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Abstract

Sorghum research needs to be placed in the context of current and future market forces related to this crop. Understanding past trends and associated causal factors helps to predict future trends in supply and demand of sorghum. They in turn indicate the demand for technology.

It is unlikely that sorghum will regain territory lost to other crops during the last three decades. Technical change in sorghum has lagged behind other cereal crops such as rice, wheat, and maize. This and its low preference as a food grain has relegated sorghum cultivation to more marginal environments in most countries. But there is a bright side to this: sorghum's comparative advantage may be precisely in those less-favourable environments. Because of its adaptability to dry and less fertile areas.
TRENDS IN SORGHUM PRODUCTION AND UTILIZATION IN ASIA

T.G. Kelley, P. Parthasarathy Rao and R.P. Singh

I. INTRODUCTION

Sorghum research needs to be placed in the context of current and future market forces related to this crop. Understanding past trends and associated causal factors helps to predict future trends in supply and demand of sorghum. They in turn indicate the demand for technology.

To understand the relative position of sorghum in a dynamic setting, it is useful to outline a few principles of structural change. As new production technologies are developed and made available to farmers, e.g., high yielding cultivars and improved crop and soil management practices, the relative profitabilities of various enterprises change. Shifts in profitability differentials are brought about by two dynamic forces: changes in technical input-output relationships and changes in relative output prices. Producers respond to both these forces and shift their production resources to those enterprises which reduce per unit cost of production.

Thus, changes in commodity prices and in per unit cost of production of specific commodities (relative to other commodities) determine their competitiveness. In the case of sorghum, technical change in and relative price changes of competing crops such as wheat, maize, sunflower, chickpea, and groundnut, have a bearing on sorghum research.

In this paper, we present an overview of sorghum production, utilization, and trade worldwide followed by a detailed look at sorghum production and utilization in Asia, with particular reference to India. The final chapter is devoted to a discussion of emerging issues relevant to the future of sorghum in India and Asia.

II. WORLD FIGURES AND TRENDS
Sorghum ranks among the important cereal crops in the world. About 60 million tons of sorghum grain were produced worldwide in 1989, placing it fifth among cereals with respect to production (FAO 1990). Sorghum production increased steadily during the 1960s and 1970s but has since slackened. There is indeed some indication of a slightly downward trend in recent years (Figure 1). World trade in sorghum has also declined during the last decade.

Sorghum producing countries can be conveniently categorized into three major groups (Table 1). The first
group includes developing countries, particularly in Asia and Africa, where sorghum is produced within traditional farming systems: the grain is utilized primarily for human consumption and stovers are fed to cattle or other livestock. Yield productivity is characteristically low and quite variable.

The second group includes developed countries where sorghum is produced on a commercial basis and used almost exclusively as animal feed, either in the domestic market or abroad through exports. The USA, Australia, and South Africa comprise this group.

The third group includes developing countries, particularly in Latin America and Asia, where sorghum is now used mainly for animal feed or other non-human food uses (e.g., alcoholic beverages). Formerly it was a staple in many of these countries. One feature of sorghum cultivation common to all three groups is its habitat: its production niche is in the comparatively drier regions of these countries, i.e., where rainfall is low or variable.

A fourth group can be defined--not as producers but users. These are developed or relatively developed countries which import considerable amounts of sorghum grain as feed for their domestic meat industries. Japan, USSR, South Korea, Israel, and Saudi Arabia comprise this group.
It is the first group we are primarily concerned with, although some Asian countries (China, Thailand) do fall into the third group. Each of the important sorghum producing or utilizing countries of Asia is discussed in section IV.

Table 1. Utilization of grain sorghum for major consuming countries, 1988 ('000 MT).

<table>
<thead>
<tr>
<th>Country</th>
<th>Prod</th>
<th>Imports</th>
<th>Export</th>
<th>Tot Cons</th>
<th>% Feed use</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>56,290</td>
<td>10,795</td>
<td>9,925</td>
<td>60,450</td>
<td>61</td>
</tr>
<tr>
<td><strong>DEVELOPED (FEED USE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>14,670</td>
<td>0</td>
<td>7,620</td>
<td>12,700</td>
<td>95</td>
</tr>
<tr>
<td>Australia</td>
<td>1,075</td>
<td>0</td>
<td>500</td>
<td>700</td>
<td>86</td>
</tr>
<tr>
<td>Rep of S. Africa</td>
<td>445</td>
<td>0</td>
<td>445</td>
<td>100</td>
<td>62</td>
</tr>
<tr>
<td><strong>DEVELOPING (FEED USE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>5,300</td>
<td>0</td>
<td>1,000</td>
<td>4,815</td>
<td>83</td>
</tr>
<tr>
<td>Mexico</td>
<td>3,650</td>
<td>2,100</td>
<td>0</td>
<td>5,440</td>
<td>99</td>
</tr>
<tr>
<td>Argentina</td>
<td>1,250</td>
<td>0</td>
<td>200</td>
<td>1,050</td>
<td>90</td>
</tr>
<tr>
<td>Venezuela</td>
<td>745</td>
<td>1,100</td>
<td>0</td>
<td>2,000</td>
<td>100</td>
</tr>
<tr>
<td>Egypt</td>
<td>580</td>
<td>0</td>
<td>580</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>420</td>
<td></td>
<td>420</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>300</td>
<td>0</td>
<td>250</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td><strong>DEVELOPING (FOOD USE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>11,500</td>
<td>0</td>
<td>0</td>
<td>11,200</td>
<td>9</td>
</tr>
<tr>
<td>Sudan</td>
<td>4,400</td>
<td>0</td>
<td>400</td>
<td>2,500</td>
<td>0</td>
</tr>
<tr>
<td>Nigeria</td>
<td>3,500</td>
<td>50</td>
<td>0</td>
<td>3,550</td>
<td>2</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>1,100</td>
<td>50</td>
<td>0</td>
<td>1,150</td>
<td>0</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>960</td>
<td>0</td>
<td>0</td>
<td>n.a</td>
<td>n.a</td>
</tr>
<tr>
<td>Pakistan</td>
<td>210</td>
<td>0</td>
<td>0</td>
<td>210</td>
<td>24</td>
</tr>
<tr>
<td>Burma</td>
<td>115</td>
<td>0</td>
<td>0</td>
<td>115</td>
<td>n.a</td>
</tr>
<tr>
<td><strong>MAJOR IMPORTERS (FEED USE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC-12</td>
<td>440</td>
<td>730</td>
<td>145</td>
<td>1,060</td>
<td>100</td>
</tr>
<tr>
<td>(France, Spain)</td>
<td>150</td>
<td>150</td>
<td>0</td>
<td>300</td>
<td>80</td>
</tr>
<tr>
<td>Taiwan</td>
<td>55</td>
<td>100</td>
<td>0</td>
<td>155</td>
<td>100</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>5</td>
<td>400</td>
<td>0</td>
<td>355</td>
<td>100</td>
</tr>
<tr>
<td>Israel</td>
<td>2</td>
<td>500</td>
<td>0</td>
<td>510</td>
<td>99</td>
</tr>
<tr>
<td>South Korea</td>
<td>0</td>
<td>4,100</td>
<td>0</td>
<td>4,100</td>
<td>100</td>
</tr>
<tr>
<td>Japan</td>
<td>0</td>
<td>1,000</td>
<td>0</td>
<td>1,000</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: PS&D View. Economic Research Service, USDA.
III. SORGHUM TRENDS IN ASIA

Unlike other important cereal crops in Asia whose production has shown an upward trend during the last 30 years, sorghum's production has been stagnant at about 20 million tons (Figure 2). Agricultural research in rice, wheat, and maize (to a lesser extent) led to impressive gains in productivity for those crops during the last three decades. This and expanding the area under crop cultivation are the two driving forces behind the increase in cereal production in Asia. Sorghum yield productivity has also increased—though not at the rate of other cereal crops— but this gain has been offset by a declining area under sorghum cultivation (Figure 3).

Sorghum utilization patterns in Asia are in a dynamic phase (Table 2). The traditional method of consumption—as a food grain staple (roti, porridge, or mixed with rice) will continue to dominate its use for some time, particularly in India, Pakistan, and Burma. But more importantly, sorghum use (and its perception) as a source of feed for livestock and poultry has developed rapidly during recent times. Presently, a little less than 20% of the sorghum produced in Asia goes for animal feed (USDA 1989). There is also considerable interest in

---

\(^2\) During the 20-year period from 1968-70 to 1988-90, for all Asia, average rice yields rose by 1.6 t ha\(^{-1}\), wheat yields by 1.3 t ha\(^{-1}\), maize yields by 1.8 t ha\(^{-1}\), and sorghum yields by 0.5 t ha\(^{-1}\).
other uses of sorghum such as starch, beer, and liquor (Subramanian 1991), and in China, already about a third of the sorghum grain production is used in making alcoholic beverages (Qing-Shan 1991). Finally, its role as a fodder crop is expanding, particularly as the demand for milk and meat products continues to increase in Asia. India, Pakistan, China, and Australia have considerable area under sorghum and sorghum-sudangrass hybrids.

Table 2. Sorghum utilization pattern in Asia: present and potential

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food grain and straw</td>
<td>India, Pakistan, Myanmar, China</td>
</tr>
<tr>
<td>Feed grain</td>
<td>Australia, China, Thailand, India, Japan, S. Korea</td>
</tr>
<tr>
<td>Industrial uses: starch, liquor</td>
<td>China, India</td>
</tr>
<tr>
<td>Green fodder</td>
<td>Australia, India, Pakistan, China, Iran, S. Korea</td>
</tr>
<tr>
<td>Export</td>
<td>China, Thailand</td>
</tr>
</tbody>
</table>

Only two countries in Asia export a significant amount of sorghum, China and Thailand. Both, however, have reduced their exports recently, presumably due to competition from domestic markets.
IV. SORGHUM PRODUCTION AND UTILIZATION IN ASIAN COUNTRIES

INDIA

A. Sorghum Area, Production, and Productivity (1965-1990)

After the USA, India is the second largest producer of sorghum grain. Its relative importance to the Indian economy, however, if judged by area under production, number of cultivators dependent on sorghum, and its role as a staple in the diet of millions of people, is considerably more than production figures alone indicate. Although area under sorghum cultivation in India has declined over the last 30 years from 18.5 to 16.0 million ha, it still covers an area four times as large as all other Asian countries and Australia combined. It accounts for more than 70% of the total production in Asia.

In India, sorghum is cultivated in two distinct seasons: rainy or kharif and post-rainy or rabi. Almost all kharif and about 90% of rabi sorghum is cultivated under rainfed conditions. For purposes of analysis, the production of sorghum in each season is treated separately--for several reasons. First, their products (grain and fodder) are qualitatively different, as reflected in their respective prices (e.g., rabi white sorghum grain commands, on average, a 30 to 40% higher market price than kharif (yellow or hybrid) sorghum. Second, productivity and area changes over time have
differed for these two sorghums and the causal factors associated with those changes require separate analysis. Finally, the regions in which each are primarily grown are quite distinct.

Kharif

The area under *kharif* sorghum in India declined by 2.3 million ha since 1965, representing a 1% decline per year (Figure 4). Most of it has been replaced by higher-valued cereal, oilseed, and pulse crops. National figures obscure regional changes that have taken place over time. In some regions, area under *kharif* sorghum has actually increased; in others, *kharif* sorghum has become almost negligible. In Figure 5, major *kharif* sorghum growing districts have been grouped according to changes in area during the last 15 years. All districts in a defined group have either increased or decreased in area under *kharif* sorghum by a minimum of 10,000 ha. Six major groups emerge. Group I (ten districts in Andhra Pradesh) lost a combined total of 360,000 ha of *kharif* sorghum; groundnut, cotton, and castor were the major gainers. In Group II (seven districts in Karnataka and an adjoining one in

---

3 Only those districts having 20,000 ha or more were considered.

4 There are two exceptions: Buldana District of Maharashtra (Group III) and Bellary District of Karnataka (Group II).
Maharashtra) 280,000 ha of kharif sorghum were replaced directly or indirectly by sunflower, groundnut, maize, and pigeonpea. Group III (nine districts in Maharashtra, seven in Madhya Pradesh, and one in Karnataka) increased its area under kharif sorghum by 360,000 ha; other crops increased as well, i.e., net cropped area rose appreciably. Group IV (nine districts in Gujarat) lost 200,000 ha and Group V (six districts in Rajasthan and two in Madhya Pradesh) lost 215,000 ha of kharif sorghum; mostly to rabi crops such as wheat, mustard, sesamum, and chickpea. Group VI was a net gainer of kharif sorghum, 290,000 ha were added; chickpea acreage declined considerably. In many other districts, where sorghum was of moderate or minor importance, it continues to decline in importance.

Despite losing 2.3 million ha of kharif sorghum since 1965, total production actually rose—by almost 3 million tons (Figure 4). Thus, production gains have come about through increases in yield per unit land area, largely through the introduction and spread of hybrids and improved varieties during the 1970s and 1980s. Average productivity rose at the rate of 2.7% per year during these two decades. Much of this occurred in Group III where, because of a more favorable environment (deep, black soils in an assured rainfall zone), modern cultivars were better adapted and hence more widely
adopted. This concurs with an earlier study by Walker (1984) which found that relative area expansion was significantly greater in those districts where the diffusion of sorghum hybrids has been more rapid. Modern cultivars have not found much acceptance in Groups I and II, regions which are generally drier red soil areas. Based on Fertilizer Statistics data (FAI 1989), approximately 55 to 60% of the total area under kharif sorghum is planted to modern cultivars. Adoption of modern cultivars and improved fertilizer management are responsible for average national yields rising from less than 0.5 t ha\(^{-1}\) in the mid 1960s to more than 0.9 t ha\(^{-1}\) presently (Figure 6). While these results are commendable, yield levels still remain considerably below world levels of 1.4 t ha\(^{-1}\) (FAO 1990).

Rabi
Rabi sorghum grain production has varied between 2.0 and 4.0 million tons since 1965 (Figure 7), showing a gradual upward trend (1.8% per annum). Production is now at 3.4 million tons (1988-90). Rabi sorghum area has declined slightly from 6.7 to 6.2 million ha. Again, these national figures obscure the regional dynamics taking place. In Figure 8, districts have been grouped

---

*Sorghum yield levels in Maharashtra are about 30 to 40% higher than the All-India average.*
according to patterns of increasing or decreasing area under rabi sorghum. Two major groups emerge here. Group I (ten districts in Andhra Pradesh and four in Maharashtra) lost a total of 500,000 ha of rabi sorghum in the last 15 years. Most of this has been replaced by cotton, groundnut, and castor, some of it due to irrigation. Group II (eight districts in Karnataka and four in Maharashtra) increased its area under rabi sorghum by 600,000 ha. Crops which reduced their area include cotton, wheat, and pearl millet. Problems with controlling insect pests in cotton have been persistent and have discouraged farmers from planting it.

Yield levels, while trending upwards over time, still lag considerably behind kharif sorghum at less than 0.6 t ha⁻¹ (Figure 6). Low yields are generally attributed to the more difficult environment in which the crop is cultivated. Rabi sorghum is sown after the cessation of the monsoon rains and after the soil becomes dry enough to cultivate and plant. The crop must then rely on a limited and receding soil moisture regime to carry it through to harvest. Although post-monsoon rainfalls do occur, their frequency and distribution are highly uncertain. Low and variable grain yields are thus frequently observed. Because of the riskiness of the production environment, adoption of modern cultivars has
been very limited. For the same reason few alternative crops can be grown there. Sorghum is well-adapted to harsh environments characteristic of the dry semi-arid tropics.

Rabi sorghum is prized as much for its fodder as it is for grain. Using data from an ICRISAT benchmark village in the heart of the rabi sorghum belt of Maharashtra and Karnataka, Kelley et al. (1990) calculated that fodder's contribution to the total value of production ranged between 34 and 59% over a recent 10-year period. In the rabi sorghum belt, sorghum straw is the staple diet for draft and milk animals. Because of higher incomes and increased demand for milk products in India-- hence increases in the derived demand for fodder-- sorghum straw has more than kept pace with inflation. Indeed, the relative value of sorghum straw to grain has doubled in the last 20 years: rabi sorghum straw to grain price ratio went from 1:6 to 1:3 (Kelley et al. 1990).

B. Sorghum Prices and Grain Utilization

Sorghum is a traditional staple food in India, but its relative importance is declining over time. Formerly,

*Limited to higher rainfall and deeper soil areas where larger amounts of soil moisture can be stored, and also to irrigated areas. About 10% of the total rabi sorghum growing area is irrigated.

7 Though both, relative to kharif production, are of higher value and command premium prices at the market.
about 10% of the population used sorghum as the primary food grain in their diet; today only 6.4% do (Murty 1991). It is gradually being replaced by other, more preferred cereals such as rice and wheat. This trend will continue. Of the major cereal grains, sorghum fetches the lowest market price, a reflection of the low consumer demand for this commodity. Data from the last two rounds of the National Sample Survey (NSS) indicate that sorghum for human food is an inferior good (Walker 1990)*. Consumers shift consumption away from sorghum, and towards preferred grains as real per capita incomes rise. Only in the rural areas of some selected areas of India (e.g., Maharashtra) does sorghum have a positive expenditure elasticity, i.e., consumers purchase more sorghum with increased income. A recent analysis by Radhakrishna and Ravi (1990) shows that cereals other than wheat and rice have the lowest expenditure elasticity coefficient of any major commodity group for rural consumers and the only negative expenditure elasticity coefficient for urban consumers (Table 3). Based on their projections, the annual growth rate in per capita demand for cereal grains such as sorghum and

* Using NSS data, Walker (1990) found that between 1977-78 and 1987-88, average All-India rural consumption fell from 1.74 to 1.00 kg per capita per month; All-India urban consumption dropped from 0.74 to 0.46 kg. It should be noted that expanding the availability of subsidized wheat and rice may also have accelerated the trend in declining per capita consumption of sorghum.
millet is -0.45°. All other commodity groups (milk products, meat, pulses, oilseeds, and fruits and vegetables) had positive growth rates. The message is clear. Unless new uses for sorghum can be found, its importance to the Indian consumer and farmer will diminish over time.

The preceding discussion relates to sorghum in general. As alluded to earlier, a significant distinction is made between different types of sorghum in the marketplace. Figure 9 illustrates price differentials for rabi (white), kharif (yellow), and hybrid (white) sorghums. The lower prices for kharif and hybrids indicate poorer grain quality characteristics which translate into even lower expenditure elasticities—assuming sorghum is restricted to its traditional use, i.e., roti. Interestingly, it is hybrid sorghum which has the best prospects for new uses in India, by virtue of its lower price. The lower price reflects its inferior quality as a traditional food, but not necessarily in other uses, such as starch production and poultry feed.

Projected growth rates in total demand are still positive (1.0 to 1.2% a year) because of population growth.
Table 3. Expenditure elasticities and projected annual growth rates of demand for various commodity groups.

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Expenditure Elasticity</th>
<th>Annual Growth Rate in Per Capita Demand*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rural</td>
<td>Urban</td>
</tr>
<tr>
<td>Rice</td>
<td>0.48</td>
<td>0.26</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.41</td>
<td>0.29</td>
</tr>
<tr>
<td>Other cereals</td>
<td>0.38</td>
<td>-0.01</td>
</tr>
<tr>
<td>Milk &amp; milk products</td>
<td>1.10</td>
<td>0.92</td>
</tr>
<tr>
<td>Edible oils</td>
<td>0.73</td>
<td>0.58</td>
</tr>
<tr>
<td>Meat, egg &amp; Fish</td>
<td>0.87</td>
<td>0.78</td>
</tr>
<tr>
<td>Sugar &amp; gur</td>
<td>0.99</td>
<td>0.59</td>
</tr>
<tr>
<td>Pulses</td>
<td>0.59</td>
<td>0.46</td>
</tr>
<tr>
<td>Fruits &amp; vegetables</td>
<td>0.75</td>
<td>0.84</td>
</tr>
<tr>
<td>Other Food</td>
<td>0.89</td>
<td>0.90</td>
</tr>
<tr>
<td>Non-food</td>
<td>1.60</td>
<td>1.49</td>
</tr>
</tbody>
</table>

* Predictions for the period 1987-2010

Source: Radhakrishna and Ravi 1990.

Presently, use of sorghum in extracting starch is still in its infant stages in India. A few factories do use sorghum in starch production, if only to a limited extent. One of the largest factories in Andhra Pradesh has used sorghum exclusively for the last 6 months and for a 10 month period in 1987. Nevertheless, maize, for various reasons, is the preferred grain. Only when the price differential exceeds Rs 80 to 100 per quintal, as it has recently, are factories interested in substituting
for maize, indicating some serious qualitative differences between sorghum and maize for starch production. The economics of using maize vs. sorghum is illustrated in Table 4 which uses data from the Laxmi Starch Factory in Hyderabad. Sorghum's future in starch production depends on maintaining a large price differential and/or technological developments which improve starch extraction from sorghum.

Prospects for sorghum substituting for maize in poultry feed are much better and more immediate. Although maize accounts for the bulk of feedgrain consumption by poultry, already many layer and broiler producers in Andhra Pradesh (AP)—the leading poultry producing state in India—are substituting to the extent of 40 to 50% of the maize component in the diet (M.P. Seshiah, President, AP Poultry Federation, personal communication). Using data from the AP Meat and Poultry Development Corporation, the major supplier of feed in AP, the growing importance of sorghum in the diets of layers and broilers is corroborated. Table 5 shows the growth in numbers of poultry in AP and India and the extent to which the sorghum fraction in the diet has changed. Once again, the future of sorghum as a viable alternative feedgrain for poultry depends on the long-term price differential between it and maize.
Table 4. Gross returns from processing 100 kg of maize and sorghum for starch and by-products.

<table>
<thead>
<tr>
<th></th>
<th>Maize (Rs)</th>
<th>Sorghum (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>415</td>
<td>302</td>
</tr>
<tr>
<td>Oil</td>
<td>70</td>
<td>11</td>
</tr>
<tr>
<td>Cake</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Glutten</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Fiber</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>528</td>
<td>331</td>
</tr>
</tbody>
</table>

Source: Lakshmi Starch Processing Unit, Hyderabad

C. Forage Sorghum

Total area under forage crops in India has increased from around 6.5 million ha in the early 1970s to 7.8 million in 1985, the last year for which All-India data is available (Figure 10). The four northern states of Punjab, Haryana, Rajasthan, and Uttar Pradesh account for 60% of total area in India. In these four states, 30% of the area under forage crops is irrigated; area under irrigation in other parts of India is much less.

Sorghum, barley, maize, oats, and barseem are the major forage crops grown in India. All-India data on individual forage crops are not readily available but the relative importance of sorghum can be seen for states for which data are available. Forage sorghum constitutes 65% of the total area under forage crops in Uttar Pradesh, 30% for Rajasthan, 20% in Gujarat, 35% in Andhra Pradesh,
and 90% in Tamil Nadu. Assuming the proportion of sorghum to all forage crops is relatively constant, area under forage sorghum grew at a rate of 1.4% for Uttar Pradesh, 1.3% for Rajasthan, 1.2% for Andhra Pradesh, and 3.5% for Tamil Nadu.

Table 5. Actual and projected sorghum feed use in Andhra Pradesh and India.

<table>
<thead>
<tr>
<th>Year</th>
<th>% of sorghum</th>
<th>Layers in diet *</th>
<th>Broilers Total</th>
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<tbody>
<tr>
<td></td>
<td>Sorghum use</td>
<td></td>
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<tr>
<td></td>
<td>(millions)</td>
<td>(‘000 tons)</td>
<td></td>
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<tr>
<td></td>
<td>Andhra Pradesh</td>
<td></td>
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</tr>
<tr>
<td>1985</td>
<td>13 6 10 47 11 58</td>
<td></td>
<td></td>
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<tr>
<td>1990</td>
<td>20 22 15 108 60 168</td>
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</tr>
<tr>
<td>1995p</td>
<td>29 55 20 209 196 405</td>
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<tr>
<td>All-India</td>
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<tr>
<td>1985</td>
<td>67 70 10 245 125 370</td>
<td></td>
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</tr>
<tr>
<td>1990</td>
<td>110 160 15 595 430 1,025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995p</td>
<td>157 304 20 1,130 1,090 2,220</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1995p - Projected figures

* Source: Personal communication R. Subba Rao, Andhra Pradesh Meat and Poultry Development Corporation, Hyderabad.

The sharp increase in the demand for forage sorghum is linked to the expanding dairy industry in India. Milk production in India has doubled in the last 15 years. Thus, the demand for feed, forage, and fodder inputs to sustain the industry has accelerated rapidly— and is expected to continue so. Radhakrishna and Ravi (1990) project the aggregate demand for milk in India to increase at the rate of 4.1% per annum for the next 20
years, providing some assurance that forage and fodder prices will remain strong well into the future. Area under forage crops, particularly forage sorghum will surely expand. Recent evidence corroborates this: sales of exclusively forage sorghum seed varieties in Maharashtra increased 10-15% in the last year or two (Mr. Koparkar, Dy. Director of Agriculture, Maharashtra, personal communication).

D. Competitiveness
Technical change and relative changes in commodity prices, together, determine an individual crop's competitiveness over time. In the case of sorghum, growth in average yield (a proxy for technical change) has lagged behind other competing cereal crops such as rice, wheat, and maize. It has lost ground at the market place as well: sorghum prices, for reasons already mentioned, have failed to keep pace with competing commodities—cereals, pulses and oilseeds alike. Together, these two factors have weakened sorghum's competitiveness over time, translating into reduced area under sorghum cultivation. This is illustrated in Figure 11. Using data from the Bulletin of Food Statistics (Govt of India 1990) and Area and Production of Principle Crops in India (Govt of India 1989), trends in crop prices, yields, and area indices have been estimated.
This was done for three crops, sorghum, wheat, and pigeonpea for the period 1970 to 1989. Trends were estimated using 1970 as the base year. 

The results are consistent with the theory that changes in area under cultivation are positively related to growth in productivity and to own commodity price. For sorghum, the average annual (linear) decline in cultivated area was 0.21%. This compares with wheat which increased at 1.8% and pigeonpea at 1.9%. Commodity price trend effects appear to dominate. Pigeonpea averaged a mere 0.35% per year linear increase in yields during this period but maintained a 0.80% per year rise in real prices. This translated into a high rate of growth in cultivated area. Area under wheat cultivation increased at an equally impressive rate, but for a different reason. Indeed, the linear rate of decline in the wheat price trend was only slightly less than for sorghum. It was rapid technical change in wheat production--higher growth in productivity and lower per unit production costs--which translated into significant positive growth in cultivated area. The combination of falling real sorghum prices and relatively poorer yield performance over time has reduced sorghum's competitiveness.

10 Because linear trends were estimated the intercept is not always at 100.
It is not likely that the price trend for sorghum will change markedly. Real prices of sorghum grain will continue to decline over time. If sorghum is to maintain its present competitive status in India, higher rates of growth in productivity—relative to competing crops—must be forthcoming.

China

Sorghum is a traditional cereal crop of China. Although formerly grown on about 10.0 million ha (1930s to 1950s), it presently occupies about 1.9 million ha (FAO 1990). Even so, in Asia, China is second only to India in area and production of sorghum. The decline in sorghum area since 1960 is illustrated in Figure 12. While area has declined, yields have risen impressively. China produced as much sorghum grain in 1989 as it did in the early 1960s—on a third of the land. National yields average 2.7 t ha$^{-1}$ but yield levels may be difficult to sustain in the future as sorghum production is forced by competition from higher-value cereals to move from the flat and fertile region of the country in the south to the dry, sandy, and alkaline regions of the north.

Sorghum grain is used for human consumption, as animal feed, and in making alcoholic beverages. Although its importance as a food grain has declined over time, in arid and semi-arid regions of China, sorghum grain it
still an important part of the people's diet—consumed as porridge mixed with rice. The stover remains a major component in the diet of farm animals. Of the 6.0 million tons of sorghum grain produced annually, 30% is used in the production of liquor and beer. Another 60% is split equally between food and feed grain uses. Exports have averaged about 500,000 tons during the last 5 years. Sorghum is also cultivated as a fodder crop in China, but estimates on area under production are not available. Presumably, in response to a growing demand for green fodder, increased attention is being given to developing improved sorghum forage hybrids.

Pakistan

After India and China, Pakistan ranks third in Asia in total area under sorghum. However, area under sorghum declined from 520,000 to 380,000 ha and production from 320,000 to 220,000 tons during the last 20 years. Traditionally, sorghum is planted during kharif season under dryland conditions. In recent years, interest in irrigated sorghum for both grain and fodder has increased. Some of the sorghum cultivated in Pakistan is now grown under irrigated conditions. This shift in cultivation practice is generated increasingly by an interest in the fodder potential of sorghum. Estimates indicate approximately 50% of the irrigated sorghum and
25% of the dryland sorghum as used exclusively for (green) fodder.

About 90% of the sorghum grain produced is utilized on the farm either as food or as seed for next year's crop. As in India, the stover serves an important function in providing dry roughage for draft and milk animals, particularly during the dry season. With the recent expansion of the poultry industry, a new market demand for sorghum grain as feed has developed. The extent to which this continues (and expands) depends on the comparative unit production costs of maize and sorghum in Pakistan. Sorghum's major advantage over maize is its low-input, low-risk crop characteristics (i.e., its adaptability to dry and less fertile areas). Because it is grown mainly in marginal areas under moisture stress conditions, average yields have remained low (0.6 t ha⁻¹).

Thailand

Currently, Thailand produces about 210,000 tons of sorghum grain annually (three-year average 1987-1989) compared to an average of 370,000 tons produced during 1983-1985. Area under sorghum is 180,000 ha, down from 310,000 ha in 1985. Strong demand for soybeans is partially responsible for this decline: soybean area increased by 150,000 ha since 1985. The major production
niche is in the rainfed areas of Northeast Thailand on land where maize generally cannot be cultivated.

About 70% of the sorghum grain is exported, mostly to Japan, Korea, and Saudi Arabia. The remaining grain is consumed domestically in the industrial and feed grain sectors. Prospects for increased production are deemed good as feed and fodder requirements (green sorghum) are expected to increase with a growing livestock industry domestically, and internationally.

Myanmar

Based on 1990/91 figures, there are about 190,000 ha under sorghum cultivation in Burma, just less than the area under maize cultivation. This represents a slightly increasing trend over the last 20 years, with some significant fluctuations in the mid 1980s. National average yields are presently about 0.75 t ha⁻¹, considerably higher than previously.

Sorghum is grown under low and variable rainfall conditions primarily as a fodder/feed crop, but sometimes as a food grain crop. When rice prices are high sorghum grain is sometimes mixed with rice; dry stovers are used for animal fodder. In the hill regions the grain is often used to make liquor. Recently, sorghum grain flour has been used for breads and biscuits and as a constituent in poultry feed.
Sorghum is a minor cereal crop in Indonesia. After nearly tripling in 1981, sorghum area declined recently to an early 1970s level of 20,000 ha. An increase in irrigation is probably responsible for this reduction. Nevertheless, during that time, average yields rose from less than 1.0 t ha⁻¹ to 1.4 t ha⁻¹. Total production averages 26,000 tons (based on 1986-1988). Maize is the major competitor to sorghum, and is generally preferred by farmers. Sorghum is more often grown by "poor farmers". Its niche appears to be in marginal environments (drought susceptible and low fertility conditions), generally planted in upland or remote areas. Use of improved varieties in these locations is limited.

Grain sorghum is used as a staple food (mixed with rice during shortages), as a snack, as livestock and poultry feed, and as a commodity for export. In recent years, Indonesia has been a net importer of sorghum (15,000 tons annually between 1984-88), largely to help supplement the maize requirement for animal feed as the meat industry has expanded rapidly. Between 1977 and 1986, the population of beef cows increased by 52% (from 6.2 to 9.5 million), of pigs by more than 100% (from 2.9 to 6.1 million), and of chickens by 260% (from 111 to 406 million). This accounts for the sharp rise in maize consumed by livestock and poultry in Indonesia during the
last 10 years (from 0.5 to 1.8 million tons)—nearly a third of which has been imported. It also ensures a strong market demand. Grain sorghum appears to be fully substitutable for maize in livestock and poultry feed in Indonesia (see Cresswel and Kateran 1978). Thus, the potential for substitution by grain sorghum is good if the right sorghum production technology can be developed and disseminated among farmers.

**Vietnam**

Sorghum is of relatively minor importance in Vietnam. According to FAO’s most recent estimate, about 4,000 ha of sorghum are grown there. Reports indicate that the area is declining but this is difficult to confirm because of inconsistent data estimates over the years. Lack of a viable market is given as the reason for the continuing decline in the importance of sorghum. Sorghum is generally cultivated in poorer soils and areas prone to drought. In these areas sorghum can compete effectively with maize, which is otherwise preferred. Cooked and eaten similar to rice, sorghum grain is utilized for human consumption only to a limited extent; it is used mostly for livestock and poultry feed.
South Korea/Japan

Sorghum is important in South Korea and Japan, but not from a production viewpoint. Indeed, area under grain sorghum is insignificant—about 1,000 ha in South Korea and nil in Japan. However, the demand for sorghum grain in these two countries is strong and likely to grow even more as incomes and demand for livestock products and industrial products (starch, alcohol) in Korea and Japan increase together. South Korea imported more than 600,000 tons of sorghum in 1989 and Japan imported nearly 4 million tons, mostly supplied by the USA and Australia.

Forage sorghums, including sorghum-sudangrass hybrids, are expanding in South Korea where about 20,000 ha of forage sorghum are cultivated at present. Current research emphasizes improved hybrid adaptation for the forage sorghums. Low-tanin and polyphenol varieties and hybrid development for feed grain sorghum and the development of low-cost production methods are envisaged for partial substitution of imported sorghum in the future.

Iran

Sorghum is a relatively new crop to Iran. Presently, it is grown on about 20,000 ha, all irrigated and grown exclusively for fodder. Maize is also grown as a fodder crop on about 80,000 ha. The potential for sorghum as a
Substitute for maize is good since its water requirements are lower. There is also some potential for sorghum as a replacement for maize in poultry feed: about one million tons of maize is imported annually for this purpose, a drain on foreign exchange.

**Australia**

Australia is one of the few countries in the world where area planted to sorghum has increased over time. Area under sorghum cultivation increased from less than 200,000 ha in the early 1960s to about 800,000 ha currently. In 1987/88, production rose to 1.7 million tons but has fallen off recently due to poor climatic conditions.

Increased production has created a rapidly expanding domestic feed grain market and has bolstered grain and meat exports. For example, grainfed (largely sorghum) beef exports to Japan alone have increased by more than 500% in the last four years and are likely to increase by a further 300% in the next four (Cameron 1991). About 23% of Australia’s sorghum grain production is currently used in beef feedlots (Australian Lotfeeders Association 1990). Maize is not used as it is too expensive. Some sorghum grain is also used as pig and poultry feed. The surplus production (varied between 0.5 and 1.2 million tons during the last 5 years) is exported to Japan and
other Asian countries. By all indications, these markets are likely to strengthen in the years ahead, exerting a positive effect on the demand for sorghum. Agroclimatic analysis indicates that the prospects for expanding the area under sorghum in the semi-arid tropics of Queensland are good (Henzell 1991).

Sorghum is grown almost exclusively under dryland conditions in Australia. Irrigated sorghum cannot compete economically with higher-valued crops such as cotton, soybeans and maize. Production niches are in areas with rainfall lower than what is required for maize. Waxy-type sorghums are planted to a limited extent for their special quality starch used in various food products. Forage sorghums, including sweet sorghum, sudan grass, and various hybrids are also grown to some extent (Sims 1983). There is no data on production and area trends for each of these.

V. OUTSTANDING ISSUES: RELEVANCE OF SORGHUM IN THE FUTURE
A. The Future of Sorghum in India

The future competitiveness of kharif sorghum depends on improving yield potential in the more favorable environments, i.e., Group III (Figure 5). Area under kharif sorghum in Group I, II, IV, and V will probably continue to decline as other crops equally adaptable to
these less favorable environments, but higher-valued (e.g., pigeonpea, safflower), replace sorghum. Thus, researchers should continue to focus on production environments with high production potential (Walker 1990), e.g., Group III, if maximizing expected returns from research is the criterion for allocation of research resources. However, probability of success in overcoming major biotic and abiotic constraints to higher yields in less favorable environments (e.g., Groups I and II) should be seriously considered too. Obviously, if prospects for removing those constraints are good (and can be estimated), a case can be made for allocating resources to those environments. Small yield improvements resulting from overcoming a single biotic constraint, distributed across several regions, could have enormous benefits. As Walker (1984) pointed out, this research path is riskier and requires more interdisciplinary activity.

But even in the more favorable environments, unless major breakthroughs in sorghum production technology are achieved, yields will remain below potential. Therefore, a careful strategy is needed to raise yields in these environments. Walker noted, "Of course, this ignores other considerations such as equity issues, which can and should be factored into those decisions."
forthcoming¹², area under sorghum will be replaced by other higher-valued crops (pigeonpea, cotton, safflower, castor). Sorghum production in India will begin to decline as it plays out its role as a staple in the diet of fewer and fewer people. In this case, it is unlikely that other non-food uses for sorghum would develop. If breakthroughs do occur, such that per unit production costs are significantly reduced, sorghum will remain competitive. Under this scenario, production will increase and prices will fall, thereby encouraging sorghum substitution for maize in various industries, e.g., for starch, poultry and dairy feed, beer adjunct. This in turn ensures long-term demand for the commodity. That is the outlook in the long-run. The bulk of sorghum grain produced in India will still be directly consumed by humans for some time to come.

There are several reasons why *rabi* sorghum area has not declined and quite likely will not decline

¹² Not the breakthroughs that are achieved under experiment station conditions. Too often one hears that "sorghum yields would double if farmers would just apply x kg of N, y kg of P, and exercise proper weed management." No doubt sorghum yields would double by following that advise. But the pertinent question is: if farmers applied those same resources to other enterprises (wheat/maize cultivation or vegetable production), would the return on the investment be higher or lower? Improvements in sorghum yields must come about, not simply through applying more resources, but through more efficient use of resources. New technologies must be well adapted to farmers conditions, i.e., economically attractive enough to persuade farmers to adopt them.
significantly over time, despite low yields. The first relates to fodder. A major objective in cultivating *rabi* sorghum is production of sufficient quantities of good quality fodder to carry draft and milk animals through the year\(^{13}\). Even in years when "crop failures" occur, or grain yields are abysmally low, farmers are able to harvest some fodder for their animals. Secondly, there are few other crops which could profitably replace *rabi* sorghum under the receding soil moisture conditions of low rainfall environments. Finally, in much of the *rabi* sorghum growing tract, sorghum is a preferred cereal, as reflected by its consistently high price. If the strong price trend continues and if yield improvements in dryland *rabi* sorghum are not likely to be forthcoming, sorghum improvement scientists may want to focus their attention and resources on *rabi* sorghum production with supplemental irrigation (Walker 1990).

Demand for forage sorghum in India will continue to grow as urban demand for milk and milk products increases. Area under forage sorghum, both irrigated and rainfed, will likely expand to meet this demand. Of related importance is the need for dual purpose cultivars with improved fodder yield and quality (Kelley et al. 1990).

\(^{13}\) The scope for tractorization is limited within the *rabi* sorghum growing region (Walker and Ryan 1990). Farmers will have to rely on bullock for field preparation and cultivation well into the next century.
The potential for exporting sorghum from India appears poor. Sorghum traded on the world market is used almost entirely for animal feed, not for human consumption as it is in India. In Figure 13, world market prices of maize (US No. 2) and sorghum (US Milo 2), and Indian sorghum prices (hybrid from Nagpur) are plotted from 1981 to 1989. This sorghum hybrid is of low quality and generally fetches a low price in India. It is clear from the figure that sorghum from India could never compete internationally, not until significant changes in domestic trade policy occurred.

B. The Future of Sorghum in Asia

This topic is perhaps best addressed by sorghum improvement scientists and economists within their respective countries. Nevertheless, a few themes run across most of the Asian countries. It is unlikely that sorghum will regain territory lost to other crops during the last three decades. Technical change in sorghum has lagged behind other cereal crops such as rice, wheat, and maize. This and its low preference as a food grain has relegated sorghum cultivation to more marginal environments in most countries. But there is a bright side to this: sorghum's comparative advantage may be precisely in those less-favorable environments.
Sorghum's major advantage over maize and other competing crops is its low-input, low-risk characteristics, i.e., its adaptability to dry and less fertile areas. Because it is grown mainly in marginal areas under moisture stress conditions, average yields have remained low— but higher than would have been obtained with other crops. This raises an important question: 'which environments should be targeted by scientists when aiming to improve sorghum productivity?' If one accepts that sorghum's future production niche is in lower rainfall, poorer soil type areas, then the answer is clear. The focus should be on drought tolerant, medium (not high)-level yielding cultivars, and on crop management practices with low to moderate inputs under rainfed conditions. In risky environments farmers are unlikely to invest or risk much. It is not realistic to expect farmers to apply 100 kg of N ha⁻¹ under unassured rainfall environments.

Developing cultivars and crop management practices for high-yield environments (e.g., assured rainfall or irrigation) would be justified only in situations where sorghum is likely to be competitive against higher-valued crops. The environments and conditions under which this would be the case should be clearly identified beforehand.
The domestic and import demand for sorghum grain as a partial substitute for maize in livestock and poultry feed is strong in Asia. It will continue to be so, provided it remains competitive in price. This, in turn, depends on technological changes which reduce per unit production costs. In this respect, the situation in Asia is not fundamentally different from the situation in India.

Finally, in cases where there is strong demand for forage, research should emphasize improved hybrid adaptation for the forage sorghums.

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Figure 1. World sorghum production trend.
Figure 2. Production of selected cereals in Asia.
Figure 3. Sorghum area and production in Asia.
Figure 4. Kharif sorghum area and production in India.
Figure 5. Changes in kharif sorghum area, 1976-78 to 1988-89.
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Figure 9. Sorghum grain price in selected market in India, 1981-89.
Figure 10. Area under fodder crops in India and North India
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Source: PS&D view, (Australia and China). For all other countries respective country reports.
Figure 13. Sorghum and maize prices.