26.8
Semi-arid tropical	-0.88	-1.78	-1.53	33.4
Arid	-0.93	0.15	-0.72	39.5

* Average area in '000 ha in 2005-07

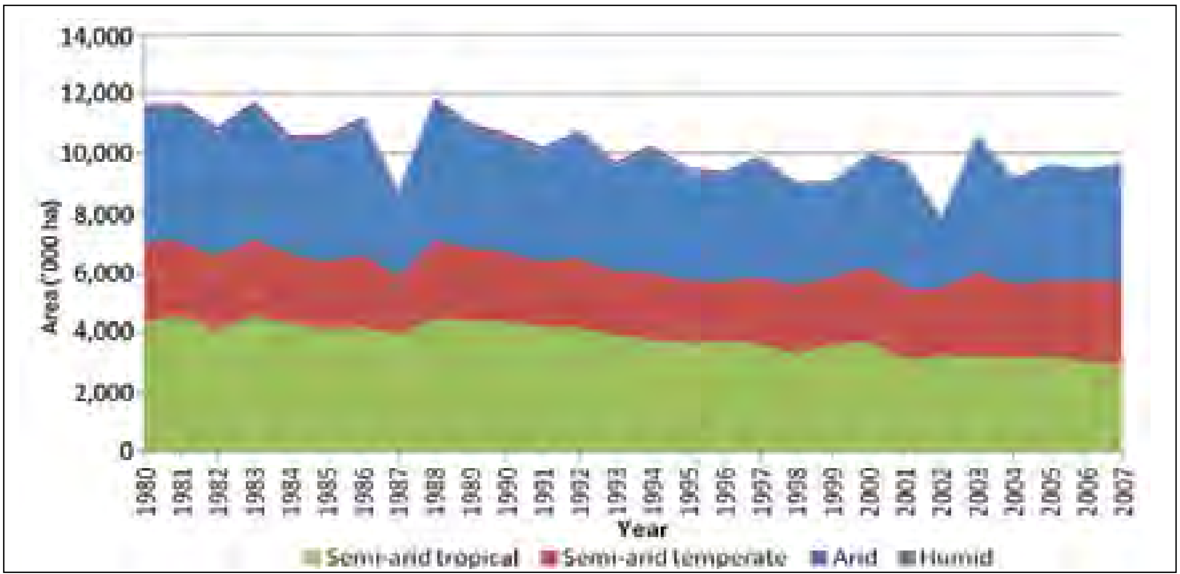


Figure 25. Pearl millet area trends by zone, India, 1980-2007.

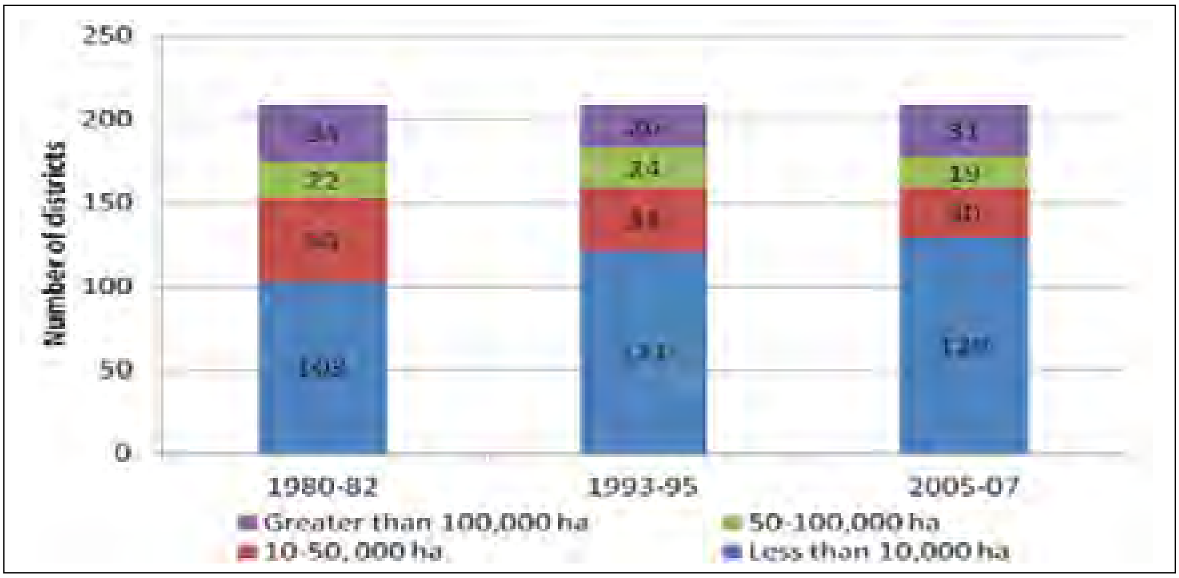


Figure 26. Distribution of pearl millet districts according to area, 1980-2007.

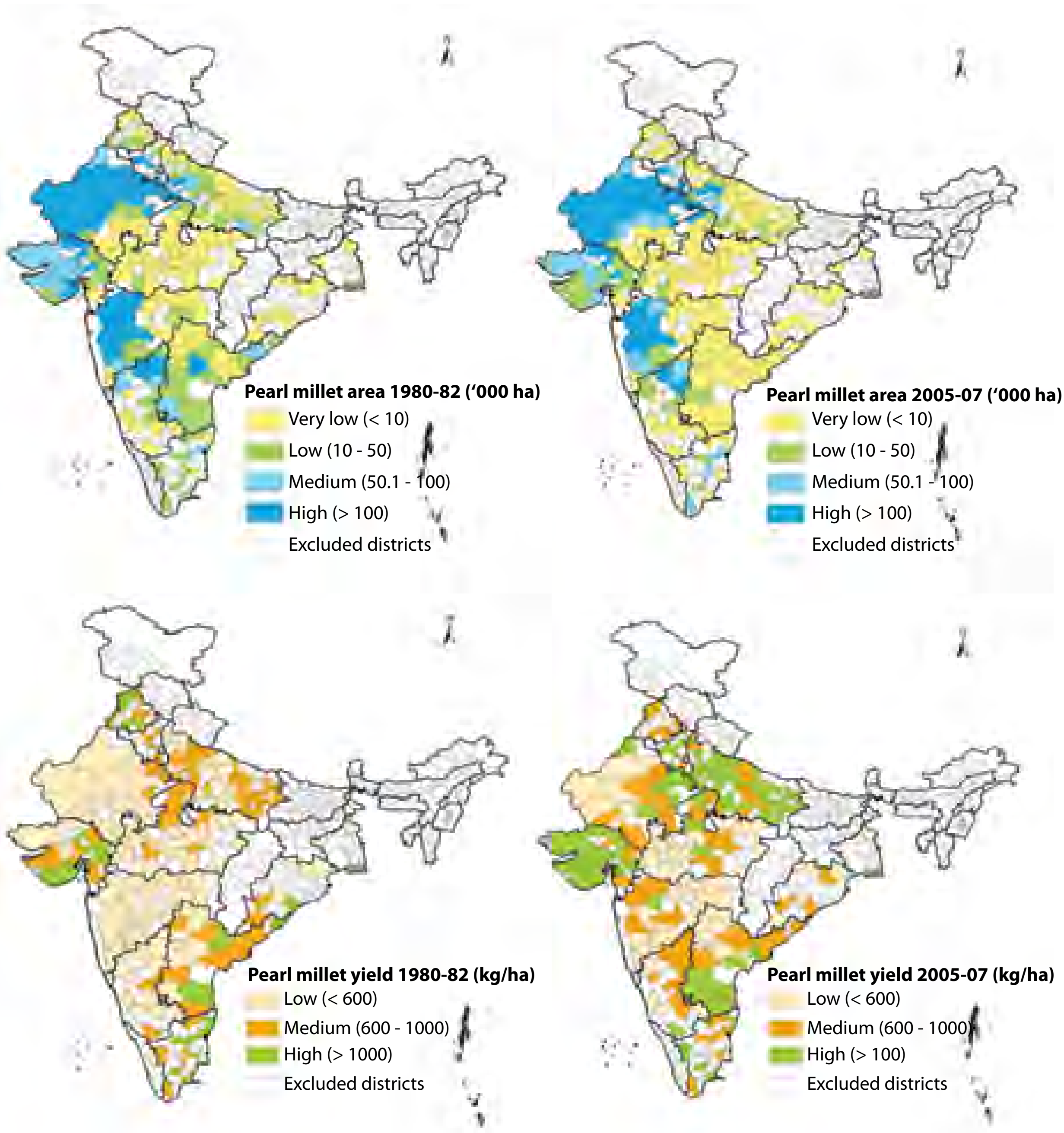
The spatial changes in area under pearl millet across districts between 1980 and 2007 are shown in Map 6. Spatially the growing domains of pearl millet in India have not changed much. Rajasthan continues to account for the largest share, while there has been a decline in some districts of Andhra Pradesh and Karnataka.

Yield

Globally millet yields registered an increase from 700 kg ha^{-1} in 1980-82 to 924 kg ha^{-1} in 2006-08 (Table 9) at an annual growth rate of 0.7% (Table 10). Most of the growth occurred in the latter part of 1995-2008, when millet yields grew by 1.8% compared to the near stagnant -0.2% in the period 1980-94.

In Africa, while overall growth in yields remained relatively low at 0.5% during 1980-2008, the period between 1995 and 2008 witnessed a positive growth rate of 2.5% compared to the negative growth rate of -1% in 1980-1994. Area expansion however, continues to be the dominating influence on overall positive growth in millets production in the region.

In Asia, yield levels were slightly above the world average at 1 t ha^{-1} in 2006-08 (Table 9).



Map 6. Variations in pearl millet area and yield by district in India.

Despite the recent reduction of area in the region, Asia continues to exert a dominating influence on the global yield levels. Overall the yield growth rate was at 1.2% between 1980 and 2008, largely influenced by the yield growth in South Asia, primarily in India (Table 10). Yield levels are relatively high in East Asia but the reduction in area under millets, particularly in China, contributes to the diminishing influence that this region has on regional yields. Yields in Southeast Asia marginally decreased at -0.6% per annum during 1980-2008. However, this decline was halted between 1995 and 2008 when yields increased by 1.9%. Similarly in West Asia, yields registered a marginal increase of 0.5% between 1980 and 2008, with much of the increase coming in the latter part of the study period. Yield levels in India were on average marginally higher than the global average at around 0.96 t ha^{-1} in 2006-08 (Table 9). Yield levels in India increased by more than 2% per annum in both the study periods.

Pearl millet: India

Overall, while the area under pearl millet has been declining in India, the yield levels were increasing at 2.8% per annum between 1980 and 2007, owing to the widespread use of improved varieties/hybrids that were introduced in the late 1980s. However, there are considerable differences in the yield levels in different zones owing to differences in soil types, rainfall and adoption of improved cultivars. Yield levels were the highest in the semi-arid temperate regions at over 1 t ha^{-1}, and grew relatively fast at 3% between 1980 and 2007 (Table 12 and Figure 27). The arid regions had the lowest yield levels

Table 12. Yields and yield growth rates by zone.

	Yield (t ha^{-1})	Yield growth rates (%)		
Zone	**2005-07**	**1980-94**	**1995-2007**	**1980-2007**
India	**881.1***	**2.64**	**2.35**	**2.75**
Humid	945.8	0.58	-1.54	0.07
Semi-arid temperate	1,395.4	3.19	2.98	3.23
Semi-arid tropical	889.2	2.44	0.36	2.05
Arid	512.6	3.35	4.44	3.47

*Note: Yields in kg/ha

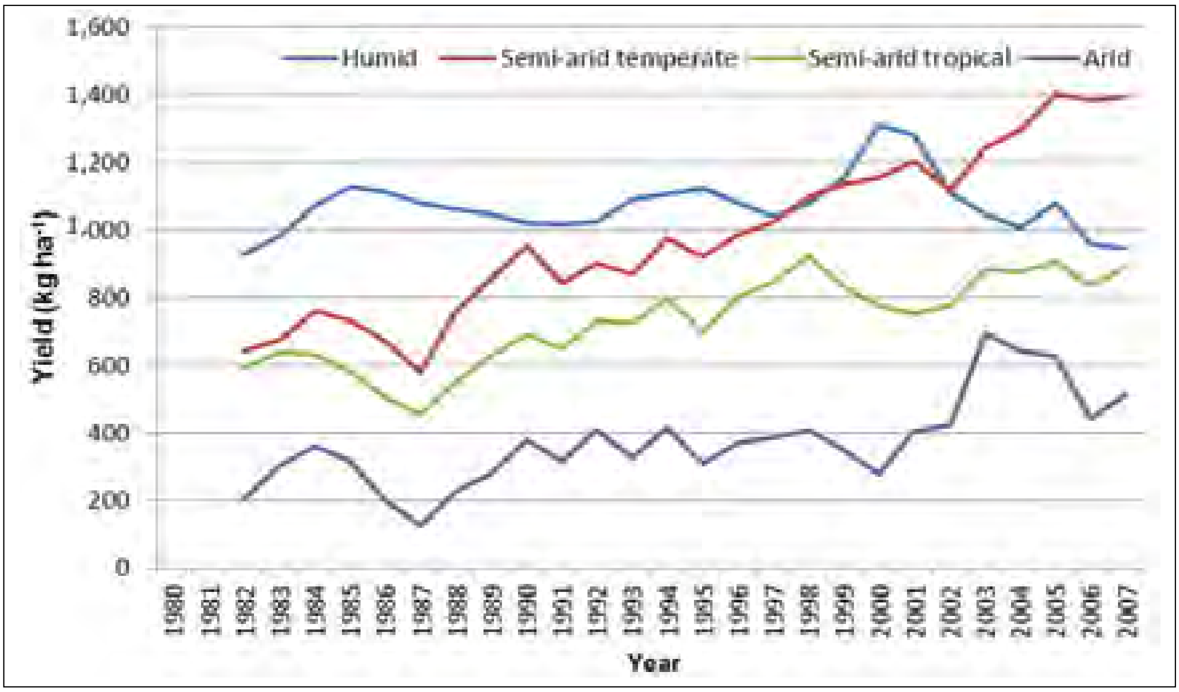


Figure 27. Pearl millet yield trends by zone, 1980-2007, (smoothed, 3 year averages).

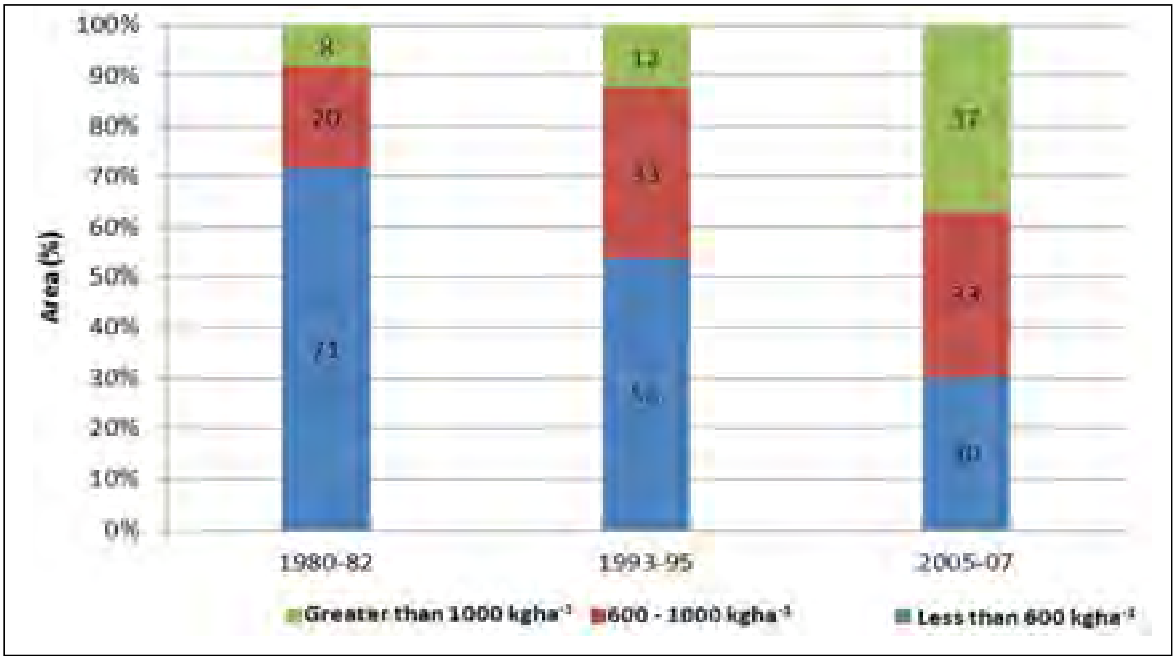


Figure 28. Distribution of pearl millet area by yield, 1980-2007.

at 0.5 t ha^{-1} but also had a high growth rate of more than 3% per annum (Table 12 and Figure 27). Yield levels in the SAT that were close to the average yields in India exhibited an increasing trend overall, but yields remained stagnant during 1995-2007 with much of the growth comming during the period 1980-94.

The impressive growth in yield is reflected in the distribution of pearl millet area under different yield levels in the last 25 years. In 1980-82, 70% of the pearl millet area had yields of less than 600 kg ha^{-1}, which declined to 30% in 2005-07 (Fig. 28). During the same period, the area with yields of 600-1000 kg ha^{-1} increased to 33% from 20% in 1980-82 and area with yields greater than 1000 kg ha^{-1} increased to 37% from 8% in 1980-82.

The spatial changes in pearl millet yields across districts between 1980 and 2007 are shown in Map 6. The spatial distribution of district with high yields reveals an interesting picture. While the major growing state of Rajasthan now had at least half the districts registering yields over 1 t ha^{-1}, it is. Gujarat and Uttar Pradesh, where area declined, that registered the main increases in yields.

Yield variability

By and large, yield variability over the years is higher for pearl millet than for sorghum. This is because pearl millet is grown mainly on marginal lands and regions characterized by erratic rainfall and poor soils. Variability is highest in the arid zone owing to the difficult growing conditions that characterize the area (Fig. 29), with yields falling by more than 25% from the long-term average yields in 12 out of 26 years. In 1987, a severe drought year, yields declined by 75% while in 2003, which was a good rainfall year, yields increased by 100% from average yield levels. In the SAT, the variability in yields is also large. Between 1980 and 2007 there were as many years where yields were at least 10% below average levels as there were years when yields were at least 10% above average levels (Fig. 30). Yield variations in the semi-arid temperate region are also high despite the region being generally better endowed in resources, with 9 out of the 26 years recording yields 10% below the long-term average yields. However, the variations reduced since the mid-1990s with yields trending below average in only 3 of the 12 years (Fig. 31).

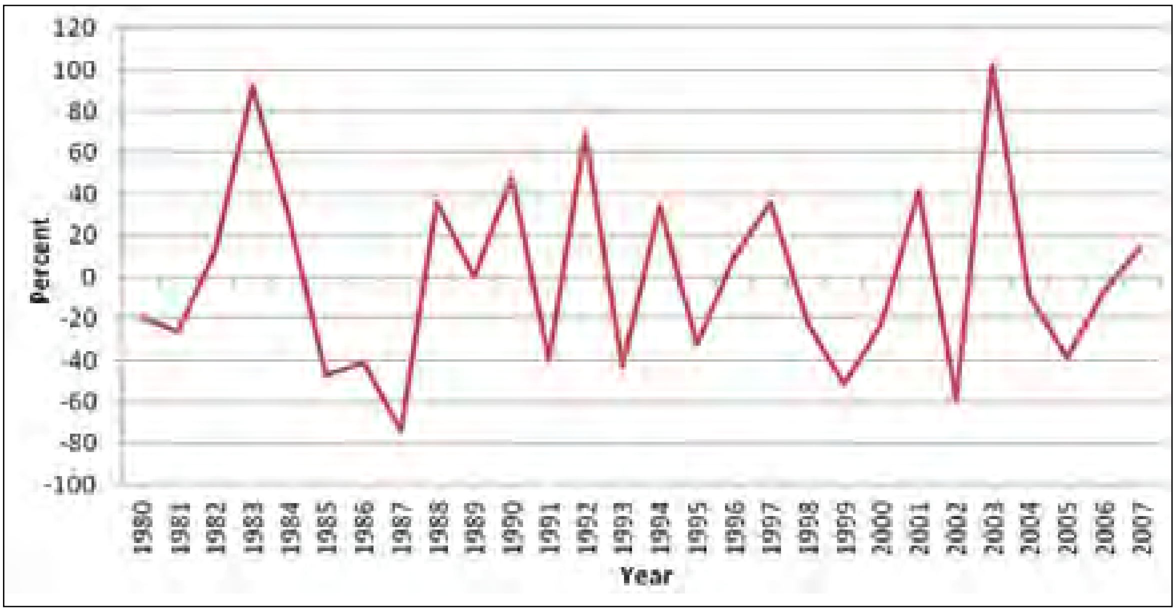


Figure 29. Yield variations in pearl millet in arid regions, India.

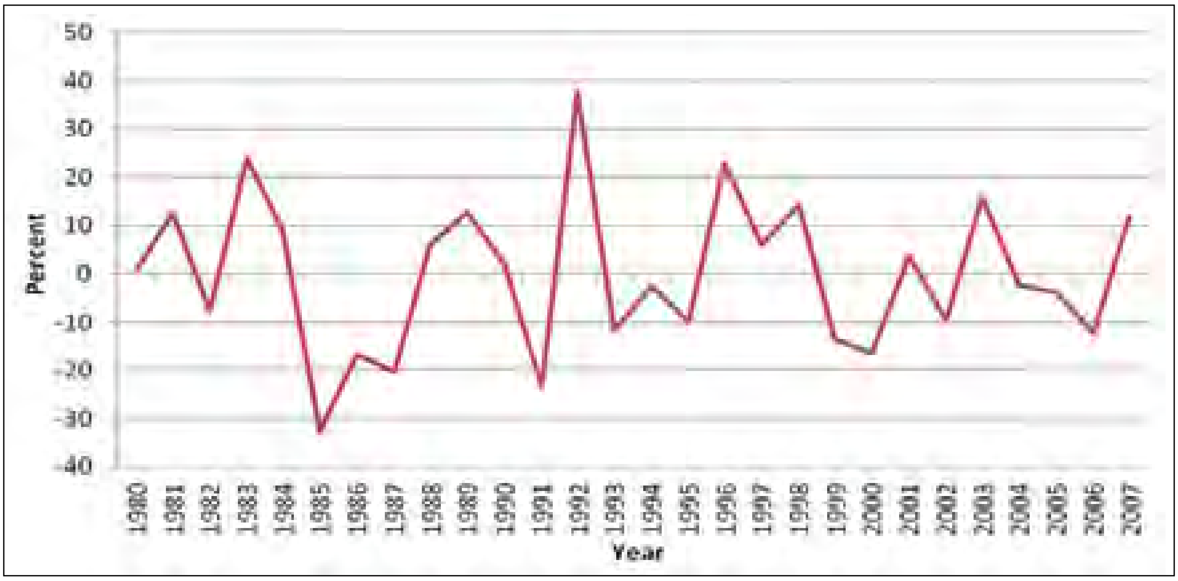


Figure 30. Yield variations in pearl millet in semi-arid tropical regions, India.

Figure 31. Yield variations in pearl millet yields in semi-arid temperate regions, India.

Production

Millet production increased at the rate of 0.5% per year between 1980 and 2008 (Table 10). The increase occurred mainly in the latter study period of 1995-2008 after a period of stagnant or negative growth. The production growth of 3.2% in Africa between 1995 and 2008 was the driving factor in overall millet production growth and this more than compensated for the lackluster growth in Asia.

Among the developed countries, North America registered the highest growth of 3.6% in 1980-2008, but since the region accounts for less than 1% of total production, this increase has not had a global impact. Production in Europe declined following the decline in area which has been the dominant trend since the 1980s.

In Asia, production declined from 16 million t in 1980-82 to 14 million t in 2006-08 in keeping with the decline in area (Table 9). However, the decline in production was not as sharp as the decline in area owing to the increases in yield following a widespread adoption of improved varieties/hybrids in the major growing countries in Asia. The single largest fall in production occurred in China, where production quantities declined from 6 million t in 1980-82 to 1.7 million t in 2006-08. In India, production of millets actually increased from 9.3 million t in 1980-82 to 11.4 million t in 2006-08 despite the decrease in area.

Pearl millet: India

Overall pearl millet production in India has been increasing over the years, at the rate of 1.8% between 1980 and 2007 (Table 13). The production of pearl millet grew faster in the second half of the study period due to the increased and widespread adoption of high-yielding cultivars.

Pearl millet production is the largest in the semi-arid temperate zone which accounts for only 27% of the sown area under pearl millet but accounts for 44% of production (Table 13). The yields in this region are consequently the highest in the country. The production share of the arid zone, which accounts for the largest area, is the lowest at 22% (Table 11). The region with the highest overall production growth is the semi-arid temperate zone which registered a growth of 3.3% between 1980 and 2007, while the SAT registered the lowest growth at 0.5%. In fact, production in the SAT has been declining in the latter part of the study period.

Production constraints

Millet production suffers from many biotic and abiotic constraints in the areas that they are grown such as poor soil fertility, low and erratic rainfall, high temperatures, widespread *Striga* infestation and downy mildew disease.

Millets are cultivated on small, fragmented landholdings. Unreliable rainfall and low market demand act as disincentives to invest in the use of inputs such as chemical fertilizer, pesticides and irrigation. In India, yields are low primarily due to this lack of input use despite widespread use of improved varieties. Additionally, despite the release of high performing hybrids and their rapid uptake, area under pearl millet in India has contracted due to market constraints. Non-availability of improved and quality seeds at the right time, the lack of proper seed marketing channels, and low returns relative to other crops under irrigated conditions are reasons commonly cited for the low adoption of high-yielding hybrids/varieties.

Table 13. Production shares and production growth rates (%) of pearl millet by zone in India.

Zone	Production share	1980-94	1995-2007	1980-2007
India	**7,685.1***	**1.7**	**2.16**	**1.83**
Semi-arid temperate	43.7	2.07	5.09	3.25
Semi-arid tropical	34.1	1.54	-1.43	0.49
Arid	21.9	2.38	4.59	2.72

* Average production in ’000 t in 2005-07

Many diseases of the different millets are quite host-specific, particularly those caused by parasites. The most important diseases include downy mildew and rust diseases for pearl millet; mildew, bacterial blight, kernel smut, and leaf spots with foxtail millet; bacterial stripe and head smut with proso millet; head smuts with Japanese millets; and *helminthosporium* with finger millet. Diseases in millets are not widespread and most can be controlled either by the use of fungicides or by using treated seeds. However, the diseases that infest millets result in considerable economic losses to farmers because these diseases affect the pearl millet ear heads and the grain. In India, downy mildew epidemics caused substantial yield losses during the 1970s and 1980s. Grain yield losses of as much as 20-60% have been reported.

Utilization

Globally the availability of millets grew from 26 million t in 1980-82 to 32 million t in 2005-07 (Table 14). Millets are consumed primarily as food in most of the developing countries. It is highly nutritious, high energy food and in recent years an important component of processed baby foods. The form in which millets are consumed varies across regions – as a thick porridge or as flatbreads (*rotis*) (see Box 2). Millets are also used as bird feed, but this use is largely restricted to the developed countries. However, the utilization pattern is changing even in developing countries where its use in alcohol manufacture and as livestock and poultry feed is growing. Millet fodder is an important feed resource in the dryland systems of Africa and Asia, particularly in the post-monsoon seasons when other feed resources are not available.

Table 14. Trends in millet utilization ('000 t).

	1980-82				2005-07			
Regions	**Total availability**	**Feed**	**Food**	**Other uses**	**Total availability**	**Feed**	**Food**	**Other uses**
World	25,896	2,513	20,517	2,867	31,546	4,122	23,693	3,730
Europe	2,052	294	1,522	235	844	542	256	46
North America	76	70	0	6	271	256	0	15
Oceania	15	15	0	0	31	31	0	0
Africa	7,474	727	5,399	1,347	16,583	1,994	12,010	2,579
LAC	119	106	0	13	14	13	0	1
Asia	16,161	1,300	13,596	1,265	13,795	1,278	11,427	1,088
East Asia	6,155	997	4,726	432	1,786	892	785	109
China	6,030	946	4,656	429	1,688	858	724	105
South Korea	63	19	41	3	62	19	40	3
South Asia	9,775	264	8,696	815	11,643	314	10,376	953
India	9,353	133	8,442	778	11,063	179	9,981	903
Nepal	121	0	106	16	290	0	260	30
Pakistan	235	118	100	18	256	127	110	19
Southeast Asia	86	10	67	8	196	26	155	14
Myanmar	84	8	67	8	178	18	146	14
West Asia	145	29	106	10	135	25	102	8
Yemen	102	0	94	7	95	0	88	7

Box 2. Utilization of different types of millets

In West Africa, a local food called '*degue*' is produced from pearl millet. Pearl millet is also used to produce a beer similar to the beer produced from maize. In India pearl millet grain is consumed in a variety of ways ranging from a thin gruel to a thick porridge. Pearl millet flour is also used to make *rotis.*

Finger millet in India and Africa is ground into flour and eaten as porridge or as an accompaniment to *dal* and curries.

Common or Proso millet can be eaten as whole grains like rice, or boiled and eaten as gruel. Ground into flour, it can be made into porridge or *chapati*. Mixed with wheat flour and yeast, it can be made into leavened bread. The green plant provides good green fodder, but the mature straw is of poor quality and cannot be used for thatching or dry fodder.

Little millet has a grain that has to be dehusked as well as threshed, and is consumed in the same way as other millets. The straw has advantages in that, when ripe and dry, it is palatable to cattle and horses. The green plant is a superior fodder, which may be grazed more than once.

Kodo millet is safe as a green plant and a useful fodder, but the grain of some varieties is toxic to both humans and livestock.

Foxtail millet is important in Asia, and is used as a rice substitute in both China and Japan. It can also be eaten as a gruel, porridge or pudding. In Russia, it used to be consumed as beer. In the UK, it is used as bird seed while in the USA use it for hay and silage in dryland areas.

Food use

The utilization of millets as food is restricted to countries in Africa and Asia. Overall, the food demand for millets increased from 21 million t in 1980-82 to 24 million t in 2005-07. However, the per capita consumption of millets fell marginally from 4.6 kg in 1980-82 to 3.6 kg in 2005-07 (Table 15). Most of the increase can be attributed to the increase in demand from Africa, where food demand increased from 5 million t to 12 million over the past twenty five years (Table 14). The food demand for millets in Europe, which is concentrated in the former USSR/ CIS regions, decreased slightly from 294,000 t in 1980-82 to 256,000 t in 2005-07. This decrease is attributable to policies that removed price subsidies in these countries during the late 1980s and early 1990s.

In Asia, the food demand has decreased over the past twenty five years. The per capita consumption trends show a halving of per capita food demand in Asia (Table 15). Much of the decrease in millet food demand is due to the sharp reduction in China, from 4.6 million t in 1980-82 to 0.7 million t in 2005-07. The reasons for this shift away from millet consumption can be attributed to the changing policy environment in the country which led to millets losing their competitive advantage in production.

Food demand in India increased from 8 million t in 1980-82 to 10 million t in 2005-07. However, the per capita consumption decreased from nearly 12 kg in 1980-82 to 9 kg in 2005-07 owing to the availability of subsidized rice and wheat through Public Distribution System (PDS), (Table 15). The increase in per capita income in India, growing urbanization, and changing tastes and preferences have contributed to the decline in the consumption trend of coarse cereals in general.

Pearl millet consumption trends in India

There is a significant difference in the levels of pearl millet consumption along the rural and urban divide. Pearl millet consumption in urban India was always low because of the low shelf life of processed flour which entails processing the grain before using it. However, the consumption trends of pearl millet in India in the past two decades, both in rural and urban area depict a decline in consumption. However the trends in both rural and urban areas are seen to plateau since the late 1990s at the current lower levels (Fig. 32).

Table 15. Per capita consumption trends of millet (kg capita^{-1} yr^{-1}).

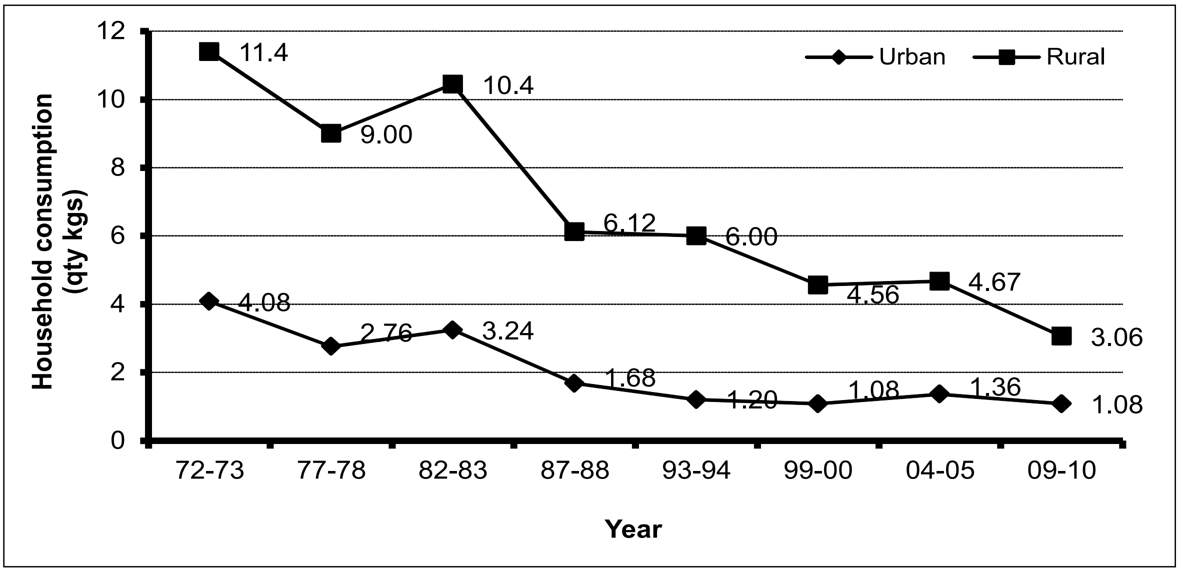
Region/ Country	1980-82	1993-95	2005-07
World	4.6	3.7	3.6
Europe	2.0	0.9	0.4
North America	0.0	0.0	0.0
Oceania	0.0	0.0	0.0
Africa	11.0	12.1	12.9
LAC	0.0	0.0	0.0
Asia	5.3	3.3	2.9
East Asia	4.0	1.7	0.5
China	4.7	2.0	0.5
South Korea	2.3	0.9	1.7
South Asia	9.1	6.6	6.5
India	11.9	8.7	8.7
Nepal	6.9	10.7	9.4
Pakistan	1.2	0.6	0.6
Southeast Asia	0.2	0.3	0.3
Myanmar	2.0	2.6	3.0
West Asia	1.2	0.5	0.6
Yemen	10.8	3.5	4.0

Pearl millet is consumed predominantly in the western and central states of India. However, it is consumed as a staple mainly in Gujarat and Rajasthan. Haryana, which was a significant consumer of pearl millet in the 1970s, saw consumption decreasing by over 85% in both urban and rural areas.

Across income classes, pearl millet is consumed mainly by the low and middle income groups. The higher income group accounts for less than 10% of total pearl millet consumed as food in rural areas and less than 5% in urban areas. About 46% of pearl millet in urban India is consumed by low income consumers (Table 16). Thus, pearl millet continues to be an important staple for the poor despite an overall decline in its consumption.

Feed use

The demand for millet grain as feed increased from 2.5 million t in 1980-82 to 4.2 million t in 2005-07. However, among the coarse cereals, the use of millets as feed is very small. Only 13% of total availability is used as animal feed compared to 45% of total sorghum availability and 62% of total maize availability. Nutritionally, millets compare well with sorghum and maize as feed for livestock. However, they are not



Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62^{stnd} Round, 2009-10

Figure 32. Annual per capita consumption of pearl millet in urban and rural India (kg).

Table16. Annual consumption of pearl millet by income class, 2004-05.

Expenditure category	Consumption ('000 t)	Consumption (%)	Per capita consumption (kg yr^{-1})	Population (%)
Rural average consumption by expenditure category				
Low (Less than Rs. 765 ($14.98) per month)	826.6	35.6	2.72	50
Medium (Rs. 765- 1477 ($14.98- 28.93 per month)	1,221.2	52.6	4.01	40
High (Greater than Rs. 1477 ($28.93) per month)	274.0	11.8	1.80	10
Urban average consumption by expenditure category				
Low (Less than Rs. 1307 ($25.60) per month)	145.9	49.8	1.29	50
Medium (Rs. 1307-3166 ($25.60- 62.02) per month)	119.2	40.6	1.06	40
High (Greater than Rs. 3166 ($62.02) per month)	28.1	9.6	0.50	10

Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62[stnd] Round, 2009-10.

an important feed source globally. The main reason for this could be that the yield levels of millets do not compare favorably with those of maize and other coarse cereals. Furthermore, millet cultivation continues to be by smallholder subsistence dominated systems which are characterized by low marketable surpluses. In these regions, millets are grown primarily for household consumption and therefore marketing and trade are restricted.

Utilization of millets for feed is concentrated in Africa and Asia. Feed consumption of millet in Africa increased from 0.7 million t in 1980-82 to 1.5 million t in 2005-07. However, the proportion of the total millet availability that goes to feed use remained the same, between 10-12%. Feed use in Asia also remained more or less the same at 1.2 million t. The developed countries, particularly Japan, the USA and Europe use millets as bird feed. The overall quantities used in these regions have registered an increase over the years. However, the scale of millet utilization in these regions continues to be very low compared to other coarse cereals in the same countries.

In India, the importance of pearl millet as cattle feed is increasing in recent years in northern states like Haryana and Punjab and the main growing state of Rajasthan. In Tamil Nadu, farmers growing improved cultivars of pearl millet are able to market their surplus to the animal feed sector, mainly poultry and cattle feed manufacturing units. Pearl millet grain is also finding increasing use as poultry feed in Haryana, where it used to be a food staple two to three decades ago (Market surveys HOPE project 2010-11) .

Fodder

Pearl millet straw is an important feed resource, particularly in India and parts of Sub-Saharan Africa. In India, particularly in the arid zone, pearl millet straw is stored and used throughout the year, particularly in the summer months when other feed resources are scarce. There is also a growing market for pearl millet straw in urban areas close to the growing centers to meet the increasing demand from urban and peri-urban dairies. Chopped pearl millet straw is commonly traded in urban markets due to its transportability and ease of consumption by animals. Pearl millet dry stover is often traded from Haryana, Punjab and UP to Rajasthan whenever pearl millet stover is in short supply due to drought. Pearl millet is also exclusively grown as a fodder crop under irrigation in Punjab, Haryana and western Uttar Pradesh.

Other uses

The use of millets in commercial brewing and distillation is very limited. In some parts of Africa, small quantities of finger millets are used to brew local beers but this is limited to the region. However in India, since 2000, large quantities of pearl millet are being used in the alcohol industry based in Rajasthan, Punjab and Haryana. Among the cereals, broken rice is most preferred by the alcohol industry, followed by pearl millet and sorghum. Pearl millet varieties with high starch content are preferred. The relative prices of different cereal crops also determine their usage.

Trade

Trade in millets is very thin with less than 1% of total production being traded. Traded volumes increased from 0.2 million t in 1980-82 to 0.3 million t in 2005-07 (Table 17). The largest exporters are India and USA. India's exports largely comprise pearl millet while USA exports primarily proso millet. Latin America, particularly Argentina, was a significant exporter in the early 1980s but in more recent times has all but ceased to export millets.

Much of the exported millets are traded within the subregions – for example, much of India's exports go towards West Asia. Europe was a significant importer in the early 1980s but in more recent years, the net trade balance has more or less evened out with higher exports from the CIS countries.

In India, inter-state trade of pearl millet from major pearl millet-growing states to primarily other urban centers has been seen. Pearl millet grain is exported from Gujarat and Uttar Pradesh to Rajasthan in years when there is drought in Rajasthan. Trade also happens within Rajasthan with the eastern regions supplying grain to the western regions of the state. Alcohol industries in Haryana and Punjab import grain from Gujarat and Rajasthan when there is surplus production there.

Table 17. Trends in millets trade ('000 t).

	Exports			Imports		
Regions	**1980-82**	**1993-95**	**2007-09**	**1980-82**	**1993-95**	**2007-09**
World	218	375	344	264	355	363
Developed countries	77	123	139	139	152	134
North America	23	60	43	138	140	9
Europe	37	48	88	0	11	122
Oceania	17	16	8	1	1	2
Developing countries	141	252	205	125	203	229
Africa	36	124	16	66	6	58
LAC	100	39	3	3	9	11
Asia	4	90	186	56	188	161
East Asia	3	24	19	51	33	48
China	3	23	19	0	2	15
Korea, Republic of	0	0	0	1	8	16
South Asia	1	63	152	0	2	20
India	0	60	153	0	0	2
Southeast Asia	0	1	10	3	9	23
Indonesia	0	0	0	0	3	9
West Asia	0	1	2	2	144	70
Yemen	0	0	1	0	0	27

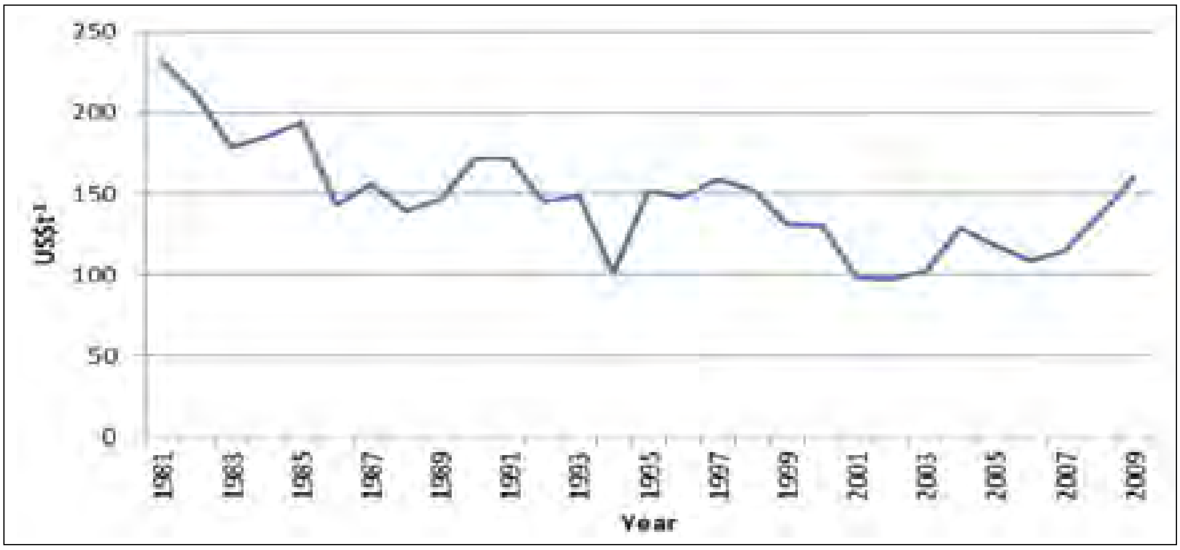


Figure 33. Trends in real export prices for millet (1983-84 prices).

Prices

The real price of millet grain shows a cyclical pattern over the course of the last four decades, and trended downwards like for other food commodities until 2000. Its prices also rose sharply after 2000 (Fig. 33). An important feature of millet prices is the sharp spikes that its price exhibits due to fluctuations in production since the crop is grown in marginal environments under low and erratic rainfall conditions.

The period 2000-2007 saw a recovery in the real price of millets, increasing at a rate of 2.45% per annum along with traded quantities. This can be attributed largely to the increase in prices of cereal crops leading to an increase in demand for millet as a substitute crop[6].

Millet producer prices

There is very little difference in the producer prices among the major millet-growing countries of the world. While prices in Mali fluctuate widely, prices in other countries such as India and Niger are relatively stable (Fig. 34).

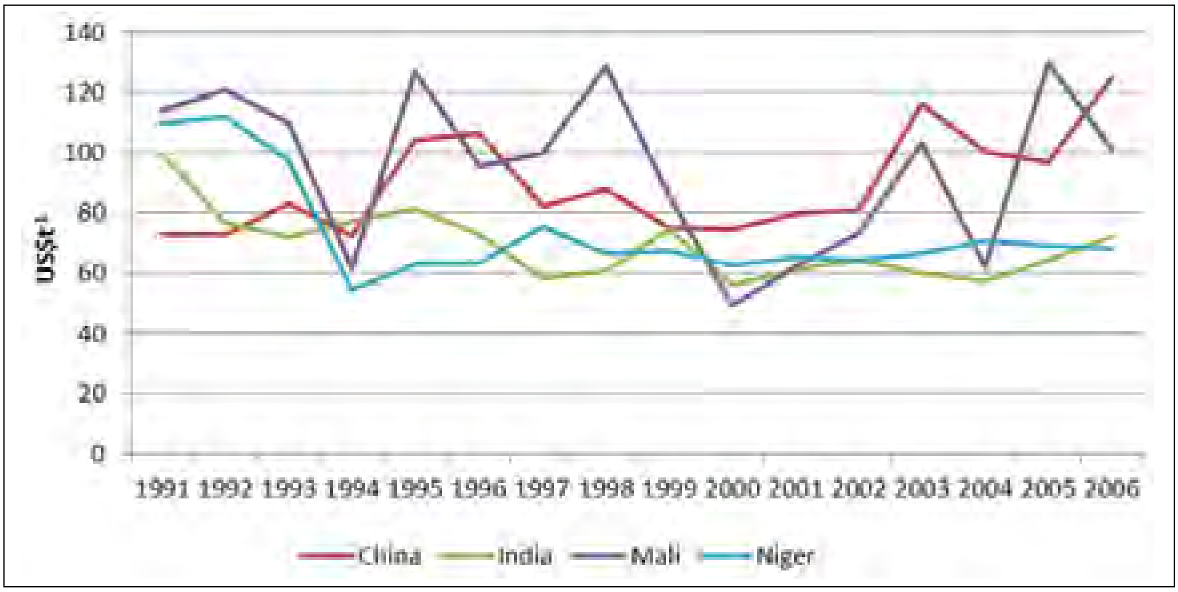


Figure 34. Trends in millet real producer prices, 1991 to 2008 (1983-84 prices).

[6] The real price of millet fell in 2004 and 2005 due to the increased production in major producing countries in Africa and Asia in response to the high real price of millets in previous years.

The prices in China have shown both an increase in fluctuations and in levels since 2002.

Pearl millet prices in India

In keeping with the rise in prices of food crops in India, the wholesale prices of pearl millet have increased from 2004, as indicated by the price trends in two major markets in India (Fig. 35). However, the rise in prices has been steeper since 2008. Most of the pearl millet harvest is intended for consumption by the farmer, and very low volumes are marketed due to fluctuating production. Consequently the variability in prices is high owing to the unpredictable volumes that enter the market. The increase in demand for pearl millet in alternative uses as well as the increase in food prices in general has contributed to the increase in prices.

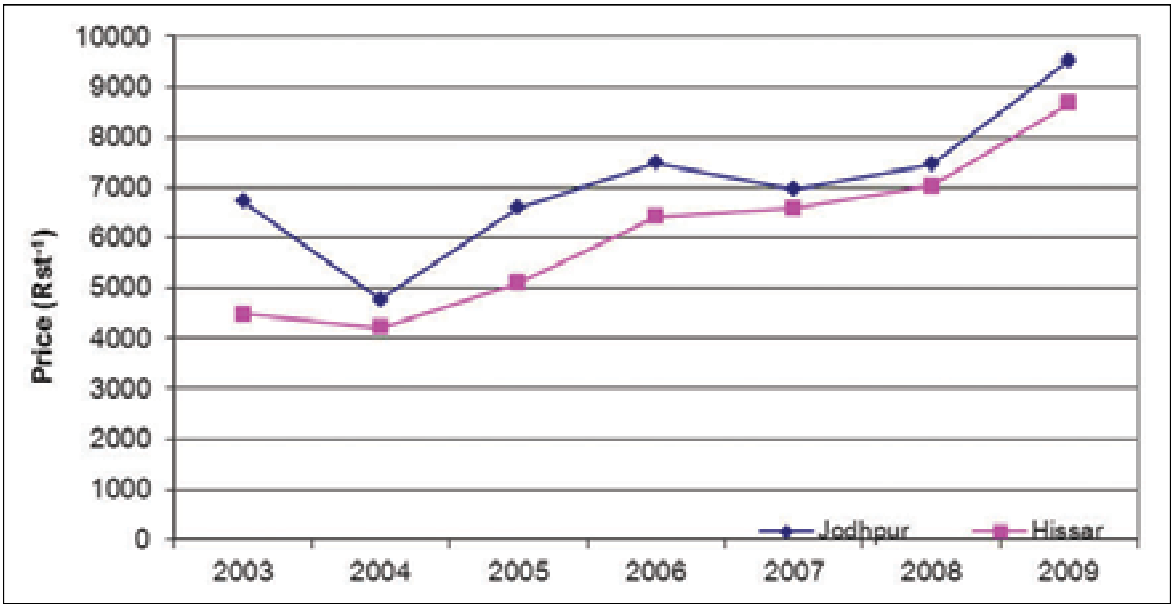


Figure 35. Trends in annual real wholesale prices of pearl millet in major Indian markets, 2003-09.

4. Markets, Institutions and Policies

4. Markets, Institutions and Policies

The prevailing trends in production, consumption and consequently trade of sorghum and millet have been the result of the domestic policies and institutional support in the major growing countries. By and large, both crops have been neglected on this front with policies favoring rice, wheat and maize. Furthermore, in the developing countries, both are primarily grown as subsistence crops and consequently variable marketed surpluses arrive to the markets. However, these crops are now also grown for the market with an increase in their utilization in alternative uses.

Producer support and trade policies

In many of the major sorghum and millet-growing countries of the developed world, there are no explicit producer support policies. Sorghum in particular is affected by the policies that are in place for maize, since it is considered a close substitute. Production of sorghum, and consequently its price, increased in those periods when stocking policies for maize were changed or when exports of maize were banned by some countries. For example, in the early 1970s, there was an increase in demand for sorghum by USA following a shift in the beef industry to the southern plains where sorghum is traditionally grown, and the low levels of sorghum stocks at that point owing to the domestic policies regarding disaster protection, which favored the cultivation of maize and wheat. (Lin and Hoffman 1989). The rising demand from South America for feedstock, in particular that of Mexico, and the restrictions placed on maize imports by Venezuela, led to further increases in the price of sorghum. Similarly, the trade embargo on maize exports from USA to the former USSR in the early 1980s increased the exports and consequently production of sorghum. In India, sorghum and millets are offered a common Minimum Support Price (MSP) by the government of India. Although the MSP has been increasing over the past few years in line with market prices (Fig. 36), by and large it is lower than the prices ruling in the market and the off take of sorghum and millet under the scheme is low and erratic. Furthermore, owing to the price fluctuations that depend on the seasonal arrivals, it is not unusual to see that the prices prevalent in the market place vary widely from the MSP.

In West Africa, owing to fiscal policies in the late 1980s, cheaper imported wheat induced urban populations to switch to bread and other

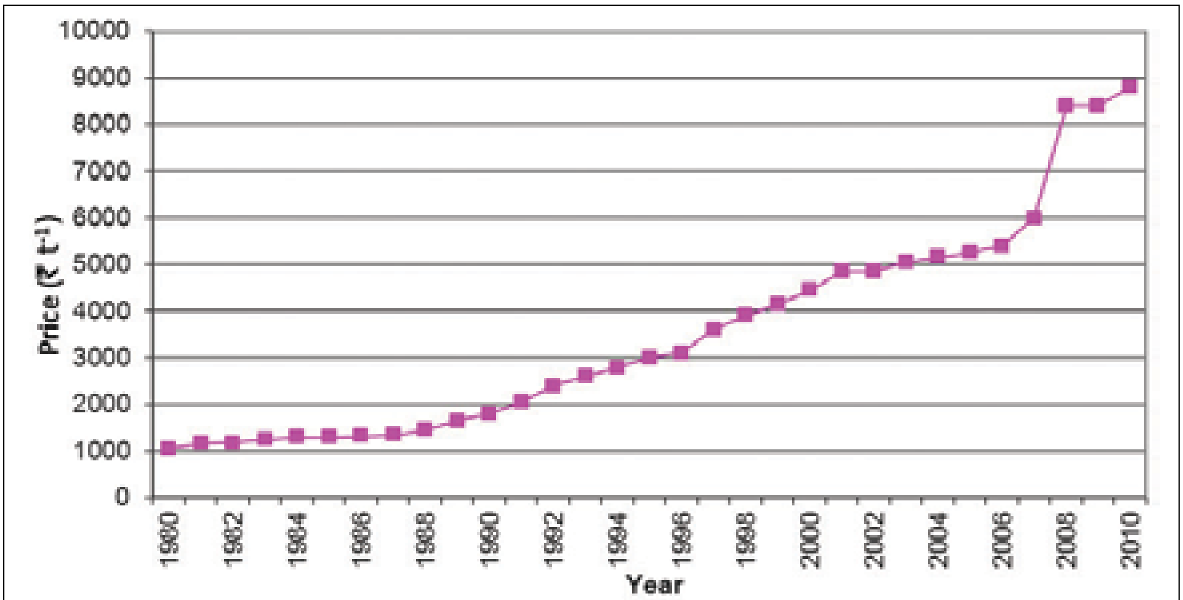


Figure 36. Trends in the minimum support prices of coarse grains in India, 1980-2010.

wheat products. However, with the adoption of the CFA, the price of imported wheat more than doubled, spurring a revival of interest in sorghum and millet. In Nigeria a ban was placed on the imports of all non-indigenous cereals, resulting in increased demand for sorghum for brewing and in the soft-drinks industry.

In eastern and southern Africa, before the late 1980s, the emphasis placed on maize as a staple with extensive institutional support ranging from the provision of subsidized inputs to the trade barriers in the maize market to protect domestic maize producers led to the increased cultivation of maize at the expense of other cereals. Surplus quantities only of maize were saleable, and could bring in cash to the household. Furthermore, the national cereals marketing agency, a monopoly, announced annual producer and consumer prices for cereals and other key food crops. These policies had the effect of changing the food preferences of consumers in the semi-arid areas away from the semi-arid food grains to maize (FAO 2005). Food relief to the semi-arid areas was often in the form of maize rather than sorghum or millets. However, post the late 1980s, following the structural adjustment programs and market liberalization policies in many African countries, farmers received less money for their maize crop than they did before while the costs of hybrid seed and fertilizer increased dramatically. Transport costs also increased owing to the institution of private marketing boards.

Marketing system

The marketing system for sorghum and millet grain varies considerably between the developing and developed countries. In developed countries where sorghum and millets are grown for feed use, the marketing system is a highly developed one with stringent quality standards for both domestic use and export. The volumes reaching the market are large. In developing countries on the other hand, sorghum and millets are usually grown for domestic consumption and stored in small quantities, mostly in traditional storage containers/structures. Whatever is in excess of the household needs makes its way to the markets, and thus consistent, large quantities are seldom accumulated. Domestic markets for sorghum and millets in Africa and Asia are characterized by low and variable volumes, high transaction costs and long distances to better markets. There is no organized marketing infrastructure for these crops in most countries, particularly the African countries, because of irregular and unpredictable supplies. In India, for example, the surplus grain is usually sold to village traders rather than in organized markets. Furthermore, compared to other cereal grains, sorghum and millets are not widely traded internationally for food use and there are very few quality standards that are met.

Marketing system in India

In India, although sorghum and pearl millet are primarily grown for domestic consumption, a significant portion of production is traded. This is particularly true for rainy season sorghum hybrids which are increasingly being used in the poultry and cattle feed industry and in the manufacture of fine grain alcohol. The feed use of sorghum is dependent on the price of maize and the quality of sorghum grain. Postrainy season sorghum continues to be traded primarily for food use.

Generally, in the major sorghum-growing areas, farmers and village traders will travel up to 60 km to regulated markets to sell their produce (Marsland and Parthasarathy Rao 1999). Wholesaler in these markets may also buy from other states to cover any local shortfall. While evidence is sketchy, it appears that manufacturers of alcohol from sorghum grain are increasingly favoring contract farming arrangements which assures the manufacturers raw materials that meet certain quality and quantity requirements.

Fodder markets in India for both sorghum and pearl millet are informal and there is no regulation on the sales and purchases. The transactions are generally carried out by middlemen who play an important role in determining the price. Although the demand for processed (chopped) fodder for both crops is increasing, there are no policies or incentives for private fodder processing.

5. Outlook for Sorghum and Millets

5. Outlook for Sorghum and Millets

Model description

In this section we examine possible future scenario for sorghum and millets in terms of likely changes in area, production, yield, consumption and trade in major Asian countries growing these crops vis-à-vis the global scenario. The analysis uses the IMPACT model developed by the International Food Policy Research Institute (IFPRI). The model was expanded in coverage of crops and geographical area by ICRISAT and IFPRI to include important dryland crops like millets, sorghum, chickpea, pigeonpea and groundnut and to include countries in the SAT.

The model simulates the behavior of a competitive world agricultural market for crops and livestock, and is specified as a set of food producing units that can be aggregated to countries or regional submodels, within each of which supply, demand and market clearing prices for agricultural commodities are generated for each year. The country and regional agricultural submodels are linked through trade in a non-spatial way, such that the effect on country-level production, consumption and commodity prices is captured through net trade flows in global agricultural markets. Demand is a function of prices, income and population growth. Growth in crop production in each country is determined by crop prices and the rate of productivity growth. World agricultural commodity prices are determined annually at levels that clear international markets. The model uses a system of linear and nonlinear equations to approximate the underlying production and demand relationships, and is parameterized with country-level elasticities of supply and demand (Rosegrant et al. 2008).

The Water Simulation Module (WSM) is an important component of the IMPACT model. The WSM simulates water availability for crops taking into consideration total renewable water, nonagricultural water demand, water supply infrastructure and economic and environmental policies related to water management at the river basin, country and regional levels. IMPACT-WATER – the integration of IMPACT and WSM – incorporates water availability as a stochastic variable with observable probability distributions to examine the impact of water availability on food supply, demand and prices. This framework allows exploration of the relationship of water availability to food production, demand and trade at various spatial scales – from river basins, countries or regions to the global level over a horizon of 25 years.

The version of the model used for this paper is the IMPACT-Water model with a base year 2000 (a three-year average of 1999-2001 FAOSTAT (http://www.faostat.fao.org) data) with projections to the year 2020.

Within the IMPACT-WATER model, there are several principal "drivers" that underlie the dynamics of agricultural production and consumption growth over time. The primary macro-economic drivers are income growth and population growth, which jointly determine the dynamics of per capita income for each country, which is a major determinant of food commodity consumption behavior. The principal drivers for agricultural growth are those which determine the expansion or contraction of available land for agriculture, and the productivity growth of irrigated and rainfed crops over time, which reflects improvements in agricultural technology and growth potential that can be realized over time. Other important policy relevant variables to consider are those which affect the market prices of the commodities directly – such as the marketing margins of the crops within their respective regions, as well as the degree of subsidy/ protection that is given to either consumers or producers.

Based on the analysis of historical data and available evidence, many of the drivers are already embedded within the business-as-usual baseline scenario in terms of income, crop yield and livestock growth rates and observed trade policies in terms of marketing margins and protection levels for specific commodities in each country.

Sorghum

Business-as-usual scenario

Given the current levels of technology, water availability, per capita income and demand conditions, projected forecasts for production, demand and net trade in sorghum are presented in Table 18. The model forecasts that India's production is set to increase from 7.8 million t in 2005 to nearly 9 million t in 2025. The increased production is primarily domestically consumed with total demand in India increasing from 8 million t in 2005 to 9 million t in 2025. The trade deficit will worsen slightly, but most of the increased demand in India will be met through its domestic sorghum production. Decreased exports from both Africa and North America are also forecast. Latin America's demand for sorghum is forecast to increase as well, and domestic production will not be sufficient to meet this. Therefore, its imports will rise, creating a trade deficit of three million t in 2025.

Millets

Business-as-usual scenario

Table 19 shows start and end year values of production, demand and net trade in millets. Given that current levels of yield growth, per capita income growth and demand structures remain the same, millet production is set to increase to 42 million t in 2025. India will account for over 25% of all millets production. There will be no marked change in the net trade position - India will continue to have a trade surplus in millets exports. In contrast, the net trade position of Africa is set to worsen. Demand for millets is projected to increase from 28 million t in 2005 to 42 million t in 2025. The main source of demand will continue to be food demand, with Africa overtaking Asia as the largest consumer of millets as food. Feed demand will be relatively low and largely concentrated in Asia.

Table 18. Business-as-usual scenario for sorghum.

	Baseline value in 2005	Baseline value in 2025	Baseline value in 2005	Baseline value in 2025	Baseline value in 2005	Baseline value in 2025	Baseline value in 2005	Baseline value in 2025
	Production ('000 t)		Yield (kg ha^{-1})		Demand ('000 t)		Net trade ('000 t)	
Region/country								
Africa	23,305	39,528	873	1,154	21,411	37,671	2,364	2,327
Northern America	10,611	10,805	3,737	4,079	6,753	7,415	4,442	3,974
Latin America	11,791	18,159	2,887	3,650	16,184	21,330	-3,954	-2,732
Europe	699	832	3,787	4,464	799	795	-66	70
Asia	11,224	13,423	985	1,249	13,950	16,939	-2,925	-3,714
East Asia	2,416	2,976	3,834	5,090	5,027	5,856	-2,468	-2,736
South Asia	8,008	9,311	795	994	7,975	9,482	-271	-475
India	7,831	9,102	800	1,001	7,747	9,144	-213	-338
Oceania	1,986	2,449	2,800	3,044	1,906	2,432	141	78
World	59,615	85,195	1,299	1,589	61,006	86,586		

Table 19. Business as usual scenario for millets.

Region/country	Production ('000 t) Baseline value in 2005	Production ('000 t) Baseline value in 2025	Yield (kg ha^{-1}) Baseline value in 2005	Yield (kg ha^{-1}) Baseline value in 2025	Demand ('000 t) Baseline value in 2005	Demand ('000 t) Baseline value in 2025	Net trade ('000 t) Baseline value in 2005	Net trade ('000 t) Baseline value in 2025
Africa	14,289	24,409	669	911	14,377	25,858	17	-1,344
Northern America	350	375	1,446	1,479	282	330	29	6
Latin America	29	44	1,584	2,084	32	44	-4	-1
Europe	972	1,319	1,038	1,497	1,196	1,183	-167	193
Asia	13,251	16,146	967	1,316	12,746	14,619	114	1,137
East Asia	1,813	2,093	1,827	2,206	2,235	2,575	-463	-522
South Asia	11,121	13,607	909	1,259	10,167	11,568	616	1,701
India	10,524	12,843	921	1,289	9,542	10,648	607	1,820
Oceania	43	50	1,206	1,271	33	39	11	10
World	28,935	42,343	797	1,052	28,665	42,073		

6. Conclusion

6. Conclusion

While sorghum and millets are primarily used for feed in developed countries, they are an important staple for the poor in the developing countries of Africa and South Asia. However in the last two decades their importance as food staples, particularly in Asia, has been declining due to various factors that include rising incomes, growing urbanization and government policies favoring the production and consumption of fine cereals like rice and wheat. However, the same factors are driving the demand for these crops in alternative uses like feed, alcohol and processed food industry (being promoted as health foods). Sorghum and pearl millet in India are witnessing resurgence as the alternative utilization patterns unfold. For both the crops more than 50% of the production is now finding its way to alternative uses as opposed to its consumption only as a staple. The one exception, however is the postrainy season sorghum grown in India on residual soil moisture that continues to be a staple because of its superior grain quality. It is, however, also finding small niches in the food processing sector.

The expanding demand for coarse cereals suggests that there are considerable opportunities for growth of this sector in Asia, which need to be harnessed by overcoming supply-side constraints through generation and diffusion of appropriate technologies for different production environments. In much of Asia, sorghum and pearl millet are grown in marginal environments characterized by low and erratic rainfall and limited irrigation facilities and hence face higher production risks. Besides promoting yield-increasing technologies that reduce per unit cost of production, crop scientists working on these crops should re-orient their focus towards developing varieties that can withstand moisture stress ensuring stability in yields and that are resistant to insect pests and diseases.

Developing varieties with traits suitable for different uses should be an important priority of crop improvement to meet end user requirement. With the recent increasing demand for coarse grains in niche markets such as health foods and gluten-free substitutes, identifying and developing processing technologies that increase the shelf-life of sorghum and peal millet flour will result in their increased use in processed products particularly in the urban centers. Since dual purpose cultivars are preferred, the focus should be both on grain and stover. Both sorghum and pearl millet stover are important sources of livestock feed and stover with high digestibility coefficients are preferred for higher milk yield.

Even as there is a need to correct policy bias against sorghum and pearl millet in particular and rainfed agriculture in general, there is a need to put in place institutions and policies linking small-scale farmers to the new sources of demand, through innovative institutional arrangements to ensure that produce of a given quality and price is delivered to end users.

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Appendix Tables

Appendix Table 1. Trends in the region and area, yield and production of coarse cereals by country.

	Area (million ha)			Yield (kg ha^{-1})			Production (million t)		
Country/Region	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**	**1980-82**	**1993-95**	**2006-08**
World	337	327	323	2,202	2,559	3,329	743	836	1,076
Developed countries	160	126	113	3,099	3,746	5,087	496	473	576
Europe	51	42	44	5,016	5,949	7,934	257	251	345
North America	104	79	63	2,329	2,695	3,506	242	213	220
Oceania	5	5	7	1,120	1,772	1,592	5	9	11
Developing countries	178	200	210	1,489	1,810	2,380	264	363	499
Africa	50	73	85	1,118	1,016	1,207	56	74	103
LAC	32	33	36	2,003	2,469	3,523	65	81	126
Asia	96	94	89	1,478	2,198	3,048	143	207	271
East Asia	32	30	34	2,680	4,259	4,951	87	127	168
China	30	29	33	2,677	4,278	5,001	81	123	165
South Asia	48	38	34	704	998	1,480	33	38	51
India	42	32	29	701	929	1,324	29	30	38
Iran	2	2	2	919	1,759	2,705	2	3	5
Pakistan	2	2	2	859	1,025	2,076	2	2	4
Southeast Asia	9	9	10	1,246	2,012	3,275	11	17	31
Indonesia	3	3	4	1,514	2,224	3,754	4	7	14
Philippines	3	3	3	979	1,526	2,506	3	4	7
Viet Nam	0	1	1	1,122	2,017	3,894	0	1	4
West Asia	8	10	8	1,460	1,659	1,998	11	16	17
Turkey	4	4	4	1,917	2,293	2,976	8	10	12

Appendix Table 2. Trends in the region and growth rates of area, yield and production of coarse cereals by country.

Country/Region	Area			Production			Yield		
	1980-2008	1980-94	1995-2008	1980-2008	1980-94	1995-2008	1980-2008	1980-94	1995-2008
World	-0.43	-0.24	-0.09	1.14	0.85	1.63	1.58	1.09	1.72
Developed countries	-1.71	-1.91	-0.84	0.38	-0.26	1.15	2.12	1.68	2.00
Europe	-0.67	-1.34	-0.47	1.32	0.53	1.71	2.00	1.89	2.18
North America	-2.49	-2.22	-1.41	-0.88	-1.28	0.33	1.66	0.96	1.77
Oceania	1.27	-1.34	3.07	2.43	0.72	1.59	1.14	2.09	-1.43
Developing countries	0.47	1.06	0.35	2.29	2.65	2.24	1.81	1.57	1.88
Africa	1.88	3.17	1.20	2.45	3.15	2.38	0.56	-0.02	1.16
LAC	0.11	-0.22	0.33	2.50	1.27	3.16	2.38	1.49	2.83
Asia	-0.43	0.15	-0.40	2.15	2.99	1.79	2.59	2.84	2.20
East Asia	0.15	-0.10	0.24	2.24	3.02	1.46	2.09	3.12	1.22
China	0.27	0.02	0.30	2.21	3.28	1.19	2.49	3.30	1.47
South Asia	-1.43	-1.77	-0.51	1.10	0.91	2.16	2.57	2.72	2.68
India	-1.61	-2.09	-0.64	2.29	2.64	2.17	0.65	0.50	1.52
Iran	-1.06	0.59	0.42	4.32	4.22	3.28	3.25	4.80	3.74
Pakistan	-0.12	-0.51	-0.07	3.24	1.60	6.01	3.11	1.07	5.94
Southeast Asia	-0.03	0.09	0.39	3.31	2.74	3.99	3.34	2.65	3.59
Indonesia	1.12	1.65	-0.19	3.27	2.91	3.90	4.43	4.59	3.72
Philippines	-1.68	-0.35	-0.50	3.46	3.38	4.03	1.72	2.98	3.52
Viet nam	4.40	2.75	5.86	5.01	3.53	4.89	9.63	6.41	11.02
West Asia	0.15	2.53	-0.92	1.74	3.61	1.16	1.58	1.05	2.10
Turkey	0.15	0.07	-0.51	1.46	1.37	2.56	1.62	1.43	2.04

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International Crops Research Institute for the Semi-Arid Tropics

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ICRISAT-Patancheru
(Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

ICRISAT-Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT- Kano
PMB 3491
Sabo Bakin Zuwo Road,
Tarauni, Kano, Nigeria
Tel: +234 7034889836;
+234 8054320384
+234 8033556795
icrisat-kano@cgiar.org

ICRISAT-Bamako
(Regional hub WCA)
BP 320
Bamako, Mali
Tel +223 20 709200
Fax +223 20 709201
icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776
Bulawayo, Zimbabwe
Tel +263 383 311 to 15
Fax +263 383 307
icrisatzw@cgiar.org

ICRISAT-Niamey
BP 12404, Niamey
Niger (Via Paris)
Tel +227 20722529,
20722725
Fax +227 20734329
icrisatsc@cgiar.org

ICRISAT-Nairobi
(Regional hub ESA)
PO Box 39063, Nairobi,
Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

ICRISAT-Lilongwe
Chitedze Agricultural
Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297, 071, 067, 057
Fax +265 1 707298
icrisat-malawi@cgiar.org

www.icrisat.org

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