Sorghum Production for Diversified Uses

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ABSTRACT

Sorghum is a unique crop produced for domestic and export markets with multiple uses as food, feed, fodder, fuel and fiber grown globally. The sorghum grain is the major ingredient in cattle feed, poultry and swine around the globe. Stover is an important fodder source for both milch and draft animals in mixed crop-livestock systems. Sorghum provides raw material to many industrial uses like potable alcohol, transport grade ethanol malt, beer, liquids, gruels, starch, adhesives, core binders for metal casting, ore refining and grits as packaging material. Spatial distribution shows that it is grown on 40.5 M ha in 98 countries of Africa, Asia, Oceania and the Americas. Nigeria, India, the USA, Mexico, Sudan, China and Argentina are the major producers of sorghum. The crop is adapted to a wide range of temperatures, including high elevations in East Africa. In South Asia, where adoption rates are high, the most significant adoption constraints are specific varietal traits (e.g., disease resistance, duration, yield, stover quality). In Africa, where adoption rates are lower, the most significant adoption constraints are access to seed and information, bird damage (associated with early-maturing varieties) and poor soil fertility/lack of fertilizer. Recent global trends also show that both grain yield and production increased reflecting increase in use of improved varieties, increased demand due to population growth and higher world prices for major cereals. The area under sorghum is increasing gradually in West and

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Central Africa (WCA) while in other regions it's area is showing a declining trend over last few decades. In general, the grain is grown in more economically advanced countries for feed purpose and in less developed countries for food purpose. According to IFPRI models, the future scenario indicates that demand for cereals is to increase by 40% over 2000 by 2020. It's demand is sustained in view of climate change, diversifying global food basket in developing nations while its use as non-food in industries drive sorghum demand in developed nations in future.

Keywords: Sorghum, production, use, distribution, cultivation, constraints, trade

1.1 Introduction

Grain crops supply approximately 85% of the world's food energy and only four other food crops (rice, wheat, maize and potatoes) are consumed more than sorghum. Sorghum is the world's fourth major cereal in terms of production, and fifth in acreage following wheat, rice, maize and barley, and is a staple food crop of millions of poor in Semi-Arid Tropics (SAT). It is mostly grown as a subsistence dry land crop by resource limited farmers under traditional management conditions in SAT regions, which are characterized by inadequate and unpredictable rainfall, recurrent drought and fragile environments. Sorghum being one of the most hardy and versatile crops, capable of growing well under contrasting climatic conditions (Espinoza and Kelley 2002). The crop is genetically suited to hot and dry agro-ecologies where it is difficult to grow other food grains. In many of these agro-ecologies, sorghum is truly a dual-purpose crop; both grain and stover are highly valued outputs. In large parts of the developing world, stover represents up to 50% of the total value of the crop, especially in drought years (FAO and ICRISAT 1996). Sorghum is a dietary staple for 500 million people in over 30 countries of SAT providing energy, protein, vitamins and minerals. It is grown on all six continents in areas where the average summer temperature exceeds 20ºC and a frost-free season. Sorghum grain is produced for domestic and export markets and is finding industrial uses. Sorghum is used not only for human food, but also for fodder and feed for livestock, building material, fencing and brooms (Doggett 1988; House 1985; Rooney and Waniska 2000). It is also a principal source of alcoholic beverages in many countries.

Sorghum production and utilization in the world fall under two broad groups. Group I countries (primarily in Asia and Africa), where production is traditional, subsistence at small-scale and use sorghum predominantly for food. Yields are generally lower and vary considerably from year to year. Group II countries (developed countries and some developing countries), where production is modern, mechanized with high-input and large-scale, and is primarily for animal feed, other uses and yields are higher. Sorghum was cultivated on 40.93 million hectares and 55.72 million metric tons of grain was produced in 2010 (FAOSTAT 2013). Of the total world area devoted to sorghum, over 80% is in developing countries. The United States of America (USA) is the largest producer, followed by Mexico, Nigeria and India. The top exporters are USA, Australia and Argentina. The average global productivity is about 1.49 t ha^{-1}. However, the productivity in several countries such as Italy (6.6 t ha^{-1}), France (5.5 t ha^{-1}), Egypt (5.0 t ha^{-1}), Argentina (4.83 t ha^{-1}) and the USA (4.50 t ha^{-1}) is quite high. As a continent, Africa is the largest producer with 23.58 million metric tons on 24.8 million hectares (FAS/USDA 2010). The following sections of this chapter discusses in detail on the crop history, adaptation, constraints, utilization pattern, geographic distribution, economics and future perspective to understand the various aspects of sorghum.

1.2 Origin and History

1.2.1 Origin

Sorghum is an ancient crop belongs to the grass family, *Gramineae* and subfamily, *Panicoideae*, tribe *Andropogoneae*, characterized by dorsally compressed spikelet's (Hitchcock 1950). The name "sorghum" comes from Italian term "sorgo", in turn evolved from Latin word "Syricum" (granum) meaning grain of Syria. Cultivated sorghum probably originated in East Central Africa, in or near Ethiopia or Sudan, because of the greater diversity of sorghum in that region (Damon 1962). The cultivated sorghum of the present day arose from a wild progenitor belonging to the subspecies *verticilliflorum* (Vavilov 1951).

1.2.2 History of Cultivation

The beginning of sorghum cultivation is shrouded in mystery. Evidence indicates that it started in eastern Africa in prehistoric times. The largest diversity of cultivated and wild sorghum has been reputed for Africa (De Wet 1977; Doggett 1988). Sorghum was apparently carried by migrating natives to many countries of Africa, there by reaching Bostswana in the 10th century AD, Zambia by 14th century and southern Africa in the 16th century (Clark 1959) and eastern Africa around 200 AD or earlier. Sorghum was brought to India from eastern Africa during first millennium BC. Its production spread across southern Asia, and reached China apparently in the 13th century (Hagerty 1941). During the Muslim agricultural revolution, sorghum was planted extensively in parts of the Middle East, North Africa, Europe and Egypt (Watson 1983). Seed of sorghum was carried from Africa to various parts of the Western Hemisphere by captive slaves during 17th and 18th centuries. Although sorghum arrived in Latin America through the slave trade and by navigators plying the Europe-Africa-Latin America trade route in the 16th century, the crop did not become important until the present century. The case is similar for Australia. Finally the culture of sorghum use for syrup and forage in USA started with the introduction of Chinese amber sorgo by France in 1853 and South Africa in 1857.

1.3 Adaptation and Adaptability

Sorghum belongs to the family *Poaceae* and is characterized by an inflorescence (raceme) and grain (caryopsis) in the form of a panicle, spikelet's borne in pairs, and extensively branching roots grown in warmer climates worldwide. The adaptive characteristics include its extensive root system that helps in gathering water, a waxy coating on the leaves that helps in water retention and the development of its seed heads over longer periods of time than other grains to enable it to bare short periods of water stress without affecting its ability to develop kernels. These adaptations that advance the individual needs of the plants for their own survival and reproduction also allows the plant to serve a larger purpose as a valuable subsistence crop for those living in semi-arid tropical regions. Sorghum requires an average temperature of at least 25°C to produce maximum grain yields in a given year. Maximum photosynthesis is achieved at daytime temperatures of at least 30°C. Night time temperatures below 13°C for more than a few days can severely impact the plant's potential grain production. Sorghum is not tolerant to cool weather and grows slowly below 20ºC, but germination and growth will occur in some varieties at temperature as low as 12ºC (House 1985). Hence, sorghum can be grown 40° latitude on either side of the equator. Inflorescence development and seed-set are normal at temperatures of 40–43°C and at 15–30% relative humidity, if soil moisture is available. The crop is adapted to a wide range of temperature regimes, including high elevations. The plants require up to 70 to 100 millimeters of moisture every 10 days in early stages of growth, and as sorghum progresses through growth stages and the roots penetrate more deeply into the soil to tap into hidden water reserves, the plant progressively needs less water. Sorghum yields are not affected by short periods of drought as severely as other crops because it develops its seed heads over longer periods of time, and short periods of water stress do not usually have the ability to prevent kernel development. Sorghum requires 332 kg of water per kg of accumulated dry matter, whereas maize required 368 kg of water, barley required 434 kg, and wheat required 514 kg (Reddy et al. 2011). Sorghum's ability to thrive with less water may be due to its ability to hold water in its foliage. It also has the capacity to resume growth upon receipt of rain after surviving dry periods (House 1985). Sorghum also withstands wet extremes better than many other cereal crops. Sorghum continues to grow, though not well, in flooded conditions (Reddy et al. 2011).

The tolerance of sorghum to abiotic stresses, especially the enhanced tolerance to drought and adaptation to marginal lands has been well documented. Under the same stressed environment the adaptation and yield stability of sorghum is more enhanced than that of other crops (Berenji and Dahlberg 2004). It has strong resistance to harsh environments such as dry weather and high temperature in comparison to other crops, it is usually grown as a low-level chemical treatment crop with limited use of pesticides and it has a potential to adapt itself to the given natural environment (Smith and Frederiksen 2012). Sorghum is valued because of its ability to produce in areas with marginal rainfall (400–600 mm) and high temperatures (i.e., SAT and subtropical regions of the world), and also, because of its relatively short growing season requirement, thus its suitability for double cropping and crop rotation systems (Smith and Frederiksen 2012). Its growth is also important in the areas with higher rainfall (up to 1,200 mm), where poor soil fertility, soil acidity and aluminum toxicity are common. Sorghum is extremely hardy and is able to produce even under very poor soil fertility conditions. With the expected increase of temperatures and decrease of precipitation as the result of global climate change scenario and their effect on production of high input crops, the wider adaptability of sorghum could help alleviate crop losses in areas affected by abiotic stresses (Dahlberg et al. 2011).

1.4 Constraints of Crop Production

The productivity of sorghum across the world is influenced by a wide array of biotic and abiotic constraints and some of which cause significant economic losses annually. The details of these have been discussed in subsequent sections.

1.4.1 Biotic Stresses

There are nearly 150 species of insect pests reported on sorghum. The significant amongst biotic constraints are shoot fly (*Atherigona soccata* Rondani), stem borers (*Chilo partellus* and *Busseola fusca*), midge (*Contarinia sorghicola* Coq.), head bug, aphid, armyworms and locusts. To manage these pests, integrated pest management systems rely on an array of different control approaches (genetic, physical, chemical, cultural, biological, etc.). The type of insect that causes economic damage depends on the environment and specific area of production.

Diseases either alone or in combination cause significant economic losses annually (Thakur et al. 2011). The major diseases include grain mold, charcoal rot (*Macrophomina phaseolina*), downy mildew (*Peronosclerospora sorghi*), anthracnose, rust (*Puccinia purpurea*), leaf blight and several viral diseases.

Striga spp. is parasitic weed which are endemic throughout most of Africa that causes significant economic damage to most of the important crops grown on that continent. In many regions of Africa, *Striga hermonthica* is a major constraint to sorghum production and causes yield losses varying from 10 to 100% depending on crop cultivar and infestation level.

1.4.2 Abiotic Stresses

Sorghum is frequently exposed to a plethora of abiotic stress conditions such as drought, salinity, high temperature, flooding, heat, oxidative stress heavy metal toxicity, etc. due to farmer's preference to take up this crop in marginal lands with poor fertility. The majority of the sorghum areas is prone to one or multiple abiotic stresses mentioned above. Abiotic stresses are the principal cause of crop failures including that of sorghum worldwide, dipping average yields for most major crops by more than 50% (Bray et al. 2000).

1.4.3 Others

In South Asia, where adoption rates are high, the most significant adoption constraints are specific varietal traits (e.g., disease resistance, duration, yield, stover quality). Lack of access to seed or information is less important. In WCA and ESA, where adoption rates are lower, the most significant adoption constraints are access to seed and information, bird damage (associated with early-maturing varieties) and poor soil fertility/lack of fertilizer.

1.5 Geographical Distribution and Cultivation

1.5.1 Current Scenario of Global Distribution

Sorghum is distributed throughout the tropical, semitropical, arid and semi-arid regions of the world. Sorghum is also found in temperate regions and at altitudes of up to 2,300 meters in the tropics. It has a potential to compete effectively with crops like maize under good environmental and management conditions. It is one of the most widely grown dry land food grains in India. Sorghum is a dietary staple of more than 500 million people

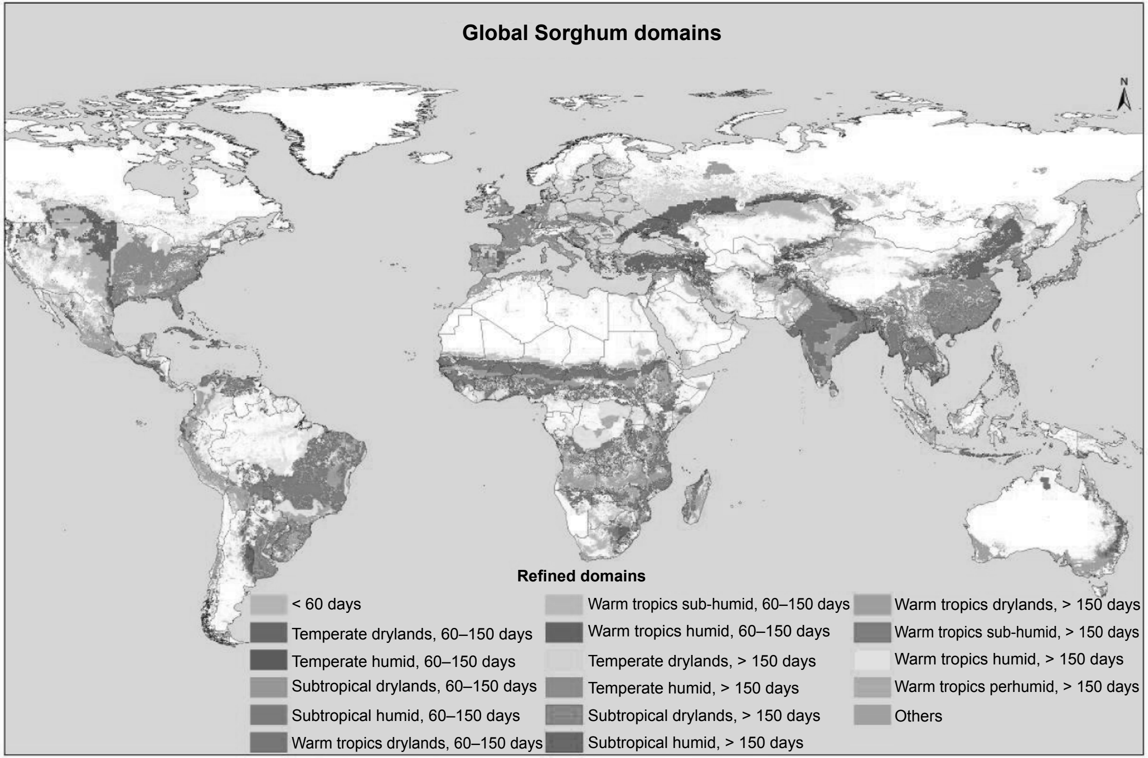

Figure 1-1 Global harvested area for sorghum. Source: ICRISAT 2012, CGIAR research program on dry land cereals.

Color image of this figure appears in the color plate section at the end of the book.

in more than 30 countries. In 2012 it was being grown on 40.93 m ha in 107 countries of Africa, Asia, Oceania and the Americas, with the highest record of 51 m ha in 1980s.

The major sorghum producing countries are Nigeria, India, the USA, Mexico, Sudan, China and Argentina. Other sorghum producing countries include Burkina Faso, Chad, Ethiopia, Gambia, Ghana, Mali, Mauritania, Mozambique, Niger, Senegal, Somalia, Tanzania and Yemen. Globally, sorghum production has remained more or less stable over the past 30 years, although there are notable regional differences. Area of production has decreased overall, but has remained essentially constant during the past five years on a global basis. The world area of production in year 2008–09 was 42.02 m ha and for the year 2009–10 was 40.93 and total production of sorghum being 64.72 million tons for the year 2008–09 and 55.72 million tons for 2009–10 respectively. A decrease of 3.47 million metric tons was reported, while the area remained more or less same (WAP/USDA 2010). The data on sorghum area, productivity and production in various regions of the world are given in Table 1-1.

The highest yield of 20.1 t ha^{-1} for grain sorghum has been reported in Texas, a similar trend was observed in case of sweet sorghum and sudangrass (Dahlberg et al. 2011). The 10 largest producers of sorghum in the world during 2010 are the USA, India, Mexico, Nigeria, Argentina, Ethiopia, Burkina Faso, China, Australia and Brazil (Table 1-2). These 10 countries together account for 54 % of the total area (22.25 m ha) and 71% of the total world production, i.e., 39.74 million tons (FAOSTAT 2013).

Of the total world area devoted to sorghum, over 80% is concentrated in developing countries. In Asia, sorghum is extensively cultivated in India, China, Yemen, Pakistan and Thailand. A decrease in area of production

Table 1-1 Area harvested, productivity and production of sorghum by region, 2010.

Region	**Area harvested (m ha)**	**% Total**	**Productivity (t ha^{-1})**	**Production (m t)**	**% Total**
Asia–Pacific	1.31	3.20	1.03	3.59	6.44
South Asia	8.01	19.5	0.85	6.84	12.2
West Asia and North Africa (WANA)	6.39	15.6	2.00	4.24	7.60
Eastern and South Africa	4.18	10.2	2.54	4.85	8.70
Western and Central Africa	14.04	34.5	1.84	12.10	21.71
Northern America	4.08	11.2	20.9	16.15	23.15
South America/Latin America	1.91	4.66	3.33	6.36	11.41
World	40.93		1.30	55.72	

Source: FAOSTAT Database 2013

Table 1-2 Leading sorghum production countries in 2010.

Country	Area harvested (m ha)	% of total area	Production (m t)	% of total production	Productivity (t ha^{-1})
USA	1.95	4.76	8.78	15.76	4.50
India	7.79	19.03	6.7	12.02	0.86
Mexico	1.8	4.40	6.94	12.46	3.92
Nigeria	4.74	11.58	4.74	8.51	1.01
Argentina	0.75	1.83	3.63	6.51	4.83
Ethiopia	1.62	3.96	2.97	5.33	1.83
Burkina Faso	1.98	4.84	1.99	3.57	1.00
China	0.54	1.32	1.73	3.10	3.16
Australia	0.51	1.25	1.6	2.87	12.85
Brazil	0.66	1.61	1.53	2.75	2.31
Total	22.25	54.58	39.74	72.88	

Source: FAOSTAT Database 2013

between years 1970 to 2010 was observed with reduction from 23 m ha (1970s) to 9.5 m ha (2010) but the grain yield increased from 0.8 to 1.4 t ha^{-1} between 1970s to 2010 (Reddy et al. 2011). Sorghum in Europe is limited to a few areas in France, Italy and Spain. In Oceania, Australia is the only producer of significance, the production is concentrated in Queensland and northern New South Wales, where about 95% of the total crop is produced (FAOSTAT 2013). In case of Africa, sorghum is grown in a large belt that spreads from the Atlantic coast to Ethiopia and Somalia, bordering the Sahara in the north and the equatorial forest in the south. This area extends through the drier parts of eastern and southern Africa, where rainfall is too low. Sorghum is the second most important cereal in Sub-Saharan Africa. West Africa, which produces about 25% of the world's sorghum, has seen a steady increase in total production over the past 25 years. Most of the increase up to 1995 was attributed to increase in area, although increase in productivity also contributed.

North and Central America produce the highest quantity of sorghum (14.62% of total production) due to higher yields. In North America, sorghum is cultivated in parts of the central and southern plains of USA where rainfall is low and variable. Kansas, Texas, Nebraska and Arkansas are the major producing states, accounting for about 80% of total production in the USA. Nebraska has averaged 23 t ha^{-1} forage yield over the last 10 years but forage yield of over 35 t ha^{-1} have been reported in the literature (Worker and Marble 1968). In Central and South America sorghum is grown in the drier parts of Mexico, El Salvador, Guatemala, Nicaragua, dry lowland interior areas of Argentina, dry areas of northern Colombia, Venezuela, Brazil and Uruguay. Mexico and Argentina are the largest producers (Table 1-2). Recent global trends show increase in both grain yield and production increases. These gains are increased due to improved varieties, better crop management practices.

1.5.2 Regional Distribution

The following section details the sorghum distribution and trends over the last four decades (1970–2010) in eight major regions of sorghum in the world.

1.5.2.1 Asia-Pacific

The sorghum area in Asia–Pacific (China, Myanmar, the Philippines, Thailand, Korea, Japan and Australia) declined by 10 fold from 5 m ha and now stabilized at 0.57 m ha during 1970–2010 while the productivity doubled from 1.6 t ha^{-1} to 3.1 t ha^{-1} (Fig. 1-2). The grain production during this period rapid declined repeatedly from 8 million tons to 1.76 million tons mainly due to increase in area under forage sorghum. In the first two decades (1970–1990) the decrease in area was drastic followed by a gradual decrease in the last two decades (1990–2010). However the decline in production was gradual. In terms of productivity there was a greater increase in first two decades as compared to the increase in last two, the

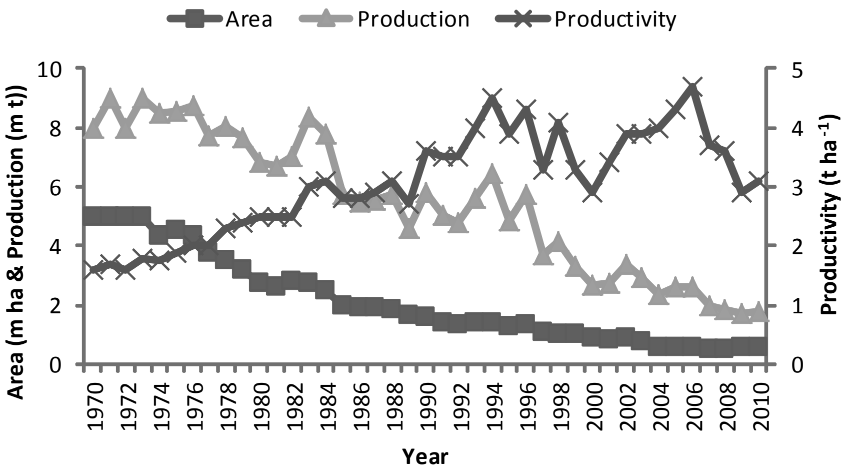

Figure 1-2 Sorghum area, production and productivity in Asia-Pacific region between 1970 and 2010.

highest being in 1994 (4.5 t ha^{-1}) and 2006 (4.7 t ha^{-1}) due to improved hybrids developed for food-market, which occupy approximately 55% of sorghum area.

1.5.2.2 South Asia

The sorghum area in South Asia (India, Pakistan, Bangladesh, Nepal, Bhutan and Srilanka) decelerated continuously at 3% per annum, from 20 m ha in 1970 to 8.01 million ha in 2010 (Fig. 1-3). However the production has marginally decreased from 8.4 million tons to 6.81 million tons during the same period in spite of 60% reduction in area, due to mainly doubling of productivity from 0.47 t ha^{-1} to 0.85 t ha^{-1}. Though there has not been much variation in area between the years 1970–1990 (first two decades), but there has been increase in production (8.4 m t to 11.9 m t) as well as productivity which doubled (0.47 t ha^{-1} to 0.8 t ha^{-1}). The increase in productivity was mainly due to spread of improved hybrids during the rainy season and high yielding varieties in post-rainy season. In South Asia yields of sorghum have risen suggesting that new technology has had a significant impact in raising yields in this region (CRP 3.6, 2012). India contributes to over 90% sorghum production in this region. The post-rainy season sorghum yield has steadily increased and is in great demand due to superior grain and stover quality. Though a decline of production is observed in South Asia between years 1980–2010, this trend of variation in production, however

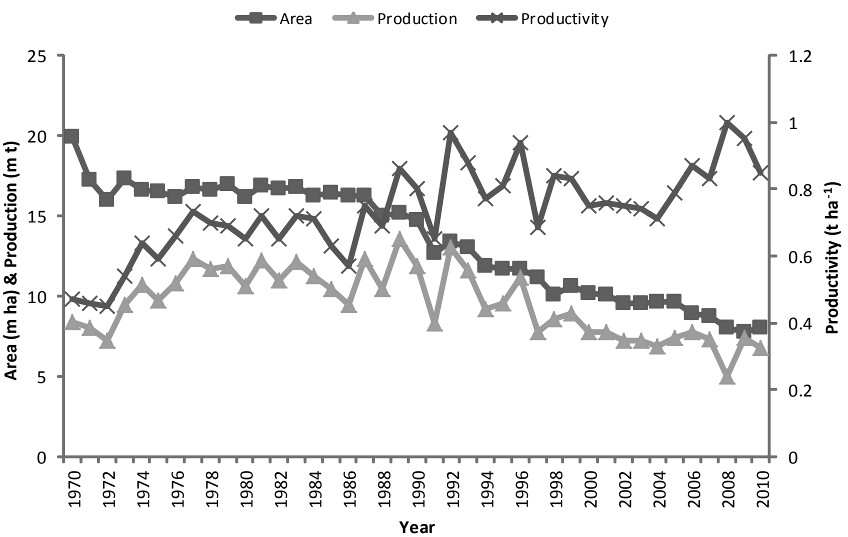

Figure 1-3 Sorghum area, production and productivity in South Asia between 1970 and 2010.

conceal very different trajectories between rainy and post-rainy season's (CRP 3.6, 2012). A close observation of the graph reveals that the sorghum area hovered between 16 m ha and 20 m ha during 1970–1987 and sharply declined from 1987 (16.3 m ha) due to concomitant increase in areas of competing crops like soybean, maize and also cotton due to increased area under irrigation. Since 2006, the sorghum area has stabilized around 8 m ha, due to gradual increase of grain demand in urban population besides stabilization of post-rainy season area in India. Sorghum grain yields in India have averaged 1170 kg ha^{-1} in the rainy season and 880 kg ha^{-1} in the post-rainy season in recent years. In this region, sorghum continues to play a prominent role in small holder farming system by providing employment, income and food for human consumption and feed for livestock. In some sorghum production states (e.g., rural Maharashtra in India) the per capita consumption is as high as 70 kg yr^{-1}) accounting for almost half (48%) of per capita consumption of all cereals. However, both production and food utilization have fallen during the 1980s and early 1990s, because of shifting consumer preferences, lopsided policy support compared to rice, wheat and other commercial crops.

1.5.2.3 West Asia and North Africa (WANA)

The sorghum cropped area in the WANA region (Algeria, Egypt, Morocco, Sudan, Tunisia, Turkey, Oman, South, Arabia, Yemen, Azerbaijan, Israel, Jordan, Lebanon, Syria Arab Republic) has witnessed a spectacular jump from 3.8 m ha in 1970 to 6.4 m ha in 2010, recording to 93% increased area (Fig. 1-4), whereas the increase in production was by 35%, i.e., from 3.1 m tons to 4.2 m tons. In case of productivity, it was stagnant around 2 t ha^{-1} till 1992 but rose by 50% to reach 5.9 t ha^{-1}. In the first two decades (between 1970–2010) there was a parallel relationship in terms of growth between area used (3.3 m ha to 3.5 m ha) and productivity (3.1 m t to 2.4 m t) and growth in productivity was less/gradual (1.8 t ha^{-1} to 1.5 t ha^{-1}). This is due to increased use of hybrids coupled with better crop management practices and increased proportion of farmers adopting new varieties, as improved seed cost is relatively low. Consumption of sorghum and its importance as a food security crop is highest in northern Africa. For example, consumption is 90–100 kg yr^{-1} in Sudan, sorghum provides over one-third of the total calorie intake. And countries like Sudan produce part of their sorghum on large farms for commercial purposes, using high inputs and sometimes supplementary irrigation.

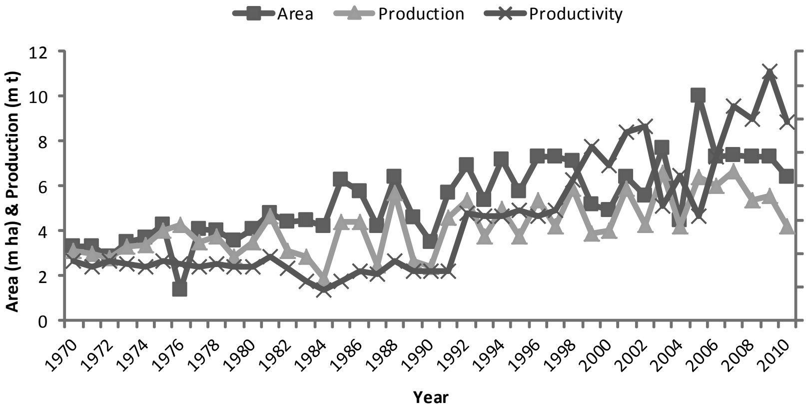

Figure 1-4 Sorghum area, production and productivity in WANA between 1970 and 2010.

1.5.2.4 Eastern and South Africa (ESA)

The sorghum area in ESA (Botswana, Burundi, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Rwanda, Somalia, South Africa, Uganda, Zambia and Zimbabwe) increased by 35% between the period, 1970–2010 from 3.7 million ha in 1970 to 5 million ha in 2010 (Fig. 1-5) and production increased in a similar range, from 3 million tons to 5.6 million tons. In case of productivity the increase is by 66% from 1.5 t ha^{-1} to 2.5 t ha^{-1} during the above period. In this region it is grown in drier regions, where precipitation is too low for the successful cultivation

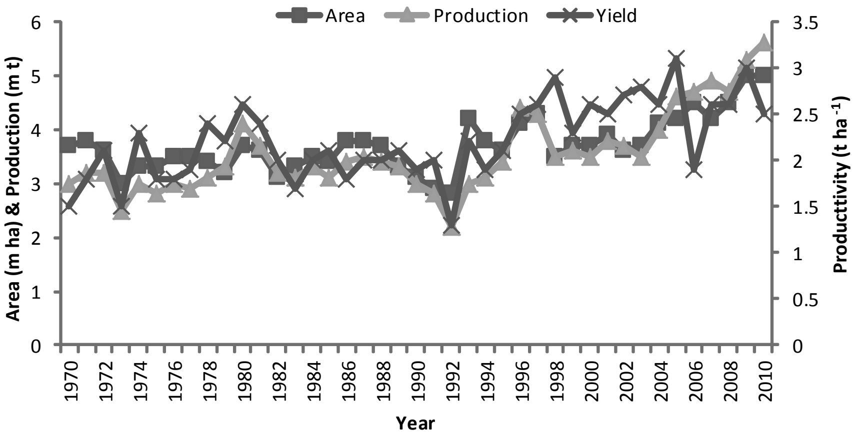

Figure 1-5 Sorghum area, production and productivity in ESA between 1970 and 2010.

of maize. Though there was decrease in sorghum production in the rest of the world, by 5% per year between 1980 and 2010, but an increase at the rate of 4% per year was observed in ESA, showing strong production growth in sorghum which suggests rising demand (CRP 3.6, 2012). Due to successful releases as well as potential adoptions, Ethiopia and Uganda have seen an increase in the area harvested to sorghum. On the other hand, the area harvested to sorghum has dwindled in South Africa and Botswana. There was no remarkable change for Zambia, Nicaragua, Honduras, El Salvador, Kenya, Zimbabwe and Mozambique (FAOSTAT 2013).

1.5.2.5 Western and Central Africa (WCA)

The sorghum area in Western and Central Africa (Benin, Burkina Faso, Cameroon, Central Africa Republic, Chad, Cote d Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo) increased by 55% between the period, 1970–2010 from 9 m ha in 1970 to 14 m ha in 2010 (Fig. 1-6) and this lead to doubling-up of production from 6.2 m tons to 12.1 m tons. The productivity increased by 38%, i.e., from 1.3 t ha^{-1} to 1.8 t ha^{-1} during the above period. In WCA, sorghum is a staple food and the supply of alternative cereal crops is limited. Hence the demand will rise for the available product in the absence of the alternatives. Due to release of successful varieties and better resource management and disease/pest control, area harvested for sorghum has increased in Nigeria, Niger, Mali, Senegal, Ghana and Burkina Faso. And production per year has increased by 7% between the periods 1980 to 2010 (CRP 3.6, 2012). At the same time the trends in demand for sorghum in

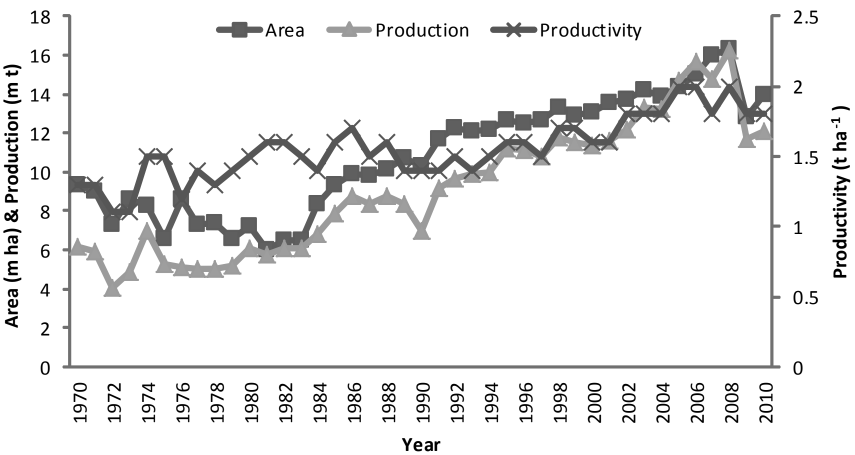

Figure 1-6 Sorghum area, production and productivity in WCA between 1970 and 2010.

western central Africa are the same for both rural and urban consumers and urban per capita consumption are expected to rise. The increase in demand for sorghum in the near future is suggested for western Central Africa by IFPRI's IMPACT model (Conforti 2011). Further, it indicates that for sorghum, per capita demand will grow strongly in this region from below 24 kg in 2010 to 28 kg by 2050.

1.5.2.6 North America and Caribbean Region

The sorghum area in North America (the USA, Cuba, Mexico, Panama, Belize, El Salvador, Guatemala and Haiti) has seen a decline gradually from 5.7 m ha in 1970 to 2 m ha in 2010. This resulted in a sharp fall in the production from 17.5 m tons to 8.8 m tons. But the productivity levels has increased significantly from 4.1 t ha^{-1} to 5.3 t ha^{-1} due to spectacular gains achieved through cultivation of improved heterotic hybrids (Fig. 1-7). Developed countries produce nearly one-third of the world's sorghum. The USA with an area of 1.94 m ha producing 8.77 m t at a productivity of 4.50 t ha^{-1} is a key player not on only in this region but impacts global sorghum trade significantly. It is the world's largest producer being the third most important grain with over 25% of global output (Kustudija 2012). In North America, it is cultivated in the central and southern plains of the USA (mainly in Kansas, Texas and Nebraska), where rainfall is low and variable. In a number of developed countries, the use of hybrid seed, fertilizer and irrigation have ensured that yields have increased even from a high base level. Sorghum production in Central America and the Caribbean is dominated by Mexico, which produces 90% of the region's total (FAOSTAT 2013). The Caribbean region is the major producer of sorghum for the feed market. There are sharp contrasts in productivity between regions. The reasons for

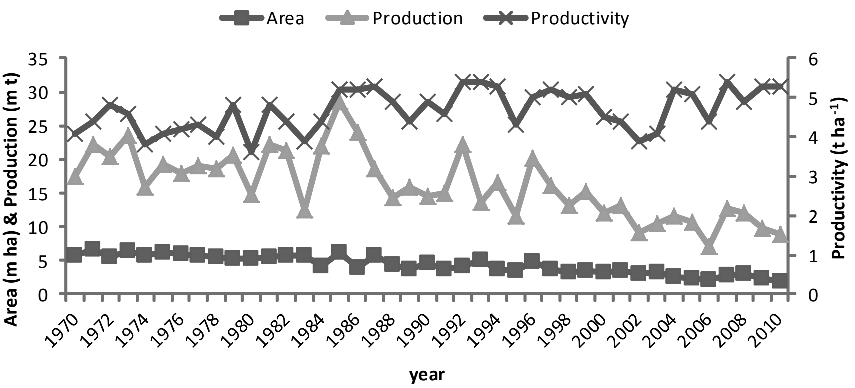

Figure 1-7 Sorghum area, production and productivity in North America and Caribbean region between 1970 and 2010.

these differences are essentially the degree of commercialization and the corresponding adoption of new technologies. Hybrids are most widely used in areas where sorghum is produced commercially. Correspondingly, the use of hybrids is concentrated in Central and North American countries. Most hybrids are developed for feed sorghum. Mexico is a good example of dramatic growth created by large-scale commercialization. The sorghum area in Mexico rose from 0.1 million to 1.5 million hectares from the 1960s through the early 1980s. Average yields rose to over 3 t/ha, exceeding the national average for maize by one-third (Deb 2004).

1.5.2.7 South America

Sorghum production area in South America (Brazil, Colombia, Argentina, Venezuela, Peru, Ecuador, Bolivia, Paraguay and Uruguay) did not vary much during the four decade period of 1970–2010, but it declined slightly from 2.2 million ha in 1970 to 1.9 million ha in 2010 (Fig. 1-8). The production has witnessed a jump from 4.2 million tons to 5.3 million tons during this period, with a record production of 9.2 million tons in 1984 though there was not much increase in area of cultivation. In case of productivity, significant jump from 1.9 t ha^{-1} to 3.3 t ha^{-1} was observed during the last four decades. In South America, production is concentrated in Argentina (60% of the regional total) and in the dry areas of Brazil, northern Colombia and Venezuela. In Argentina, sorghum production fell from 8 million tons in 1983 to 3 million tons in 1988, because there was a drastic fall in imports by the former USSR. The former USSR was a large importer of maize and sorghum from the USA. Following the grain embargo led by the USA in the early 1980s, USSR began importing large quantities of sorghum from Argentina. These purchases fell drastically after the ban was lifted, as price

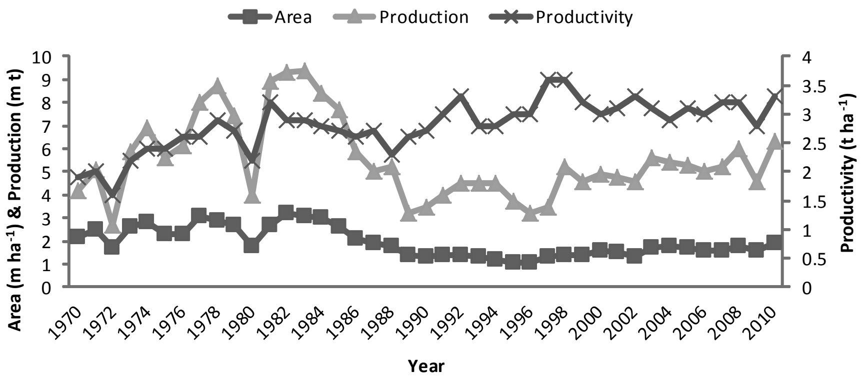

Figure 1-8 Sorghum area, production and productivity in South America between 1970 and 2010.

trends favored the purchase of maize (from the USA) (FAOSTAT 2013). Latin America is major producers of sorghum for the feed market and produce sorghum on a commercial basis, primarily for animal feed. The use of modern agricultural practices is widespread, and yields correspondingly average 3–5 t ha^{-1}.

1.5.2.8 Europe

The area under sorghum in Europe (Belgium, Germany, France, Italy, Spain, and the United Kingdom) is very less compared to other regions of the world and is stagnant between 0.19 m ha and 0.15 m ha during 1970–2010 did not change much during this period (Fig. 1-9). However, the grain production has increased from 0.4 m t to 0.7 m t due to 79% increase in productivity from 2.5 t ha^{-1} to 4.4 t ha^{-1} in the last four decades. Production in Europe is limited to a few areas in France, Italy, Spain and the southeastern countries. Europe is deficient in grain sorghum, considerable amounts of sorghum grain are imported. Belgium, Germany and the United Kingdom are major countries importing sorghum (FAOSTAT 2013).

Sorghum production increased due to improved cultivars, combine harvesting, multiple-row planting equipment, improved tillage and machinery permitting the cultivation of large acreages as a cash crop. The development of early maturing varieties provided an expansion into northern and westward areas of higher altitude, where temperatures are cooler. The development of productive hybrids resistant to insects and diseases enabled sorghum to compete with other crops (such as maize and wheat) in sub humid and humid areas and further increase both the acreage and average yield. Sorghum has high yield potential, comparable

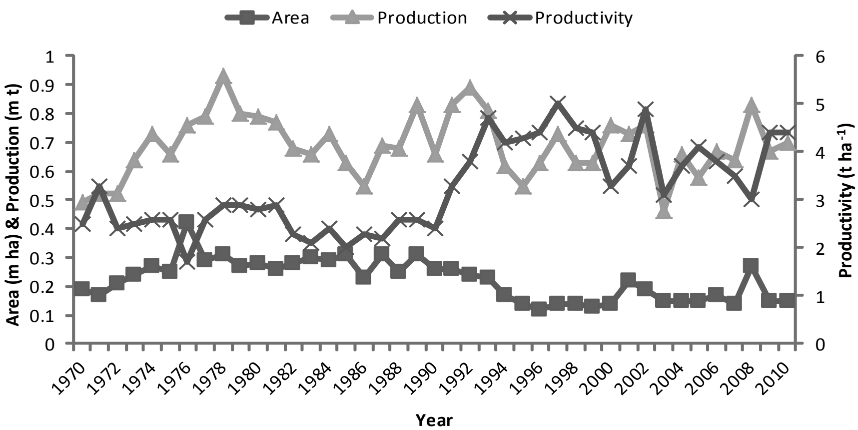

Figure 1-9 Sorghum area, production and productivity in Europe between 1970–2010.

to those rice, wheat and maize. On a field basis, yields have exceeded 11 t ha^{-1}, with above average yields ranging from 7 to 9 t ha^{-1} where moisture is a limiting factor. In those areas where sorghum is commonly grown, yields of 3 to 4 t ha^{-1} are obtained under good management. The excellent yield response of sorghum to ample soil moisture and high soil nitrogen levels resulted in larger acreages of the crop on irrigated and summer-fallowed land. These practices, together with improved hybrids, better control of insects, diseases, and weeds, more optimum plant populations and better and more timely cultural operations are chiefly responsible for the increase in yield. With increased yield productivity coupled with reduction in unit cost of production, farmers adopting the improved varieties have more access to food for their families as well as a marketable surplus, thus raising their income levels.

1.6 Utilization Pattern

Sorghum is a unique crop with multiple uses as food, feed, fodder, fuel and fiber. Sorghum is generally grown in rainy season (spring) but in India it is grown in both rainy (June–October) and post-rainy (November–March) seasons. The post-rainy season sorghum grain is valued more for its food (Reddy et al. 2009).

1.6.1 Grain

Grain sorghum is the most commonly cultivated agronomic type worldwide. The current gross production value for grain sorghum in the year 2010 was US$14,571 million (FAOSTAT 2013). Sorghum grain is mostly used for food (55%) and is a major food crop in Africa, Central America and South Asia. It is also consumed in the form of porridges (thick or thin) and flat breads, however it is also an important feed grain (33%), especially in Australia and the Americas. In Africa and India, it is an important part of the diet in the form of unleavened bread, boiled porridge and specialty foods such as popped grain and beer. Grain sorghum is becoming a potential field crop in Europe for cattle feed (Berenji and Dahlberg 2004). Sorghum could find a significant niche in the nutritional food markets in the developed countries. Unique health foods with high levels of catechins, flavonoids, phytates can be made from sorghums. Tannin sorghums having anti-cancer properties (Chung et al. 1998) are gaining importance. Similarly sorghum brans could be exploited as a source of phytonutrients in foods (Klopfenstein and Hoseney 1995).

1.6.2 Feed

Sorghum grain is one of the major ingredients in cattle feed, poultry and swine around the globe. Demand for feed is increasing in countries like India due to increase in poultry production that is growing at 15 to 20% per annum for broilers and 10 to 15% for layers (Dayakar Rao et al. 2003). Studies have revealed that sorghum varieties with low tannin content are appropriate feeds for pigs comparable with corn (Brand et al. 1992; Douglas et al. 1993) and nutritive value of sorghum is 85 to 97% of corn. Pigs fed with sorghum have low of tannins reached the same performance parameters as the pigs fed with corn (Brand et al. 1990). Sweet sorghum and sudan grass is used for cattle feed in Europe.

1.6.3 Fodder

Stover is an important fodder source to both milch and draft animals in mixed crop-livestock synergy systems. Sorghum is a good source of green fodder due to its quick growth and high yield and quality of biomass. Grain sorghum is used for silage, but less commonly then sweet sorghum as they have higher silage yield with better quality. Sorghum can do well in both high and low potential areas where crops such as maize and Napier grass cannot grow well. As fodder, it can be used in place of maize for making silage. When freshly chopped, this crop can be given to cows, goats, sheep, pigs and even chickens as it has the same energy levels as maize and other cereals. Forage sorghums are coarse, fast growing warm season grasses that provide livestock feed in mid-summer (Juerg et al. 2009). Typically forage sorghums are used for silage or for a single hay cutting. Proper cultivar choice and production technology will completely eliminate prussic acid (HCN, Hydrogen cyanide) problems sometimes associated with fresh sweet sorghum or sudangrass used for feed. Sudangrass is used for grazing, multiple hay cuttings and silage. Sorghum-sudangrass hybrids are best suited for hay and grazing. Further the brown midrib (*bmr*) forage genotypes contain less lignin and have reduced lignin chemical composition (Oliver et al. 2005a). The reduced lignin content of *bmr* sorghum increases its energy conversion efficiency and its nutritive value as a livestock feed (Gressell 2008).

1.6.4 Biofuels

In response to soaring food and fuel prices around the world, a smart crop like sweet sorghum that provides food, fuel and fodder, could be a viable option. While sorghum fresh stalks, apart from forage are used in jaggery, ethanol and industrial alcohol and biofuel production, dry stalks (stover) are used as animal fodder, building material and in paper and cardboard production. Sorghum cultivars are primarily processed for production of table syrups and livestock feed. They possess readily available fermentable sugars within the culm, which gives sorghum an economical advantage over starch based crops. The juice from sorghum can be converted to alcohol. The bagasse can be utilized to generate electricity or steam or as a biomass feedstock for cellulosic biofuel production (Srinivasa Rao et al. 2009, 2010, 2012). Commercialization of this feedstock requires strong local government's policy support to compete with the existing ethanol value chains of corn, sugarcane and cassava. In India commercialization of this novel feedstock had failed during 2008–10 due to lack of aid whereas Brazil, China are utilizing this crop on a large scale, while the USA, Philippines and Mozambique are actively conducting pilot studies. Sorghum forages could produce high biomass yields over a wide number of years and could average 6,146 l ha^{-1} of renewable fuels with a maximum production of 8,422 l ha^{-1} (Dahlberg et al. 2011). These findings and sorghums diversity as a feedstock for renewable fuels production has potential to formulate alternative energy production strategies.

1.6.5 Other Industrial Uses

Sorghum provides raw material to many industries. The grain is used for industrial uses like potable alcohol, malt, beer, liquids, gruels, starch, adhesives, core binders for metal casting, ore refining and grits as packaging material. Sorghum fibers are used in wallboard, fences, biodegradable packaging materials and solvents. Dried stalks are used as cooking fuel and dye extracted from the plant used to color leather. The classic example of industrial use of sorghum in Europe is broomcorn (Berenji and Sikora 2002a,b). Trends favoring ecological and natural products of all kinds have led to renewed interest in old-fashioned, biodegradable, wooden handled brooms, which have had a positive impact on broomcorn production (Berenji et al. 2011).

1.7 Economics and Trade

1.7.1 Economics

Sorghum is grown primarily for food in most countries of Africa and Asia. While the grain is grown mainly for livestock feed in Latin America, but some areas use large amount for food purposes. In the USA, sorghum is used as an ingredient in food items. More than half of world production is believed to be for human consumption. In general, the grain is grown in the more economically advanced countries for animal feed and in the less developed countries primarily for food. The use of sorghum for industrial purposes is relatively insignificant and limited to more economically advanced countries. India devotes about 3.4 times as much land to sorghum vis a vis the USA, but produces only 2/3rd as much of the grain. Sorghum is grown in most parts of the country but the principal production is the central and southern India. Sorghum is cultivated more intensively in India with the application of fertilizers and wide adoption of hybrids/improved cultivars. Next to China, India has the highest level of adoption of improved cultivars in Asia (65% of total sorghum area). The use of improved varieties of sorghum decreased the unit cost of production between 1980s and 1990s as compare to the early 1970s (Pray and Nagarajan 2009). Adoption of these improved cultivars benefits more than 9 million farmers and enhances food security for the poor in the Indian SAT. In case of China, sorghum is a staple food, probably more than half is consumed as food. A small amount is used as feed and a considerable quantity is used in making wine and brandy. Most countries in Africa grow sorghum characterized by low input use intensity and low productivity. The largest producing area extends through the central savannah region of the continent from Senegal on the west coast to Somalia on the east coast. Nigeria, largest grower among African countries, produced 4.73 million tons during the year 2010. Most of the produce in Africa is consumed by those producing sorghum hence, little marketed surplus moves through organized markets. In North American countries, the USA and Mexico contributed nearly 90% of production, while Latin America and Argentina contributed more than 50% to the average annual production recorded during 2010. El Salvador, Honduras and Haiti contributed 5% production of total North American production in year 2010 (FAOSTAT 2013). Australia produces a surplus of sorghum and exports 34% of its total annual production. Europe is deficit in feed grain production. Considerable amounts of sorghum grain are imported from the USA, Australia, India, and the Netherlands (FAOSTAT 2013). A large number of producers received a high share of returns and the acreage involved in sorghum grain production going into food and industrial uses reflects its importance.

The emerging trends in the use of sorghum for alternative purposes will lead to increased demand. Thus, the future success of sorghum is gaining a large share of the food and industrial markets for cereal-derived products will depend on its ability to compete with other major crops including maize and cash crops. If sorghum and industrial markets for sorghum grain were to develop sufficiently in the proximity of major regions of production, the relative price of sorghum compare to its competing crops need to be favorable in order to improve its competitiveness. To expand the use of sorghum products on large scale, the traditional long established use patterns employing products of other grains must be displaced or altered in a sizeable part of the using industry. Farming is no longer the major content of agriculture. Technology, increasing incomes, growing demand for the product variety and more services have moved the manufacture of farm production requisites and the processing and marketing of farm products from rural farm to urban and periurban centers. Each became a large segment of the agricultural economy in its own right.

1.7.2 Trade

Sorghum, apart from being a subsistence crop, has turned out to be a commercial and export crop for the USA, Australia and Argentina (FAOSTAT 2013). The volume of trade in sorghum is small compared with major grains such as wheat, maize, barley and rice. The main importers of sorghum are Japan and Europe. Within most developing countries, bulk of the sorghum output goes towards consumption thus marketed surplus is low. It is grown mainly for home consumption unless there is a bumper crop, or if cash is needed as observed in WCA, SEA and SA. The market price for sorghum is a function of its value in terms of its demand, its purpose and nutritional quality (AGSI/FAO 1999). Trade has become a sizeable part of sorghum's market. Average annual exports increased from 5 million to US$6.7 million in last 5 years (2005–2010). They averaged 6.9 million during 2008–10. In comparison, the USA supplied about 71% of the sorghum entering world trade in year 2010 (Fig. 1-10). Argentina exported about 30% of its production and emerging the second largest exporter,

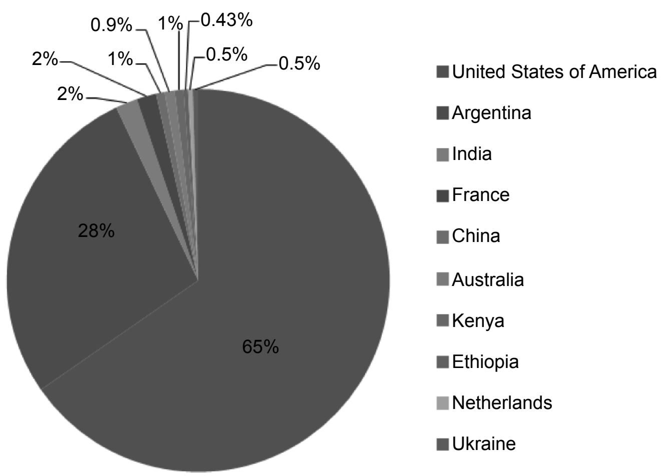

Figure 1-10 Percentage of sorghum exports, 2010.

Color image of this figure appears in the color plate section at the end of the book.

followed by India being the third largest supplier (2% of total exports). In France, China, Australia, Kenya, Ethiopia, the Netherlands, Ukraine, Italy, Egypt, Sudan, Burkina Faso, Thailand and Bolivia, trading has been miniscule. Thus USA occupied more dominant position in the export of sorghum grain (FAOSTAT 2013).

Direction of trade

The major markets for sorghum grain are in the feed grain deficit areas. Mexico, Japan, Ethiopia, Chile, Spain (Fig. 1-11), have been the major importing countries.

The USA highest exports are to Israel, Ethiopia, Japan, Mexico, Sudan and Spain. Mexico imported the highest quantity of 2.2 million tons in 2010, the major share is from the USA. Sorghum grain export market is a substantial one and is increasingly based on dollar sales. It is tied to an expanding poultry and livestock industry. Demand for feed grain increased in some countries, which are importing due to increasing population and increasing meat consumption per capita. However trade in supply of sorghum grain to importing nations depends on the importing nations ability to expand sorghum grain (or other feed) production in their own country, and competition with other exporting countries.

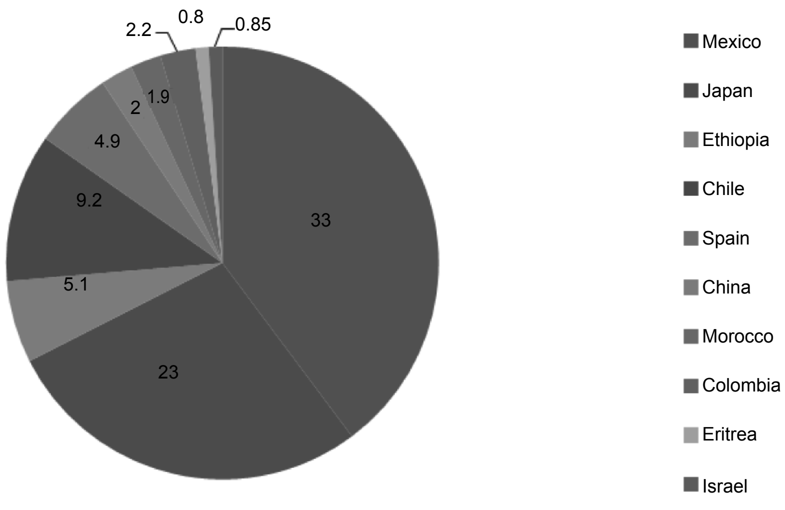

Figure 1-11 Percentage of sorghum imports, 2010.

Color image of this figure appears in the color plate section at the end of the book.

1.8 Future

The major share of sorghum will continue to be used for food in WCA, ESA and SA regions. In WCA, the largest sorghum producing region, the share of sorghum used for food is 75%. According to IFPRI models (Rosegrant et al. 2012), demand for cereals in the target regions is forecasted to increase by about 40% by 2020 (over the 2000 baseline), driven not only by population growth, but also by regional dynamics such as the growing demand for livestock feed/fodder, adverse effects of climate change, and trends toward urbanization of the population. However, the aggregate demand for sorghum varies widely between the regions. Between 2000 and 2050, total demand will grow strongly in WCA, which will account for most of the demand for sorghum by 2050. Demand is also projected to grow in ESA, where production of sorghum will overtake SA by 2030. In contrast, total demand for sorghum in SA is virtually flat (Conforti 2011). There is a perception that consumption of sorghum will decline over time as consumers switch to more preferred superior cereals. The IMPACT model indicates that for sorghum, demand will grow strongly in WCA from below 24 kg in 2010 to 28 kg in 2050 and from 10 to 12 kg in ESA. Only in SA demand expected to decline slightly from 3.3 to 3.0 kg by 2050.

Other than being driven by the need for food security, the big driver of demand for dryland cereals is now non-food uses. It is expected that sweet sorghum will be largely grown for fodder as well as for biofuel production in conjunction with the biofuel policy with the local governments (Srinivasa Rao et al. 2013). The use of sorghum for industrial use is expected to grow in countries like the USA, Brazil, China due to favorable policies. The IMPACT model shows that non-food uses of sorghum grain accounted for about 20–30% of utilization in 2000–05. Increasing affluence is contributing to a rising demand in urban markets for value-added products, especially those with more nutritive value as it has inherently higher content of fiber, micronutrients such as iron and zinc besides possessing low glycemic index. The inclusion of sorghum grain in public distribution system besides procurement at minimum support price will have a strong bearing on sustaining the area under this crop in India. In other developing countries too, it's demand is sustained in view of climate change, realization of diversifying global food basket while its use as non-food/raw material in industries drive's sorghum demand in developed nations in future.

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