Climate vulnerability of sorghum and millet

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Sorghum and millet are the most important cereals for resource-poor farmers of West Africa. They are the only staple crops that can withstand the ravages of weather in that area. Temporal and spatial variations in rainfall and the persistence and patterns of rainfall shortages, especially since 1969, have contributed to low productivity over the last 2 decades. Increased yields can only be achieved through effective management of available resources, both physical and biological. Ongoing research in West Africa offers hope, but significant changes in present farming methods will be needed to reduce the climatic vulnerability of sorghum and millet.

Given the excellent analysis of the influence of climate on sorghum and millet production in India (Rao et al, this volume), I would like to focus on another region of the world—West Africa—where these crops are the most important cereal food for millions of resource-poor farmers. In northern Nigeria, sorghum contributes 73% of total calorie intake and 52% of per capita protein (Simmons 1976). Sorghum and millet play an important role in rural economies and are put to various uses: the grain is used to prepare a variety of local foods and drinks, the hay is used as animal feed, and the stalks are used to construct fences and thatched houses.

West Africa is the poorest region in the world, with the lowest gross national product per capita. About 90% of the population in this region live in villages and depend on subsistence agriculture for their survival. The population growth rate in the 1970s averaged 2.7% and is projected to remain about 3% across 1980-2000 (FAO 1981). This is the only region in the world where capita food production declined over the last two decades (World Bank 1984) and the ratio of food imports to total food increased.

Several factors are responsible for low agricultural productivity in West Africa. Some are climatic, principally low and highly variable rainfall and high demand for water imposed by the consistently high temperatures and radiation. In a large belt across West Africa, there were serious crop failures during 1968-73.

Rainfall variability

Rainfall in West Africa is low and variable. The scale of variability determines the magnitude of crop vulnerability and the extent of regional crop failures. Temporal or time-dependent variations in rainfall are common, and can be represented by three time scales: annual, monthly, and daily. The coefficient of variation of annual rainfall ranges between 15 and 30%. Variability in monthly rainfall is larger, since the rainfall is usually limited to 3-5 mo May-October. Rainfall variability reaches its maximum at the level of daily rainfall.

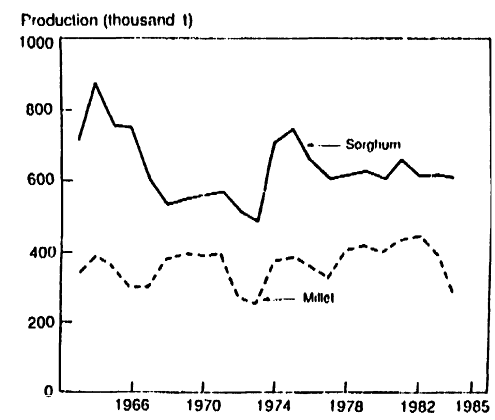
Rainfall in the semiarid regions is characterized by high spatial variability. Over the 500-ha research farm at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center (ISC), Sadore, Niger, we consistently observe 30-40% deviations in individual rain gauges from the central observatory; in isolated cases, deviations up to 80% have been recorded.

One unusual feature of the rainfall in West Africa is rainfall shortages persisting over one to two decades (Nicholson 1982). Rainfall fluctuations also are associated with a geographic pattern. For example, reduction in mean annual rainfall in both Niger and Burkina Faso after 1969 was characteristic of the entire region. After 1969, rainfall isohyets were displaced farther south showing that rainfall changes affect large areas.

Crop vulnerability

Rainfall variability leads to instability in traditional methods of crop production. In Burkina Faso, sorghum and millet production was stagnant (Fig. 1) between 1963 and 1984. Total sorghum production decreased while millet production stayed the same. However, average productivity/ha of both crops declined (Fig. 2). India achieved a more than 40% increase in sorghum and millet productivity between 1963 and 1984, Niger and Burkina Faso showed a negative productivity (Table 1).

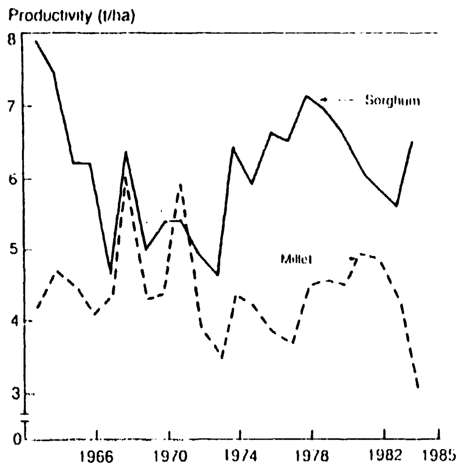
When average rainfall in the Lower-Casamance region of Senegal decreased between 1969 and 1984 to levels consistently below normal, the area planted to sorghum and millet in the Bignona department decreased from 21,000 to 7,700 ha



1. Total sorghum and millet production in Burkina Faso, 1963-84.

and production declined from 16,000 to 5,000 t (Posner et al 1985). As a result, instead of the food surpluses of 100 kg per capita recorded 1962-63, Bignona now faces food shortages of 170 kg per capita.

Based on these experiences, one may wonder why the farmers grow these crops. But sorghum and millet are the only staple crops that can withstand the climatic constraints of West Africa. For the short growing season of the Sahelian region, the crop that will give the highest relative yield is millet; in the regions with longer growing seasons, sorghum is ideal. Under drought stress, millet, with its shorter developmental phases, rapid regrowth, and greater plasticity conferred by asynchronous tillering, can make better use of the short periods of water availability. Water-use efficiency of sorghum also is higher than that of most agronomic crops (Kanemasu et al 1984). Reported optimum and maximum temperatures for the different phenological stages of sorghum and millet are higher than for other cereals.



2. Average productivity of sorghum and millet in Burkina Faso, 1963-84.

Table 1. Expected and actual yields of sorghum and millet in 1984 based on 1963 yield levels.

Country	Crop	Yield (thousand t)		Difference (%)
		Expected	Actual	
Niger	Millet	1,491	900	–40
	Sorghum	619	200	–68
Burkina Faso	Millet	389	280	–28
	Sorghum	729	600	–18
India	Millet	8,048	11,800	+47
	Sorghum	8,250	11,800	+43
	Wheat	17,417	31,564	+81

That makes them ideal choices in the high-temperature environments of West Africa.

From a socioeconomic standpoint, an important consideration for growing these crops is that production in West Africa is primarily subsistence-oriented. Farmers who grow sorghum and millet market only 10-20% of their production; they consume up to 700 g per capita per d (Ryan and Von Oppen 1984).

Current situation, potential, and research needs

Despite the important role of sorghum and millet in the rural economics of West Africa and the need for increased production to feed the growing population, little progress has been made. During 1975-79, cereal self-sufficiency in Africa was only 75%. By 2000, it is expected to decrease to 56% (FAO 1981). The vulnerable countries in West Africa could have food deficits more than three times the deficit experienced in recent years. With little hard cash to pay for costly imports, the situation appears bleak.

The production increases needed to sustain food needs, according to FAO (1981) projections, will be achieved through higher yields (51%), increasing arable land (27%), and improving cropping intensity (22%). Ryan and Von Oppen (1984) question that projection for higher yields. Between 1961 and 1980, yield and intensity increases together contributed only 50% to production growth in West and eastern Africa.

The yield jumps projected by FAO as needed for 2000 can be achieved only through effective management of available physical and biological resources. Considerable potential for raising the yields of sorghum and millet above the current averages exists. At the ISC, Niger, during a 5-yr period (1982-86), yields of CIVT, an improved variety of millet, were 100-470% above average millet yields (0.5 t/ha) and 16-78% above yields of the local cultivar (Sivakumar, this volume). In 1984, when the lowest annual rainfall of this century was recorded and when 2.5 million people were directly affected (Timberlake 1985), we harvested 1.1 t/ha with a seasonal rainfall of only 213 mm. Significantly, the maximum yield advantage (78%) of the improved cultivar was obtained in this severe drought year. With moderate application of nitrogen and phosphorus fertilizer, we achieved a threefold to fourfold increase in millet yields at ISC (ICRISAT 1985).

High yields on research stations, such as those at ISC, give rise to considerable optimism and provide evidence that sorghum and millet are not that vulnerable to climate after all. However, farmers in West Africa who have gone through the worst droughts during 1970-84 do not share this optimism. A critical examination shows that their farming methods are hardly suited to harvesting stable and high yields.

Farming systems in much of West Africa are land-extensive, diversified, and fragmented. Low man-land ratios have encouraged long bush-fallow systems with little or no use of nonlabor inputs. Matlon (1985) gave the average NPK applied in 1978-82 as 3 kg/ha among the 8 Sahelian countries and less than 5 kg/ha for West Africa as a whole. Less than 5% of the area planted to sorghum and millet is plowed before planting and fewer than 5% of the farmers use improved varieties. Their poor resource base (particularly capital, labor, and management) makes adoption of improved varieties difficult, as was shown by Banta and Bbuyemusoke (1985) in the "Guided Change Project" in northern Nigeria. There, only 47% of 153 farmers adopted an improved sorghum variety.

The World Development Report (World Bank 1982) stated: "Yield increases still depend on the subtle interaction between soil, water, seeds, and sunlight, but the process is not as well understood under rainfed conditions as it is with irrigated land." Agrometeorologists play an important role in mapping adaptation zones for sorghum and millet varieties of different growth cycle lengths and in identifying areas with maximum potential.

Much research remains to be done in developing stable and high-yielding varieties for the marginal areas. The more marginal the ecological conditions, the more important the need for adaptation of a variety to specific conditions. The agenda for action for sub-Saharan Africa (World Bank 1981) states that agricultural research has not succeeded in producing varieties adapted to these special conditions. Research carried out by the sorghum and millet improvement teams of ICRISAT in West Africa is aimed at breeding varieties adapted to these marginal conditions. The resource management team is addressing the development of appropriate technologies for optimal use of the human, biological, and physical resources of the region. Multidisciplinary interinstitutional research should be able to reduce the climatic vulnerability of sorghum and millet.

References cited

Banta A, Bbuyemusoke S (1985) Improved sorghum production technology in northern Nigeria. Pages 204-217 *in* Appropriate technologies for farmers in semi-arid West Africa. H. W. Ohm and J. G. Nagy, eds. Purdue University, Indiana.

FAO Food and Agriculture Organization (1981) Agriculture: toward 2000. Rome, Italy.

ICRISAT — International Crops Research Institute for the Semi-Arid Tropics (1985) Annual report 1984. Patancheru, Andhra Pradesh, India.

Kanemasu E T, Piara Singh, Chaudhuri U N (1984) Water use and water use efficiency of pearl millet and sorghum. Pages 175-182 *in* Agrometeorology of sorghum and millet in the semi-arid tropics. Proceedings of the international symposium, 15-20 Nov 1982, ICRISAT Center, India. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Matlon P J (1985) A critical review of objectives, methods and progress to date in sorghum and millet improvement: a case study of ICRISAT/Burkina Faso. Pages 154-179 *in* Appropriate technologies for farmers in semi-arid West Africa. H. W. Ohm and J. G. Nagy, eds. Purdue University, Indiana.

Nicholson S E (1982) The Sahel: a climatic perspective. Club du Sahel, Paris, France.

Posner J, Kamuanga M, Sall S (1985) Production systems in the lower Casamance and strategies adopted by farmers for the water shortage. Pages 179-203 *in* Appropriate technologies for farmers in semi-arid West Africa. H. W. Ohm and J. G. Nagy, eds. Purdue University, Indiana.

Rao N G P, Rao G R K, Acharya H S (1989) Yield stability of sorghum and millet across climates. Pages 165-186 *in* Climate and food security. International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Ryan J G, Von Oppen M (1984) Global production and demand for sorghum and millet to the year 2000. Pages 41-62 *in* Agrometeorology of sorghum and millet in the semi-arid tropics. Proceedings of the International Symposium, 15-20 Nov 1982, ICRISAT Center, India. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Simmons E B (1976) Rural household expenditure in three villages of Zaria province, May 1970-July 1971. Samaru Miscellaneous Paper No. 56. Institute for Agricultural Research, Ahmadu Bello University, Zaria.

Sivakumar M V K (1989) Some strategies to cope with drought in the Sahelian zone. Pages 541-555 *in* Climate and food security. International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Timberlake L. (1985) Africa in crisis. The causes, cures of environmental bankruptcy. Earthscan, International Institute for Environment and Development, London.

World Bank (1981) Accelerated development in sub-Saharan Africa: an agenda for action. Washington, D.C.

World Bank (1982) World development report 1982. Oxford University Press, New York.

World Bank (1984) Toward sustained development in sub-Saharan Africa. Washington, D.C.

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