

The Humid and Subhumid Tropics

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The humid and subhumid tropics in African regions where rainfall exceeds potential evapotranspiration for five months or more include most of the area from Guinea through central Africa plus the southern part of East Africa. They cover 12 million square kilometers, or 43 percent of the total land area, and include the humid forest zone of central Africa. Rainfall is over 1 thousand millimeters per annum. Regimes prevalent in these zones are monomodal in the derived savannas, with four to six humid months; bimodal in the transition zones of the tropical forest region, with a major cropping season of four months and a minor season of about two and a half months; and pseudobimodal in the wetter forest regions, with seven to nine or more humid months.

In West Africa, the three rainfall patterns occur in ecozones parallel to the coast. The subhumid band adjoins the semiarid Sudan savanna and the Guinea savanna, which generally have a monomodal rainfall. The next band is bimodal. The pseudobimodal band is nearer the coast and has over 2 thousand millimeters rainfall. Similar transitions generally occur in other parts of Africa (Lawson 1979).

Despite increased available water and lower drought risk, conditions for agricultural production deteriorate rather than improve with the transition from dry to wet climate. The productive potential of the transition zone of the Guinea savanna, with monomodal rainfall of about 1,000 to 1,200 millimeters, often is greater than that of the adjoining bimodal region, with 1,200 to 1,600 millimeters. This, in turn, has a somewhat better potential than the more humid tropical regions. These decreases are due to several factors—principally, decreasing solar radiation, decreasing soil fertility, and increasing problems with pests and diseases (Kassam 1977).

The climatic characteristics of four areas in Nigeria and the calculated net

Table 7.1 Climatic characteristics of four locations in Nigeria

Location	Latitude	Ecology	Growing season (days)	Daily solar radiation (calories per square centimeters per day)	Growing season temperature (average of daily averages)	Annual rainfall (millimeters)
Kano	12°03'	Sudan savanna	138	471	26.2°C	869
Samaru	11°11'	Guinea savanna	187	452	25.3°C	1,095
Ibadan	7°29'	Savanna-forest transition area	276	400	26.2°C	1,227
Port Harcourt	4°5'	Forest	331	369	26.7°C	2,334

Source: Kassam 1977.

biomass production per day and computed yields for three crops under rainfed conditions are shown in tables 7.1 and 7.2. Table 7.2 reflects the potential agronomic performance based on crop adaptability characteristics and climatic factors. Total biomass production is very much influenced by the average rate for the four locations. The dominant role of solar radiation is obvious when looking at the data in the two tables.

The major soils of the subhumid and humid tropics of Africa are ultisols, alfisols, and inceptisols. Oxisols and entisols are present in smaller areas but are important for their agricultural potential (Moormann and van Wambeke 1978). Ultisols are generally confined to the humid forest zone with pseudobimodal rainfall. They are very acidic, have low base status, low activity clays, and very low fertility.

African alfisols are usually confined to the somewhat drier bimodal and monomodal transition zones between the forest and the savannas. They often have a higher base status and nutrient content and are only slightly acidic, but they have poor structural stability, poor water-holding capacity, and low organic matter content once cultivated. Most African alfisols are dominated by low-activity clays. The oxisols generally occur in the same high-rainfall belts as the ultisols but are more heavily textured and structurally more stable. They are better drained and less subject to erosion. Entisols are formed on less-weathered materials in scattered areas and have retained a higher level of fertility than the older soils.

The inceptisols in Africa are mainly in river floodplains and inland valleys in the bimodal and monomodal rainfall areas. They have a more mixed clay mineralogy, higher organic matter content, and are more productive when excess water can be controlled.

The overall agricultural potentials of sub-Saharan Africa using climate

Table 7.2 Daily production and annual yield for phaseolus beans, maize, and cassava in four locations in Nigeria

Location	Daily net biomass (kilograms per hectare)			Yield (tons per hectare)		
	Phaseolus beans ^a	Maize ^b	Cassava ^c	Phaseolus beans ^a	Maize ^b	Cassava ^c
Kano	93.5	129.0	182.0	4.3	10.1	...
Samaru	84.0	120.3	169.0	4.4	11.2	12.4
Ibadan	59.4	99.6	133.0	3.9	8.6	15.1
Port Harcourt	47.4	78.9	108.0	3.4	7.1	14.4

Source: Kassam 1977.

^a100-day growing season

^b120-day growing season; harvest indexes used are Kano = 0.45, Samaru = 0.5, and Ibadan and Port Harcourt = 0.4.

^cFull growing season (see table 7.1).

Table 7.3 Land suitable for growing five crops in four agroecological zones of tropical Africa

Agroecological zone by growing days (millions of hectares)	Sorghum		Maize		Soybeans		Sweet potatoes		Cassava	
	Millions of hectares	Percent of area	Millions of hectares	Percent of area	Millions of hectares	Percent of area	Millions of hectares	Percent of area	Millions of hectares	Percent of area
90-149 (186.6)	33.8	18.1	25.7	13.8	20.1	10.8	12.7	6.9	0.8	0.0
150-209 (401)	175.7	43.8	179.0	44.6	168.2	41.9	136.6	34.1	29.6	7.4
210-269 (264.6)	37.2	14.1	59.3	22.4	58.9	22.3	97.2	36.7	92.9	35.1
270 and over (424.4)	0.0	0.0	7.5	1.8	7.9	1.9	42.6	10.0	113.2	26.7

Source: FAO 1978a.

Note: "Suitable land" excludes marginal land and includes only high-input land.

and soil characteristics have been worked out in a general way in the FAO agro-ecological zones project (FAO 1978a). The FAO study computed suitabilities for the production of 10 food crops and cotton for both lowland and highland tropical areas. The calculations used agroclimatic constraints and soil data to modify the agronomic production potentials, classing land as very suitable (80 percent or over of theoretical potential), suitable (40 to 80 percent of theoretical potential), marginally suitable (20 to 40 percent of theoretical potential) and unsuitable.

The data clearly demonstrate that with longer growing seasons and increased rainfall, both suitability for food crop production and the number of food crops that can be produced decrease, especially grains and grain legumes (table 7.3). Root crops, however, become dominant on a relatively smaller acreage. The implications for nutrition and trade are obvious.

Local variations within the broad land-suitability classes, particularly in the many small, inland stream valleys, may occasionally be important. Generally, these have a better soil nutrient and moisture regime than adjacent uplands.

AGRICULTURAL PRODUCTION SYSTEMS

Shifting cultivation and bush-fallow production systems dominate the humid and subhumid regions in sub-Saharan Africa. In terms of land, these are quite inefficient, since considerably more land is held in unproductive fallow than in productive use. The shifting cultivation system relies on a rather precarious balance between the regenerative powers of the fallow vegetation and the destructive forces of soil erosion and degradation during the short cultivation phase of each cycle. Approximately 2 to 4 years of production are followed by 10 to 25 years of fallow.

Bush fallowing is well suited to subsistence agriculture, which relies on very limited external inputs. But it has few possibilities for rapidly increasing output of food in response to external demand. Large-scale production for local consumption is rare, though many schemes continue to be tried in a number of countries. Most of these have relied on systems and equipment of the temperate regions. They have failed because they lacked technologies for stable crop production over many years.

Shifting cultivation has been defined by Ruthenberg (1980) and others as a production system that involves cropping for a few years on selected and cleared plots followed by a lengthy period when the soil is rested and natural vegetation takes over. Land-use intensity (the ratio of land cultivated at any one time to the total land available to the farmer) has an upper limit of 33 percent. Systems with a ratio of 33 to 66 percent are commonly termed fallow systems, and those with a higher ratio are classified as permanent agriculture.

The two systems of the humid tropics in Africa, shifting cultivation and

bush fallow, involve low levels of technology and high degrees of subsistence food production. However, they are never simple. It is common for many crops to be grown on the same piece of land. Frequently, cultivated plots are interspersed with perennial tree crops that either have cash income value (for example, oil palm, cocoa, and coffee) or are valuable for fuelwood or staking. Farmers in many areas retain woody species in their cropland to regenerate soil during the fallow cycle.

The multiplicity of food crops are partly a response to demand for a varied food supply within the smallholder's household and partly a way to reduce risks associated with pests, diseases, and climate. There is good evidence that mixed cropping makes better use of nutrients, moisture, and light, protects the environment, and delays the effects of soil degradation more effectively than monocropping (ter Kuile and Kang 1983). Total biomass production with mixed cropping is higher, and more residual biomass is returned to the topsoil, resulting in better maintenance of organic matter and nutrients.

The humid and subhumid tropics of Africa are also marked generally by an absence of the grazing systems common in semiarid regions. This is not due to a lack of grasslands, which are becoming increasingly common, but to animal disease problems, particularly trypanosomiasis. The extension of grasslands appears to be the result of progressive deterioration of the original fallow systems. The gradual elimination of the woody plants by fire or other means has led to an increase in grassy fallows, which are intrinsically less efficient in recycling nutrients and restoring soil productivity (Greenland and Lal 1977). However, underutilization of grazing areas appears to be a problem that could be solved in the foreseeable future. Control of ruminant diseases, especially trypanosomiasis, would open the way to the development of mixed farming systems in many areas.

A recent survey of 294 smallholder farmers in three regions of Nigeria listed more than 40 crops commonly found on their farms (IITA 1982). Twenty were found on more than a quarter of the farms. Most of the one- to two-hectare farms grew at least four different crops, often interspersed with garden vegetables for daily use. The survey revealed large differences among major ecozones in the cropping sequences practiced both by farmers using shifting cultivation and those using bush fallow. Certain valuable crops, such as yams, are grown early in the production cycle, while crops tolerant to low fertility, such as cassava, are grown just before the land is returned to fallow.

CONSTRAINTS ON IMPROVEMENT OF AGRICULTURAL PRODUCTION

Soil degradation is probably the most important constraint in increasing food production in the humid and subhumid tropics of Africa. This can take different forms in different areas, depending on climate, soil type, topography, and so

forth. In the humid tropics, the principal degradation process is leaching and acidification, which leads to toxicities and nutrient imbalances. In the subhumid tropics, leaching is less severe and degradation is largely physical—through horizontal and vertical erosion and loss of structure. Most of the soils of humid forest areas are relatively stable structurally, while those of the subhumid forest-savanna transition zones often are lighter, with fragile structure and frequently with gravelly or ferralitic horizons.

When a farmer clears the jungle and starts cultivating the land, the soils can change rapidly for the worse in many ways. The most important changes are chemical, physical, and biological (ter Kuile and Kang 1983).

Chemical Changes

Chemical changes result mainly from leaching and the relatively limited return of nutrients from plant litter to the topsoil. Low exchange capacity of the soils quickly results in rapid loss of base saturation, acidification, and an increase of soluble aluminum. This results in nutrient imbalances and frequent toxicities of aluminum, iron, and manganese. The tolerance of most food crops to such toxicities is quite low, but several weeds appear to be fully adapted to them. These processes are more pronounced in the humid tropics than in many parts of the subhumid regions.

Physical Changes

Elimination of much of the plant cover by land clearing results in drastic temperature increases in the surface soil. For example, daily maximums at Ibadan, Nigeria, rose from 22° to 23° centigrade to 45° centigrade. Such increases result in very fast decomposition of organic matter and in decreases in exchange capacity and in capacity to form stable aggregates with low-activity clays. Fine particles of soil are lost through surface erosion or leaching, and the soil becomes more dense and less permeable, leading to greater surface runoff. The amount of moisture that can be stored in the soil declines so drastically that crops are frequently subject to drought stress despite nominally adequate rainfalls.

Biological Changes

Earthworms appear to play an important role in maintaining structure and macroporosity in the soils of the tropical forest regions. Worm casts has been measured at 40 tons per hectare per year. Land clearing and cultivation can eliminate these beneficial animals quite rapidly.

The last few decades have seen an intensification of land use resulting from population growth and rapid urbanization, leading smallholders to extend

cropping areas at the expense of fallow land. In many areas the shifting cultivation system has given way to bush fallows in which up to two-thirds of the land is cultivated and rest and recuperation periods are greatly reduced. The ecological balance is often upset, because the fallow periods are too short for soil fertility restoration. The soils are gradually being mined and permanently degraded (Ruthenberg 1980).

Different problems affect the deltas, tidal and large swamps, floodplains, and inland stream valleys, which could be the most promising areas for development in the tropical regions of Africa. They are greatly underutilized in most countries. Their major constraints are human and animal diseases, such as bilharzia, trypanosomiasis, and onchocerciasis, abundant weed growth throughout the year, and a lack of technology for controlling excess water. However, the African wetlands have more fertile soils than upland areas and are generally less subject to degradation. The area in wetlands appears to be substantial. In West Africa, over 20 million hectares were estimated to be in inland stream valleys (Hekstra 1983).

The tropics of Africa are subject to the damaging impact of very heavy rainfalls and to low levels of solar radiation. High temperatures and humidity bring on exceptionally rapid attacks by a wide variety of diseases and pests. The spread of the cassava mealybug and green spider mite across the continent and the outbreaks of yellow mottle virus in rice and of black sigatoka in plantains bear witness to this serious problem. Another serious constraint is fierce competition from weeds that are better adapted to the hot climate and infertile soils than food crops.

POTENTIAL SOLUTIONS TO CONSTRAINTS ON AGRICULTURAL PRODUCTION

It has become clear that a solution to controlling soil degradation and weed growth may lie in the direction of maintaining protective organic mulches on the soil surface by maximizing biomass production (that is, organic residue production) while minimizing negative competitive effects on crops being produced. Selective herbicides in the preplanting and preemergence stages can play a role, especially in insuring timely controls. Intercropping and relay cropping also have promise, as do seasonal cover crops. However, use of these promising techniques depends on the development of new equipment for such soil and crop management systems (Hartmans and ter Kuile 1983).

The basic problem of agriculture in the African humid tropics is that no easy technology is readily available for general application that will change bush-fallow systems to permanent cultivation of food crops. Normal land-use intensity in the African humid tropics ranges from 15 to 40 percent, varying with the quality and rate of degradation of the land. Population density is low

compared with many other tropical regions. Although food crop production could be increased substantially by expanding total acreage used each year, this would be accompanied by a quick loss in productivity of the land and an increasing shortage of labor in rural areas.

The present small size of farm holdings, which average one to two hectares in many parts of the region, is an outcome of the high labor requirements and low labor productivity of both the shifting cultivation and the bush-fallow systems. In recent studies in Nigeria, about 90 percent of the labor in these farming systems is used for weeding and clearing of forest to replace worn-out land. This obviously leaves little opportunity for expanding the cultivated area and improving crop husbandry. Unfortunately, machinery and mechanized farming technology used in temperate climates has proven unsuitable for soils of the African humid tropics. Apart from their reliance on costly external inputs, they have frequently led to accelerated erosion and degradation of the land. Appropriate equipment and energy sources must be developed that would release labor from weeding and land clearing for more productive tasks.

Many other socioeconomic constraints affect the food production potential and the possibilities for introducing better technologies in the region, such as the lack of infrastructure, financing, and production inputs. Furthermore, many of the young, educated, and enterprising people have left rural areas, leaving them more and more populated by old folks and their grandchildren.

RECENT DEVELOPMENTS AND TECHNOLOGY TRENDS

Agricultural research in the wet tropics of Africa is still in its infancy. The many complex problems in food production have prevented noticeable improvement in technology and agricultural production. Nevertheless, a rather large number of technological components have been developed that can be used to improve local farming systems. These are discussed below.

Land Development and Forest Clearing Techniques Long-term experiments at the International Institute of Tropical Agriculture and elsewhere show that soil degradation in the wet tropics generally starts with inappropriate methods of clearing land for agriculture (IITA 1982, 1983). Use of heavy machinery that mixes the soil to considerable depth is particularly likely to cause a rapid breakdown of soil structure and a depletion of organic matter and fertility. It also leads to rapid compaction and decreased permeability of the fragile soils common in the tropics. More efficient, partly manual, clearing methods are needed so that light equipment can be used. Stabilization of the topsoil by an aggressive leguminous cover crop can prevent the disastrous erosion that frequently takes place after land clearing. Burning the forest vegetation in place, rather than windrowing and then burning, will also keep the limited available nutrients in the tilled land.

Pest and Weed Management A great amount of research has been carried out to develop good recommendations for pest and weed control, using chemical sprays in most areas. These generally require technology and inputs that are still out of reach for many small farmers. Integrated management and biological control systems, including chemical methods at low input levels, show much promise. Weeding is often the most labor-intensive farm activity in the humid tropics. The use of herbicides has proven to be very economical in areas where labor availability and costs create production bottlenecks. More research is needed on complementary methods of weed control that require lower inputs and less technology.

Mechanization High labor requirements for weeding and bush clearing in the traditional systems make it imperative that tools be developed to make more efficient use of the energy available in the smallholder's family. Equipment is also needed for minimum tillage, mulching, and alley cropping. Progress in animal-drawn farm equipment has been made in recent years. IITA's rolling injection planter and related items and the International Rice Research Institute's paddy rice equipment hold promise for increasing the efficiency and quality of crop establishment. Small-scale equipment for improving the efficiency and timeliness of harvesting is badly needed, as is the development of low-cost, low-weight power units that can be coupled with this equipment to make it possible for 1.5-hectare farmers to triple or quadruple their cultivated area. It is difficult to find large industries interested in developing small equipment that can only slowly become a money earner.

Mulching and Fertilizer In addition to less destructive land clearing, a drastic decrease in tillage is needed, with careful preservation of protective organic residues and mulches on the surface. On alfisols in Nigeria and northern Australia, these practices have proven effective in maintaining good productivity with limited inputs. However, they are difficult to apply in large-scale farming and depend on effective weed control. Research is needed on good mulch-producing covercrops for specific ecosystems, and new farm equipment will have to be developed. In the more acid soils, use of lime and fertilizers shows considerable promise (IITA 1982, 1983).

Selection and Breeding of Crop Varieties Improvement of crop varieties was one of the first research goals, and most staple crops have now been improved by selection and breeding. As yet, little breeding has been done for nonconventional but promising production systems, such as mixed cropping, agroforestry, and zero-tillage mulch conditions.

Transfer of Technologies Recently, a number of organizations have started research on holistic and interdisciplinary farming systems designed to be cost effective in generating technologies appropriate to the production and consumption goals of farm households in defined areas (Norman 1980; Byerlee

and Collinson 1980; CGIAR 1978). This research is an extension of traditional, experiment station research and embraces a range of activities, including diagnoses of farming systems and their constraints, identification of farmer's needs, and on-farm research to adapt and verify pretested technologies under the farmer's management. The approach will lessen the time between generation of technology and adoption by farmers. Continuous feedback will enable research establishments and policymakers to focus more clearly on the real needs at the farm level.

Agroforestry The stability of shifting cultivation and bush-fallow systems has generated much research on agroforestry systems, in which tree crops with deep root systems are combined with annual food crops to maximize biomass production and to recycle nutrients and organic materials. Alley cropping involving small trees and shrubs in rows between food crops is probably the most advanced of such methods and has gained strong support in several areas of Nigeria and Sri Lanka. In its present form, mulch on the soil surface is produced by leguminous trees, such as *leucaena leucocephala*, which are pruned regularly to prevent shading of growing food crops. Soil productivity can thus be maintained. The methodology is ready for adoption by smallholders, but research for large-scale farms is needed.

Mixed Cropping and Relay Cropping Smallholders in the tropics traditionally interplant different food crops in the same field. This method often outyields sole cropping systems and appears to be more stable and to better conserve the soil's fertility. A good example is maize-cassava intercropping, which not only greatly outproduces sole maize production but can be continued for many years without appreciable soil degradation when combined with minimum tillage and residue mulch. More research has to be done before such technologies can be used on a large scale, but at the smallholder level improved mixed cropping is ready for transfer.

Livestock Introduction Little research has been done on livestock in mixed farming in the humid tropics of Africa. Trypanosomiasis is to blame for a large part of this neglect. The International Livestock Center for Africa has started long-term research on the role of small ruminants in the farming systems of the African humid tropics. Improved pastures, fodder production, and animal traction could play a valuable role in smallholder farming systems, once the disease threat is eliminated.

CONCLUSIONS

Ecological and natural resource constraints impose severe limitations on the food crop potential of the African humid tropics. Traditional responses of farmers to these constraints—the shifting cultivation and bush-fallow sys-

tems—are ecologically conservative but not capable of substantial increases in productivity and total output nor can they be easily displaced by a different system. A much greater research effort is required nationally and internationally to develop improved systems. Furthermore, national and international development agencies should be more conscious of the often irrevocable loss of resources that can result over the medium and long term from land development schemes that are not based on sound technology.

Sustained increases in food production in the humid and subhumid tropics of Africa will depend greatly on the adoption of environmentally sound farm and land management practices coupled with low-cost energy and low-cost labor-saving equipment for on-farm use. In view of the continued trend toward forest and bush clearing, high priority should be given to methods that do not involve heavy machinery and to research on less destructive forest clearing. Improved manual clearing with lightweight equipment and early plant covers for cleared areas need to be developed for each ecosystem. The conservation of soil productivity through cycling organic matter and nutrients and through minimum tillage will be essential.

Mixed cropping, agroforestry, and cover crop fallows all appear to be important options. In particular, alley cropping, mixing of tree crops and food crops, and multistory fallows, all of which help in the fast regeneration of degraded soils, show promise in this regard. However, considerably more research is needed in these areas.

Large-scale production of annual food crops is extremely difficult in the tropics and limited to very few crops. Nevertheless, high priority should be given to research on the development and management of these wetlands for use by small farmers, coupled with greater research on animal and humid diseases.

Along with this agenda, there is an urgent need for improved methods for adapting new technology and transferring it to the farmers, coupled with better feedback systems from farmers to researchers. Future African food production will greatly depend on how successfully each component developed through research is adopted by the small farmers in the humid and subhumid tropics.