JA 645

550

Agriculture, Ecosystems and Environment, 31 (1990) 115-132
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

Changes in West African Savanna Agriculture in Response to Growing Population and Continuing low Rainfall*

H.I.D. VIERICH** and W.A. STOOP***

International Crops Research Institute for the Semi-Arid Tropics ICRISAT/UNDP, P.O. Box 1165, Ouagadougou (Burkina Faso)

(Accepted for publication 12 September 1989)

ABSTRACT

Vierich, H.I.D. and Stoop, W.A., 1990. Changes in West African Savanna agriculture in response to growing population and continuing low rainfall. *Agric. Ecosystems Environ.*, 31: 115-132.

Changes in village farming systems, brought about by population growth and continuing low rainfall, are described for the three main agro-ecological zones in Burkina Faso. The toposequential landuse and cropping patterns were used as the basis for a model, which describes the long-term ecological degradation from declining proportions of fallow land and over-cropping. The implications of these changes for land tenure systems have also been considered. The results provide a human and ecological setting for the current land degradation problem in the West African savanna and thereby indicate possible directions and priorities for future agricultural research.

INTRODUCTION

The West African savanna, comprising the Sahel, Sudanian and Guinean zones is an important agricultural area for both crop and livestock production. However, relatively poor soils and an unreliable rainfall result in poor agricultural productivity. These two natural constraints are compounded by a prolonged period of below average annual rainfall that began in 1970, and rapidly increasing human and livestock populations. These factors and the use of agricultural and pastoral technologies no longer appropriate for the present situation are threatening the future production potential of the area.

Rural African populations are currently increasing at over 2% per annum.

*Journal Article No. JA-645. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Patancheru P.O. Andhra Pradesh 502-324, India.

**Present address: Department of Anthropology, University of Alberta, Edmonton, Canada.
***Present address: International Service for National Agricultural Research (ISNAR), P.O. Box 93375, 2509 AJ The Hague, The Netherlands.

0167-8809/90/$03.50

TABLE 1

Rainfall in the ICRISAT Study Villages (Matlon, 1983)

Region	Village	Long-term average annual rainfall[1] (mm)	1981		1982		1983	
			Annual total (mm)	Percent of long-term average	Annual total (mm)	Percent of long-term average	Annual total (mm)	Percent of long-term average
Djibo	Woure	567	449	79	382	67	473	83
	Silguey		509	90	347	61	449	79
Yako	Kolbila	756	707	93	586	78	650	86
	Ouonon		547	72	552	73	NA	NA
Boromo	Koho	981	NA	NA	849	87	778	79
	Sayero		907	92	605	62	622	63

[1]Virmani et al. (1980).

West Africa's birthrate is one of the highest in the world: 50 per 1000 population per annum compared with a worldwide average of 34 per 1000. In the six ICRISAT study villages, which represent the three major agroclimatic zones in Burkina Faso, a recent census showed that in five of the villages a net population growth (after migration) of over 14% occurred between 1975 and 1983 (ICRISAT, 1983).

Meanwhile, there is evidence that sub-Saharan rainfall has not returned to its 1941–1971 average. Reduced rainfall has persisted for at least 14 years (Lamb, 1982) and continued during the study period, as confirmed by the rainfall figures gathered since 1981 in the study villages (Table 1).

The objective of this paper is to show how West African subsistence farmers have responded to these environmental constraints. Farmers have been introducing technological and crop variety changes in their farming systems to cope with the effects of reduced rainfall and increased population pressure. By following a "Farming systems approach to agricultural research" (Norman, 1980), the present interdisciplinary on-farm studies have provided direct contacts between farmers and researchers. Similarly there has been a close connection between on-station and on-farm experimentation. Consequently, a better understanding of the various local farming systems, their technical, economical, and social constraints and their needs for improved technologies has been developed.

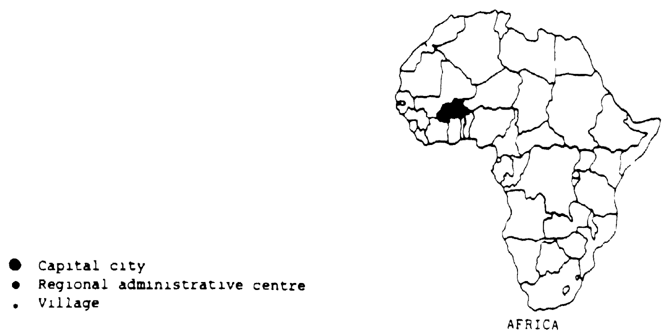
THE ICRISAT VILLAGE STUDIES IN BURKINA FASO: SETTING AND METHODS

Table I summarizes the features of the six ICRISAT study villages and their rainfall characteristics and Table 2 summarizes population characteristics and land use. There are two villages located in each of three agroclimatic zones

TABLE 2

General data on population, cultivated area, and cropping patterns during the 1982 season for the ICRISAT study villages

Ecological zone	Village	Territory (ha)	Population		People km^{-2}		% of land cultivated			White sorghum		Millet		Red sorghum		Maize		Rice	
			1975	1982	1975	1982	% total	% arable	ha per capita	% area	kg ha^{-1}	% area	kg ha^{-1}	% area	kg ha^{-1}	% area	kg ha^{-1}	% area	kg ha^{-1}
Sahelian	Woure	1875	377	755	21	41	48	75	1.20	5.3	94	90.4	178	-	-	1.1	95	-	-
	Silguey	1552	481	636	31	41	55	61	1.30	2.6	200	93.9	165	-	-	1.2	45	0.4	600
Sudanian	Kolbila	1946	905	1321	46	67	32	40	0.47	45.4	335	25.4	228	5.4	616	1.0	975	0.5	1000
	Ouonon	-	868	1224	-	-	-	-	-	22.6	137	68.1	204	4.3	353	1.8	601	0.03	268
Guinean	Koho	1316	962	1145	73	86	48	48	0.53	34.1	253	24.7	218	5.9	482	6.2	1008	2.2	492
	Sayero	3845	867	931	23	25	22	22	0.55	41.4	524	23.1	419	15.3	358	6.3	1215	2.2	780



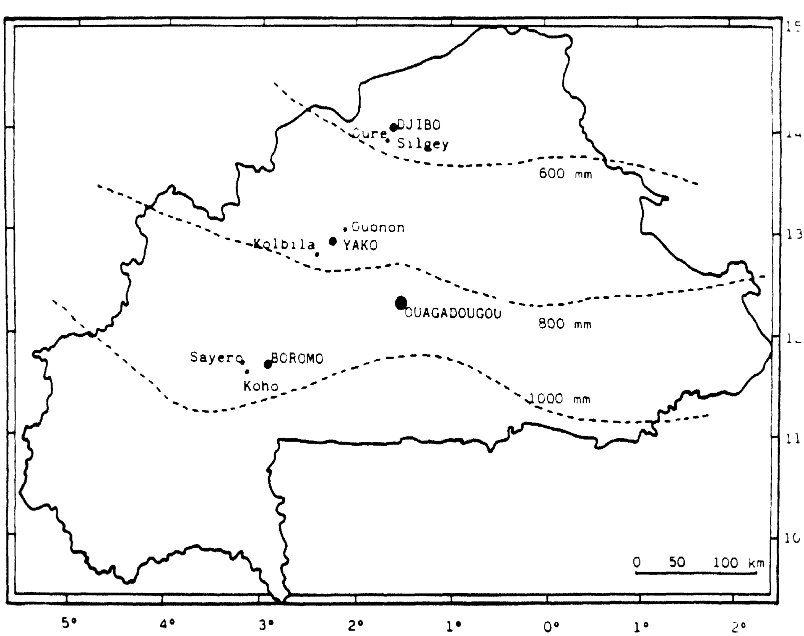


Fig. 1. Agroclimatic zones and locations of ICRISAT study villages in Burkina Faso. ● Capital city; • Regional administrative centre; • Village. Note: Since 1968, rainfall throughout the region was generally below long-term averages, thus the agroclimatic zones pictured on the map have in fact been displaced southwards during the period of the study.

(Fig. 1). These zones roughly correspond to three major types of savanna: the Sahel (500–700 mm, 2 1/2–4 months rainy season); the North Sudanian savanna, which includes the Mossi plateau (700–900 mm, 5–7 months rainy season); the South Sudanian or North Guinean savanna (900–1100 mm, 7–9 months rainy season). These zones are not fixed, but shift with long-term rainfall variations; each zone may be displaced northward during a period of higher rainfall and southward during a period of lower rainfall.

Historically, settlement throughout the mostly gently rolling landscape of the savanna zones has tended to concentrate near lakes and ponds (McIntosh and McIntosh, 1981). Habitats near larger flowing rivers were less populated and located on the upper slopes and plateaus because of the risks of river blindness disease, which is associated with running water. The farmers from these settlements developed two broad continuities in land use: the "toposequential" pattern derived from the differential fertility of soils located along the toposequence (Stoop and Pattanayak, 1980) and the "ring" pattern derived from the increase in soil fertility around human habitations resulting from the accumulation of refuse, offal and faecal materials (Charreau, 1974).

The most fertile soils of the toposequence occur near the bottom of river valleys, where organic matter and clay contents, as well as moisture availability are greatest. By contrast, the upper slope and plateau lands, which comprise 65% of the total land area, generally have more sandy topsoils with low organic matter contents ($<0.8\%$). In many locations these soils are shallow overlying hard laterite. Consequently, moisture stress, surface crusting and low fertility are major problems (Stoop, 1987b); inappropriate soil management readily leads to increased runoff and erosion, and to further depletion of soil fertility, especially of available nitrogen, phosphorus, potassium, and magnesium. Table 3 contrasts soil data from upland bush fields, and from a permanently farmed compound plot with data from other major agricultural soils in the world. These data underscore the poor and fragile nature of these West African soils.

The described environments are the basis for two types of studies.

(1) Agronomic research included experiments conducted at the Kamboinse station near Ouagadougou (1977–1983), on-farm trials and pilot studies of farming in two villages located near the Kamboinse station (1979–1983), as well as on-farm trials carried out in the six ICRISAT study villages (1982–1983). The trials dealt with varietal testing for sorghum and millet (including striga resistant cultivars), adaptation of cereal crops and their major intercropping systems to the different land types of the toposequences as well as crop rotational and fertilizer residual effects. Results of these studies were reported in a series of articles (Stoop and Pattanayak, 1980; van Staveren and Stoop, 1985; Stoop, 1986, 1987a,b).

(2) Socio-economic research included baseline studies (1981–1985): these involved structured formal surveys and regular in-depth interviews with selected farmers and their families to document the ethno-historic changes in

TABLE 3

A comparison of soil properties for topsoils (0–15 cm) of some major groups of agricultural soils in the world with soil data from various fields in the ICRISAT Burkina Faso study villages

	Soil texture			Organic matter (%)	pH water	Cation exchange capacity (mEq/100 g soil)	Exchangeable cations (mEq/100 g soil)		
	Sand (%)	Silt (%)	Clay (%)				Ca	Mg	K
Black clay soils (Vertisol, India)	22.3	16.5	61.1	1.03	7.6	57.6	47.3	8.5	0.6
Red soils (Alfisol, India)	64.5	6.0	29.6	0.46	6.7	10.0	6.7	1.5	0.7
Tsjernozem soils (Millisol, Romenia)	-	-	39.5	2.6	7.1	33.9	22.4	6.6	0.6
(Inceptisol, Holland)	-	-	48.9	3.0	7.4	18.5	15.1	2.0	1.2
Sahel zone: Djibo area (Alfisol-bush field)	93.6	3.9	2.6	0.17	5.7	2.0	0.01	0.06	0.12
North Sudanian zone: Yako area (Alfisol — bush field)	70.2	21.7	8.2	0.95	6.6	6.3	1.80	0.40	0.25
South Sudanian zone: Boromo area (Alfisol — bush field)	65.6	28.4	5.9	0.96	6.5	4.7	0.9	0.25	0.13
Boromo area (Alfisol — compound plot)	59.3	30.7	10.1	1.07	7.4	5.7	2.0	0.45	0.45

farming practices, land use and land tenure that occurred in the same six villages. Detailed results of these studies were reported by ICRISAT (1982, 1983).

Field days followed by group discussions with participating farmers to review the results of on-farm trials and prepare the next season's experiments were conducted jointly by socio-economists and agronomists. By drawing on both the agronomic and social insights obtained from these studies and discussions a more complete understanding of local technologies, their constraints and their evolution is achieved than would be possible for a single discipline operating in either research stations or villages.

RESULTS AND DISCUSSION

Current farming systems and access to land

The agronomic research showed that farmers generally follow an ecological approach by matching different crops, cropping systems, and management practices with variations in soils and land types. Thus, the most drought-tolerant crops like millet, groundnut, cowpea and cotton are grown on the dry uplands with maize, sorghum, taro, and rice on the humid lowlands (see also Kaboré et al., 1983). Through this strategy farmers minimize the risks of yield losses from droughts or floods, while maximizing the returns to labor (Matlon, 1980).

Moreover, by intercropping rice with maize on the lowlands, sorghum with taro or maize on lower slopes and sorghum with millet on upper slopes, the risks of a total crop failure are reduced even further. Farmers in the Boromo area emphasized the increased stability of intercropping by generally guaranteeing the harvest of at least one of the component crops (see also Okigbo and Greenland, 1976); experiment station trials also showed increased total production (Stoop, 1987a). The cropping systems gradually become less diverse towards the lower rainfall zones of the north; around the Djibo villages rice occurs in the lowlands followed by a narrow band of sorghum on the lower slope and millet/cowpea systems and grazing areas on all remaining higher grounds.

Until a generation ago, the fragile soils of upper slopes and uplands were commonly fallowed 20 years or more after 5 to 6 years of cropping. Because of this practice and the isolated locations and relatively small sizes of the bush fields, farmers were not concerned about managing soil fertility through applications of manure and the use of crop rotations, nor with water management to control erosion and runoff.

On the regularly manured compound plots, permanent cultivation has been possible in spite of the originally poor upland soils. Red sorghum, sweet white sorghums, maize, tobacco, melons, calabashes and other vegetables are commonly grown in the fertile ring around habitations. Traditionally, these locations have been reserved for crops requiring the closest tending, highest fertility, and/or which mature most rapidly.

These cropping patterns are sometimes modified, when access to different land types is influenced by land tenure arrangements and other social factors. For areas of higher fertility, such as compound fields and fields near the valleys, land rights are relatively permanent in all of the agro-ecological zones and are usually passed down from father to son. Land rights in upland areas traditionally consisted of use-right tenure or usufruct which tended to lapse when cultivation was abandoned.

Not all farmers in the study villages had equal access to land of different types. Generations ago the village lands were divided among the various lineages or clans and subsequently between the various land-holding groups known as "compounds". Thus late-comer and politically subordinate lineages tended to get land of poorer quality. As land becomes scarcer the same happens to the junior members of a family holding.

This differential access to land by different ethnic groups was studied for the Koho study village. Koho has some 1200 inhabitants, of whom about 62% are Dagara-djoula, 34% are Bwaba, and 4% are Fulani. The first two ethnic groups are primarily farmers, and the Fulani primarily herders. The Bwaba ethnic group settled in the area during the period 1917–1950, when the relatively fertile lowlands were already occupied by the founding and politically dominant group of Dagara-djoula, who actually control 14.2 ha (88%) of the 16.2 ha of the lowland available to the population sampled (Table IV).

This land occupation pattern has greatly affected the respective farming systems. The Bwaba had to occupy poor uplands and hence were restricted in their production of rice, maize, red sorghum, taro, mangoes, and various marketable vegetables including tomatoes and green beans. Although the average Bwaba farms more land than his Dagara counterpart (0.41 ha per capita and 0.30 ha per capita respectively), this reflects the poorer quality soils to which the Bwaba are confined (Table IV). With the introduction in 1965 of cotton, a crop specifically adapted to uplands, the Bwaba got an opportunity to earn cash for buying other food crops. Thus a cotton-based crop rotation was rapidly adopted: in 1982, 37% of their acreage was in cotton, for the Dagara this was only 15%. Therefore, within the same village, variations in farmers' access to various land types resulted in different specialized farming systems.

The above examples show that the general cropping systems pattern and its adaptation to local ecological conditions can be modified by social factors and historical events. To understand the present situation and its most probable future development, it is useful to describe cropping systems and land tenure arrangements in a historical context.

TABLE 4

Differences between ethnic groups in their access to arable land of different land types, Koho 1982[1]

	Land types				
	River valley	Lower slopes	Mid-slopes	Uplands	Total
Bwaba farmers:					
Cultivated area (ha)	0.1	1.8	15.1	43.1	60.1
% of cultivated land	0.2	3.0	25.1	71.7	100.0
Dagara-djoula farmers:					
Cultivated area (ha)	5.8	8.8	21.2	47.7	83.5
% of cultivated land	7.0	10.5	25.4	57.4	100.0
Total cultivated area (ha)	5.9	10.6	36.3	90.8	143.6
% cultivated by Bwaba farmers	1.7	17.0	41.7	41.6	–
% cultivated by Dagara-djoula farmers	98.3	83.0	58.4	58.4	–

[1]Based on data collected in 1982 from a sample of 28 farm units, of which 12 were Bwaba, and 16 Dagara-djoula.

The on-going changes in farming systems

Ethno-historic evidence; implications for tenure systems and migration

Ethno-historic research in the study villages suggests three stages in the evolution of the farming systems (Fig. 2). There was an early stage of light land use (long-fallow) in which mainly the upper slopes and plateaus were cultivated as these were easier to clear than the forests of the lowlands. The curtailment of intervillage raiding and warfare following the establishment of colonial rule around 1900 allowed farmers to extend their farms safely and pasture their animals further afield. This extension, mainly on the uplands, was aided by the introduction of bicycles and carts in later years.

A second stage started when, because of the declining fertility of the uplands, people were forced to start cultivating the river valleys. Most probably it was during this stage that farmers developed the more complex strategies to exploit different soil types along the toposequence.

With increasing population pressure most farming systems now appear to be entering a third stage. Farmers have limited opportunity to expand cultivation in the river valleys. They are forced once again to expand cultivation on previously abandoned uplands, and also to explore various options for intensification. The second and third stage have been extensively documented by Marchal (1977, 1983) for the Ouahigouya region, and by Broekhuyse (1983) for the Kaya region. At present, most farming systems of the study villages on the Mossi Plateau appear to be moving into the third stage (Vierich, 1984).

The implications of these processes are that land use will become more permanent and intensive, and that the tenure systems will evolve towards heritable property rather than usufruct (especially when national governments follow policies favoring private tenure: see Schapera, 1928; Mair, 1948; Manners, 1967 for similar examples from Southern Africa, Botswana and Kenya). Studies of land tenure in the ICRISAT villages also confirm these trends (Drabo and Vierich, 1983). In the most heavily populated villages, all fields including the marginal uplands, that are traditionally in long-term fallow systems, are becoming heritable property though as yet no market for the land has developed.

This change in land use and tenure has increased the grazing pressure on the remaining pastures (Marchal, 1983; Broekhuyse and Allen, in press). In Kolbila on the Mossi Plateau, the tension over land has led to the exodus of nearly all the Fulani pastoralists within the last decade. Out of 10 Fulani camps that had been in Kolbila in 1975, only one remained in 1984.

The "marginalization" of farmers with less secure access to land — i.e., latecomer lineages, disadvantaged ethnic groups, and younger men not in the main line of succession — is a major problem (see also Blaikie, 1981) that has caused much migration of unskilled, often temporary, labor mainly to the Ivory Coast. Broekhuyse and Allen (in press) estimate that about 25% of the total population has left the Kaya area (northern Mossi Plateau); in the remaining famfertilizers and the introduction of early maturing cereal cultivars are major elements, has been recorded in more detail for the study villages.

Agricultural intensification

Increased population pressure and more marketing opportunities have been responsible for the expansion of cultivated areas, and intensification of agricultural production. In that context retrospective data on fertilizer use revealed that the practice of manure and chemical fertilizer applications, even to more distant fields, started around 1972 in the Boromo and Yako villages; chemical fertilizer use in the Sahel remains negligible. In Koho, a manure market was organized by Fulani herdsmen, and stimulated by the introduction of donkey carts. In Kolbila, compound fertilizer use on sorghum bush fields increased rapidly after 1970 (Fig. 3), reflecting both increased demand and increased availability of chemical fertilizer in the Yako area. Chemical fertilizer use in the southern villages has been linked to the introduction of cotton, which today covers 25–35% of the farmland. These high levels of cash cropping were attained from the early 1960s. However, there is increasing evidence that in the absence of manure and lime applications the processes of fertility degradation and loss of soil structure, especially on marginal upland soils will be

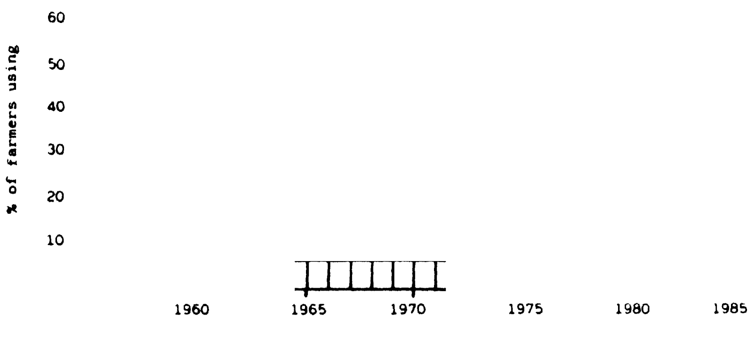


Fig. 3. Increase in use of chemical fertilizers on bush fields, Kolbila village, ICRISAT sample farmers.

accelerated by these cotton-based rotations (IRCT, 1979; Pichot et al., 1981; Ange, 1984; Heen et al., 1984).

Farmers in all zones, including the Sahel, are also intensifying their agriculture in other ways. Local systems of soil and moisture conservation have spread rapidly over the last decade (Reij, 1987). Investments in irrigated gardens of fruit trees and vegetables are also becoming more common in the study villages. Similar trends are reported elsewhere in Burkina Faso (Delgado, 1979), and in other developing countries, where agricultural production for cash is increasing with mounting population pressures (Boserup, 1965), and rising urban incomes.

Variety changes in the cereals

In all the study villages, local experimentation with shorter-cycle varieties of major cereal crops has been common, being triggered by lower rainfall and a shorter cropping season. Since 1968, 86% of the interviewed farmers in the southern village of Koho had abandoned 140–160 day sorghum varieties in favor of 120–140 day local varieties of the Guiniensis type (Fig. 4). One of the new varieties was introduced from eastern Burkina Faso by the regional extension agent. Another variety, supposedly with greater drought tolerance, was introduced from the Mossi Plateau by Fulani herdsmen in about 1975. Subsequently, several farmers have again replaced the extension service variety with the Fulani variety.

The farmers in the Yako villages of the central zone (the Mossi Plateau) were also changing to shorter-cycle, local white sorghum varieties. The change began in the late 1960s, and gathered momentum as the dry years continued (Fig. 4). The new varieties were discovered in neighboring villages and were adopted after several years of local experimentation. In Kolbila, shorter-cycle local varieties covered nearly 70% of the area sown to white sorghum by the sample farmers (ICRISAT, 1982).

In the Sahel villages, some use of shorter-cycle varieties of millet is being made, although the pace of change is slower in the Sahel than further south: in 1981, the sample farmers in Wouré village had sown only about 16% of their millet area to shorter-cycle varieties.

In addition to the shorter-cycle varieties introduced recently from other regions and currently tested, farmers also tend to maintain a large assortment of other sorghum materials. This assortment allows them to switch varieties readily in response to the commonly recognized cycles of relatively dry and wet years.

The trend towards shorter-cycle varieties may be related to both the increased use of marginal uplands and to the prolonged period of low rainfall years. In the former case, this would indicate a permanent change in cropping patterns because shorter-cycle cultivars are less vulnerable to the end-of-season droughts, that are common on the shallow upland soils. Longer-cycle

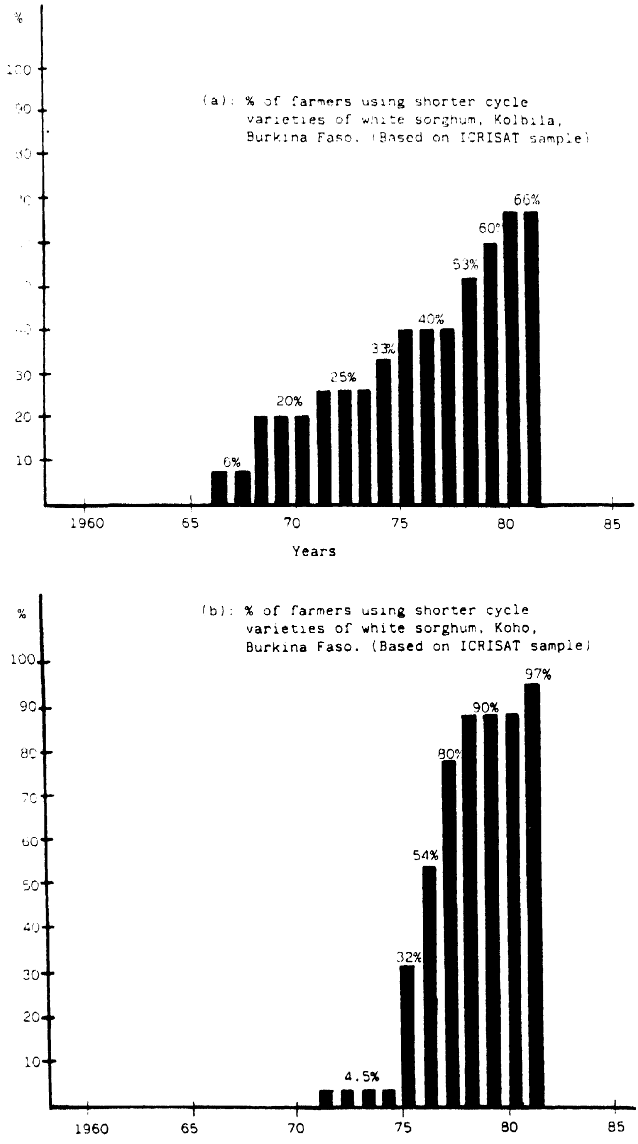


Fig. 4. Changes in varieties of white sorghum grown in two villages in Burkina Faso since the early 1960s.

sorghums are typically adapted to the more fertile, humid lowlands (van Staveren and Stoop, 1985). Moreover, the increasing incidence of the parasitic weed *Striga spp*, particularly on slopes and uplands (Ramaiah, 1983), dictates that future sorghum and millet varieties should combine *Striga* resistance with drought tolerance, and an earlier maturity. Crop improvement programs will need to emphasize these and other secondary crop characteristics such as grain quality and storability (Matlon, 1985), if the poor adoption of new sorghum cultivars in West Africa is to be improved (Stoop et al., 1982). Moreover these programs will have to offer a wider assortment of improved cultivars to meet the needs of the very variable and diverse farming environments.

SUMMARY AND CONCLUSIONS

Several earlier studies have emphasized the flexibility of traditional African agricultural systems (Johnson, 1972; Colsen, 1979; Ruthenberg, 1980; Richards, 1985). This was also confirmed by the present studies. Increased population pressure and an extended cycle of low rainfall years starting in 1970 have had pronounced impacts on farming in Burkina Faso with serious land degradation, particularly for uplands in the Sahelian and North Sudanian zones as a major consequence. The Guinean zone, because of its higher rainfall was less affected, though the same processes of fertility depletion and soil crusting of uplands which caused the serious situation in the north (Stoop, 1987b) have also been set in motion in the South. To offset these trends farmers in all three zones have been introducing, to various extents, more intensive practices (manure and fertilizer use; irrigated gardens; moisture conservation practices) and earlier maturing cereal cultivars. These technical changes took place in rapidly changing ecological and social environments characterized in several ways.

(1) The expansion of farms onto marginal lands of low fertility and the shortening of the fallow periods in all three zones.

(2) The increased degradation of upland fields, their subsequent abandonment and deterioration of the moisture balance for the entire watershed in the Djibo and Yako areas (representing the Northern and Central zones).

(3) The increased cultivation of cotton in the Boromo area (the Southern zone) particularly by ethnic groups that are limited to holdings of marginal upland fields.

(4) The increased competition for land between farmers and pastoralists, and the subsequent migration of the latter with their herds from the Yako area, but also the important role of pastoralists in organizing manure markets in the Boromo area.

(5) The importance of permanent and temporary migration of the young male labor force because of the shortage of good lands in all three zones.

Together these elements provide an essential basis for agricultural research aimed at developing improved technologies that are adapted to both the needs and means of small farmers. For instance, the recorded changes in cropping systems, the need for sustainable farming systems adapted to the fragile uplands, and the search for a wide range of earlier maturing *Striga* resistant cereal varieties, provide valuable orientations for technical, on-station, research programs. The resulting research contributions would complement the important, mostly farmer-initiated changes described in this article.

The network of study villages in Burkina Faso with its detailed baseline information, provides a unique opportunity to monitor long-term technical, cultural, and ecological changes. A follow-up study in 5 or 10 years time, involving socio-economic and technical disciplines would therefore prove invaluable. This monitoring will contribute to more accurate predictions of the changing needs in the various farming systems and provide a basis for adjusting research programs.

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