Agroclimatological Characteristics of the Groundnut-Growing Regions in the Semi-Arid Tropics

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Abstract

*Groundnut (*Arachis hypogaea *L.) is grown in many diverse agroenvironments. It is cultivated in some 90 countries around the world. In semi-arid tropical (SAT) areas it is an important cash crop in subsistence farming systems, as well as an important food source. The total output of groundnuts in SAT countries is about one-half of the total world production.*

Within the SAT, India has the largest groundnut production area. It produces 52% of the combined output of all the SAT countries. Other SAT countries producing significant amounts of groundnut are Senegal, Nigeria, Sudan (each producing between 5-7.5% of combined SAT production); Zaire, Brazil, Burma, Argentina (2.6-5%); and Thailand, Malawi, Zimbabwe, Cameroon, Central African Republic, Chad, Mali, and Gambia (1-2.5%).

Groundnuts are grown primarily in rainfed dryland conditions. In India, the crop is cultivated in soils ranging from coastal sands to Vertic Inceptisols. In the African subcontinent it is grown on Alfisols and Oxisols. Groundnut soils have generally low (≤ 100 mm) to medium (≈ 200 mm) available-water holding capacity (AWC) in the root profile.

In the Indian groundnut-growing areas the annual rainfall varies from about 400-1500 mm, usually received between 2-4 rainy months. the crop is grown from 8-32°N latitudes. In northern India, where the rainfall is unimodal, groundnuts are grown during the rainy season from June to September. In south India, below 10°N, the rainfall tends to be bimodal and temperatures are suitable for groundnut cultivation almost the whole year; two crops are raised. The first crop is grown from July to September/October (first rainy season) with another crop in October/November to January/February during the second rainy season with some supplemental irrigation.

In the Sahelian West Africa, the groundnut crop is cultivated in a narrow belt between 10-15°N latitude. It is sown in July and harvested in October. The total seasonal rainfall varies between 300 and 1200 mm. The main rainy season lasts 2-3 months beginning in late June.

The groundnut-growing areas in the SAT have short (75-110 d) growing seasons and are characterized by intermittent drought periods. We have examined the probability estimates of moisture adequacy for a few selected locations in relation to crop-water needs. This study showed that the amount of soil moisture in the surface soil is fairly restricted at the time of seed formation and maturity, thus leading to pod development and harvesting problems. Our data also showed that groundnut yields are likely to be significantly reduced once in every 3 years due to failure of seasonal rainfall in the SAT.

Résumé

Caractéristiques agrométéorologiques des régions où l'on cultive l'arachide dans les tropiques semi-arides : *L'arachide (*Arachis hypogaea *L.) est cultivée dans près de 90 pays, dans*

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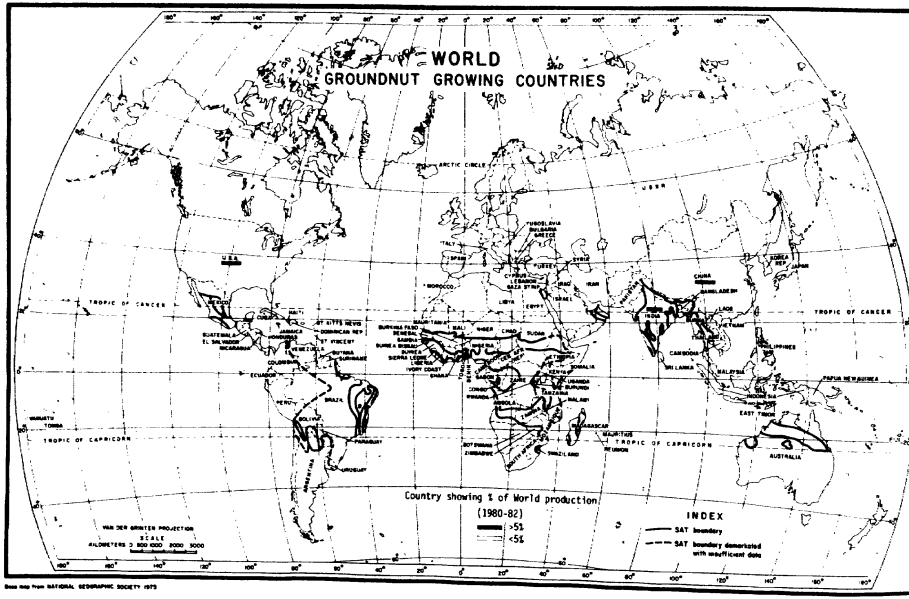

Base map from NATIONAL GEOGRAPHIC SOCIETY 1973

Figure 1. World groundnut-growing countries.

Plusieurs milieux agro-climatiques différents. Dans les zones tropicales semi-arides, il s'agit d'une importante culture de rente au sein des systèmes agricoles de subsistance. Il s'agit également d'une importante source alimentaire. La production totale d'arachide dans les pays tropicaux semi-arides représente environ la moitié de toute la production mondiale.

Parmi ces pays, c'est l'Inde qui consacre la plus grande partie de son territoire à la culture de l'arachide. Sa production représente 52% de celle de tous les pays tropicaux semi-arides. Suit le Sénégal, le Nigeria et le Soudan (la part de chacun étant de 5 à 7,5% de la production d'ensemble de ces pays), le Zaïre, le Brésil, la Birmanie et l'Argentine (de 2,6 à 5%), et la Thaïlande, le Malawi, le Zimbabwe, le Cameroun, la République centrafricaine, le Tchad, le Mali et la Gambie (de 1 à 2,5%).

La culture de l'arachide a lieu principalement en terre aride non irriguée. En Inde, l'arachide est cultivée dans des sols qui varient des sables côtiers aux Vertic Inceptisols. Dans le sous-continent africain elle pousse dans des Alfisols et des Oxisols. En général, les sols propices à la culture de l'arachide présentent une capacité pour l'eau disponible de basse (≃100 mm) à moyenne (≃ 200 mm) dans le profil racinaire.

En Inde, dans les régions de culture de l'arachide, les précipitations annuelles varient entre 400 mm et 1500 mm. Elles ont lieu habituellement au cours d'une période de pluie qui couvre de deux à quatre mois. La zone de culture est située entre 8°N et 32°N de latitude dans une grande variété de modèles de précipitations. En Inde du nord où les précipitations ont un caractère unimodal, les arachides croissent pendant la saison des pluies qui s'étend de juin à septembre. En Inde méridionale où les précipitations sont bimodales et où la température est propice à la culture de l'arachide presque tout au long de l'année, deux récoltes ont lieu. La période qui va de juillet à septembre/octobre (première saison des pluies) est la première consacrée à la culture de l'arachide, alors que la deuxième période, qui va d'octobre/novembre à janvier/février se situe au cours de la deuxième saison des pluies, nécessitant une irrigation additionnelle.

Dans la région sahélienne de l'Afrique occidentale, la culture de l'arachide a lieu dans une frange étroite située entre 10°-15°N de latitude. Le mois de juillet est celui de semis et la récolte a lieu en octobre. Dans cette zone, l'ensemble des précipitations saisonnières varie entre 300 et 1200 mm. La principale saison des pluies dure de deux à trois mois et commence vers les derniers jours de juin.

Les zones de culture de l'arachide des pays tropicaux semi-arides connaissent une brève saison de croissance (de 75 à 100 jours) et se caractérisent par des périodes de sécheresse intermittente. Nous avons procédé à l'examen des estimations probables sur l'adéquation de la teneur en eau de quelques emplacements sélectionnés aux besoins en eau de cette culture. Cette étude a montré que l'importance de l'humidité du sol dans les terres arables est assez limitée à l'époque de la germination et de la maturité, ce qui provoque des problèmes de développement des gousses et de récolte. Nos données ont également démontré qu'il est probable que le rendement de l'arachide diminue nettement une fois tous les trois ans, en raison de l'absence de précipitations saisonnières dans les pays tropicaux semi-arides.

Introduction

Groundnut (*Arachis hypogaea* L.) is a widely grown crop. It is cultivated in some 90 countries around the world. It requires tropical, subtropical, or warm temperate climates for optimum production. The approximate limits of its current commercial production lie between 40°N and 40°S (Fig.1). According to FAO (1982) 18.8 million ha were sown, and 19 million t of groundnuts in shell were harvested in 1980-82. The average yield was a little over 1 t ha^{-1}.

Groundnuts are produced predominantly in developing countries. About 90% of total world production comes from this region. India and China produce about one-half of world production. The United States of America is also a major producer. In the developing world SAT countries account for over 60% of production (11 million t from 14 million ha).

Groundnut yields average 805 kg ha^{-1}, but vary widely in the SAT countries. In Brazil, yields exceed 1450 kg ha^{-1}. In Nigeria, Burma, Sudan, India, and Mali, the yields vary between 800-1000 kg ha^{-1} (FAO, 1982). In Malawi, Senegal, and Zaire yields range between 673-716 kg ha^{-1}. With the sole exception of Brazil, in all other SAT countries the per hectare yield is lower than the world average (Fig.2 and FAO 1982).

The groundnut crop is an important component of the mixed cropping patterns of the small farms of the dry tropics. It is a cash crop. It is a legume. Farmers depend on the extra cash it produces to

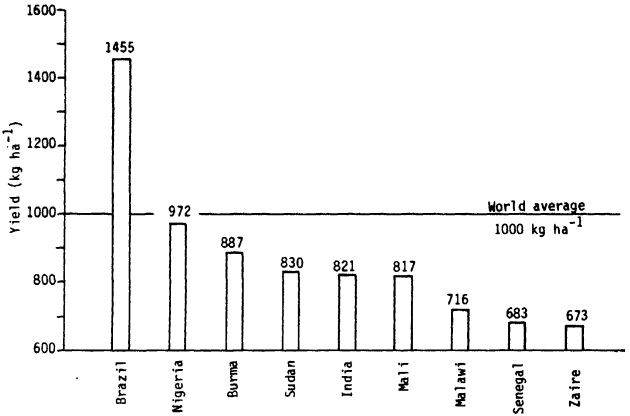

Figure 2. Groundnut yield in selected SAT countries. (Source: FAO 1982).

purchase inputs for cereals in the cropping systems. Groundnut not only produces oil for human food, but it also fuels the change of traditional low-input farms to modern agriculture. High and stable groundnut production is an essential element for the introduction of efficient farming systems in the SAT.

In many of the groundnut-producing countries the crop is consumed locally. India, the world's largest producer, is also one of the largest importers of vegetable oils. The countries of sub-Sahelian West Africa have been traditional exporters of groundnuts, but production there has declined recently. There is thus an urgent need to increase the productivity of the groundnut crop for sustained growth of semi-arid agriculture.

In this paper we will present:

- the ecological features of some important groundnut-producing areas of the SAT;
- agroclimatic analyses of some selected locations for identifying the soil and climatic constraints for increased groundnut production in different regions; and finally
- the analysis of rainfall environment for quantifying changes that have occurred in the groundnut-growing areas of sub-Sahelian West Africa in recent years.

Ecological Features of Principal Groundnut-Growing Areas of the SAT

South America

The SAT groundnut-growing area in this continent is in Brazil between 19° and 23° 5'S, with the major producing area between 20° and 23° 5'S. The total annual rainfall in this region varies from 1000-1400 mm. The crop is grown on Ustic-Ultisols (Ustults) that are dry for more than 90 d a^{-1}. The relative humidity of the area averages 73% for the year, but is higher during the groundnut cropping season. The main rainy season lasts 5 months—from November

About significant amounts of rainfall may be received in October and April. Less than 20% of the total rainfall is received during the dry period from May to August. Total number of sunshine hours in the groundnut-growing area vary from 2200-2700 h a^{-1}. During the crop growing season the duration of sunlight hours is around 6 h d^{-1}. Annual potential evapotranspiration of the groundnut-growing areas of Brazil averages around 2000 mm. The annual rainfall meets about 50-60% of the annual climatic water demand (WMO 1971). During the rainy season, however, the rainfall more or less equals the potential evapotranspiration (PE) demand (1250 mm). Mean annual temperature is 24°C.

West Africa

In the West African region between 5-15° N, there is an extensive area in Senegal, Gambia, Mali, Burkina Faso, Niger, and Nigeria where groundnuts are grown. Senegal cultivated over 1 million ha of groundnuts in 1982 (FAO 1982). Other major groundnut-growing areas are in northwestern Mali, southeastern Burkina Faso, southern Niger, and northern Nigeria (Fig.1). The crop is sown in this region in June or July and harvested in September-October. The growing period lasts about 2-4.5 mo. The annual rainfall in the region ranges between 600 and 1000 mm, with an evapotranspiration rate (ET) of about 1700 mm a^{-1}. The ET for the growing season is about 550 mm. The average annual temperature is about 25°C, but it is generally about 30°C during the groundnut-growing season. The relative humidity during this period averages 80% (WMO 1971). In Sahelian West Africa groundnuts are grown primarily in sandy Alfisols and Oxisols.

Central and Southern Africa

The groundnut-growing countries in Central Africa are Central African Republic, Chad, Sudan, Uganda, and Zaire. In southern Africa groundnuts are grown in Malawi, Mozambique, and Zimbabwe. Some other countries have small areas under the crop (Fig.1). In Malawi the crop forms a significant part of the national agricultural production. It is cultivated on Ustic Oxisols and Alfisols (Ustoxs and Ustalfs) and some Udic Ultisols. The rainfall varies from 500-1500 mm. In Central Africa groundnuts are grown from June to September, while in Southern Africa these are sown in November/December and harvested in March. In Malawi the annual average temperature of the groundnut-growing areas is about 16°C. Total number of sunshine hours annually in the Malawian groundnut-growing areas is about 2550 (WMO 1971).

India and Southeast Asia

Over 7 million ha of groundnuts are cultivated annually in India. The total production is about 6 million t. Burma and Indonesia are also significant producers in the SAT (FAO 1982).

In India, groundnuts are cultivated on Ustic Alfisols, Oxisols, and Usterts (the dry Vertic soils), from 7-30° N. The major groundnut-producing areas are located in western India. The crop is raised primarily under rainfed dryland conditions. In northern India (20° N) groundnuts are sown with the onset of the rainy season in late June or July and harvested in October. In the eastern coast of southern India, where the rainfall is bimodal, two crops are raised per year. The second crop is raised with some supplemental irrigation. The first cropping season is from June to September or October, and the second from October/November through February. The average temperature during the growing season is 27°C, with total sunshine hours per annum in the groundnut-growing areas varying between 2381 and 2900 from south to north. The relative humidity during the cropping season is generally around 70%, with annual rainfall from 500-1500 mm (WMO 1971).

Agroclimatic Analysis of some Selected Locations

It is apparent from the ecological data that groundnuts are cultivated over a variety of soils and agroclimatic environments within the SAT. However, some generalizations can be made:

- in the groundnut region the rainfall is seasonal;
- the evapotranspiration rates are high;
- the rainfall is variable from year to year;
- the soils are mostly sandy and do not have adequate moisture-holding capacity; and therefore,
- the key factor affecting groundnut growth and yield is the characteristic and length of the moisture environment during the crop-growing season.

At ICRISAT Center we have collected extensive

Table 1. Locations selected for detailed agroclimatic analysis.

Region	Country	Location	Geocoordinates	
South America	Brazil	Campo Grande	20° 28'S	54° 40'W
West Africa	Senegal	Dakar (Yoff)	14° 44'N	17° 30'W
	Nigeria	Kano	12° 03'N	08° 32'E
Southern Africa	Malawi	Lilongwe	13° 58'S	33° 42'E
South and Southeast Asia	India	Ahmedabad	23° 04'N	72° 38'E
		Madras	13° 00'N	80° 11'E

climatological data sets for several groundnut-growing countries. For example, we have rainfall data for over 100 locations of Brazil extending back 30 years or more. Monthly values of potential evapotranspiration have been calculated for these locations. For West and Southern Africa, we have access to meteorological data for over 200 locations. In the case of India, we have a library of climatic data sets including daily rainfall, temperature, and open-pan evaporation for about 70 locations. For some locations in India, West and Southern Africa, we have also collected extensive micrometeorological data for some representative groundnut-based cropping systems.

We used the clustering procedure available in the statistical analysis system (SAS) package at Kansas State University, USA, to select a few representative locations from each of the major groundnut-growing regions for detailed analysis. We used the monthly and annual rainfall, moisture-availability index (MAI), and annual temperature as variables for clustering different locations. Our aim was to select one or two locations from each of the major groundnut-growing regions of the SAT which would represent about 80% of the sites within a given region with a unit ± standard deviation for the selected agroclimatic characteristics. By following these procedures, we identified locations for which we had at least 30 years of data (Table 1).

The moisture environment for these locations has been assessed by calculating the MAI at different probability levels. The amount of expected rainfall has been calculated using an incomplete gamma statistical procedure (WMO 1971). The potential evapotranspiration was calculated following modified Penman's procedure (Rao et al. 1971). Values of MAI less than 0.33 reflect a moisture environment insufficient for active plant growth, while values between 0.34-0.99 show adequate rainfall to meet plant-water needs. Values of MAI above 1.00 show that water is present in excessive amounts (after Hargreaves 1971). The values of MAI and the length of the growing season obtained at different probability levels for each of the locations studied are shown in Table 2. A brief description for the different locations follows.

Table 2. Moisture-availability index (MAI) and growing-season length of some selected groundnut-growing locations in the SAT.

Brazil: Campo Grande
20° 28'S 54° 40'W
Annual rainfall: 1437 mm

Soil: Ustult AWC¹ 175 mm
Data: 1931-60

Probability (%)	Moisture-availability index						Growing season (days)
	Oct	Nov	Dec	Jan	Feb	Mar	
80	0.29	0.24	0.58	0.69	0.58	0.50	135
Mean	0.69	0.54	0.99	1.19	0.97	0.61	200
40	0.85	0.58	1.09	1.36	1.15	0.77	+200

Continued.

Continued.

Senegal: Dakar (Yoff)
14° 44'N 17° 30'W
Annual rainfall: 578 mm

Soil: Ustalf AWC 75 mm
Data: 1931-60

Probability	Moisture-availability index				Growing season
(%)	Jul	Aug	Sep	Oct	(days)
80	0.21	0.95	0.80	0.06	70
Mean	0.54	1.76	1.14	0.33	135
40	0.55	1.90	1.15	0.37	+142

Nigeria: Kano
12° 03'N 08° 32'E
Annual rainfall: 872 mm

Soil: Ustalf AWC 75 mm
Data: 1931-60

Probability	Moisture-availability index				Growing season
(%)	Jun	Jul	Aug	Sep	(days)
80	0.55	1.11	3.05	0.60	140
Mean	0.66	1.46	2.53	1.02	154
40	0.70	1.52	2.60	1.03	161

Malawi: Lilongwe
13° 58'S 33° 42' E
Annual rainfall: 849 mm

Soil: Ustox AWC 75 mm
Data: 1931-60

Probability	Moisture-availability index					Growing season
(%)	Nov	Dec	Jan	Feb	Mar	(days)
80	0.13	0.44	0.84	0.79	0.39	120
Mean	0.39	0.76	1.26	1.37	0.77	160
40	0.45	0.85	1.28	1.62	0.85	+160

India: Ahmedabad
24° 04'N 72° 38'E
Annual rainfall: 804 mm

Soil: Ustert AWC 150 mm
Data: 1931-60

Probability	Moisture-availability index					Growing season
(%)	Jun	Jul	Aug	Sep	Oct	(days)
80	0.10	1.03	0.74	0.18	0.00	50
Mean	0.43	2.41	1.78	1.12	0.01	135
40	0.46	2.46	1.82	1.22	0.01	+135

13° 00'N 80° 11'E
Annual rainfall: 1233 mm

Soil: Ustalf AWC 50 mm
Data: 1931-60

Probability	Moisture-availability index							Growing season
(%)	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(days)
80	0.12	0.27	0.44	0.47	1.10	1.28	0.18	120
Mean	0.28	0.52	0.80	0.89	2.12	2.85	1.18	180
40	0.29	0.54	0.90	0.95	2.03	3.17	1.50	+187

1. AWC = Available-water holding capacity of root profile.

Brazil: Campo Grande

The MAI values exceed the lower threshold value of 0.33 in all the rainy months at the various probability levels studied except October and November at 80% probability. The data for the length of the growing season show that it is at least 135 d in 8 out of 10 years. In 2 years out of 10, the rains will be insufficient at sowing time. Sowing may be delayed to late November in such cases. In this groundnut-growing area, soil fertility and its physical limitations are likely to be more important constraints to increased groundnut production compared to the soil-moisture adequacy for crop growth.

Senegal: Dakar (Yoff)

The MAI values (Table 2) at the 80% probability level are below the lower threshold of 0.33 for July and October. This means that in 1 out of every 5 years the growing season is likely to be restricted to about 70 d; it would be in the order of 135 d or more for many of the years (6 out of 10). Sir
have low available-water holding capacity (
in the root profile, and the rainfall is low (578 m
soil-moisture conservation would be an important
component of improved groundnut-management systems in this West African region.

Nigeria: Kano

The rainfall at this location is 872 mm. Most of the precipitation occurs in the 4 months from June to September. At the 80% probability level (Table 2) the MAI values exceed the lower threshold values of 0.33 for each of the rainy months, thus ensuring a growing season of at least 140 d in most years (8 out of 10). The groundnut crop is raised on Alfisols in this region. This soil has about 100 mm AWC. Improved management of soil fertility and adequate water-conservation techniques would be important technology elements to increase groundnut production in this region.

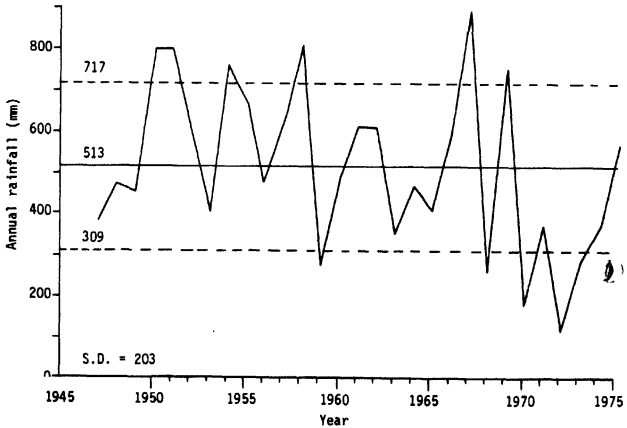

Figure 3. Annual rainfall trend at Dakar (Yoff), Senegal.

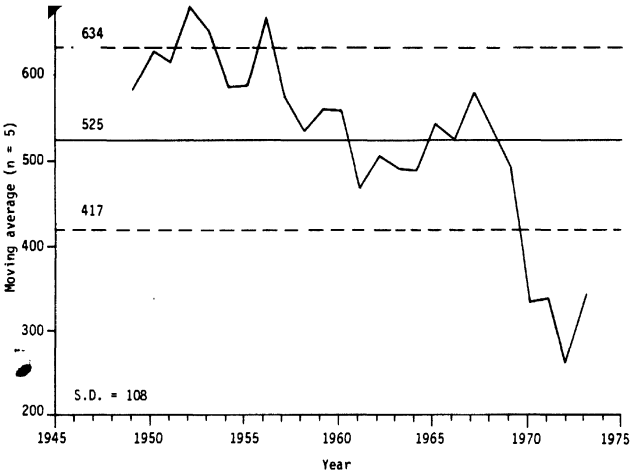

Figure 4. Five-year moving average of annual rainfall at Dakar (Yoff), Senegal (14°44'N, 17°38'W), 1947-1975.

Malawi: Lilongwe

In this Southern African country, the rainfall is fairly dependable except that sowing may be delayed due to low rainfall in the month of November in 1 out of every 5 years. The growing season exceeds 120 d in 8 out of every 10 years (Table 2). On average, it is 160 d. The soils on which groundnuts are grown have < 75 mm AWC. Management of soil chemical properties would be important to increase groundnut production in this area.

India: Ahmedabad

In this north Indian groundnut-growing location, the crop is grown during the southwest monsoon. Average length of the growing season is 135 d. In 2 out of every 10 years, the growing season is likely to be highly restricted (to less than 50 d). October has very low MAI values (Table 2). Since the crop is grown on Vertic soils in this region, harvesting groundnut may present serious problems in most years. Water conservation would be an important aspect of improved dryland groundnut production in this area.

India: Madras

This southern Indian coastal location receives rainfall from both the southwest and northeast monsoons. Two growing seasons are utilized for raising groundnuts—the first from June to October and the second from October to January or February. However, two groundnut crops are rarely grown sequentially on the same dryland field. The data on MAI (Table 2) show that a 120-day crop could be raised in

8 years out of 10 in this area. The average growing season there is 180 d. Groundnuts are raised on Alfisols and Oxisols in this region. These soils have low AWC (≤ 50 mm). Soil and water management would be an important component of the improved groundnut-management systems in this region.

Changes in Rainfall Environment in Groundnut-Growing Areas of Sub-Sahelian West Africa

The West African sub-Sahelian zone is characterized by high evapotranspiration rates, low to medium seasonal rainfall, and sandy soils. The average rainfall barely meets the climatic water demand represented by high potential evapotranspiration. Any negative change in the amount of rain region could have serious consequences for in and stable crop production. In order to quantify a changes in the rainfall of this region, we studied the precipitation records for 1947-1975 for Dakar (Yoff), Senegal. A plot of annual rainfall (Fig. 3) shows that precipitation has been highly variable from year to year over the past 30 years. The number of years of below-average rainfall has increased somewhat in the 1960-75 period. This observation is further confirmed by the 5-year moving-average data shown in Figure 4. In order to evaluate the agricultural significance of this trend we analyzed the probabilities of weekly rainfall ($R/PE \geq 0.33$) for the periods 1947-1955, 1956-1965, and 1966-1975 (Table 3) which are shown in Figure 5. Since a crop-growing season of

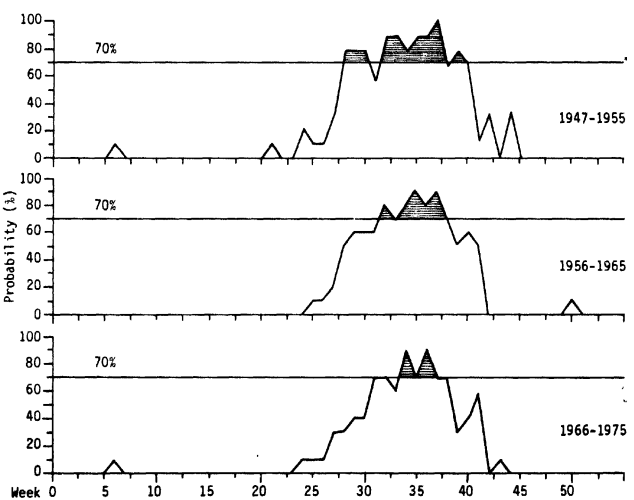

Figure 5. Rainfall probability estimates of $R/PE \geq 0.33$ for three selected datum periods, Dakar (Yoff), Senegal (14°44'N, 17°38'W).

robabilities (R/PE ≥ 0.33) of weekly rainfall in
ar (Yoff), Senegal.

Data-collection period	Weeks rainfall probability exceeded 70%	Probability of having a growing season of 10-12 weeks (%)
1947-1955	10	80
1956-1965	7	60
1966-1975	6	40

about 84 d is required for optimal groundnut production in western Senegal, the constraint imposed by shortening the length of the growing season could have grave consequences on crop yield.

We have also analyzed, on a similar basis, the precipitation data of a few other African groundnut-growing locations. We observed a similar trend. These results show that the agroclimate of the groundnut-growing areas is fragile. The rainfall of these areas is low and seasonal, and preliminary indications are that it decreased in the past few decades. The growing season is getting shorter. Further, the groundnut-growing soils are sandy, shallow, and in many cases highly prone to erosion. A serious interdisciplinary farming systems research effort must be continued and further intensified to evolve new and improved groundnut-production systems to increase and stabilize yields in the SAT.

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