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Cowpea in traditional cropping systems

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Abstract

The production of cowpea in Africa and America is reviewed briefly. In traditional cropping systems in West Africa, a diversity of both systems and varieties is observed. The contribution of cowpea to overall productivity is small (on average about a tenth of grain yields, averaging 1.5 t/ha), and this fact, together with drought and pest vulnerability, creates a paradox in view of its widespread popularity. The answer to this paradox may lie in cowpea's labor complementarity with the major grain crops, and its value for human diets, livestock fodder, and soil nutrient interactions. Farming systems in this region are changing and are being driven by four sets of factors: population growth (increasing land scarcities), market integration (urban demand), technological change (new cultivars and production methods), and intensification (adaptive change in soil fertilization regimes). Cowpea plays an important role in nutrient cycling (N) in the high-intensity system of the Kano close-settled zone in northern Nigeria, while genetic diversity is exploited to minimize risk in the drier areas. Research and extension agencies should recognize the systemic linkages of cowpea in maintaining sustainable farming systems, and the need to support diversity and indigenous technology.

Introduction

Cowpea originated in Africa and it became an integral part of traditional cropping systems throughout Africa, particularly in the semiarid region of West African savanna (Steele 1972). Cowpea moved to Asia much earlier than America, but it has been entrenched in the cropping systems of both continents, even if it is less important than in Africa (Ng and Marechal 1985). Of the world total of about 8 million ha, Africa accounts for 6 million ha. Cowpea is adapted to warm weather and requires less rainfall than most crops; therefore, it is primarily cultivated in the semiarid regions of lowland tropics and subtropics, where soils are poor and rainfall is limited. The crop is often grown without inputs. Consequently, the yields are poor. Whereas the way cowpea is cultivated in different continents depends upon the agroclimatic conditions, its use has depended upon the socioeconomic conditions, ethnic culture, and traditions of the people who grow it. This paper briefly reviews cowpea cultivation in different continents and focuses on the use and role of cowpea in smallholder farming systems in sub-Saharan Africa with special reference to the dry savanna in Nigeria, which represents one of the major cowpea growing areas of West Africa. Finally, the key constraints in cowpea productivity are analyzed, and their implications in strategies for cowpea improvement are discussed.

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Cowpea production and utilization in different continents

Asia and Oceania. Cowpea is widely grown in India, Nepal, China, Pakistan, Bangladesh, Sri Lanka, Burma, Indonesia, Philippines, Korea, Thailand, Vietnam, Cambodia, Laos, and Australia (Mishra et al. 1985). The cultivated cowpeas in this region are of three types—grain, vegetable (yard-long bean and bush sitao), and fodder. The grain and fodder cowpeas are more prevalent in the Indian subcontinent and vegetable types are common in China, Korea, and other far eastern countries. Grain-type cowpeas range in maturity and plant type from early-erect to late-spreading and indeterminate types. The early-erect types are grown as a pure crop in different niches with cereals, particularly in rice or wheat fallows (Pandey and Ngarm 1985). The late-spreading and indeterminate types are invariably grown in mixture with maize, sorghum, millet, etc., with very low density. Immature pods are often picked at 4- to 6-day intervals throughout the growing season for use as a vegetable, called "Bori" in parts of India, Bangladesh, and Nepal; and the dry grains are used like other pulses in diverse forms. The yard-long bean is a very popular vegetable in China, Korea, Indonesia, Philippines, and Thailand, where it is grown as a pure crop in wide rows with trellis support. The bush-type vegetable cowpea (bush sitao) is relatively early maturing, and it has a semierect plant type and long peduncles, with 25–30 cm long pods that are thick, fleshy, and succulent. These are often grown as a pure crop without any trellis support. Fodder-type cowpeas are grown pure or in intercrop with maize and sorghum in high densities, and harvested along with the cereals at the time of flowering for green fodder.

Europe and northern America. Both fodder and grain type varieties are grown in southern Turkey, Greece, Italy, Bulgaria, Spain, and in southern USA, mostly as a pure crop. Large-seeded blackeye/browneye cowpeas are commercially grown in the states of Georgia, California, Texas, Mississippi, Arkansas, and Tennessee and most of the cultivation is mechanized (Fery 1990). A limited amount of vegetable cowpeas, both yard-long bean and bush sitao, are also grown.

Central and South America. Cowpea is an important crop in several countries of Central and South America, particularly in the drier regions of Brazil, Venezuela, Peru, Panama, El Salvador, Haiti, Ecuador, Guyana, and Suriname (Watt et al. 1985). Cowpea is mostly cultivated as a pure crop but is also grown as an intercrop with maize (Mafra and Cardoso 1988). Both grain-type and vegetable-type varieties are grown. Climbing-type indeterminate cowpeas are grown on a small scale in the wetter regions, with trellis support. There is a great deal of diversity in preference for seed color in this region. Therefore, varieties with different seed colors such as white, red, brown, black, cream, and speckled are found in the region.

East and southern Africa. Cowpea is a very important legume crop in the coastal savanna covering Somalia, Kenya, Tanzania, Mozambique, and the dry savanna of Tanzania, Kenya, Zambia, Zimbabwe, and Botswana (Amable and Rugambisa 1992). Cowpea is also cultivated in the drier low hills of Tanzania, Kenya, Uganda, Rwanda, and Burundi. It is normally planted as a pure crop in the coastal regions, and as a mixed crop with maize in other regions. It is consumed both as grain and as a vegetable, but unlike in Asia where green pods are eaten, in East and southern Africa, the tender leaves are regularly picked and eaten as spinach. Actually, cowpea leaves are a more important source of food than cowpea grain in this region. Almost every household has a few rows of late-maturing, drought-tolerant spreading type cowpea exclusively for leaf picking, and the same varieties are also grown as an intercrop with maize at very low densities to produce grains. The planting pattern differs widely from farmer to farmer. Cowpea may be planted in alternating rows with maize in good rainfall regions, or as one row of cowpea for 2–3 rows of maize in drier regions.

Central and West Africa. Cowpea is the major food legume in Central and West Africa, where more than 60% of the world's cowpea is cultivated. The bulk of the crop is grown in the northern savannas as an intercrop with sorghum and millet, but cowpea is also planted in the humid zone as an intercrop with yam, cassava, and maize. Cowpea is used primarily as a food grain, except for a few pockets such as Benin Republic and eastern Nigeria, where the tender leaves and green pods are used as a vegetable. In the savanna areas, cowpea fodder is equally important because of the large number of cattle and the long dry season when there is not much to graze upon. In these areas the farmers grow two types of varieties in the same field: (1) a grain type which matures earlier; and (2) a fodder type which matures late and is normally harvested at the end of the rainy season, just before permanent wilting sets in.

Traditional intercropping systems in West Africa

Diversity in cropping systems

Cowpea is grown throughout West Africa from wet to dry zones in a variety of crop mixtures, but the importance of cowpea as a component crop is greater towards the northern areas, where rainfall is less and soils are poor. A general survey of cropping systems in West and Central Africa from 1988 to 1990 (Singh 1993) covering Nigeria, Benin Republic, Niger Republic, Togo, Cameroon, and Burkina Faso identified 15 major cropping systems (Table 1), in addition to several others which vary from farmer to farmer. In the forest and Guinea savanna zones, cowpea is intercropped primarily with maize, cassava, yam, and groundnut. The cowpea density is very low (1000–5000 hills/ha) and interspersed among the companion crops. In the northern Guinea savanna, cowpea is intercropped with groundnut and/or sorghum. Planting of component crops is normally done in rows with systematic intercropping patterns, which may vary from alternate row intercropping to within-row intercropping, with varying distances giving a grid of groundnut or sorghum rows crossed by the cowpea rows every 2–3 m. The cowpea population is low, but individual plants spread over a 2–3 m radius.

Cowpea is intercropped with millet and/or sorghum, with or without groundnut, in the Sudan savanna, in several diverse and complex patterns with varying interplant distances and planting sequences of component crops. In a commonly practiced cropping system in Minjibir and Gezawa local government areas of Kano state, Nigeria (Fig. 1), millet is planted first in wide rows (1.5–3 m apart) at the onset of the rains (May–June), with a 1 m hill-to-hill distance within rows, reaching 4000–6000 hills/ha. Grain-type early cowpea varieties are planted between alternate millet rows at a hill-to-hill distance of 1 m, when the rains become more stable towards the end of June. Fodder-type, late-maturing cowpea is

Table 1. Cowpea in the major cropping systems of West Africa.

A. Forest and southern Guinea savanna
   1. Cassava-cowpea
   2. Maize-cassava-cowpea
   3. Maize-cowpea
   4. Maize-cowpea, relay or double crop in second rainy season
   5. Maize-groundnut-cowpea

B. Northern Guinea savanna
   6. Maize-cowpea-relay
   7. Groundnut-cowpea
   8. Groundnut-sorghum-cowpea with or without millet
   9. Sorghum-cowpea

C. Sudan savanna
   10. Sorghum-groundnut-cowpea
   11. Millet-sorghum-cowpea, relay with or without groundnut
   12. Millet-sorghum-cowpea-groundnut
   13. Millet-groundnut-cowpea

D. Sahelian zone
   14. Millet-cowpea
   15. Millet or cowpea

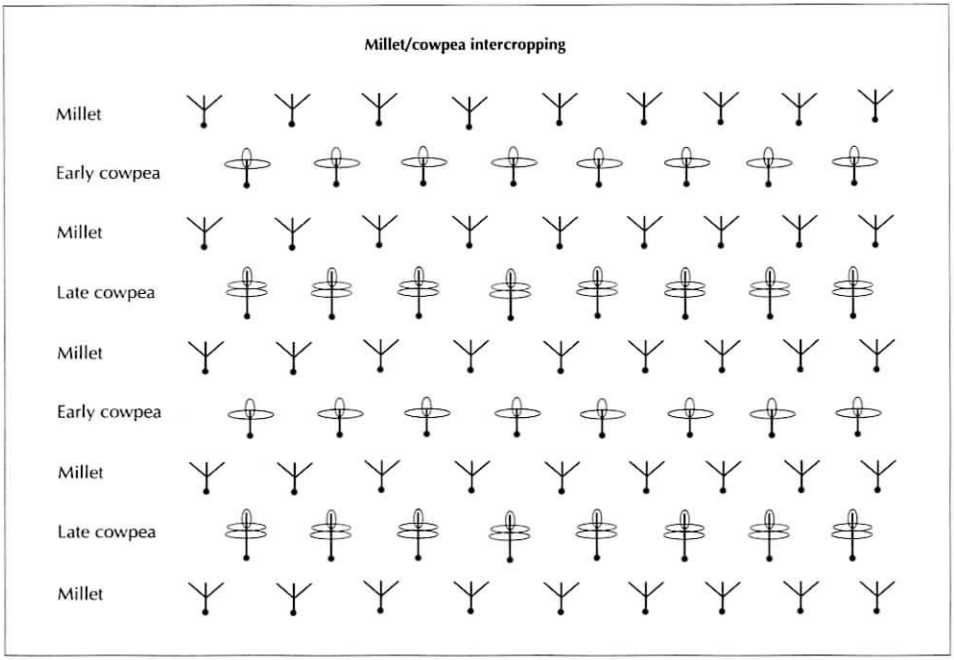

Figure 1. Traditional intercropping systems involving relay with early and late cowpeas in millet fields.

planted late, in mid-July, in the remaining rows. Thus, the pattern of "millet-early cowpea and millet-late cowpea" is repeated. Sorghum and groundnut can either replace or supplement millet and early cowpea in the rows, resulting in a more complex mixture. The early cowpea and millet are harvested at the end of August end or the beginning of September, and the late cowpea/sorghum are left in the field until the onset of the dry season (October–November). The farmers wait until the cowpea leaves show signs of wilting and then they cut cowpea plants from the base and roll the plants into bundles with all the leaves still intact. These bundles are kept on roof tops or in tree forks for drying, to be sold/used in the peak dry season (March–May) when fodder prices are up. If there are rains in October–November or if residual moisture is sufficient, both fodder cowpea and sorghum produce a reasonable amount of grain and fodder. Thus, the cropping system practiced in northern Kano state utilizes rainfall from May to October quite effectively, and the emphasis is on both grain and fodder.

Diversity in crop varieties

Within the two types of cowpea varieties—grain type and fodder type—there is wide variation for seed type, seed size, seed color, hilum color, and plant type. Individual samples from 36 farmers' fields have shown from 1 to 11 seed types in cowpeas of early grain-type and from 3 to 7 seed types in the late fodder-type cowpeas. The varieties have local names that often describe their characteristics. The genetic diversity within each group of varieties is probably maintained by the farmers, to ensure stability under the harsh environmental conditions in which cowpea is grown.

Contribution of the component crops in overall productivity

A detailed study to quantify the contribution of each component crop in the mixed cropping systems revealed major constraints, as well as overall productivity, of different systems (Singh 1993). The study covered 14 farmers' fields in Minjibir and Gezawa local government areas of Kano state, Nigeria, which is the heart of the cowpea growing region in West and Central Africa. A 20 x 20 m block was studied in each field and detailed notes were taken on field, history, land preparation, crops and varieties planted, dates of planting, planting patterns, diseases, insects, maturity, harvesting, and yields of grain and fodder. Yields of component crops were estimated on each farmer's plot (Table 2). The average grain yield of cowpea was 110 kg/ha, with about 1200 kg/ha of millet or 937 kg/ha of sorghum, with large variation in the fodder yield. The total biomass ranged from 2.35 t/ha to 14.52 t/ha (thickly planted late sorghum). The principal constraints for cowpea production were insects (primarily *Maruca*), low plant density, drought stress for late cowpea, and competition with cereals.

Though the findings of a study of this type may differ from year to year because of variation in weather, pests, and other factors, the data gathered indicated that the average cowpea grain yield under traditional intercropping systems is < 100 kg/ha in the Kano area, and that the millet/sorghum yields are about 1 t/ha. Thus, the average grain productivity of traditional cropping systems in this part of Kano state is being sustained at < 1.5 t/ha. The challenge is to find ways of improving this productivity without using additional inputs, which are not presently available. Varietal improvement and modified cropping systems may be the answers.

Table 2. Yields of component crops in different cropping systems (Minjibir and Gezawa local government areas, Kano state, Nigeria, 1991)†.

Cropping system	Grain yield (kg/ha) Ecp	Mlt	Srg	Gnt	Total	Fodder yield (kg/ha) Lcp	Mlt	Srg	Total	Total biomass (kg/ha)
Mlt+Ecp+Lcp	123	1455	–	–	1578	1643	2300	–	3943	5521
Ecp+Srg+Gnt	138	–	2150	168	2456	–	–	3270	3270	5726
Ecp+Srg	405§	–	905	–	1310	–	–	7083	7083	8393
Ecp+Srg+Lcp	128	–	945	–	1073	–	–	4710	7673	8746
Ecp+Srg	173	–	280	–	453	–	–	14065	14065	14518
Mlt+Ecp+Lcp	83	1858	–	–	1941	2365	3060	–	5425	7366
Ecp+Mlt+Gnt+Lcp	60	1663	–	43	1666	1598	3075	–	673	6339
Ecp+Srg+Gnt	75	–	1505	38	1718	–	7060	–	7060	8778
Ecp+Mlt+Srg+Lcp	160	693	628	–	1481	1365	1602	965	3932	5413
Ecp+Mlt+Srg+Lcp	23	750	1318	–	2091	775	1105	5030	6910	9001
Mlt+Lcp	–	1363	–	–	1363	1920	4208	–	6128	7491
Mlt+Ecp+Srg	148	700	105	–	953	–	2283	830	3113	4066
Mlt+Ecp+Lcp	125	1348	–	–	1473	748	3815	–	563	6036
Ecp+Srg+Gnt+Lcp	85	–	503	270	858	850	–	640	1493	2351
Mean	132	1216	937	129	1458	1580	3056	4575	5667	7124

† Mlt = millet, Ecp = early cowpea, Srg = sorghum, Gnt = groundnut, Lcp = late cowpea.
§ Sprayed twice with cymbush.

Role of cowpea in sustainability of traditional farming systems

Three paradoxical characteristics of the cowpea component in rainfed farming systems in the dry savanna should be noted.

1. *Generally low yields.* Yields of < 100 kg/ha are not uncommon (Table 2), and such yields are not regarded by farmers as evidence of failure. When considered as a return to invested labor and capital, however, they seem marginal in conventional terms.

2. *Vulnerability to drought.* Although cowpea is considered to be a drought-resistant crop, rainfall failure is a frequent cause of shortfalls in output. The increased incidence of drought since the mid-1960s has driven a shift to early-maturing varieties brought (according to farmers' own perceptions) from farther north.

3. *Vulnerability to pest attack.* In most systems in question, the high probability of heavy yield loss from pest infestation is fully recognized, and many of the predators and their life cycles are known. However, no economically viable control measures seem to be available.

Yet, notwithstanding these disincentives, cowpea is an extremely widespread and highly valued component, not merely of the cropping system, but of the farming system as a whole, in drought- and pest-prone environments with soils of low intrinsic fertility. This paradox can be understood, in socioeconomic terms, by reference to four complementarities observed:

1. *Labor complementarity.* (a) cowpea planting follows that of cereals, minimizing competition with them for scarce labor; (b) intercropping cowpea with cereals on land that has to be cleared or ridged anyway gives cowpea almost a 'free ride' on account of the low labor input; (c) the spreading habit of the crop minimizes weeding for the whole mixture (on the other hand, weeding may require more skill); (d) harvesting is spread out over time, allowing flexible use of labor; and (e) female labor is normally used extensively in harvesting cowpea, whereas cereal harvesting is mainly men's work, thereby maximizing the use of the labor force.

2. *Dietary complementarity.* Although much cowpea is sold, it has a most important subsistence role in household diets, complementing nutritional deficiencies of cereals.

3. *Livestock interactions.* Cowpea residues are highly valued as fodder in systems where every adult, male or female, and some children own or aspire to own small ruminants or cattle.

4. *Soil nutrient interactions.* Although little data has been adduced to show the quantitative impact of nitrogen fixation in cowpea mixtures on farmers' fields, the beneficial interaction of cowpea with cereals is usually recognized by farmers, either in intercropping or in rotation systems.

These considerations imply that to look at cowpea in conventional field-crop terms (or to assume that output maximization is the producer's main objective) is inappropriate. Of course, it has long been acknowledged, principally in connection with cereals such as sorghum and millet, that (1) security of food output is more important than its maximization, and (2) intercropping two or more crops actually does maximize output per hectare in many dry rainfed systems, vis-à-vis monocropping. But here, we are looking at something else. Cowpea production is essential for the viability of the farming system as a whole, yet alongside the cereal crops, its importance, measured in economic terms, is secondary. There is little doubt that output maximization, consistent with security goals, drives cereal production. The complexity of the cowpea component in the system is, however, of a different order. Its success or failure does not by itself determine the food sufficiency of households, because, in any case, all households grow it.

The dynamics of farming systems

It is essential to understand dry savanna farming systems, not merely in terms of factor ratios as we find them today, but in a longitudinal perspective. Their evolution in West Africa is being driven by (1) population growth; (2) market integration; (3) technological change responding to, among other things, significantly increased aridity since the mid-1960s; and (4) adaptive change, which is dominated by an intensification imperative, where the land supply can support long bush fallow regimes.

Population growth. Population growth in the West African Sahel has been estimated to be in the order of 2.2% per year (IUCN 1989), and the average annual growth rate in northern Nigeria between 1962 and the recently published census of 1991 was 2.2% per year. Such a rate is considerably lower than the rates of over 3% commonly estimated for African countries in recent years (Kenya, for example, maintained 3.76% between 1969 and 1979). Also, it needs to be recognized that in the Sahel, outmigration (and exceptionally high infant and child mortality) produces localized anomalies, where population stagnates or declines.

Increasing population density increases both the demand for food and the labor available to produce it; it lowers interaction and education costs, facilitates the growth and diversification of markets, and drives technological change. A new study of dryland management in Machakos district, Kenya, over the past six decades traces a dramatic turnaround in conservation to these factors and argues a "Boserupian" theory of agricultural change (Boserup 1965; Tiffen et al. 1994; English et al. 1994). Density-driven intensification has been argued for the Kano close-settled zone, Nigeria (Mortimore 1993b).

Market integration. The West African dry savanna farming systems were incorporated into the world market historically through the agency of groundnut cultivation. Policy, research, and extension were concentrated on this crop. Nevertheless, the impact of groundnut cultivation on the evolution of smallholder systems is imperfectly understood and controversial. For example, the widely published interpretation of groundnut expansion as a soil degrading process in Senegal (Franke and Chasin 1980) stands in contrast to an absence of such interpretations of the equally important northern Nigerian groundnut zone (Mortimore 1989). Cowpea, however, being produced for subsistence or for local markets, was ignored by officials during the colonial period. By the 1960s and 1970s, there was a long-established cowpea trade network, linking the producing areas in northern Nigeria with the major centers of demand in the south (Mortimore 1980).

Technological change. In response to persistent African drought (Hulme and Kelly 1993), dryland farmers have adapted their technologies and management, within the constraints imposed by environmental conditions and available choices. A study conducted in the 1980s in the francophone Sahel, which compared six distinct farming systems, emphasized the shift toward more intensive use of wet sites (Boulier and Jouve 1988), and showed that farmers do search for adaptive options. In Nigeria, the range of such options has been extended since the 1960s. For example, the adoption of the fast weeding tool, "ashasha", roughly doubles the size of holding that can be effectively weeded using family labor. Early-maturing varieties of millet, cowpea, and sorghum have spread into Nigeria from farther north.

Adaptive change towards intensification. The transect represented by the three sites (Table 3) proceeds from high to low population densities and from a wetter to a drier ecology. Tumbau and Futchimiram represent stability at high and low densities, while Dagaceri represents areas with rapid conversions of natural vegetation to arable. In all three systems, cowpea features prominently.

Contrary to expectations based on the widely promoted linkage between population growth and environmental degradation, the farming system of the Kano close-settled zone, of which Tumbau forms a part, is managed sustainably on the basis of highly integrated crop, livestock, and tree components, as shown by historical and decadal-scale evidence,

Table 3. Land-use change in three farming systems.

	Location		
	Tumbau	Dagaceri	Futchimiram
Mean annual rainfall (1960–91), mm	728	427	452
Annual rainfall received (1992–95)†, mm	533	360	301
Population density/km^2	300	170	<100
Cultivated land (%)			
1950–57	77.8	35.6	22.1
1969–71	86.4	56.1	22.2
Grassland and woodland (%)			
1950–57	12.8	60.1	76.1
1969–71	6.7	36.8	73.7

† Based on 3 years (1992, 1993, 1995) for Tumbau, all 4 years for Dagaceri, and 3 years (1992, 1994, 1995) for Futchimiram.
Source: Turner (in preparation).

soil fertility indicators, and preliminary nutrient cycling measurements (Mortimore and Turner 1993a,b). Under annual cultivation, soil nutrient status held up between 1977 and 1990 (13 years) in respect of organic carbon, total nitrogen, magnesium, calcium, and pH. Physical properties remained stable.

At the other end of the transect (Futchimiram), there was no significant change in the percentage of arable area over time, or land shortage. Fallows of 8–10 years appear to restore soil nutrient status to levels comparable to land that has never entered the cultivation cycle. Fallow cycles often follow cultivation for up to 20 years or more. This system is not, therefore, under stress. Cowpeas are grown in rotation with millet, and intercropping is not practiced.

If the spatial density variations (Table 3) provide an analogue of change through time in dry savanna farming systems, fundamental changes in the ratio of land to labor, and therefore in the economics of intensification, should be expected to occur in the medium or long term. If the land-use changes—not yet begun at Futchimiram, in full swing at Dagaceri, and more or less completed at Tumbau—are also predictable, soil fertility maintenance would be the key to the sustainability of these systems. Of the strategies available to maintain soil fertility, those having the widest social distribution (lowest cost) are organic manure (mostly derived from animals) and nitrogen-fixing crops.

An association has been found, in African dryland farming systems, between population density, livestock density, and crop-livestock integation (McIntire et al. 1992; Mortimore and Turner 1993). Integration brings conservation benefits to the soil, which explains why prognoses of degradation following increased human and livestock densities have frequently been wrong (Turner et al. 1993).

Set in this context of farming system dynamics, cowpea is recognized in local practice as having beneficial interactions, both economic and nutrient. These cannot always be distinguished easily in farmers' thinking. "For a legume to contribute significantly to the long term maintenance of soil fertility, it must leave behind in the cropping system more N than it removes from the soil" (Giller and Wilson 1991). But the economic value of the crop may lead to removals threatening its beneficial effects on soil N, as observed in Tumbau, where cowpea is in demand for straw and the beans are sold as well as eaten.

Cowpea in nutrient cycling

The Kano close-settled zone has an intensive farming system. Most of the land (86.4%) was under cultivation in 1971, with only a small amount (6.7%) remaining as grassland or woodland (Table 3). Farmers integrate the cultivation of crops with trees and livestock. Crops such as groundnut and cowpea, whose residues provide good fodder for livestock, are intercropped with cereals. Trees are grown in association with crops on farmers' fields.

As mentioned earlier, the four main crops in the system are sorghum, millet, groundnut, and cowpea. These are always intercropped, and may be planted in a variety of mixtures and densities. Yields of cowpea ranged from 19–236 kg/ha of threshed grain, and 100–400 kg/ha of cowpea fodder harvests in 1993. The wide range in yields is due, in part, to the variability in planting patterns (Table 4).

The livestock (predominantly small ruminants) are allowed to graze fields during the dry season, but are kept tethered in compounds at night and throughout the rainy season. The manure they produce is collected. Rejected feed is trampled by the animals and incorporated into the farmyard manure. Ash from cooking fires and any other waste material is also added to the farmyard manure. The practice of using crop residues and weeds as animal fodder and collecting the manure to be used as fertilizer results in a very efficient recyling of nutrients within the system.

Table 4. Crop yields in Tumbau, Kano close-settled zone, 1993.

	Grain (kg/ha)		Residues (kg/ha)	
Crop	Mean	Range	Mean	Range
Cowpea	109	19–236	337	100–400
Groundnut	232	33–396	479	108–856
Sorghum	306	52–847	985	146–2011
Millet	618	144–1128	1328	127–3060

Table 5. Nutrients (%) removed by 100 kg of grain and fodder in the harvest at Tumbau, 1993.

Nutrient	Threshed cowpeas (100 kg)†	Cowpea fodder (100 kg)
Nitrogen	2.37	1.19
Phosphorus	0.15	0.13
Potassium	2.02	1.38
Magnesium	0.58	0.33
Calcium	0.51	0.89

† Equivalent to 128 kg unthreshed.

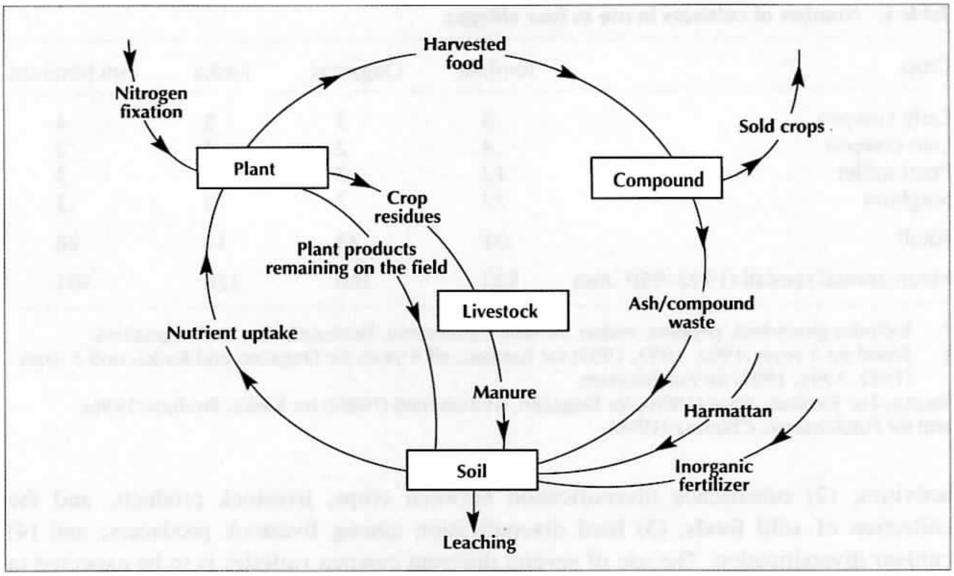

Figure 2. Nutrient cycling in the Kano close-settled zone.

A diagram of biomass produced from one farm shows that the majority of the material coming from the land is used within the farmer's compound, and the nutrients within it are eventually recycled to the soil (Fig. 2). The key to this system is the use of leguminous crops that provide not only valuable food crops for the farmer, but also valuable animal fodder. Moreover, cowpea and groundnut fix nitrogen, thereby introducing more of this nutrient into the system.

While nutrients are removed from the soil in harvesting cowpea grain and fodder (Table 5), the roots of cowpea plants are left in the soil. Most of the nitrogen in cowpea plants comes from the atmosphere via nitrogen fixation, rather than from the soil. Even though other crops growing in the same field may benefit indirectly from nitrogen fixation due to more soil nitrogen being available for nonfixing plants, the main benefit of nitrogen fixation to the soil is only seen after the nutrients within the cowpea plants have been cycled through livestock and returned to the soil as manure (Fig. 2). Reliable estimates of nitrogen fixation by cowpea within this cropping system are not available. Much of the research on nitrogen fixation in field crops has been done in trials where basal doses of fertilizer (phosphorus, but sometimes nitrogen as well) have been applied, and where the situation was simplified by monocropping (Singh and Rachie 1985; Giller and Wilson 1991; Mulongoy et al. 1992). Trials have included inoculation with appropriate strains of rhizobia (Eaglesham et al. 1982; Ofori et al. 1987). There are so many variables involved that "many measurements of nitrogen fixed in the field remain little better than informed guesses" (Giller and Wilson 1991).

Cowpea in biodiversity management

Diversification as a strategy for mitigating risk is expressed in several forms in dry savanna livelihood systems: (1) income diversification between farm, livestock, and nonfarm

Table 6. Number of cultivars in use in four villages.

Crop	Tumbau	Dagaceri	Kaska	Futchimiram
Early cowpea	5	3	5	4
Late cowpea	4	2	4	2
Pearl millet	12	7	6	3
Sorghum	22	7	3	3
Total†	51	33	34	28
Mean annual rainfall (1992–95)§, mm	533	360	326	301

† Includes groundnut, peppers, melon, bambara groundnut, beniseed, rice, and vegetables.
§ Based on 3 years (1992, 1993, 1995) for Tumbau, all 4 years for Dagaceri and Kaska, and 3 years (1992, 1994, 1995) for Futchimiram.
Source: For Tumbau, Yusuf (1996); for Dagaceri, Mohammed (1996); for Kaska, Ibrahim (1996); and for Futchimiram, Chiroma (1996).

activities; (2) subsistence diversification between crops, livestock products, and the collection of wild foods; (3) herd diversification among livestock producers; and (4) cultivar diversification. The use of several different cowpea varieties is to be expected in this context.

In four sites distributed along a gradient from wetter to drier agroecological conditions in northern Nigeria, the numbers of cowpea varieties found in use in each site were 9, 5, 9, and 6 (Table 6). This diversity is consistent with that of the food cereals and other crops.

Diversity enhances the choice in conditions of spatial and temporal variability in rainfall and pest hazards. Although one or two cultivars are most frequently used (in particular, the short-cycle "dan arba'in"), the other cultivars form a genetic reserve. In the past two or three decades, falling rainfall expectations have led farmers to prefer short-cycle varieties. Some of the late-maturing varieties which were once popular are on the verge of disappearing in the dry sites. Newly introduced, early-maturing varieties have come from the north (Niger Republic) or the east. This underlines the fact that adaptation to drier ecological conditions is taking place. Insect pressure may be a factor in the continued use of low-priced or otherwise disadvantaged varieties. Shrubby growth habit minimizes insect damage. Drought resistance was also considered important and, if absent, could be traded off against high yield or good taste and price. Fodder production was regarded highly.

Implications for research and extension

1. The importance of cowpea in dry savanna farming systems is linked to its economic and ecological interactions with the other components of the system. These interactions are imperfectly understood, and vary from system to system. Appropriate agro-economic and biochemical research methods need to be applied to representative systems. Output maximization as a sole breeding objective takes inadequate account of these interactions.

2. Farming is evolving towards more labor-intensive systems in many areas, driven by demographic and economic forces. Cowpea has a crucial role to play in the achieve-

ment of sustainability. It facilitates crop-livestock integration, which is associated, in dryland Africa, with intensification and land-conserving investments. In fixing N, it imports nutrients into the cycle. Its economic function in the system is complementary to that of cereals. It is universally known, understood, and accepted.

3. The diversity of farming systems, their temporal variability, and exposure to pest hazards, pose a major challenge to breeding. Rather than a few high-yielding varieties, whose adaptability is unknown to users, site-specific menus of diverse cultivars may be more useful. Research must be interactive with farmers. Improved pest resistance is more likely to benefit farming households than marginal yield increases.

4. The following cowpea breeding objectives at IITA (Singh 1993) are relevant to the problems encountered by smallholder farmers in the semiarid regions:

   - develop grain, fodder, and dual-purpose varieties;
   - develop varieties for intercropping, as well as pure cropping;
   - combine resistance to major insects, such as aphid, bruchid, thrips, *Maruca*, and pod bugs, along with resistance to major diseases;
   - combine drought, heat, and shade tolerance;
   - develop varieties with an inherent capacity for good growth under low fertility, i.e., for better N fixation and nutrient use.

   In addition to these objectives, however, a strategy is necessary to deal with ecological diversity (soil, rainfall), the complexity of system interactions, and the diversity of farmers' practice and objectives.

5. A majority of cowpea growers have no contact with formal extension agents. However, their interest in improved varieties (from whatever source) generates indigenous, adaptive, technological change. Formal extension systems must integrate with such autonomous technological change if the limited resources available to governments are to be effectively used.

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